



crunchy data

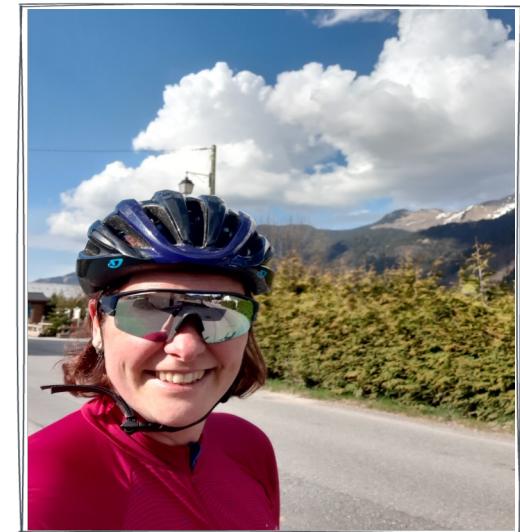
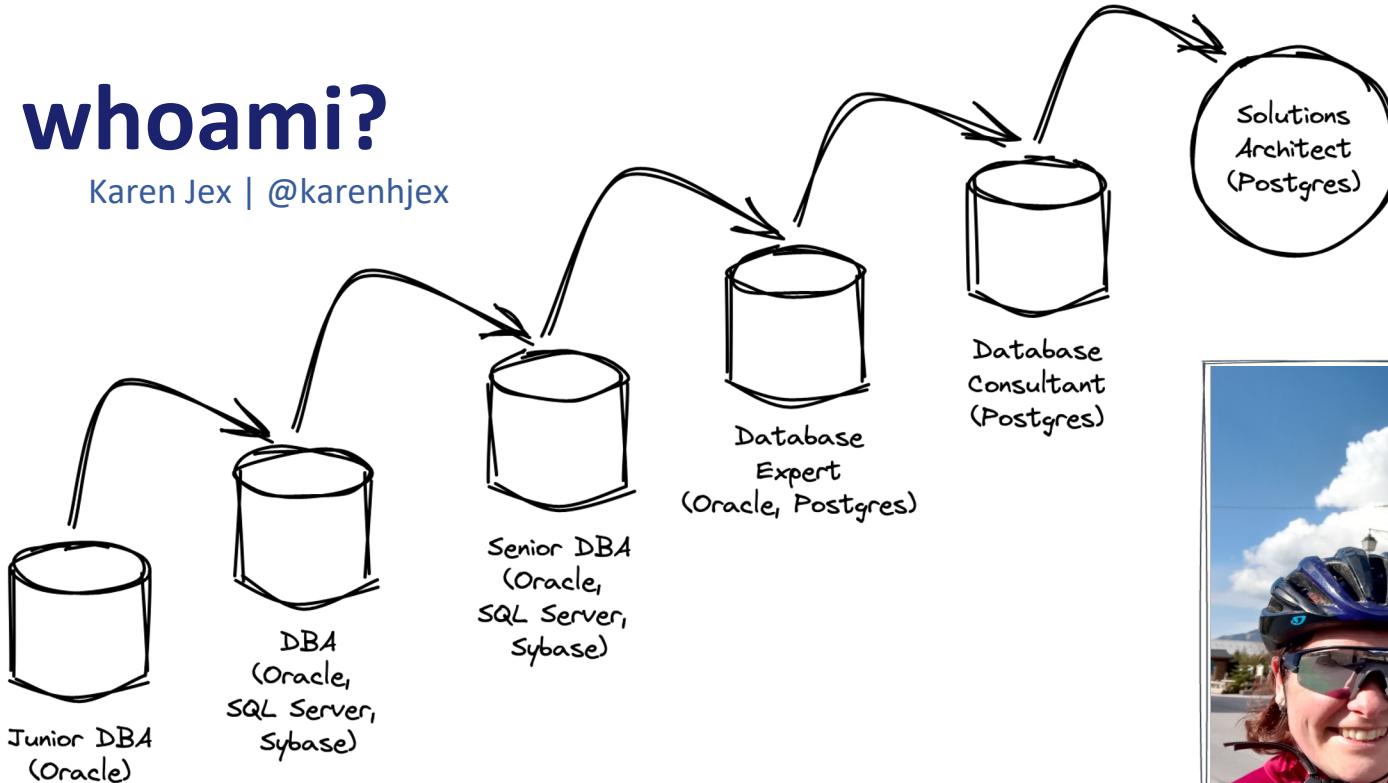
Everything You Wanted to Know about Databases as a Developer but Were Too Afraid to Ask Your DBA

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PyCon Italia, Florence | May 2023

whoami?

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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

- Postgres Playground (Postgres in your browser)

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



- Commands used during workshop

https://raw.githubusercontent.com/karenjex/talk-slides/main/script_files/pycon_workshop_commands.txt

