Advanced SQL with Postgres

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Oct 2025

Lesson Plan

- **14:00 - 17:00**
- **Start with review of prior day**
- **End with time to try things out and ask questions**
- **Hands on**

Monday	Quick intro to key concepts of relational databases Connecting to the Postgres database w. pgAdmin and psql Tables and query basics: Insert, update, delete, select *Time to exercise and ask questions*
Tuesday	*Review of prior session and Q&A* Operators in the WHERE clause and computations in the SELECT clause Primary keys, constraints, and foreign key relationships Data Types: Numbers, Characters, JSON, and more *Time to exercise and ask questions*
Wednesday	*Review of prior session and Q&A* Indexes Organizing data with schemas and entity-relationship diagrams Queries revisited (limit, distinct, not in, joins, views, and aggregates) *Time to exercise and ask questions*
Thursday	*Review of prior session and Q&A* Data Normalization ACID compliance, Transactions, and Isolation Levels A simple project: Creating your own database with schema, tables, and foreign keys
Friday	*Review of prior session and Q&A* Completing the project Stored procedures Common Table Expressions (CTE) Recap, Q&A, resources

Intro and Advanced SQL Classes

Practical Introduction to SQL with Postgres

Audience: Beginners

Tool: Graphical UI (pgAdmin)

Duration: 3 days @ 3 hours

Goal:

- Familiarize with SQL and relational databases
- Write simple queries
- Read and understand data models

Advanced SQL with Postgres

Audience: Prior hands-on experience with database or programming tools

Tool: Command line (psql) & GUI (pgAdmin)

Duration: 5 days @ 3 hours

Goal:

- Read and write complex queries
- Understand transactions, indexes, and analytics concepts
- Develop normalized data models
- Develop stored procedures

Day 1

- Connect to the VMs
- Quick intro to key concepts of relational databases
- Connecting to the Postgres database w. pgAdmin and psql
- Tables and query basics: Insert, update, delete, select

Connecting to the DLH Course VMs

Quick Intro to Databases

What is a database?

A **database** is an organized collection of structured data, typically stored electronically in a computer system.

Use Case Examples

- All orders that were taken, shipped, invoiced and paid in a store or eCommerce applications
- List of all laws that are currently in place
- Register of all the inhabitants of a country with their age, marital status, and domicile
- Collections of documents, X-ray images, chat conversations, and emails
- The WWW
- Data can include numbers, text, geo-locations, images, videos, links, vectors, lists, …

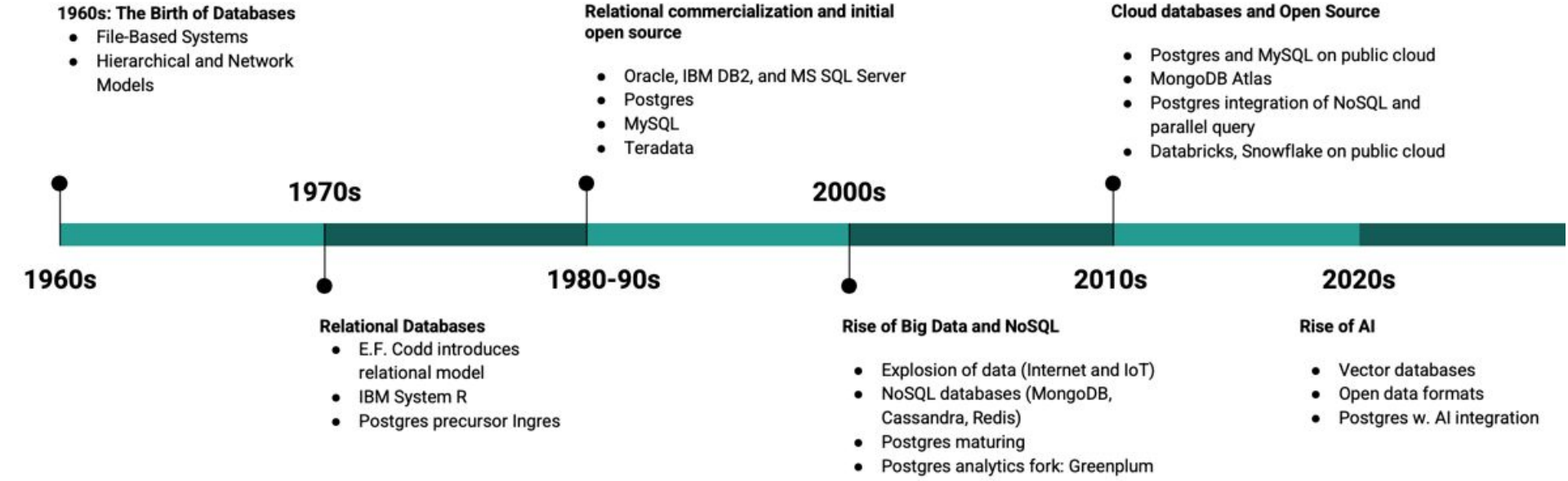
Key Functions of a Database

- **Data Storage**: Securely store large volumes of data.
- **Data Retrieval**: Quickly fetch specific data using queries.
- **Data Manipulation**: Insert, update, or delete data as needed.
- **Data Integrity**: Ensure accuracy and consistency through constraints and rules.
- **Data Security**: Protect data from unauthorized access with authentication and encryption.
- **Data Analysis**: Support complex queries and reporting for decision-making.

Components of a Database

- **Data**: The actual information stored, such as customer records, product details, or transaction logs.
- **Database Management System (DBMS)**: Software that interacts with the database, enabling users to define, create, query, update, and manage data. Examples include MySQL, PostgreSQL, Oracle, and MongoDB.
- **Schema**: The structure or blueprint of the database, defining how data is organized (e.g., tables, fields, relationships).
- **Query Language**: A language used to interact with the database, such as SQL (Structured Query Language) for relational databases.

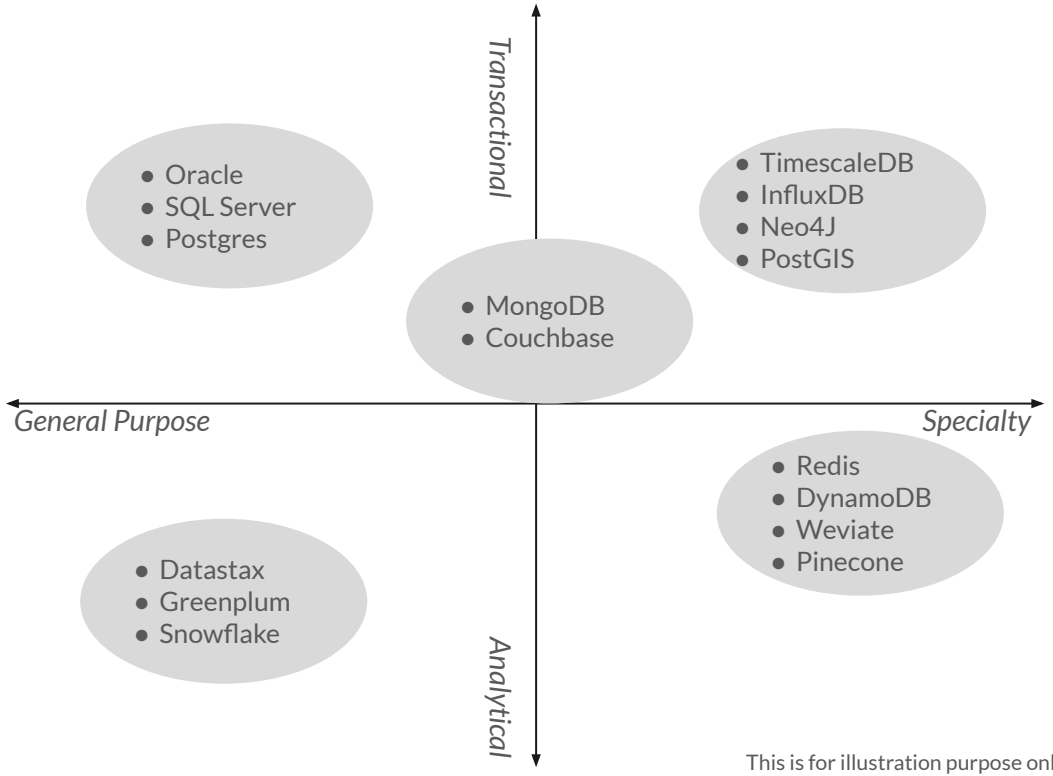
History of Databases



Principal Types of Databases

- There are many, many types of databases
- Key database types (not exhaustive)
  - Relational ⇐ Our focus this week (Oracle, My SQL, Postgres, SQL Server, IBM DB2, Sybase, …)
  - Document (MongoDB, Couchbase, …)
  - Key Value Pair (Redis, RocksDB, Amazon Dynamo, …)
  - Graph (Neo4J)
  - AI and vector (Pinecone, Weviate, …)
- Features are merging!
  - Relational databases are adopting graph, document, KVP, and AI vector capabilities

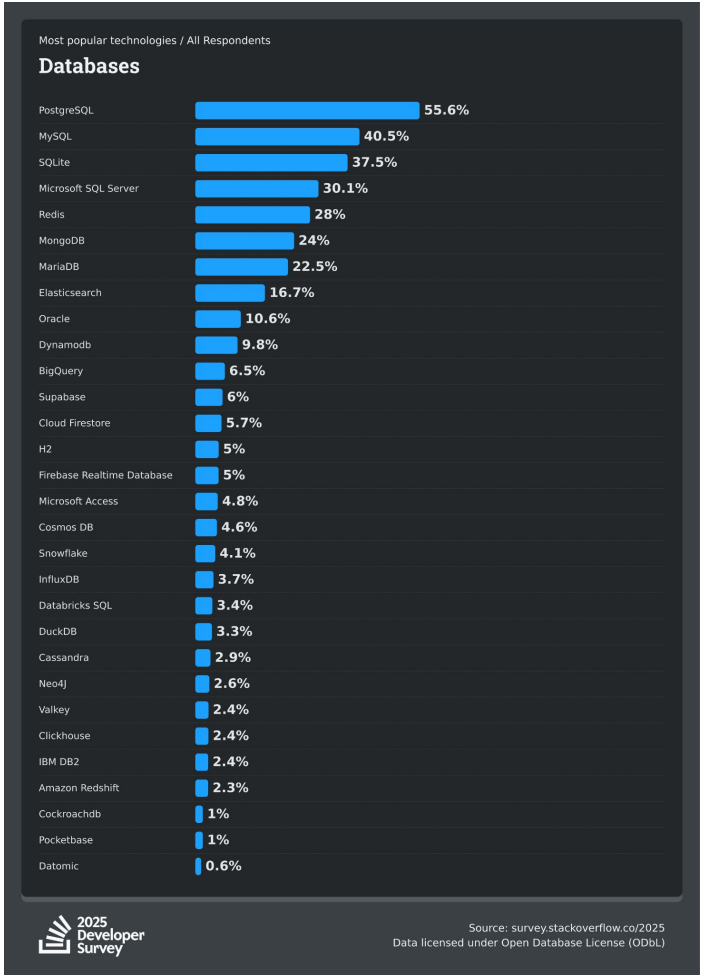
Database Landscape



This is for illustration purpose only
There are many, many databases and many ways to classify them

Stackoverflow Developer Survey 2025

Year	Rank	Developers using Postgres	Key Competitors
2025	#1	55.6%	MySQL (40.5%), SQLite (37.5%)
2024	#1	51%	MySQL (45%), SQLite (34%)
2023	#1	47%	MySQL (47%), SQLite (32%)
2022	#2	46%	MySQL (47%), SQLite (32%)
2021	#2	40%	MySQL (51%), SQLite (32%)
2020	#2	38%	MySQL (55%), SQLite (32%)
2019	#2	34%	MySQL (58%), SQLite (32%)
2018	#3	32%	MySQL (58%), SQL Server (36%)



Relational Databases

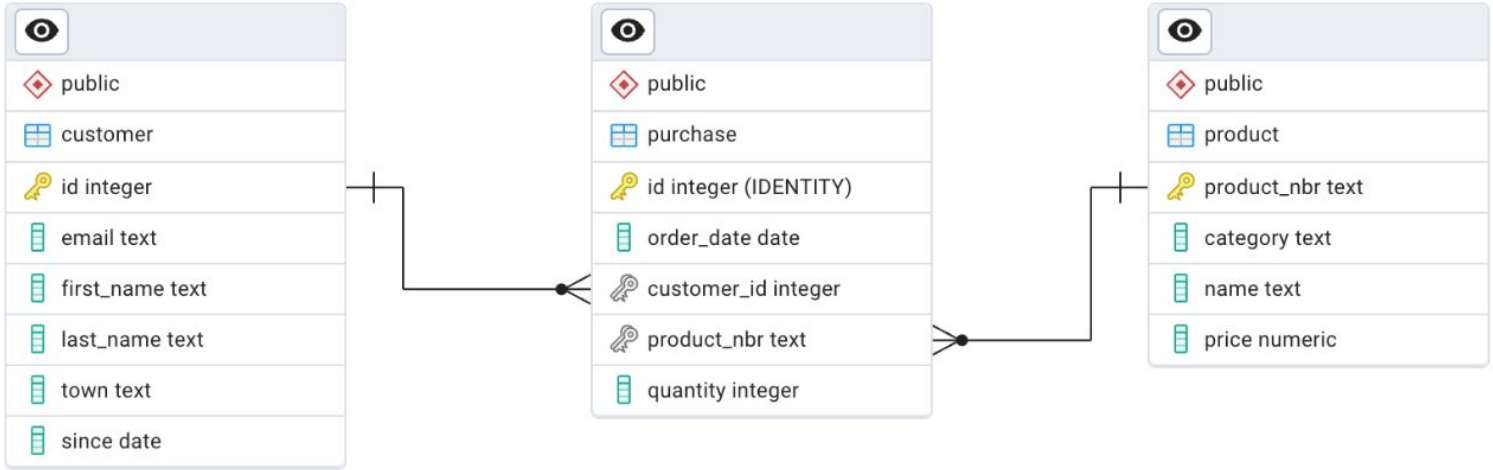
- Tables, e.g., products, customers
- Relations, e.g., which customer bought which product
- Schemas, e.g., structured collections of tables and relations
- Data types, e.g., integer, numeric, float, text, time, date, …
- Data Definition Language (DDL), e.g. CREATE TABLE, CREATE INDEX, ….
- Data Manipulation Language (DML), e.g., SELECT name FROM product, INSERT (first_name, last_name) VALUES (‘marc’, ‘linster’) INTO customer

Relational Databases

id	timestamp	product_id	customer_id	store_id	qty	unit_price	extended_price
80	2025-12-26 6:41:08	1405	279	1	61	208.23	12702.03
8	2025-12-07 7:20:22	392	75	4	71	203.4	14441.4
61	2025-12-08 22:50:43	1476	237	2	27	155.91	4209.57
59	2025-12-17 11:45:05	2232	331	3	6	132.73	796.38
10	2025-12-11 19:56:24	113	33	4	23	153.06	3520.38
66	2025-12-22 9:03:43	2178	70	1	61	125.83	7675.63
51	2025-12-07 21:30:30	2082	485	2	61	138.98	8477.78
52	2025-12-03 16:47:22	1105	443	3	69	49.7	3429.3
79	2025-12-19 21:46:07	236	126	4	15	81.04	1215.6
36	2025-12-27 10:37:25	1359	469	1	59	95.92	5659.28

name	description	manufacturer_id	size	color	sku	price
Cotton T-Shirt	Handcrafted details	3	XXL	Light Green	FSH-89166-000000000165	11.4
Wool Socks	Trendy and fashionable	1	M	Dark Yellow	FSH-53451-000000000138	146.26
Wool Dress Pants	Elegant and stylish	2	S	Turquoise	FSH-25089-0000000001213	102.79
Evening Gown	Waterproof and windproof	3	XS	Light Green	FSH-47771-000000000115	103.36
Wool Dress Pants	Elegant and stylish	2	XXL	Dark Blue	FSH-13141-000000000164	16.41
Baseball Cap	Versatile and functional	3	XL	Light Red	FSH-43094-000000000151	160.5
Slacks	Trendy and fashionable	3	XL	Dark Blue	FSH-82072-000000000154	39.63
Leather Jacket	Comfortable and durable	3	XS	Amber	FSH-15582-0000000001114	172.11
Sunglasses	Quick-drying	2	L	Dark Blue	FSH-65791-000000000144	18.73
Leather Belt	Comfortable and durable	3	XXL	Amber	FSH-11391-0000000001614	62.81

Entity-Relationship Diagrams



Document Database

- Documents encapsulate and encode data, e.g., customer
- Collections gather similar documents, e.g., customer**s**
- No standard schema, e.g., some customer documents can have fields that differ. For example
  - Customer1: firstname, lastname, address_line_1, city, postalcode
  - Customer2: firstname, **middlename**, lastname, address_line_1, **address_line_2**, city, postalcode

Document Database


```
{
  "customer_id": "12345",
  "name": "John Doe",
  "email": "johndoe@example.com",
  "phone": "+1234567890",
  "address": {
      "street": "123 Main St",
      "city": "Anytown",
      "state": "CA",
      "zip": "90210"
  },
"orders": [
    {
      "order_id": "67890",
      “customer_id”: “12345”,
      "date": "2023-10-01",
      "total_amount": 150.75,
      "items": [
        {
            "product_id": "p123",
            "product_name": "Wireless
Mouse",
            "quantity": 1,
            "price": 50.25
        },
        {
            "product_id": "p456",
            "product_name": "Bluetooth
Keyboard",
            "quantity": 1,
            "price": 100.50
        }
      ]
    },
```

Key Value Pair Database

- ‘Values’ associated with a ‘Key’
  - `Customer: 123 name “Marc Linster” city “Junglinster”`
  - `Product:xyz price “192,17” color”blue”`

- Extremely fast access to data
- Usually stored in memory
- Used as cache or working memory for applications

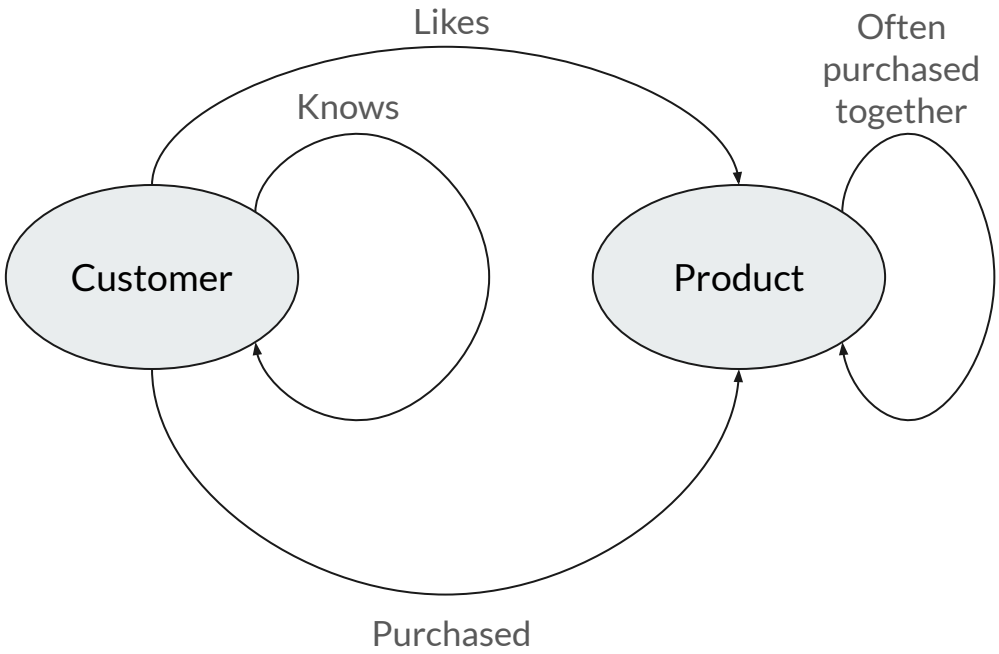
Key Value Pair Database

```
HSET customer:12345 name "John Doe" email "johndoe@example.com" phone "+1234567890"
HSET customer:12345 address '{"street": "123 Main St", "city": "Anytown", "state": "CA", "zip": "90210"}'

HSET customer:67890 name "Jane Smith" email "janesmith@example.com" phone "+0987654321"
HSET customer:67890 address '{"street": "456 Elm St", "city": "Othertown", "state": "NY", "zip": "10001"}'
```

```
HSET order:67890 customer_id "12345" date "2023-10-01" total_amount "150.75"
HSET order:67890 items '[{"product_id": "p123", "product_name": "Wireless Mouse", "quantity": 1, "price":
50.25}, {"product_id": "p456", "product_name": "Bluetooth Keyboard", "quantity": 1, "price": 100.50}]'

HSET order:67891 customer_id "12345" date "2023-10-05" total_amount "75.00"
HSET order:67891 items '[{"product_id": "p789", "product_name": "USB-C Hub", "quantity": 2, "price":
37.50}]'
```

Graph Database

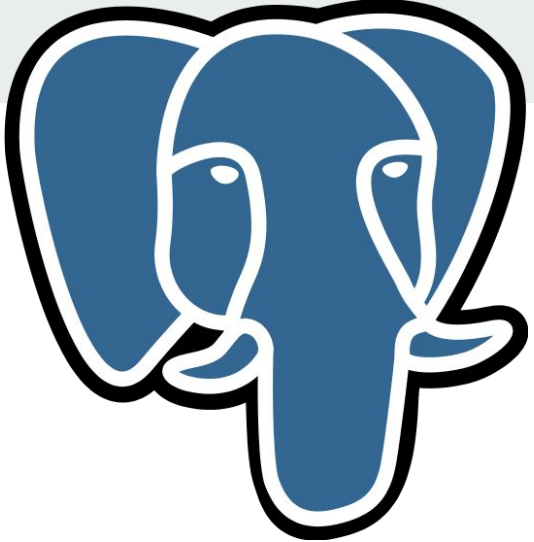
- Nodes, e.g., customer, product
- Relationships, e.g., purchased, likes, knows



Graph Database

```
CREATE (c1:Customer {id: 1, name: "John Doe", email: "johndoe@example.com"});
CREATE (c2:Customer {id: 2, name: "Jane Smith", email: "janesmith@example.com"});
CREATE (c3:Customer {id: 3, name: "Alice Johnson", email: "alicej@example.com"});

CREATE (p1:Product {id: 101, name: "Wireless Mouse", price: 25.99});
CREATE (p2:Product {id: 102, name: "Bluetooth Keyboard", price: 49.99});
CREATE (p3:Product {id: 103, name: "USB-C Hub", price: 35.50});
CREATE (p4:Product {id: 104, name: "Monitor", price: 199.99});


MATCH (c1:Customer {id: 1}), (p1:Product {id: 101}) CREATE (c1)-[:LIKES]->(p1);
MATCH (c1:Customer {id: 1}), (p2:Product {id: 102}) CREATE (c1)-[:LIKES]->(p2);
MATCH (c2:Customer {id: 2}), (p3:Product {id: 103}) CREATE (c2)-[:LIKES]->(p3);
MATCH (c3:Customer {id: 3}), (p4:Product {id: 104}) CREATE (c3)-[:LIKES]->(p4);
```

Connecting to a Postgres Database



Tools for this course

Editor

- pgAdmin 9.8
- License: Postgres License

Postgres

- PostgreSQL V18
- License: Postgres License

Exercises and Samples

- License: Creative Commons (no Rights Reserved)

