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Unit 1 (Introduction to Database Systems)

Introduction to Database Systems -Databases and Database users: Introduction, An example, Characteristics of Database Approach, Data Models, Schemas and Instances, Three-schema Architecture and Data Independence, The Database System Environment.
Data Modeling Using the Entity-Relationship Model- High-Level Conceptual Data Models for Database Design; A Sample Database Application; Entity Types, Entity Sets, Attributes and Keys; Relationship types, Relationship Sets, Roles and Structural Constraints; Weak Entity Types

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- Database Languages and Interfaces
- The Database System Environment.

Basic Definitions

- **Database:**
  - A collection of related data.
- **Data:**
  - Known facts that can be recorded and have an implicit meaning.
- **Mini-world:**
  - Some part of the real world about which data is stored in a database. For example, student grades and transcripts at a university.
- **Database Management System (DBMS):**
  - A software package/ system to facilitate the creation and maintenance of a computerized database.
- **Database System:**
  - The DBMS software together with the data itself. Sometimes, the applications are also included.

Problems with traditional approach

- Inconsistency
- Redundancy
- Loss of flexibility
- Multiple files
- Update Problem

Types of Databases and Database Applications

- Traditional Applications:
  - Numeric and Textual Databases
- More Recent Applications:
  - Multimedia Databases
  - Geographic Information Systems (GIS)
  - Data Warehouses
  - Real-time and Active Databases
  - Many other applications

