POSTGRESQL is an open-source, full-featured relational database. This presentation covers advanced administration topics.

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Outline

1. Installation
2. Configuration
3. Maintenance
4. Monitoring
5. Recovery
1. Installation

- Click-through Installers
  - MS Windows
  - Linux
  - OS X
- Ports
  - RPM
  - DEB
  - PKG
  - other packages
- Source
  - obtaining
  - build options
  - installing
$ initdb /u/pgsql/data
  The files belonging to this database system will be owned by user "postgres".
  This user must also own the server process.

  The database cluster will be initialized with locale "en_US.UTF-8".
  The default database encoding has accordingly been set to "UTF8".
  The default text search configuration will be set to "english".

  Data page checksums are disabled.

  fixing permissions on existing directory /u/pgsql/data ... ok
  creating subdirectories ... ok
  selecting default max_connections ... 100
  selecting default shared_buffers ... 128MB
  selecting dynamic shared memory implementation ... posix
  creating configuration files ... ok
  running bootstrap script ... ok
  performing post-bootstrap initialization ... ok
  syncing data to disk ... ok

  WARNING: enabling "trust" authentication for local connections
  You can change this by editing pg_hba.conf or using the option -A, or
  --auth-local and --auth-host, the next time you run initdb.

  Success. You can now start the database server using:

    pg_ctl -D /u/pgsql/data -l logfile start
pg_controldata

$ pg_controldata
pg_control version number: 1002
Catalog version number: 201707211
Database system identifier: 654463619067825437
Database cluster state: shut down
pg_control last modified: Sun 15 Apr 2018 07:20:58 AM EDT
Latest checkpoint location: 0/15C09E0
Prior checkpoint location: 0/15C0708
Latest checkpoint's REDO location: 0/15C09E0
Latest checkpoint's REDO WAL file: 000000000000000000000000000000001
Latest checkpoint's TimelineID: 1
Latest checkpoint's PrevTimelineID: 1
Latest checkpoint's full_page_writes: on
Latest checkpoint's NextXID: 0:555
Latest checkpoint's NextOID: 12296
Latest checkpoint's NextMultiXactId: 1
Latest checkpoint's NextMultiOffset: 0
Latest checkpoint's oldestXID: 548
Latest checkpoint's oldestXID's DB: 1
Latest checkpoint's oldestActiveXID: 0
Latest checkpoint's oldestMultiXid: 1
Latest checkpoint's oldestMulti's DB: 1
Latest checkpoint's oldestCommitTsXid: 0
Latest checkpoint's newestCommitTsXid: 0
Time of latest checkpoint: Sun 15 Apr 2018 07:20:58 AM EDT
Fake LSN counter for unlogged rels: 0/1
Minimum recovery ending location: 0/0
Min recovery ending loc's timeline: 0
Backup start location: 0/0
Backup end location: 0/0
End-of-backup record required: no
wal_level setting: replica
wal_log_hints setting: off
max_connections setting: 100
max_worker_processes setting: 8
System Architecture

- Utility Plan
- Optimal Path
- Query
- Postmaster
- Postgres
- Libpq
- Generate Plan
- Traffic Cop
- Utility Command
  - utility: `CREATE TABLE, COPY`
  - `SELECT, INSERT, UPDATE, DELETE`
- Parse Statement
- Rewrite Query
- Generate Paths
  - Optimal Path
- Execute Plan

Storage Managers
- Catalog
- Utilities
- Access Methods
- Nodes / Lists
Session Creation
Starting Postmaster

- manually
- pg_ctl start
- on boot
Stopping Postmaster

- manually
- `pg_ctl stop`
- on shutdown
Connections

- local — unix domain socket
- host — TCP/IP, both SSL or non-SSL
- hostssl — only SSL
- hostnossl — never SSL
Authentication

- trust
- reject
- passwords
  - scram-sha-256
  - md5
  - password (cleartext)
- local authentication
  - socket permissions
  - 'peer' socket user name passing
  - host ident using local identd
remote authentication
  ▶️ host ident using pg_ident.conf
  ▶️ kerberos
    ▶️ gss
    ▶️ sspi
  ▶️ pam
  ▶️ ldap
  ▶️ radius
  ▶️ cert
Access

- hostname and network mask
- database name
- role name (user or group)
- filename or list of databases, role
- IPv6
```
# TYPE DATABASE USER ADDRESS METHOD

# "local" is for Unix domain socket connections only
local all all trust

# IPv4 local connections:
host all all 127.0.0.1/32 trust

# IPv6 local connections:
host all all ::1/128 trust

# Allow replication connections from localhost, by a user with the
# replication privilege.
local replication postgres trust
host replication postgres 127.0.0.1/32 trust
host replication postgres ::1/128 trust
```
### pg_hba.conf Example

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>all</td>
<td>all</td>
<td></td>
<td>trust</td>
</tr>
</tbody>
</table>

"local" is for Unix domain socket connections only

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>host</td>
<td>all</td>
<td>all</td>
<td>127.0.0.1/32</td>
<td>trust</td>
</tr>
</tbody>
</table>

IPv4 local connections:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>host</td>
<td>all</td>
<td>all</td>
<td>::1/128</td>
<td>trust</td>
</tr>
</tbody>
</table>

IPv6 local connections:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>host</td>
<td>all</td>
<td>all</td>
<td>192.168.1.254/32</td>
<td>reject</td>
</tr>
</tbody>
</table>

Disable connections from the gateway machine

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>host</td>
<td>all</td>
<td>all</td>
<td>192.168.1.0/24</td>
<td>scram-sha-256</td>
</tr>
</tbody>
</table>

Enable local network

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>host</td>
<td>all</td>
<td>all</td>
<td>0.0.0.0/0</td>
<td>reject</td>
</tr>
</tbody>
</table>

