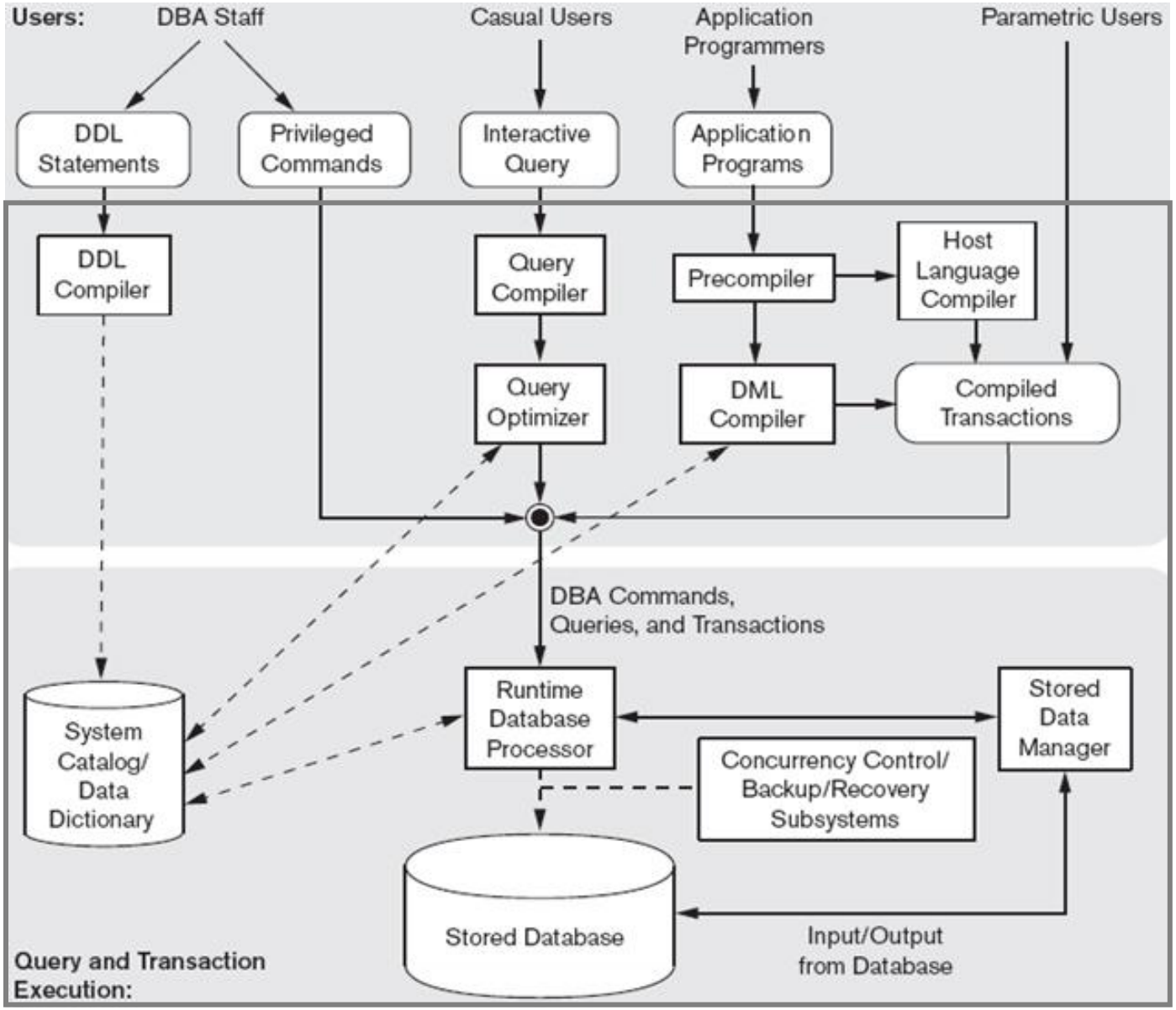
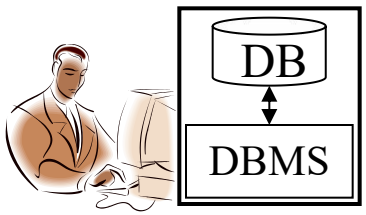
Chapter 2 Database System Concepts and Architecture



