Conceptual and Logical Database Design

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CS411: Database Systems

Overview of Database Design

- Conceptual design: (ER & UML Models are used for this.)
  - What are the **entities** and **relationships** we need?
- Logical design:
  - Transform ER design to Relational Schema
- Schema Refinement: (Normalization) <-next lecture
  - Check relational schema for redundancies and related anomalies.
- Physical Database Design and Tuning:
  - Consider typical workloads; (sometimes) modify the database design; select file types and indexes.

Conceptual Database Design

From user/application requirements to Entity-Relationship Diagrams OR

Unified Modeling Language design

Entity-Relationship Model is a different model than the Relational Model

- Relational model has:
  - tables (relations) with attributes, keys, foreign keys, domain definitions for attributes
- Entity-Relationship model has:
  - Entities and entity sets with attributes, keys, and domain definitions for attributes
  - Relationships among entities and relationship sets with uniqueness or cardinality constraints

Entity Relationship Model
Unified Modeling Language

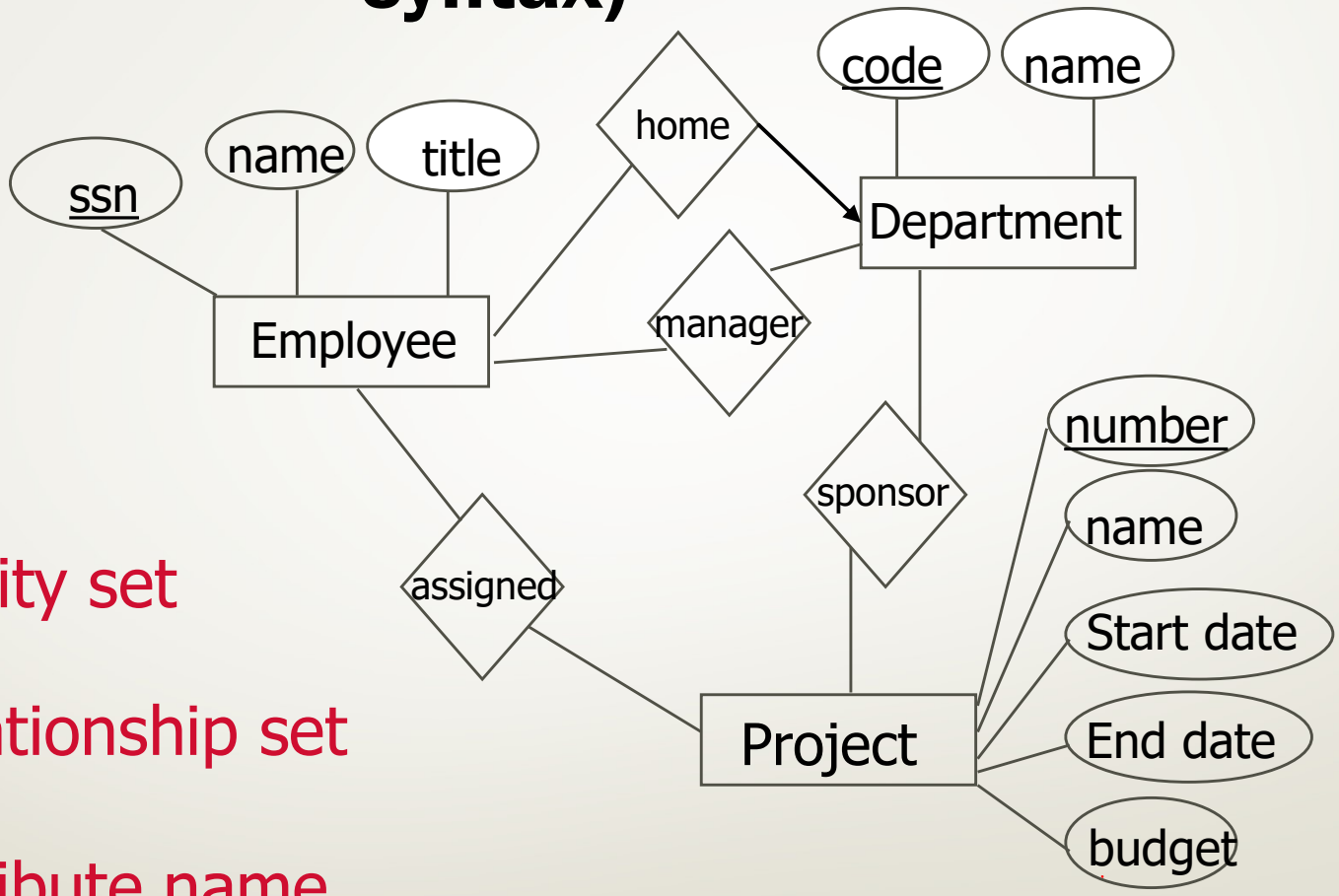
ER Model

- Proposed by Peter Chen in 1976
- Gives us a language to specify
  - What information the database must hold
  - How the bits of information relate to one another

UML Model

- UML is a standard language for designing software systems
  - also used for DB design
- created by the Object Management Group (OMG)
- **UML** 1.0 specification draft was proposed to the OMG in early 1997.

Entity-Relationship Diagram (original syntax)



Legend:

Entity set

Relationship set

Attribute name

Definitions

- *Entity:* Real-world object distinguishable from other objects.

  An entity is described using a set of *attributes.*

- *Entity Set*: A collection of similar entities. E.g., all employees.

  (often referred to as just entity, which blurs the distinction between type and collection)

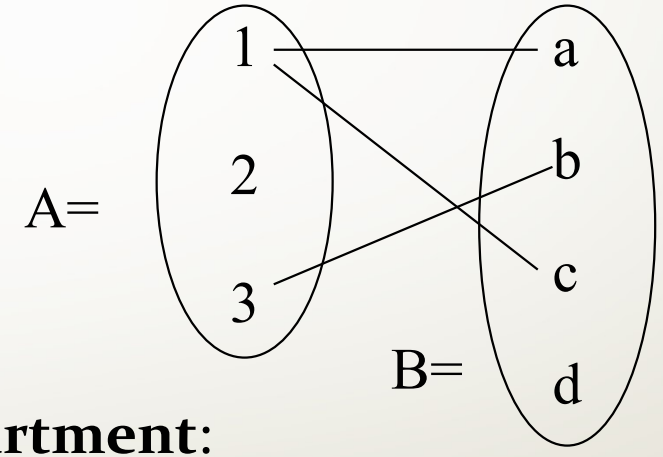
- *Relationship*: Association among 2 or more entities. E.g., Kristin's home department is Research & Development.

