CS3402
Database Systems

Teaching Staff's Information

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    yufeicui3-c@my.cityu.edu.hk (Mr. CUI)

Course Overview

- Course Format:
  - Regular lectures
    - Class timetable:
      - Tuesday 5:00pm - 6:50PM lectures (LT-8)
  - Tutorial and lab classes
      - One-hour tutorial **or** lab class every week
      - Patterns:

        w2-3, w7-9, w12-13: tutorial classes;

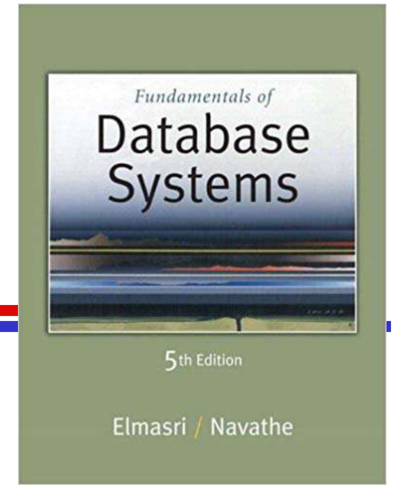
        w4-6, w10-11: lab classes (@MMW1411)

Assessment

- Coursework *-- 40%* :
  - Tutorial and lab attendance *-- 5%*
    - *Proportional to number of attendances*
    - *5% for at least 10 attendances*
  - Mid-term *-- 20%*
  - Homework assignments *-- 15%*

- Final examination *-- 60%*
  - *Get 30 out of 100 to pass*

Course Materials



- Text books
  - "**Fundamentals of Database Systems**", 4th/5th 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!

Databases is everywhere

- You cannot avoid it and it's everywhere!
- You can say it actually makes the current society and your life work!
- Banking/Credit card /Social Security Info…
- Online shopping/booking…


Amazon.com: Online Shopping for Electronics, Apparel, Computers, Books, DVDs & more - Mozilla Firefox
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Approximation Algorithms Hardcover by Vijay V. Vazirani
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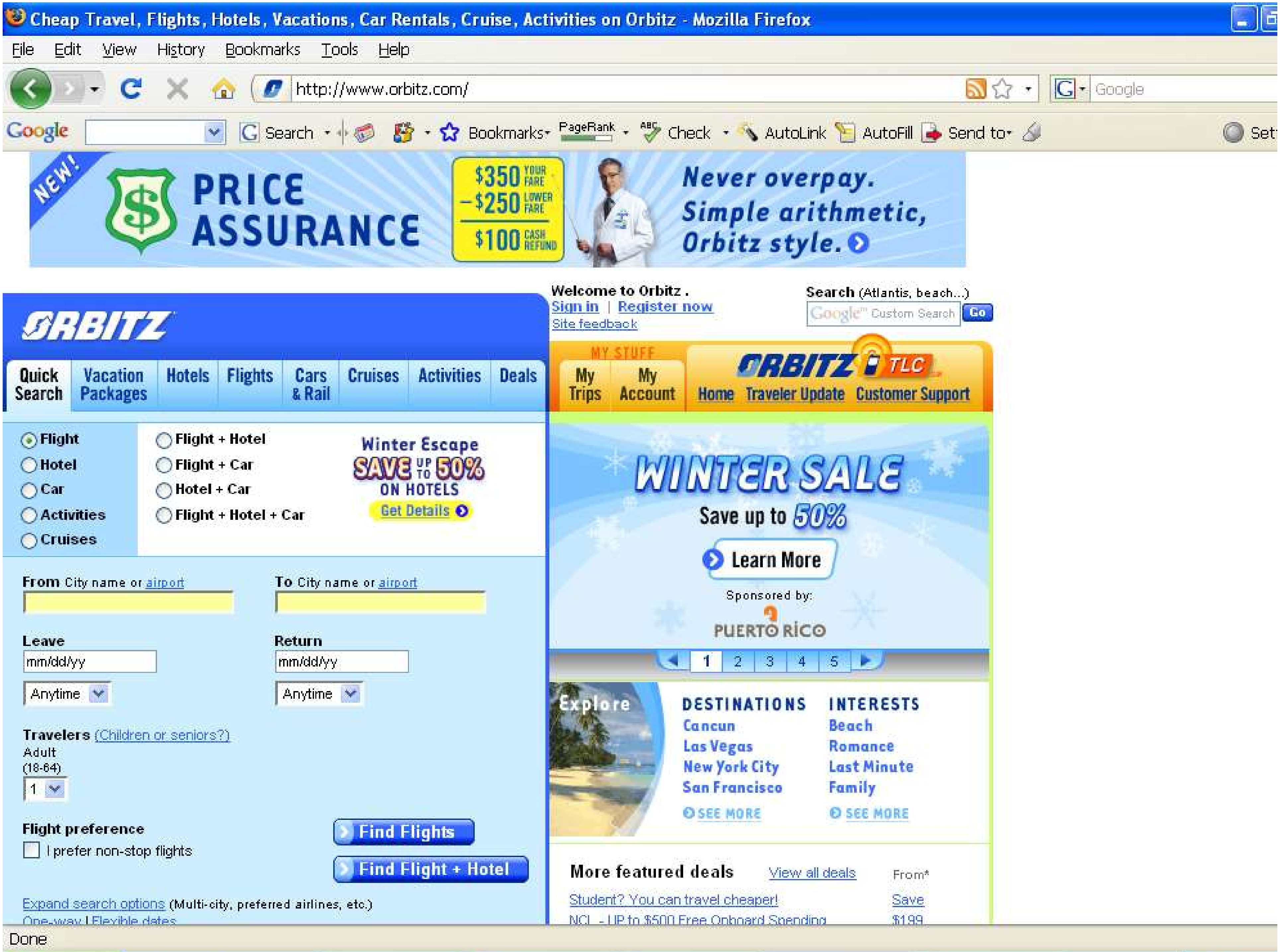
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SAVE UP TO 50% ON HOTELS
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Travelers (Children or seniors?)
Adult (18-64)
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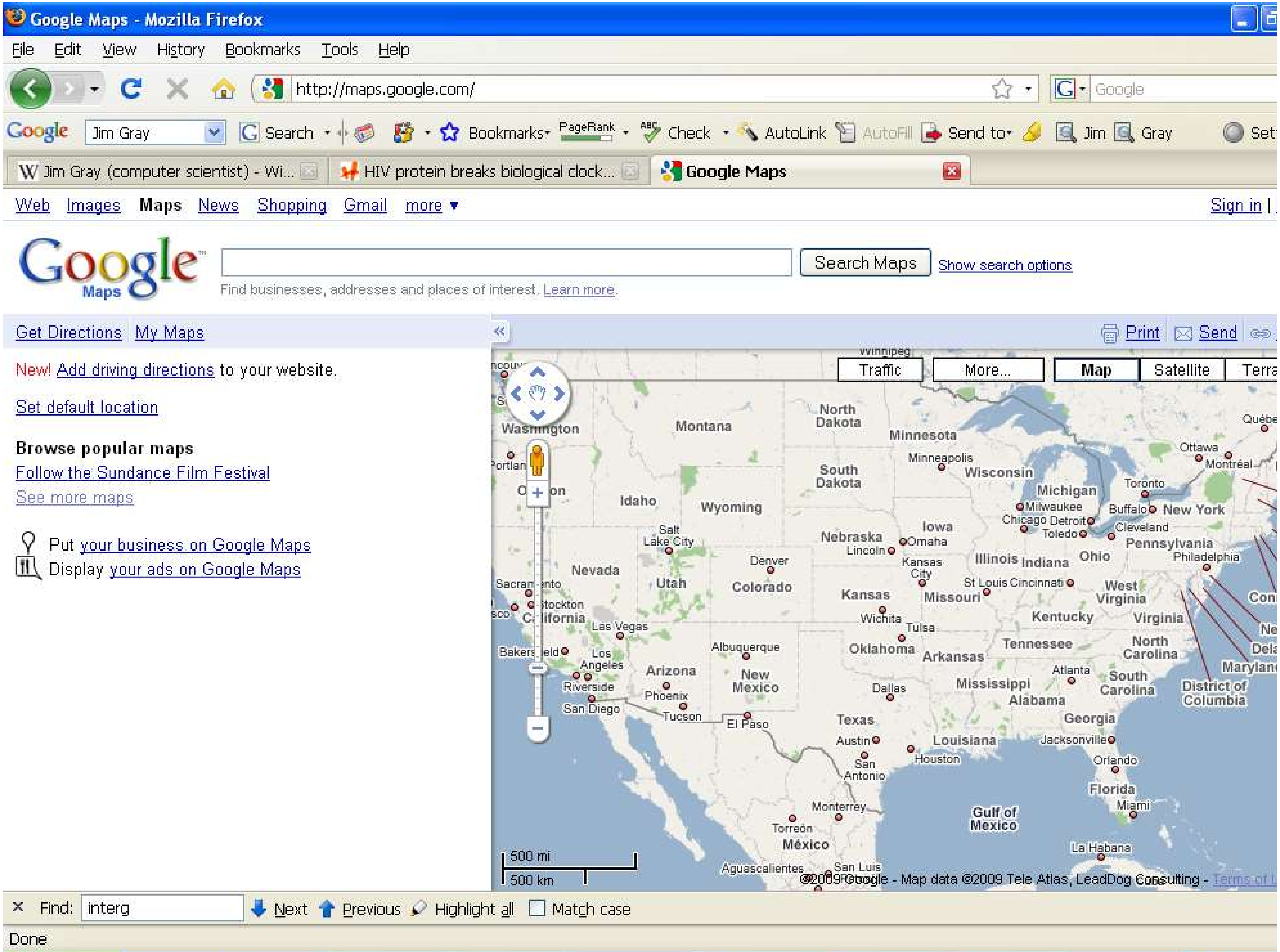
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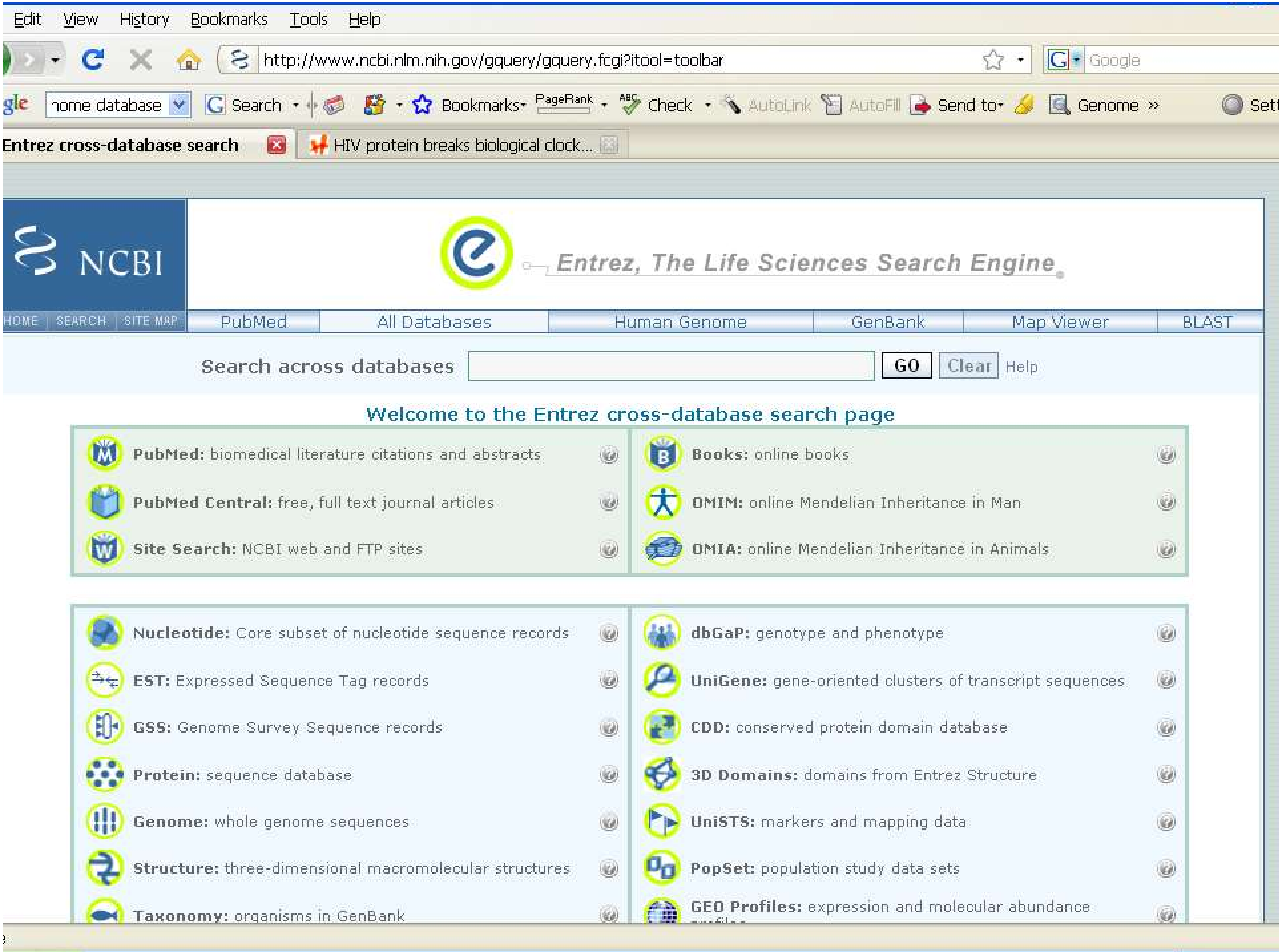
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PubMed Central: free, full text journal articles
Site Search: NCBI web and FTP sites
Books: online books
OMIM: online Mendelian Inheritance in Man
OMIA: online Mendelian Inheritance in Animals
Nucleotide: Core subset of nucleotide sequence records
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
UniSTS: markers and mapping data
PopSet: population study data sets
GEO Profiles: expression and molecular abundance

