CSC10006 – Introduction to Database

# Chapter 1
# Overview of Database Systems


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KHOA CÔNG NGHỆ THÔNG TIN
TRƯỜNG ĐẠI HỌC KHOA HỌC TỰ NHIÊN

# Content

- Introduction of databases
- Evolution of database systems
- Characteristics of the database approach
- Database management systems (DBMS)
- Data models
- Database languages
- Database users

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# Databases: WHAT and WHY?

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## A Day In Susan's Life

See how many databases she interacts with each day

*Before leaving for work, Susan checks her Facebook and Twitter accounts*

Where is the data about the friends and groups stored?

Where are the "likes" stored and what would they be used for?


*On her lunch break, she picks up her prescription at the pharmacy*

Where is the pharmacy inventory data stored?

What data about each product will be in the inventory data?

What data is kept about each customer and where is it stored?


*After work, Susan goes to the grocery store*

Where is the product data stored?

Is the product quantity in stock updated at checkout?

Does she pay with a credit card?


*At night, she plans for a trip and buys airline tickets and hotel reservations online*

Where does the online travel website get the airline and hotel data from?

What customer data would be kept by the website?

Where would the customer data be stored?


*Then she makes a few online purchases*


Where are the product and stock data stored?

Where does the system get the data to generate product "recommendations" to the customer?

Where would credit card information be stored?

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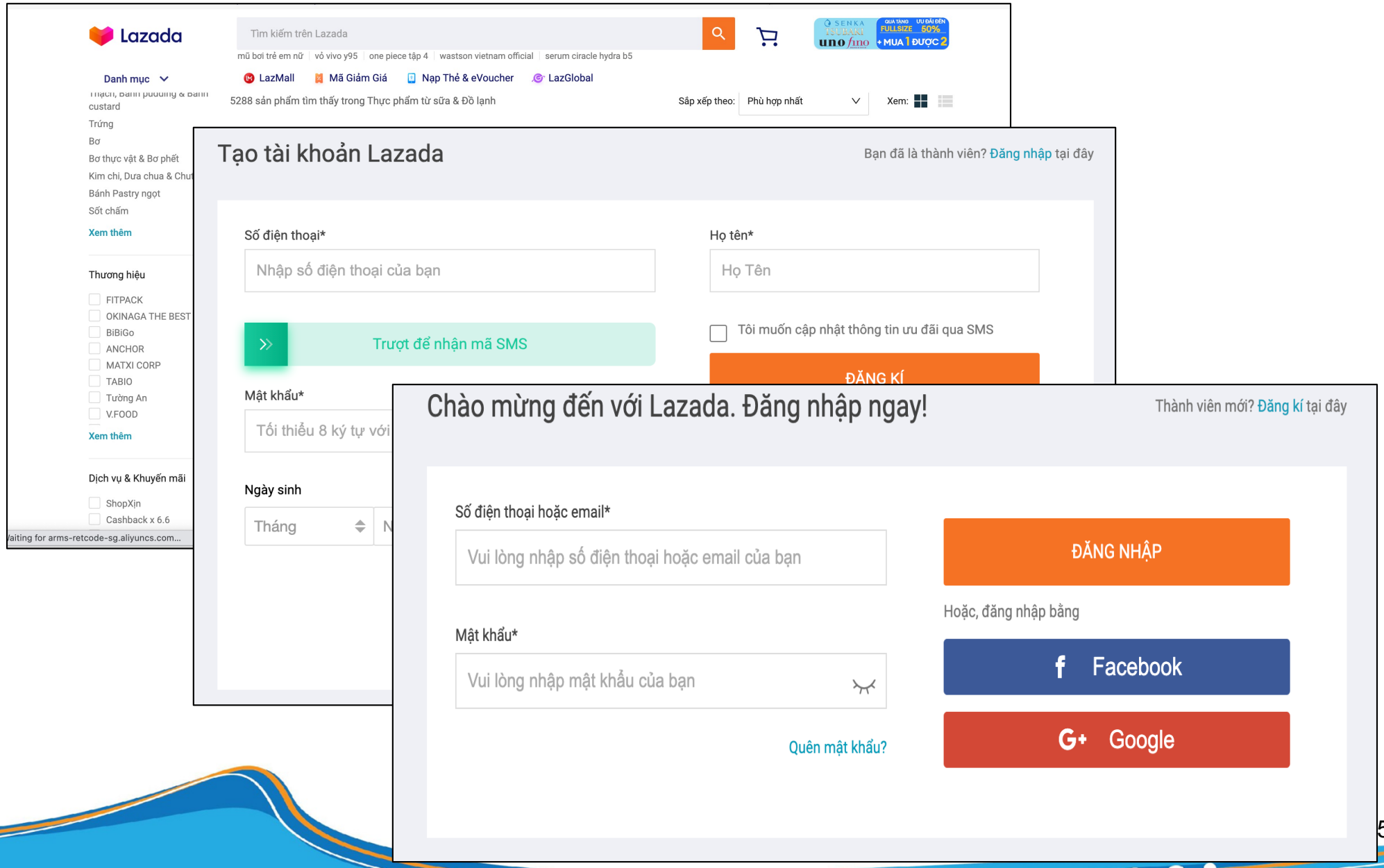
# Databases: WHAT and WHY?



# Databases: HOW

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Real business & application (marketing, production, banking, …)

Database Design Process

Develop

Automate & support tasks

Computers

**HOW can computers understand the real-world domain to digitize & support automation?**

# Databases: HOW

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Real business & application (marketing, production, banking, …)

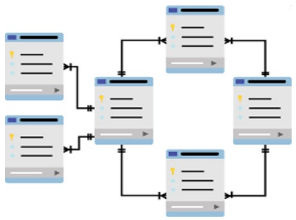

Database Design Process

Develop

Automate & support tasks

Analyze & Design

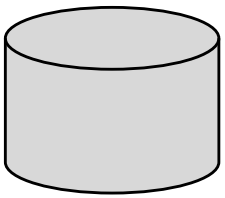
Data



Functionalities, Interfaces

Implementation

Computers

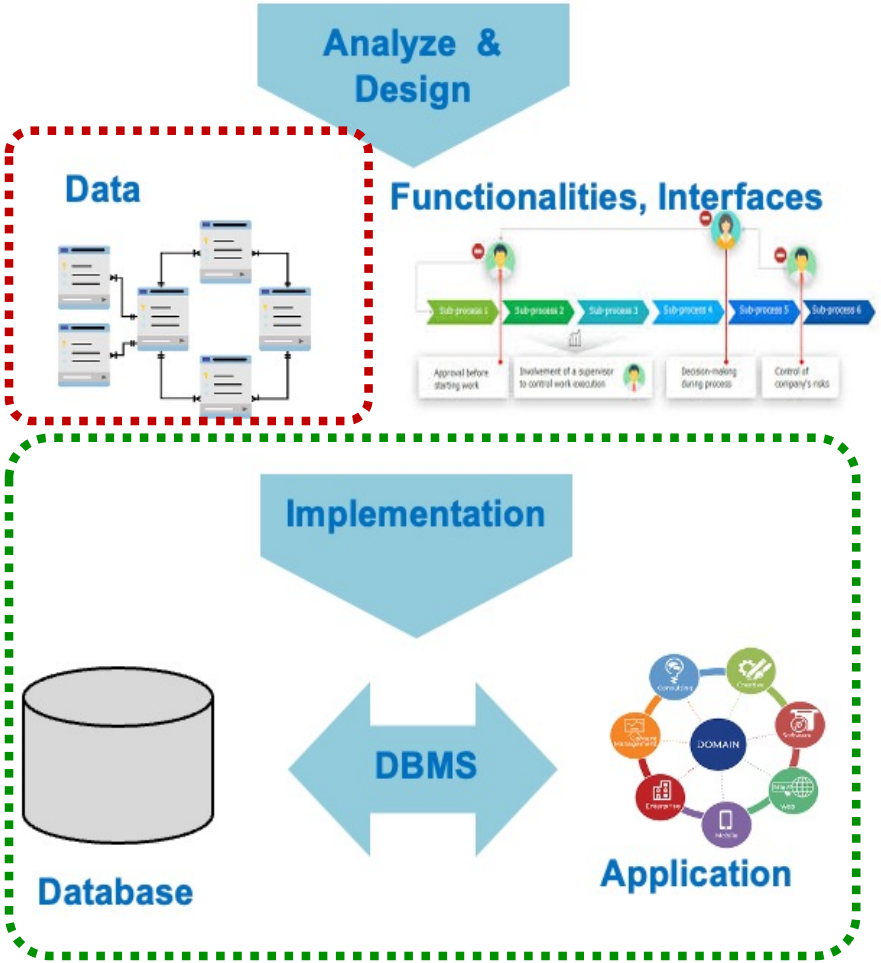


Database

DBMS


Application

# Database Design Process




**HOW** to represent data structures and their characteristics, relations, constraints, etc.?

**Data models**
Entity Relationship Model
Relational Model
Object-oriented Model
Network Model
…

**Database languages**
SQL
Relational Algebra
Relational Calculus
(& Integrity Constraints)

**HOW** to define, operate, and manipulate (relational) database?

# Definition

- **Data**: *Stored* representations of *meaningful objects* and *events*.
  - Structured: numbers, text, dates.
  - Unstructured: images, video, documents.
- **Information**: Data *processed* and *organized* to increase knowledge in the person using the data.
- **Database**: *Collection* of logically *related data* which provides information *relevant to a business/enterprise*.