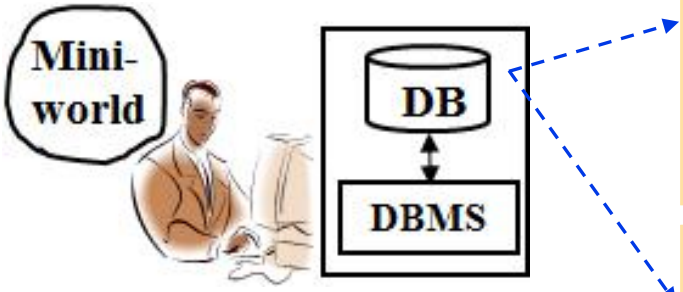


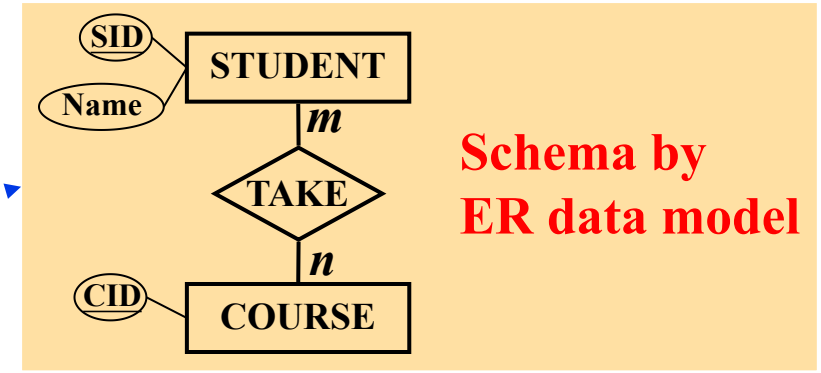
Database System Concepts and Architecture

- Data models, schemas, and instances
- Three-schema architecture and data independence
- Database languages and interfaces
- The database system environment
- Centralized and client/server architectures for DBMSs
- Classification of database management systems

Data Models

- **Data Model**
  - A set of concepts to describe the *structure* of a database, and certain *constraints* that the database should obey.
    - ER data model: {entity, relationship, attribute, key, …}
    - Relational data model: {relation, tuple, attribute, primary key, …}





Schema by Relational data model

STUDENT

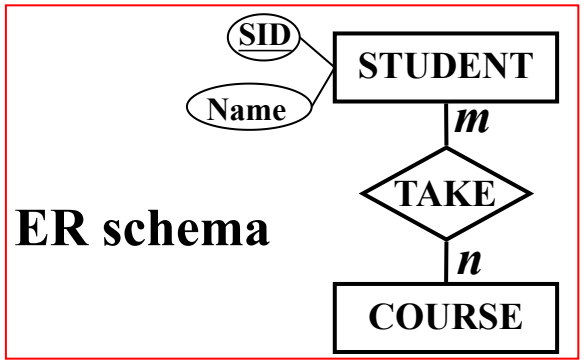
Name	StudentNumber	Class	Major

COURSE

CourseName	CourseNumber	CreditHours	Department

Categories of data models

- **Conceptual (high-level, semantic)** data models:
  - Provide concepts that are close to the way many users *perceive* data, e.g. ER model.
  - 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.
- **Implementation (representational)** data models:
  - Provide concepts that fall between the above two, balancing user views with some computer storage details, e.g. relational model.



Relational DB schema

STUDENT

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COURSE

CourseName	CourseNumber	CreditHours	Department

History of Data Models

- Network Model:
  - 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.).
- Hierarchical Data Model:
  - 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.)
- Relational Model:
  - proposed in 1970 by E.F. Codd (IBM), first commercial system in 1981-82. Now in several commercial products (SQL Server, ORACLE, DB2, INFORMIX, SYBASE).

History of Data Models

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

Schemas versus Instances

- **Database Schema**:
  - ✓ The *description* of a database. Includes descriptions of the **database structure** and the **constraints** that should hold on the database.
- **Database Instance:**
  - ✓ The actual data stored in a database at a *particular moment in time*. Also called **database state** (or **occurrence**).

STUDENT

Name	StudentNumber	Class	Major

COURSE

CourseName	CourseNumber	CreditHours	Department

PREREQUISITE

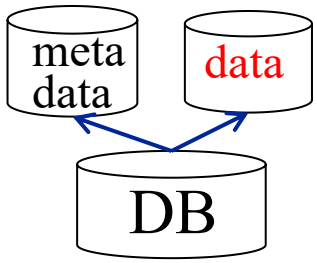
CourseNumber	PrerequisiteNumber

SECTION

SectionIdentifier	CourseNumber	Semester	Year	Instructor

GRADE_REPORT

StudentNumber	SectionIdentifier	Grade



COURSE

Course_name	Course_number	Credit_hours	Department
Intro to Computer Science	CS1310	4	CS
Data Structures	CS3320	4	CS
Discrete Mathematics	MATH2410	3	MATH
Database	CS3380	3	CS

STUDENT

Name	Student_number	Class	Major
Smith	17	1	CS
Brown	8	2	CS

PREREQUISITE

Course_number	Prerequisite_number
CS3380	CS3320
CS3380	MATH2410
CS3320	CS1310

. . .

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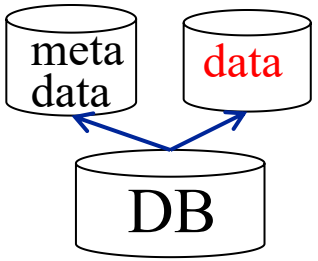
Database Schema Vs. Database State

- **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; e.g., constraint: age≦ 120, CreditHours ≦ 4
- **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**.



