Lecture 1

Introduction

COMP3278A

Introduction to Database Management Systems

Dr. Ping Luo

Email : pluo@cs.hku.hk

Department of Computer Science, The University of Hong Kong

Acknowledgement: **Dr. Chui Chun Kit**

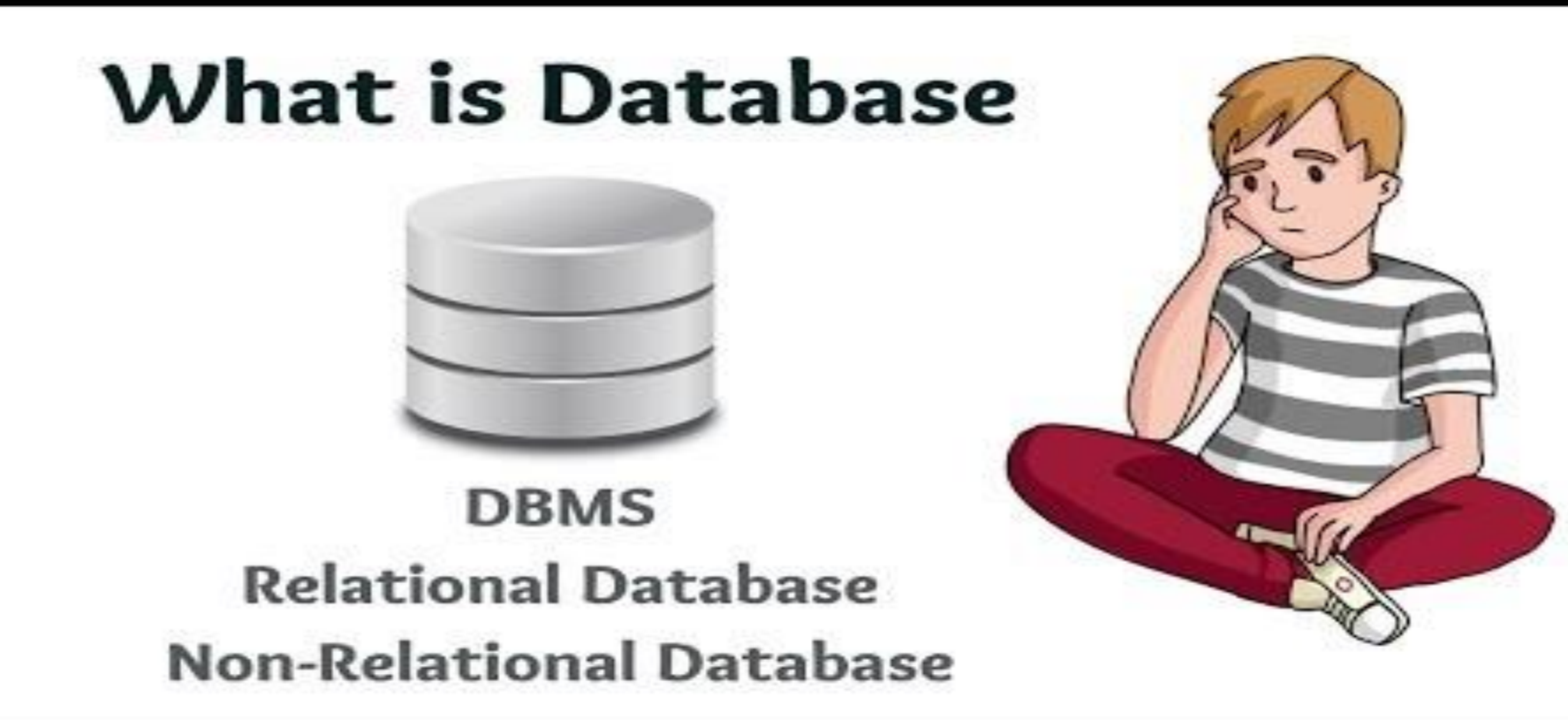
We are going to learn…

- **Getting started…**
  - What is a database management system (DBMS)?
  - Why is a DBMS important?
  - Why don’t we simply use a file to store all the data?
- **A brief introduction to a DBMS**

Section 1.1

What is a Database?

What is a database?



https://www.youtube.com/watch?v=j09EQ-xlh88

What is a database?

Three Concepts

- **Data**
  - Some values referring to real world facts.
  - May be in various formats, e.g., text, image, audio file, video file, etc.
- **Database**
  - A large collection of inter-related data.
- **Database management system (DBMS)**
  - DBMS = database(s) + a set of programs that store and access the data.

Database applications

- **Many daily applications involve databases.**
  - Banking

What data are stored in the backend database of an ATM machine?

Customers records | Login Password | Transactions | Account balance | ...

DBMS

Database applications

- **Many daily applications involve databases.**
  - Banking
  - Airline

What data are stored in the backend database of an airline booking system?

Airport information

Aircraft

Flight (date, time, origin, destination…)

Customer record

Booking

DBMS

Database applications

- **Many daily applications involve databases.**
  - Banking
  - Airlines
  - Social network

Member information

Friend list

Friend request

News feed

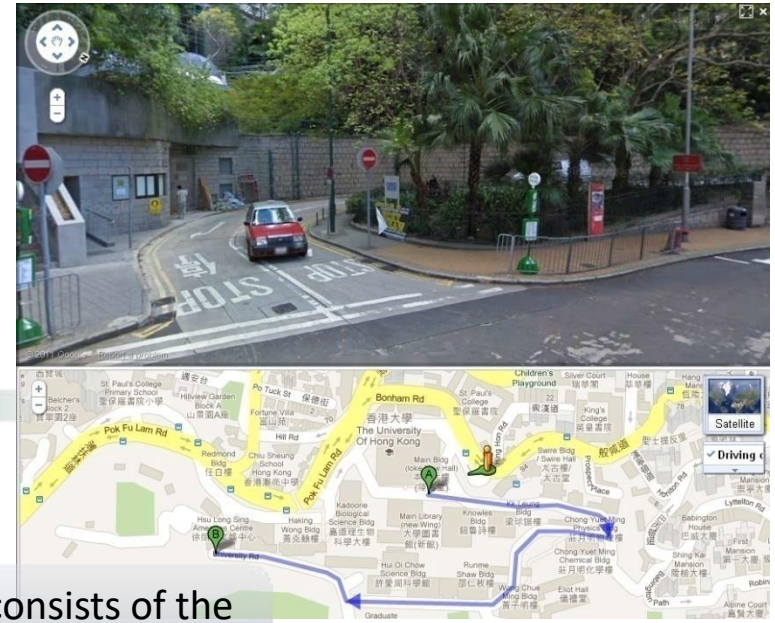
Inbox

Check-in locations

DBMS

Database applications

- **Many daily applications involve databases.**
  - Banking
  - Airlines
  - Social network
  - Online maps



Google Street View

Application program

DBMS

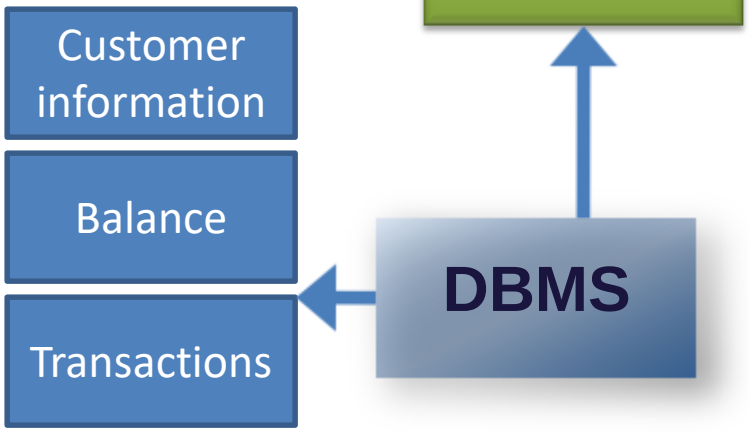
Locations | Roads | Images

An information system can consists of the **data layer** and the **application layer**.

Database applications

- **Many daily applications involve databases.**
  - Banking
  - Airlines
  - Universities
  - Social network
  - Online maps
  - Smart card systems

One database may support many different applications simultaneously.



File system v.s. DBMS

- **In the early days, application programs were built on top of file systems. (e.g., DOS, Windows file explorer)**

Why don't we simply use **a file system** to manage our data?

So that I don't need to spend resources (e.g., $$$) on maintaining a database/ hiring a database administrator…

Boss, let us use a database to organize our data ☺!

File system v.s. DBMS

- **6 drawbacks of storing data in a file system:**
  - **1. Difficulty in accessing data** - May be **inefficient** to locate a piece of information.

⋮

Ping; 12345670; CB326, HKU, Pokfulam Rd; account balance : $100

Jolly; 91234567; CYC 311; HKU, Pokfulam Rd; account balance: $2,000

Yvonne; 31234567; CB 415, HKU, Pokfulam Rd; account balance: $1,000

Savings-account records

If we keep all the savings account records in a text file, I need to scan the file once to retrieve any particular record.

File system v.s. DBMS

- **6 drawbacks of storing DB in file systems:**
  - **2. Data redundancy and inconsistency** - Data got updated in one place but forget to update the other one.

