CS3402
Database Systems

Teaching Staff's Information

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  - Mr. Wang cwang355-c@my.cityu.edu.hk
  - Mr. Du haodu8-c@my.cityu.edu.hk

Course Overview

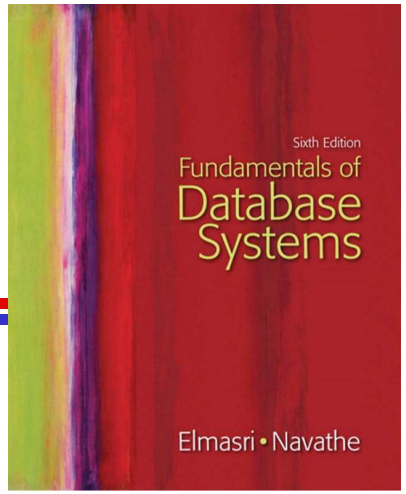
- Course Format:
  - Regular lectures
    - Time: Tuesday 3:00pm - 4:50pm lecture
    - Venue: Online via Zoom
  - Tutorial and lab classes
    - Pattern: 8 Tutorials + 4 Labs
    - Time: Six sessions (Mon, Tue, Wed, Thu)
    - Venue: Face-to-face, MMW 2478

Assessment

- Coursework *-- 40%* :
  - Mid-term (week 7, open-book, online)*-- 25%*
  - Homework assignments (3 times)*-- 15%*

- Final examination (open-book)*-- 60%*
  - *Get 30 out of 100 to pass*

Course Materials



- Text books
  - **"Fundamentals of Database Systems"**, 6th edition (***or later***), by R. Elmasri, S.B. Navathe, Addison-Wesley.
  - "Database System Concepts", 5th edition (*or later*), by A. Silberschatz, H. Korth, S. Sudarshan, McGraw-Hill Companies Inc.

- Notations may vary in different books. Please stick to the ones used in this lecture notes!

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- You cannot avoid it and it's everywhere!
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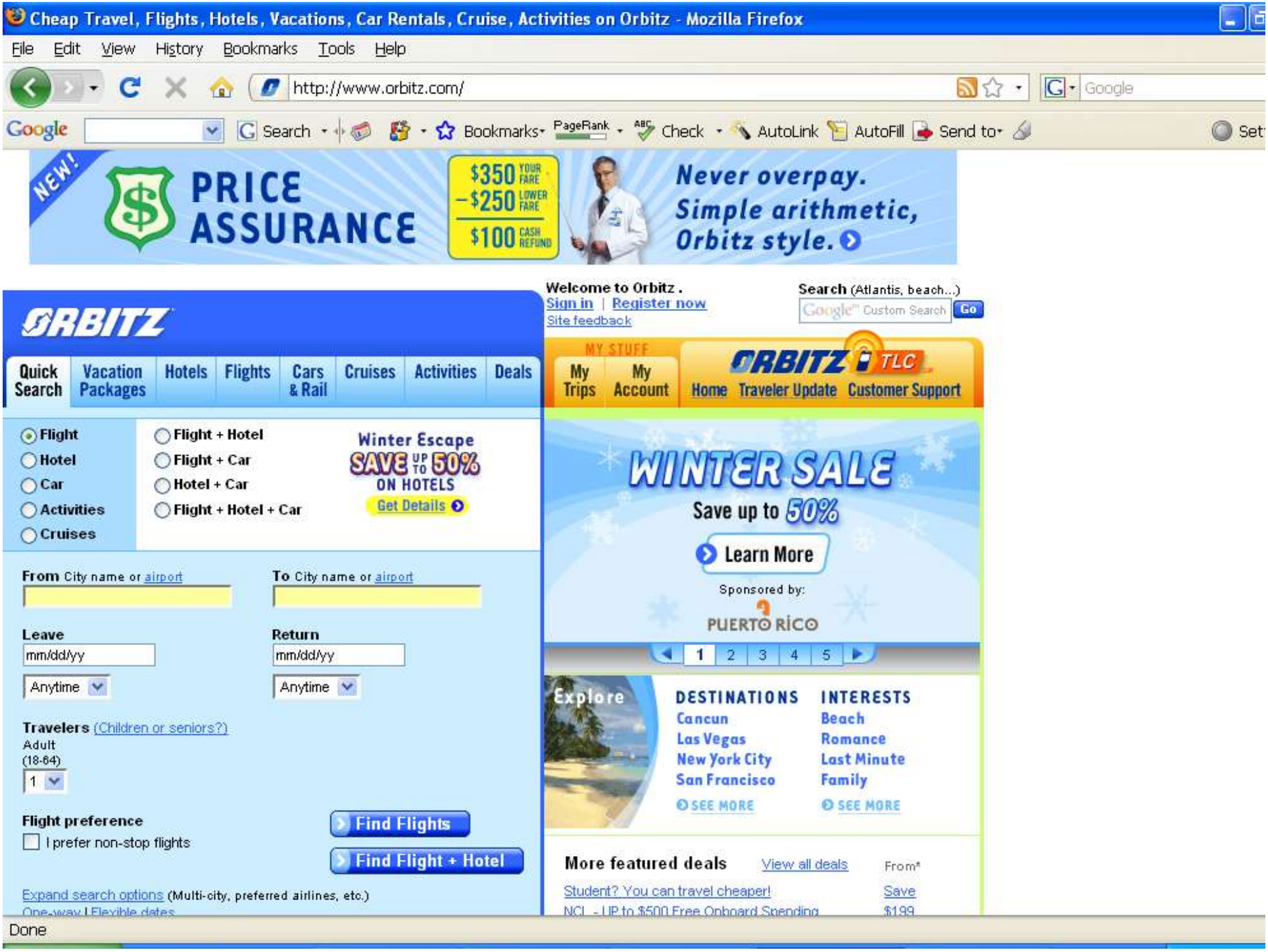
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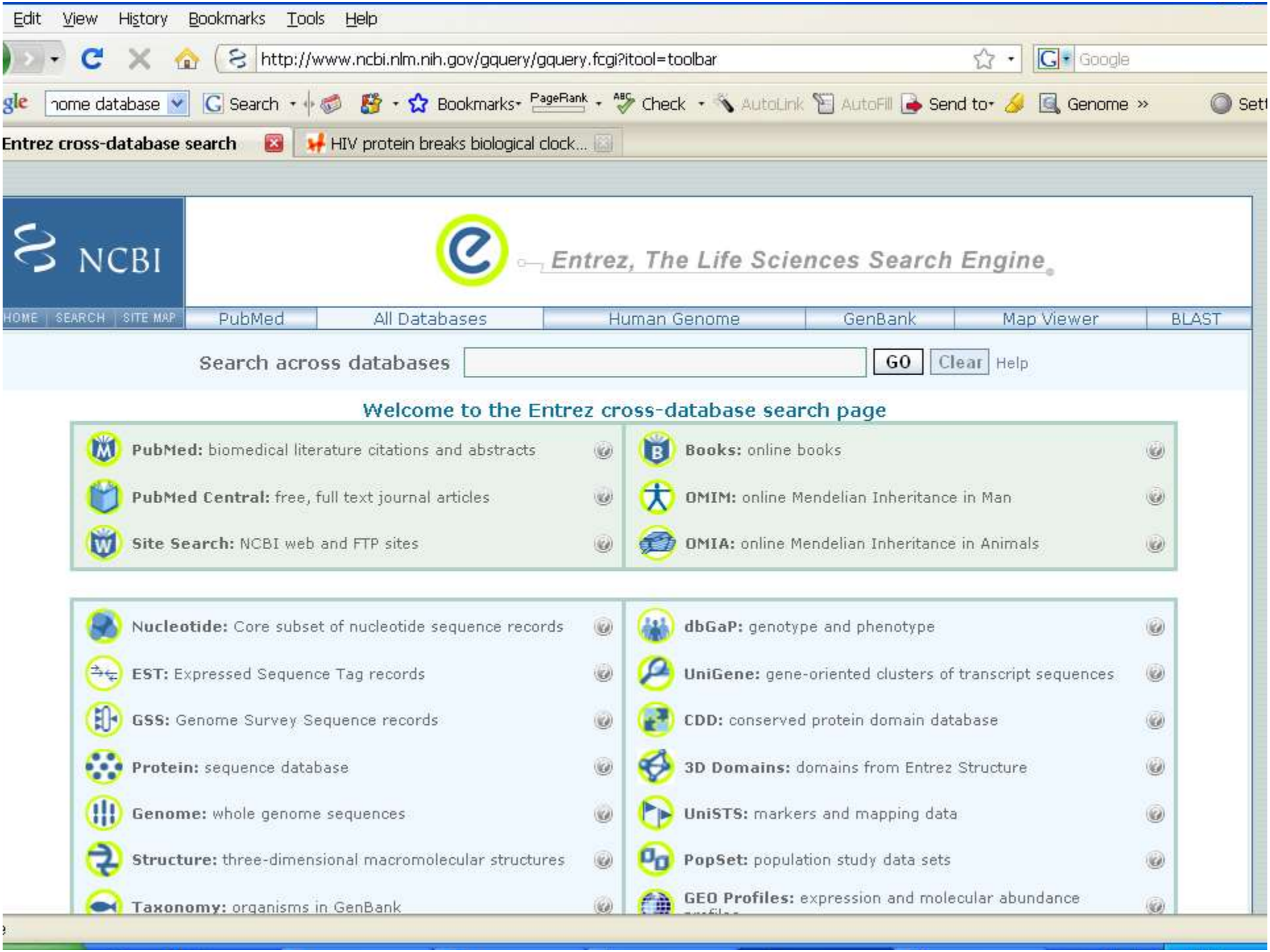
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EST: Expressed Sequence Tag records
GSS: Genome Survey Sequence records
Protein: sequence database
Genome: whole genome sequences
Structure: three-dimensional macromolecular structures
Taxonomy: organisms in GenBank
dbGaP: genotype and phenotype
UniGene: gene-oriented clusters of transcript sequences
CDD: conserved protein domain database
3D Domains: domains from Entrez Structure
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Carnegie Mellon University **Database** Group More Info: http://db.cs.cmu.edu.

