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Slide 2

Database Concept & Architecture

CSF2600700 - BASIS DATA

SEMESTER GENAP 2018/2019

Outline

- Data Models
  - Categories of Data Models
  - History of Data Models
- Schema
  - Three-Schema Architecture
- DBMS Component
- DBMS Architecture

Data Models

- **Data Model**:

  A set of concepts to describe the *structure* of a database, and certain *constraints* that the database should obey.

- **Data Model Operations**:

  Operations for specifying database retrievals and updates by referring to the concepts of the data model. Operations on the data model may include *basic operations* and *user-defined operations*.

Categories of data models

- **Conceptual** (**high-level**, **semantic**) data models: Provide concepts that are close to the way many users *perceive* data. Such as: entity, attribute, relationship among entities (will explain more detail in ER model)
- **Physical** (**low-level**, **internal**) data models: Provide concepts that describe details of how data is stored in the computer. Ex. Tree, Graph, dsb
- **Implementation** (**representational**) data models: Provide concepts that fall between the above two, balancing user views with some computer storage details. Such as: relational, network or hierarchical data model

History of Data Models

- <u>Network Model</u>:
  - the first one to be implemented by Honeywell in 1964-65 (IDS System).
  - Adopted heavily due to the support by CODASYL (CODASYL - DBTG report of 1971).
  - Later implemented in a large variety of systems - IDMS (Cullinet - now CA), DMS 1100 (Unisys), IMAGE (H.P.), VAX -DBMS (Digital Equipment Corp.).
  - Data in a Network in terms of Interdependencies and Connections Among Data Items
  - Graphs
- <u>Hierarchical Data Model</u>:
  - implemented in a joint effort by IBM and North American Rockwell around 1965.
  - Resulted in the IMS family of systems. The most popular model. Other system based on this model: System 2k (SAS inc.)
  - Data in Hierarchies in terms of Interdependencies and Connections Among Data Items
  - Tree

History of Data Models

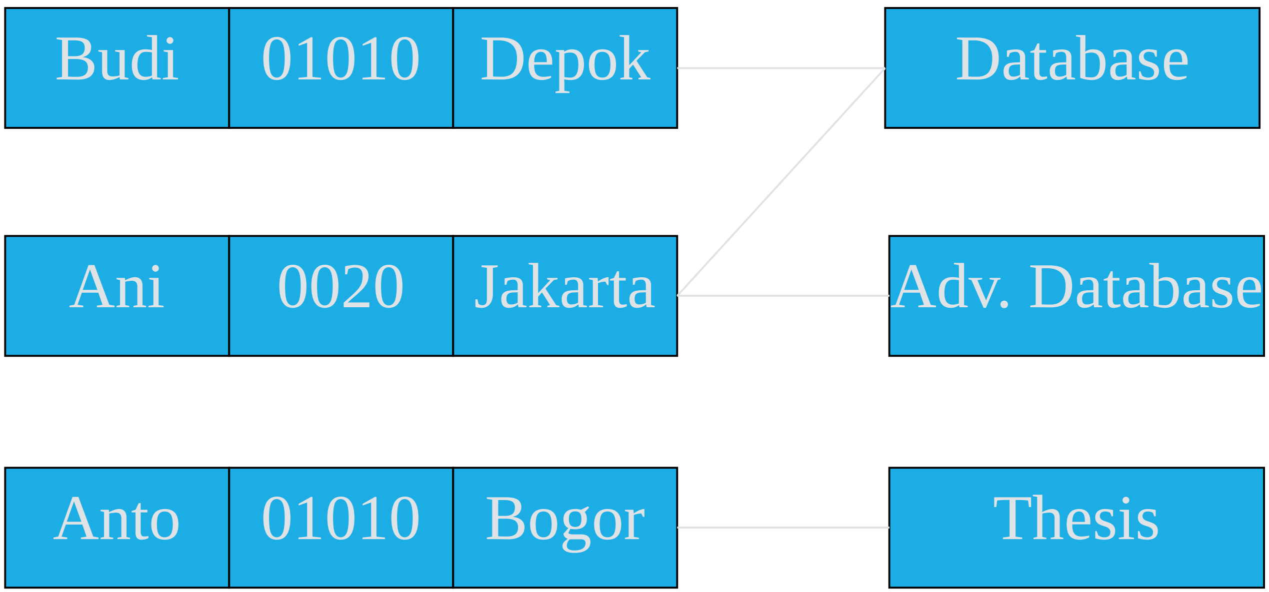
- Relational Model:
  - proposed in 1970 by E.F. Codd (IBM),
  - first commercial system in 1981-82.
  - Now in several commercial products (DB2, ORACLE, SQL Server, SYBASE, INFORMIX).
- Object-oriented Data Model(s):
  - several models have been proposed for implementing in a database system.
  - One set comprises models of persistent O-O Programming Languages such as C++ (e.g., in OBJECTSTORE or VERSANT), and Smalltalk (e.g., in GEMSTONE).
  - Additionally, systems like O_2, ORION (at MCC - then ITASCA), IRIS (at H.P.- used in Open OODB).

History of Data Models

- Object-Relational Models:
  - Most Recent Trend.
  - Started with Informix Universal Server.
  - Exemplified in the latest versions of Oracle-10g, DB2, and SQL Server etc. systems.

