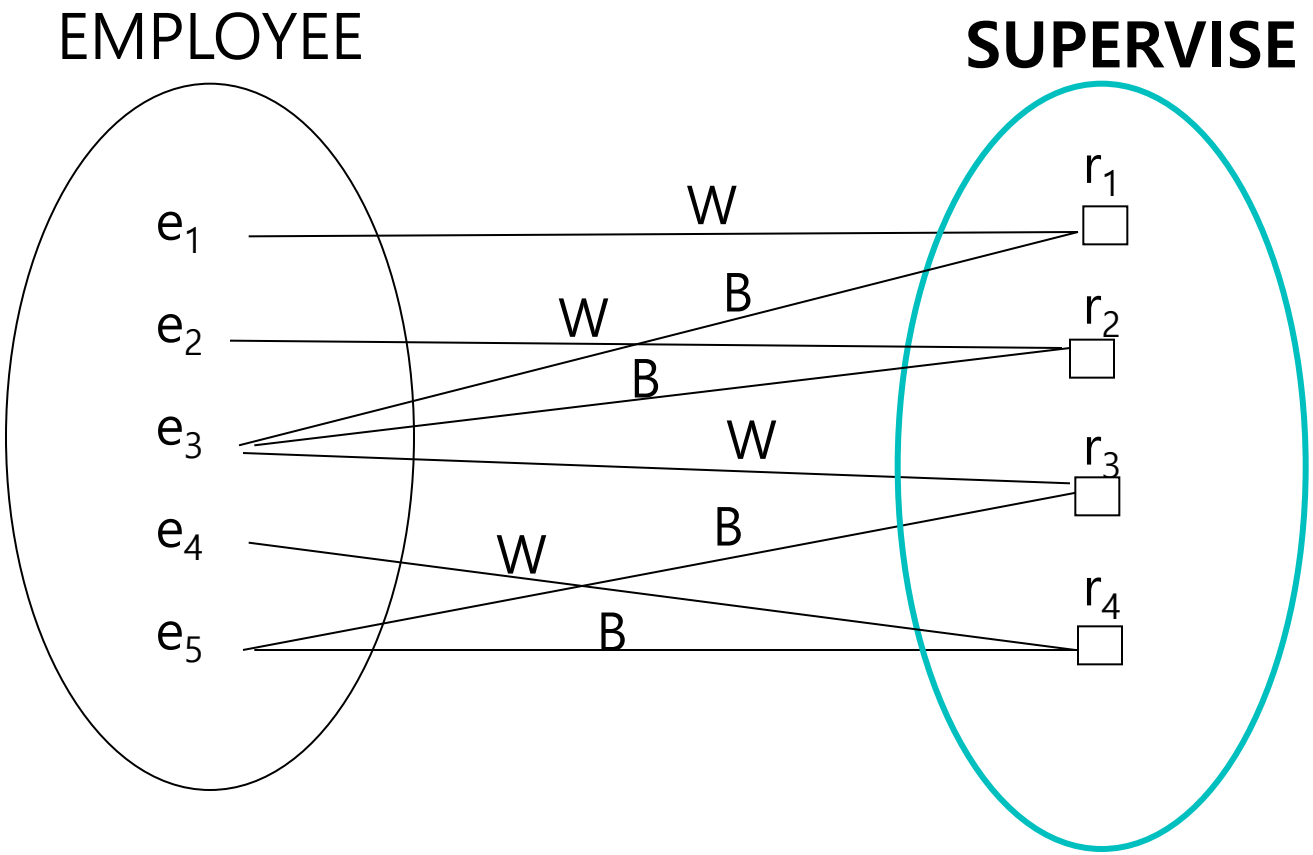
Recursive Relationship

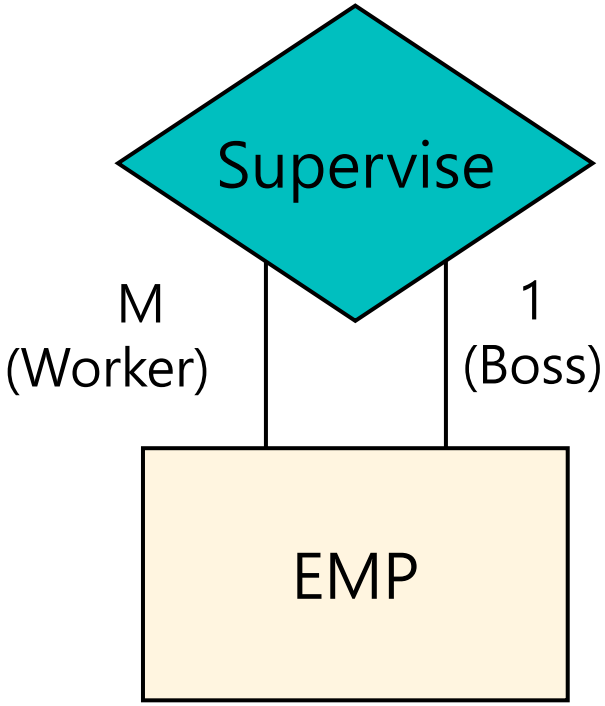
- Relationship with degree 1 is called **recursive**.
- Both participating entity types are the same.
- For example :
  - 사람과 사람들간의 관계
  - 학생과 학생들간의 관계
  - 과목과 과목들 간의 관계
  - (컴퓨터) 부품과 부품들 간의 관계
- 참여하는 양쪽의 동일한 entity type들을 구분하기 위해 서로 맡은 다른 **role (역할)**들이 필요함.
- ER diagram 그릴 때 role을 표기함.

Recursive Relationship : SUPERVISE



- role W : Supervisee (Worker)
- role B : Supervisor (Boss)

Recursive Relationship
1 : M

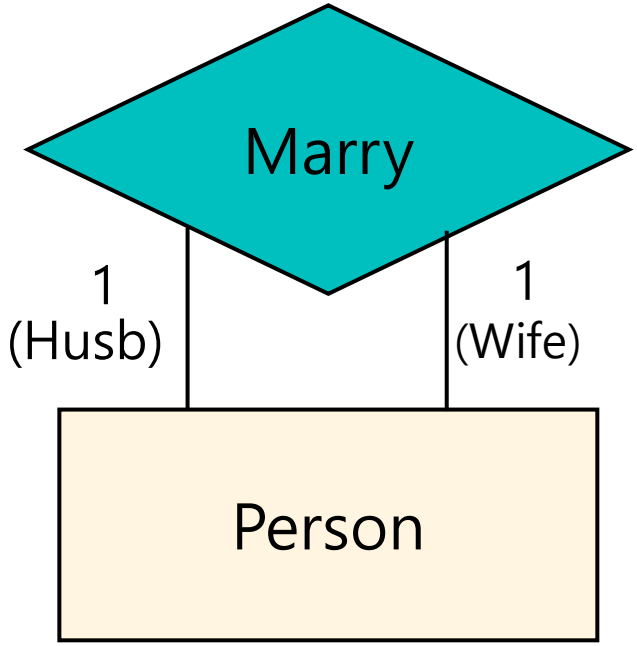


Example :

worker	boss
bob	joe
abe	joe
joe	ann
ann	eve

- "Each boss can have many workers" (1 : M)
- "Each worker can have only one boss" (M : 1)

Recursive Relationship
1 : 1

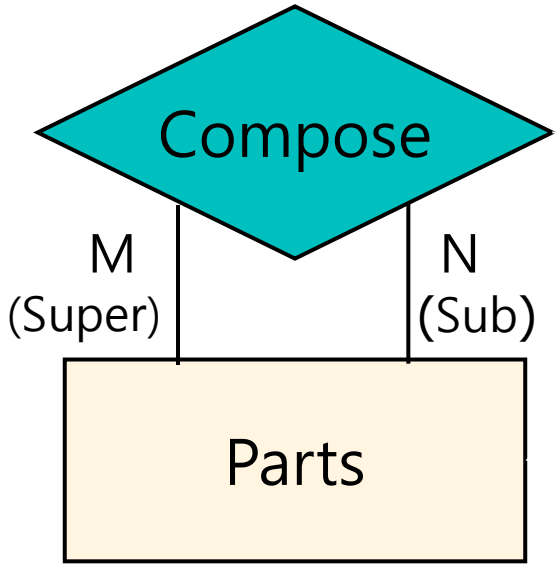


Example :

hus	wife
adam	eve
tarjan	jane
dick	jane
pete	jolie

- "Each person can have only one wife" (1 : 1)
- "Each person can have only one husband" (1 : 1)

Recursive Relationship
M : N



Example :

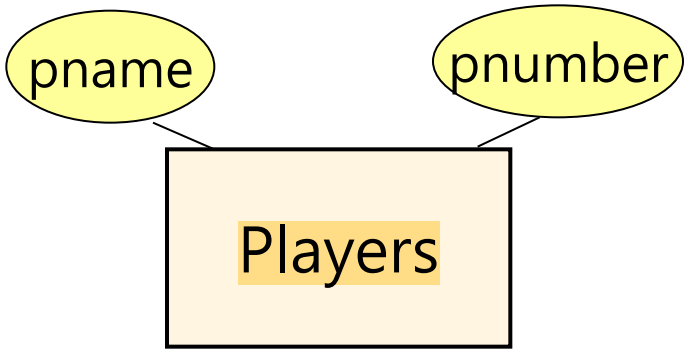
Super	Sub
A	B
A	C
B	D
B	E
F	C

- "A part consists of many different subparts" (1 : M)
- "A part can be subparts of many different parts" (N : 1)

Weak Entity Types

- In real world, some entity type may not have its key.
- An entity type that does not have a key, is called a **weak** entity type.
- To identify weak entities uniquely, we must find its **owner (= strong)** entity type.
- Owner entity type has a weak relationship with weak entity type;
- Owner has always its own key.

Weak Entity Types : Example

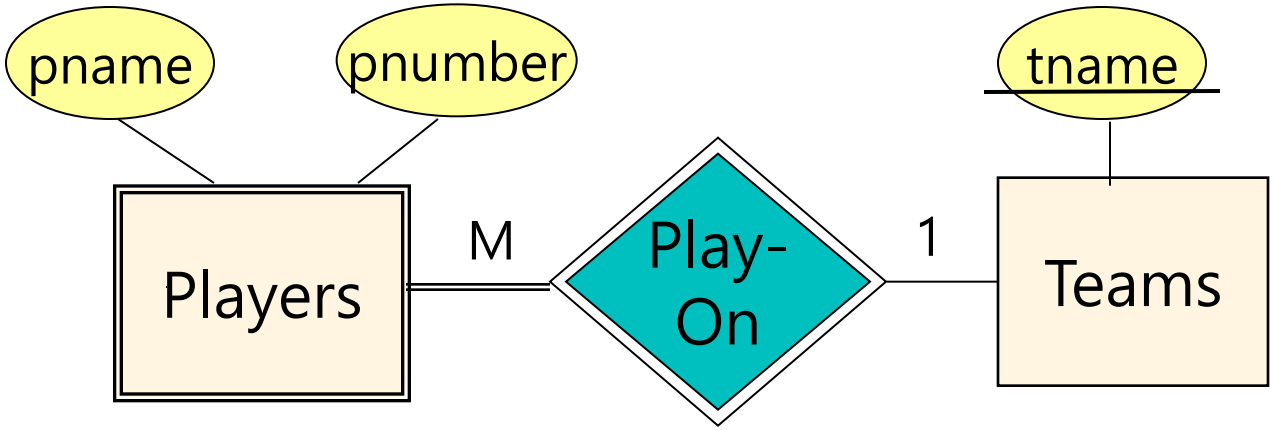


- 'pname' is almost a key for players, but there may be two with the same name.

- 'pnumber' is certainly a key within a same team. But, players on two different teams could have the same number.

- How to identify players uniquely?
  : Player들과 relationship을 갖는 Team들을 찾아 냄.
  이들 team들은 key가 존재하고 이를 owner라 함.

Weak Entity Types : Example



- "Players" (by double box) is a **weak** entity type.
- "Teams" is an **owner** (= identifying) entity type.
  : It has its own key "(team) name"
- "Plays-On" (by double diamond) is a **weak** relationship.

Weak Entity Type : Properties

(1) Weak entity type은 Owner와 **M : 1 (1 : 1)** 관계;

(2) Weak entity type은 항상 **total** participation;

(3) Weak entity type의 Key는?

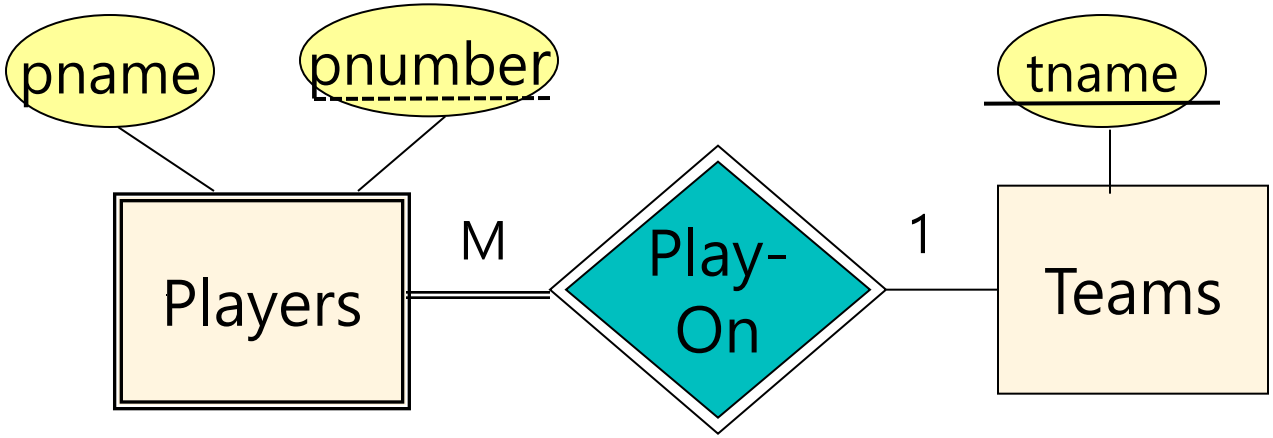
Key of **Owner** + **Partial Key** of **Weak entity type**

(**Partial key**는 owner key의 도움을 받아 weak entity들을 식별할 수 있는 일종의 부분 key를 의미)

(4) **Existence Dependency**

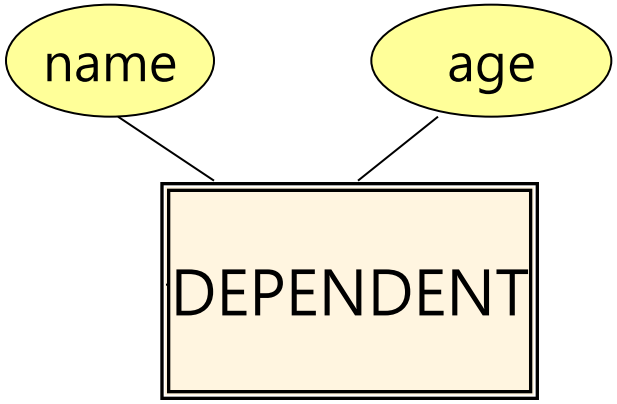
(Weak entity의 존재는 owner에 종속됨. 만약 어떤 owner entity가 DB에서 삭제되면, 이와 relationship 을 갖는 weak entity들 모두 역시 삭제되어야 함)

Weak Entity Types : Example



- "Teams" 의 key는?
- "Players" 의 partial key는?
- "Players" 의 key는?
- 만약 어떤 team이 해체 (즉 DB에서 삭제)된다면?