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

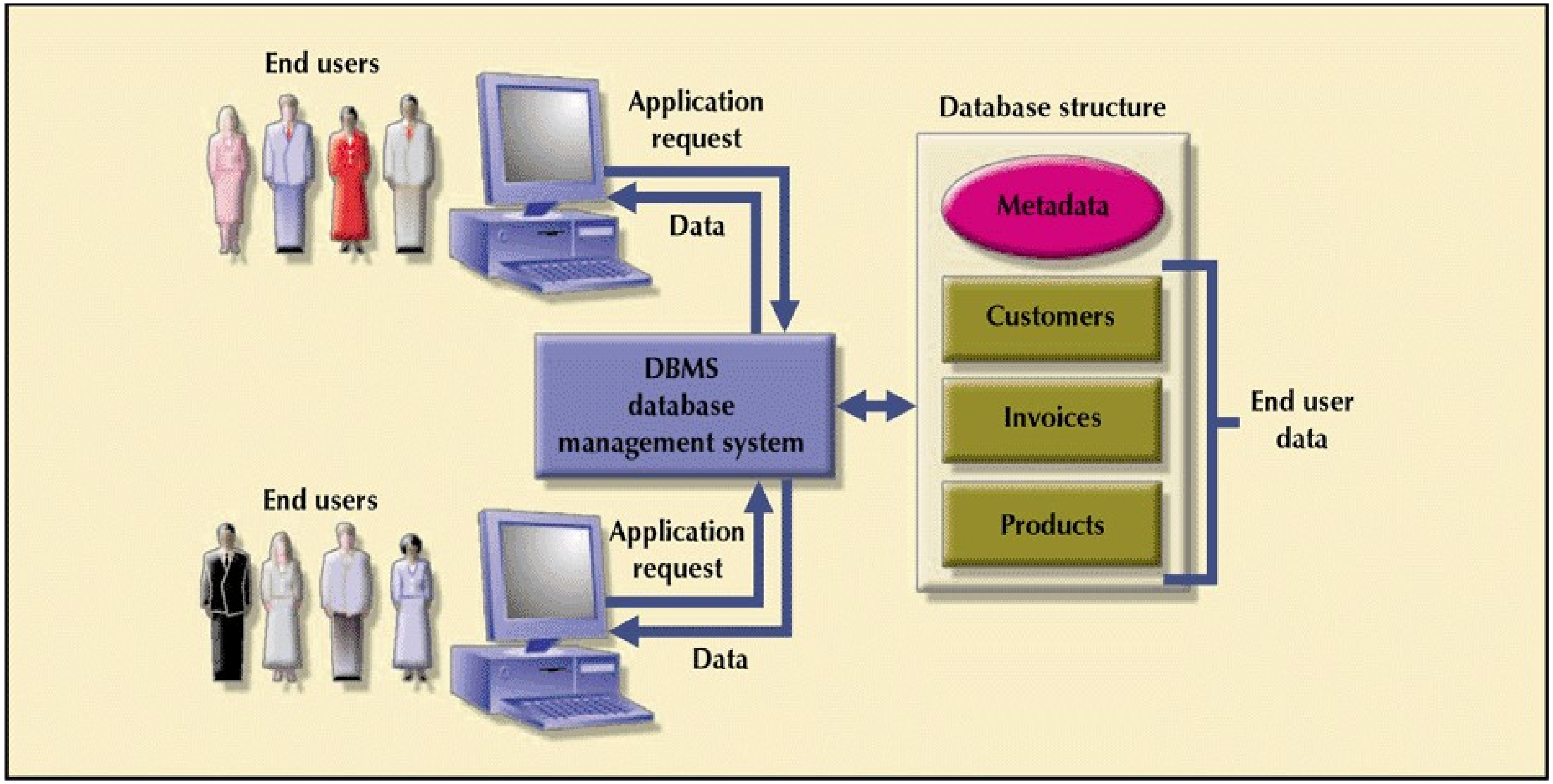
Introduction to DB Systems

- 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.

