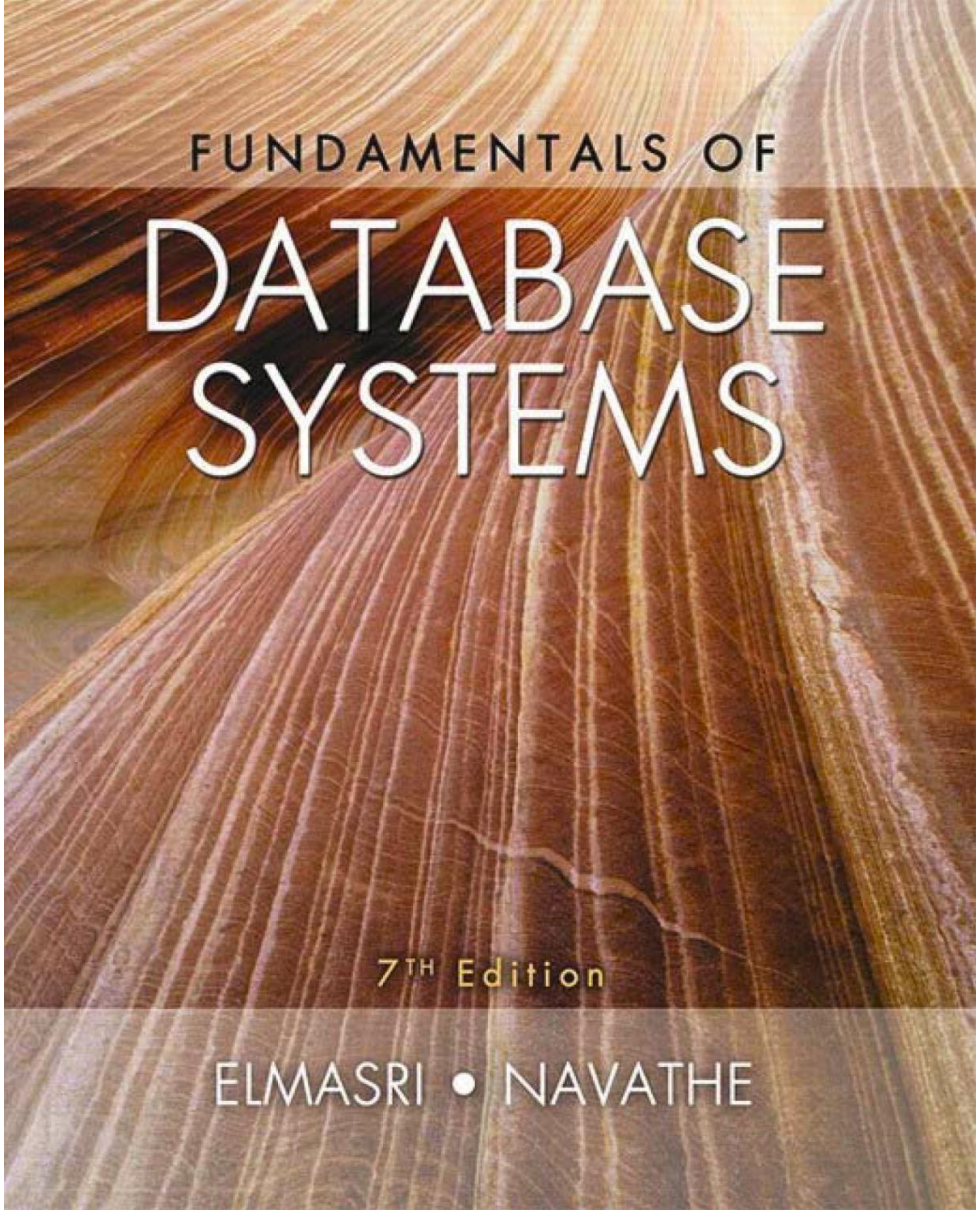
Data Management

Jakob Hviid



Course Description - Materials

- → Fundamentals of Database Systems
  - → Elmasri, Navathe
  - → 7th edition
  - → ISBN-13: 9781292097619.
  - → I recommend a digital version, as the book is quite large/heavy ~ 1270 pages.
- → NO-SQL Materials TBA
- → RDF Paper TBA

Course Description Knowledge

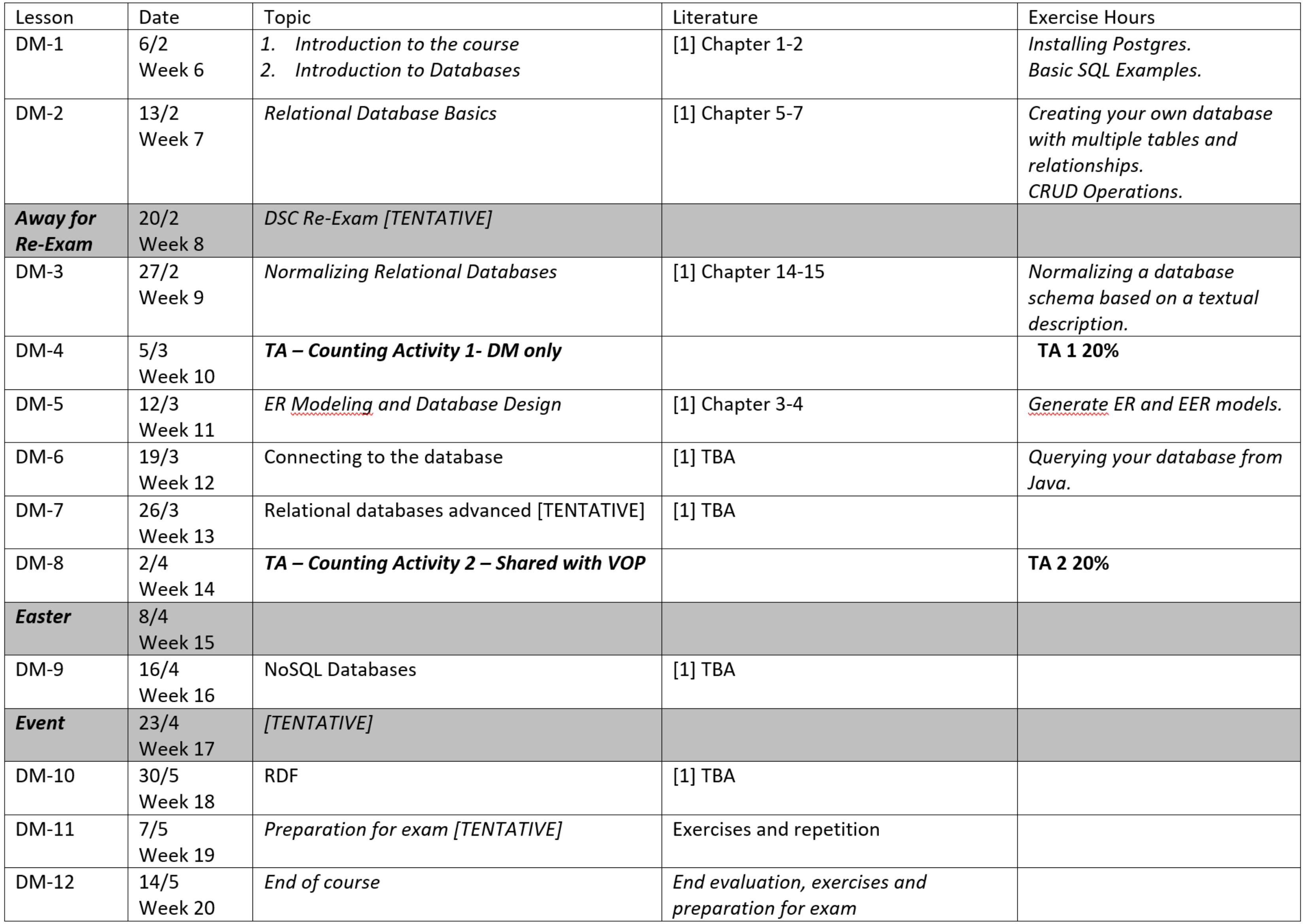
- → Describe fundamental properties for different types of database systems.
- → Describe regular expressions and grammars.
- → Describe different forms of data representations (JSON, RDF, etc.).

