COMP 3311
DATABASE MANAGEMENT SYSTEMS

LECTURE 1
DATABASE MANAGEMENT SYSTEMS

DATABASE MANAGEMENT SYSTEMS: OUTLINE

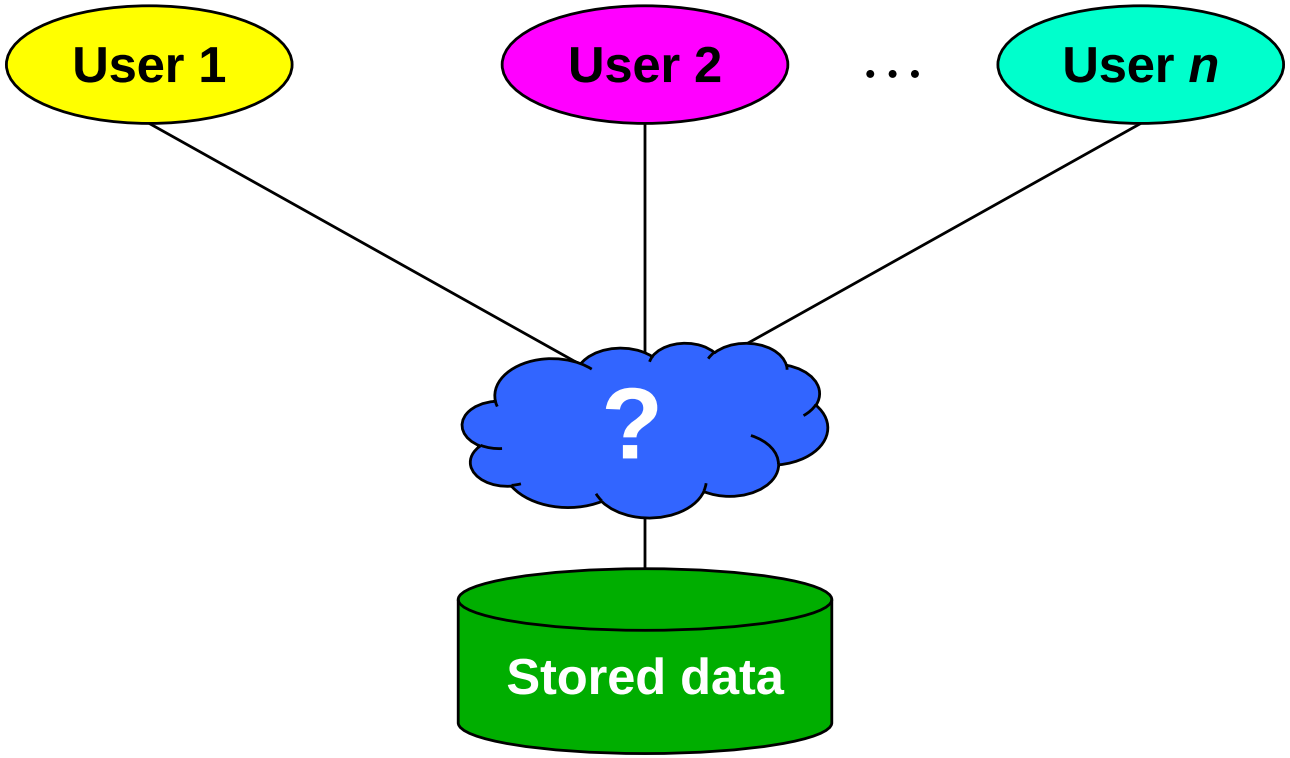
What Is A Database Management System (DBMS)?

Why Do We Need Database Management Systems?

Data Models and Levels of Abstraction

DBMS Architecture and Users

THE PROBLEM WE WANT TO ADDRESS



How best to manage stored data?

☞ **organize, access, share, protect, … .**

DATABASE

A *database* is a collection of related data within a specific business process or problem setting.

Data are facts such as age, salary, name, address, etc.

- A database has the following properties.
  - It is designed, built and populated with data for a specific purpose.