- 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

Database Management System



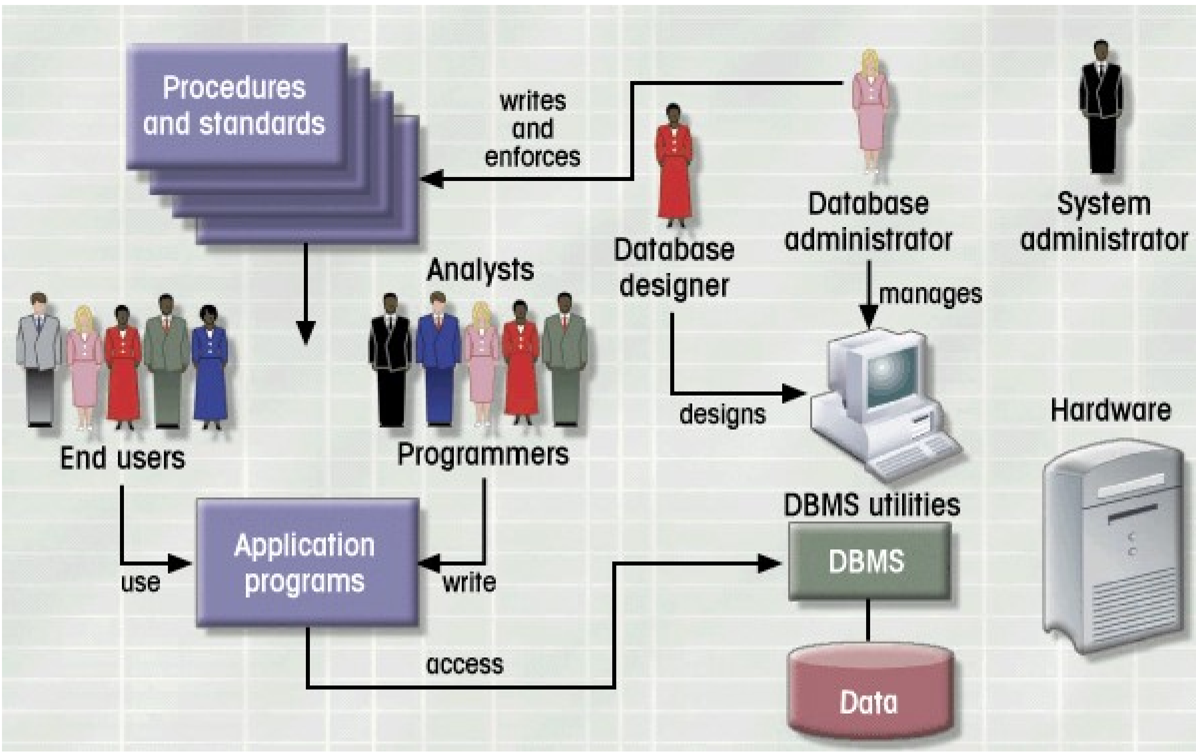
Database Systems: Design, Implementation, & Management: Rob & Coronel

- 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

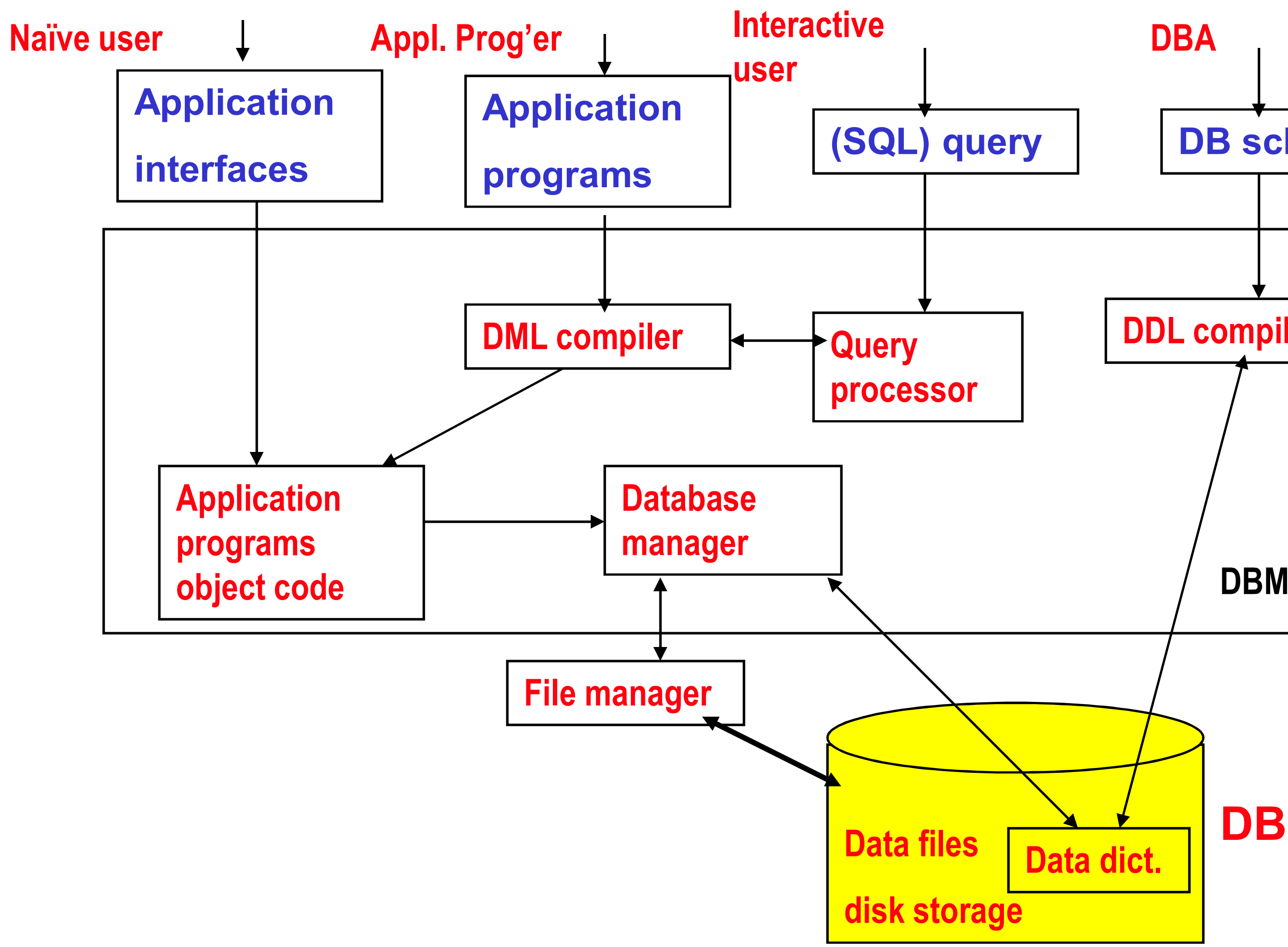
Database System



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

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

DB System Architecture



DB System Architecture

- *Data Definition Language (DDL)*

  - a language for defining DB schema

  - DDL statements compile to a data dictionary which is a file containing **metadata** (data about data), e.g., descriptions about the tables

- *Data Manipulation Language (DML)*

  - a language that enables users to manipulate data

  - an important subset for retrieving data is called Query Language

  - two types of DML: ***procedural*** (specify "what" & "how") vs. ***declarative*** (just specify "what")

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

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

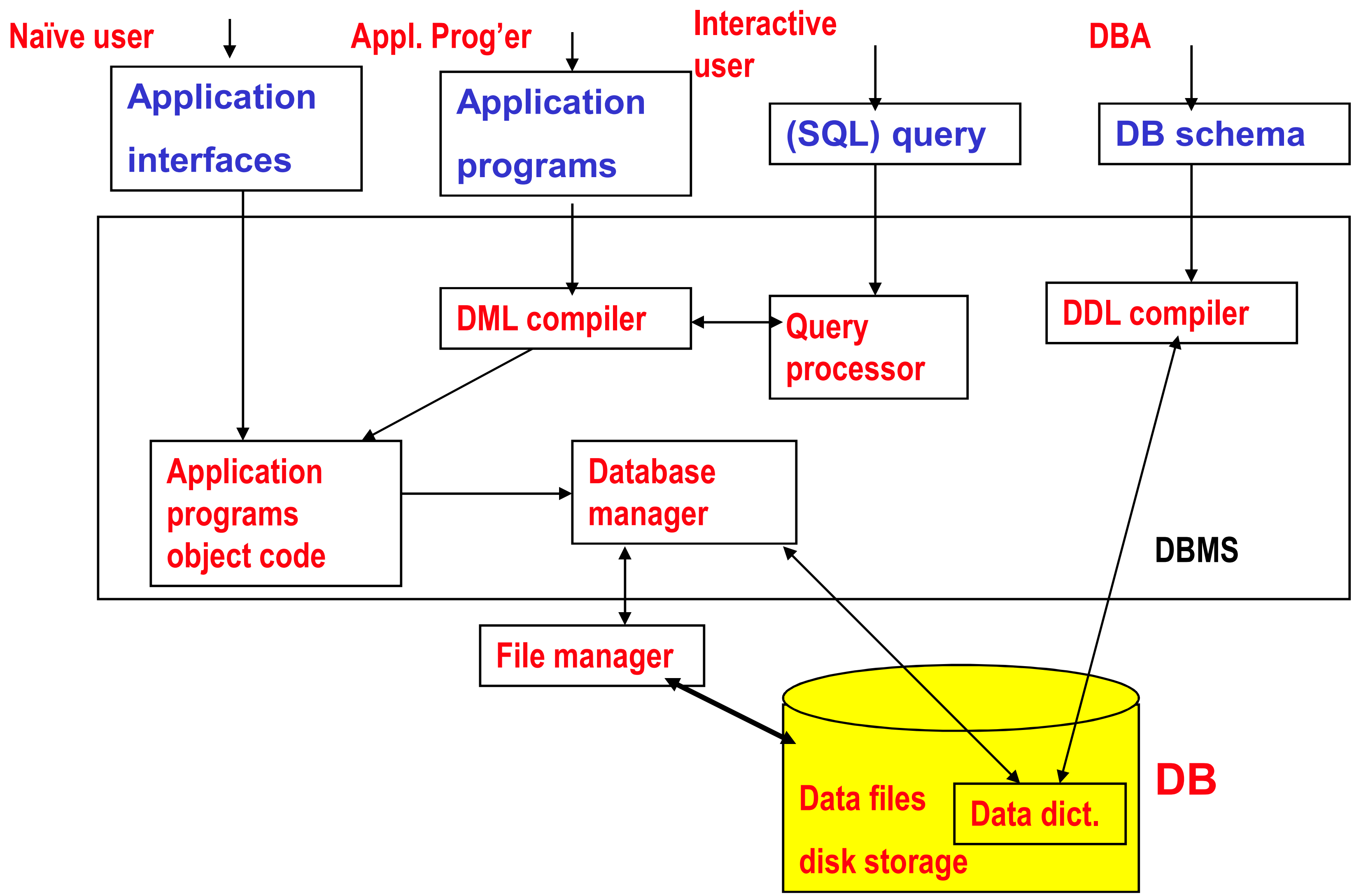
DB System Architecture

- File Manager
  - allocation of space
  - operations on files
- 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