- *Relationship Set*: Collection of similar relationships. E.g., Home (often referred to as just relationship)

Relationships

- Formal definition:
  - if A, B are sets, then a relation R is a subset of A x B
- A={1,2,3}, B={a,b,c,d},

  R = {(1,a), (1,c), (3,b)}

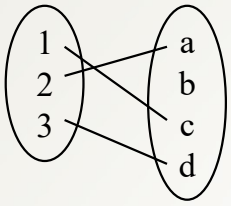


Same story w/ entity sets

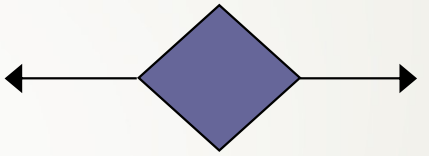
sponsor is a subset of **Project** x **Department**:

Multiplicity of ER Relationships

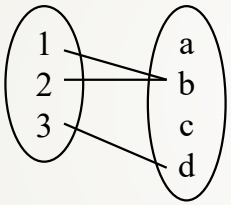
- one-one:



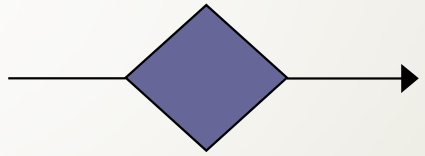
One on LHS/RHS connected to at most one on RHS/LHS



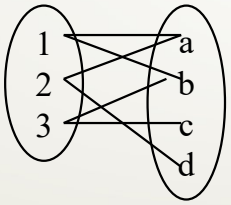
- many-one:



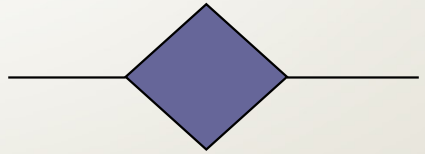
One on LHS connected to at most one on RHS



- many-many:

