Database Management Systems

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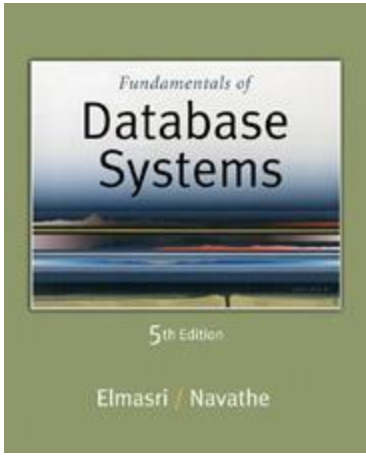

Lecture 3

PEARSON
Addison
Wesley

Chapter 7

Data Modeling Using the Entity-Relationship (ER) Model

Chapter Outline

- Overview of Database Design Process
- Example Database Application (COMPANY)
- ER Model Concepts
  - Entities and Attributes
  - Entity Types, Value Sets, and Key Attributes
  - Relationships and Relationship Types
  - Weak Entity Types
  - Roles and Attributes in Relationship Types
- ER Diagrams - Notation
- ER Diagram for COMPANY Schema

Overview of Database Design Process

- Database application includes 2 main activities:
  - Database design
  - Applications design
- Focus in this chapter on database design
  - To design the **conceptual** data model for a database application
- Applications design focuses on the programs and interfaces that access the database
  - Generally considered part of software engineering

Overview of Database Design Process

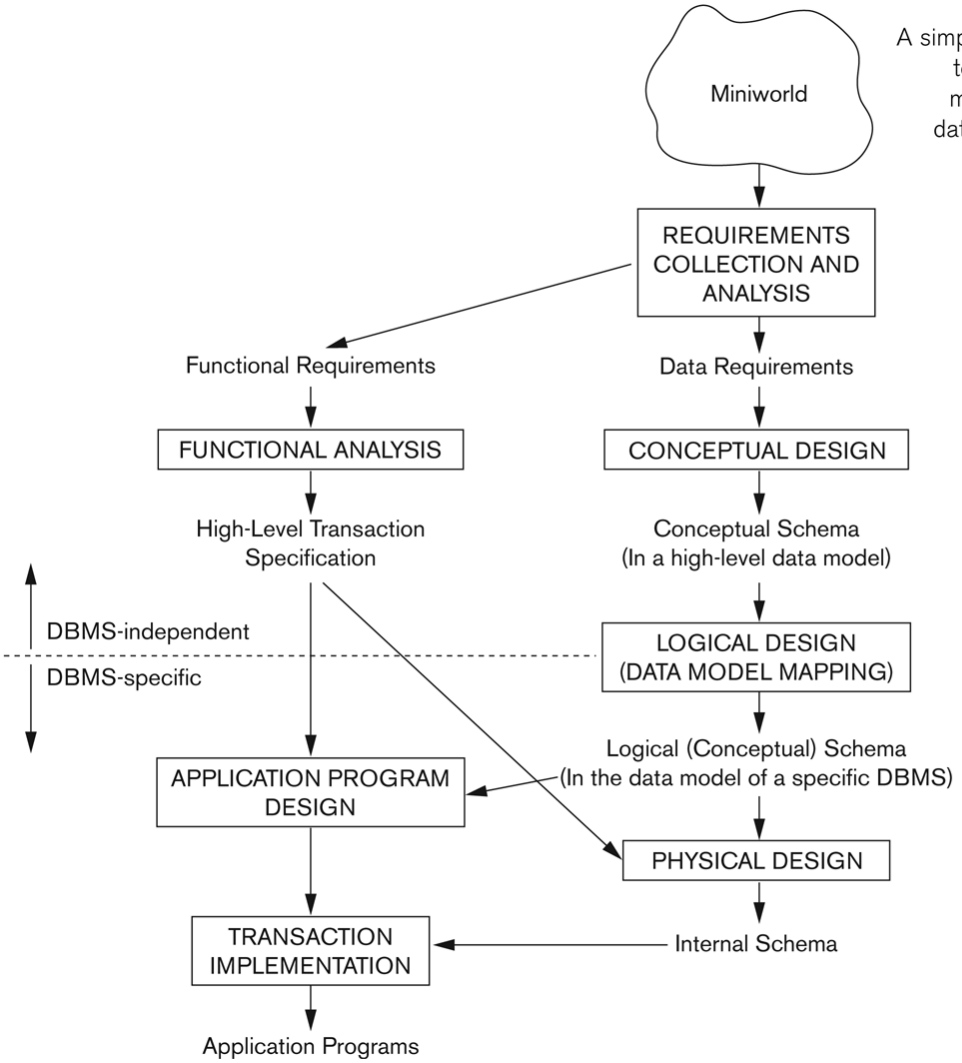

Figure 3.1
A simplified diagram to illustrate the main phases of database design.

Entity-Relationship (ER) model

- A popular high-level conceptual data model.
- Also known as ER diagram (ERD).
- visualize and organize data in terms of entities, attributes, and relationships between entities.
- **Components of the ER Model:**

1. **Entities:** Represent real-world objects or concepts.
   - Example: A "Student" entity represents an actual student in the system.
2. **Attributes:** Describe the characteristics of the entity.
   - Example: The "Student" entity has attributes like "Student_ID", "Name", and "Age".
3. **Relationships:** Describe how entities are related to each other. ➔ Example: "Student" **enrolls in** "Course" is a relationship

Example COMPANY Database

- We need to create a database schema design based on the following (simplified) **requirements** of the COMPANY Database:
  - 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* a number of PROJECTs. Each project has a unique name, unique number and is located at a single location.

Example COMPANY Database (Contd.)

- We store each EMPLOYEE's social security number, address, salary, sex, and birth date.
  - Each employee *works for* one department but may *work on* several projects.
  - We keep track of the number of hours per week that an employee currently works on each project.
  - We also keep track of the *direct supervisor* of each employee.
- Each employee may *have* a number of DEPENDENTs.
  - For each dependent, we keep track of their name, sex, birthdate, and relationship to the employee for insurance purposes.