    Applications: sales, human resources, manufacturing, banking, real estate, stock trading, inventory management, social media, ride sharing, …
  - It usually represents some aspect of the real world.
  - The data have some inherent meaning.

☞ **Databases touch all aspects of our lives!**

DATABASE MANAGEMENT SYSTEM

A *database management system (DBMS)* is a general purpose software system used to manage databases.

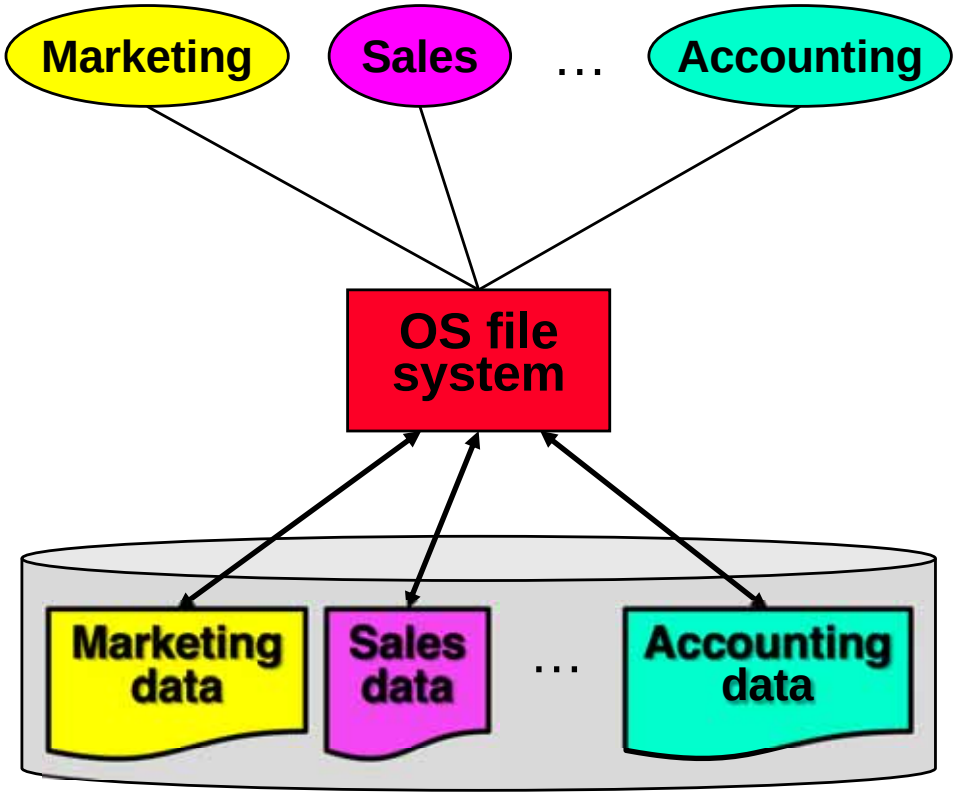
- A DBMS provides support/facilities for:
  - defining types, structures, constraints on data
  - storing and managing data on a storage device
  - manipulating data (querying, updating)
  - sharing data among many users
  - protecting data from loss, corruption, unauthorized access

Company	*Product*
Oracle	Oracle Database
IBM	DB2
Microsoft	Access, SQL Server
Sybase	Adaptive Server
Informix	Dynamic Server

A DBMS provides an environment for managing data that is both *convenient* and *efficient* to use.

FILE-BASED APPROACH TO MANAGING DATA

Applications access stored data using the facilities provided by an operating system file system.