订阅

What is Database & SQL?

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https://www.guru99.com/introduction-to-**database**-sql.html This **Database** tutorial explains the concept of DBMS (**Database** ...

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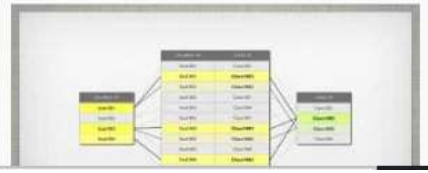


Relational Database Concepts

Prescott Computer Guy • 75万次观看 • 8年前

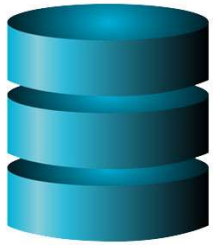
Basic Concepts on how relational **databases** work. Explains the concepts of tables, key IDs, and relations at an introductory level.

Motivating Example

Data: in Computer system, Data is any sort of information which is stored in computer memory.

Student ID	Student name	Course	Course Name	Grade
50000000	Peter Wong	CS3402	Database Systems	B+
50000000	Peter Wong	CS2302	Data Structures	A
50000001	Mary Tsui	CS3402	Database Systems	A-
50000002	Bob Lee	CS3402	Database Systems	B

- This way of storing data good?
- How to improve?



Introduction to DB Systems

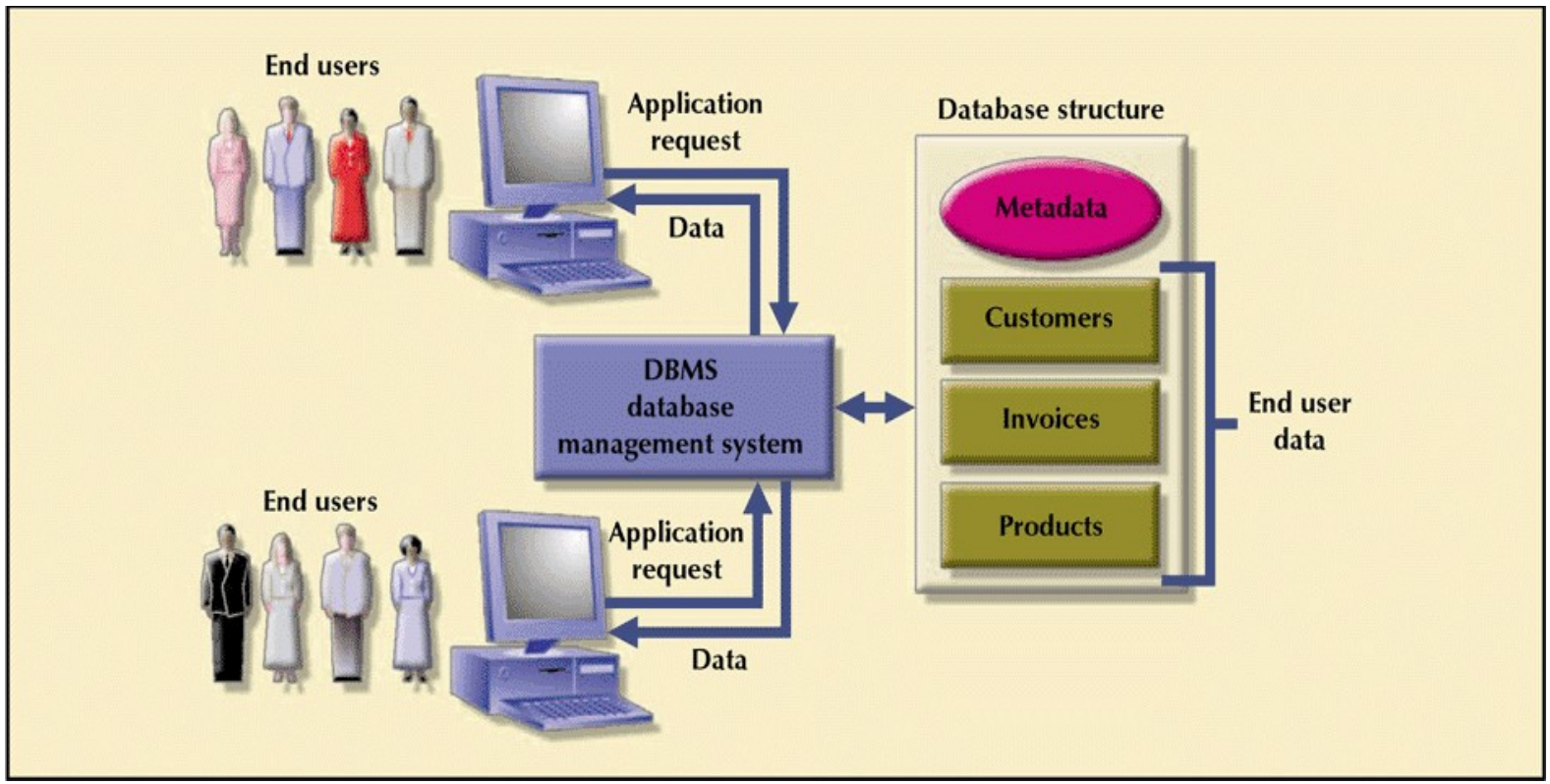
- Motivations
  - File-processing Systems
    - permanent records stored in various files
    - application programs written to extract & add records
  - Disadvantages of traditional file-processing systems
    - data redundancy & inconsistency
    - difficulty in accessing data
    - data isolation & different data formats
    - concurrent access anomalies
    - security problem
    - integrity problem

Introduction to DB Systems

- What is a Database (DB)?
  - A non-redundant, persistent collection of logically-related records/files that are structured to support various processing and retrieval needs.

- Database Management System (DBMS)
  - A set of software programs for creating, storing, updating, and accessing the data of a DB.
  - E.g.: Oracle, Mysql，Oceanbase

Database Management System



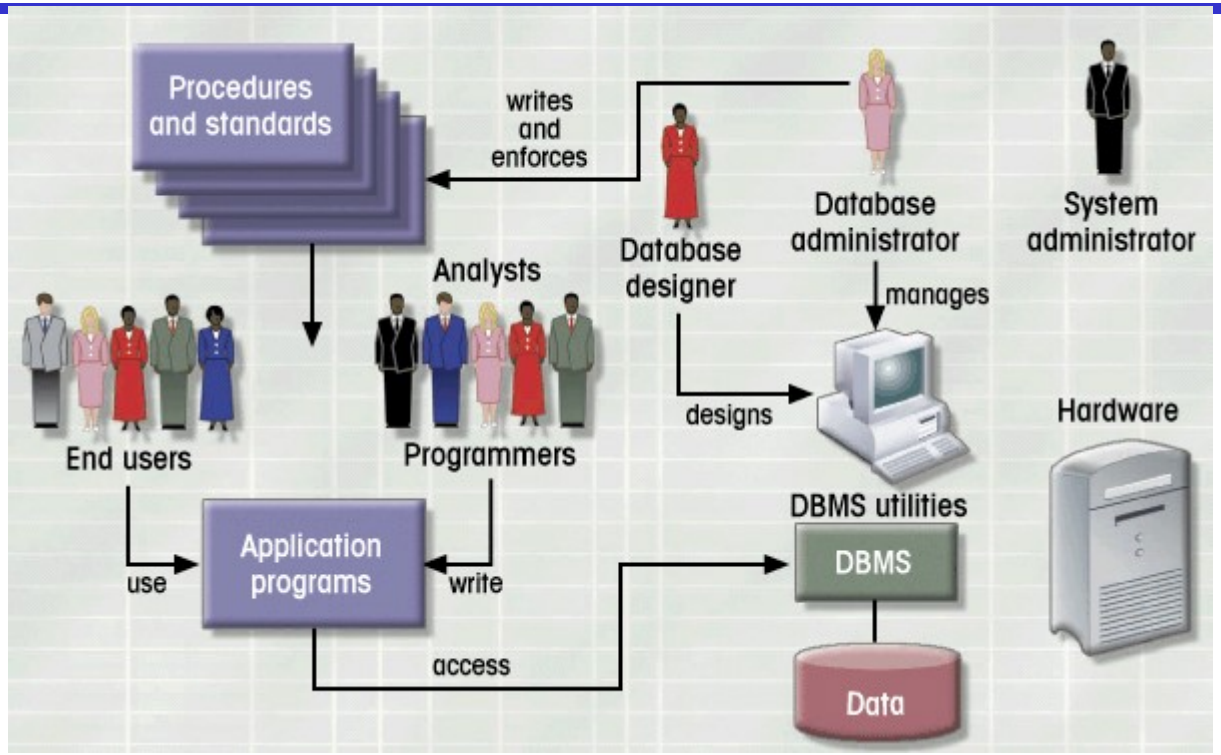
Database Systems: Design, Implementation, & Management: Rob & Coronel

- manages interaction between end users and database

Database Management System

- Difference between DBMS & other programming systems
  - the ability to manage persistent data
  - primary goal of DBMS: to provide an environment that is convenient, efficient, and robust to use in retrieving & storing data
- Other DBMS capabilities
  - data modeling
  - high-level languages to define, access and manipulate data
  - transaction management & concurrency control
  - access control
  - recovery