Course Description - Skills

- → Design a fitting conceptual model for a database, based on a problem description.
- → Transform a conceptual model of a database to a fitting relational model.
- → Write SQL to query a relational database.
- → Create a NoSQL database.
- → Execute queries on a NoSQL database.
- → Access a database from a programming language.
- → Save and access data in different data representations.

Tentative Plan

→ Plan is only tentative – Changes WILL happen!
→ Do **NOT** rely on a download version!
→ Exercise hours are for last weeks lecture content.



Lesson	Date	Topic	Literature	Exercise Hours
DM-1	6/2 Week 6	1. *Introduction to the course* 2. *Introduction to Databases*	[1] Chapter 1-2	*Installing Postgres.* *Basic SQL Examples.*
DM-2	13/2 Week 7	*Relational Database Basics*	[1] Chapter 5-7	*Creating your own database with multiple tables and relationships.* *CRUD Operations.*
Away for Re-Exam	20/2 Week 8	*DSC Re-Exam [TENTATIVE]*		
DM-3	27/2 Week 9	*Normalizing Relational Databases*	[1] Chapter 14-15	*Normalizing a database schema based on a textual description.*
DM-4	5/3 Week 10	***TA – Counting Activity 1- DM only***		**TA 1 20%**
DM-5	12/3 Week 11	*ER Modeling and Database Design*	[1] Chapter 3-4	*Generate ER and EER models.*
DM-6	19/3 Week 12	Connecting to the database	[1] TBA	*Querying your database from Java.*
DM-7	26/3 Week 13	Relational databases advanced [TENTATIVE]	[1] TBA	
DM-8	2/4 Week 14	***TA – Counting Activity 2 – Shared with VOP***		**TA 2 20%**
Easter	8/4 Week 15			
DM-9	16/4 Week 16	NoSQL Databases	[1] TBA	
Event	23/4 Week 17	*[TENTATIVE]*		
DM-10	30/5 Week 18	RDF	[1] TBA	
DM-11	7/5 Week 19	*Preparation for exam [TENTATIVE]*	Exercises and repetition	
DM-12	14/5 Week 20	*End of course*	*End evaluation, exercises and preparation for exam*	

Exercise Classes

- → Every week right after the lectures (lecture from 14-16, exercises from 16-18)
- → For now, we stay at U45. This might change soon.
  - → Stay updated on blackboard!

What is a database?

- Storing large amounts of data in a structured way
- Allows for dynamic queries for data

- It used to be about storing:
  - Corporate data
    - Payrolls, inventory, sales, customers, accounting, documents, …
    - Banking Systems
    - Stock Exchanges
    - Airline Systems
    - Etc.

- Today, databases are used in all fields:
  - Web backends:
    - Web search (google, bing, etc.)
    - Social Networks (Facebook, Instagram, etc.)
    - Blogs, Forums, etc.
  - Mobile applications
  - Data Warehouses
  - Big Data
  - AI
  - Etc.

Why use a database?