Weak Entity Types : Exercise



- 어느 회사 사원들의 가족(DEPENDENT)들임.
- 이들의 key를 찾을 수 없음.
- 위의 ER Diagram을 완성시켜라.

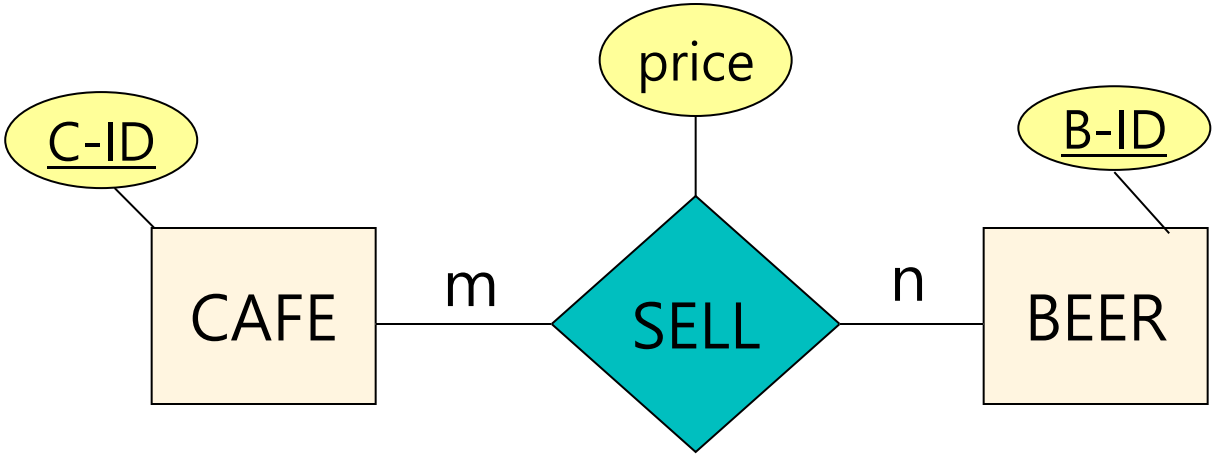
(Owner Entity type? 즉, 이 가족들을 부양하는 사원(EMPLOYEE))

Attributes on Relationship

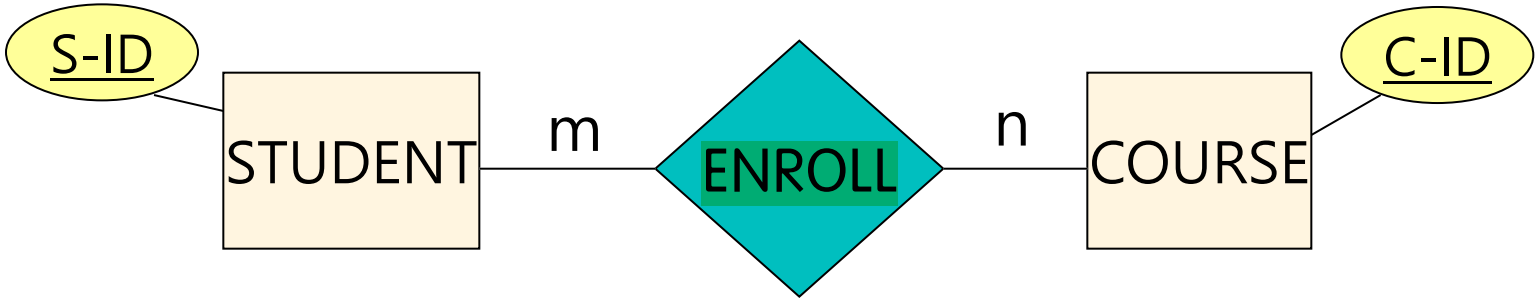
- Sometimes, it is useful to attach an attribute to a relationship; Thus, a relationship can also have its own attributes;
- 일반적으로 m : n 관계를 갖는 relationship에서 요구됨.
- 1 : n 혹은 1 : 1 relationship에서는 특별한 주의 요함.
- 1 : 1인 경우, relationship의 attribute를 양쪽 entity type들 중 어떤 쪽으로도 이동해도 상관없음;
- 반면에 m : 1 인 경우에는 반드시 m-side의 entity type으로만 이동해야 함.

Attributes on Relationship : Example

- 'Price' attribute is a function value of both the cafe and the beer, not of one alone.



- We want add "grade" attribute; Where to attach?

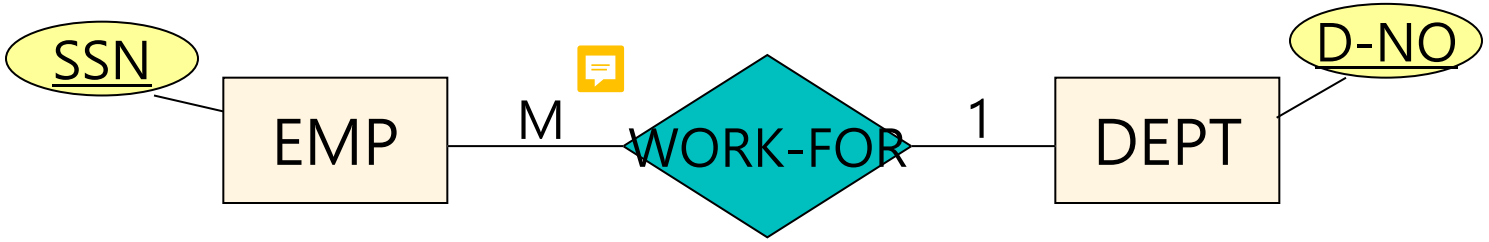


Attributes on Relationship : Example

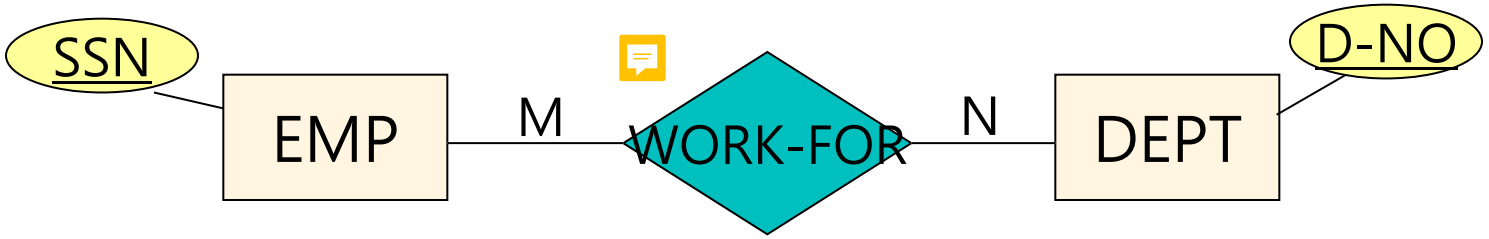
- We want add "start-date" attribute;

a)

b)



c)



Ternary Relationships

- Sometimes, we need a relationship that connects more than two entity types. (for example, ternary!)

- Consider the following requirements;

  (1) Entities : employees, beers, cafes

  (2) Relationship :

  "Employees only drink certain beers at certain cafes."

  For example;

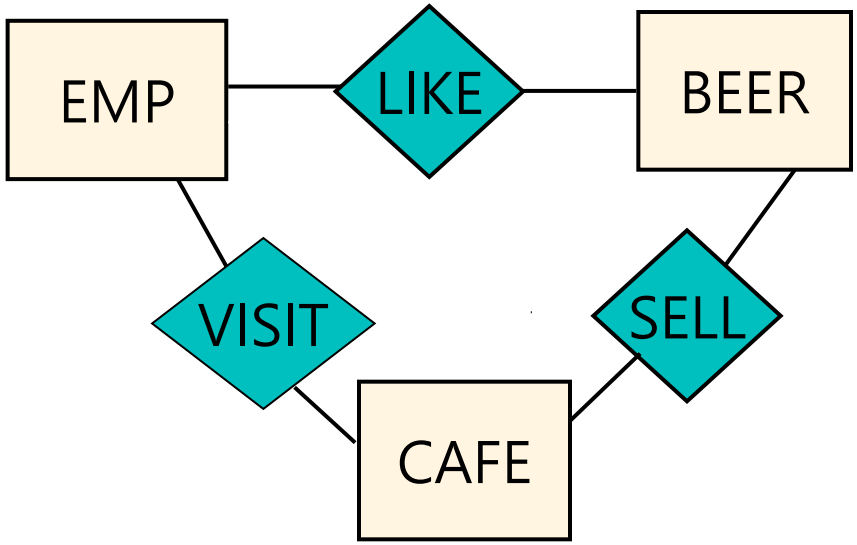
  - 'Joe' only drinks 'Bud' at 'Cheers'.
  - 'Bob' only drinks 'Guiness' at 'Warbar'.
  - 'Joe' only drinks 'IPA' at 'Cheers'.

  . . . . . .

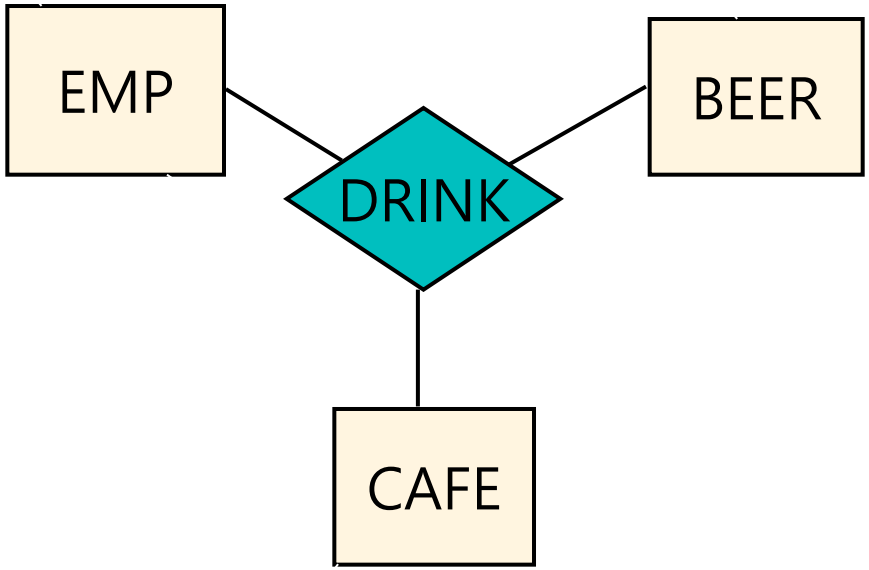
- 위의 요구사항을 정확히 ER model로 표현하라.

Two Possible ER Modeling

(a) Three Binary relationship

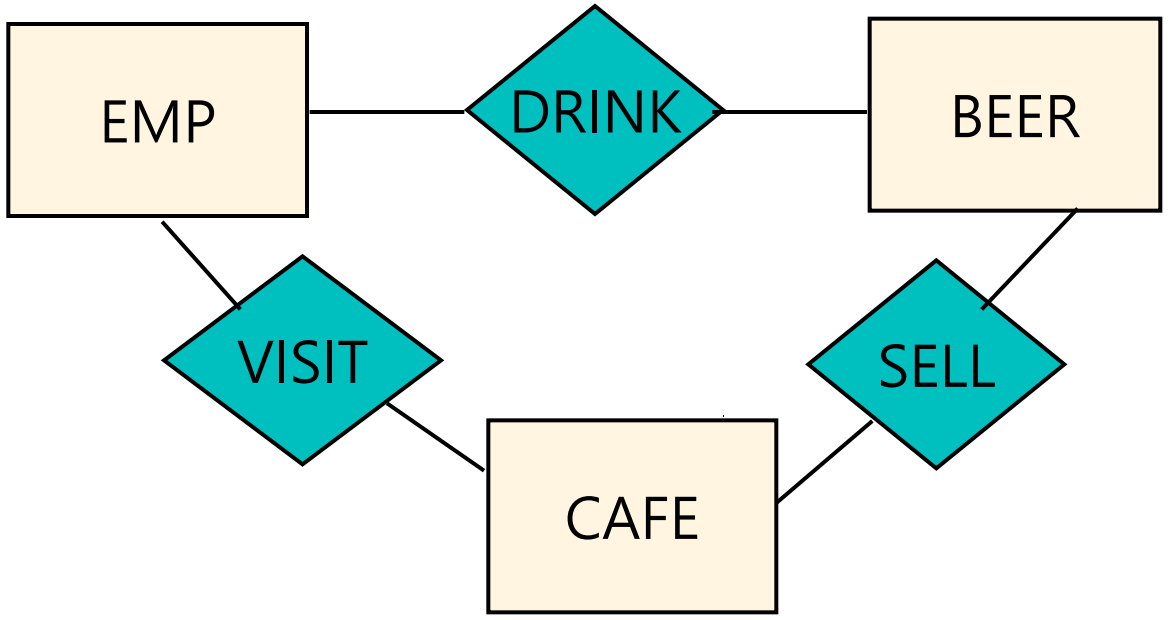


(b) Ternary relationship



- Which one seems correct? Answer will be (b)

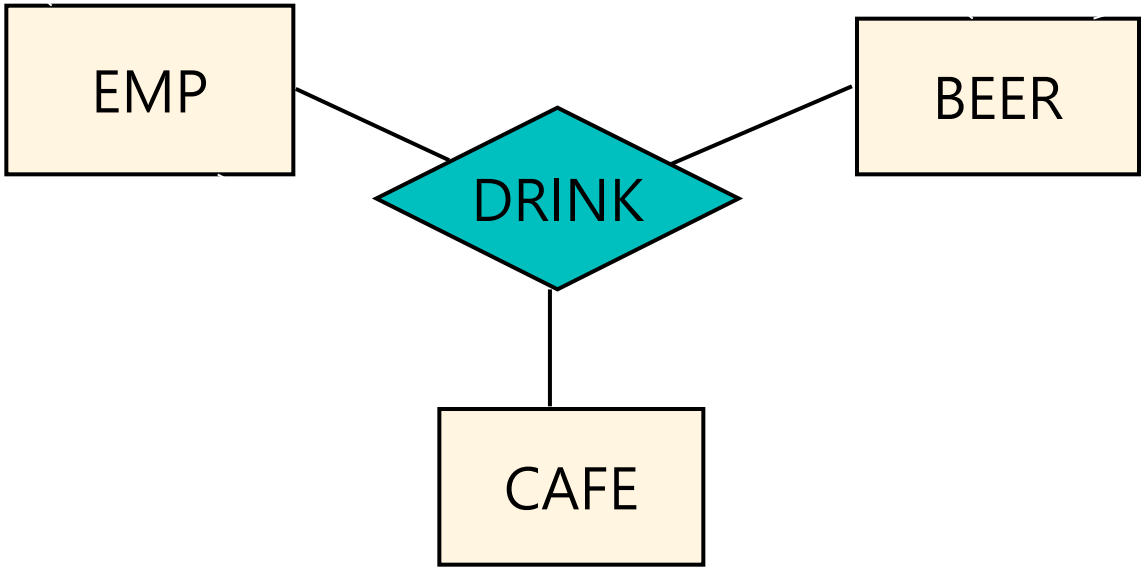
(a) Three Binary Relationships



- Employees DRINK certain beers (but which cafe?) : (e, b, ?)
- Cafes SELL certain beers (but to whom?) : (c, b, ?)
- Employees VISIT certain cafes (but which beer) : (e, c, ?)

