

Introduction to Database Systems

Database Systems

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1. What is Database?

❖ What is data?

- Since birth, we are surrounded with data
- Since people first started writing, they have recorded their observations
- Since computers were invented in the 1950s, data is known as **information that is stored or shared electronically**
- In simple words, data means facts, numbers, charts, or information that a computer stores or uses

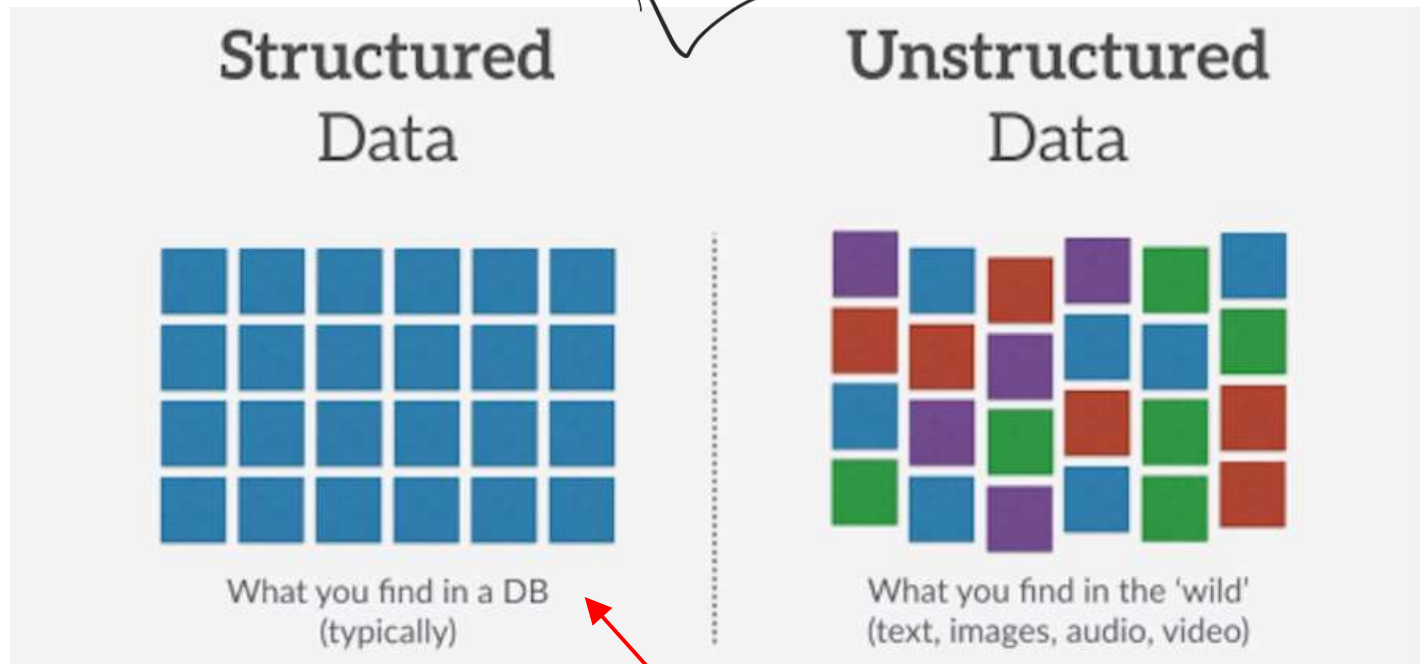
1. What is Database?

❖ What types of data exist?

- Structured vs. Unstructured data

semi-structured data → JSON

Table[☆]



In this lecture, we will focus on Structured Data

1. What is Database?

❖ Database

- An organized collection of data

❖ Examples of Database Applications

- Universities: student management, registration, grades
- Airlines: reservations, schedules
- Hospitals: patient data
- Retail: customers, products, purchases, order track
- Banking and finance
 - customer information, accounts, loans, and card usage

2. Data Model

❖ What is Data Model?

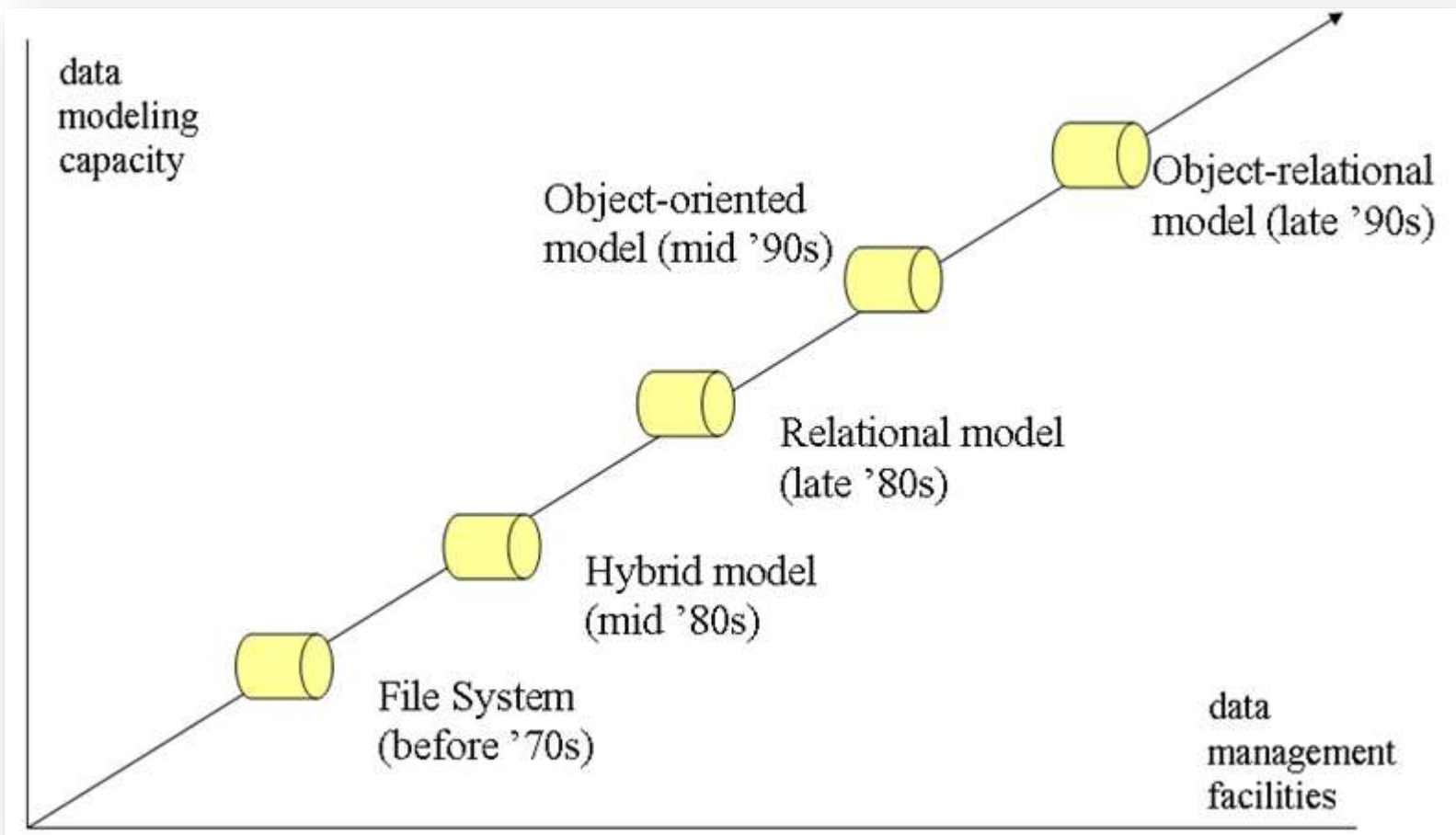
- Used to show how data is **stored**, **connected**, **accessed** and **updated** in the database