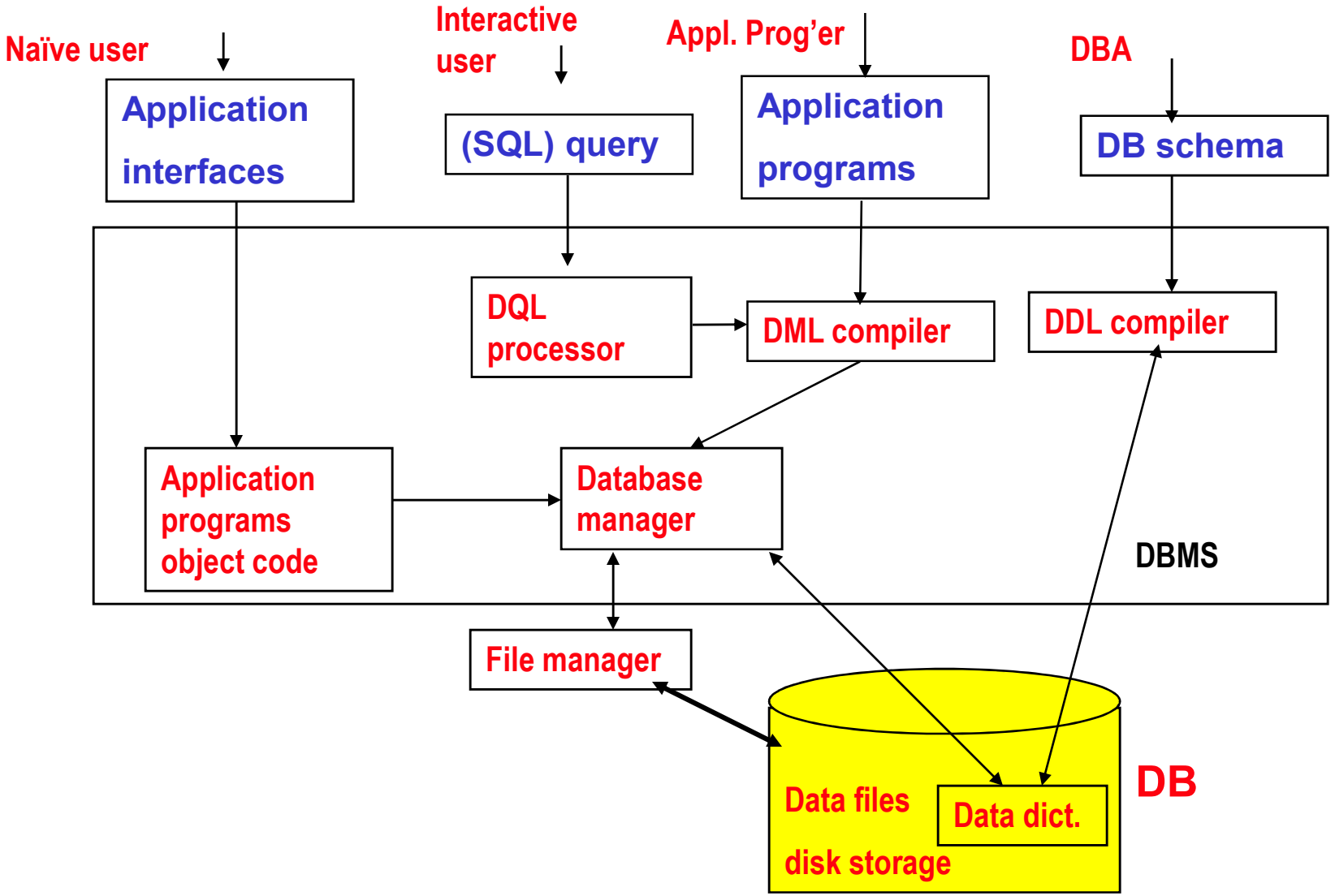
Database System



- **Hardware**
- **Software**
  - OS
  - DBMS
  - Applications
- **People**
- **Procedures**
- **Data**

- Database System
  - an integrated system of hardware, software, people, procedures, and data
  - that define and regulate the collection, storage, management, and use of data within a database environment

DB System Architecture



DB System Architecture

- *Database Users*
  - Naive Users:
    - Running application programs
  - Interactive Users:
    - Using query languages
  - Application Programmers
    - Writing embedded DML in a host language

DB System Architecture

- *Database Administrator (DBA)*
  - DBA is the person who has central control over the DB
  - Main functions of DBA:
    - schema definition
    - storage structure and access method definition
    - schema and physical organization modification
    - granting of authorization for data access
    - integrity constraint specification

DB System Architecture

- *Data Query Language (DQL)*
- a language used to make queries in databases
- e.g. search records with giving conditions (sex="Female")
- *Data Manipulation Language (DML)*
- a language that enables users to manipulate data
- e.g. insert or delete records
- *Data Definition Language (DDL)*

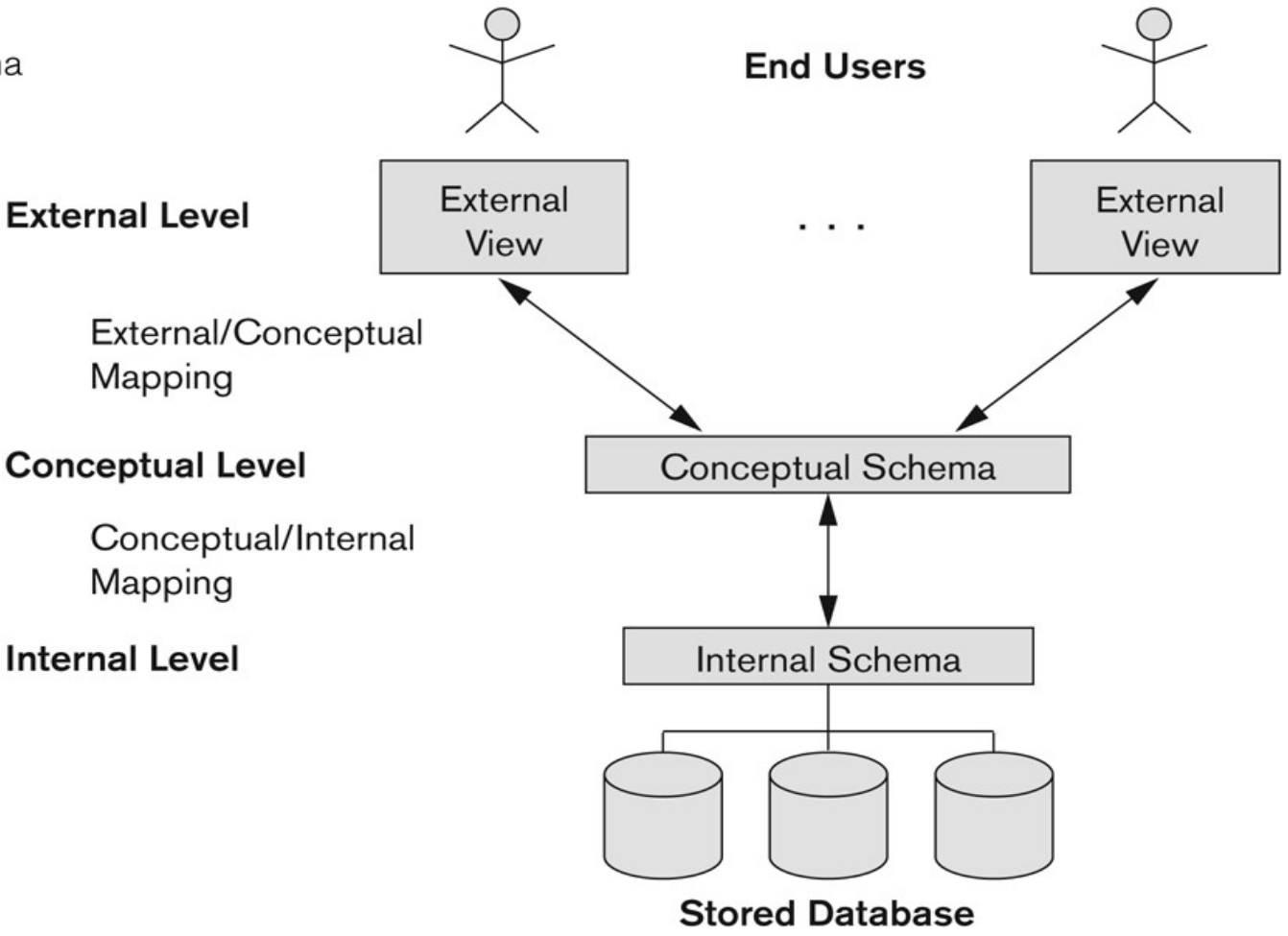
- a language for defining DB schema
- e.g., create, modify, and remove database objects such as tables, indexes, and users.

DB System Architecture

- DB Manager
  - interface between stored data and application programs/queries
  - translate conceptual level commands into physical level ones
  - responsible for
    - access control
    - concurrency control
    - backup & recovery
    - integrity
- File Manager
  - allocation of space
  - operations on files

Data Abstraction: 3-level architecture

Figure 2.2
The three-schema architecture.



Data Abstraction

- Data Abstraction
  - Abstract view of the data
    - simplify interaction with the system
    - hide details of how data is stored and manipulated
  - Levels of abstraction
    - Physical/internal level: **internal schema** uses a physical data model and describes the complete details of data storage and access paths for the database.
    - Conceptual level: **conceptual schema** describes the structure of the whole database for a community of users and hides the details of physical storage structures.
    - View/external level: **external schema** describes the part of the database that a particular user group is interested in and hides the rest from that group.

