



crunchy data

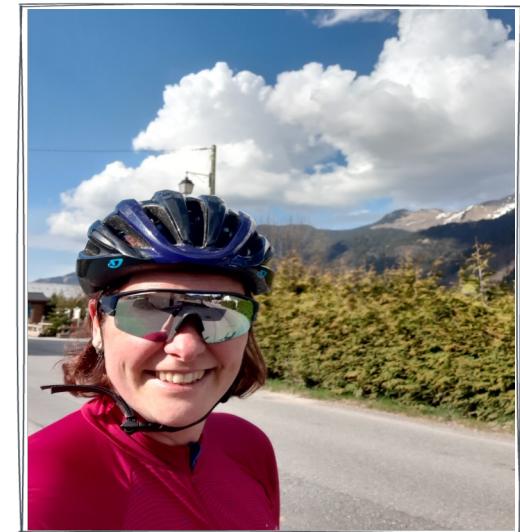
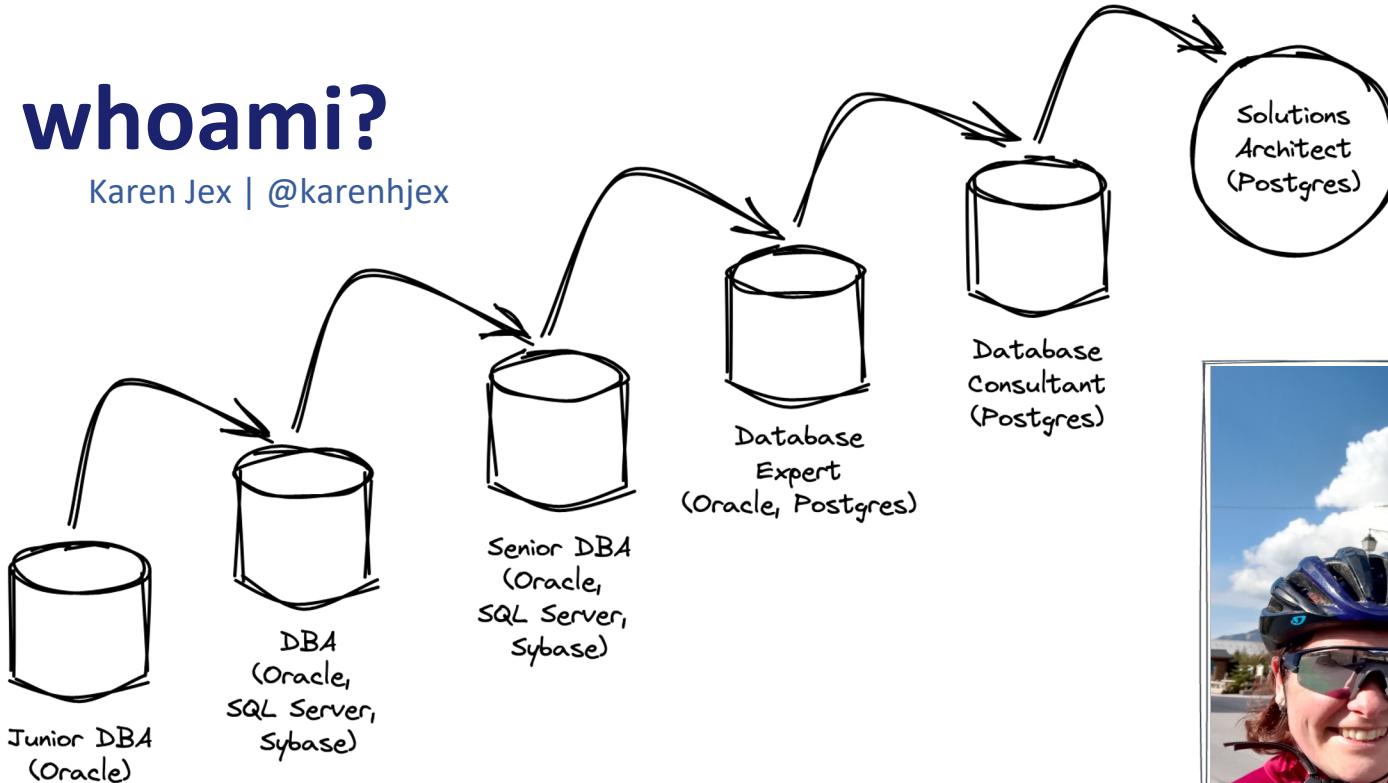
Everything You Wanted to Know about Databases as a Developer but Were Too Afraid to Ask Your DBA

Karen Jex | Senior Solutions Architect @ Crunchy Data

PyCon Italia, Florence | May 2023

whoami?

Karen Jex | @karenhjex



Introduction

- Databases are essential to most applications
- Most developers aren't trained in database administration
- DBAs are ~~grumpy~~ busy people

Agenda

- Database Architecture
- Users and Roles
- Database Objects
- Database Connections
- Database Operations and Transactions
- WAL
- Documentation

How to join in

- Your own Postgres server
- Postgres Playground:

<https://www.crunchydata.com/developers/playground>

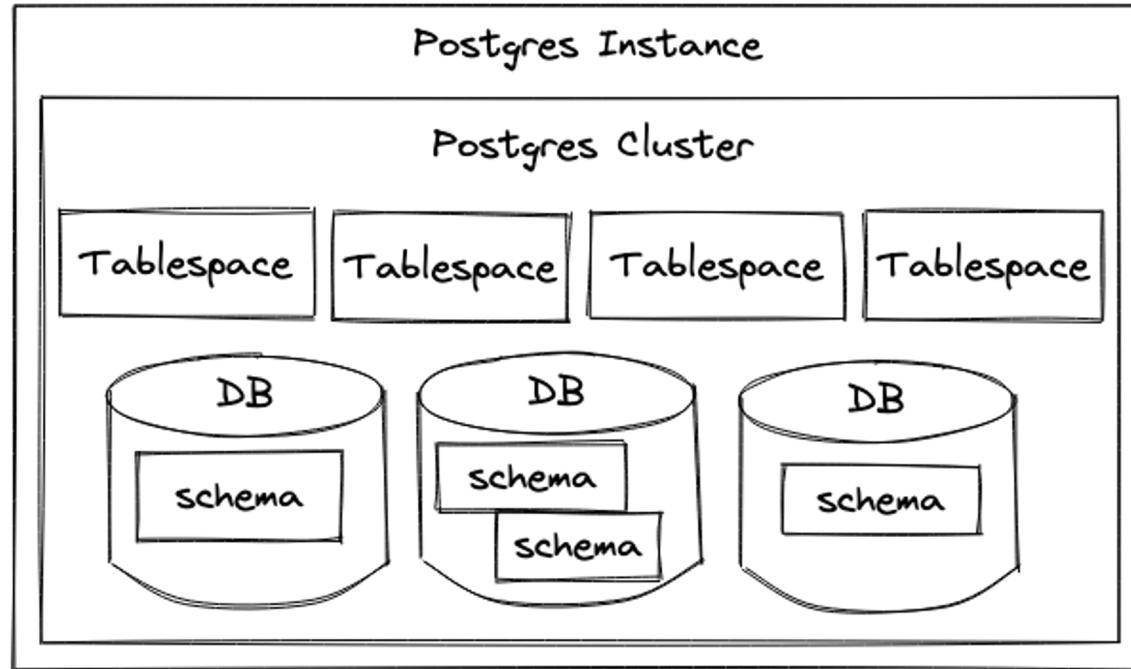


Agenda

- **Database Architecture**
- Users and Roles
- Database Objects
- Database Connections
- Database Operations and Transactions
- WAL
- Documentation

Database Architecture

<https://www.postgresql.org/docs/current/tutorial-arch.html>

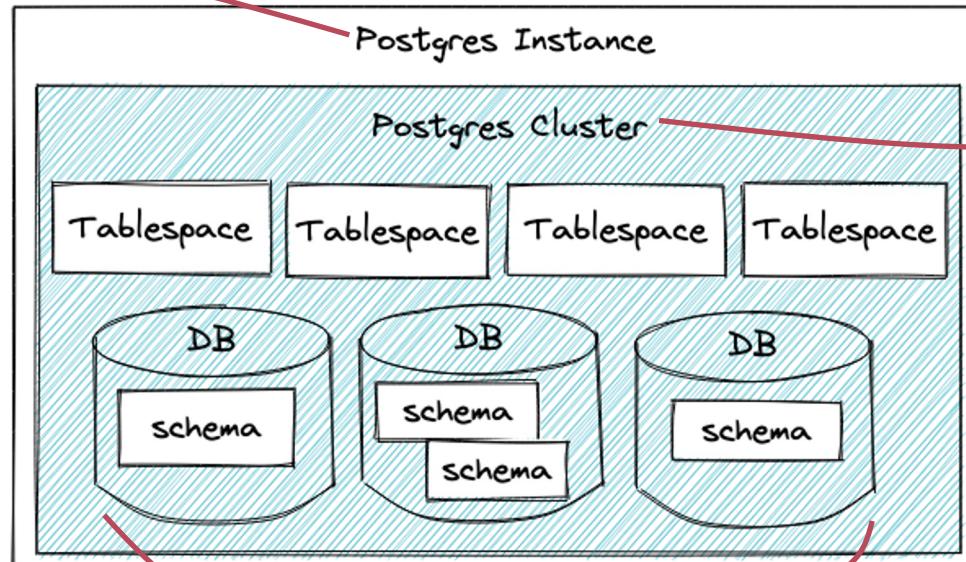


What is a PostgreSQL Cluster?

What is a PostgreSQL Cluster?

<https://www.postgresql.org/docs/current/creating-cluster.html>

managed by
single instance



Collection of DBs

How do I Install PostgreSQL?

How do I Install Postgres?

- Install from source code

<https://www.postgresql.org/docs/current/install-procedure.html>

- Install package for given platform

<https://www.postgresql.org/download/>

- Choose a managed service

<https://crunchybridge.com/register>

How do I Install Postgres?

Ubuntu 22.10 (Kinetic Kudu)

```
# 1. Configure the PostgreSQL repository
karen@ubuntu $ sudo sh -c 'echo "deb http://apt.postgresql.org/pub/repos/apt $(lsb_release -cs)-pgdg main" > /etc/apt/sources.list.d/pgdg.list'

# 2. Import the repository signing key
karen@ubuntu $ wget --quiet -O - https://www.postgresql.org/media/keys/ACCC4CF8.asc | sudo apt-key add -

# 3. Update the package lists
karen@ubuntu $ sudo apt-get update

# 4. Install PostgreSQL
karen@ubuntu $ sudo apt-get -y install postgresql-15
```

How do I Install Postgres?

Rocky Linux 9

```
# 1. Enable the pgdg repository  
  
karen@rocky9 $ sudo dnf install -y https://download.postgresql.org/pub/repos/yum/reporpm/EL-  
9-x86_64/pgdg-redhat-repo-latest.noarch.rpm  
  
# 2. Disable the build-in PostgreSQL module:  
  
karen@rocky9 $ sudo dnf -qy module disable postgresql  
  
# 3. Install PostgreSQL  
  
karen@rocky9 $ dnf -y install postgresql15-server
```

How do I Create a PostgreSQL Cluster?

How do I create a PostgreSQL Cluster?

```
postgres@rocky9 $ export PATH=$PATH:/usr/pgsql-15/bin  
postgres@rocky9 $ export PGDATA=/var/lib/pgsql/15/data  
postgres@rocky9 $
```

```
postgres@ubuntu $ export PATH=$PATH:/usr/lib/postgresql/15/bin  
postgres@ubuntu $ export PGDATA=/var/lib/postgresql/15/main
```

How do I create a PostgreSQL Cluster?

