# Module 1
# Database Systems Concepts and Architecture

Need for database systems – Characteristics of Database Approach – Advantages of using DBMS approach - Actors on the Database Management Scene: Database Administrator - Classification of database management systems- **Data Models – Schemas and Instances - Three-Schema Architecture - The Database System Environment -Centralized and Client/Server Architectures for DBMSs – Overall Architecture of Database Management Systems**

## Reference :

- ***R. Elmasri & S. B. Navathe, Fundamentals of Database Systems, Addison Wesley, 7th Edition, 2016***
- ***A. Silberschatz, H. F. Korth & S. Sudarshan, Database System Concepts, McGraw Hill,7th Edition 2019.***

## Data Models

- **Definition :** A collection of concepts that can be used to describe the structure of a database.
- Data model provides the necessary means to achieve this **abstraction**
- **Structure of a database -** includes
- data types
- relationships
- constraints that apply to the data
- Most data models also include a set of **basic operations** for specifying retrievals and updates on the database.

## Data Models -Three Main Categories

- **Conceptual (High-level)**
  - ✓ Entity-Relationship (ER) Model

- **Representational (Implementation-level)**
  - ✓ Relational Model (most common)
  - ✓ Network Model (legacy)
  - ✓ Hierarchical Model (legacy)

- **Physical (Low-level)**
  - ✓ Linear
  - ✓ Hierarchical (Tree-based)
  - ✓ Indexes, File Storage

## Schemas, Instances, and Database State

- **Schema:** Description/structure of the database
  - Defined during **database design**
  - Rarely changes; used by the **DBMS**
  - Describes:
    - Record types,Attributes,Constraints
  - Also called **Intension**
  - Stored in **DBMS catalog** (as metadata)
- **Instance:** Actual data stored in the database at a given moment
- **Database State:** The content of the database at a specific time (snapshot)