It's all 100% Open Source

Take it home, use it,
learn from it

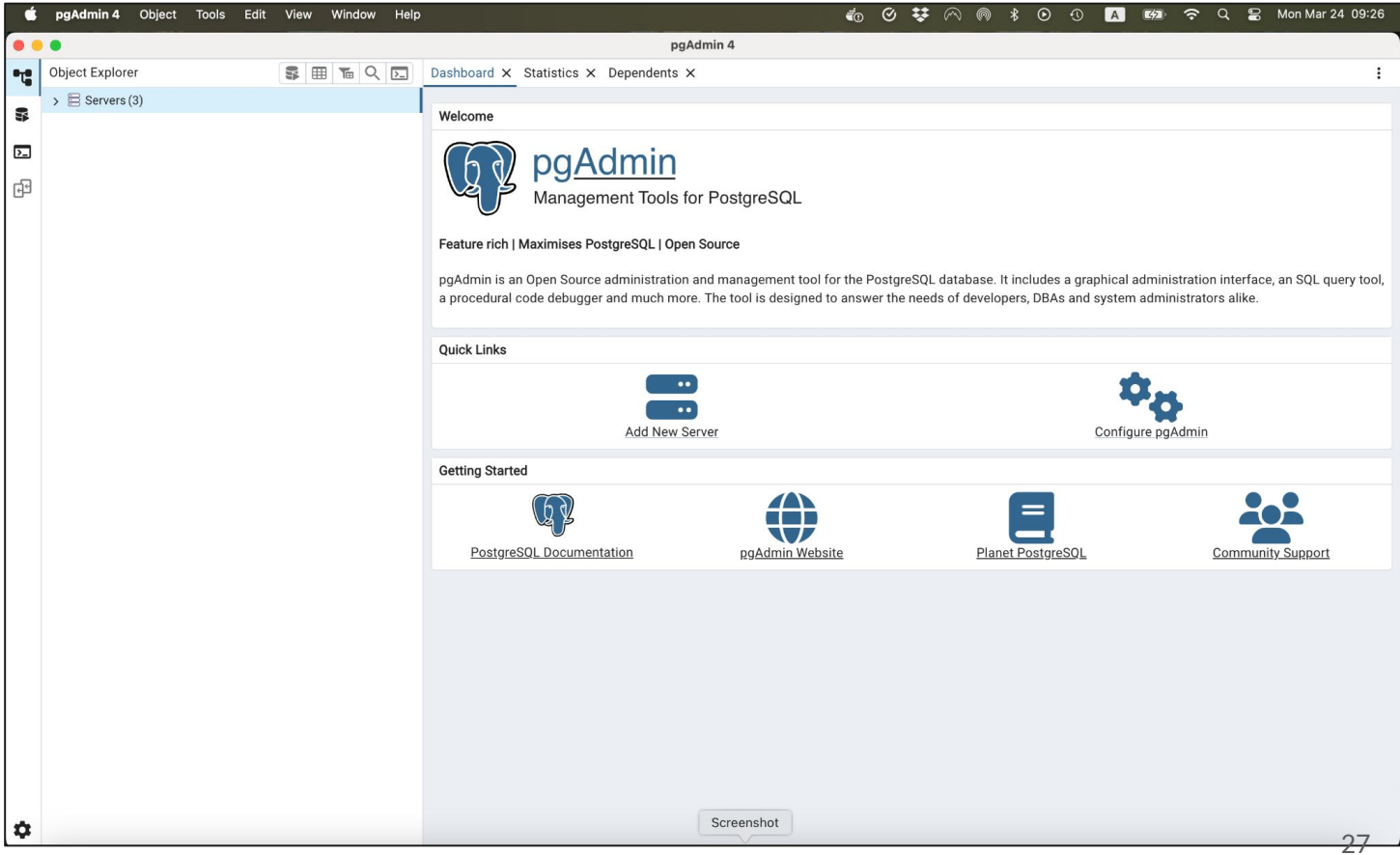
Basic elements of a Postgres database connection from pgAdmin

Connection name	The name in the GUI	• **Postgres17** ⇐ • My connection 1
Where is the database server?	Network address (IP address and port)	IP Address • **Localhost** ⇐ • 188.115.7.175 • mydb.aws.com Port • **5432** ⇐ • 80
Which database do I connect to?	Name of the database on the servers	• **dlh1** ⇐ • dlh2 • dlh3 • inventory
Who am I?	Username and password	Username • **postgres** ⇐ • jDoe Password • **postgres** ⇐ • xd67$566
Security parameters	Encryption on the network	• Not applicable in training

Connection elements

- Network address
  - IP V4 example: 188.115.7.175
  - IP V6 example: 2001:7e8:c415:f601:c0fe:c98b:257a:a45b
  - url: mydb.post.lu
  - Special address: **localhost** (always the local computer. In IPV4: "127.0.0.1", in IPV6: "::1")
- (Network) Port:
  - The port defines which service at a specific network address I want to use, and what 'language' (protocol) I can speak at that port
  - Examples:
    - Port 20: SMTP (email)
    - Port 80: HTTP (WWW)
    - **Port 5432: Postgres**

pgAdmin


pgAdmin 4 Object Tools Edit View Window Help
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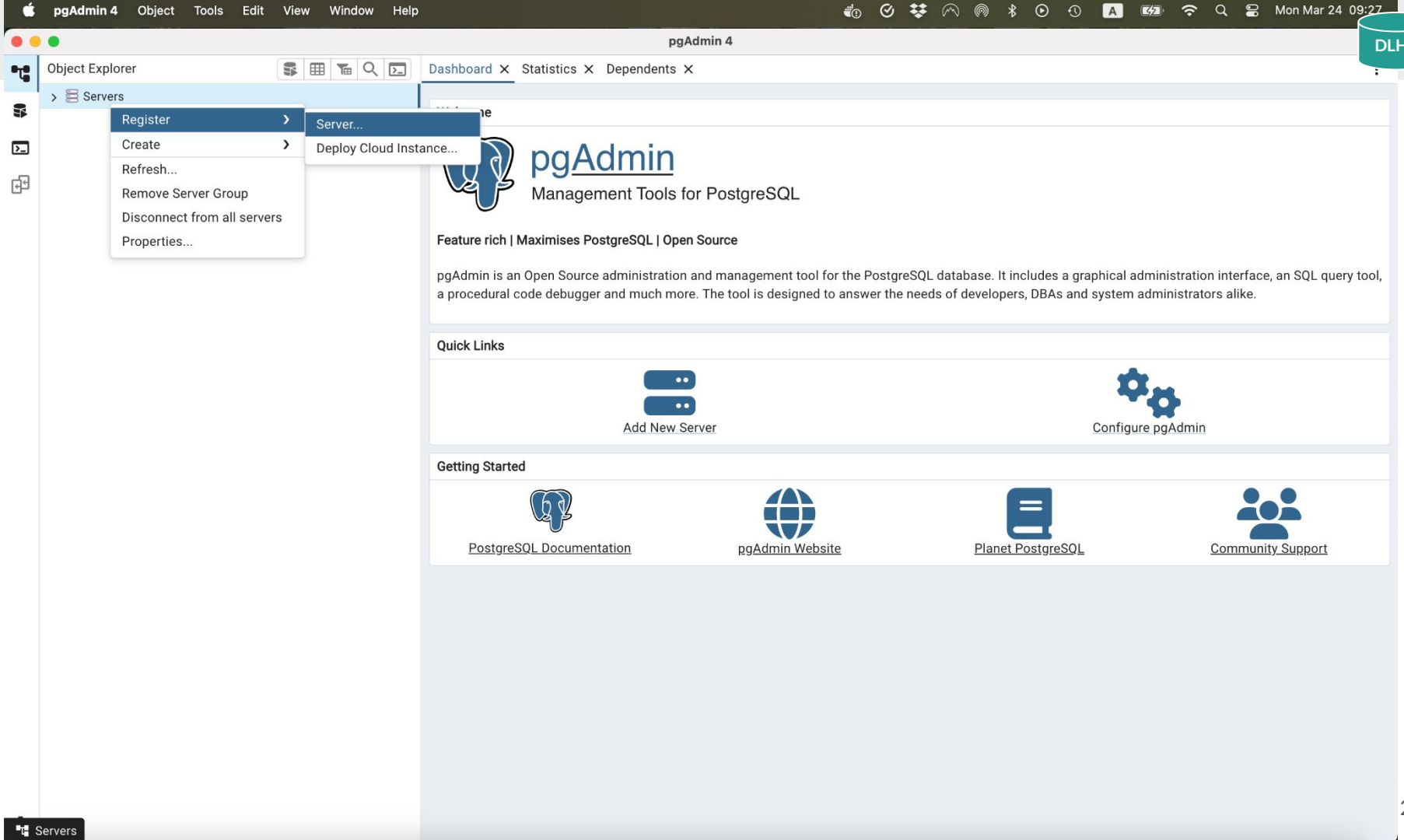
pgAdmin 4
Object Explorer
Servers (3)
Dashboard
Statistics
Dependents
Welcome
pgAdmin
Management Tools for PostgreSQL
Feature rich | Maximises PostgreSQL | Open Source
pgAdmin is an Open Source administration and management tool for the PostgreSQL database. It includes a graphical administration interface, an SQL query tool, a procedural code debugger and much more. The tool is designed to answer the needs of developers, DBAs and system administrators alike.
Quick Links
Add New Server
Configure pgAdmin
Getting Started
PostgreSQL Documentation
pgAdmin Website
Planet PostgreSQL
Community Support
Screenshot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pgAdmin 4
DLH1
Object Explorer
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Statistics
Dependents
Servers
Register
Create
Refresh...
Remove Server Group
Disconnect from all servers
Properties...
Server...
Deploy Cloud Instance...
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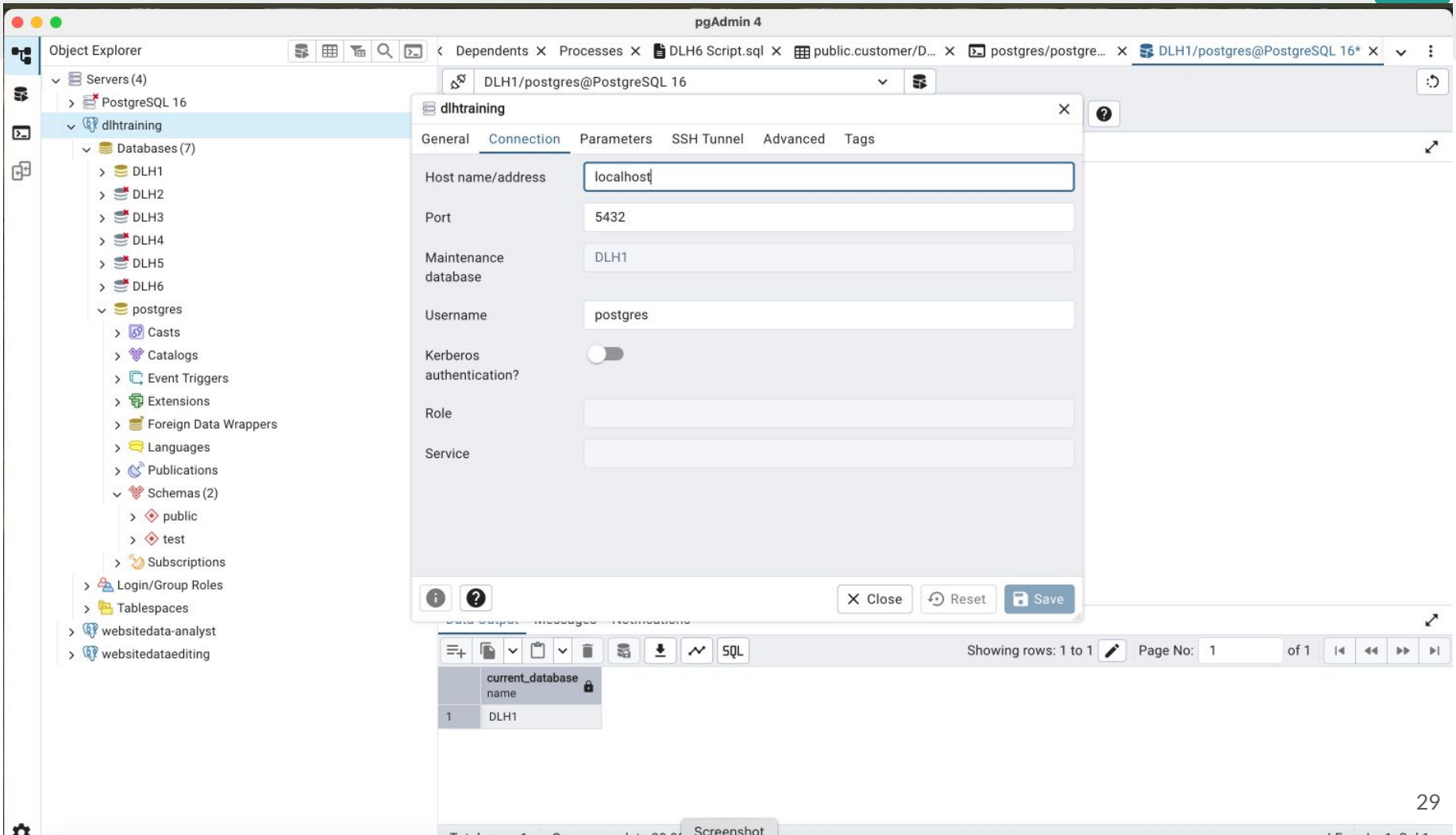
pgAdmin 4
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PostgreSQL 16
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Databases (7)
DLH1
DLH2
DLH3
DLH4
DLH5
DLH6
postgres
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Foreign Data Wrappers
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Subscriptions
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Tablespaces
websitedata-analyst
websitedataediting
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public.customer/D...
postgres/postgre...
DLH1/postgres@PostgreSQL 16*
DLH1/postgres@PostgreSQL 16
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Parameters
SSH Tunnel
Advanced
Tags
Host name/address
localhost
Port
5432
Maintenance database
DLH1
Username
postgres
Kerberos authentication?
Role
Service
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current_database
name
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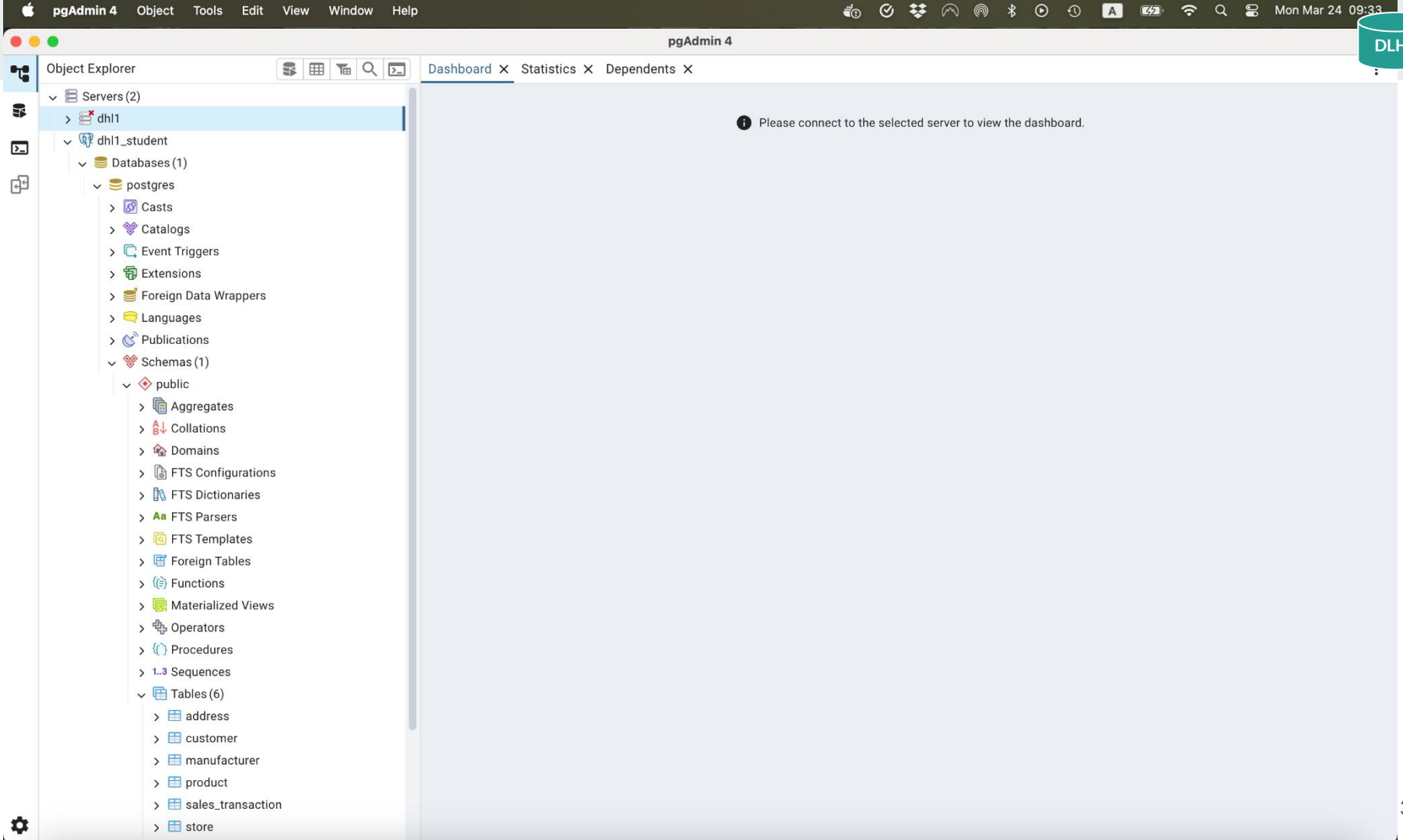
Screenshot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Please connect to the selected server to view the dashboard.
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dhl1
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Databases (1)
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Casts
Catalogs
Event Triggers
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Foreign Data Wrappers
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Schemas (1)
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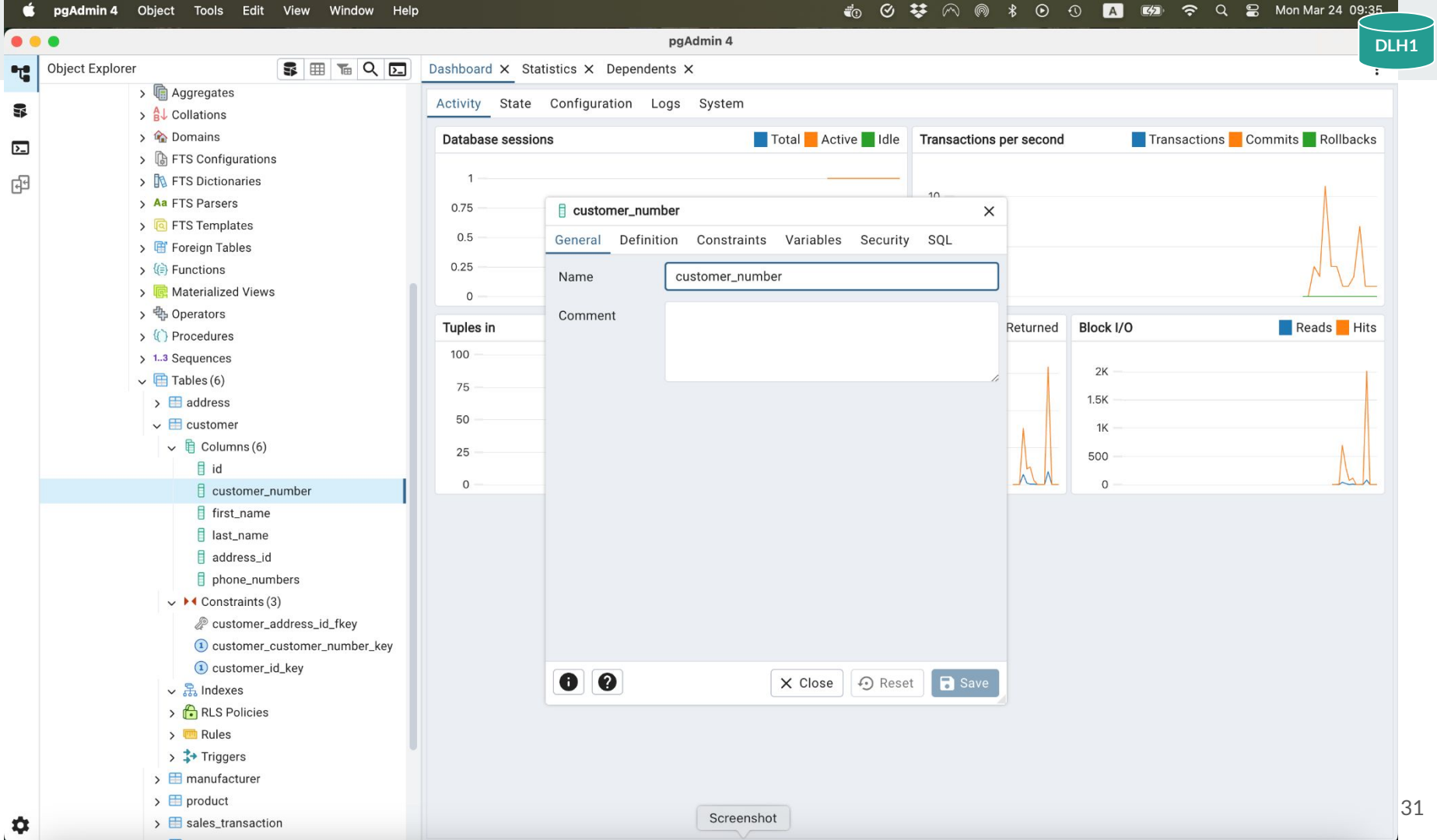
Aggregates
Collations
Domains
FTS Configurations
FTS Dictionaries
FTS Parsers
FTS Templates
Foreign Tables
Functions
Materialized Views
Operators
Procedures
Sequences
Tables (6)
address
customer
manufacturer
product
sales_transaction
store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Sequences
Tables (6)
address
customer
Columns (6)
id
customer_number
first_name
last_name
address_id
phone_numbers
Constraints (3)
customer_address_id_fkey
customer_customer_number_key
customer_id_key
Indexes
RLS Policies
Rules
Triggers
manufacturer
product
sales_transaction
Dashboard
Statistics
Dependents
Activity
State
Configuration
Logs
System
Database sessions
Total
Active
Idle
Transactions per second
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Commits
Rollbacks
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Returned
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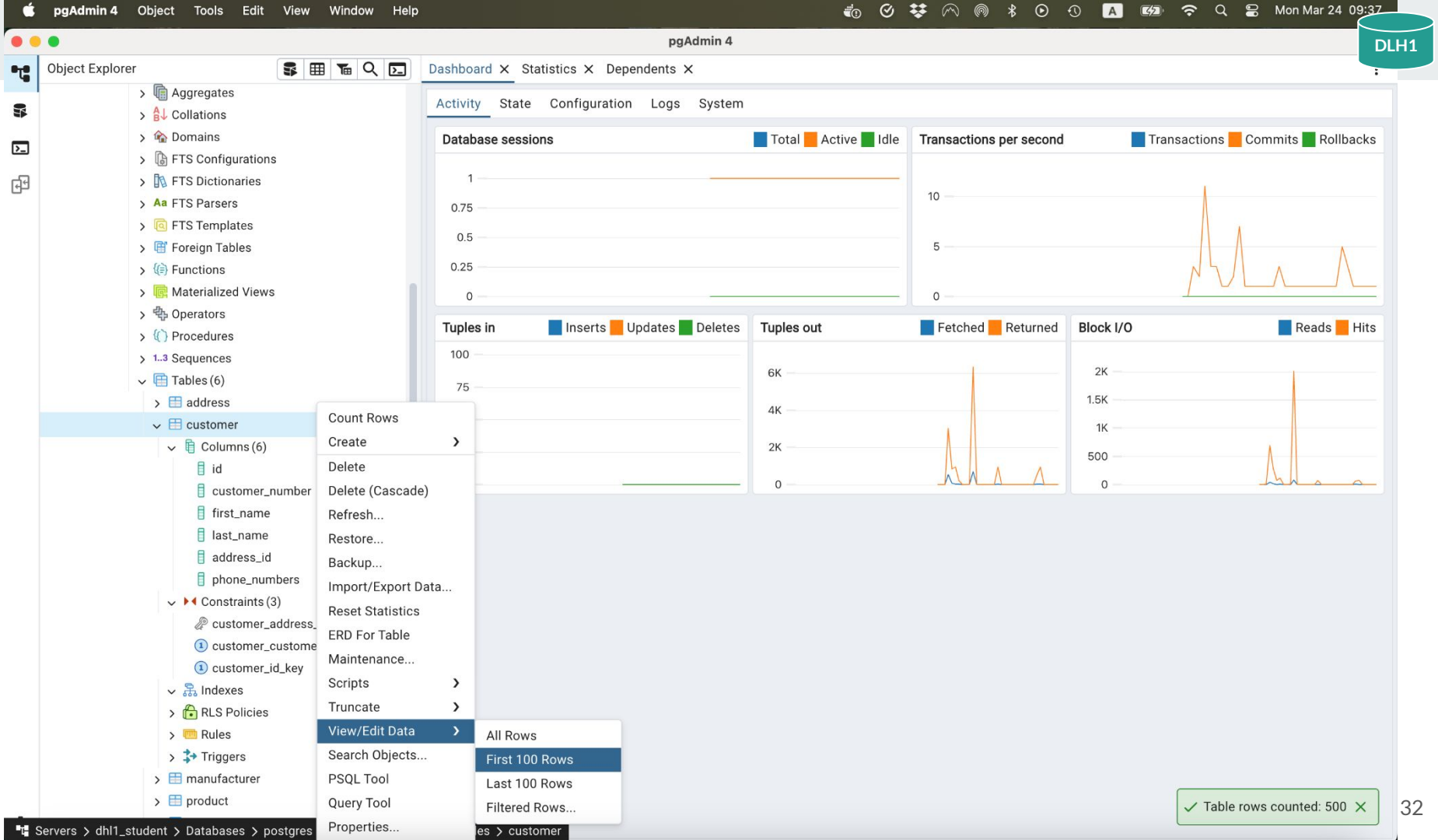
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Triggers
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product
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Delete
Delete (Cascade)
Refresh...
Restore...
Backup...
Import/Export Data...
Reset Statistics
ERD For Table
Maintenance...
Scripts
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View/Edit Data
Search Objects...
PSQL Tool
Query Tool
Properties...
All Rows
First 100 Rows
Last 100 Rows
Filtered Rows...
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Dependents
Activity
State
Configuration
Logs
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Transactions per second
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Commits
Rollbacks
Tuples in
Inserts
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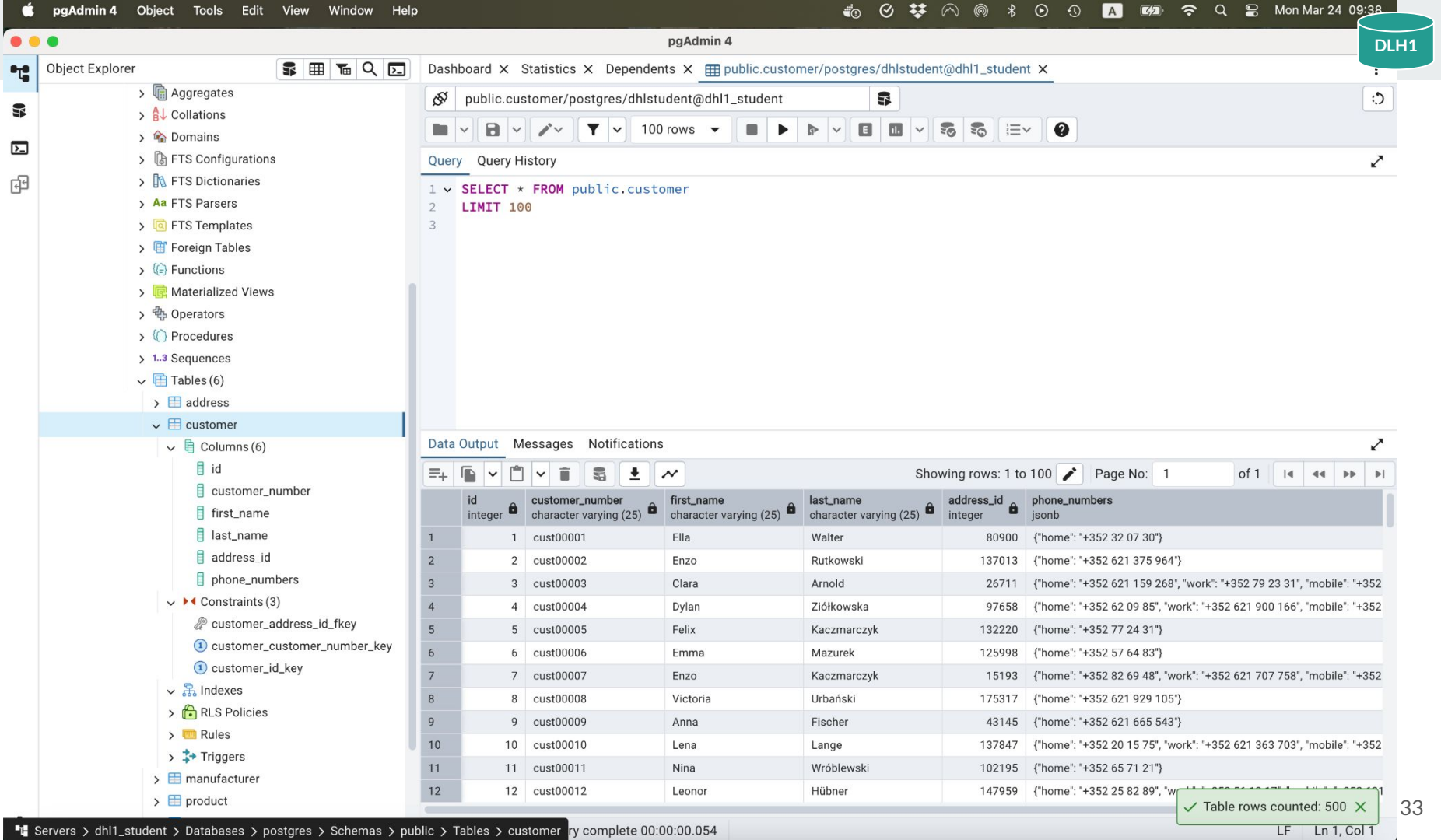
customer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product
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Statistics
Dependents
public.customer/postgres/dhlstudent@dhl1_student
public.customer/postgres/dhlstudent@dhl1_student
100 rows
Query
Query History
1 SELECT * FROM public.customer
2 LIMIT 100
3
Data Output
Messages
Notifications
Showing rows: 1 to 100
Page No: 1
of 1
id integer
customer_number character varying (25)
first_name character varying (25)
last_name character varying (25)
address_id integer
phone_numbers jsonb
1 1 cust00001 Ella Walter 80900 {"home": "+352 32 07 30"}
2 2 cust00002 Enzo Rutkowski 137013 {"home": "+352 621 375 964"}
3 3 cust00003 Clara Arnold 26711 {"home": "+352 621 159 268", "work": "+352 79 23 31", "mobile": "+352
4 4 cust00004 Dylan Ziółkowska 97658 {"home": "+352 62 09 85", "work": "+352 621 900 166", "mobile": "+352
5 5 cust00005 Felix Kaczmarczyk 132220 {"home": "+352 77 24 31"}
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7 7 cust00007 Enzo Kaczmarczyk 15193 {"home": "+352 82 69 48", "work": "+352 621 707 758", "mobile": "+352
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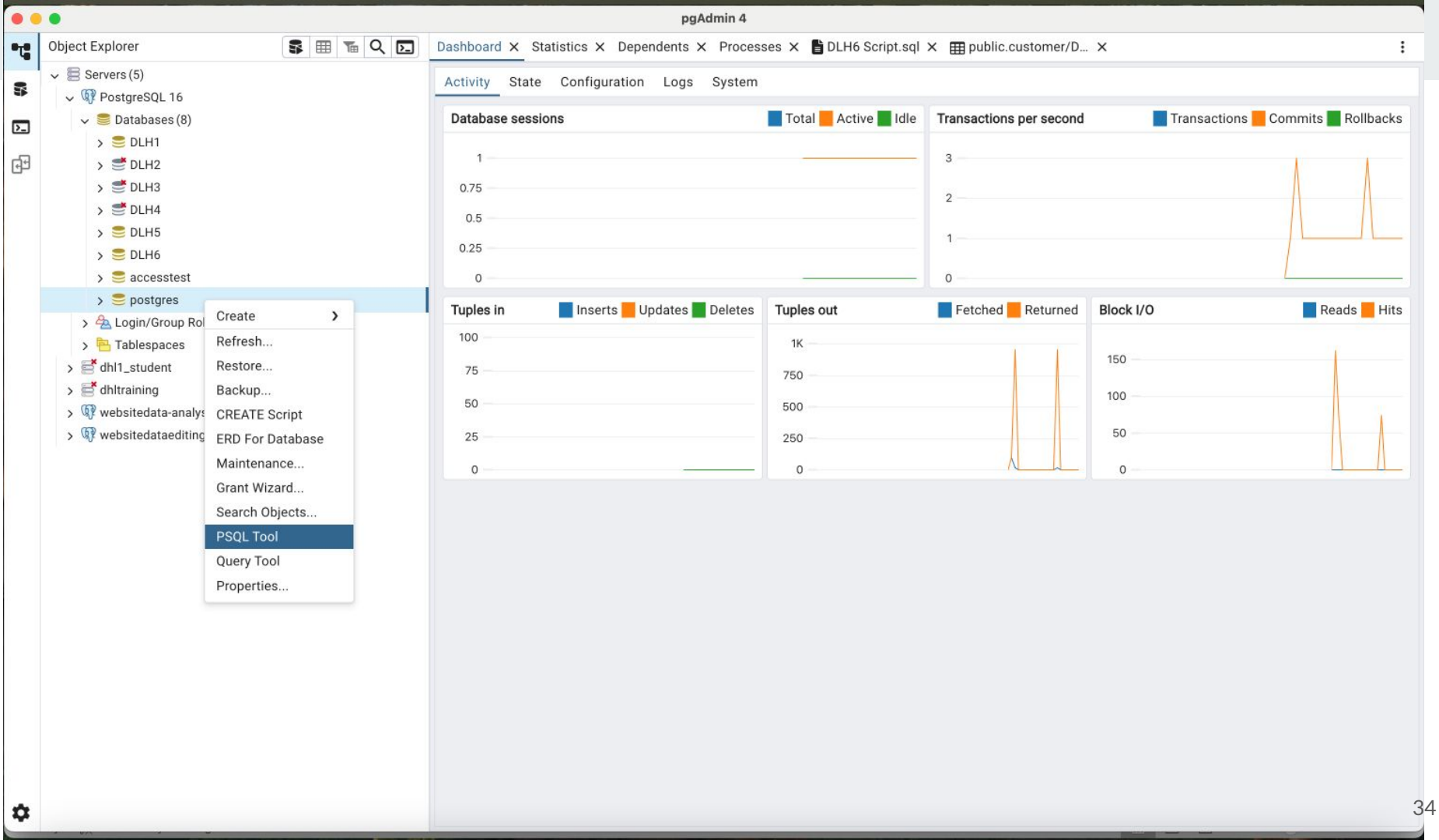
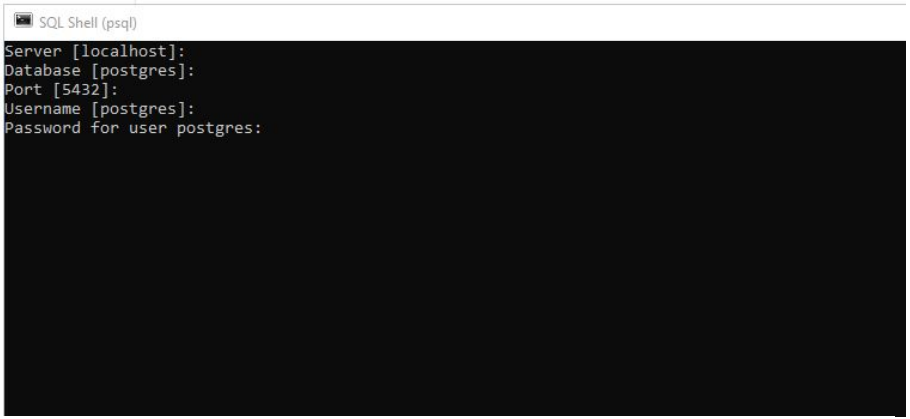
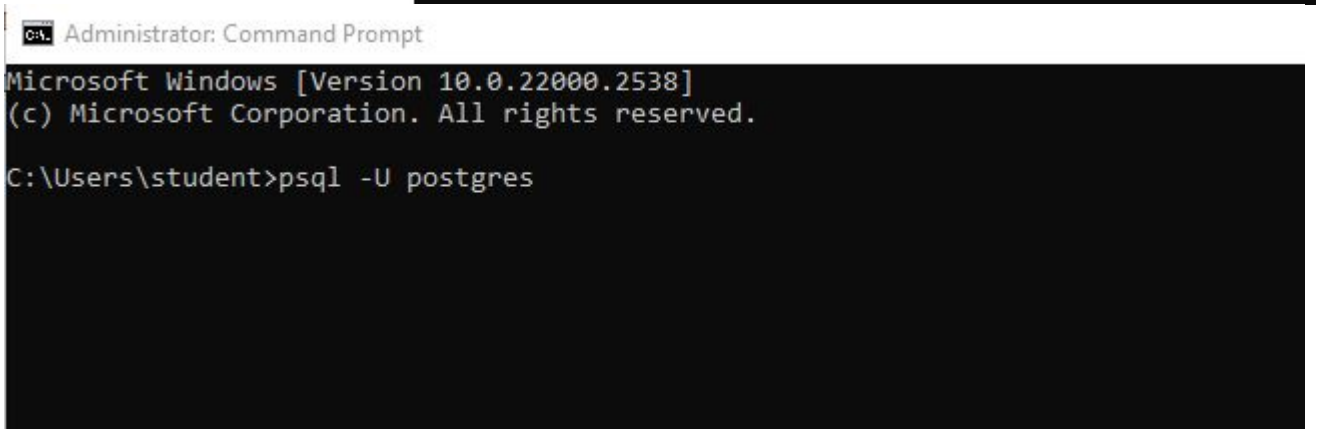
9 9 cust00009 Anna Fischer 43145 {"home": "+352 621 665 543"}
10 10 cust00010 Lena Lange 137847 {"home": "+352 20 15 75", "work": "+352 621 363 703", "mobile": "+352
11 11 cust00011 Nina Wróblewski 102195 {"home": "+352 65 71 21"}
12 12 cust00012 Leonor Hübner 147959
Table rows counted: 500
Servers > dhl1_student > Databases > postgres > Schemas > public > Tables > customer
ry complete 00:00:00.054
LF
Ln 1, Col 1