Drawbacks

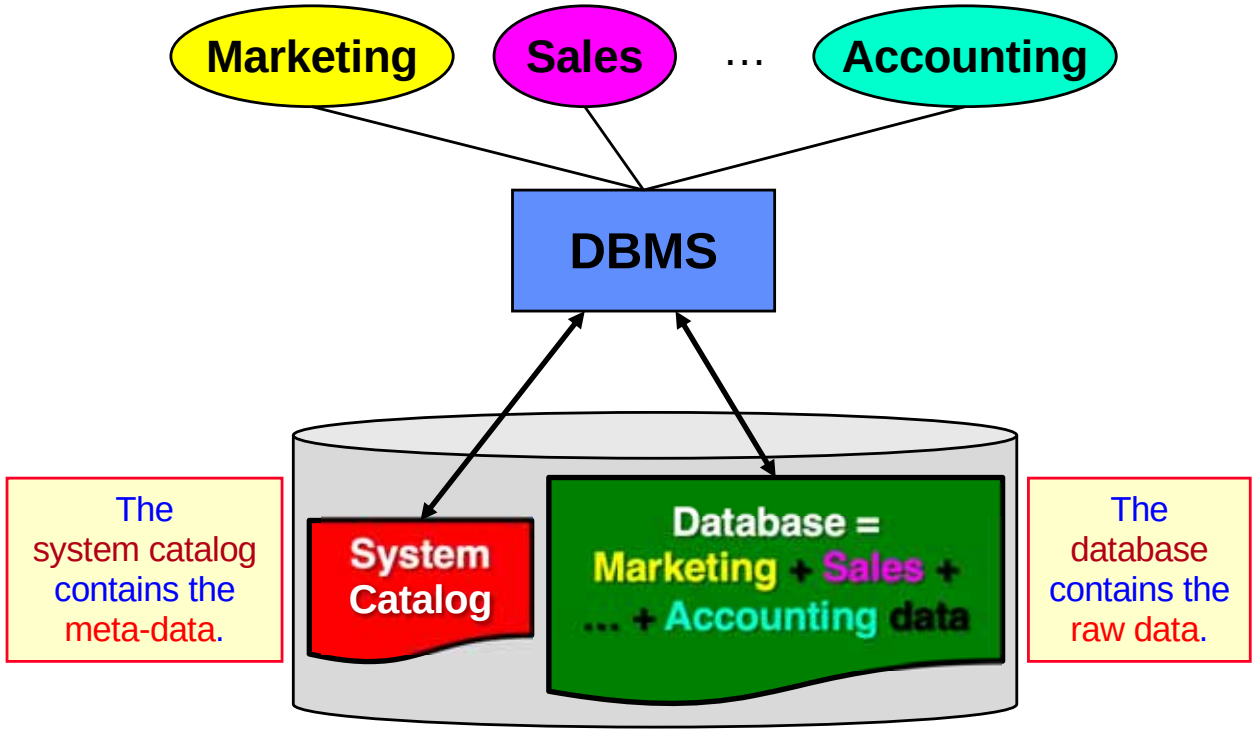
- Data duplication and inconsistency
- Difficulty in accessing data
- Data isolation
- Data integrity problems
- Atomicity of updates
- Concurrent access
- Security problems

FILE-BASED APPROACH: DRAWBACKS

- **Data duplication and inconsistency**
  - Data may be duplicated in several files leading to data inconsistency.
- **Difficulty in accessing data**
  - Unanticipated data needs often require writing new application programs.
- **Data isolation**
  - Data are often scattered in different files and in different formats making writing new application programs challenging.
- **Data integrity problems**
  - Constraints on data become part of the program code making them hard to change and making it hard to know what constraints apply.
  - New constraints are often hard to enforce especially across several files.
- **Atomicity of updates**
  - Since changes to data may involve several updates (e.g., a bank account transfer), hardware/software failures can cause data to become inconsistent.
- **Concurrent access**
  - Data may become inconsistent due to simultaneous access by many users (e.g. lost update).
- **Security problems**
  - Enforcing security can be challenging due to *ad hoc* data management.

DATABASE APPROACH TO MANAGING DATA

Applications access stored data using the facilities provided by a DBMS.



Major Principles

- **integrates** an organization's data.
- **separates** meta-data (description of data) and data.
- **supports** multiple views of data.
- **controls** definition and access of data centrally.

A DBMS provides automated solutions for the data management problems encountered when using file systems.

