CS3402: Lecture 1

Database Systems

(Sem B, 2024-2025)

Teaching Staff's Information

- Lecturers
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Course Overview

- Course Format:
  - Face-to-face (F2F) lectures
    - One-hour practice questions
    - Two-hour lecture
  - Tutorial classes **(Start in Week 5 or 6** for seven weeks**)**
    - One-hour F2F tutorial
    - Pattern: 1 time Q&A + 6 labs
    - Bonus for lab attendance

Assessment

- Coursework *-- 40%* :
  - Mid-term *-- 25%*
    - Date: **March 6 (Thur)**
    - Time: Lecture time
    - Format: Open-book exam
  - Homework assignments (3 times) *-- 15%*
  - Lab attendance (At least 5 of the 6 labs) *-- 3% bonus (such that coursework is capped to 40%)*

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

Questions about course content?

- Lecture slides & practice questions:
  - Ask questions in lecture time (most efficient)
    - Priority for F2F session
  - Email instructor
    - May be directed to TAs to shorten response time
- Grading:
  - Will let you know who to contact in Canvas later

Teaching Staff (in alphabetical order)

- Teaching assistants (Teaching tutorial sessions):

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Assessment

- **Plagiarism will not be tolerated**
  - But you are welcome to discuss with other students. Just don't copy from one another.
  - https://www.cityu.edu.hk/pvdp/ah/uni-ah-req.htm

Attendance

- If you need to apply for a leave for mid-term and final exams, follow the procedures as laid out in ARRO's webpage (https://www.cityu.edu.hk/arro/asmt/mitg_main.htm) to submit the mitigation request via AIMS no later than 5 working days of the scheduled examination, with supporting documents (e.g., medical certificate).
- If you are ill and cannot attend a lab, obtain a medical note and email it to the instructor of your tutorial section as soon as possible and no later than a week after your absence.

Mark Appeal

- Students are responsible to keep track on their marks.
- Any objection to the course marks should be made to the TA by email within one week of mark announcement. No change will be made afterwards.

Course Materials

- Textbook
  - "**Fundamentals of Database Systems**", **7**th edition, by R. Elmasri and S.B. Navathe, Addison-Wesley.

- 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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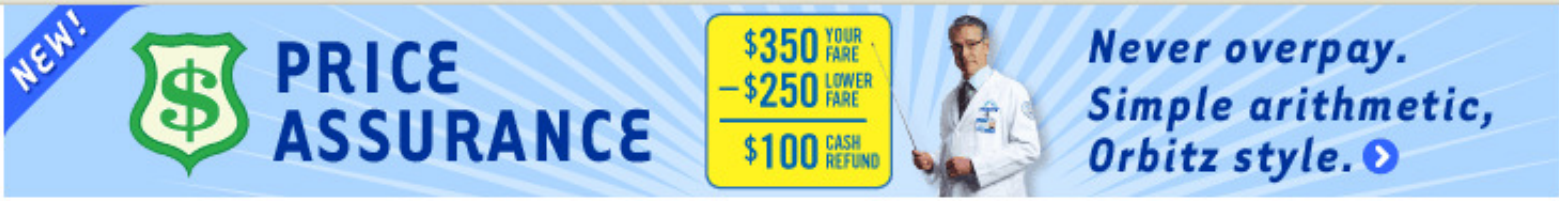

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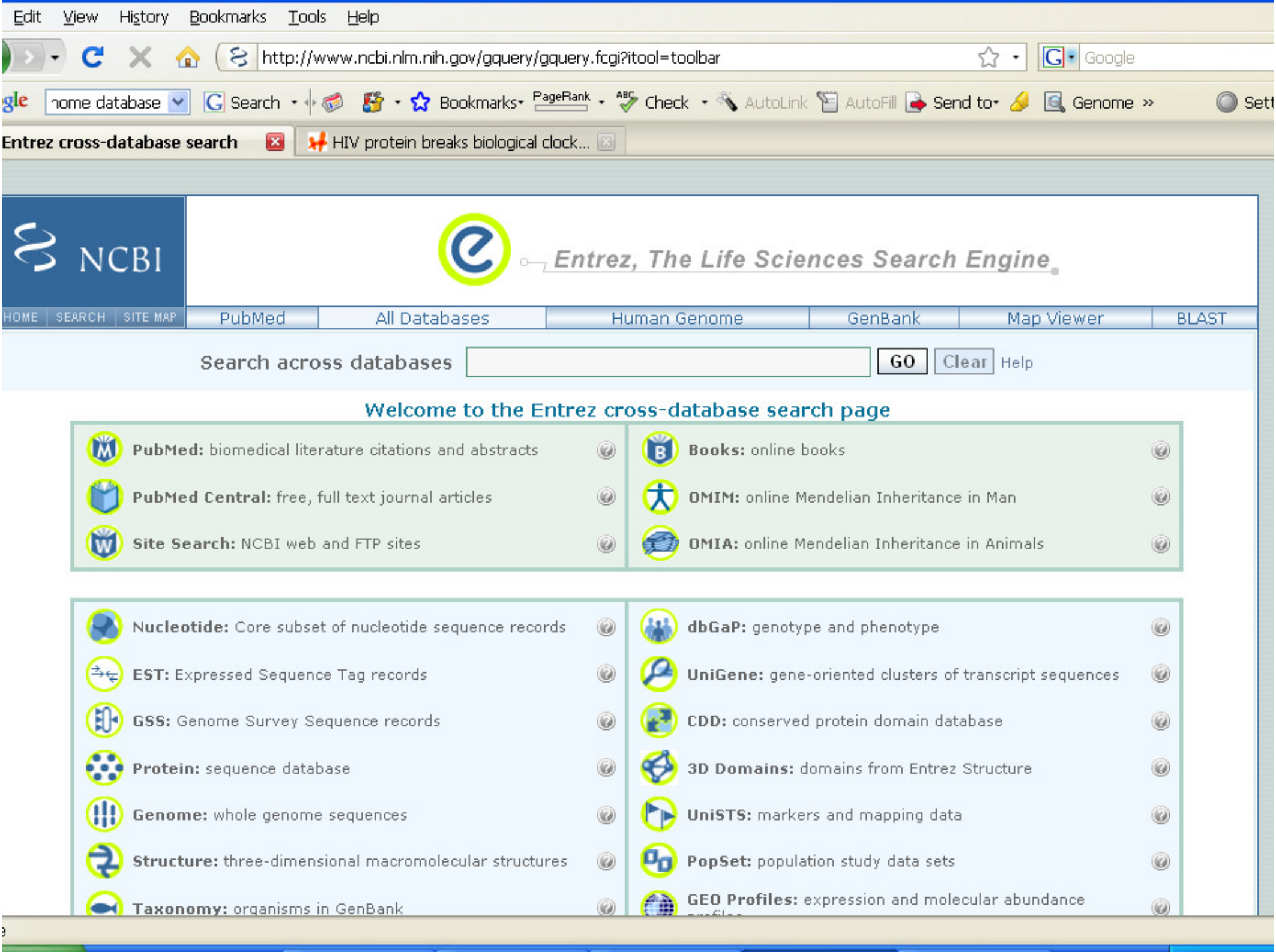
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EST: Expressed Sequence Tag records
GSS: Genome Survey Sequence records
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Genome: whole genome sequences
Structure: three-dimensional macromolecular structures
Taxonomy: organisms in GenBank
dbGaP: genotype and phenotype
UniGene: gene-oriented clusters of transcript sequences
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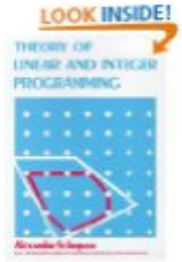

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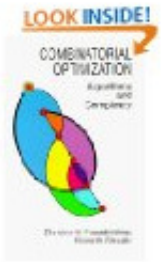

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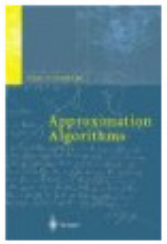
Paperback by Christos H.