## Schema diagram for the database

**STUDENT**

| Name | Student_number | Class | Major |
|---|---|---|---|

**COURSE**

| Course_name | Course_number | Credit_hours | Department |
|---|---|---|---|

**PREREQUISITE**

| Course_number | Prerequisite_number |
|---|---|

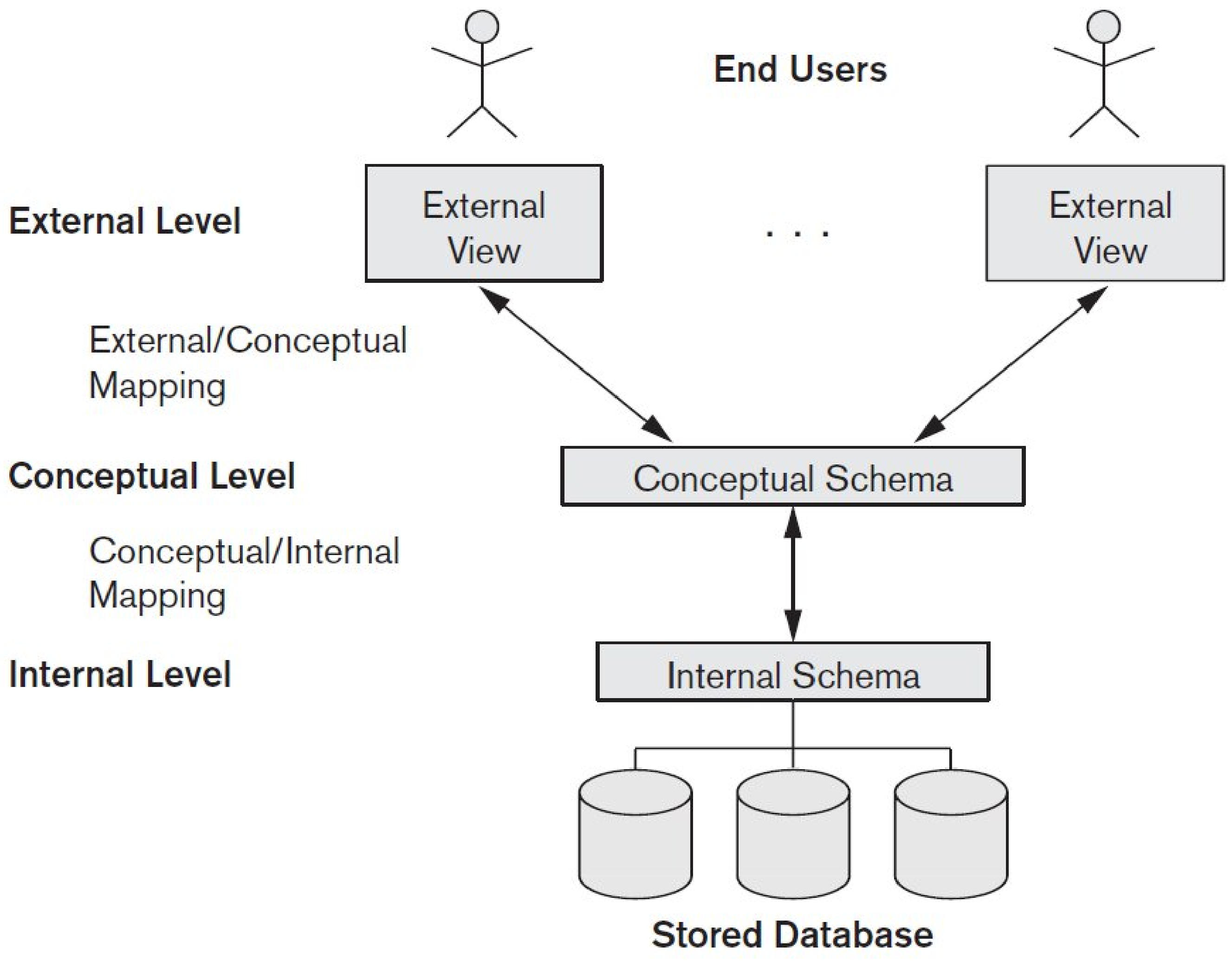
**SECTION**

| Section_identifier | Course_number | Semester | Year | Instructor |
|---|---|---|---|---|

**GRADE_REPORT**

| Student_number | Section_identifier | Grade |
|---|---|---|

# The Three-Schema Architecture



## Goal for the Three-Schema Architecture

- Self-describing database using **catalog**
- **Program-data independence**
- **Support for multiple user views**
- Visualize and manage **data abstraction**

**Separates user applications from physical storage**

Composed of:

1) Internal Level - Describes **physical storage structure**

•Uses **physical data model and**

•Specifies:

- File structures
- Indexing/access paths
- Record layouts

•Known as the internal schema

## Three-Schema Architecture

**Conceptual Level**

Describes **entire logical structure** of the database

Uses **representational data model**

Independent of physical storage

Captures:

- Entities, relationships
- Data types, operations
- Integrity constraints

Known as the **conceptual schema**

**External Level (User Views)**

Defines **user-specific views** of data

Multiple external schemas possible

Hides details irrelevant to the user

Each view tailored for a **specific user group**

Known as **external schema**

## Three-Schema Architecture

**Data Independence :** nature whereby one can change the structure of the database without having to change its implementation or data.

**Physical Data Independence**:

Change in internal schema does **not** affect conceptual schema

**Examples of changes under Physical Data Independence**

- It is by the use of new storage devices like Hard Drive or Magnetic Tapes
- Modifying the file organization technique in the Database
- Switching to different data structures.
- Changing the access method.
- Modifying indexes.
- To change the compression techniques or hashing algorithms.
- To change the Location of the Database from say C Drive to D Drive.