<https://www.postgresql.org/docs/current/app-initdb.html>

```
postgres@rocky9 $ export PATH=$PATH:/usr/pgsql-14/bin  
postgres@rocky9 $ export PGDATA=/var/lib/pgsql/14/data  
postgres@rocky9 $ initdb
```

How do I create a PostgreSQL Cluster?

<https://www.postgresql.org/docs/current/app-initdb.html>

```
postgres@rocky9 $ export PATH=$PATH:/usr/pgsql-14/bin  
postgres@rocky9 $ export PGDATA=/var/lib/pgsql/14/data  
postgres@rocky9 $ initdb
```

...

Success. You can now start the database server using:

```
pg_ctl -D /var/lib/pgsql/15data -l logfile start
```

How do I Start (or Stop) PostgreSQL?

How do I Start Postgres?

<https://www.postgresql.org/docs/current/app-pg-ctl.html>

```
postgres@rocky9 $ pg_ctl -l logfile start
```

How do I Start Postgres?

<https://www.postgresql.org/docs/current/app-pg-ctl.html>

```
postgres@rocky9 $ pg_ctl -l logfile start
```

```
waiting for server to start.... done  
server started
```

How do I Start Postgres?

<https://www.postgresql.org/docs/current/app-pg-ctl.html>

```
postgres@rocky9 $ ps -ef|grep postgres
postgres  65021      1  0 12:43 ?          00:00:00 /usr/pgsql-15/bin/postgres
postgres  65022  65021  0 12:43 ?          00:00:00 postgres: logger
postgres  65023  65021  0 12:43 ?          00:00:00 postgres: checkpointer
postgres  65024  65021  0 12:43 ?          00:00:00 postgres: background writer
postgres  65026  65021  0 12:43 ?          00:00:00 postgres: walwriter
postgres  65027  65021  0 12:43 ?          00:00:00 postgres: autovacuum launcher
postgres  65028  65021  0 12:43 ?          00:00:00 postgres: logical replication launcher
```

How do I Stop Postgres?

<https://www.postgresql.org/docs/current/app-pg-ctl.html>

```
postgres@rocky9 $ pg_ctl stop
```

How do I Stop Postgres?

<https://www.postgresql.org/docs/current/app-pg-ctl.html>

```
postgres@rocky9 $ pg_ctl stop  
waiting for server to shut down.... done  
server stopped
```

How do I Control Postgres using systemd?

```
root@rocky9 $ systemctl start postgresql-15  
root@rocky9 $
```

How do I Control Postgres using systemd?

```
root@rocky9 $ systemctl start postgresql-15  
root@rocky9 $ systemctl status postgresql-15
```

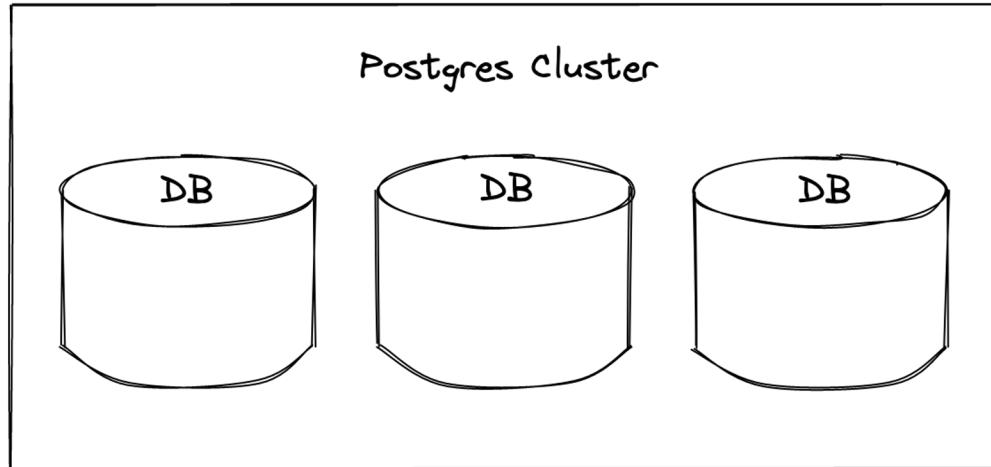
How do I Control Postgres using systemd?

```
root@rocky9 $ systemctl start postgresql-15
root@rocky9 $ systemctl status postgresql-15
● postgresql-15.service - PostgreSQL 15 database server
...
Active: active (running) since Thu 2023-05-11 13:16:40 UTC; 7s ago
...
...
```

What is a Database?

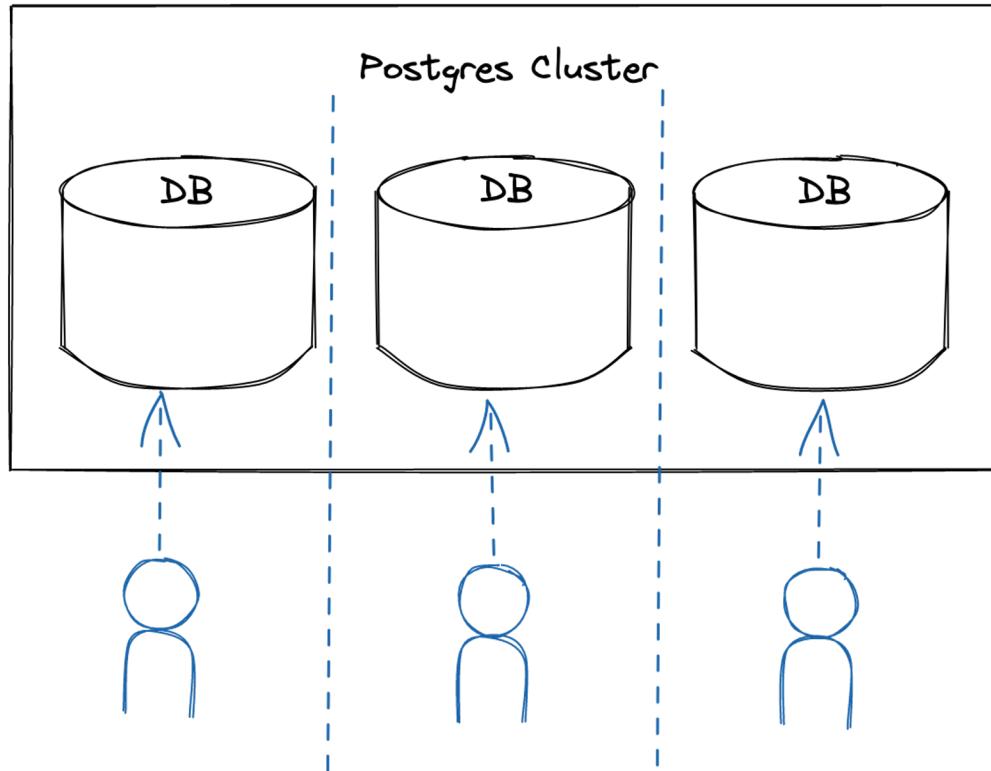
What is a Database?

<https://www.postgresql.org/docs/current/managing-databases.html>



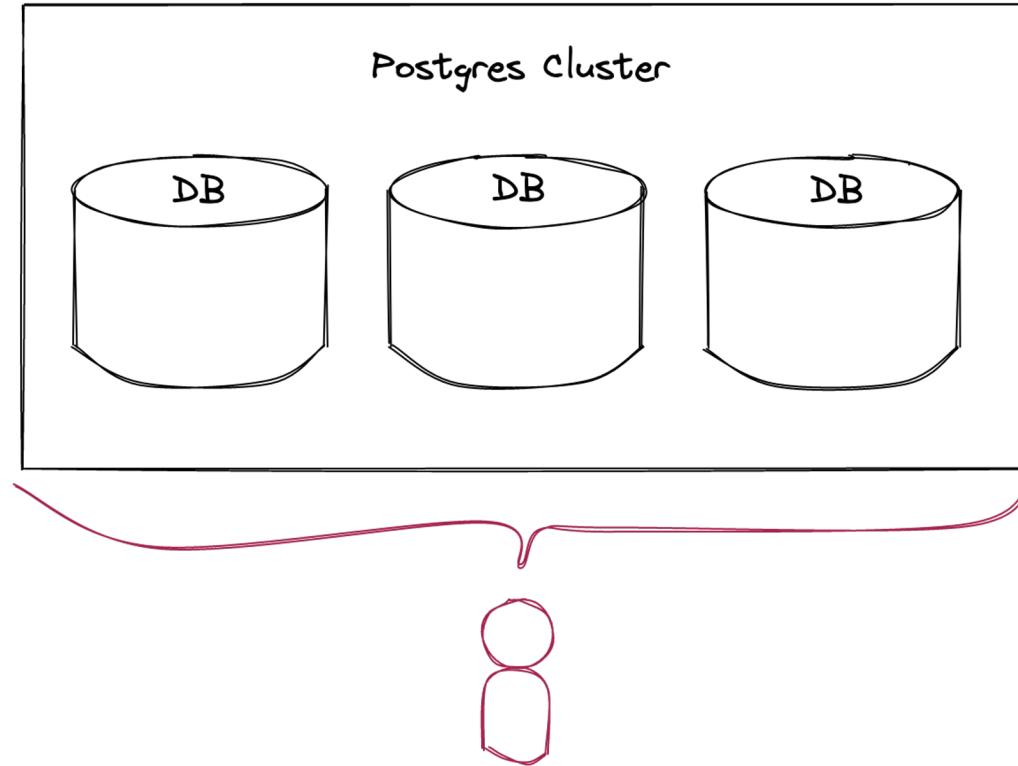
What is a Database?

<https://www.postgresql.org/docs/current/managing-databases.html>



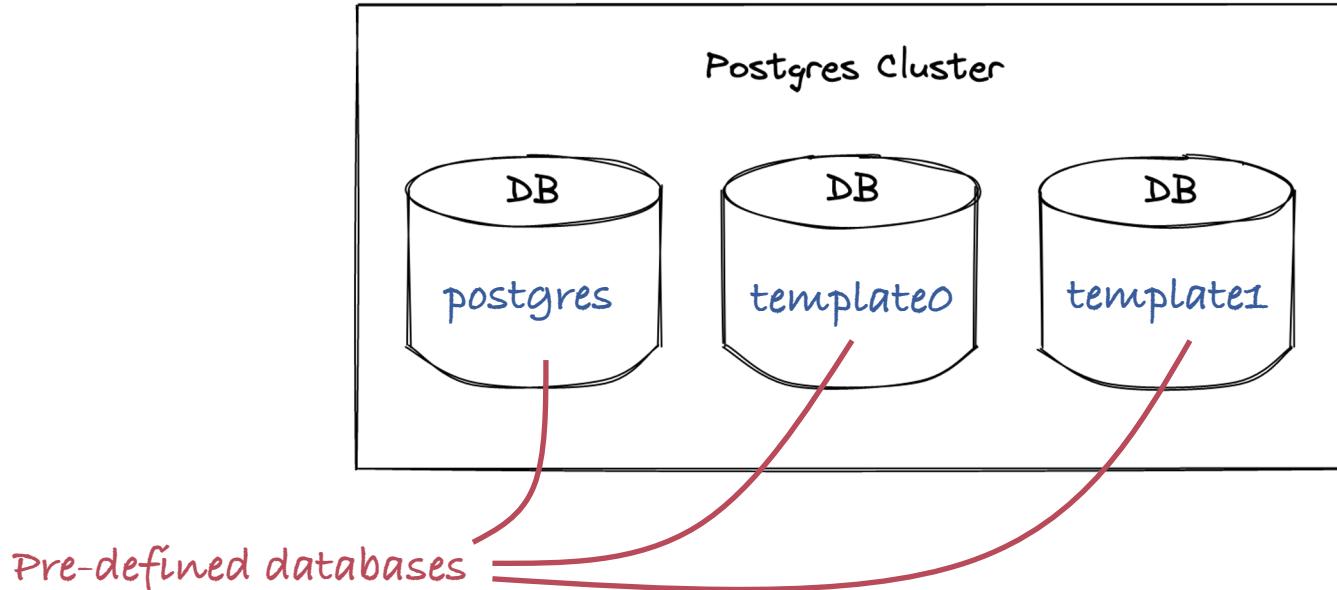
What is a Database?

