Lab 2: Exploring the Database

In this lab, we'll cover the following topics:

- What version is the server?
- What is the server uptime?
- Locating the database server files
- Locating the database server's message log
- Locating the database's system identifier
- Listing databases on the database server
- How many tables are there in a database?
- How much disk space does a database use?
- How much disk space does a table use?
- Which are my biggest tables?
- How many rows are there in a table?
- Quickly estimating the number of rows in a table
- Listing extensions in this database
- Understanding object dependencies

What version is the server?

We will find out the version by querying the database server directly:

1. Connect to the database and issue the following command:

```
postgres=# SELECT version();
```

2. You'll get a response that looks something like this:

```
PostgreSQL 14.0 (Debian 14.0-1.pgdg100+1) on x86_64-pc-linux-gnu, compiled by
gcc (Debian 8.3.0-6) 8.3.0, 64-bit
```

That's probably too much information all at once!

Another way of checking the version number in your programs is as follows:

```
postgres=# SHOW server_version;
```

The preceding shows the version in text form, so you may also want a numerical value that is easier to compare using a greater than symbol, in which case you execute this command instead:

```
postgres=# SHOW server_version_num;
```

Another alternative is via command-line utilities, such as this:

```
bash # psql --version
psql (PostgreSQL) 14.0 (Debian 14.0-1.pgdg100+1)
```

However, be wary that this shows the client software version number, which may differ from the server software version number. This will usually be reported to you so that you're aware.

What is the server uptime?

Issue the following SQL from any interface:

```
postgres=# SELECT date_trunc('second', current_timestamp - pg_postmaster_start_time())
as uptime;
```

You should get the output as follows:

```
     uptime
-------------------------------------
 2 days 02:48:04
```

How it works...

Postgres stores the server start time, so we can access it directly, as follows:

```
postgres=# SELECT pg_postmaster_start_time();
pg_postmaster_start_time
-----------------------------------------------
2021-10-01 19:37:41.389134+00
```

Then, we can write a SQL query to get the uptime, like this:

```
postgres=# SELECT current_timestamp - pg_postmaster_start_time();
?column?
-----------------
 02:59:18.925917
```

Finally, we can apply some formatting:

```
postgres=# SELECT date_trunc('second', current_timestamp - pg_postmaster_start_time())
as uptime;
     uptime
----------
 03:00:26
```

Locating the database server files

Database server files are initially stored in a location referred to as the **data directory**. Additional data files may also be stored in tablespaces if any exist.

In this topic, you will learn how to find the location of these directories on a given database server.

Getting ready

You'll need to get operating system access to the database system, which is what we call the platform on which the database runs.

How to do it...

If you can connect using psql, then you can use this command:

```
postgres=# SHOW data_directory;
    data_directory
----------------------
 /var/lib/pgsql/data/
```

On Debian or Ubuntu systems, the configuration files are located in `/etc/postgresql/MAJOR_RELEASE/main/`, where `main` is just the name of a database server. Other names are also possible. For the sake of simplicity, we assume that you only have a single installation, although the point of including the release number and database server name as components of the directory path is to allow multiple database servers to coexist on the same host.

Note

The `pg_lsclusters` utility is specific to Debian/Ubuntu and displays a list of all the available database servers, including information for each server.

The information for each server includes the following:

- Major release number
- Port
- Status (for example, online and down)
- Data directory
- Log file

The `pg_lsclusters` utility is part of the `postgresql-common` Debian/Ubuntu package, which provides a structure under which multiple versions of PostgreSQL can be installed, and multiple clusters can be maintained, at the same time.

In the packages distributed with Red Hat RHEL, CentOS, and Fedora, the default data directory location also contains the configuration files (`*.conf`) by default. However, note that the packages distributed by the PostgreSQL community use a different default location: `/var/lib/pgsql/MAJOR_RELEASE/data/`.

Again, that is just the default location. You can create additional data directories using the `initdb` utility.

The `initdb` utility populates the given data directory with the initial content. The directory will be created for convenience if it is missing but, for safety, the utility will stop if the `data` directory is not empty.
The `initdb` utility will read the `data` directory name from the `PGDATA` environment variable unless the `-d` command-line option is used.

There's more...