## Three-Schema Architecture- Data Independence

**Logical Data Independence**:

Change in conceptual schema does **not** affect external schemas

**Examples of changes under Logical Data Independence**

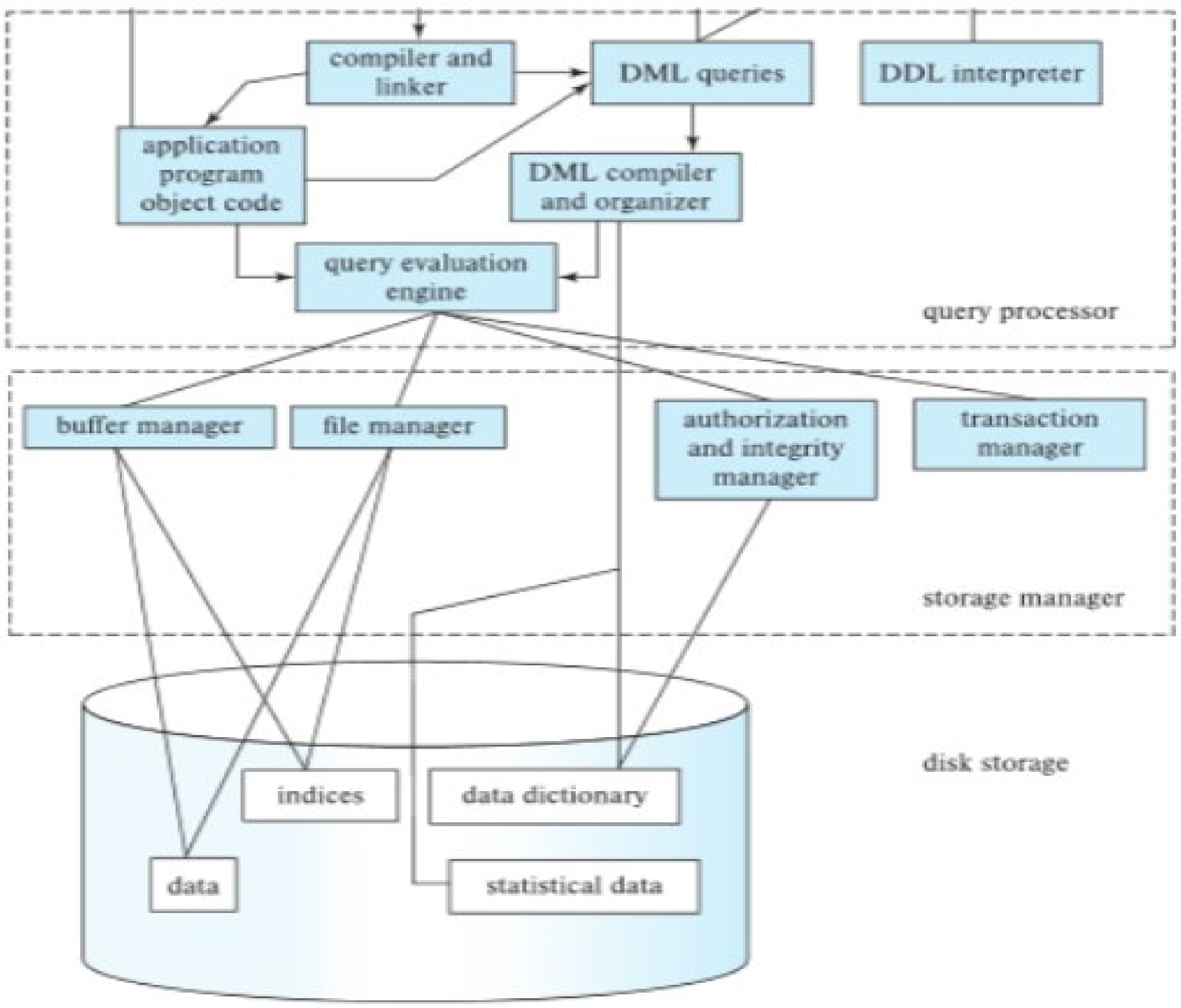
- To Add/Modify/Delete a new attribute, entity or relationship is possible without a rewrite of existing application programs.
- Merging two records into one.
- To break an existing record i.e to divide the record into two or more records.