Data Independence

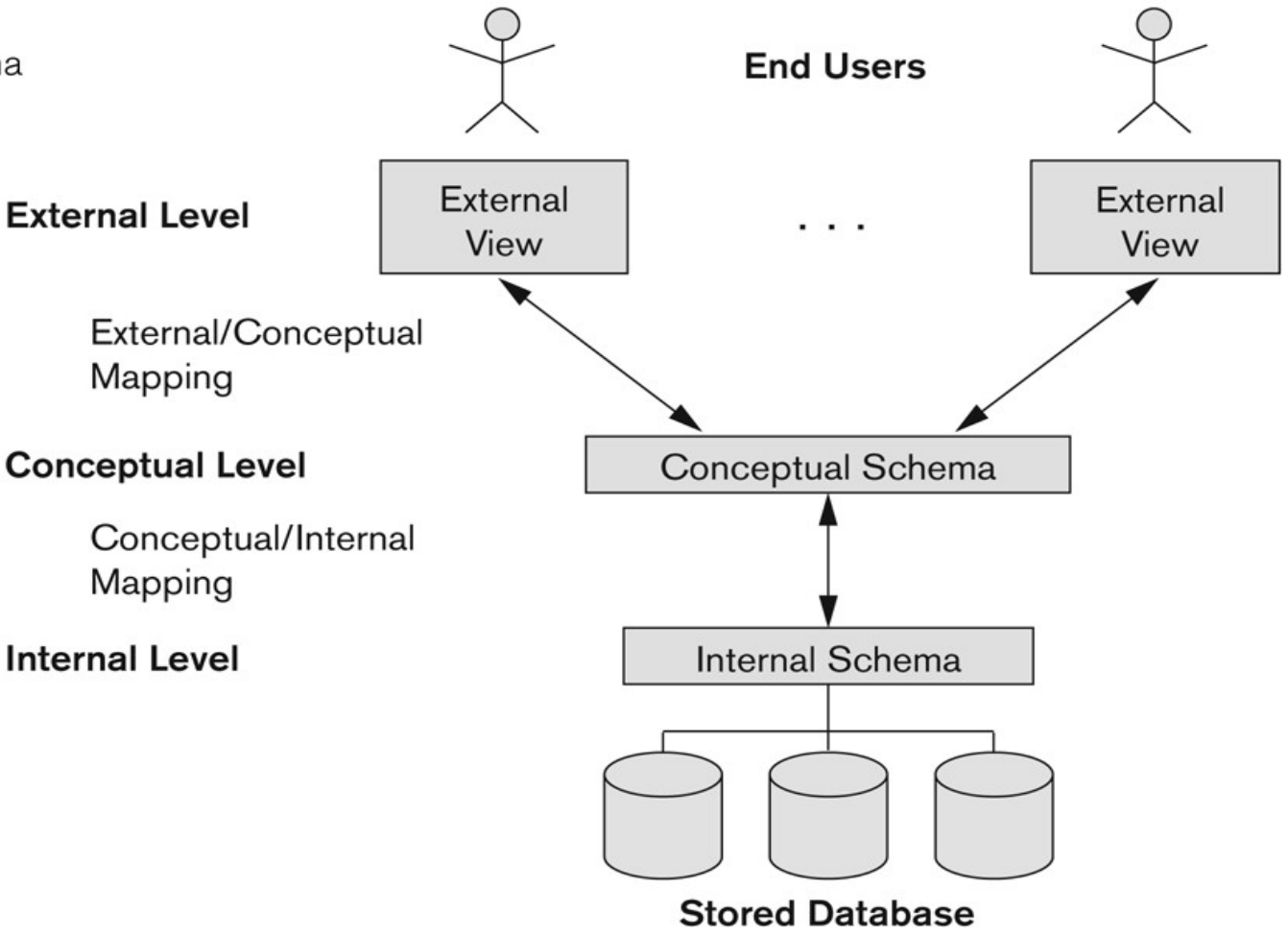
- the ability to modify a schema definition in one level without affecting a schema in the next higher level
- there are two kinds (a result of the 3-level architecture):
  - ***physical data independence***

    -- the ability to modify the physical schema without altering the conceptual schema and thus, without causing the application programs to be rewritten
  - ***logical data independence***

    -- the ability to modify the conceptual schema without causing the application programs to be rewritten

Data Abstraction: 3-level architecture

Figure 2.2
The three-schema architecture.

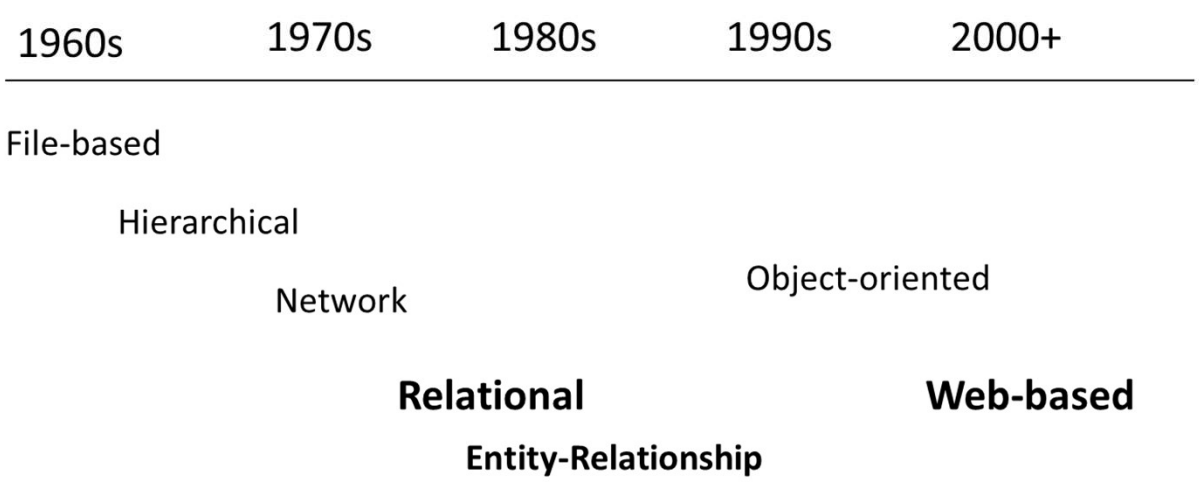


Data Models

- Data Model (conceptual level)
  - A collection of conceptual tools for describing data, data relationships, operations, and consistency constraints
  - the "core" of a database

Evolution of Data Models

- Timeline



Course Objectives

- ER model: characterize relationships among entities
- Relational model: transform from ER diagram to tables
- SQL: language for writing queries
- Relational Algebra: logical way to represent queries
- Normal Forms: how to design good tables
- File Organization: provide file level structure to speed up query
- Query Optimization: transform queries into more efficient ones
- Transactions and Concurrency Control: handle concurrent operations and guarantee correctness of the database

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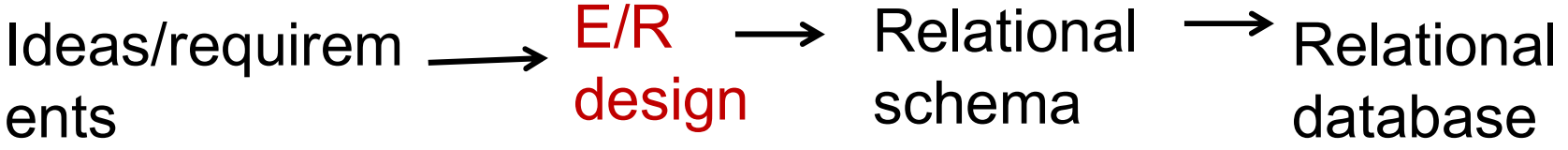
The Entity-Relationship Model

- Preliminaries
  - Proposed by P. Chen in 1976
  - Direct, easy-to-understand graphical notation
  - Translates readily to relational schema for database design



- **Three basic concepts:**

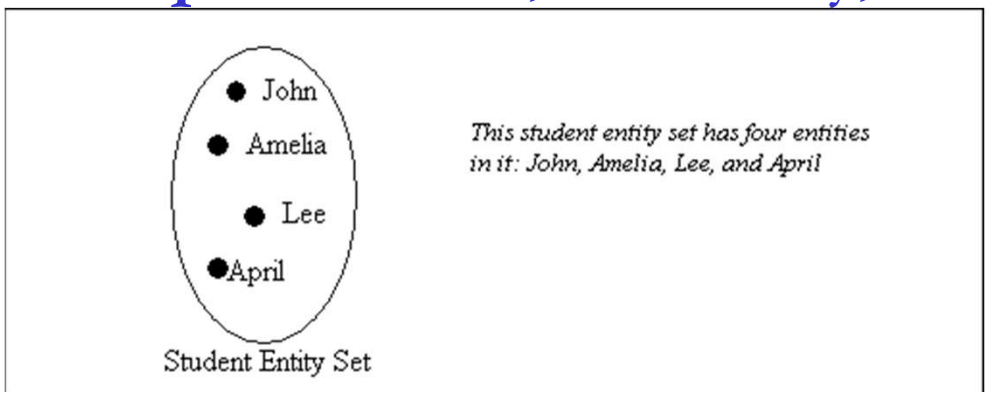
  Entity, Attribute, Relationship

ER Model Concepts

- **Entity**
  - a distinguishable object with an independent existence

    Example: John Chan, CityU, HSBC, …
- **Entity Set**
  - a set of entities of the same type

    Example: Student, University, Bank, ...