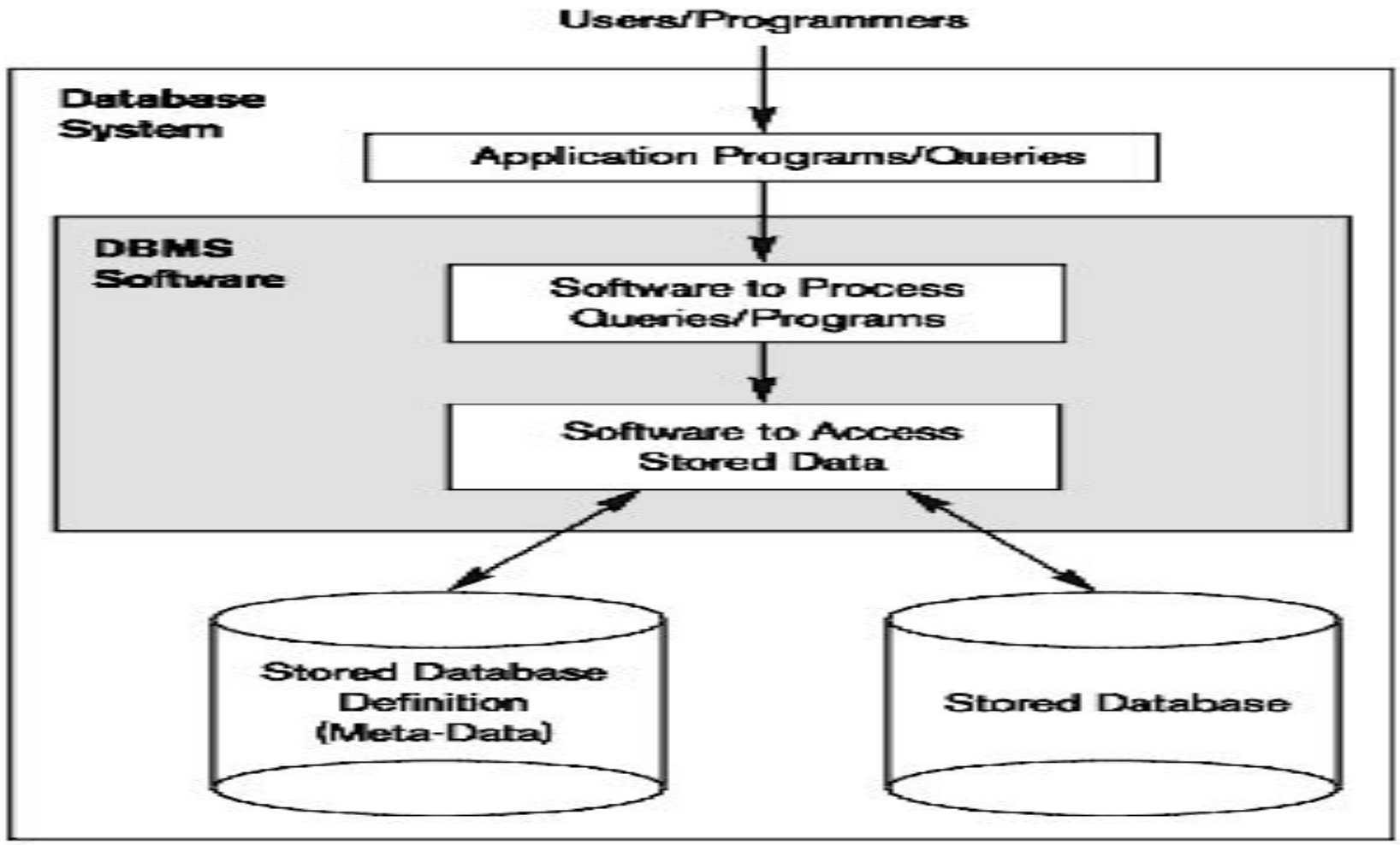
Typical DBMS Functionality

- *Define* a particular database in terms of its data types, structures, and constraints
- *Construct* or Load the initial database contents on a secondary storage medium
- *Manipulating* the database:
  - Retrieval: Querying, generating reports
  - Modification: Insertions, deletions and updates to its content
  - Accessing the database through Web applications
- *Processing* and *Sharing* by a set of concurrent users and application programs – yet, keeping all data valid and consistent

Typical DBMS Functionality

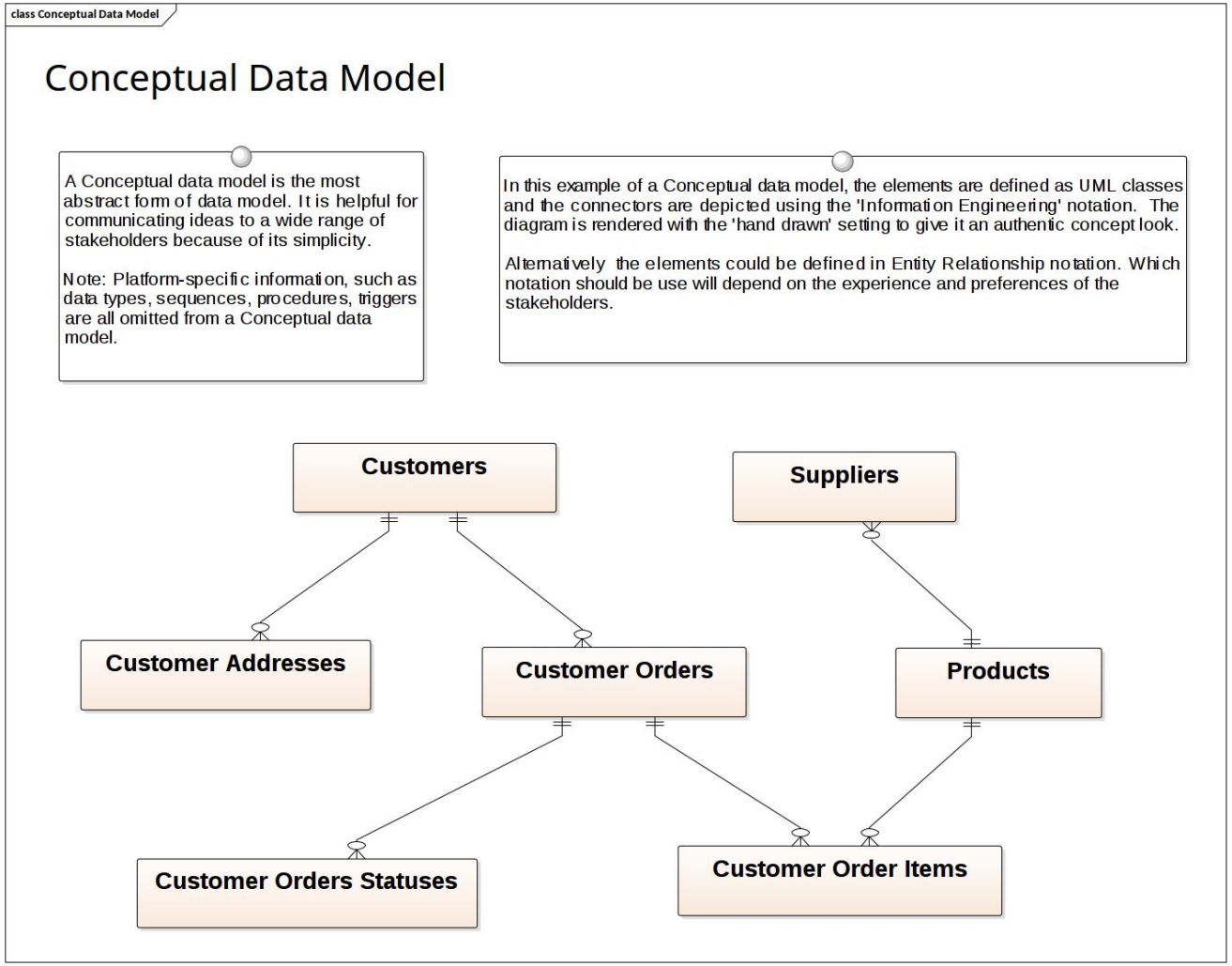
- Other features:
  - Protection or Security measures to prevent unauthorized access
  - Presentation and Visualization of data
  - Maintaining the database and associated programs over the lifetime of the database application
    - Called database, software, and system maintenance