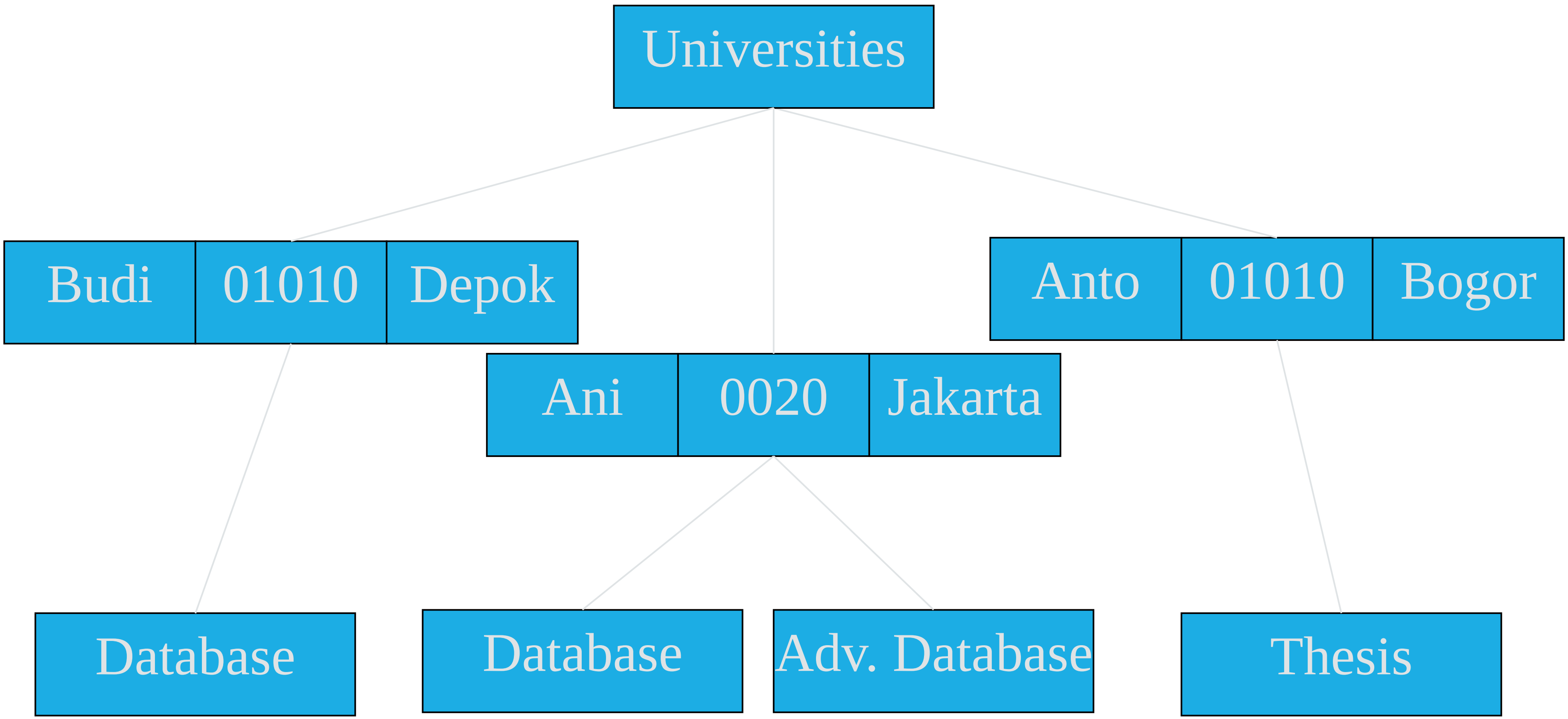
Data Models examples

- Network model



Data Models examples

- Hierarical model



Data Models examples

- Relational model

Student

Name	ID	City	CID
Budi	01010	Depok	010
Ani	0020	Jakarta	001
Anto	01010	Bogor	011

Course

CID	CName
010	Database
011	Adv. Database
001	Thesis

Data Models examples

- Object-Oriented model

Relational Model

- Relational Model of Data Based on the Concept of a Relation
- Relation - a Mathematical Concept Based on Sets
- Strength of the Relational Approach to Data Management Comes From the Formal Foundation Provided by the Theory of Relations
- RELATION: A Table of Values
  - A Relation May Be Thought of as a Set of Rows
  - A Relation May Alternately be Though of as a Set of Columns
  - Each Row of the Relation May Be Given an **Identifier**
  - Each **Column** Typically is Called by its Column Name or Column Header or Attribute Name

Relational Tables - Rows/Columns/Tuples

STUDENT	Name	StudentNumber	Class	Major
	Smith	17	1	CS
	Brown	8	2	CS

COURSE	CourseName	CourseNumber	CreditHours	Department
	Intro to Computer Science	CS1310	4	CS
	Data Structures	CS3320	4	CS
	Discrete Mathematics	MATH2410	3	MATH
	Database	CS3380	3	CS

SECTION	SectionIdentifier	CourseNumber	Semester	Year	Instructor
	85	MATH2410	Fall	98	King
	92	CS1310	Fall	98	Anderson
	102	CS3320			
	112	MATH2410			
	119	CS1310			
	135	CS3380			

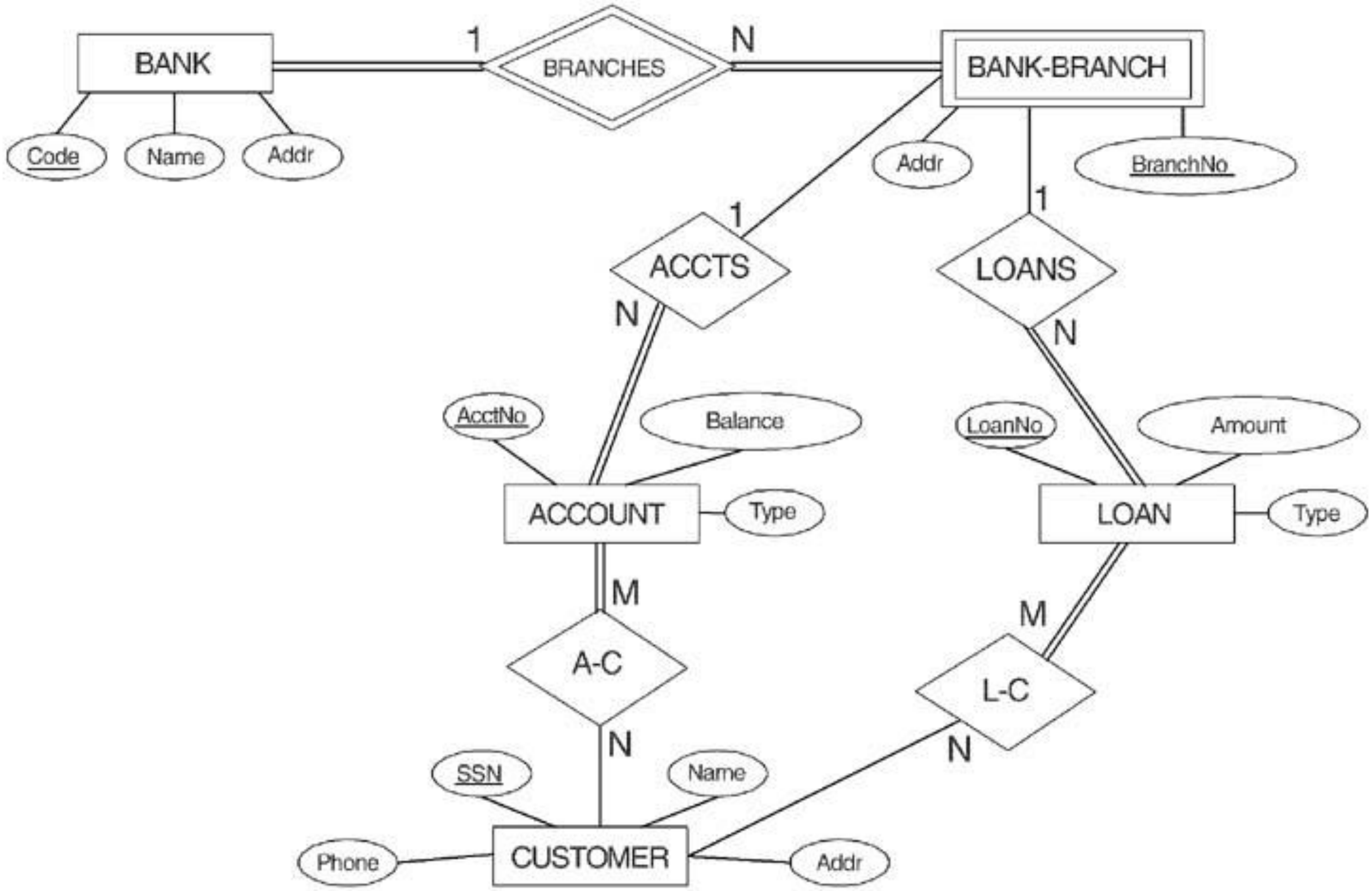
GRADE_REPORT	StudentNumber	SectionIdentifier	Grade
	17	112	B
	17	119	C
	8	85	A
	8	92	A
	8	102	B
	8	135	A