Once you've located the data directory, you can look for the files that comprise the PostgreSQL database server. The layout is as follows:

Subdirectory	Purpose
`base`	This is the main table storage. Beneath this directory, each database has its own directory, within which the files for each database table or index are located.
`global`	Here are the tables that are shared across all databases, including the list of databases.
`pg_commit_ts`	Here we store transaction commit timestamp data (from 9.5 onward).
`pg_dynshmem`	This includes dynamic shared memory information (from 9.4 onward).
`pg_logical`	This includes logical decoding status data.
`pg_multixact`	This includes files used for shared row-level locks.
`pg_notify`	This includes the `LISTEN/NOTIFY` status files.
`pg_replslot`	This includes information about replication slots (from 9.4 onward).
`pg_serial`	This includes information on committed serializable transactions.
`pg_snapshots`	This includes exported snapshot files.
`pg_stat`	This includes permanent statistics data.
`pg_stat_tmp`	This includes transient statistics data.
`pg_subtrans`	This includes subtransaction status data.
`pg_tblspc`	This includes symbolic links to tablespace directories.
`pg_twophase`	This includes state files for prepared transactions.
`pg_wal`	This includes the transaction log or Write-Ahead Log (WAL) (formerly `pg_xlog`).
`pg_xact`	This includes the transaction status files (formerly `pg_clog`).

None of the aforementioned directories contain user-modifiable files, nor should any of the files be manually deleted to save space, or for any other reason. *Don't touch it, because you'll break it, and you may not be able to fix it!*

The only things you are allowed to touch are configuration files, which are all `*.conf` files, and server message log files. Server message log files may or may not be in the data directory. For more details on this, refer to the next topic, *Locating the database server's message log*.

Locating the database server's message log

The database server's message log is a record of all messages recorded by the database server. This is the first place to look if you have server problems and a good place to check regularly.

This log will include messages that look something like the following:

```
2021-09-01 19:37:41 GMT [2507-1] LOG:  database system was shut down at 2021-09-01
19:37:38 GMT
2021-09-01 19:37:41 GMT [2506-1] LOG:  database system is ready to accept connections
```

We'll explain some more about these logs once we've located the files.

Getting ready

You'll need to get operating system access to the database system, which is what we call the platform on which the database runs.

The server log can be in a few different places, so let's list all of them first so that we can locate the log or decide where we want it to be placed:

- The server log may be in a directory beneath the data directory.
- It may be in a directory elsewhere on the filesystem.
- It may be redirected to `syslog`.
- There may be no server log at all. In this case, it's time to add a log soon.

If not redirected to `syslog`, the server log consists of one or more files. You can change the names of these files, so it may not always be the same on every system.

How to do it...

The following is the default server log locations: systems: `/var/log/postgresql`.

The current server log file is named `postgresql-MAJOR_RELEASE-SERVER.log`, where `SERVER` is the name of the server (by default, `main`), and `MAJOR_RELEASE` represents the major release of the server, for example, 9.6 or 11 (as we mentioned in a prior topic, from release 10 onward, the major release is composed by just one number). An example is `postgresql-14-main.log`, while older log files are numbered as `postgresql-14-main.log.1`. The higher the final number, the older the file, since they are being rotated by the `logrotate` utility.

How it works...

The server log is just a file that records messages from the server. Each message has a severity level, the most typical of them being `LOG`, although there are others, as shown in the following table:

PostgreSQL severity	Meaning	Syslog severity	Windows Event Log
`DEBUG 1` to `DEBUG 5`	This comprises the internal diagnostics.	`DEBUG`	`INFORMATION`
`INFO`	This is the command output for the user.	`INFO`	`INFORMATION`
`NOTICE`	This is helpful information.	`NOTICE`	`INFORMATION`
`WARNING`	This warns of likely problems.	`NOTICE`	`WARNING`
`ERROR`	This is the current command that is aborted.	`WARNING`	`ERROR`
`LOG`	This is useful for sysadmins.	`INFO`	`INFORMATION`
`FATAL`	This is the event that disconnects one session only.	`ERR`	`ERROR`
`PANIC`	This is the event that crashes the server.	`CRIT`	`ERROR`

You can adjust the number of messages that appear in the log by changing the `log_min_messages` server parameter. You can also change the amount of information that is displayed for each event by changing the

`log_error_verbosity` parameter. If the messages are sent to a standard log file, then each line in the log will have a prefix of useful information that can also be controlled by the system administrator, with a parameter named `log_line_prefix`.

You can also alter the *what* and the *how much* that goes into the logs by changing other settings such as `log_statements`, `log_checkpoints`, `log_connections` / `log_disconnections`, `log_verbosity`, and `log_lock_waits`.

There's more...

The `log_destination` parameter controls where the log messages are stored. The valid values are `stderr`, `csvlog`, `syslog`, and `eventlog` (the latter is only on Windows).

The logging collector is a background process that writes to a log file everything that the PostgreSQL server outputs to `stderr`. This is probably the most reliable way to log messages in case of problems since it depends on fewer services.

Log rotation can be controlled with settings such as `log_rotation_age` and `log_rotation_size` if you are using the logging collector. Alternatively, it is possible to configure the `logrotate` utility to perform log rotation, which is the default on Debian and Ubuntu systems.

Locating the database's system identifier

Each database server has a system identifier assigned when the database is initialized (created). The server identifier remains the same if the server is backed up, cloned, and so on.