<https://www.postgresql.org/docs/current/managing-databases.html>



What is a Database?

<https://www.postgresql.org/docs/current/managing-databases.html>



Aside: What is psql?

Aside: What is a psql?

<https://www.postgresql.org/docs/current/app-psql.html>

- Command line tool
- Execute commands and/or scripts against the database
 - SQL
 - psql commands: e.g. \c to connect to a database \d to view table details

How do I Create a Database?

How do I Create a Database?

<https://www.postgresql.org/docs/current/sql-createdatabase.html>

```
postgres@rocky9 $ psql
psql (15.2)
Type "help" for help.
```

```
postgres=#
```

How do I Create a Database?

<https://www.postgresql.org/docs/current/sql-createdatabase.html>

```
postgres@rocky9 $ psql
psql (15.2)
Type "help" for help.

postgres=# CREATE DATABASE firenze;
```

How do I Create a Database?

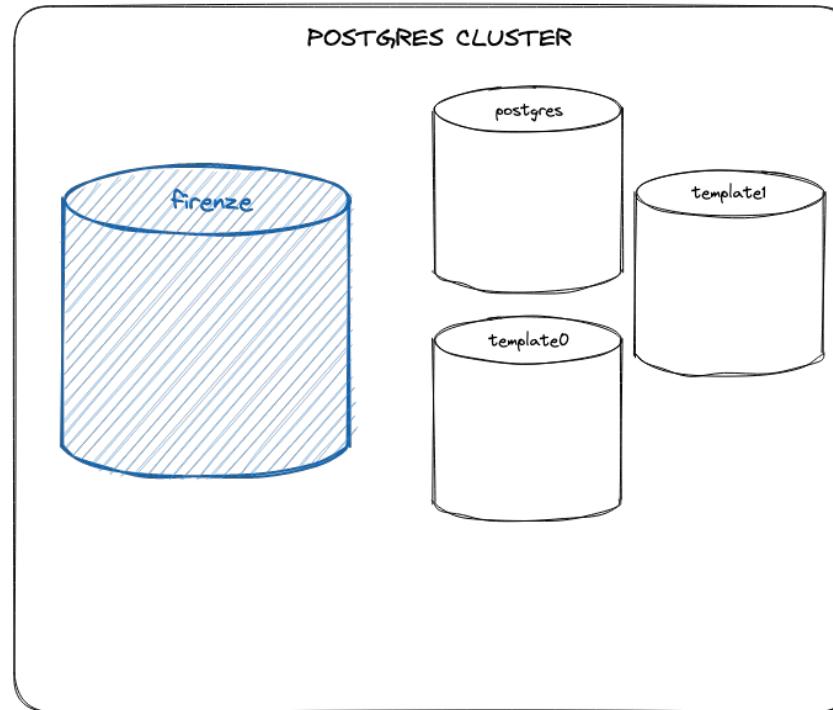
<https://www.postgresql.org/docs/current/sql-createdatabase.html>

```
postgres@rocky9 $ psql
psql (15.2)
Type "help" for help.

postgres=# CREATE DATABASE firenze;
CREATE DATABASE
```

How do I List my Databases?

The cluster so far:



How do I List my Databases?

```
postgres=# \l
```

How do I List my Databases?

```
postgres=# \l
                                         List of databases
   Name    |  Owner   | Encoding | Collate      | Ctype      | ...
-----+-----+-----+-----+-----+-----+...
 firenze | postgres | UTF8     | en_US.UTF-8 | en_US.UTF-8 | ...
 postgres | postgres | UTF8     | en_US.UTF-8 | en_US.UTF-8 | ...
 template0 | postgres | UTF8     | en_US.UTF-8 | en_US.UTF-8 | ...
                               |          |           |           |           | ...
 template1 | postgres | UTF8     | en_US.UTF-8 | en_US.UTF-8 | ...
                               |          |           |           |           | ...
(4 rows)
```

How do I List my Databases?

<https://www.postgresql.org/docs/current/catalogs.html>

```
postgres=# SELECT datname FROM pg_database;
```

How do I List my Databases?

<https://www.postgresql.org/docs/current/catalogs.html>

```
postgres=# SELECT datname FROM pg_database;

datname
-----
firenze
Postgres
template0
template1
(4 rows)
```

What is a Tablespace?

What is a Tablespace?

And why should I create one?

- Physical location of the database objects
- Default tablespace pg_default
- Allows control of the disk layout of a PostgreSQL installation
- Accessible to the **entire cluster**

How do I Create a Tablespace?

How do I Create a Tablespace?

<https://www.postgresql.org/docs/current/sql-createtablespace.html>

```
karen@rocky9 $ sudo mkdir -p /pycon_tablespaces/duomo
karen@rocky9 $ sudo chown postgres:postgres /pycon_tablespaces/duomo
```

How do I Create a Tablespace?

<https://www.postgresql.org/docs/current/sql-createtablespace.html>

```
postgres@rocky9 $ psql -c "CREATE TABLESPACE duomo location '/pycon_tablespaces/duomo'"
```

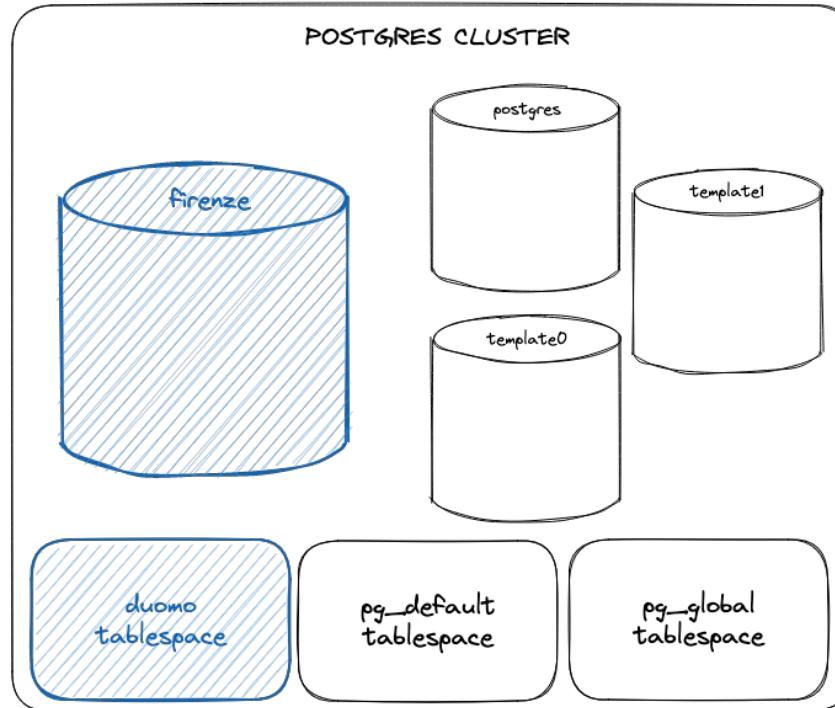
How do I Create a Tablespace?

<https://www.postgresql.org/docs/current/sql-createtablespace.html>

```
postgres@rocky9 $ psql -c "CREATE TABLESPACE duomo location '/pycon_tablespaces/duomo'"  
CREATE TABLESPACE
```

How do I List my Tablespaces?

The cluster so far:



How do I List my Tablespaces?

```
postgres=# \db
```

How do I List my Tablespaces?

```
postgres=# \db
              List of tablespaces
   Name    |  Owner   |          Location
-----+-----+-----+
 pg_default  | postgres |
 pg_global   | postgres |
 duomo       | postgres | /pycon_tablespaces/duomo
(3 rows)
```

How do I List my Tablespaces?

```
postgres=# \db+ duomo
```

How do I List my Tablespaces?

```
postgres=# \db+ duomo
          Name | Owner | Location | Access privileges | Options | Size | ...
-----+-----+-----+-----+-----+-----+-----+
duomo | postgres | /pycon_tablespaces/duomo |           |        | 0 bytes | ...
(1 row)
```

How do I List my Tablespaces?

<https://www.postgresql.org/docs/current/catalogs.html>

```
postgres=# SELECT spcname FROM pg_tablespace;
```

How do I List my Tablespaces?

<https://www.postgresql.org/docs/current/catalogs.html>

```
postgres=# SELECT spcname FROM pg_tablespace;

          spcname
-----
pg_default
pg_global
duomo
(3 rows)
```

a namespace

logical collection of objects

belongs to a database

What is a Schema?

not a physical location

may be different from owner

How do I Create a Schema?

How do I Create a Schema?

<https://www.postgresql.org/docs/current/sql-createschema.html>

```
postgres-# \c firenze
You are now connected to database "firenze" as user "postgres".
firenze-#
```

How do I Create a Schema?

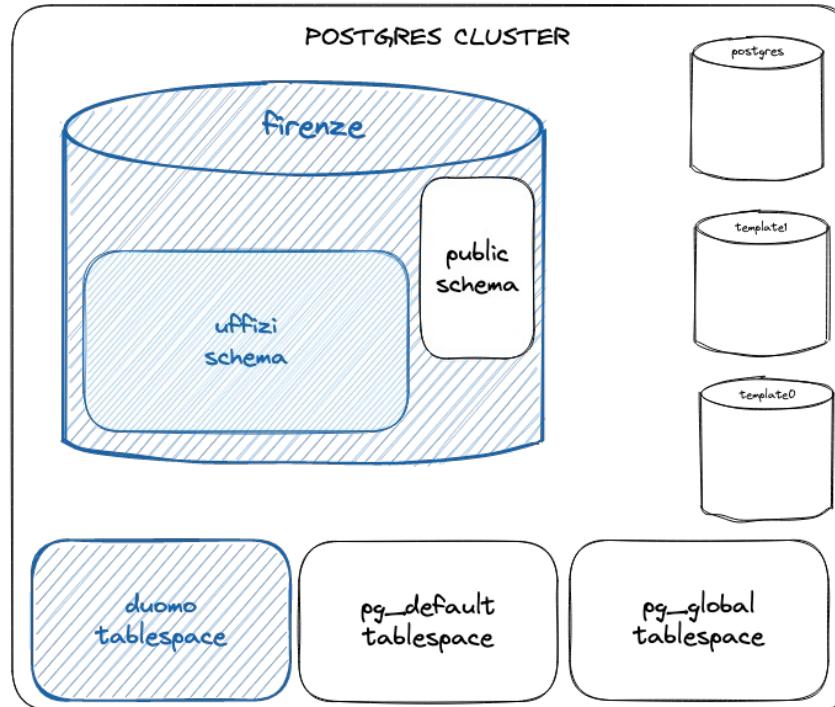
<https://www.postgresql.org/docs/current/sql-createschema.html>

```
postgres-# \c firenze
You are now connected to database "firenze" as user "postgres".
firenze-# CREATE SCHEMA uffizi;
CREATE SCHEMA
```

How do I List my Schemas?

```
postgres=# \dn
      List of schemas
 Name |        Owner
-----+-----
 uffizi | postgres
 public | pg_database_owner
(2 rows)
```

The cluster so far:



Agenda

- Database Architecture
- **Users and Roles**
- Database Objects
- Database Connections
- Database Operations and Transactions
- WAL
- Documentation

What's the Difference Between a User and a Role?