→ Easy to use

→ Flexible search

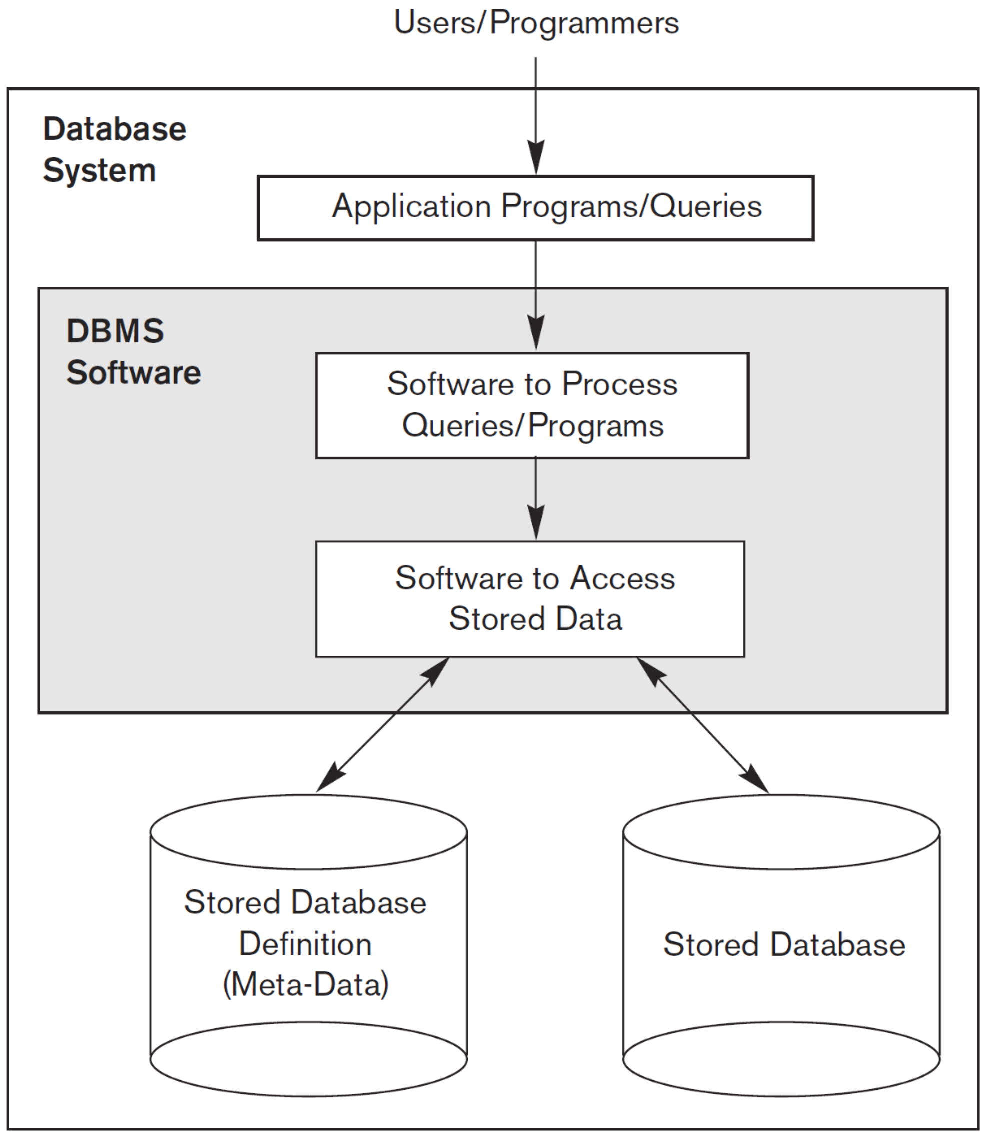
→ Efficient

→ Centralized storage

→ Multi-user access

→ Scalability

→ Security and consistency


Users/Programmers
Database System
Application Programs/Queries
DBMS Software
Software to Process Queries/Programs
Software to Access Stored Data
Stored Database Definition (Meta-Data)
Stored Database

Definitions 1/2

→ Database Management System (DBMS) – A system that enables users to create and maintain a database.

→ Database – A collection of related data. A collection of random data is not a database. Often the word database also, incorrectly, refers to a DBMS.

→ Data – Known facts that can be recorded that has implicit meaning.

→ Mini-World / Universe of Discourse – a database that represents some aspect of the real world. (Mostly here as the book refers to it)

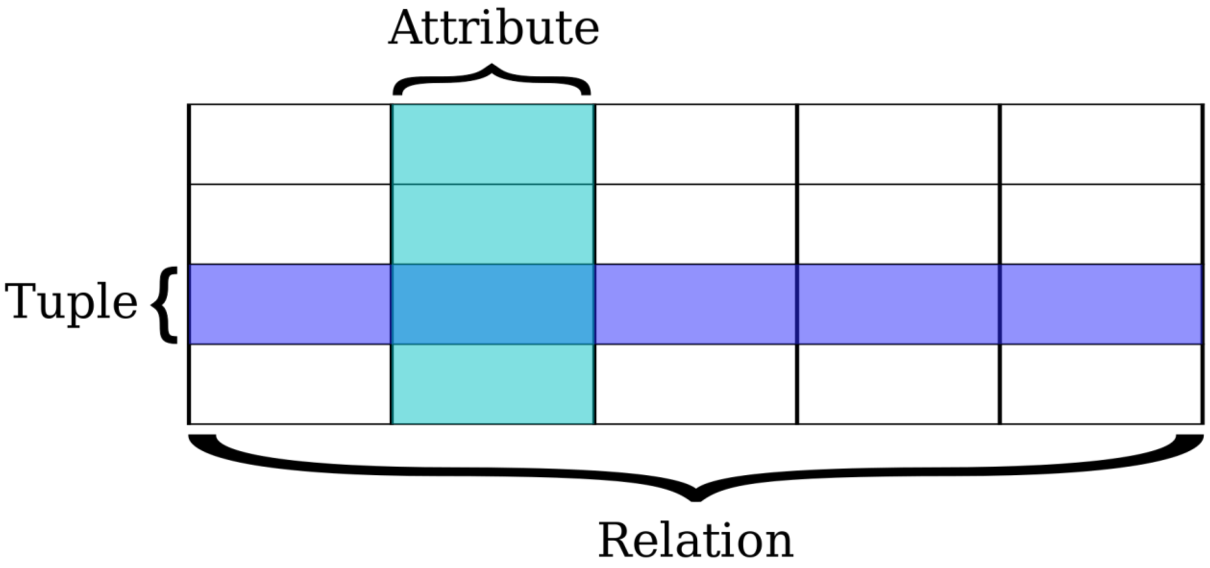
→ Meta data – Data about data, or data that gives context to other data.

→ Schema – A definition of table structures and their relationships.

→ SQL – Structured Query Language – A language to extract data from a database.

Source: Fundamentals of DB Systems, by Elmasri and Navathe

Definitions 2/2



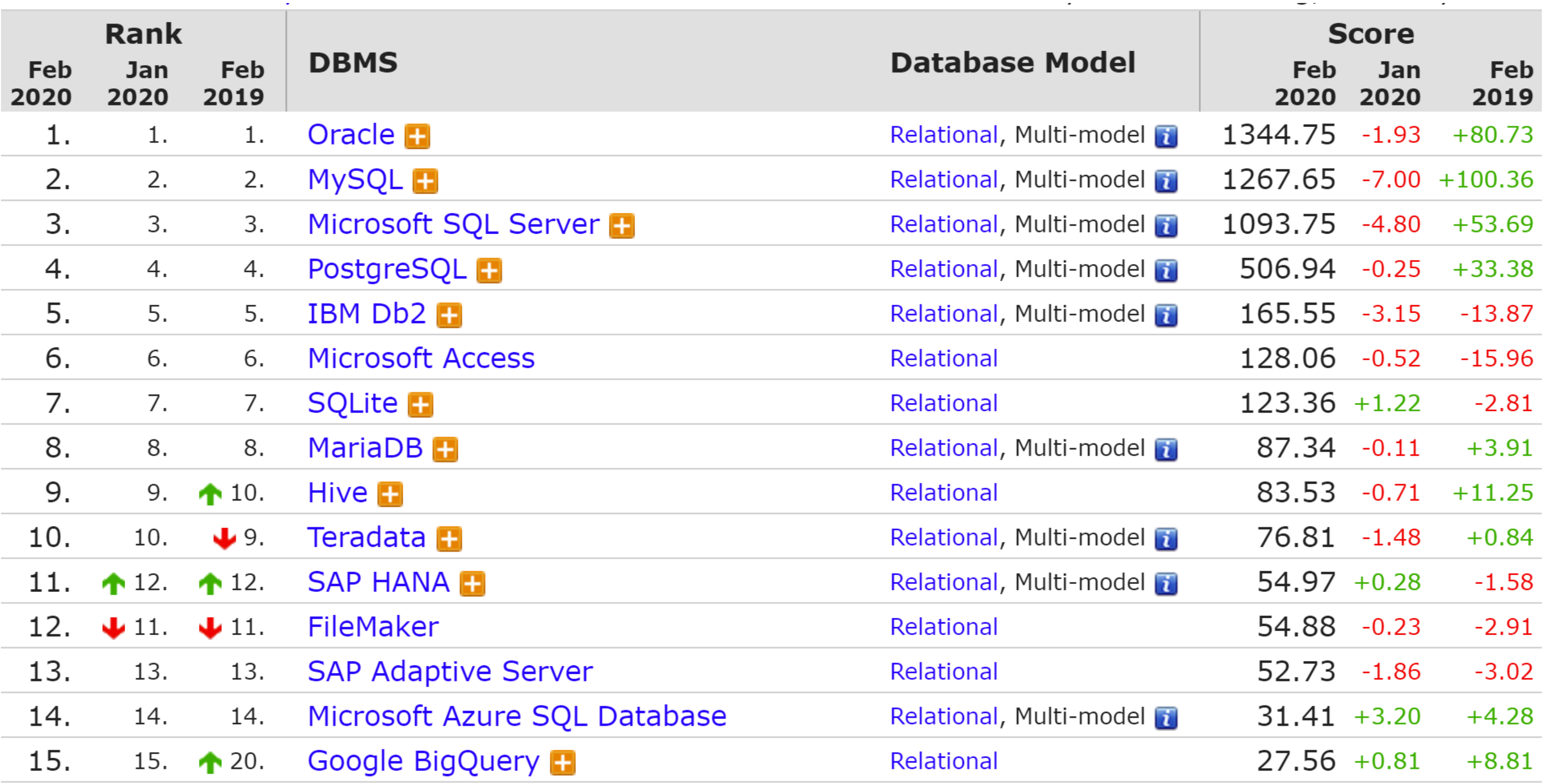
- → Table – A collection of rows and columns that contains Cells.
- → Row, Tuple, or Record – A collection of cells that together form a set of data that has a concrete Relation to each other. Shown as the horizontal line to the left.
- → Column, Attribute, or Field – A collection of Cells that that are all the same type. They are a part of multiple Rows.
- → Cell – A specific Rows Column. Ergo the intersection.
- → Relation – The relationship between data in a Row.
- → Value – The information saved in the specific Cell.
- → View / Result Set – The table that is created in memory and sent to the client as a result of a query.