Approximation Algorithms Hardcover by Vijay V. Vazirani

Done

Course Objectives

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

Introduction to DB Systems

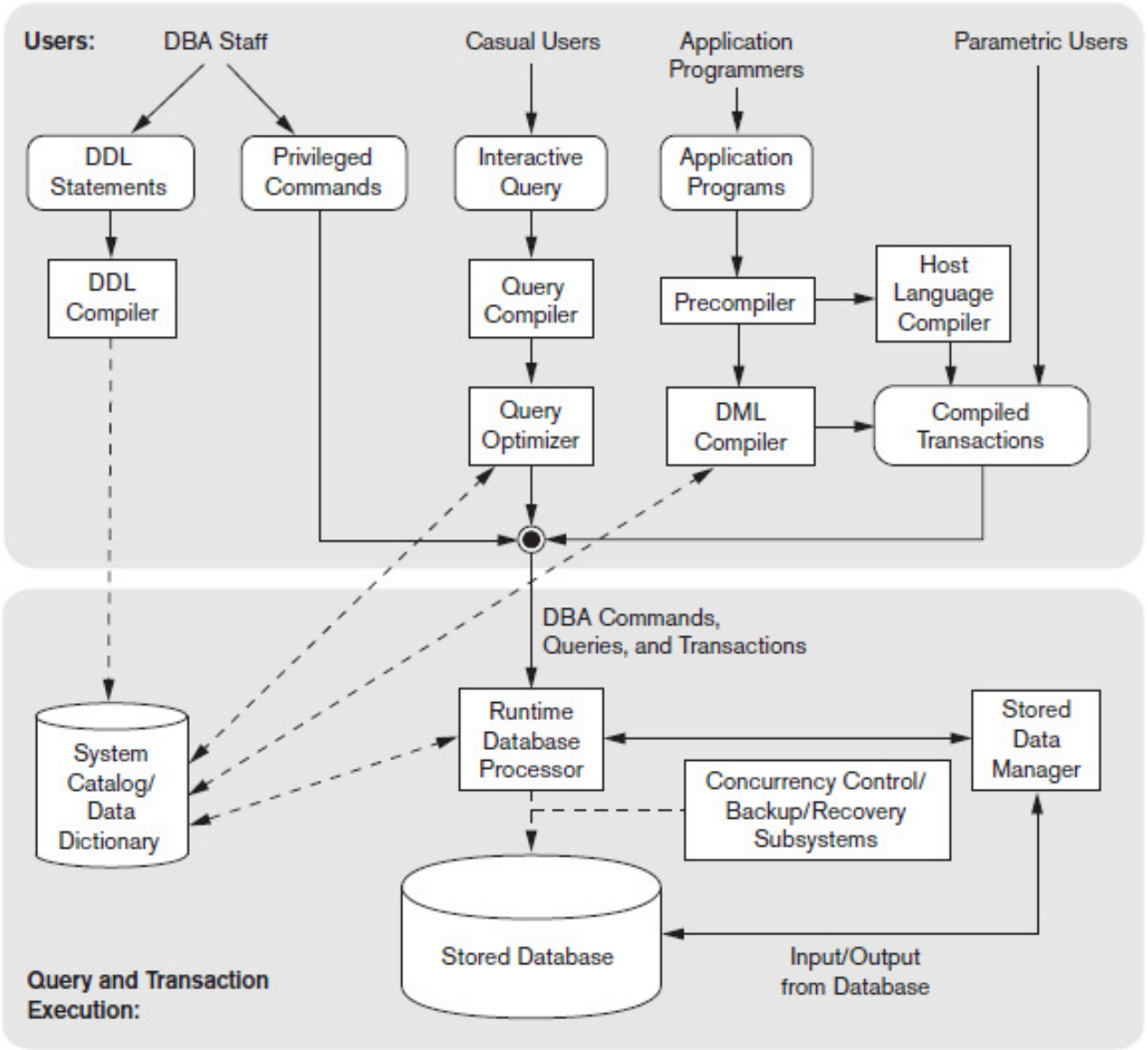
- What is a Database (DB)?
  - A non-redundant, persistent collection of logically-related records/files that are structured to support various processing and retrieval needs.

- 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

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



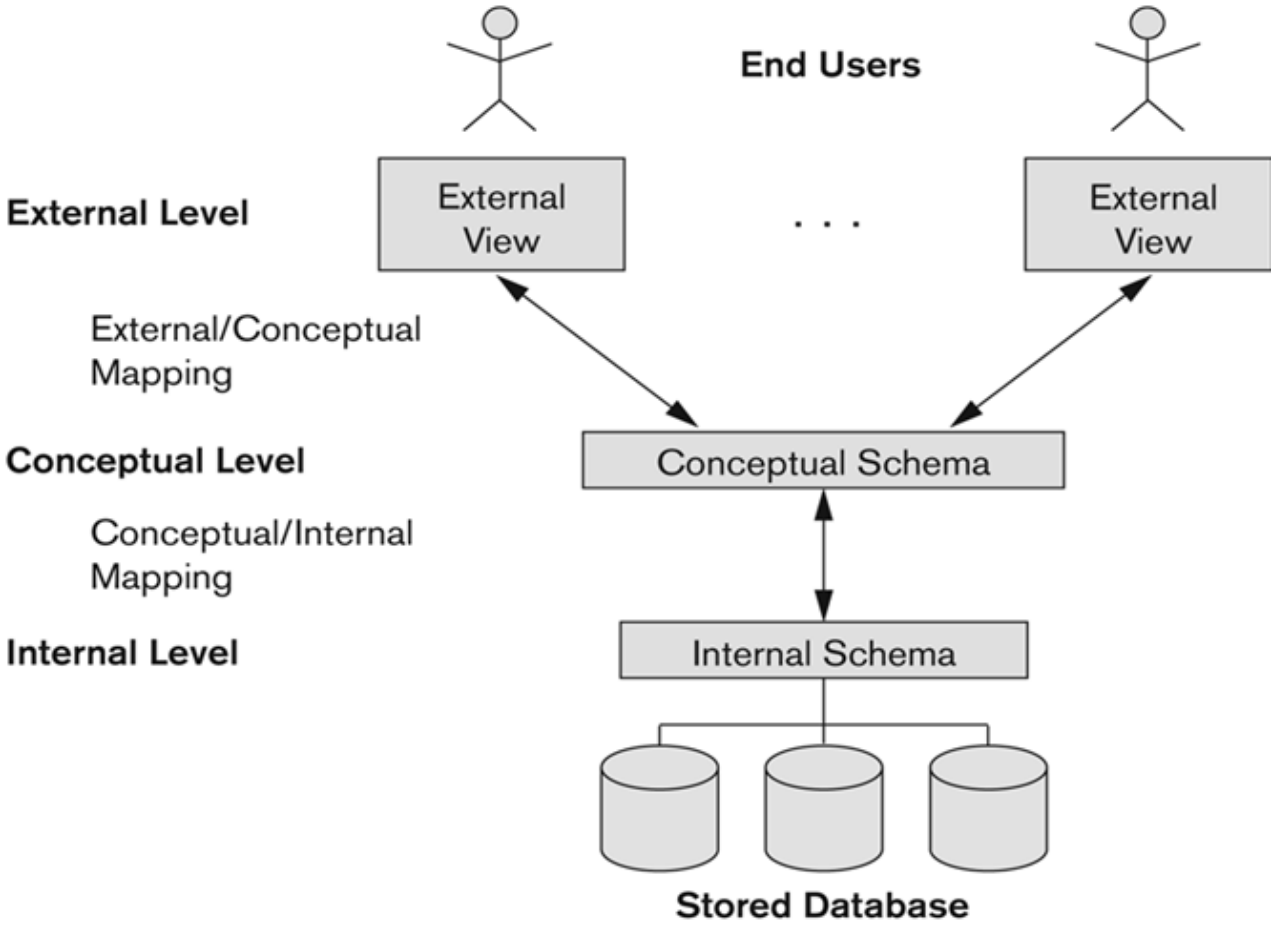
DB System Architecture

- *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 (i.e., Causal Users):
    - Using query languages
  - Naive Users (i.e., Parametric Users):
    - Running application programs

Three-schema architecture



- Goal: Separate the user applications from the physical database
- Schema can be defined in 3 levels

Three-schema architecture

- Physical/internal level: **internal schema** uses a physical data model and describes the complete details of data storage and access paths for the database.