Require SSL for external connections, but do not allow the superuser

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>hostssl</td>
<td>all</td>
<td>postgres</td>
<td>0.0.0.0/0</td>
<td>scram-sha-256</td>
</tr>
<tr>
<td>hostssl</td>
<td>all</td>
<td>all</td>
<td>0.0.0.0/0</td>
<td>scram-sha-256</td>
</tr>
</tbody>
</table>
Permissions

- Host connection permissions
- Role permissions
  - create roles
  - create databases
  - table permissions
- Database management
  - template1 customization
  - system tables
  - disk space computations
$ ls -CF
base/  pg_ident.conf  pg_serial/  pg_tblspc/  postgresql.auto.conf
global/ pg_logical/  pg_snapshots/ pg_twophase/ postgresql.conf
pg_commit_ts/ pg_multixact/ pg_stat/  PG_VERSION postmaster.opts
pg_dynshmem/ pg_notify/  pg_stat_tmp/  pg_wal/
pg_hba.conf  pg_replslot/  pg_subtrans/  pg_xact/
Database Directories

$ ls -CF global/
1136  1214_fsm  1261_vm  2671  2846  2967  6000_vm
1136_fsm  1214_vm  1262  2672  2846_vm  3592  6001
1136_vm  1232  1262_fsm  2676  2847  3592_vm  6002
1137  1233  1262_vm  2677  2964  3593  pg_control
1213  1260  2396  2694  2964_vm  4060  pg_fileno.node.map
1213_fsm  1260_fsm  2396_fsm  2695  2965  4060_vm  pg_internal.init
1213_vm  1260_vm  2396_vm  2697  2966  4061
1214  1261  2397  2698  2966_vm  6000

$ ls -CF base/
1/  12406/  12407/  16384/

$ ls -CF base/16384
112  1249_fsm  2606_vm  2652  2699  3081  3598_vm
113  1249_vm  2607  2653  2701  3085  3599
12242  1255  2607_fsm  2654  2702  3118  3600
12242_fsm  1255_fsm  2607_vm  2655  2703  3118_vm  3600_fsm
12242_vm  1255_vm  2608  2656  2704  3119  3600_vm
12244  1259  2608_fsm  2657  2753  3164  3601
12246  1259_fsm  2608_vm  2658  2753_fsm  3256  3601_fsm

...
Transaction/WAL Directories

$ ls -CF pg_wal/
0000000100000000000000001 archive_status/

$ ls -CF pg_xact/
0000
$ ls -CF share/
conversion_create.sql  postgres.bki  snowball_create.sql
extension/  postgres.description  sql_features.txt
information_schema.sql  postgresql.conf.sample  system_views.sql
pg_hba.conf.sample  postgres.shdescription  timezone/
pг_ident.conf.sample  psqlrc.sample  timezonesets/
pg_service.conf.sample  recovery.conf.sample  tsearch_data/
2. Configuration

https://www.flickr.com/photos/mwichary/
# PostgreSQL configuration file
#
# This file consists of lines of the form:
# name = value
#
# (The "=" is optional.) Whitespace may be used. Comments are introduced with
# "#" anywhere on a line. The complete list of parameter names and allowed
# values can be found in the PostgreSQL documentation.
#
# The commented-out settings shown in this file represent the default values.
# Re-commenting a setting is NOT sufficient to revert it to the default value;
# you need to reload the server.
This file is read on server startup and when the server receives a SIGHUP signal. If you edit the file on a running system, you have to SIGHUP the server for the changes to take effect, run "pg_ctl reload", or execute "SELECT pg_reload_conf()". Some parameters, which are marked below, require a server shutdown and restart to take effect.

Any parameter can also be given as a command-line option to the server, e.g., "postgres -c log_connections=on". Some parameters can be changed at run time with the "SET" SQL command.

Memory units:  kB = kilobytes       Time units:  ms = milliseconds
MB = megabytes       s = seconds
GB = gigabytes       min = minutes
TB = terabytes       h = hours
d = days
# The default values of these variables are driven from the -D command-line option or PGDATA environment variable, represented here as ConfigDir.

`#data_directory = 'ConfigDir'`  # use data in another directory
`#hba_file = 'ConfigDir/pg_hba.conf'`  # host-based authentication file
`#ident_file = 'ConfigDir/pg_ident.conf'`  # ident configuration file

`# If external_pid_file is not explicitly set, no extra PID file is written. external_pid_file = ''`  # write an extra PID file
#listen_addresses = 'localhost'  # what IP address(es) to listen on;  
# comma-separated list of addresses;  
# defaults to 'localhost'; use '*' for all  
# (change requires restart)

#port = 5432  
max_connections = 100  
#superuser_reserved_connections = 3  
#unix_socket_directories = '/tmp'

#unix_socket_group = ''  
#unix_socket_permissions = 0777

#bonjour = off

#bonjour_name = ''  
# (change requires restart)  
#advertise server via Bonjour  
# (change requires restart)  
#defaults to the computer name  
# (change requires restart)
# Authentication

```python
#authentication_timeout = 1min       # 1s-600s
#ssl = off
#ssl_ciphers = 'HIGH:MEDIUM:+3DES:!aNULL'  # allowed SSL ciphers
#ssl_prefer_server_ciphers = on
#ssl_ecdh_curve = 'prime256v1'
#ssl_dh_params_file = ''
#ssl_cert_file = 'server.crt'
#ssl_key_file = 'server.key'
#ssl_ca_file = ''
#ssl_crl_file = ''
#password_encryption = md5           # md5 or scram-sha-256
#db_user_namespace = off
#row_security = on

# GSSAPI using Kerberos
#krb_server_keyfile = ''
#krb_caseins_users = off
```
#tcp_keepalives_idle = 0
# TCP_KEEPIDLE, in seconds;
# 0 selects the system default

#tcp_keepalives_interval = 0
# TCP_KEEPINTVL, in seconds;
# 0 selects the system default