pgAdmin 4
Object Explorer
Servers (5)
PostgreSQL 16
Databases (8)
DLH1
DLH2
DLH3
DLH4
DLH5
DLH6
accesstest
postgres
Login/Group Rol
Tablespaces
dhl1_student
dhltraining
websitedata-analys
websitedataediting
Create
Refresh...
Restore...
Backup...
CREATE Script
ERD For Database
Maintenance...
Grant Wizard...
Search Objects...
PSQL Tool
Query Tool
Properties...
Dashboard
Statistics
Dependents
Processes
DLH6 Script.sql
public.customer/D...
Activity
State
Configuration
Logs
System
Database sessions
Total
Active
Idle
Transactions per second
Transactions
Commits
Rollbacks
Tuples in
Inserts
Updates
Deletes
Tuples out
Fetched
Returned
Block I/O
Reads
Hits

Access plsql tool

- via menu SQL Shell (plsql)
- via CMD with
  - psql -U postgres





PSQL Cheat Sheet (essentials only)

Connection

`\c[onnect] {[DBNAME|- USER|- HOST|- PORT}`	connect to database
`\conninfo`	display information about current connection
`\set`	displays info about current psql parameters
`\! clear`	clears the display

Informational: (options: S = show system objects, + = additional detail)

`\d[S+]`		list tables, views, and sequences
`\d[S+]`	`NAME`	describe table, view, sequence, or index
`\dg[S+]`	`[PATTERN]`	list roles
`\di[S+]`	`[PATTERN]`	list indexes
`\dm[S+]`	`[PATTERN]`	list materialized views
`\dn[S+]`	`[PATTERN]`	list schemas
`\do[S]`	`[PATTERN]`	list operators
`\dp`	`[PATTERN]`	list table, view, and sequence access privileges

Display etc

`\x`	Switch to expanded display (toggle)
`\time`	Measure execution time (toggle)
`\watch`	Repeated execution of query

`\drds [PATRN1 [PATRN2]]`	list per-database role settings
`\ds[S+] [PATTERN]`	list sequences
`\dt[S+] [PATTERN]`	list tables
`\dT[S+] [PATTERN]`	list data types
`\du[S+] [PATTERN]`	list roles
`\dv[S+] [PATTERN]`	list views
`\l[+] [PATTERN]`	list databases
`\sf[+] FUNCNAME`	show a function's definition
`\sv[+] VIEWNAME`	show a view's definition

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

Tables and queries: Basics

Table Basics

- Rows = records (a.k.a. tuples in Postgres)
- Columns = data elements
- Example: mycustomer table
  - ID = a way to uniquely identify a customer ⇒ usually a large number
  - Email = the email address, a text field, sometimes limited in length
  - First name ⇒ a text field, sometimes limited in length
  - Last name ⇒ a text field, sometimes limited in length
  - Since => a date field

```
postgres=# SELECT * FROM mycustomer;
 id |        email         | first_name | last_name |   since
----+----------------------+------------+-----------+------------
  1 | marc@marclinster.com | Marc       | Linster   | 2025-01-01
  2 | jmu@gmail.lu         | Jeff       | Mueller   | 2025-01-02
  3 | bini@hotmail.lu      | Jean       | Bintner   | 2025-01-03
```

Tables

- All rows/records have the same columns,
  - E.g., for every customer we have id, first_name, last_name, since
- Every column has a data type, which constrains what data can be in that position
  - E.g., ‘since’ is always a date, first_name is always a text
- Most important data types
  - Boolean: Yes/No
  - Character types: char, varchar, text
  - Numeric: integer, floating point, …
  - Temporal types: date, time, timestamp, interval
  - UUID: Unique identifies
  - Array: arrays of strings, numbers, etc
  - JSON: structured documents
  - Special types for network addresses, XML, geographic points, etc

https://www.postgresql.org/docs/current/datatype.html

More on data types later!

Illustrating Select Postgres Data Types

Boolean: 'true' or 'false'

Character Types

- Fixed length: CHARACTER(n), CHAR(n)
- Variable length w. length limit: CHARACTER VARYING (n), VARCHAR (n)
- Variable w.o. length limit: TEXT, VARCHAR

Number Types

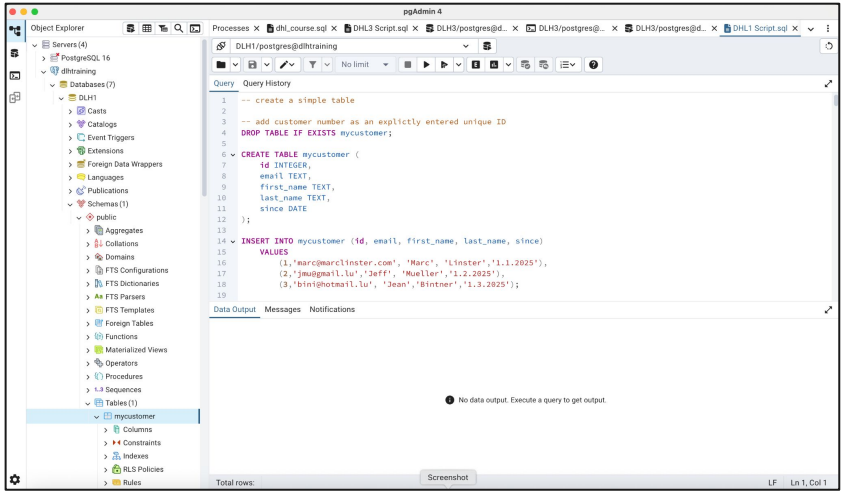
- INTEGER:
  - SMALLINT (+/- 32,768), INTEGER (+/- 2,147,483,648), BIGINT (+/- 9,223,372,036,854,775,808)
- NUMERIC/DECIMAL:
  - NUMERIC (5,2) - 5 digits before the period, two after the period, for example 172.99

Let's try it out

- pgAdmin Query Tool
  - Make sure you are connected to DLH1!
    - Enter "`SELECT current_database();`" to check where you connected
  - Try this:

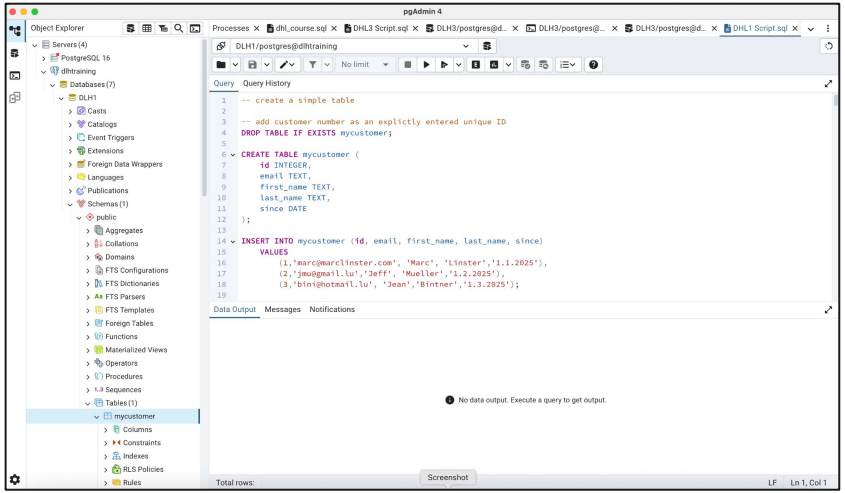
```
CREATE TABLE mycustomer (
      id INTEGER,
      email TEXT,
      first_name TEXT,
      last_name TEXT,
      since DATE
);
```

  - Check out the list of tables in the pgAdmin tree browser (hit refresh)



Let's try something else

- pgAdmin Query Tool
  - Create the table mycustomer1 using the GUI
    - Add columns
      - `id INTEGER,`
      - `email TEXT,`
      - `first_name TEXT,`
      - `last_name TEXT,`
      - `since DATE`
  - Check out the list of tables in the pgAdmin tree browser (hit refresh)

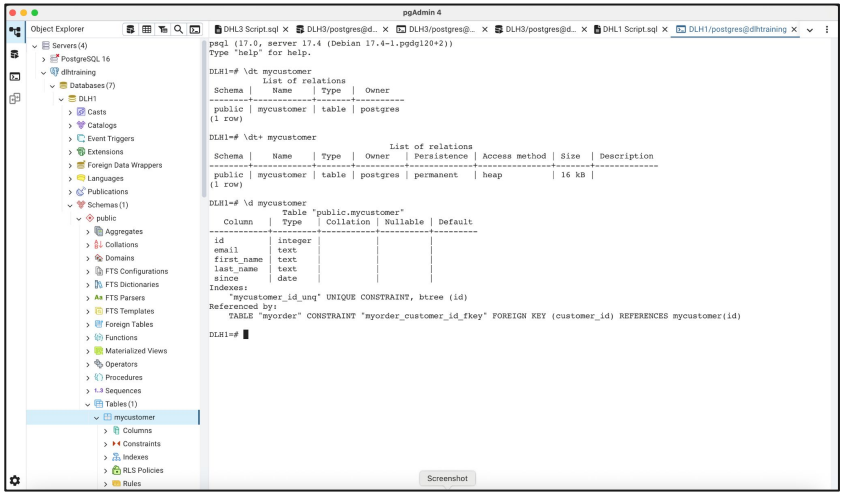


PSQL Tool

- Try:
  - \c (which database am I connected to?)
  - \c dlh1 (connect me to DLH1
  - \l (list all the databases)

```
CREATE TABLE mycustomer2 (
    id INTEGER,
    email TEXT,
    first_name TEXT,
    last_name TEXT,
    since DATE
);
```

  - \dt, \dt+ and \d mycustomer2
  - DROP TABLE mycustomer1;
  - DROP TABLE mycustomer2;
  - \dt