❖ Types of data models

- Hierarchical Model 계층형 모델
- Network Model 연결형 “
- Hybrid Model (Combination of Hierarchical and Network Model)
- **Relational Model <- This lecture will focus on Relation Model**
- Object-Oriented Model
- Object-Relational Model

2. Data Model

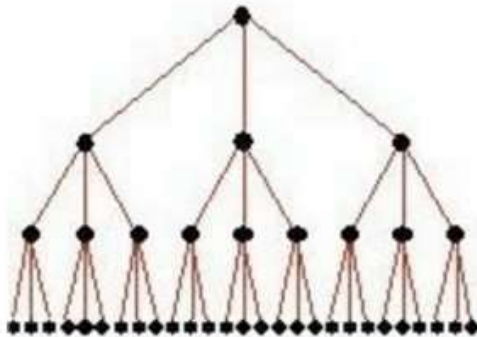
❖ History of Data Models



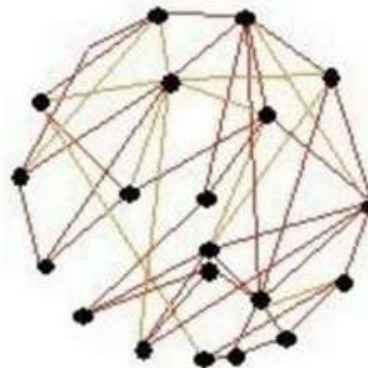
2. Data Model

❖ Hybrid Models

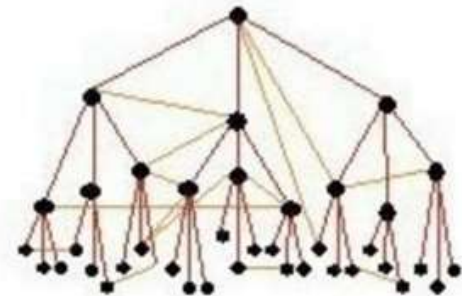
- **Hierarchical Data Model:** Organizes the data in the tree-like structure
- **Network Data Model:** Organizes the data in directed graph structure
- **Hybrid Data Model:** Combination of Hierarchical and Network Data Models



Hierarchy



Network



Hybrid

2. Data Model

❖ Relational Model

- Represents the database as **a collection of relations**
 - Relation = table

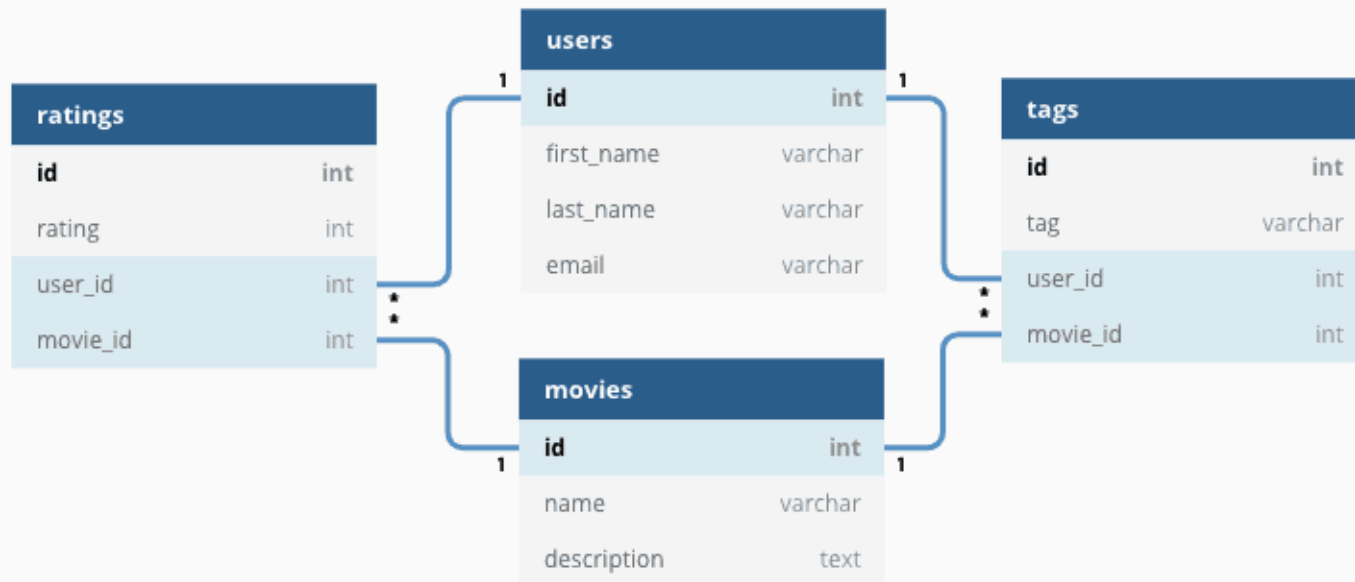
<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