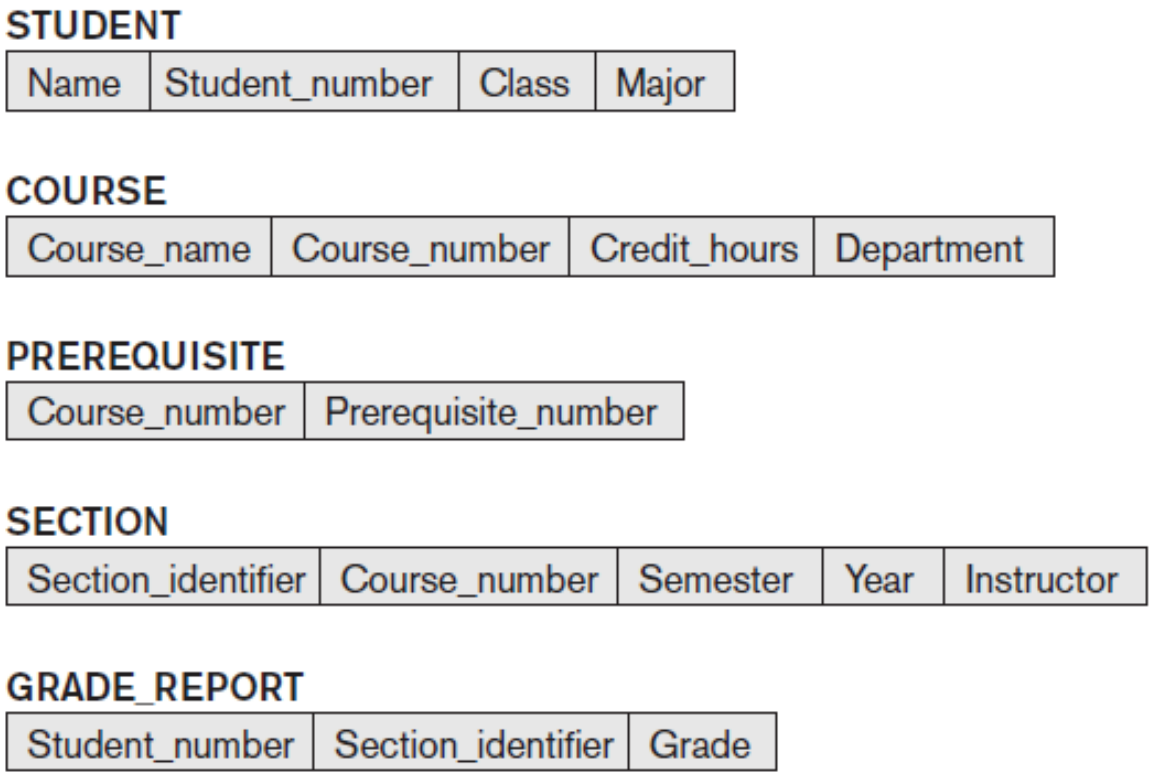
Data Item Name	Starting Position in Record	Length in Characters (bytes)
Name	1	30
Student_number	31	4
Class	35	1
Major	36	4

Figure 1.4
Internal storage format for a STUDENT record, based on the database catalog in Figure 1.3.

Three-schema architecture

- Conceptual level: **conceptual schema** describes the structure of the whole database for a community of users and hides the details of physical storage structures.

Figure 2.1
Schema diagram for the database in Figure 1.2.



Three-schema architecture

- 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.

TRANSCRIPT

Student_name	Student_transcript				
	Course_number	Grade	Semester	Year	Section_id
Smith	CS1310	C	Fall	08	119
	MATH2410	B	Fall	08	112
Brown	MATH2410	A	Fall	07	85
	CS1310	A	Fall	07	92
	CS3320	B	Spring	08	102
	CS3380	A	Fall	08	135

(a)

COURSE_PREREQUISITES

Course_name	Course_number	Prerequisites
Database	CS3380	CS3320
		MATH2410
Data Structures	CS3320	CS1310

(b)

Figure 1.5
Two views derived from the database in Figure 1.2. (a) The TRANSCRIPT view. (b) The COURSE_PREREQUISITES view.

Data Independence

- Data Independence: the ability to modify a schema definition in one level without affecting a schema in the next higher level
- two types of data independence:
  - ***logical data independence***

    -- the ability to modify the conceptual schema without causing the application programs to be rewritten
  - ***physical data independence***

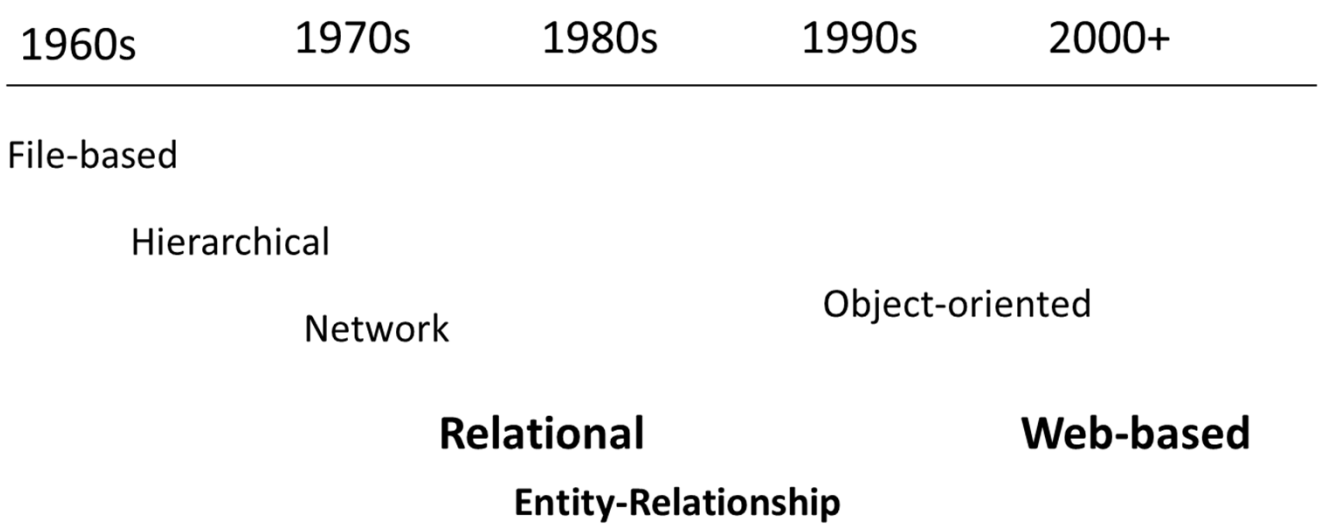
    -- the ability to modify the physical schema without altering the conceptual schema and thus, without causing the application programs to be rewritten

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

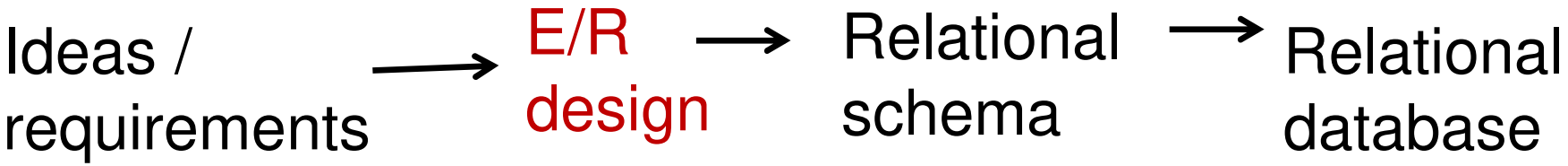
Evolution of Data Models

- Timeline



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:**

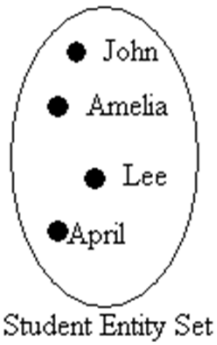
  Entity, Attribute, Relationship

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, ...



