

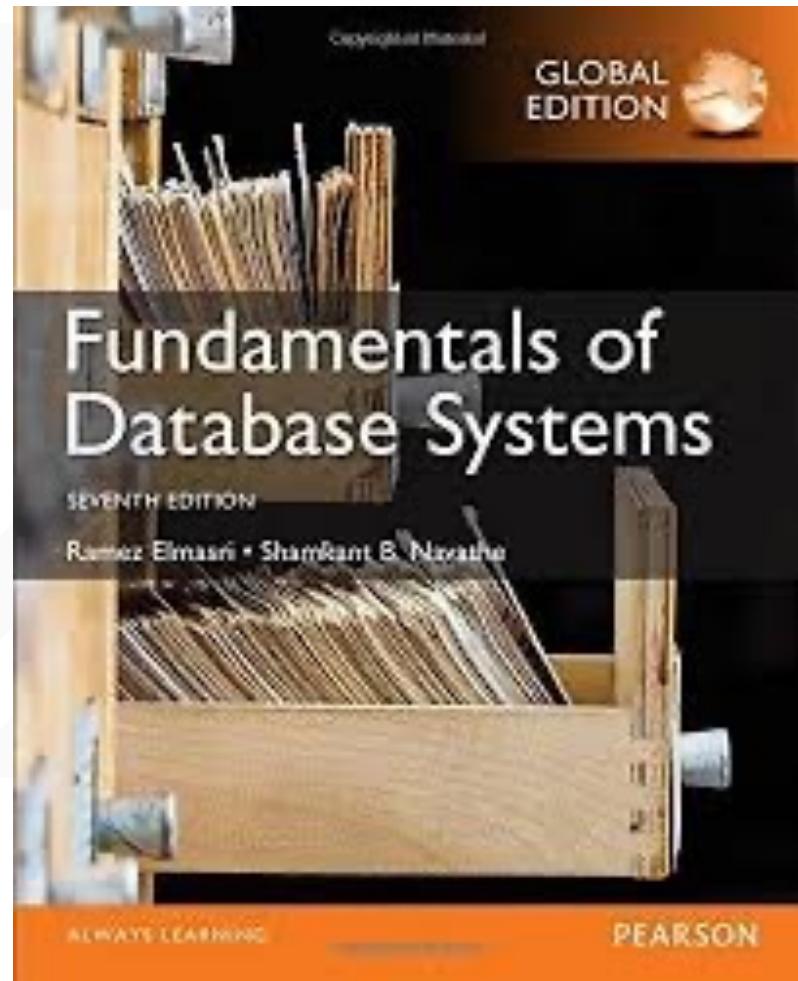
Database Systems

Program in Computer Engineering
School of Engineering

King Mongkut's Institute of Technology Ladkrabang

Text

- Ramez Elmasri and Shamkant B. Navathe.
“Fundamentals of Database Systems”
7th Edition., Pearson, 2017



Chapter 3

Data Modeling Using the Entity-Relationship (ER) Model

Data Models (from Ch 2)

- A set of concepts to describe the ***structure*** of a database, the ***operations*** for manipulating these structures, and certain ***constraints*** that the database should obey.

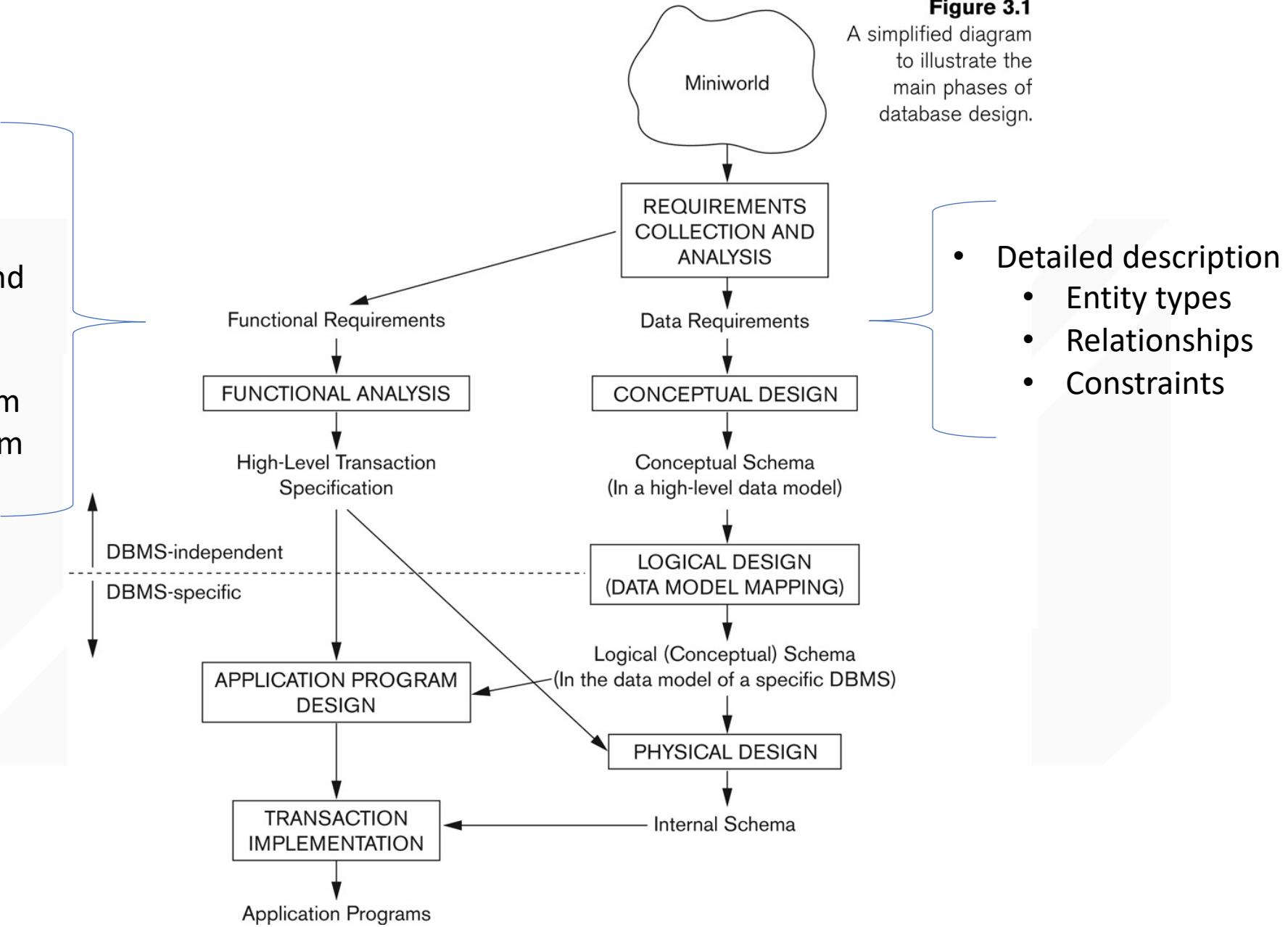
ข้อกำหนดเงื่อนไขในด้านธุรกรรมของฐานข้อมูล

Overview of Database Design Process

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

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

- User defined **operations** (or **transactions**) including **retrievals** and **updates**.
- Common tools
 - Data flow diagram
 - Sequence diagram
 - Scenarios etc.



Example COMPANY Database

- 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.

- The database will store each EMPLOYEE's social security number, 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

Entities and Attributes

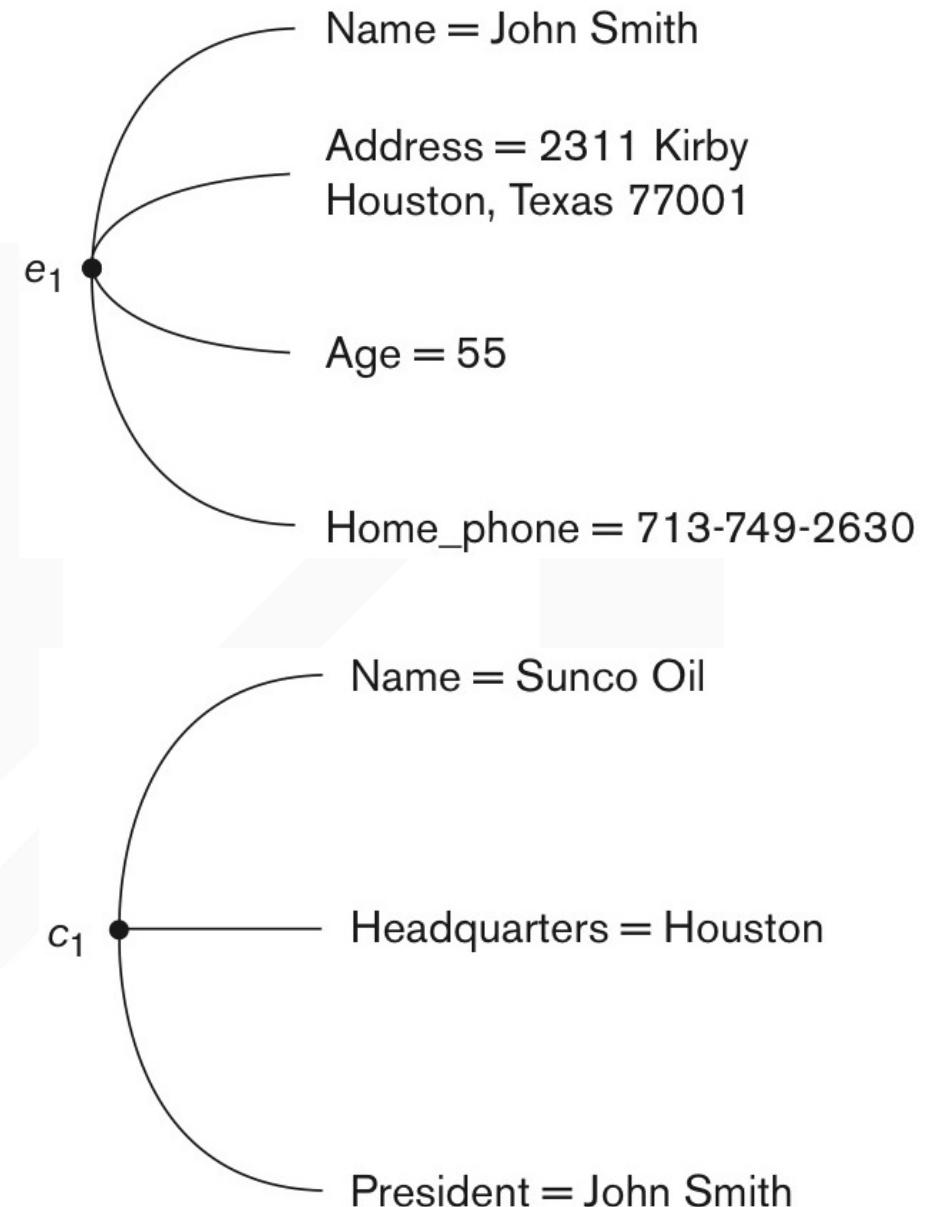
- **Entity** is a basic concept for the ER model.