#tcp_keepalives_count = 0
# TCP_KEEPCNT;
Memory Usage

```sql
shared_buffers = 128MB

#huge_pages = try

#temp_buffers = 8MB
#max_prepared_transactions = 0

# Caution: it is not advisable to set max_prepared_transactions nonzero unless
# you actively intend to use prepared transactions.
#work_mem = 4MB
#maintenance_work_mem = 64MB
#replacement_sort_tuples = 150000
#autovacuum_work_mem = -1
#max_stack_depth = 2MB
dynamic_shared_memory_type = posix

# min 128kB
# (change requires restart)
# on, off, or try
# (change requires restart)
# min 800kB
# zero disables the feature
# (change requires restart)
# min 64kB
# min 1MB
# limits use of replacement selection sort
# min 1MB, or -1 to use maintenance_work_mem
# min 100kB
# the default is the first option
# supported by the operating system:
# posix
# sysv
# windows
# mmap
# use none to disable dynamic shared memory
# (change requires restart)
```
Memory Usage (Continued)

Query and Checkpoint Operations

Transaction Durability

PostgreSQL Shared Buffer Cache

Write-Ahead Log

Kernel Disk Buffer Cache

Disk Blocks
Sizing Shared Memory

<table>
<thead>
<tr>
<th>RAM</th>
<th>Kernel Disk Buffer Cache</th>
<th>Free</th>
<th>Shared Buffer Cache (sharedBuffers)</th>
<th>Postgres Session (work_mem)</th>
</tr>
</thead>
</table>

Page Out

Page In (bad)

Swap
Disk and Kernel Resources

# - Disk -

#temp_file_limit = -1

# limits per-process temp file space
# in kB, or -1 for no limit

# - Kernel Resource Usage -

#max_files_per_process = 1000

# min 25
# (change requires restart)

#shared_preload_libraries = ''

# (change requires restart)
Vacuum and Background Writer

# - Cost-Based Vacuum Delay -

```sql
#vacuum_cost_delay = 0  # 0-100 milliseconds
#vacuum_cost_page_hit = 1  # 0-10000 credits
#vacuum_cost_page_miss = 10  # 0-10000 credits
#vacuum_cost_page_dirty = 20  # 0-10000 credits
#vacuum_cost_limit = 200  # 1-10000 credits
```

# - Background Writer -

```sql
#bgwriter_delay = 200ms  # 10-10000ms between rounds
#bgwriter_lru_maxpages = 100  # 0-1000 max buffers written/round
#bgwriter_lru_multiplier = 2.0  # 0-10.0 multiplier on buffers scanned/round
#bgwriter_flush_after = 512kB  # measured in pages, 0 disables
```

# - Asynchronous Behavior -

```sql
#effective_io_concurrency = 1  # 1-1000; 0 disables prefetching
#max_worker_processes = 8  # (change requires restart)
#max_parallel_workers_per_gather = 2  # taken from max_parallel_workers
#max_parallel_workers = 8  # maximum number of max_worker_processes that can be used in parallel queries
#old_snapshot_threshold = -1  # 1min-60d; -1 disables; 0 is immediate
```
Write-Ahead Log (WAL)

#wal_level = replica
# minimal, replica, or logical
# (change requires restart)
#fsync = on
# flush data to disk for crash safety
# (turning this off can cause
# unrecoverable data corruption)
#synchronous_commit = on
# synchronization level;
# off, local, remote_write, remote_apply, or
# the default is the first option
# supported by the operating system:
# open_datasync
# fdatasync (default on Linux)
# fsync
# fsync_writethrough
# open_sync
# recover from partial page writes
# enable compression of full-page writes
# also do full page writes of non-critical
# (change requires restart)
# wal_buffers = -1
# min 32kB, -1 sets based on sharedBuffers
# (change requires restart)
#wal_writer_delay = 200ms
# 1-10000 milliseconds
#wal_writer_flush_after = 1MB
# measured in pages, 0 disables
# commit_delay = 0
# range 0-100000, in microseconds
#commit_siblings = 5
# range 1-1000
Write-Ahead Logging (Continued)

Query and Checkpoint Operations

Transaction Durability

PostgreSQL Shared Buffer Cache

Write-Ahead Log

fsync

fsync

Disk Blocks
# Checkpoints and Archiving

```
#checkpoint_timeout = 5min  # range 30s-1d
#max_wal_size = 1GB
#min_wal_size = 80MB
#checkpoint_completion_target = 0.5  # checkpoint target duration, 0.0 - 1.0
#checkpoint_flush_after = 256kB  # measured in pages, 0 disables
#checkpoint_warning = 30s  # 0 disables

# - Archiving -

#archive_mode = off  # enables archiving; off, on, or always
# (change requires restart)
#archive_command = ''  # command to use to archive a logfile segment
# placeholders: %p = path of file to archive
#               %f = file name only
# e.g., 'test ! -f /mnt/server/archivedir/%f && cp
#archive_timeout = 0  # force a logfile segment switch after this
# number of seconds; 0 disables
```
Write-Ahead Logging (Continued)

PostgreSQL Shared Buffer Cache

Begin 1

Write-Ahead Log

End 1

Rotate
# Set these on the master and on any standby that will send replication data.

```
#max_wal_senders = 10  # max number of walsender processes
                    # (change requires restart)
#wal_keep_segments = 0 # in logfile segments, 16MB each; 0 disables
#wal_sender_timeout = 60s # in milliseconds; 0 disables

#max_replication_slots = 10 # max number of replication slots
                            # (change requires restart)
#track_commit_timestamp = off # collect timestamp of transaction commit
                            # (change requires restart)
```
Primary Replication Server

# These settings are ignored on a standby server.

#synchronous_standby_names = ''  # standby servers that provide sync rep
    # method to choose sync standbys, number of sync standbys,
    # and comma-separated list of application_name
    # from standby(s); '*' = all
#vacuum_defer_cleanup_age = 0    # number of xacts by which cleanup is delayed
# These settings are ignored on a master server.

```sql
#hot_standby = on
#max_standby_archive_delay = 30s
#max_standby_streaming_delay = 30s
#wal_receiver_status_interval = 10s
#hot_standby_feedback = off
#wal_receiver_timeout = 60s
#wal_retrieve_retry_interval = 5s

# "off" disallows queries during recovery
# (change requires restart)
# max delay before canceling queries when reading WAL from archive;
# -1 allows indefinite delay
# max delay before canceling queries when reading streaming WAL;
# -1 allows indefinite delay
# send replies at least this often
# 0 disables
# send info from standby to prevent query conflicts
# time that receiver waits for communication from master
# in milliseconds; 0 disables
# time to wait before retrying to retrieve WAL after a failed attempt
```
# These settings are ignored on a publisher.