This student entity set has four entities in it: John, Amelia, Lee, and April

Figure 1-6. Entity set and its entities

ER Model Concepts

- **Attribute**(Property) -- a piece of information describing an entity
  - *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 attributes
  - Attributes that are not divisible.
  - Example: SSN, gender
- Composite attributes
  - The attribute may be composed of several components.
  - Composition may form a hierarchy where some components are themselves composite

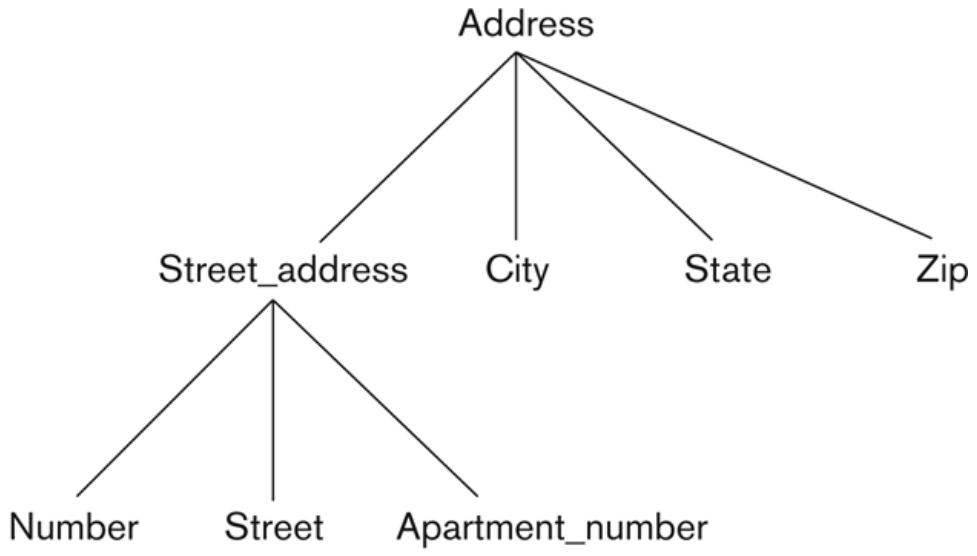


Figure 3.4
A hierarchy of composite attributes.

Types of Attributes

- Single-valued attributes
  - Most attributes have a single value for a particular entity
    - E.g., Age of a person
- Multi-valued attributes
  - An entity may have multiple values for that attribute.
    - E.g., Color of a CAR: {red, black} (i.e., two-tone car)

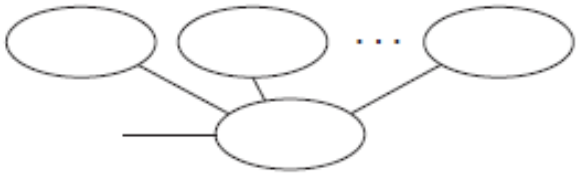
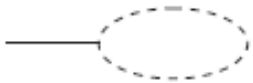
Complex Attributes

- 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)}:
  - Multi-valued: Multiple PreviousDegrees values can exist
  - Composite: Each has four subcomponent attributes (College, Year, Degree, Field)

Key Attributes

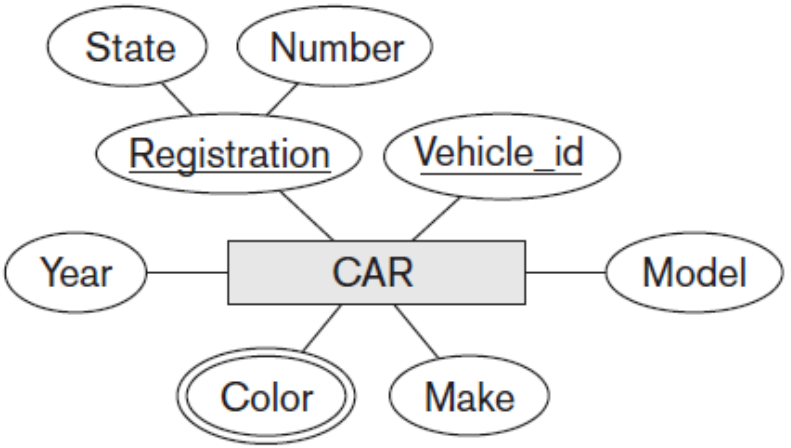
- An important constraint on the entities of an entity type is the key constraint on attributes.
- Key attribute: One or more attributes whose values are distinct for each individual entity in the entity set.
  - Its values can be used to identify each entity uniquely.
- Example: Consider a STUDENT entity type
  - Is student name a key attribute?
  - Is student ID a key attribute?

ER Model Diagram

Symbol	Meaning
	Entity
	Attribute
	Key Attribute
	Multivalued Attribute
	Composite Attribute
	Derived Attribute

Key Attributes (cont'd)

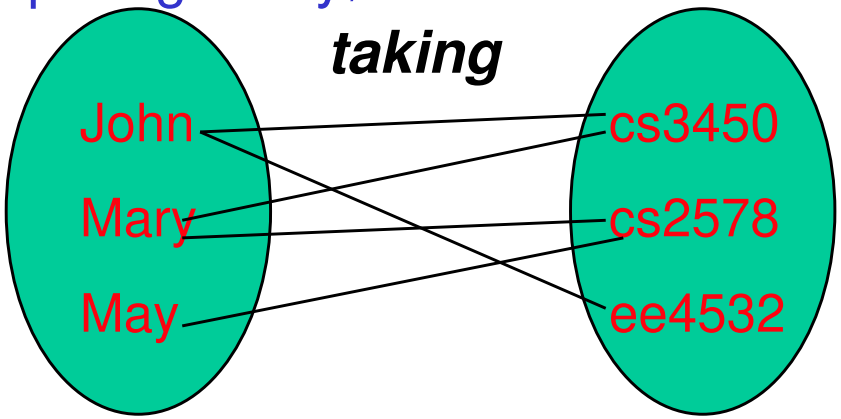
- Sometimes several attributes together form a key
  - Define a composite attribute and designate it as a key attribute of the entity type.
- Notice that such a composite key must be minimal:
  - All component attributes must be included in the composite attribute to have the uniqueness property.
  - Superfluous attributes must not be included in a key.
- Some entity types have more than one key attribute.