DATA MODELS

A *data model* is a set of concepts for describing data that defines
– properties – relationships – semantics – constraints

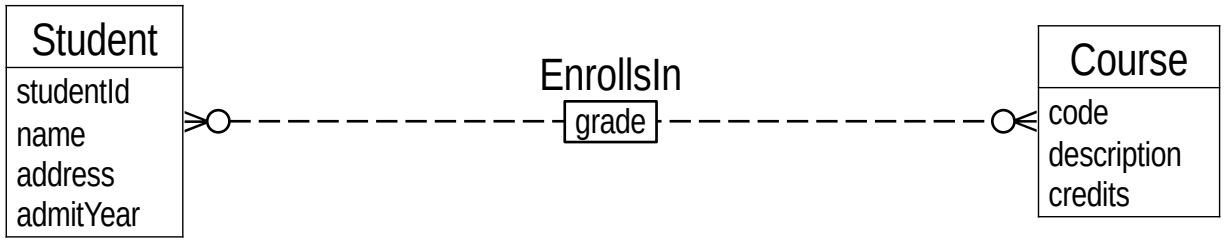
A data model is the fundamental mechanism used by a DBMS to describe and organize data and consists of:

1. **data structure types** ⟹ specify logical organization (properties, relationships and semantics)
2. **integrity constraints** ⟹ specify constraints (restrictions on properties and relationships)
3. **operations** ⟹ specify how data is accessed (e.g., R,I,U,D—Read, Insert, Update, Delete)

A data model describes how data can be organized logically as well as any restrictions on the data.