Simplified database system environment



Example of a Database (with a Conceptual Data Model)

- **Mini-world for the example:**
  - Part of a UNIVERSITY environment.
- **Some mini-world *entities*:**
  - STUDENTs
  - COURSEs
  - SECTIONs (of COURSEs)
  - (academic) DEPARTMENTs
  - INSTRUCTORs



Example of a Database (with a Conceptual Data Model)

- **Some mini-world *relationships*:**
  - SECTIONs *are of specific* COURSEs
  - STUDENTs belong to SECTIONs
  - COURSEs *have prerequisite* COURSEs
  - INSTRUCTORs *teach* SECTIONs
  - COURSEs *are offered by* DEPARTMENTs
  - STUDENTs *major in* DEPARTMENTs

Main Characteristics of the Database Approach

- **Self-describing nature of a database system:**
  - A DBMS **catalog** stores the description of a particular database (e.g. data structures, types, and constraints)
  - The description is called **meta-data**.
  - This allows the DBMS software to work with different database applications such as University DB, Banking DB or Company DB.

- **Insulation between programs and data:**
  - Called **program-data independence**.
  - Allows changing data structures and storage organization without having to change the DBMS access programs.

Main Characteristics of the Database Approach

- **Data Abstraction:**
  - The characteristic that allows program-data independence and program-operation independence
    - Program-operation independence

      Allows changing data storage structures and operations without having to change the DBMS access programs.
  - A **data model** is used to hide storage details and present the users with a conceptual view of the database.
  - Relational model hides how the data is stored and how the operations are implemented. DB is represented in terms of entities, attributes and relationships among entities that is understood by most users.
  - Programs refer to the data model constructs rather than data storage details
- **Support of multiple views of the data:**
  - Each user may see a different view of the database, which describes **only** the data of interest to that user.

Main Characteristics of the Database Approach

- A DBMS must enforce following transaction properties
  - Isolation
    - Each transaction appears to execute in isolation from other transactions.
  - Atomicity
    - Either all the database operations in a transaction are executed or none are.
- *Concurrency control* within the DBMS guarantees that each **transaction** is correctly executed or aborted
- *Recovery* subsystem ensures each completed transaction has its effect permanently recorded in the database
- **OLTP** (Online Transaction Processing) is a major part of database applications. This allows hundreds of concurrent transactions to execute per second.

Database Users

- Users may be divided into
  - Those who actually use and control the database content, and those who design, develop and maintain database applications (called “Actors on the Scene”), and
  - Those who design and develop the DBMS software and related tools, and the computer systems operators (called “Workers Behind the Scene”).

Database Users

- Actors on the scene

  - **Database Administrators:**
    - Responsible for authorizing access to the database, for coordinating and monitoring its use, acquiring software and hardware resources, controlling its use and monitoring efficiency of operations.

  - **Database Designers:**
    - Responsible to define the content, the structure, the constraints, and functions or transactions against the database. They must communicate with the end-users and understand their needs.

  - **System Analysts and Application Programmers (Software Engineers)**
    - Familiar with the full range of capabilities provided by the DBMS to accomplish their tasks

Categories of End-users

- **End-users:** They use the data for queries, reports and some of them update the database content. End-users can be categorized into:
  - **Casual**: access database occasionally when needed
  - **Naïve** or Parametric: they make up a large section of the end-user population.
    - They use previously well-defined functions in the form of "canned transactions" against the database.
    - Examples are bank-tellers or reservation clerks who do this activity for an entire shift of operations.
  - **Sophisticated:**
    - These include business analysts, scientists, engineers, others thoroughly familiar with the system capabilities.
    - Many use tools in the form of software packages that work closely with the stored database.
  - **Stand-alone:**
    - Mostly maintain personal databases using ready-to-use packaged applications.
    - An example is a tax program user that creates its own internal database.
    - Another example is a user that maintains an address book

Workers behind the Scene

- DBMS System Designers and Implementers

  Example: Engineers at companies like Oracle, Microsoft (SQL Server), or IBM (DB2) work on developing DBMS features such as query processing, transaction management, and user interface tools.