Uppercase, lowercase, white spaces, etc

- Postgres ignores case - all names for tables, columns, functions, procedures etc. are lowercase
  - Postgres automatically lower cases all identifiers!!!
  - SQL identifiers and keywords must begin with a letter or an underscore (_).
  - Subsequent characters can be letters, underscores, digits (0-9), or dollar signs ($).
  - Note that dollar signs are not allowed in identifiers according to the letter of the SQL standard, so their use might render applications less portable.
- Customername = CustomerName = CUSTOMERNAME = customername <> "CustomerName" <> "customerName" <> "CUSTOMERNAME'
- Do not use camelCase, use snake_case to improve readability of identifiers, e.g. customer_name
- Spaces (' ') cannot be used in identifiers
- Double quotes "" can be used to create mixed case identifiers that include spaces

DON'T DO IT!!!
Mixed case and spaces cause all kinds of problems later on

Query basics

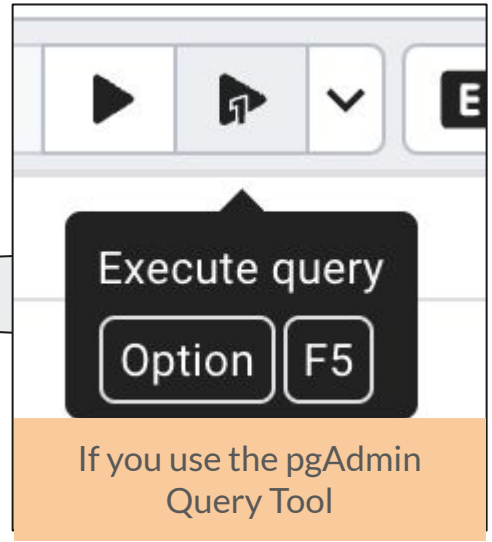
Query types

- SELECT: List data from tables that meet certain conditions
- UPDATE: Change data in records that meet certain conditions
- INSERT: Add records
- DELETE: Remove Records

Let's try it out in the GUI Query Tool

```
SELECT * FROM mycustomer;
```

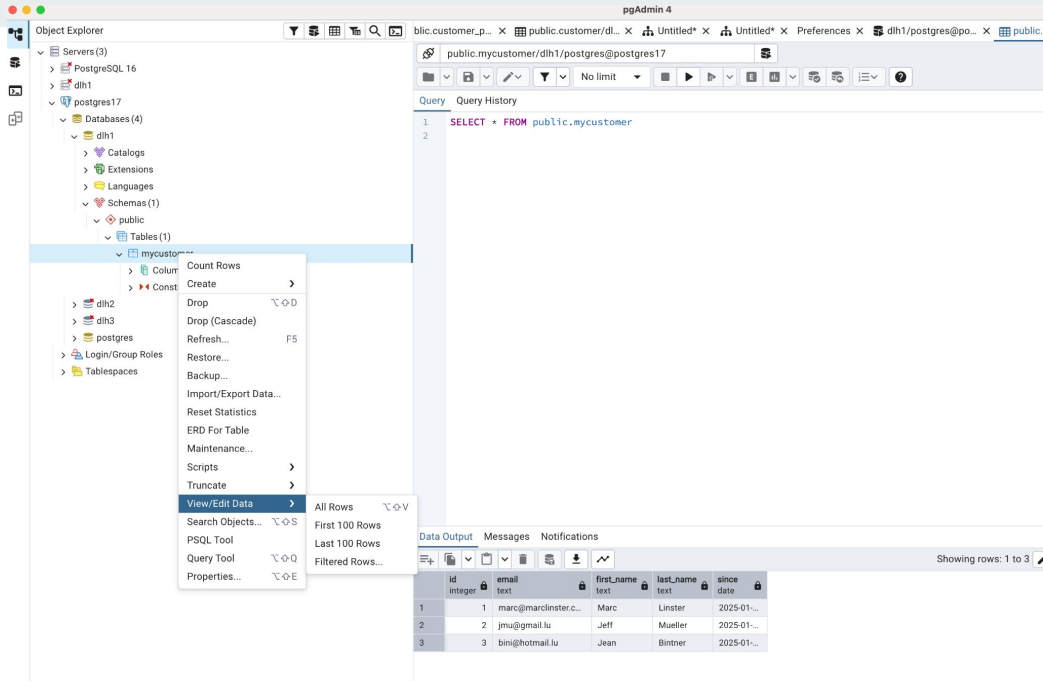
- Remember the ';'
- Click




```
INSERT INTO mycustomer (id, email, first_name, last_name, since)
     VALUES
          (1,'marc@marclinster.com', 'Marc', 'Linster','1.1.2025');

INSERT INTO mycustomer (id, email, first_name, last_name, since)
     VALUES
          (2,'jmu@gmail.lu','Jeff', 'Mueller','1.2.2025'),
          (3,'bini@hotmail.lu', 'Jean','Bintner','1.3.2025');

SELECT first_name FROM mycustomer;
SELECT first_name, last_name FROM mycustomer;
SELECT * FROM customer WHERE last_name = 'Linster';
SELECT * FROM customer WHERE first_name LIKE 'Je%';
```

Use the GUI to see the rows

- Go to dlh1/public/mycustomer
- Choose select all rows



Use PLSQL

- Add two more customers with id 4 and 5

Building Blocks of the simple SELECT Query

- SELECT
  - Columns to be selected, maybe using AS to provide a meaningful name
  - For example `last_name AS ln`
- FROM
  - Table(s) from which to select. Can also use AS to provide a new name
  - For example `customer AS c`
- WHERE
  - Filter clauses to select a subset of records
  - Can use the new names from the AS clause
  - For example `c.ln LIKE 'Li%'`
- ORDER BY
  - Organizes the output of the SELECT clause
  - Can use the new names from the AS clause
  - For example: `c.ln ASC, since DESC`

Alias (AS)

- improves readability
- Only available in the context of this query
- Key word 'AS' is optional

More complex building blocks for SELECT queries (JOIN, GROUP BY, HAVING, GROUPING, WITH, ...) will be introduced later

Let's try it out

```
UPDATE mycustomer SET first_name = 'Mark' WHERE id = 1;
SELECT * FROM mycustomer;
DELETE FROM mycustomer WHERE id = 1;
SELECT * FROM mycustomer;
SELECT * FROM mycustomer ORDER BY last_name ASC;
```

Try it in pgAdmin Query Tool and in PSQL

Day 2

- Review of Day 1
- Operators in the WHERE clause and computations in the SELECT clause
- Primary keys, constraints, and foreign key relationships
- Data Types: Numbers, Characters, JSON, and more

Operators in the WHERE Clause

Postgres Operators in the WHERE Clause

`=`	Equal to
`<`	Less than
`>`	Greater than
`<=`	Less than or equal to
`>=`	Greater than or equal to
`<>`	Not equal to
`!=`	Not equal to
`LIKE`	Check if a value matches a pattern (case sensitive)
`ILIKE`	Check if a value matches a pattern (case insensitive)
`AND`	Logical AND
`OR`	Logical OR
`IN`	Check if a value is between a range of values
`BETWEEN`	Check if a value is between a range of values
`IS NULL`	Check if a value is NULL
`NOT`	Makes a negative result e.g. `NOT LIKE`, `NOT IN`, `NOT BETWEEN`

Let's try it out

```
SELECT * FROM mycustomer WHERE first_name LIKE 'Je%';

SELECT * FROM mycustomer WHERE first_name LIKE 'je%';

SELECT * FROM mycustomer WHERE first_name ILIKE 'je%';

SELECT * FROM mycustomer WHERE first_name LIKE '_e%';

SELECT * FROM mycustomer WHERE first_name LIKE '_e%' AND last_name = 'Bintner';

SELECT * FROM mycustomer WHERE since
    BETWEEN '2025-01-02' AND '2025-02-01';
```

Computations in Select

Postgres functions in the SELECT clause

Some of the key string functions

||	String append	`'a'||'_'||'b' → a_b`
lpad/rpad	Create a padded string	`rpad('hi', 5, 'xy') → hixyx`
substring	Create a substring	`substring('Thomas' from 2 for 3) → hom`
::string	Cast a number (and other types) as string	`1::TEXT||'_'||2::TEXT → 1_2`

Many, many more in the Postgres documentation: https://www.postgresql.org/docs/current/functions-string.html

Synonyms

- 'AS' defines a synonym
- Can be used for table names and column names
- Explicit form: `SELECT mc.email AS email_address FROM mycustomer AS mc;`
    - Using 'AS' makes the query more readable
    - Use snake_case for the pretty names
- Short form: `SELECT mc.email email_address FROM mycustomer mc;`

Lets try it out

```
SELECT
     FIRST_NAME || ' ' || LAST_NAME
          AS customer_name
FROM
     MYCUSTOMER
WHERE
     FIRST_NAME LIKE 'Je%';
```

Other Calculations

- TO_CHAR – convert a timestamp or a numeric value to a string.
  - SELECT TO_CHAR (NOW(), 'DAY');
  - SELECT TO_CHAR (NOW(), 'MON');
  - SELECT TO_CHAR (CURRENT_DATE, 'Day Month, DD, YYYY');
  - SELECT TO_CHAR (12345.55, '99G999G999D99L');
  - https://www.postgresql.org/docs/current/functions-formatting.html
- Format
  - SELECT FORMAT ('This is a string with a %s and a %s', 'first placeholder', 'second placeholder');
  - https://www.postgresql.org/docs/current/functions-string.html#FUNCTIONS-STRING-FORMAT
- Extract

EXTRACT

- EXTRACT from timestamp or date
  - CENTURY
  - DAY (day of the month)
  - DOW (day of the week - Sunday(0) to Saturday (6)
  - ISODOW (ISO standard day of the week - Monday (1) to Sunday (7)
  - DOY (day of the year)
  - HOUR, MINUTE, ….
- Try it out:
  - `SELECT 'It is the ' || EXTRACT (DOY FROM current_date) || 'th day of the year';`

```
             ?column?
--------------------------------
 It is the 234th day of the year
```

- Name the column using AS
  - `SELECT 'It is the ' || EXTRACT (DOY FROM current_date) || 'th day of the year' as day_of_year;`

A better way to format strings: FORMAT

```
SELECT
     FORMAT ('%s %s', first_name, last_name)
          AS customer_name
FROM
     MYCUSTOMER
WHERE
     FIRST_NAME LIKE 'Je%';
```

Calculations in the SELECT statement

```
SELECT
      FIRST_NAME || ' ' || LAST_NAME
            AS customer_name,
      FORMAT('Customer for %s days', CURRENT_DATE - since)
            AS how_long
FROM
      MYCUSTOMER;
```

```
customer_name |          how_long
--------------+-----------------------
 Marc Linster  | Customer for 111 days
 Jeff Mueller  | Customer for 110 days
 Jean Bintner  | Customer for 109 days
```

EXTRACT (field FROM source)

- Field: DAY, DOW, DOY, YEAR, …
- SOURCE: Date, timestamp or interval

See:
https://neon.tech/postgresql/postgresql-date-functions/postgresql-extract

Order By

```
SELECT * FROM mycustomer
     ORDER BY last_name ASC;

SELECT * FROM mycustomer
     WHERE first_name LIKE 'Je%'
     ORDER BY last_name ASC, first_name ASC;
```

Try it out

- Create a query that
  - Selects customers from the customer table
  - Puts the name in the format ‘last name, first name’, e.g., Linster, Marc
  - Adds a columns entitled 'customer_since'
  - Sorts descending by last name, ascending by first name

Primary Keys, Constraints and Relationships

Constraints and Relationships

- Constraints and relationships make sure your data in the tables is consistent
  - For example:
    - Orders always have quantities > 0
    - Products with prices > 0
    - Products each having different names
    - Orders referring to existing products
- Constraints and relationships complement the definition of tables, columns, and data types

Constraints and Relationships

- **Check Constraints:** The value in the column has to meet certain criteria, e.g., price > 0
- **Not-Null Constraints:** The column needs to have a value
- **Unique Constraints:** No two records have the same value
- **Primary Keys:** like the Unique Constraint, but excludes NULL and always creates an index
  - ⇒ A primary key can also be a combination of columns
- **Foreign Keys:** the data needs to be a valid reference to another table
  - You can assign a ‘trigger’ to handle deletions

Primary Keys

- A unique way to find a row in the table
  - Cannot be NULL
  - Must be unique
- Can be a combination of rows

id	email	first_name	last_name	since
1	marc@marclinster.com	Marc	Linster	2025-01-01
2	jmu@gmail.lu	Jeff	Mueller	2025-01-02
3	bini@hotmail.lu	Jean	Bintner	2025-01-03

This is what we are trying to do

- 3 tables
  - mycustomer
  - myproduct
  - myorder
- Orders refer to customers and products
  - Every order links to one customer and one product (simplified model)
  - Make sure only existing customer can place an order
  - Make sure that all products actually exist

Table Basics

```
CREATE TABLE myproduct (
    product_nbr VARCHAR(10),
    name TEXT,
    price numeric
);
```

Problems:

- Every product should have a unique id (or product number)
- No two products should have the same name
- Every product should have a price > 0

Table Basics

```
DROP TABLE IF EXISTS myproduct;

CREATE TABLE myproduct (
     nbr VARCHAR(10) PRIMARY KEY,
     name TEXT UNIQUE NOT NULL,
     price NUMERIC NOT NULL CHECK (price > 0)
);
```

Try it out

- Insert 4 product records
- Use SELECT to make sure it worked
- Sort them by price ascending

- Add primary key to uniquely identify every record
  - PRIMARY KEY = UNIQUE + NOT NULL + indexed
  - Only one primary key per table
- Make sure that no products can have the same name
- All prices have to be greater than 0

```
SELECT * FROM myproduct;
 nbr          |           name           | price
--------------+--------------------------+-------
 ham_001      | Hammer 200gr             | 19.95
 ham_002      | Hammer 1kg               | 25.00
 chisel_004   | Chisel stone             | 39.95
 pli_019      | Pliers red, adjustable   | 13.50
```

CREATE TABLE myorder

- Introducing new capabilities:
  - Automatically generate a primary key
  - Link the order to a customer
  - Link the order to a product

Relations and foreign keys

```
DROP TABLE IF EXISTS myorder;

CREATE TABLE myorder (
      id INT PRIMARY KEY GENERATED BY DEFAULT AS IDENTITY,
      date DATE,
      customer_id INTEGER NOT NULL,
      product_nbr VARCHAR(10) NOT NULL,
      qty INTEGER NOT NULL CHECK (qty > 0)
)
```

Nonsense order:

```
INSERT INTO myorder (date, customer_id, product_nbr, qty)
      VALUES (current_date, 25, 'big_thing', 11);
```

- Create PRIMARY KEY
- Automatically generate a unique ID

Problems:

- No guarantee that the product_nbr is actually in the `myproduct` table
- Not sure if the customer is actually defined!

Relations and foreign keys

```
DROP TABLE IF EXISTS myorder;

CREATE TABLE myorder (
      id INT PRIMARY KEY GENERATED BY DEFAULT AS
IDENTITY,
      date DATE,
      customer_id INTEGER REFERENCES mycustomer (id),
      product_nbr VARCHAR(10) REFERENCES myproduct (nbr),
      qty INTEGER NOT NULL CHECK (qty > 0)
);
```

Definition fails as mycustomer (id) does not have a unique constraint

```
ALTER TABLE mycustomer ADD CONSTRAINT mycustomer_id_unq
UNIQUE (id);
```

try to create an order for a non-existing product

```
INSERT INTO myorder (date, customer_id,
product_nbr, qty)
      VALUES (current_date, 25, 'big_thing', 11);
```

```
      ERROR:  insert or update on table
"myorder" violates foreign key constraint
"myorder_customer_id_fkey"
Key (customer_id)=(25) is not present in
table "mycustomer".

SQL state: 23503
Detail: Key (customer_id)=(25) is not
present in table "mycustomer".
```

```
SELECT * FROM myproduct;
    nbr     |          name          | price
------------+------------------------+-------
 ham_001    | Hammer 200gr           | 19.95
 ham_002    | Hammer 1kg             | 25.00
 chisel_004 | Chisel stone           | 39.95
 pli_019    | Pliers red, adjustable | 13.50
```

```
SELECT * FROM mycustomer;
 id |        email         | first_name | last_name |   since
----+----------------------+------------+-----------+------------
  1 | marc@marclinster.com | Marc       | Linster   | 2025-01-01
  2 | jmu@gmail.lu         | Jeff       | Mueller   | 2025-01-02
  3 | bini@hotmail.lu      | Jean       | Bintner   | 2025-01-03
```

Let's add orders

```
\d myorder
                                  Table "public.myorder"
   Column    |          Type           | Collation | Nullable |              Default
-------------+-------------------------+-----------+----------+-----------------------
 id          | integer                 |           | not null | generated by default …
 date        | date                    |           |          |
 customer_id | integer                 |           |          |
 product_nbr | character varying(10)   |           |          |
 qty         | integer                 |           | not null |
Indexes: "myorder_pkey" PRIMARY KEY, btree (id)
Check constraints: "myorder_qty_check" CHECK (qty > 0)
Foreign-key constraints:
    "myorder_customer_id_fkey" FOREIGN KEY (customer_id) REFERENCES mycustomer(id)
    "myorder_product_nbr_fkey" FOREIGN KEY (product_nbr) REFERENCES myproduct(nbr)
```

```
INSERT INTO myorder (date, customer_id, product_nbr, qty)
     VALUES
          (current_date, 1, 'ham_001', 1),
          (current_date, 1, 'ham_002', 1),
          (current_date-1, 2, 'chisel_004', 2),
          ('2025-03-01', 2, 'pli_019', 4);
```

Queries that work on multiple tables

SELECT <column_names> ⇐ comma separated list

FROM <table_names> ⇐ comma separated list

WHERE

ORDER BY

} Optional

```
SELECT * FROM myorder o,
          myproduct p,
          mycustomer c
     WHERE
          o.product_nbr = p.nbr
     AND
          o.customer_id = c.id;
```

```
-[ RECORD 1 ]--------------------
id          | 1
date        | 2025-02-02
product_nbr | chisel_004
qty         | 9
customer_id | 1
nbr         | chisel_004
name        | Chisel stone
price       | 39.95
id          | 1
email       | marc@marclinster.com
first_name  | Marc
last_name   | Linster
since       | 2025-01-01
```

Uses the \x command in PSQL Tool to show the records in expanded mode

Try it out

1) Add products to myproduct table (up to 5 total)
2) Add several customers (max 5)
3) Add at least 5 orders for different products and customers. Orders dating in February 2025
4) Create a query that displays the orders with
    - Order id
    - Order date (ascending)
    - Customer name in format 'last_name, first_name'
    - Product name
    - Product price
    - Order quantity
    - Extended price (quantity * price)

Data Types in Postgres

Key Data Types in SQL

Boolean	Logical true or false	true, false
Numbers	Integers: Decimals Floating-point	1,2, 45, 987 (smallint, integers, bigint) 7.25 3.14159265
Binary	Raw data	PDF, images
Character types	Fixed/limited length Unlimited length (max 1 GB)	
Date time	Date Time Timestamp Interval	2025-09-23 16:49:47.70598 2025-09-23 16:49:47.70598 1 day
JSON/JSONB	JSON/JSONB	{"home": "47 25 07", "mobile": "621 599-314"}
Array	INTEGER[]	{1,2,5,19,27}
Ranges	Date ranges Number ranges	[2025-03-01, 2025-03-31) [1, 9]
UUID	Universally Unique IDs	01995196-02ef-7db9-b11b-b906ee7b4926

Numbers

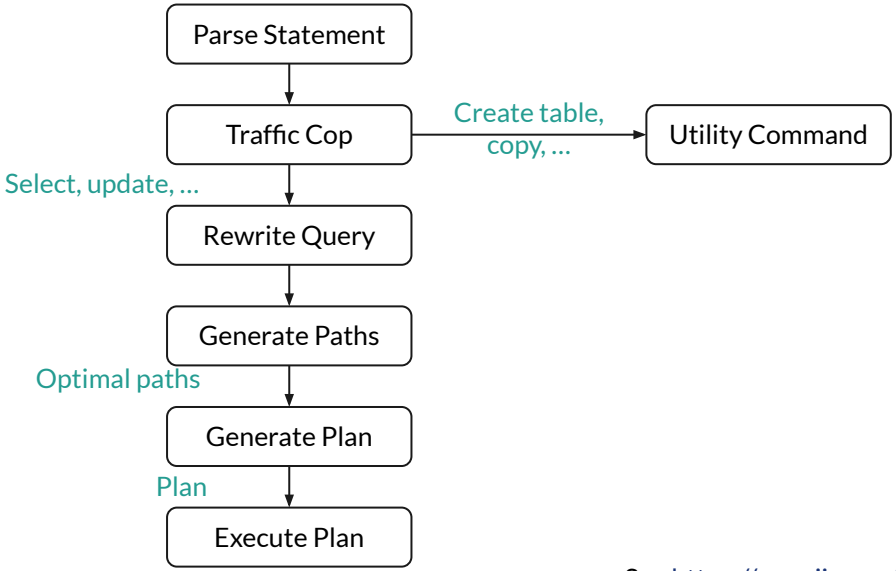
Data Type	Range	Storage	Pro	Con
SMALINT	+/- 32,768	2 bytes	Fast computation Small storage	No fractions Automatic rounding
INTEGER	+/- 2,147 M	4 bytes		
BIGINT	+/- 9,223 B	8 bytes		
NUMERIC/ DECIMAL	Max. 131072 digits bef. decimal point; max 16383 digits aft. decimal point	Variable	No rounding errors	More storage Slower calculations
REAL	-3.40282347 × 1E38 to 3.40282347 × 1E38	4 bytes	Imprecise w. rounding errors	Fast calculations Less storage than NUMERIC/DECIMAL
DOUBLE PRECISION	1E-307 to 1E+308	8 bytes		

Day 3

- Review of Day 2
- Indexes
- Organizing data with schemas and entity-relationship diagrams
- Queries revisited (joins, views, and aggregates)

Indexes

How does Postgres process a query?



See https://momjian.us/main/writings/pgsql/internalpics.pdf

How does a database find data?