USER and ROLE are synonyms

CREATE USER:

LOGIN by default

CREATE ROLE:

LOGIN by default

Users and Roles

Cluster-wide

can be granted to another user/role

represents a user or a group

can own objects

How do I Create a Role?

How do I Create a Role?

<https://www.postgresql.org/docs/current/sql-createrole.html>

```
postgres@rocky9 $ psql -c "CREATE ROLE michelangelo"  
CREATE ROLE  
  
postgres@rocky9 $
```

How do I Create a Role?

<https://www.postgresql.org/docs/current/sql-createrole.html>

```
postgres@rocky9 $ psql -c "CREATE ROLE michelangelo"  
CREATE ROLE  
  
postgres@rocky9 $ psql -d firenze -U michelangelo
```

How do I Create a Role?

<https://www.postgresql.org/docs/current/sql-createrole.html>

```
postgres@rocky9 $ psql -c "CREATE ROLE michelangelo"
CREATE ROLE

postgres@rocky9 $ psql -d firenze -U michelangelo
psql: error: connection to server on socket "/var/run/postgresql/.s.PGSQL.5432"
failed: FATAL:  role "michelangelo" is not permitted to log in
```

How do I Create a User?

How do I Create a User?

<https://www.postgresql.org/docs/current/sql-createuser.html>

```
postgres@rocky9 $ psql -c "CREATE USER botticelli"
```

How do I Create a User Role?

<https://www.postgresql.org/docs/current/sql-createuser.html>

```
postgres@rocky9 $ psql -c "CREATE USER botticelli"  
CREATE ROLE
```

How do I Create a User Role?

<https://www.postgresql.org/docs/current/sql-createuser.html>

```
postgres@rocky9 $ psql -c "CREATE USER botticelli"  
CREATE ROLE  
  
postgres@rocky9 $ psql -d firenze -U botticelli
```

How do I Create a User Role?

<https://www.postgresql.org/docs/current/sql-createuser.html>

```
postgres@rocky9 $ psql -c "CREATE USER botticelli"  
CREATE ROLE
```

```
postgres@rocky9 $ psql -d firenze -U botticelli  
psql (15.2)  
Type "help" for help.
```

```
firenze=>
```

How do I List my Roles?

```
postgres=# \du

List of roles
Role name | Attributes | Member of
-----+-----+-----+
botticelli |           | {}
michelangelo | Cannot login | {}
postgres     | Superuser, Create role, Create DB, Replication, Bypass RLS | {}
```

What is a Privilege?

What is a Privilege?

SELECT, INSERT, UPDATE,
DELETE, TRUNCATE, CREATE...

DATABASE, FUNCTION,
SCHEMA, TABLE...

- Permission to perform **action(s)** on **object(s)**
- Granted by owner of object (or by a superuser)
- e.g. Michelangelo allows Botticelli to view all works in Uffizi
- Default privileges apply to certain objects created in the future
- e.g. allow Botticelli to view any future works installed in Uffizi

Granting Privileges

<https://www.postgresql.org/docs/current/ddl-priv.html>

```
firenze=# GRANT CREATE ON DATABASE firenze TO michelangelo;
GRANT

firenze=# GRANT ALL ON SCHEMA uffizi TO michelangelo;
GRANT

firenze=# GRANT CREATE ON TABLESPACE duomo TO michelangelo;
GRANT

firenze=# ALTER ROLE michelangelo WITH LOGIN;
ALTER ROLE
```

Granting Privileges

<https://www.postgresql.org/docs/current/sql-alterdefaultprivileges.html>

```
firenze=# GRANT SELECT ON ALL TABLES IN SCHEMA uffizi TO botticelli;  
GRANT
```

```
firenze=# ALTER DEFAULT PRIVILEGES IN SCHEMA uffizi  
Firenze-# GRANT SELECT ON TABLES TO botticelli;  
ALTER DEFAULT PRIVILEGES
```

Agenda

- Database Architecture
- Users and Roles
- **Database Objects**
- Database Connections
- Database Operations and Transactions
- WAL
- Documentation

Database Objects

- Table
- Index
- Constraint
- View
- Materialized View
- Sequence

What is a Table?

What is a Table?

hall_id	hall_num	floor	description
1	10-14	2	Botticelli
2	35	2	Michelangelo & the Florentines
3	66	1	Raphael

hall

- A “relation”
- Data in columns and rows
- Rows (“tuples”) are not ordered

work_id	work_title	work_artist	hall_id
1	The Spring	Botticelli	1
2	Tondo Doni	Michelangelo	2
3	Self-Portrait	Raphael	3

artwork

How do I Create a Table?

How do I Create a Table?

<https://www.postgresql.org/docs/current/sql-createtable.html>

```
postgres@rocky9 $ psql -d firenze -U michelangelo
psql (15.2)
Type "help" for help.

firenze=>
```

How do I Create a Table?

<https://www.postgresql.org/docs/current/sql-createtable.html>

```
firenze=> CREATE TABLE uffizi.hall (  
firenze(>
```

hall_id	hall_num	floor	description
1	10-14	2	Botticelli
2	35	2	Michelangelo & the Florentines
3	66	1	Raphael

hall

How do I Create a Table?

<https://www.postgresql.org/docs/current/sql-createtable.html>

```
firenze=> CREATE TABLE uffizi.hall (
firenze(> hall_id integer,
firenze(> hall_num text,
firenze(> floor integer,
firenze(> description text)
firenze->
```

hall_id	hall_num	floor	description
1	10-14	2	Botticelli
2	35	2	Michelangelo & the Florentines
3	66	1	Raphael

hall

How do I Create a Table?

<https://www.postgresql.org/docs/current/sql-createtable.html>

```
firenze=> CREATE TABLE uffizi.hall (
firenze(> hall_id integer,
firenze(> hall_num text,
firenze(> floor integer,
firenze(> description text)
firenze-> TABLESPACE duomo;
CREATE TABLE
```

hall_id	hall_num	floor	description
1	10-14	2	Botticelli
2	35	2	Michelangelo & the Florentines
3	66	1	Raphael

hall

What is a Sequence?

What is a Sequence?

Object that generates a sequence of integers

- Specific to a schema
- Used to generate unique numeric identifiers
- Implemented as a single row table

1, 2, 3, 4, 5, 6...

How do I Create a Sequence?

How do I Create a Sequence?

<https://www.postgresql.org/docs/current/sql-createsequence.html>

```
firenze=> CREATE SEQUENCE uffizi.s_hall  
firenze-> INCREMENT BY 1 MINVALUE 1 NO MAXVALUE;  
CREATE SEQUENCE
```

How do I Create a Sequence?

<https://www.postgresql.org/docs/current/sql-createsequence.html>

```
firenze=> CREATE SEQUENCE uffizi.s_hall
firenze-> INCREMENT BY 1 MINVALUE 1 NO MAXVALUE;
CREATE SEQUENCE

firenze-> \ds *.*  
      List of relations  
 Schema |   Name    |   Type   |   Owner  
-----+-----+-----+-----  
 uffizi | s_hall | sequence | michelangelo  
(1 row)
```

How do I Create a Sequence?

<https://www.postgresql.org/docs/current/sql-createsequence.html>

```
firenze=> ALTER TABLE uffizi.hall
firenze-> ALTER COLUMN hall_id
firenze-> SET DEFAULT nextval('uffizi.s_hall');
ALTER TABLE
```

How do I Auto Generate an ID Column?

How do I Auto Generate an ID Column?

<https://www.postgresql.org/docs/current/sql-createtable.html>

```
firenze=> CREATE TABLE uffizi.artwork (
firenze(> work_id integer,
firenze(> work_title text,
firenze(> work_artist text,
firenze(> hall_id integer)
```

work_id	work_title	work_artist	hall_id
1	The Spring	Botticelli	1
2	Tondo Doni	Michelangelo	2
3	Self-Portrait	Raphael	3

artwork

How do I Auto Generate an ID Column?

<https://www.postgresql.org/docs/current/sql-createtable.html>

```
firenze=> CREATE TABLE uffizi.artwork (
firenze(> work_id integer GENERATED ALWAYS AS IDENTITY,
firenze(> work_title text,
firenze(> work_artist text,
firenze(> hall_id integer)
```

work_id	work_title	work_artist	hall_id
1	The Spring	Botticelli	1
2	Tondo Doni	Michelangelo	2
3	Self-Portrait	Raphael	3

artwork

How do I Auto Generate an ID Column?

<https://www.postgresql.org/docs/current/sql-createtable.html>

```
firenze=> CREATE TABLE uffizi.artwork (
firenze(> work_id integer GENERATED ALWAYS AS IDENTITY,
firenze(> work_title text,
firenze(> work_artist text,
firenze(> hall_id integer)
firenze-> TABLESPACE duomo;
CREATE TABLE
```

work_id	work_title	work_artist	hall_id
1	The Spring	Botticelli	1
2	Tondo Doni	Michelangelo	2
3	Self-Portrait	Raphael	3

artwork

How do I View the Table Definitions?

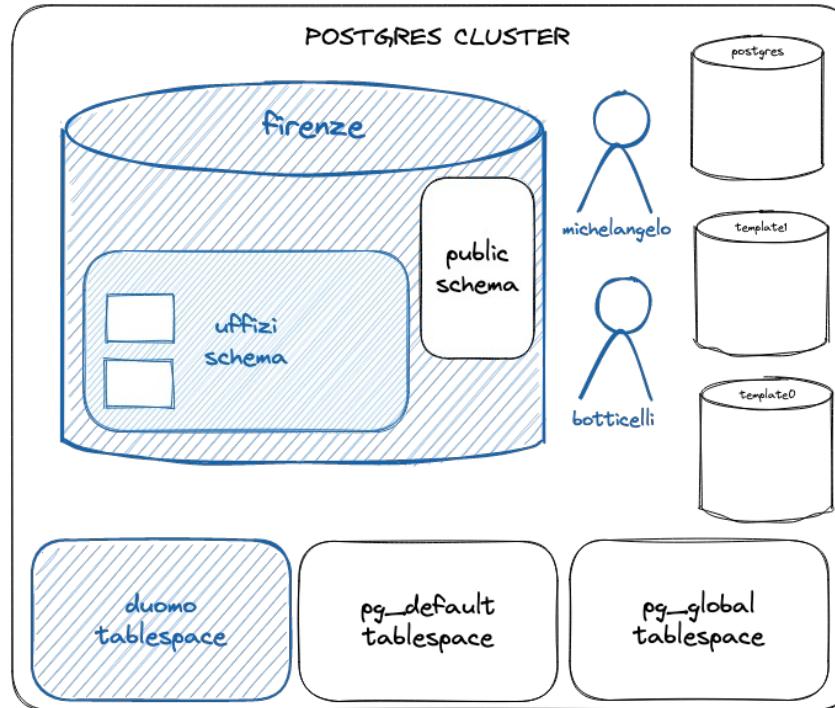
How do I View the Table Definitions?

```
firenze=> \d uffizi.hall
              Table "uffizi.hall"
   Column |  Type   | Collation | Nullable |          Default
-----+-----+-----+-----+
 hall_id | integer |           |          | nextval('uffizi.s_hall'::regclass)
 hall_num | text    |           |          |
 floor    | integer |           |          |
 description | text   |           |          |
Tablespace: "duomo"
```

How do I View the Table Definitions?

```
firenze=> \d uffizi.artwork
Table "uffizi.artwork"
 Column | Type | Collation | Nullable | Default
-----+-----+-----+-----+
 work_id | integer |           | not null | generated always as identity
 work_title | text |           |
 work_artist | text |           |
 hall_id | integer |           |
Tablespace: "duomo"
```

The cluster so far:



What is an Index?