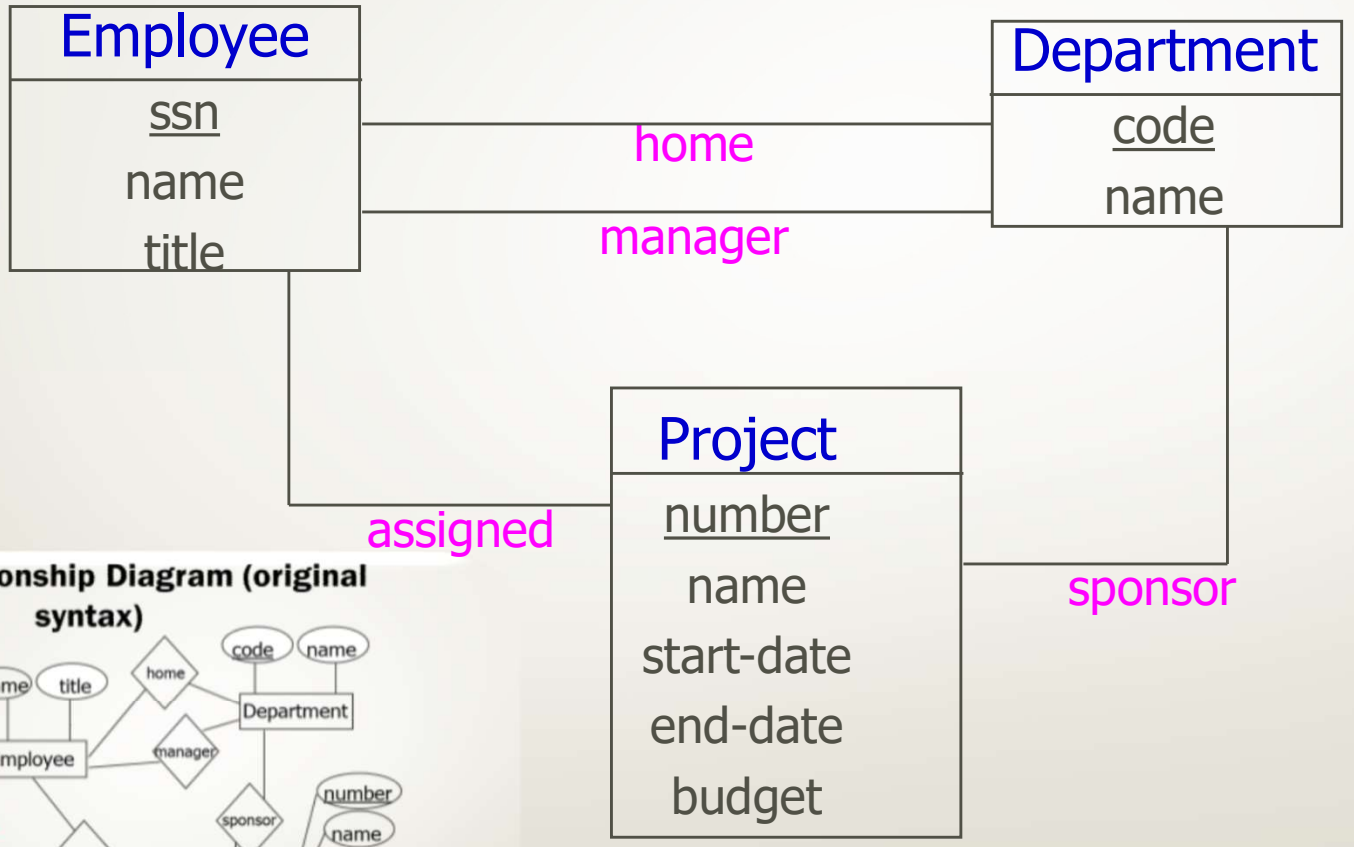


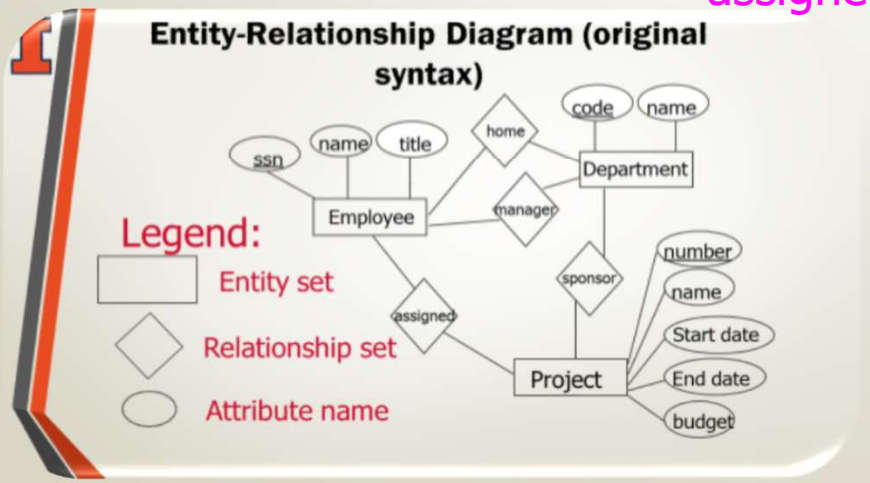
No constraints



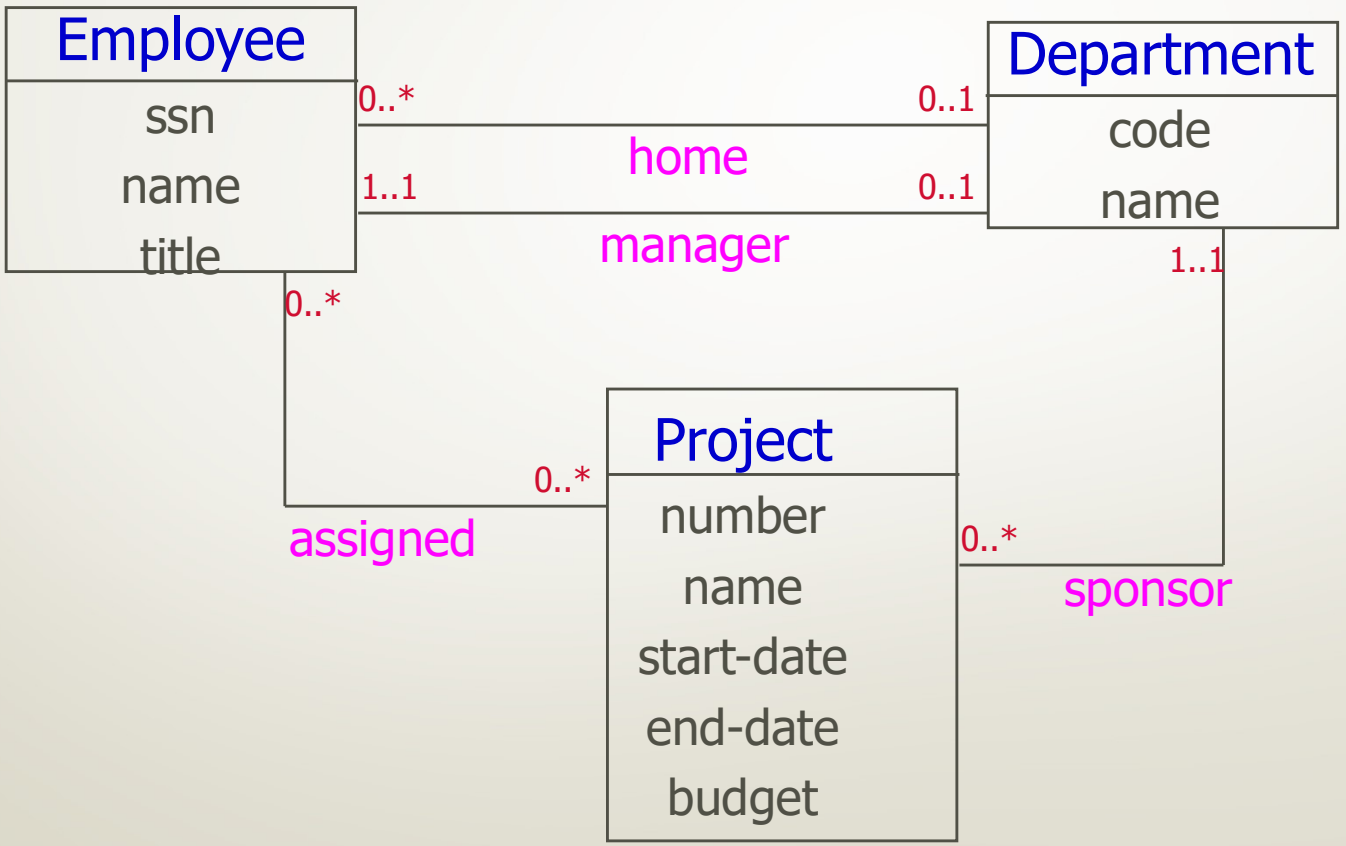
  - Multiplicity can be shown with arrows
  - Arrow = at most 1