Entities are specific things or objects in the mini-world that are represented in the database.

- 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

Entities and Attributes

- 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, date, enumerated type, ...



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.

- **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}.

- In general, composite and multi-valued attributes may be nested arbitrarily to any number of levels, although this is rare.
 - 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

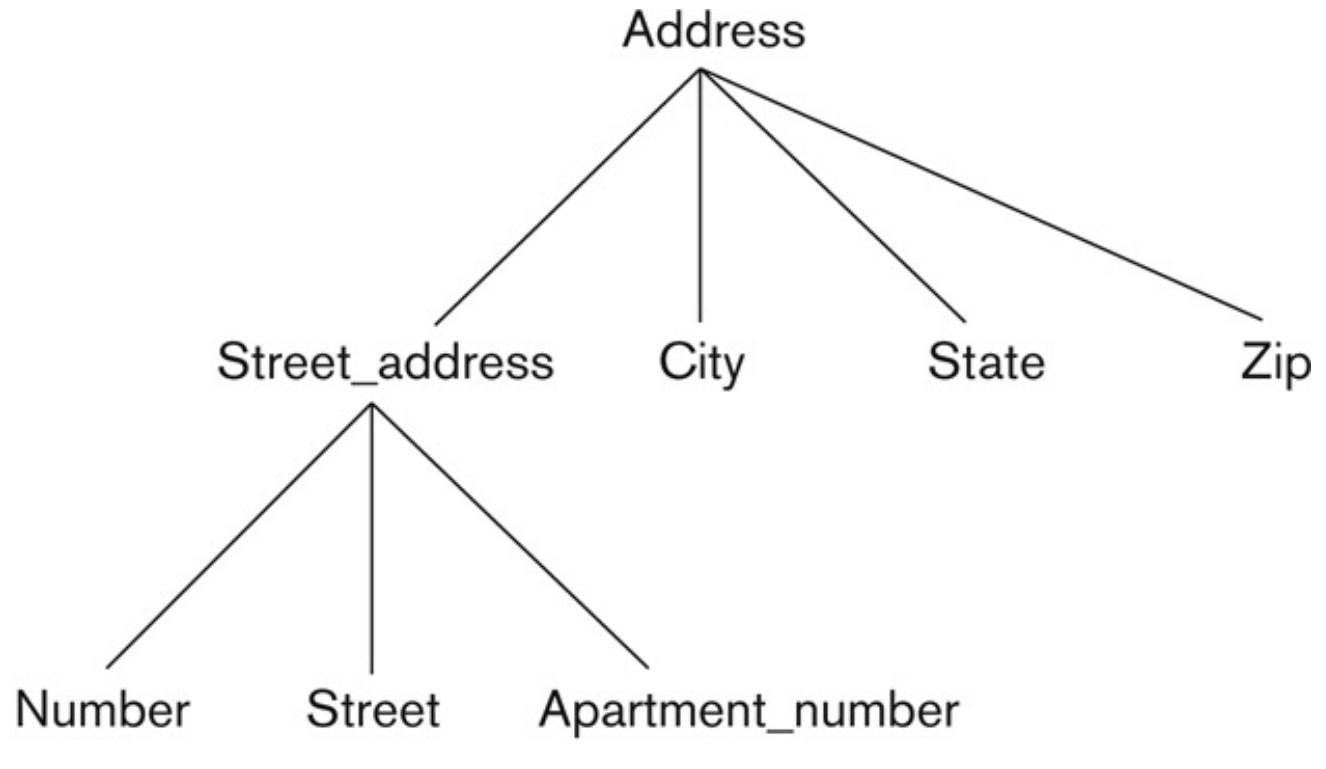


Figure 3.4
A hierarchy of composite attributes.

- **Stored vs. Derived Attributed**

- Two or more attribute values are related
 - E.g., **Birth_date** vs. **Age**
 - The **Age** attribute is derived from **Birth_date**.
 - **Age** is called a **derived attribute** and **is derivable from** the **Birth_date**.
- Some attribute values can be derived from related entities
 - E.g., **Number_of_employees** of a **DEPARTMENT** entity
 - Can be derived by counting the number of employee related to (working for) that department.

- **NULL value**

- Not applicable
- Unknown
 - The attribute value is missing or
 - Not known

Entity Types

- Entities with the same basic attributes are grouped or typed into an entity type.
 - For example, the entity type EMPLOYEE and PROJECT.

Entity Type Name:

EMPLOYEE

COMPANY

Name, Age, Salary

Name, Headquarters, President

e_1 •

(John Smith, 55, 80k)

c_1 •

(Sunco Oil, Houston, John Smith)

e_2 •

(Fred Brown, 40, 30K)

c_2 •

(Fast Computer, Dallas, Bob King)

e_3 •

(Judy Clark, 25, 20K)

⋮

Entity Set:
(Extension)

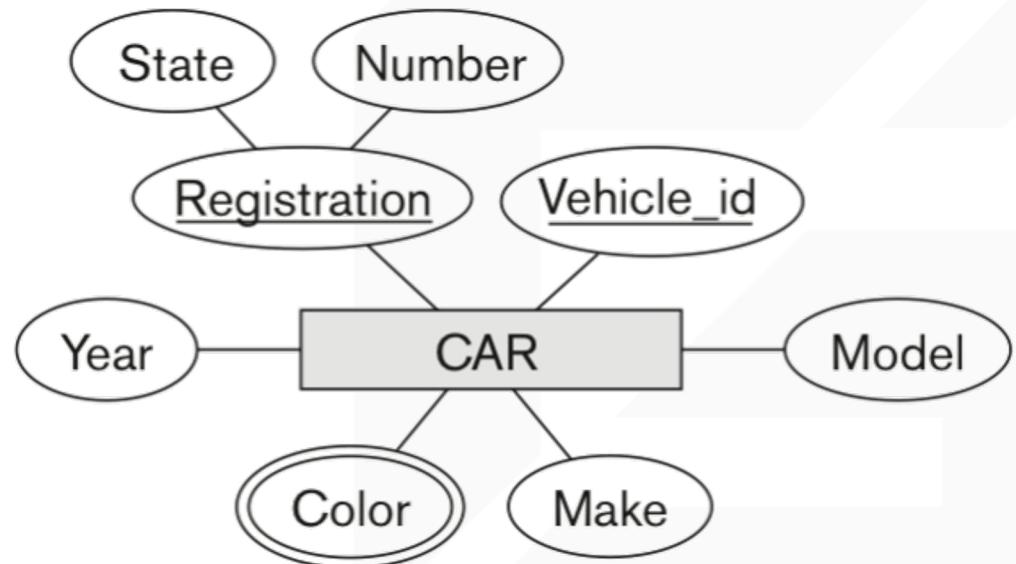
Entity Sets

- Each entity type will have a collection of entities stored in the database
 - Called the **entity set** or sometimes **entity collection**
 - Same name used to refer to both the **entity type** and the **entity set**
 - However, entity type and entity set **may be given different names**
 - Entity set is **the current state of the entities of that type** that are stored in the database

Key Attribute

- 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.
- A key attribute may be composite.
 - VehicleTagNumber is a key of the CAR entity type with components (Number, State).

- An entity type may have more than one key.
 - The CAR entity type may have two keys:
 - VehicleIdentificationNumber (popularly called VIN)
 - VehicleTagNumber (Number, State), aka license plate number
- Each key is underlined
 - Note: this is different from the relational schema where only one “primary key” is underlined.



The CAR entity type with two key attributes; [Registration](#) and [Vehicle_id](#).

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

CAR₁
((ABC 123, TEXAS), TK629, Ford Mustang, convertible, 2004 {red, black})

CAR₂
((ABC 123, NEW YORK), WP9872, Nissan Maxima, 4-door, 2005, {blue})

CAR₃
((VSY 720, TEXAS), TD729, Chrysler LeBaron, 4-door, 2002, {white, blue})

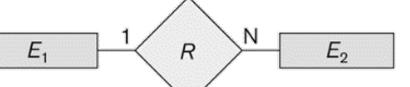
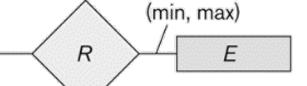
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Entity set with three entities

Displaying an Entity type

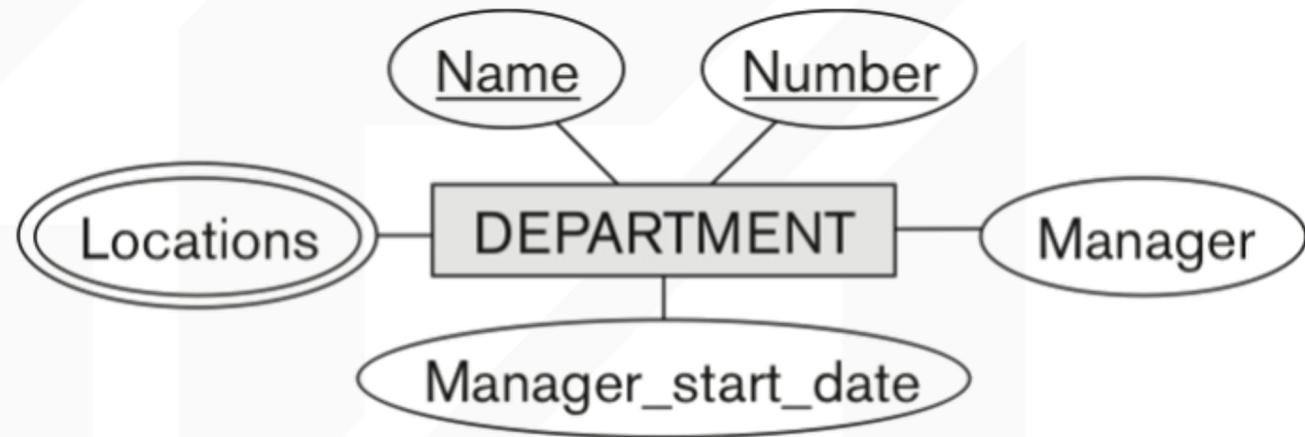
- In ER diagrams, an **entity type** is displayed in a **rectangular box**
- **Attributes** are displayed in **ovals**
 - Each attribute is connected to its entity type
 - Components of a composite attribute are connected to the oval representing the composite attribute
 - Each key attribute is **underlined**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

Figure 3.14
Summary of the notation for ER diagrams.