PREREQUISITE	CourseNumber	PrerequisiteNumber
	CS3380	CS3320
	CS3380	MATH2410
	CS3320	CS1310

Entity Relationship (ER) Data Model

- Originally Proposed by P. Chen, ACM TODS, Vol. 1, No. 1, March1976
- Conceptual Modeling of Database Requirements
- Allows an Application's Information to be Characterized
- Basic Building Blocks are Entities and Relationships
- Well-Understood and Studied Technique
- Well-Suited for Relational Database Development
- Did Not Originally Include Inheritance!!

ER Diagram



BANK
1
BRANCHES
N
BANK-BRANCH
Code
Name
Addr
Addr
BranchNo
1
1
ACCTS
LOANS
N
N
AcctNo
Balance
LoanNo
Amount
ACCOUNT
Type
LOAN
Type
M
M
A-C
L-C
N
N
SSN
Name
Phone
CUSTOMER
Addr

Schemas

- **Database Schema**: The *description* of a database. Includes descriptions of the database structure and the constraints that should hold on the database.
- **Schema Diagram**: A diagrammatic display of (some aspects of) a database schema.
- **Schema Construct**: A component of the schema or an object within the schema, e.g., STUDENT, COURSE.
- **Database State/Snapshot**: The actual data stored in a database at a *particular moment in time*. Also called the **current set of occurrences/instances**).

Schema diagram

STUDENT

Name	StudentNumber	Class	Major

COURSE

CourseName	CourseNumber	CreditHours	Department

PREREQUISITE

CourseNumber	PrerequisiteNumber

SECTION

SectionIdentifier	CourseNumber	Semester	Year	Instructor

GRADE_REPORT

StudentNumber	SectionIdentifier	Grade

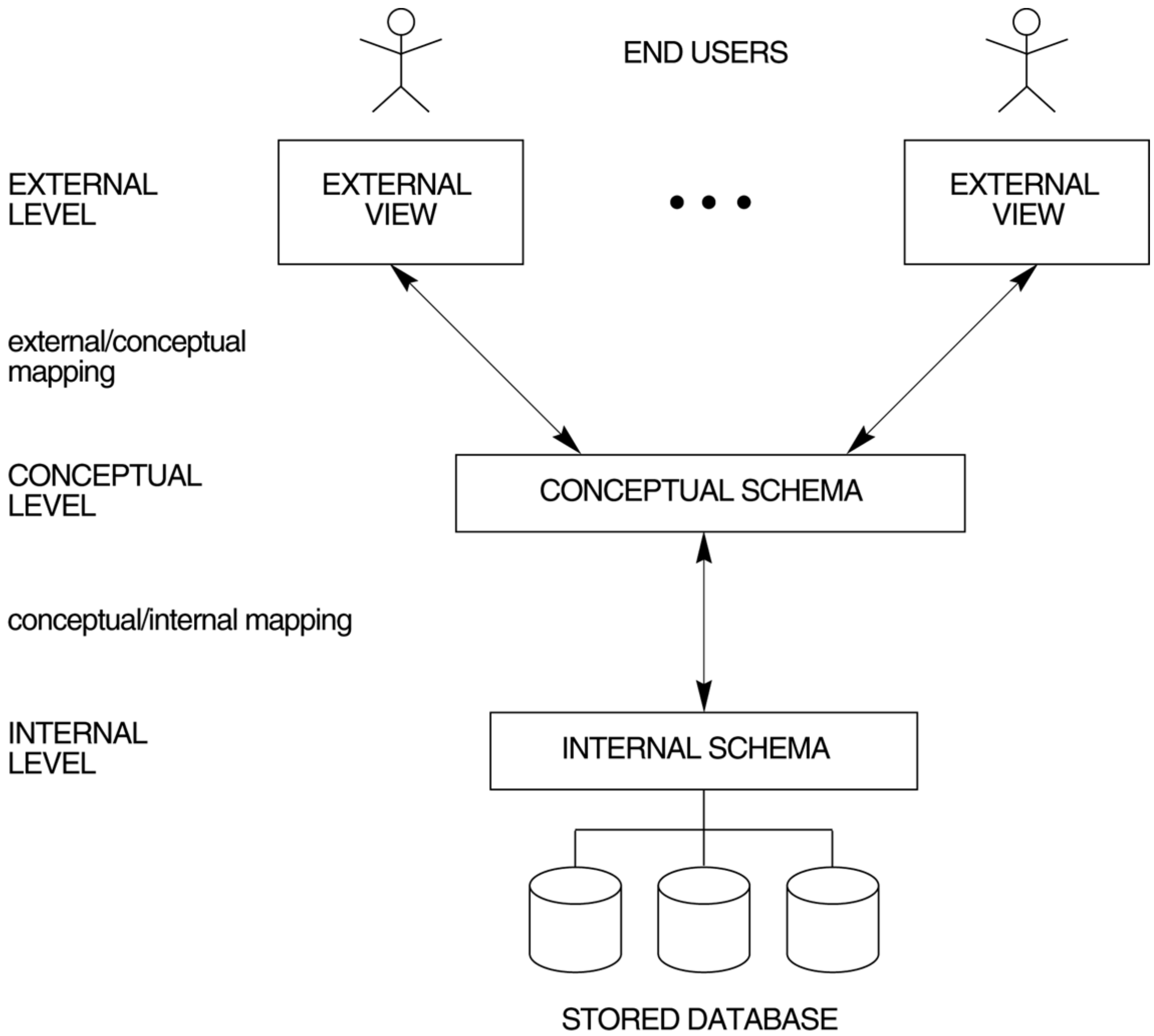
Database Schema Vs. Database State

- **Database State:** Refers to the content of a database at a moment in time.
- **Initial Database State:** Refers to the database when it is loaded
- **Valid State:** A state that satisfies the structure and constraints of the database.
- **Distinction**
  - The **database schema** changes *very infrequently*. The **database state** changes *every time the database is updated.*
  - **Schema** is also called **intension**, whereas **state** is called **extension**.