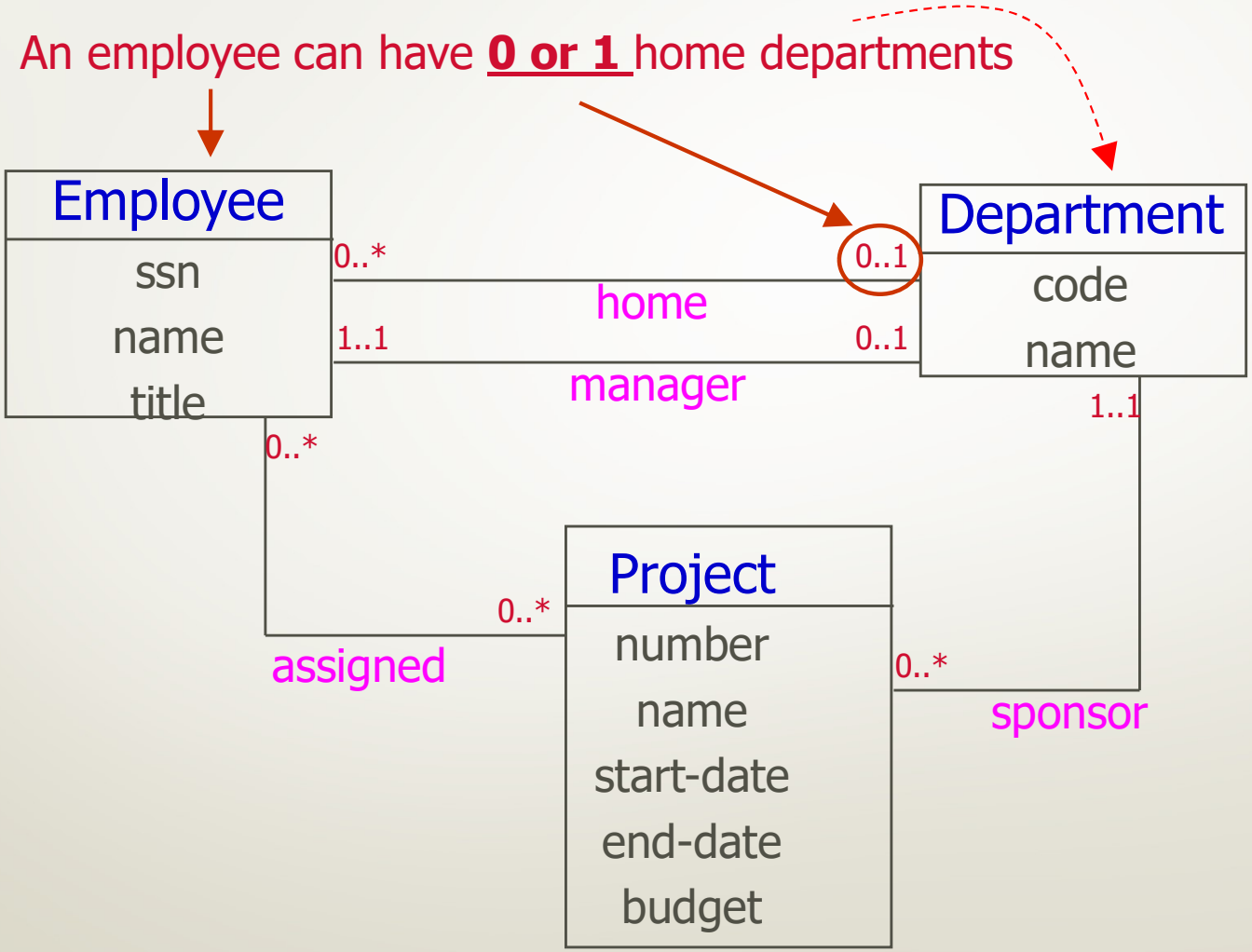
UML version of the same E-R Diagram

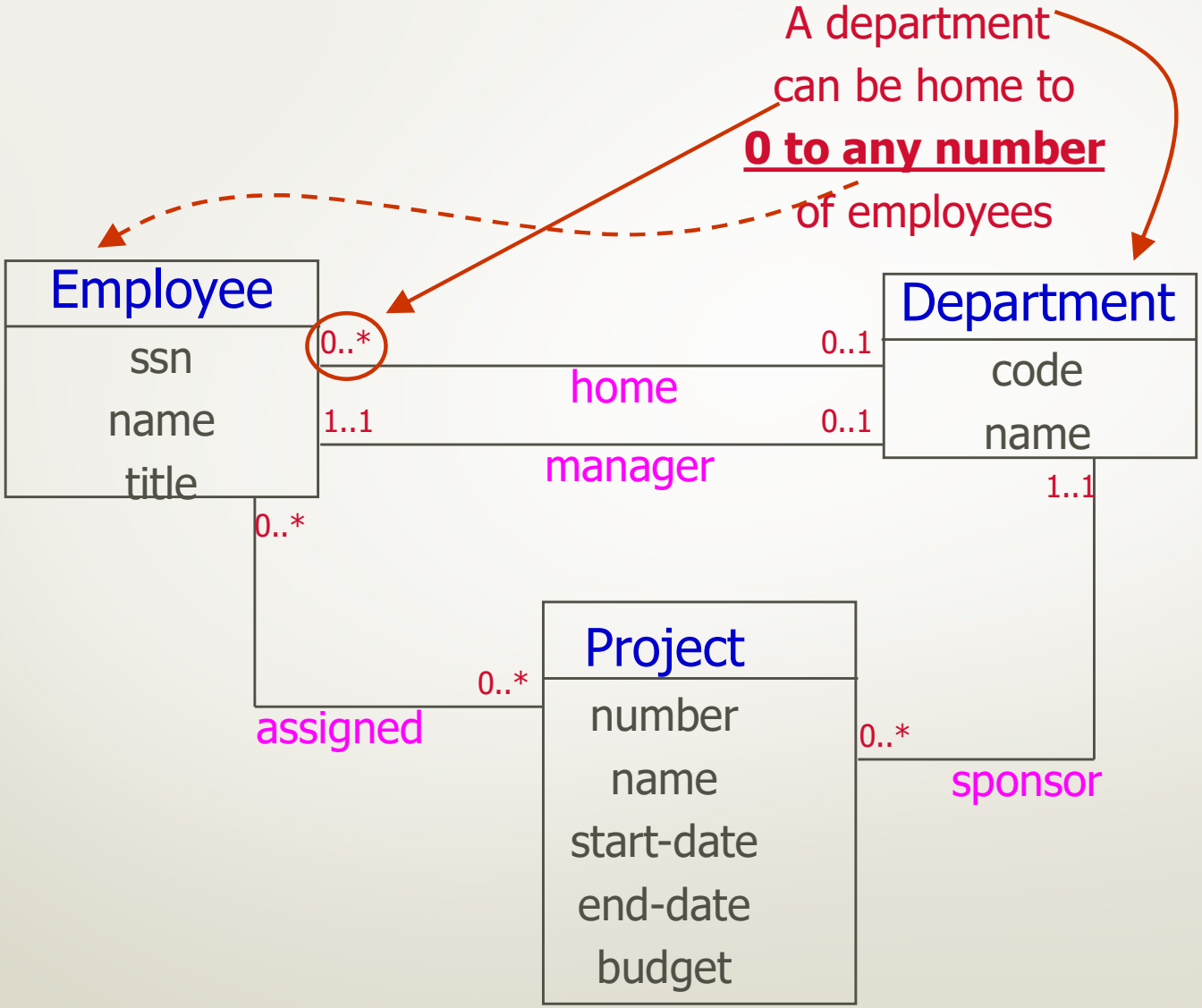




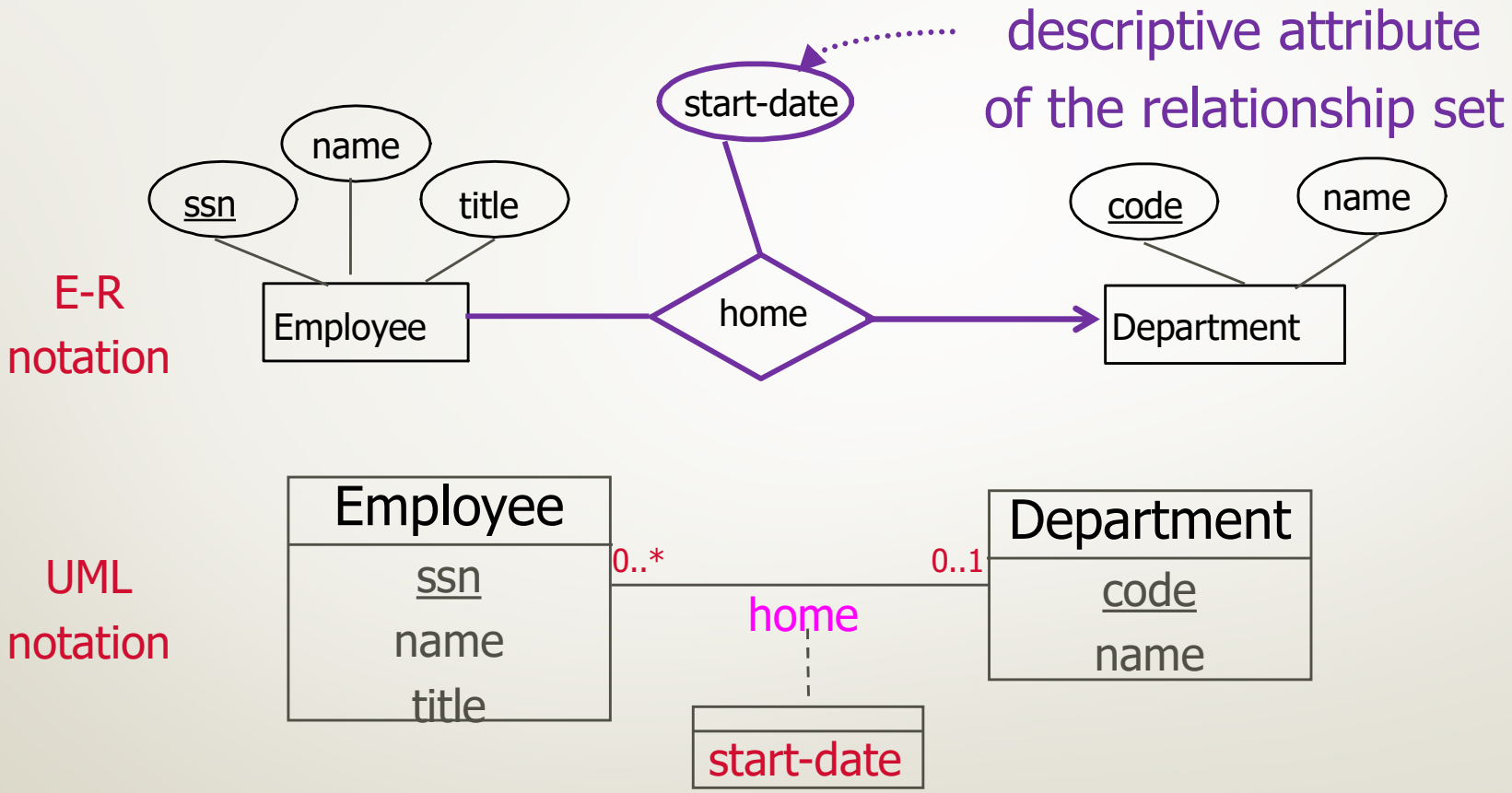
Cardinality Constraints on Relationship sets: How many entities can participate?




An employee can have 0 or 1 home departments
Employee
ssn
name
title
Department
code
name
Project
number
name