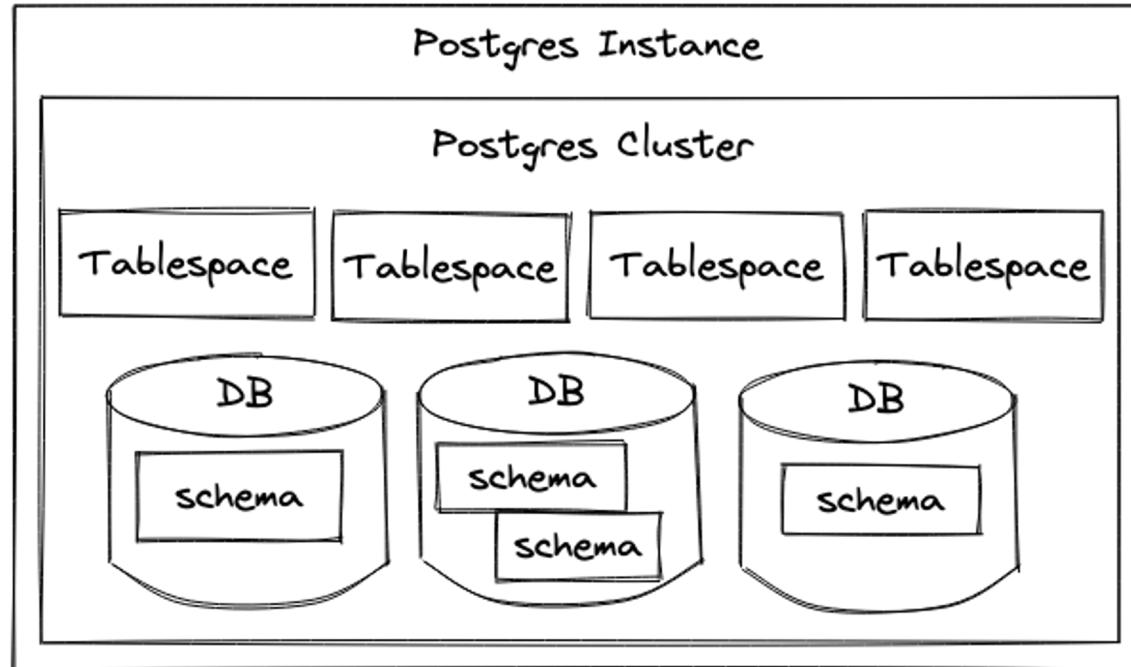


Agenda

- **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>

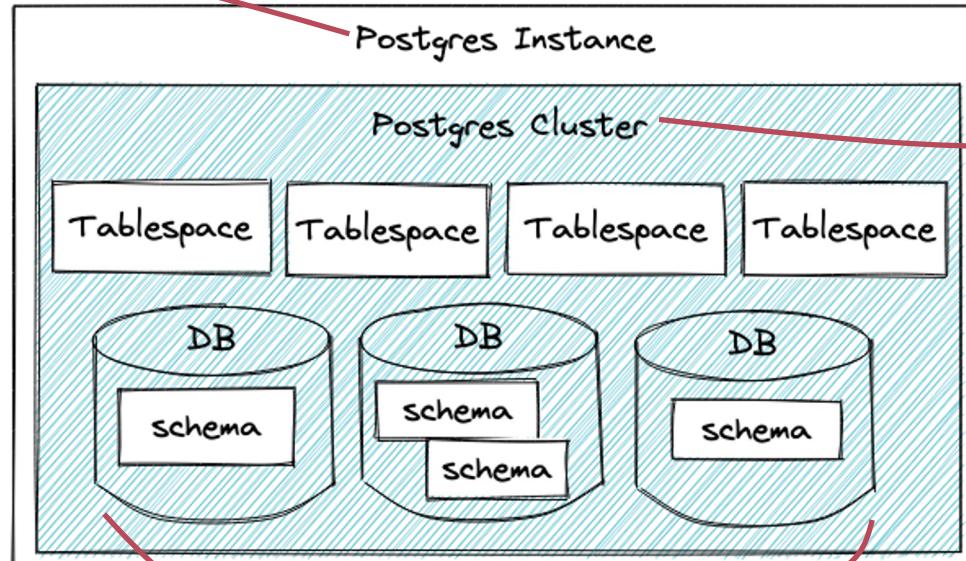


What is a PostgreSQL Cluster?

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
```

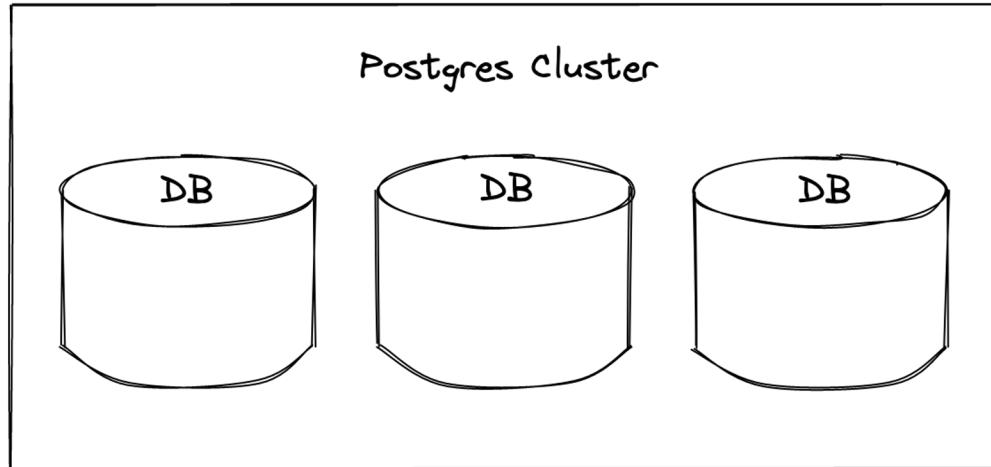
How do I Control Postgres using systemd?

```
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?