ER DIAGRAM for the COMPANY datbase

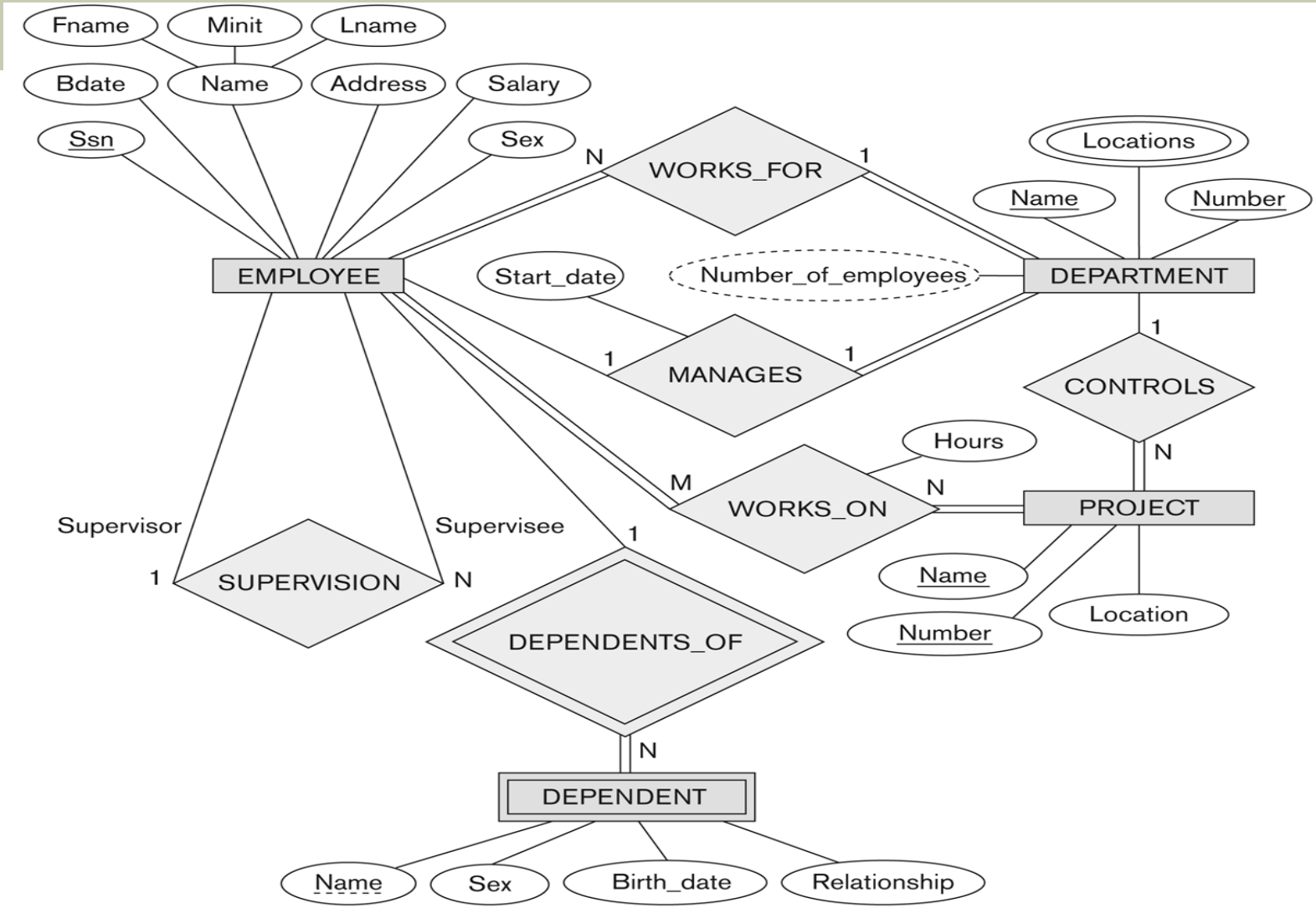

Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

ER Model Concepts

- **Entities and Attributes**
  - **Entities** are **specific objects or things** in the mini-world that are represented in the database. An entity may be an object with a physical existence (for example, a particular person, car, or with a conceptual existence (for instance, a company, a job, or a university course)
    - For example the EMPLOYEE John Smith, the Research DEPARTMENT, the ProductX PROJECT
  - **Attributes** are properties used to **describe an entity**.
    - For example an EMPLOYEE entity may have the attributes Name, SSN, Address, Sex, BirthDate
  - A specific entity will have a **value** for each of its attributes.
    - For example a specific employee entity may have Name='John Smith', SSN='123456789', Address ='731, Fondren, Houston, TX', Sex='M', BirthDate='09-JAN-55‘
  - Each attribute has a ***value set*** **(or data type)** associated with it – e.g. integer, string, …

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

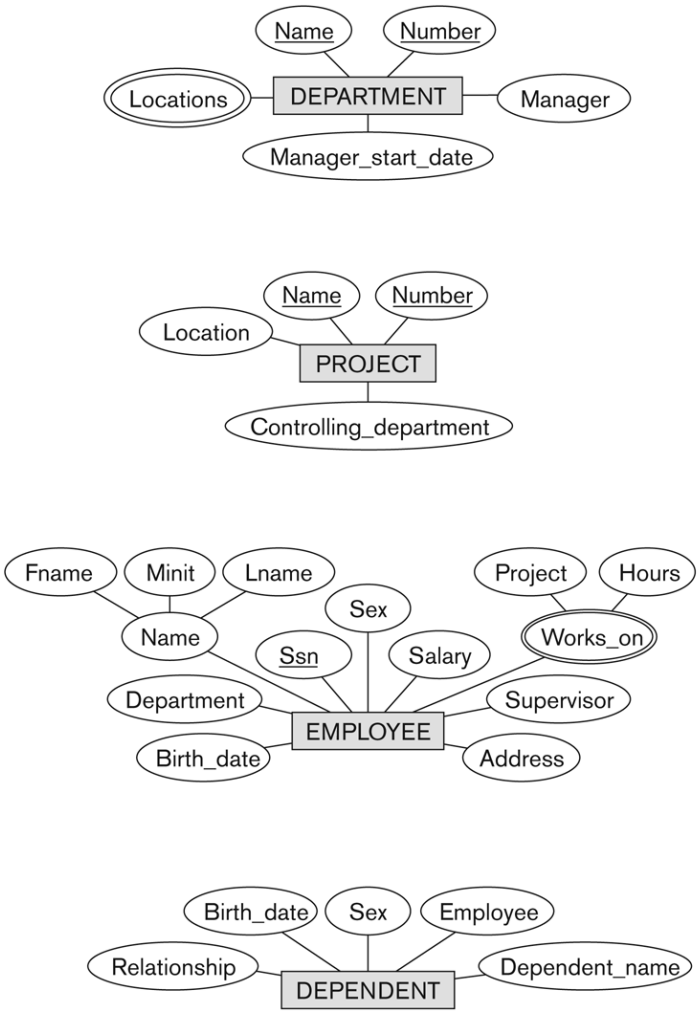

Figure 3.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

Types of Attributes

- *Simple versus composite*
- *Single-valued* versus *multi-valued*
- *Stored versus derived*

Types of Attributes

- Simple
  - Each entity has a **single atomic value** for the attribute. For example, SSN or Sex.
- Composite ()
  - The attribute may be composed of several components. For example:
    - Address(Apt#, House#, Street, City, State, ZipCode, Country), or
    - Name(FirstName, MiddleName, LastName).
    - Composition may form a hierarchy where some components are themselves composite.

Example of a composite attribute

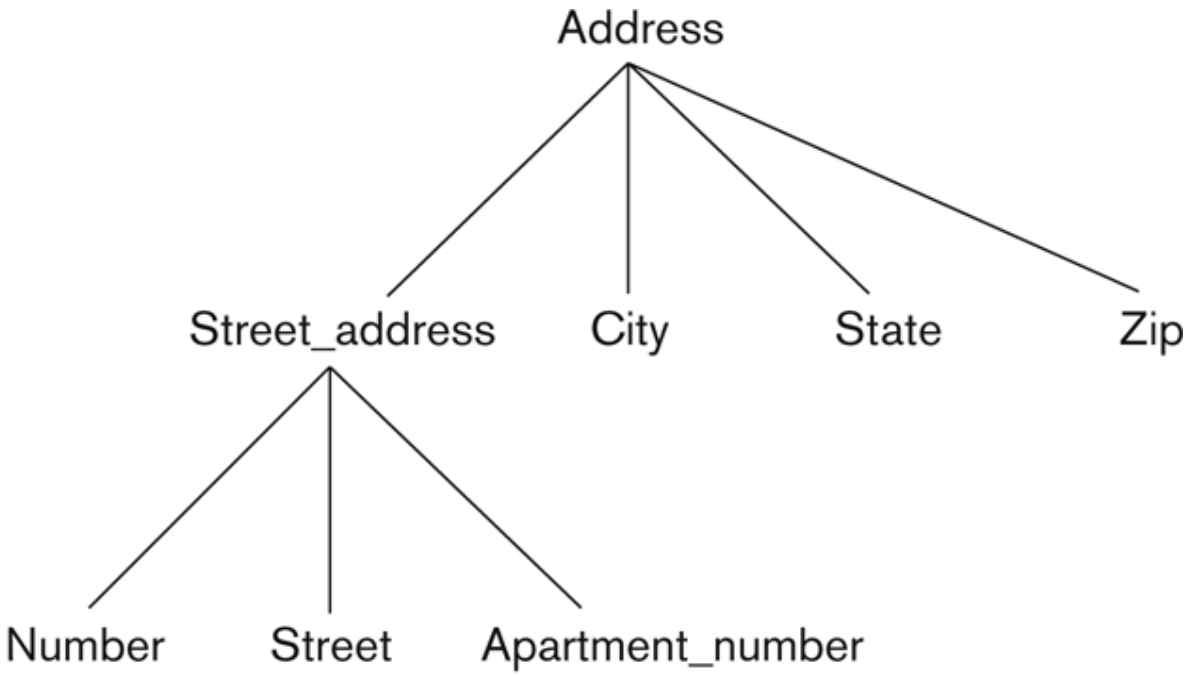

Figure 3.4
A hierarchy of composite attributes.

Types of Attributes

- Age is a single-valued attribute of a person.
- Multi-valued {}
  - An entity may have **multiple values** for that attribute. For example, Color of a CAR or College_degree of a PERSON.
    - Denoted as {Color} or {College_degree}.
  - It may have upper bounds to constrain the *number of values* allowed for each individual entity (Ex: a car can have three colors at most)
- **Complex Attributes:** In general, composite and multi-valued attributes may be **nested arbitrarily to any number of levels**, although this is rare.
  - For example, College_degree of a STUDENT is a composite multi-valued attribute denoted by {College_degree(College, Year, Degree, Field)}
  - Multiple College_degree values can exist
  - Each has four subcomponent attributes:
    - College, Year, Degree, Field