The *instructor* relation

2. Data Model

❖ What is relational database?

- Allows related data to be **stored across multiple tables**, and linked by establishing a **relationship between the tables**



3. Database Management System (DBMS)

❖ DBMS

- A software designed to **store, retrieve, define, and manage** data in a database

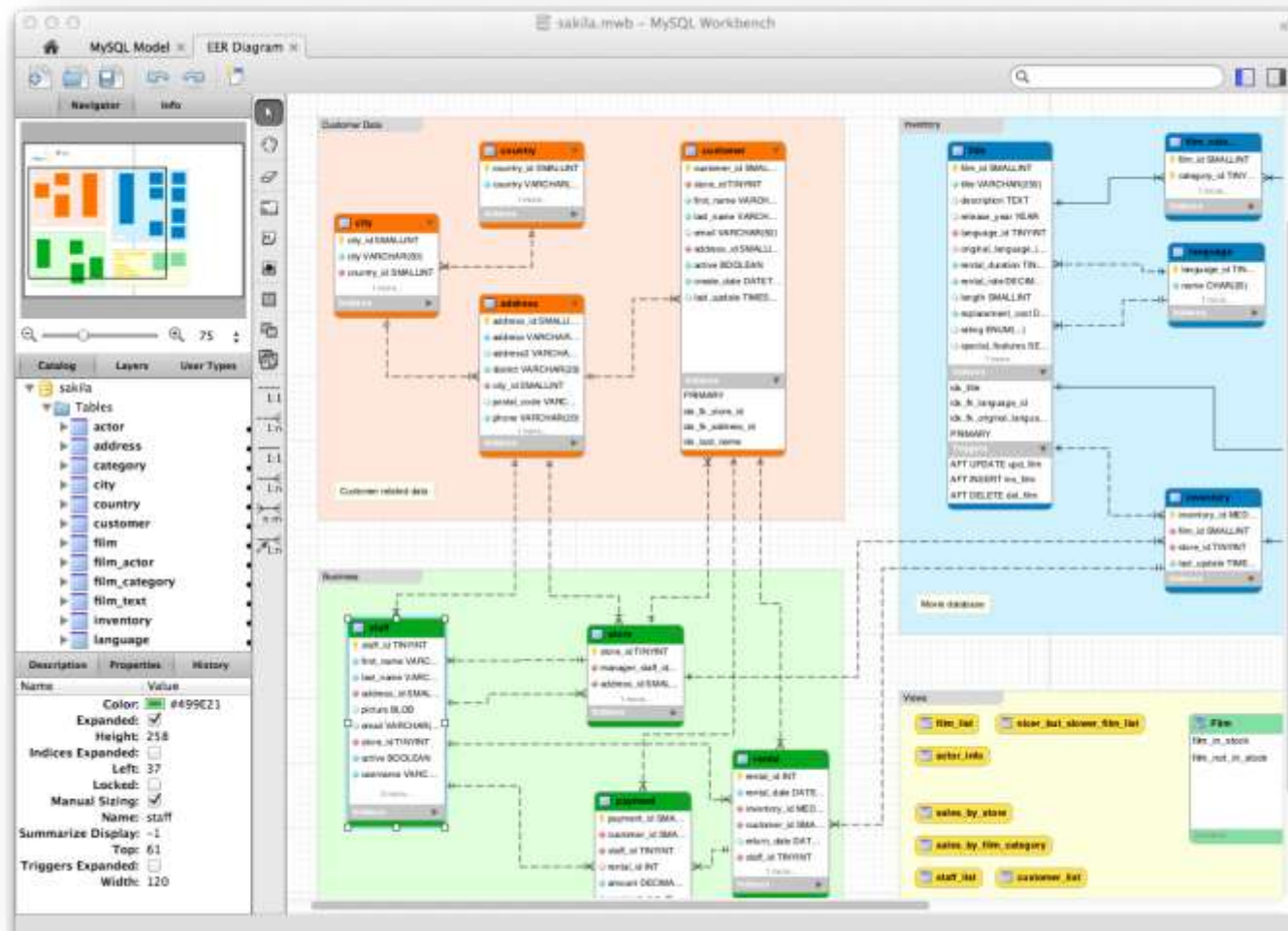
❖ Ranking of various well-known DBMS

424 systems in ranking, September 2025

Rank			DBMS	Database Model	Score		
Sep 2025	Aug 2025	Sep 2024			Sep 2025	Aug 2025	Sep 2024
1.	1.	1.	Oracle	Relational, Multi-model ⓘ	1170.62	-50.08	-115.97
2.	2.	2.	MySQL	Relational, Multi-model ⓘ	891.77	-23.69	-137.72
3.	3.	3.	Microsoft SQL Server	Relational, Multi-model ⓘ	717.32	-36.84	-90.45
4.	4.	4.	PostgreSQL	Relational, Multi-model ⓘ	657.17	-14.08	+12.81
5.	5.	5.	MongoDB 📄	Document, Multi-model ⓘ	380.50	-15.08	-29.74
6.	6.	📈 7.	Snowflake	Relational	190.19	+11.29	+56.47
7.	7.	📉 6.	Redis	Key-value, Multi-model ⓘ	145.17	-2.02	-4.25
8.	8.	📈 9.	IBM Db2	Relational, Multi-model ⓘ	124.19	-3.12	+1.14
9.	9.	📈 14.	Databricks	Multi-model ⓘ	124.06	+8.25	+39.82
10.	10.	📉 8.	Elasticsearch	Multi-model ⓘ	118.26	+3.99	-10.53