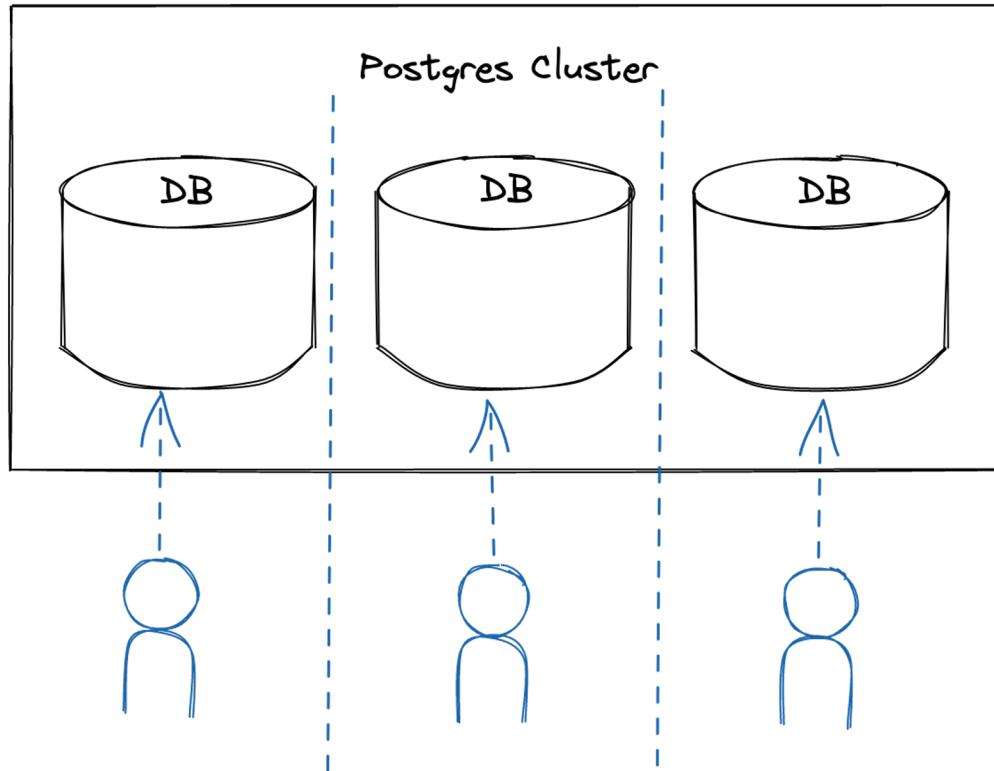
What is a Database?

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



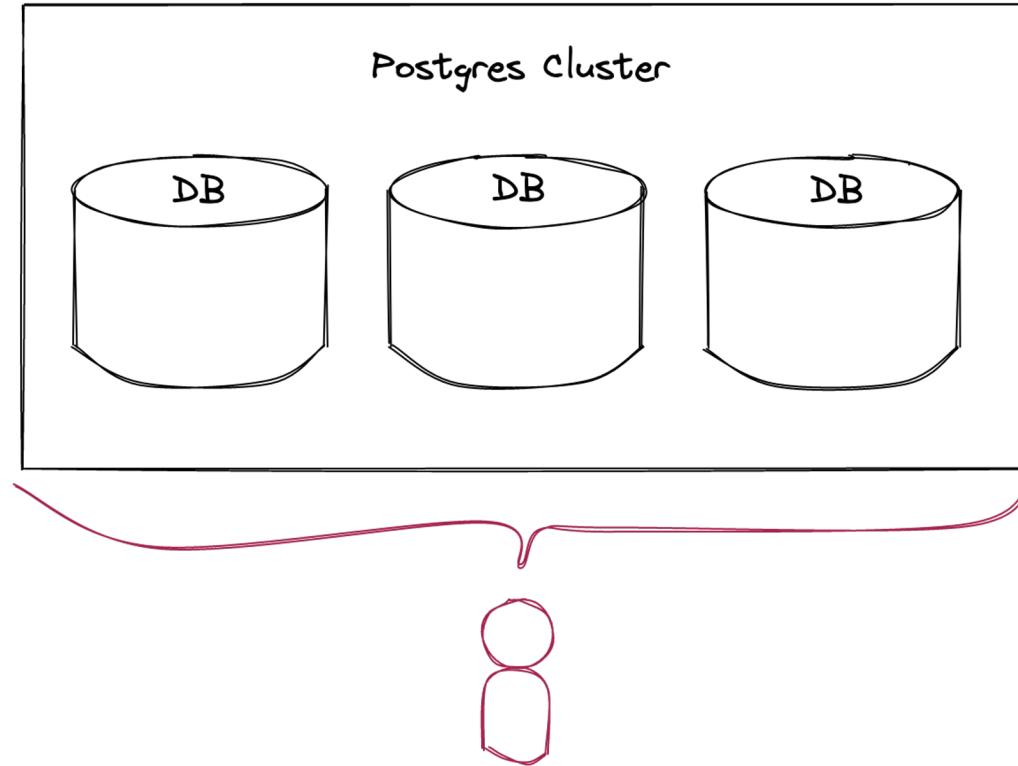
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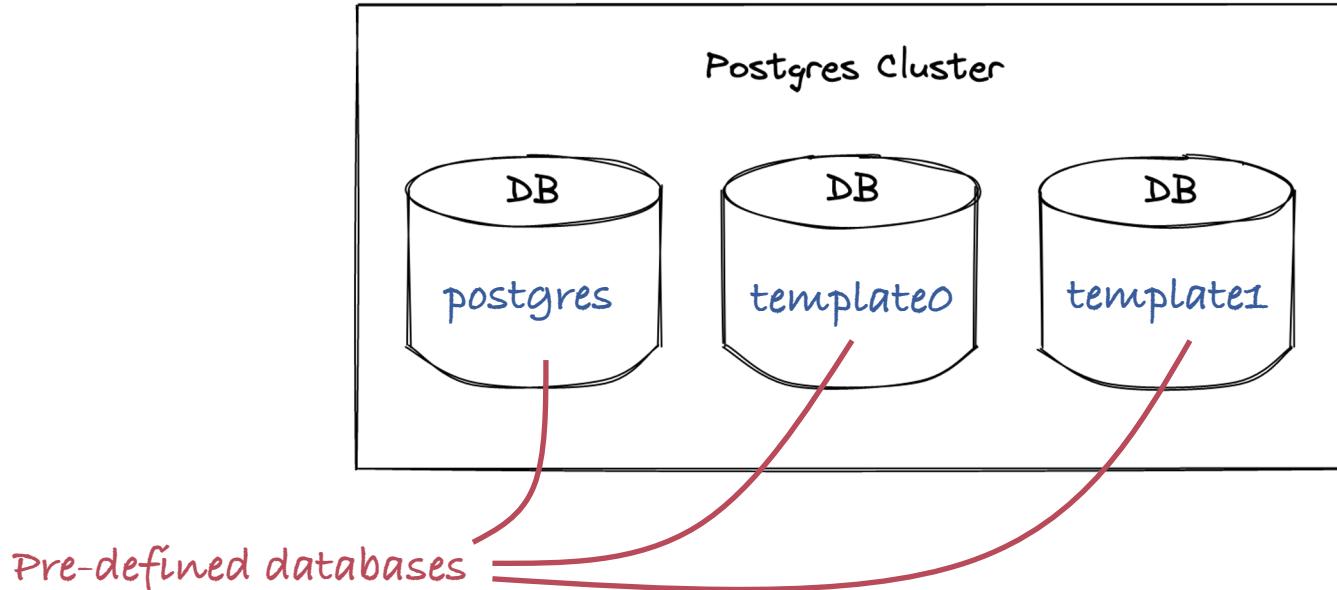
What is a Database?