Initial Design of Entity Types:
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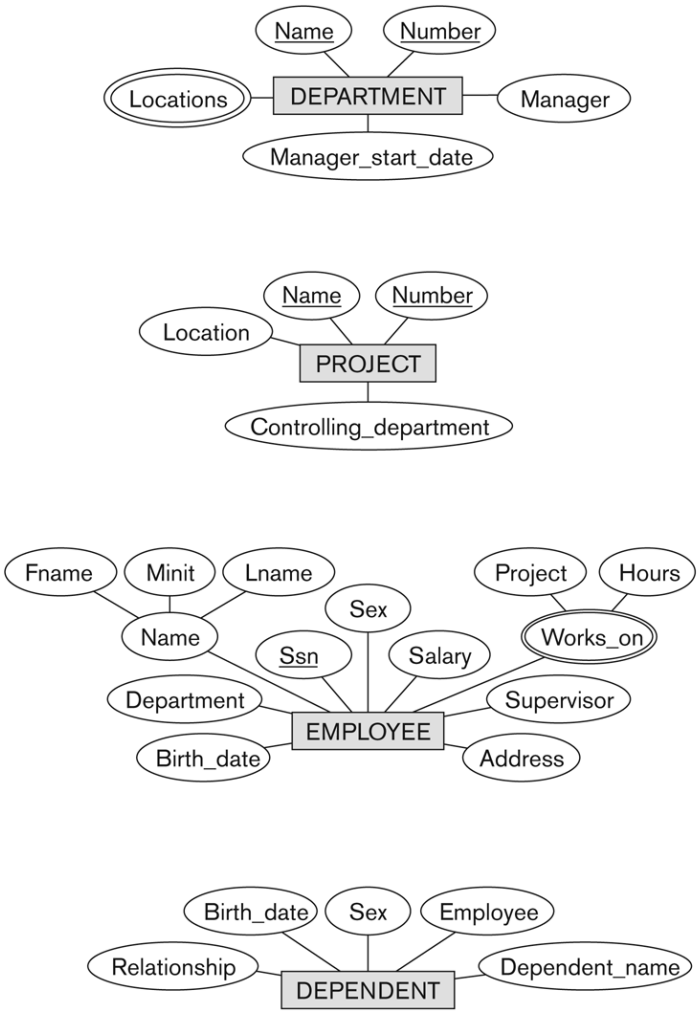


Figure 3.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

Types of Attributes

- **Derived Attributes:**
  - For example, the Age and Birth_date attributes of a person.
  - The Age attribute is called a **derived attribute and is said to be derivable from the Birth_date attribute,** which is called a **stored attribute.**
  - **Some attribute values can be derived from** *related entities; for example, an attribute Number_of_employees of a DEPARTMENT* entity can be derived by counting the number of employees related to (working for) that department.

ER DIAGRAM for the COMPANY datbase

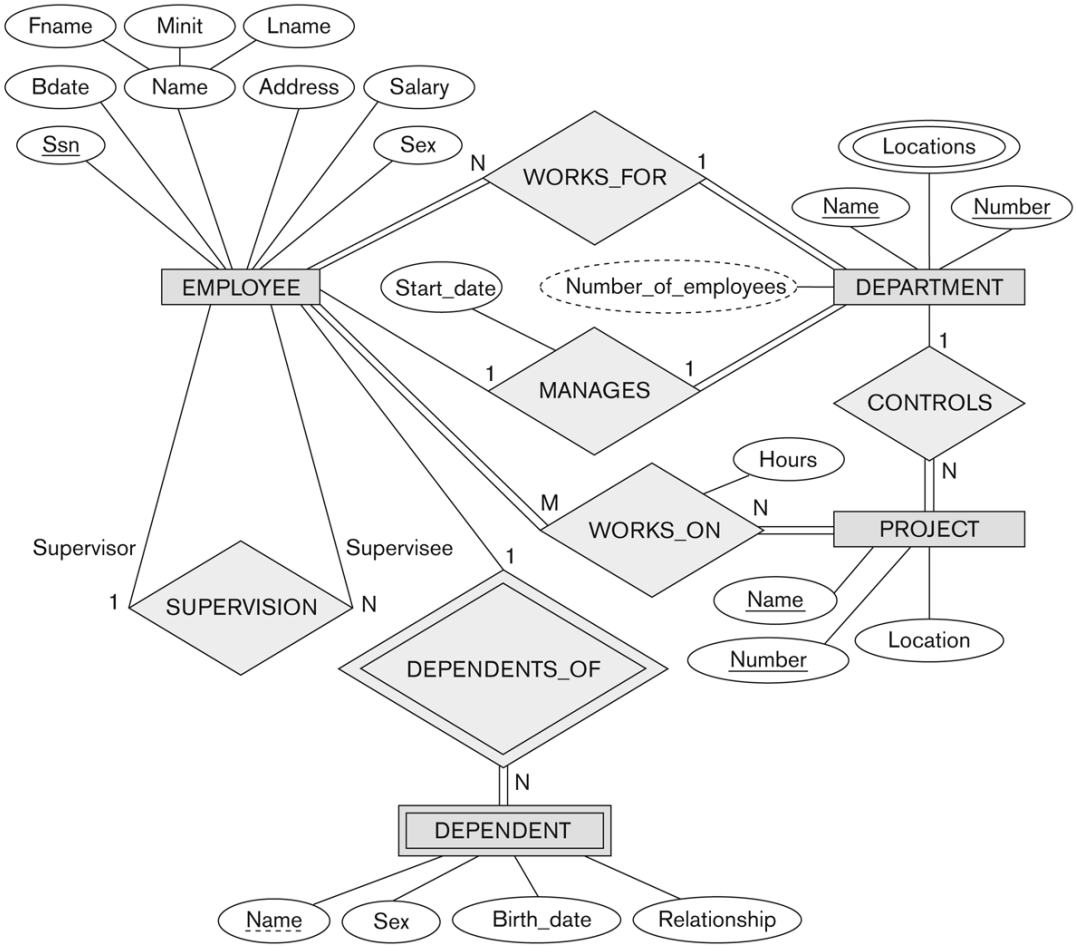


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

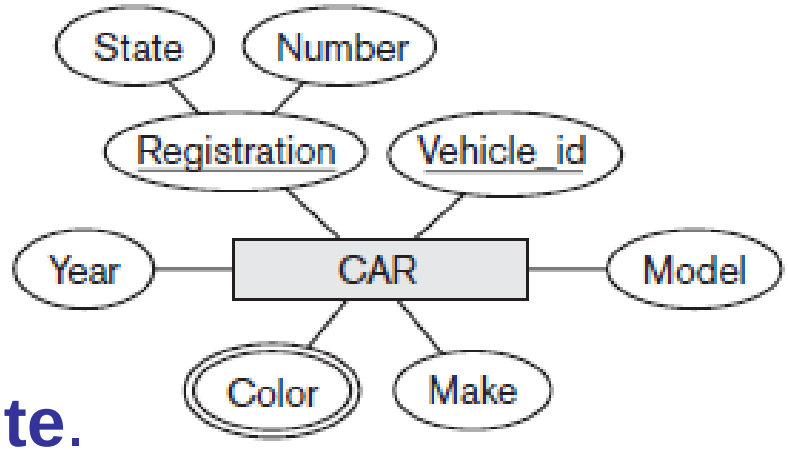
Null – 3 cases

- **Case 1 (Not applicable): a particular entity may not have an applicable value** for an attribute.
  - For example, the Apartment_number and a College_degrees attribute
- **Case 2 (Unknown):** NULL can also be used if we **do not know** the value of an attribute for a particular entity
  - Exists but is *missing—for instance, if the Height attribute of a* person is listed as NULL.
  - *Not known whether the attribute value exists*—for example, if the Home_phone attribute of a person is NULL.

Entity Types and Key Attributes

- Entities with the same basic attributes are grouped or typed into an **entity type**.
  - For example, the entity type EMPLOYEE and PROJECT.
- An attribute of an entity type for which each entity **must have a unique value is called a key attribute of the entity type.**
  - For example, SSN of EMPLOYEE.

Entity Types and Key Attributes



- A key attribute may be **composite**.
  - Registration is a key of the CAR entity type with components (Number, State).
- An entity type may have **more than one key (candidate key)**.
  - The CAR entity type may have two keys:
    - Vehicle_Id
    - Registration (Number, State), plate number.
- Each key is underlined
- An entity type may also have *no key, in which case it is called a weak entity type*