  - Design and implement the DBMS modules and interfaces as a software package

  - Tool Developers

    Example: Developers who create ER modeling tools (like ERwin or Lucidchart for database design) or optimization tools that improve database performance, indexing, and query efficiency.

    - Design and implement tools – the software packages that facilitate database modeling and design, database system design, and improved performance

  - Operators and Maintenance Personnel

    Example: IT operators who monitor the database server's health, perform regular backups, and update security patches to keep the database safe and functional

    - Responsible for the actual running and maintenance of the hardware and software environment for the database system

Data Models

- **Data Abstraction**
  - Suppression of details of data organization and storage and the highlighting of the essential features for an improved understanding of data

- **Data Model:**
  - A collection of concepts to describe the ***structure*** of a database, the ***operations*** for manipulating these structures, and certain ***constraints*** that the database should obey.
  - It provides necessary means to achieve data abstraction

- **Data Model Structure and Constraints:**
  - Constructs are used to define the database structure
  - Constructs typically include ***elements*** (and their ***data types***) as well as groups of elements (e.g. ***entity, record, table***), and ***relationships*** among such groups
  - Constraints specify some restrictions on valid data; these constraints must be enforced at all times

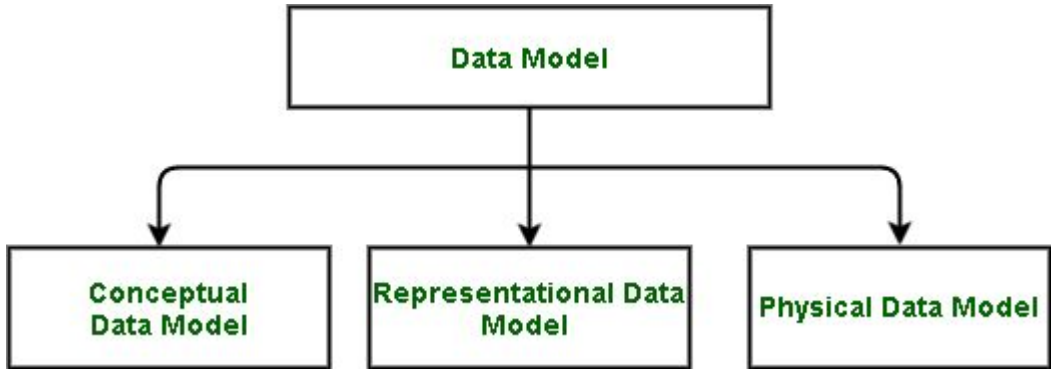
Data Models

- **Data Model Operations:**
  - These operations are used for specifying database *retrievals* and *updates* by referring to the constructs of the data model.
  - Operations on the data model may include ***basic model operations*** (e.g. generic insert, delete, update) and ***user-defined operations*** (e.g. compute_student_gpa, update_inventory)

Categories of Data Models

- **Conceptual (high-level, semantic) data models:**
  - Provide concepts that are close to the way many users perceive data.
    - (Also called ***entity-based*** or ***object-based*** data models.)
- **Physical (low-level, internal) data models:**
  - Provide concepts that describe details of how data is stored in the computer. These are usually specified in an ad-hoc manner through DBMS design and administration manuals
- **Implementation (representational) data models:**
  - Provide concepts that fall between the above two, used by many commercial DBMS implementations (e.g. relational data models used in many commercial systems).

Conceptual models provide an intuitive, user-oriented view of data.
Physical models focus on storage and retrieval specifics.
Implementation models blend both, serving as the practical framework for most databases in use today.



Database Schema

- Database Schema
  - The ***description*** of a database.
  - Includes descriptions of the database structure, data types, and the constraints on the database.
- Schema Diagram
  - An ***illustrative*** display of (most aspects of) a database schema.
- Schema Construct
  - A ***component*** of the schema or an object within the schema, e.g., STUDENT, COURSE.