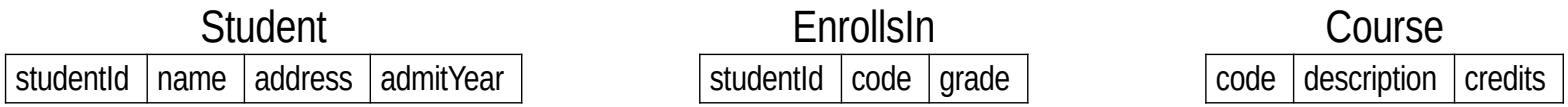
DATA MODELS: EXAMPLE

Entity-Relationship (E-R) model



☞ **Users view data as entities and explicit relationships among entities.**

Relational model



☞ **Users view data as tables and implicit relationships among tables.**

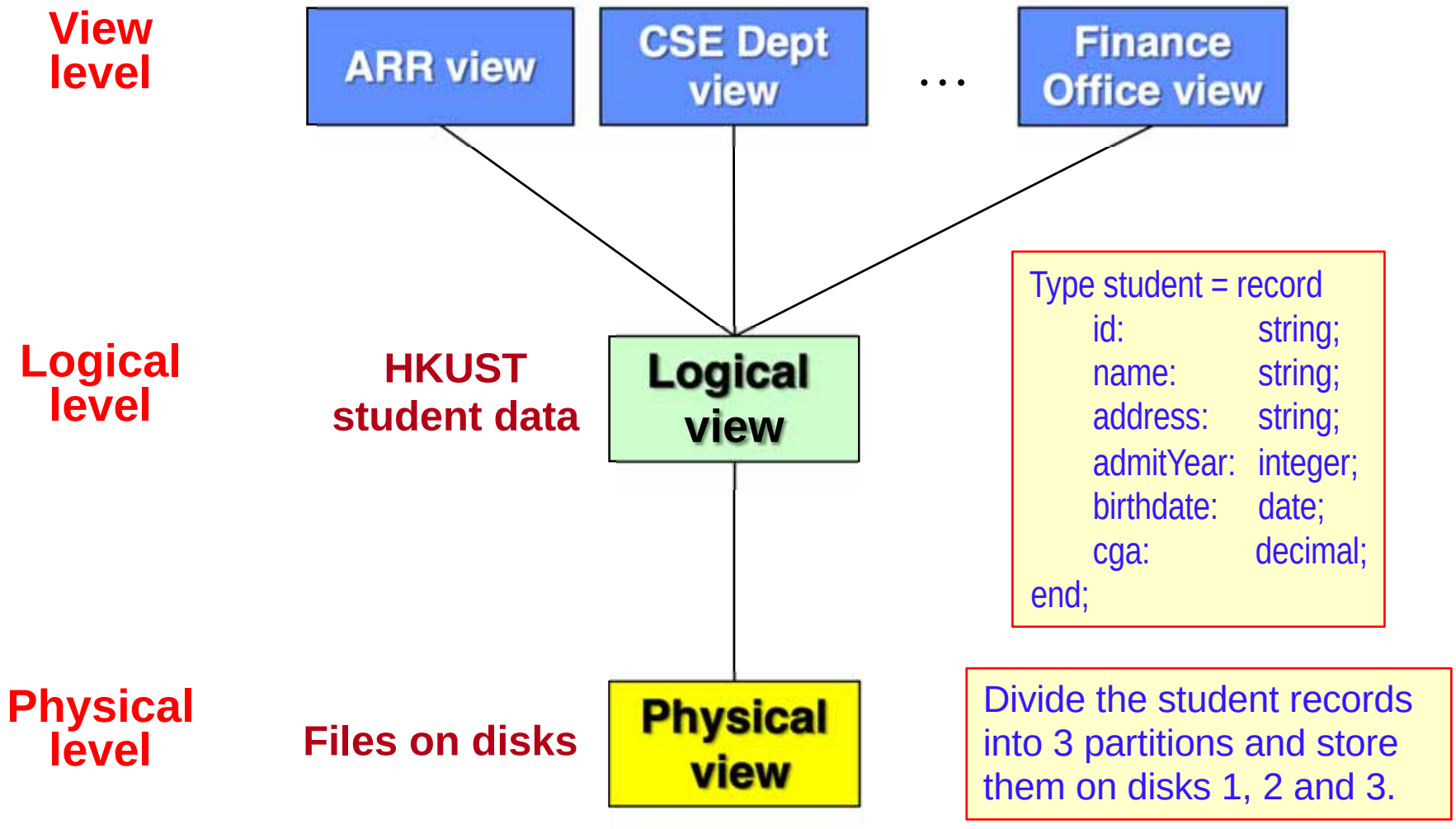
LEVELS OF ABSTRACTION

- One big problem in application development is the *separation* of application programs (i.e., code) from the data that they access.

- **Do I have to change my application program when I …**
  - replace my hard drive?
  - partition the data into two physical files (or merge two physical files into one)?
  - store salary as a floating point number instead of an integer?
  - develop other applications that use the same data?
  - add more data fields to support other applications?
  - index the data using a B^+-tree instead of a hash index?

A DBMS provides separation of application programs and data via several levels of abstraction.

LEVELS OF ABSTRACTION (CONTD)



LEVELS OF ABSTRACTION (cont'd)

Physical level: Describes how the data are actually stored on disk.

- Divide the student records into 3 partitions and store them on disks 1, 2 and 3.

Logical level: Describes what data are stored in the database and the relationships among the data.

- E.g., students are related to courses and also to fee information.
- Hides the details of how the data are physically stored from users.