INDEX

KEYWORD

Botticelli

Caravaggio

Correggio

Giotto

Leonardo

Mantegna

Michelangelo

Raffaello

PAGES

12,65,43,227

5,128, 206

7,42,48

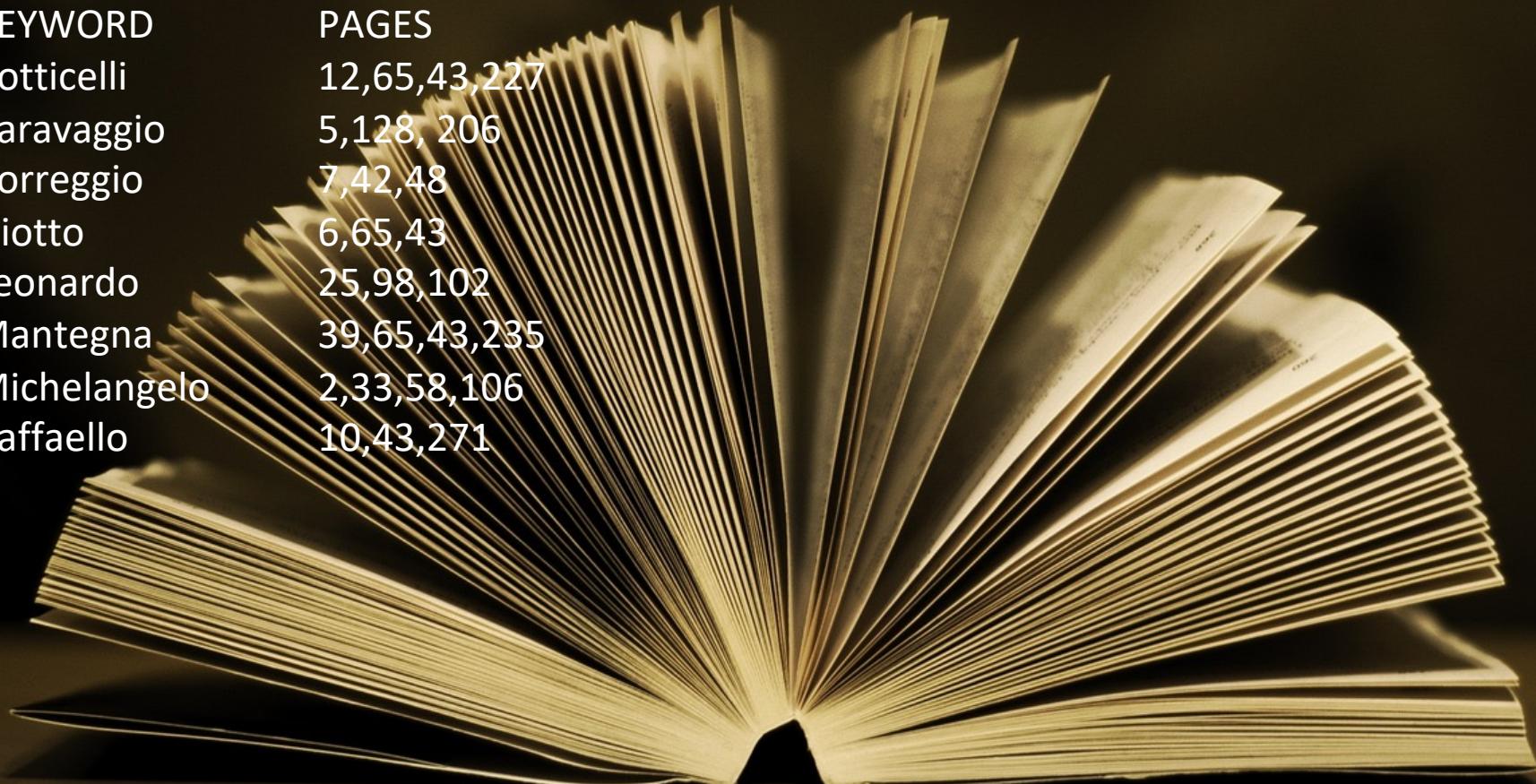
6,65,43

25,98,102

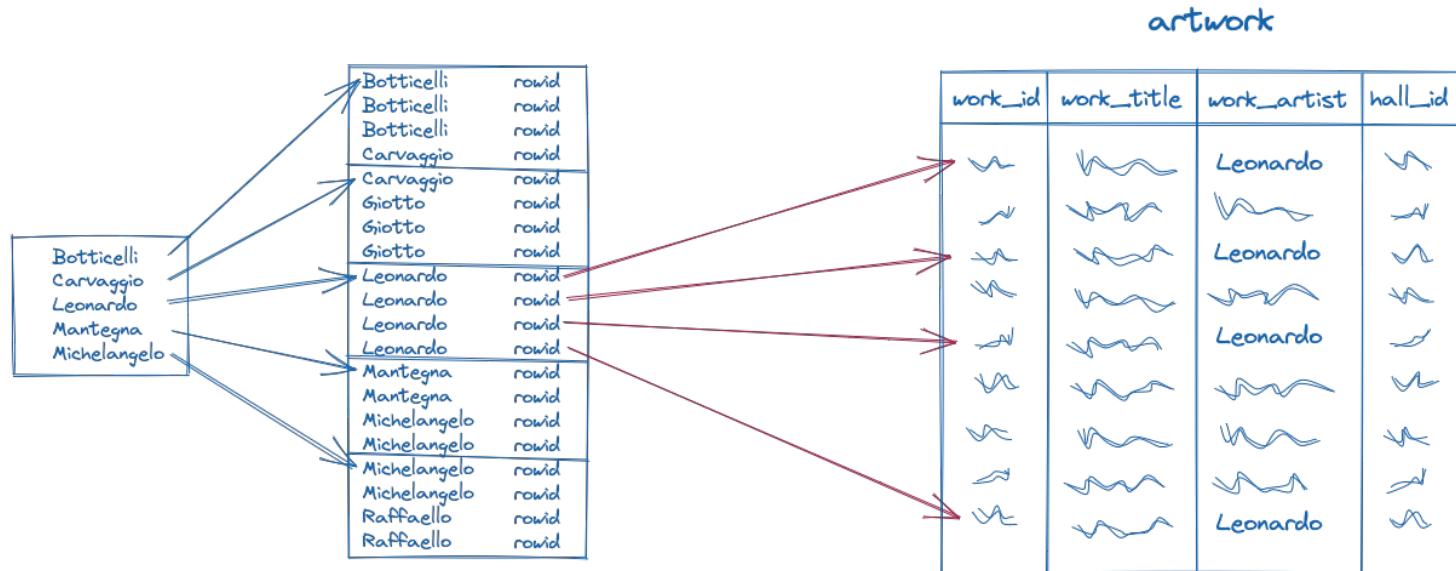
39,65,43,235

2,33,58,106

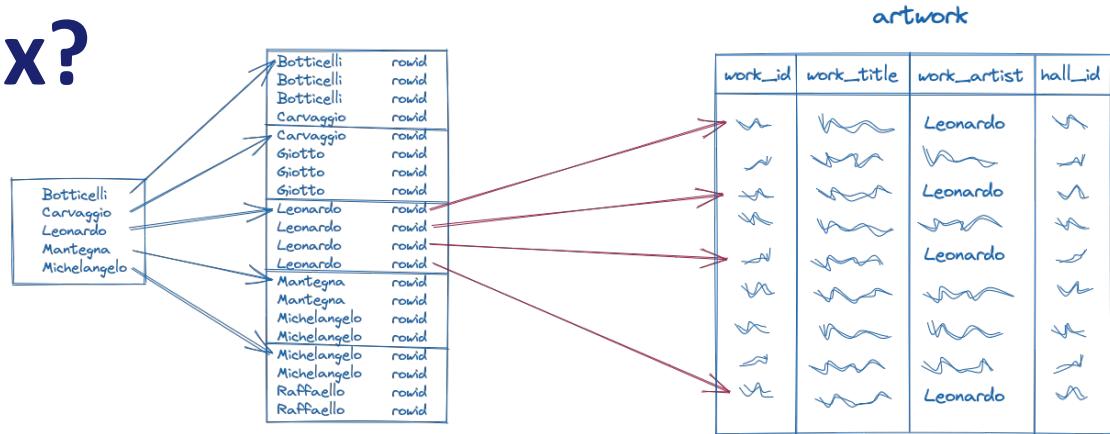
10,43,271



What is an Index?



What is an Index?



- Can create on one or more columns or expressions
- Can speed up searches based on values of column(s) in the index
- Postgres index types: b-tree, Hash, GiST, SP-GiST, GIN and BRIN
- Default type is **b-tree** (balanced tree)

How do I Create an Index?

How do I Create an Index?

<https://www.postgresql.org/docs/current/sql-createindex.html>

```
firenze=> CREATE INDEX artwork_artist  
firenze->
```

How do I Create an Index?

<https://www.postgresql.org/docs/current/sql-createindex.html>

```
firenze=> CREATE INDEX artwork_artist
firenze-> ON uffizi.artwork( lower(work_artist) )
firenze->
```

useful for this type of query:

```
SELECT * FROM uffizi.artwork
WHERE lower(work_artist)='leonardo';
```

How do I Create an Index?

<https://www.postgresql.org/docs/current/sql-createindex.html>

```
firenze=> CREATE INDEX artwork_artist
firenze-> ON uffizi.artwork( lower(work_artist) )
firenze-> TABLESPACE duomo;
CREATE INDEX

firenze=> CREATE INDEX artwork_hall_id
firenze-> ON uffizi.artwork(hall_id)
firenze-> TABLESPACE duomo;
CREATE INDEX
```

How do I Create an Index?

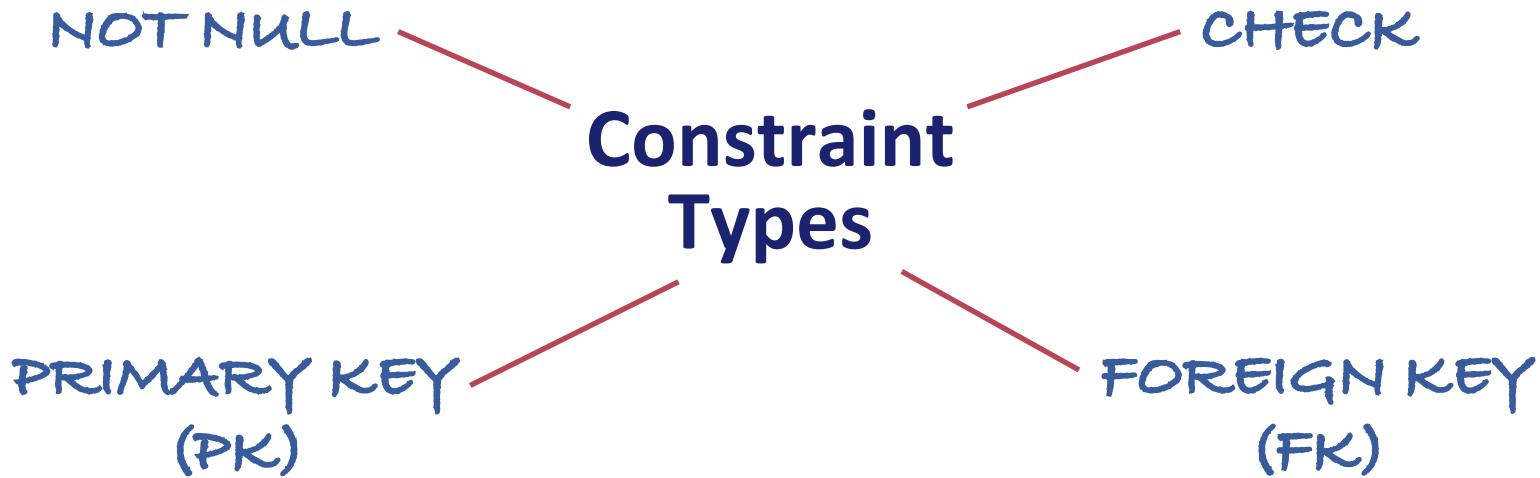
<https://www.postgresql.org/docs/current/sql-createindex.html>

```
firenze=> \d uffizi.artwork
              Table "uffizi.artwork"
   Column  |  Type   | Collation | Nullable |          Default
-----+-----+-----+-----+-----+
 work_id | integer |           | not null | generated always as identity
 work_title | text |           |           |
 work_artist | text |           |           |
 hall_id | integer |           |           |
Indexes:
    "artwork_artist" btree (lower(work_artist)), tablespace "duomo"
    "artwork_hall_id" btree (hall_id), tablespace "duomo"
Tablespace: "duomo"
```

What is a Constraint?