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	Discrete Mathematics	MATH2410	3	MATH
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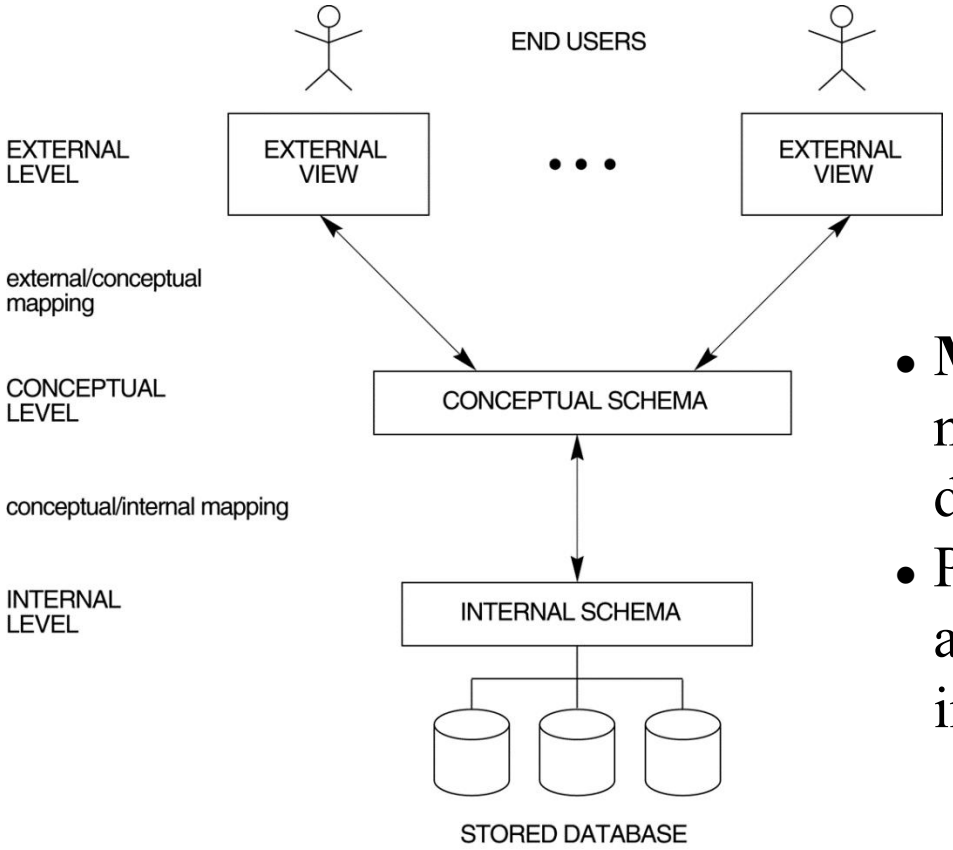
Three-Schema Architecture

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



- **Mappings** among schema levels are needed to transform requests and data.
- Programs refer to an external schema, and are mapped by the DBMS to the internal schema for execution.

Three-Schema Architecture

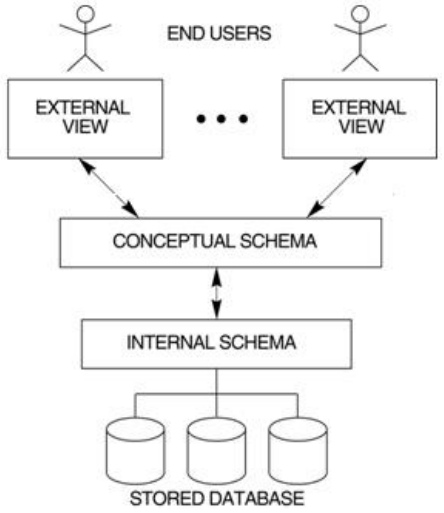
- Defines DBMS schemas at *three levels*:
  - ✓ **External schemas**

    at the external level to describe the various user views. Usually uses the same data model as the conceptual level.
  - ✓ **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.
  - ✓ **Internal schema**

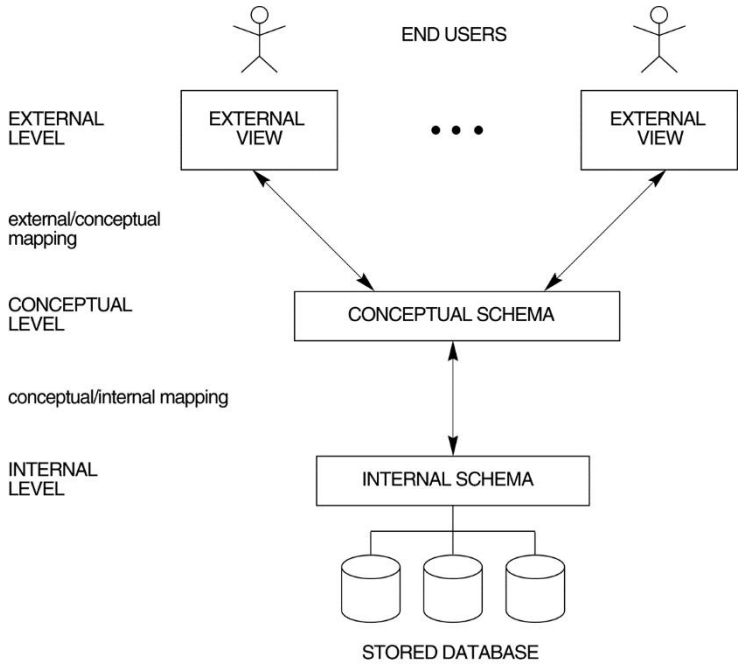
    at the internal level to describe physical storage structures and access paths. Typically uses a *physical* data model.

DBA defines DB schema



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.