Relational Databases

→ Consists of multiple tables

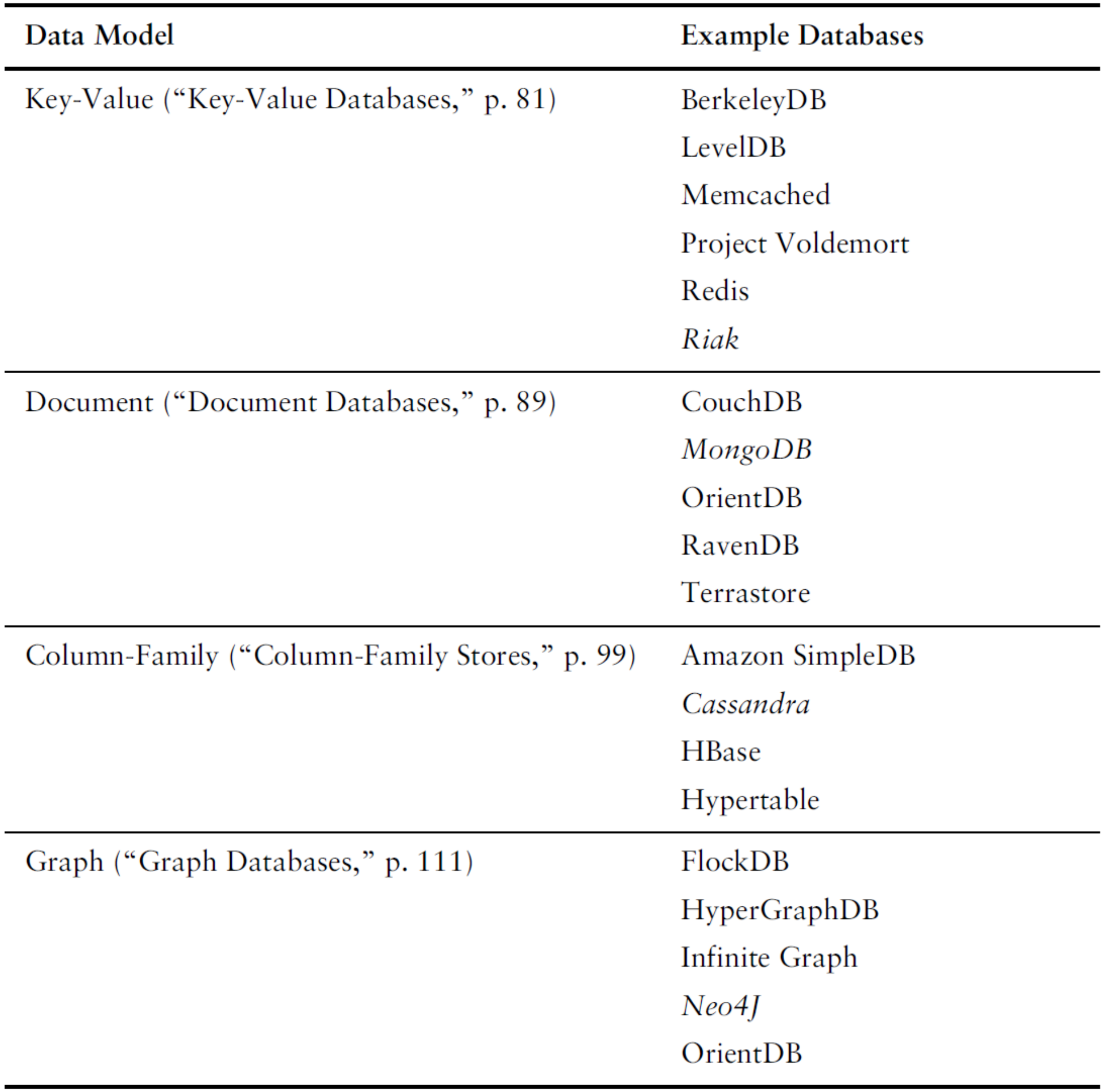
→ Tables relate to each other

→ Uses primary and foreign keys to enforce the relationship constraints



Rank			DBMS	Database Model	Score		
Feb 2020	Jan 2020	Feb 2019			Feb 2020	Jan 2020	Feb 2019
1.	1.	1.	Oracle	Relational, Multi-model	1344.75	-1.93	+80.73
2.	2.	2.	MySQL	Relational, Multi-model	1267.65	-7.00	+100.36
3.	3.	3.	Microsoft SQL Server	Relational, Multi-model	1093.75	-4.80	+53.69
4.	4.	4.	PostgreSQL	Relational, Multi-model	506.94	-0.25	+33.38
5.	5.	5.	IBM Db2	Relational, Multi-model	165.55	-3.15	-13.87
6.	6.	6.	Microsoft Access	Relational	128.06	-0.52	-15.96
7.	7.	7.	SQLite	Relational	123.36	+1.22	-2.81
8.	8.	8.	MariaDB	Relational, Multi-model	87.34	-0.11	+3.91
9.	9.	↑ 10.	Hive	Relational	83.53	-0.71	+11.25
10.	10.	↓ 9.	Teradata	Relational, Multi-model	76.81	-1.48	+0.84
11.	↑ 12.	↑ 12.	SAP HANA	Relational, Multi-model	54.97	+0.28	-1.58
12.	↓ 11.	↓ 11.	FileMaker	Relational	54.88	-0.23	-2.91
13.	13.	13.	SAP Adaptive Server	Relational	52.73	-1.86	-3.02
14.	14.	14.	Microsoft Azure SQL Database	Relational, Multi-model	31.41	+3.20	+4.28
15.	15.	↑ 20.	Google BigQuery	Relational	27.56	+0.81	+8.81