Many actions on the server are keyed to the system identifier, and you may be asked to provide this information when you report a fault.

In this topic, you will learn how to display the system identifier.

Getting ready

You need to connect as the Postgres OS user, or another user with execute privileges on the server software.

How to do it...

In order to display the system identifier, we just need to launch the following command:

```
pg_controldata <data-directory> | grep "system identifier"
Database system identifier:           7015545877453537036
```

Note that the preceding syntax will not work on Debian or Ubuntu systems, for the same reasons explained in relation to `initdb` in the *Locating the database server files* topic. However, in this case, there is no `postgresql-common` alternative, so if you must run `pg_controldata`, you need to specify the full path to the executable, as in this example:

```
/usr/lib/postgresql/14/bin/pg_controldata $PGDATA
```

Tip

Don't use `-D` in front of the data directory name. This is the only PostgreSQL server application where you don't need to do that.

How it works...

The `pg_controldata` utility is a PostgreSQL server application that shows the content of a server's control file. The control file is located within the `data` directory of a server, and it is created at database initialization time. Some of the information within it is updated regularly, and some is only updated when certain major events occur.

The full output of `pg_controldata` looks like the following (some values may change over time as the server runs):

```
pg_control version number:            1300
Catalog version number:               202107181
Database system identifier:           7015545877453537036
Database cluster state:               in production
pg_control last modified:             Tue 05 Oct 2021 12:46:26 BST
Latest checkpoint location:           0/16F2EC0
… (not shown in full)
```

Tip

Never edit the PostgreSQL control file. If you do, the server probably won't start correctly, or you may mask other errors. And if you do that, people will be able to tell, so fess up as soon as possible!

Listing databases on the database server

When we connect to PostgreSQL, we always connect to just one specific database on any database server. If there are many databases on a single server, it can get confusing, so sometimes you may just want to find out which databases are parts of the database server.

This is also confusing because we can use the word `database` in two different, but related, contexts. Initially, we start off by thinking that PostgreSQL is a database in which we put data, referring to the whole database server by just the word *database*. In PostgreSQL, a database server (also known as a **cluster**) is potentially split into multiple, individual databases, so, as you get more used to working with PostgreSQL, you'll start to separate the two concepts.

How to do it...

If you have access to `psql`, you can type the following command:

```
bash $ psql -l
                                 List of databases
   Name    | Owner  | Encoding |   Collate   |    Ctype    | Access privileges
-----------+--------+----------+-------------+-------------+-------------------
 postgres  | sriggs | UTF8     | en_GB.UTF-8 | en_GB.UTF-8 |
 template0 | sriggs | UTF8     | en_GB.UTF-8 | en_GB.UTF-8 | =c/sriggs        +
           |        |          |             |             | sriggs=CTc/sriggs
 template1 | sriggs | UTF8     | en_GB.UTF-8 | en_GB.UTF-8 | =c/sriggs        +
           |        |          |             |             | sriggs=CTc/sriggs
(3 rows)
```

You can also get the same information while running `psql` by simply typing `\l`.

The information that we just looked at is stored in a PostgreSQL catalog table named `pg_database`. We can issue a SQL query directly against that table from any connection to get a simpler result, as follows:

```
postgres=# select datname from pg_database;
datname
-----------
template1
template0
postgres
(3 rows)
```

How it works...

PostgreSQL starts with three databases: `template0`, `template1`, and `postgres`. The main user database is `postgres`.

You can create your own databases as well, like this:

```
CREATE DATABASE testdb;
```

You can do the same from the command line, using the following expression:

```
bash $ createdb testdb2
```

From now on, we will run our examples in the `postgres` database.

When you create another database, it actually takes a copy of an existing database. Once it is created, there is no further link between the two databases.

The `template0` and `template1` databases are known as **template databases**.
The `template1` database can be changed to allow you to create a localized template for any new databases that you create. The `template0` database exists so that, when you alter `template1`, you still have a pristine copy to fall back on. In other words, if you break `template1`, then you can drop it and recreate it from `template0`.

You can drop the database named `postgres`. But don't, okay? Similarly, don't try to touch `template0`, because you won't be allowed to do anything with it, except use it as a template. On the other hand, the `template1` database exists to be modified, so feel free to change it.

There's more...