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

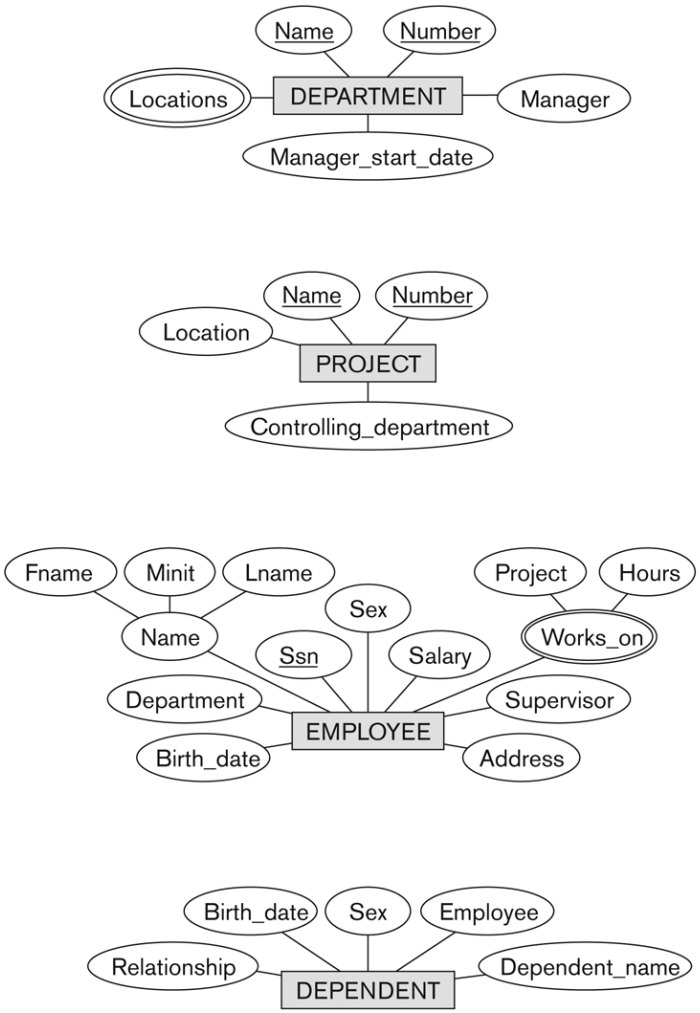


Figure 3.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

Displaying an Entity type

- In ER diagrams, an entity type is displayed in a rectangular box
- Attributes are displayed in ovals
  - Each attribute is connected to its entity type
  - Components of a composite attribute are connected to the oval representing the composite attribute
  - Each key attribute is underlined
  - Multivalued attributes displayed in double ovals
- See CAR example on next slide

Entity Type CAR with two keys and a corresponding Entity Set

(a)

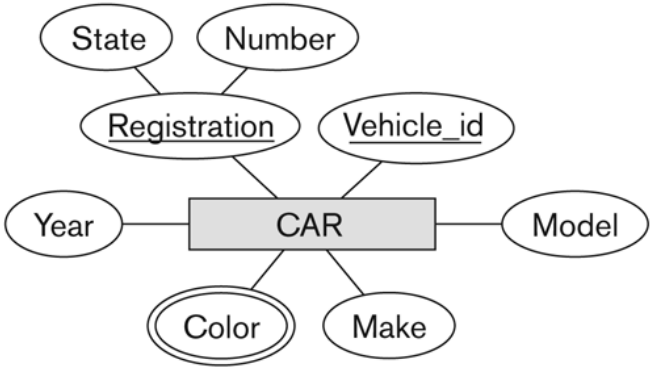


Figure 3.7
The CAR entity type with two key attributes, Registration and Vehicle_id. (a) ER diagram notation. (b) Entity set with three entities.

(b)

CAR
Registration (Number, State), Vehicle_id, Make, Model, Year, {Color}

CAR_1
((ABC 123, TEXAS), TK629, Ford Mustang, convertible, 2004 {red, black})

CAR_2
((ABC 123, NEW YORK), WP9872, Nissan Maxima, 4-door, 2005, {blue})

CAR_3
((VSY 720, TEXAS), TD729, Chrysler LeBaron, 4-door, 2002, {white, blue})

⋮

Initial Design of Entity Types for the COMPANY Database Schema

- Based on the requirements, we can identify four initial entity types in the COMPANY database:
  - DEPARTMENT
  - PROJECT
  - EMPLOYEE
  - DEPENDENT
- Their **initial design** is shown on the following slide
- The initial attributes shown are **derived from the requirements description**

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

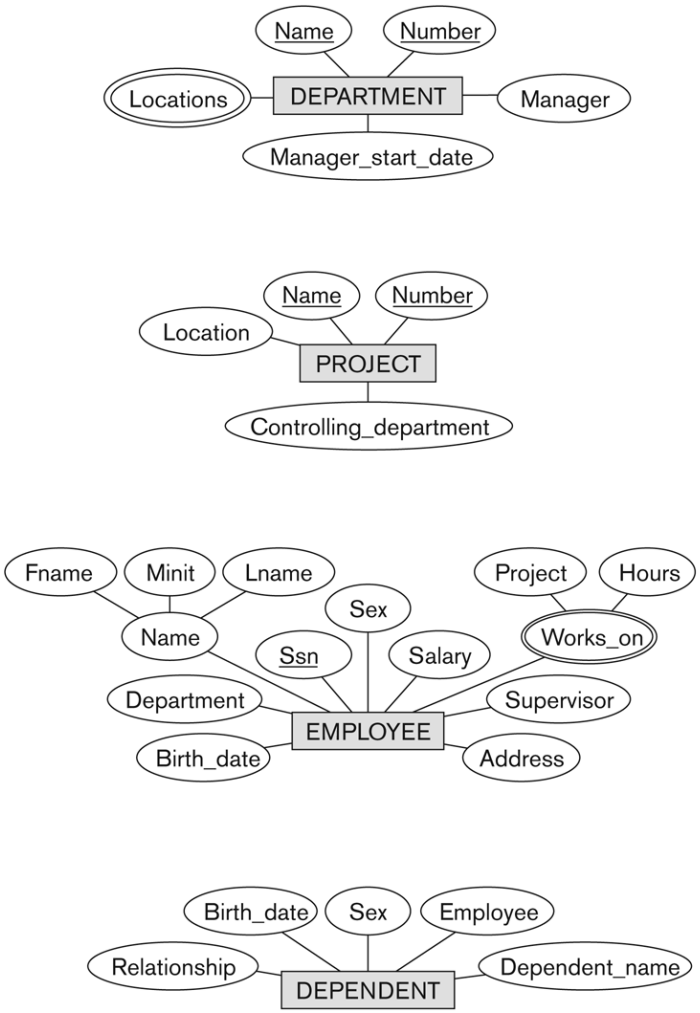


Figure 3.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

Refining the initial design by introducing **relationships**

- The initial design is typically not complete
- ER model has three main concepts:
  - Entities
  - Attributes (simple, composite, multivalued)
  - Relationships
- Some aspects in the requirements will be represented as **relationships**
- whenever an attribute of one entity type refers to another entity type, some relationship exists.
- In the ER model, these references should not be represented as attributes but as **relationships**

Relationships and Relationship Degree

- A **relationship** relates two or more distinct entities with a specific meaning.
  - For example, EMPLOYEE John Smith *works on* the ProductX PROJECT, or EMPLOYEE Franklin Wong *manages* the Research DEPARTMENT.
- The **degree** of a relationship type is the number of participating entity types.
  - Both MANAGES and WORKS_ON are *binary* relationships.

Relationship type

- In ER diagrams, we represent the *relationship type* as follows:
  - **Diamond-shaped box** is used to display a relationship type
  - Connected to the participating entity types via straight lines

Refining the COMPANY database schema by introducing relationships

- By examining the requirements, six relationship types are identified
- All are ***binary* relationships**(degree 2)
- Listed below with their participating entity types:
  - WORKS_FOR (between EMPLOYEE, DEPARTMENT)
  - MANAGES (also between EMPLOYEE, DEPARTMENT)
  - CONTROLS (between DEPARTMENT, PROJECT)
  - WORKS_ON (between EMPLOYEE, PROJECT)
  - SUPERVISION (between EMPLOYEE (as subordinate), EMPLOYEE (as supervisor))
  - DEPENDENTS_OF (between EMPLOYEE, DEPENDENT)

ER DIAGRAM – Relationship Types are:

WORKS_FOR, MANAGES, WORKS_ON, CONTROLS, SUPERVISION, DEPENDENTS_OF

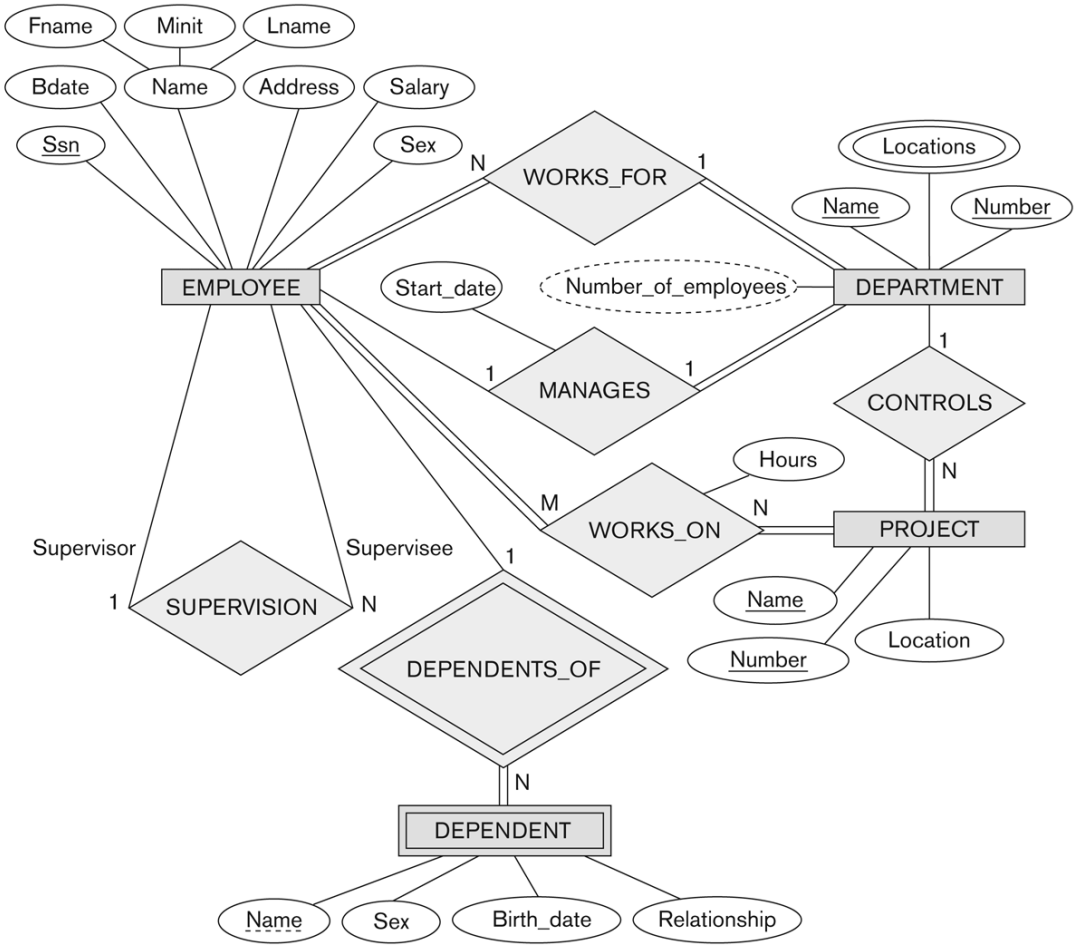
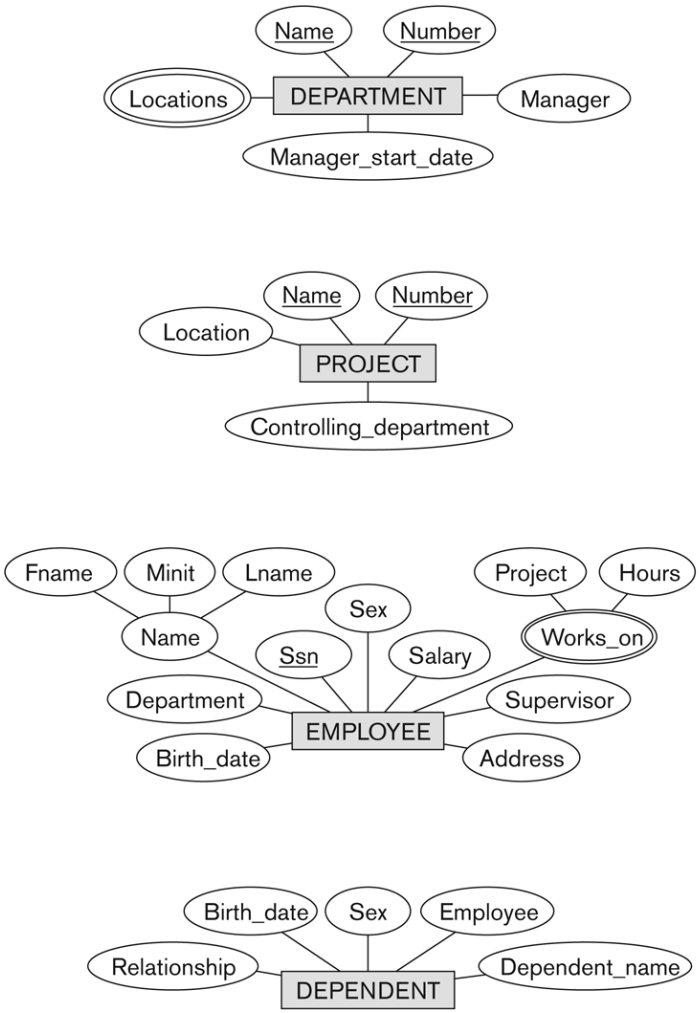


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

Discussion on Relationship Types

- In the refined design, **some attributes from the initial entity types are refined into relationships**:
  - Manager of DEPARTMENT -> MANAGES
  - Works_on of EMPLOYEE -> WORKS_ON
  - Department of EMPLOYEE -> WORKS_FOR
  - etc
- In general, **more than one relationship type can exist between the same participating entity types**
  - MANAGES and WORKS_FOR are distinct relationship types between EMPLOYEE and DEPARTMENT
  - Different meanings and different relationship instances.

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



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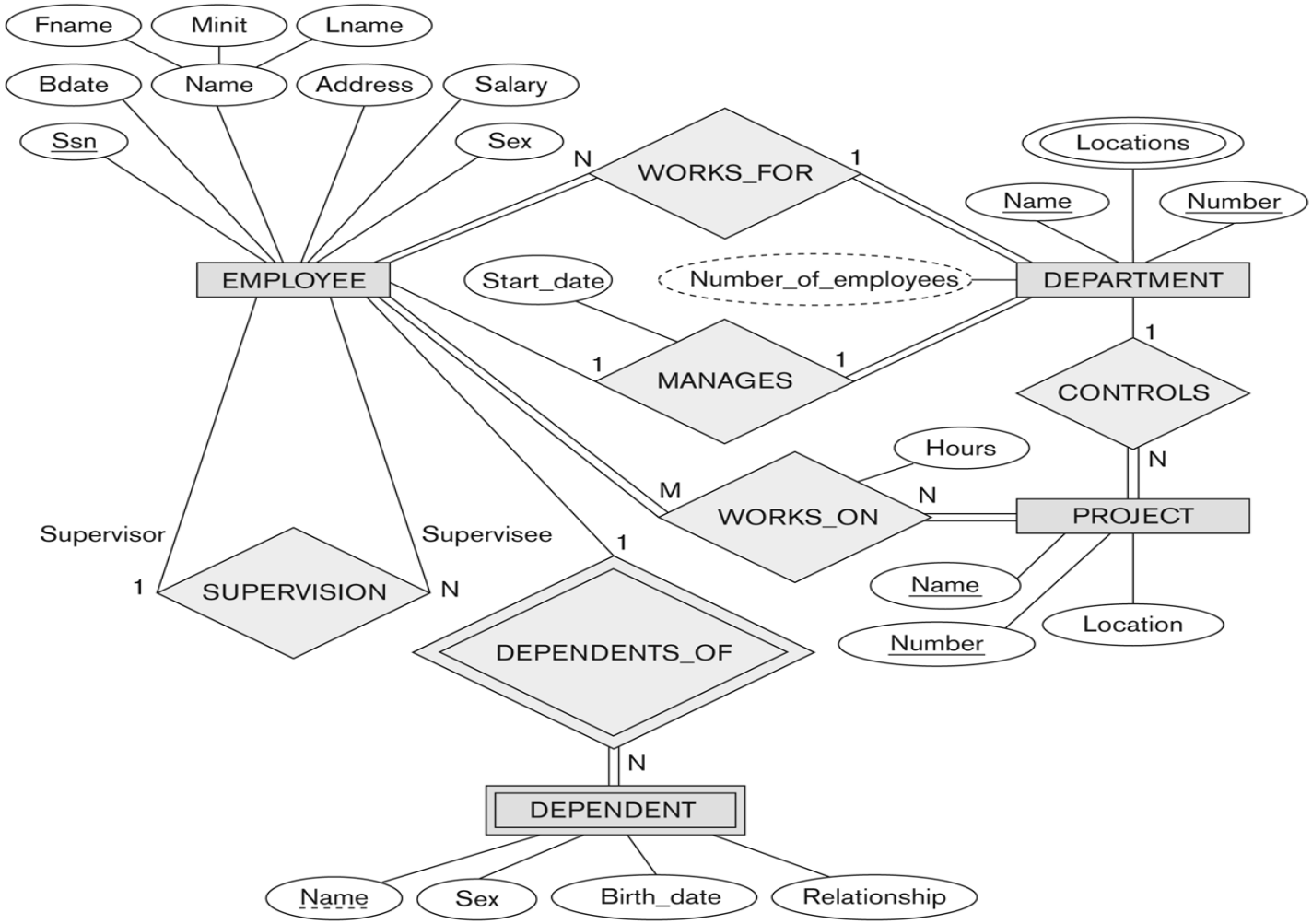

Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

Role Names and Recursive Relationships

- A relationship type with the same participating entity type in **distinct roles**
- Example: the SUPERVISION relationship
- EMPLOYEE participates twice in two distinct roles:
  - supervisor (or boss) role
  - supervisee (or subordinate) role
- Each relationship instance relates two distinct EMPLOYEE entities:
  - One employee in *supervisor* role
  - One employee in *supervisee* role

Displaying a recursive relationship

- In a recursive relationship type.
  - Both participations are same entity type in different roles.
  - For example, SUPERVISION relationships between EMPLOYEE (in role of supervisor or boss) and (another) EMPLOYEE (in role of subordinate or supervisee).
- In ER diagram, need to display role names to distinguish participations.