NoSQL Databases

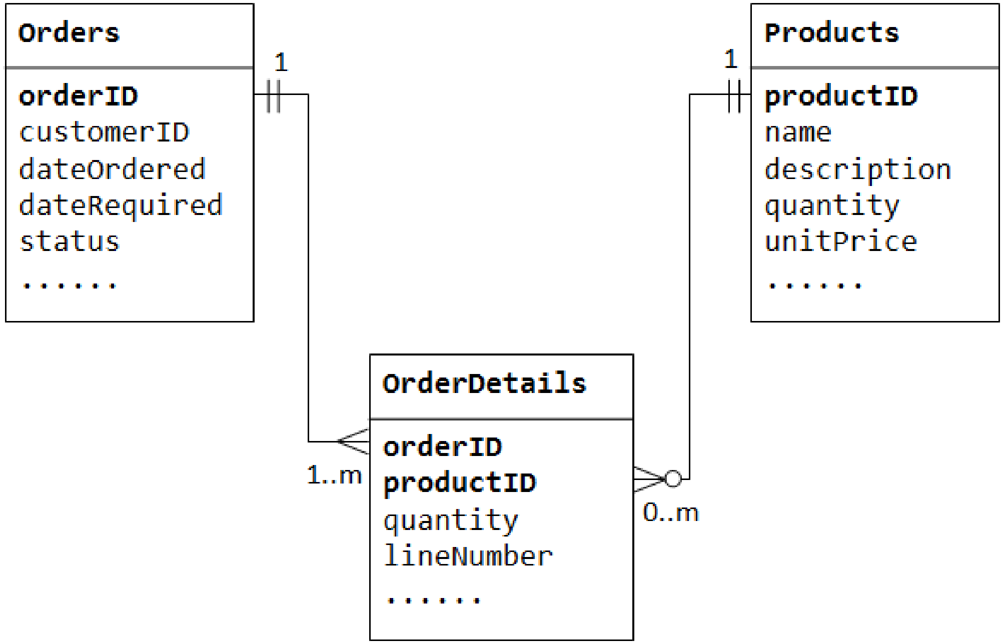


Data Model	Example Databases
Key-Value (“Key-Value Databases,” p. 81)	BerkeleyDB LevelDB Memcached Project Voldemort Redis *Riak*
Document (“Document Databases,” p. 89)	CouchDB *MongoDB* OrientDB RavenDB Terrastore
Column-Family (“Column-Family Stores,” p. 99)	Amazon SimpleDB *Cassandra* HBase Hypertable
Graph (“Graph Databases,” p. 111)	FlockDB HyperGraphDB Infinite Graph *Neo4J* OrientDB

Source: NoSQL Distilled, by P. Sadalage and M. Fowler

- → NoSQL means **N**ot **o**nly **SQL**
- → NoSQL covers multiple types of databases
- → More about NoSQL will be covered later in the course

What is a relational database?



Orders

orderID
customerID
dateOrdered
dateRequired
status
......

Products

productID
name
description
quantity
unitPrice
......

OrderDetails

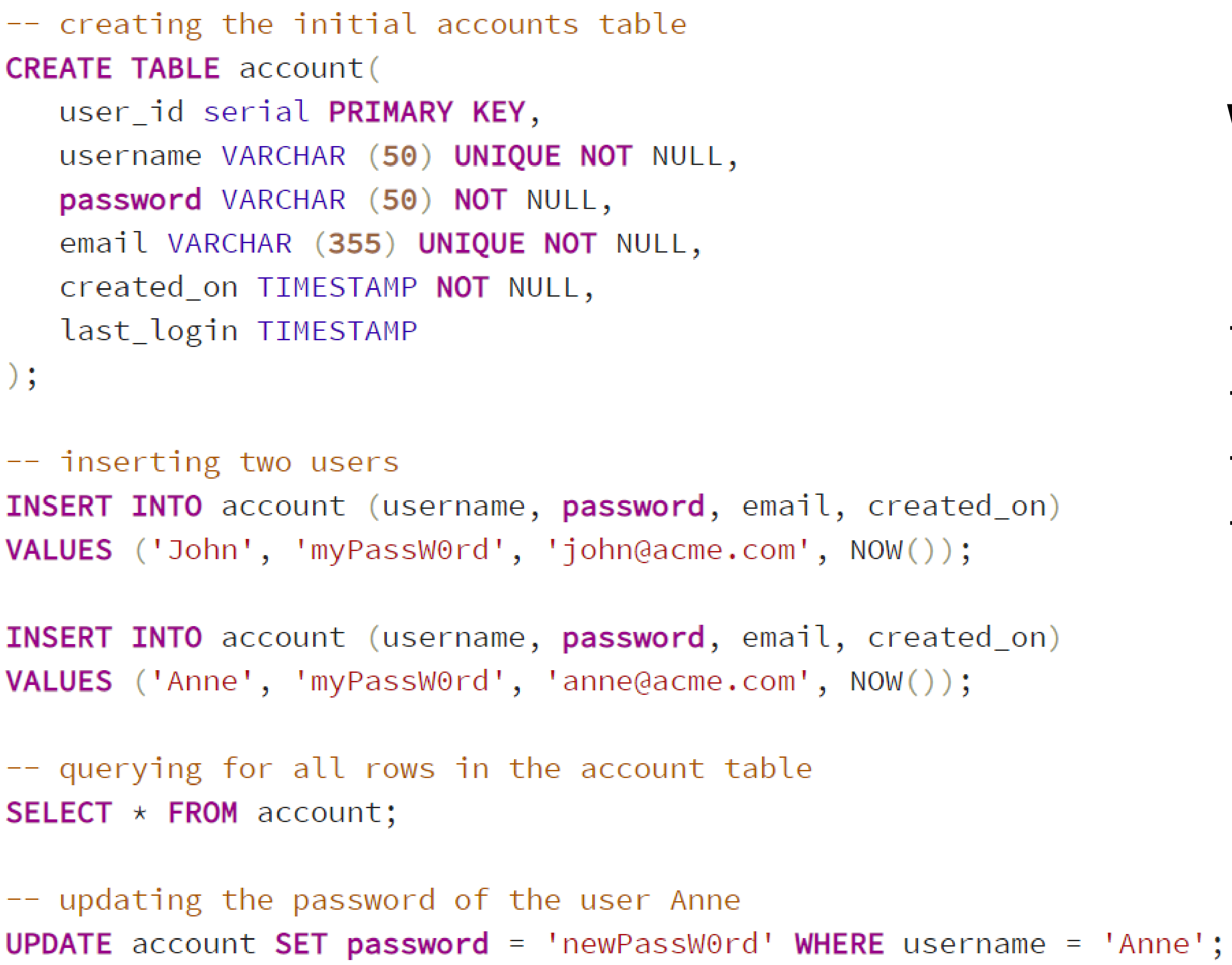
orderID
productID
quantity
lineNumber
......