ER Model Concepts

- **Relationship** -- an association among several entities
  - *Example*: Patrick and Eva are friends
    John is taking cs3450
- a relationship can carry attributes: properties of the relationship
  - Example: John takes cs3450 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) }

Example COMPANY Database

- We need to create a database schema (definition) based on the following (simplified) application requirements of the COMPANY Database:
  - R1. The company is organized into DEPARTMENTs
  - R2. Each DEPARTMENT has a unique name, unique number and an EMPLOYEE who *manages* the department
  - R3. We keep track of the start date of the department manager. A department may have several locations
  - R4. Each DEPARTMENT controls/has a number of PROJECTs
  - R5. Each project has a unique name, unique number and is located at a single location

Example COMPANY Database

- R6. The database will store each EMPLOYEE's social security number (ssn), name(first name, last name and middle init), address, salary, sex, and birthdate
  - a. Each employee *works for* one department but may *work on* several projects
  - b. The DB will keep track of the number of hours per week that an employee currently works on each project
  - c. It is required to keep track of the *direct supervisor* of each employee

- R7. Each employee may *have* a number of DEPENDENTs
  - a. For each dependent, the DB keeps a record of name, sex, birthdate, and relationship to the employee

Initial Conceptual Design of Entity Sets

- 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

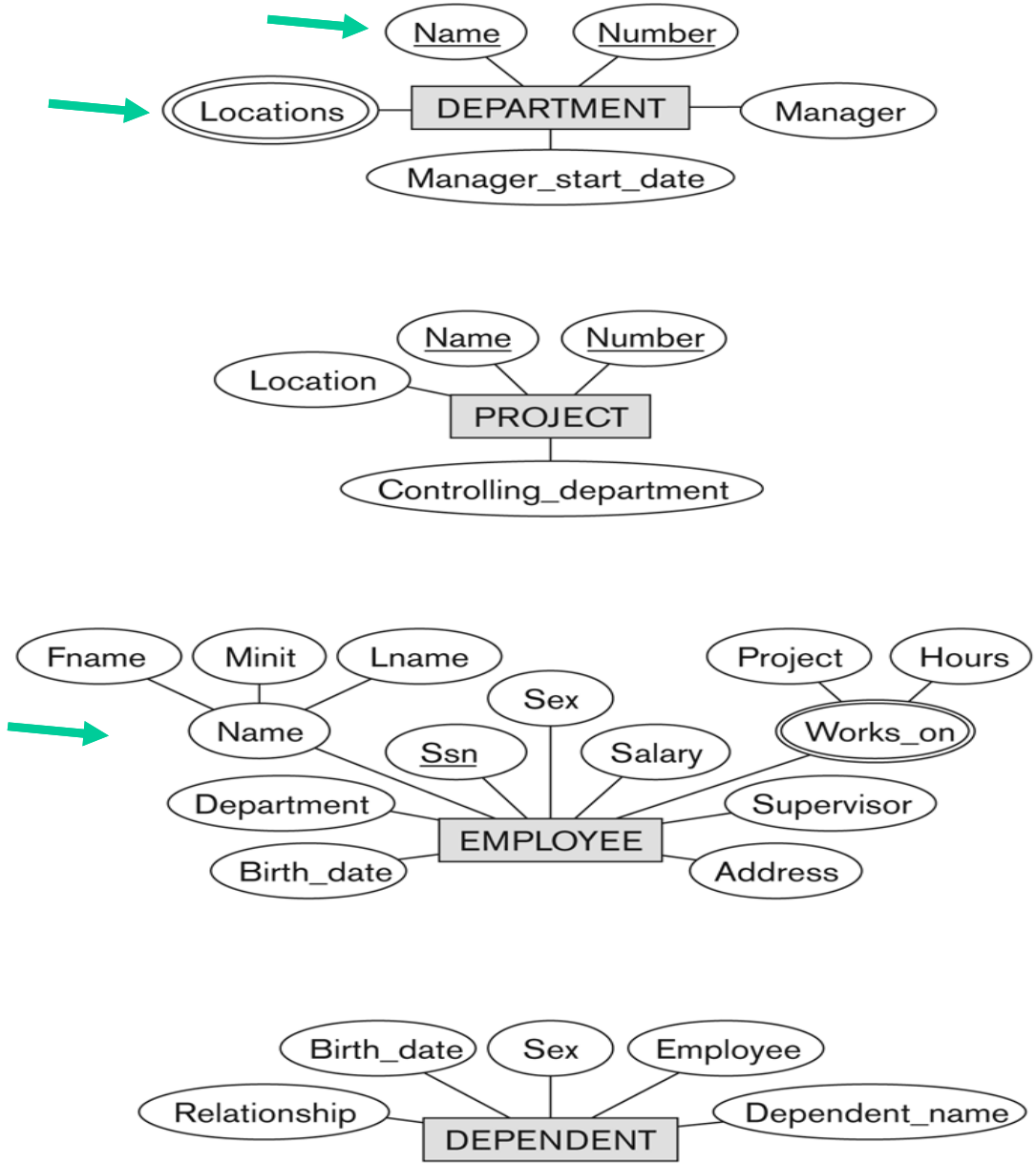


Figure 3.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

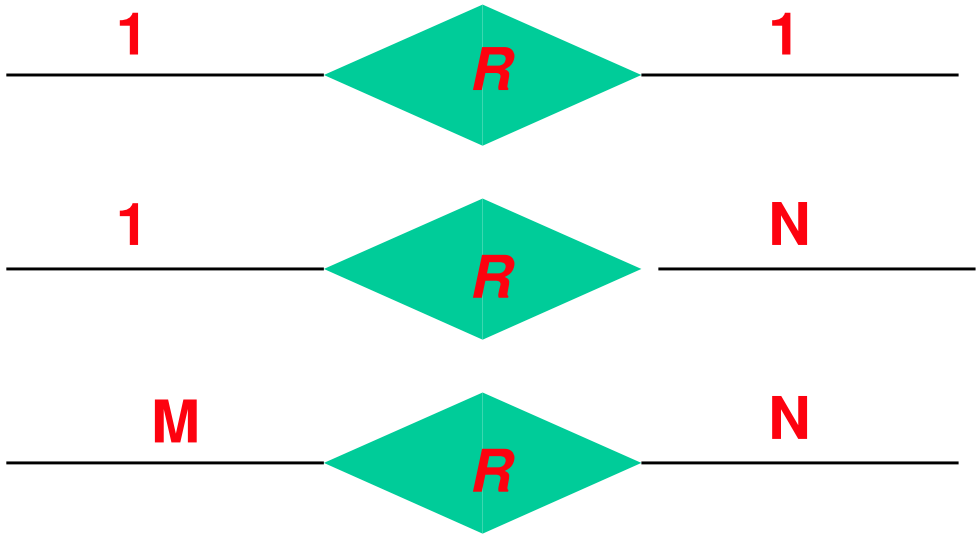
Refining the initial design by introducing relationships