Recursive Relationship Type is: SUPERVISION (participation role names are shown)

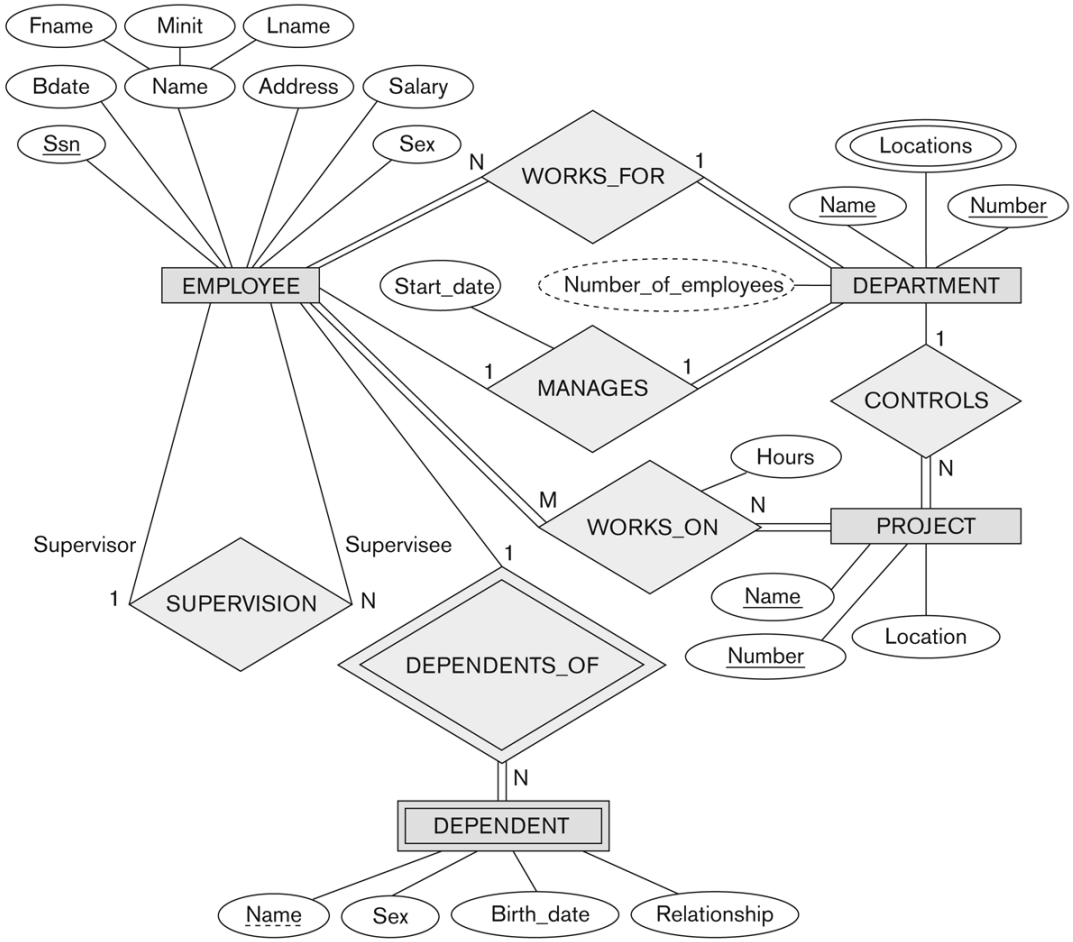

Figure 3.2
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Constraints on Relationships

- Structural Constraints on Relationship Types
  - **Cardinality Ratio** (specifies *maximum* participation)
    - One-to-one (1:1)
    - One-to-many (1:N) or Many-to-one (N:1)
    - Many-to-many (M:N)
  - **Existence Dependency Constraint** (specifies ***minimum*** participation) (also called participation constraint)
    - zero (**optional** participation, not existence-dependent)
    - one or more (**mandatory** participation, existence-dependent)

ER DIAGRAM – Relationship Types are:

WORKS_FOR, MANAGES, WORKS_ON, CONTROLS, SUPERVISION, DEPENDENTS_OF

Works_For

Emp	Dept
1	1
N	1

N : 1

Manages

Emp	Dept
1	1
1	1

1 : 1

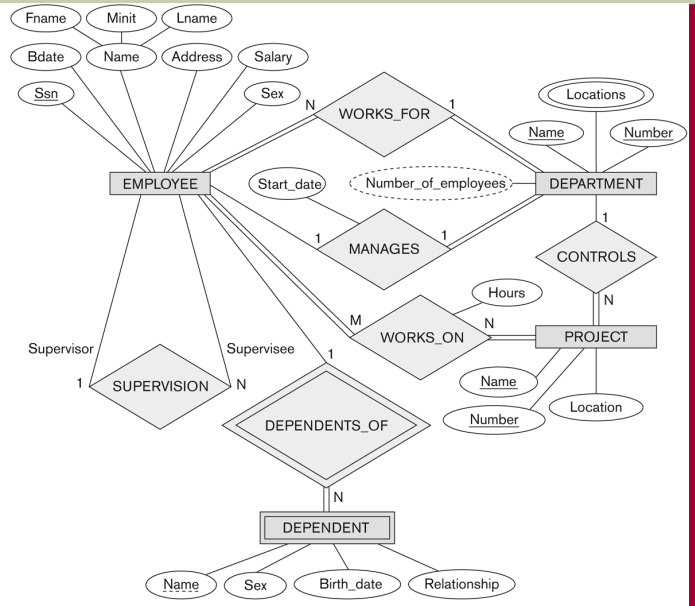


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

Works_On

Emp	Project
1	N
N	1

M : N

Supervision

Supervisor	Supervisee
1	N
1	1

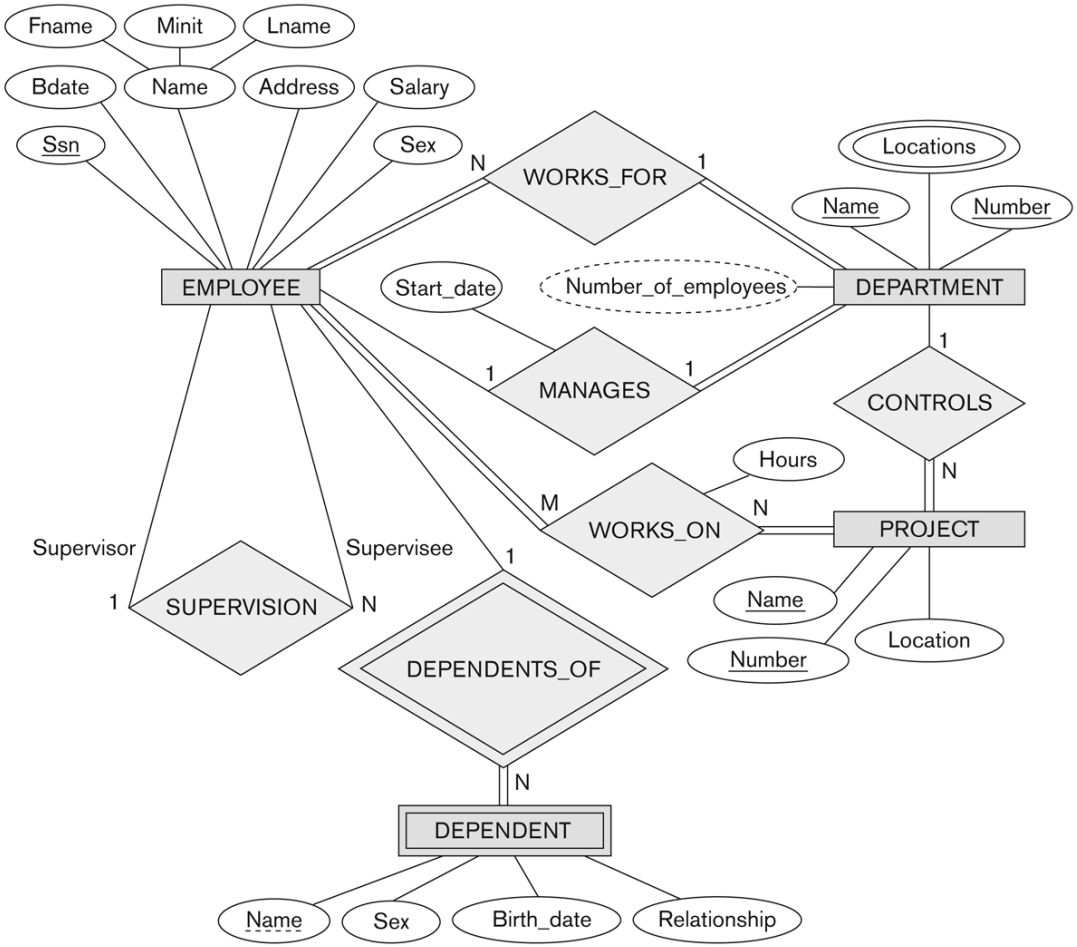
1 : N

Notation for Constraints on Relationships

- Cardinality ratio (of a binary relationship): 1:1, 1:N, N:1, or M:N
  - Shown by placing appropriate numbers on the relationship edges.
- Participation constraint (on each participating entity type): total (called existence dependency) or partial.
  - Total shown by double line, partial by single line.