The information that we just saw is stored in a PostgreSQL catalog table named `pg_database`. We can look at this directly to get some more information. In some ways, the output is less useful as well, as we need to look up some of the code in other tables:

```
postgres=# \x
postgres=# select * from pg_database;
-[ RECORD 1 ]-+------------------------------
oid           | 1
datname       | template1
datdba        | 10
encoding      | 6
datcollate    | en_GB.UTF-8
datctype      | en_GB.UTF-8
```

```
datistemplate | t
datallowconn  | t
datconnlimit  | -1
datlastsysoid | 11620
datfrozenxid  | 644
datminmxid    | 1
dattablespace | 1663
datacl        | {=c/sriggs,sriggs=CTc/sriggs}
-[ RECORD 2 ]-+------------------------------
oid           | 13706
datname       | template0
datdba        | 10
encoding      | 6
datcollate    | en_GB.UTF-8
datctype      | en_GB.UTF-8
datistemplate | t
datallowconn  | f
datconnlimit  | -1
datlastsysoid | 11620
datfrozenxid  | 644
datminmxid    | 1
dattablespace | 1663
datacl        | {=c/sriggs,sriggs=CTc/sriggs}
-[ RECORD 3 ]-+------------------------------
oid           | 13707
datname       | postgres
datdba        | 10
encoding      | 6
datcollate    | en_GB.UTF-8
datctype      | en_GB.UTF-8
datistemplate | f
datallowconn  | t
datconnlimit  | -1
datlastsysoid | 11620
datfrozenxid  | 644
datminmxid    | 1
dattablespace | 1663
datacl        |
-[ RECORD 4 ]-+------------------------------------
oid           | 16408
datname       | postgres
datdba        | 16384
encoding      | 6
datcollate    | en_GB.UTF-8
datctype      | en_GB.UTF-8
datistemplate | f
datallowconn  | t
datconnlimit  | -1
datlastsysoid | 13706
datfrozenxid  | 726
datminmxid    | 1
```

```
dattablespace | 1663
datacl        |
```

First of all, look at the use of the `\x` command. It makes the output in `psql` appear as one column per line, rather than one row per line.

We've already discussed templates. The other interesting things are that we can turn connections on and off for a database, and we can set connection limits for them, as well.

Also, you can see that each database has a default tablespace. Therefore, data tables get created inside one specific database, and the data files for that table get placed in one tablespace.

How many tables are there in a database?

The number of tables in a relational database is a good measure of the complexity of a database, so it is a simple way to get to know any database. But the complexity of what? Well, a complex database may have been designed to be deliberately flexible in order to cover a variety of business situations, or a complex business process may have a limited portion of its details covered in the database. So, a large number of tables might reveal a complex business process or just a complex piece of software.

In this topic, we will show you how to compute the number of tables.

How to do it...

From any interface, type the following SQL command:

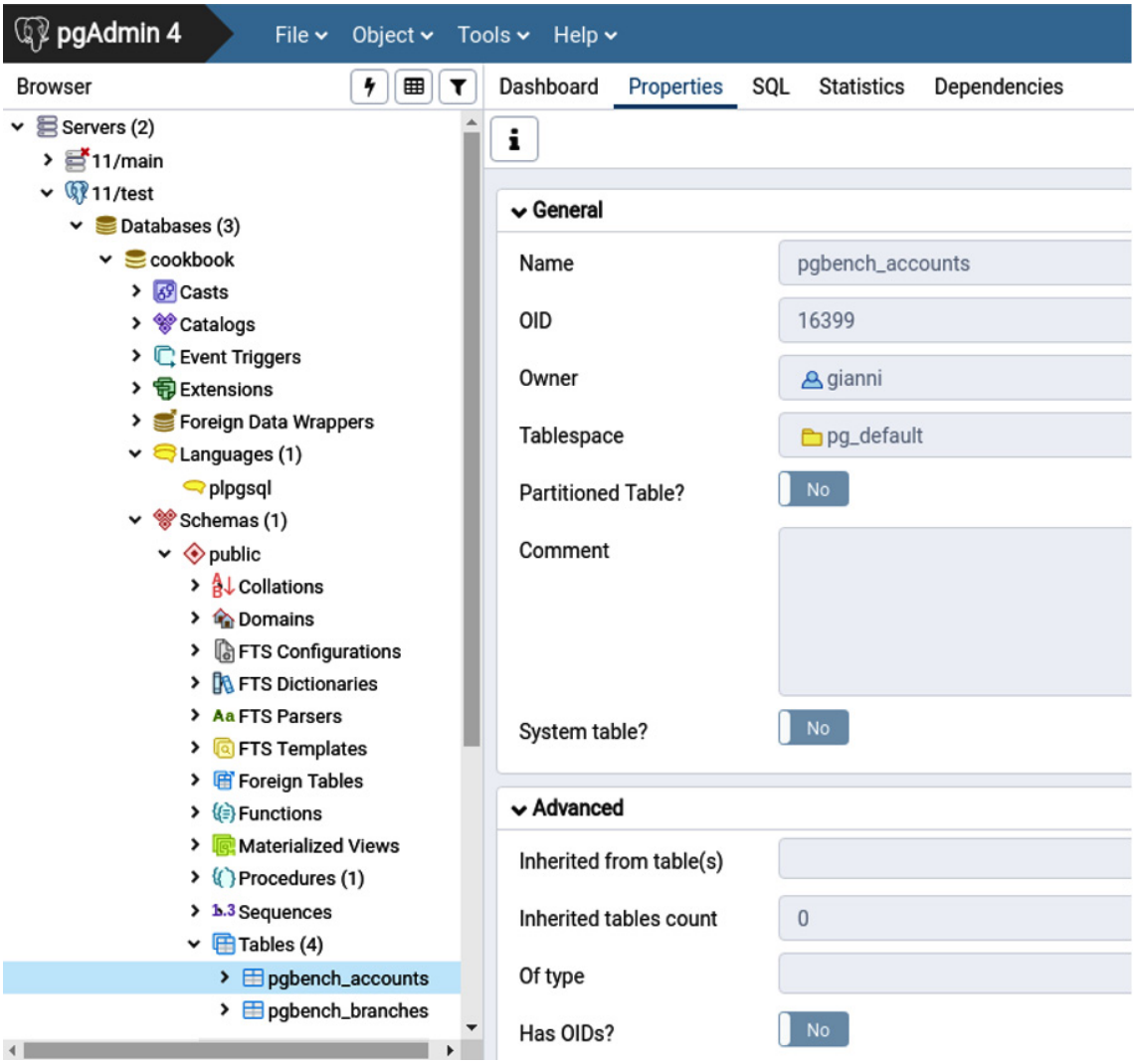
```
SELECT count(*) FROM information_schema.tables
WHERE table_schema NOT IN ('information_schema','pg_catalog');
```