DB System Architecture

- Query Processor
  - translate high-level queries into low-level instructions
  - query optimization
- DML (Pre)compiler
  - translates DML statements embedded in application program into procedure calls
- DDL (Pre)compiler
  - converts DDL statements to data dictionary items (eg, table descriptions)

DB System Architecture

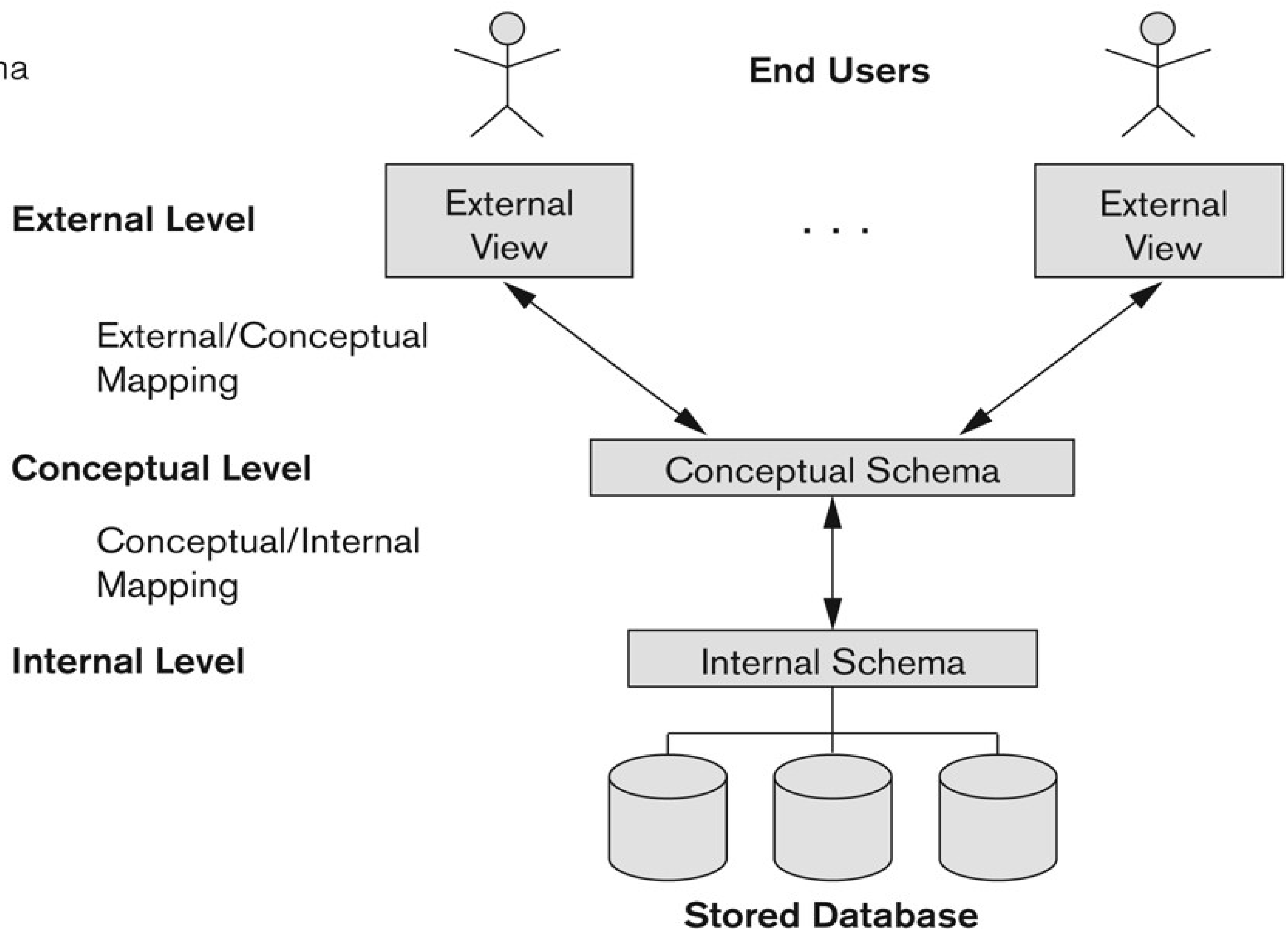


Data Abstraction

- Data Abstraction
  - Abstract view of the data
    - simplify interaction with the system
    - hide details of how data is stored and manipulated
  - Levels of abstraction
    - view/external level: partial schema
    - conceptual level: schema, what data are actually stored
    - physical/internal level: data structures; how data are actually stored

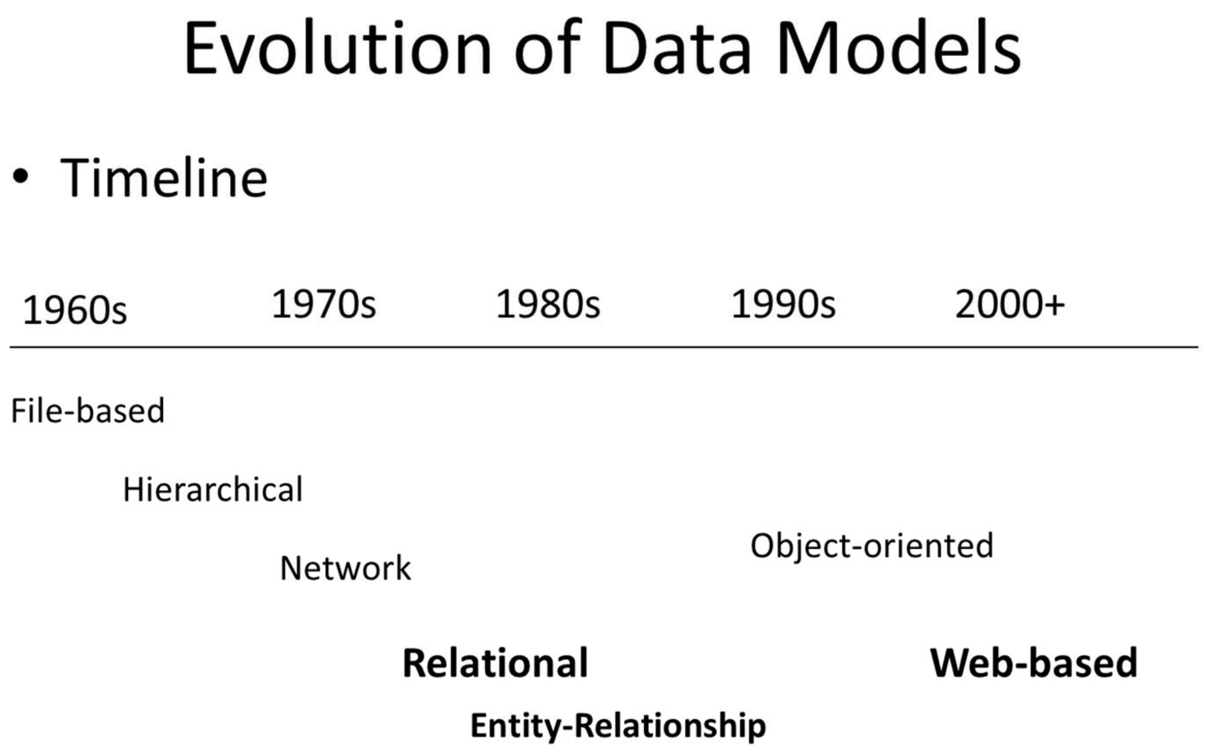
Data Abstraction: 3-level architecture

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



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*

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

Ideas/requirements → E/R design → Relational schema → Relational database

- **Three basic concepts:**

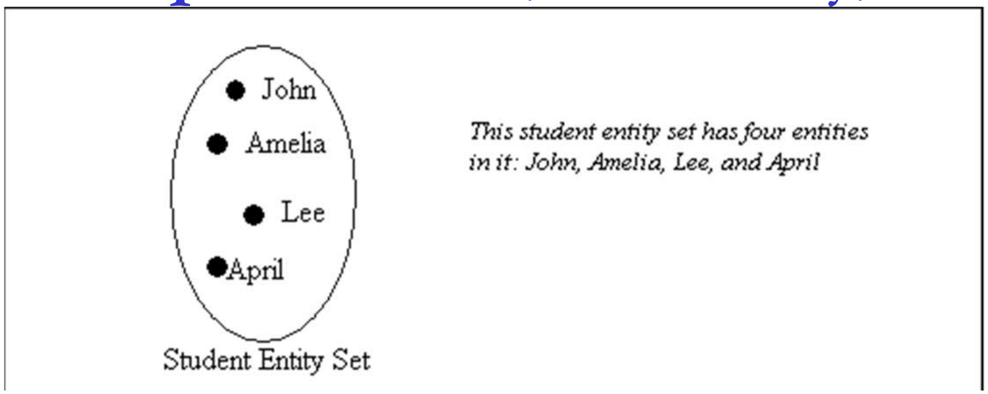
  Entity, Attribute, Relationship

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
  - *Example*: Name, ID, Address, DoB 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