ER Model Concepts

- **Attribute**(Property) -- a piece of information describing an entity or relationship
  - *Example*: Name, ID, Address, Sex are attributes of a student entity
  - Each attribute can take a value from a domain

    Example: Name $\in$ Character String,

    ID $\in$ Integer, ...
  - Formally, an attribute **A** is a function which maps from an entity set **E** into a domain **D**:

    $$\mathbf{A: E \rightarrow D}$$

Types of Attributes

- Simple
  - Each entity has a **single** atomic value for the attribute. For example, SSN or Sex, name…
- Composite
  - The attribute may be composed of several components. For example:
    - Address(Flat, Block, Street, City, State, Country)
    - Composition may form a hierarchy where some components are themselves composite
- Multi-valued
  - An entity may have multiple values for that attribute. For example, Color of a CAR or PreviousDegrees of a STUDENT
    - Denoted as {Color} or {PreviousDegrees}
    - E.g., {{BSc, 1990}, {MSc, 1993}, {PhD, 1998}}

Example of a composite attribute

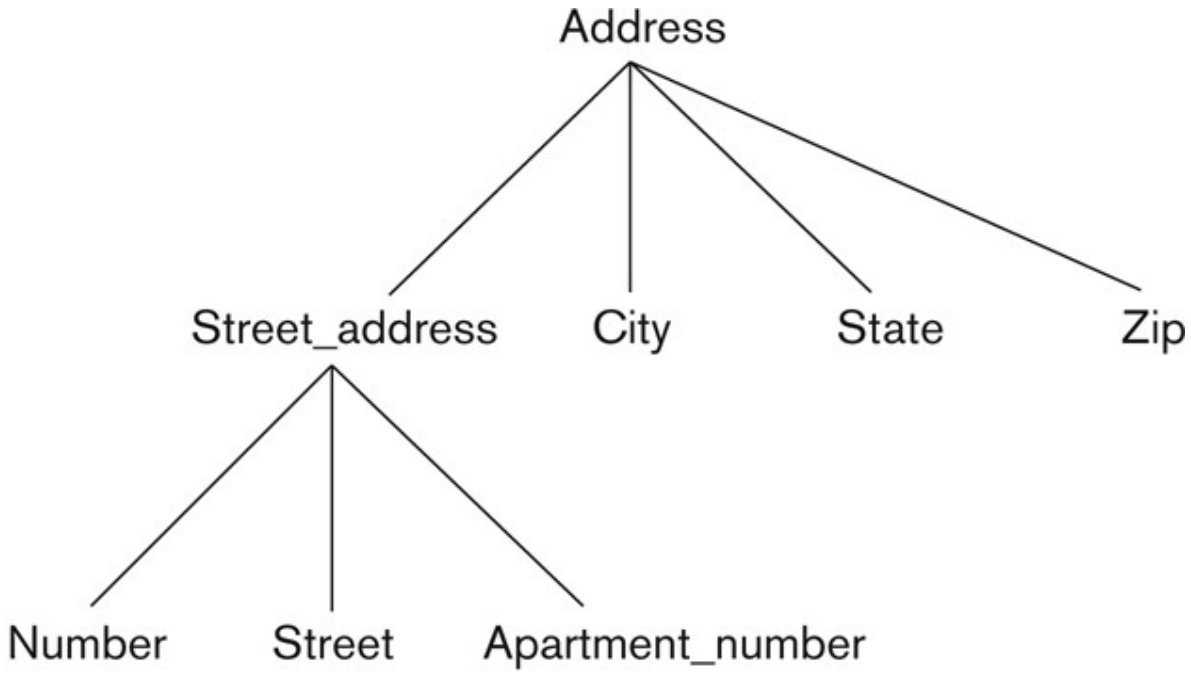


Figure 3.4
A hierarchy of composite attributes.

Types of Attributes

- In general, composite and multi-valued attributes may be nested to any number of levels
  - For example, PreviousDegrees of a STUDENT is a composite multi-valued attribute denoted by {PreviousDegrees (College, Year, Degree, Field)}
  - Multiple PreviousDegrees values can exist
  - Each has four subcomponent attributes:
    - College, Year, Degree, Field

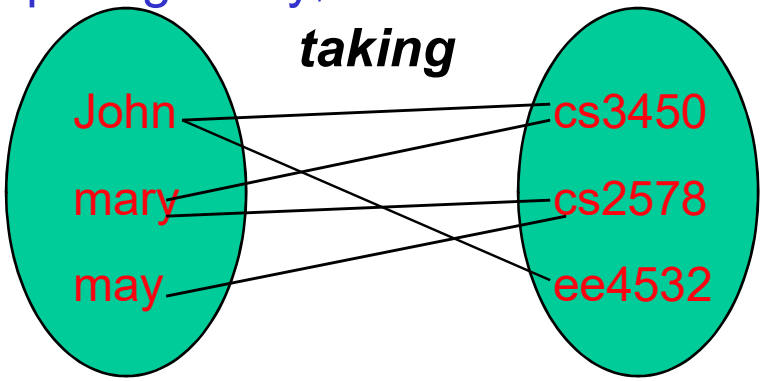
Attributes can form the keys

- Keys: to distinguish individual entities or relationships
  - **superkey** -- a set of one or more attributes which, taken together, identify uniquely an entity in an entity set
    - Example: {student ID, Name} identify a student
  - **candidate key** -- ***minimal*** set of attributes which can identify uniquely an entity in an entity set
    - a superkey for which no proper subset is a superkey
    - Example: student ID identify a student,
      but Name is not a candidate key (WHY?)
    - Minimal does not need to be a single attribute.
  - **primary key** -- a candidate key chosen by the DB designer to identify an entity or relationship

ER Model Concepts

- **Relationship** -- an association among several entities
  - *Example*: Patrick and Eva are friends
    Patrick is taking cs3450
- a relationship can carry attributes: properties of the relationship
  - Example: Patrick takes cs2450 with a grade of B+

- **Relationship Set** -- a set of relationships of the same type (same attribute, same participating entity, same constraints)
  - Example:



  - Formally, a relationship **R** is a subset of:
    { (e1, e2, …, ek) | e1 ∈ E1, **e2** ∈ E2, …, **ek** ∈ Ek) }

Constraints on relationship

- Cardinality

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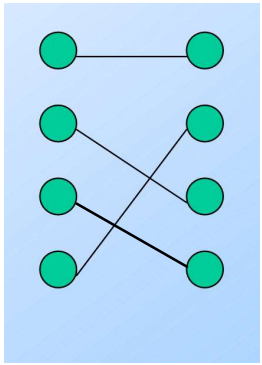

One-to-one(1:1)

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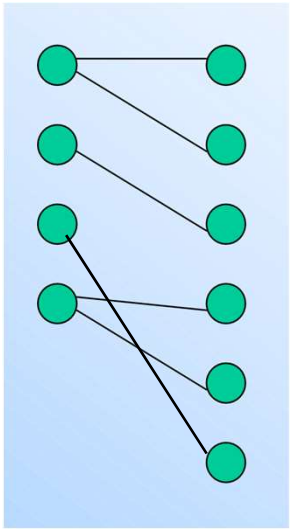

One-to-many (1:N)

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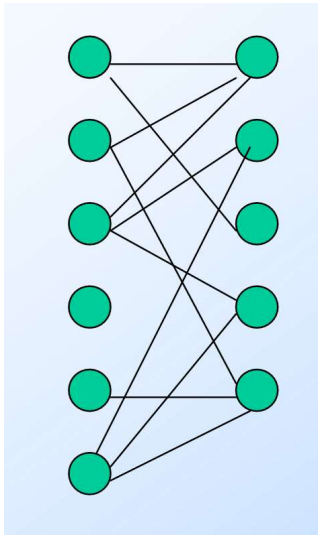
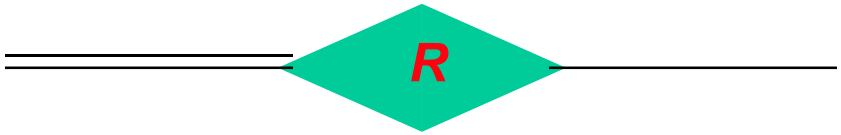


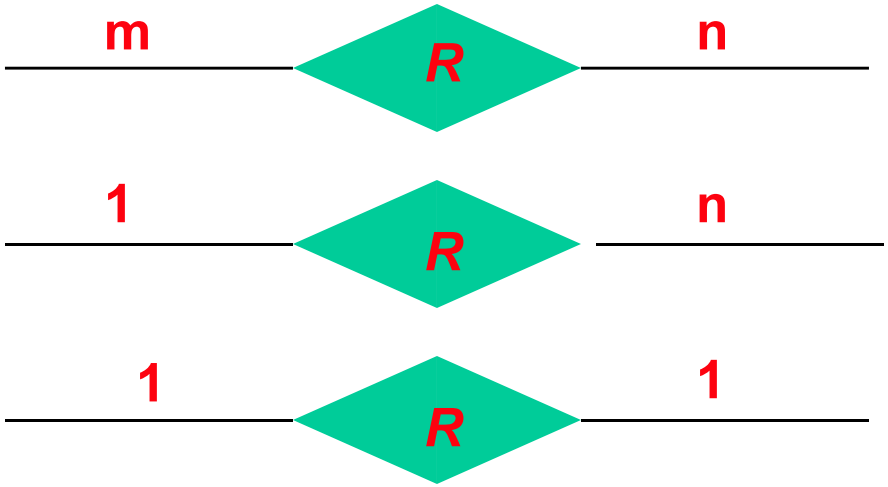
Many-to-many (M:N)

- Participation: whether every entity in the entity set participates in the relationship set: total v.s. partial

ER Model Diagram

- ER Diagram
  - Rectangles: Entity Sets
  - Oval: Attributes
  - Diamonds: Relationship Sets
  - Lines: Attributes to Entity/Relationship Sets
    or, Entity Sets to Relationship Sets





Example COMPANY Database

- We need to create a database schema (definition) based on the following (simplified) application requirements of the COMPANY Database:
  - The company is organized into DEPARTMENTs
  - Each DEPARTMENT has a unique name, unique number and an EMPLOYEE who *manages* the department
  - We keep track of the start date of the department manager. A department may have several locations
  - Each DEPARTMENT controls/has a number of PROJECTs
  - Each project has a unique name, unique number and is located at a single location

Example COMPANY Database

- The database will store each EMPLOYEE's social security number (ssn), name(first name, last name and middle init), address, salary, sex, and birthdate
  - Each employee *works for* one department but may *work on* several projects
  - The DB will keep track of the number of hours per week that an employee currently works on each project
  - It is required to keep track of the *direct supervisor* of each employee