⋮

Ping; 12345670; CB326, HKU, Pokfulam Rd; account balance : $100

Jolly; 91234567; CYC 311; HKU, Pokfulam Rd; account balance: $2,000

Yvonne; 31234567; CB 415, HKU, Pokfulam Rd; account balance: $1,000

Savings-account records

⋮

Ben/ account balance: $100,000/ CYC 314, HKU, Pokfulam Rd/ 21234567/

Ping/ account balance: $4,000/ CB326, The University of Hong Kong, Pokfulam Rd, Hong Kong/ 12345670 /

Kevin/ account balance $20,000/ 2nd Floor … Central/ 62234567/

Checking-account records

Address information duplicated among different files!

File system v.s. DBMS

- **6 drawbacks of storing DB in file systems:**
  - **3. Data isolation** – Because data are scattered in different files, and files may be in **different formats**, writing new programs to retrieve the appropriate data is difficult.

⋮

Ping; 12345670; CB326, HKU, Pokfulam Rd; account balance : $100

Jolly; 91234567; CYC 311; HKU, Pokfulam Rd; account balance: $2,000

Yvonne; 31234567; CB 415, HKU, Pokfulam Rd; account balance: $1,000

Savings-account records

⋮

Ben/ account balance: $100,000/ CYC 314, HKU, Pokfulam Rd/ 21234567/

Ping/ account balance: $4,000/ CB326, The University of Hong Kong, Pokfulam Rd, Hong Kong/ 12345670 /

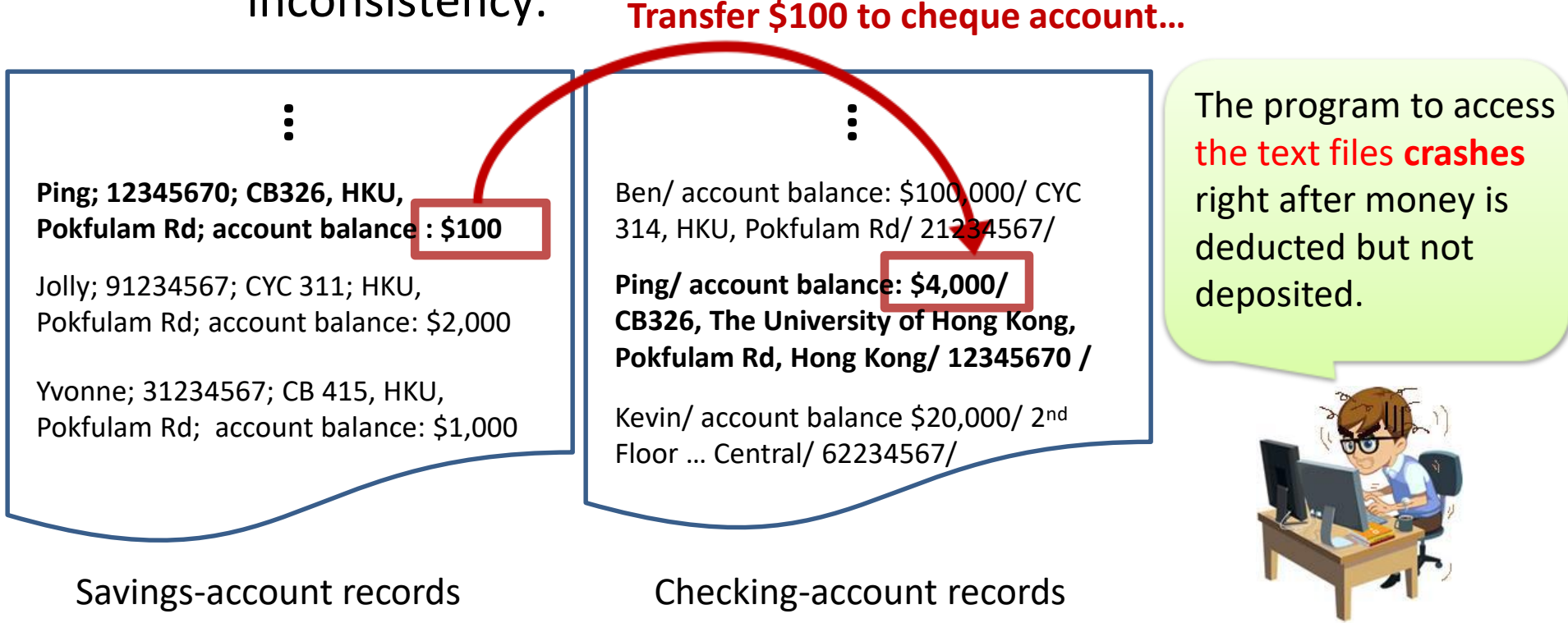
Kevin/ account balance $20,000/ 2nd Floor … Central/ 62234567/

Checking-account records

One file uses ";" to separate fields while the other uses "/", also, the fields are in different orders!

File system v.s. DBMS

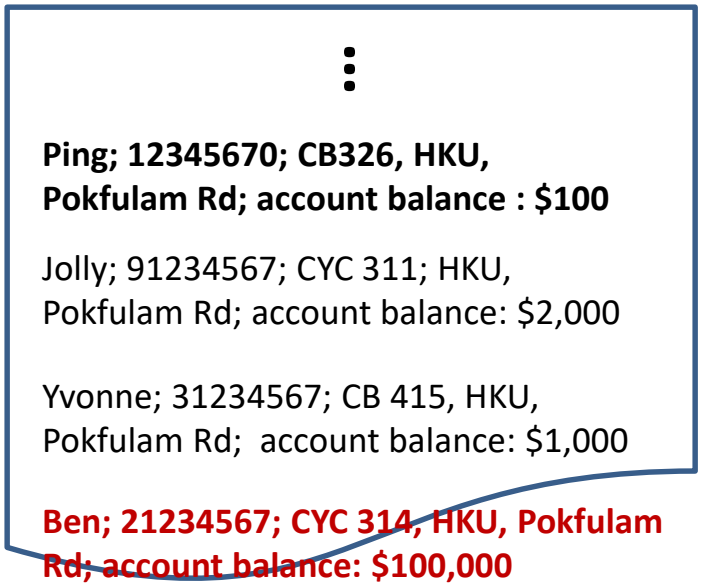
- **6 drawbacks of storing DB in file systems:**
  - **4. Atomicity problems** – It's difficult to ensure that a transfer of money is done completely, leading to failure and inconsistency.



The program to access the text files **crashes** right after money is deducted but not deposited.

File system v.s. DBMS

- **6 drawbacks of storing DB in file systems:**
  - **5. Concurrent access problems** – Inconsistency can occur, e.g., two customers reading and updating a balance at the same time.



Savings-account records

10:00 Ping opens the file.

10:15 Boss opens the same file.

11:00 Boss added one more customer "Ben" to the file and saved the file.

12:00 Ping saves the file and overwrite the file boss saved.

13:00 Boss open the file and found that **"Ben" is not in the file**!

File system v.s. DBMS

- **6 drawbacks of storing DB in file systems:**
  - **6. Integrity problem** – Programmers need to enforce consistency constraints by adding code in many application programs, which is hard to design and manage.

⋮

Ping; 12345670; CB326, HKU, Pokfulam Rd; account balance : $100

Jolly; 91234567; CYC 311; HKU, Pokfulam Rd; account balance: $2,000

Yvonne; 31234567; CB 415, HKU, Pokfulam Rd; account balance: $1,000

Savings-account records

The savings account records should have at least $200 in the account balance.

A checker program has to be added before every withdraw and transfer transactions.

Database Management System

- Big DBMS vendors: Oracle, IBM DB2, Microsoft, SAP Sybase etc.

- Open source DBMS: PostgreSQL, MySQL.