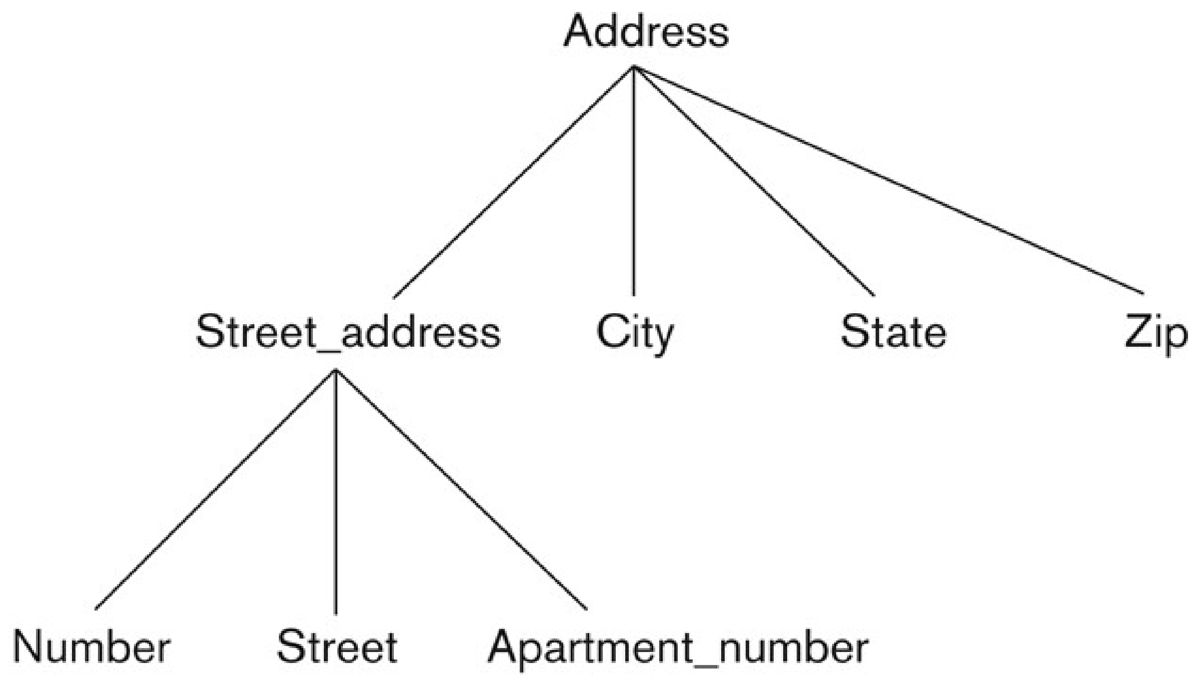


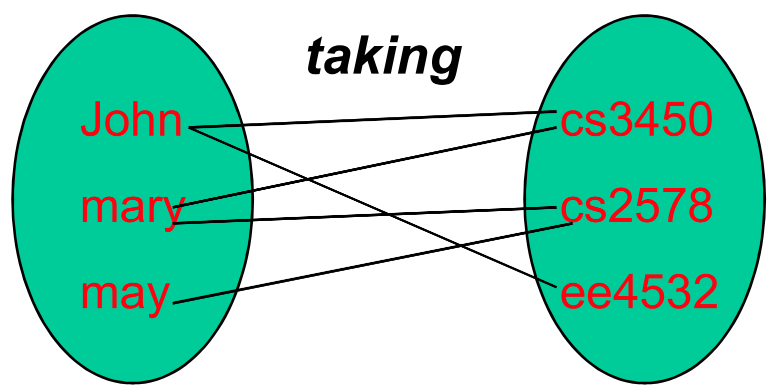
Figure 3.4
A hierarchy of composite attributes.

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

ER Model Concepts

- **Relationship** -- an association among several entities
  - *Example*: Patrick and Eva are friends
    Patrick is taking cs3450
- **Relationship Set** -- a set of relationships of the same type
  - Example:



  - Formally, a relationship **R** is a subset of:
    $\{ (\mathbf{e1}, \mathbf{e2}, \ldots, \mathbf{ek}) \mid \mathbf{e1} \in E1, \mathbf{e2} \in E2, \ldots, \mathbf{ek} \in Ek) \}$

ER Model Concepts

- **Relationship** vs. **Attribute**
  - an attribute **A: E** $\rightarrow$ **D** is a "simplified" form of a relationship:
    - If we allow **D** to be an Entity Set, then **A** becomes a relationship
  - a relationship can carry attributes
    - properties of the relationship
    - <u>Example</u>: Patrick takes cs2450 with a grade of B+
      Supplier S supplies item T with a price of P

ER Model Concepts

- **Entity Set** vs. **Attribute**
  - When to use attribute, and when to use entity set?
    - <u>Example</u>: Employee and Phone

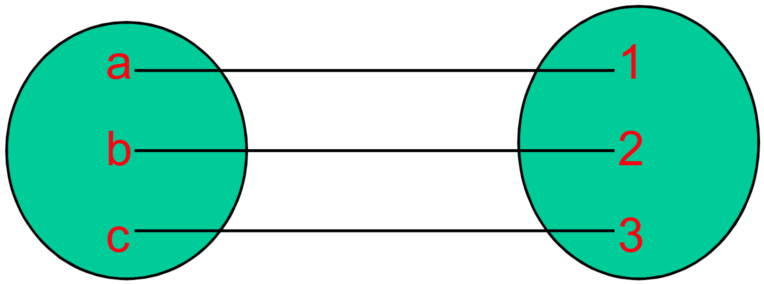
      1) *employee* entity set with attribute *phone#*

      2) *empPhn* relationship set with entity sets *employee* and *phone#*
  - No simple answer, depending on
    - what we want to model
    - meaning of attributes

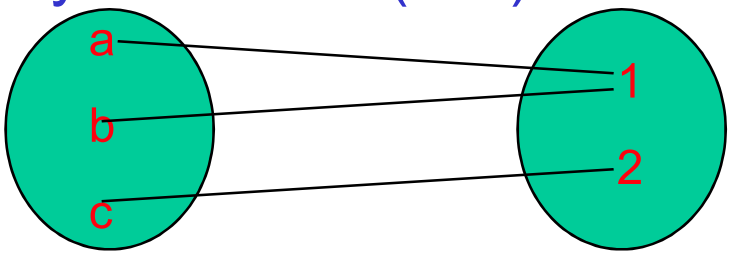
ER Model Concepts

- Integrity Constraints: are the requirements (i.e., rules) imposed by a relationship that must be met when updating the database.

    - Mapping Cardinalities
        - One - to - One (1:1)



        - One - to - Many (1:M) / Many - to - One (N:1)



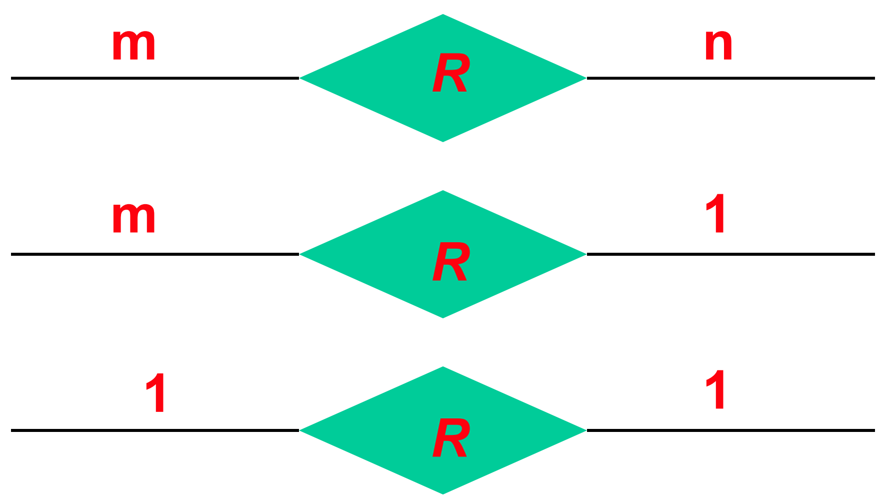
        - Many - to - Many (M:N) ?