<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?

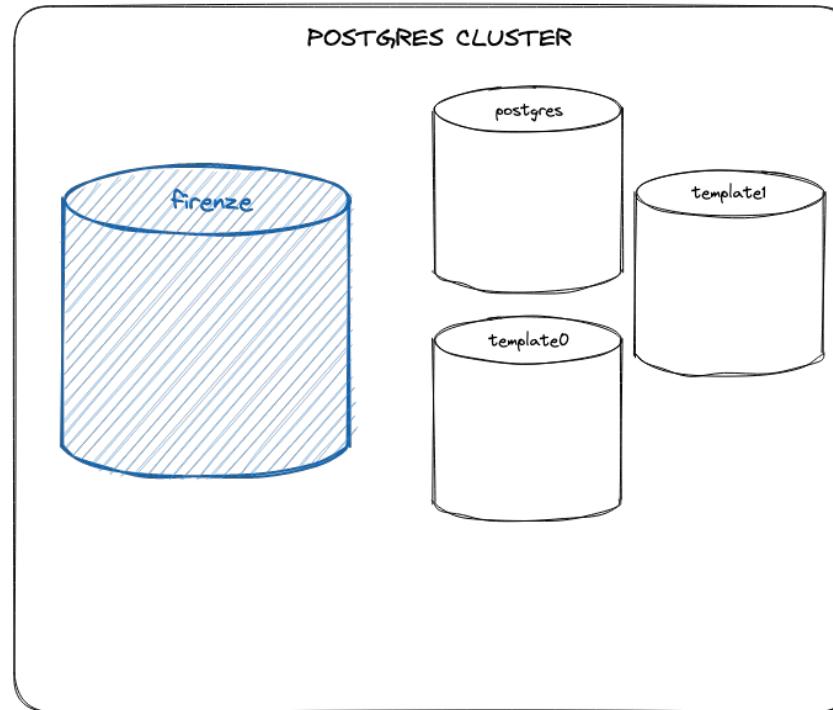
<https://www.postgresql.org/docs/current/sql-createdatabase.html>

```
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'"
```

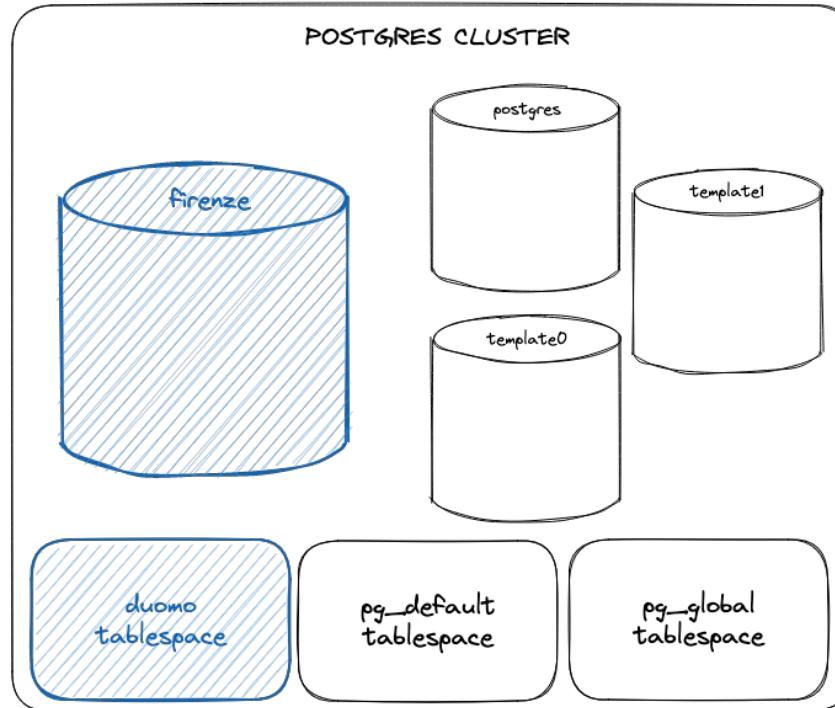
How do I Create a Tablespace?

<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?