What is a Constraint?

<https://www.postgresql.org/docs/current/ddl-constraints.html>



What is a NOT NULL Constraint?

<https://www.postgresql.org/docs/current/ddl-constraints.html>

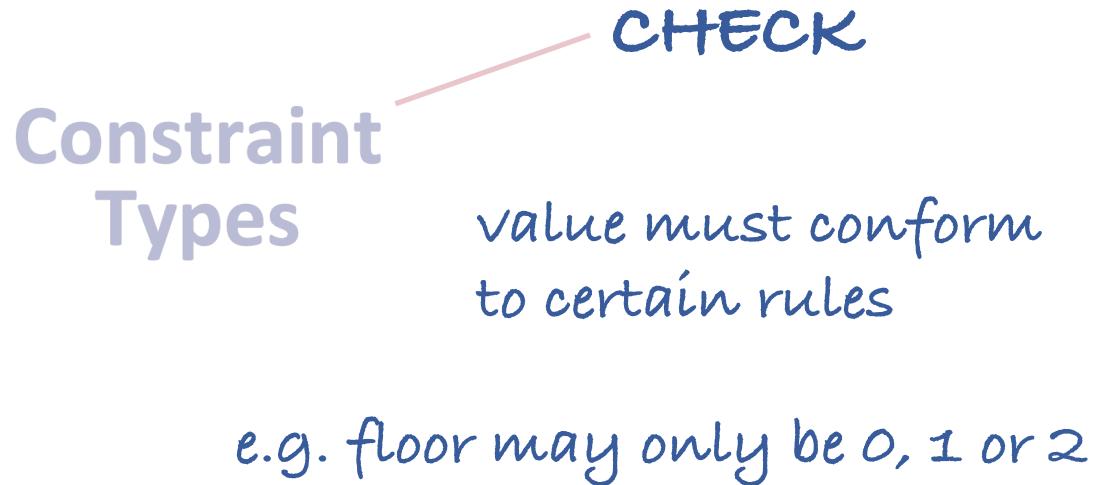
NOT NULL

Column must
contain a value

Constraint
Types

What is a CHECK Constraint?

<https://www.postgresql.org/docs/current/ddl-constraints.html>



What is a PRIMARY KEY Constraint?

<https://www.postgresql.org/docs/current/ddl-constraints.html>

PRIMARY KEY
(PK)

Constraint
Types

- Primary Key column(s) uniquely identify a table row
- PK Constraint + unique index
- only one PK per table
- Cols in PK must be NOT NULL

What is a FOREIGN KEY Constraint?

<https://www.postgresql.org/docs/current/ddl-constraints.html>

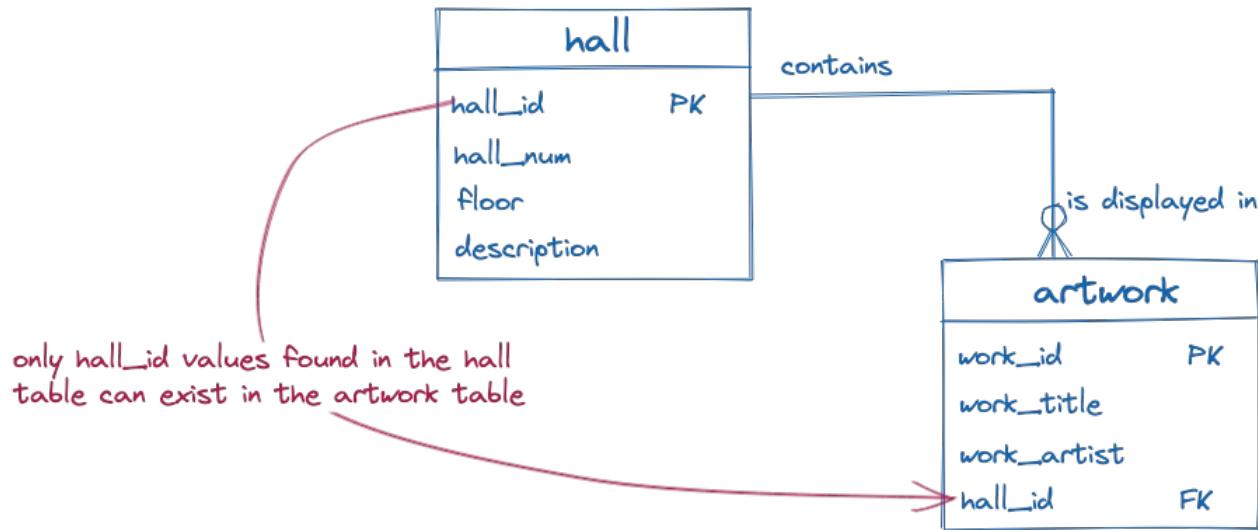
- Relationship between parent table and child table
- Enforces referential integrity
- FK column in child table must match a value in the parent table

Constraint Types

FOREIGN KEY
(FK)

What is a FOREIGN KEY Constraint?

<https://www.postgresql.org/docs/current/ddl-constraints.html>



How do I Create a Primary Key Constraint?

How do I Create a PK Constraint?

<https://www.postgresql.org/docs/current/sql-altertable.html>

```
firenze=> ALTER TABLE uffizi.hall
firenze-> ADD CONSTRAINT hall_pk PRIMARY KEY (hall_id)
firenze-> USING INDEX TABLESPACE duomo;
ALTER TABLE
```

How do I Create a PK Constraint?

<https://www.postgresql.org/docs/current/sql-altertable.html>

```
firenze=> \d uffizi.hall
              Table "uffizi.hall"
   Column  |  Type   | Collation | Nullable |          Default
-----+-----+-----+-----+-----+
 hall_id | integer |           | not null | nextval('uffizi.s_hall'::regclass)
 hall_num | text    |           |           |
 floor    | integer |           |           |
 description | text   |           |           |

Indexes:
  "hall_pk" PRIMARY KEY, btree (hall_id), tablespace "duomo"
Tablespace: "duomo"
```

How do I Create a PK Constraint?

<https://www.postgresql.org/docs/current/sql-altertable.html>

```
firenze=> CREATE UNIQUE INDEX artwork_pk
firenze-> ON uffizi.artwork(work_id)
firenze-> TABLESPACE duomo;
CREATE INDEX

firenze=> ALTER TABLE uffizi.artwork
firenze-> ADD CONSTRAINT artwork_pk PRIMARY KEY
firenze-> USING INDEX artwork_pk;
ALTER TABLE
```

How do I Create a Foreign Key Constraint?

How do I Create a FK Constraint?

<https://www.postgresql.org/docs/current/sql-altertable.html>

```
firenze=> ALTER TABLE uffizi.artwork
firenze-> ADD CONSTRAINT artwork_hall_fk FOREIGN KEY (hall_id)
firenze-> REFERENCES uffizi.hall(hall_id);
ALTER TABLE
```

How do I Create a FK Constraint?

<https://www.postgresql.org/docs/current/sql-altertable.html>

```
firenze=> \d uffizi.artwork
...
Foreign-key constraints:
  "artwork_hall_fk" FOREIGN KEY (hall_id) REFERENCES uffizi.hall(hall_id)
...
firenze=> \d uffizi.hall
...
Referenced by:
  TABLE "uffizi.artwork" CONSTRAINT "artwork_hall_fk" FOREIGN KEY (hall_id)
  REFERENCES uffizi.hall(hall_id)
...
```

Aside: What is a Search Path?

Aside: What is a Search Path?

Schema(s) that will be searched if you don't use fully-qualified object names

```
firenze=> SHOW search_path;  
search_path  
-----  
"$user", public  
firenze=>
```



uffizi.object_name

Aside: What is a Search Path?

Schema(s) that will be searched if you don't use fully-qualified object names

```
firenze=> SHOW search_path;  
search_path  
-----  
"$user", public  
  
firenze=> SELECT * FROM hall;  
ERROR:  relation "hall" does not exist  
LINE 1: SELECT * FROM hall;  
                                ^
```



uffizi.object_name

Aside: What is a Search Path?

Schema(s) that will be searched if you don't use fully-qualified object names

```
firenze=> SET search_path=uffizi;  
SET  
  
firenze=> SHOW search_path;  
search_path  
-----  
uffizi  
  
firenze=>
```

Aside: What is a Search Path?

Schema(s) that will be searched if you don't use fully-qualified object names

```
firenze=> SET search_path=uffizi;
SET
firenze=> SHOW search_path;
search_path
-----
uffizi
firenze=> SELECT * FROM hall;
hall_id | hall_num | floor | description
-----+-----+-----+-----+
(0 rows)
```

Setting Search Path Automatically

Adding commands to .psqlrc file

```
postgres@rocky9 $ echo 'set search_path to uffizi' >> ~/.psqlrc  
postgres@rocky9 $
```

Setting Search Path Automatically

Adding commands to .psqlrc file

```
postgres@rocky9 $ echo 'set search_path to uffizi' >> ~/.psqlrc
postgres@rocky9 $ psql -d firenze -U michelangelo
SET
psql (15.2)
Type "help" for help.

firenze=>
```

Setting Search Path Automatically

Adding commands to .psqlrc file

```
postgres@rocky9 $ echo 'set search_path to uffizi' >> ~/.psqlrc
postgres@rocky9 $ psql -d firenze -U michelangelo
SET
psql (15.2)
Type "help" for help.

firenze=> SHOW search_path;
search_path
-----
uffizi
(1 row)
```

How do I Populate my Tables?

How do I Populate my Tables?

<https://www.postgresql.org/docs/current/sql-insert.html>

```
firenze=> INSERT INTO hall (hall_num, floor, description)
firenze-> VALUES ('10-14', 2, 'Botticelli'),
firenze->      ('35',     2, 'Michelangelo & the Florentines'),
firenze->      ('66',     1, 'Raffaello');
INSERT 0 3

firenze=>
```

How do I Populate my Tables?

<https://www.postgresql.org/docs/current/sql-insert.html>

```
firenze=> INSERT INTO hall (hall_num, floor, description)
firenze-> VALUES ('10-14', 2, 'Botticelli'),
firenze->      ('35',     2, 'Michelangelo & the Florentines'),
firenze->      ('66',     1, 'Raffaello');
INSERT 0 3

firenze=> SELECT * FROM hall ORDER BY hall_id;
   hall_id | hall_num | floor |           description
-----+-----+-----+
       1 | 10-14   |     2 | Botticelli
       2 | 35       |     2 | Michelangelo & the Florentines
       3 | 66       |     1 | Raffaello
(3 rows)
```

How do I Populate my Tables?