ER DIAGRAM – Relationship Types are:

WORKS_FOR, MANAGES, WORKS_ON, CONTROLS, SUPERVISION, DEPENDENTS_OF



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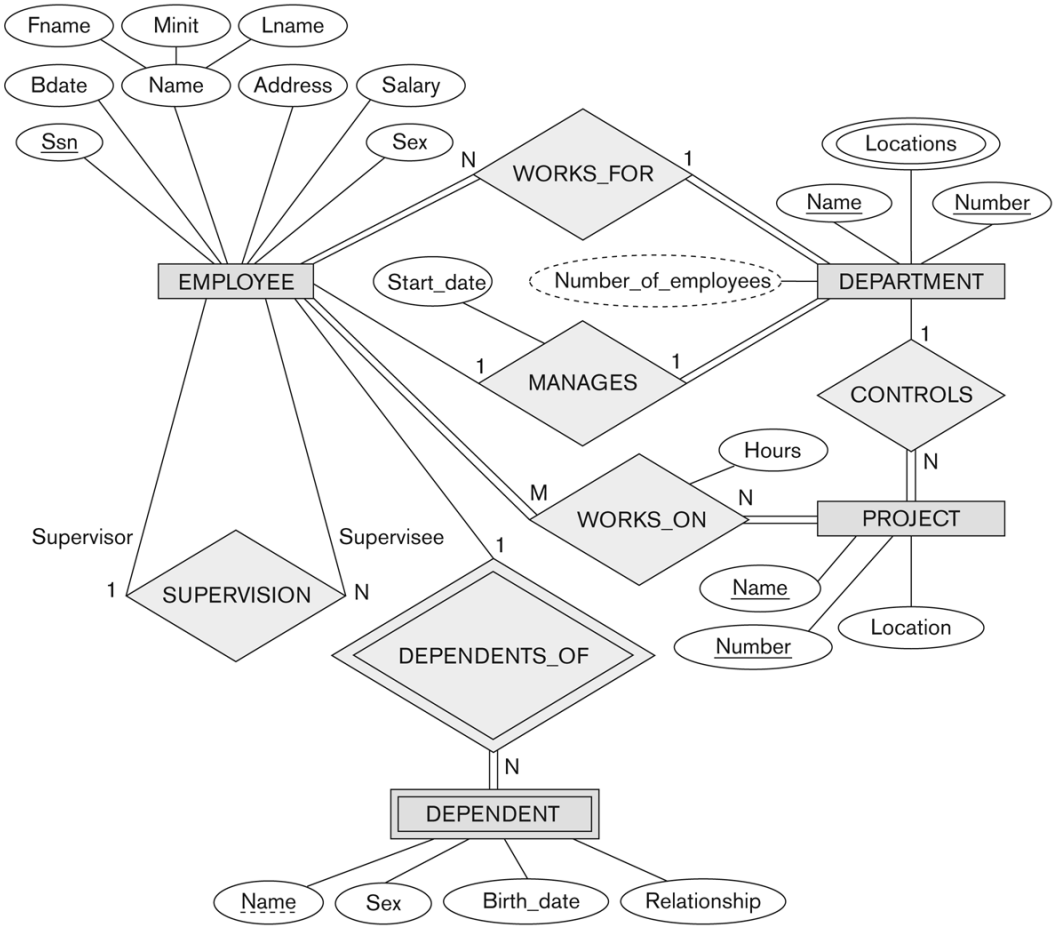
Attributes of Relationship types

- A relationship type can have attributes:
  - For example, HoursPerWeek of WORKS_ON
  - Its value for each relationship instance describes the number of hours per week that an EMPLOYEE works on a PROJECT.
    - A value of HoursPerWeek depends on a particular (employee, project) combination
  - Most relationship attributes are used with M:N relationships
    - In **1:N relationships**, they can be transferred to the entity type on **the N-side of the relationship**
    - For example, if the WORKS_FOR relationship also has an attribute Start_date

Example Attribute of a Relationship Type: Hours of WORKS_ON



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

Weak Entity Types

- An entity that does not have a key attribute
- A weak entity must participate in an **identifying** relationship type with an **owner** or **identifying entity** type
- Entities are identified by the combination of:
  - A **partial key** of the weak entity type *(Dots)*
  - The particular entity they are related to in the identifying entity type
- **Example:**
  - A DEPENDENT entity is identified by the dependent's first name, *and* the specific EMPLOYEE with whom the dependent is related
  - Name of DEPENDENT is the *partial key*
  - DEPENDENT is a *weak entity type*
  - EMPLOYEE is its identifying entity type via the identifying relationship type DEPENDENT_OF

ER DIAGRAM – Relationship Types are:

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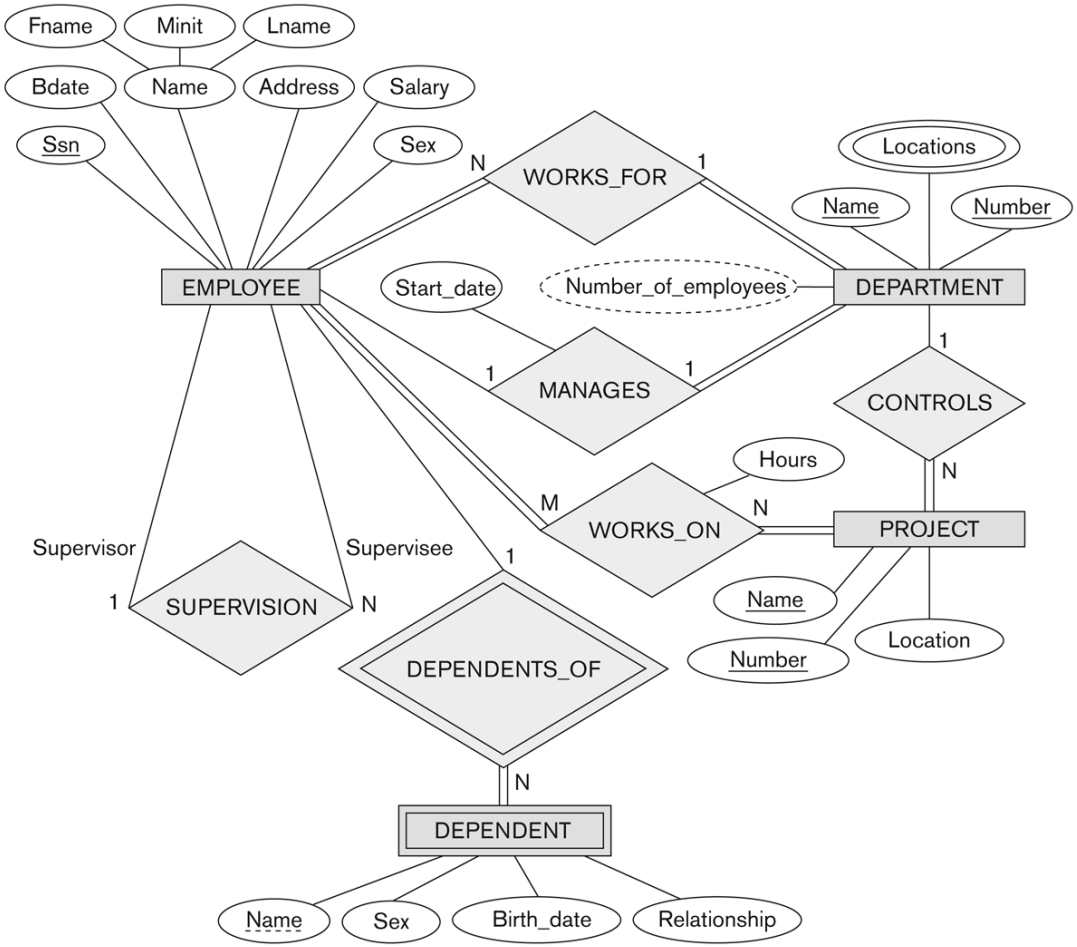