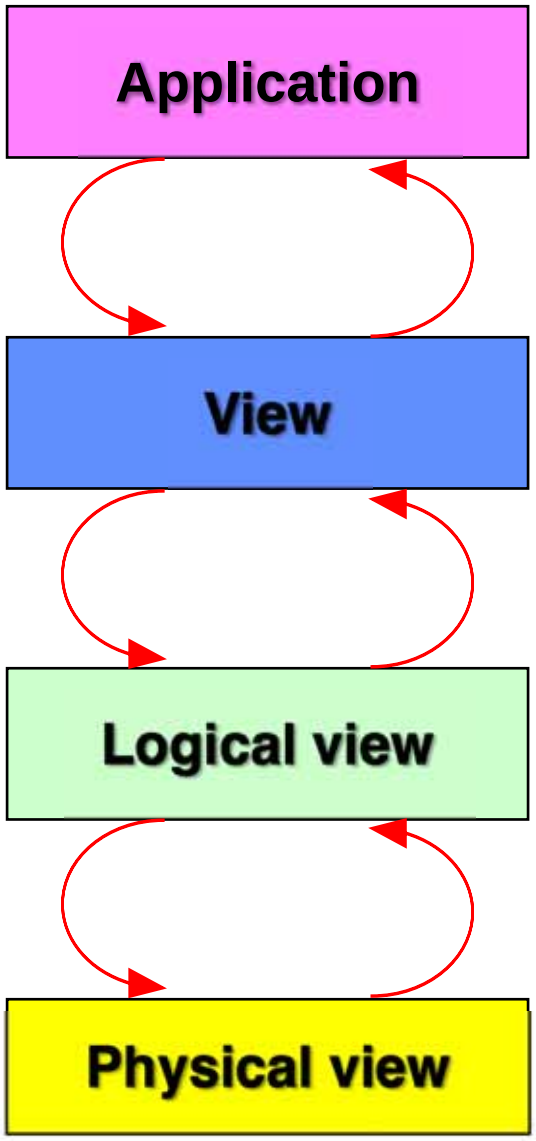
View level: Defines a subset (part) of the database for a particular application.

- Views can hide information for security/privacy purposes (e.g., cga) or add information not actually stored (e.g., age).

SCHEMAS AND INSTANCES

- A database *schema* describes the overall design of a database.
  - ☞ **A database schema changes infrequently, if at all.**
  - ☞ **A database schema is stored in the system catalog.**
- A DBMS uses several schemas, one for each level of abstraction, which *describes* the data at the corresponding level.
  - A view (subschema) describes the data that a user can access.
  - A logical schema describes the logical structure of the database (e.g., the set of students, courses and the relationship between them).
  - A physical schema describes the file formats and locations where the data are stored on disk.
- A database *instance* refers to the actual content of the database at a particular point in time.
  - ☞ **A database instance changes frequently as data are changed.**
  - ☞ **A database instance must conform to its corresponding schema.**

DATA INDEPENDENCE



Data independence **is the ability to modify a schema definition in one level of abstraction without affecting a schema definition in a higher level.**

(described by) ↔ **View (subschema)**

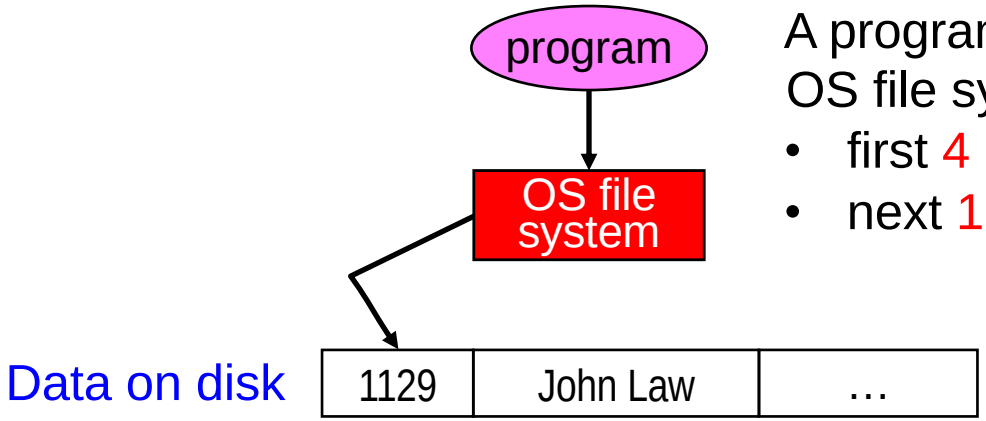
Logical data independence
(shields users from changes in the *logical structure*)

(described by) ↔ **Logical schema**

Physical data independence
(shields users from changes in the *physical structure*)