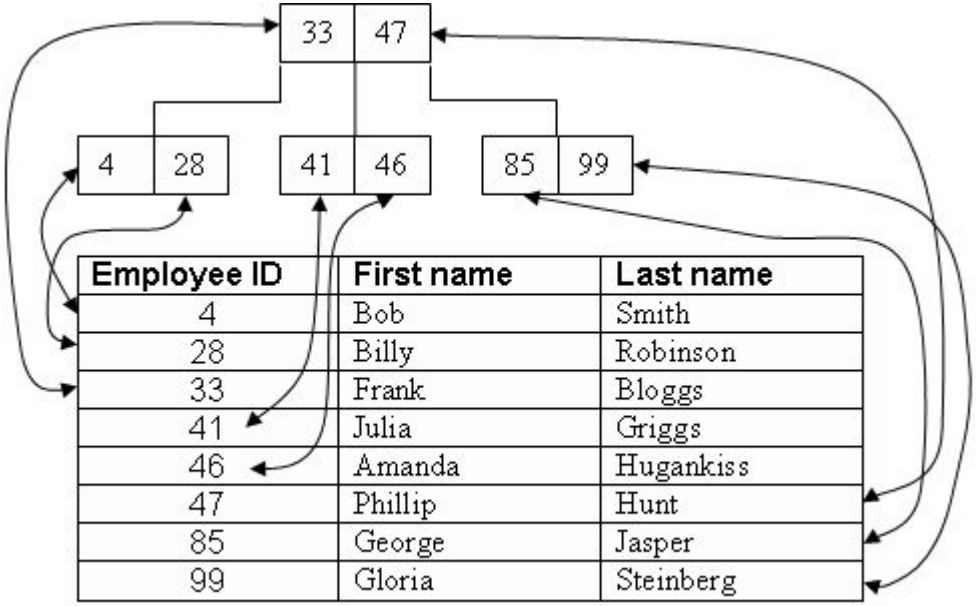
- Every table is stored in 8k data blocks on disk, in files that are 1GB (or less)
- Example: `SELECT * from customer WHERE last_name = 'Voigt';`
- Without Index
  - Sequential scan of all data blocks for that table
  - If block is not in memory (shared buffers), get it from disk and load it into memory
    - “**Sequential Scan**”
- With Index
  - Load the index into memory (usually much smaller than data table)
  - Ask the index which blocks have the data
  - Load only those blocks
    - “**Index Scan**”

Many types of Indexes

- **Balanced Tree (B-Tree)**
  - **Every database has it. The most common and used for 90%+ of all cases. The default in Postgres**
  - **Ideal for looking up unique values and maintaining unique indexes**
  - **High concurrency implementation - very fast**
- Block-Range Index (BRIN)
  - Ideal for very large datasets that are organized according to the index
- Generalized Inverted Index (GIN)
  - Best for indexing values with many keys or values, e.g.,text documents, JSON, multi-dimensional data, arrays
  - Ideal for columns containing many duplicate
- Hash Index
  - Equality, non-equality lookups; no range lookups
- Generalized Search Tree (GiST)
  - Used for GIS, key-value store
- Space-Partitioned Generalized Search Tree (SP-GIST)
  - Specialized index

https://momjian.us/main/writings/pgsql/indexing.pdf

Very Fast Access to Data



Employee ID	First name	Last name
4	Bob	Smith
28	Billy	Robinson
33	Frank	Bloggs
41	Julia	Griggs
46	Amanda	Hugankiss
47	Phillip	Hunt
85	George	Jasper
99	Gloria	Steinberg

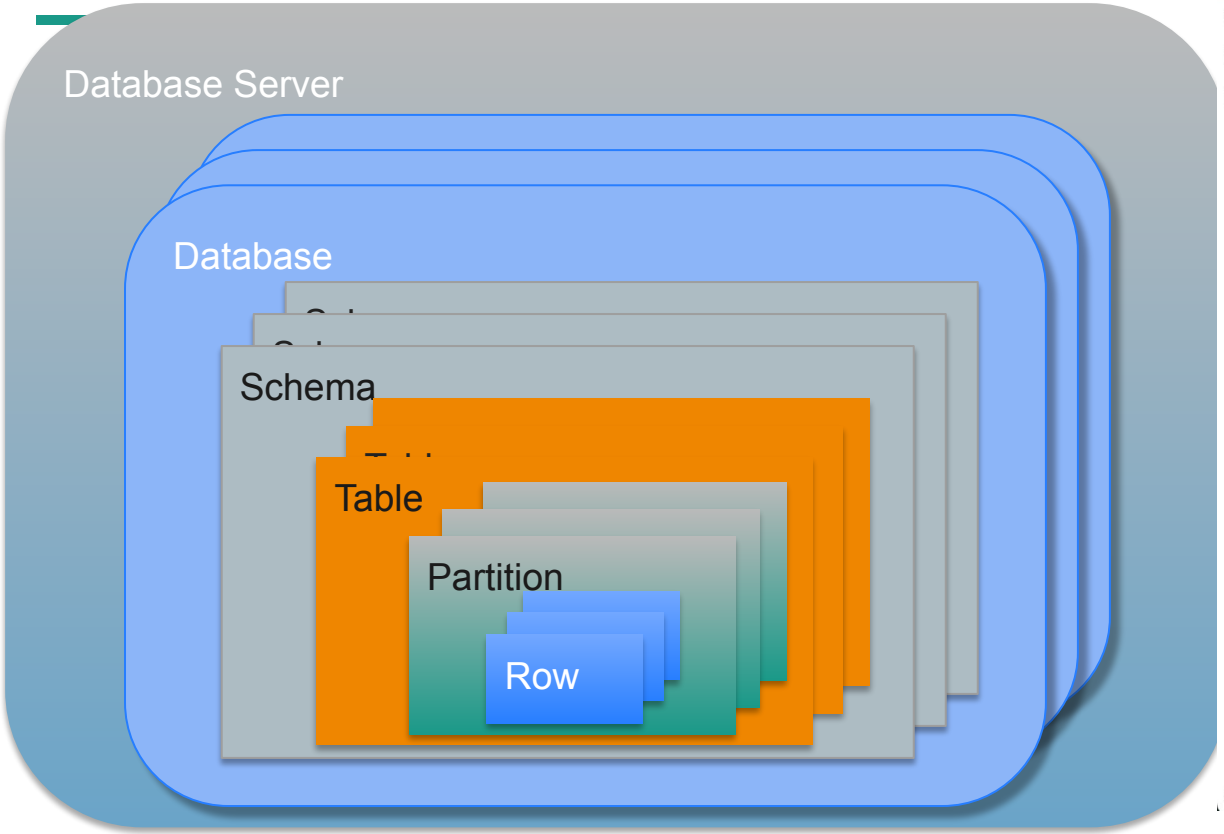
https://en.wikipedia.org/wiki/Database

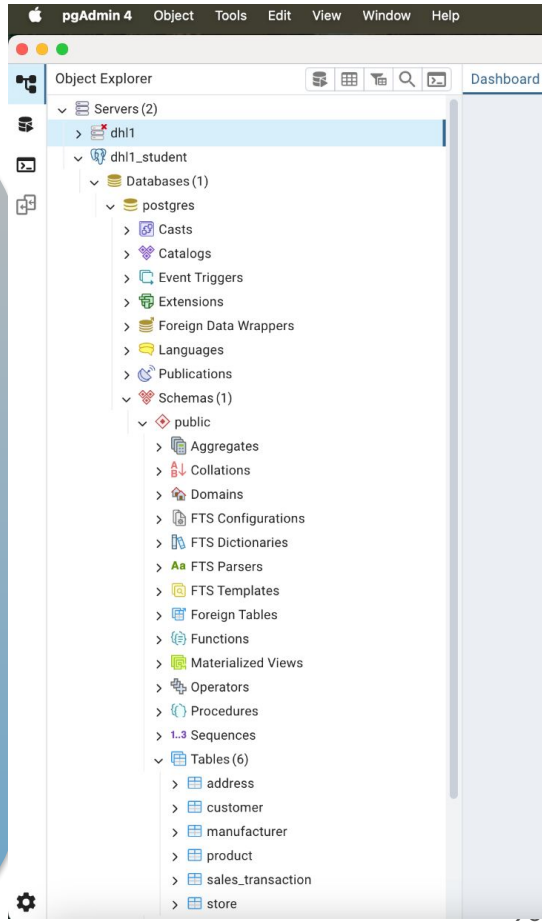
Creating an Index

- \d <tablename> shows all existing columns and indexes
- CREATE INDEX idx_my_customer ON mycustomer(last_name, first_name);
- \d

Organizing data - schemas, and entity relationship diagrams

Hierarchy of Postgres and SQL

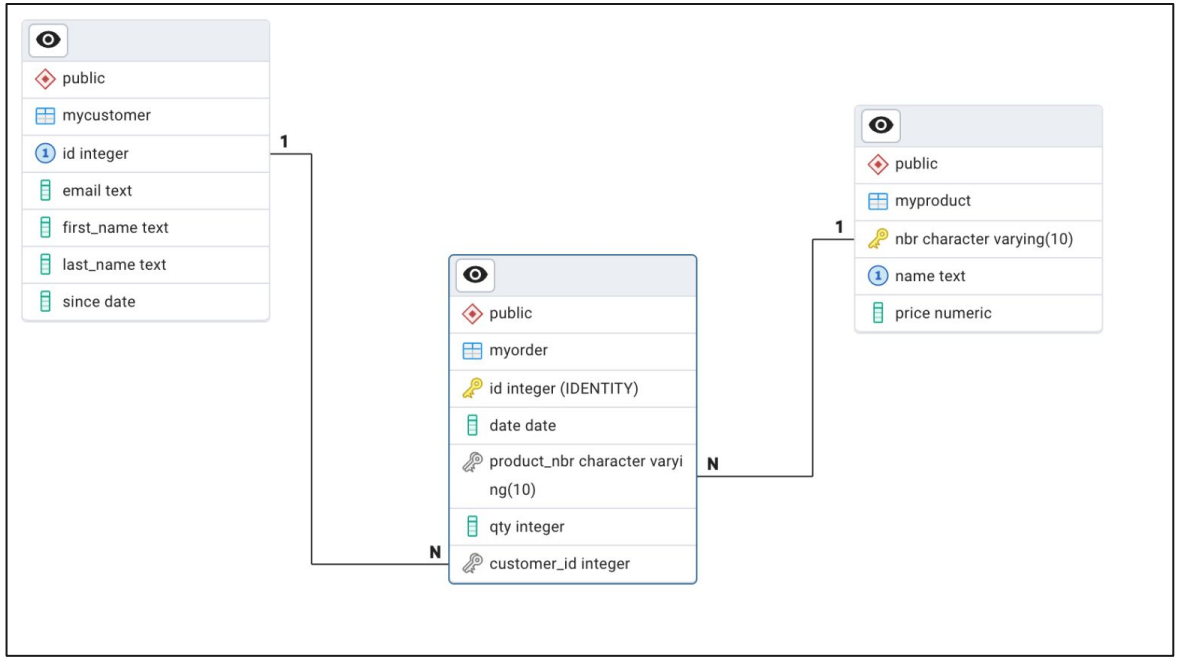




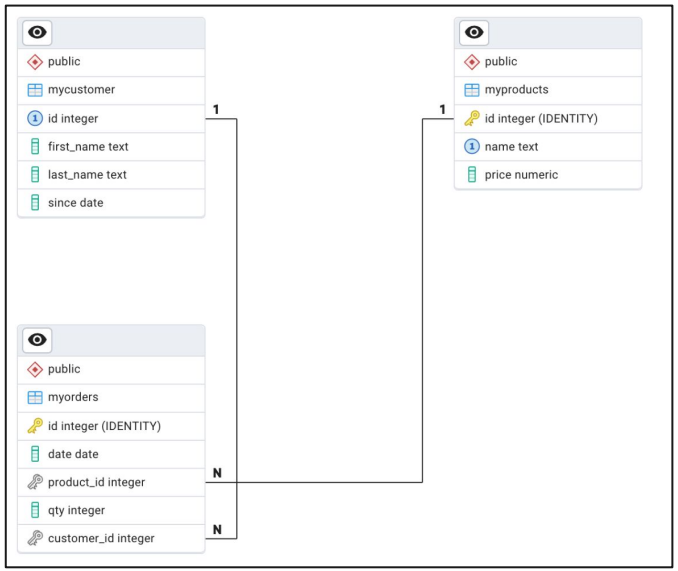
Schemas

Graphical view of the schema

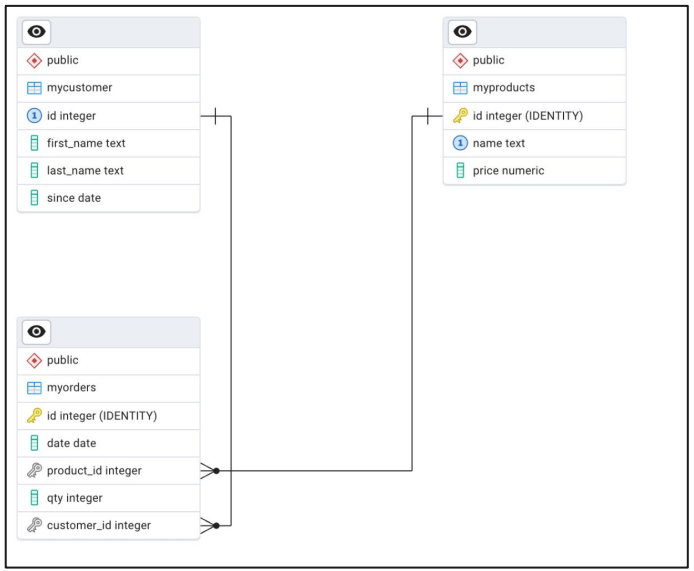
- Tables
- Columns
- Constraints
- Relationships
  - 1:1
  - 1:N
  - N:M



Two Notations



Chen Notation



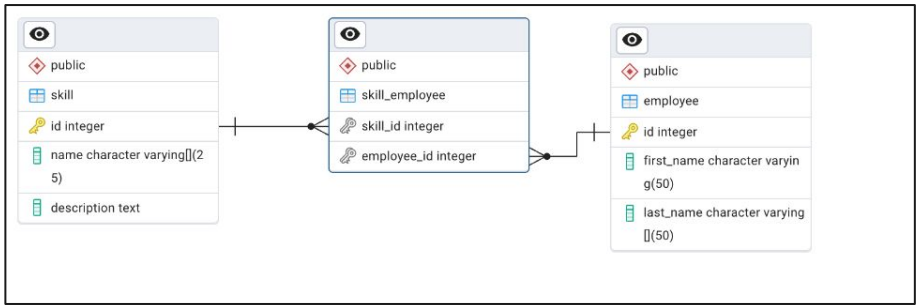
Crow Foot Notation

Different database

DLH2

Use ERD Diagramming to create simple database

- Make sure you are connected to database DLH2
- Tables
  - Employees
  - Skills
  - Employees that have skill sets
- Use ERD tool to generate SQL
- Execute the generated SQL
- Inspect the results using the tree browser
- Connect to DLH2 with PSQL
- Inspect using the PSQL commands



Remove the **BEGIN;** and **END;** statement at the end of the generated SQL before executing

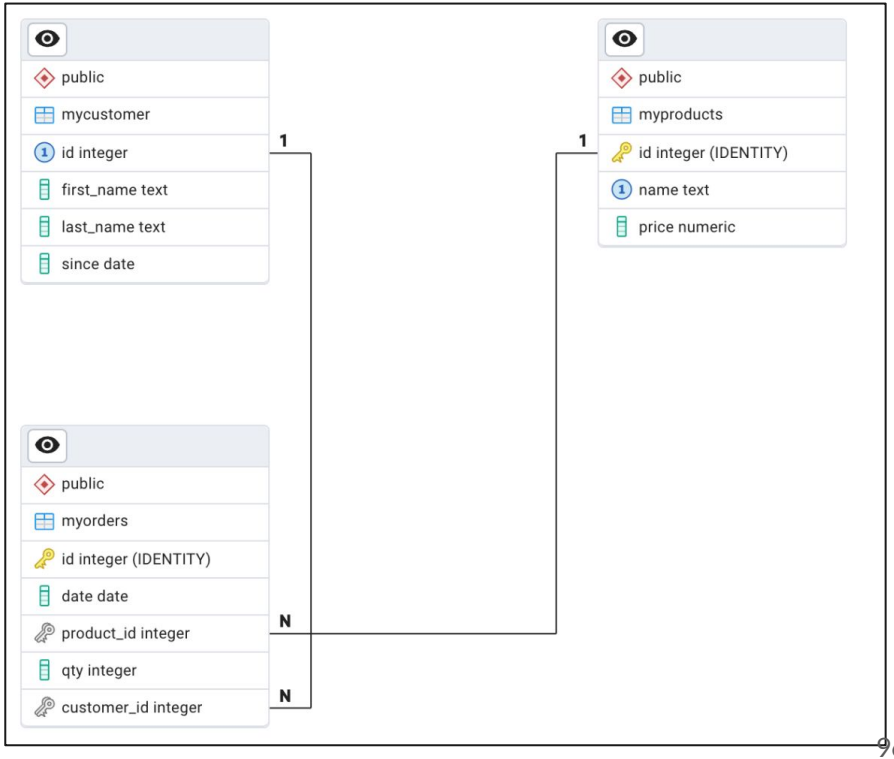
Queries revisited (joins, views, and aggregates)

Joins

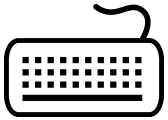
‘JOIN … ON …’ connects Two or more tables

Types of joins:

- (INNER) JOIN
- LEFT/RIGHT (OUTER) JOIN
- FULL (OUTER) JOIN
- CROSS JOIN



Different database



Customers who ordered something

```
SELECT * FROM myorder
     JOIN mycustomer
     ON myorder.customer_id = mycustomer.id;
```

```
-[ RECORD 1 ]--------------------
id          | 1
date        | 2025-02-02
product_nbr | chisel_004
qty         | 9
customer_id | 1
nbr         | chisel_004
name        | Chisel stone
price       | 39.95
id          | 1
email       | marc@marclinster.com
first_name  | Marc
last_name   | Linster
since       | 2025-01-01
```

Uses the \x command in PSQL Tool to show the records in expanded mode

- N.B.:
  - Explicit JOIN/ON improves readability
  - Using table alias (o,c) improves readability and avoids errors

```
SELECT
     o.id AS order_id,
     o.date AS order_date,
     o.qty AS order_quantity,
     c.first_name || ' ' || c.last_name AS customer_name
FROM myorder o
     JOIN mycustomer c
     ON o.customer_id = c.id;

 order_id | order_date | order_quantity | customer_name
----------+------------+----------------+---------------
        1 | 2025-02-02 |              9 | Marc Linster
```

How about the customers without orders?

LEFT OUTER JOIN

LEFT (OUTER) JOIN:

- All records from the first (left) table
- Joined with second (right) table if available ; show NULL (empty) columns otherwise
- ‘OUTER’ is optional

```
SELECT * FROM mycustomer c
      LEFT OUTER JOIN myorder o
      ON c.id = o.customer_id;
```

id	first_name	last_name	since	id	date	product_id	qty	customer_id
1	Marc	Linster	2025-01-01	1	2025-02-02	3	3	1
2	Jeff	Mueller	2025-01-02					
3	Jean	Bintner	2025-01-03					

Explaining Left Join

mycustomer (left of join)

id	email	first_	last_	since
1	marc@marclinster.com	Marc	Linster	1/1/2025
2	jmu@gmail.lu	Jeff	Mueller	1/2/2025
3	bini@hotmail.lu	Jean	Bintner	1/3/2025

myorder (right of join)

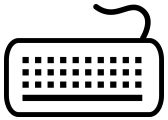
id	date	product_nbr	qty	customer_id
1	2/2/2025	chisel_004	9	1

In simple join:

- align customers and orders using mycustomer.id = myorder.customer_id
- List only the customers that have a matching order, and the orders that have a matching customer

In left join:

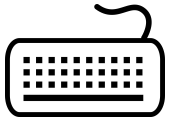
- align customers and orders using mycustomer.id = myorder.customer_id
- List all the customers (left) and if there is a matching order, list it too



Joining more tables: Customer with orders and product details

```
SELECT * FROM mycustomer c
     JOIN myorder o ON c.id = o.customer_id
     JOIN myproduct p ON o.product_id = p.id;
```

```
 id | first_name | last_name |   since    | id |    date    | product_id | qty | customer_id | id |  name   | price
----+------------+-----------+------------+----+------------+------------+-----+-------------+----+---------+-------
  1 | Marc       | Linster   | 2025-01-01 |  1 | 2025-02-02 |          3 |   3 |           1 |  3 | pliers  |     2
```



All customers, with orders and products (if they ordered anything)

```
SELECT * FROM mycustomer c
     LEFT JOIN myorder o ON c.id = o.customer_id
     LEFT JOIN myproduct p ON o.product_nbr = p.nbr;
```

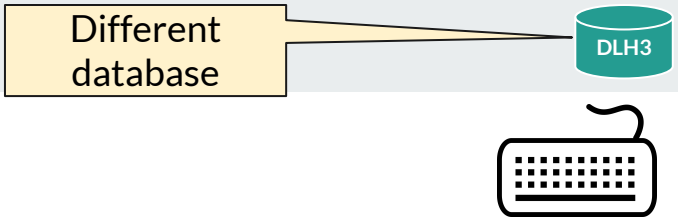
```
 id | first_name | last_name |   since    | id |    date    | product_id | qty | customer_id | id |  name   | price
----+------------+-----------+------------+----+------------+------------+-----+-------------+----+---------+-------
  1 | Marc       | Linster   | 2025-01-01 |  1 | 2025-02-02 |          3 |   3 |           1 |  3 | pliers  |     2
  2 | Jeff       | Mueller   | 2025-01-02 |    |            |            |     |             |    |         |
  3 | Jean       | Bintner   | 2025-01-03 |    |            |            |     |             |    |         |
(3 rows)
```

- See the importance of meaningful alias
- 'id' appears three times.
- customer_id, order_id, product_id would improve readability and reduce errors

Try It Out

- Find the customers who didn't order anything.
  - Show only the name and since when they are customers
- Find the products that were never ordered

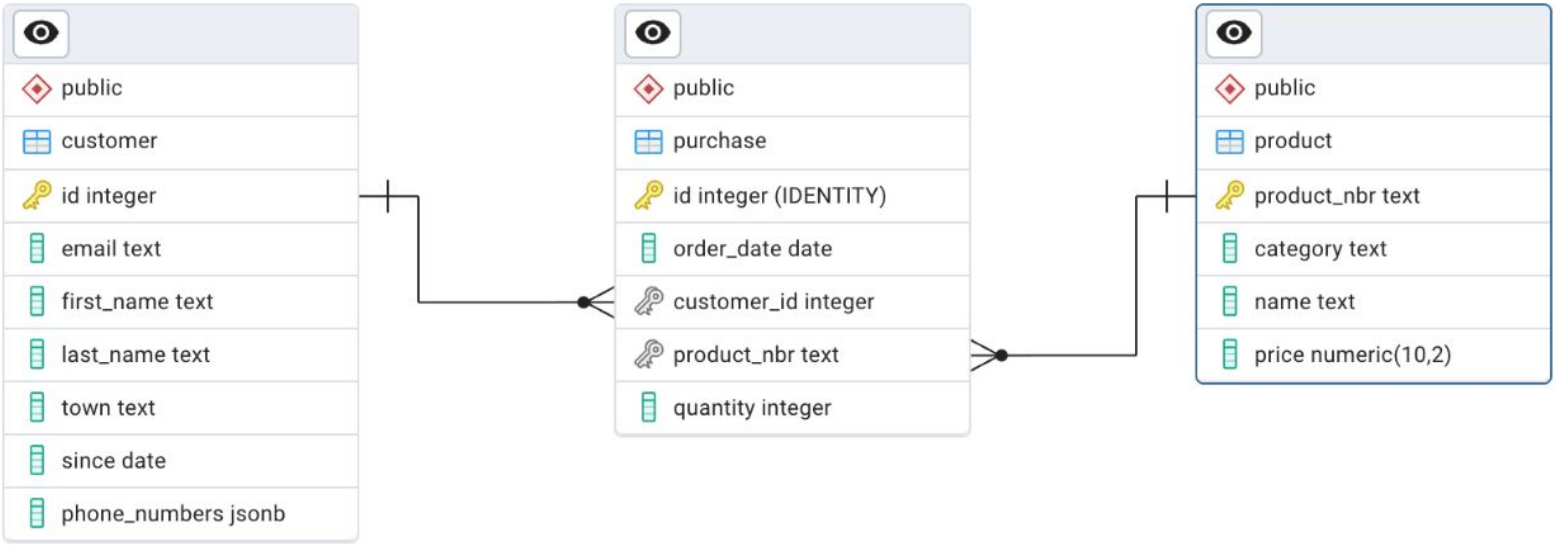
```
SELECT DISTINCT(p.*) FROM myproduct p
     LEFT JOIN myorder o ON o.product_nbr = p. nbr
     WHERE o.id IS NULL
```



Explore the data set

- Connect to database DLH3
- Create the ERD Diagram
- Explore the tables
  - How many customers?
  - How many customers from Koerich?
  - List all the customers from Koerich that became a customer in June 2025. Order by date asc
  - How many orders were placed by customers from Differdange?
  - Which products did customers from Koerich order?
  - Which product categories did customers from Koerich order?