# Example 1 – Course Management

| MÔNHỌC | TênMH | MãMH | SốTC | Khoa |
|---|---|---|---|---|
| | Khoa học máy tính | CS1310 | 4 | CNTT |
| | Cấu trúc dữ liệu | CS3320 | 4 | CNTT |
| | Toán rời rạc | MATH2410 | 3 | TOÁN |
| | Cơ sở dữ liệu | CS3380 | 3 | CNTT |

| SINHVIÊN | Tên | MSSV | Lớp | Khoa |
|---|---|---|---|---|
| | Trang | 17 | 1 | CNTT |
| | Ngọc | 8 | 2 | CNTT |

| HỌCPHẦN | MãHP | MãMH | HọcKỳ | Năm | GiáoViên |
|---|---|---|---|---|---|
| | 85 | MATH2410 | 1 | 2008 | Anh |
| | 92 | CS1310 | 1 | 2007 | Tiến |
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| | 119 | CS1310 | 2 | 2007 | Tiến |

| KẾTQUẢ | MSSV | MãHP | Điểm |
|---|---|---|---|
| | 17 | 112 | 10 |
| | 17 | 119 | 7 |
| | 8 | 85 | 6 |
| | 8 | 92 | 9 |

| ĐIỀUKIỆN | MãMH | MãMH_Trước |
|---|---|---|
| | CS3380 | CS3320 |
| | CS3380 | MATH2410 |
| | CS3320 | CS1310 |

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# Example 2 – Project Management

| EMPLOYEE | LName | MName | FName | SSN | BirthDate | SuperSSN | DNo |
|---|---|---|---|---|---|---|---|
| | Tran | Hong | Quang | 987987987 | 03/09/1969 | 987654321 | 4 |
| | Nguyen | Thanh | Tung | 333445555 | 12/08/1955 | 888665555 | 5 |
| | Nguyen | Manh | Hung | 666884444 | 09/15/1962 | 333445555 | 5 |
| | Tran | Thanh | Tam | 453453453 | 07/31/1972 | 333445555 | 5 |

| PROJECT | PName | PNumber | PLocation | DNum |
|---|---|---|---|---|
| | San pham X | 1 | VUNG TAU | 5 |
| | San pham Y | 2 | NHA TRANG | 5 |
| | San pham Z | 3 | TP HCM | 5 |
| | Tin hoc hoa | 10 | HA NOI | 4 |

| WORKS_ON | SSN | PNo | Hours |
|---|---|---|---|
| | 123456789 | 1 | 32.5 |
| | 123456789 | 2 | 7.5 |
| | 666884444 | 3 | 40.0 |
| | 453453453 | 1 | 20.0 |

# Characteristics of Databases

- A logically coherent collection of data with some inherent meaning.
  - Random assortment of data cannot correctly be a database.
- Is designed, built, and populated with data for a specific purpose, for intended group of users or applications.
  - Example: University management, Hospital management
- Data is stored using a structure ➔ structured database
  - Relational databases store data in two-dimensional tables.
- Other types of database: unstructured databases, document databases, graph databases.

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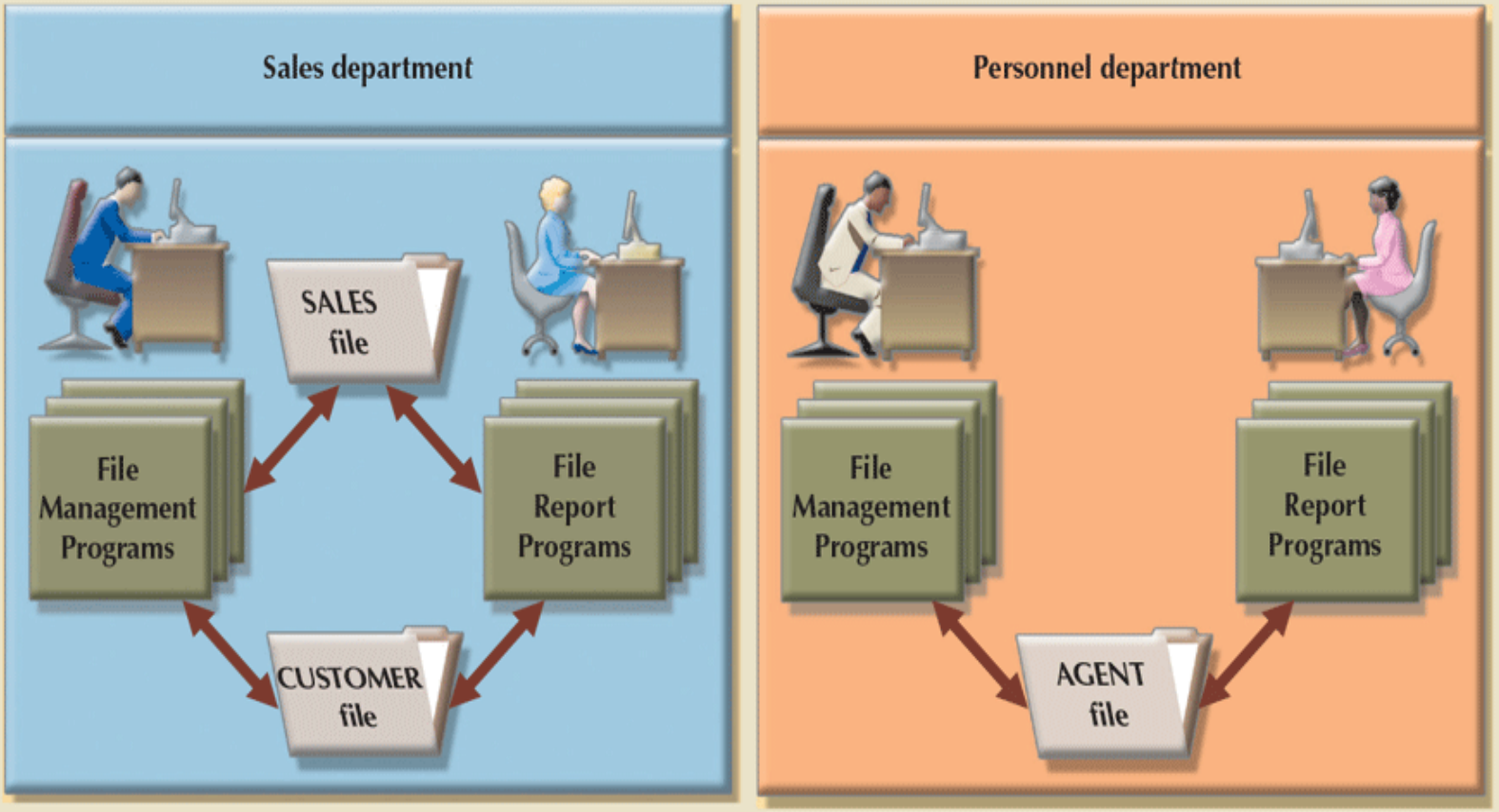
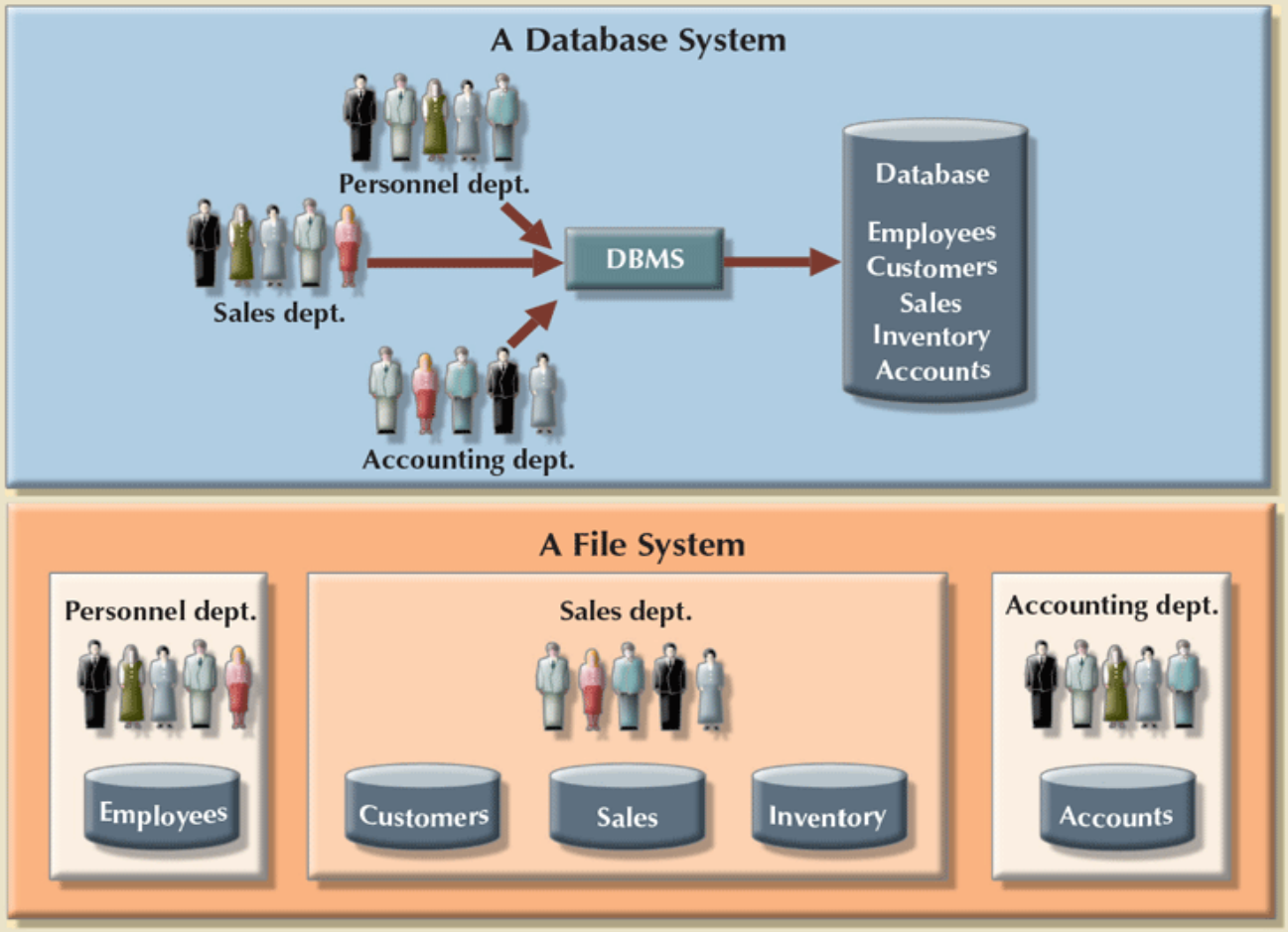
# Evolution of Database Systems