#max_logical_replication_workers = 4  # taken from max_worker_processes
# (change requires restart)
#max_sync_workers_per_subscription = 2 # taken from max_logical_replication_workers
Planner Method Tuning

#enable_bitmapscan = on
#enable_hashagg = on
#enable_hashjoin = on
#enable_indexscan = on
#enable_indexonlyscan = on
#enable_material = on
#enable_mergejoin = on
#enable_nestloop = on
#enable_seqscan = on
#enable_sort = on
#enable_tidscan = on
Planner Constants

#seq_page_cost = 1.0  # measured on an arbitrary scale
#random_page_cost = 4.0  # same scale as above
#cpu_tuple_cost = 0.01  # same scale as above
#cpu_index_tuple_cost = 0.005  # same scale as above
#cpu_operator_cost = 0.0025  # same scale as above
#parallel_tuple_cost = 0.1  # same scale as above
#parallel_setup_cost = 1000.0  # same scale as above
#min_parallel_table_scan_size = 8MB
#min_parallel_index_scan_size = 512kB
#effective_cache_size = 4GB
Planner GEQO

#geqo = on
#geqo_threshold = 12
#geqo_effort = 5
#geqo_pool_size = 0
#geqo_generations = 0
#geqo_selection_bias = 2.0
#geqo_seed = 0.0

# range 1-10
# selects default based on effort
# range 1.5-2.0
# range 0.0-1.0
#default_statistics_target = 100  # range 1-10000
#constraint_exclusion = partition  # on, off, or partition
#cursor_tuple_fraction = 0.1  # range 0.0-1.0
#from_collapse_limit = 8  # 1 disables collapsing of explicit
#join_collapse_limit = 8  # JOIN clauses

#force_parallel_mode = off
Where To Log

#log_destination = 'stderr'

# Valid values are combinations of
# stderr, csvlog, syslog, and eventlog,
# depending on platform. csvlog
# requires logging_collector to be on.

# This is used when logging to stderr:
#logging_collector = off

# Enable capturing of stderr and csvlog
# into log files. Required to be on for
# csvlogs.
# (change requires restart)

# These are only used if logging_collector is on:
#log_directory = 'log'

# directory where log files are written,
# can be absolute or relative to PGDATA

#log_filename = 'postgresql-%Y-%m-%d_%H%M%S.log'

# log file name pattern,
# can include strftime() escapes

#log_file_mode = 0600

# creation mode for log files,
# begin with 0 to use octal notation
#log_truncate_on_rotation = off

# If on, an existing log file with the same name as the new log file will be truncated rather than appended to. But such truncation only occurs on time-driven rotation, not on restarts or size-driven rotation. Default is off, meaning append to existing files in all cases.

#log_rotation_age = 1d

# Automatic rotation of logfiles will happen after that time. 0 disables.

#log_rotation_size = 10MB

# Automatic rotation of logfiles will happen after that much log output. 0 disables.
Where to Log (syslog)

#syslog_facility = 'LOCAL0'
#syslog_ident = 'postgres'
#syslog_sequence_numbers = on
#syslog_split_messages = on

# This is only relevant when logging to eventlog (win32):
# (change requires restart)
#event_source = 'PostgreSQL'
When to Log

#client_min_messages = notice

# values in order of decreasing detail:
#   debug5
#   debug4
#   debug3
#   debug2
#   debug1
#   log
#   notice
#   warning
#   error

#log_min_messages = warning

# values in order of decreasing detail:
#   debug5
#   debug4
#   debug3
#   debug2
#   debug1
#   info
#   notice
#   warning
#   error
#   log
#   fatal
#   panic
When to Log (Continued)

```
#log_min_error_statement = error
# values in order of decreasing detail:
#   debug5
#   debug4
#   debug3
#   debug2
#   debug1
#   info
#   notice
#   warning
#   error
#   log
#   fatal
#   panic (effectively off)

#log_min_duration_statement = -1
# -1 is disabled, 0 logs all statements and their durations, > 0 logs only statements running at least this number of milliseconds
```
What to Log

#debug_print_parse = off
#debug_print_rewritten = off
#debug_print_plan = off
#debug_pretty_print = on
#log_checkpoints = off
#log_connections = off
#log_disconnections = off
#log_duration = off
#log_error_verbosity = default  # terse, default, or verbose messages
#log_hostname = off
What To Log: Log_line_prefix

```
*log_line_prefix = '%m [%p]'#

# special values:
#  %a = application name
#  %u = user name
#  %d = database name
#  %r = remote host and port
#  %h = remote host
#  %p = process ID
#  %t = timestamp without milliseconds
#  %m = timestamp with milliseconds
#  %n = timestamp with milliseconds (as a
#       %i = command tag
#  %e = SQL state
#  %c = session ID
#  %l = session line number
#  %s = session start timestamp
#  %v = virtual transaction ID
#  %x = transaction ID (0 if none)
#  %q = stop here in non-session
#       processes
#  %% = '%'
# e.g., '<%u%%d> '
```
#log_lock_waits = off
#log_statement = 'none'
#log_replication_commands = off
#log_temp_files = -1

log_timezone = 'US/Eastern'