- 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

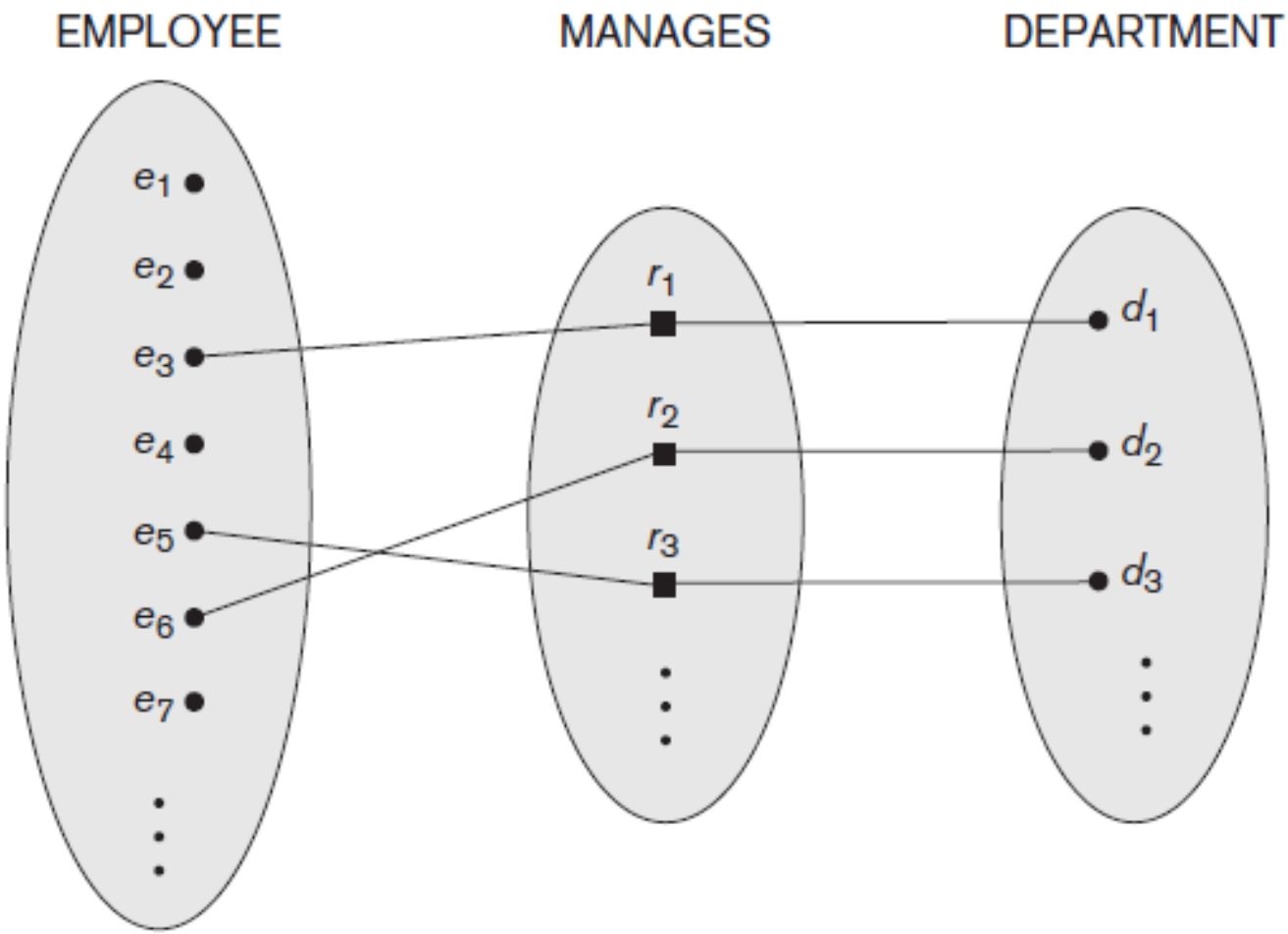
Constraints on relationship

- Cardinality ratio: specifies the maximum number of relationship instances that an entity can participate in
- Possible cardinality ratios for binary relationship types: 1:1, 1:N, N:1, or M:N

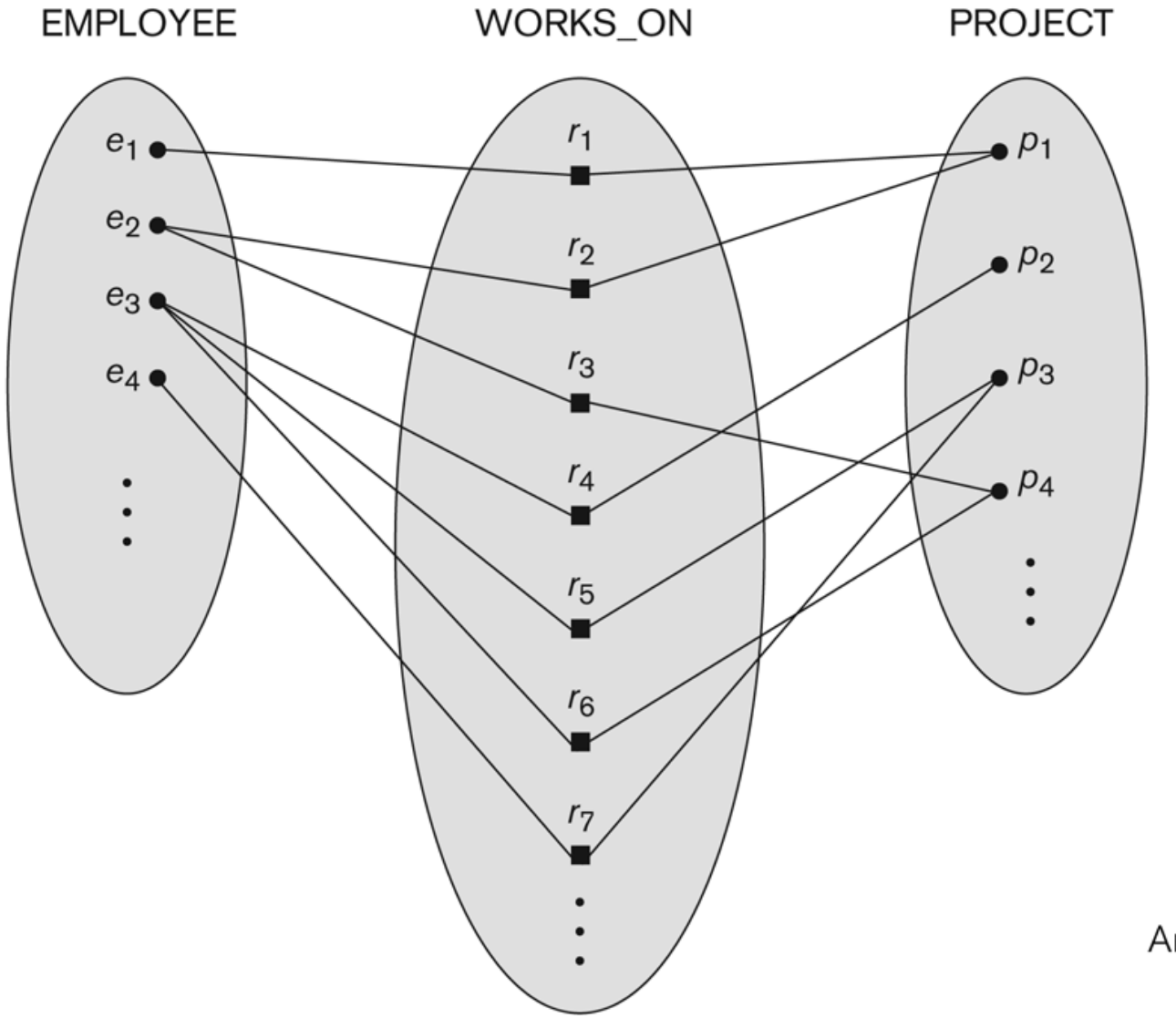


One-to-one (1:1) Relationship

Figure 3.12
A 1:1 relationship, MANAGES.