● 3 개의 Binary 관계로는 요구사항을 정확히 표현하지 못 함.

(b) Ternary Relationship

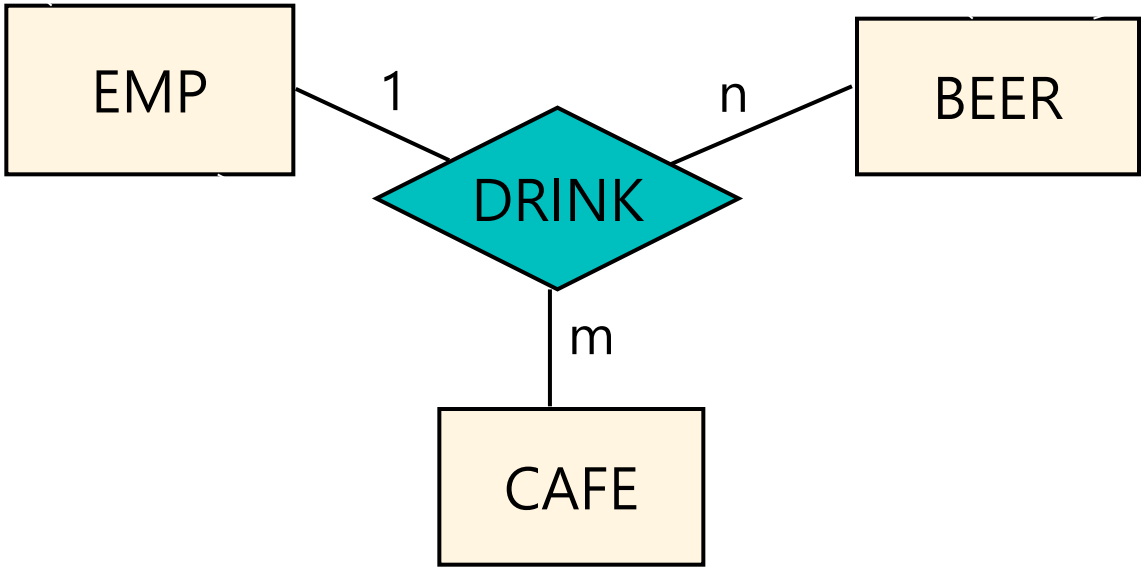


- Employees only drink certain beers at certain cafes : (e, b, c)
  (e2, b1, c2), (e3, b2, c1), (e5, b4, c5), . .

- In general, from 3 binary relationships (c, b), (e, b), and (e, c)

we can not infer a ternary relationship (e, b, c), but reverse is true.

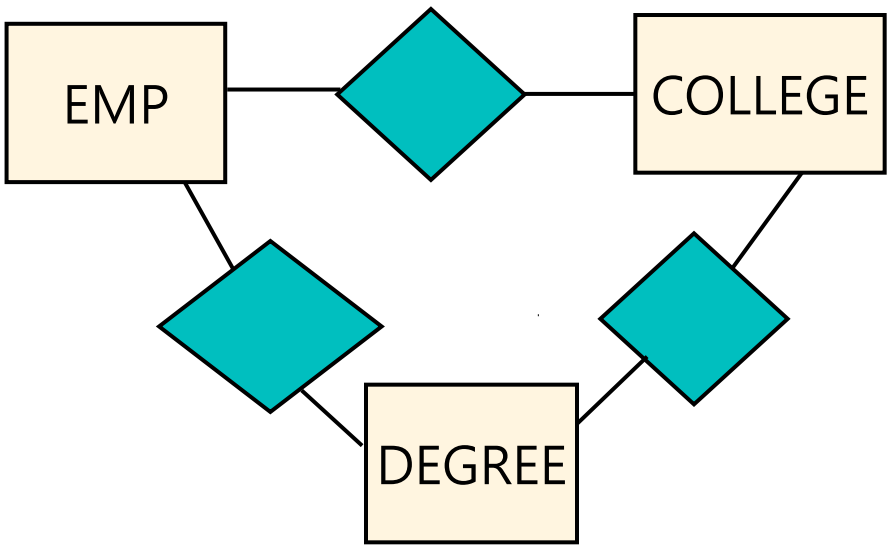
Ternary Relationship with Mapping : Example



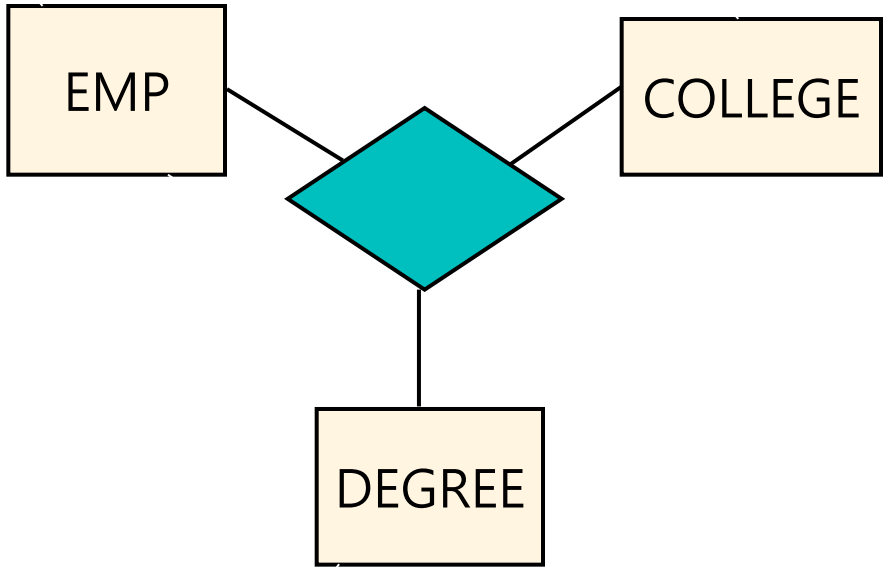
- For certain beer and cafe combination, only one employee exists; That means : "Only one employee drink a certain beer at a certain café".
- Each (b, c) combination uniquely determine a single employee.
- Question : What is a key of "DRINK"?

Another Case

(a) Three Binary relationship



(b)Ternary relationship

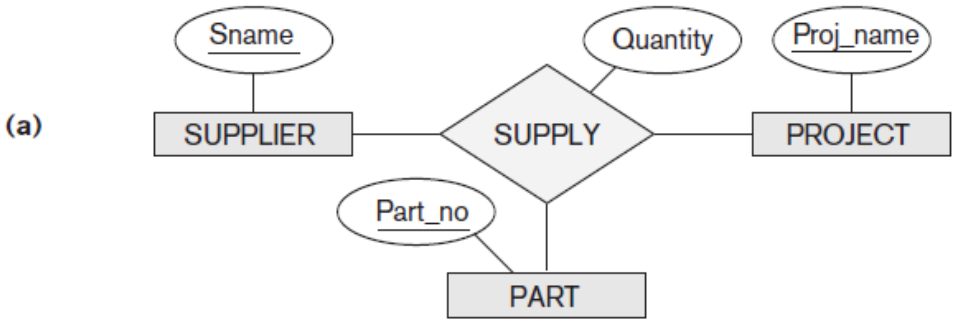


- Are they both represent the same information?

Binary vs. Ternary Relationships

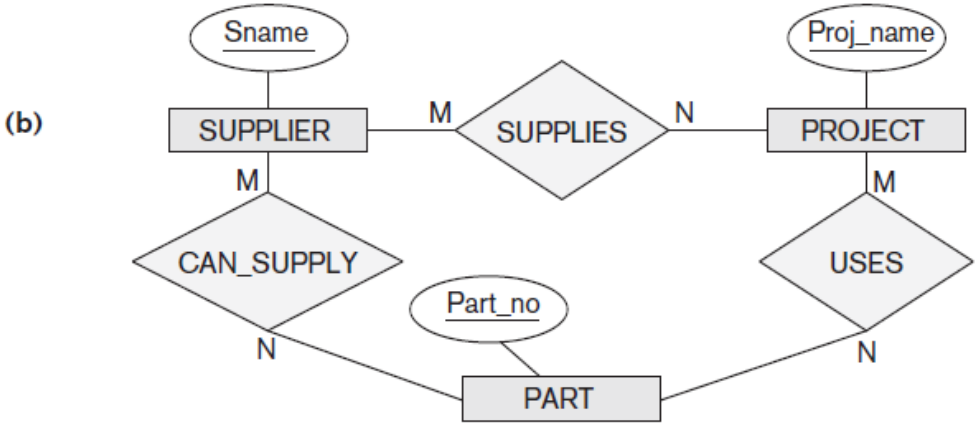
- Some database design tools does not permit ternary (or more) relationships.
  - Ternary relationship can be represented by several binary relationships;
  - It can be represented as a weak entity type
  - Each entity in ternary relationship is identified by 3 owners with no partial key
- Every n-ary relationship can be represented by binary relationships.

(a) Ternary relationship :



(b) Binary relationships :

Note: (b) is not equal to (a)



(c) Binary relationships by using weak entity type :

Note: (c) is equal to (a)

(c) SUPPLY의 key = {Sname, Proj-name, Part-no}

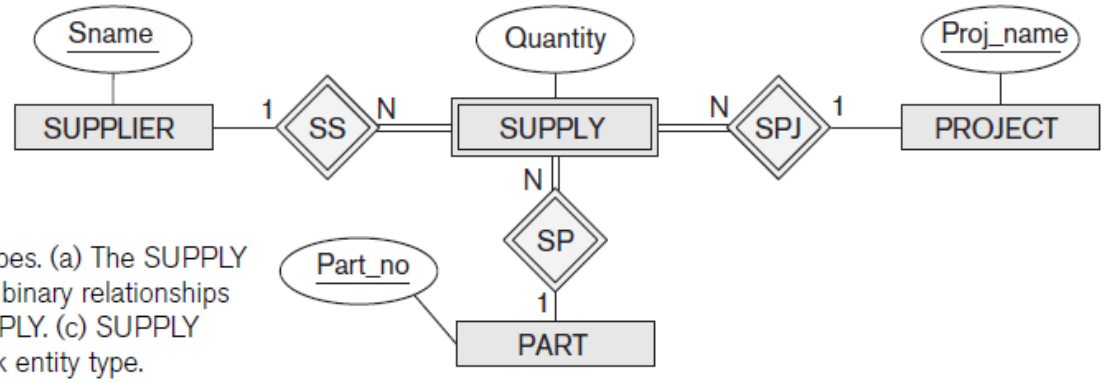
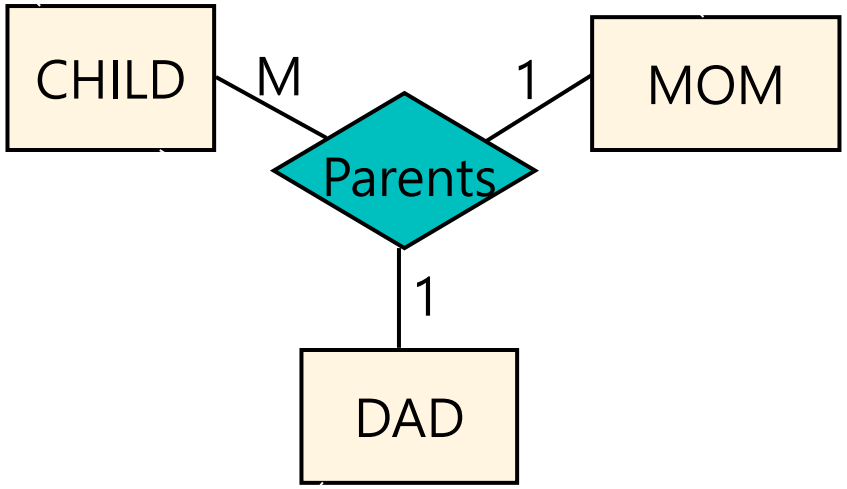


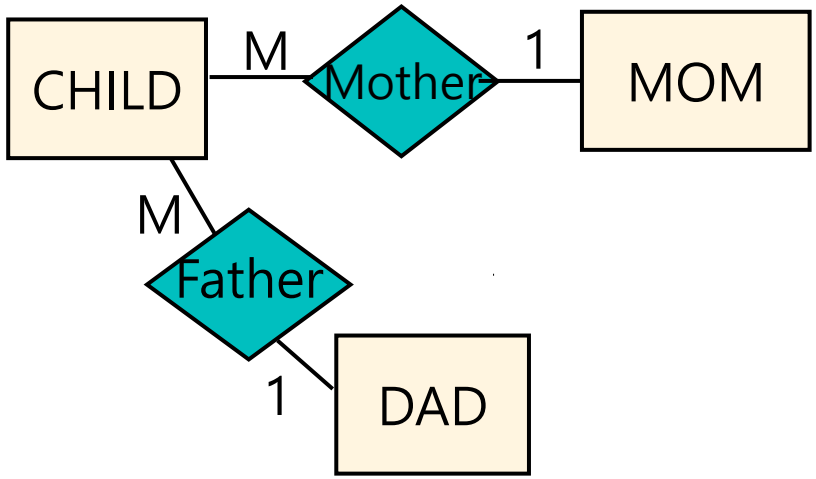
Figure 7.17
Ternary relationship types. (a) The SUPPLY relationship. (b) Three binary relationships not equivalent to SUPPLY. (c) SUPPLY represented as a weak entity type.