ER Model Concepts

- Integrity Constraints (cont'd)
  - 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?)
    - **primary key** -- a candidate key chosen by the DB designer to identify an entity in an entity set

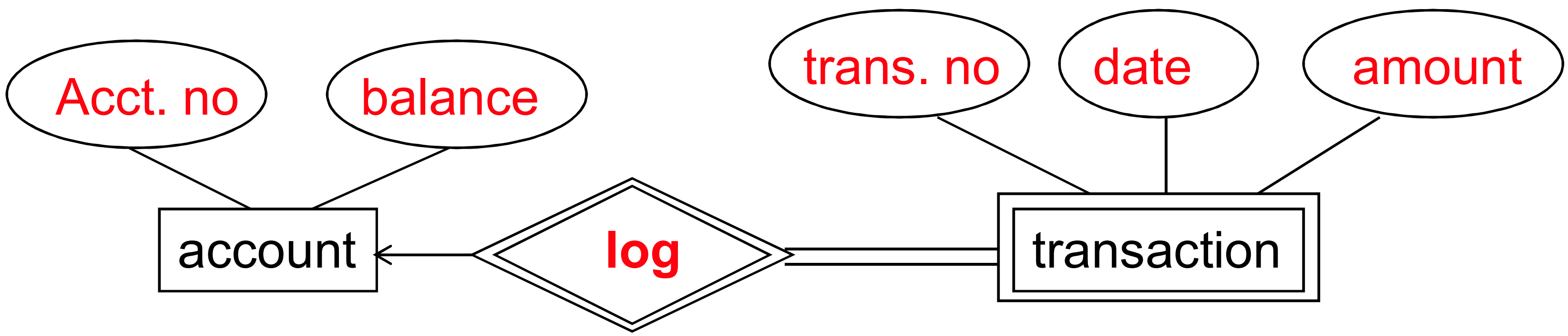
ER Model Diagram

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

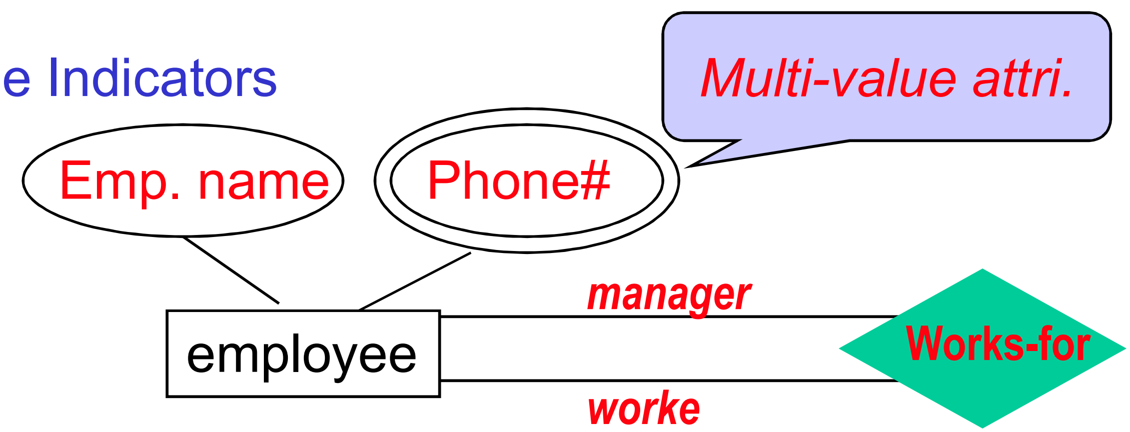


ER Model Diagram

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

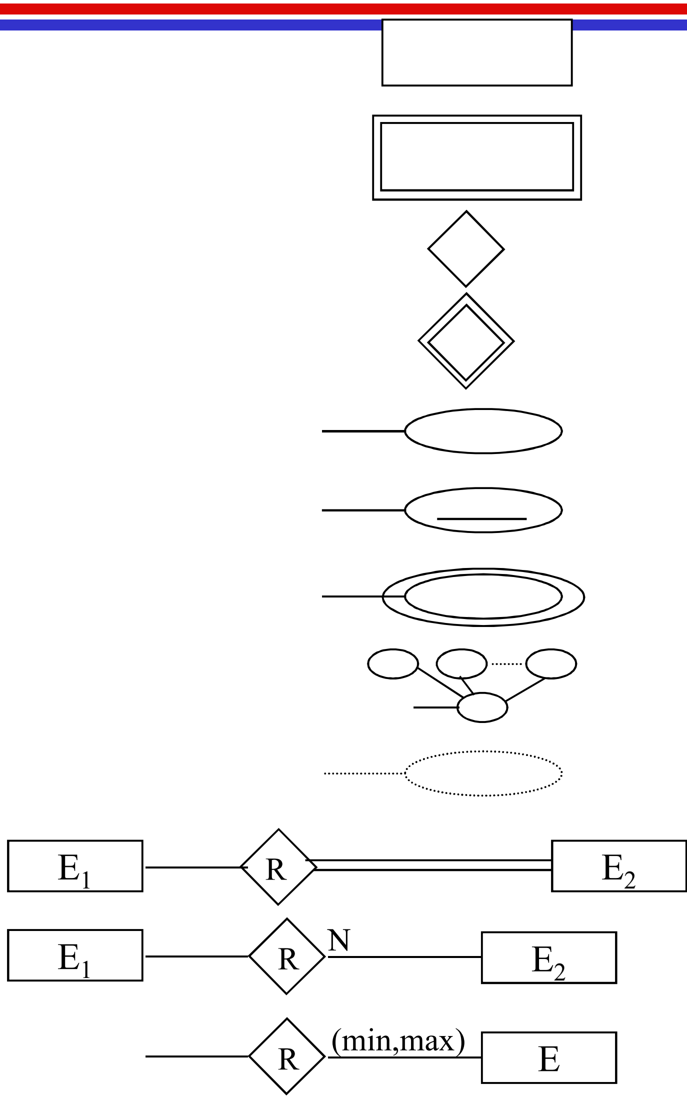


- Role Indicators



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

Example COMPANY Database

- We need to create a database schema (definition) based on the following (simplified) application requirements of the COMPANY Database
- Refer to textbook for more detailed description of requirements:
    - The company is organized into DEPARTMENTs
    - Each DEPARTMENT has a name, 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), 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

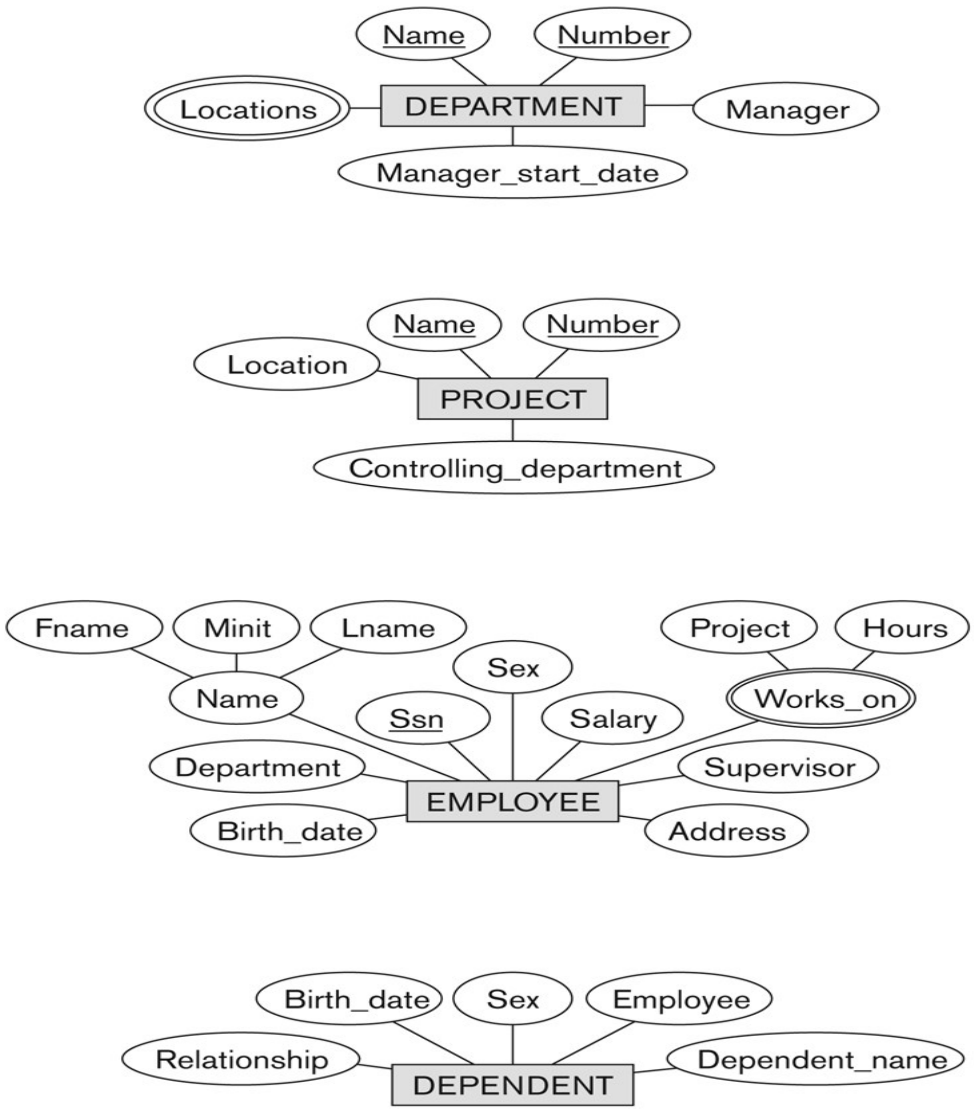
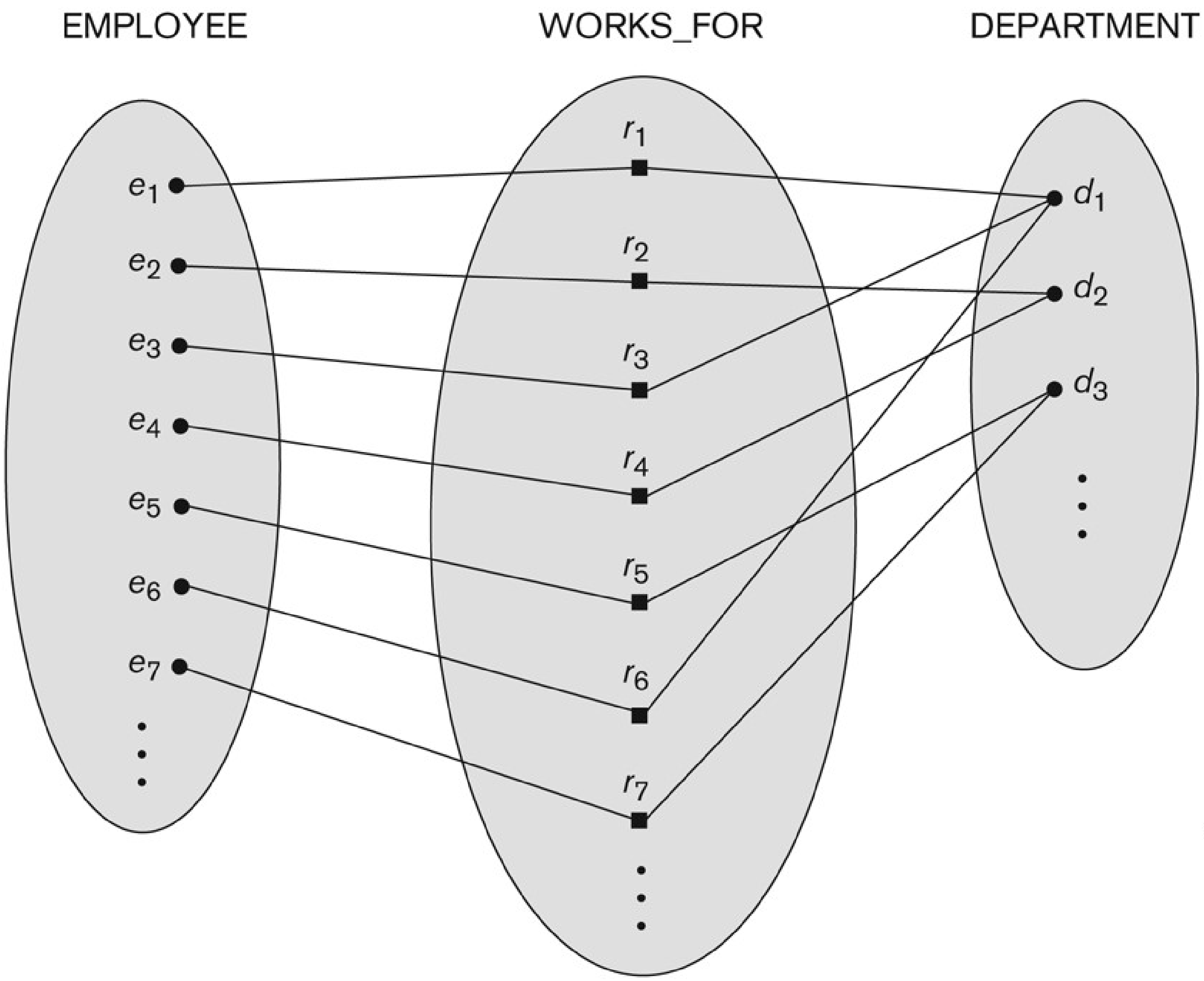