3. Database Management System (DBMS)

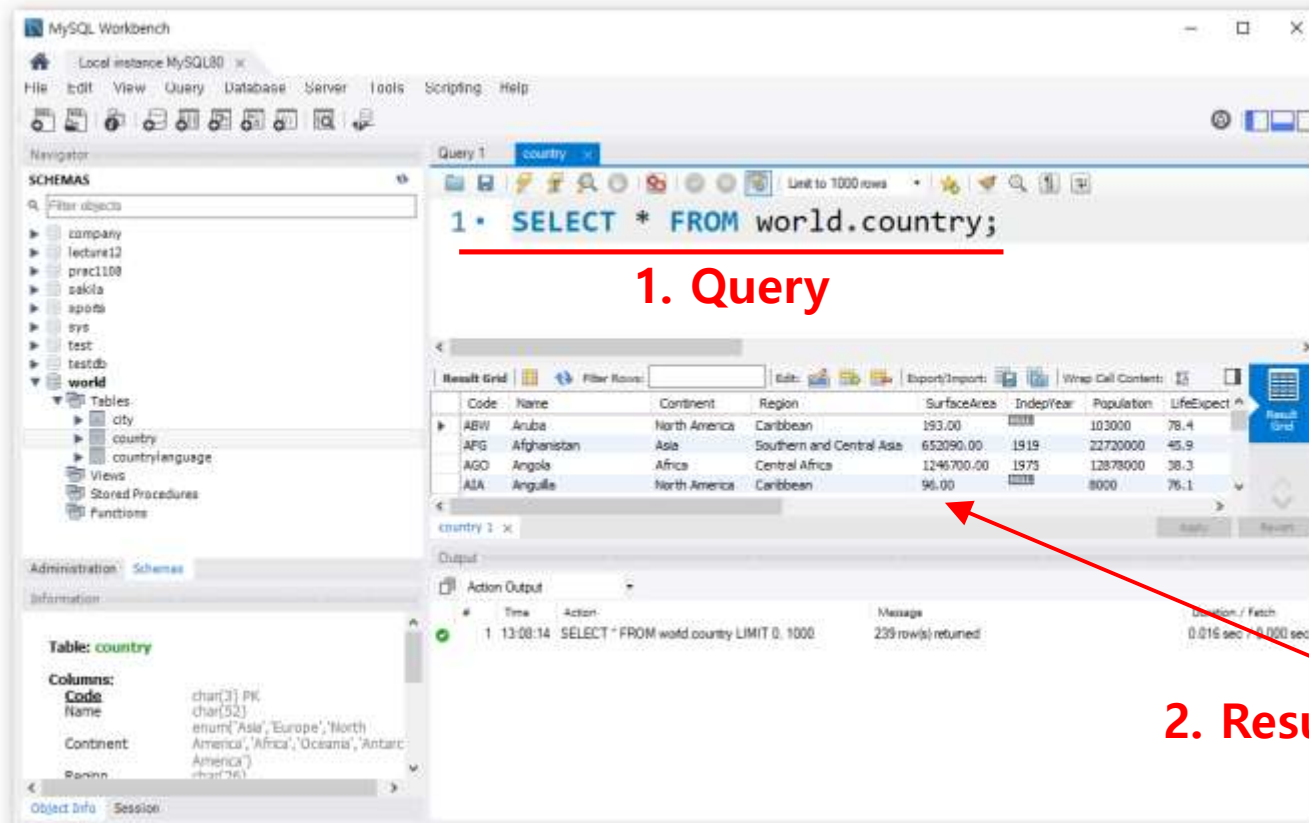
❖ GUI Interface of MySQL *RDBMS*



3. Database Management System (DBMS)

❖ Query

- A query in a database is a request for information from a DBMS
 - Retrieve data or change (add or remove) information in a database



The screenshot displays the MySQL Workbench interface. On the left, the 'Navigator' pane shows the 'world' database selected, with tables like 'city', 'country', and 'countrylanguage' visible. The main window shows a query editor with the following SQL statement:

```
1 • SELECT * FROM world.country;
```

A red arrow points from the text '1. Query' to this SQL statement.

Below the query editor, the 'Result Grid' shows the output of the query. A red arrow points from the text '2. Result of query' to this grid. The grid contains the following data:

Code	Name	Continent	Region	SurfaceArea	IndepYear	Population	LifeExpect
ABW	Aruba	North America	Caribbean	193.00	1986	103000	78.4
AFG	Afghanistan	Asia	Southern and Central Asia	652090.00	1919	22730000	45.9
AGO	Angola	Africa	Central Africa	1246700.00	1975	12878000	38.3
ALA	Anguilla	North America	Caribbean	96.00	1980	8000	76.1

At the bottom, the 'Action Output' pane shows the execution details: '1 13:08:14 SELECT * FROM world.country LIMIT 0, 1000' and '239 row(s) returned'.