You can also look at the list of tables directly, and judge whether the list is a small or large number.

In `psql`, you can see your own tables by using the following command:

```
$ psql -c "\d"
        List of relations
 Schema |   Name   | Type  |  Owner
--------+----------+-------+----------
 public | accounts | table | postgres
 public | branches | table | postgres
```

In **pgAdmin 4**, you can see the tables in the tree view on the left-hand side, as shown in the following screenshot:



How it works...

PostgreSQL stores information about the database in catalog tables. They describe every aspect of the way the database has been defined. There is a main set of catalog tables stored in a schema, called `pg_catalog`. There is a second set of catalog objects called the **information schema**, which is the standard SQL way of accessing information in a relational database.

We want to exclude both of these schemas from our query, to avoid counting non-user objects. We excluded them in the preceding query using the `NOT IN` phrase in the `WHERE` clause.

Excluding partitions from the count is more involved. The information schema shows partitions as the same as tables, which is true for PostgreSQL, so somewhat misleading. So, what we want to do is exclude tables that are also partitions. Partitions are marked in the `pg_catalog.pg_class` table, with a Boolean column of relispartition. If we use `pg_class`, we also need to exclude non-tables and ensure we don't include internal schemas, which leaves us with this much more complex query:

```
SELECT count(*) FROM pg_class
WHERE relkind = 'r'
AND not relispartition
```

```
AND relnamespace NOT IN (
     SELECT oid FROM pg_namespace
     WHERE nspname IN ('information_schema','pg_catalog', 'pg_toast')
     AND nspname NOT LIKE 'pg_temp%' AND nspname NOT LIKE 'pg_toast_temp%'
);
```

Note

Note that this query shows only the number of tables in one of the databases on the PostgreSQL server. You can only see the tables in the database to which you are currently connected, so you'll need to run the same query on each database in turn.

There's more...

The highest number of distinct, major tables I've ever seen in a database is 20,000, without counting partitions, views, and worktables. That clearly rates as a very complex system.

Number of distinct tables (entities – not partitions!)	Complexity rating
20,000	This is incredibly complex. You're either counting wrong or you have a big team to manage this.
2,000	This is a complex business database. Usually, few of these are seen.
200	This is a typical modern business database.
20	This is a simple business database.
2	This is a database with a single, clear purpose, strictly designed for performance or some other goal.
0	This tells you that you haven't loaded any data yet!

Of course, you can't always easily tell which tables are entities, so we just need to count the tables. Some databases use a lot of partitions or similar tables, so the numbers can grow dramatically. I've seen databases with up to 200,000 tables (of any kind). That's not recommended, however, as the database catalog tables then begin to become awfully large.

How much disk space does a database use?

It is very important to allocate sufficient disk space for your database. If the disk gets full, it will not corrupt the data, but it might lead to database server panic and then consequent shutdown.

For planning or space monitoring, we often need to know how big the database is.

How to do it...

We can do this in the following ways:

- Look at the size of the files that make up the database server.
- Run a SQL request to confirm the database size.

If you look at the size of the actual files, you'll need to make sure that you include the data directory and all subdirectories, as well as all other directories that contain tablespaces. This can be tricky, and it is also difficult to break out all the different pieces.

The easiest way is to ask the database a simple query, like this:

```
SELECT pg_database_size(current_database());
```

However, this is limited to just the current database. If you want to know the size of all the databases together, then you'll need a query such as the following:

```
SELECT sum(pg_database_size(datname)) from pg_database;
```

How it works...