Convert Ternary into Binary

(A) Ternary relationship



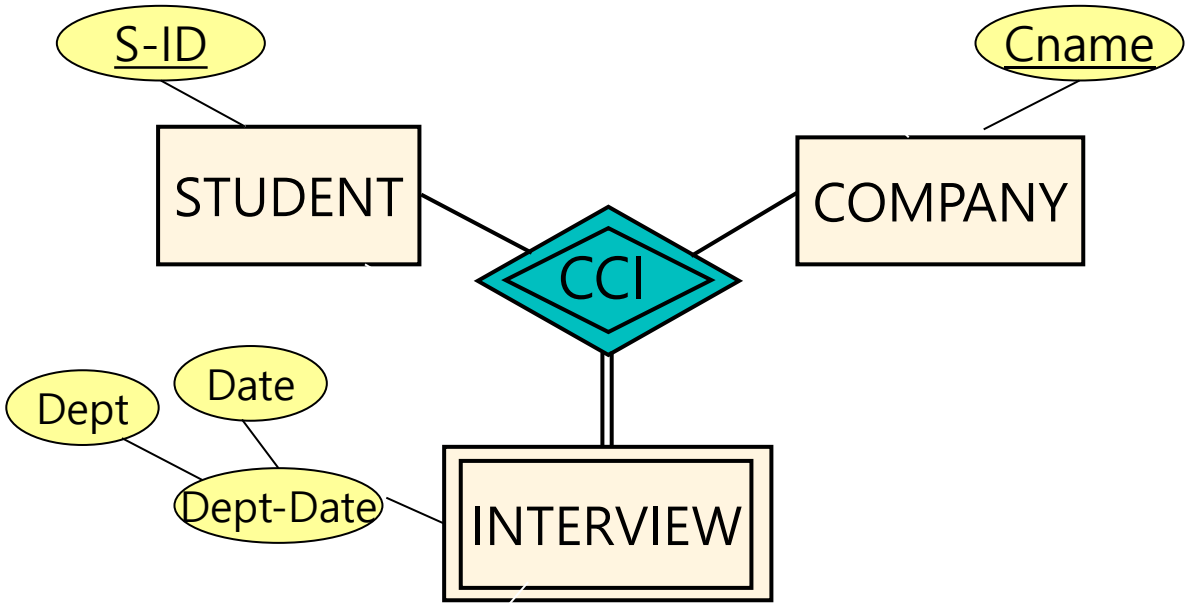
(B) Two Binary relationships



- A ternary relationship "Parents", relating a child to his/her mom and dad, is naturally replaced by two binary relationships, "Father" and "Mother".
- Note that both (A) and (B) represent the same information.

Weak Entity with Ternary Relationship

- It is possible to have a weak entity type with a ternary relationship.



Weak entity type "INTERVIEW" with ternary relationship

- A student can have multiple interviews with the same company; For example, with different company departments, or separate dates.
- Here, "INTERVIEW" is represented as weak entity type; It has two owners; "STUDENT" and "COMPANY" with partial key "Dept-Date".
- "INTERVIEW" 의 key = {S-ID, Cname, {Dept, Date}}

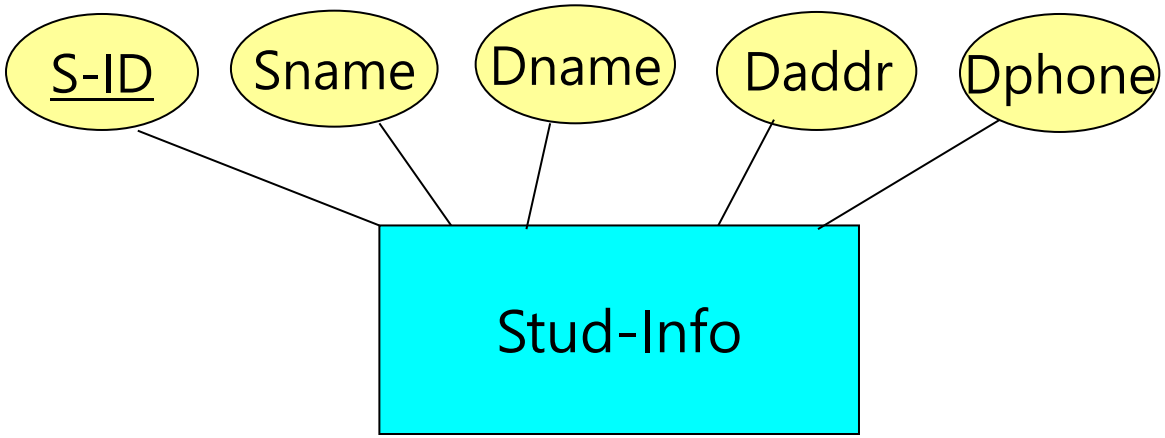
A Few ER Design Guidelines

- Avoid Redundancy; Redundancy wastes space and occurs inconsistency.
  - Repeats of the same information may become inconsistent if we change one and forget to change the other.

- Do not use an entity type when an attribute will do; Entity type must satisfy at least one of the following conditions:
  - It is more than the name of something; it has at least one non-key attribute.

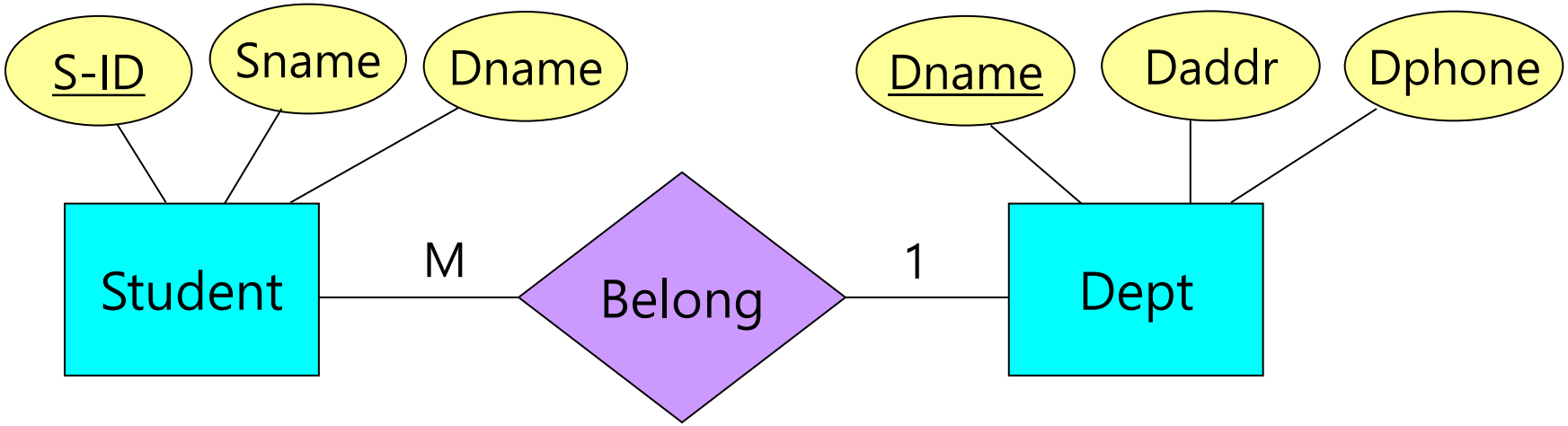
    or
  - It is the "Many" side in a M : 1 relationship.

Redundancy : Very Bad Design



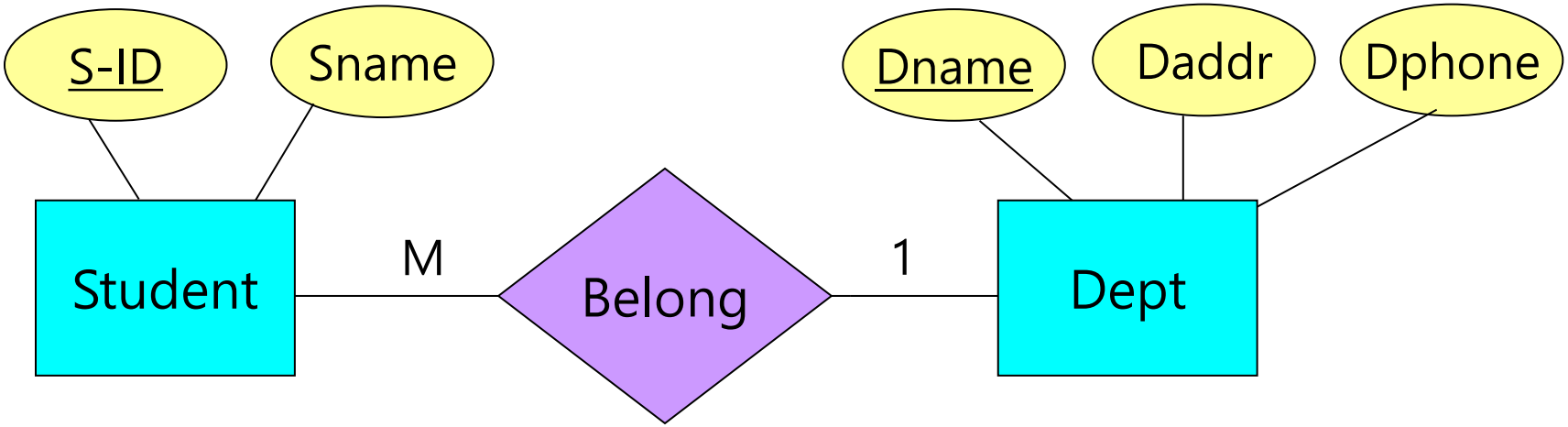
- The same department's information (i.e., Daddr, Dphone) is repeated many times.
- If we want to update some department's information?
- If we want to delete some department's information?
- If we want to add the new department's information later?

Redundancy : Bad Design



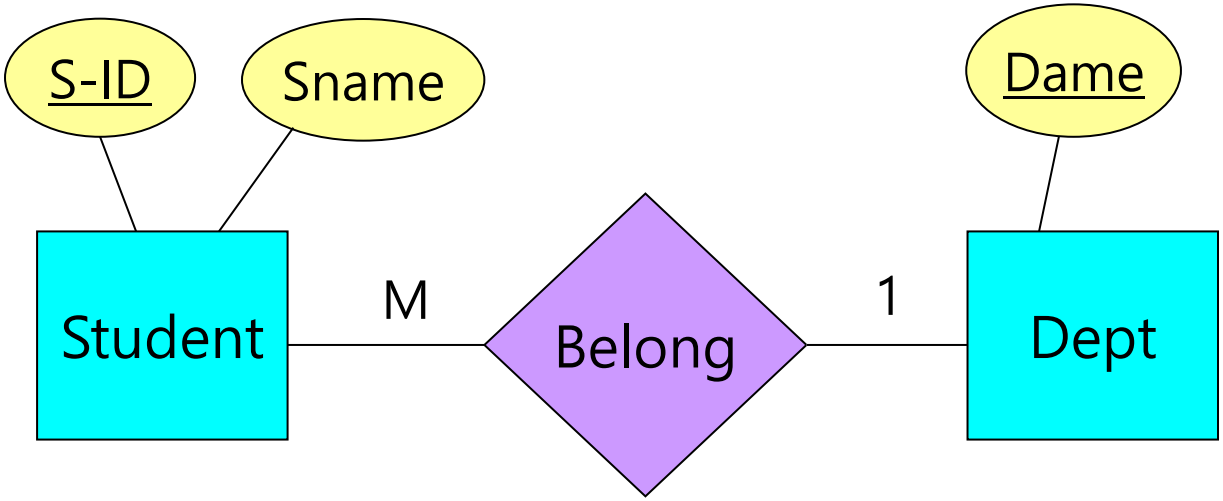
- Better! But this design still repeats the Dname of a department twice: as an attribute and as a related entity.

No Redundancy : Good Design



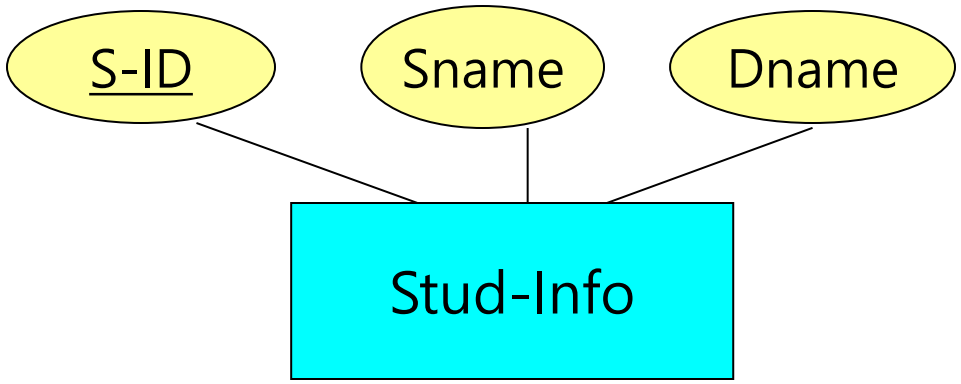
- This design represents the information of each department only once.
- If we want to update some department's information?
- If we want to delete some department's information?
- If we want to add the new department's information later?

Entity vs Attribute : Bad



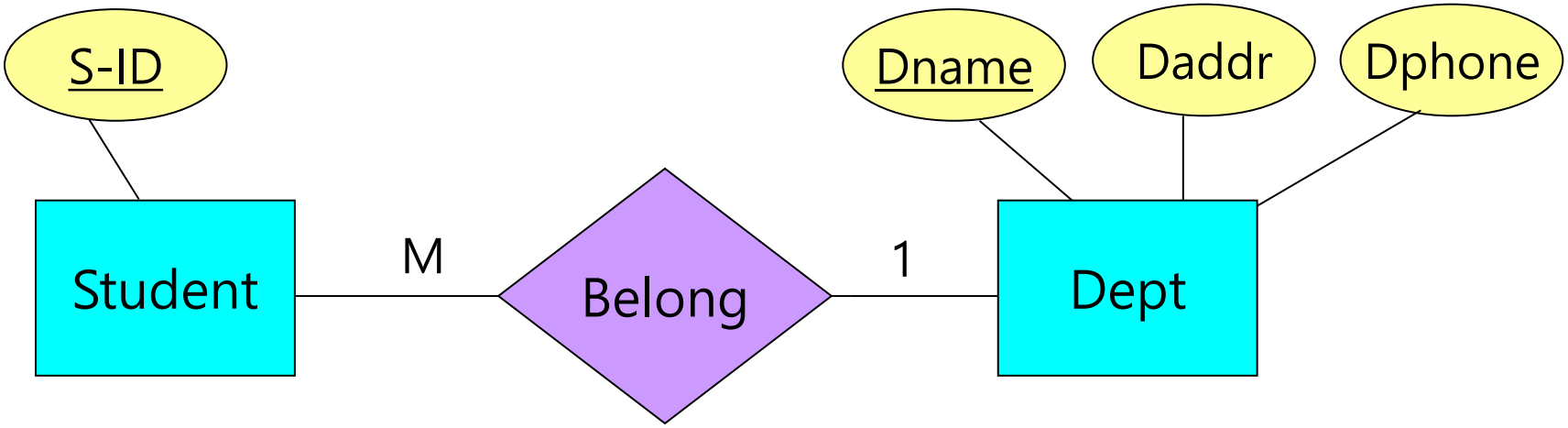
- The department is nothing but a name, and is not at the "Many" side of this relationship, it should not be an entity type.