3. Database Management System (DBMS)

❖ Purpose of DBMS

- Allows to create a new database
- Allows you to specify the structure of the database
- Allows users to query and modify data efficiently
- Protects data from system failure or unauthorized users
- Controls access to the database by multiple users at the same time

4. Database Systems

❖ Database Schema

- The overall logical structure of the database, also called **metadata**
 - Ex: department(dept_name, building, budget) → *schema* [☆]

instance

<i>dept_name</i>	<i>building</i>	<i>budget</i>
Comp. Sci.	Taylor	100000
Biology	Watson	90000
Elec. Eng.	Taylor	85000
Music	Packard	80000
Finance	Painter	120000
History	Painter	50000
Physics	Watson	70000

→ *structure, metadata, schema*

The *department* table

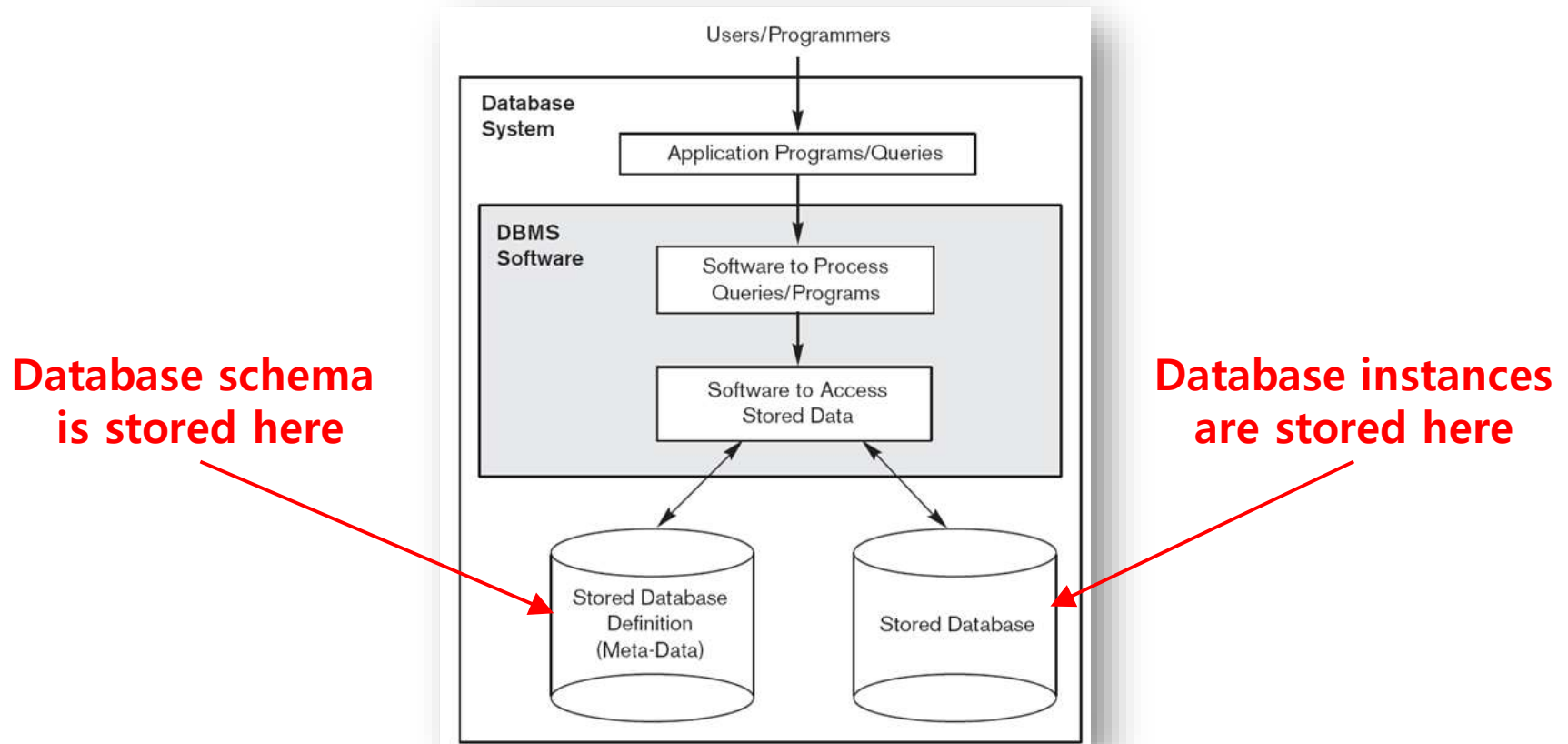
❖ Database Instance

- The actual content of the database at a particular point in time

4. Database Systems

❖ What is Database Systems?

- Users, application programs, DBMS and stored database are referred to as a database system



4. Database Systems

❖ Characteristics of Database Systems

- Allows multiple users to access and manipulate data in the database simultaneously
동시에 e.g) 수강신청 등 .
- Eliminates data redundancy by storing data in a centralized database
- Enforces integrity constraints to ensure data consistency and accuracy
- Enables data independence by separation of data and application programs
- Provides security features to protect the data from unauthorized access
- Supports backup and recovery features to prevent data loss

4. Database Systems

❖ Database users

- Naïve Users
 - Users with no knowledge in DBMS, but frequently use the database application in their daily life
- Database Designers
 - Users who design the structure of database
 - tables, indexes, views, triggers, stored procedures and constraints
- Application Programmers
 - Back-end developers who design, debug, test, and maintain set of programs to interact with database

4. Database Systems

❖ Database users

- Sophisticated users
 - Interact with database without writing programs. Typically, using database query language like SQL
- Database Administrators (DBA)
 - Routine maintenance
 - Granting of authorization for data access
 - Backup and recovery
 - Database tuning and performance monitoring