FIGURE 1.9 A SIMPLE FILE SYSTEM



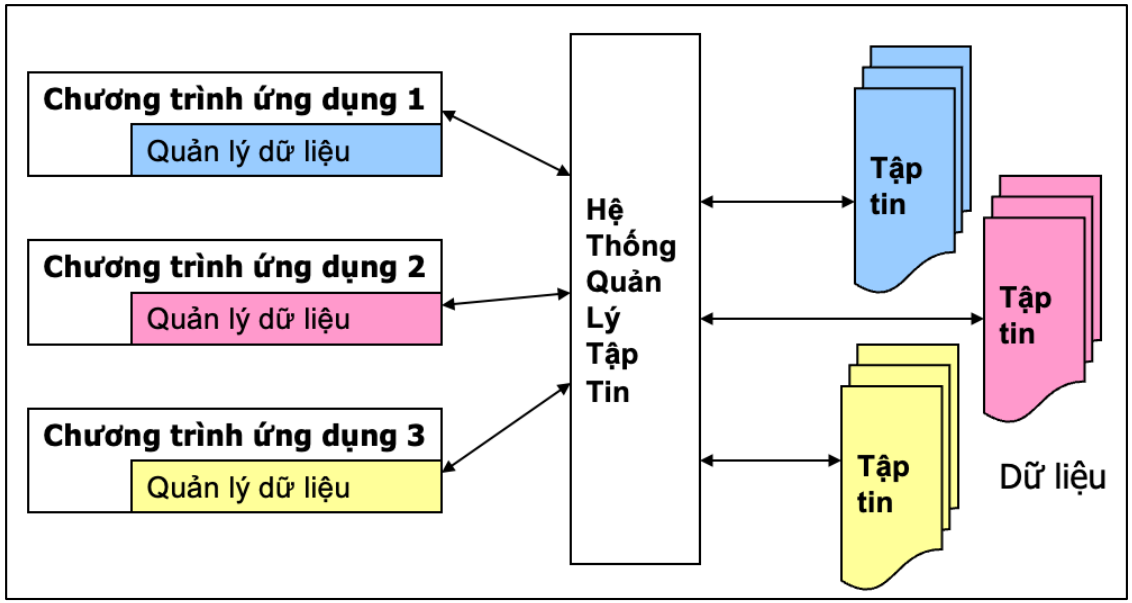
# Evolution of Database Systems

FIGURE 1.10 CONTRASTING DATABASE AND FILE SYSTEMS



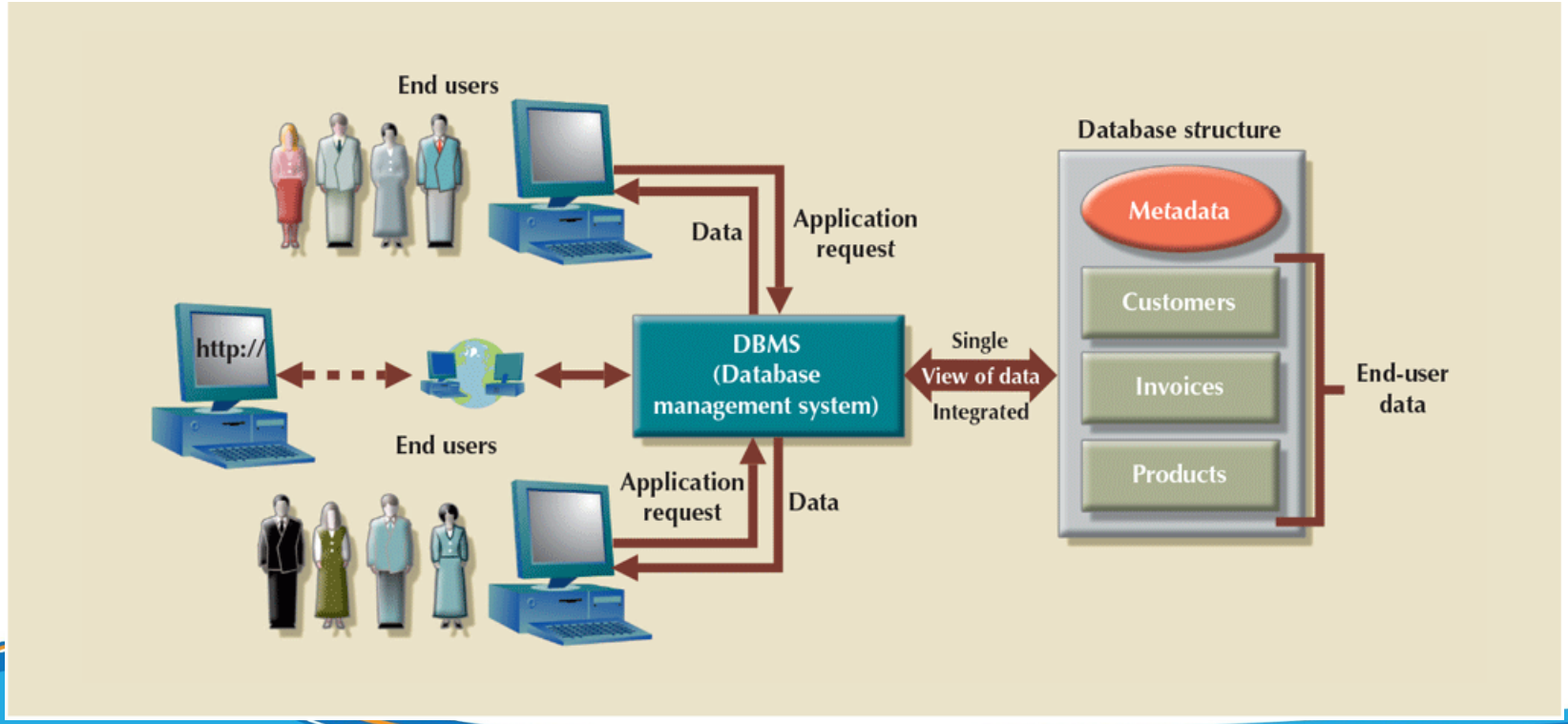
# Disadvantages of File Processing

- Program-Data Dependence
- Duplication of Data
- Lack of Security and Limited Data Sharing
- Expensive and Lengthy Program Development
- Excessive Program Maintenance

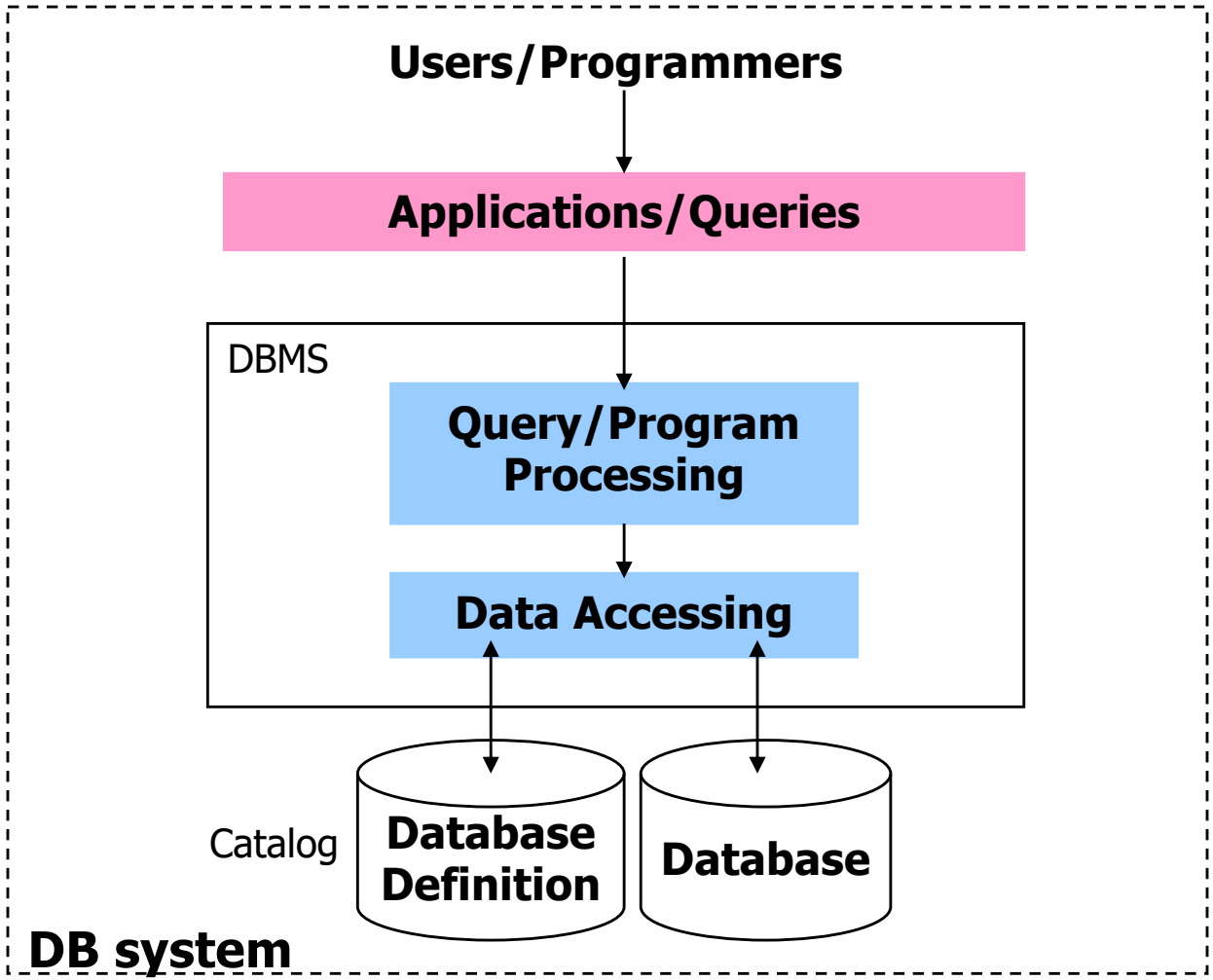


# Database Systems

- Central repositories of shared data
- Data is stored, processed, and managed in a suitable and standardized manner
- Data is managed by a controlling agent
- ➔ Requires a Database Management System (DBMS)