Three-Schema Architecture

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

The three-schema architecture



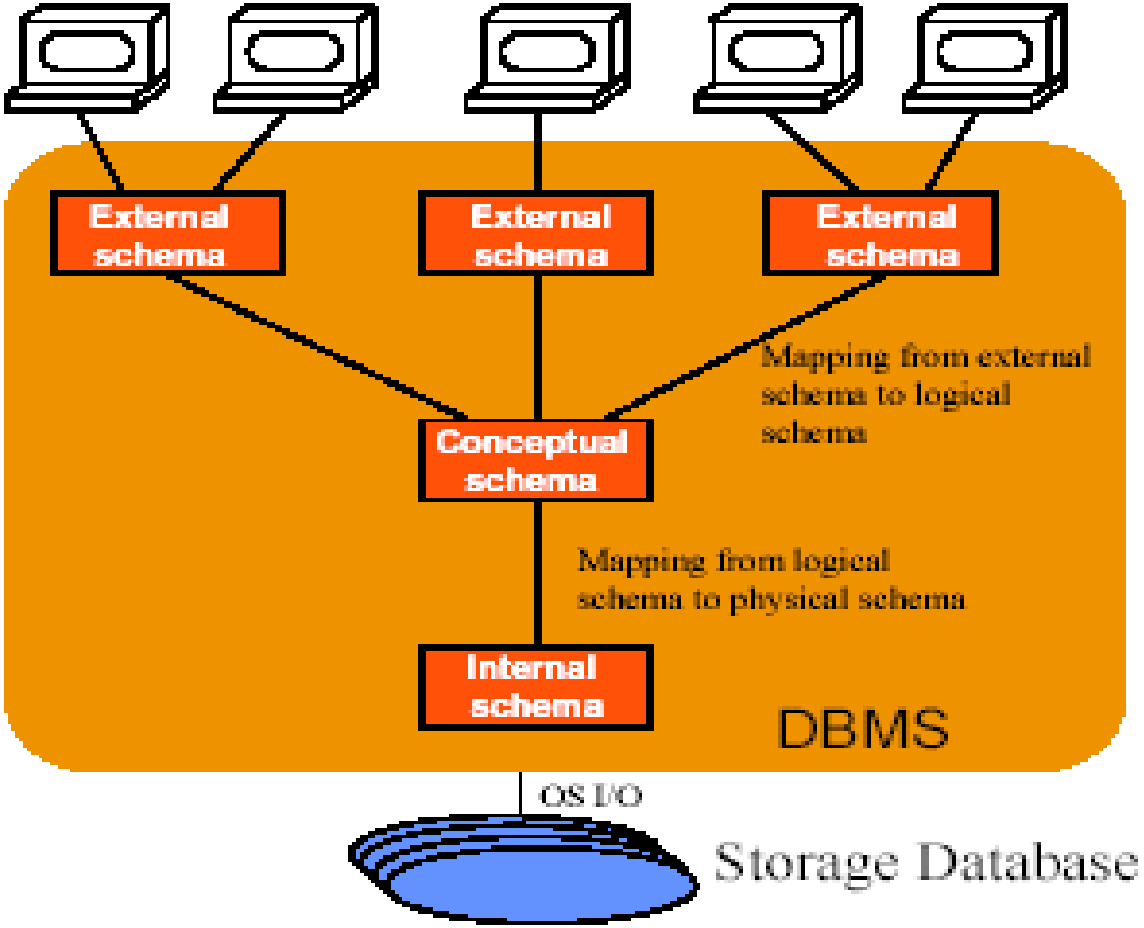
Another view: Three Schema Architecture

Users

User's view on the **use of data**

Logical schema: the **meaning of data**

Physical schema: the **storage of data**



Three-Schema Architecture

- Defines DBMS schemas at *three levels*:
  - **Internal schema** at the internal level to describe physical storage structures and access paths. 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. Uses a *conceptual* or an *implementation* data model.
  - **External schemas** at the external level to describe the various user views. Usually uses the same data model as the conceptual level.

Conceptual Schema

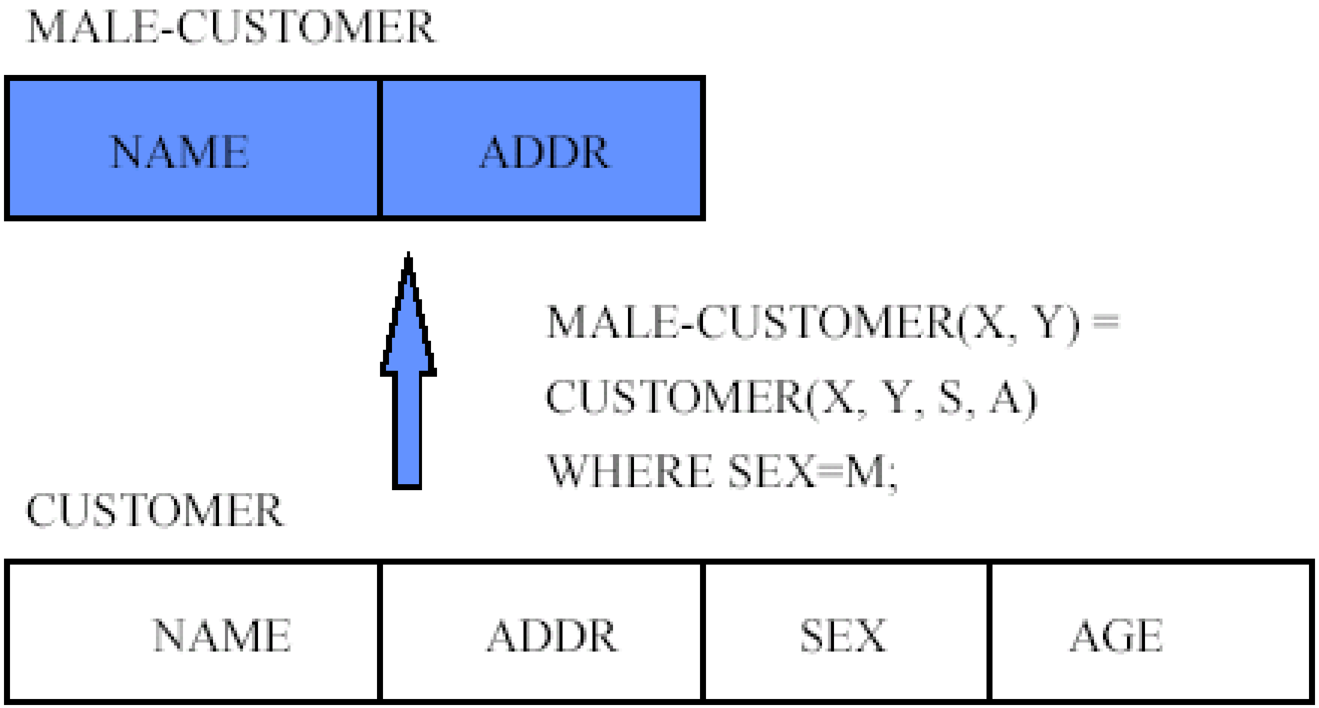
- Describes the meaning of data in the universe of discourse
  - Emphasizes on general, conceptually relevant, and often time invariant structural aspects of the universe of discourse
- Excludes the physical organization and access aspects of the data