Figure 3.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

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

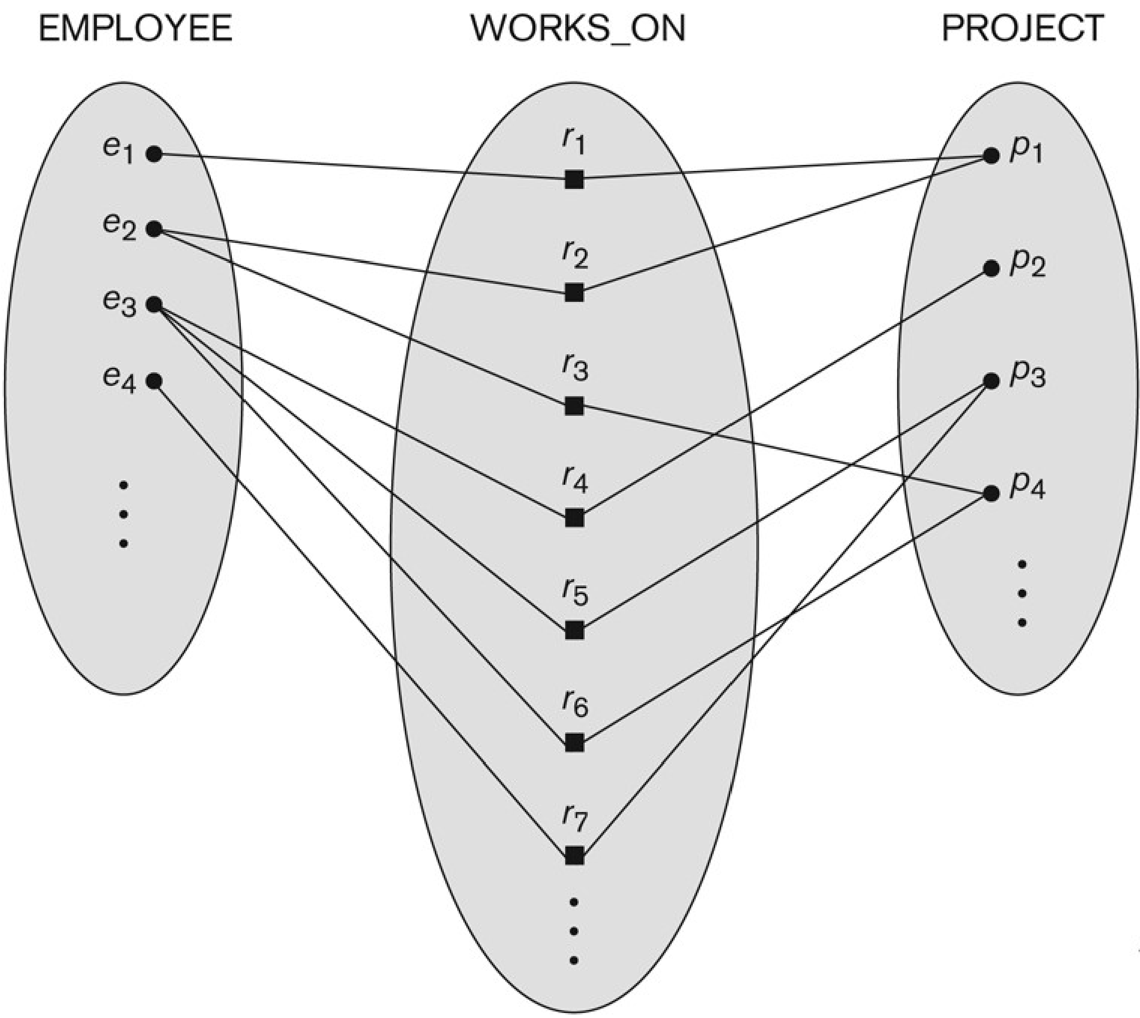


N-to-1

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

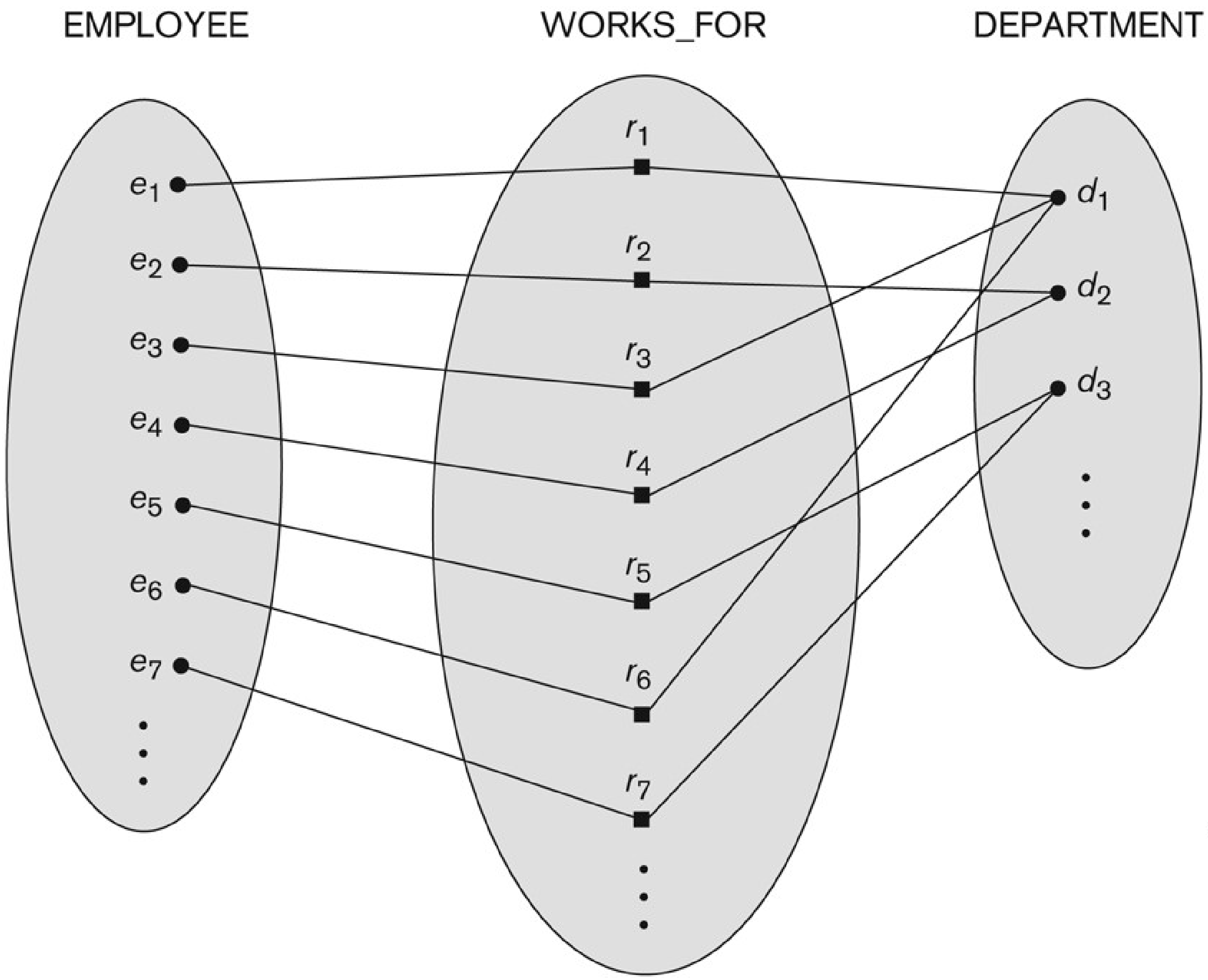


M-to-n

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

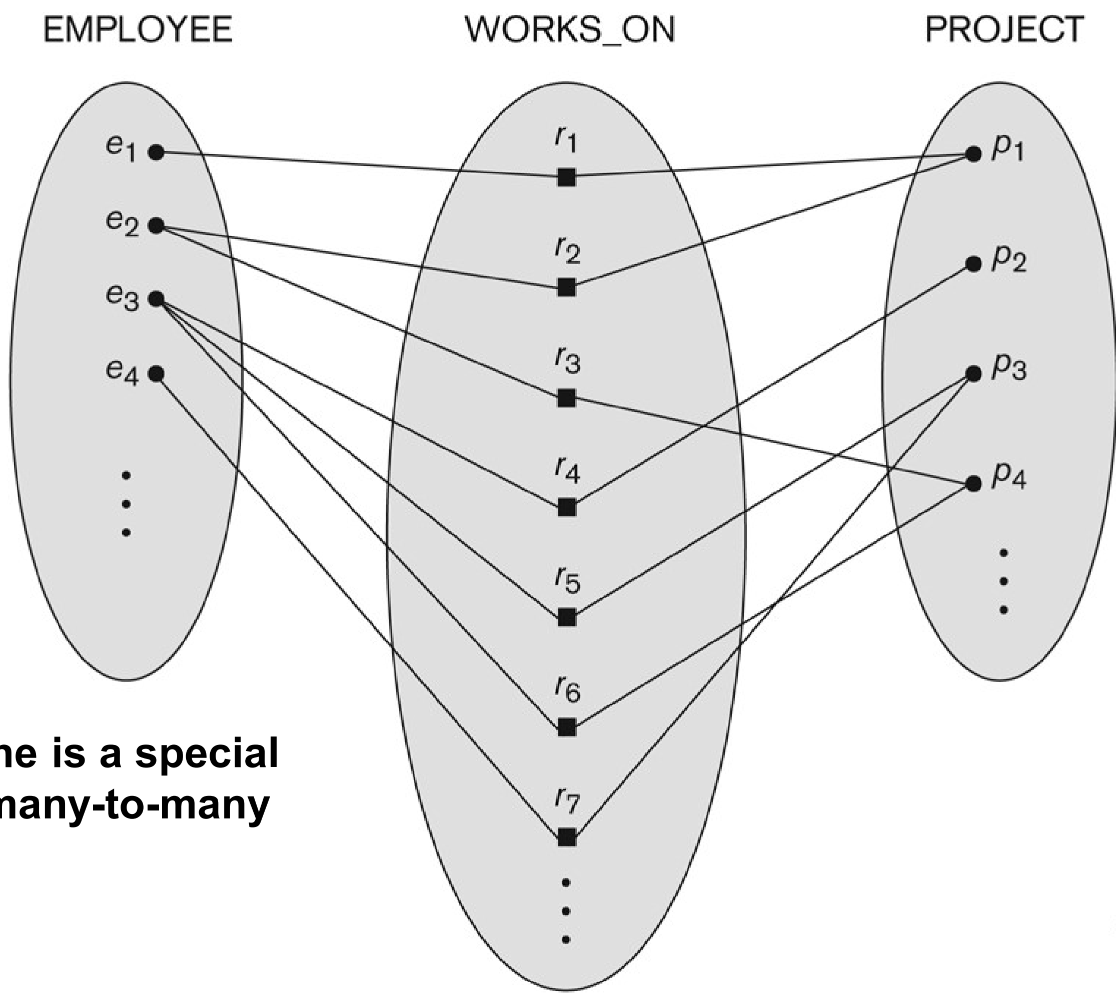