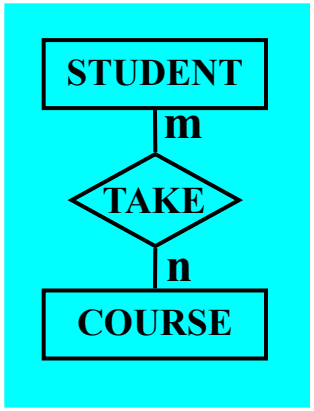


- When a schema at a lower level is changed, only the **mappings** between this schema and higher-level schemas need to be changed in a DBMS that fully supports data independence. The higher-level schemas themselves are *unchanged*.

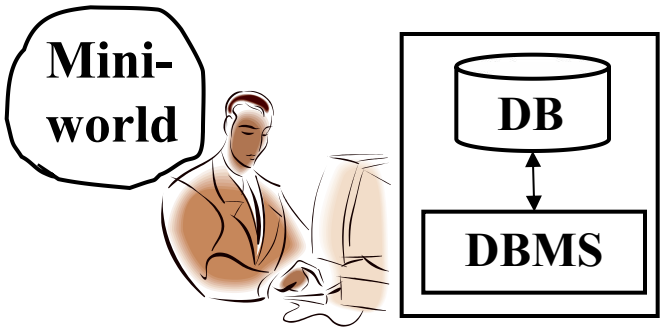
DBMS Languages

- **DDL and DML**
- **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).

Design DB by designer
(using conceptual data model)



Define DB

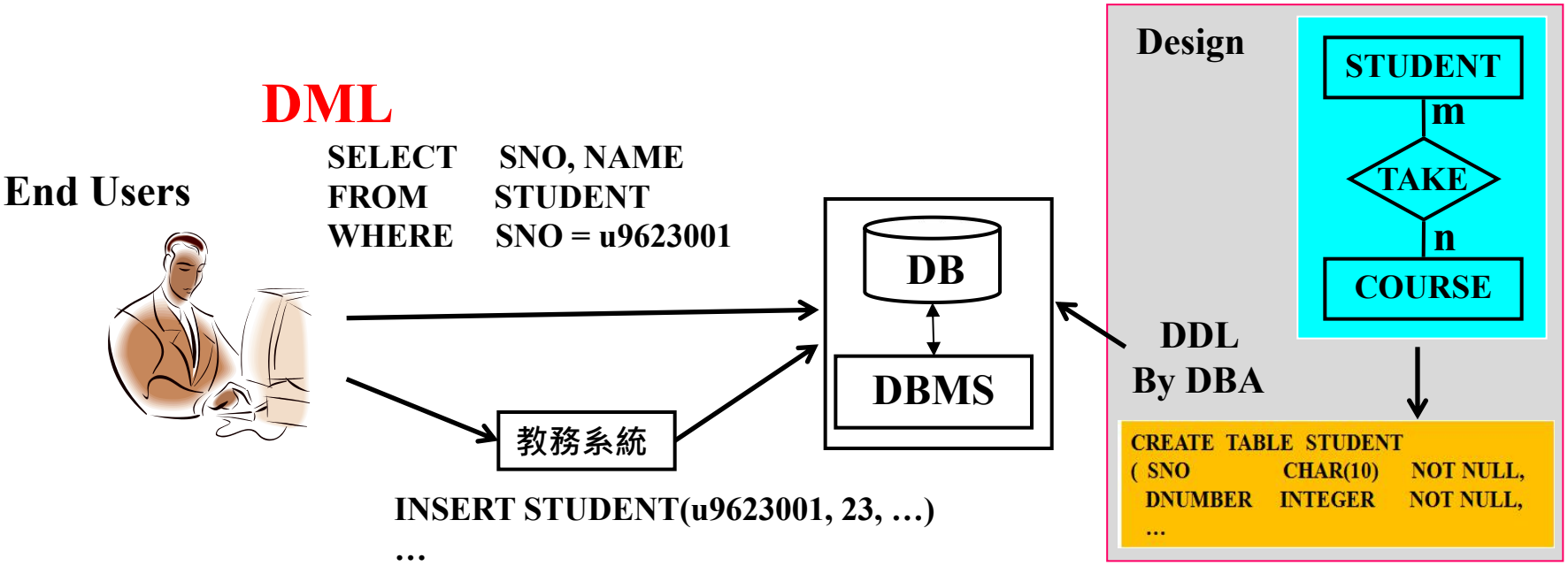


DDL

```
CREATE  TABLE  STUDENT
( SNO            CHAR(10)    NOT NULL,
  DNUMBER        INTEGER     NOT NULL,
  …
```

DBMS Languages

- **Data Manipulation Language (DML):**
  - Used to specify database retrievals and updates.
  - ***Stand-alone*** DML commands can be applied directly (**query language**).
  - DML commands (**data sublanguage**) can be ***embedded*** in a general-purpose programming language (**host language**), such as Java, C or Delphi.