Example of a Database Schema

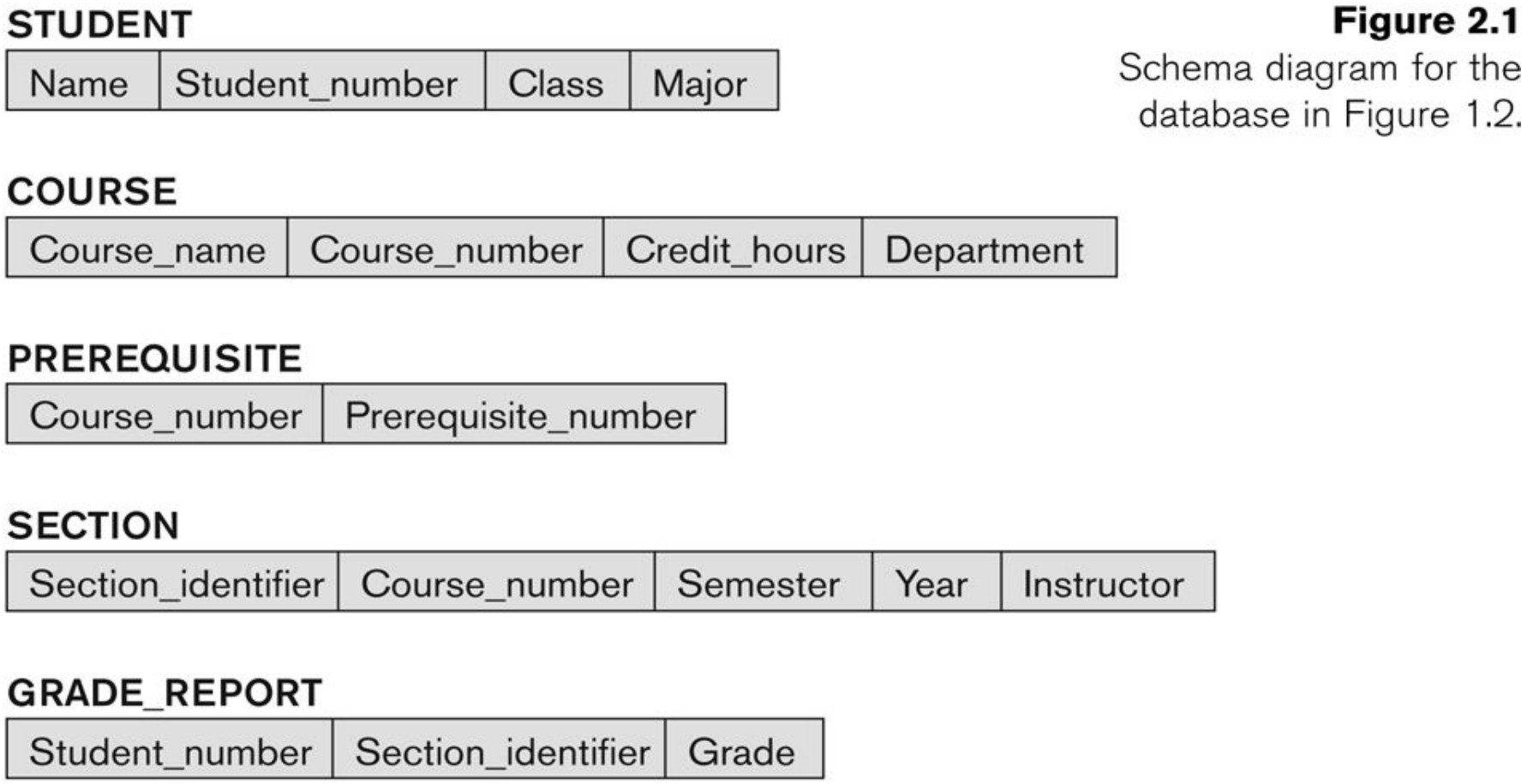


Figure 2.1
Schema diagram for the database in Figure 1.2.

Database State

In summary, the database state is a momentary capture of all data in the database, with specific terms for instances and distinctions for initial and valid states.

- Database State
  - The actual data stored in a database at a ***particular moment in time***. This includes the collection of all the data in the database.
  - Also called database instance (or occurrence or snapshot).
    - The term *instance* is also applied to individual database components, e.g. *record instance, table instance, entity instance*
    - Refers to the ***content*** of a database at a moment in time.
- Initial Database State
  - Refers to the database state when it is initially loaded into the system.
- Valid State
  - A state that satisfies the structure and constraints of the database.

DB Schema v/s DB State

- Distinction
  - The ***database schema*** changes very infrequently.
  - The ***database state*** changes every time the database is updated.
- **Schema** is also called **intension**.
- **State** is also called **extension**.

Three-Schema Architecture

- Proposed to support DBMS characteristics of:
  - **Program-data independence.**
  - Support of **multiple views** of the data.