<https://www.postgresql.org/docs/current/sql-insert.html>

```
firenze=> INSERT INTO artwork (work_title, work_artist, hall_id)
firenze-> SELECT 'The Spring','Botticelli', hall_id
firenze-> FROM hall WHERE hall_num='10-14';
INSERT 0 1

firenze=> INSERT INTO artwork (work_title, work_artist, hall_id)
firenze-> VALUES ('Tondo Doni',      'Michelangelo', 2),
firenze->           ('Self-Portrait', 'Raffaello',     3);
INSERT 0 2
```

What if I try to insert an invalid hall_id?

<https://www.postgresql.org/docs/current/sql-insert.html>

```
firenze=> INSERT INTO artwork (work_title, work_artist, hall_id)
firenze-> VALUES ('Annunciation', 'Leonardo', 4);
ERROR: insert or update on table "artwork" violates foreign key constraint "artwork_hall_fk"
DETAIL: Key (hall_id)=(4) is not present in table "hall".
firenze=>
```

What if I try to insert an invalid hall_id?

<https://www.postgresql.org/docs/current/sql-insert.html>

```
firenze=> INSERT INTO artwork (work_title, work_artist, hall_id)
firenze-> VALUES ('Annunciation', 'Leonardo', 4);
ERROR: insert or update on table "artwork" violates foreign key constraint "artwork_hall_fk"
DETAIL: Key (hall_id)=(4) is not present in table "hall".

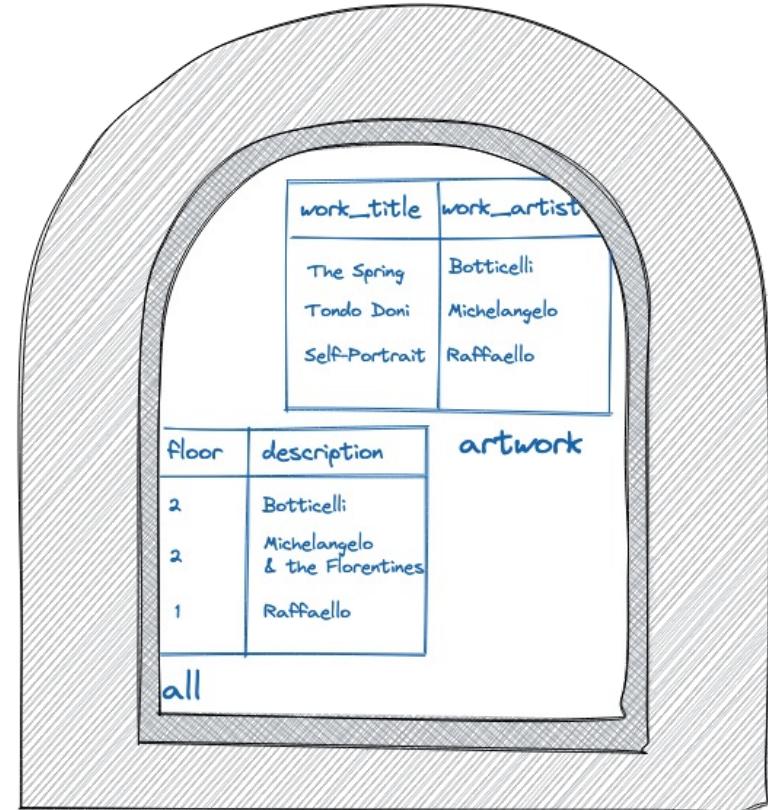
firenze=> INSERT INTO hall (hall_num, floor, description)
firenze-> VALUES ('15', 2, 'Leonardo da Vinci');
INSERT 0 1
firenze=> INSERT INTO artwork (work_title, work_artist, hall_id)
firenze-> VALUES ('Annunciation', 'Leonardo', 4);
INSERT 0 1
```

What is a View?

What is a View?

A virtual table, based on a query

- Doesn't take up any space
- Executed in real-time
- Shorthand for a long query
- Return limited data



How do I Create a View?

How do I Create a View?

<https://www.postgresql.org/docs/current/sql-createview.html>

```
firenze=> CREATE VIEW artwork_desc_view AS
firenze-> SELECT work_id, work_title||' by '||work_artist AS artwork_desc
firenze-> FROM artwork
firenze-> ORDER BY work_artist;
CREATE VIEW

firenze=> SELECT * FROM artwork_description;
 work_id |      artwork_desc
-----+-----
    1 | The Spring by Botticelli
    4 | Annunciation by Leonardo
    2 | Tondo Doni by Michelangelo
    3 | Self-Portrait by Raffaello
(4 rows)
```

What is a Materialized View?

What is a Materialized View?

A table that contains the results of a query

- Query is **not** executed in real-time
- Can be “refreshed” with latest data
- Useful for aggregating data
- Avoids re-executing queries

How do I Create a Materialized View?

How do I Create a Materialized View?

<https://www.postgresql.org/docs/current/sql-creatematerializedview.html>

```
firenze=> CREATE MATERIALIZED VIEW artwork_desc_mview
firenze-> TABLESPACE duomo AS
firenze-> SELECT work_id, work_title||' by '||work_artist AS artwork_desc
firenze-> FROM artwork;
SELECT 4

firenze=> SELECT * FROM artwork_desc_mview;
 work_id |      artwork_desc
-----+-----
    1 | The Spring by Botticelli
    2 | Tondo Doni by Michelangelo
    3 | Self-Portrait by Raffaello
    5 | Annunciation by Leonardo
(4 rows)
```

How do I Refresh a Materialized View?

First, update some data

```
firenze=> UPDATE artwork
firenze-> SET work_artist = 'Leonardo da Vinci'
firenze-> WHERE work_artist = 'Leonardo';
UPDATE 1

firenze=>
```

How do I Refresh a Materialized View?

First, update some data

```
firenze=> UPDATE artwork
firenze-> SET work_artist = 'Leonardo da Vinci'
firenze-> WHERE work_artist = 'Leonardo';
UPDATE 1

firenze=> SELECT work_artist
firenze-> FROM artwork
firenze-> WHERE work_artist like 'Leonardo%';
work_artist
-----
Leonardo da Vinci
```

How do I Refresh a Materialized View?

First, update some data

```
firenze=> SELECT artwork_desc FROM artwork_desc_view
firenze-> WHERE artwork_desc like '%Leonardo%';
          artwork_desc
-----
```

Annunciation by Leonardo da Vinci

```
firenze=> SELECT artwork_desc FROM artwork_desc_mview
firenze-> WHERE artwork_desc like '%Leonardo%';
          artwork_desc
-----
```

Annunciation by Leonardo

How do I Refresh a Materialized View?

First, update some data

```
firenze=> REFRESH MATERIALIZED VIEW artwork_desc_mview;  
REFRESH MATERIALIZED VIEW  
  
firenze=>
```

How do I Refresh a Materialized View?

First, update some data

```
firenze=> REFRESH MATERIALIZED VIEW artwork_desc_mview;
REFRESH MATERIALIZED VIEW

firenze=> SELECT artwork_desc FROM artwork_desc_mview
firenze-> WHERE artwork_desc like '%Leonardo%';
      artwork_desc
-----
Annunciation by Leonardo da Vinci
```

Agenda

- Database Architecture
- Users and Roles
- Database Objects
- **Database Connections**
- Database Operations and Transactions
- WAL
- Documentation

How do I Connect to my Database?

Connecting to the Database: Configuration

<https://www.postgresql.org/docs/current/runtime-config-connection.html>

```
postgres@rocky9 $ vi $PGDATA/postgresql.conf

#-----
# CONNECTIONS AND AUTHENTICATION
#-----

# - Connection Settings -

listen_addresses = '*'          # what IP address(es) to listen on;
```

Connecting to the Database: Configuration

<https://www.postgresql.org/docs/current/auth-pg-hba-conf.html>

```
postgres@rocky9 $ vi $PGDATA/pg_hba.conf
```

#	host	DATABASE	USER	ADDRESS	METHOD
	host	firenze	michelangelo	all	scram-sha-256

```
karen@rocky9 $ sudo systemctl restart postgresql-15
```

Connecting to the Database: Configuration

<https://www.postgresql.org/docs/current/sql-alteruser.html>

```
postgres@rocky9 $ psql -U michelangelo -d Firenze

firenze=> ALTER USER michelangelo WITH PASSWORD 'supersecretpassword';
ALTER ROLE

firenze=> \password
Enter new password for user "michelangelo":
Enter it again:
```

Connecting to the Database: What information do I need?

- host PGHOST
 - port PGPORT
 - database PGDATABASE
 - username PGUSER
 - password/certificate PGPASSWORD
- not recommended
- Default: `~/.pgpass`
- `hostname:port:database:username:password`
- PGPASSFILE

Connecting to the Database: **psql**

<https://www.postgresql.org/docs/current/app-psql.html>

```
psql -h 127.0.0.1 -p 5432 -U michelangelo firenze
```

database host

database port (5432 by default)

name of database to connect to

database username

Connecting to the Database: **psql**

<https://www.postgresql.org/docs/current/app-psql.html>

```
postgres@rocky9 $ psql -d firenze -h 10.128.0.6 -U michelangelo
```

```
Password for user michelangelo:
```

```
firenze=>
```

```
postgres@rocky9 $ echo '10.128.0.6:5432:firenze:michelangelo:secretpassword' >> ~/.pgpass
```

```
postgres@rocky9 $ psql -d firenze -h 10.128.0.6 -U michelangelo
```

```
firenze=>
```

Connecting to the Database: **psycopg2**

<https://www.psycopg.org/docs/module.html#psycopg2.connect>

```
conn = psycopg2.connect(  
    user='michelangelo',  
    host='localhost',  
    port='5432',  
    dbname='database')
```

or

```
conn_string="user=michelangelo host=localhost port=5432 dbname=database"  
conn = psycopg2.connect(conn_string)
```

Connecting to the Database: SQLAlchemy

<https://docs.sqlalchemy.org/en/latest/core/engines.html#postgresql>

```
from sqlalchemy import URL, create_engine

url_object = URL.create("postgresql",
                        username="michelangelo",
                        host="127.0.0.1",
                        database="firenze", )

engine = create_engine(url_object)

or

engine = create_engine('postgres://michelangelo@127.0.0.1:5432/firenze')
```

Connecting to the Database: Django (settings.py configuration file)

<https://docs.djangoproject.com/en/4.2/ref/databases/#postgresql-notes>

```
DATABASES = {  
    'default': {  
        'ENGINE': 'django.db.backends.postgresql',  
        'NAME': 'firenze',  
        'USER': 'michelangelo',  
        'HOST': '127.0.0.1',  
        'PORT': '5432'  
    }  
}
```

Agenda

- Database Architecture
- Users and Roles
- Database Objects
- Database Connections
- **Database Operations and Transactions**
- WAL
- Documentation

What is a Transaction?

What is a Transaction?

BEGIN

- Single unit of work
- One or more operations
- COMMIT all operations permanently applied
- ROLLBACK all operations cancelled
- Only visible to other transactions after COMMIT
- (Some) locks held until end of transaction

COMMIT | ROLLBACK

What is autocommit mode?

BEGIN

- CAREFUL!
- Some tools are in **autocommit** mode by default
- Each command is a transaction with implicit COMMIT

```
BEGIN;  
UPDATE ARTWORK SET WORK_ARTIST='Karen';  
COMMIT;
```

COMMIT | ROLLBACK

What is autocommit mode?