(described by) ↔ **Physical schema**

DATA INDEPENDENCE: EXAMPLE

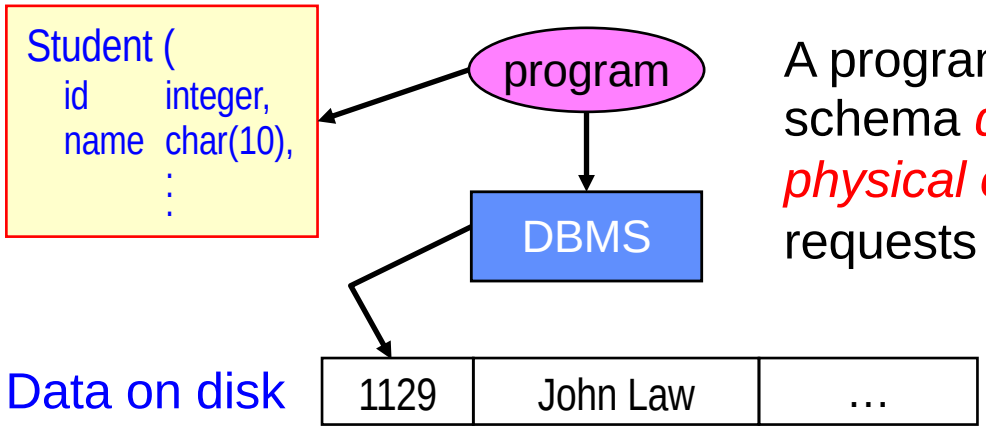


A program accessing the data via the OS file system has to know:

- first 4 bytes is an id (a number)
- next 10 bytes is a name (a string)