ERD Diagram


public
customer
id integer
email text
first_name text
last_name text
town text
since date
phone_numbers jsonb
public
purchase
id integer (IDENTITY)
order_date date
customer_id integer
product_nbr text
quantity integer
public
product
product_nbr text
category text
name text
price numeric(10,2)

One more datatype: JSON for NoSQL

JSON - a way to store unstructured data

- JSON(B) - JavaScript Object Notation (**B**inary)
- Allows to create complex data structures that are not subject to the usual rules of normalization and standardization

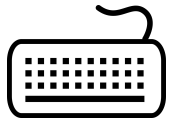
```
CREATE TABLE customer (
    id integer NOT NULL GENERATED BY DEFAULT AS IDENTITY,
    …
    phone_numbers JSONB)

select * from customer where id = 6;
-[ RECORD 1 ]---+-------------------------------------------------------------------------------
id              | 6
customer_number | cust00006
first_name      | Louis
last_name       | Lewandowski
address_id      | 111795
phone_numbers   | {"home": "+352 621 453 975", "work": "+352 621 794 818", "mobile": "+352 80 37 20"}
```

Complex JSON Example

```
  "firstName": "John",          -- String Type
  "lastName": "Smith",          -- String Type
  "isAlive": true,              -- Boolean Type
  "age": 25,                    -- Number Type
  "height_cm": 167.6,           -- Number Type
  "address": {                  -- Object Type
    "streetAddress": "21 2nd Street”,
    "city": "New York”,
    "state": "NY”,
    "postalCode": "10021-3100”
  },
  "phoneNumbers": [        // Object Array
    {                     // Object
      "type": "home”,
      "number": "212 555-1234”
    },
    {
      "type": "office”,
      "number": "646 555-4567”
    }
  ],
  "children": [],
  "spouse": null          // Null
}
```

1. Number:
   - Signed decimal number that may contain a fractional part and may use exponential notation.
   - No distinction between integer and floating-point
2. String
   - A sequence of zero or more Unicode characters.
   - Strings are delimited with double-quotation mark
   - Supports a backslash escaping syntax.
3. Boolean
   - Either of the values true or false.
4. Array
   - An ordered list of zero or more values,
   - Each values may be of any type.
   - Arrays use square bracket notation with elements being comma-separated.
5. Object
   - An unordered associative array (name/value pairs).
   - Objects are delimited with curly brackets
   - Commas to separate each pair
   - Each pair the colon ':' character separates the key or name from its value.
   - All keys must be strings and should be distinct from each other within that object.
6. null
   - An empty value, using the word null

Working with JSONB



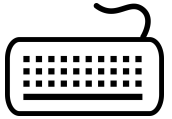
Try this in the PLSQL Tool or Query Tool

```
SELECT first_name, JSONB_PRETTY(phone_numbers) FROM customer LIMIT 5;
```

```
SELECT
     first_name,
     phone_numbers,
     phone_numbers ->> 'home' AS home_phone_number,
     phone_numbers ->> 'mobile' AS mobile_phone_number
FROM customer;
```

```
SELECT first_name, phone_numbers
FROM customer
WHERE phone_numbers ? 'mobile';
```

```
SELECT first_name, phone_numbers
FROM customer
WHERE NOT(phone_numbers ? 'home');
```



Working with JSONB

- Adding to a JSON data element

```
UPDATE customer
     SET phone_numbers =
          jsonb_insert (phone_numbers, '{new}', '"123 456 789"')
WHERE id = 1;
```

- Removing a JSON data element

```
UPDATE customer
     SET phone_numbers =
          phone_numbers - 'new'
     WHERE id = 1
```

https://www.postgresql.org/docs/current/functions-json.html

What to know about JSONB?

- Use it for complex read-only data elements where data structure and type are less critical
  - Logs, telemetry, IOT data, data personalization
  - Tags for documents, multiple phone numbers, multiple addresses
  - Data collections with sparse columns
- Do not use it with foreign keys
- It can be indexed very efficiently using the GIN index
- It does not perform well for frequent updates - especially when the JSON data element is large
- Always prefer JSONB over JSON (older format)
- ROW_TO_JSON() and JSON_TABLE make integration between JSON and standard tables very easy

Querying JSON documents

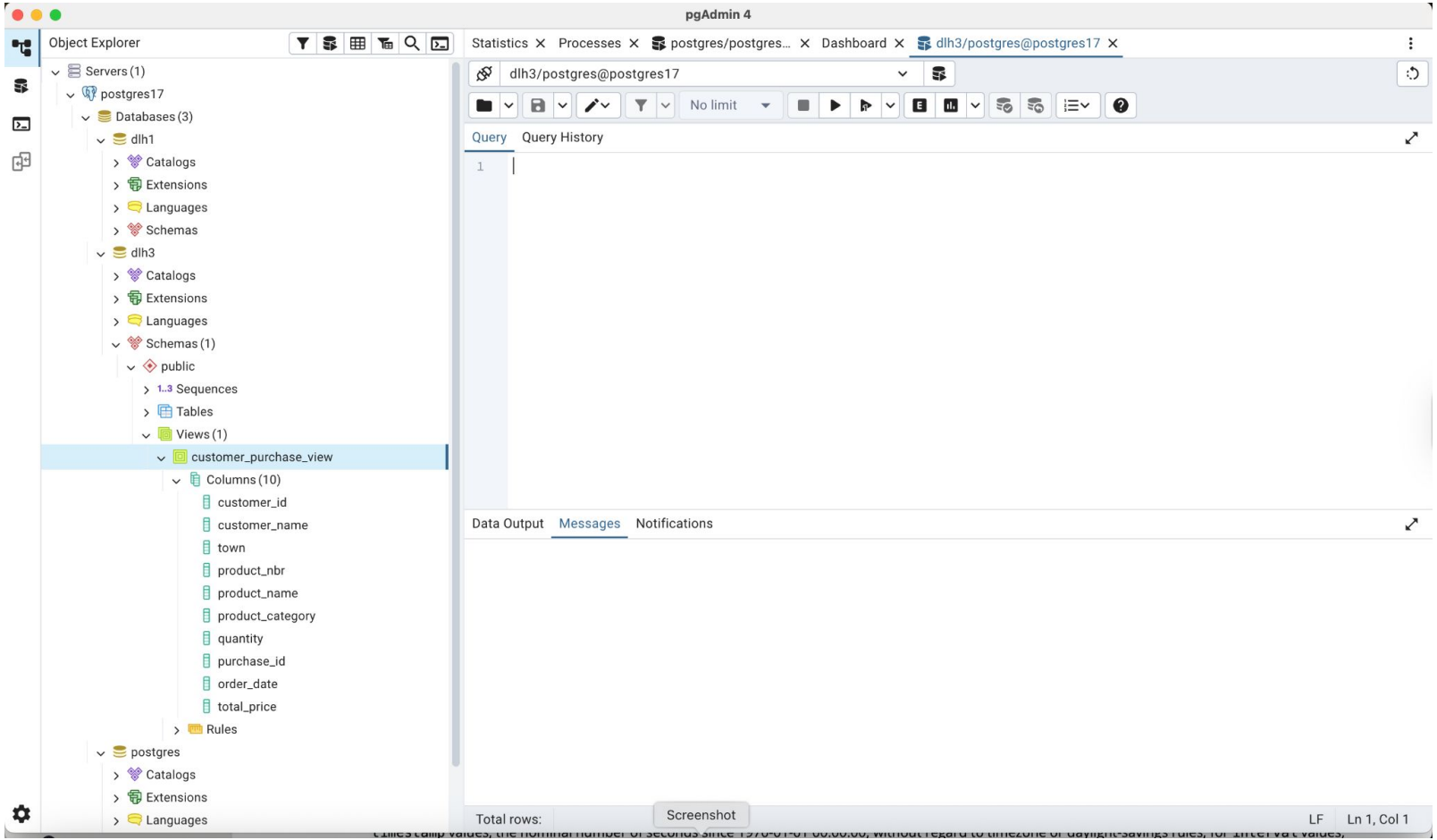
```
SELECT id, nbrs.*
FROM
     customer,
     JSON_TABLE (
          phone_numbers,
          '$' COLUMNS (
               mobile TEXT PATH '$.mobile',
               home TEXT PATH '$.home'
          )
     ) nbrs
WHERE
     nbrs.mobile IS NOT NULL
LIMIT 5;
```

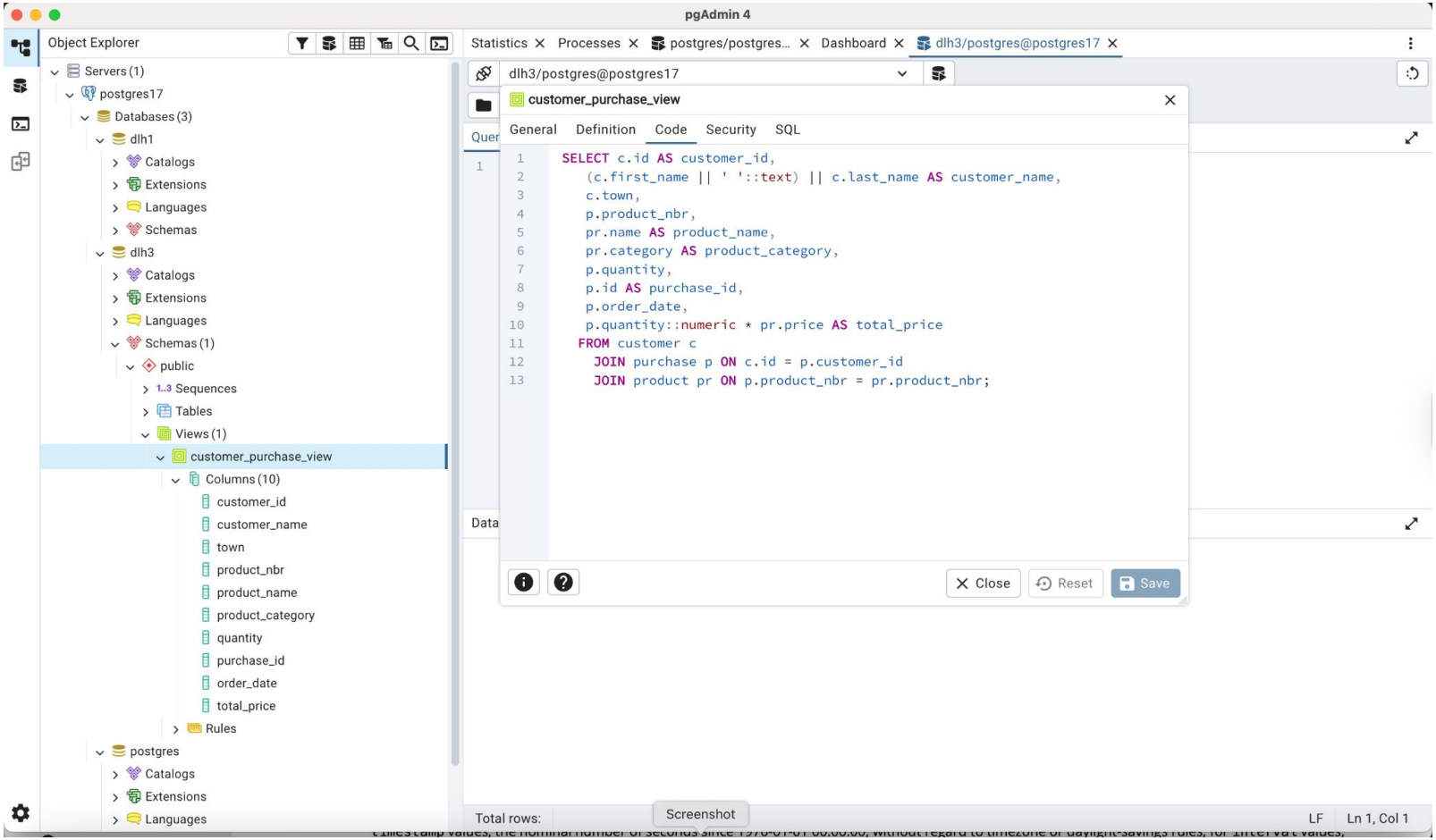
Views

CREATE VIEW

Views are named queries that are stored in the database server

```
CREATE VIEW customer_purchase_view AS
    SELECT
        c.id AS customer_id,
        c.first_name || ' ' || c.last_name AS
customer_name,
        c.town,
        p.product_nbr,
        pr.name AS product_name,
        pr.category as product_category,
        p.quantity,
        p.id AS purchase_id,
        p.order_date,
        (p.quantity * pr.price) AS total_price
    FROM customer c
    JOIN purchase p ON c.id = p.customer_id
    JOIN product pr ON p.product_nbr = pr.product_nbr;
```


pgAdmin 4
Object Explorer
Servers (1)
postgres17
Databases (3)
dlh1
Catalogs
Extensions
Languages
Schemas
dlh3
Catalogs
Extensions
Languages
Schemas (1)
public
Sequences
Tables
Views (1)
customer_purchase_view
Columns (10)
customer_id
customer_name
town
product_nbr
product_name
product_category
quantity
purchase_id
order_date
total_price
Rules
postgres
Catalogs
Extensions
Languages
Statistics
Processes
postgres/postgres...
Dashboard
dlh3/postgres@postgres17
dlh3/postgres@postgres17
No limit
Query
Query History
1
Data Output
Messages
Notifications
Total rows:
Screenshot
LF
Ln 1, Col 1


pgAdmin 4
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dlh1
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Languages
Schemas
dlh3
Catalogs
Extensions
Languages
Schemas (1)
public
Sequences
Tables
Views (1)
customer_purchase_view
Columns (10)
customer_id
customer_name
town
product_nbr
product_name
product_category
quantity
purchase_id
order_date
total_price
Rules
postgres
Catalogs
Extensions
Languages
Statistics
Processes
postgres/postgres...
Dashboard
dlh3/postgres@postgres17
dlh3/postgres@postgres17
customer_purchase_view
General
Definition
Code
Security
SQL
SELECT c.id AS customer_id,
(c.first_name || ' '::text) || c.last_name AS customer_name,
c.town,
p.product_nbr,
pr.name AS product_name,
pr.category AS product_category,
p.quantity,
p.id AS purchase_id,
p.order_date,
p.quantity::numeric * pr.price AS total_price
FROM customer c
JOIN purchase p ON c.id = p.customer_id
JOIN product pr ON p.product_nbr = pr.product_nbr;
Close
Reset
Save
Total rows:
Screenshot
LF
Ln 1, Col 1

Aggregates

Questions that require aggregates

For example

- How many customers do we have in every town?
- Which town has the most customers?
- How much did the top 10 customers buy?

SQL Aggregates

- GROUP BY, e.g., group the customers by location
  - GROUP BY … HAVING allows to limit the groups

After the WHERE clause

- SUM, AVG, MIN, MAX, e.g, the total/ average/ minimum/ maximum within a group

Part of the SELECT clause

Aggregates

SELECT group_by_element_1, group_by_element_2, …, aggregate_1, aggregate_2, …

FROM table1

JOIN table2 ON ….

WHERE condition

GROUP BY group_by_element_1, group_by_element_2, …

```
SELECT town, COUNT(id)
FROM customer
GROUP BY TOWN
ORDER BY town ASC;
```

Aggregates

```
SELECT town, COUNT(id) customer_count FROM customer
      GROUP BY TOWN
      ORDER BY town ASC;
```

Single group - one aggregate (COUNT)

```
SELECT town, COUNT(id) AS customer_count FROM customer
      WHERE since >= '2024-01-01' AND since < '2024-12-31'
      GROUP BY TOWN
      HAVING COUNT(id) > 1;
```

Single group - one aggregate; WHERE clause + limit of the groups

```
SELECT town, COUNT(id) AS customer_count FROM customer
      WHERE since >= '2024-01-01' AND since < '2024-12-31'
      GROUP BY TOWN
      HAVING COUNT(id) > 1
      ORDER BY customer_count DESC;
```

Single group - one aggregate; WHERE clause + limit of the groups + ORDER BY for groups

Aggregates

```
SELECT
    town,
    EXTRACT (YEAR FROM since) AS since_year,
    COUNT(id) AS customer_count FROM customer
GROUP BY town, since_year
HAVING COUNT(id) > 1
ORDER BY town ASC, since_year ASC;
```

Use the 'HAVING' clause to remove groups with small customer counts

```
SELECT
    town,
    EXTRACT (YEAR FROM since) AS since_year,
    COUNT(id) AS customer_count FROM customer
WHERE TOWN <> 'ESCH'
GROUP BY town, since_year
HAVING COUNT(id) > 1
ORDER BY town ASC, since_year ASC;
```

Use the 'HAVING' clause to remove groups with small customer counts
+
Use WHERE clause to filter on data set

Exercises

- How many food items did we sell in 2024
  - Join purchases and products
  - Filter by category food
  - Count(*)
- How many things did the top 10 customers buy?
  - Join the customer table with the purchase table
  - Group by customer and count the quantities
  - LIMIT 10
- How much did the top 10 customers spend every month?
  - Take a look at the view customer_purchase_view
  - Group by customer_name and make an aggregate of the total price
  - Order by price
  - LIMIT 10

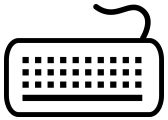
GROUPING SETS, ROLLUPS and CUBE

ROLLUP (a,b,c) corresponds to

```
GROUPING SETS
    (
        (a,b,c),
        (a,b),
        (c),
        ()
    )
```

CUBE (a, b, c) corresponds to

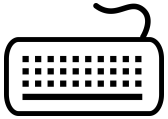
```
GROUPING SETS
    (
        ( a, b, c ),
        ( a, b    ),
        ( a,    c ),
        ( a       ),
        (    b, c ),
        (    b    ),
        (       c ),
        (         )
    )
```



GROUP BY ROLLUP

```
SELECT product_category, product_name, sum(quantity)
    FROM customer_purchase_view
    GROUP BY ROLLUP (product_category, product_name)
    ORDER BY product_category, product_name;

SELECT FORMAT ('%s living in %s', customer_name, town) AS customer_town ,
product_category, product_name, sum(quantity)
    FROM customer_purchase_view
    WHERE TOWN <> 'Esch'
    GROUP BY ROLLUP (customer_town, product_category, product_name)
    ORDER BY customer_town, product_category, product_name;
```



GROUP BY ROLLUP

```
SELECT FORMAT ('%s living in %s', customer_name, town) AS customer_town ,
product_category, product_name, sum(quantity)
    FROM customer_purchase_view
    WHERE TOWN <> 'Esch'
    GROUP BY CUBE (customer_town, product_category, product_name)
    ORDER BY customer_town, product_category, product_name;
```

Guidelines for Writing Good Queries

Summary: Keys to Writing Good Queries

1. Limit the number of rows that are returned
2. Limit the number of columns that are returned
3. Define aliases in the SELECT clause using 'AS' to avoid duplicate column names
4. Use aliases in the WHERE and GROUP clause to avoid typos and shorten the code
5. Define highly selective WHERE clauses, especially when using JOINS
6. Leverage indexes where available
7. Use JOINs to help the planner; organize JOINs to start with the smallest table
8. Avoid CROSS JOINS (data set explodes!)
9. Use VIEWS to standardize complex, often repeated queries (e.g., sales_transaction combined with sales_transaction_line)
10. Use snake_case names for tables and columns
11. Study EXPLAIN plans to understand where complexity occurs

See Jimmy Angelakos' book: https://livebook.manning.com/book/postgresql-mistakes-and-how-to-avoid-them/welcome/v-9/

```
EXPLAIN SELECT count(*) FROM customer WHERE postal_code like 'MA%';
                        QUERY PLAN
-----------------------------------------------------------------
 Aggregate  (cost=45.69..45.70 rows=1 width=8)
   ->  Seq Scan on customer  (cost=0.00..44.67 rows=407 width=0)
         Filter: ((postal_code)::text ~~ 'MA%'::text)
```

```
CREATE INDEX idx_customer_postal_code ON customer(postal_code);

EXPLAIN SELECT count(*) FROM customer WHERE postal_code like 'MA%';
-------------------------------------------------------------------------------------------------
 Aggregate  (cost=33.74..33.75 rows=1 width=8)
   ->  Index Only Scan using idx_customer_postal_code on customer  (cost=0.28..32.72 rows=407 width=0)
         Filter: ((postal_code)::text ~~ 'MA%'::text)
```

```
SELECT c.id, c.first_name, c.last_name, SUM(stl.qty * stl.price_at_sale) AS total_sales
FROM customer c                                                                    JOIN
sales_transaction st ON c.id = st.customer_id
JOIN sales_transaction_line stl ON st.id = stl.sales_transaction_id
WHERE st.transaction_date >= CURRENT_DATE - INTERVAL '1 month'
GROUP BY c.id, c.first_name, c.last_name
ORDER BY total_sales DESC
LIMIT 10;

Limit  (cost=2920.00..2920.02 rows=10 width=54)
  ->  Sort  (cost=2920.00..2923.53 rows=1414 width=54)
        Sort Key: (sum(((stl.qty)::numeric * stl.price_at_sale))) DESC
        ->  HashAggregate  (cost=2871.77..2889.44 rows=1414 width=54)
              Group Key: c.id
              ->  Hash Join  (cost=910.00..2821.90 rows=4987 width=33)
                    Hash Cond: (st.customer_id = c.id)
                    ->  Hash Join  (cost=846.19..2744.95 rows=4987 width=20)
                          Hash Cond: (stl.sales_transaction_id = st.id)
                          ->  Seq Scan on sales_transaction_line stl  (cost=0.00..1663.21 rows=89721 width=21)
                          ->  Hash  (cost=823.57..823.57 rows=1809 width=19)
                                ->  Seq Scan on sales_transaction st  (cost=0.00..823.57 rows=1809 width=19)
                                      Filter: (transaction_date >= (CURRENT_DATE - '1 mon'::interval))
                    ->  Hash  (cost=46.14..46.14 rows=1414 width=22)
                          ->  Seq Scan on customer c  (cost=0.00..46.14 rows=1414 width=22)
```

```
CREATE INDEX idx_sales_transaction_date ON sales_transaction(transaction_date);
CREATE INDEX idx_sales_transaction_line_st_idtransaction_date_line ON
                    sales_transaction_line(sales_transaction_id);
```

```
  ->  Sort  (cost=2233.64..2237.18 rows=1414 width=54)
        Sort Key: (sum(((stl.qty)::numeric * stl.price_at_sale))) DESC
        ->  HashAggregate  (cost=2185.41..2203.09 rows=1414 width=54)
              Group Key: c.id
              ->  Hash Join  (cost=64.40..2135.54 rows=4987 width=33)
                    Hash Cond: (st.customer_id = c.id)
                    ->  Nested Loop  (cost=0.58..2058.59 rows=4987 width=20)
                          ->  Index Scan using idx_sales_transaction_date on sales_transaction st  (cost=0.29..312.12 rows=1809 width=19)
                                Index Cond: (transaction_date >= (CURRENT_DATE - '1 mon'::interval))
                          ->  Index Scan using idx_sales_transaction_line_st_idtransaction_date_line on sales_transaction_line stl  (cost=0.29..0.94
rows=3 width=21)
                                Index Cond: (sales_transaction_id = st.id)
```

FYI: SQL Order of Execution

1. **FROM/JOIN**: Specifies the tables from which to retrieve data.
2. **WHERE**: Filters the rows that meet the condition before grouping.
3. **GROUP BY**: Groups rows that share a property.
4. **HAVING**: Filters groups based on conditions, applied after grouping.
5. **SELECT**: Specifies the columns to retrieve or calculate.
6. **DISTINCT**: Removes duplicate rows from the result set.
7. **ORDER BY**: Sorts the result set by specified columns.
8. **LIMIT**: Specifies the maximum number of rows to return.
9. **OFFSET**: Specifies how many rows to skip before starting to return rows.