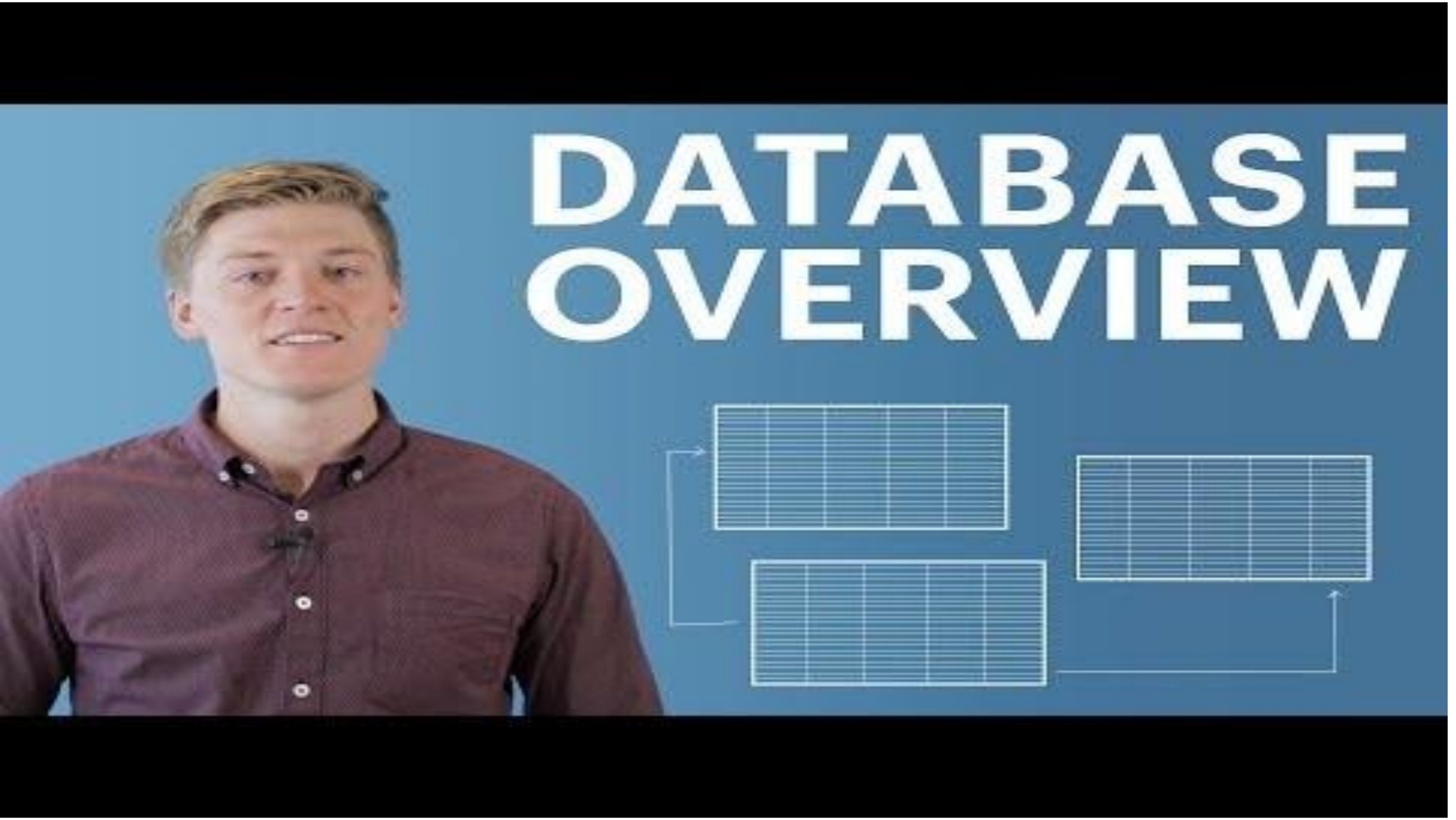
PostgreSQL

To Recap

- **What is a database? Data, Database, and DBMS**
  - Data: some values referring to real world facts.
  - Database: a large collection of inter-related data.
  - DBMS = database(s) + a set of programs that store and access the data.
- **File vs. Database**

1. **Difficulty in accessing data** - May be **inefficient** to locate a piece of information.
2. **Data redundancy and inconsistency** - Data got updated in one place but forget to update the other one.
3. **Data isolation** – Because data are scattered in different files, and files may be in **different formats**, writing new programs to retrieve the appropriate data is difficult.
4. **Atomicity problems** – It's difficult to ensure that a transfer of money is done completely, leading to failure and inconsistency.
5. **Concurrent access problems** – Inconsistency can occur, e.g., two customers reading and updating a balance at the same time.
6. **Integrity problem** – Programmers need to enforce consistency constraints by adding code in many application programs, which is hard to design and manage.

What is DBMS?



Database Management System

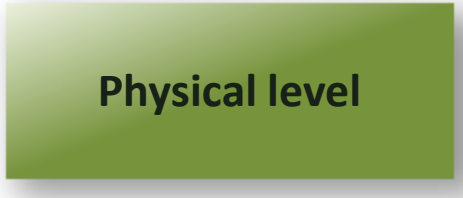
- **A good DBMS aims at handling all problems related to large DB management.**
- **DBMS provides an environment that is both convenient and efficient to use.**
- **Three powerful concepts supported by a DBMS:**
  - 1. Data abstraction.
  - 2. Data modeling.
  - 3. Database languages.

1. Data abstraction

- **Three levels of data abstraction.**

1. Physical level

- Describes **HOW** the data are actually stored in the computer system.
- Describes complex low-level data structures in detail.
- E.g., Whether the data are **compressed** or not? With **what data compression methods**?

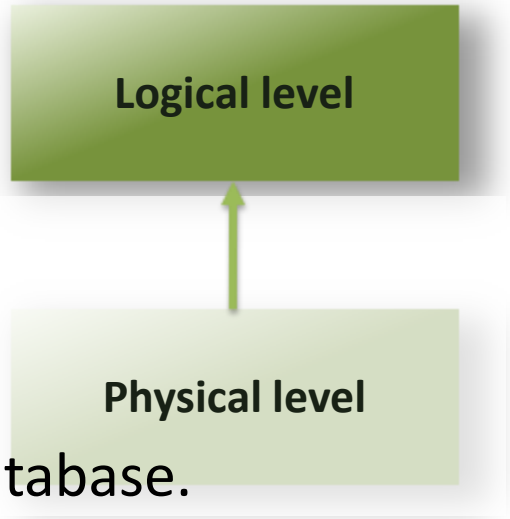


1. Data abstraction

- **Three levels of data abstraction.**

2. Logical level

- Describes **WHAT** data are stored.
- Describes the **relationship** among data.
- **It's independent to physical data!**
  - Adding an index to speed up the access won't affect the data stored in the database.
  - Compressing the data in the physical level also won't affect application programs or user interfaces.
- We use the logical level of abstraction to model the relational information in the database.

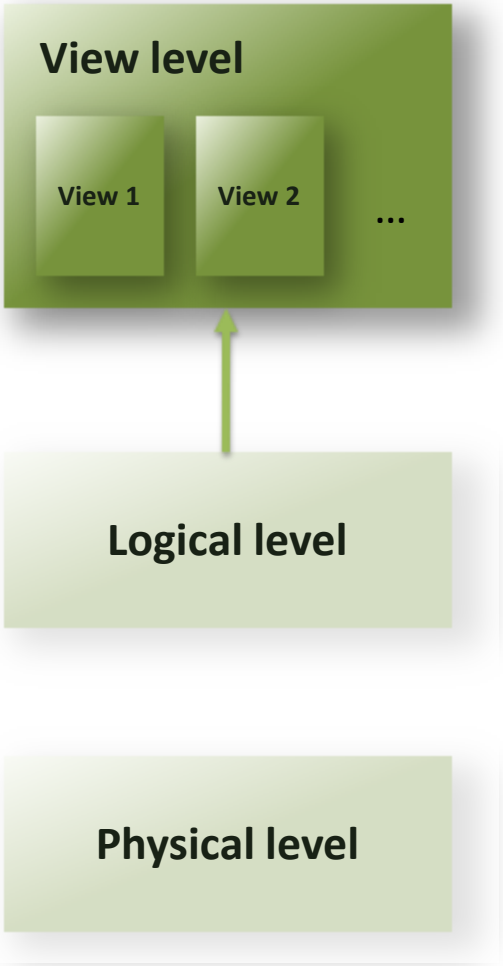


1. Data abstraction

- **Three levels of data abstraction.**

3. View level

- Describes only **part of** the entire DB.
- Many users of the database system do not need to access all information in the database. i.e. different users should have different **view** to the database.
- It simplify users' interaction with the database system.



1. Data abstraction

- **Important concept of Schema and Instance**
  - A **Schema** describes the structure of the database.
  - An **Instance** is the actual data of the database at a particular time.

Schema and **instance** are analog to **type** and **value** in programming.

```
customer {
    string customer_name;
    string customer_address;
}
```

A **schema** of customer

Logical level

Name	Address
Ping	CB326, University of Hong Kong …
Ben	CB314, University of Hong Kong …

An **instance** of customers

Name	Address
Ping	CB326, University of Hong Kong …
Jolly	CB311, University of Hong Kong …

Another **instance** of customers

Database Management System

- **Three powerful concepts supported by a DBMS:**
  - 1. Data abstraction.
  - 2. Data modeling.
  - 3. Database languages.

2. Data modeling

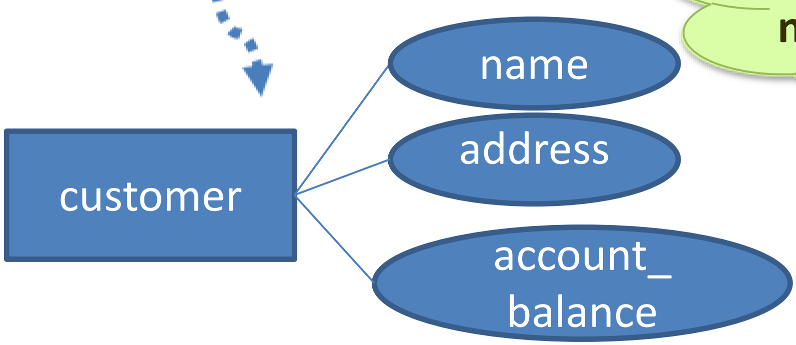
- **Data modeling is used to describe data in a systematic way.**

What **DATA** should be stored?

I would like to store the account records of my customers.

I need to store the "**Customer**" data, and for each customer, I will store his/ her **name**, **address** and **account** balance!