- Each employee may *have* a number of DEPENDENTs
  - For each dependent, the DB keeps a record of name, sex, birthdate, and relationship to the employee

Initial Conceptual Design of Entity Sets for the COMPANY Database Schema

- Based on the requirements, we can identify four initial entity sets in the COMPANY database:
  - DEPARTMENT
  - PROJECT
  - EMPLOYEE
  - DEPENDENT

- The initial attributes shown are derived from the requirements description:

Initial Design of Entity Sets:
EMPLOYEE, DEPARTMENT, PROJECT, DEPENDENT

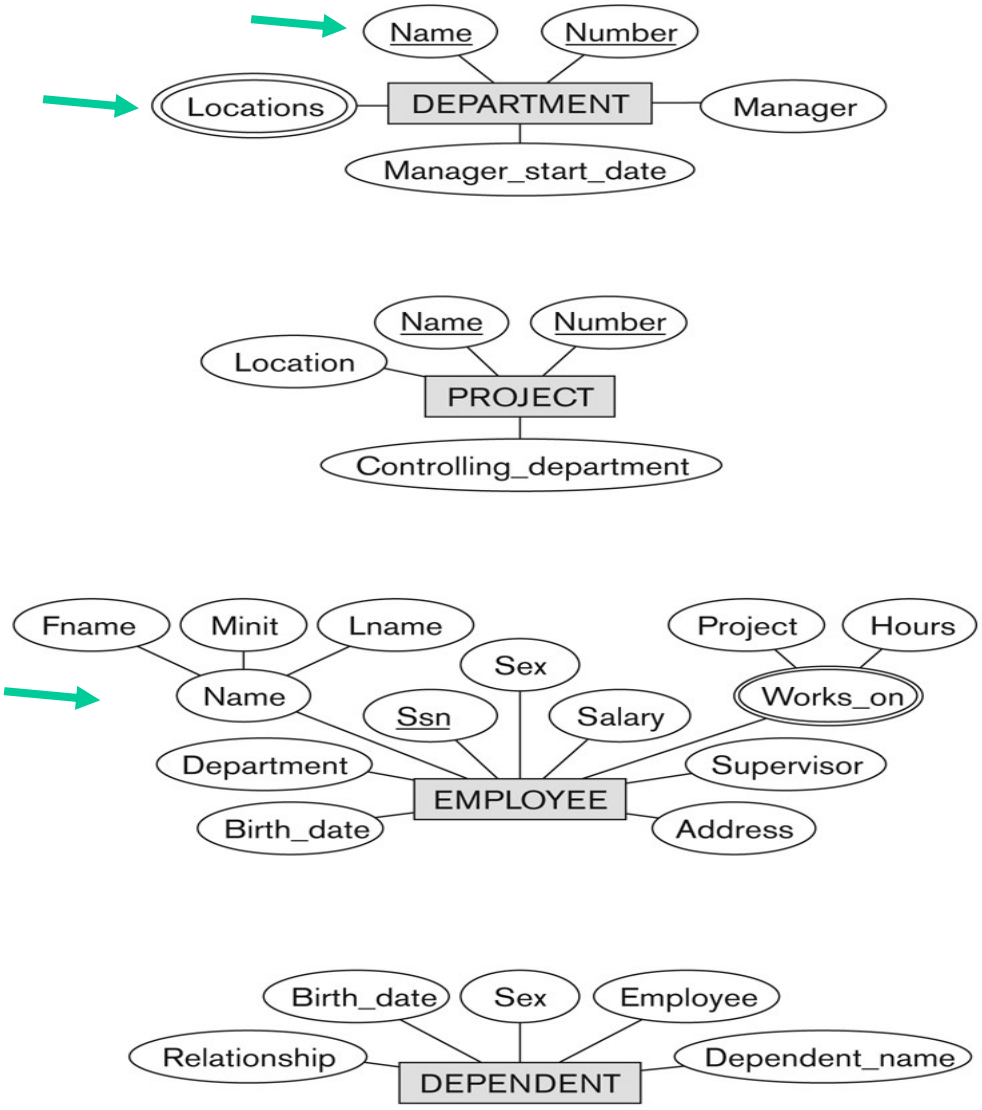


Figure 3.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

Refining the initial design by introducing relationships

- Find relationships relating two or more distinct entities/entity types with a specific meaning

- By examining the requirements, six relationship types are identified:
  - EMPLOYEE *works on* PROJECT
  - EMPLOYEE *works for* DEPARTMENT
  - EMPLOYEE *manages* DEPARTMENT
  - EMPLOYEE *supervises* EMPLOYEE
  - DEPENDENT *depends on* EMPLOYEE
  - DEPARTMENT *controls* PROJECT

ER DIAGRAM – Relationship Types are:

WORKS_FOR, MANAGES, WORKS_ON, CONTROLS, SUPERVISION, DEPENDENTS_OF

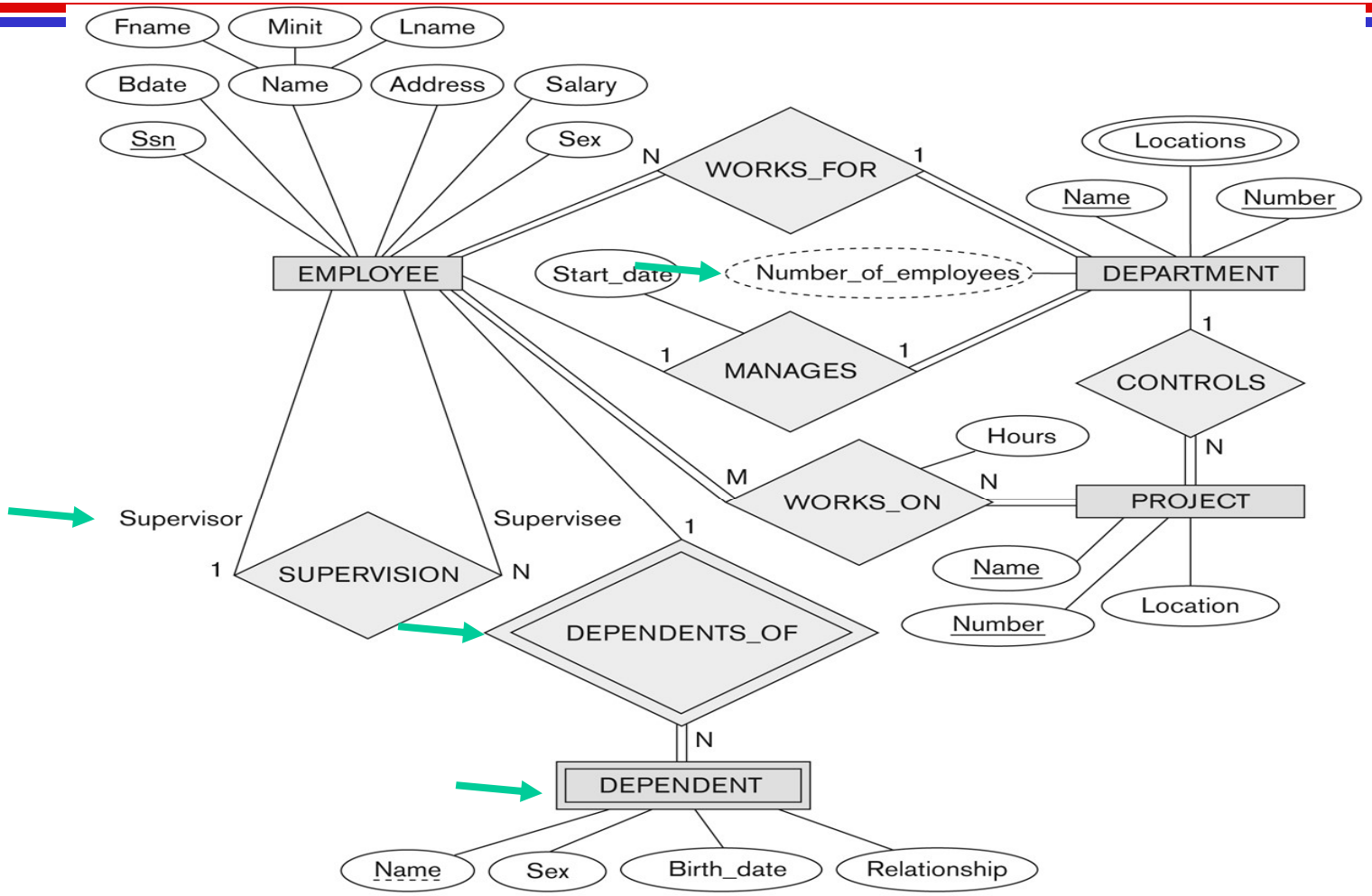
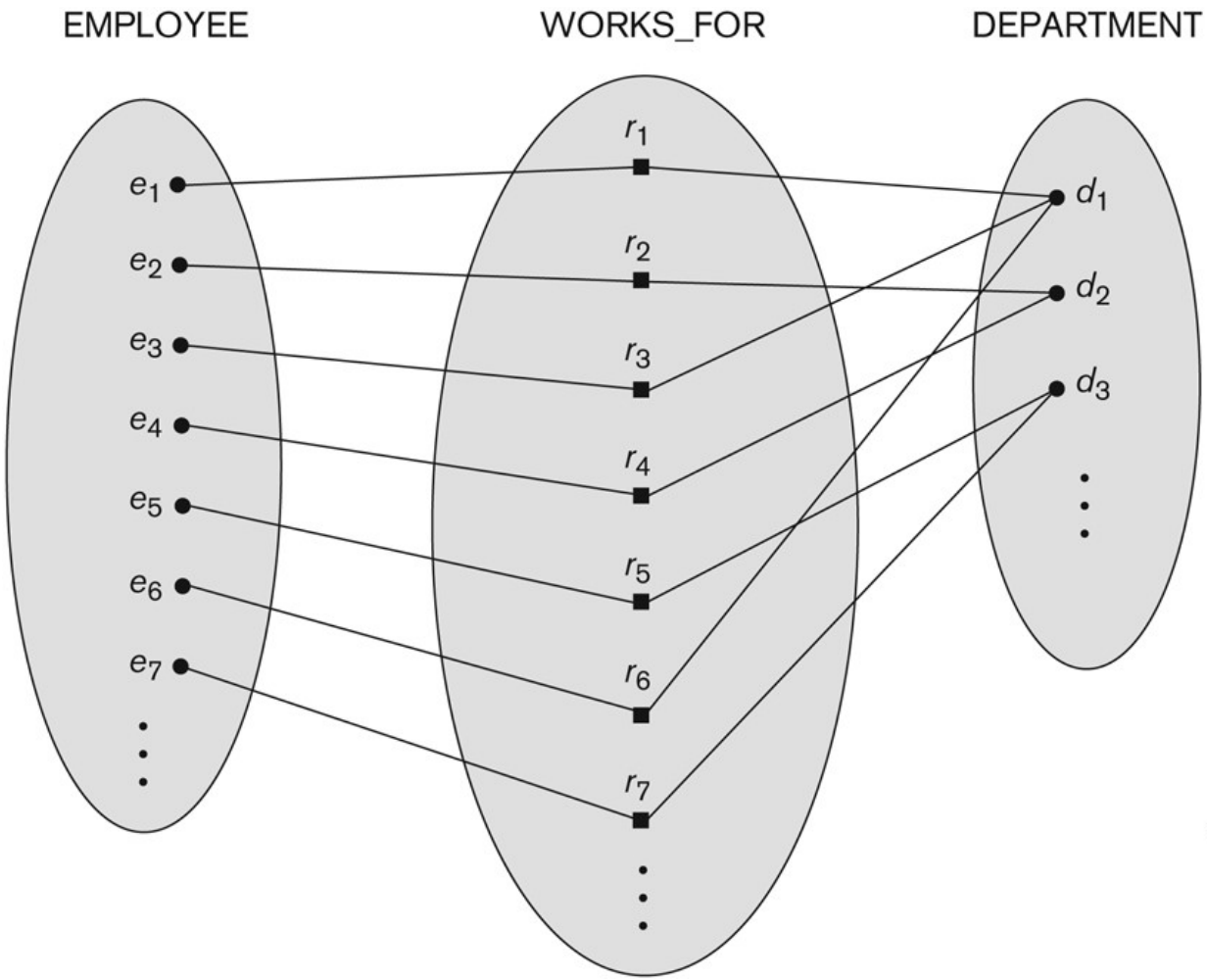