Entity vs Attribute : Good



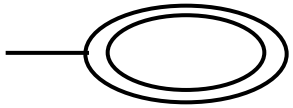
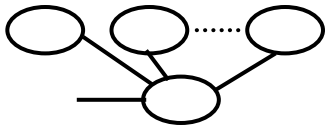
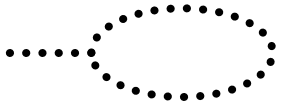
- There is no need to make the department an entity type, because we record nothing about departments besides their name.

Entity vs Attribute : Good

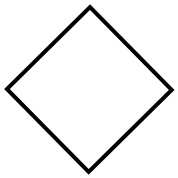
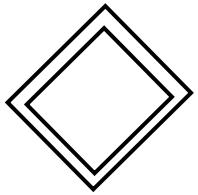
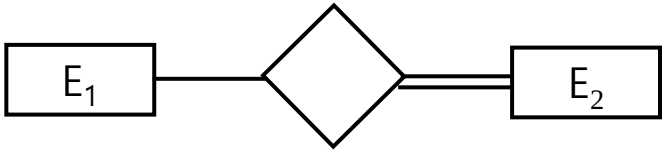
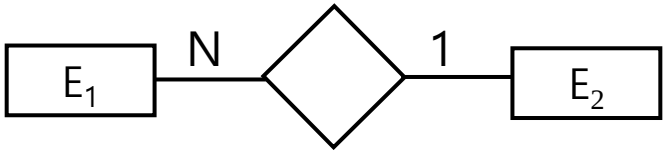
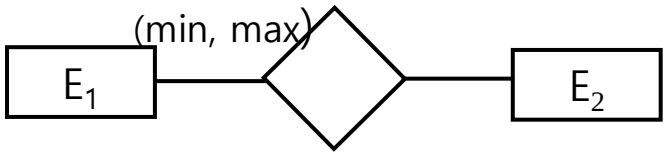


- Department deserves to be an entity type because of the non-key attributes (i.e., Daadr, Dphone).
- Student deserves to be an entity type because it is the "Many" of the M : 1 relationship Belong.

Notation for ER Diagram (1)

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

Notation for ER Diagram (2)

Symbol	Meaning
	Relationship Type
	Weak Entity Type
	Weak Relationship Type
	Total/Partial Participation
	N : 1 Mapping
	(Min, Max)

Example: COMPANY Database

- Identifying **Entities, Relationships, Attributes,** and **Constraints:**

- Our company is organized into **departments**. Each department has a name, number and an *only one* **employee** who ***manages*** the department. We keep track of the start date of the department manager.

- Each department ***controls*** *many* **projects**. Each project is controlled by *only one* department. Each project has a name, number, location.

- We store each **employee**'s ssn, 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, birth-date, and ***supported*** relationship to employee. (etc.)

ER Diagram : COMPANY Databases

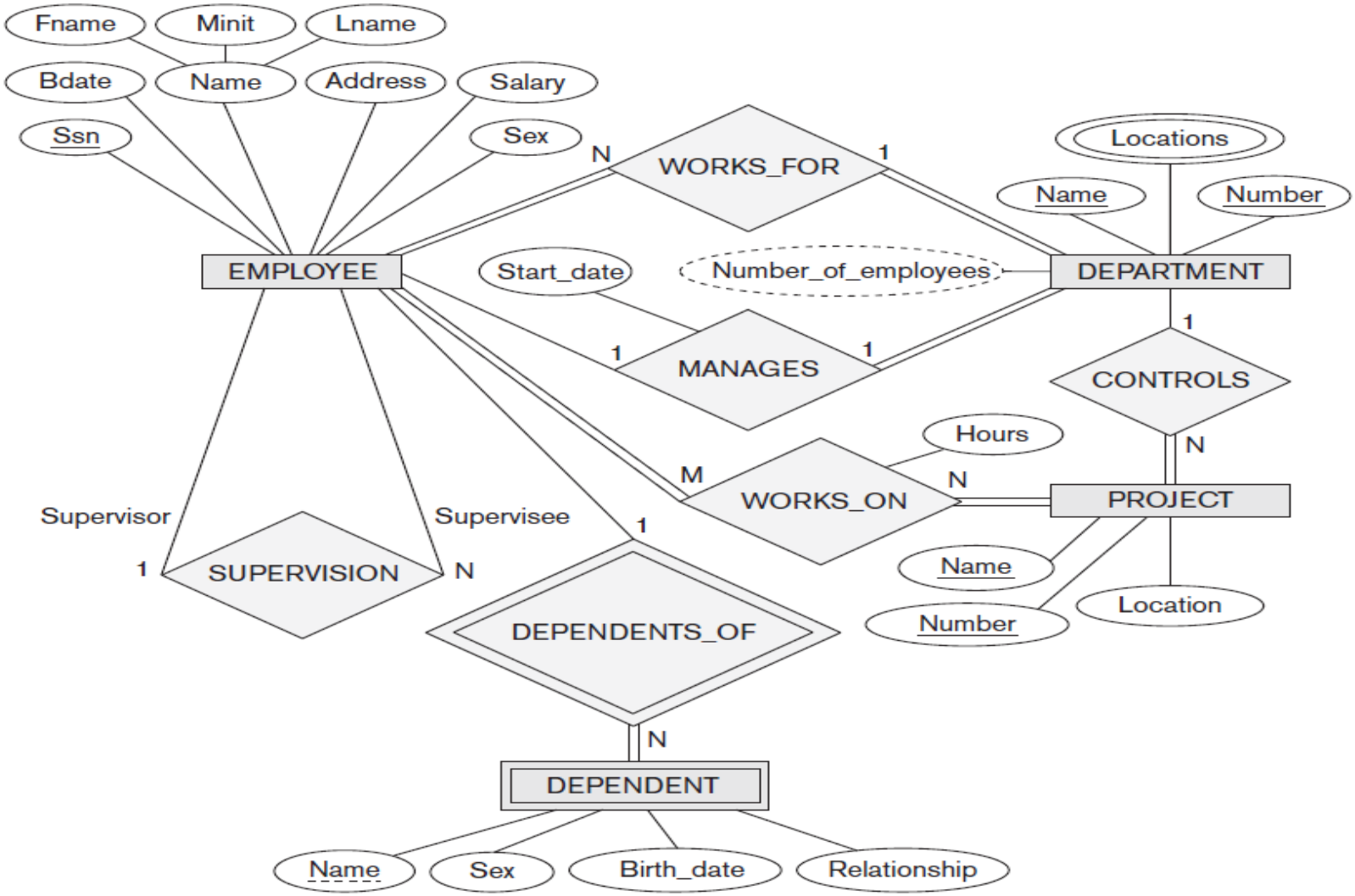


Figure 7.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter and is summarized in Figure 7.14.

ER Diagram using (Min, Max) : COMPANY Databases

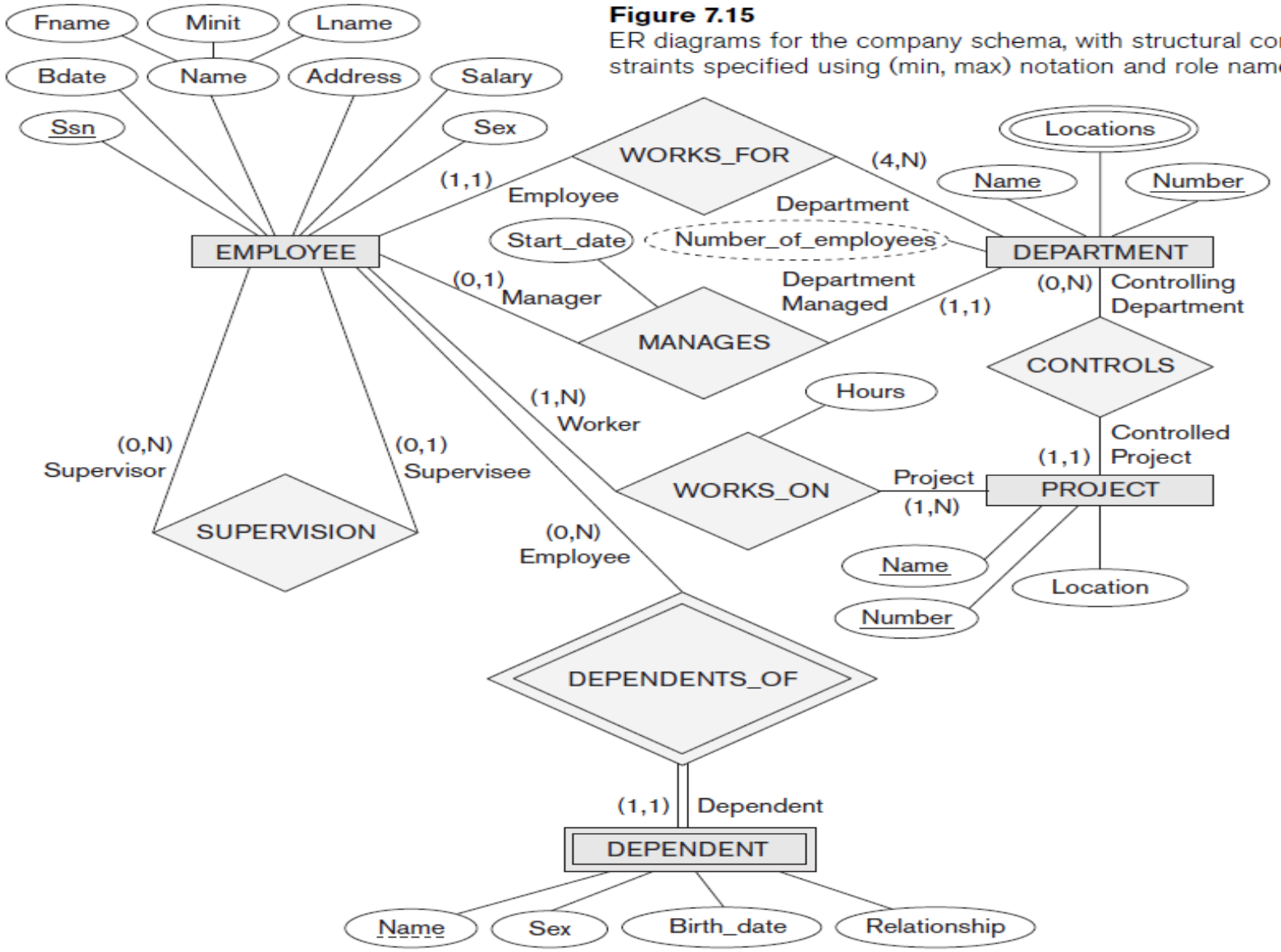
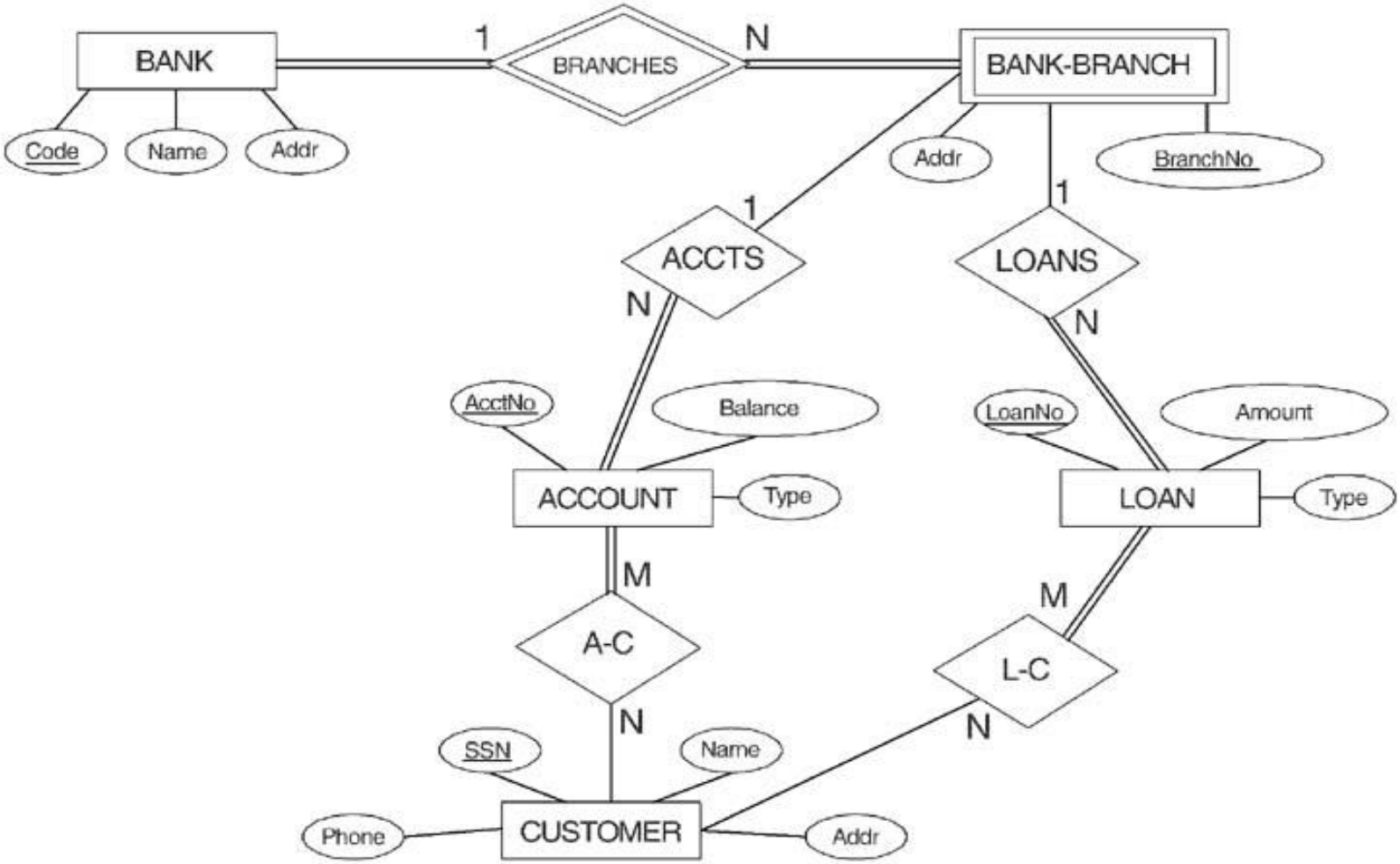


Figure 7.15
ER diagrams for the company schema, with structural constraints specified using (min, max) notation and role names.