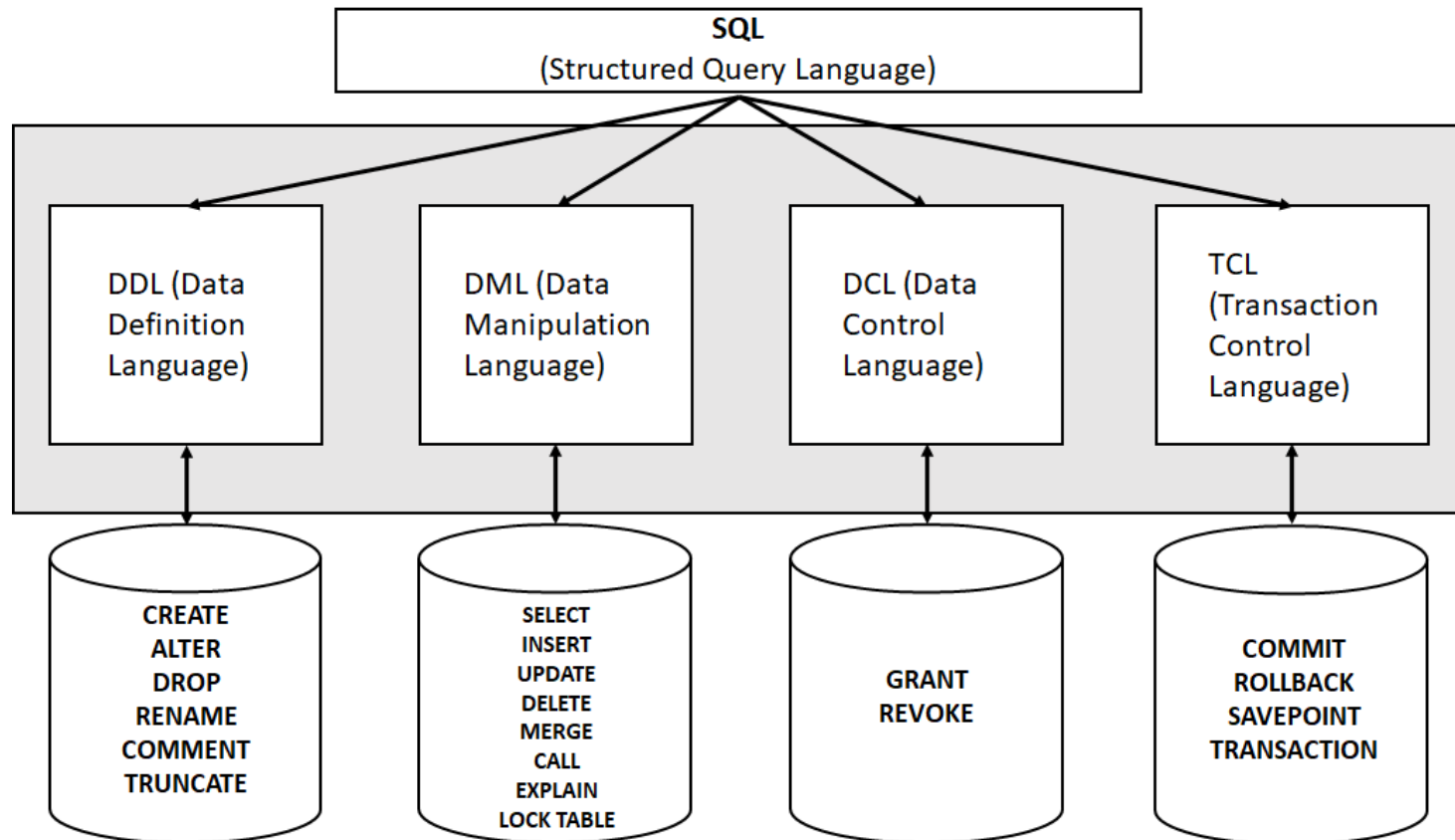
5. Database Languages

❖ Structural Query Language (SQL)

- Define queries to access and manipulate the data from database
- A procedural language, not a programming language
प्रक्रिया 27
- A standard language for RDBMS → software ★.
 - Oracle, MySQL, Microsoft SQL and others
- SQL statements are divided into four major categories
 - Data Definition Language (DDL)
 - Data Manipulation Language (DML)
 - Data Control Language (DCL)
 - Transaction Control Language (TCL)

5. Database Languages

❖ Structural Query Language (SQL)



5. Database Languages

❖ Data Definition Language (DDL)

- A language for defining the database schema
 - Used to **create** and **modify** the structure of your tables and database objects

schema
metadata

DDL → DDL DDL DDL

- Example (Creating a new table)

CREATE TABLE department(
dept_name **varchar**(20),
building **varchar**(20),
budget **numeric**(8,2))

- Other DDL statements include **ALTER**, **DROP**, **RENAME**, **COMMENT** and **TRUNCATE**

DDL

DDL

5. Database Languages

- ❖ ²⁶¹ Data Manipulation Language (DML)
 - A language for **searching**, **modifying**, **inserting** and **deleting** the desired data in the database
 - DML also known as query language
 - Example (Selecting rows)
SELECT *name*
FROM *instructor*
WHERE *dept_name*='Comp.Sci.'
 - Other DML statements include **INSERT**, **UPDATE**, **DELETE** and others

5. Database Languages

Security + Protection

❖ Data Control Language (DCL)

- Mainly deal with the **rights, permissions, and other controls** of the database system

- Example (Granting privilege)

GRANT SELECT ON department

TO 'aziz'@'localhost';

GRANT = 권한부여
REVOKE = 권한회수

- Other DCL statements include REVOKE

5. Database Languages

❖ Transaction Control Language (TCL)

- Used to manage **data security, data integrity, data recovery** and **data concurrency**

동시성

Transaction = 데이터의 상태 변화..?