- → Has a Schema that defines the Tables
- → Uses multiple tables to store data
- → Uses the notion of Primary Keys and Foreign keys to relate table content to each other.
- → Uses SQL which makes CRUD (Create, Read, Update, Delete) operations on Schemas, Tables, and Rows.

PostgreSQL

- → This course will use PostgreSQL (AKA Postgres)
- → However, this is **NOT** a PostgreSQL course!

- → PostgreSQL is:
  - → A Relational Database
  - → Cross-Platform (Windows, Mac OS, Linux, BSD, Solaris)
  - → Licensed under the PostgreSQL License, a liberal Open Source license, similar to the BSD or MIT licenses.
  - → Open Source (https://github.com/postgres/postgres)
- → Documentation and usage sites:
  - → https://www.postgresql.org/docs/12/index.html
  - → https://www.postgresqltutorial.com/



```
-- creating the initial accounts table
CREATE TABLE account(
   user_id serial PRIMARY KEY,
   username VARCHAR (50) UNIQUE NOT NULL,
   password VARCHAR (50) NOT NULL,
   email VARCHAR (355) UNIQUE NOT NULL,
   created_on TIMESTAMP NOT NULL,
   last_login TIMESTAMP
);

-- inserting two users
INSERT INTO account (username, password, email, created_on)
VALUES ('John', 'myPassW0rd', 'john@acme.com', NOW());

INSERT INTO account (username, password, email, created_on)
VALUES ('Anne', 'myPassW0rd', 'anne@acme.com', NOW());

-- querying for all rows in the account table
SELECT * FROM account;

-- updating the password of the user Anne
UPDATE account SET password = 'newPassW0rd' WHERE username = 'Anne';
```

What is SQL?

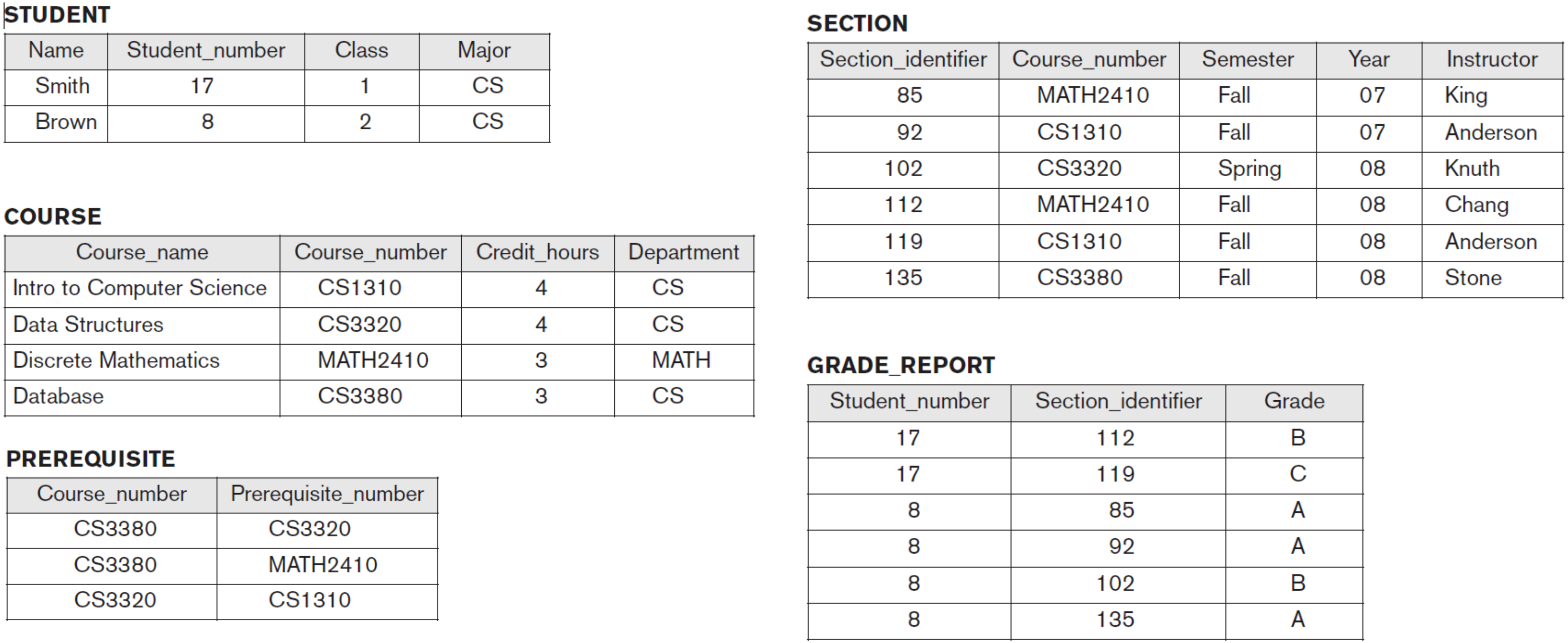
→ Acronym for: **S**tructured **Q**uery **L**anguage.

→ Pronounced either Sequel, or SQL.

→ Allows for retrieval of data from a database.

→ A query results in a result set, which is structured as a table with rows and columns.