Design a data model

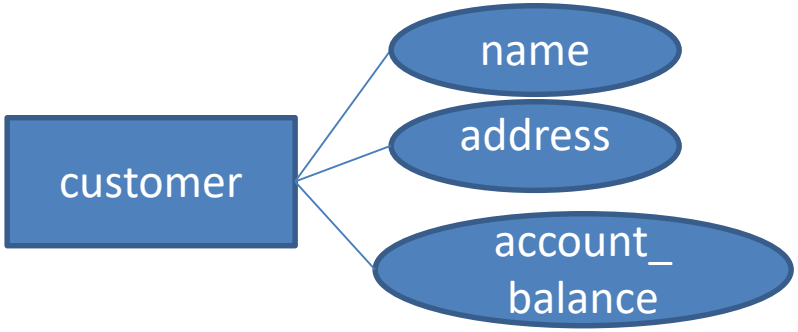


Name	Address	Account balance
Ping	HKU…	$100
Ben	…	$2,000

The **data model** → The **data instance**

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**



The **data model**

Name	Address	Account balance
Ping	HKU…	$100
Ping	…	$2,000

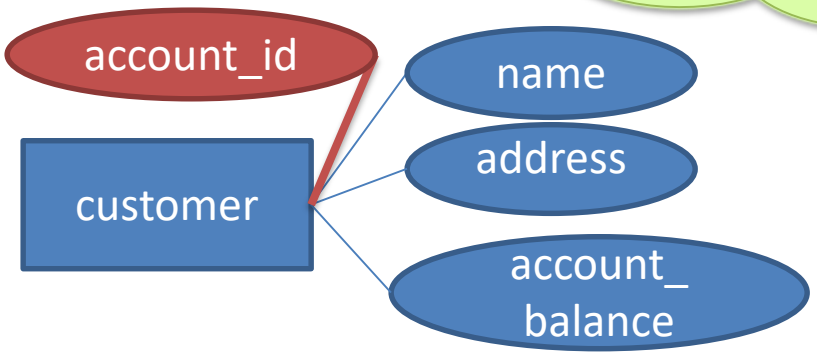
The **data instance**

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**

Easy ☺! I add a **unique account ID** to distinguish different account of the same customer!

A customer can have more than one account!!!

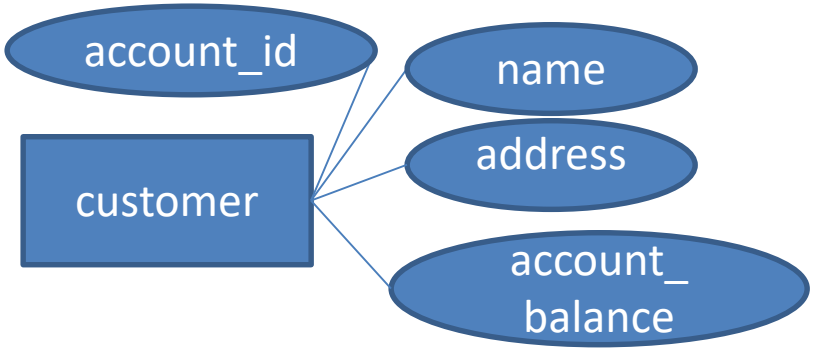


Account ID	Name	Address	Account balance
1	Ping	HKU…	$100
2	Ping	HKU…	$2,000

The **data model** ⇢ The **data instance**

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**



The **data model**

Data redundancy

Account ID	Name	Address	Account balance
1	Ping	HKU…	$100
2	Ping	HKU…	$2,000

The **data instance**

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**

Let me **separate** the customer information with the account information.

Customer ID	Name	Address
1	Ping	HKU…
2	…	…

Account ID	Balance
1	$100
2	$2,000

Account ID	Name	Address	Account balance
1	Ping	HKU…	$100
2	Ping	HKU…	$2,000

The **data instance**

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**

An extra information is needed to represent the **relationship** of the **customers** with the **accounts**, then one customer can have more than one account, and the customer info will not be duplicated ☺!

Customer ID	Account ID
1	1
1	2

Customer ID	Name	Address
1	Ping	HKU…
2	…	…

Account ID	Balance
1	$100
2	$2,000

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**

An extra information is needed to represent the **relationship** of the **customers** with the **accounts**, then one customer can have more than one account, and the customer info will not be duplicated ☺!

Customer ID	Account ID
1	1
1	2

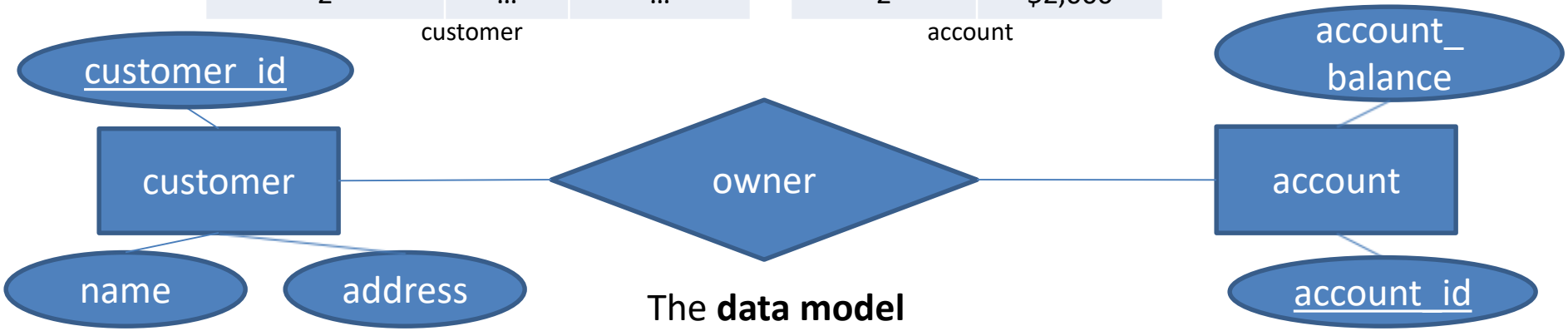
owner

Customer ID	Name	Address
1	Ping	HKU…
2	…	…

customer

Account ID	Balance
1	$100
2	$2,000

account



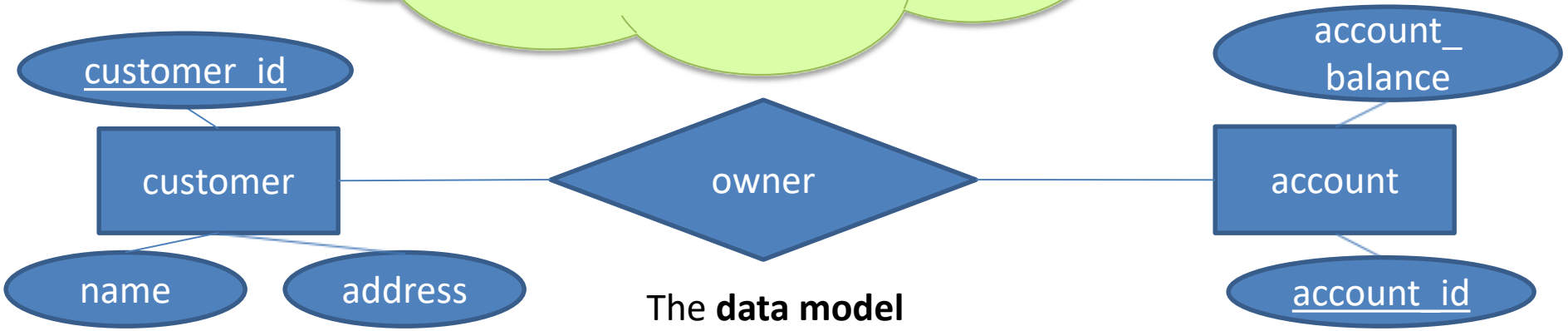
The **data model**

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**

We need to **design the data model** carefully so that it can:

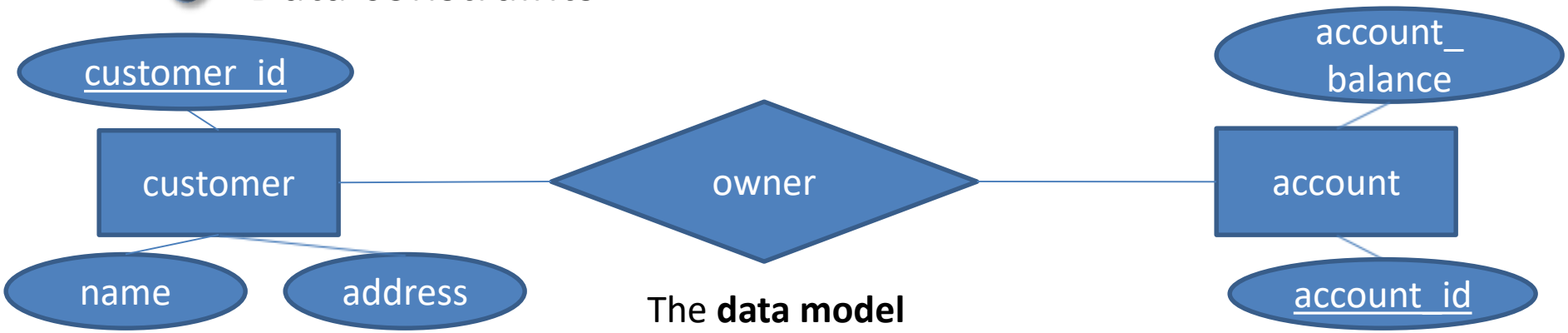
1. **Capture user requirements.**
2. **Store/ access data efficiently.**



The **data model**

2. Data modeling

- **Data modeling is used to describe data in a systematic way.**
- **A collective tool for describing**
  - Data
  - Data relationships
  - Data semantics
  - Data constraints