**Logical Data Independence Harder to Achieve Compared to Physical Data Independence?**

- The application programs are heavily dependent on logical format of the data they access, hence a change in conceptual level might require the change of the entire program application .

- But ,change in the location of database or modifying file organization or use of new storage device etc. Will not require the change at the higher logical levels.

# Overall Architecture of Database Management Systems



## Overall Architecture of Database Management Systems

**Database Architecture** refers to the internal components of the DBMS, including the Query Processor, Storage Manager, and Disk Storage. It also defines the interaction of these components.

**Query Processor**:

- Interprets and executes user queries from application programs.
- Translates high-level queries into low-level instructions for execution.

**Components of Query Processor**:

- **DML Compiler**:
  Converts Data Manipulation Language (DML) statements into low-level machine instructions.
- **DDL Interpreter**:
  Processes Data Definition Language (DDL) statements and generates metadata stored in system catalog tables.
- **Embedded DML Pre-compiler**:
  Translates DML statements embedded in application programs into standard procedural calls.
- **Query Optimizer**:
  Improves query efficiency by selecting the optimal query execution plan.
  Considers factors like indexes, join order, and system resources to minimize execution time.

## Overall Architecture of Database Management Systems

### Storage Manager (Database Control System)

- Acts as an interface between the physical database and user queries.
- Manages **data storage, retrieval, updating, and deletion**.
- Ensures **data integrity, consistency, and security** by enforcing constraints and executing DCL (Data Control Language) statements.

**Components of Storage Manager**:

- **Authorization Manager**:
  Ensures **role-based access control**; verifies user permissions before allowing any operation.
- **Integrity Manager**:
  Validates **integrity constraints** during database modifications to maintain data correctness.
- **Transaction Manager**:
  Controls **concurrent transactions** to ensure that the database stays in a **consistent state** before and after execution.
- **File Manager**:
  Handles **file organization and storage**, including managing the structure and space of physical database files.
- **Buffer Manager**:
  Manages **cache memory**, coordinating the movement of data between **main memory** and **secondary storage** for efficient access.

## Overall Architecture of Database Management Systems

**Role of Database Administrator (DBA)**

- responsible for the **overall management and maintenance** of the database system.
- Ensures **data availability, security, integrity, and performance**.
- **Database Design & Architecture**:
  - Plans and structures the **logical and physical design** of the database.
  - Ensures scalability, normalization, and proper data modeling.
- **Security Management**:
  - Implements **Role-Based Access Control (RBAC)**.
  - Applies **encryption** to protect data.
  - Enforces **strong authentication mechanisms**, including **Multi-Factor Authentication (MFA)**.
- **Backup & Recovery**:
  - Schedules and manages **regular backups**.
  - Develops and tests **disaster recovery plans** to ensure data restoration in case of failure or loss.
- **Performance Tuning**:
  - Monitors and optimizes **query execution**, **indexing**, and **resource allocation**.
  - Ensures the DBMS performs **efficiently under varying workloads**.

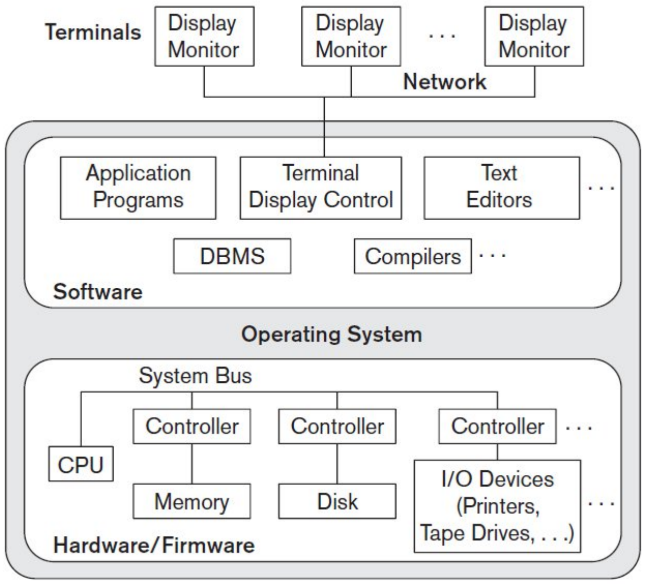
# Centralized DBMS Architecture

All database processing and application logic occur on a **single central computer** (usually a mainframe or powerful server).