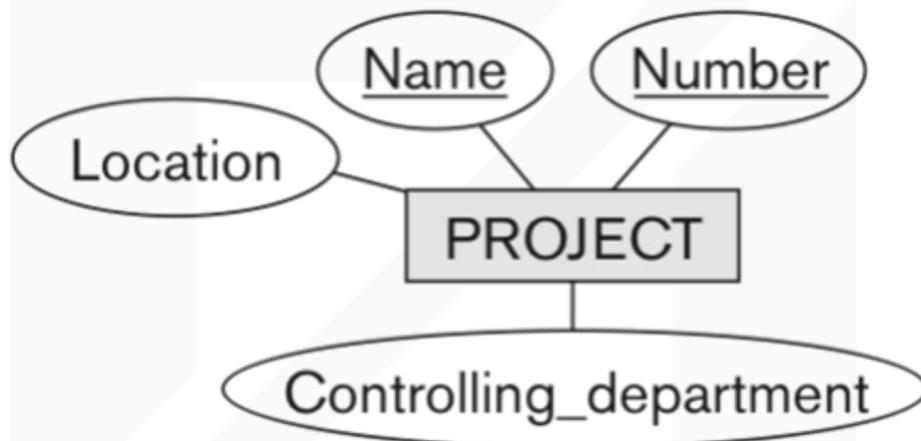
Symbol	Meaning
	Entity
	Weak Entity
	Relationship
	Identifying Relationship
	Attribute
	Key Attribute
	Multivalued Attribute
	Composite Attribute
	Derived Attribute
	Total Participation of E_2 in R
	Cardinality Ratio 1: N for $E_1:E_2$ in R
	Structural Constraint (min, max) on Participation of E in R

Initial Conceptual Design

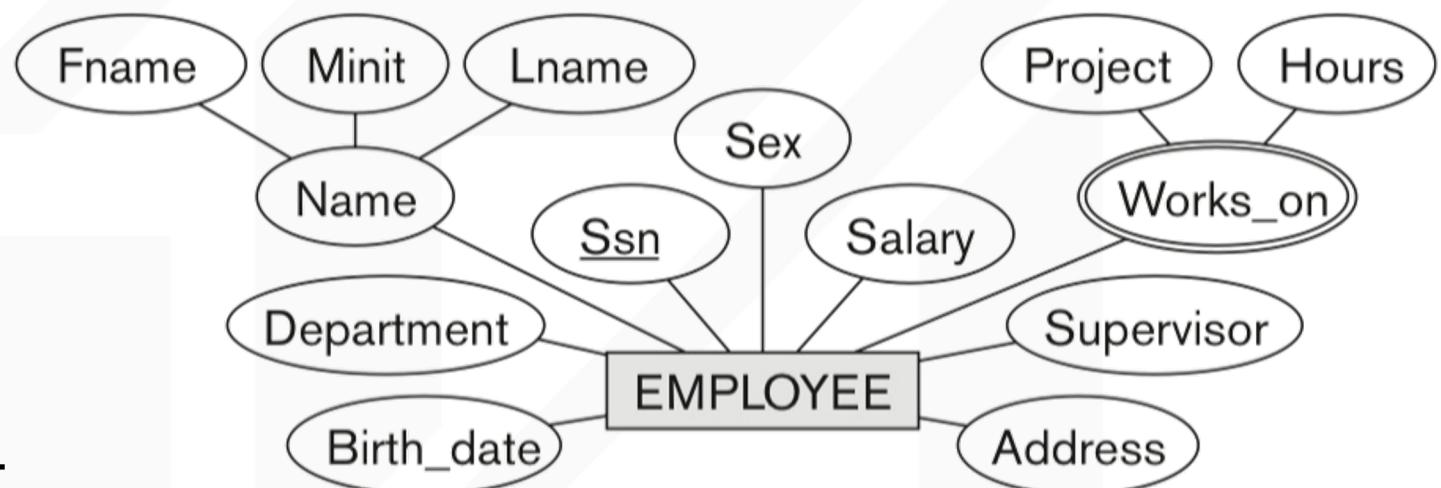
- The company is organized into **DEPARTMENTS**. Each department has a **name**, **number** and an employee who *manages* the department. We keep track of the **start date** of the **department manager**. A department may have **several locations**.



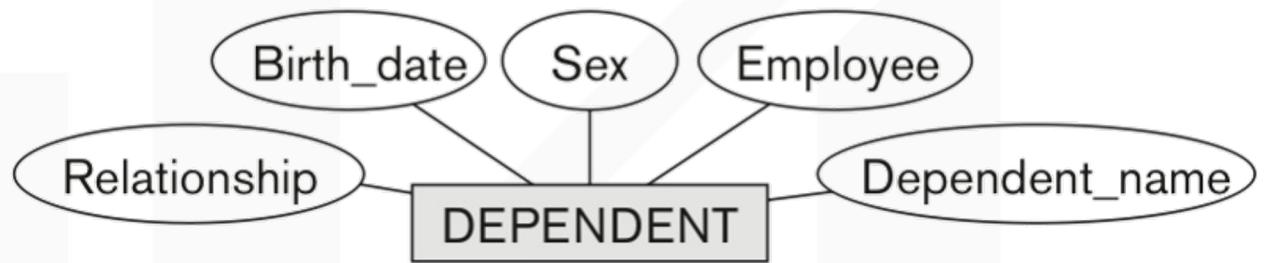
- Each **department** controls a number of **PROJECTs**
- Each project has a **unique name**, **unique number** and is located at a **single location**.

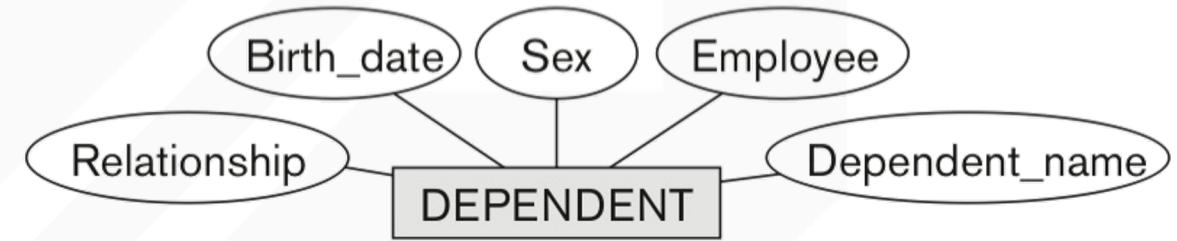
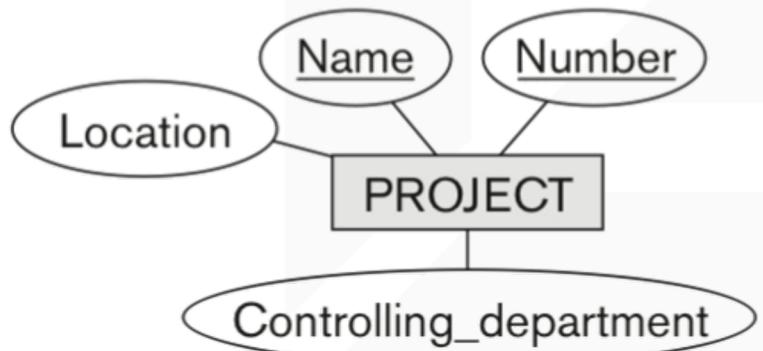
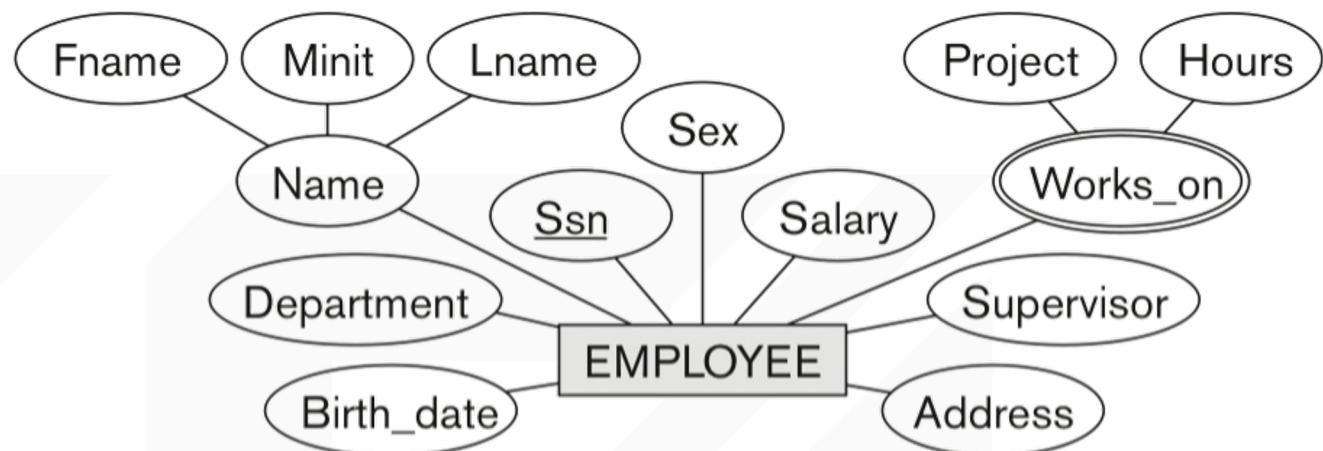
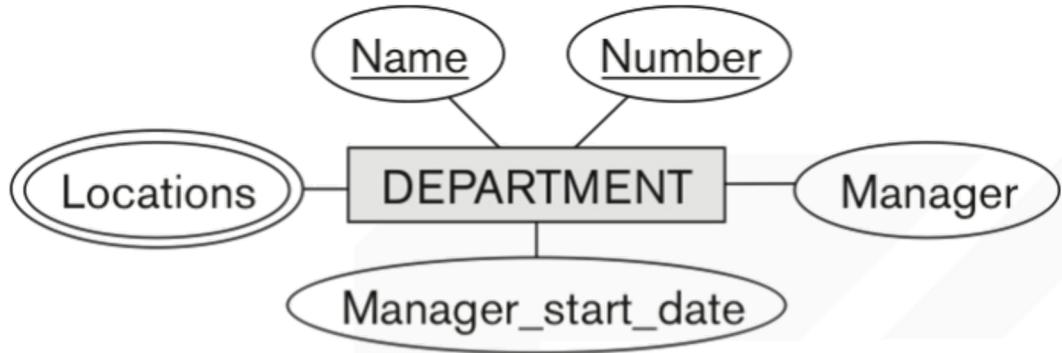