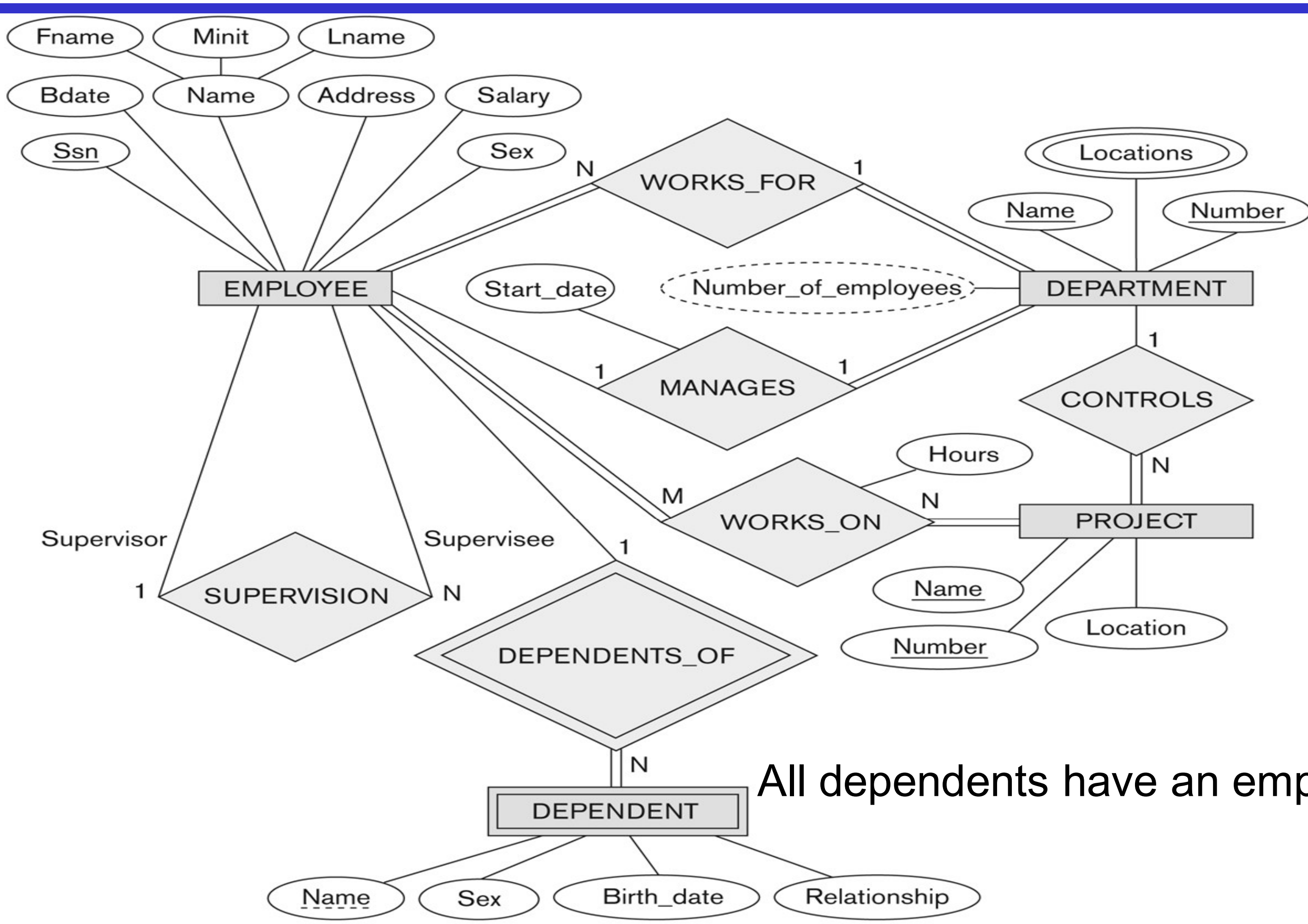


Figure 3.13
An M:N relationship, WORKS_ON.

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

ER DIAGRAM – Relationship Types are:

WORKS_FOR, MANAGES, WORKS_ON, CONTROLS, SUPERVISION, DEPENDENTS_OF



All dependents have an employee

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

Summary

- 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)