ER Diagram : BANK Databases



Enhanced-ER (EER) Model:

- 기존의 ER model에 다음의 기능들을 추가 확장한 model
  - Subclasses/Superclasses
  - Inheritance
  - Multiple Inheritance
  - Disjoint/Overlap Constraints
  - Specialization
  - Generalization

- This model is used to model applications more completely and accurately if needed

Subclass and Superclass (1)

- 일반적으로 한 entity type은 여러 개의 의미있는 sub-entity type 들로 group화 할 수 있음.
- 예 : **EMPLOYEE**를 다음과 같이 group화 함.

  {SECRETARY, ENGINEER, TECHNICIAN}

  - Each of these groupings is a **subset** of EMPLOYEE entities
  - Each of these grouping is called a **subclass** of EMPLOYEE
  - EMPLOYEE is the **superclass** for each of these subclasses

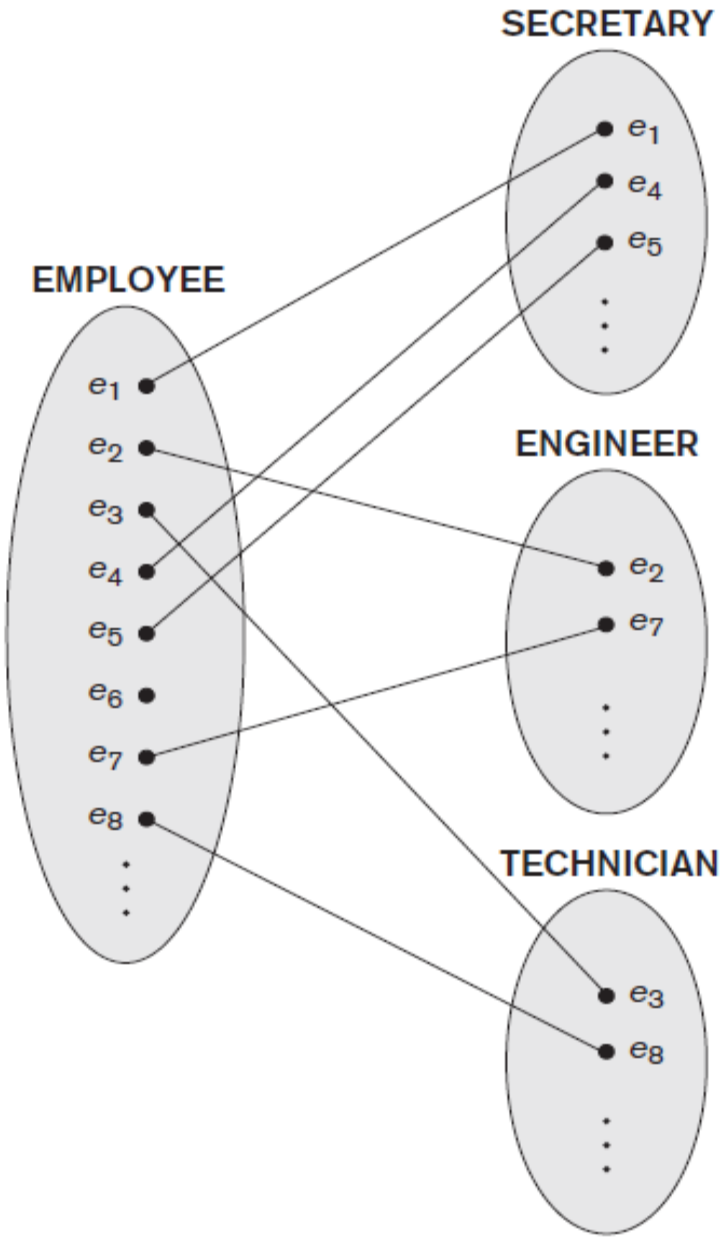


Figure 8.2
Instances of a specialization.

Subclass and Superclass

- Subclass와 superclass 관계를 **IS-A** (혹은 **Inclusion**) relationship 라고 함. IS-A는 ⟶ 로, Inclusion은 ⟵∈ 로 표기함

- Subclass에 속한 한 entity는 superclass에 속한 어떤 entity와 실제로는 같은 entity임.

- Subclass에 속한 모든 entity들은 superclass에 속해야 함. (즉, subclass에 속했지만, superclass에는 속하지 않은 entity는 존재할 수 없음)

- Superclass에 속한 모든 entity들이 반드시 어떤 subclass에 속할 필요는 없음.

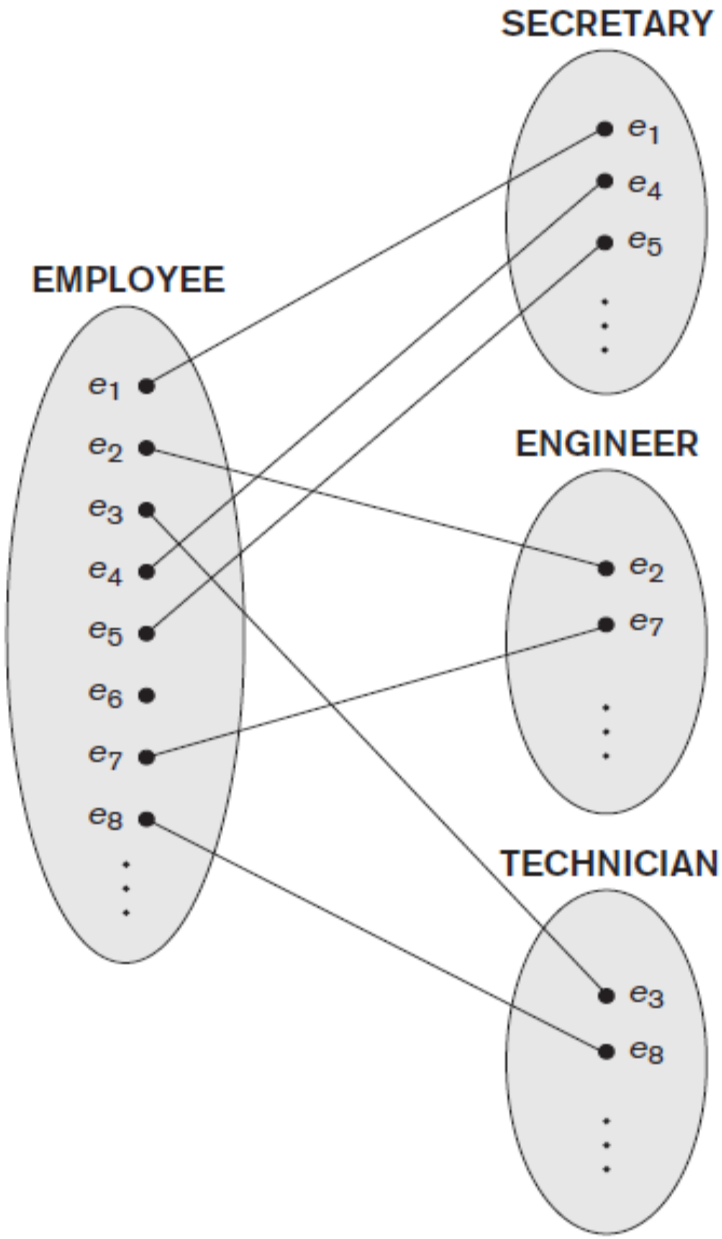
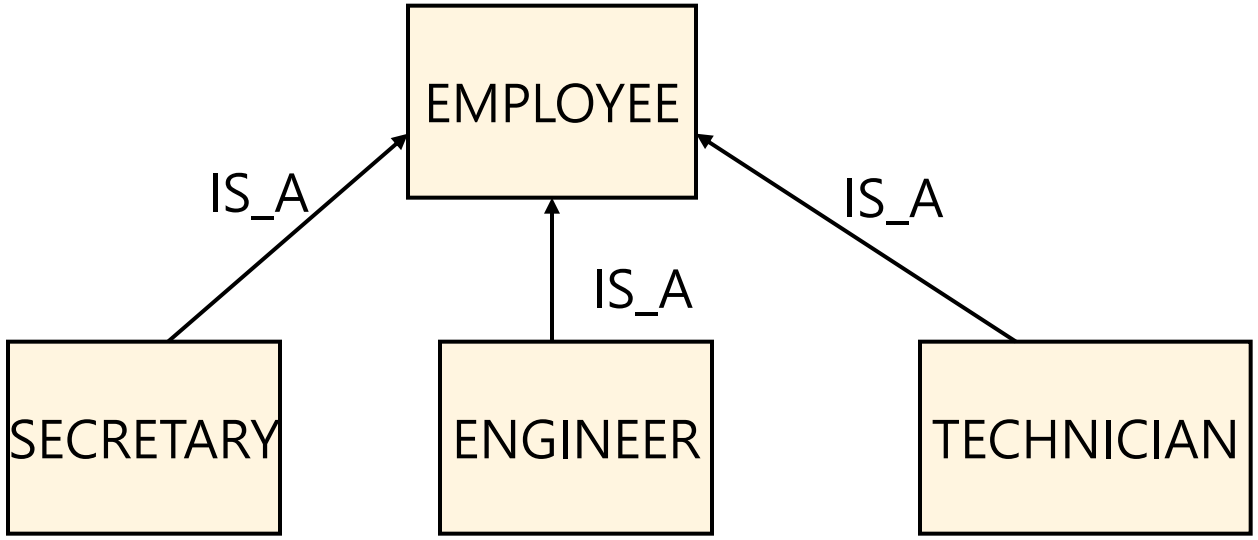


Figure 8.2
Instances of a specialization.

Subclass and Superclass (3)



- Relationship between subclass and superclass : **IS_A**
  - ✓ SECRETARY "eve" IS-A EMPLOYEE "eve";
  - ✓ ENGINEER "joe" IS-A EMPLOYEE "joe";
  - ✓ TECHNICIAN "bob" IS-A EMPLOYEE "bob";

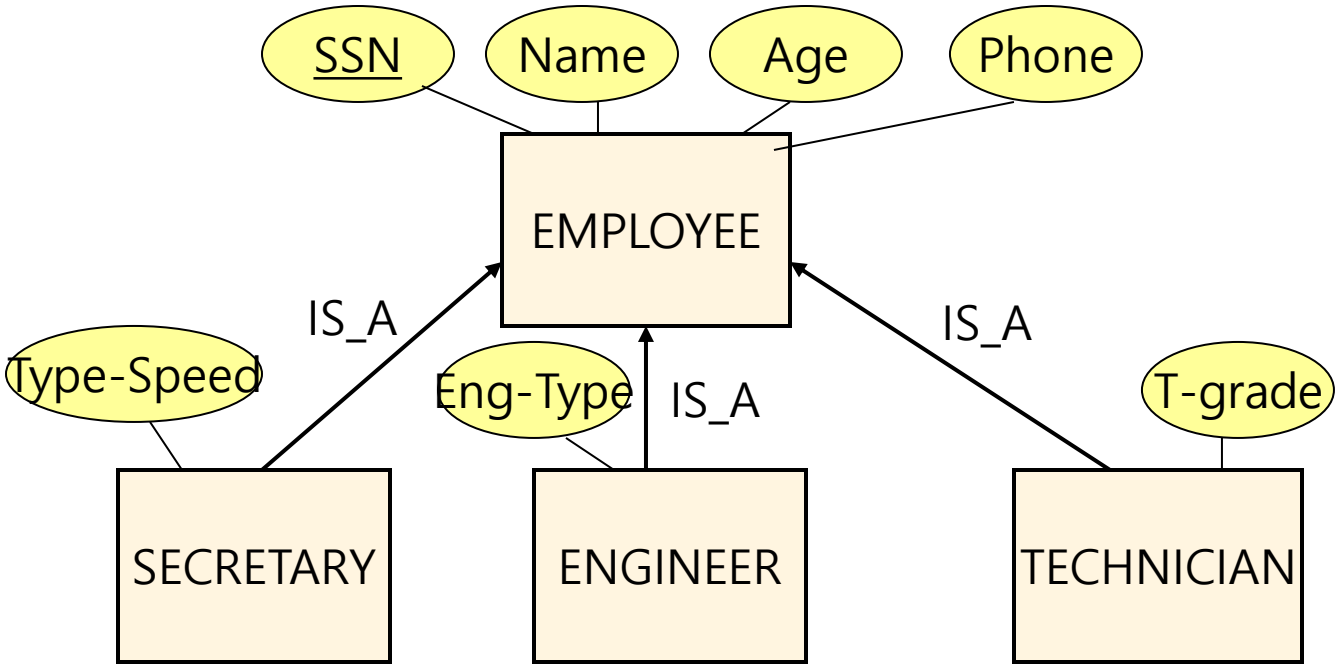
Subclass and Superclass (4)

- 각 subclass는 superclass 보다 더 적은 entity들을 가짐.
- 각 Subclass는 superclass 보다 더 많은 attribute들을 가짐
  (즉 superclass의 attribute들 외에 자신만의 고유한 attribute들을 추가로 가질 수 있음.
- 예 : 각 class는 다음의 attribute들을 가짐.
  - EMPLOYEE : {SSN, Name, Age, Phone}
  - SECREATRY : {SSN, Name, Age, Phone} ∪ {Type-Speed}
  - ENGINEER : {SSN, Name, Age, Phone} ∪ {Eng-Type}
  - TECHINICIAN : {SSN, Name, Age, Phone} ∪ {T-Grade}
- 위의 요구사항을 어떻게 ER modeling 할까?

Inheritance

- An entity that is member of a subclass **inherits** **all attributes** of the entity as a member of the superclass
- It also inherits **all relationships**
- It also inherits **all functions** (= programs)
- It also has **its own relationship** with other classes
  - Example: BELONG-TO_UNION of SALARY_EMP
- By inheritance, we can **reuse** existing ER schema for building new ER schema;
  (Thus, we can **avoid** unnecessary database **redesign**.)