- The database will store each **EMPLOYEE's social security number, address, salary, sex, and birthdate**.
- Each employee works for one **department** but may work on several **projects**.
- The DB will keep track of the **number of hours per week** that an employee currently works on each project.
- 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**





- **ER model has three main concepts:**
 - **Entities** (and their entity types and entity sets)
 - **Attributes** (simple, composite, multivalued)
 - **Relationships** (and their relationship types and relationship sets)

Relationships and Relationship Types

- 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.

- Relationships of the same type are grouped or typed into a **relationship type**.
 - For example,
 - The **WORKS_ON** relationship type in which EMPLOYEES and PROJECTS participate
 - The **MANAGES** relationship type in which EMPLOYEES and DEPARTMENTS participate.

- The degree of a relationship type is the number of participating entity types.
 - Both **MANAGES** and **WORKS_ON** are **binary** relationships

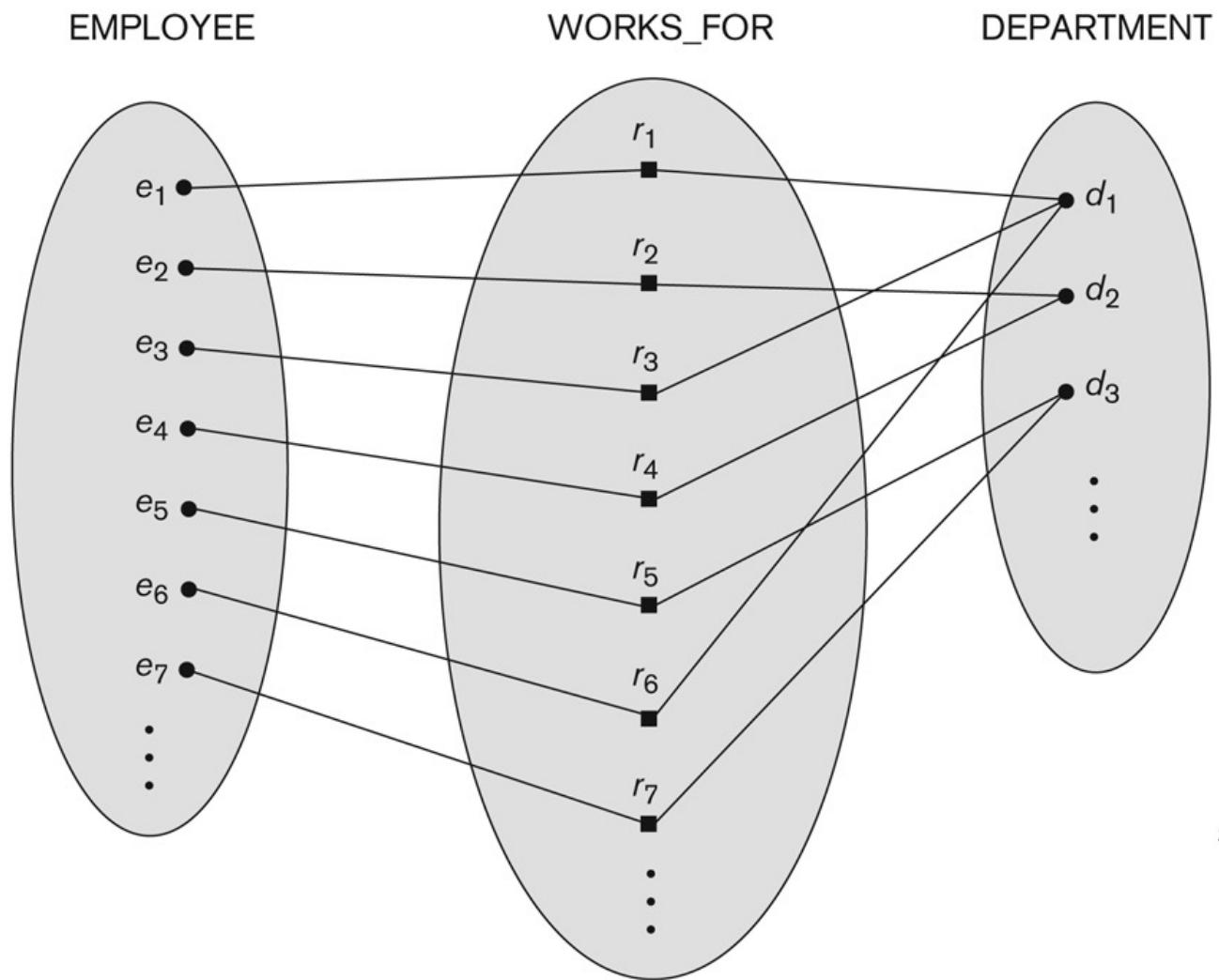


Figure 3.9
 Some instances in the WORKS_FOR relationship set, which represents a relationship type WORKS_FOR between EMPLOYEE and DEPARTMENT.

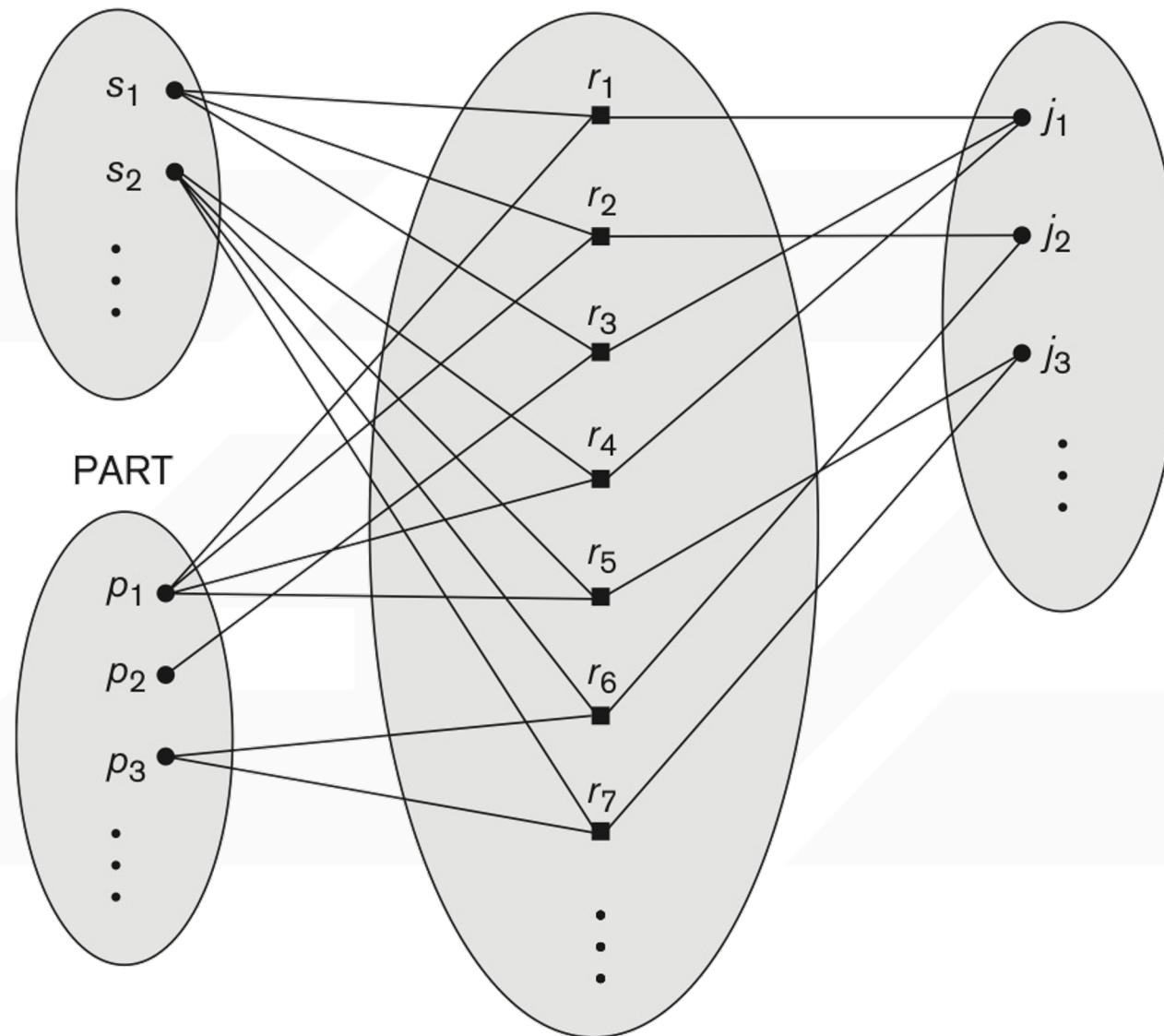
• Degree of a Relationship Type

- The number of participating entity type.
 - E.g., the WORKS_FOR relationship is of degree two
- Degree of two is called binary
- Degree of three is called ternary.