DBMS Languages

- **High Level** or **Non-procedural Languages:**
  - Also called *declarative* languages.
  - e.g., SQL, are *set-oriented* and specify *what* data to retrieve than how to retrieve.
- **Low Level** or **Procedural Languages:**
  - *record-at-a-time*; they specify *how* to retrieve data and include constructs such as looping.

```
SELECT    SNO, NAME
FROM      STUDENT
WHERE     SEX = M
```

```
for (i = 0, TotalStuNum, i++)
    if (Student[i].Sex == M)
        print(Student[i].Sno, Student[i].Name)
```

FIGURE 9.14 Program segment JDBC2, a JAVA program segment that uses JDBC for a query with a collection of tuples in its result.

```
//Program Segment JDBC2:
0)    import java.io.* ;
1)    import java.sql.*
      …
2)    class printDepartmentEmps {
3)       public static void main (String args []) throws SQLException, IOException {
4)       try { Class.forName("oracle.jdbc.driver.OracleDriver")
5)       } catch (ClassNotFoundException x) {
6)          System.out.println ("Driver could not be loaded") ;
7)          }
8)       String dbacct, passwrd, lname ;
9)       Double salary ;
10)      Integer dno ;
11)      dbacct = readentry("Enter database account:") ;
12)      passwrd = readentry("Enter pasword:") ;
13)      Connection conn = DriverManager.getConnection
14)         ("jdbc:oracle:oci8:" + dbacct + "/" + passwrd) ;
15)      dno = readentry("Enter a Department Number: ") ;
16)      String q = "select LNAME, SALARY from EMPLOYEE where DNO = " +
         dno.tostring() ;
17)      Statement s = conn.createStatement() ;
18)      ResultSet r = s.executeQuery(q) ;
19)      while (r.next()) {
20)         lname = r.getString(1) ;
21)         salary = r.getDouble(2) ;
22)         system.out.printline(lname + salary) ;
23)      } }
24)   }
```