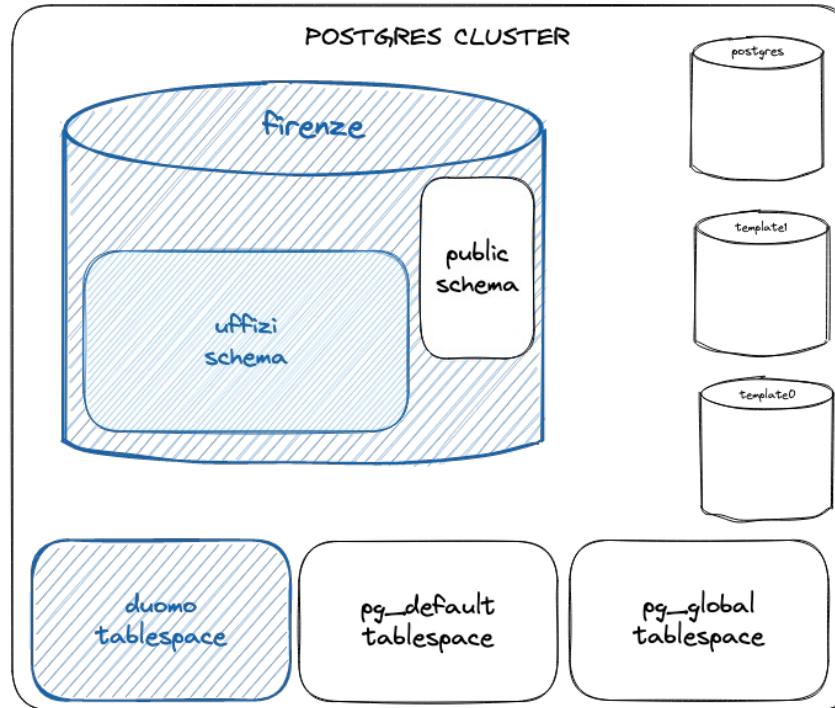
<https://www.postgresql.org/docs/current/sql-createschema.html>

```
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
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- 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?

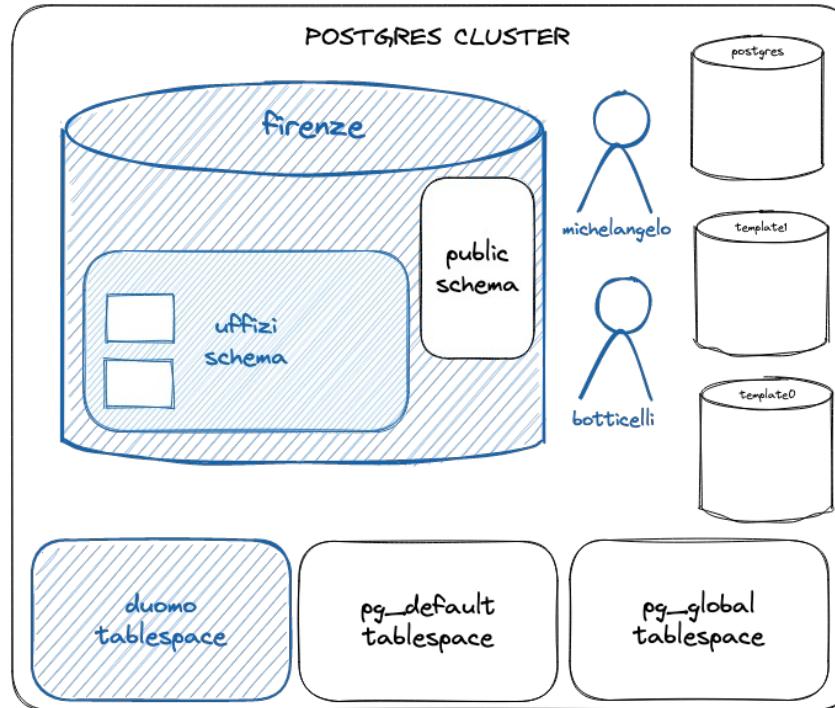
How do I View the Table Definitions?