# Database Systems



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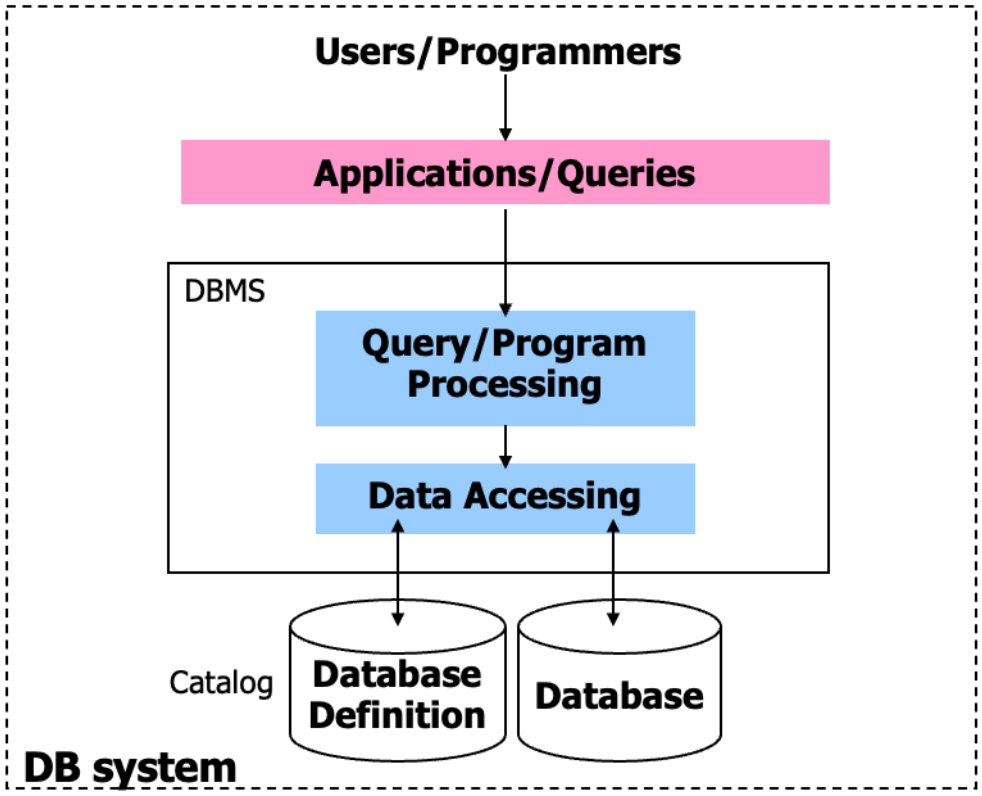
# Self-Describing (Meta-data)

- A **catalog** called "metadata" contains information such as the structure of data, type and storage format of data items, and constraints on the data.




**RELATION**

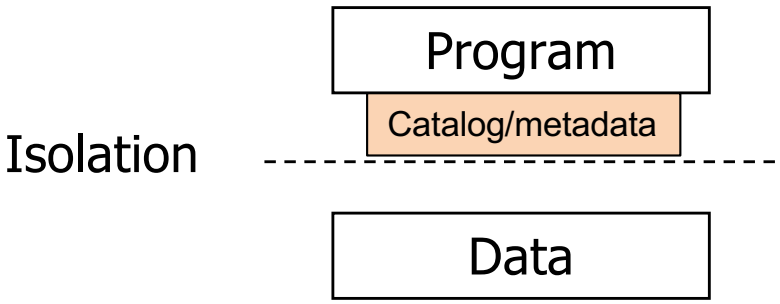
| Relation_name | No_of_columns |
|---|---|
| EMPLOYEE | 7 |
| PROJECT | 4 |
| WORKS_ON | 3 |

**COLUMN**

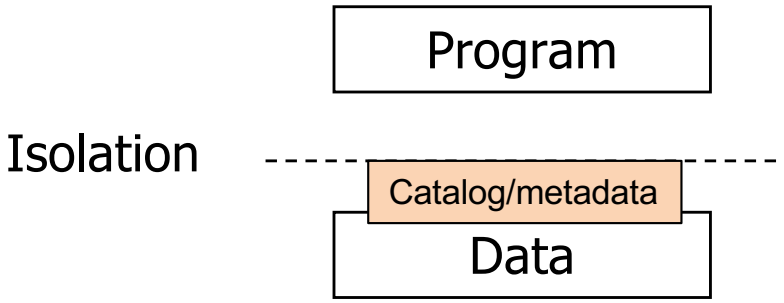
| Column_name | Data_type | Belongs_to_relation |
|---|---|---|
| LName | Character(10) | EMPLOYEE |
| FName | Character(10) | EMPLOYEE |
| ... | ... | ... |

# Isolation
## (Program-Data independence)

- The structure of data is stored in **catalog separately** from the access **programs**.




Program contains catalog □ data structure depends on program



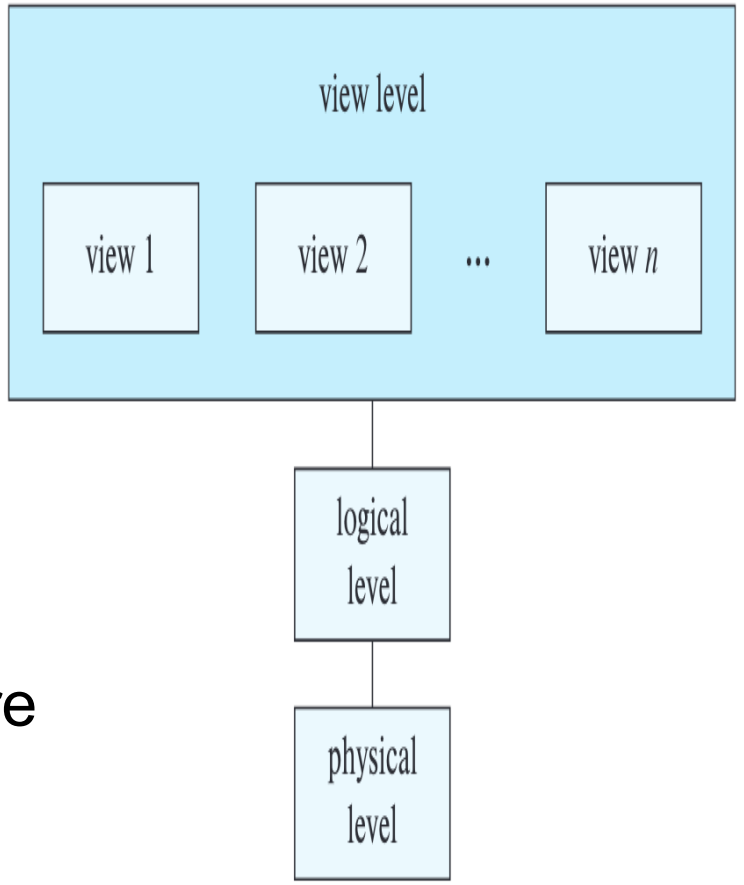

DBMS contains catalog □ data is independent of program

☺ A little change in the structure happens.

☺ Application programs are rarely revised.

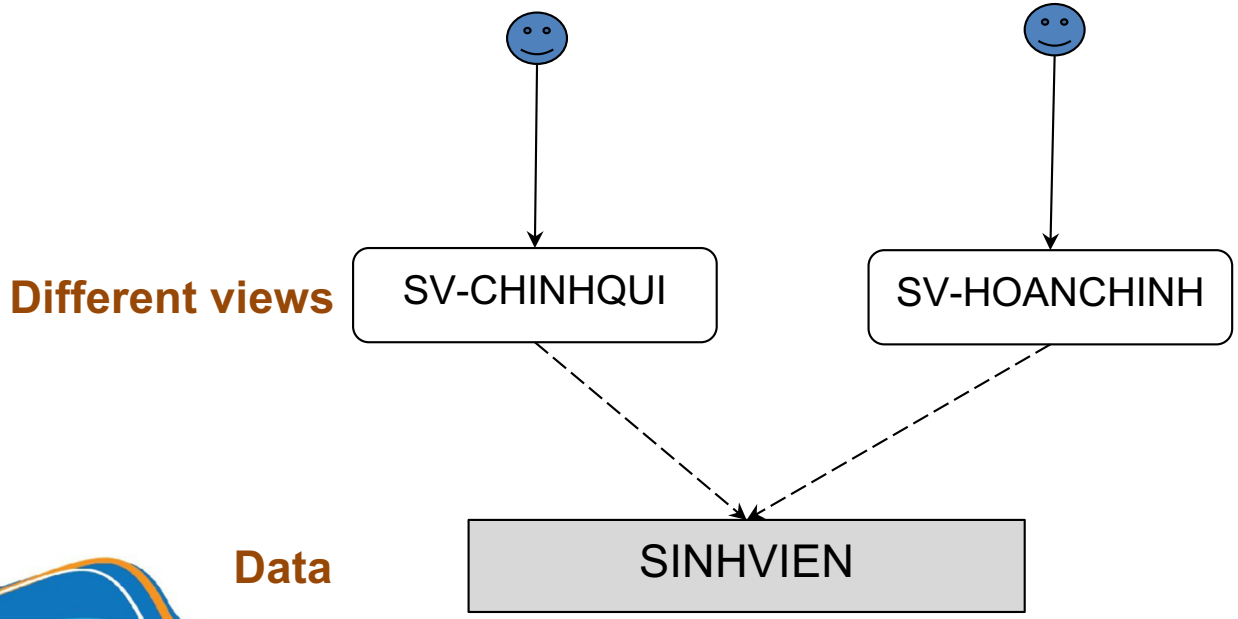
# Data Abstraction
## (Conceptual-Logical-Physical Levels)

- Hide the data structure complexity from users through several levels of data abstraction to simplify users' interaction with the systems.
  - **Physical level**: HOW data is stored.
  - **Logical level**: WHAT data are stored
  - **View level**: PART of the entire database for a specific USERS.



# Data Abstraction
## (Conceptual-Logical-Physical Levels)

- A DB has many users who may require a different perspective or view of the database.
- Example of (user) views:
  - A subset of the database.
  - Aggregate data that are derived from the database.