CUSTOMER

NAME	ADDR	SEX	AGE

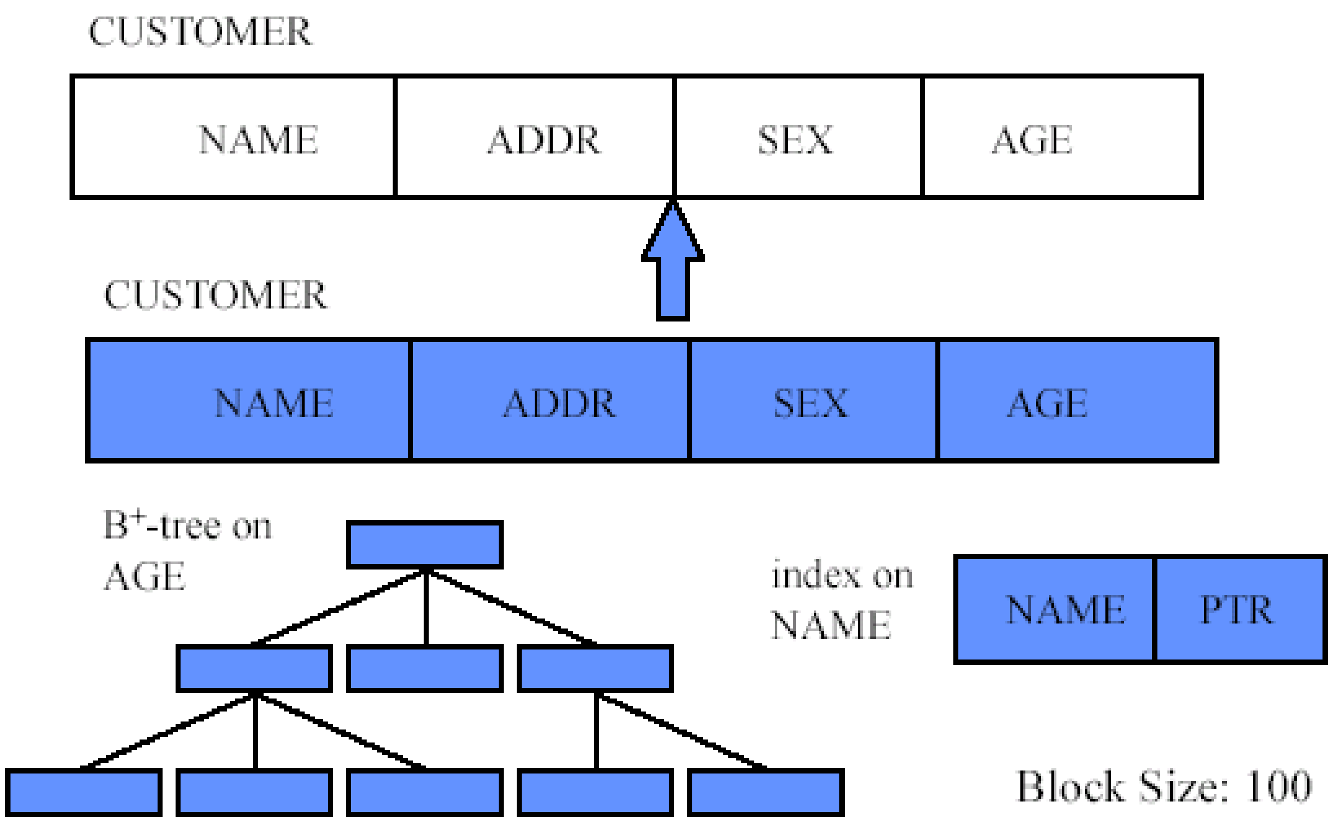
External Schema

- Describes parts of the information in the conceptual schema in a form convenient to a particular user group's view
- Derived from the conceptual schema



Internal Schema

- Describes how the information described in the conceptual schema is physically represented in a database to provide the overall best performance



Unified Example of Three Schemas

An Example Query:

"List all employees whose has more than 5 years working experience?"

SELECT e.ENAME, e.DEPT, e.EXP
FROM EMP e
WHERE e.EXP > 5 year.

External Schema:

CREATE EMP(ENAME, DEPT, EXP)
AS VIEW OF EMPLOYEE(EN, DNO, EXP_YEAR)

CREATE PAYROLL(EN, SAL, SSN, BirthDate)
AS VIEW OF EMPLOYEE(SSN,EN,SALARY,BDATE)

Conceptual Schema:

EMPLOYEE(SSN, EN, DNO, SALARY, EXP_YEAR, BDATE, STARTDATE)

Internal Schema:

Cluster Index on SNN;

No-cluster B-tree Indexes on DNO, EXP_YEAR, STARTDATE.