// Procedural language: JAVA

// embedded SQL

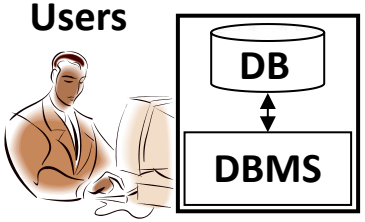
set-at-a-time

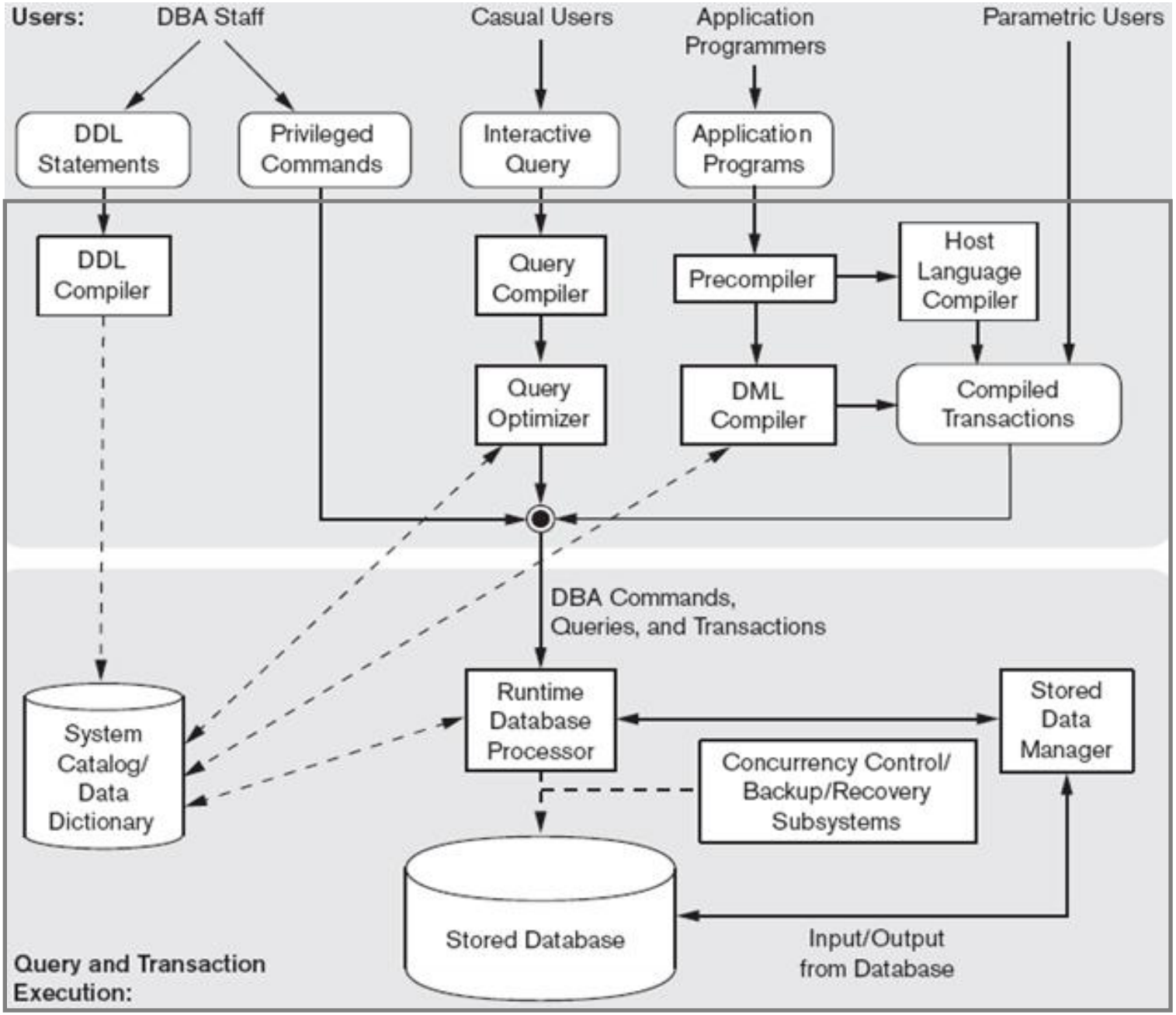
record-at-a-time

DBMS Interfaces and Other Utilities

Users

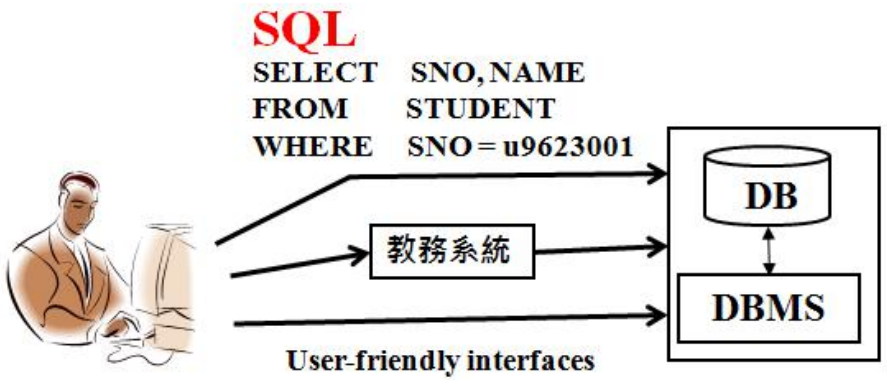
DBMS
+
DB





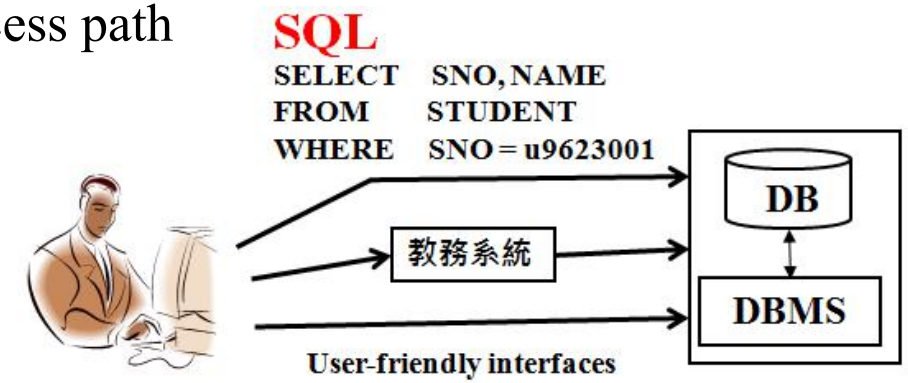
DBMS Interfaces

- Stand-alone query language interfaces (e.g., SQL).
- Programmer interfaces for embedding DML in programming languages:
  - Pre-compiler Approach
  - Procedure (Subroutine) Call Approach
- User-friendly 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
  - Combinations of the above



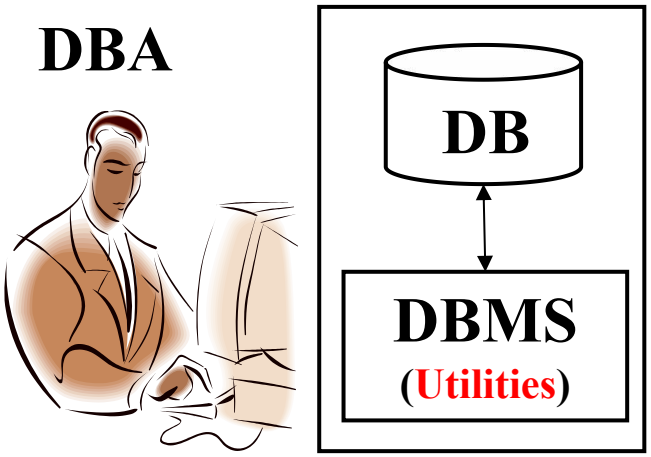
Other DBMS Interfaces

- Speech as Input and Output
- Web Browser as an interface
- 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