Day 4

- Review of Day 3
- Data Normalization
- ACID compliance, Transactions, and Isolation Levels
- Creating your own database with schema, tables, and foreign keys

Data Normalization

Normalization and Avoiding Redundancy

- Data Normalization, a.k.a. 1NF/2NF,3NF is key to relational database design
- Data Normalization concepts do not exist in non-relational databases
    - Make sure every column only has one data element of the same type
    - Avoid redundancy (same data in multiple places)
    - Eliminate unintentional dependencies

Database Normal Forms

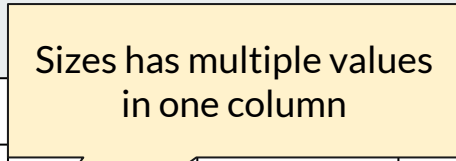
- **1st Normal Form (1NF)**: Tables do not include other tables; every column has one data element of the same type
- **2nd Normal Form (2NF)**: All data elements depend on the whole primary key
- **3rd Normal Form (3NF)**: No internal dependencies between data elements

Other (higher) normal forms exist, but are rarely applied in practice

Example

Article	Description	Brand	Country of origin	Sizes	Colors	Price
501 Jeans by Levis	The original button-fly jeans	Levis	USA	32/36 30/34 30/36	Blue	95.00
501 Jeans by Levis	The original button-fly jeans	Levis	USA	32/36 30/34 30/36	Black	110.99
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	32/36 30/34 30/36	Blue	98.00
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	32/36 30/34 30/36	Black	105.99
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	32/36 30/34 30/36	Stone wash	101.99
Journey Trousers	Cotton gabardine Journey trousers	Brioni	Italy	36 38 40 42	Ivory White	125.95
Trucker Jacket	Rugged jeans jacket	Levis	USA	S M L	Blue	113.00

Example



Article	Description	Brand	Country of origin	Sizes		
501 Jeans by Levis	The original button-fly jeans	Levis	USA	32/36 30/34 30/36	Bl	95.00
501 Jeans by Levis	The original button-fly jeans	Levis	USA	32/36 30/34 30/36	Black	110.99
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	32/36 30/34 30/36	Blue	98.00
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	32/36 30/34 30/36	Black	105.99
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	32/36 30/34 30/36	Stone wash	101.99
Journey Trousers	Cotton gabardine Journey trousers	Brioni	Italy	36 38 40 42	Ivory White	125.95
Trucker Jacket	Rugged jeans jacket	Levis	USA	S M L	Blue	113.00

Article	Description	Brand	Country of origin	Colors	Price
501 Jeans by Levis	The original button-fly jeans	Levis	USA	Blue	95.00
501 Jeans by Levis	The original button-fly jeans	Levis	USA	Black	110.99
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	Blue	98.00
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	Black	105.99
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA	Stone wash	101.99
Journey Trousers	Cotton gabardine Journey trousers	Brioni	Italy	Ivory White	125.95
Trucker Jacket	Rugged jeans jacket	Levis	USA	Blue	113.00

Article	Size
501 Jeans by Levis	32/36
501 Jeans by Levis	30/34
501 Jeans by Levis	30/36

To transform this into 1NF, we need to move the content of column Sizes to a separate table.

2NF: All data elements depend on the whole primary key

To meet the requirements of 2NF, where all attributes must depend on the *whole* primary key, we must address the following:

1. Category and Brand depend on Article, that is, Article is the primary key for the content in columns Category and Brand
2. Article + Color are the combined primary key for Price

This leads us to create a separate table that links Article and Color to Price

2NF: Create a separate table that links Article and Color to Price

Article	Description	Brand	Country of origin
501 Jeans by Levis	The original button-fly jeans	Levis	USA
Wrangler Cowboy Cut	Western jeans for a great day	Wrangler	USA
Journey Trousers	Cotton gabardine Journey trousers	Brioni	Italy
Trucker Jacket	Rugged jeans jacket	Levis	USA

Article	Colors	Price
501 Jeans by Levis	Blue	95.00
501 Jeans by Levis	Black	110.99

3NF: No internal dependencies between data elements

Brand	Country of Origin
Levis	USA
Wrangler	USA
Brioni	Italy

Country of origin depends on brand (only). Move to separate table

3NF - No duplication; Easy access to data

Article	Description	Brand
501 Jeans by Levis	The original button-fly jeans	Levis
Wrangler Cowboy Cut	Pants	Wrangler
Journet Trousers	Pants	Brioni
Trucker Jacket	Outerwear	Levis

Brand	Country of Origin
Levis	USA
Wrangler	USA
Brioni	Italy

Article	Attributes	Price
501 Jeans by Levis	{color: Blue, size: 32/36}	95.00
501 Jeans by Levis	{color: Blue, size: 30/34}	95.00
501 Jeans by Levis	{color: Black, size: 30/34}	110.99
501 Jeans by Levis	{color: Black, size: 30/36}	110.99

Normalization Matters!

- Avoids managing the same data in multiple places
- Avoids strange deletion situations, e.g., brand disappears when no article uses it
- Makes sure there is always a way to refer to data in a unique way
- Avoids designing the process into the data

Transactions and ACID Compliance

Transactions

- Sample Transaction

```
BEGIN
    Remove Euro 100 from Marc's account
    Add Euro 100 to 'Caves Wengler' account
COMMIT
```

- Key Considerations for a Database:
  - **A**tomic: All or nothing
  - **C**onsistent: After the transaction both accounts are updated immediately and all constraints are validated (e.g., account > 0). Every user always see a consistent picture
  - **I**solated: Multiple transactions can happen at the same time. They either see the state before the transaction, or after the transaction - never in-between
  - **D**urable: Once a transaction has completed, the result remains true.

ACID - continued

- Atomic:
  - Multiple statements (INSERT, UPDATE, DELETE, …) are executed as one atomic unit. If one of them fails, the others roll back. Even if power fails, an error occurs etc
  - Only completed transactions are written to disk and persisted
- Consistent:
  - All conditions (constraints, primary keys, foreign key constraints, data types) are true at the end of a transaction - otherwise the transaction roll back
  - Every transaction leaves the database in a consistent state
- Isolation:
  - Transactions ‘in flight’ and their results (e.g., Marc’s account deducted by Euro 100, but funds are not year in ‘Caves Wengler’ account) are not visible
  - Transactions work on a snapshot of what is true when the transaction starts
- Durable
  - Once a transaction completes (is committed), its results remain true
  - Databases log every transaction to disk (aka Write Ahead Log). ‘COMMIT’ only happens when the transaction has been written to non-volatile memory.

Does every database provide ACID compliance

- ACID databases (e.g., SQL Server, Oracle, Postgres) prioritize consistency over availability
  - They reject transactions when ACID cannot be guaranteed
  - Important for business transactions
- Other databases prioritize availability over consistency
  - BASE: Basically Available, Soft state, and Eventually consistent
  - Used for high throughput systems where temporary inconsistency is OK, e.g., social media
- Isolation (in ACID) comes in multiple flavors
  - Read Uncommitted (not used in current relational databases)
  - Read Committed - most common model
  - Read Repeatable - needs locks on data and can impact performance
  - Read Serializable - locks the data used by the transaction and forces other transactions to wait (seldom used)

Different database

Exploring ACID Transactions

```
CREATE TABLE account (id INT, amount NUMERIC);

INSERT INTO account VALUES (1, 100);
INSERT INTO account VALUES (2, 0);
```

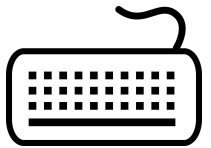
Create the tables and add the data

Verity with `SELECT * FROM account;`

Make sure you are in DLH5!!!

- `\c` (in PSQL)
- `SELECT current_database();` (in Query Tool)

```
 id | amount
----+--------
  1 |     50
  2 |     50
```



Open up two pgAdmin Query Tools (or PSQL)

```
(1)   SELECT * FROM account
            ORDER BY id ASC;
```

```
(2)  SELECT * FROM account
            ORDER BY id ASC;
```

```
(3)   BEGIN;
```

```
(4)  SELECT * FROM account
            ORDER BY id ASC;
```

```
(5)   UPDATE account
            SET amount = amount - 50
      WHERE id = 1;
```

```
(6)  SELECT * FROM account
            ORDER BY id ASC;
```

```
(7)   SELECT * FROM account
            ORDER BY id ASC;
```

```
(8)   UPDATE account
            SET amount = amount + 50
      WHERE id = 2;
```

```
(9)   COMMIT;
```

```
(10)  SELECT * FROM account
            ORDER BY id ASC;
```

Nota Bene

- By default, “;” commits the transaction
  - ⇒ Every line of SQL is a transaction in pgAdmin (by Default)
  - From the Postgres docs:
    - PostgreSQL actually treats every SQL statement as being executed within a transaction. If you do not issue a `BEGIN` command, then each individual statement has an implicit `BEGIN` and (if successful) `COMMIT` wrapped around it. A group of statements surrounded by `BEGIN` and `COMMIT` is sometimes called a *transaction block*.
- More complex transactions with multiple statements must be wrapped into a transaction block

```
BEGIN;

      ….

COMMIT;
```

- Try the prior example without the BEGIN/COMMIT

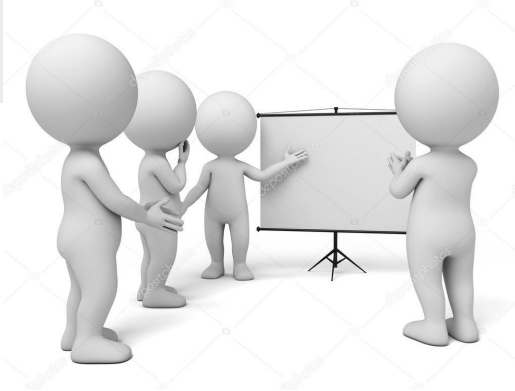
Transaction Isolation Levels

Read Uncommitted:	Transactions can see uncommitted changes from other transactions, risking dirty reads. ***(Not available in Postgres)***
Read Committed:	Transactions can only see committed changes, preventing dirty reads but allowing non-repeatable reads. **(Default in Postgres)**
Read Repeatable:	A transaction's reads are consistent, preventing dirty and non-repeatable reads but allowing phantom reads.
Serializable:	Transactions are fully isolated, executed in a serial order to prevent dirty, non-repeatable, and phantom reads

Isolation Levels and Anomalies

Isolation Level/ Anomaly	Dirty Read	Non-Repeatable Read	Phantom Read
Read Uncommitted	✗ Possible	✗ Possible	✗ Possible
Read Committed	✓ Not possible	✗ Possible	✗ Possible
Read Repeatable	✓ Not possible	✓ Not possible	✗ Possible
Serialized	✓ Not possible	✓ Not possible	✓ Not possible

A sample project



Project

- Build a database (dlhx) for a company with departments, employees and managers working in departments, projects, employee assignment to projects, and hours recorded for the employees working on the project
- Simple queries
  - Who worked on which project?
  - Who had the most hours total last month?
  - What were the total hours last month for each project?
  - Did we have any projects with 0 hours?
  - What is the reporting hierarchy in the company?

Day 5

- Review of Day 4; Revisit and complete the project
- Stored procedures & functions
- Common Table Expressions (CTE)
- Users, permissions and access control
- Recap, Q&A, resources

Stored Procedures

Stored Procedures Automate Repeated Tasks

```
CREATE PROCEDURE <procedure name> (
IN/OUT p_parameter1 <DATATYPE>
     DEFAULT = <x>;
…)
AS
$$
     DECLARE
          v_variable1 <DATATYPE>;
     …;
BEGIN
     <STATEMENT>;
     <STATEMENT>;
END
$$ LANGUAGE <language>;
```

Signature (name + parameters)

Variables that we need

Body of the procedure

Programming language (sql, plpgsql, plpython, …)

Simple Example

```
CREATE OR REPLACE PROCEDURE increase_price (IN category TEXT, IN increase NUMERIC)
LANGUAGE SQL
AS $$
    UPDATE product
    SET price = price + increase
    WHERE category = category;
$$;

SELECT * FROM product WHERE category = 'food';

CALL increase_price ('food', 1.00);
```

Iterating through the records in a table

```
DECLARE
        <record_variable> RECORD;
        ...;
BEGIN
        FOR <record variable>  IN SELECT * FROM product
        LOOP
                <statement 1>;
                ...
        END LOOP;
END;
```

Controlling the Flow

```
IF <condition> THEN
        <statement1>;
        …;
ELSE
        <statement1>;
        …;
END IF;
```

IF ... THEN ... ELSIF ... THEN ... ELSE ... END IF;

```
CASE search-expression
  WHEN expression [, expression [ ... ]] THEN
    statements
 [ WHEN expression [, expression [ ... ]] THEN
    statements
  ... ]
 [ ELSE
    statements ]
END CASE;
```

```
CREATE OR REPLACE PROCEDURE increase_price_differentiated
    (IN general_increase_percent NUMERIC, IN food_increase_percent NUMERIC)
LANGUAGE PLPGSQL
AS $$
DECLARE
    v_product RECORD;
BEGIN
    FOR v_product IN SELECT * FROM product
    LOOP
        IF v_product.category = 'food' THEN
            UPDATE product
            SET price = price + (price * food_increase_percent / 100)
            WHERE product_nbr = v_product.product_nbr;
            RAISE NOTICE 'Increased price of % by % percent', v_product.name, food_increase_percent;
        ELSE
            UPDATE product
            SET price = price + (price * general_increase_percent / 100)
            WHERE product_nbr = v_product.product_nbr;
            RAISE NOTICE 'Increased price of % by % percent', v_product.name, food_increase_percent;
        END IF;
    END LOOP;
END;
$$;

SELECT category, name, price FROM product
    ORDER BY category, name;

CALL increase_price_differentiated (5, 10);
```

Try it out

- add a parameter for the category 'snacks' with a different price increase
- Use IF / ELSEIF ….
- Use CASE

Simple Function

```
CREATE FUNCTION my_mult (p1 INT, p2 INT) RETURNS INT
AS
$$
        BEGIN
                RETURN p1 * p2;
        END;
$$ LANGUAGE PLPGSQL;

SELECT * FROM my_mult (2, 3);
```

Function with If/Then/...

```
CREATE FUNCTION my_math (p1 INT, p2 INT, p_op text) RETURNS INT
AS
$$
	DECLARE v_result INT;
	BEGIN
		IF p_op = 'addition' THEN
			v_result = p1 + p2;
		ELSEIF p_op = 'multiplication' THEN
			v_result = p1 * p2;
		ELSE v_result = 0;
		END IF;
		RETURN v_result;
	END;
$$ LANGUAGE PLPGSQL;

SELECT * FROM my_math(2,3, 'multiplication');
SELECT * FROM my_math(2,3, 'addition');
```

Try it out

- Convert the function to use the case statement
- Make sure it returns -1 when the operator does not match

Introduction to CTEs

Common Table Expressions

What are Common Table Expressions?

1. Simplify the writing of complex queries by **decomposing** queries into separate pieces
    - Avoid subqueries
    - Comparable to writing local views that can only be used inside one query
2. Writing recursive queries
    - Iterate through **hierarchical data structures**
    - E.g. organizational charts, directory structures, or any data that has a parent-child relationship.

CTEs are available in most relational databases

CTE Building Blocks

1) ‘WITH’ defines one or several named queries that creates subsets of data. These are temporary result sets
2) ‘SELECT’ statement can access those queries

```
WITH cte_name (column1, column2, ...) AS
     (SELECT ...)
-- Main query using the CTE
SELECT ...FROM cte_name;
```

CTE Building Blocks

```
WITH cte_name (column1, column2, ...) AS
     (SELECT ...)
-- Main query using the CTE
SELECT ...FROM cte_name;
```

- **WITH clause:** Introduces the CTE
- **CTE name**: Names the CTE. Name must be unique in scope of query.
- **Column List** (optional): If not provided, the column definitions are inherited from the SELECT clause
- **AS keyword**: The CTE definition.
- **CTE query**: This is a query that defines the CTE, which may include JOINs, WHERE, GROUP BY clauses, and other valid SQL constructs. Several queries, each with their own CTE name, are allowed.
- **Main query**: Can reference the CTE(s) by name. In the main query, you can use the CTE as if it were a regular table, simplifying the structure of complex queries.

Benefits of Using CTEs

- Readability and maintenance: CTEs are more readable and break complex queries down into simpler parts.
- Ease of debugging: Test parts of a complex query independently, making debugging easier.
- Performance: They can make query optimization by the planner more effective

Putting CTEs to use

- What products are the Top 10 customers buying?
  - Create a CTE to find the Top 10 customers
  - Create a CTE that shows product sales by customer
  - Join both CTEs
  - Apply proper formatting

Sample CTE: What did my overall top 10 customers by in June?

```
WITH top10_customers AS (
    SELECT customer_id, SUM(total_price) AS total_spent
    FROM customer_purchase_view
    GROUP BY customer_id
    ORDER BY total_spent DESC
    LIMIT 10
)
SELECT
    cpv.customer_name,
    cpv.product_name,
    SUM(cpv.quantity) AS total_qty,
    SUM(cpv.total_price) AS total_spent
FROM customer_purchase_view cpv
    JOIN top10_customers tc ON cpv.customer_id = tc.customer_id
WHERE cpv.order_date >= '2025-06-01' AND cpv.order_date < '2025-07-01'
GROUP BY ROLLUP (cpv.customer_name, cpv.product_name)
ORDER BY cpv.customer_name, total_spent ASC;
```

Common Table Expression - who are the overall top 10 customers?

Given these customers:
What did they buy in June 2025

CTEs for Recursive Queries

- Used to process hierarchical type data structures
  - Bill of materials
  - Company hierarchy
  - ....
- The CTE results are appended to the base table

Building Blocks of the Recursive CTE

```
WITH RECURSIVE cte_name (column1, column2, columnN)
AS(
    SELECT columns FROM table1 WHERE condition

    UNION [ALL]

    SELECT columns FROM cte_name
         WHERE recursive_condition
)
SELECT columns FROM cte_name;
```

- WITH RECURSIVE introduces the recursive CTE
- List of columns (optional)
- Initial SELECT clause to build the first record of the CTE (i.e. the non-recursive term)
- UNION to append the next clauses to the initial clause
- Recursive SELECT clause
- UNION appends the results of the recursive clause and the initial clause to build the result set
- WHERE ends the recursion
- Main query (last SELECT) works on the CTE result set as if it was a table

Nota Bene

- The column counts and definitions between the non-recurring clause and the recurring clause must be identical
- UNION ALL brings both data sets together
- UNION (without ALL) removes duplicates
- UNION (without ALL) is much slower as it has to check for duplicates

Different database

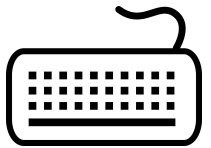
Example Data Set

```
CREATE TABLE employee (
      id INT PRIMARY KEY,
      name TEXT,
      manager_id INT);
```

Dataset has been pre-loaded in DLH4.

Try `SELECT name ORDER BY salary ASC;`

id	name	manager_id	salary
15	Bill		75000
1	Marc	15	67500
2	Susi	15	68300
3	Jake	15	66450
4	Karin	2	62450
5	Bill	2	63000
6	John	4	49000
7	Frank	4	51000
8	Siggi	4	53000
9	Theo	4	52600
10	Barbara	9	46750



DLH4

CTE for Simple Hierarchy

```
WITH RECURSIVE employee_hierachy (id, name, manager_id)
AS (
     SELECT id, name, manager_id
          FROM employee
          WHERE manager_id IS NULL
     UNION ALL
     SELECT e.id, e.name, e.manager_id
          FROM employee e
          INNER JOIN employee_hierachy eh
                    ON e.manager_id = eh.id
          )
SELECT * FROM employee_hierachy;
```

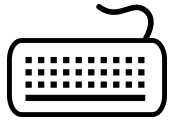
- WITH RECURSIVE introduces the recursive CTE
- List of columns (optional)
- Initial SELECT clause to build the first record of the CTE (i.e. the non-recursive term)
- UNION to append the next clauses to the initial clause
- Recursive SELECT clause
- UNION appends the results of the recursive clause and the initial clause to build the result set
- WHERE ends the recursion
- Main query (last SELECT) works on the CTE result set as if it was a table

DLH4

Hierarchy with Level Count

```
WITH RECURSIVE employee_hierachy AS (
     SELECT id, name, manager_id, 1 AS level -- initiate level count
          FROM employee WHERE manager_id IS NULL -- define starting point
     UNION ALL
     SELECT e.id, e.name, e.manager_id,
          eh.level +1 -- add to the level count
          FROM employee e
          INNER JOIN employee_hierachy eh ON e.manager_id = eh.id
)
SELECT * FROM employee_hierachy;
```

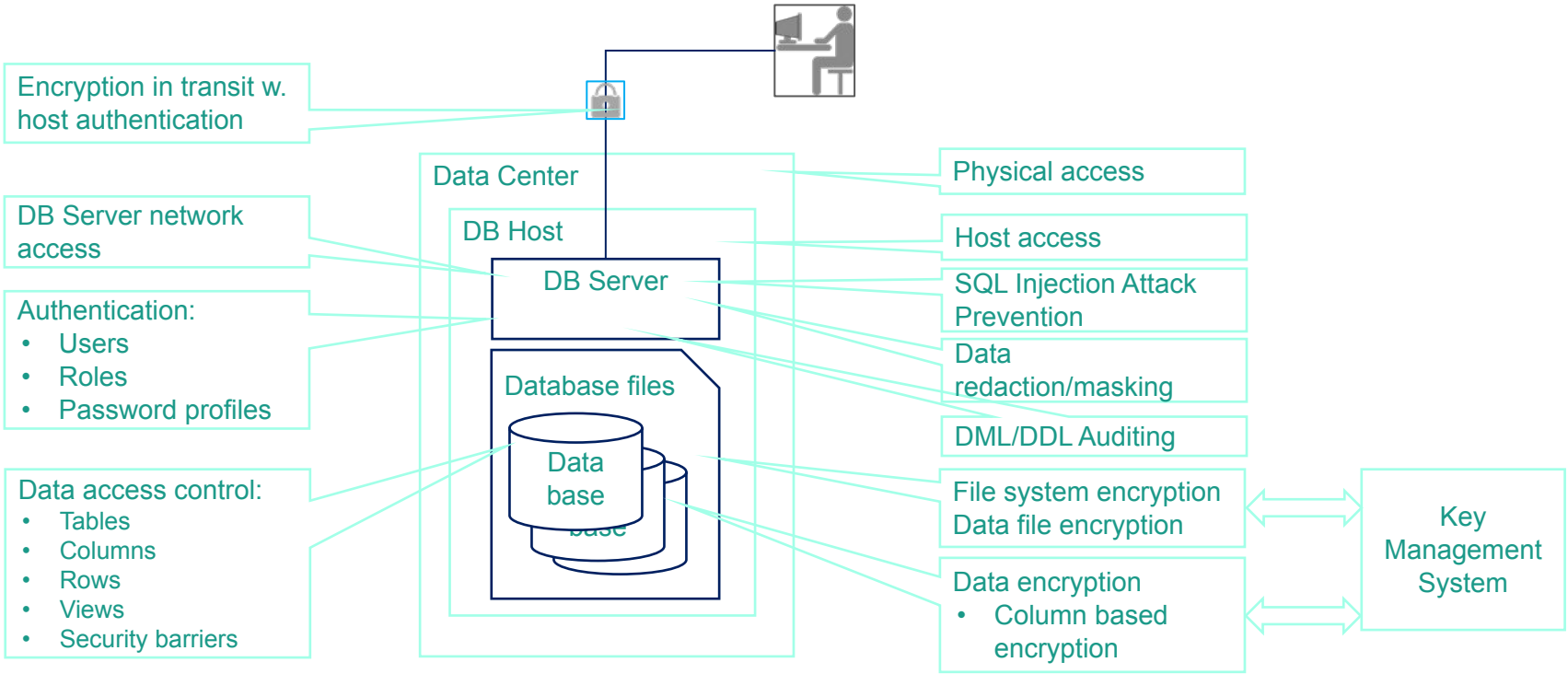
Hierarchy with Manager Name and Reporting Line



```
WITH RECURSIVE employee_hierachy AS (
      SELECT id, name, manager_id, NULL AS manager_name,
            1 AS level,
            'Top' as reporting_line
            FROM employee
            WHERE manager_id IS NULL
      UNION ALL
      SELECT e.id, e.name, eh.id, eh.name AS manager_name, eh.level +1,
            FORMAT('%s/%s', eh.reporting_line, eh.name) -
            FROM employee e
            INNER JOIN employee_hierachy eh ON e.manager_id = eh.id
)
SELECT
      employee_hierachy.manager_id,
      employee_hierachy.manager_name,
      employee_hierachy.level as reporting_level,
      employee_hierachy.id as employee_id,
      employee_hierachy.name as employee_name,
      employee_hierachy.reporting_line
      FROM employee_hierachy
      ORDER BY reporting_level, manager_name ASC
```

Users, permissions and access control

MULTIPLE LAYERS OF SECURITY



From: Dave Page & Marc Linster - Best Practices in Security with PostgreSQL (EDB Webinar 2021)

Today's Focus

- Roles, Users and Groups
  - Users: Roles with login rights
  - Groups: Roles without login rights; used the regroup rights definitions
- Access Controls
  - Databases
  - Schemas
  - Tables
  - Columns
  - Rows
  - Functions & procedures
  - Sequences
  - etc

Managing Users

CREATE ROLE name [[WITH] option [...]]
where option can be:

SUPERUSER | NOSUPERUSER
| CREATEDB | NOCREATEDB
| CREATEROLE | NOCREATEROLE
| INHERIT | NOINHERIT
| LOGIN | NOLOGIN
| REPLICATION | NOREPLICATION
| BYPASSRLS | NOBYPASSRLS
| CONNECTION LIMIT connlimit
| [ENCRYPTED] PASSWORD 'password' | PASSWORD NULL
| VALID UNTIL 'timestamp'
| IN ROLE role_name [, ...]
| ROLE role_name [, ...]
| ADMIN role_name [, ...]
| SYSID uid

URL: https://www.postgresql.org/docs/current/sql-createrole.html;

Access to database objects

#1 rule:

- Minimal access!
- Grant users the least amount of rights (privileges) that they need to do their work
- Start by removing all rights and privileges, and then grant only those that are necessary
- Use groups to manage the rights

GRANT/REVOKE

SELECT
INSERT
UPDATE
DELETE
TRUNCATE
REFERENCES
TRIGGER
CREATE
CONNECT
TEMPORARY
EXECUTE
USAGE
SET
ALTER SYSTEM
MAINTAIN

Example

- Goal:
  - Create a new database called `dlh6` with a single schema `websitedata` and a single table `customer`
  - Create two new user groups
    - `websiteanalyst` - they have read only access to the schema and the table
    - `website editor` - they have read/write access
- Approach:
  - Lets use `PSQL` - the Postgres command interface for most of this

Create a new database, schema and table (use PSQL!)