Data Independence

- Ability that allows application programs not being affected by changes in irrelevant parts of the conceptual data representation, data storage structure and data access methods
- Invisibility (transparency) of the details of entire database organization, storage structure and access strategy to the users
  - Both logical and physical
- Recall software engineering concepts:
  - ***Abstraction*** the details of an application's components can be hidden, providing a broad perspective on the design
  - ***Representation independence***: changes can be made to the implementation that have no impact on the interface and its users

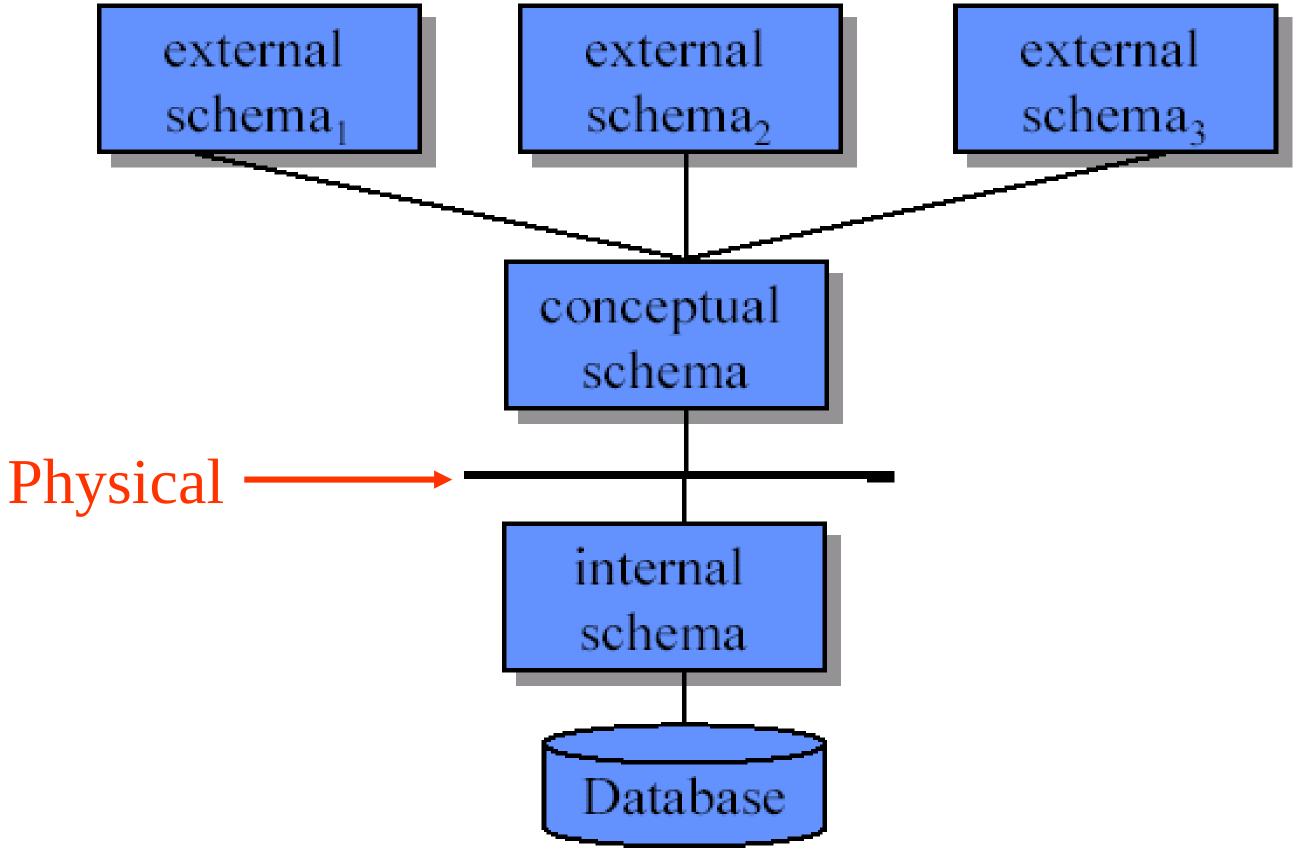
Data Independence

- **Logical Data Independence**: The capacity to change the conceptual schema without having to change the external schemas and their application programs.
- **Physical Data Independence**: The capacity to change the internal schema without having to change the conceptual schema.

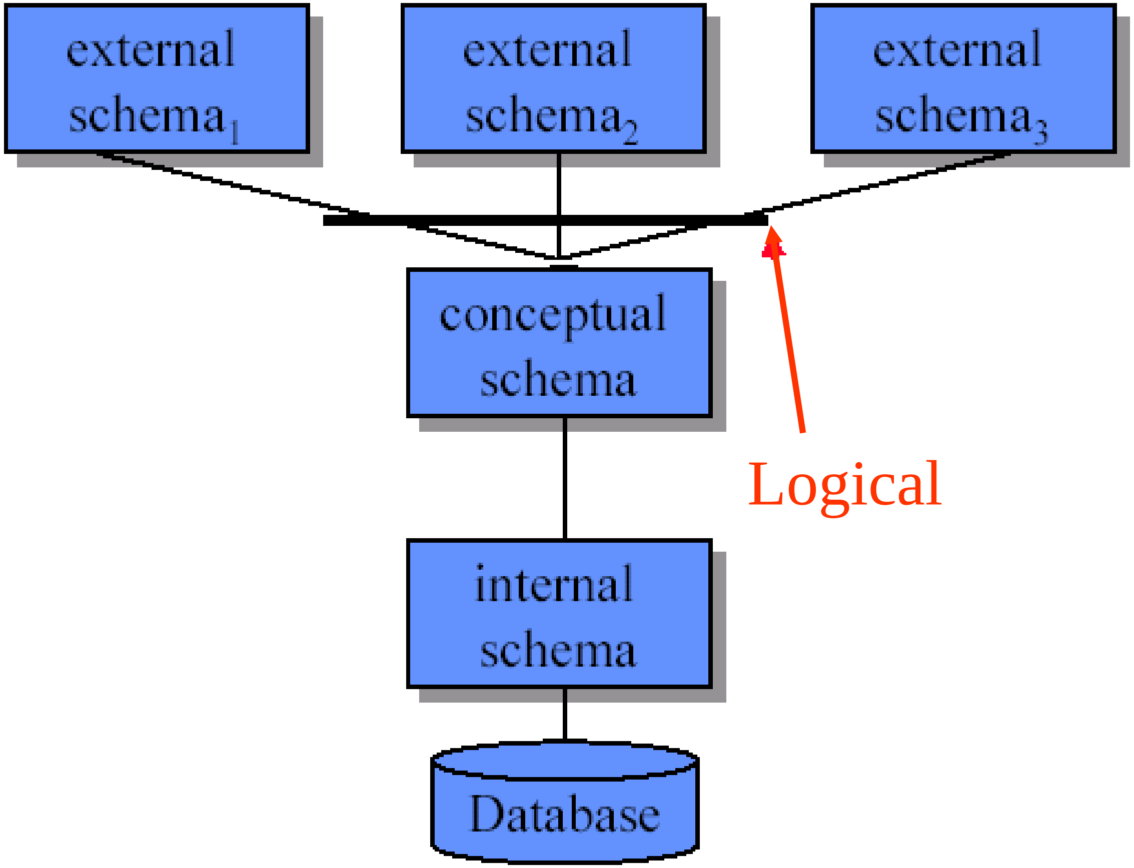
Data Independence

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.