start-date
end-date
budget
0..*
0..1
home
1..1
0..1
manager
0..*
1..1
0..*
assigned
0..*
sponsor

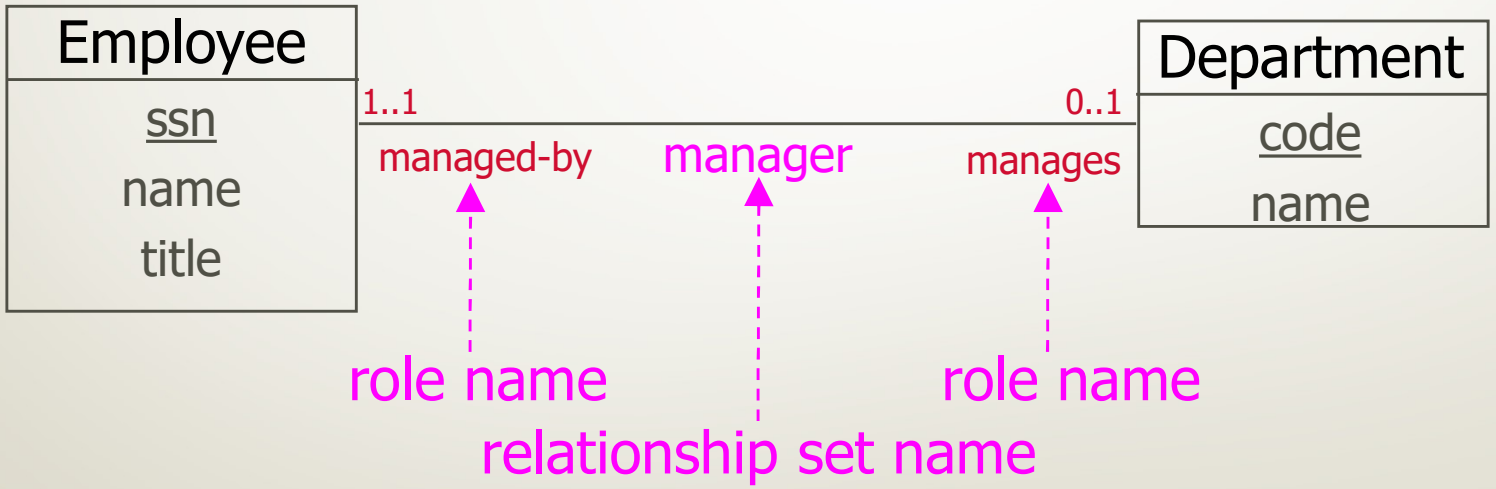

A department
can be home to
0 to any number
of employees
Employee
ssn
name
title
Department
code
name
Project
number
name
start-date
end-date
budget
0..*
0..1
home
1..1
0..1
manager
0..*
1..1
0..*
assigned
0..*
sponsor