Step	Description
`Right click on PostgreSQL17/postgres and select PSQL`	Connect to database **postgres** as user postgres (super user) using the PSQL Tool
`\connectioninfo`	Shows the database and user. Make sure we are in the right place (database **postgres**) with the right login
`CREATE DATABASE DLH6;`	Create an empty database
`\c DLH6;`	Connect to the new database
`\dn;`	List the currently defined schemas
`DROP SCHEMA public;`	Drop unnecessary schema
`CREATE SCHEMA websitedata;`	Create an empty schema
`ALTER DATABASE dlh6 SET SEARCH_PATH = websitedata;`	Make sure that all commands will execute in this schema by default

`CREATE TABLE customer (id INT, name TEXT);`
`INSERT INTO customer VALUES (1, 'Marc Linster');`
`INSERT INTO customer VALUES (2, 'Jean Muller');`
	Create the table with some seed data

Create Users and Groups

Step	Description

`CREATE GROUP websiteeditor WITH`
`  NOSUPERUSER`
`  NOCREATEDB`
`  NOCREATEROLE`
`  INHERIT`
`  NOLOGIN;`
	New group (i.e. role without login)

`CREATE USER erika WITH`
`  LOGIN`
`  PASSWORD 'password'`
`  IN ROLE websiteeditor;`
	New user, member of that role

`CREATE GROUP websiteanalyst WITH`
`  NOSUPERUSER`
`  NOCREATEDB`
`  NOCREATEROLE`
`  INHERIT`
`  NOLOGIN;`	

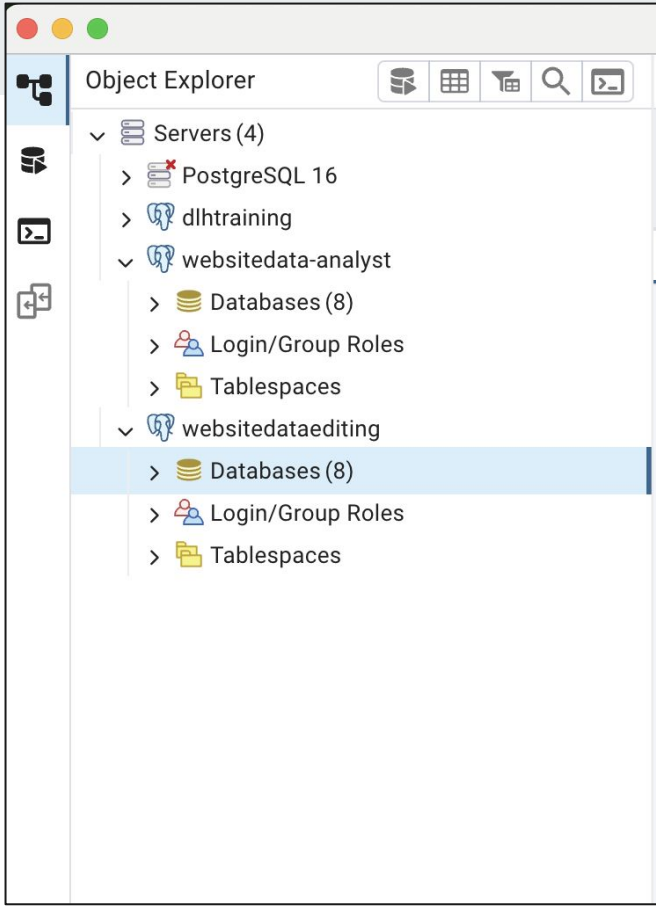
`CREATE USER jane WITH`
`  LOGIN`
`  PASSWORD 'password'`
`  IN ROLE websiteanalyst;`	

Assign rights and access controls

Step	Description
`GRANT CONNECT ON DATABASE "DLH6" TO websiteanalyst;` `GRANT CONNECT ON DATABASE "DLH6" TO websiteeditor;`	Grant both groups the right to connect to the new database
`GRANT USAGE ON SCHEMA websitedata TO websiteanalyst;` `GRANT USAGE ON SCHEMA websitedata TO websiteeditor;`	Grant both groups the right to access the new schema
`GRANT SELECT, INSERT, UPDATE, DELETE ON ALL TABLES IN SCHEMA websitedata to websiteeditor;`	Grant the editor group (role) read/write access to the data
`GRANT SELECT ON TABLE customer TO websiteanalyst;`	Grant the analyst group (role) read-only access to the data

Try it out

- Create a new server in pgAdmin (e.g., a new database connection) to DLH6 as user Jane
  - Call it ‘websitedataanalysis’. Fill in the correct connection parameters
  - Query the customer table
  - Try to insert or update
- Create a new server (e.g., a new database connection) to DLH6 as user Erika
  - Call it ‘websitedataediting’. Fill in the correct connection parameters
  - Query the customer table
  - Try to insert or update
  - Try to create a new table

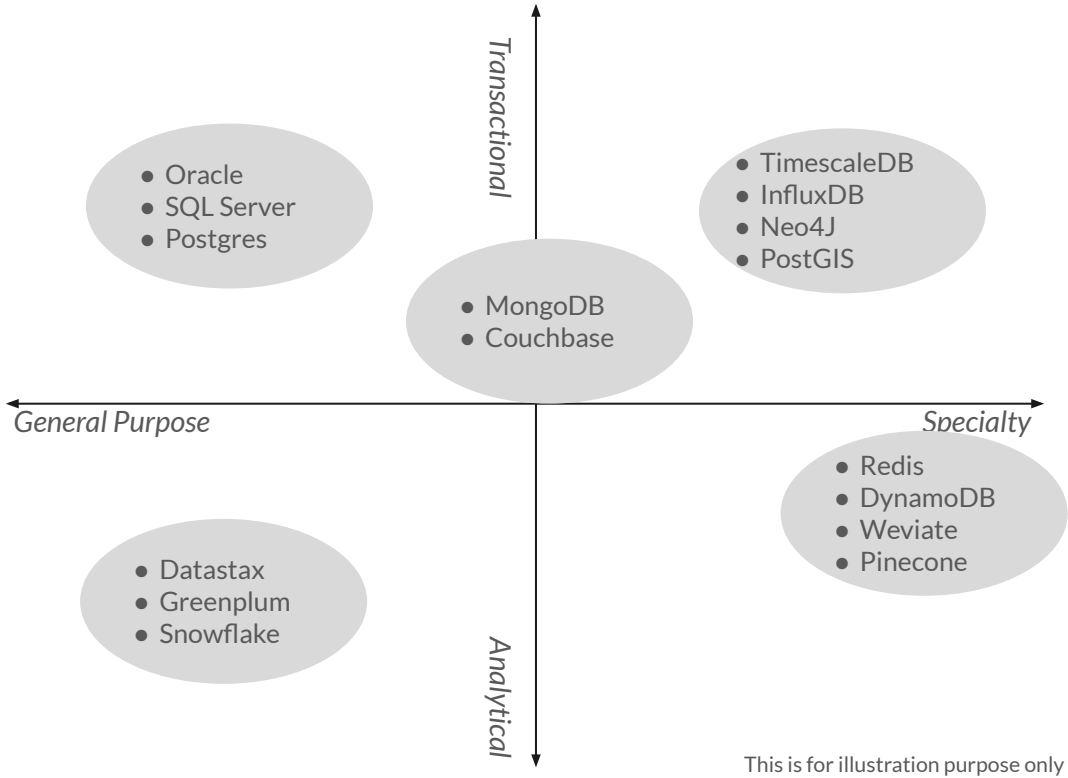


Exercise

- Create a new database `experiment` with schema `shopping`
- Add a table
- Make this table editable for Erika and readable for Jane

Recap

Database Landscape



This is for illustration purpose only
There are many, many databases and many ways to classify them

Table Basics

- Rows = records (a.k.a. tuples in Postgres)
- Columns = data elements
- Example: mycustomer table
  - ID = a way to uniquely identify a customer ⇒ usually a large number
  - Email = the email address, a text field, sometimes limited in length
  - First name ⇒ a text field, sometimes limited in length
  - Last name ⇒ a text field, sometimes limited in length
  - Since => a date field

```
CREATE TABLE mycustomer (
      id INTEGER,
      email TEXT,
      first_name TEXT,
      last_name TEXT,
      since DATE
);
```

```
postgres=# SELECT * FROM mycustomer;
 id |        email         | first_name | last_name |   since
----+----------------------+------------+-----------+------------
  1 | marc@marclinster.com | Marc       | Linster   | 2025-01-01
  2 | jmu@gmail.lu         | Jeff       | Mueller   | 2025-01-02
  3 | bini@hotmail.lu      | Jean       | Bintner   | 2025-01-03
```

Query types

- SELECT: List data from tables that meet certain conditions
- UPDATE: Change data in records that meet certain conditions
- INSERT: Add records
- DELETE: Remove Records

Building Blocks of the simple SELECT Query

- SELECT
  - Columns to be selected, maybe using AS to provide a meaningful name
  - For example `last_name AS ln`
- FROM
  - Table(s) from which to select. Can also use AS to provide a new name
  - For example `customer AS c`
- WHERE
  - Filter clauses to select a subset of records
  - Can use the new names from the AS clause
  - For example `c.ln LIKE 'Li%'`
- ORDER BY
  - Organizes the output of the SELECT clause
  - Can use the new names from the AS clause
  - For example: `c.ln ASC, since DESC`

Alias (AS)

- improves readability
- Only available in the context of this query
- Key word 'AS' is optional

More complex building blocks for SELECT queries (JOIN, GROUP BY, HAVING, GROUPING, WITH, ...) will be introduced later

Postgres Operators in the WHERE Clause

`=`	Equal to
`<`	Less than
`>`	Greater than
`<=`	Less than or equal to
`>=`	Greater than or equal to
`<>`	Not equal to
`!=`	Not equal to
`LIKE`	Check if a value matches a pattern (case sensitive)
`ILIKE`	Check if a value matches a pattern (case insensitive)
`AND`	Logical AND
`OR`	Logical OR
`IN`	Check if a value is between a range of values
`BETWEEN`	Check if a value is between a range of values
`IS NULL`	Check if a value is NULL
`NOT`	Makes a negative result e.g. `NOT LIKE`, `NOT IN`, `NOT BETWEEN`

Postgres functions in the SELECT clause

Some of the key string functions

||	String append	`'a'||'_'||'b' → a_b`
lpad/rpad	Create a padded string	`rpad('hi', 5, 'xy') → hixyx`
substring	Create a substring	`substring('Thomas' from 2 for 3) → hom`
::string	Cast a number (and other types) as string	`1::TEXT||'_'||2::TEXT → 1_2`

Many, many more in the Postgres documentation: https://www.postgresql.org/docs/current/functions-string.html

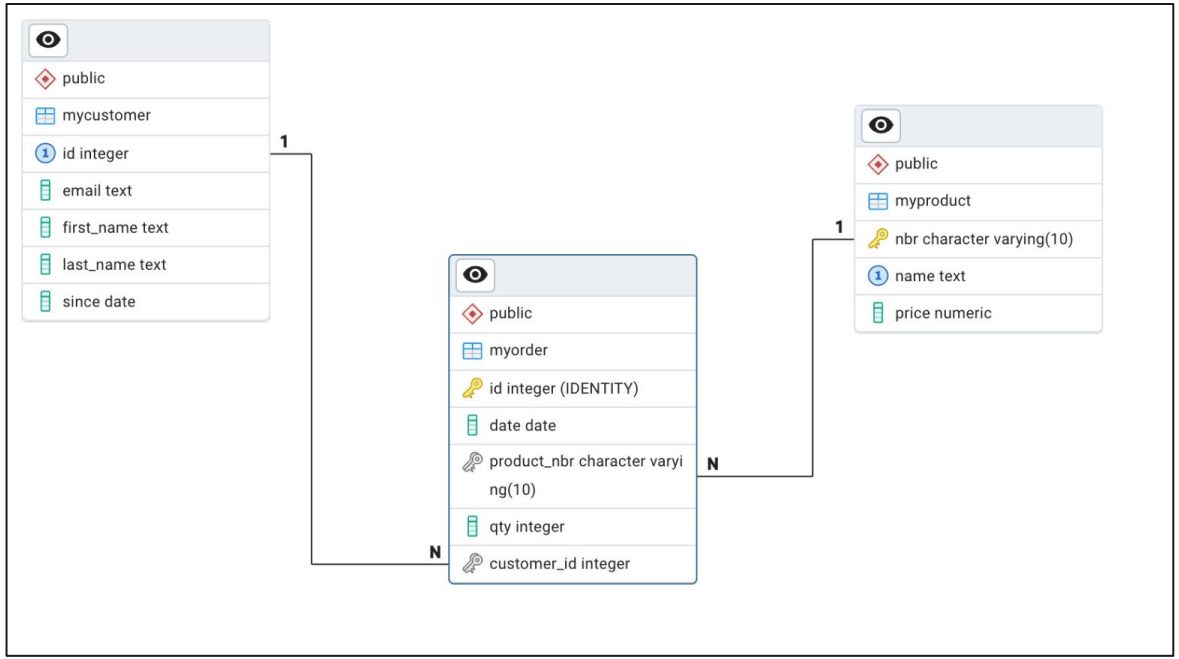
Constraints and Relationships

- **Check Constraints:** The value in the column has to meet certain criteria, e.g., price > 0
- **Not-Null Constraints:** The column needs to have a value
- **Unique Constraints:** No two records have the same value
- **Primary Keys:** like the Unique Constraint, but excludes NULL and always creates an index
  - ⇒ A primary key can also be a combination of columns
- **Foreign Keys:** the data needs to be a valid reference to another table
  - You can assign a ‘trigger’ to handle deletions

Schemas

Graphical view of the schema

- Tables
- Columns
- Constraints
- Relationships
  - 1:1
  - 1:N
  - N:M



3rd Normal Form

Title	Author	Pages	Thickness	Publisher	Genre ID
Beginning MySQL Database Design and Optimization	Chad Russell	520	Thick	Apress	1
The Relational Model for Database Management: Version 2	E.F.Codd	538	Thick	Addison-Wesley	2

Title	Format	Price
Beginning MySQL Database Design and Optimization	Hardcover	49.99
Beginning MySQL Database Design and Optimization	E-book	22.34
The Relational Model for Database Management: Version 2	E-book	13.88
The Relational Model for Database Management: Version 2	Paperback	39.99

Publisher	Country
Apress	USA
Addison-Wesley	USA

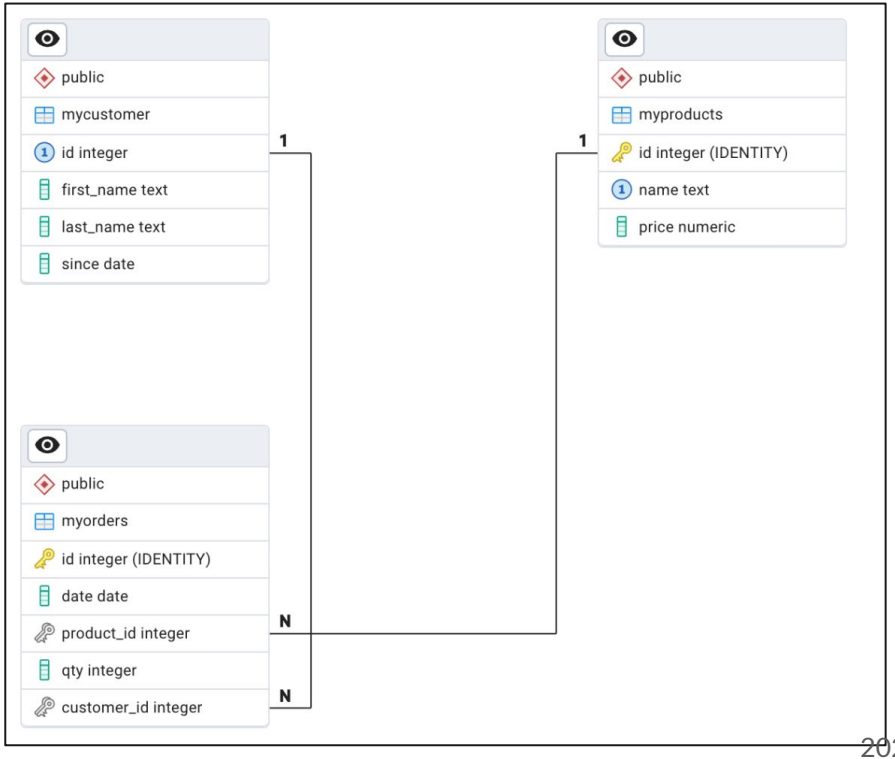
Genre ID	Name
1	Tutorial
2	Popular science

Author	Author Nationality
Chad Russell	American
E.F.Codd	British

‘JOIN … ON …’ connects Two or more tables

Types of joins:

- (INNER) JOIN
- LEFT/RIGHT (OUTER) JOIN
- FULL (OUTER) JOIN
- CROSS JOIN



CREATE VIEW

Views are named queries that are stored in the database server

```
CREATE VIEW customer_purchase_view AS
    SELECT
        c.id AS customer_id,
        c.first_name || ' ' || c.last_name AS
customer_name,
        c.town,
        p.product_nbr,
        pr.name AS product_name,
        pr.category as product_category,
        p.quantity,
        p.id AS purchase_id,
        p.order_date,
        (p.quantity * pr.price) AS total_price
    FROM customer c
    JOIN purchase p ON c.id = p.customer_id
    JOIN product pr ON p.product_nbr = pr.product_nbr;
```

SQL Aggregates

- GROUP BY, e.g., group the customers by location
  - GROUP BY … HAVING allows to limit the groups
  - GROUP BY GROUPING SETS (...) creates sub totals
- SUM, AVG, MIN, MAX, e.g, the total/ average/ minimum/ maximum within a group

After the WHERE clause

Part of the SELECT clause

Many types of Indexes

- Balanced Tree (B-Tree)
  - Every database has it. The most common and used for 90%+ of all cases. The default in Postgres
  - Ideal for looking up unique values and maintaining unique indexes
  - High concurrency implementation - very fast
- Block-Range Index (BRIN)
  - Ideal for very large datasets that are organized according to the index
- Generalized Inverted Index (GIN)
  - Best for indexing values with many keys or values, e.g.,text documents, JSON, multi-dimensional data, arrays
  - Ideal for columns containing many duplicate
- Hash Index
  - Equality, non-equality lookups; no range lookups
- Generalized Search Tree (GiST)
  - Used for GIS, key-value store
- Space-Partitioned Generalized Search Tree (SP-GIST)
  - Specialized index

https://momjian.us/main/writings/pgsql/indexing.pdf

Transactions

- Sample Transaction

```
BEGIN
    Remove Euro 100 from Marc's account
    Add Euro 100 to 'Caves Wengler' account
COMMIT
```

- Key Considerations for a Database:
  - **A**tomic: All or nothing
  - **C**onsistent: After the transaction both accounts are updated immediately and all constraints are validated (e.g., account > 0). Every user always see a consistent picture
  - **I**solated: Multiple transactions can happen at the same time. They either see the state before the transaction, or after the transaction - never in-between
  - **D**urable: Once a transaction has completed, the result remains true.

Summary: Keys to Writing Good Queries

1. Limit the number of rows that are returned
2. Limit the number of columns that are returned
3. Leverage indexes where available
4. Define aliases in the SELECT clause using 'AS' to avoid duplicate column names
5. Use the aliases in the WHERE and GROUP clause to avoid typos and shorten the code
6. Define highly selective WHERE clauses, especially when using JOINS
7. Avoid CROSS JOINS (data set explodes!)
8. Use VIEWS to standardize complex, often repeated queries (e.g., sales_transaction combined with sales_transaction_line)
9. Use snake_case names for tables and columns
10. Study EXPLAIN plans to understand where complexity occurs

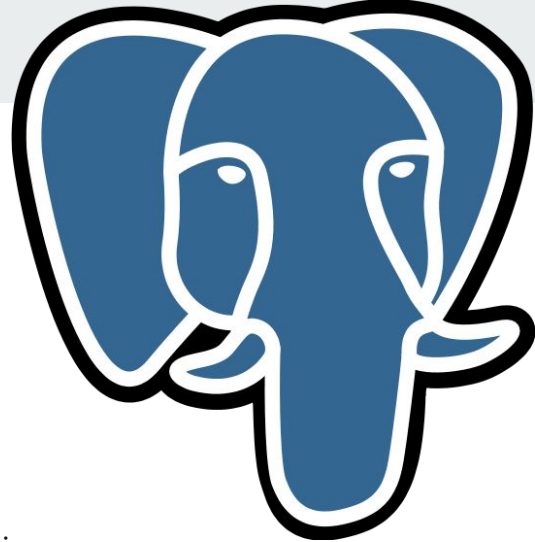
See Jimmy Angelakos' book: https://livebook.manning.com/book/postgresql-mistakes-and-how-to-avoid-them/welcome/v-9/

FYI: SQL Order of Execution

1. **FROM/JOIN**: Specifies the tables from which to retrieve data.
2. **WHERE**: Filters the rows that meet the condition before grouping.
3. **GROUP BY**: Groups rows that share a property.
4. **HAVING**: Filters groups based on conditions, applied after grouping.
5. **SELECT**: Specifies the columns to retrieve or calculate.
6. **DISTINCT**: Removes duplicate rows from the result set.
7. **ORDER BY**: Sorts the result set by specified columns.
8. **LIMIT**: Specifies the maximum number of rows to return.
9. **OFFSET**: Specifies how many rows to skip before starting to return rows.

Resources

Resources



Books:

- PostgreSQL 16 Administration Cookbook; Gianni Ciolli, Boris Mejias, Jimmy Angelakos, Vibhor Kumar, Simon Riggs, 2023
- PostgreSQL Up and Running; Regina Obe and Leo Hsu, 2020
- Introduction to PostgreSQL for the data professional; Ryan Booz and Grant Fritchey 2025 (coming from SQL Server)
- Mastering PostgreSQL 17: Elevate your database skills with advanced deployment, optimization, and security strategies 6th ed. Hans-Jürgen Schönig, 2023

Blogs & online:

- Postgres documentation: https://www.postgresql.org/docs/current/index.html
- Neon's Postgres Tutorial: https://neon.tech/postgresql/tutorial
- Bruce Momjian's blog about SQL and Postgres: https://momjian.us/main/presentations/sql.html
- Bruce Momjian's blog about Postgres performance: https://momjian.us/main/presentations/performance.html
- Laetitia Avrot's excellent blog about DBA topics: https://mydbanotebook.org/
- Vibhor Kumar's blog: https://vibhorkumar.wordpress.com/
- Stormatics' blog: https://stormatics.tech/our-blogs
- pgAdmin Website (with videos): https://www.pgadmin.org/