SUPPLIER

SUPPLY

PROJECT

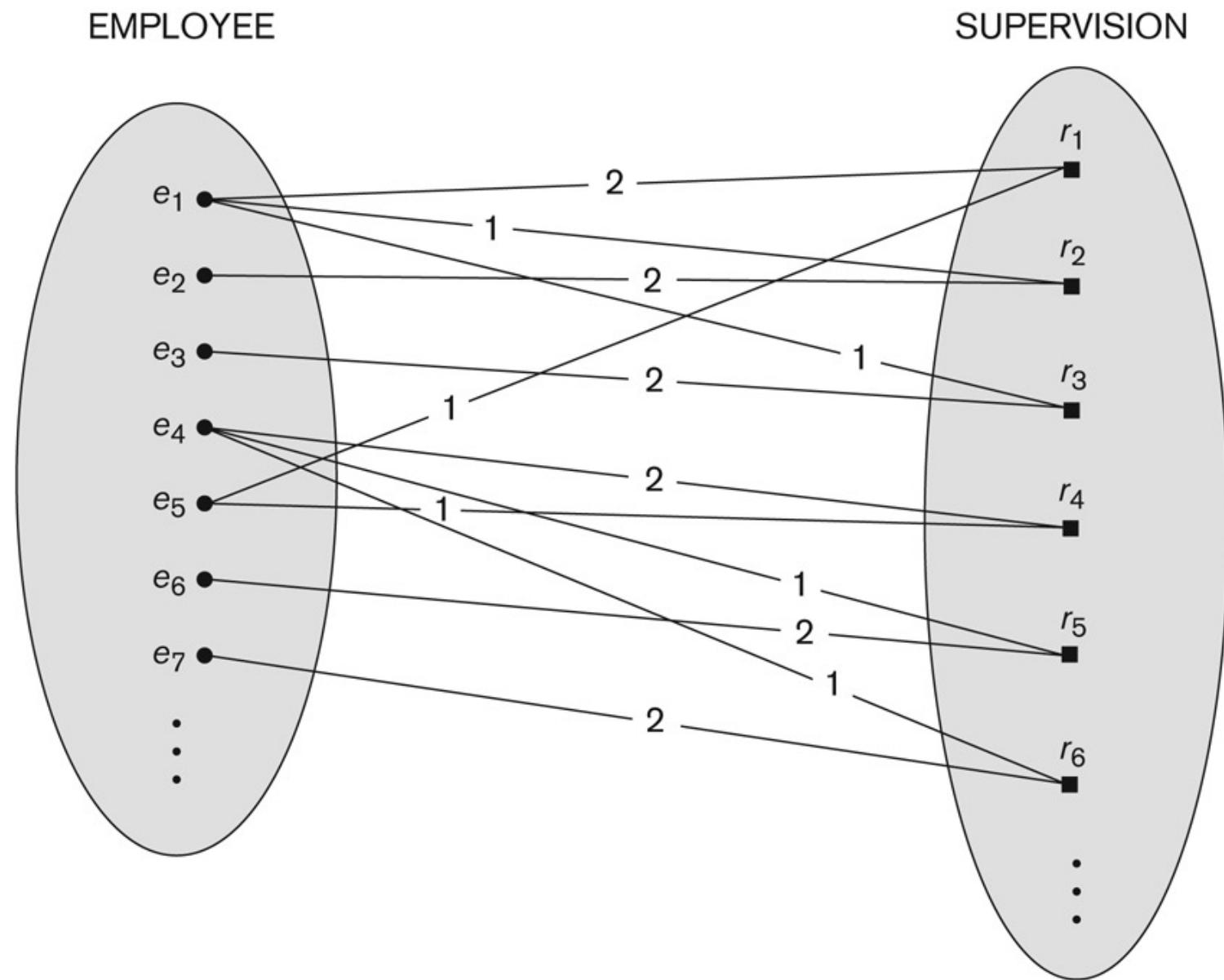


• Recursive Relationship Type

- A relationship type between the same participating entity type in **distinct roles**
- Also called a **self-referencing** relationship type.
- Example: the SUPERVISION relationship

- 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

- 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 worker).

**Figure 3.11**

A recursive relationship **SUPERVISION** between **EMPLOYEE** in the *supervisor* role (1) and **EMPLOYEE** in the *subordinate* role (2).

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

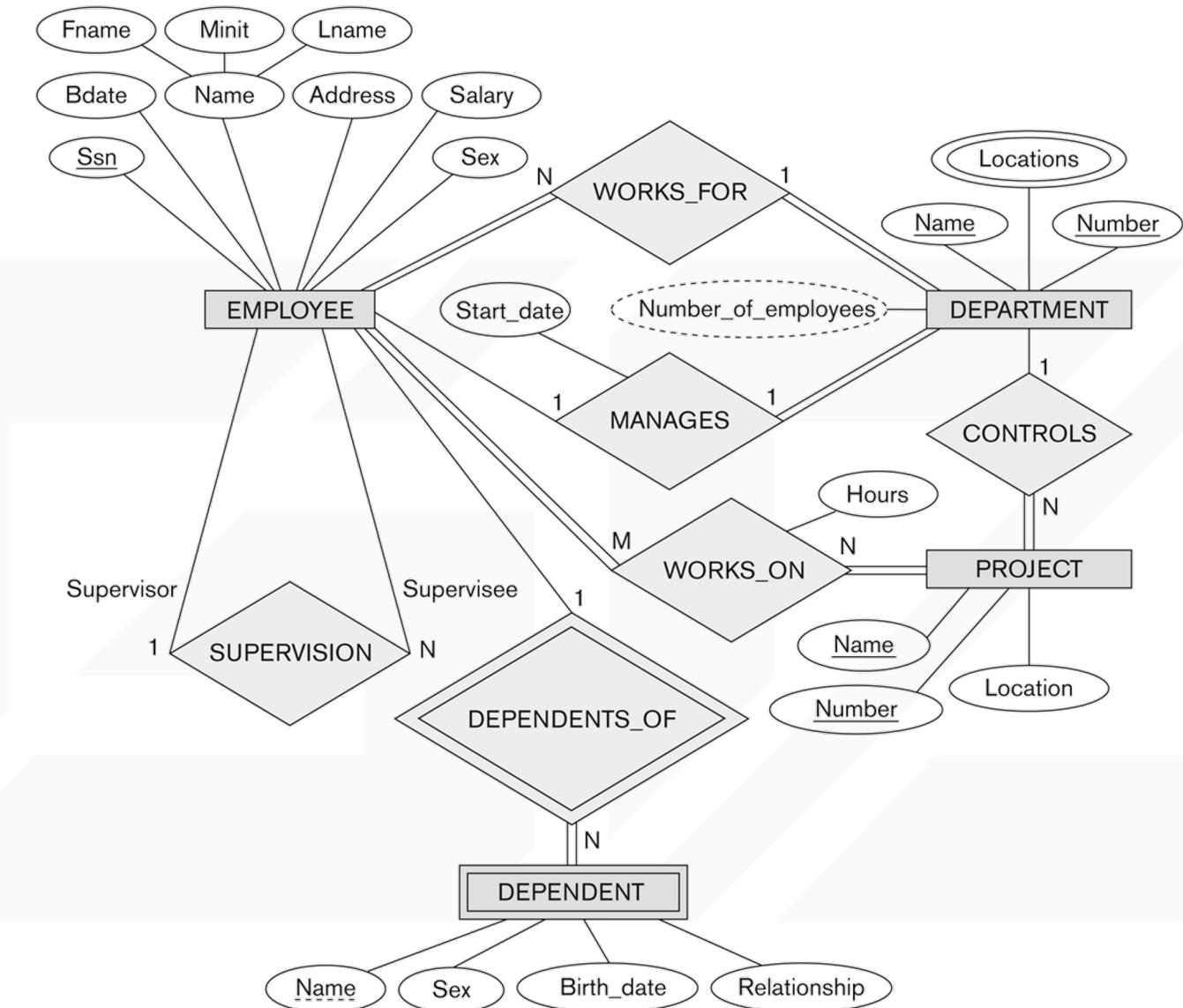


Figure 3.2

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

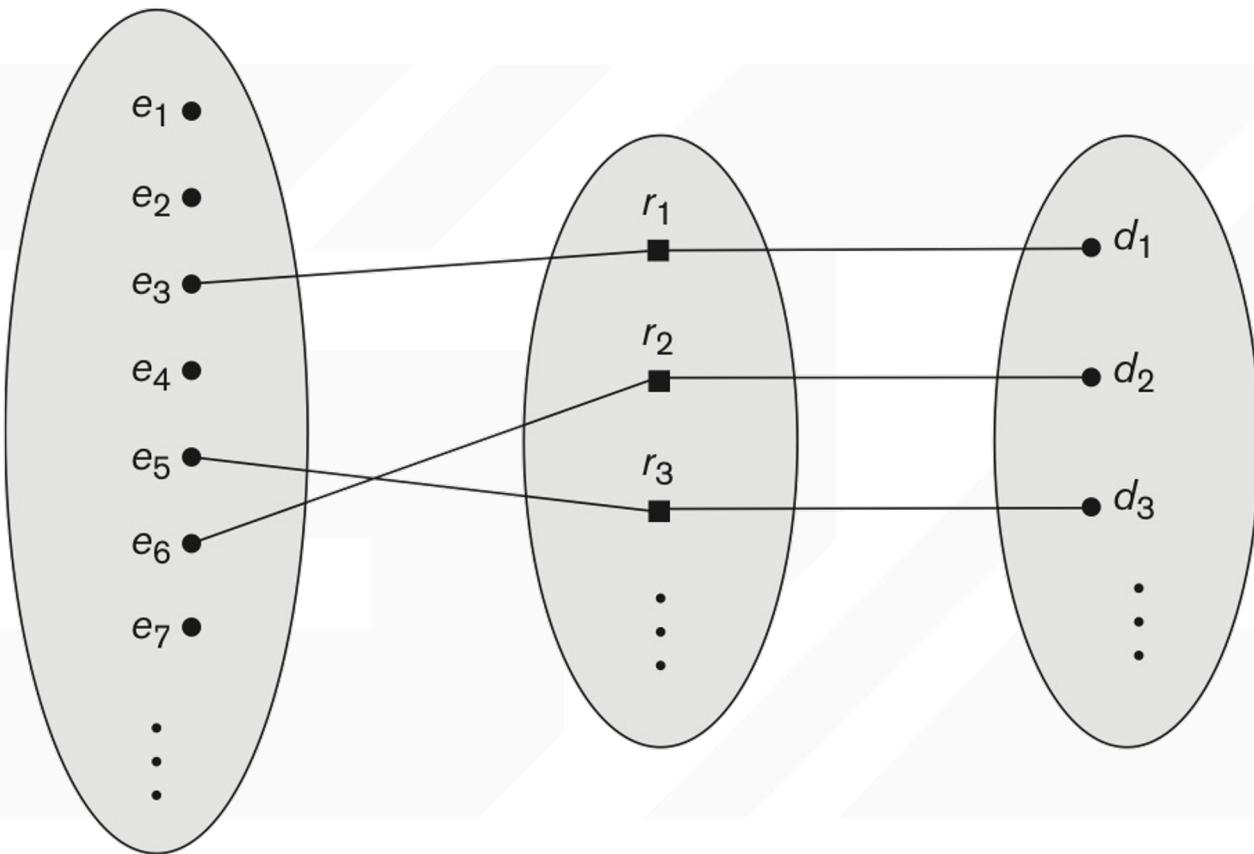
Constraints on Relationships

- **Constraints on Relationship Types**
 - Also known as ratio constraints
 - 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)