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

Relationship instances of the WORKS_FOR N:1 relationship between EMPLOYEE and DEPARTMENT

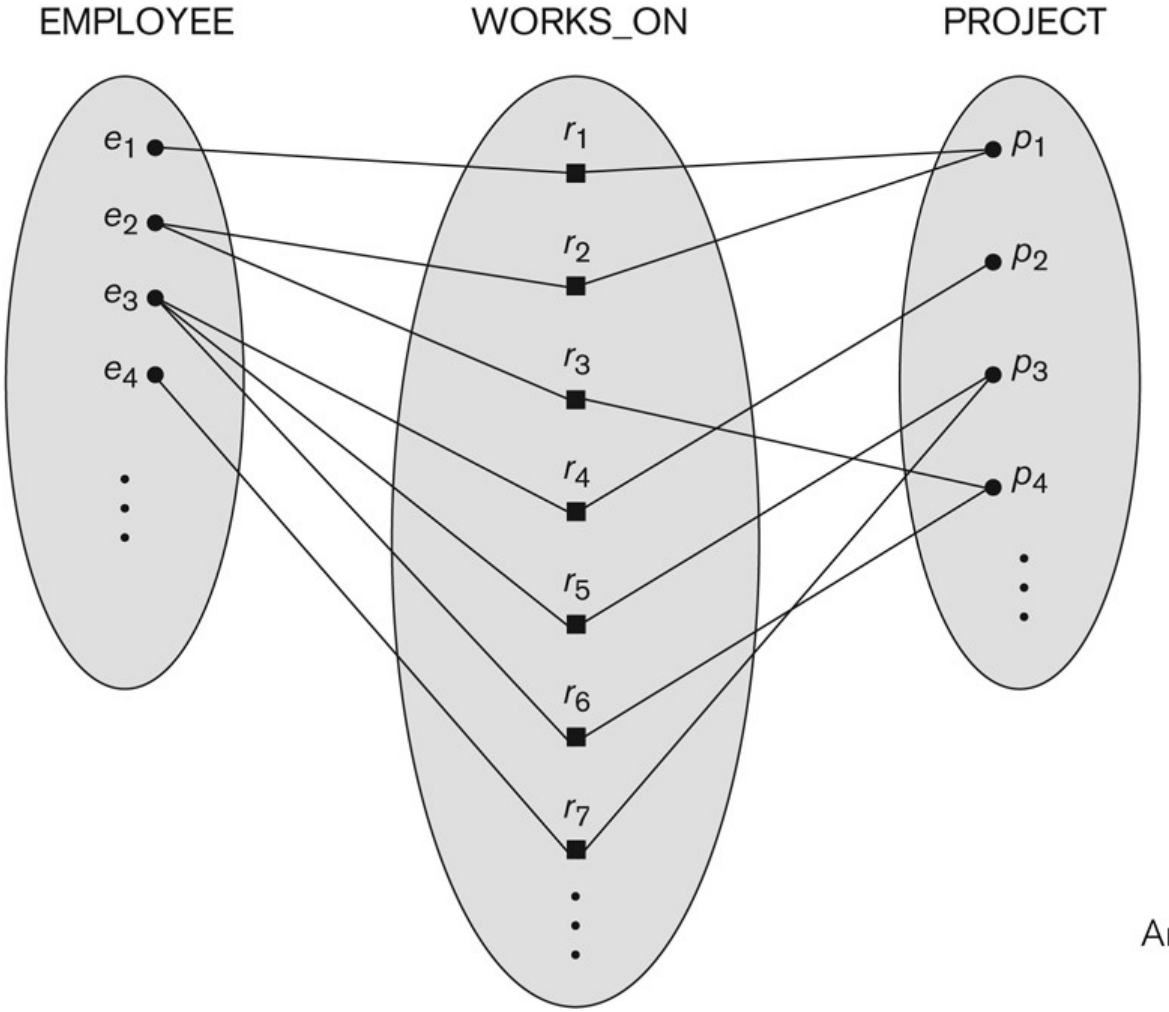


N-to-1

Many employees in the same department

Figure 3.9
Some instances in the WORKS_FOR relationship set, which represents a relationship type WORKS_FOR between EMPLOYEE and DEPARTMENT.

Relationship instances of the M:N WORKS_ON relationship between EMPLOYEE and PROJECT

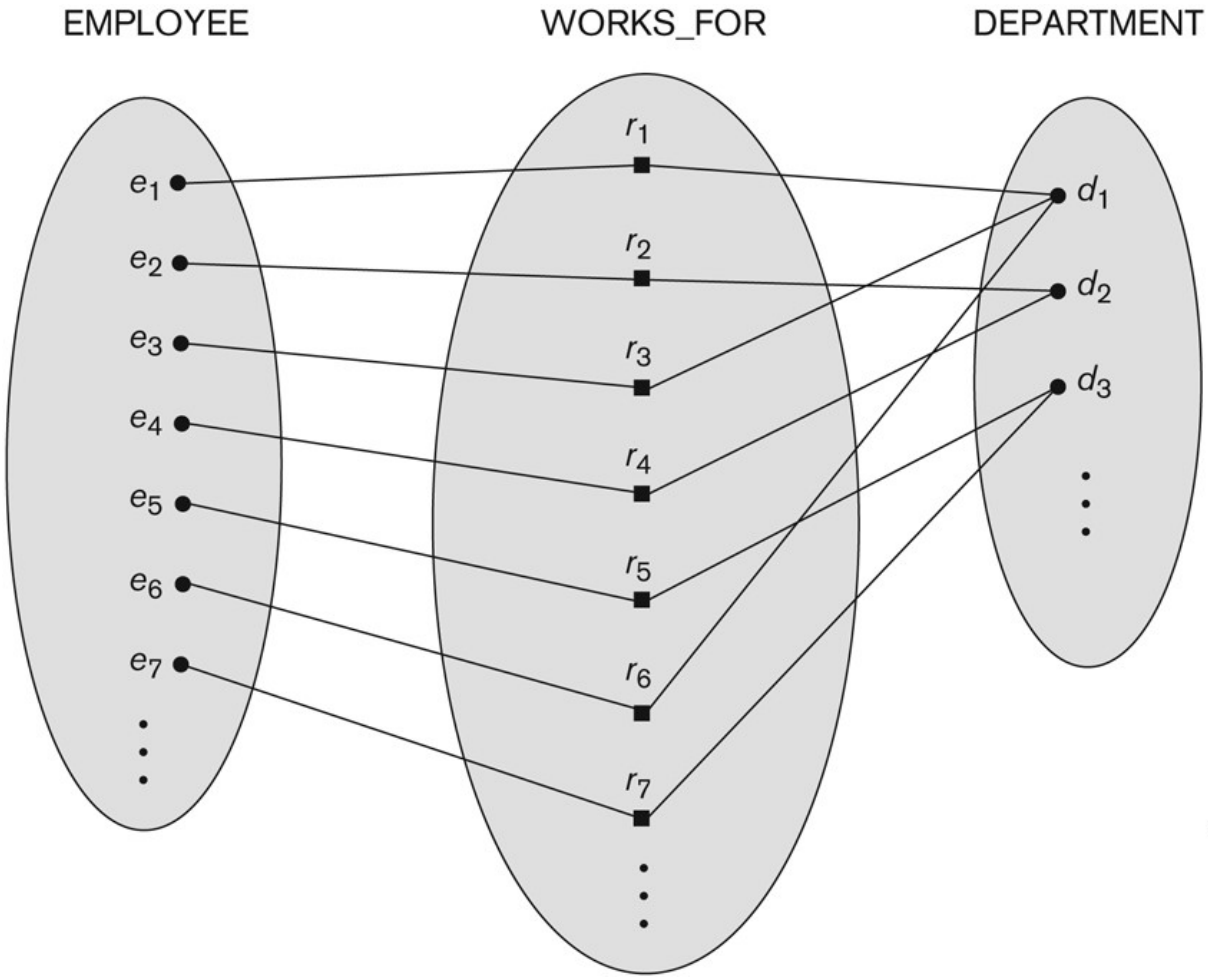


M-to-n

Many employee work on many projects

Figure 3.13
An M:N relationship, WORKS_ON.