Inheritance

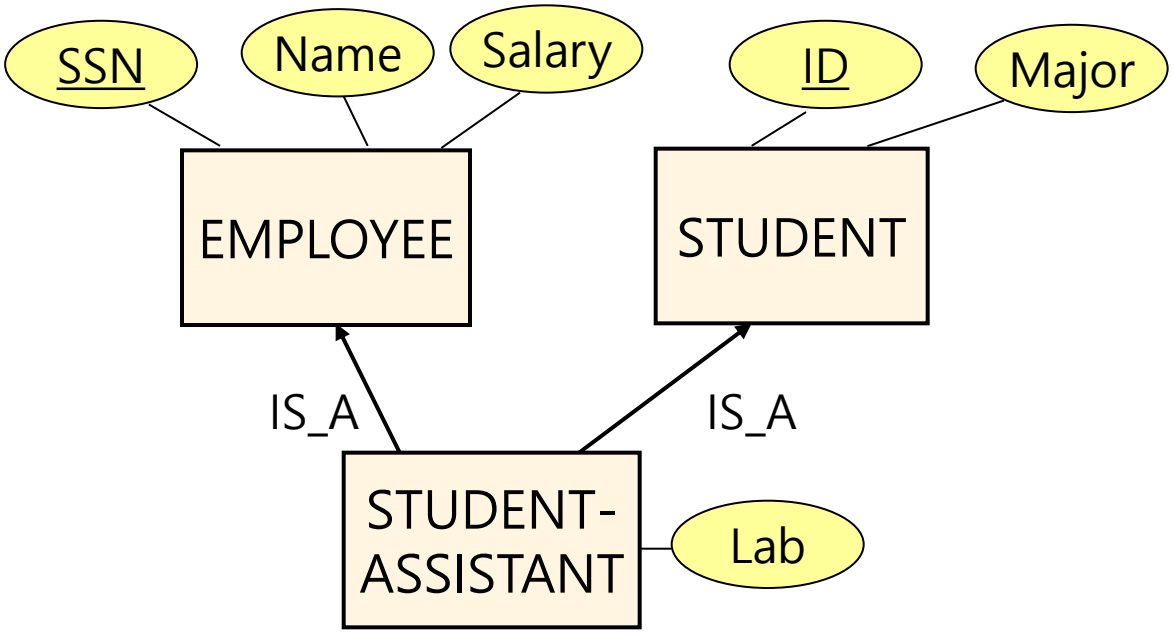


- Each subclass SECRETARY, ENGINEER, TECHINICAIN inherits all attributes from its superclass EMPLOYEE

Multiple Inheritance

- **Single Inheritance**
  - Every subclass has only one superclass.
  - It forms a class **hierarchy** (= like tree).
- **Multiple Inheritance**
  - A subclass can have **more than one** superclasses.
  - A subclass can inherit attributes of **each of its superclasses.**
  - 즉, 각 superclass는 자기 자신 고유의 이질적인 특성들을 가질 수 있음.

Multiple Inheritance



- A subclass STUD-ASSISTANT can inherits all attributes from both EMPLOYEE and STUDENT superclasses.

Constraints

- **Disjoint**

  : an entity of superclass must be a member of at most one of its subclasses

- **Overlap**

  : an entity of superclass can be a member of more than one of its subclasses

- **Total**

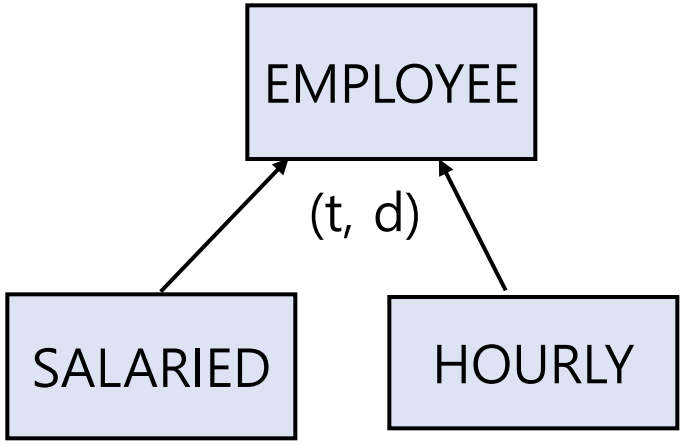
  : every entity of superclass must belong to some of its subclasses

- **Partial**

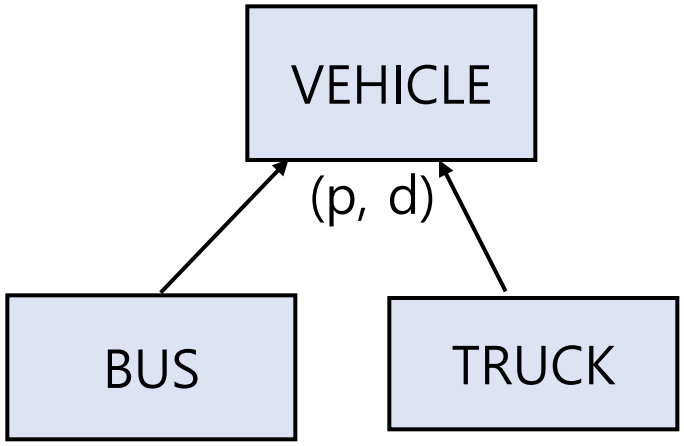
  : some entity of superclass may not belong to any of its subclasses

Constraints

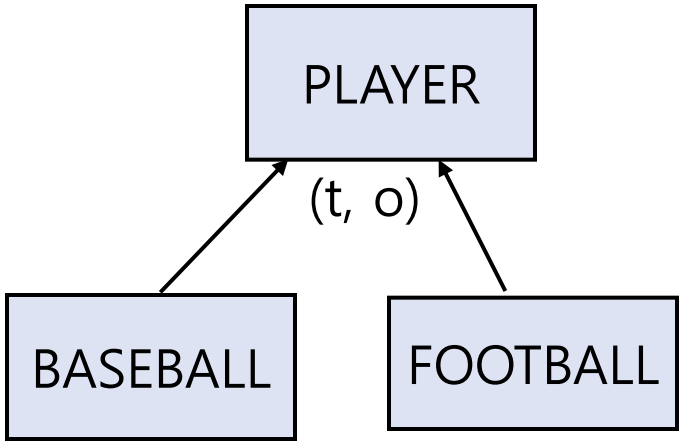
a) Total-Disjoint



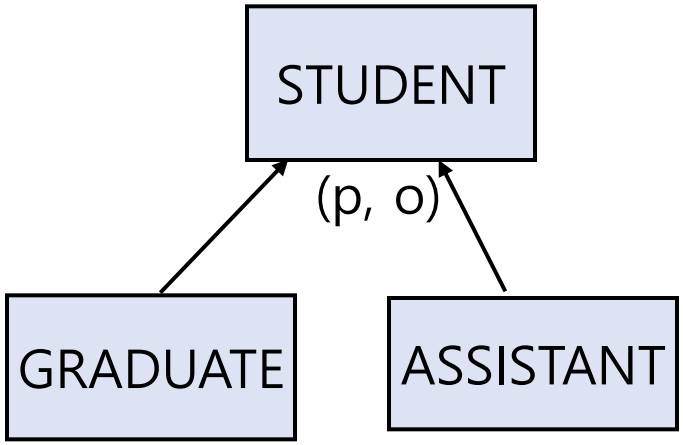
b) Partial-Disjoint



c) Total-Overlap



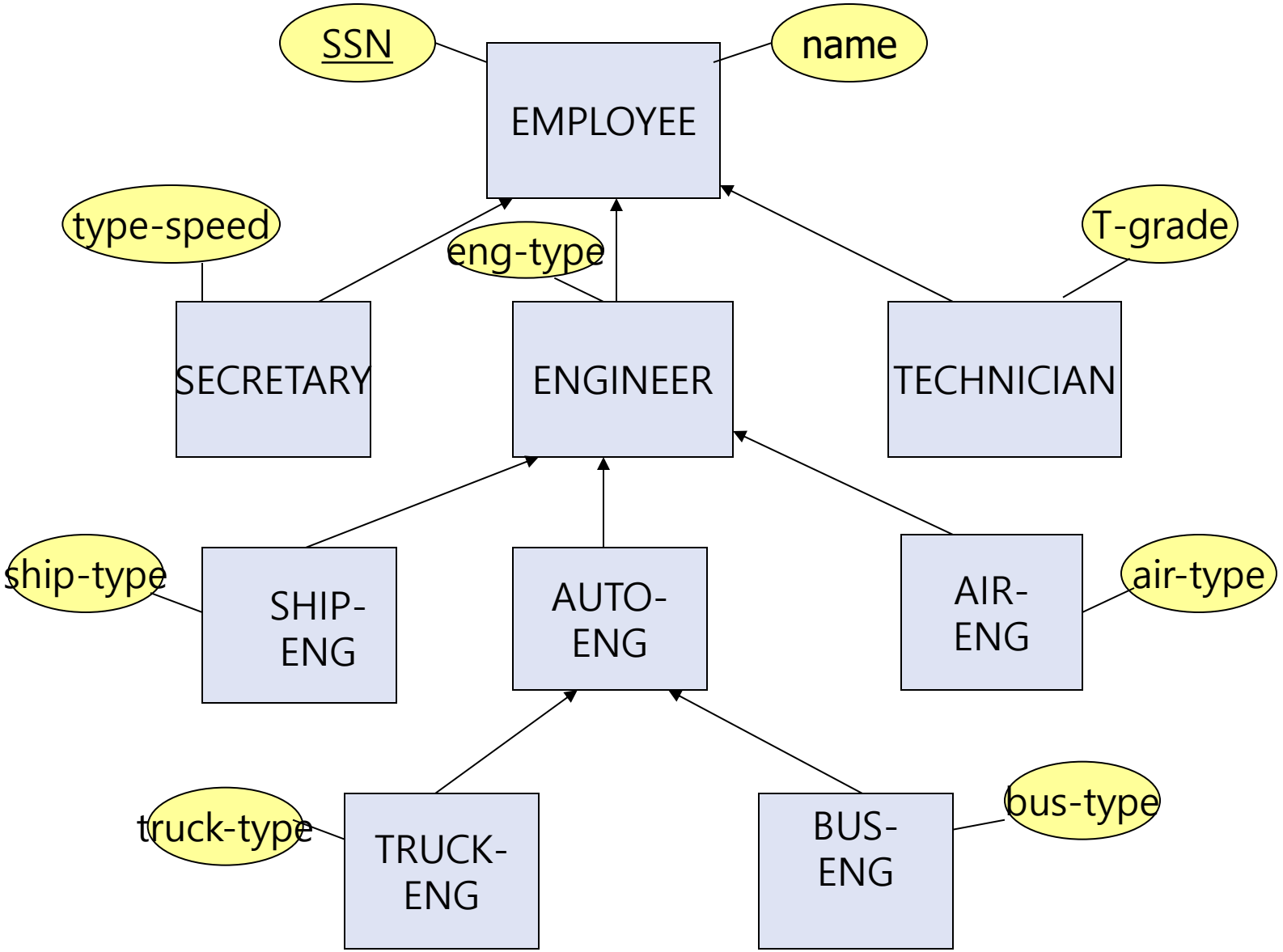
d) Partial-Overlap



Specialization

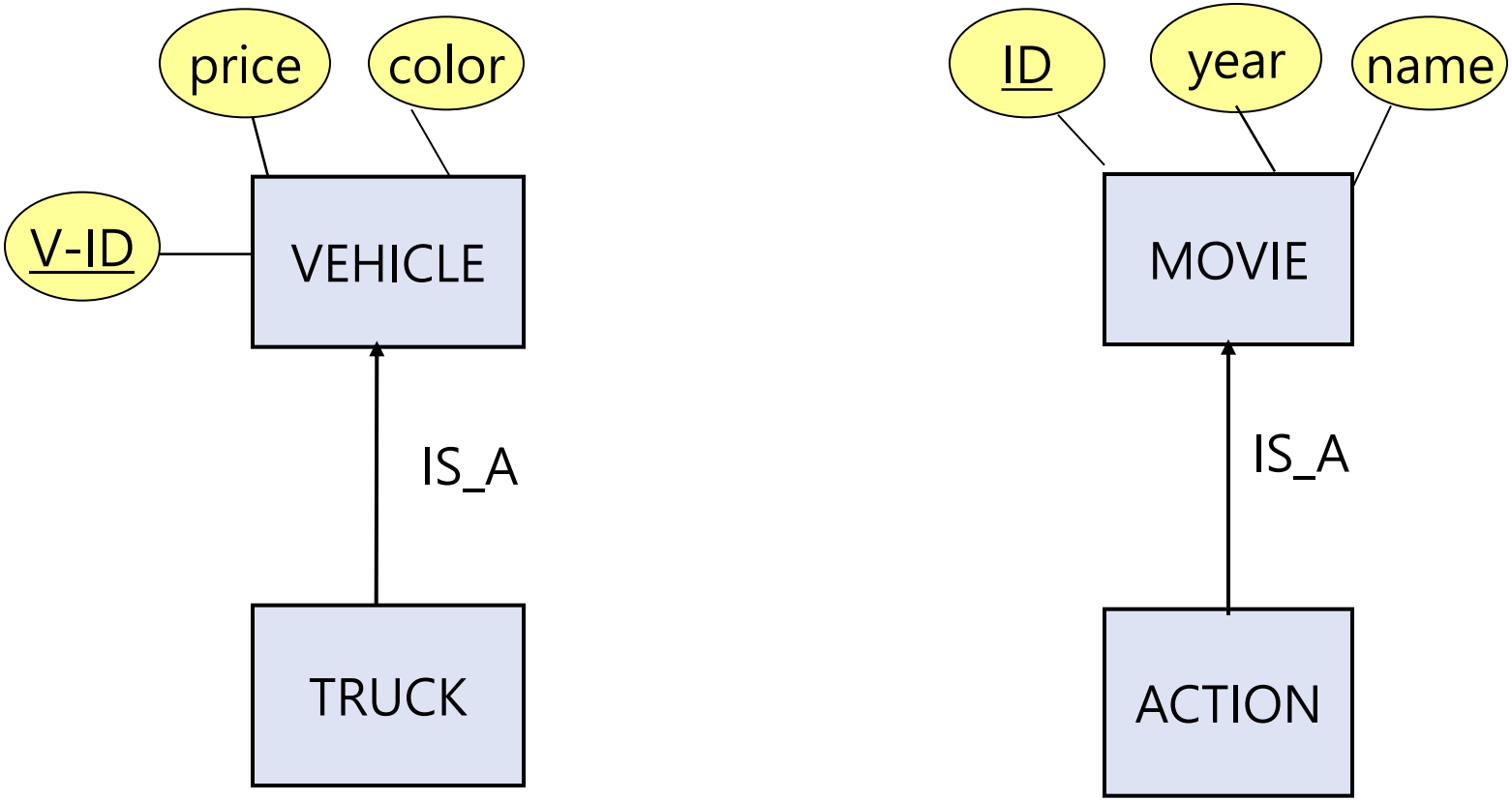
- Process of defining a set of subclasses from superclass
- Top-Down (= Refinement) Modeling
- Based on IS_A relationship
- A subclass inherits attributes of its **all direct** or **indirect** superclasses
- Example:
  {SECRETARY, ENGINEER, TECHNICIAN} is a specialization of EMPLOYEE based upon *job type*.
- Example:
  {SALARY_EMP, HOURLY_EMP} is a specialization of EMPLOYEE based in *payment type*

Specialization



Specialization

- 다음 VEHICLE과 MOVIE에 대한 specialization을 각각 완성시켜라.