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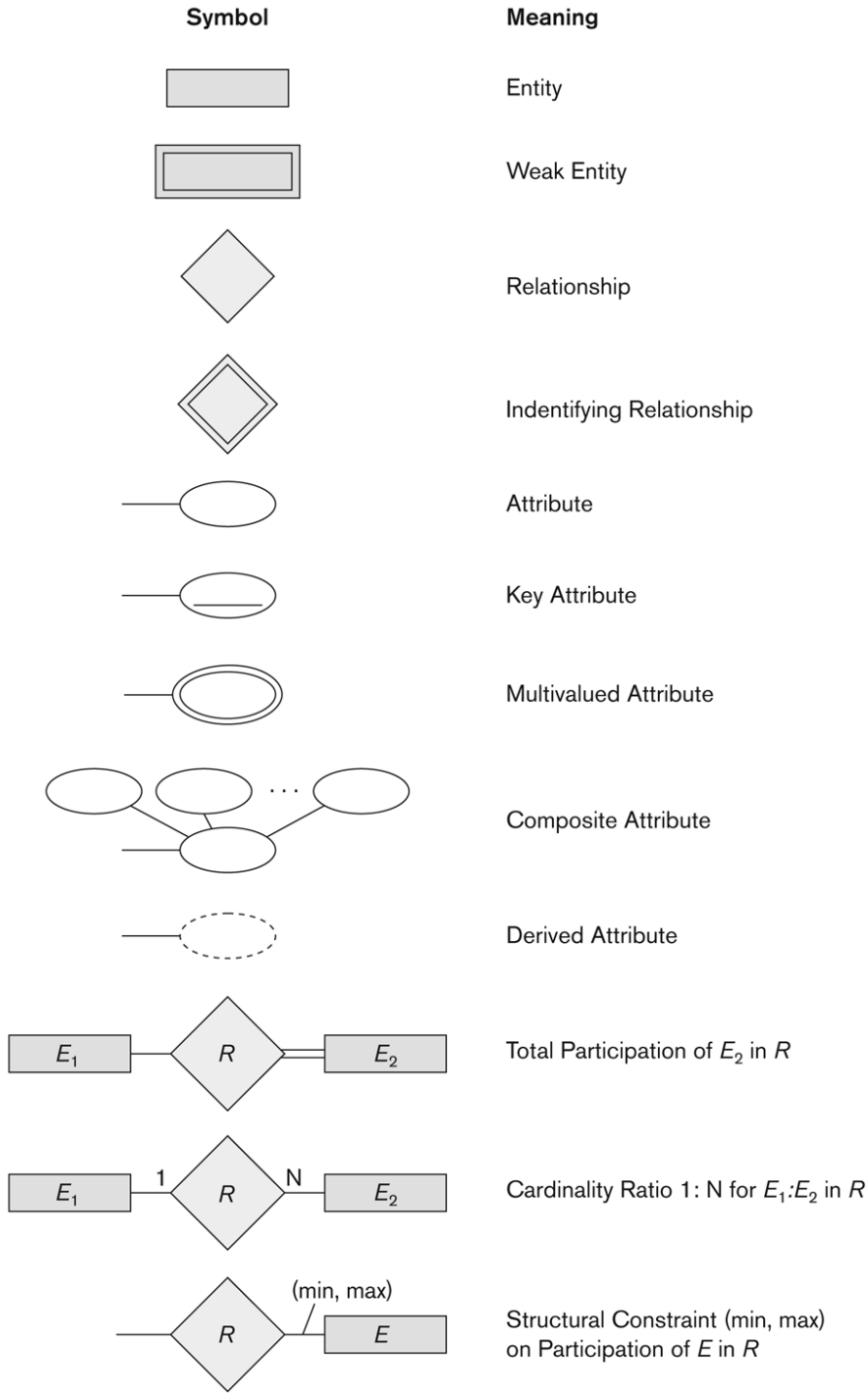
Weak Entity Types

- A weak entity type always has a *total participation constraint (existence dependency)* with respect to its identifying relationship.
  - Not every existence dependency results in a weak entity type For example, a DRIVER_LICENSE entity cannot exist unless it is related to a PERSON entity, even though it has its own key (License_number) and hence is not a weak entity.
- Weak entity types can sometimes be represented as complex (composite, multivalued) attributes.
  - We could specify a multivalued attribute Dependents for EMPLOYEE, which is a composite attribute with component attributes Name, Birth_date, Sex, and Relationship.
- The choice of which representation to use is made by the database designer.
- If the weak entity participates independently in relationship types other than its identifying relationship type, then it should not be modeled as a complex attribute.

Summary of notation for ER diagrams

Figure 3.14
Summary of the notation for ER diagrams.



- More than relationship between the same entities
- Self relation
- No isolated entity without relationship
- No entity for system
- Weak entity can be multivalued composite attribute
- No entity without Key
- No relation without cardinality

Relationships of Higher Degree

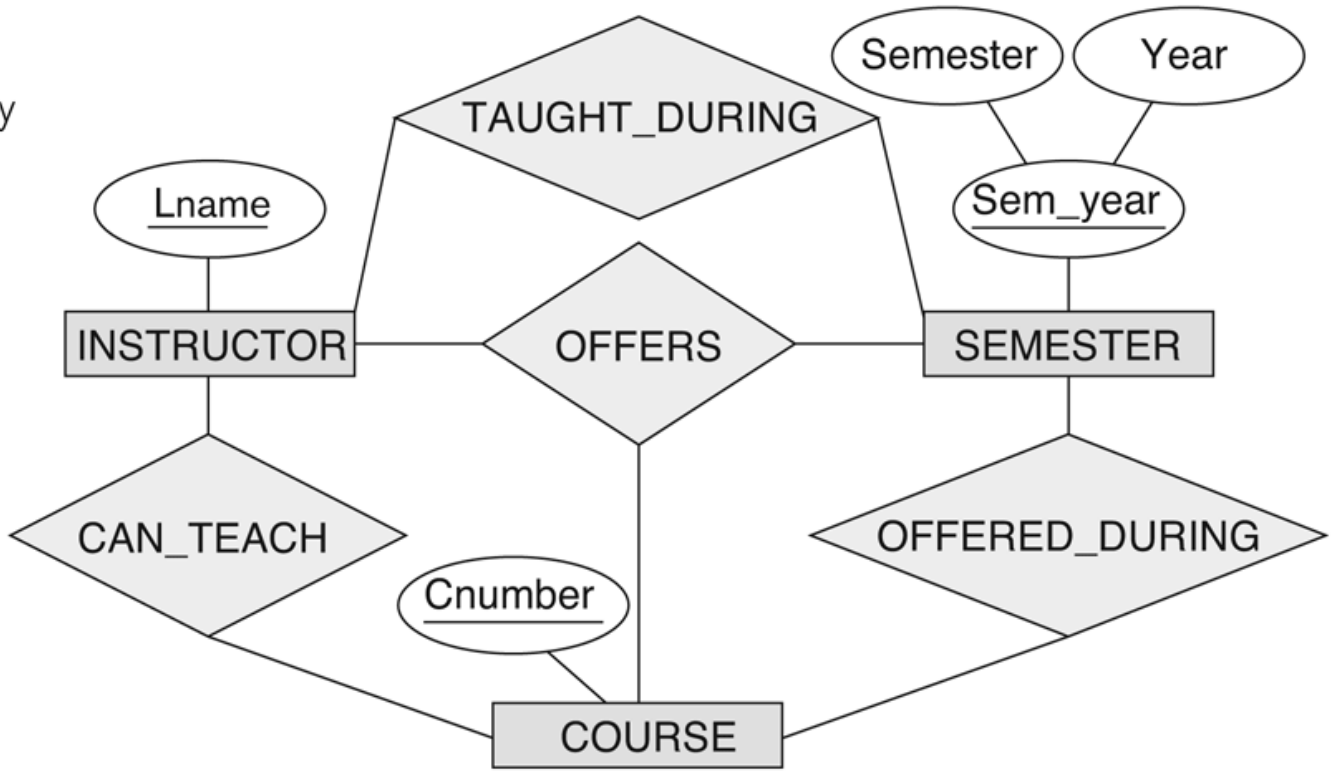
- Relationship types of degree 2 are called **binary**
- Relationship types of degree 3 are called **ternary** and of degree n are called n-ary
- In general, an n-ary relationship is not equivalent to n binary relationships
- Constraints are harder to specify for higher-degree relationships (n > 2) than for binary relationships

Discussion of n-ary relationships (n > 2)

- If a particular binary relationship can be derived from a higher-degree relationship at all times, then it is redundant
- For example, the TAUGHT_DURING binary relationship in Figure 3.18 (see next slide) can be derived from the ternary relationship OFFERS (based on the meaning of the relationships)
- Although in general three binary relationships *cannot replace a ternary relationship,* they may do so under certain *additional constraints. In our example, if the* CAN_TEACH relationship is 1:1 (an instructor can teach one course, and a course can be taught by only one instructor), then the ternary relationship OFFERS can be left out because it can be inferred from the three binary relationships CAN_TEACH, TAUGHT_DURING, and OFFERED_DURING.
- The schema designer must analyze the meaning of each specific situation to decide which of the binary and ternary relationship types are needed.

Another example of a ternary relationship

Figure 3.18
Another example of ternary versus binary relationship types.



Chapter Summary

- ER Model Concepts: Entities, attributes, relationships
- Constraints in the ER model
- Using ER in step-by-step conceptual schema design for the COMPANY database
- ER Diagrams - Notation