Physical Data Independence



Logical Data Independence



DBMS Languages

- **Data Definition Language (DDL)**: Used by the DBA and database designers to specify the *conceptual schema* and *internal schema* of a database and any mapping between the two.
- In many DBMSs where a clear separation of conceptual and internal schema, **DDL** is used to define conceptual schema only. **Storage definition language (SDL)** define the internal schema and **view definition language (VDL)** are used to define user view and their mapping to the conceptual schemas.
- Most DBMSs, the **DDL** is used to define both conceptual and external schemas

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 or an Assembly Language.
  - Alternatively, *stand-alone* DML commands can be applied directly (**query language**).

DBMS Languages

- **High Level** or **Non-procedural Languages:** e.g., SQL, are *set-oriented* and specify what data to retrieve than how to retrieve. Also called *declarative* languages.
- **Low Level** or **Procedural Languages:** record-at-a-time; they specify *how* to retrieve data and must be embedded in programming language

DBMS Interfaces

- Menu-based, popular for browsing on the web
- Forms-based, designed for naïve users
- Graphics-based (Point and Click, Drag and Drop etc.)
- Natural language: requests in written English → "Show the student that have GPA above 3.0"
- Combinations of the above

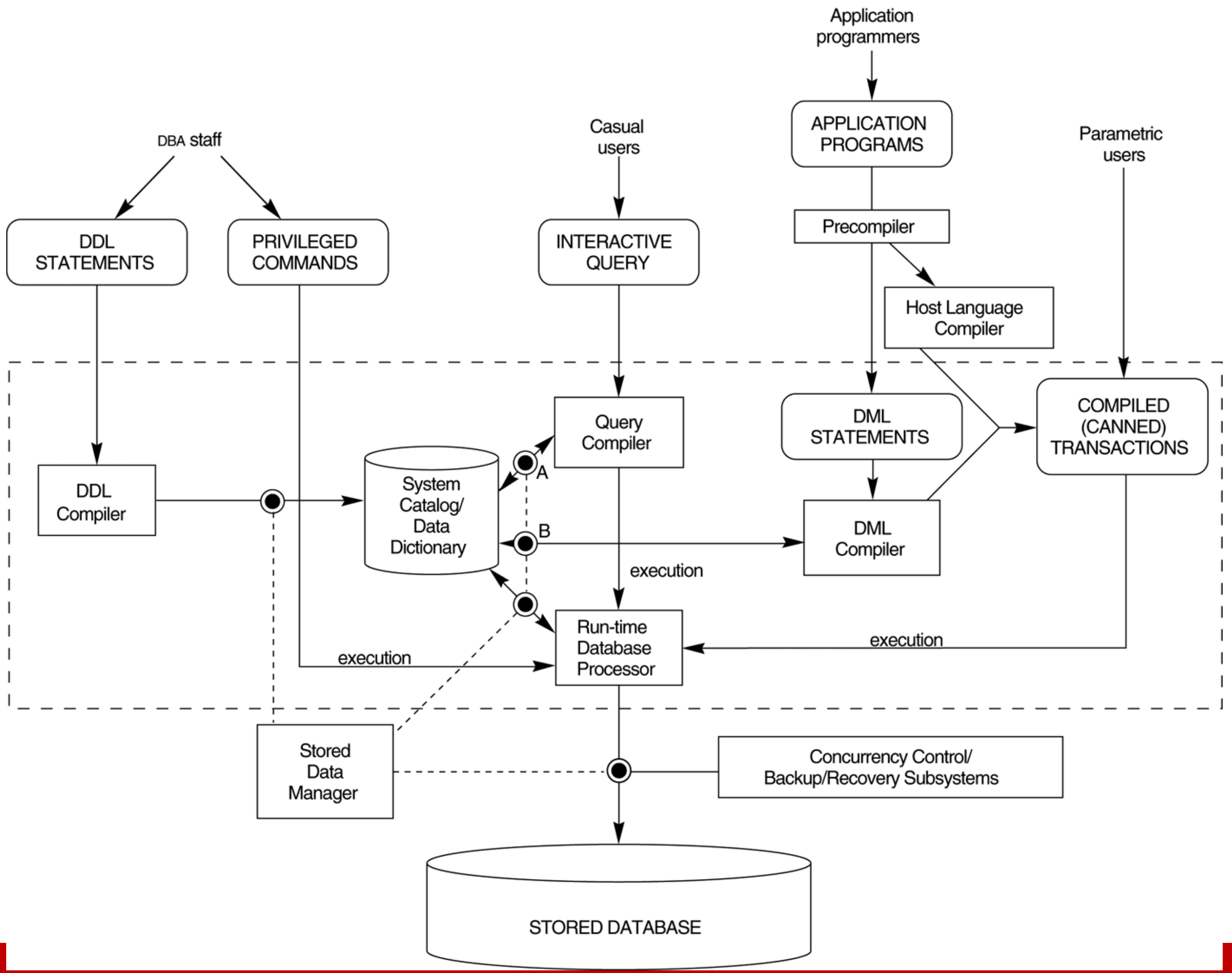
Other DBMS Interfaces

- Speech as Input and Output
- Parametric interfaces (e.g., bank tellers) using function keys.
- Interfaces for the DBA:
  - Creating accounts, granting authorizations
  - Setting system parameters
  - Changing schemas or access path

The Database System Environment

- Main DBMS modules
  - DDL compiler
  - DML compiler
  - Ad-hoc (interactive) query compiler
  - Run-time database processor
  - Stored data manager
  - Concurrency/back-up/recovery subsystem
- DBMS utility modules
  - Loading routines
  - Backup utility
  - …

Component modules of a DBMS and their interactions



Database System Utilities

- To perform certain functions such as:
  - *Loading* data stored in files into a database. Includes data conversion tools.
  - *Backing up* the database periodically on tape.
  - *Reorganizing* database file structures.
  - *Report generation* utilities.
  - *Performance monitoring* utilities.
  - Other functions, such as *sorting*, *user monitoring*, *data compression*, etc.

Other Tools

- **Data dictionary/repository**:
  - Used to store schema descriptions and other information such as design decisions, application program descriptions, user information, usage standards, etc.
- **Application Development Environments and CASE (computer-aided software engineering) tools:**
  - Power builder, Builder, VB, Java, C, C++, dsb
  - Ms. Visio, ER-Win, DBDesigner, dsb

Centralized Architectures

- **Centralized DBMS:** combines everything into single system (PC) including- DBMS software, hardware, application programs and user interface processing software.