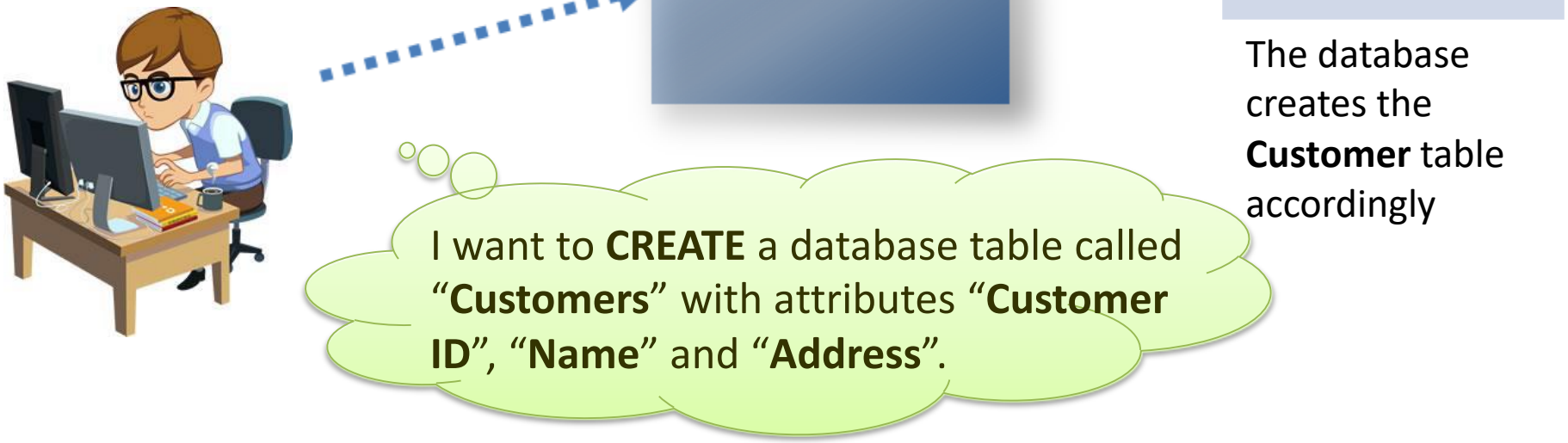
The **data model**

Database Management System

- **Three powerful concepts supported by a DBMS:**
  - 1. Data abstraction.
  - 2. Data modeling.
  - 3. Database languages.

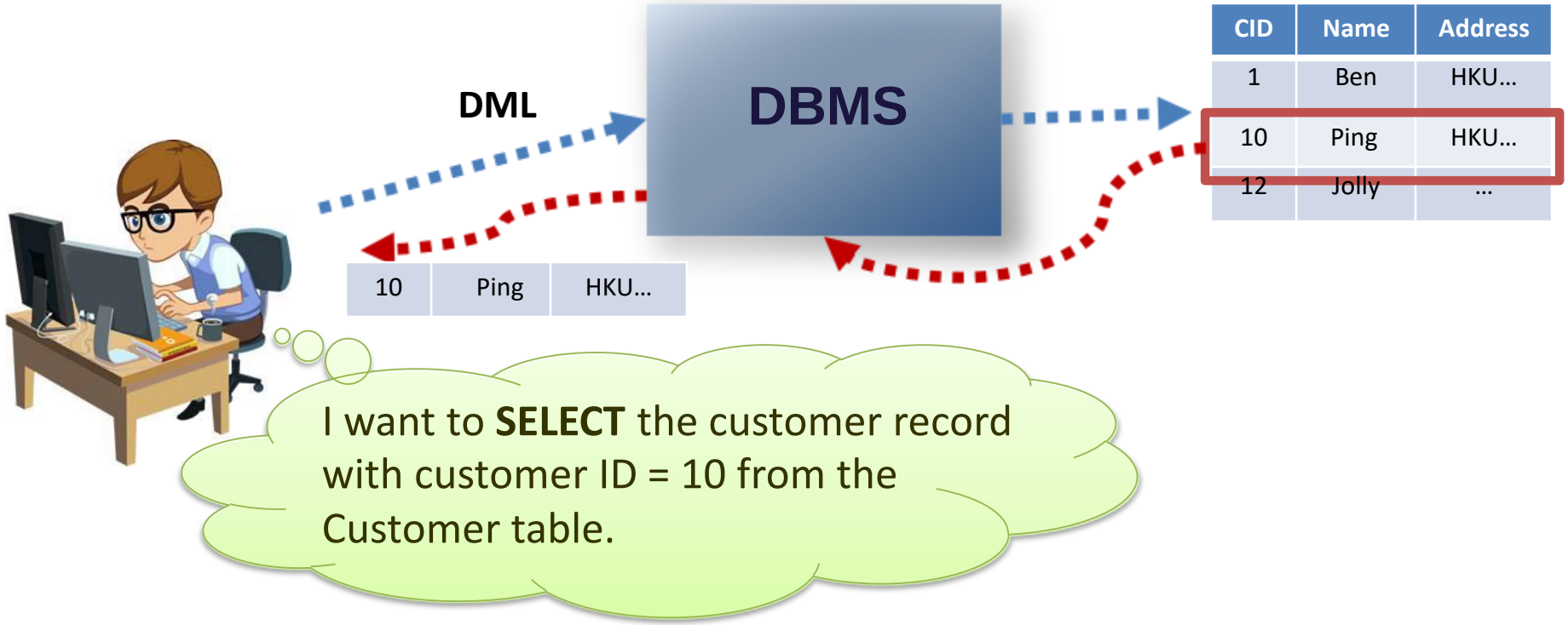
3. Database languages

- **DBMS provide different tools for managing data.**
  - Data definition language (DDL)



3. Database languages

- **DBMS provide different tools for managing data.**
  - Data definition language (DDL)
  - Data manipulation language (DML)



To Recap

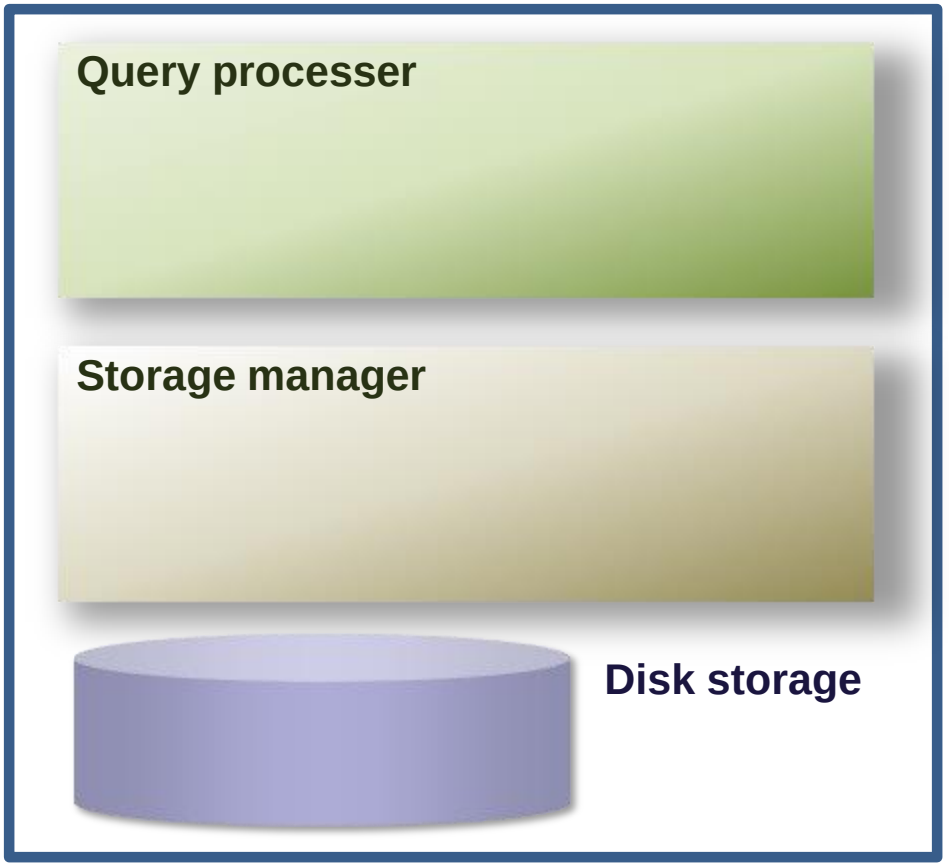
- **What is a database? Data, Database, and DBMS**
- **File vs. Database**
  - 6 drawbacks of file systems
- **Three concepts supported by a DBMS**
  1. Data Abstraction (Physical/Logical/View)
  2. Data Modeling (Table/Attributes/Relationships)
  3. Database Language (DDL & DML)