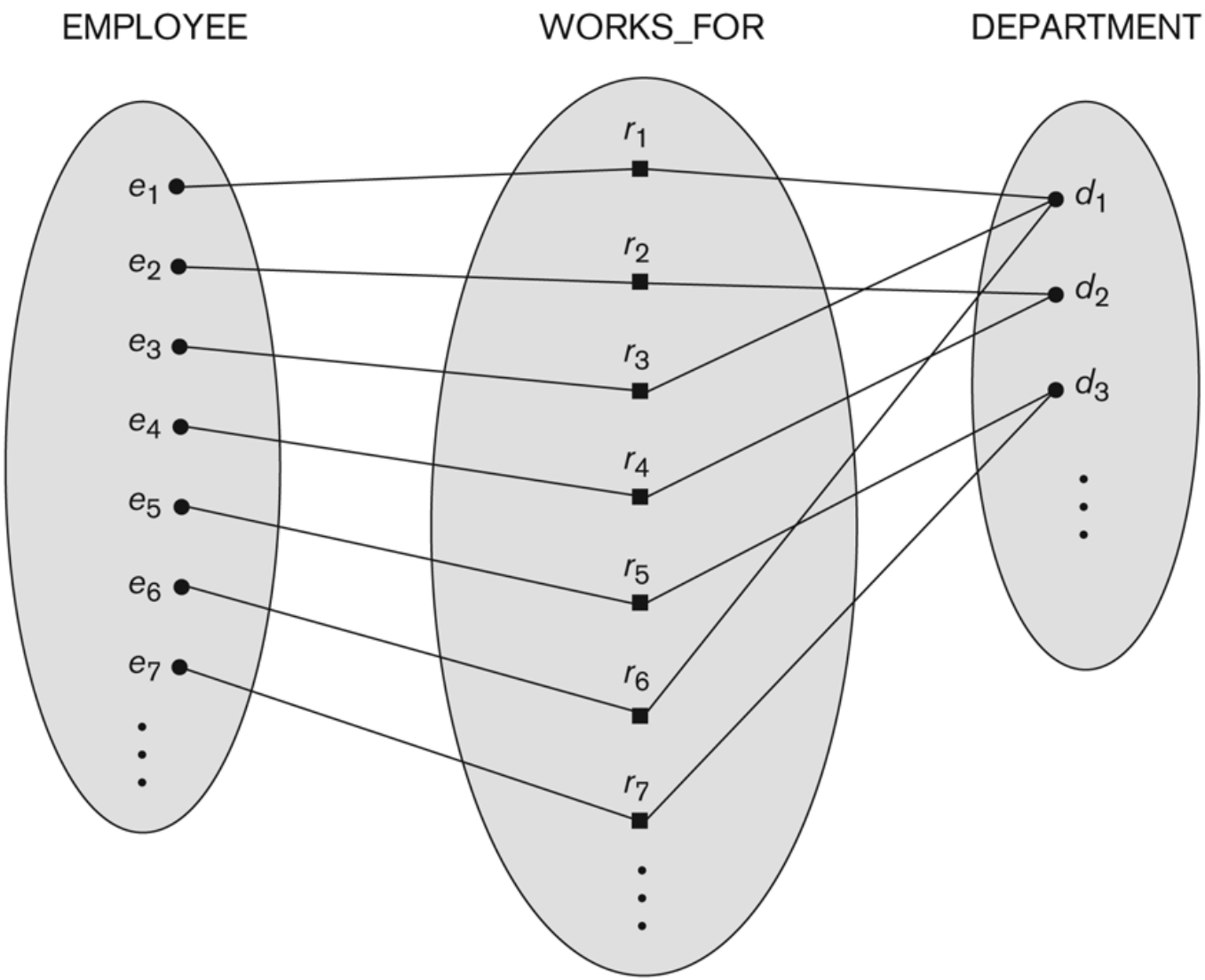
Many-to-many (M:N) Relationship



Many employee work on many projects

Figure 3.13
An M:N relationship, WORKS_ON.

Many-to-one (N:1) Relationship

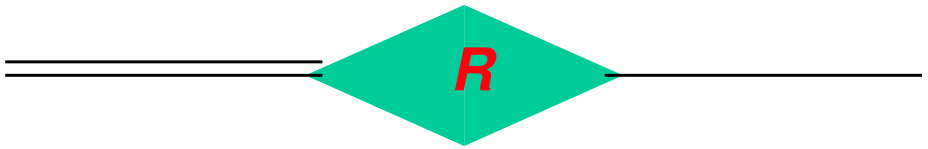


Many employees in the same department

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

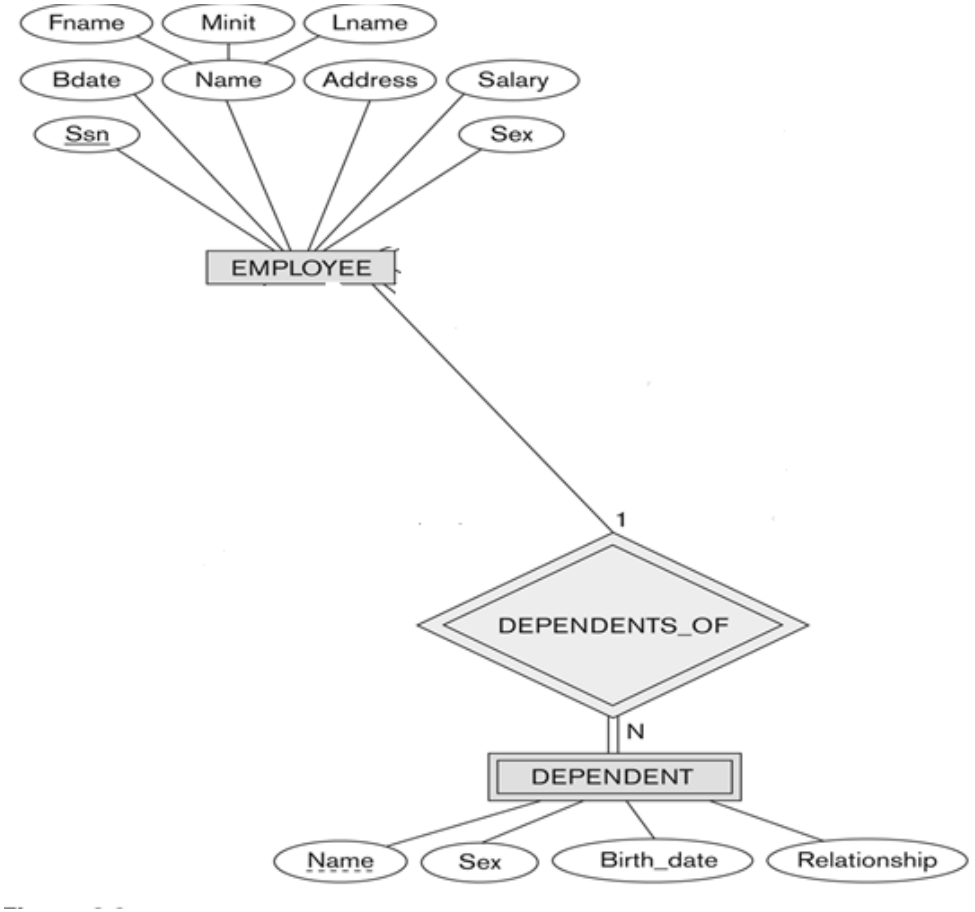
Constraints on relationship

- Participation constraint:
  - specifies the minimum number of relationship instances that an entity can participate in
  - Two types of participation constraints:
    - Total participation: shown by double line
    - Partial participation: shown by single line