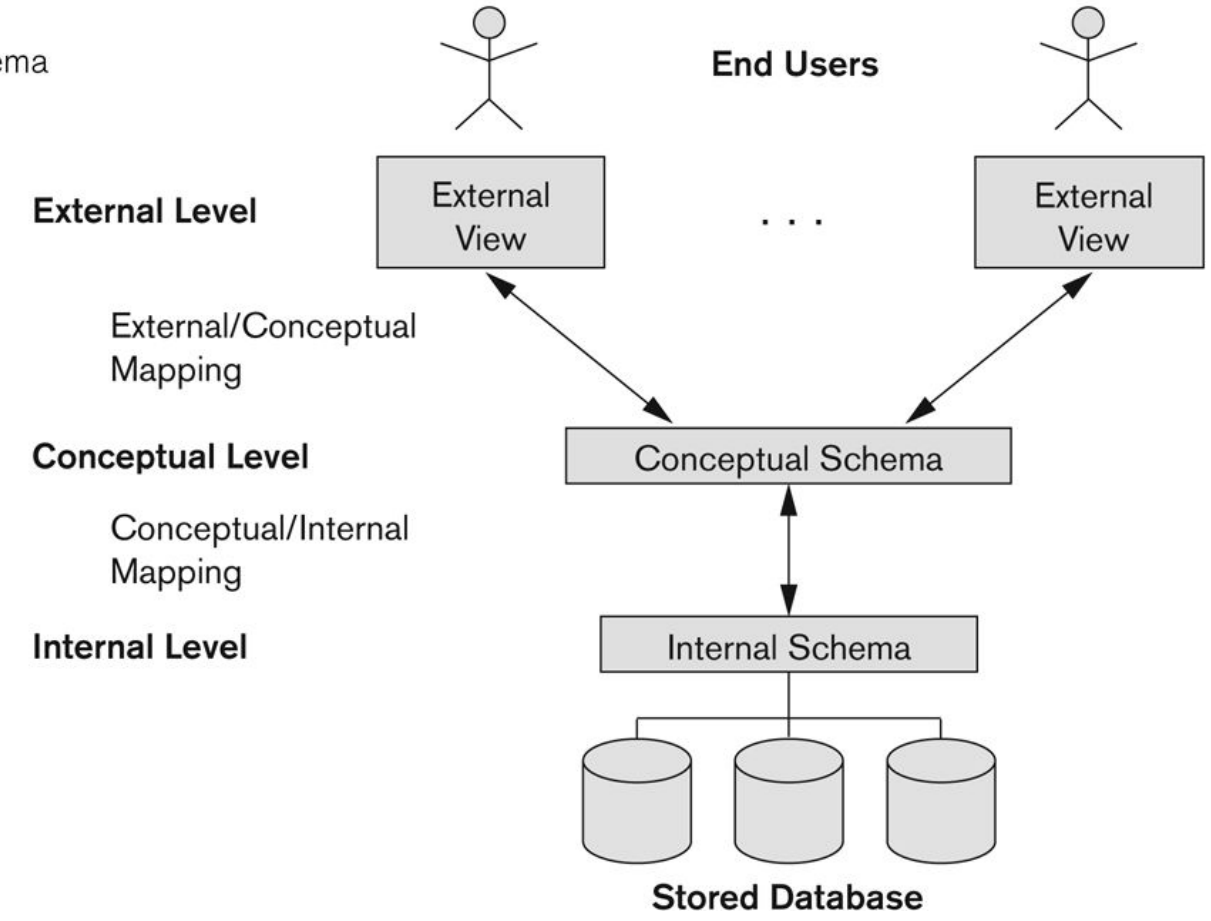
- Its goal is to separate the user applications and the physical database.

The Three-Schema Architecture

- Defines DBMS schemas at ***three*** levels:
  - **Internal schema** at the internal level to describe physical storage structures and access paths (e.g indexes).
    - Typically uses a **physical** data model.
  - **Conceptual schema** at the conceptual level to describe the structure and constraints for the whole database for a community of users. It describes entities, data types, relationships, user operations and constraints.
    - Uses a **conceptual** or an **implementation** data model.
  - **External schemas** at the external level (or view level) to describe the various user views.
    - Usually uses the same data model as the conceptual schema.

The Three-Schema Architecture

Figure 2.2
The three-schema architecture.



Data Independence

- **Logical Data Independence:**
  - The capacity to change the conceptual schema without having to change the external schemas and their associated application programs.
- **Physical Data Independence:**
  - The capacity to change the internal schema without having to change the conceptual schema.
  - For example, the internal schema may be changed when certain file structures are reorganized or new indexes are created to improve database performance

Data Independence

- When a schema at a lower level is changed, only the **mappings** between this schema and higher-level schemas need to be changed in a DBMS that fully supports data independence.

- The higher-level schemas themselves are **unchanged**.
  - Hence, the application programs need not be changed since they refer to the external schemas.