Section 1.2

Database Overview

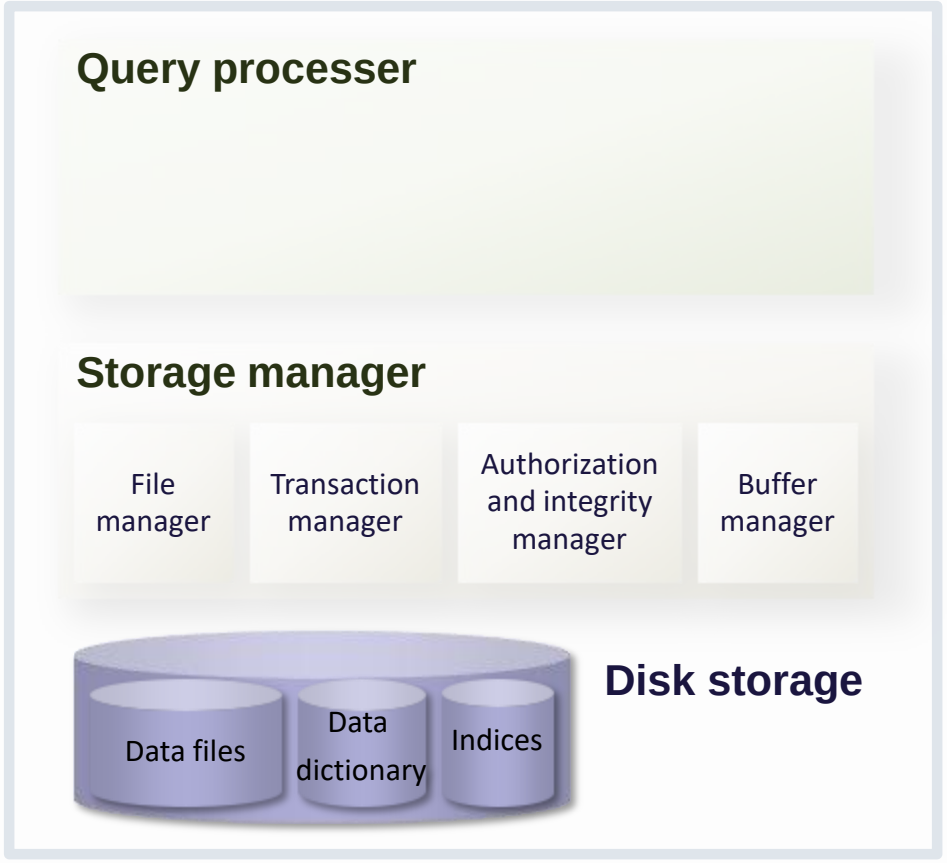
Database Overview

- **A DBMS is a complex system partitioned into modules that deal with each of the responsibilities of the overall system.**
- **The functional components can be broadly divided into**
  - Disk Storage
  - Storage manager
  - Query processer



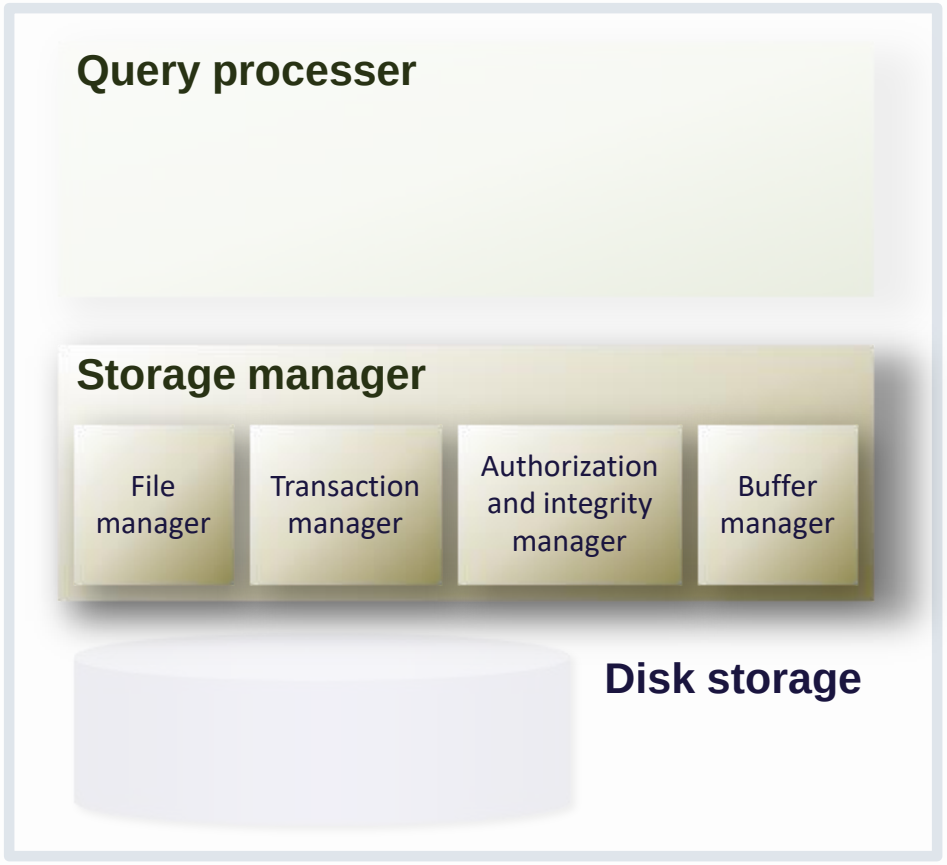
Disk storage

- **Disk storage consists of**
  - **Data files** – stores the database itself.
  - **Data dictionary** – stores metadata about the structure of the database, in particular the schema of the database.
  - **Indices** – provide fast access to data records.



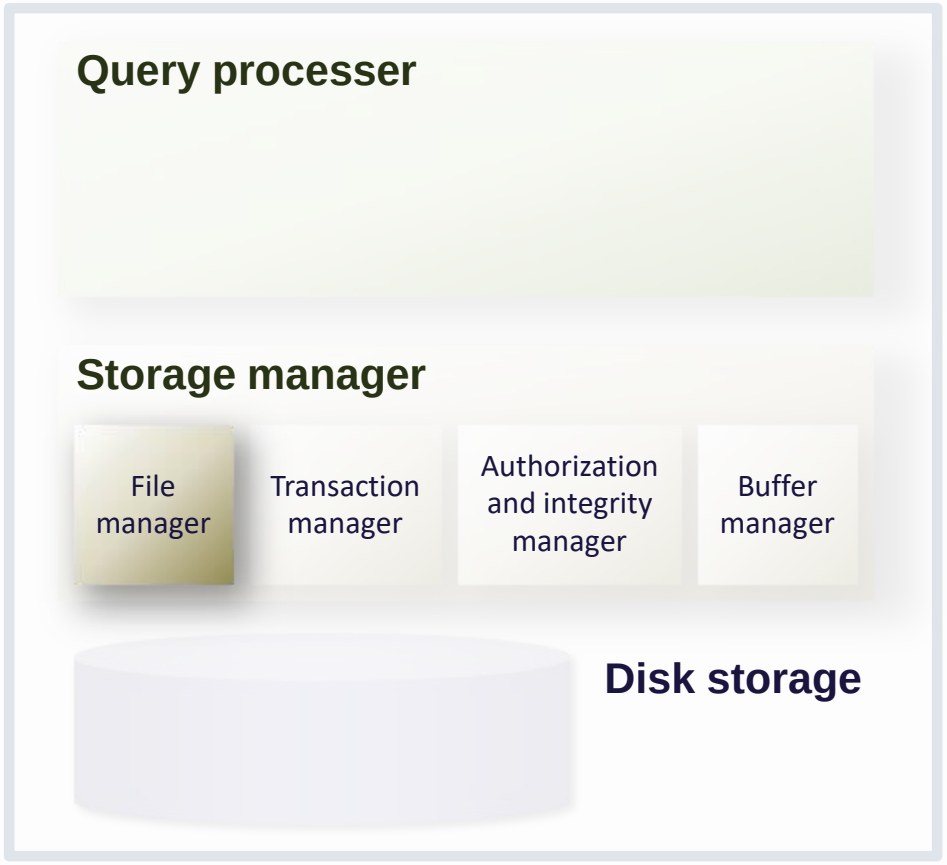
Storage manager

- **A program module in DBMS that provides interface between the low-level data and the application programs/queries.**
- **Consists of**
  - File manager
  - Transaction manager
  - Authorization and integrity manager
  - Buffer manager



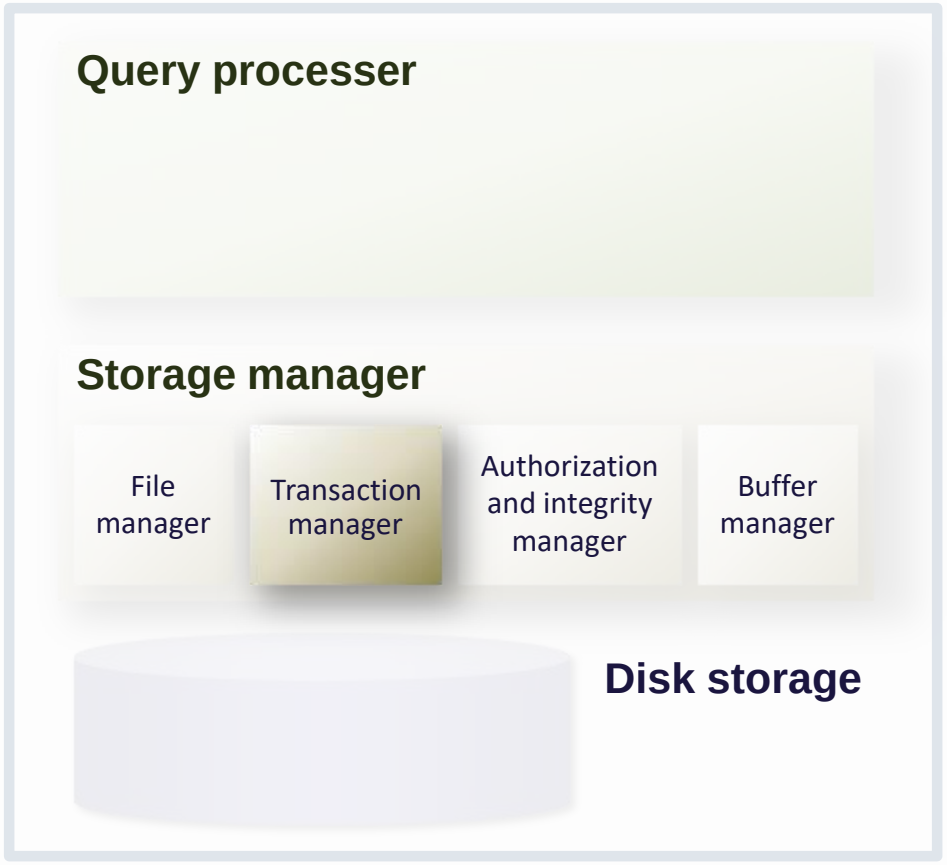
File manager

- Manages the allocation of space on disk storage and the data structures used to represent information stored on disk.