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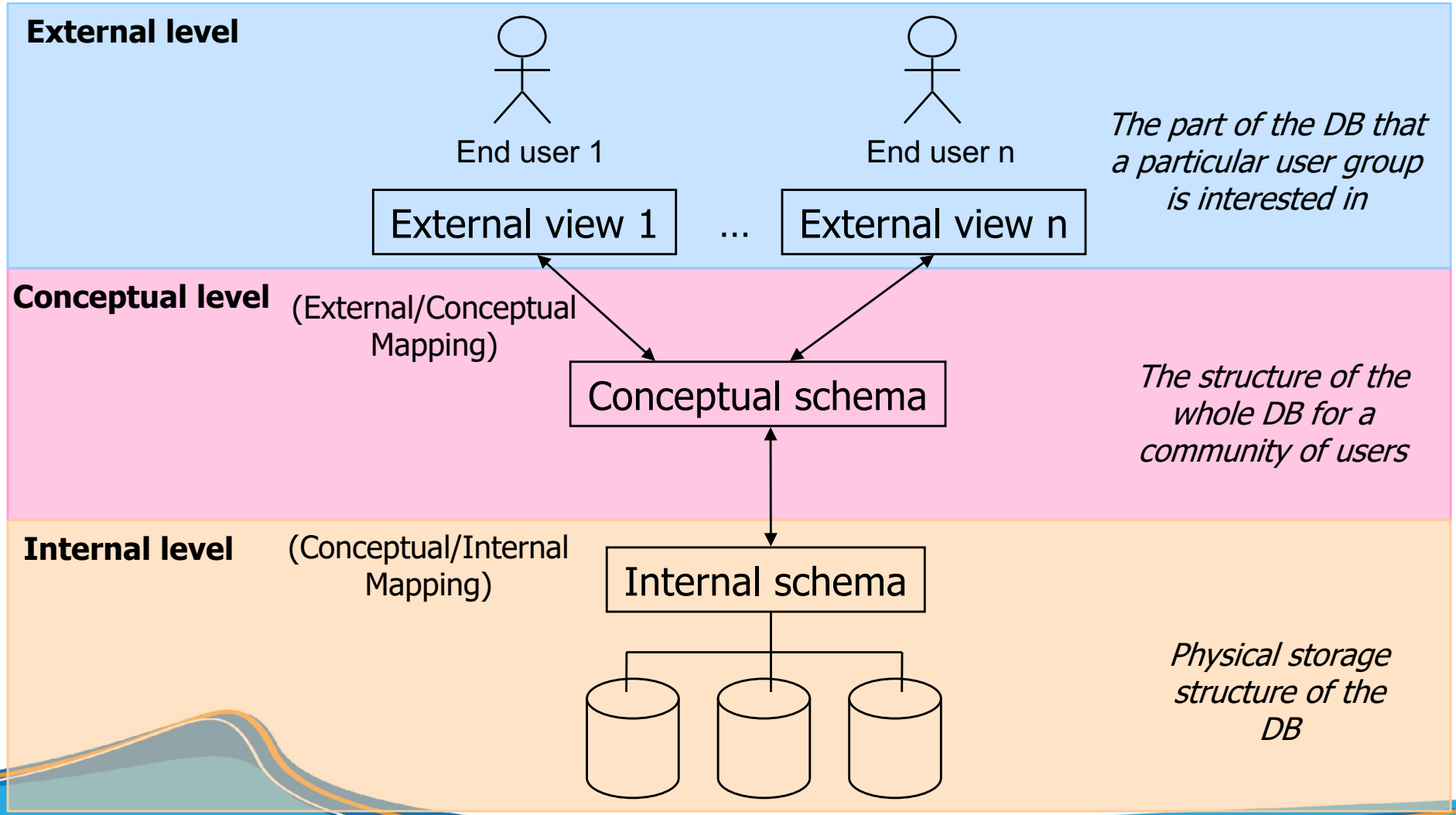
# Data Abstraction
## (Conceptual-Logical-Physical Levels)

### THREE-SCHEMA ARCHITECTURE



# Sharing Data (Multiusers)

- A multiuser DBMS: Allows multiple users to access the DB at the same time.
  - Data for many applications are integrated and maintained in a single DB.
  - Using concurrency control mechanisms to access the data reasonably
  - Ensure the data will always be valid when they are accessed.

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# DBMS

- A collection of programs that enables users to **create**, **operate**, and **maintain** a database.
  - **Definition**: Specifying the data types, structures, and constraints for the data.
  - **Construction**: Storing the data itself on some storage medium.
  - **Manipulation**: Querying the database to retrieve data, updating the database to reflect changes, generating reports from the data.
  - **Sharing**: Allowing multiple users/programs to access the database concurrently.

# DBMS Functions

- Data dictionary management
  - Data dictionary stores definitions of data elements and their relationships (meta-data)
- Data storage management
  - Performance tuning ensures efficient performance of the database in terms of storage and access speed
- Data transformation and presentation
  - Data is formatted to conform to required data structures
- Security management
  - Enforces user security and data privacy



(Coronel and Morris, 2015) (Hoffer et al., 2019)

# DBMS Functions

- Multiuser access control
  - Sophisticated algorithms ensure that multiple users can access the database concurrently without compromising its integrity.
- Backup and recovery management
  - Enables recovery of the database after a failure
- Data integrity management
  - Minimizes redundancy and maximizes consistency



(Coronel and Morris, 2015) (Hoffer et al., 2019)

# DBMS Functions

- Database access languages and application programming interfaces
  - **Query language**: lets the user specify what must be done without having to specify how
  - **Structured Query Language (SQL)**: a structured query language and data access standard supported by the majority of DBMS vendors
- Database communication interfaces
  - Accept end-user requests via multiple, different network environments



(Coronel and Morris, 2015) (Hoffer et al., 2019)

# DBMS Disadvantages

- Increased costs
- Management complexity
- Maintaining currency
- Vendor dependence
- Frequent upgrade/replacement cycles



(Coronel and Morris, 2015) (Hoffer et al., 2019)

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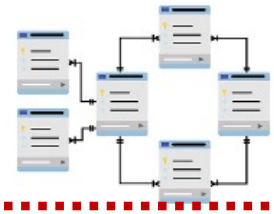
# Recall: DB Design Process

Analyze & Design

Data



Functionalities, Interfaces

**HOW** to represent data structures and their characteristics, relations, constraints, etc.?

**Data models**

Entity Relationship Model

Relational Model

Object-oriented Model

Network Model

…

**Database languages**

SQL

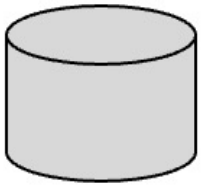
Relational Algebra

Relational Calculus

(& Integrity Constraints)

**HOW** to define, operate, and manipulate (relational) database?

Implementation

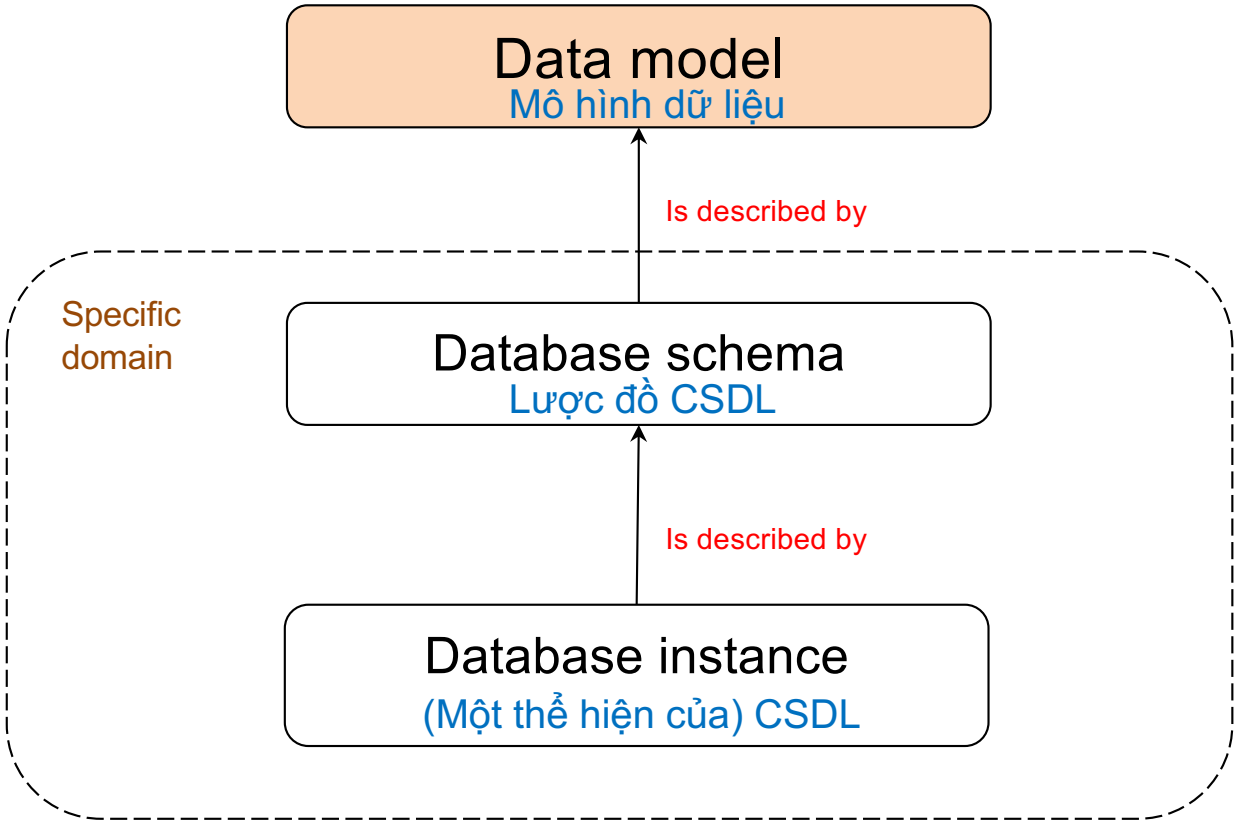


DBMS


Database

Application

# Data Models


Data model
Mô hình dữ liệu
Is described by
Specific domain
Database schema
Lược đồ CSDL
Is described by
Database instance
(Một thể hiện của) CSDL

# Data Models

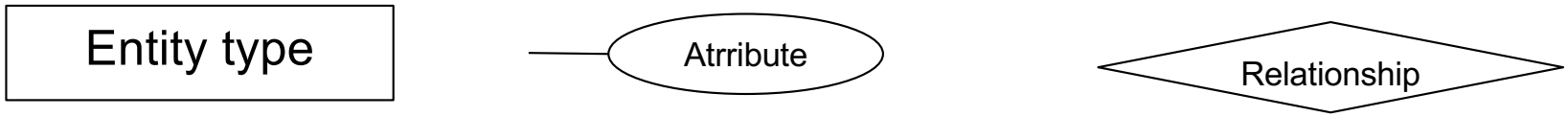
- A collection of **concepts** used to describe the structure of a DB (data types, relationships, and constraints, etc.)
- Including a set of basic **operations** for specifying retrievals and updates on the DB.
- Example:
  - ER model: entity, relationships, cardinality constraints, etc.
  - Relational (data) model: relations, primary keys, etc.

# Data Models

- Categories:
  - High-level (or conceptual) models: Provide concepts that are close to the way (business) users perceive data (ER model, object-oriented model, etc.).
  - Implementation (or logical) data models: Provide concepts that are understood by end users, but not too far from the way data is organized within the computer (relational model, network model, etc.).
  - Low-level (or physical) data models: Provide concepts that describe the details of how data is stored in the computer.