# - Process Title -

#cluster_name = ''

#update_process_title = on

# log lock waits >= deadlock_timeout
# none, ddl, mod, all

# log temporary files equal or larger
# than the specified size in kilobytes;
# -1 disables, 0 logs all temp files

# added to process titles if nonempty
# (change requires restart)
# - Query/Index Statistics Collector -

#track_activities = on
#track_counts = on
#track_io_timing = off
#track_functions = none
#track_activity_query_size = 1024
#stats_temp_directory = 'pg_stat_tmp'

# - Statistics Monitoring -

#log_parser_stats = off
#log_planner_stats = off
#log_executor_stats = off
#log_statement_stats = off
#log_statement_stats = off
#autovacuum = on

#log_autovacuum_min_duration = -1

#autovacuum_max_workers = 3

#autovacuum_naptime = 1min
#autovacuum_vacuum_threshold = 50

#autovacuum_analyze_threshold = 50

#autovacuum_vacuum_scale_factor = 0.2
#autovacuum_analyze_scale_factor = 0.1
#autovacuum_freeze_max_age = 200000000

#autovacuum_multixact_freeze_max_age = 400000000

#autovacuum_vacuum_cost_delay = 20ms

#autovacuum_vacuum_cost_limit = -1

# Enable autovacuum subprocess? 'on'
# requires track_counts to also be on.
# -1 disables, 0 logs all actions and their durations, > 0 logs only actions running at least this number of milliseconds.
# max number of autovacuum subprocesses (change requires restart)
# time between autovacuum runs
# min number of row updates before vacuum
# min number of row updates before analyze
# fraction of table size before vacuum
# fraction of table size before analyze
# maximum XID age before forced vacuum (change requires restart)
# maximum multixact age before forced vacuum (change requires restart)
# default vacuum cost delay for autovacuum, in milliseconds;
# -1 means use vacuum_cost_delay default vacuum cost limit for
Statement Behavior

```
#search_path = '"$user", public'  # schema names
#default_tablespace = ''  # a tablespace name, '' uses the default
#temp_tablespaces = ''  # a list of tablespace names, '' uses
# only default tablespace

#check_function_bodies = on
#default_transaction_isolation = 'read committed'
#default_transaction_read_only = off
#default_transaction_deferrable = off
#session_replication_role = 'origin'
#statement_timeout = 0  # in milliseconds, 0 is disabled
#lock_timeout = 0  # in milliseconds, 0 is disabled
#idle_in_transaction_session_timeout = 0  # in milliseconds, 0 is disabled
#vacuum_freeze_min_age = 50000000
#vacuum_freeze_table_age = 150000000
#vacuum_multixact_freeze_min_age = 5000000
#vacuum_multixact_freeze_table_age = 150000000
#bytea_output = 'hex'  # hex, escape
#xmlbinary = 'base64'
#xmloption = 'content'
#gin_fuzzy_search_limit = 0
#gin_pending_list_limit = 4MB
```
locale, Formatting, and Full Text Search

datestyle = 'iso, mdy'
#intervalstyle = 'postgres'
timezone = 'US/Eastern'
#timezone_abbreviations = 'Default'

#extra_float_digits = 0
#client_encoding = sql_ascii

# These settings are initialized by initdb, but they can be changed.
lc_messages = 'en_US.UTF-8'    # locale for system error message strings

lc_monetary = 'en_US.UTF-8'    # locale for monetary formatting
lc_numeric = 'en_US.UTF-8'     # locale for number formatting
lc_time = 'en_US.UTF-8'        # locale for time formatting

# default configuration for text search
default_text_search_config = 'pg_catalog.english'
Other Defaults

#dynamic_library_path = '$libdir'
#local_preload_libraries = ''
#session_preload_libraries = ''
Lock Management

#deadlock_timeout = 1s
#max_locks_per_transaction = 64

#max_pred_locks_per_transaction = 64

#max_pred_locks_per_relation = -2

#max_pred_locks_per_page = 2

# min 10
# (change requires restart)
# min 10
# (change requires restart)
# negative values mean
# (max_pred_locks_per_transaction
# / -max_pred_locks_per_relation) - 1
# min 0
# - Previous PostgreSQL Versions -

$array_nulls = on$
#backslash_quote = safe_encoding # on, off, or safe_encoding
#default_with_oids = off
#escape_string_warning = on
#lo_compat_privileges = off
#operator_precedence_warning = off
#quote_all_identifiers = off
#standard_conforming_strings = on
#synchronize_seqscans = on

# - Other Platforms and Clients -

#transform_null_equals = off
# Error Handling

```plaintext
#exit_on_error = off
#restart_after_crash = on

# terminate session on any error?
# reinitialize after backend crash?
```
#include_dir = 'conf.d'
#include_if_exists = 'exists.conf'
#include = 'special.conf'

#include files ending in '.conf' from directory 'conf.d'
#include file only if it exists
#include file
Interfaces

▷ Installing
  ▷ Compiled Languages (C, ecpg)
  ▷ Scripting Language (Perl, Python, PHP)
  ▷ SPI

▷ Connection Pooling
Include Files

```
$ ls -CF include/
ecpg_config.h libpq/ pgtypes_date.h sql3types.h
ecpgerrno.h libpq-events.h pgtypes_error.h sqlca.h
ecpg_informix.h libpq-fe.h pgtypes_interval.h sqllda-compat.h
ecpglib.h pg_config_ext.h pgtypes_numeric.h sqlda.h
ecpgtype.h pg_config.h pgtypes_timestamp.h sqllda-native.h
informix/ pg_config_manual.h postgres_ext.h
internal/ pg_config_os.h server/
```
Library Files