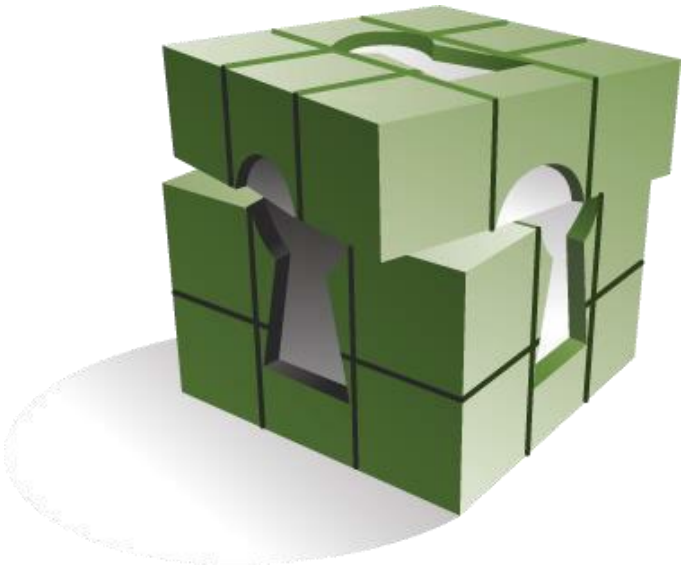
Transaction manager

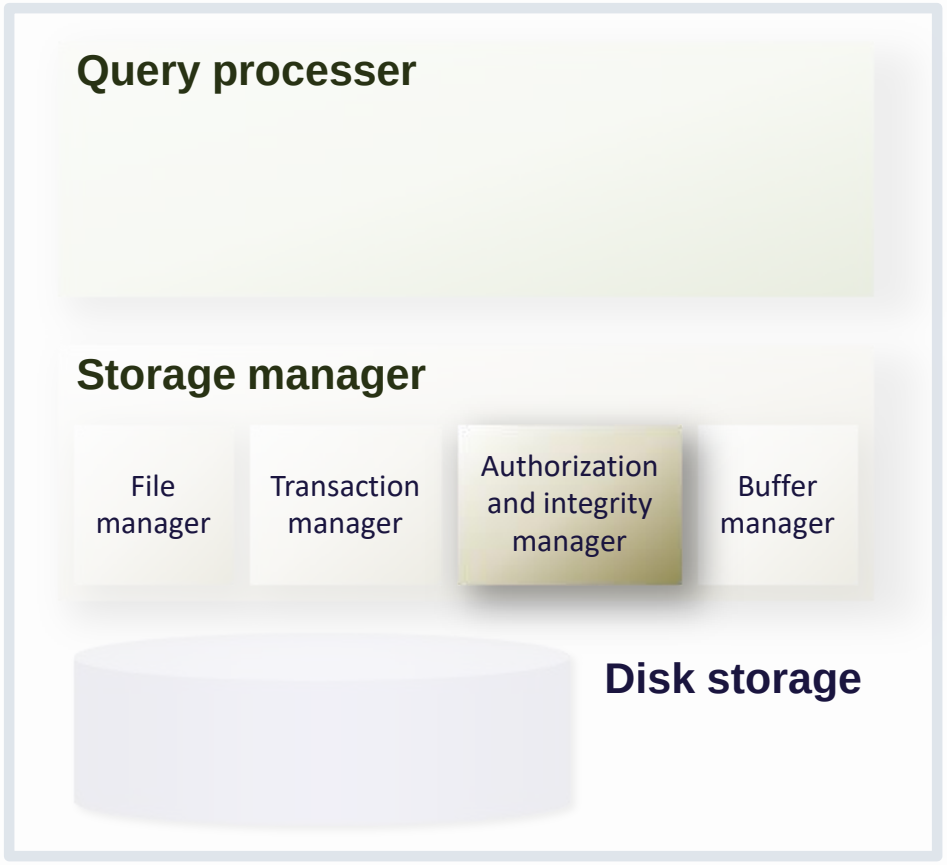
- Ensures that the database remains in a consistent (correct) state despite system failures.
- Ensures interaction among all concurrent transactions does not make the DB inconsistent.



Authorization and integrity manager

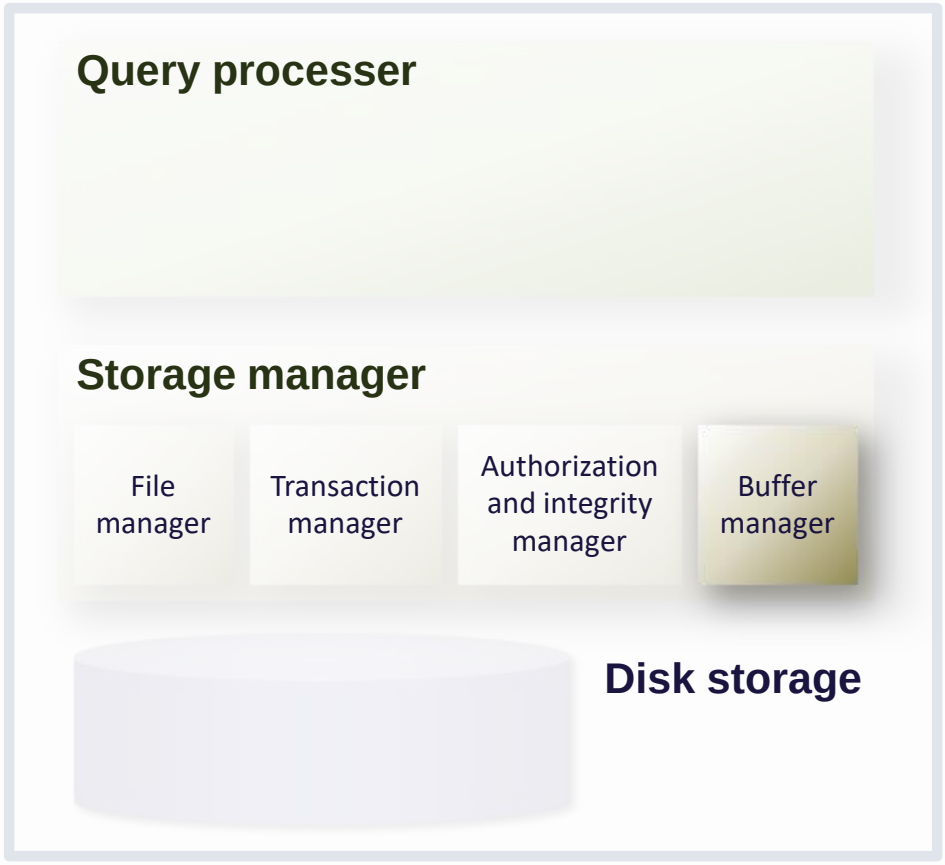
- Tests for the satisfaction of integrity constraints and checks the authority of users to access data.





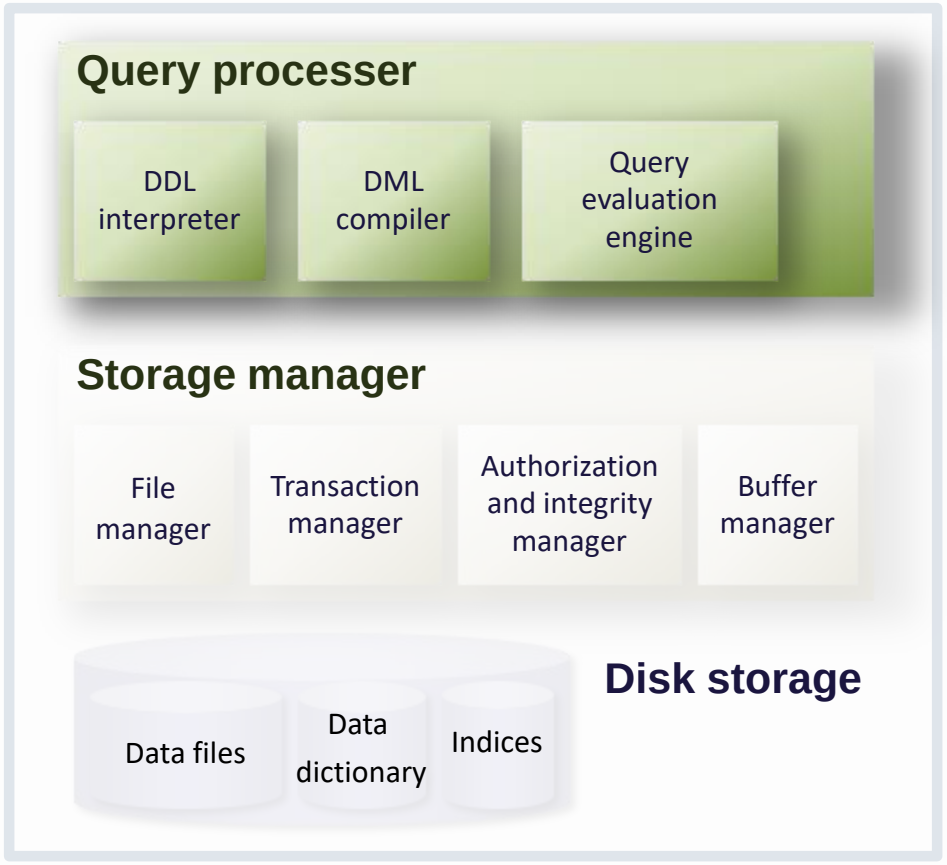
Buffer manager

- Responsible for fetching data from disk storage into main memory.
- Decide what data to cache in main memory.