```
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

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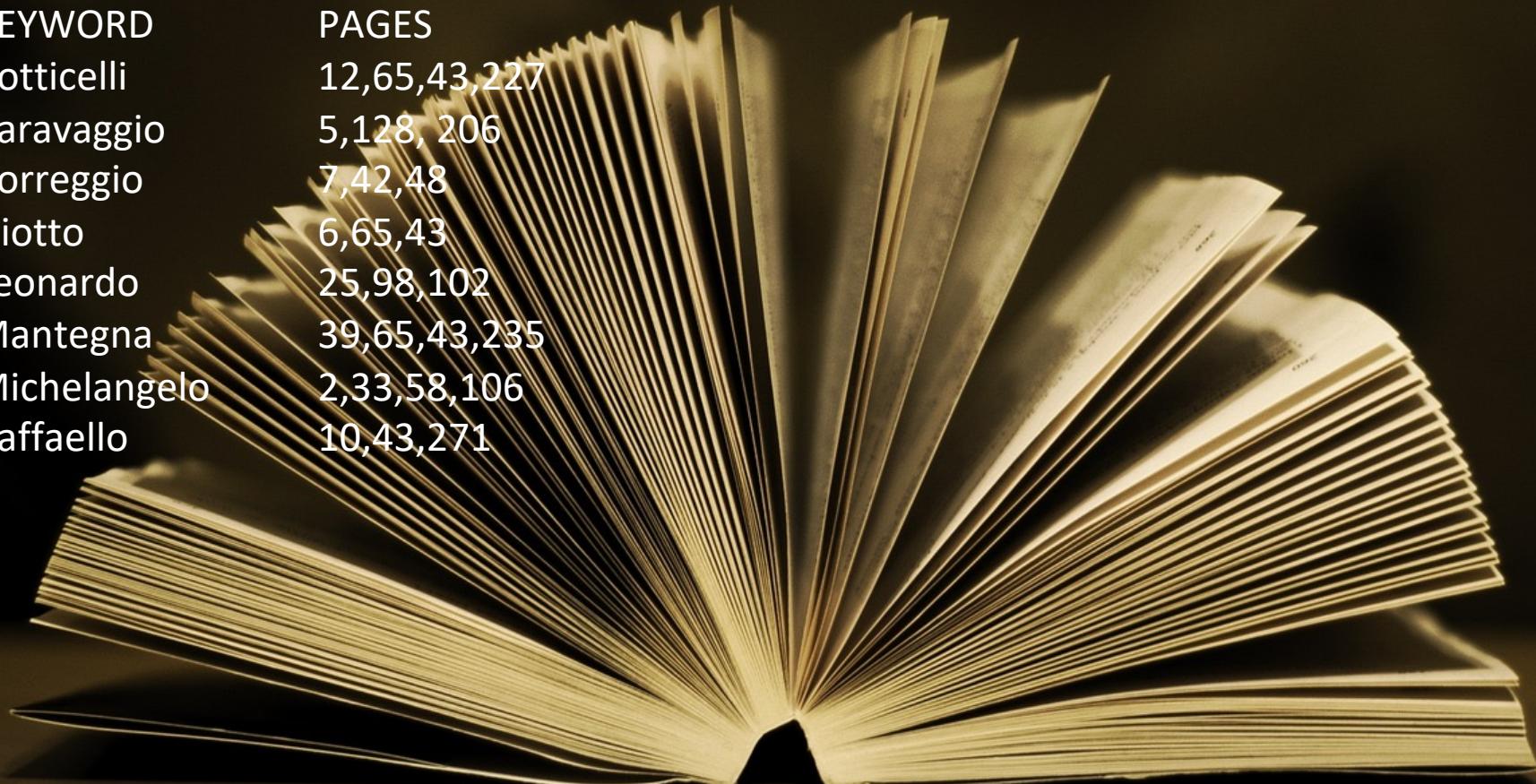
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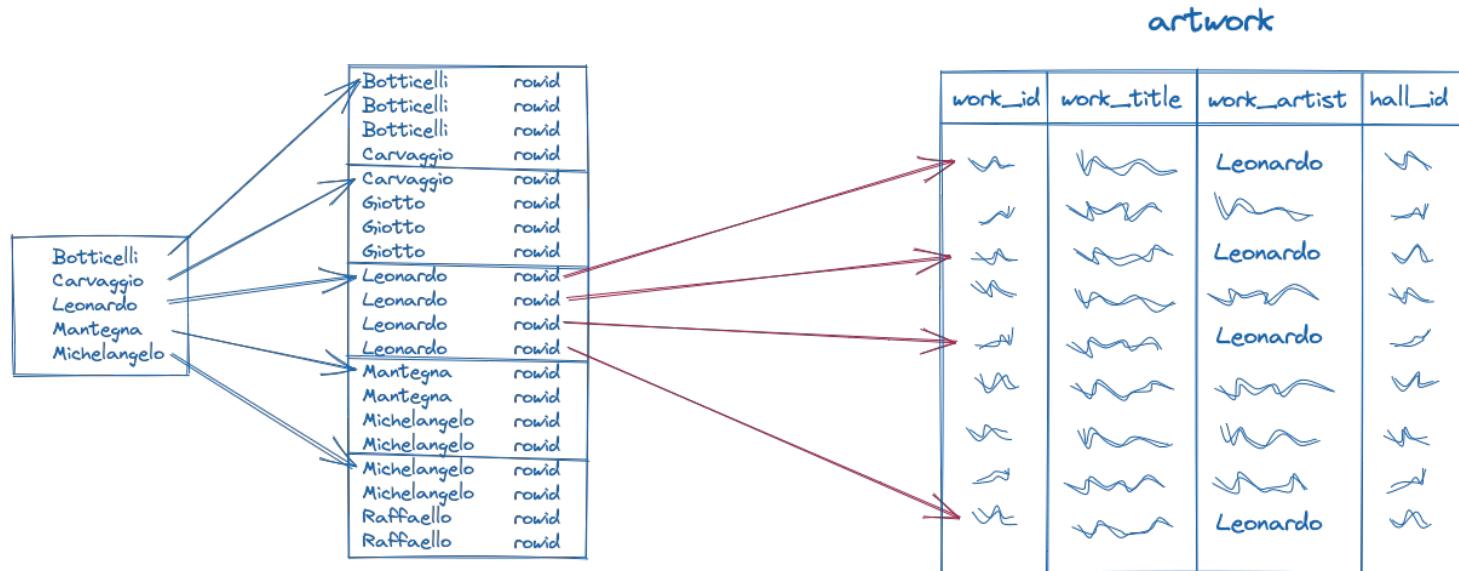
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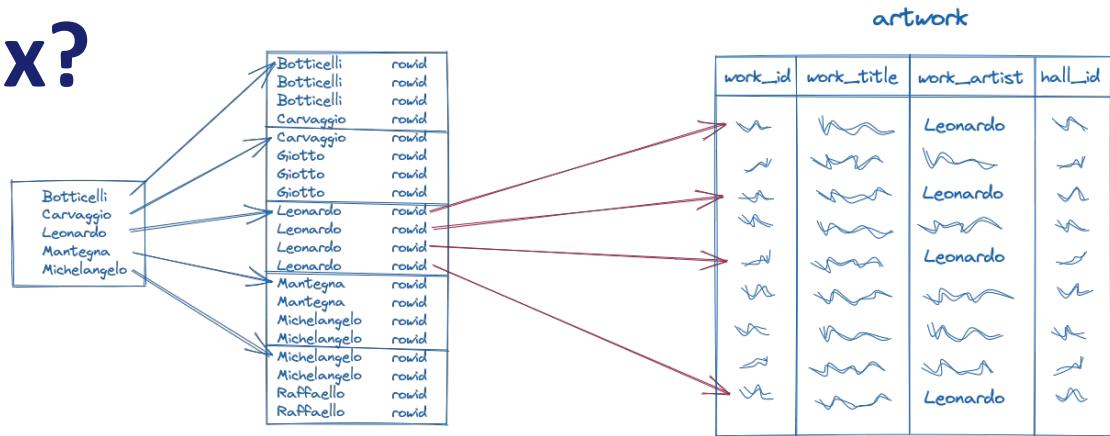
10,43,271



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?