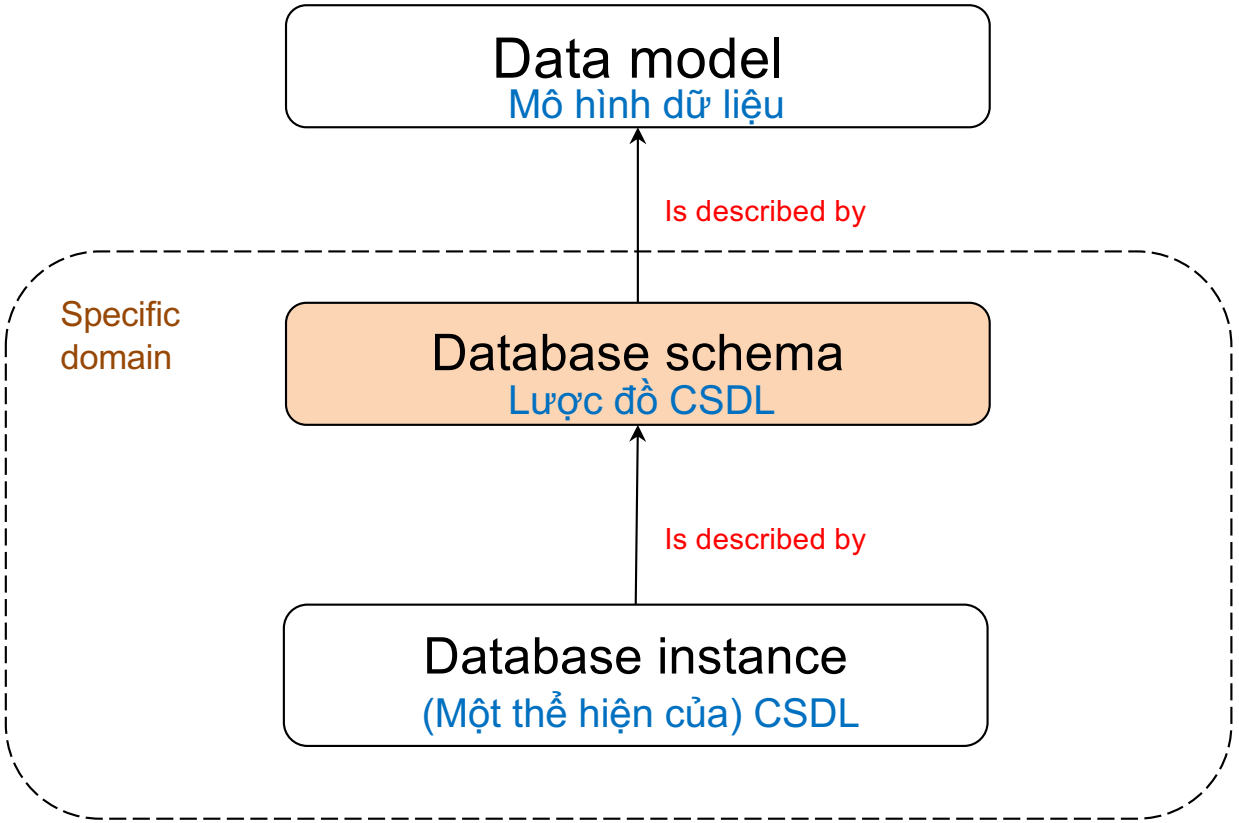
# Examples of Data Models

- Entity Relationship Diagram



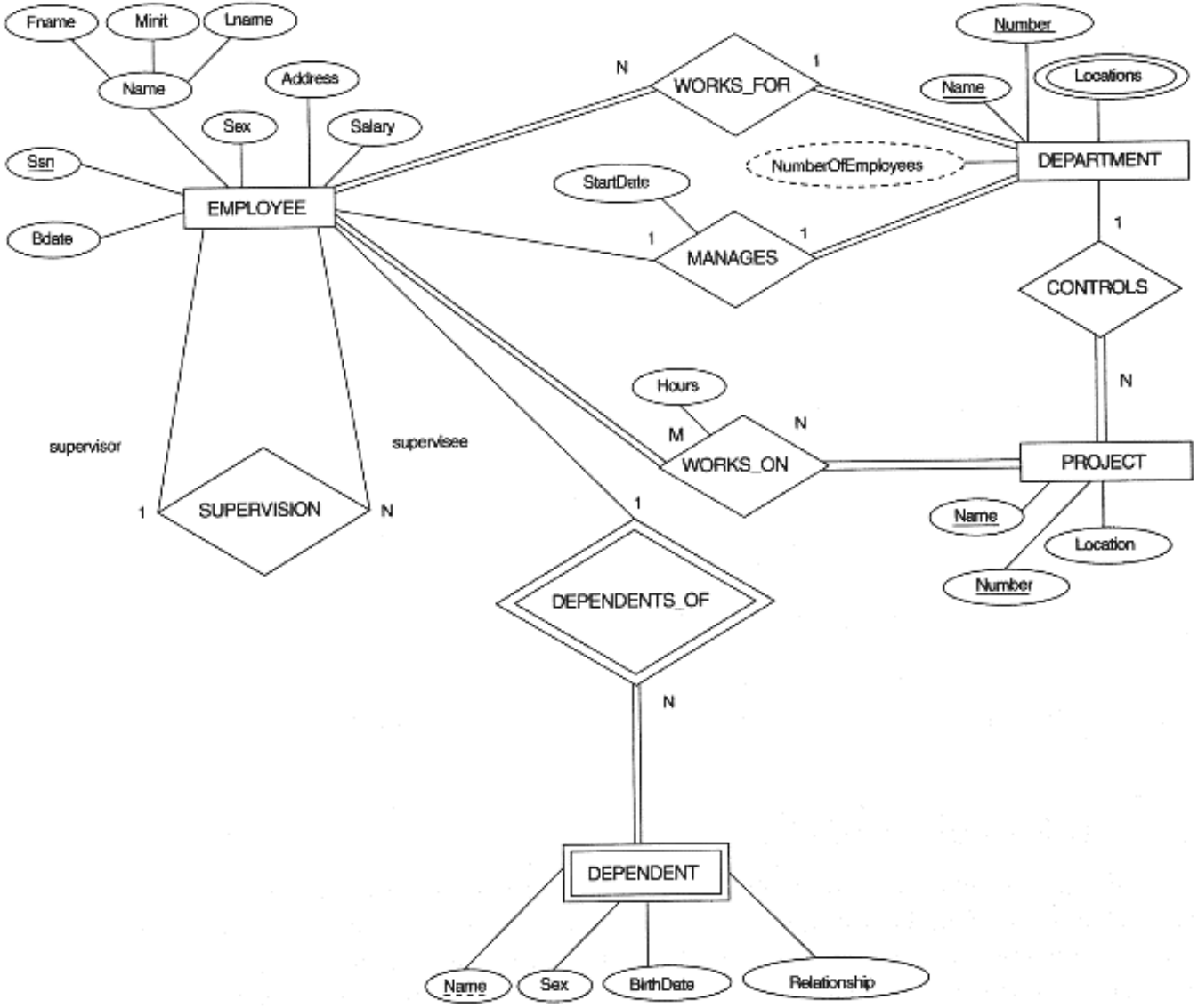

- Network data model

# Database Schema




- Description of the **structure** and **constraints** on the **database** about a **particular domain** (banking, education, marketing, etc.) based on a data model.

# Example of ER Database Schema (ER Diagram)



# Example of (Relational) Database Schema

| SINH VIÊN | TÊNSV | MÃSV | LỚP | NGÀNH |
|---|---|---|---|---|

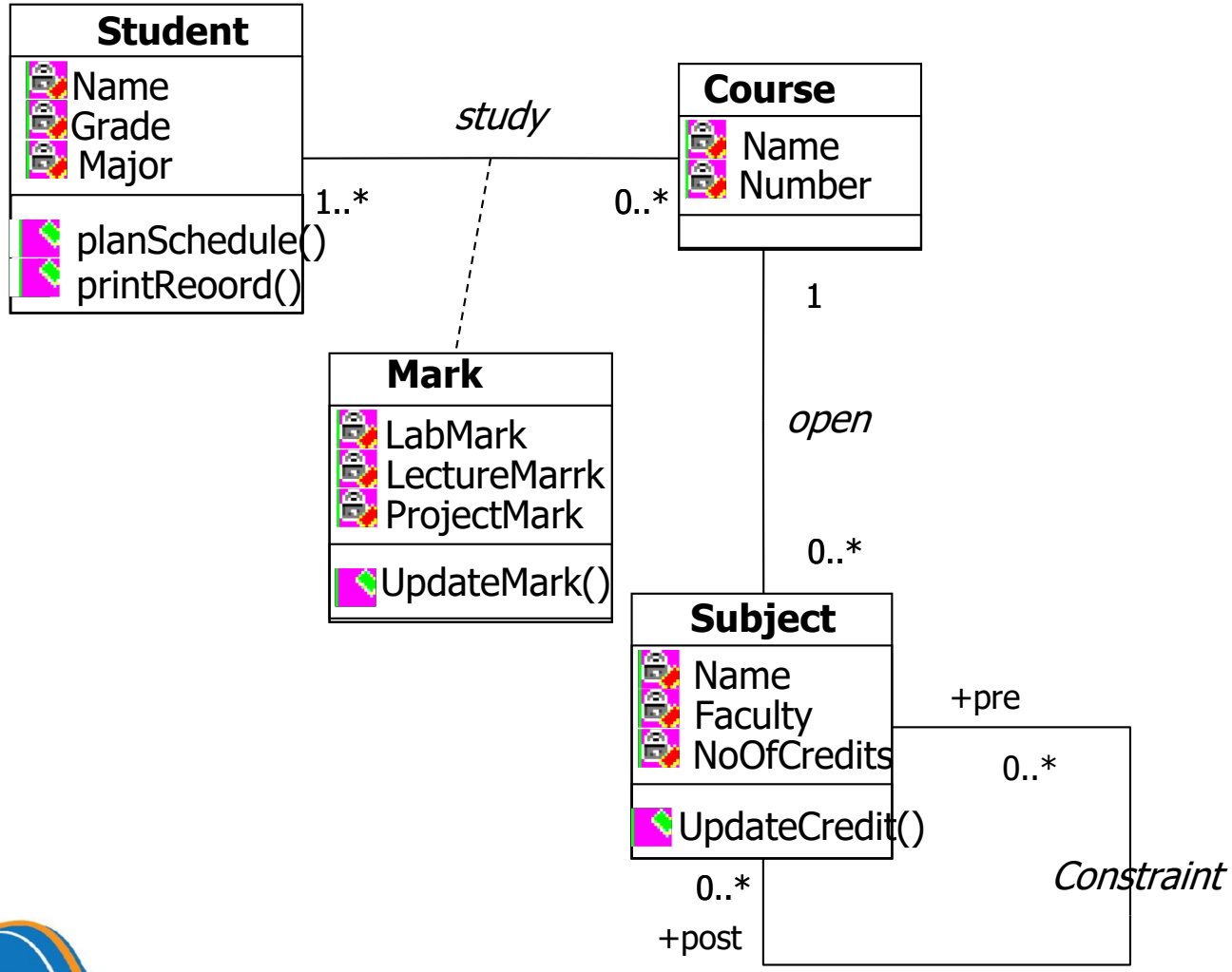
| MÔN HỌC | TÊNMH | MÃMH | KHOA | TÍNCHỈ |
|---|---|---|---|---|