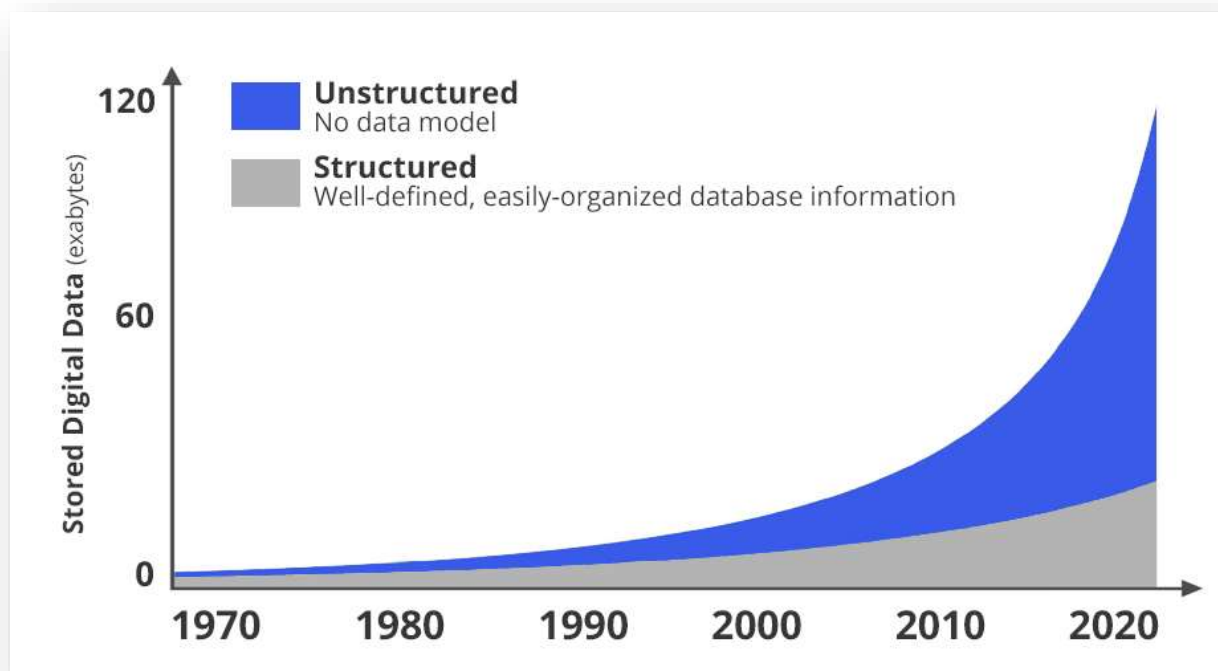
▪ TCL Commands

- COMMIT
- ROLLBACK
- SAVEPOINT
- SET TRANSACTION

correctness

6. Recent Techs in Database Systems

- ❖ According to Seagate, the volume of data generated worldwide will increase from 33 in 2018 to about 175 zettabytes in 2025
- ❖ Data Growth



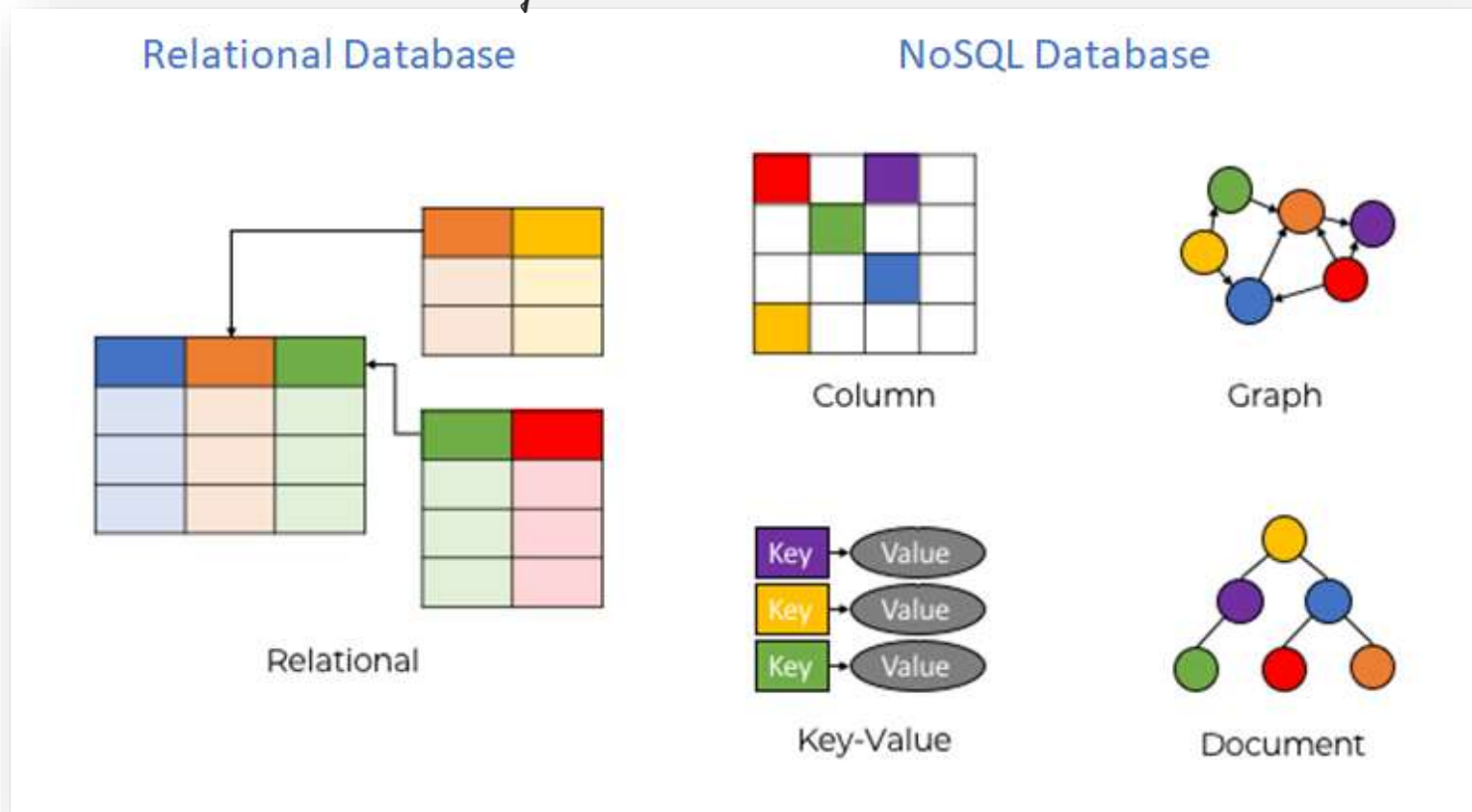
6. Recent Techs in Database Systems

❖ NoSQL

- Non-relational databases

structured

*unstructured
no table = no relation*



6. Recent Techs in Database Systems

❖ NoSQL

- Example of data in MongoDB (Document database)