$ ls -CF lib/
ascii_and_mic.so*
cyrillic_and_mic.so*
dict_snowball.so*
euc2004_sjis2004.so*
euc_cn_and_mic.so*
euc_jp_and_sjis.so*
euc_kr_and_mic.so*
euc_tw_and_big5.so*
latin2_and_win1250.so*
latin_and_mic.so*
libecpg.a
libecpg_compat.a
libecpg_compat.so@
libecpg_compat.so.3@
libecpg_compat.so.3.10*
libecpg.so@
libecpg.so.6@
libecpg.so.6.10*
libpgcommon.a
libpgfeutils.a
libpgport.a
libpgtypes.a
libpgtypes.so@
libpgtypes.so.3@
libpgtypes.so.3.10*
libpq.a
libpq.so@
libpq.so.5@
libpq.so.5.10*
libpqwalreceiver.so*
pqoutput.so*
pgxs/
pgoutput.so*
pgxs/
plperl.so*
plpgsql.so*
plpython2.so*
utf8_and_ascii.so*
utf8_and_big5.so*
utf8_and_cyrillic.so*
utf8_and_euc2004.so*
utf8_and_euc_cn.so*
utf8_and_euc_jp.so*
utf8_and_euc_kr.so*
utf8_and_euc_tw.so*
utf8_and_gb18030.so*
utf8_and_gbk.so*
utf8_and_iso8859_1.so*
utf8_and_iso8859.so*
utf8_and_johab.so*
utf8_and_sjis2004.so*
utf8_and_sjis.so*
utf8_and_uhc.so*
utf8_and_win.so*
3. Maintenance
Backup

- File system-level (physical)
  - tar, cpio while shutdown
  - file system snapshot
    - rsync, shutdown, rsync, restart
- pg_dump/pg_dumpall (logical)
- Restore/pg_restore with custom format
Continuous Archiving / Point-In-Time Recovery (PITR)

File System-Level Backup

Continuous Archive (WAL)
PITR Backup Procedures

1. archive_mode = on
2. wal_level = archive
3. archive_command = 'cp -i %p /mnt/server/pgsql/%f < /dev/null'
4. SELECT pg_start_backup('label');
5. Perform file system-level backup (can be inconsistent)
6. SELECT pg_stop_backup();

`pg_basebackup` does this automatically.
PITR Recovery

File System–Level Backup
Continuous Archive (WAL)
PITR Recovery Procedures

1. Stop postmaster
2. Restore file system-level backup
3. Make adjustments as outlined in the documentation
4. Create recovery.conf
5. \texttt{restore\_command = 'cp /mnt/server/pgsql/%f %p'}
6. Start the postmaster
Continuous Archive Management

Simplify backups and WAL archive file management with:

- *pgBackRest*
- *barman*
Data Maintenance

- **VACUUM** (nonblocking) records free space into .fsm (free space map) files
- **ANALYZE** collects optimizer statistics
- **VACUUM FULL** (blocking) shrinks the size of database disk files
Autovacuum handles vacuum and analyze tasks automatically.
Checkpoints

- Write all dirty shared buffers
- Sync all dirty kernel buffers
- Recycle WAL files
- Controlled by `checkpoint_timeout` and `max_wal_size`
4. Monitoring
$ ps -f -Upostgres
postgres  825   1   0  Tue12AM ??  0:06.57  /u/pgsql/bin/postmaster -i
postgres  829  825   0  Tue12AM ??  0:35.03  writer process  (postmaster)
postgres  830  825   0  Tue12AM ??  0:16.07  wal writer process  (postmaster)
postgres  831  825   0  Tue12AM ??  0:11.34  autovacuum launcher process  (postmaster)
postgres  832  825   0  Tue12AM ??  0:07.63  stats collector process  (postmaster)
postgres 13003 825   0  3:44PM ??  0:00.01  postgres test [local] idle (postmaster)
postgres 13002 12997  0  3:44PM  ttyq1  0:00.03  /u/pgsql/bin/psql test
$ top -c

top - 10:29:47 up 23 days, 18:53, 6 users, load average: 1.73, 1.49, 0.81
Tasks: 387 total, 2 running, 385 sleeping, 0 stopped, 0 zombie
%Cpu(s): 5.9 us, 0.5 sy, 0.0 ni, 93.7 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
KiB Mem: 24734444 total, 19187724 used, 5546720 free, 532280 buffers
KiB Swap: 6369276 total, 168292 used, 6200984 free. 16936936 cached Mem

PID USER PR NI VIRT RES SHR S %CPU %MEM TIME+ COMMAND
32037 postgres 20 0 190980 27940 21420 R 100.0 0.1 0:09.74 postgres: postgres test [local] INSERT
32061 root 20 0 26056 3240 2444 R 0.7 0.0 0:00.09 top -c
# Query Monitoring