EMPLOYEE

MANAGES

DEPARTMENT

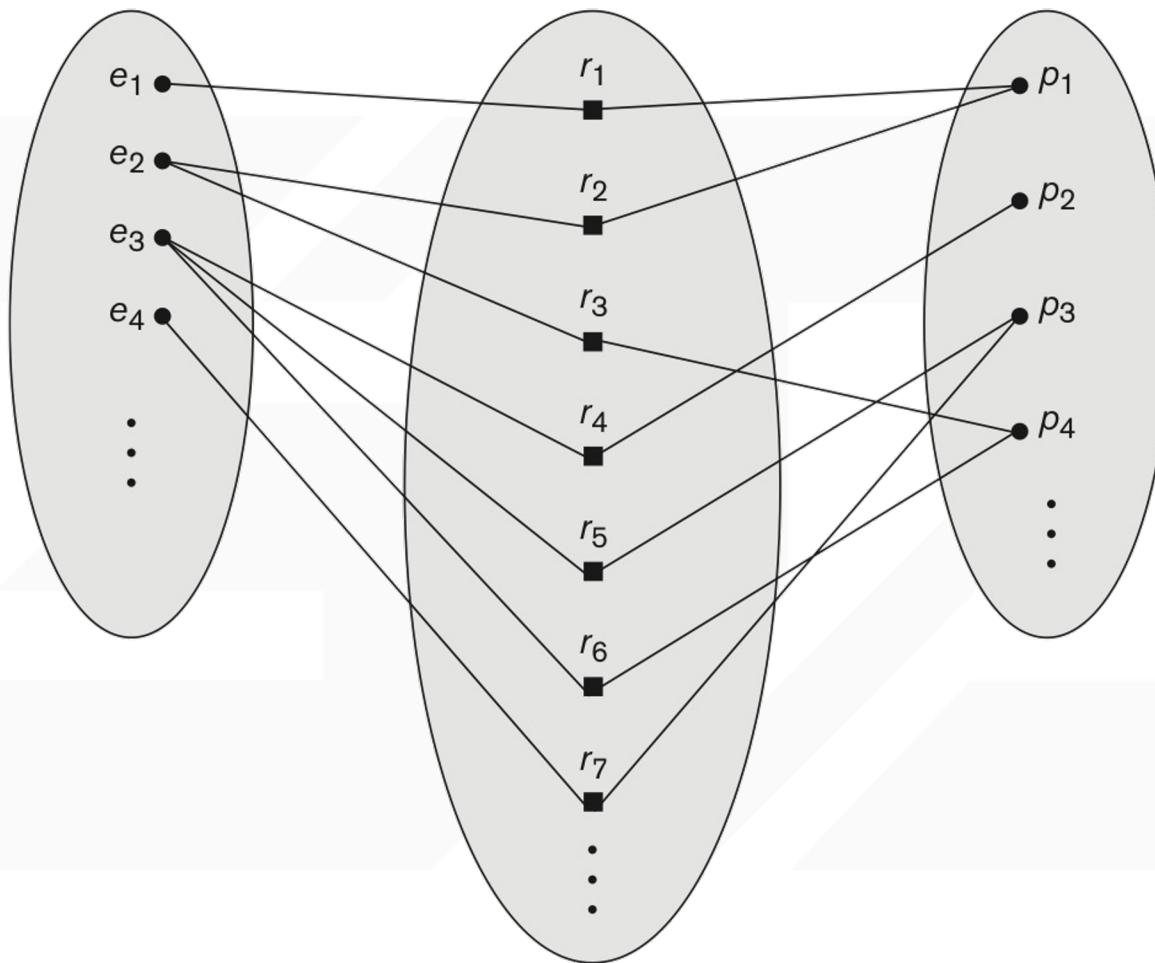


A 1:1 relationship, MANAGES

EMPLOYEE

WORKS_ON

PROJECT



An M:N relationship, WORKS_ON

Weak Entity Types

- An entity that **does not have a key attribute** and that **is identification-dependent on another entity type**.
- 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
 - The particular entity they are related to in the identifying relationship 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**