Relationship sets can have attributes

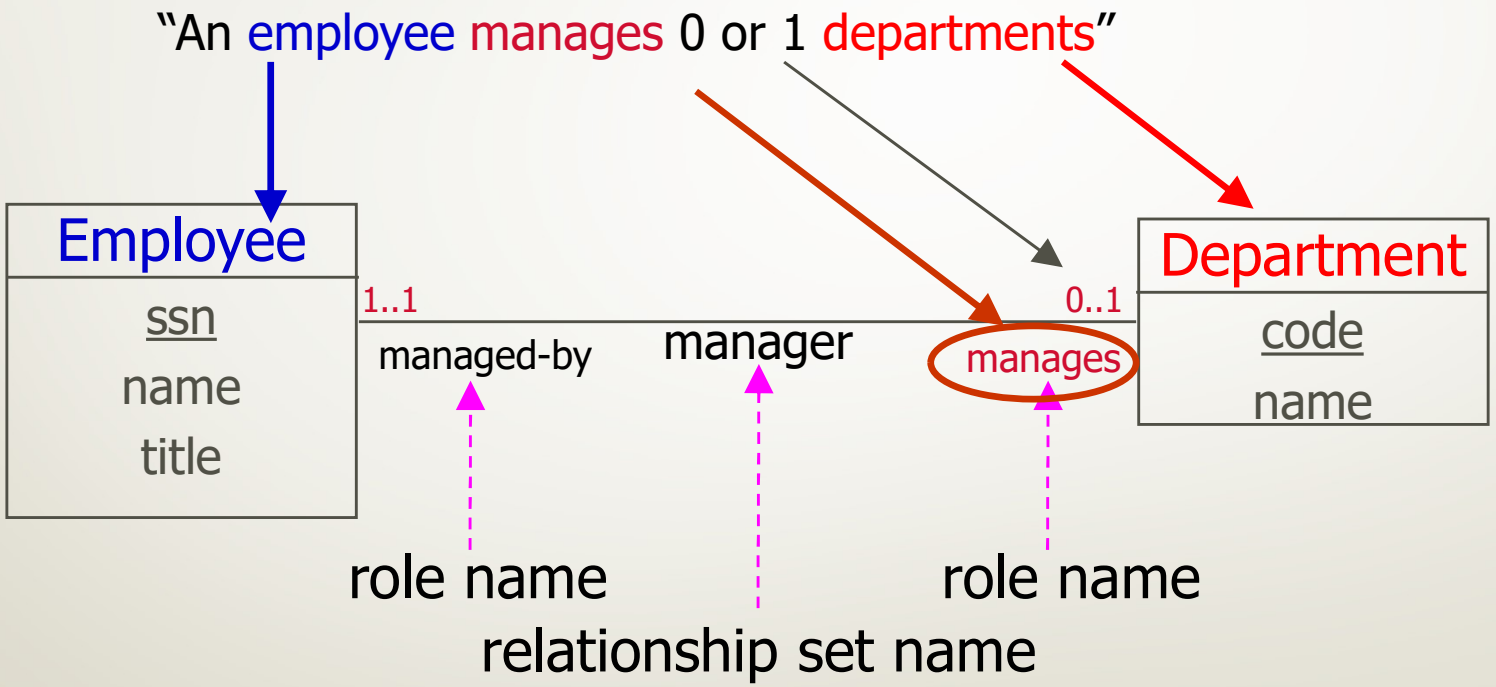


Relationship sets can have role names

(in addition to the name of the relationship set)

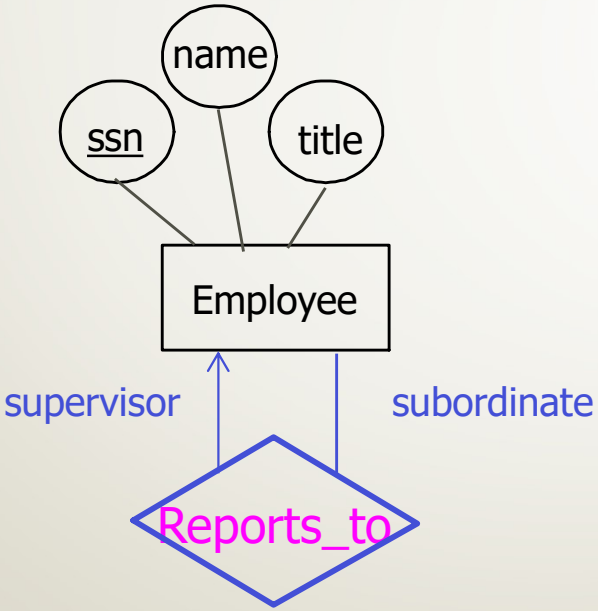


Example: reading role names

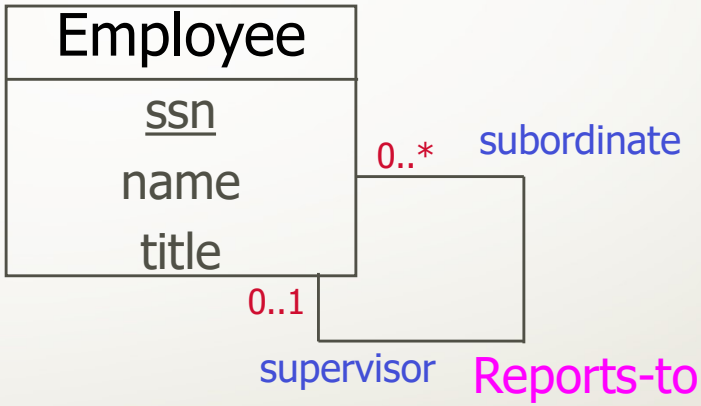


Same entity sets can participate in different "roles" for the same relationship set