DBMS Languages

- Data Definition Language (DDL)

- Data Manipulation Language (DML)
  - High-Level or Non-procedural Languages: These include the relational language SQL
    - May be used in a standalone way or may be embedded in a programming language

  - Low Level or Procedural Languages:
    - These must be embedded in a programming language

DBMS Languages

- **Data Definition Language (DDL):**
  - Used by the DBA and database designers to specify the conceptual schema of a database.
  - In many DBMSs, the DDL is also used to define internal and external schemas (views).
  - In some DBMSs, separate **storage definition language (SDL)** and **view definition language (VDL)** are used to define internal and external schemas.
    - SDL is typically realized via DBMS commands provided to the DBA and database designers

DBMS Languages

- **Data Manipulation Language (DML):**
  - Used to specify database retrievals and updates
  - DML commands (data sublanguage) can be *embedded* in a general-purpose programming language (host language), such as COBOL, C, C++, or Java.
    - A library of functions can also be provided to access the DBMS from a programming language
  - Alternatively, stand-alone DML commands can be applied directly (called a *query language*).

Types of DML

- **High Level or Non-procedural Language:**

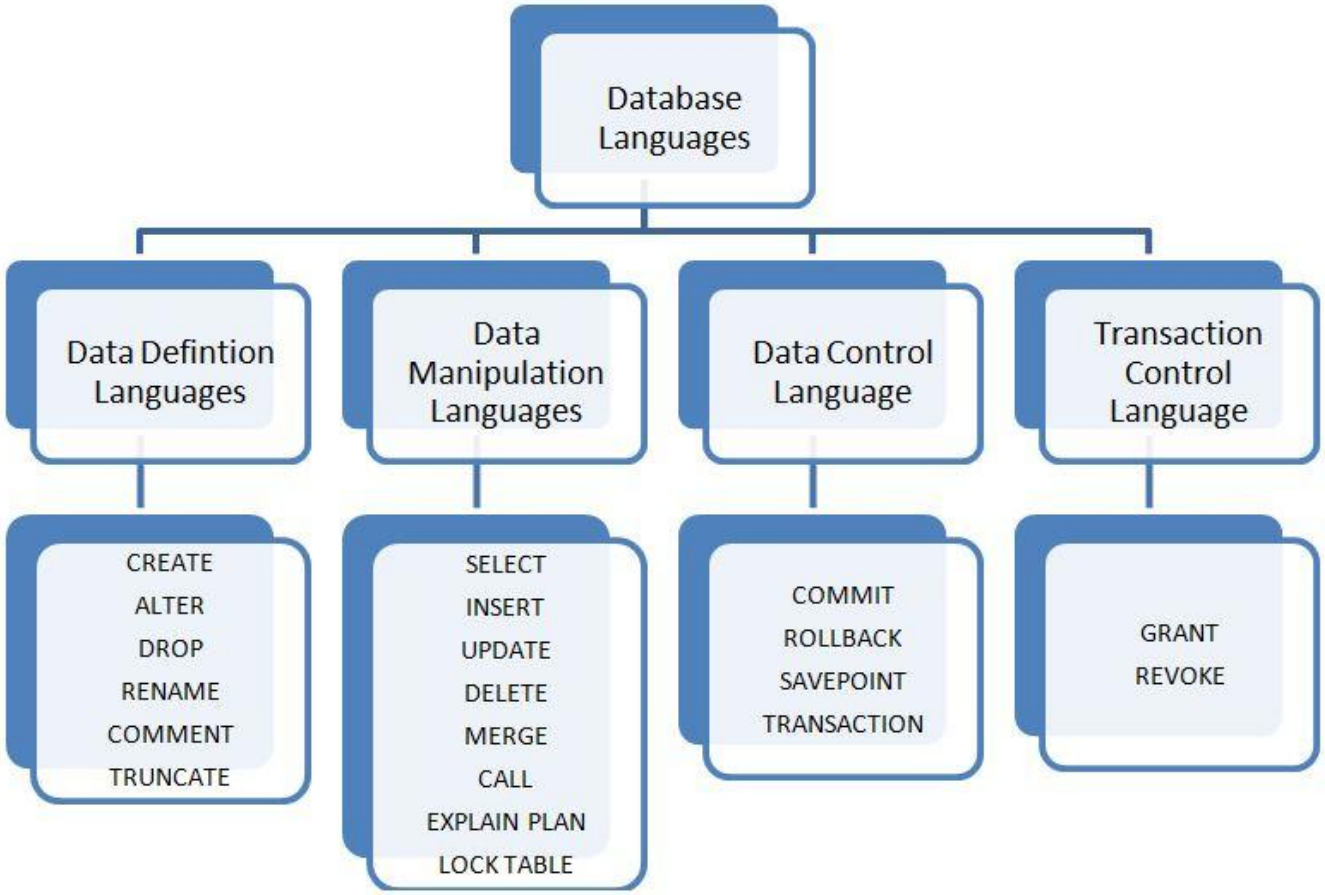
Allows users to specify what data to retrieve or manipulate without detailing how to perform these operations.
Operates on sets of data (multiple records) in a single statement, hence referred to as set-oriented DML.