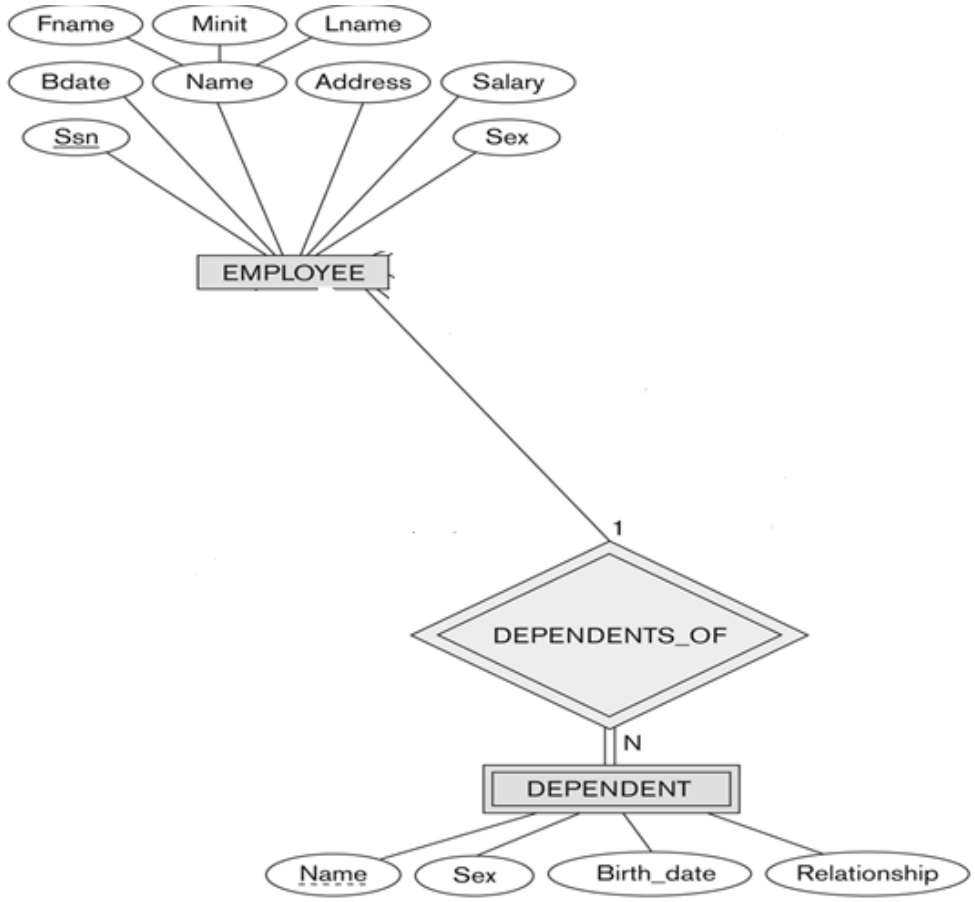
Weak Entity Types

- Strong entity types: Regular entity types that have key attribute(s).
- Weak entity types: Entity types that do **not** have key attributes of their own.
- Entities belonging to a weak entity type are identified by being related to specific entities from an owner entity type in combination with one of their attribute values.
- Identifying relationship of weak entity type: The relationship type that relates a weak entity type to its owner.



Weak Entity Types (cont'd)

- A weak entity type always has a total participation constraint (existence dependency) with respect to its identifying relationship.
  - Reason: a weak entity cannot be identified without an owner entity.
- A weak entity type normally has a partial key, which is the attribute that can uniquely identify weak entities that are related to the same owner entity



ER DIAGRAM – Relationship Types are:

WORKS_FOR, MANAGES, WORKS_ON, CONTROLS, SUPERVISION, DEPENDENTS_OF

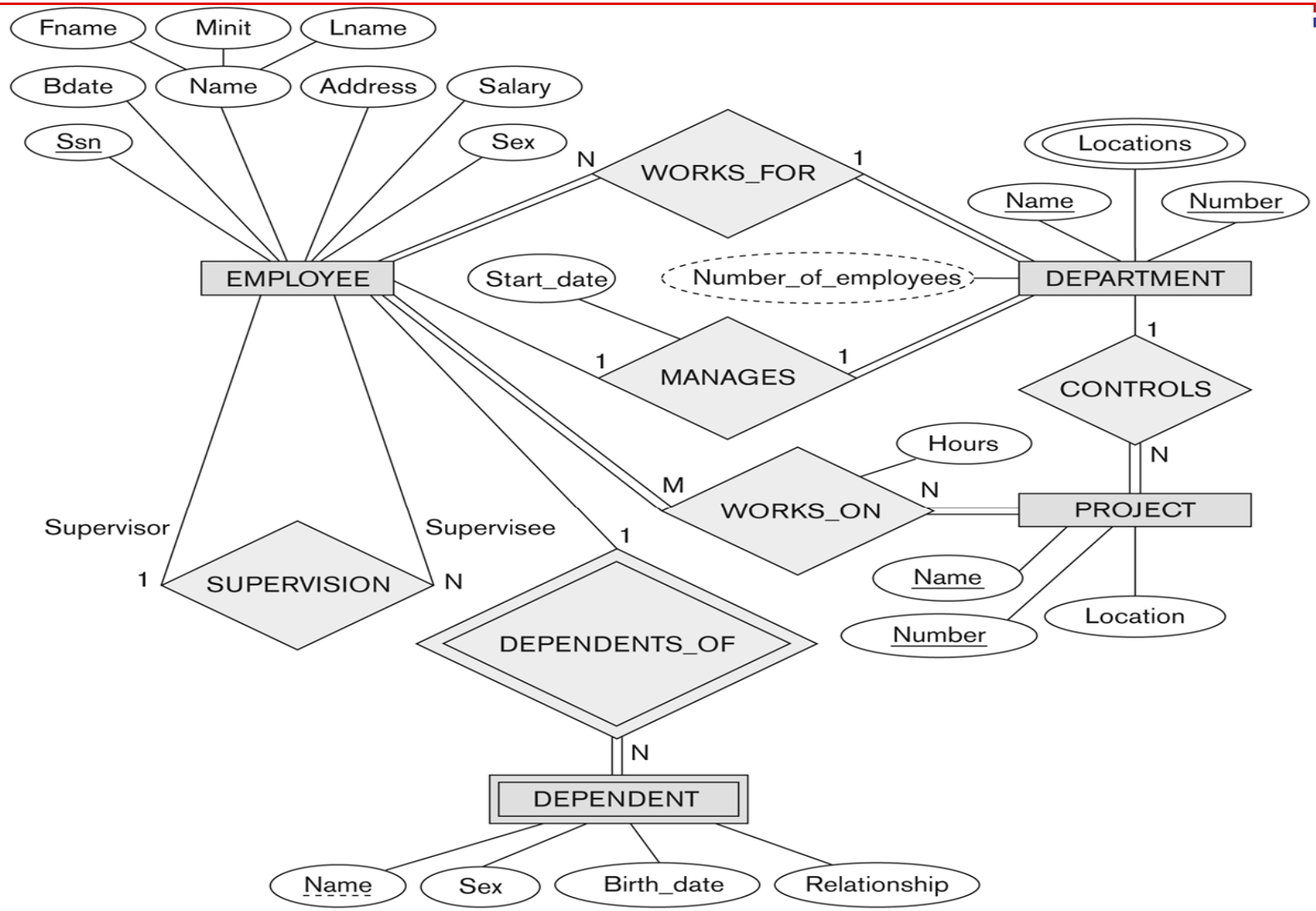
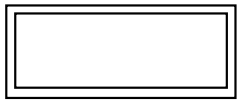
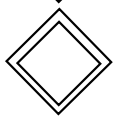
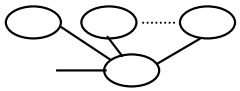
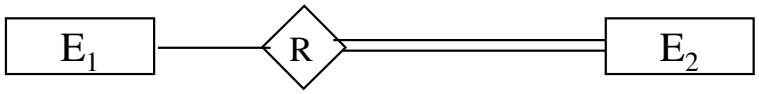
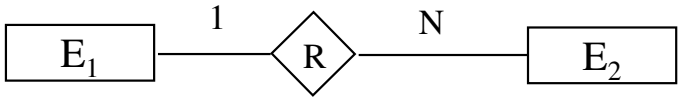
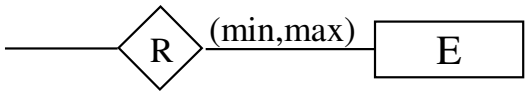


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

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

- ER diagram
  - Notations (e.g., entity, attribute, relationship)
  - Key attributes
  - Cardinality ratio
  - Participation constraint

References

- 7e
  - Ch. 2
  - Ch. 3