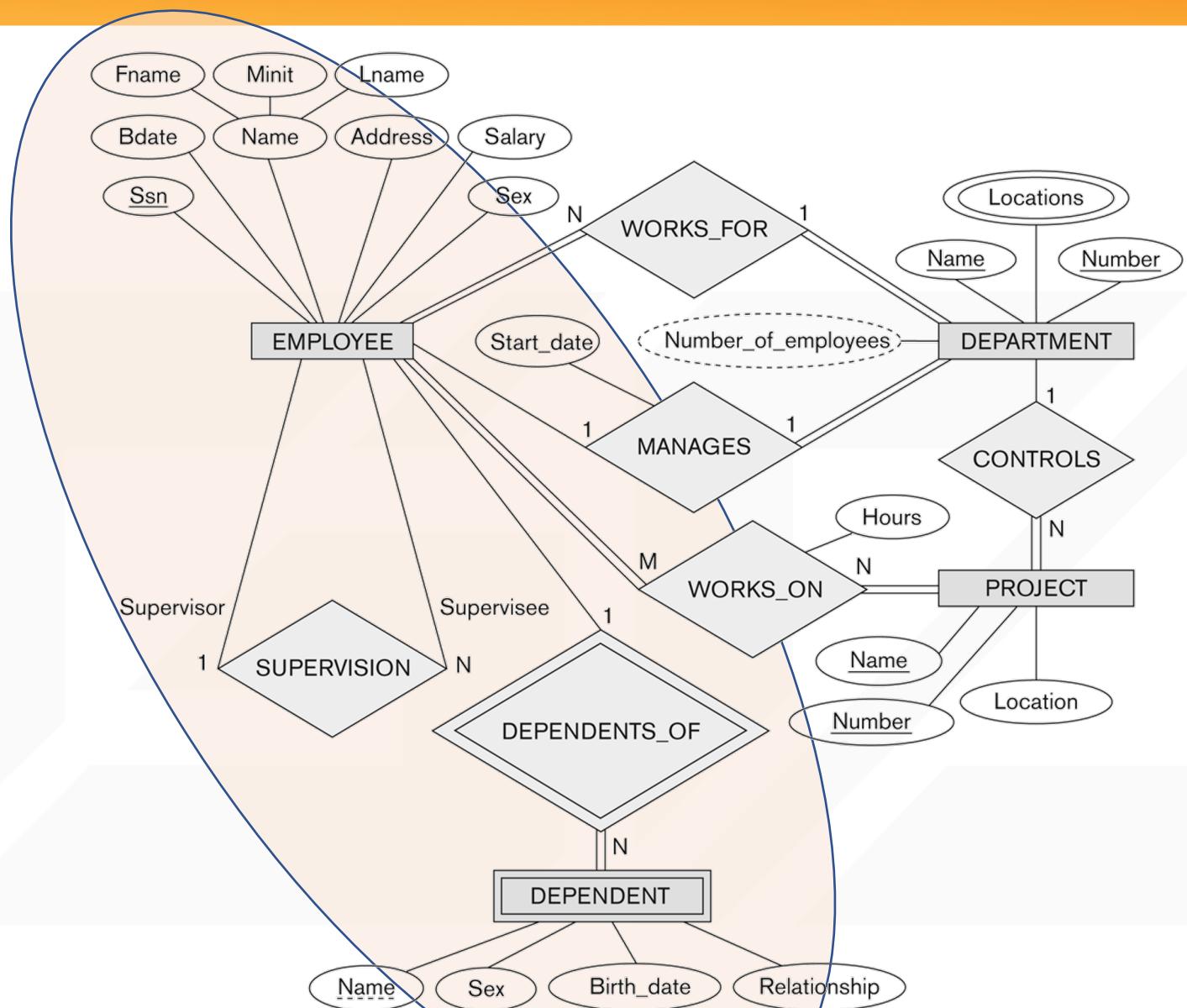


Figure 3.2

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

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

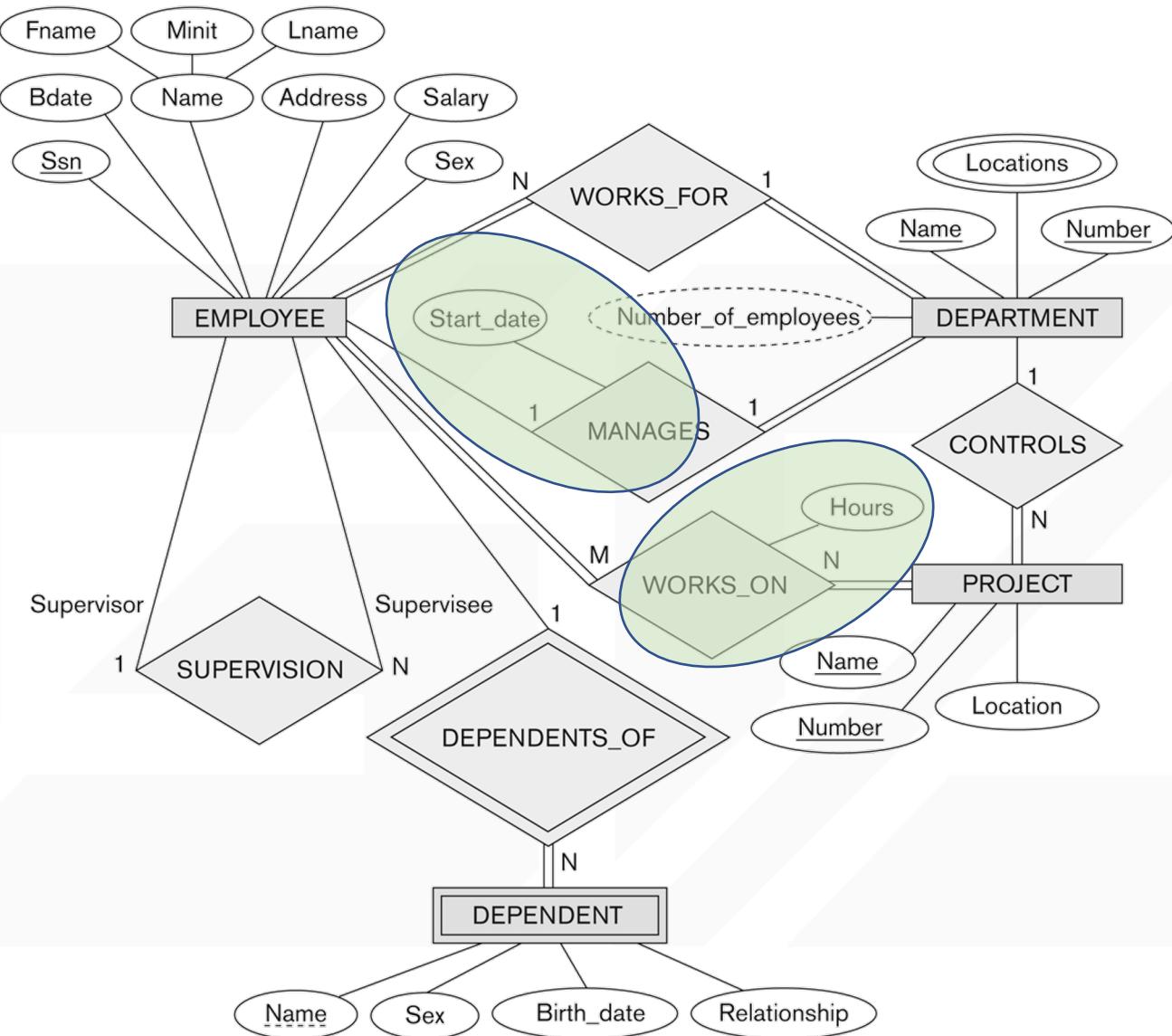
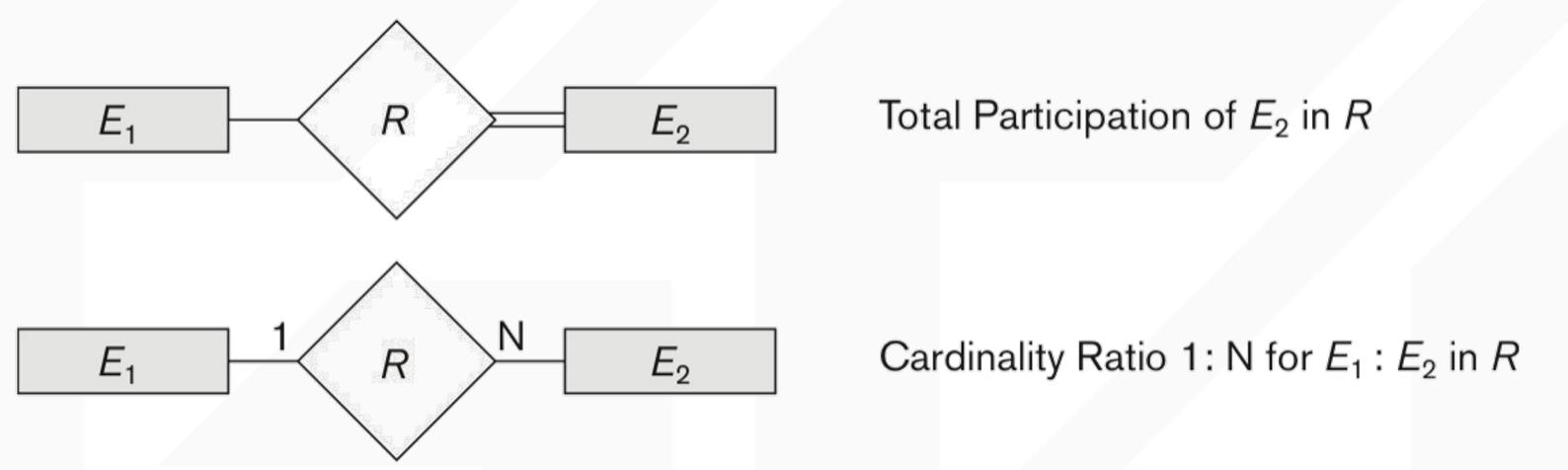


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Notation for Constraints on Relationships



- **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.

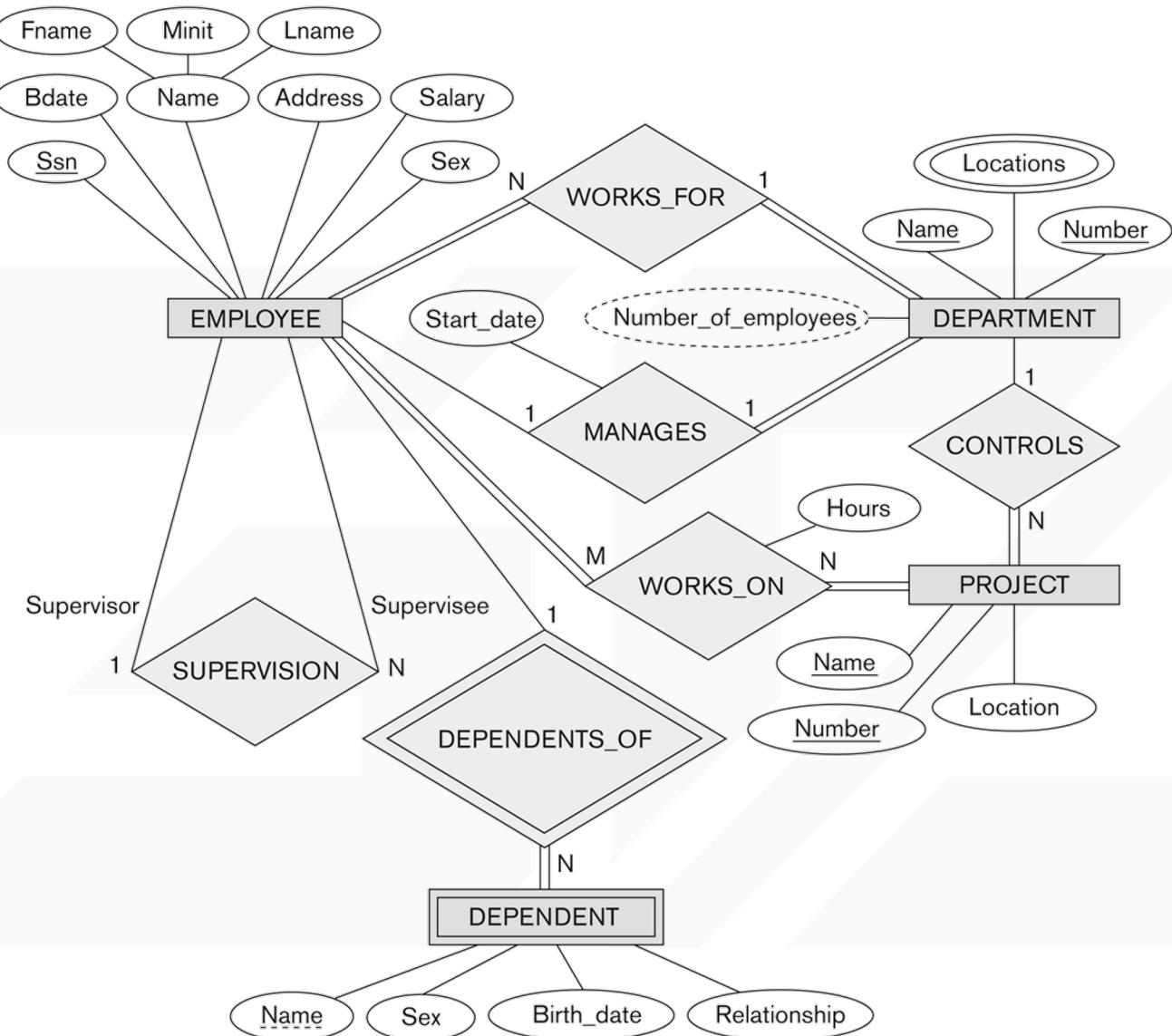
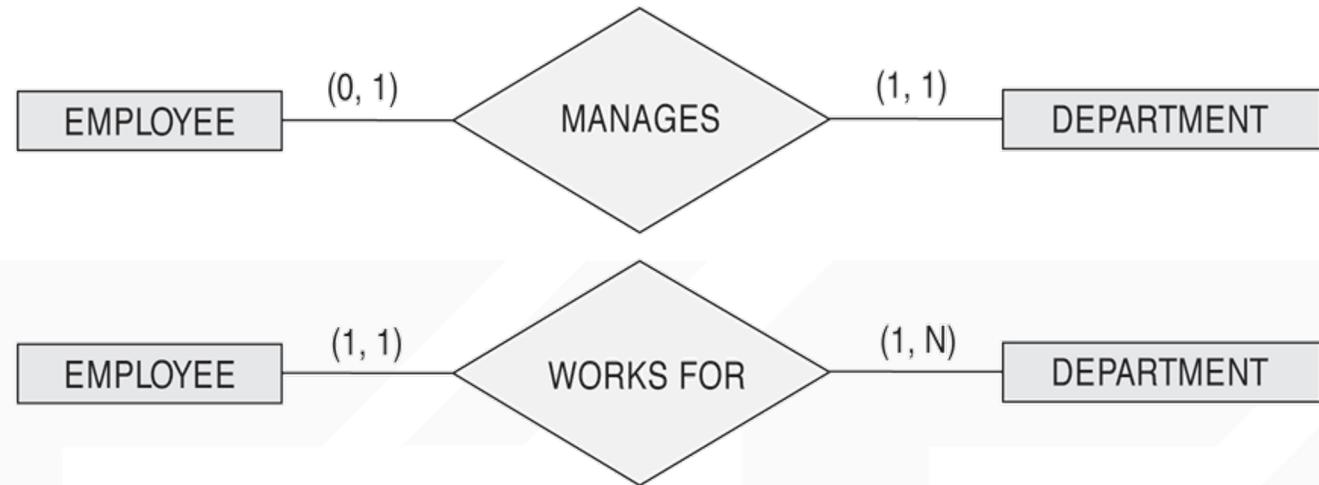