test=> SELECT * FROM pg_stat_activity;
...
<table>
<thead>
<tr>
<th>datid</th>
<th>16384</th>
</tr>
</thead>
<tbody>
<tr>
<td>datname</td>
<td>test</td>
</tr>
<tr>
<td>pid</td>
<td>16382</td>
</tr>
<tr>
<td>usesysid</td>
<td>10</td>
</tr>
<tr>
<td>usename</td>
<td>postgres</td>
</tr>
<tr>
<td>application_name</td>
<td>psql</td>
</tr>
<tr>
<td>client_addr</td>
<td></td>
</tr>
<tr>
<td>client_hostname</td>
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</tr>
<tr>
<td>client_port</td>
<td>-1</td>
</tr>
<tr>
<td>backend_start</td>
<td>2018-04-15 09:00:26.467813-04</td>
</tr>
<tr>
<td>xact_start</td>
<td>2018-04-15 09:00:48.028667-04</td>
</tr>
<tr>
<td>query_start</td>
<td>2018-04-15 09:00:48.028667-04</td>
</tr>
<tr>
<td>state_change</td>
<td>2018-04-15 09:00:48.028671-04</td>
</tr>
<tr>
<td>wait_event_type</td>
<td></td>
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<td>wait_event</td>
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<tr>
<td>state</td>
<td>active</td>
</tr>
<tr>
<td>backend_xid</td>
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</tr>
<tr>
<td>backend_xmin</td>
<td>556</td>
</tr>
<tr>
<td>query</td>
<td>SELECT * FROM pg_stat_activity;</td>
</tr>
<tr>
<td>backend_type</td>
<td>client backend</td>
</tr>
<tr>
<td>Access Statistics</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td>pg_stat_all_indexes</td>
<td>view</td>
</tr>
<tr>
<td>pg_stat_all_tables</td>
<td>view</td>
</tr>
<tr>
<td>pg_stat_database</td>
<td>view</td>
</tr>
<tr>
<td>pg_stat_sys_indexes</td>
<td>view</td>
</tr>
<tr>
<td>pg_stat_sys_tables</td>
<td>view</td>
</tr>
<tr>
<td>pg_stat_user_indexes</td>
<td>view</td>
</tr>
<tr>
<td>pg_stat_user_tables</td>
<td>view</td>
</tr>
<tr>
<td>pg_statio_all_indexes</td>
<td>view</td>
</tr>
<tr>
<td>pg_statio_all_sequences</td>
<td>view</td>
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<tr>
<td>pg_statio_all_tables</td>
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<td>pg_statio_sys_tables</td>
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<tr>
<td>pg_statio_user_indexes</td>
<td>view</td>
</tr>
<tr>
<td>pg_statio_user_sequences</td>
<td>view</td>
</tr>
<tr>
<td>pg_statio_user_tables</td>
<td>view</td>
</tr>
</tbody>
</table>
test=> SELECT * FROM pg_stat_database;
...
-[ RECORD 4 ]-+----------
| datid | 16384 |
datname | test |
numbackends | 1 |
xact_commit | 188 |
xact_rollback | 0 |
| blks_read | 95 |
| blks_hit | 11832 |
tup_returned | 64389 |
tup_fetched | 2938 |
tup_inserted | 0 |
tup_updated | 0 |
tup_deleted | 0 |
### Table Activity

```
SELECT * FROM pg_stat_all_tables;
```

```
- [ RECORD 10 ]---+------------------------
  relid     | 2616
  schemaname | pg_catalog
  relname    | pg_opclass
  seq_scan   | 2
  seq_tup_read | 2
  idx_scan   | 99
  idx_tup_fetch | 99
  n_tup_ins  | 0
  n_tup_upd  | 0
  n_tup_del  | 0
  n_tup_hot_upd | 0
  n_live_tup | 0
  n_dead_tup | 0
  last_vacuum
  last_autovacuum
  last_analyze
  last_autoanalyze
```
```sql
SELECT * FROM pg_statio_all_tables;
```

<table>
<thead>
<tr>
<th>relid</th>
<th>2602</th>
</tr>
</thead>
<tbody>
<tr>
<td>schemaname</td>
<td>pg_catalog</td>
</tr>
<tr>
<td>relname</td>
<td>pg_amop</td>
</tr>
<tr>
<td>heap_blks_read</td>
<td>3</td>
</tr>
<tr>
<td>heap_blks_hit</td>
<td>114</td>
</tr>
<tr>
<td>idx_blks_read</td>
<td>5</td>
</tr>
<tr>
<td>idx_blks_hit</td>
<td>303</td>
</tr>
<tr>
<td>toast_blks_read</td>
<td></td>
</tr>
<tr>
<td>toast_blks_hit</td>
<td></td>
</tr>
<tr>
<td>tidx_blks_read</td>
<td></td>
</tr>
<tr>
<td>tidx_blks_hit</td>
<td></td>
</tr>
</tbody>
</table>

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Analyzing Activity

- Heavily used tables
- Unnecessary indexes
- Additional indexes
- Index usage
- TOAST usage
$ vmstat 5

<table>
<thead>
<tr>
<th>proc</th>
<th>memory</th>
<th>page</th>
<th>disks</th>
<th>faults</th>
<th>cpu</th>
</tr>
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<td>5721</td>
<td>819</td>
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<td>0</td>
<td>0</td>
<td>253</td>
<td>5736</td>
<td>948</td>
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<td>0</td>
<td>0</td>
<td>249</td>
<td>5917</td>
<td>959</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>261</td>
<td>6417</td>
<td>890</td>
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<td>0</td>
<td>0</td>
<td>84</td>
<td>113</td>
<td>0</td>
</tr>
</tbody>
</table>
```plaintext
$ iostat 5

tty     sd0     sd1     sd2
     tin  tout  sps  tps mspss    sps  tps mspss    sps  tps mspss    sps  tps mspss

7  119  244  11  6.1  0  0  27.3  0  0  18.1  9  1  4  0  86
0  86   20   1  1.4  0  0  0.0  0  0  0.0  2  0  2  0  96
0  82   61   4  3.6  0  0  0.0  0  0  0.0  2  0  2  0  97
0  65   6    0  0.0  0  0  0.0  0  0  0.0  1  0  2  0  97
12  90   31   2  5.4  0  0  0.0  0  0  0.0  4  0  3  0  93
24 173   6    0  4.9  0  0  0.0  0  0  0.0 48  0  3  0  49
0  91  3594  63  4.6  0  0  0.0  0  0  0.0 11  0  4  0  85
```
### Disk Usage

```bash
test=> \df *size*
```

<table>
<thead>
<tr>
<th>Schema</th>
<th>Name</th>
<th>Result data type</th>
<th>Argument data types</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>pg_catalog</td>
<td>pg_column_size</td>
<td>integer</td>
<td>&quot;any&quot;</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_database_size</td>
<td>bigint</td>
<td>name</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_database_size</td>
<td>bigint</td>
<td>oid</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_indexes_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_relation_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_relation_size</td>
<td>bigint</td>
<td>regclass, text</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_size_pretty</td>
<td>text</td>
<td>bigint</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_table_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_tablespace_size</td>
<td>bigint</td>
<td>name</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_tablespace_size</td>
<td>bigint</td>
<td>oid</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_total_relation_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
</tbody>
</table>
$ oid2name
All databases:
---------------------------------
18720  = test1
1      = template1
18719  = template0
18721  = test
18735  = postgres
18736  = cssi
$ cd /usr/local/pgsql/data/base
$ oid2name
All databases:
---------------------------------
16817 = test2
16578 = x
16756 = test
1 = template1
16569 = template0
16818 = test3
16811 = floattest