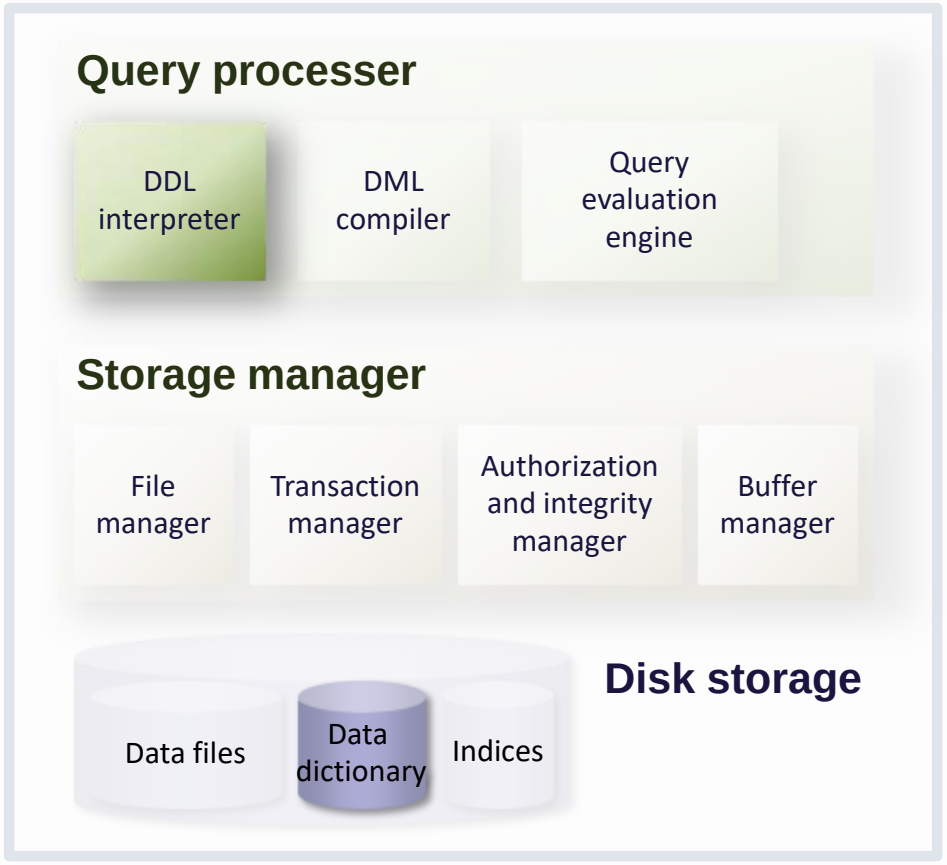
Query processer

- A program module in DBMS that converts high-level user requests to efficient low-level commands to DB.
- Consists of
  - DDL interpreter
  - DML compiler
  - Query evaluation engine



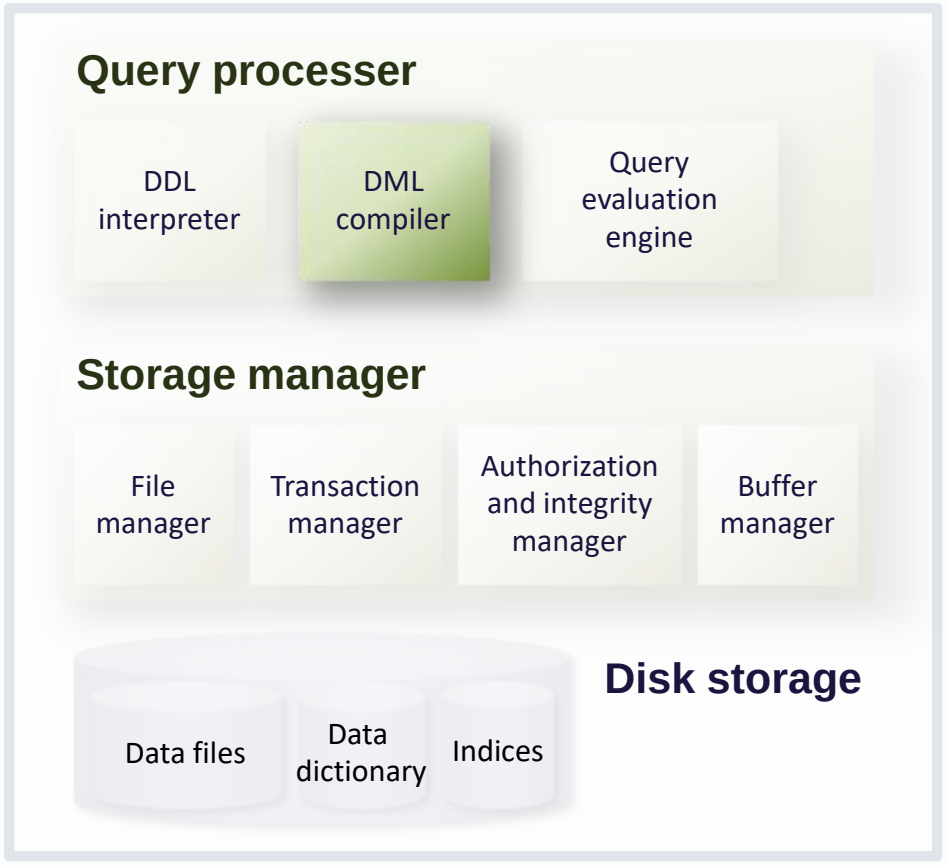
DDL interpreter

- **Interprets the DDL statements and records the definition in the data dictionary (i.e. structure of the DB)**



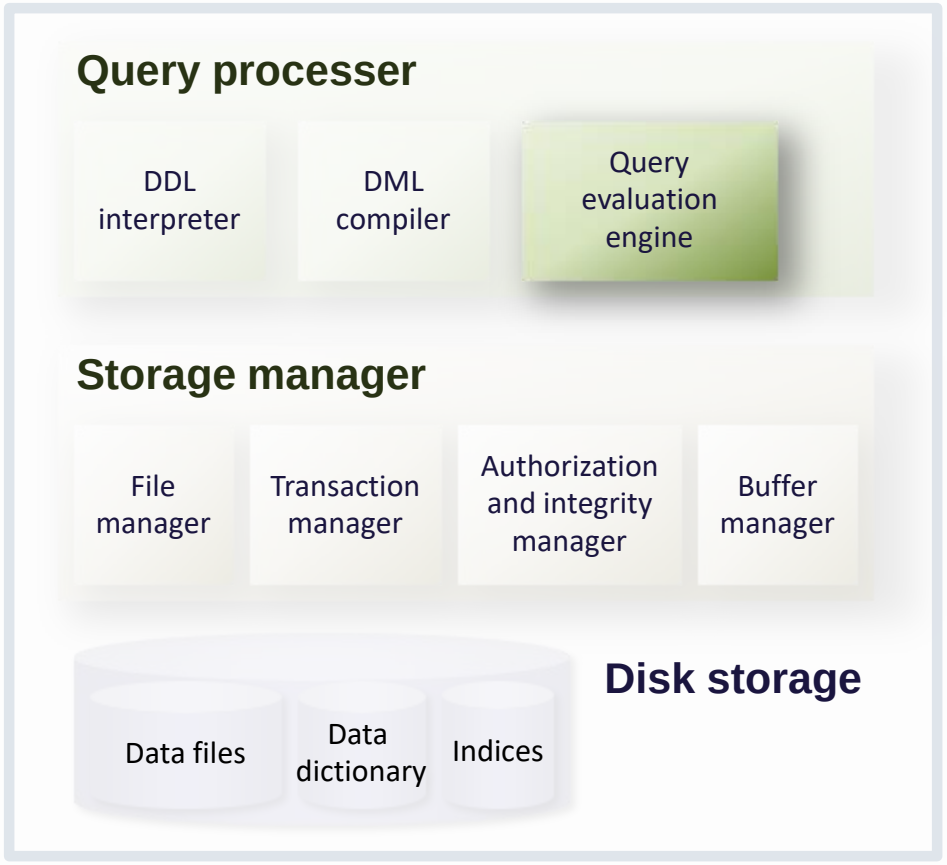
DML compiler

- **Translates DML statements in a query language into an evaluation plan.**
  - **Evaluation plan** - low-level instructions that the query evaluation engine understand.
  - **Query optimization** – Picks the lowest cost evaluation from among the alternative plans.



Query evaluation engine

- **Executes low-level instructions generated by the DML compiler.**



Summary

- Simple file systems are inadequate for enterprise needs – the 6 drawbacks.
- **Three powerful concepts supported by a DBMS:**
  - Data abstraction - 3 levels of abstraction, schema and instances.
  - Data modeling.
  - Database languages – DDL and DML.

Summary

- **Three functional components of a DBMS**
  - Disk Storage: data files, data dictionary, indexes
  - Storage manager: File manager, Transaction manager, Authorization and integrity manager, Buffer manager
  - Query processer: DDL interpreter, DML complier, Query evaluation engine

Where is a Database?

Physical security.

Lecture 1.

END

COMP3278A

Introduction to Database Management Systems

Dr. Ping Luo

Email : pluo@cs.hku.hk

Department of Computer Science, The University of Hong Kong