Figure 3.2

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Alternative (min, max) notation for relationship structural constraints:

- Specified on each participation of an entity type E in a relationship type R
- Specifies that each entity e in E participates in at least *min* and at most *max* relationship instances in R
- Default(no constraint): $\text{min}=0$, $\text{max}=n$ (signifying no limit)
- Must have $\text{min} \leq \text{max}$, $\text{min} \geq 0$, $\text{max} \geq 1$
- Derived from the knowledge of mini-world constraints

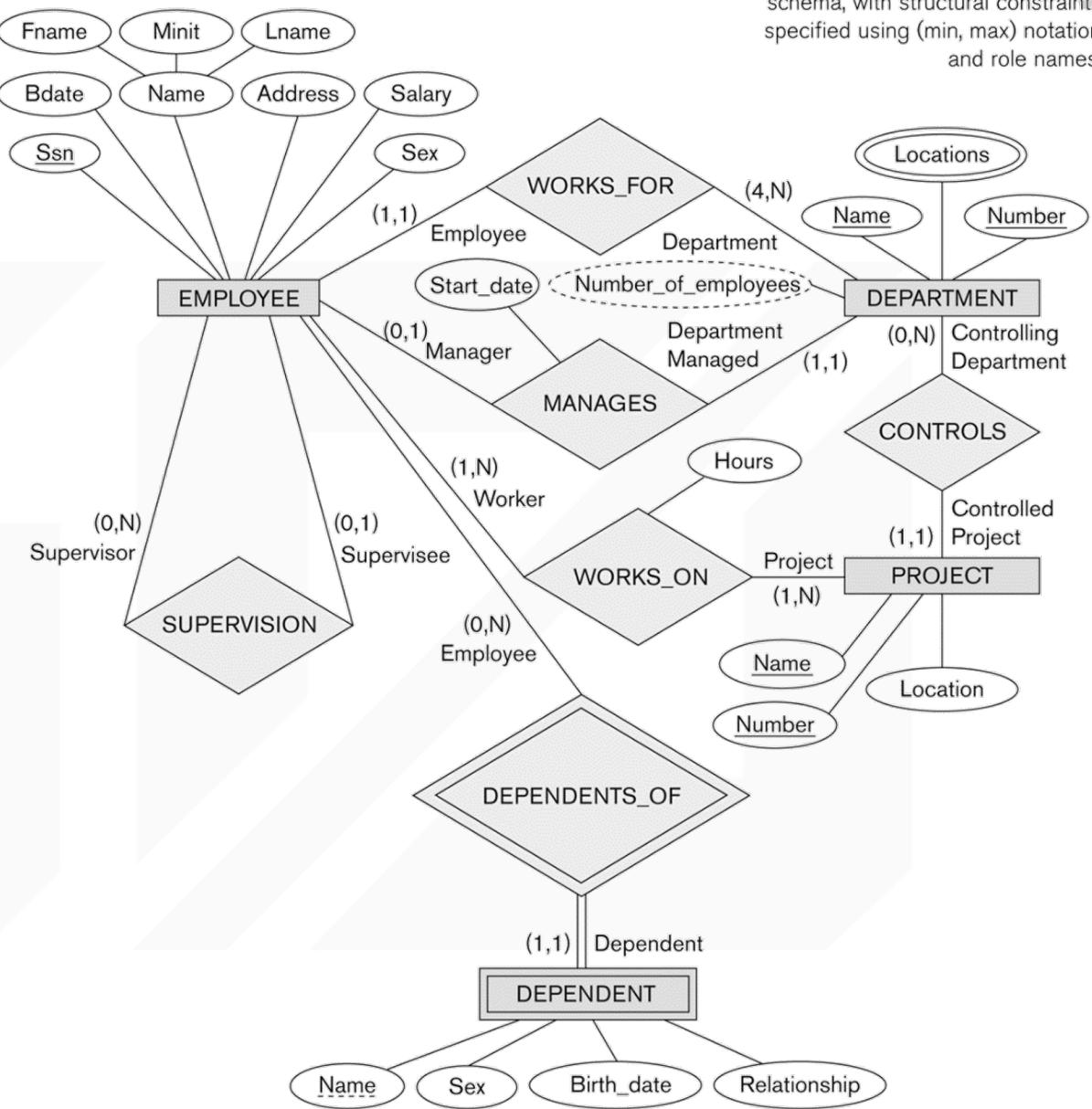
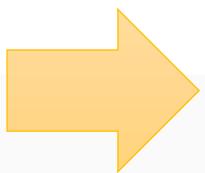
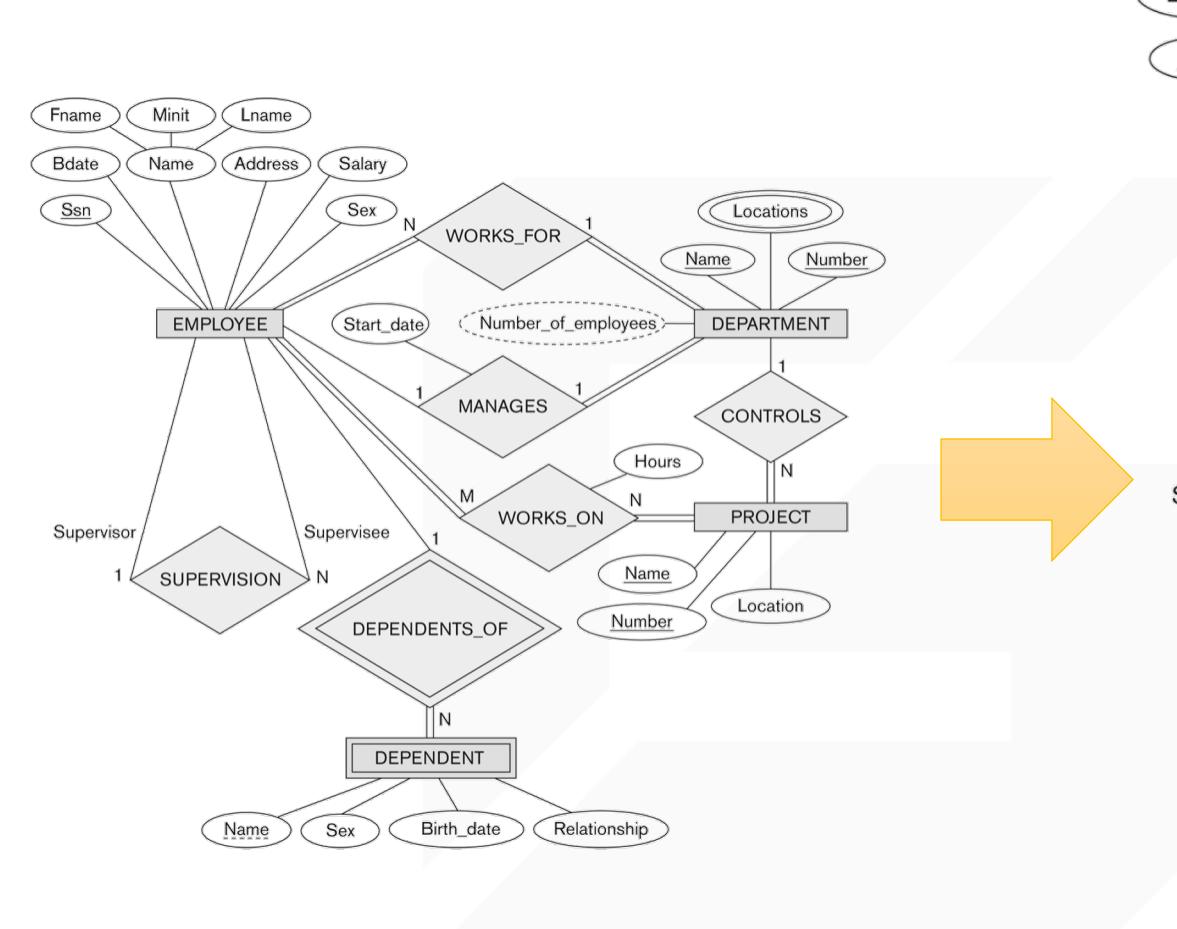


• Examples:

- A department has exactly one manager and an employee can manage at most one department.
 - Specify (0,1) for participation of EMPLOYEE in MANAGES
 - Specify (1,1) for participation of DEPARTMENT in MANAGES
- An employee can work for exactly one department but a department can have any number of employees.
 - Specify (1,1) for participation of EMPLOYEE in WORKS_FOR
 - Specify (0,n) for participation of DEPARTMENT in WORKS_FOR

Figure 3.15

ER diagrams for the company schema, with structural constraints specified using (min, max) notation and role names.



UML class diagrams

- Represent classes (similar to entity types) as large rounded boxes with three sections:
 - Top section includes entity type (class) name
 - Second section includes attributes
 - Third section includes class operations (operations are not in basic ER model)
- Relationships (called associations) represented as lines connecting the classes
 - Other UML terminology also differs from ER terminology
- Used in database design and object-oriented software design
- UML has many other types of diagrams for software design

UML class diagram for COMPANY database schema