Many-to-one (N:1) Relationship

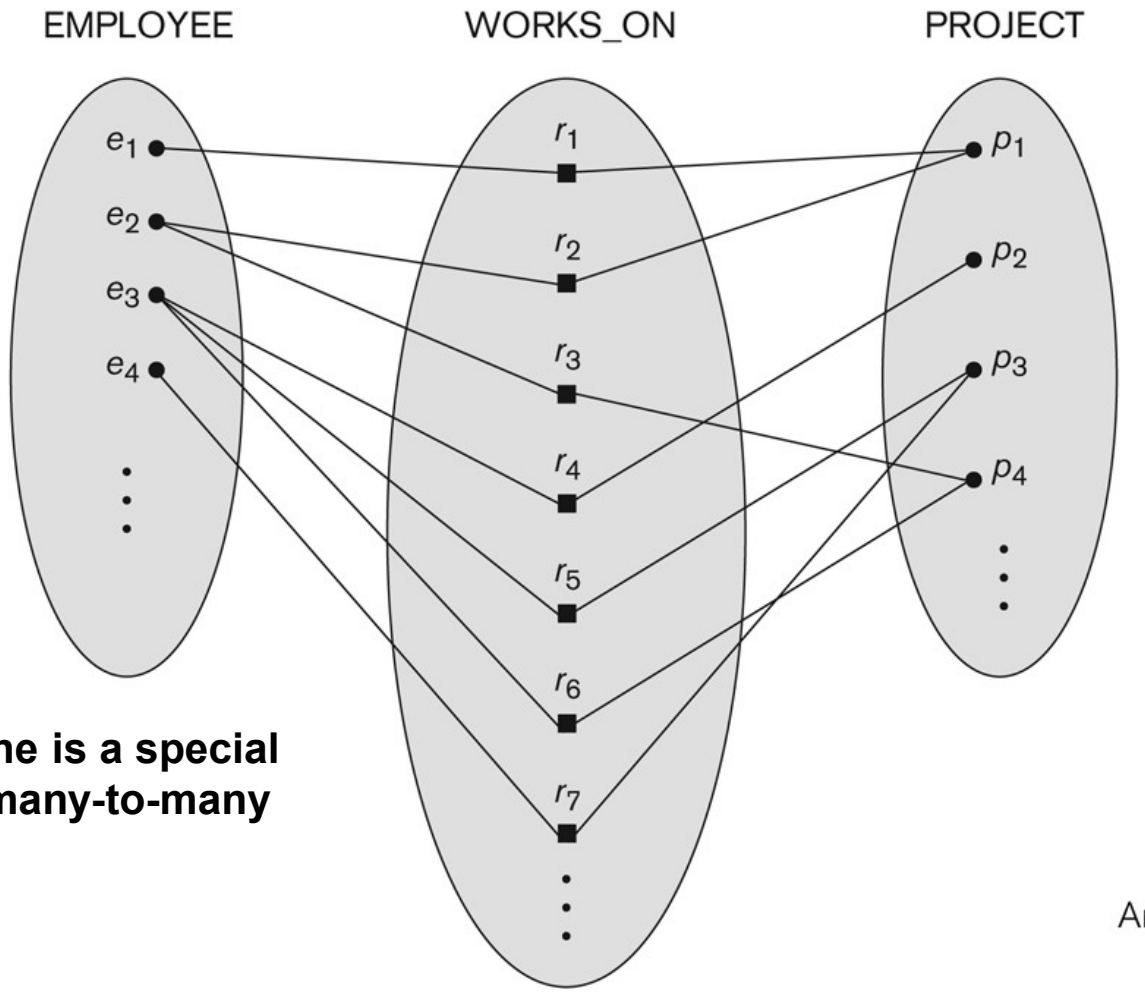


Select anyone in EMPLOYEE, one can be identified in DEPARTMENT

One-to-one is special case of Many-to-one

Figure 3.9
Some instances in the WORKS_FOR relationship set, which represents a relationship type WORKS_FOR between EMPLOYEE and DEPARTMENT.

Many-to-many (M:N) Relationship

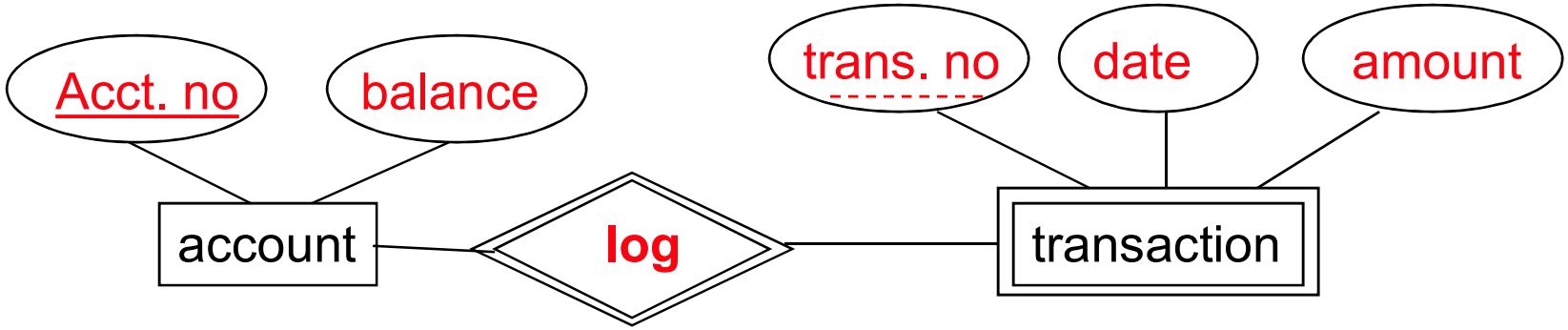


Many-to-one is a special case of a many-to-many

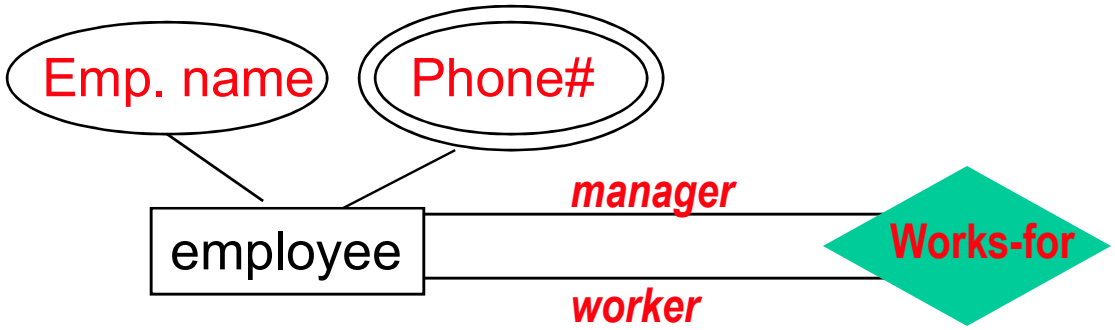
Figure 3.13
An M:N relationship, WORKS_ON.

ER Model Diagram

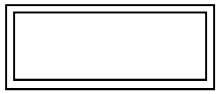
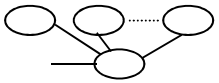
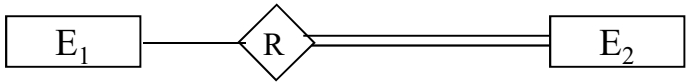
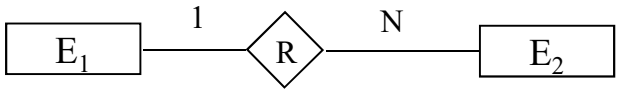
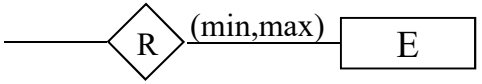
- Weak Entity Set
  - an entity set that does NOT have enough attributes to form a primary/candidate key



- Role Indicators



Summary of ER-Diagram Notation

Symbol	Meaning
	ENTITY TYPE
	WEAK ENTITY TYPE
	RELATIONSHIP TYPE
	IDENTIFYING RELATIONSHIP TYPE
	ATTRIBUTE
	KEY ATTRIBUTE
	MULTIVALUED ATTRIBUTE
	COMPOSITE ATTRIBUTE
	DERIVED ATTRIBUTE
	TOTAL PARTICIPATION OF E_2 IN R
	CARDINALITY RATIO 1:N FOR E_1:E_2 IN R
	STRUCTURAL CONSTRAINT (min, max) ON PARTICIPATION OF E IN R

Summary

- Concepts of database system, DBMS, data abstraction, Data model.

- The ER Model is regarded as the 1st “conceptual/semantic” model centered around relationships, not attributes
- It combines successfully the best features of the previous data models
- simple and easy to understand

- can be mapped to tables (relational model) in a straightforward manner

  (to be studied in the coming lecture series)