Specialization : Company

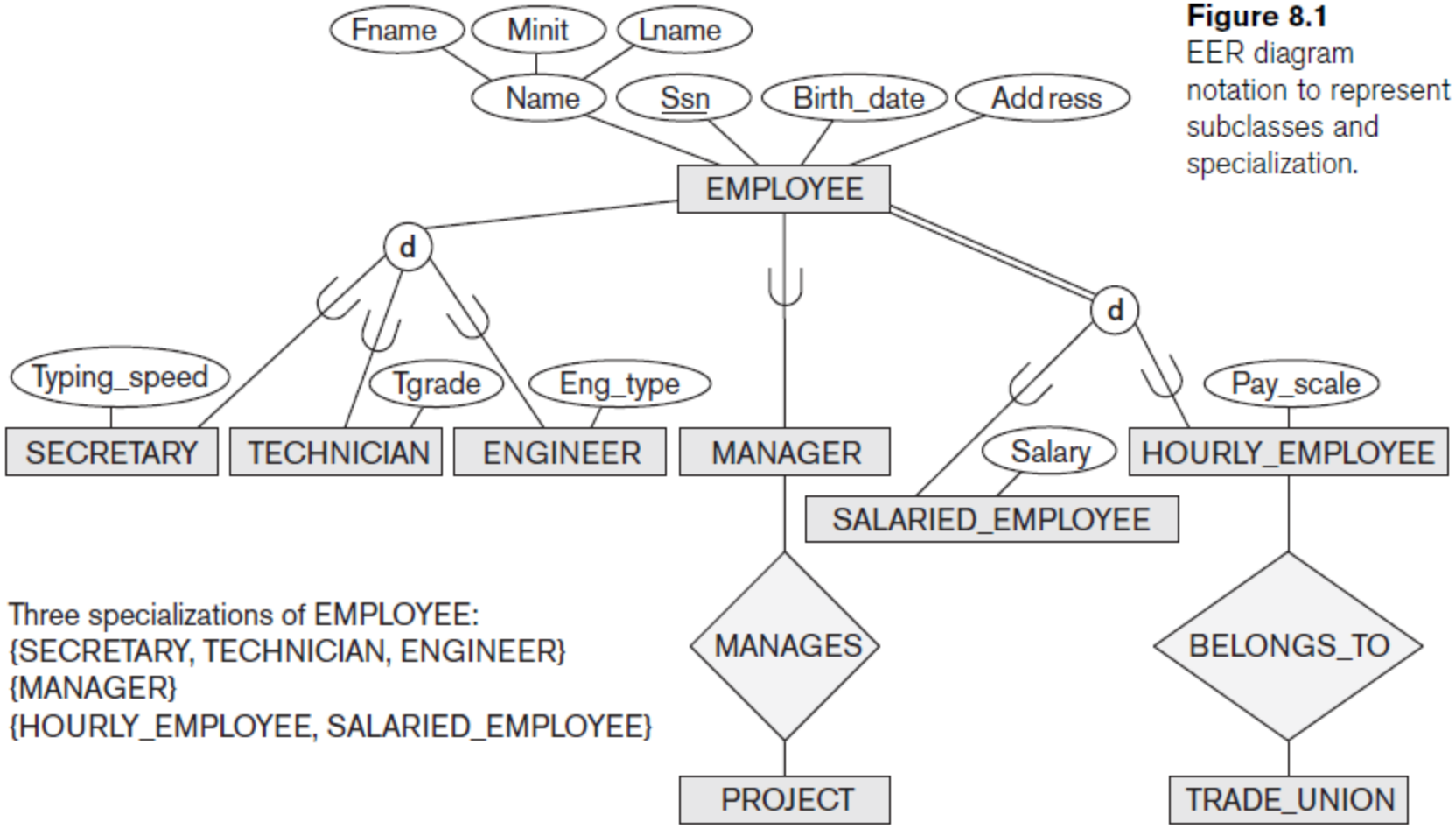


Figure 8.1
EER diagram notation to represent subclasses and specialization.

Three specializations of EMPLOYEE:
{SECRETARY, TECHNICIAN, ENGINEER}
{MANAGER}
{HOURLY_EMPLOYEE, SALARIED_EMPLOYEE}

Specialization : University

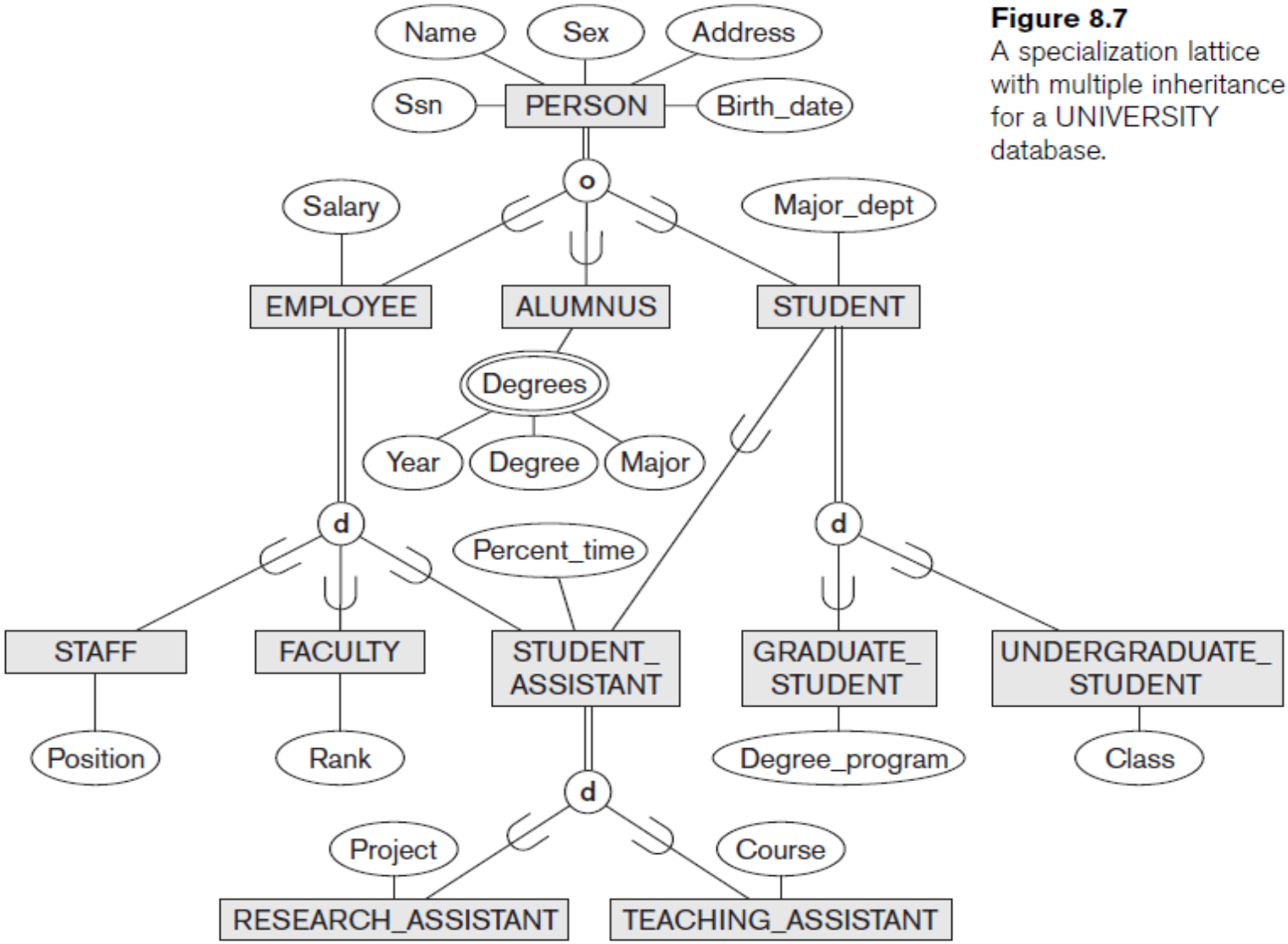


Figure 8.7
A specialization lattice with multiple inheritance for a UNIVERSITY database.

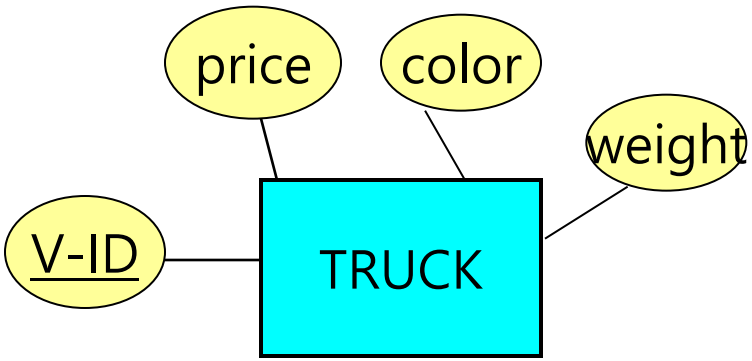
Generalization

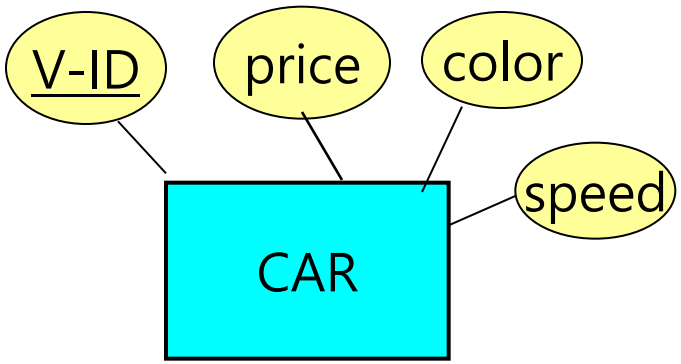
- The reverse of the Specialization process
- Bottom-Up (= Synthesis) modeling
- Based on IS-A relationship
- Several classes with common features are generalized into a superclass; Original classes become its subclasses
- Example:

  {CAR, TRUCK, BUS} can be generalized into VEHICLE;

Exercise

- 다음 TRUCK과 CAR에 대한 Generalization을 완성시켜라.





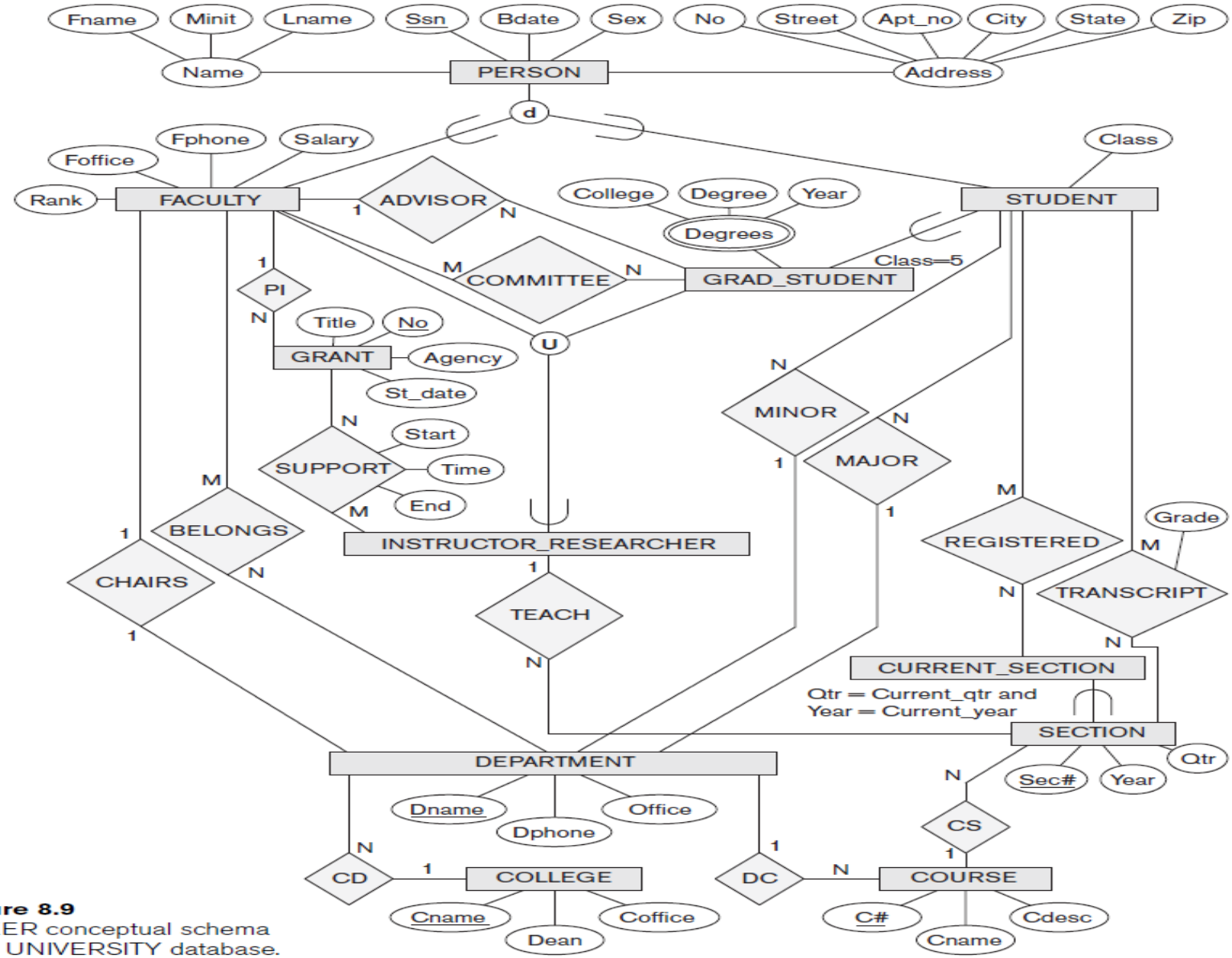


Figure 8.9
An EER conceptual schema for a UNIVERSITY database.