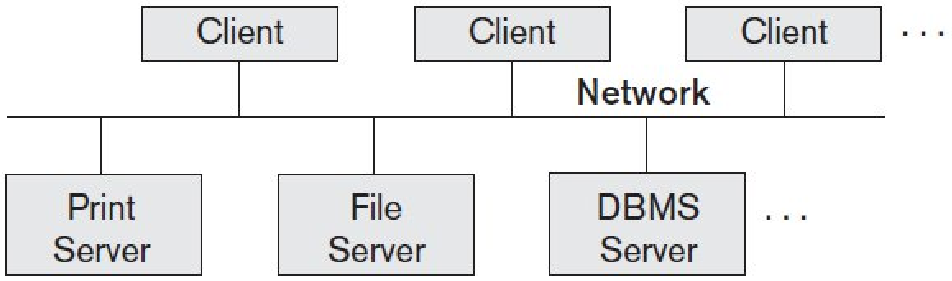
- **User Access**:

Users accessed the system via **dumb terminals** with no processing power
only capable of displaying output and sending input.

- **Characteristics**:
  - Central system handled:
    - ❖ User interface
    - ❖ Application program execution
    - ❖ All DBMS functionality
  - **No local processing** at the user's side
  - Simplified control but limited scalability.



# Client/Server Architecture



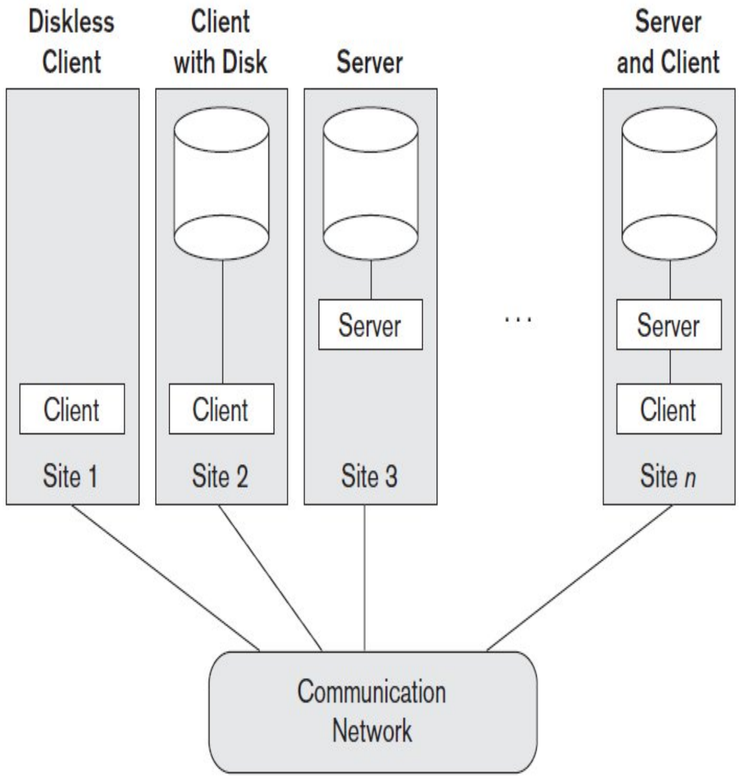
- A **distributed computing environment** where functionality is split between **clients (user machines)** and **servers (resource providers)**.
- **Client Role**:
- ❖ Provides **user interface** and **local processing**.
- ❖ Sends requests to the server for services it cannot perform locally (e.g., database access).
- **Server Role**:
- ❖ Provides **specific services** like database access, file storage, printing, etc.
- ❖ Can be a **dedicated machine** or a system with both server and client capabilities.
- **Network Dependency**:
  Relies on **LANs and other networks** to connect multiple client and server machines.