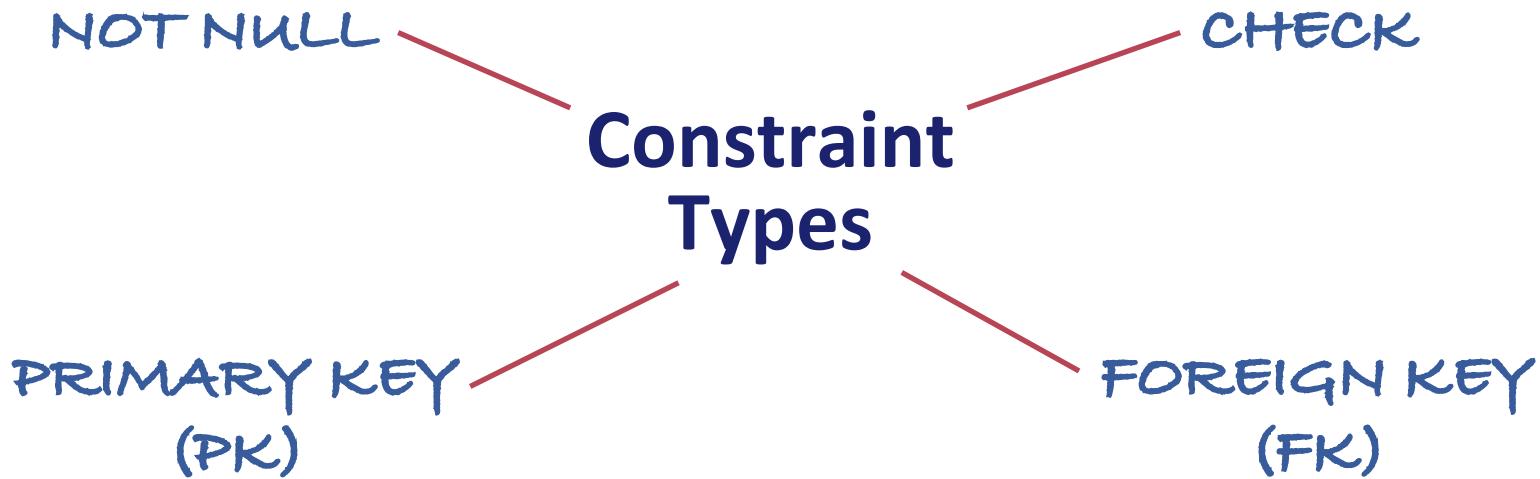
<https://www.postgresql.org/docs/current/sql-createindex.html>

```
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>

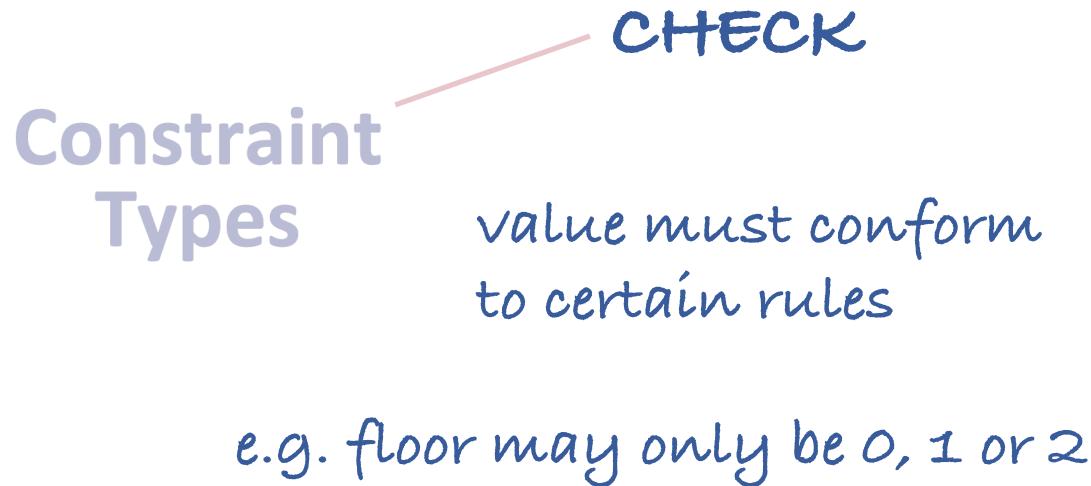
NOT NULL

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>

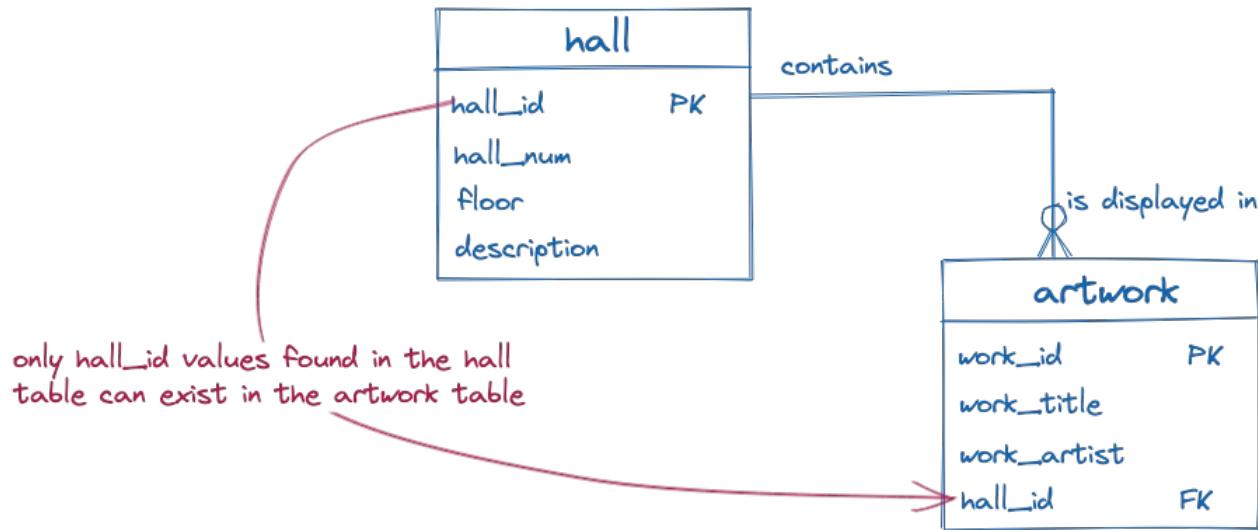
- Relationship between parent table and child table
- Enforces referential integrity
- FK column in child table must match a value in the parent table

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".

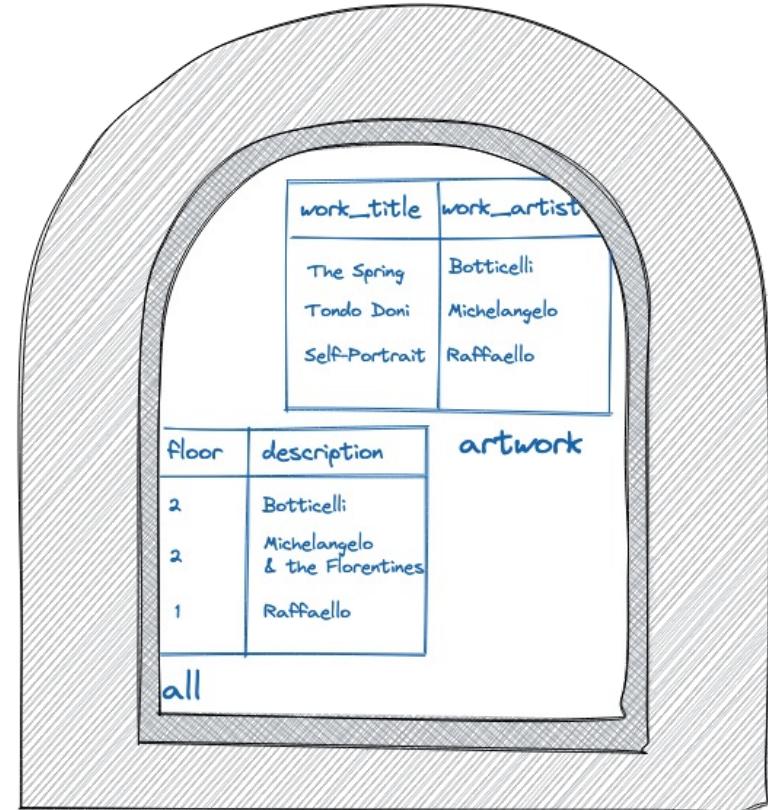
firenze=> INSERT INTO hall (hall_num, floor, description)
firenze-> VALUES ('15', 2, 'Leonardo da Vinci');
INSERT 0 1
firenze=> INSERT INTO artwork (work_title, work_artist, hall_id)
firenze-> VALUES ('Annunciation', 'Leonardo', 4);
INSERT 0 1
```