The database server knows which tables it has loaded. It also knows how to calculate the size of each table, so the `pg_database_size()` function just looks at the file sizes.

How much disk space does a table use?

The maximum supported table size in the default configuration is 32 TB and it does not require large file support from the operating system. The filesystem size limits do not impact the large tables, as they are stored in multiple 1 GB files.

Large tables can suffer performance issues. Indexes can take much longer to update and query performance can degrade. In this topic, we will see how to measure the size of a table.

How to do it...

We can see the size of a table by using this command:

```
postgres=# select pg_relation_size('pgbench_accounts');
```

The output of this command is as follows:

```
pg_relation_size
------------------
           13582336
(1 row)
```

We can also see the total size of a table, including indexes and other related spaces, as follows:

```
postgres=# select pg_total_relation_size('pgbench_accounts');
```

The output is as follows:

```
pg_total_relation_size
------------------------
         15425536
(1 row)
```

We can also use a `psql` command, like this:

```
postgres=# \dt+ pgbench_accounts
                        List of relations
 Schema |       Name       | Type  | Owner  | Size  | Description
--------+------------------+-------+--------+-------+-------------
 gianni | pgbench_accounts | table | gianni | 13 MB |
(1 row)
```

How it works...

In PostgreSQL, a table is made up of many relations. The main relation is the data table. In addition, there are a variety of additional data files. Each index created on a table is also a relation. Long data values are placed in a secondary table named `TOAST`, so, in most cases, each table also has a `TOAST` table and a `TOAST` index.

Each relation consists of multiple data files. The main data files are broken into 1 GB pieces. The first file has no suffix; others have a numbered suffix (such as `.2`). There are also files marked `_vm` and `_fsm`, which represent the visibility map and free space map, respectively. They are used as part of maintenance operations. They stay fairly small, even for very large tables.

There's more...

The preceding functions, which measure the size of a relation, output the number of bytes, which is normally too large to be immediately clear. You can apply the `pg_size_pretty()` function to format that number nicely, as shown in the following example:

```
SELECT pg_size_pretty(pg_relation_size('pgbench_accounts'));
```

This yields the following output:

```
pg_size_pretty
----------------
13 MB
(1 row)
```

TOAST stands for **The Oversized-Attribute Storage Technique**. As the name implies, this is a mechanism used to store long column values. PostgreSQL allows many data types to store values up to 1 GB in size. It transparently stores large data items in many smaller pieces, so the same data type can be used for data ranging from 1 byte to 1 GB. When appropriate, values are automatically compressed and decompressed before they are split and stored, so the actual limit will vary, depending on compressibility.

You may also see files ending in `_init`; they are used by unlogged tables and their indexes, for restoring them after a crash. Unlogged objects are called this way because they do not produce WAL. So, they support faster writes, but in the event of a crash they must be truncated; that is, restored to an empty state.

Which are my biggest tables?

We've looked at getting the size of a specific table, so now it's time to widen the problem to related areas. Rather than having an absolute value for a specific table, let's look at the relative sizes.

How to do it...

The following basic query will tell us the 10 biggest tables:

```
SELECT quote_ident(table_schema)||'.'||quote_ident(table_name) as name
      ,pg_relation_size(quote_ident(table_schema)
              || '.' || quote_ident(table_name)) as size
FROM information_schema.tables
WHERE table_schema NOT IN ('information_schema', 'pg_catalog')
ORDER BY size DESC
LIMIT 10;
```

The tables are shown in descending order of size, with at the most 10 rows displayed. In this case, we look at all the tables in all the schemas, apart from the tables in `information_schema` or `pg_catalog`, as we did in the *How many tables are in the database?* topic.

How it works...

PostgreSQL provides a dedicated function, `pg_relation_size`, to compute the actual disk space used by a specific table or index. We just need to provide the table name. In addition to the main data files, there are other files (called **forks**) that can be measured by specifying an optional second argument. These include the **Visibility Map** (**VM**), the **Free Space Map** (**FSM**), and the **initialization fork** for unlogged objects.

How many rows are there in a table?

There is no limit on the number of rows in a table, but the table is limited to available disk space and memory/swap space. If you are storing rows that exceed an aggregated data size of 2 KB, then the maximum number of rows may be limited to 4 billion or fewer.

Counting is one of the easiest SQL statements, so it is also many people's first experience of a PostgreSQL query.

How to do it...

From any interface, the SQL command used to count rows is as follows:

```
SELECT count(*) FROM table;
```

This will return a single integer value as the result.

In `psql`, the command looks like the following:

```
postgres=# select count(*) from orders;
 count
-------
   345
(1 row)
```

How it works...