  - For example, the SQL relational language
  - Are "set"-oriented and specify what data to retrieve rather than how to retrieve it. Many records can be retrieved in one DML statement
  - Also called **declarative** languages.

- **Low Level or Procedural Language:**
  - Retrieve data one record-at-a-time;
  - Constructs such as looping are needed to retrieve multiple records, along with positioning pointers.

equires users to specify how to retrieve and process data, often operating on one record at a time.
Needs to be embedded in a programming language to control the flow of data processing.

DBMS Languages



Typical DBMS Component Modules

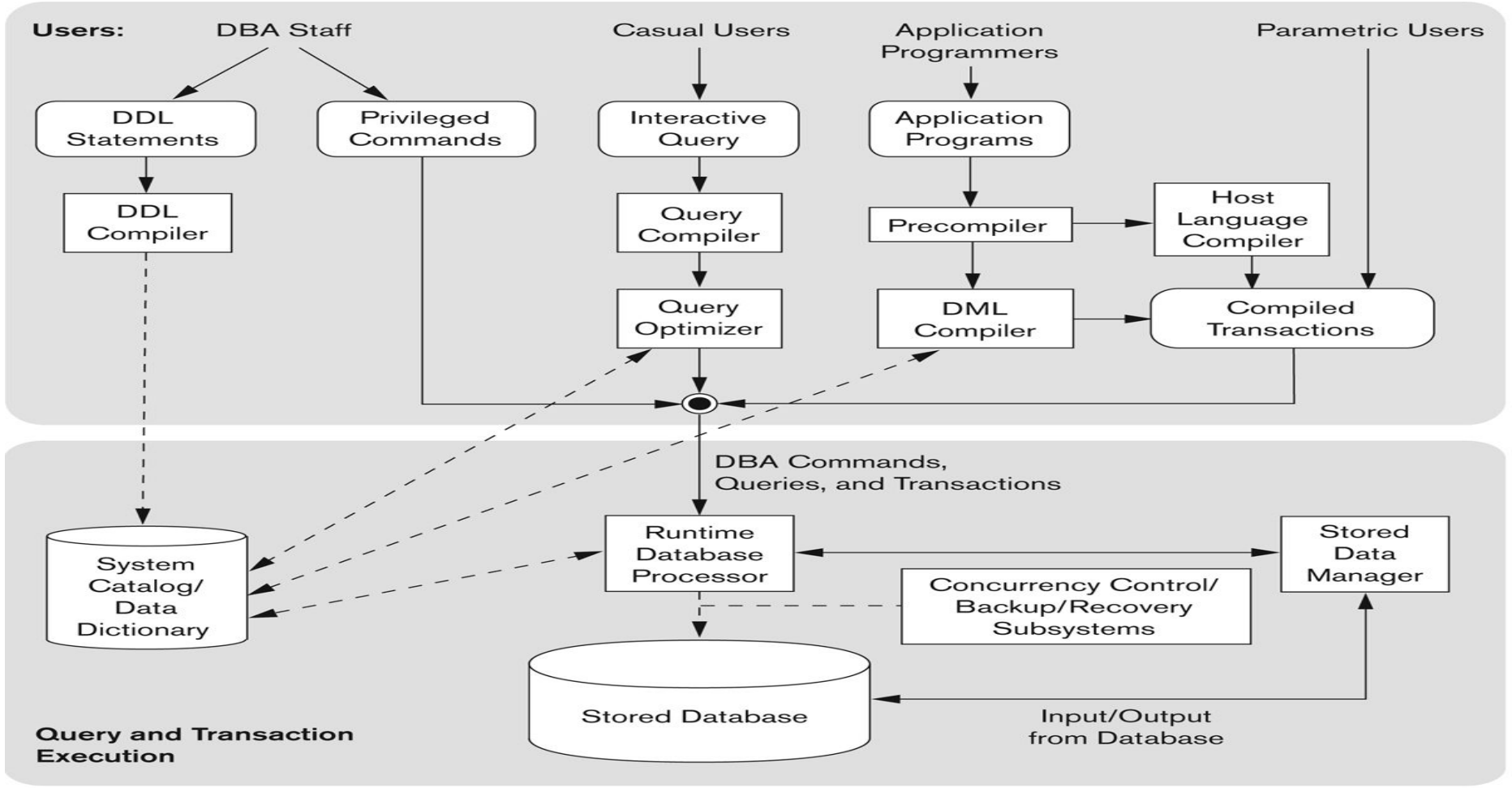


Figure 2.3
Component modules of a DBMS and their interactions.

Thank YOU