BEGIN

- CAREFUL!
- Some tools are in **autocommit** mode by default
- Each command is a transaction with implicit COMMIT

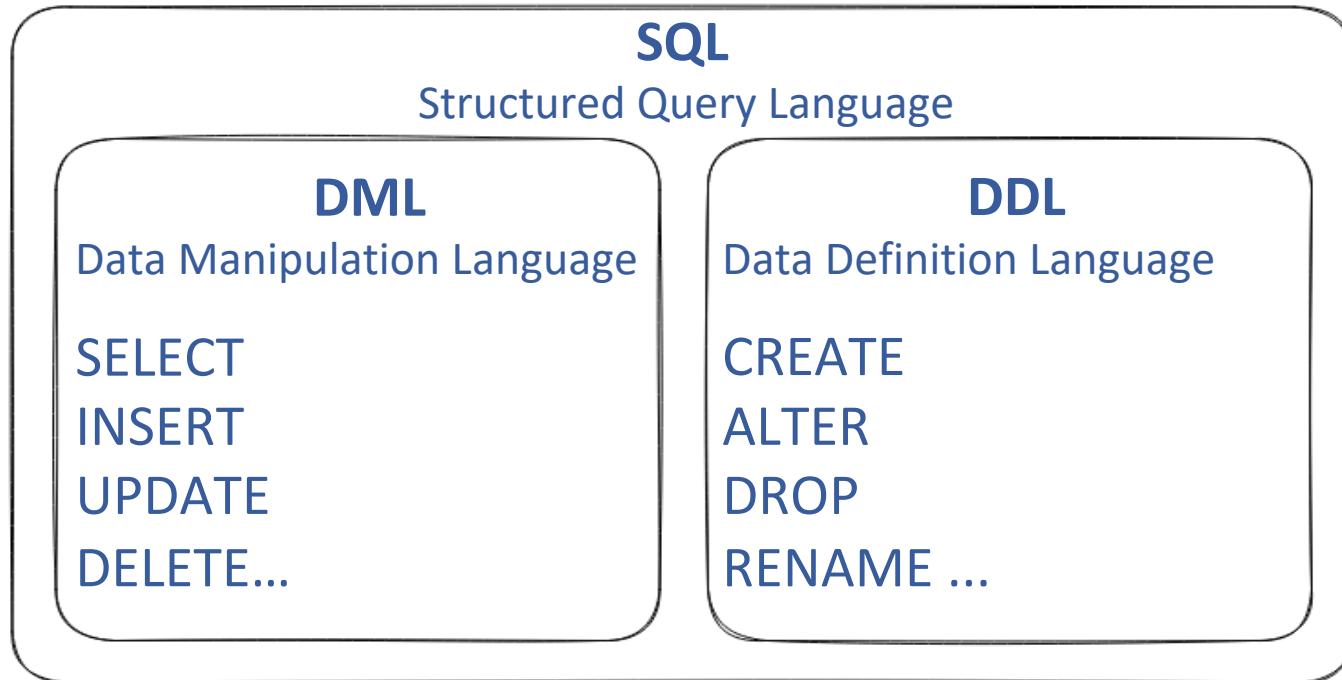
```
BEGIN;  
UPDATE ARTWORK SET WORK_ARTIST='Karen';  
COMMIT; | ROLLBACK;
```

COMMIT | ROLLBACK

What is SQL/DML/DDL?

What is SQL/DML/DDL?

<https://www.postgresql.org/docs/current/sql.html>



What is a Join?

What is a Join?

Combine information from multiple tables in one statement

work_id	work_title	work_artist	hall_id
1	The Spring	Botticelli	1
2	Tondo Doni	Michelangelo	2
3	Self-Portrait	Raffaello	3
4	Annunciation	Leonardo	4
5	Medusa	Carvaggio	

artwork

hall_id	hall_num	floor	description
1	10-14	2	Botticelli
2	35	2	Michelangelo & the Florentines
3	66	1	Raffaello
4	15	2	Leonardo da Vinci
5	58	1	Andrea del Sarto

hall

What are the Different Types of Join?

Types of Join: [INNER] JOIN

```
firenze=> SELECT a.work_id, a.work_title, a.work_artist,
firenze->           h.hall_num, h.floor
firenze-> FROM   artwork a JOIN hall h
firenze-> ON     a.hall_id = h.hall_id;
```

work_id	work_title	work_artist	hall_num	floor
1	The Spring	Botticelli	10-14	2
2	Tondo Doni	Michelangelo	35	2
3	Self-Portrait	Raffaello	66	1
4	Annunciation	Leonardo da Vinci	15	2

(4 rows)

work_id	work_title	work_artist	hall_id	hall_num	floor
1	The Spring	Botticelli	1	10-14	2
2	Tondo Doni	Michelangelo	2	35	2
3	Self-Portrait	Raffaello	3	66	1
4	Annunciation	Leonardo	4	15	2

artwork

hall

Types of Join: LEFT [OUTER] JOIN

```
firenze=> SELECT a.work_id, a.work_title, a.work_artist,
firenze->           h.hall_num, h.floor
firenze-> FROM artwork a LEFT JOIN hall h
firenze-> ON a.hall_id = h.hall_id;
```

work_id	work_title	work_artist	hall_num	floor
1	The Spring	Botticelli	10-14	2
2	Tondo Doni	Michelangelo	35	2
3	Self-Portrait	Raffaello	66	1
4	Annunciation	Leonardo da Vinci	15	2
5	Medusa	Caravaggio		

(5 rows)

work_id	work_title	work_artist	hall_id	hall_num	floor
1	The Spring	Botticelli	1	10-14	2
2	Tondo Doni	Michelangelo	2	35	2
3	Self-Portrait	Raffaello	3	66	1
4	Annunciation	Leonardo	4	15	2
5	Medusa	Caravaggio			

artwork

hall

Types of Join:

RIGHT [OUTER] JOIN

```
firenze=> SELECT a.work_id, a.work_title, a.work_artist,
firenze->           h.hall_num, h.floor
firenze-> FROM artwork a RIGHT JOIN hall h
firenze-> ON a.hall_id = h.hall_id;
```

work_id	work_title	work_artist	hall_num	floor
1	The Spring	Botticelli	10-14	2
2	Tondo Doni	Michelangelo	35	2
3	Self-Portrait	Raffaello	66	1
4	Annunciation	Leonardo da Vinci	15	2
			58	1

(5 rows)

work_id	work_title	work_artist	hall_id	hall_num	floor
1	The Spring	Botticelli	1	10-14	2
2	Tondo Doni	Michelangelo	2	35	2
3	Self-Portrait	Raffaello	3	66	1
4	Annunciation	Leonardo	4	15	2
			5	58	1

artwork

hall

Types of Join:

FULL [OUTER] JOIN

```
firenze=> SELECT a.work_id, a.work_title, a.work_artist,
firenze->           h.hall_num, h.floor
firenze-> FROM artwork a FULL JOIN hall h
firenze-> ON      a.hall_id = h.hall_id;
```

work_id	work_title	work_artist	hall_num	floor
1	The Spring	Botticelli	10-14	2
2	Tondo Doni	Michelangelo	35	2
3	Self-Portrait	Raffaello	66	1
4	Annunciation	Leonardo da Vinci	15	2
5	Medusa	Caravaggio	58	1

(6 rows)

work_id	work_title	work_artist	hall_id	hall_num	floor
1	The Spring	Botticelli	1	10-14	2
2	Tondo Doni	Michelangelo	2	35	2
3	Self-Portrait	Raffaello	3	66	1
4	Annunciation	Leonardo	4	15	2
5	Medusa	Caravaggio	5	58	1

artwork

hall

What is an Execution Plan?

Execution Plan:

Steps to execute a SQL statement

- How the tables will be scanned: sequential scan, index scan...
- What join algorithm will be used: nested loop, hash, merge
- Estimated # rows
- Estimated cost

How do I Generate an Execution Plan?

How do I Generate an Execution Plan?

<https://www.postgresql.org/docs/current/using-explain.html>

```
firenze=> EXPLAIN
firenze-> SELECT a.work_id, a.work_title, a.work_artist, h.hall_num, h.floor
firenze-> FROM artwork a JOIN hall h ON a.hall_id = h.hall_id;

          QUERY PLAN
-----
Hash Join  (cost=28.23..48.46 rows=810 width=104)
  Hash Cond: (a.hall_id = h.hall_id)
    -> Seq Scan on artwork a  (cost=0.00..18.10 rows=810 width=72)
    -> Hash  (cost=18.10..18.10 rows=810 width=40)
          -> Seq Scan on hall h  (cost=0.00..18.10 rows=810 width=40)
(5 rows)
```

How do I Generate an Execution Plan?

<https://www.postgresql.org/docs/current/using-explain.html>

<https://www.postgresql.org/docs/current/sql-analyze.html>

```
firenze=> ANALYZE artwork, hall;

firenze=> EXPLAIN
firenze-> SELECT a.work_id, a.work_title, a.work_artist, h.hall_num, h.floor
firenze-> FROM artwork a JOIN hall h ON a.hall_id = h.hall_id;

                                QUERY PLAN
-----
Hash Join  (cost=1.11..2.19 rows=5 width=34)
  Hash Cond: (a.hall_id = h.hall_id)
    -> Seq Scan on artwork a  (cost=0.00..1.05 rows=5 width=31)
    -> Hash  (cost=1.05..1.05 rows=5 width=11)
          -> Seq Scan on hall h  (cost=0.00..1.05 rows=5 width=11)
(5 rows)
```

How do I Generate an Execution Plan?

<https://www.postgresql.org/docs/current/using-explain.html>

```
firenze=> EXPLAIN ANALYZE
firenze-> SELECT a.work_id, a.work_title, a.work_artist, h.hall_num, h.floor
firenze-> FROM artwork a JOIN hall h ON a.hall_id = h.hall_id;

                                QUERY PLAN
-----
Hash Join  (cost=1.11..2.19 rows=5 width=34) (actual time=0.118..0.121 rows=4 loops=1)
  Hash Cond: (a.hall_id = h.hall_id)
    -> Seq Scan on artwork a  (cost=0.00..1.05 rows=5 width=31) (actual time=0.016..0.017 rows=5 loops=1)
    -> Hash  (cost=1.05..1.05 rows=5 width=11) (actual time=0.021..0.022 rows=5 loops=1)
          Buckets: 1024  Batches: 1  Memory Usage: 9kB
            -> Seq Scan on hall h  (cost=0.00..1.05 rows=5 width=11) (actual time=0.005..0.006 rows=5 loops=1)
Planning Time: 0.280 ms
Execution Time: 0.149 ms
(8 rows)
```

Agenda

- Database Architecture
- Users and Roles
- Database Objects
- Database Connections
- Database Operations and Transactions
- **WAL**
- Documentation

What is WAL?

What is WAL?

<https://www.postgresql.org/docs/current/wal-intro.html>

- Write-ahead log
- Details of changes executed against the Postgres cluster
- Allows crash-recovery, online backups and restores
- WAL files can be archived to allow point in time recovery (PITR)
- DON'T DELETE THEM!

Where are my WAL files?

<https://www.postgresql.org/docs/current/wal-intro.html>

```
postgres@my_vm$ ls -ltr $PGDATA/pg_wal
total 49152
drwx----- 2 postgres postgres 6 May 11 12:29 archive_status
-rw----- 1 postgres postgres 16777216 May 15 20:37 000000100000000000000001
-rw----- 1 postgres postgres 16777216 May 15 20:38 000000100000000000000002
-rw----- 1 postgres postgres 16777216 May 15 20:39 000000100000000000000003
```

Agenda

- Database Architecture
- Users and Roles
- Database Objects
- Database Connections
- Database Operations and Transactions
- **Documentation**

Where's the PostgreSQL documentation?

Current version: <https://www.postgresql.org/docs/current/index.html>

How can I interact with the community?

Slack Channel | Mailing Lists

- <https://postgres-slack.herokuapp.com/>
- Over 100 channels
- 20k members
- <https://lists.postgresql.org/>
- Linked to PostgreSQL Community account
- Many different lists

Congratulations!





Thank You!

Karen Jex | @karenhjex | karen.jex@crunchydata.com

Slides: <https://github.com/karenjex/talk-slides>