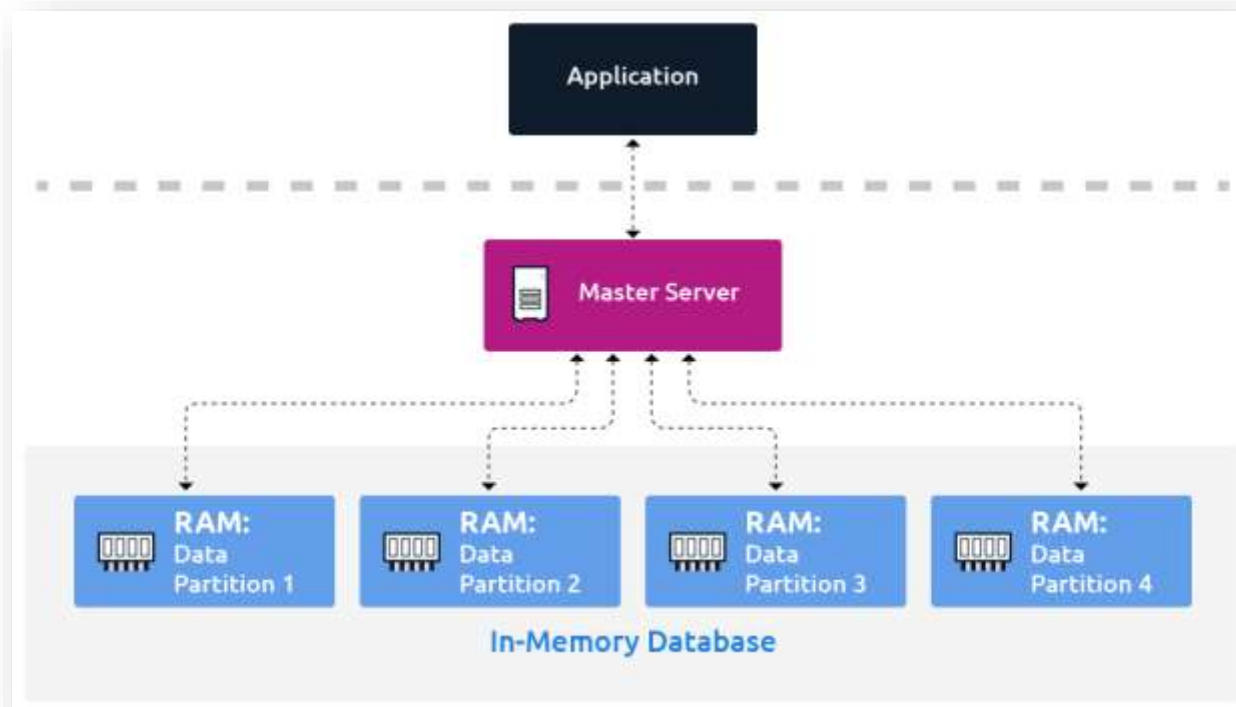
```
{
  '_id' : 1,
  'artistName' : { 'Iron Maiden' },
  'albums' : [
    {
      'albumname' : 'The Book of Souls',
      'datereleased' : 2015,
      'genre' : 'Hard Rock'
    }, {
      'albumname' : 'Killers',
      'datereleased' : 1981,
      'genre' : 'Hard Rock'
    }, {
      'albumname' : 'Powerslave',
      'datereleased' : 1984,
      'genre' : 'Hard Rock'
    }, {
      'albumname' : 'Somewhere in Time',
      'datereleased' : 1986,
      'genre' : 'Hard Rock'
    }
  ]
}
```

<Data stored in JSON format>

6. Recent Techs in Database Systems

❖ In-Memory Databases

- Data is stored directly in the computer's main memory (RAM)
 - Enable minimal response times by eliminating the need to access hard disks



6. Recent Techs in Database Systems

❖ In-Memory Databases

- Popular DBMS



7. Summary and Discussions

❖ Database

- An organized collection of data

❖ Database Management Systems (DBMS)

- A **software** designed to store, retrieve, define, and manage data in a database *MySQL*

❖ Meta-Data (System Catalog or Data Dictionary) *Schema*

- Describes the structure of the database

❖ Database Systems

- Users, application programs, DBMS and stored database are referred to as a database system *instance*

7. Summary and Discussions

- ❖ Data Models are used to show how data is stored, connected, accessed and updated in the DBMS
- ❖ Types of data models
 - Hierarchical Model
 - Network Model
 - Relational Model
 - Object-Oriented Model
 - Object-Relational Model
- ❖ Relational Model
 - Represents the database as a collection of relations

7. Summary and Discussions

- ❖ Structural Query Language (SQL)
 - Define queries to access and manipulate the data from database

- ❖ SQL statements are divided into four major categories
 - Data Definition Language (DDL)
 - Data Manipulation Language (DML)
 - Data Control Language (DCL)
 - Transaction Control Language (TCL)

- ❖ Recent Techs in DB
 - NoSQL Databases
 - In-Memory Databases

Quiz

1. What is Big Data? Where do you often encounter the Big Data?
2. What do you think where it is NOT recommended to use the database?
3. Given the following relation, indicate database schema and instances.

<u>ID</u>	Name	Major	Grade	Email
1000	Tim	Computer	Male	tim@gmail.com
1001	Sonya	Art	Female	sonya@naver.com
1002	Brain	Social	Male	brain@yahoo.com
1003	Natasha	Math	Female	natasha@outlook.com

The *student* relation