# Two-Tier Client/Server Architecture

- **Tier 1 (Client)**:
  User interface and local application logic.
- **Tier 2 (Server)**:
  Centralized **DBMS server** for handling database queries and data storage.

**Features**:

- Client machines access **specialized servers** (e.g., file servers, printer servers, database servers).
- Improved resource sharing and **decentralized processing** compared to centralized architecture.
- Suitable for small to medium-scale applications.



## Two-Tier Client/Server Architecture

**Client Side**:

Runs **user interface** and **application programs**.
Sends SQL queries to the server.

**Server Side**:

Called **SQL Server**, **Query Server**, or **Transaction Server**.
Handles SQL processing and database transactions.

**Communication**:

Uses **ODBC** (for various languages) or **JDBC** (for Java) to connect and interact with the DBMS.

**Object-Oriented DBMS Variation**:

DBMS functions are split between client and server more deeply.
Server: handles storage, local concurrency, recovery.
Client: handles complex object structuring, global control functions.

**Advantages**:

**Simple** and easy to implement.
Works well with **existing systems**.

**Limitation**:

Less scalable; led to **Three-Tier Architecture** with the rise of web applications.

# Two-Tier Client/Server Architecture

**Structure**:

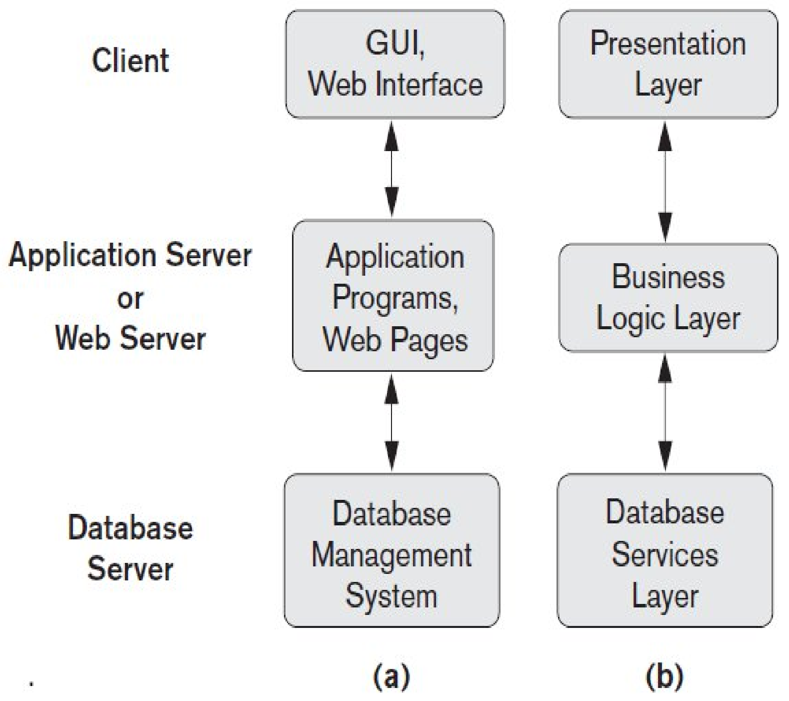
- ❖ **Client (Presentation Tier)** : User interfac (GUI)
- ❖ **Application Server (Middle Tier)** : Business logic and rules
- ❖ **Database Server (Data Tier)** : Data storage and query processing

**Functionality**:

- ❖ **Middle tier** handles client requests, applies business rules, and interacts with the database.
- ❖ Improves **security** by validating client credentials before accessing the database.
- ❖ Passes processed or raw data back to the client for presentation.

**Advantages**:

- ❖ **Modularity**: UI, business logic, and data access are separated.
- ❖ **Security**: Middle tier acts as a gatekeeper.
- ❖ **Scalability**: More users can be supported efficiently.



a) Web applications with an intermediate layer between the client and the database server
b)architecture used by database and other application package vendors.