| ĐIỀU KIỆN | MÃMH_TRƯỚC | MÃMH |
|---|---|---|

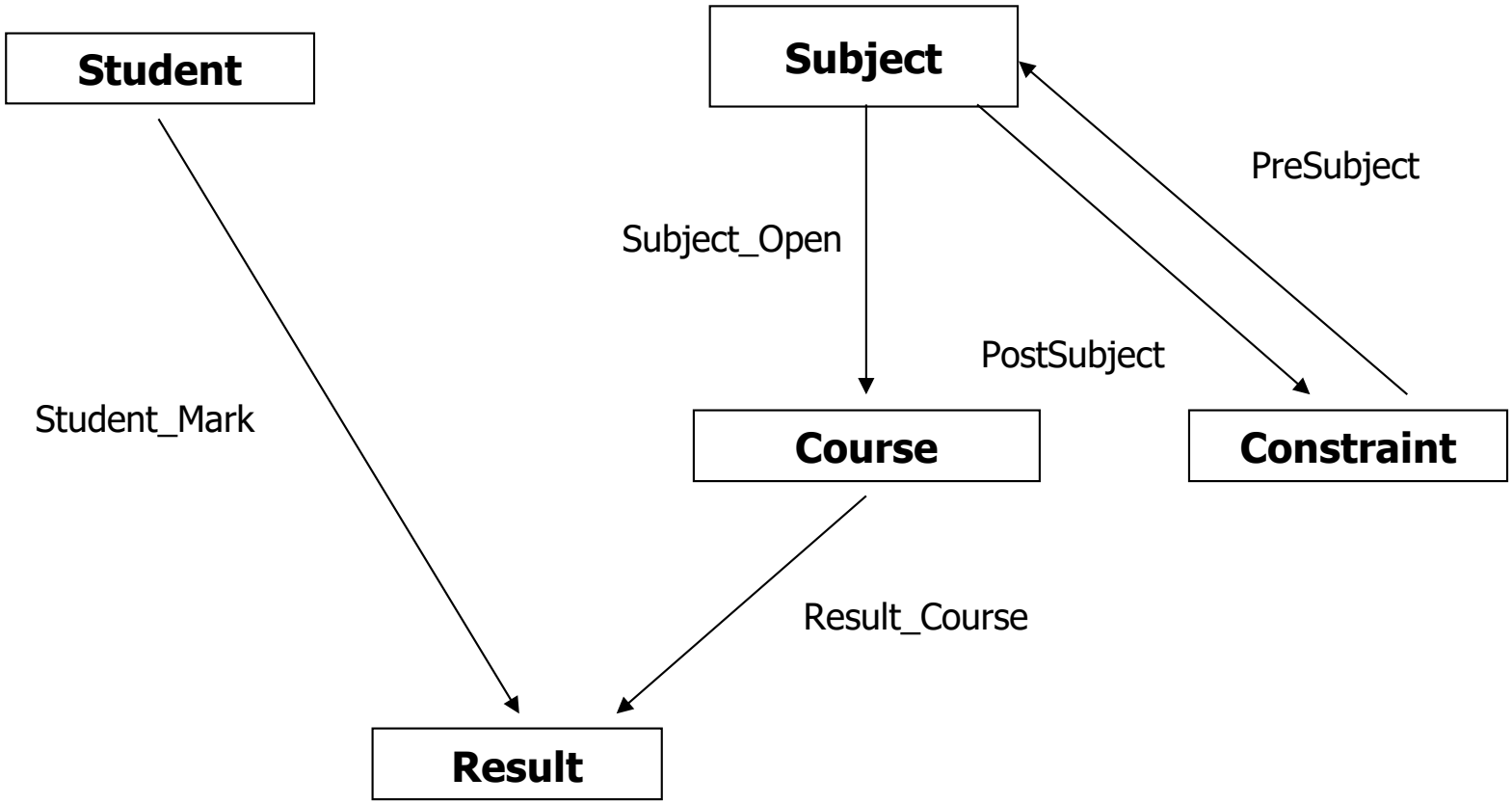
| HỌC PHẦN | MÃHP | GIÁOVIÊN | HỌCKỲ | NĂM |
|---|---|---|---|---|

| KQ_HỌC | MÃSV | MÃHP | ĐIỂM |
|---|---|---|---|

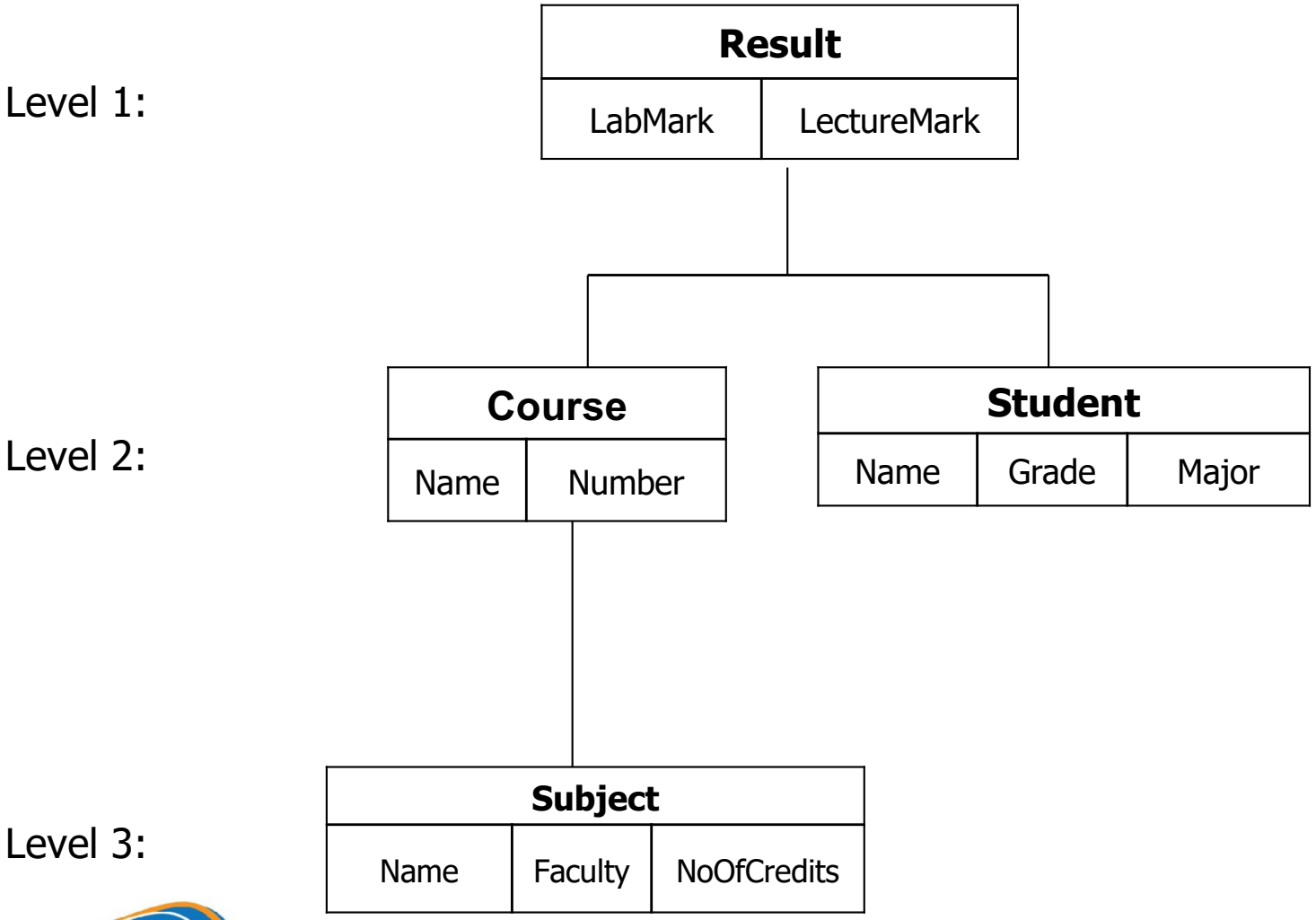
# Example of Object-Oriented Database Schema