E-R notation



UML notation



Constraints in ER diagram

- Recall that a constraint is an assertion about the database that must be true at all times
- Part of the database schema = structure

  (so it must be part of the ER diagram)
- Very important in database design

Modeling Constraints

Finding constraints is part of the modeling process.
Commonly used constraints:

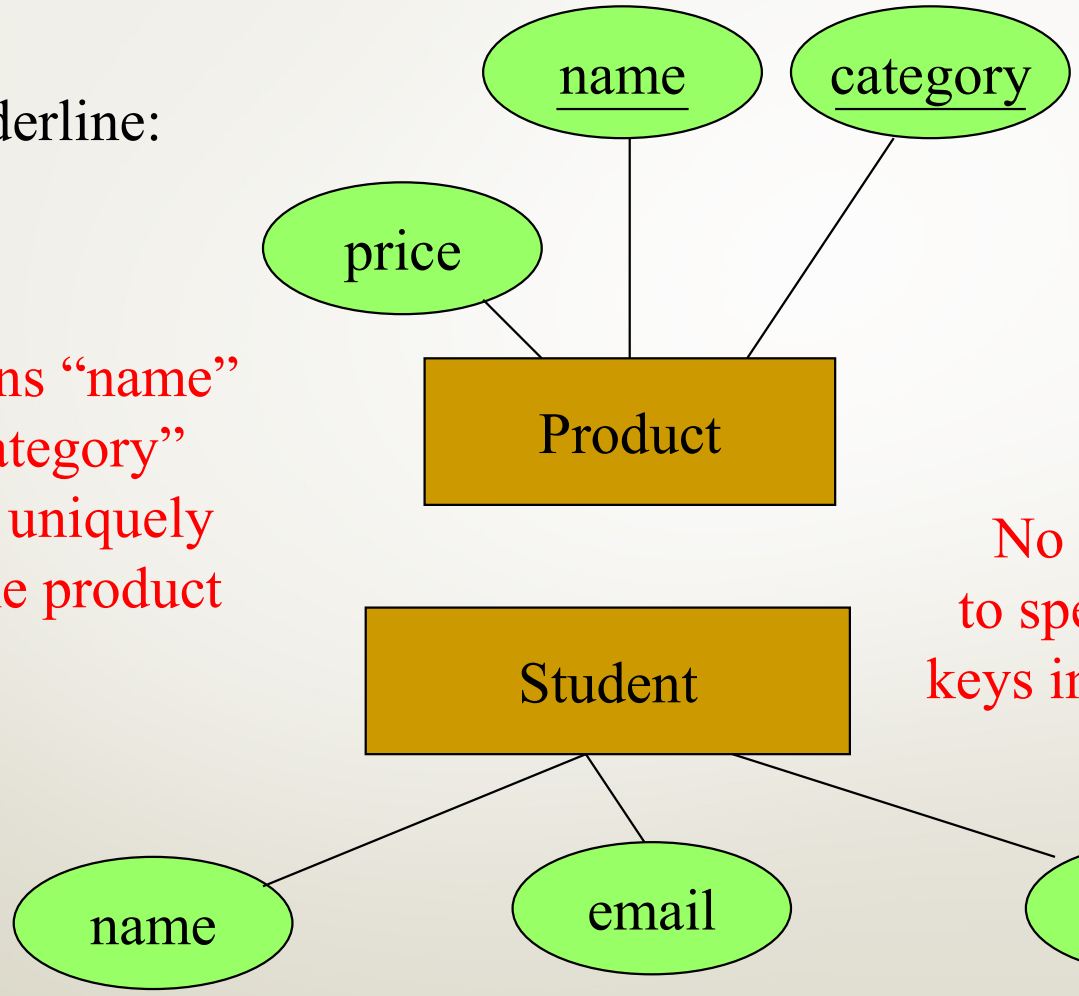
- Keys: attributes that identify entities in an entity set
  e.g., social security number uniquely identifies a person.

- Referential integrity constraints: relationship-based constraints
  e.g., if you work for a company, it must exist in the database.

- Domain constraints: peoples' ages are between 0 and 150.
- General constraints: all others (at most 50 students enroll in a class)

Keys in E/R Diagrams

Underline:



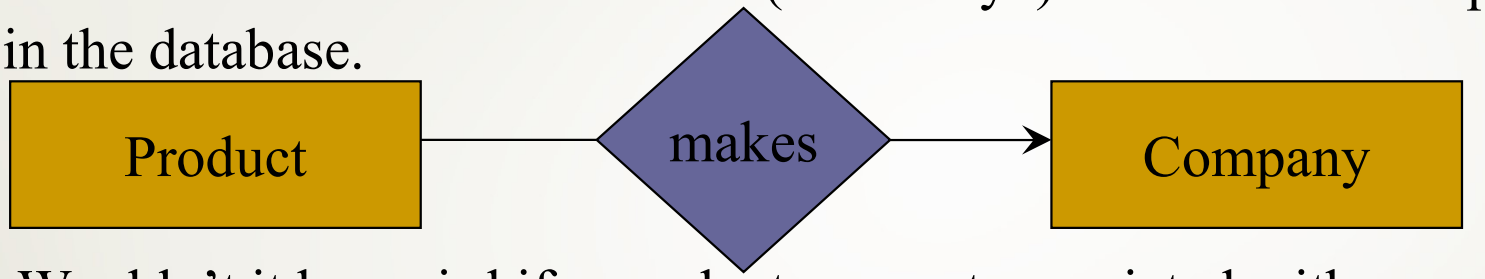
This means "name" and "category" together uniquely determine product