PostgreSQL can choose between two techniques available to compute the SQL `count(*)` function. Both are available in all the currently supported versions:

- The first is called **sequential scan**. We access every data block in the table one after the other, reading the number of rows in each block. If the table is on the disk, it will cause a beneficial disk access pattern, and

the statement will be fairly fast.
- The other technique is known as an **index-only scan**. It requires an index on the table, and it covers a more general case than optimizing SQL queries with `count(*)`.

Some people think that the `count` SQL statement is a good test of the performance of a DBMS. Some DBMSs have specific tuning features for the `count` SQL statement, and Postgres optimizes this using index-only scans. The PostgreSQL project has talked about this many times, but few people thought we should try to optimize this. Yes, the `count` function is frequently used within applications, but without any `WHERE` clause, it is not that useful. Therefore, the index-only scans feature has been implemented, which applies to more real-world situations, as well as this topic.

We scan every block of the table because of a major feature of Postgres, named **Multiversion Concurrency Control** (**MVCC**). MVCC allows us to run the `count` SQL statement at the same time that we are inserting, updating, or deleting data from the table. That's a very cool feature, and we went to a lot of trouble in Postgres to provide it for you.

MVCC requires us to record information on each row of a table, stating when that change was made. If the changes were made after the SQL statement began to execute, then we just ignore those changes. This means that we need to carry out visibility checks on each row in the table to allow us to work out the results of the `count` SQL statement. The optimization provided by index-only scans is the ability to skip such checks on the table blocks that are already known to be visible to all current sessions. Rows in these blocks can be counted directly on the index, which is normally smaller than the table, and is, therefore, faster.

If you think a little deeper about this, you'll see that the result of the count SQL statement is just the value at a moment in time. Depending on what happens to the table, that value could change a little or a lot while the `count` SQL statement is executing. So, once you've executed this, all you really know is that, at a particular point in the past, there were exactly *x* rows in the table.

Quickly estimating the number of rows in a table

We don't always need an accurate count of rows, especially on a large table that may take a long time to execute. Administrators often need to estimate how big a table is so that they can estimate how long other operations may take.

How to do it...

The Postgres optimizer can provide a quick estimate of the number of rows in a table simply by using its statistics:

```
EXPLAIN SELECT * FROM mytable;
                          QUERY PLAN
---------------------------------------------------------------
 Seq Scan on mytable  (cost=0.00..2640.00 rows=100000 width=97)
(1 row)
```

We can directly compute a similar number using roughly the same calculation:

```
SELECT (CASE WHEN reltuples > 0 THEN pg_relation_size(oid)*reltuples/(8192*relpages)
ELSE 0
END)::bigint AS estimated_row_count
FROM pg_class
WHERE oid = 'mytable'::regclass;
```

This gives us the following output:

```
 estimated_row_count
---------------------
               99960
(1 row)
```

Both queries return a row count very quickly, no matter how large the table that we are examining is, because they use statistics that were collected in advance. You may want to create a SQL function for the preceding calculation, so you won't need to retype the SQL code every now and then.

The following function estimates the total number of rows using a mathematical procedure called **extrapolation**. In other words, we take the average number of bytes per row resulting from the last statistics collection, and we apply it to the current table size:

```
CREATE OR REPLACE FUNCTION estimated_row_count(text)
RETURNS bigint
LANGUAGE sql
AS $$
SELECT (CASE WHEN reltuples > 0 THEN
              pg_relation_size($1)*reltuples/(8192*relpages)
             ELSE 0
             END)::bigint
FROM pg_class
WHERE oid = $1::regclass;
$$;
```

How it works...

We saw the `pg_relation_size()` function earlier, so we know that it brings back an accurate value for the current size of the table.

When we vacuum a table in Postgres, we record two pieces of information in the `pg_class` catalog entry for the table. These two items are the number of data blocks in the table (`relpages`) and the number of rows in the table (`reltuples`). Some people think they can use the value of `reltuples` in `pg_class` as an estimate, but it could be severely out of date. You will also be fooled if you use information in another table named `pg_stat_user_tables` .

The Postgres optimizer uses the `relpages` and `reltuples` values to calculate the average rows per block, which is also known as the **average tuple density**.

If we assume that the average tuple density remains constant over time, then we can calculate the number of rows using this formula: *Row estimate = number of data blocks * rows per block*.

We include some code to handle cases where the `reltuples` or `relpages` fields are zero. The Postgres optimizer actually works a little harder than we do in that case, so our estimate isn't very good.

The `WHERE oid = 'mytable'::regclass;` syntax introduces the concept of object identifier types. They just use a shorthand trick to convert the name of an object to the object identifier number for that object. The best way to understand this is to think of that syntax as meaning the same as a function named `relname2relid()` .

There's more...

The good thing about the preceding topic is that it returns a value in about the same time, no matter how big the table is. The bad thing about it is that `pg_relation_size()` requests a lock on the table, so if any other user has

an `AccessExclusiveLock` lock on the table, then the table size estimate will wait for the lock to be released before returning a value.