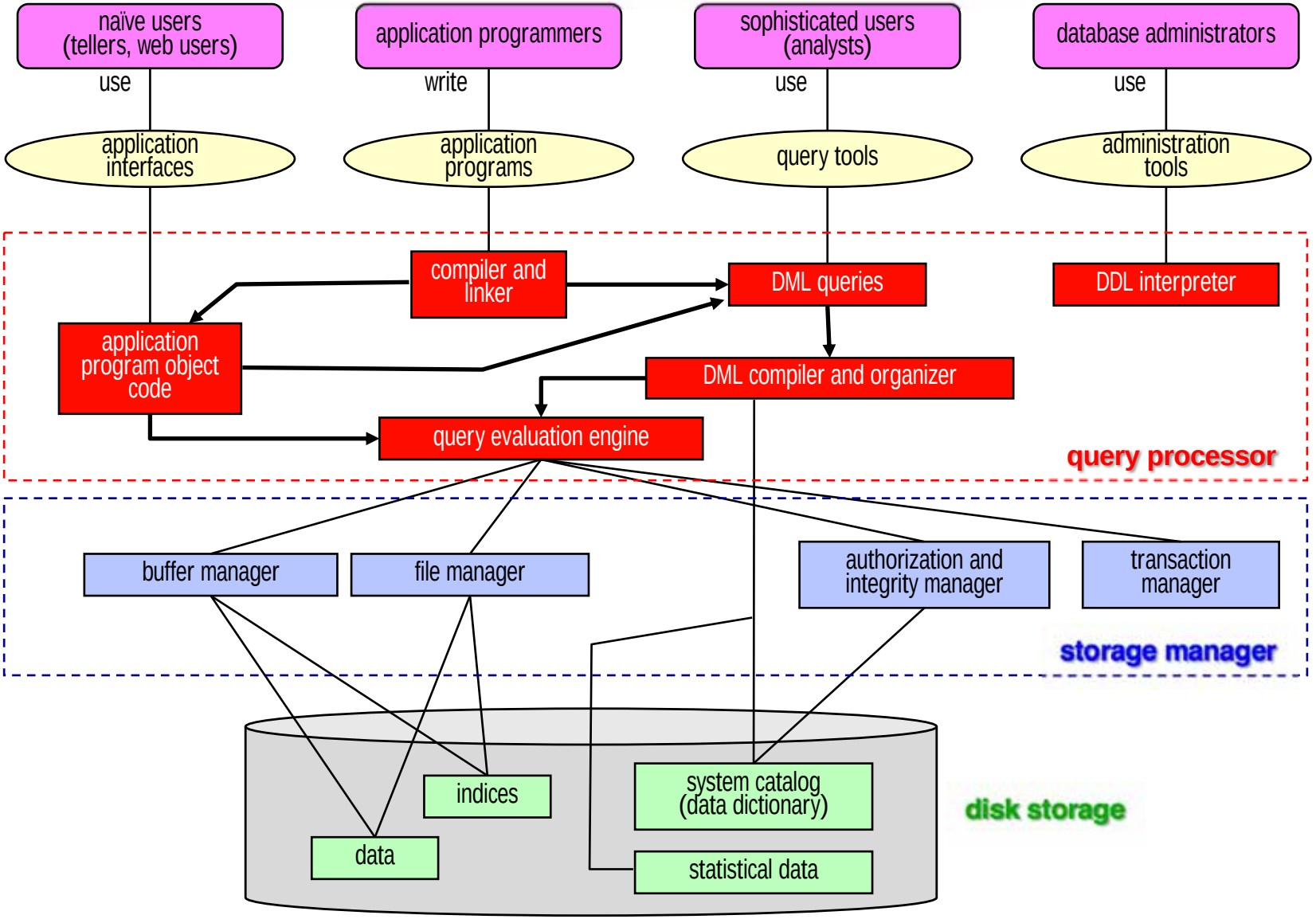
⋮

Schema



A program accessing the data via a schema *does not need to know its physical organization*; it simply requests the student's id, name, etc.

DBMS ARCHITECTURE



DBMS ARCHITECTURE: STORAGE MANAGER

- The ***storage manager*** provides the interface between the low-level data stored in the database and the application programs and queries submitted to the system.

  ☞ **It is responsible for storing, retrieving and updating data in the database.**

- The storage manager components include:
  - buffer manager (*fetches data from disk and caches it in main memory*)
  - file manager (*manages allocation of disk space*)
  - authorization and integrity manager (*controls database access; enforces constraints*)
  - transaction manager (*ensures database consistency despite system failures and concurrent access by multiple users*)

DBMS ARCHITECTURE: QUERY PROCESSOR

- The ***query processor*** translates nonprocedural queries and updates into efficient physical disk-level operations.

  ☞ **It simplifies and facilitates data access while providing good performance.**

- The query processor components include two languages:
  - *data definition language* (*DDL*) used to define the database schema (i.e., meta-data) in a formal language according to a data model.
  - *data manipulation language* (*DML*) used to access and manipulate data as organized by a data model.
    - Procedural DML: user specifies both *what* data is required and *how* to get the data.
    - Nonprocedural (declarative) DML: user specifies only *what* data is required not how to get the data
      - Structured Query Language (SQL) is a nonprocedural DML used in all commercial relational DBMSs.

DBMS USERS

End Users

Naïve users

- Use existing application programs (e.g., print monthly sales report).
- Interact with applications through a graphical user interface (GUI).

Application programmers

- Develop applications that interact with DBMS through DML calls.

Sophisticated users

- Issue queries either directly using a database query language (e.g., SQL) or via tools such as data analysis software.

Database Administrator (DBA)

– Coordinates all activities of the database system.

- Defines and maintains the schemas.
- Defines and maintains the physical organization.
- Monitors and optimizes the database performance.
- Monitors access and grants access rights.

A DBA must have a good understanding of an enterprise's information resources and needs.

DATABASE MANAGEMENT SYSTEMS: SUMMARY

- **Database management systems (DBMSs)** address the limitations of OS file systems for managing an enterprise's data.
- **Data independence** is fundamental to understanding how a DBMS manages data at different abstraction levels.
- **Data models** are the foundation for developing a database—the entity-relationship (E-R) model and relational model are commonly used in practice.
- **A DBMS provides many facilities** for query processing and storage management to efficiently handle the data management and data access needs of various users.