$ cd 16756
$ ls 1873*
18730 18731 18732 18735 18736 18737 18738 18739
$ oid2name -d test -o 18737
Tablename of oid 18737 from database "test":
-----------------------------------
18737  = ips

$ oid2name -d test -t ips
Oid of table ips from database "test":
-----------------------------------
18737  = ips

$ # show disk usage per database
$ cd /usr/local/pgsql/data/base
$ du -s * |
> while read SIZE OID
> do
>   echo "$SIZE `oid2name -q | grep ^$OID'`"
> done |
> sort -rn
2256  18721  = test
2135  18735  = postgres
Disk Balancing

- Move pg_wal to another drive using symlinks
- Tablespaces
Per-Database Tablespaces

DB1 → Disk 1
DB2 → Disk 1
DB3 → Disk 2
DB4 → Disk 3
Per-Object Tablespaces

disk 1

Disk 1

Disk 2

Disk 3
Analyzing Locking

$ ps -f -U postgres

<table>
<thead>
<tr>
<th>PID</th>
<th>TT</th>
<th>STAT</th>
<th>TIME</th>
<th>COMMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>9874</td>
<td>??</td>
<td>I</td>
<td>0:00.07</td>
<td>postgres test [local] idle in transaction (postmaster)</td>
</tr>
<tr>
<td>9835</td>
<td>??</td>
<td>S</td>
<td>0:00.05</td>
<td>postgres test [local] UPDATE waiting (postmaster)</td>
</tr>
<tr>
<td>10295</td>
<td>??</td>
<td>S</td>
<td>0:00.05</td>
<td>postgres test [local] DELETE waiting (postmaster)</td>
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</tbody>
</table>

test=> SELECT * FROM pg_locks;

<table>
<thead>
<tr>
<th>relation</th>
<th>database</th>
<th>transaction</th>
<th>pid</th>
<th>mode</th>
<th>granted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17142</td>
<td></td>
<td>9173</td>
<td>AccessShareLock</td>
<td>t</td>
</tr>
<tr>
<td>17143</td>
<td>17142</td>
<td></td>
<td>9173</td>
<td>RowExclusiveLock</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>472</td>
<td>ExclusiveLock</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>468</td>
<td>ShareLock</td>
<td>f</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>470</td>
<td>ExclusiveLock</td>
<td>t</td>
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<tr>
<td>16759</td>
<td>17142</td>
<td></td>
<td>9380</td>
<td>AccessShareLock</td>
<td>t</td>
</tr>
<tr>
<td>17143</td>
<td>17142</td>
<td></td>
<td>9338</td>
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<td>t</td>
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<tr>
<td>17143</td>
<td>17142</td>
<td></td>
<td>9338</td>
<td>RowExclusiveLock</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>468</td>
<td>ExclusiveLock</td>
<td>t</td>
</tr>
</tbody>
</table>
Log file rotation, syslog

Upgrading
  - pg_dump, restore
  - pg_upgrade
  - Slony

Migration
Administration Tools

- pgadmin
- phppgadmin
External Monitoring Tools

- Alerting: check_postgres, tail_n_mail, Nagios
- Server analysis: Munin, Cacti, Zabbix, Nagios, MRTG, Prometheus, Grafana
- Queries: pg_stat_statements, auto_explain, pgbadger
- Commercial: Postgres Enterprise Manager (PEM), Circonus, VividCortex
Monitoring Summary

Reporting

Operating System: vmstat, iostat
Process/Session: ps, top −c, pg_stat_activity
Query: pg_stat_activity.query, log_statement, log_statement_stats
Parser: log_parser_stats
Planner: log_planner_stats
Executor: log_executor_stats, pg_locks, log_lock_waits, pg_stat_activity.wait_event
time

Alerting / Aggregation

sar, check_postgres, log_temp_files
tail_n_mail
pg_stat_statements, log_min_duration_statement, pgbadger
auto_explain
e.g. pg_stat_all_tables
5. Recovery

https://www.flickr.com/photos/coastguardnews/
Nothing Required. Transactions in progress are rolled back.
Nothing Required. Transactions in progress are rolled back.
Nothing Required. Transactions in progress are rolled back.
Nothing Required. Transactions in progress are rolled back. Partial page writes are repaired.
Disk Failure

Restore from previous backup or use PITR.
Accidental DELETE

Recover table from previous backup, perhaps using pg_restore. It is possible to modify the backend code to make deleted tuples visible, dump out the deleted table and restore the original code. All tuples in the table since the previous vacuum will be visible. It is possible to restrict that so only tuples deleted by a specific transaction are visible.
Write-Ahead Log (WAL) Corruption

See pg_resetwal. Review recent transactions and identify any damage, including partially committed transactions.
File Deletion

It may be necessary to create an empty file with the deleted file name so the object can be deleted, and then the object restored from backup.
Accidental DROP TABLE

Restore from previous backup.
Accidental DROP INDEX

Recreate index.
Accidental DROP DATABASE

Restore from previous backup.
Restart problems are usually caused by write-ahead log problems. See pg_resetwal. Review recent transactions and identify any damage, including partially committed transactions.
Use REINDEX.
Table Corruption

Try reindexing the table. Try identifying the corrupt OID of the row and transfer the valid rows into another table using `SELECT...INTO...WHERE oid != ###`. Use `pageinspect` to analyze the internal structure of the table.
Conclusion

https://momjian.us/presentations