Tables and relationships



STUDENT

Name	Student_number	Class	Major
Smith	17	1	CS
Brown	8	2	CS

COURSE

Course_name	Course_number	Credit_hours	Department
Intro to Computer Science	CS1310	4	CS
Data Structures	CS3320	4	CS
Discrete Mathematics	MATH2410	3	MATH
Database	CS3380	3	CS

PREREQUISITE

Course_number	Prerequisite_number
CS3380	CS3320
CS3380	MATH2410
CS3320	CS1310

SECTION

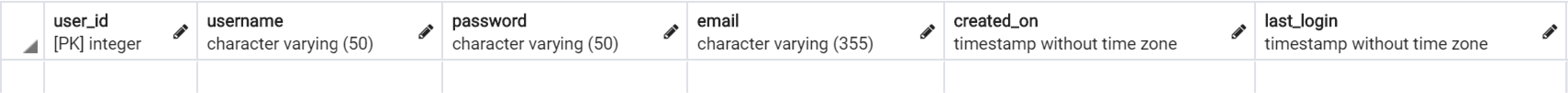
Section_identifier	Course_number	Semester	Year	Instructor
85	MATH2410	Fall	07	King
92	CS1310	Fall	07	Anderson
102	CS3320	Spring	08	Knuth
112	MATH2410	Fall	08	Chang
119	CS1310	Fall	08	Anderson
135	CS3380	Fall	08	Stone

GRADE_REPORT

Student_number	Section_identifier	Grade
17	112	B
17	119	C
8	85	A
8	92	A
8	102	B
8	135	A

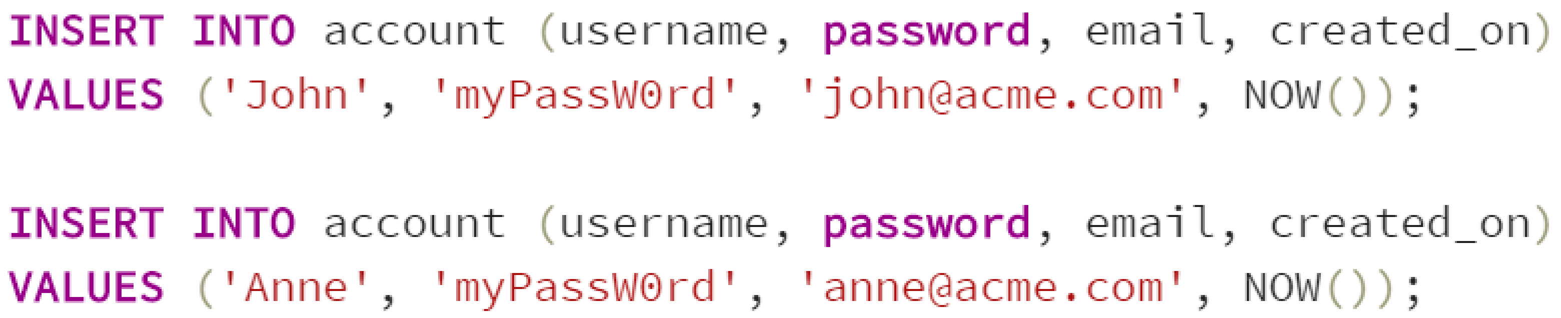
Creating a Table

```
CREATE TABLE account(
   user_id serial PRIMARY KEY,
   username VARCHAR (50) UNIQUE NOT NULL,
   password VARCHAR (50) NOT NULL,
   email VARCHAR (355) UNIQUE NOT NULL,
   created_on TIMESTAMP NOT NULL,
   last_login TIMESTAMP
);
```

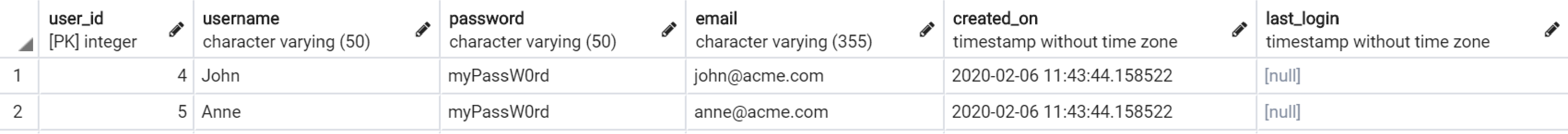


	user_id	username	password	email	created_on	last_login
	[PK] integer	character varying (50)	character varying (50)	character varying (355)	timestamp without time zone	timestamp without time zone

Inserts (CRUD)



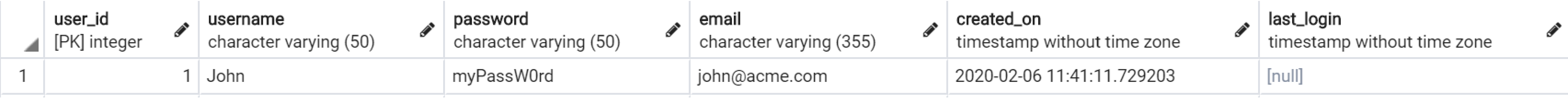
```
INSERT INTO account (username, password, email, created_on)
VALUES ('John', 'myPassW0rd', 'john@acme.com', NOW());

INSERT INTO account (username, password, email, created_on)
VALUES ('Anne', 'myPassW0rd', 'anne@acme.com', NOW());
```



	user_id [PK] integer	username character varying (50)	password character varying (50)	email character varying (355)	created_on timestamp without time zone	last_login timestamp without time zone
1	4	John	myPassW0rd	john@acme.com	2020-02-06 11:43:44.158522	[null]
2	5	Anne	myPassW0rd	anne@acme.com	2020-02-06 11:43:44.158522	[null]

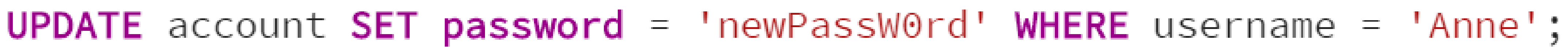
Selects (CRUD)

```
SELECT * FROM account;

SELECT username, created_on FROM account WHERE email = 'john@acme.com';

SELECT username, created_on FROM account WHERE email LIKE '%anne%';
```

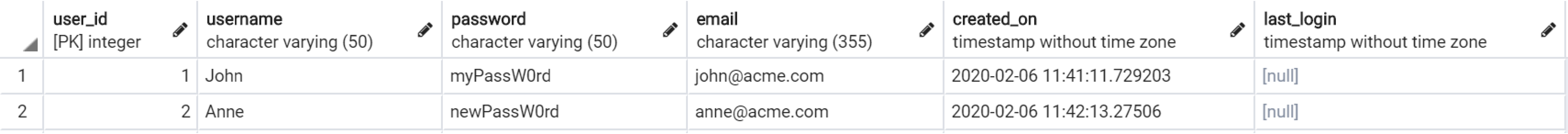


	user_id [PK] integer	username character varying (50)	password character varying (50)	email character varying (355)	created_on timestamp without time zone	last_login timestamp without time zone
1	1	John	myPassW0rd	john@acme.com	2020-02-06 11:41:11.729203	[null]

Updates (CRUD)