Client-Server Architectures

- **Servers:**
  - **Specialized Servers with Specialized functions**
  - **Ex. Database Server, File Server, Web Server, Email Server**

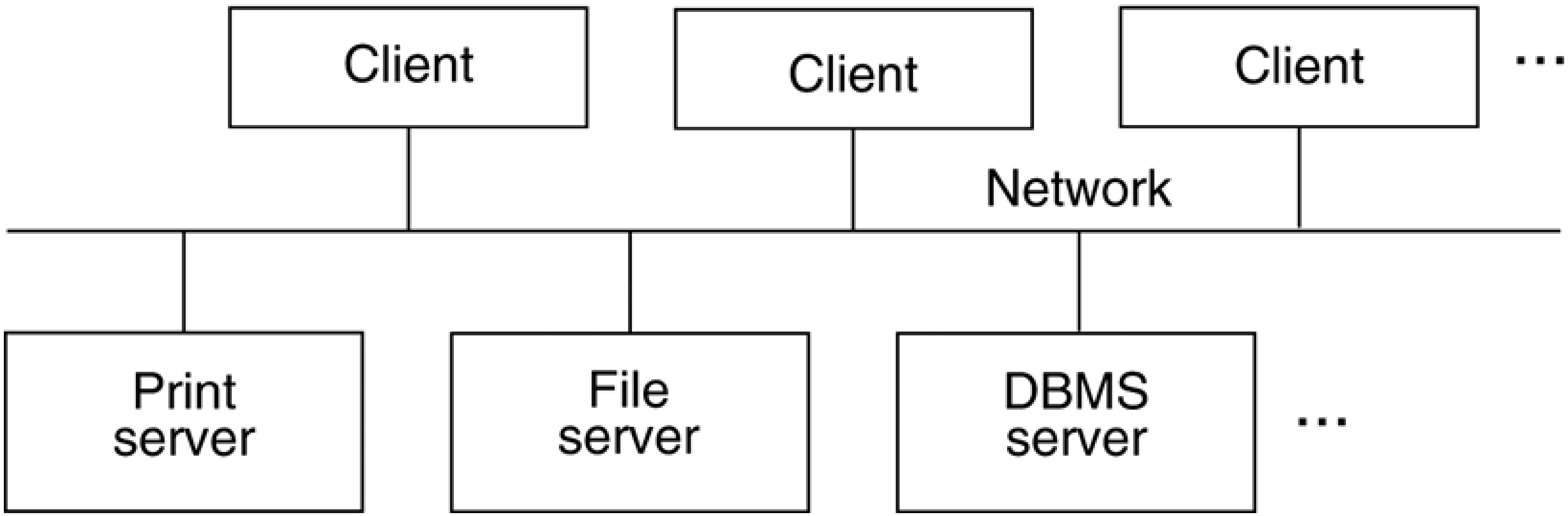
Client-Server Architectures

- Client:
  - Provide appropriate interfaces and a client-version of the system to access and utilize the server resources.
  - Clients maybe diskless machines or PCs or Workstations with disks with only the client software installed.
  - Connected to the servers via some form of a network.
    (LAN: local area network, wireless network, etc.)

Two Tier Client-Server Architecture

- **User Interface Programs and Application Programs** run on the client side
- Interface called **ODBC (Open Database Connectivity)** provides an Application program interface (API) allow client side programs to call the DBMS. Most DBMS vendors provide ODBC drivers.

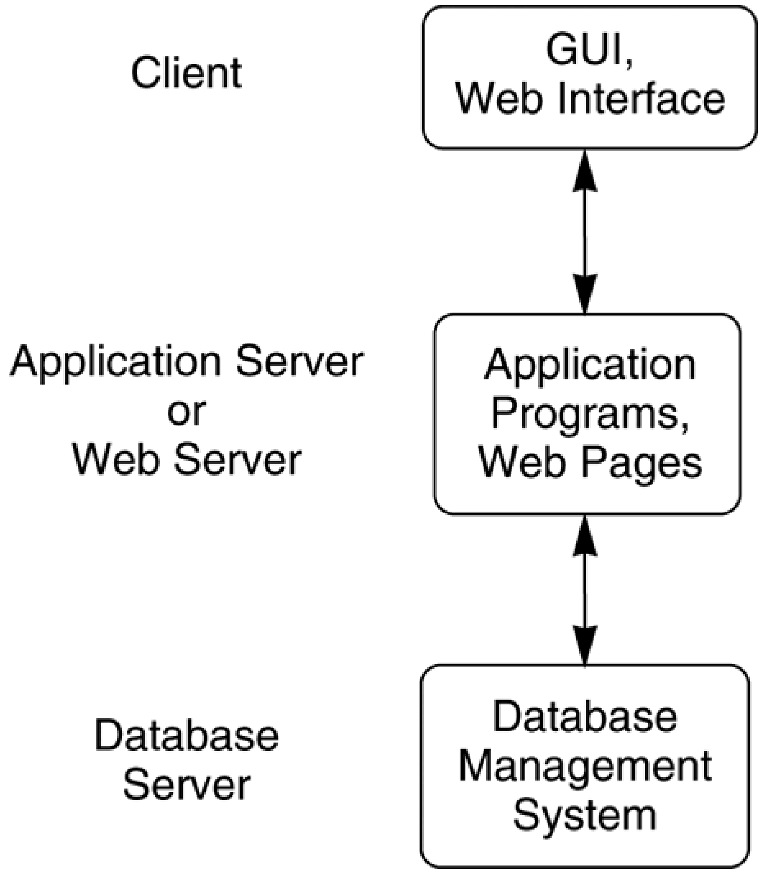
Logical two-tier client/server architecture



Three Tier Client-Server Architecture

- Common for **Web applications**
- Intermediate Layer called **Application Server** or **Web Server:**
  - stores the web connectivity software and **the rules and business logic (constraints)** part of the application used to access the right amount of data from the database server
  - acts like a conduit for sending partially processed data between the database server and the client.
- **Additional Features- Security:**
  - encrypt the data at the server before transmission
  - decrypt data at the client

Logical three-tier client/server architecture



Database Classification

According to the data models	• object-oriented DBMS (ObjectStore, Ontos, etc.) • **relational DBMS** (Oracle, Sybase, Informix, DB2, Microsoft SQL server etc.) • network DBMS (DBTG ...) • hierarchical DBMS (IMS ...)
According to the number of users	• single-user DBMS (mainly for PCs) • multi-user DBMS
According to the number of sites	• centralized DBMS (Oracle, Sybase, etc.) • distributed DBMS (R*, ...) • federated DBMS homogeneous DBS heterogeneous DBS
According to the types of access methods	• general purpose DBMS • special purpose DBMS