Err... so what is an `AccessExclusiveLock` lock? While performing a SQL maintenance action, such as changing the data type of a column, PostgreSQL will lock out all other actions on that table, including `pg_relation_size`, which takes a lock in the `AccessShareLock` mode. For me, a typical case is when I issue some form of SQL maintenance action, such as `ALTER TABLE`, and the statement takes much longer than I thought it would. At that point, I think, *Oh, was that table bigger than I thought? How long will I be waiting?* Yes, it's better to calculate that beforehand, but hindsight doesn't get you out of the hole you are in right now. So, we need a way to calculate the size of a table without needing the lock.

A solution is to look at the operating system files that Postgres uses to store data, and figure out how large they are, but that requires a high level of security than most people usually allow. In any case, looking at files without a lock could cause problems if the table were dropped or changed.

Listing extensions in this database

Every PostgreSQL database contains some objects that are automatically brought in when the database is created. Every user will find a `pg_database` system catalog that lists databases, as shown in the *Listing databases on this database server* topic. There is little point in checking whether these objects exist because even superusers are not allowed to drop them.

On the other hand, PostgreSQL comes with tens of collections of optional objects, called **modules**, or equivalently **extensions**. The database administrator can install or uninstall these objects, depending on the requirements. They are not automatically included in a newly created database because they might not be required by every use case. Users will install only the extensions they actually need, when they need them; an extension can be installed while a database is up and running.

In this topic, we will explain how to list extensions that have been installed on the current database. This is important for getting to know the database better, and also because certain extensions affect the behavior of the database.

How to do it...

In PostgreSQL, there is a catalog table recording the list of installed extensions, so this topic is quite simple. Issue the following command:

```
postgres=> SELECT * FROM pg_extension;
```

This results in the following output:

```
-[ RECORD 1 ]--+--------
oid            | 13693
extname        | plpgsql
extowner       | 10
extnamespace   | 11
extrelocatable | f
extversion     | 1.0
extconfig      |
extcondition   |
```

Note

Note that the format is expanded, as if the `\x` meta command has been previously issued.

To get the same list with fewer technical details, you can use the `\dx` meta command, as when listing databases.

How it works...

A PostgreSQL extension is represented by a control file, `<extension name>.control`, located in the `SHAREDIR/extension` directory, plus one or more files containing the actual extension objects. The control file specifies the extension name, version, and other information that is useful for the extension infrastructure. Each time an extension is installed, uninstalled, or upgraded to a new version, the corresponding row in the `pg_extension` catalog table is inserted, deleted, or updated, respectively.

See also

To get an idea of which extensions are available, you can browse the list of additional modules shipped together with PostgreSQL, which are almost all extensions, at https://www.postgresql.org/docs/current/static/contrib.html.

Understanding object dependencies

In most databases, there will be dependencies between objects in the database. Sometimes, we need to understand these dependencies to figure out how to perform certain actions, such as modifying or deleting existing objects. Let's look at this in detail.

Getting ready

We'll use the following simple database to understand and investigate them:

1. Create two tables as follows:

```
CREATE TABLE orders (
 orderid integer PRIMARY KEY
);
CREATE TABLE orderlines (
 orderid integer
,lineid smallint
,PRIMARY KEY (orderid, lineid)
);
```

2. Now, we add a link between them to enforce what is known as **referential integrity**, as follows:

```
ALTER TABLE orderlines ADD FOREIGN KEY (orderid)
REFERENCES orders (orderid);
```

3. If we try to drop the referenced table, we get the following message:

```
DROP TABLE orders;
ERROR: cannot drop table orders because other objects depend on it
DETAIL: constraint orderlines_orderid_fkey on table orderlines depends on table
orders
HINT: Use DROP ... CASCADE to drop the dependent objects too.
```

Be very careful! If you follow the hint, you may accidentally remove all the objects that have any dependency on the `orders` table. You might think that this would be a great idea, but it is not the right thing to do. It might work,

but we need to ensure that it will work.

Therefore, you need to know what dependencies are present on the `orders` table, and then review them. Then, you can decide whether it is okay to issue the `CASCADE` version of the command, or whether you should reconcile the situation manually.

How to do it...

You can use the following command from `psql` to display full information about a table, the constraints that are defined upon it, and the constraints that reference it:

```
\d+ orders
```

You can also get specific details of the constraints by using the following query:

```
SELECT * FROM pg_constraint
WHERE confrelid = 'orders'::regclass;
```

The aforementioned queries only covered constraints between tables. This is not the end of the story, so read the *There's more...* section.

How it works...

When we create a foreign key, we add a constraint to the catalog table, known as `pg_constraint`. Therefore, the query shows us how to find all the constraints that depend upon the `orders` table.