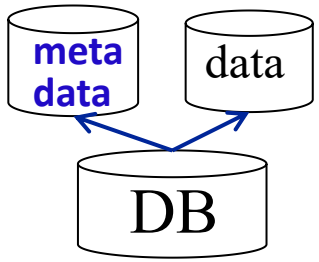


Database System Utilities

- 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

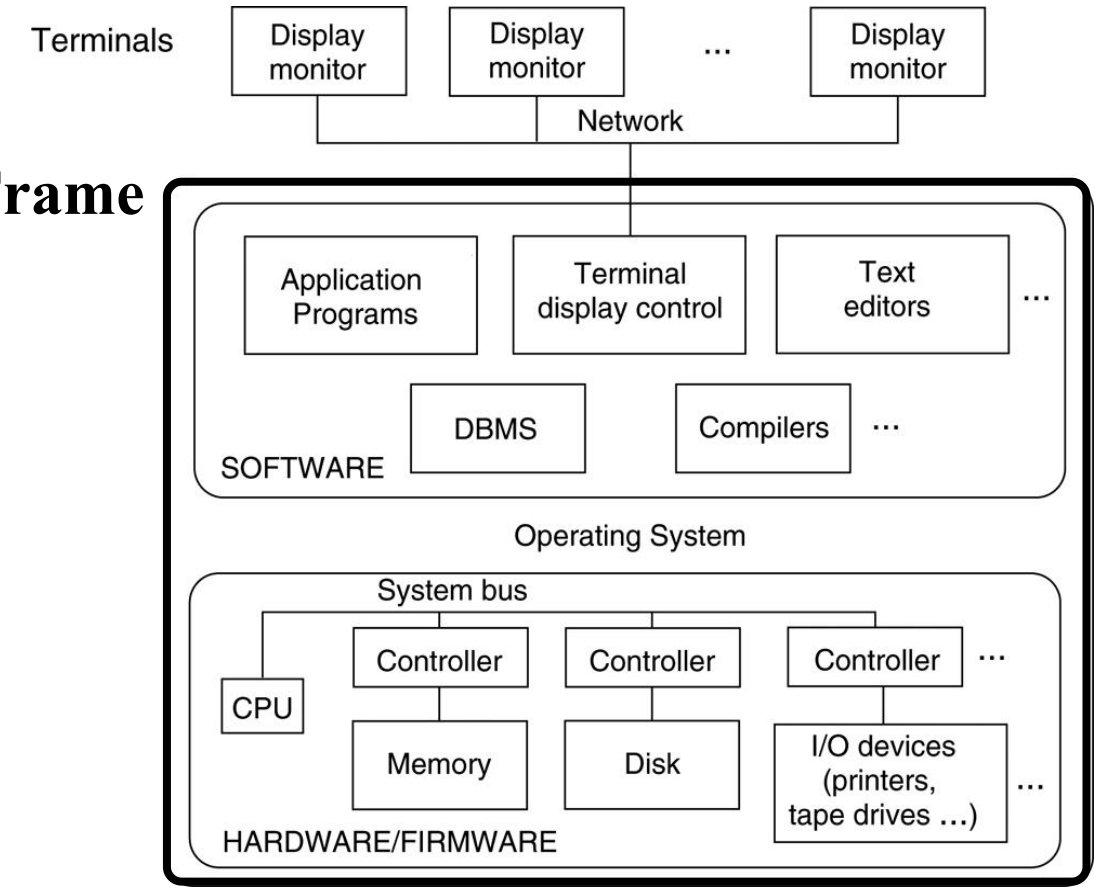


- **Data dictionary / repository**:
  - ✓ Used to store schema descriptions and constraints
- **Information repository**
  - ✓ Extended data dictionary
  - ✓ Including other information such as *design decisions*, *application program descriptions*, *user information*, *usage standards*, etc.
- **Application Development Environments and CASE (computer-aided software engineering) tools:**
  - ✓ Examples – Power builder (Sybase), Builder (Borland)

Centralized and Client-Server Architectures

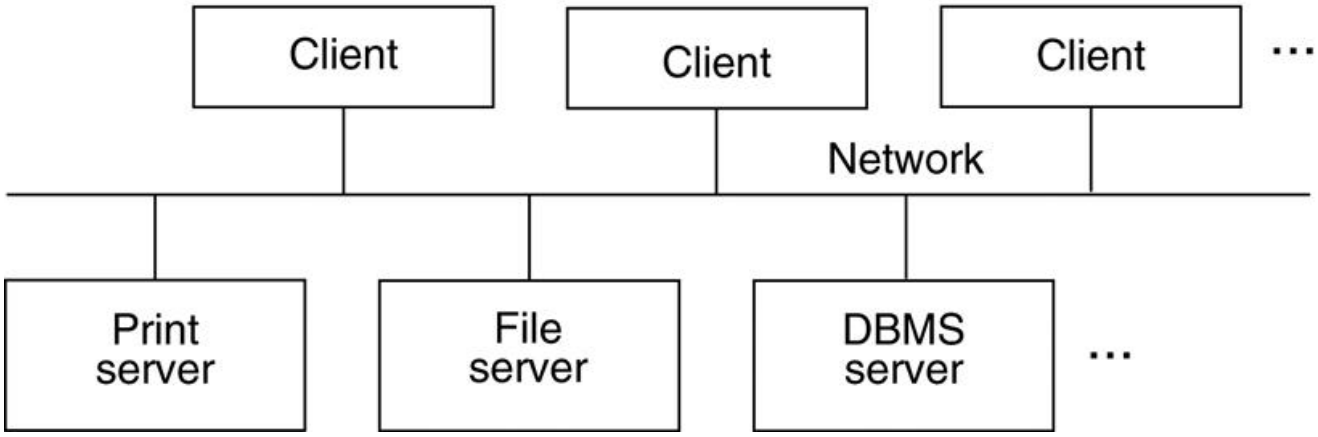
- **Centralized DBMS:**
  - combines everything into single system including- DBMS software, hardware, application programs and user interface processing software.