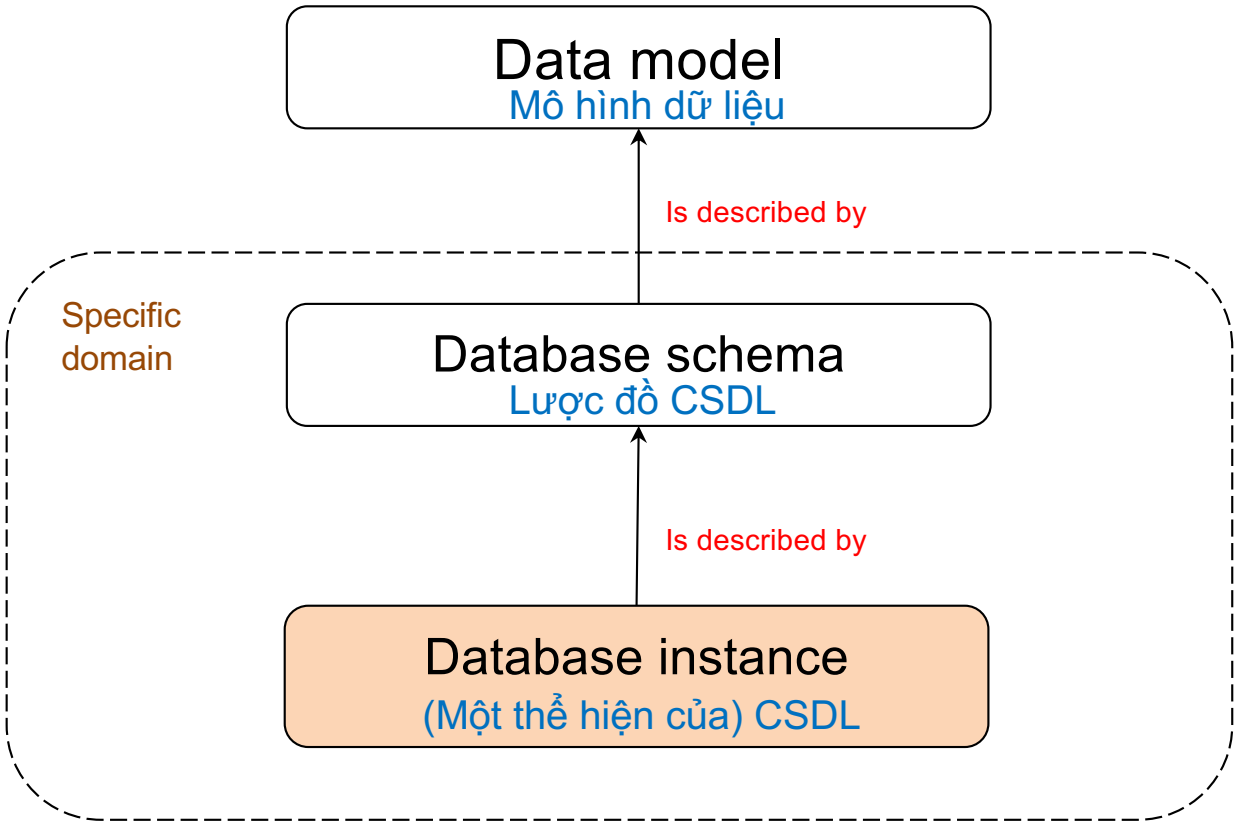
# Example of Network Database Schema



# Example of Hierarchical Database Schema



# Database Instances




- The **data** stored in a database at **a particular moment** of time is called an instance of the database.

# Example of a (Relational) DB Instance

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The (relational) database schema of the database Student Management

| | | | | |
|---|---|---|---|---|
| SINH VIÊN | TÊNSV | MÃSV | LỚP | NGÀNH |
| MÔN HỌC | TÊNMH | MÃMH | KHOA | TÍNCHỈ |
| ĐIỀU KIỆN | MÃMH_TRƯỚC | MÃMH | | |
| HỌC PHẦN | MÃHP | GIÁOVIÊN | HỌCKỲ | NĂM |
| KQ_HỌC | MÃSV | MÃHP | ĐIỂM | |

Is described by

An instance of the database Student Management (at a moment t)

| MÔNHỌC | TênMH | MãMH | SốTC | Khoa |
|---|---|---|---|---|
| | Khoa học máy tính | CS1310 | 4 | CNTT |
| | Cấu trúc dữ liệu | CS3320 | 4 | CNTT |
| | Toán rời rạc | MATH2410 | 3 | TOÁN |
| | Cơ sở dữ liệu | CS3380 | 3 | CNTT |

| KẾTQUẢ | MSSV | MãHP | Điểm |
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| | 17 | 119 | 7 |
| | 8 | 85 | 6 |
| | 8 | 92 | 9 |

| ĐIỀUKIỆN | MãMH | MãMH_Trước |
|---|---|---|
| | CS3380 | CS3320 |
| | CS3380 | MATH2410 |
| | CS3320 | CS1310 |

| HỌCPHẦN | MãHP | MãMH | HọcKỳ | Năm | GiáoViên |
|---|---|---|---|---|---|
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| | 92 | CS1310 | 1 | 2007 | Tiến |
| | 112 | MATH2410 | 2 | 2008 | Anh |
| | 119 | CS1310 | 2 | 2007 | Tiến |

| SINHVIÊN | Tên | MSSV | Lớp | Khoa |
|---|---|---|---|---|
| | Trang | 17 | 1 | CNTT |
| | Ngọc | 8 | 2 | CNTT |

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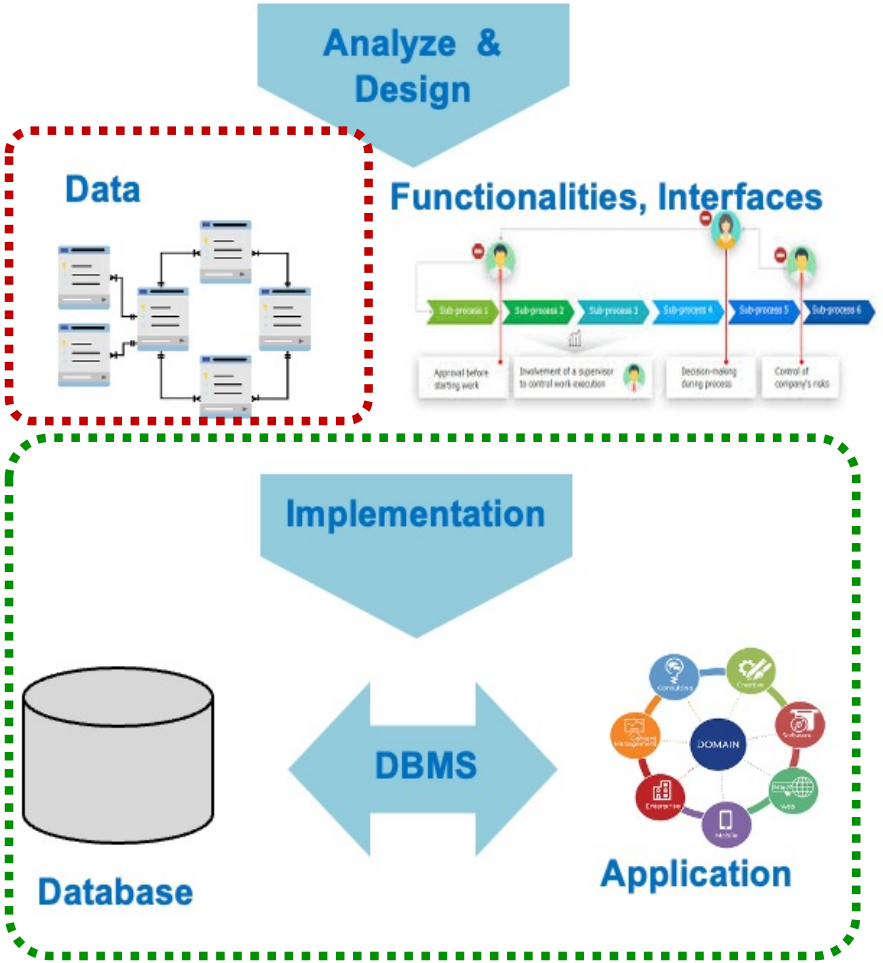
Network Model
…




**Database languages**
**SQL**
Relational Algebra
Relational Calculus
(& Integrity Constraints)

**HOW** to define, operate, and manipulate (relational) database?

# Data Languages
## (for Relational Model)

- High-level (practical) language
  - Entered interactively from a display monitor/terminal or embedded in a general-purpose programming language.
  - E.g.: **SQL** Standard (extension: T-SQL, PL/SQL).
- Low-level (formal) language
  - Embedded in a general-purpose programming language.
  - Offer the fundamental principles for the practical language.
  - E.g.: **Relational Algebra**, **Relation Calculus**

# SQL Standard

- **DDL** – Data Definition Language
  - Identify descriptions of the **schema constructs and store** them in the DBMS catalog.
- **DML** – Data Manipulation Language
  - Provide a set of operations including **retrieval**, **insertion**, **deletion** and **modification** of the data.
- **SDL** – Storage Definition Language
  - Specify the internal schema and the mappings between two schemas.
- **VDL** – View Definition Language.
  - Specify user views and their mapping to the conceptual schema.

# Example of SQL DDL

```
CREATE TABLE GIAOVIEN (
        MAGV        CHAR(9) PRIMARY KEY,
        HOTEN       NVARCHAR(50) NOT NULL,
        LUONG       INT DEFAULT (1000),
        PHAI        CHAR(3) CHECK (PHAI IN( 'Nam' , 'Nu' )),
        NGAYSINH    DATETIME,
        SONHA       NVARCHAR(10),
        DUONG       NVARCHAR(50),
        QUAN        NVARCHAR(50),
        THANHPHO    NVARCHAR(50),
        GVQLCM      CHAR(9),
        MABM        CHAR(9)
)
```

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# Example of SQL DML
## (Create – Read – Update - Delete)

**C**

```
INSERT INTO THAMGIADT VALUES('002', '001', 2, 1.2, NULL)
```

**R**

```
SELECT MAKHOA, TENKHOA, PHONG FROM KHOA
WHERE PHONG='I53' AND NAMTL = '1995'
```

**U**

```
UPDATE GIAOVIEN SET LUONG=LUONG*1.1
```

**D**

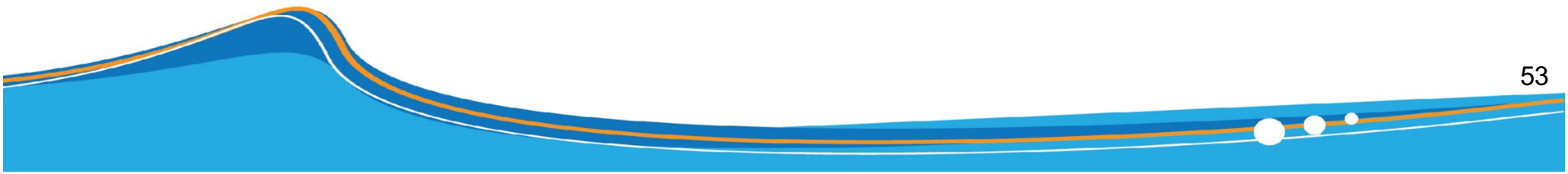
```
DELETE FROM GIAOVIEN WHERE MAGV = 'GV001'
```

# Content

- Introduction of databases
- Evolution of database systems
- Characteristics of the database approach
- Database management systems (DBMS)
- Data models
- Database languages
- Database users

# Database Administrator

- Many people use the same resources
  - Need a chief administrator to oversee and manage
- Responsibility
  - Administering the DB
  - Authorizing access to the DB
  - Coordinating and monitoring the use of DB
  - Acquiring software and hardware resources as needed



# Database Designer

- Responsibility
  - Identifying the data to be stored in the DB
  - Choosing appropriate structures to represent and store the DB
  - Communicating with all DB users to understand their requirements, to produce a design that meet the requirements.

- Can be
  - Staff of the DBA
  - Other staffs taking responsibilities after the DB designed is completed

# End User

- People whose jobs require to access to the DB
  - Querying, updating, generating reports
- Categories
  - Casual end user
  - Naïve or parametric end user
  - Sophisticated end user