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

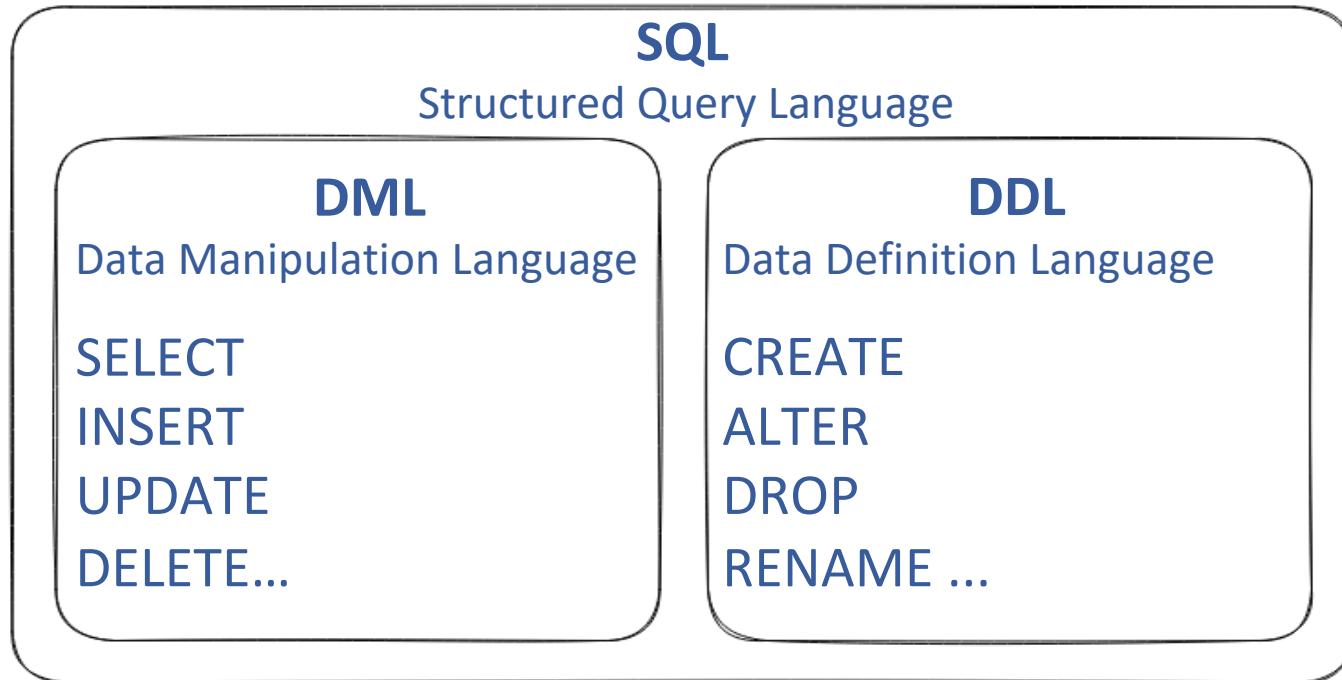
```
BEGIN;  
UPDATE ARTWORK SET WORK_ARTIST='Karen';  
COMMIT; | ROLLBACK;
```

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!

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