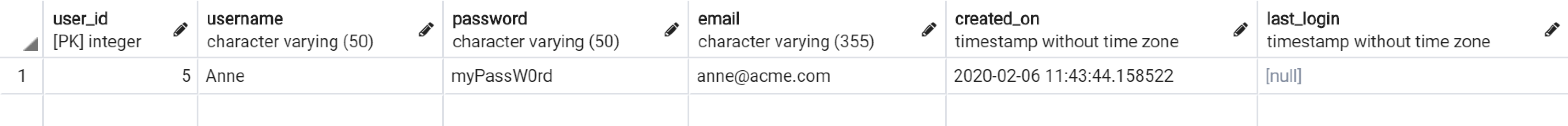
```
UPDATE account SET password = 'newPassW0rd' WHERE username = 'Anne';
```



	user_id [PK] integer	username character varying (50)	password character varying (50)	email character varying (355)	created_on timestamp without time zone	last_login timestamp without time zone
1	1	John	myPassW0rd	john@acme.com	2020-02-06 11:41:11.729203	[null]
2	2	Anne	newPassW0rd	anne@acme.com	2020-02-06 11:42:13.27506	[null]

Delete (CRUD)

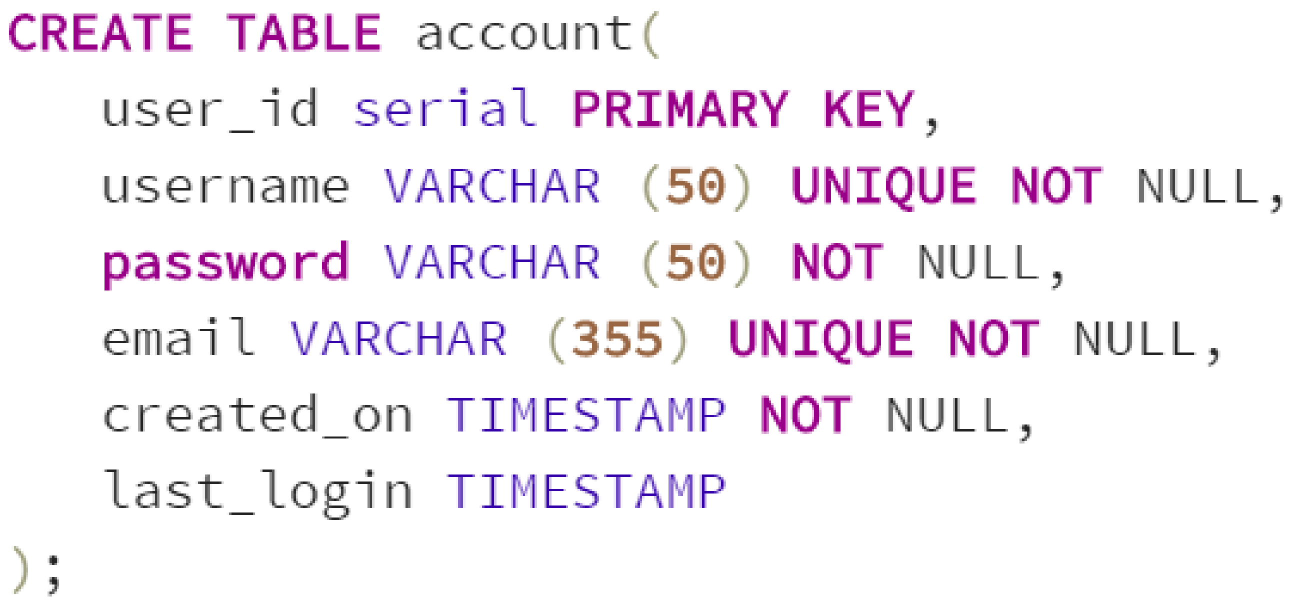
```
DELETE FROM account WHERE email = 'john@acme.com';
```



	user_id [PK] integer	username character varying (50)	password character varying (50)	email character varying (355)	created_on timestamp without time zone	last_login timestamp without time zone
1	5	Anne	myPassW0rd	anne@acme.com	2020-02-06 11:43:44.158522	[null]

BEWARE of doing this: `DELETE FROM account;`

Constraints and Data types in SQL



```
CREATE TABLE account(
   user_id serial PRIMARY KEY,
   username VARCHAR (50) UNIQUE NOT NULL,
   password VARCHAR (50) NOT NULL,
   email VARCHAR (355) UNIQUE NOT NULL,
   created_on TIMESTAMP NOT NULL,
   last_login TIMESTAMP
);
```

Constraints – Abbreviated, more later.

→ PRIMARY KEY – The unique identifier for the current row, which is always NOT NULL

→ FOREIGN KEY – A key that refers to a primary key in a different table, signifying their relationship to each other

→ UNIQUE – Two cells in this Column cannot be the same

→ NOT NULL – This attribute HAS to be specified

PostgreSQL Data Types 1/3

- → Null – Value Missing
- → Boolean – 1 bit
  - → Converts Boolean values e.g., 1, yes, y, t, true are converted to true, and 0, no, n false, f are converted to false.
- → Character types
  - → CHAR(n) – Fixed length text. Unused space is padded with space characters.
  - → VARCHAR(n) – Variable length string, as in “store up to”.
  - → TEXT – Large size text lengths such as book texts.

PostgreSQL Data Types 2/3

- Numeric types
  - Integer
    - SMALLINT – 2 byte, ranges from -32.768 to 32.767 (2 byte = 2 x 8 bit = 256 x 256 = 65.536)
    - INT – 4 byte integer, rage from -2,147,483,648 to 2,147,483,647
    - SERIAL – Same as INT, but used for auto incrementing.
  - Floating-point
    - FLOAT(n) – floating point number with at the precision of n, and a maximum of 8 bytes. (n as in numbers after the ",")
    - REAL – A floating point number. 0.001, 0.00000001, etc.
- Temporal types
  - DATE – dates only
  - TIME – time of day values
  - TIMESTAMP – both date and time values
  - INTERVAL – periods of time

PostgreSQL Data Types 3/3

- → UUID for storing Universally Unique Identifiers
- → Array for storing array strings, numbers, etc.
- → JSON stores JSON data
- → hstore stores key-value pair
- → Special types
  - → box, line, point, lseg, polygon, inet, macaddr.

→ See more here: https://www.postgresql.org/docs/12/datatype.html

Live Demo

Pay attention, and don’t try to replicate what I do right now!

You will have time to do that afterwards.

Exercise - 30 min

- → Install Postgres SQL
  - → Download from: https://www.enterprisedb.com/downloads/postgres-postgresql-downloads
  - → Remember your password!
- → Start “pgAdmin 4”
- → Create Database
- → Find example queries here: https://shorturl.at/DFNX3
  - → Full link here: https://gist.github.com/jakobhviid/e11a5540395e93ece585ebdceea2109d
- → Run operations
  - → Create Table
  - → Insert two unique Rows
  - → Query for all rows
  - → Query for the data in one of the Rows
  - → Delete one of the Rows
  - → Verify deletion by querying for all Rows again