Main Frame



Basic Client-Server Architectures

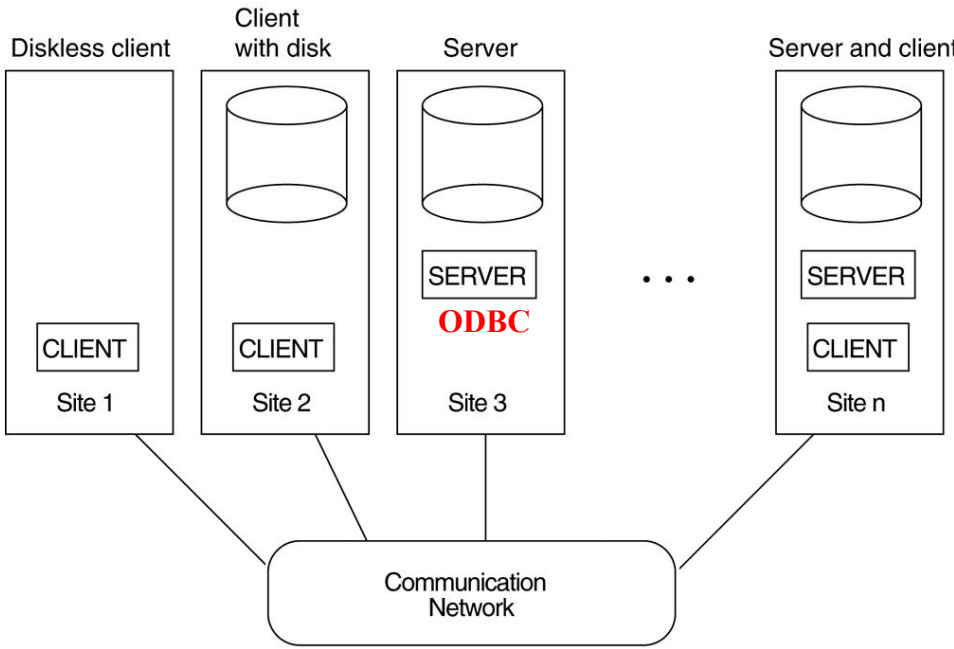
- Specialized Servers with Specialized functions
  - Printer, file, email, Web, DBMS servers
- **DBMS Servers**
  - Provides **database query** and **transaction services** to the clients
  - Sometimes called query and transaction servers



Two Tier Client-Server Architecture

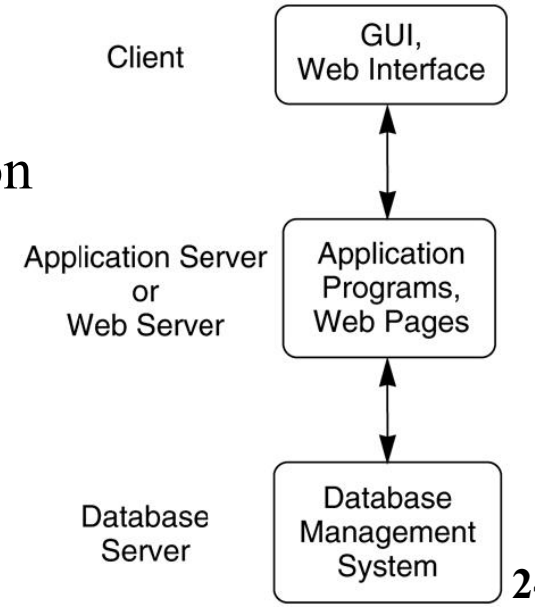
- **User Interface Programs and Application Programs** run on the client side
- Interface called **ODBC (Open Database Connectivity)**
  - ✓ provides an **Application Program Interface (API)** allow client side programs to call the DBMS. Most DBMS vendors provide ODBC drivers.
- A client program may connect to several DBMSs.
- Other variations of clients are possible:

  e.g., in some DBMSs, more functionality is transferred to clients including data dictionary functions, optimization and recovery across multiple servers, etc. In such situations the server may be called the **Data Server**.



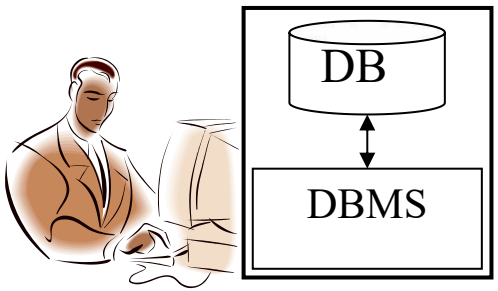
Three Tier Client-Server Architecture

- 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



Classification of DBMSs

- Based on the data model used:
  - Traditional: Relational, Network, Hierarchical.
  - Emerging: Object-oriented, Object-relational.
- Other classifications:
  - Single-user (typically used with micro- computers) vs. multi-user (most DBMSs).
  - Centralized (uses a single computer with one database) vs. distributed (uses multiple computers, multiple databases)



Variations of Distributed Environments

- Homogeneous DDBMS
- Heterogeneous DDBMS
- Federated (or Multidatabase) Systems
  - Loosely coupled and have a degree of local autonomy