No formal way to specify multiple keys in E/R diagrams

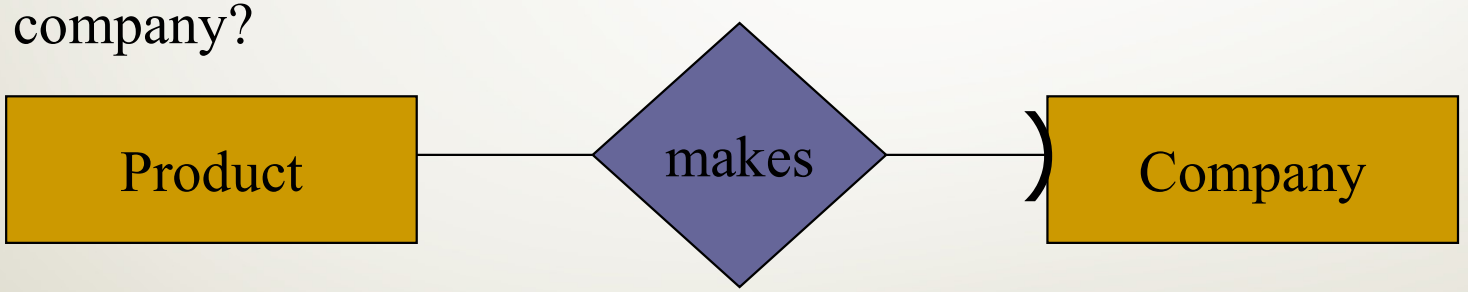
Referential Integrity Constraints

Recall: the arrow meant “at most one”.

Each Product must be related to (“made by”) at most one Company in the database.



Wouldn’t it be weird if a product was not associated with any company?



This says “exactly one”.

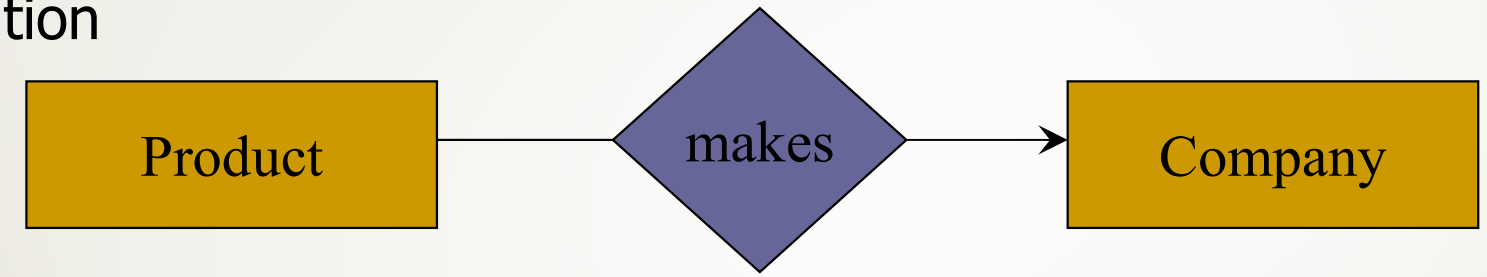
Each Product must be related to (“made by”) exactly one Company in the database.

Arrow = at most 1

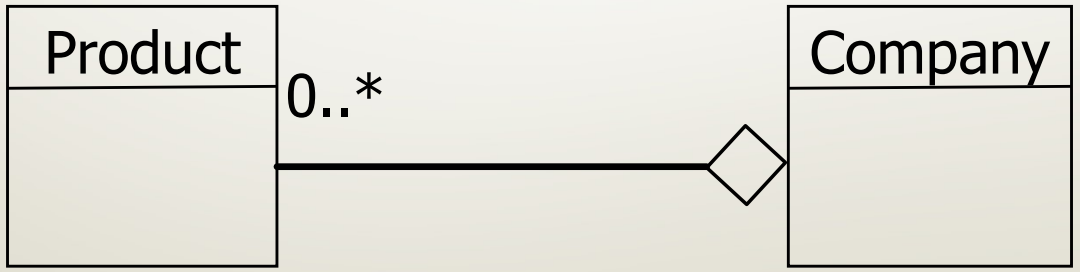
Semicircle = exactly 1

Referential Integrity Constraints
UML: Aggregation

ER Notation

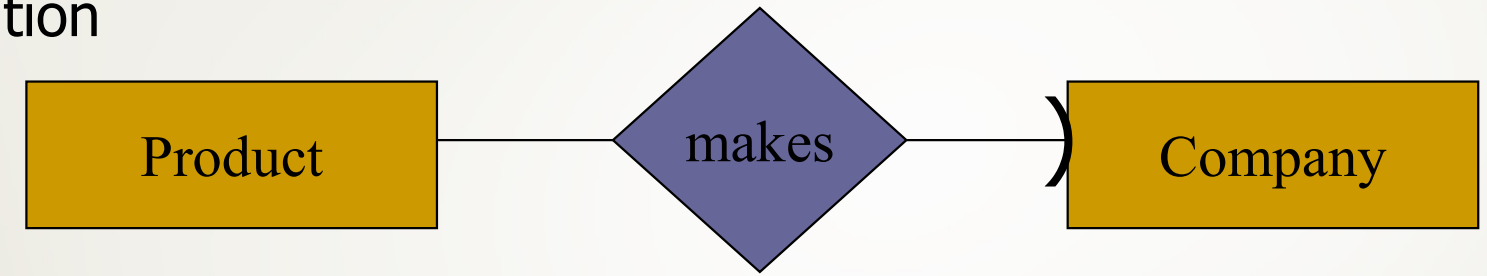


UML Notation

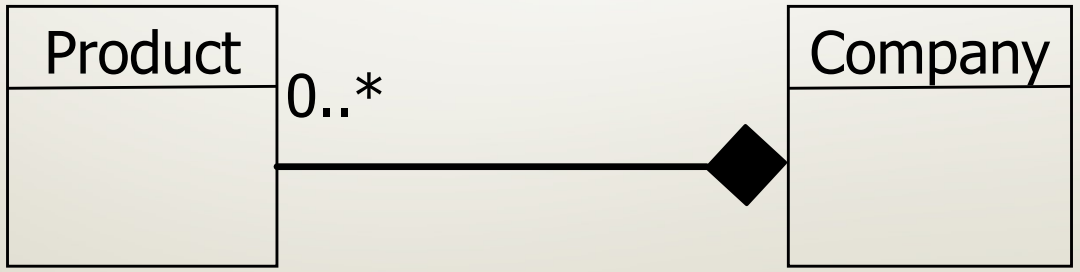


Referential Integrity Constraints
UML: Composition

ER Notation



UML Notation



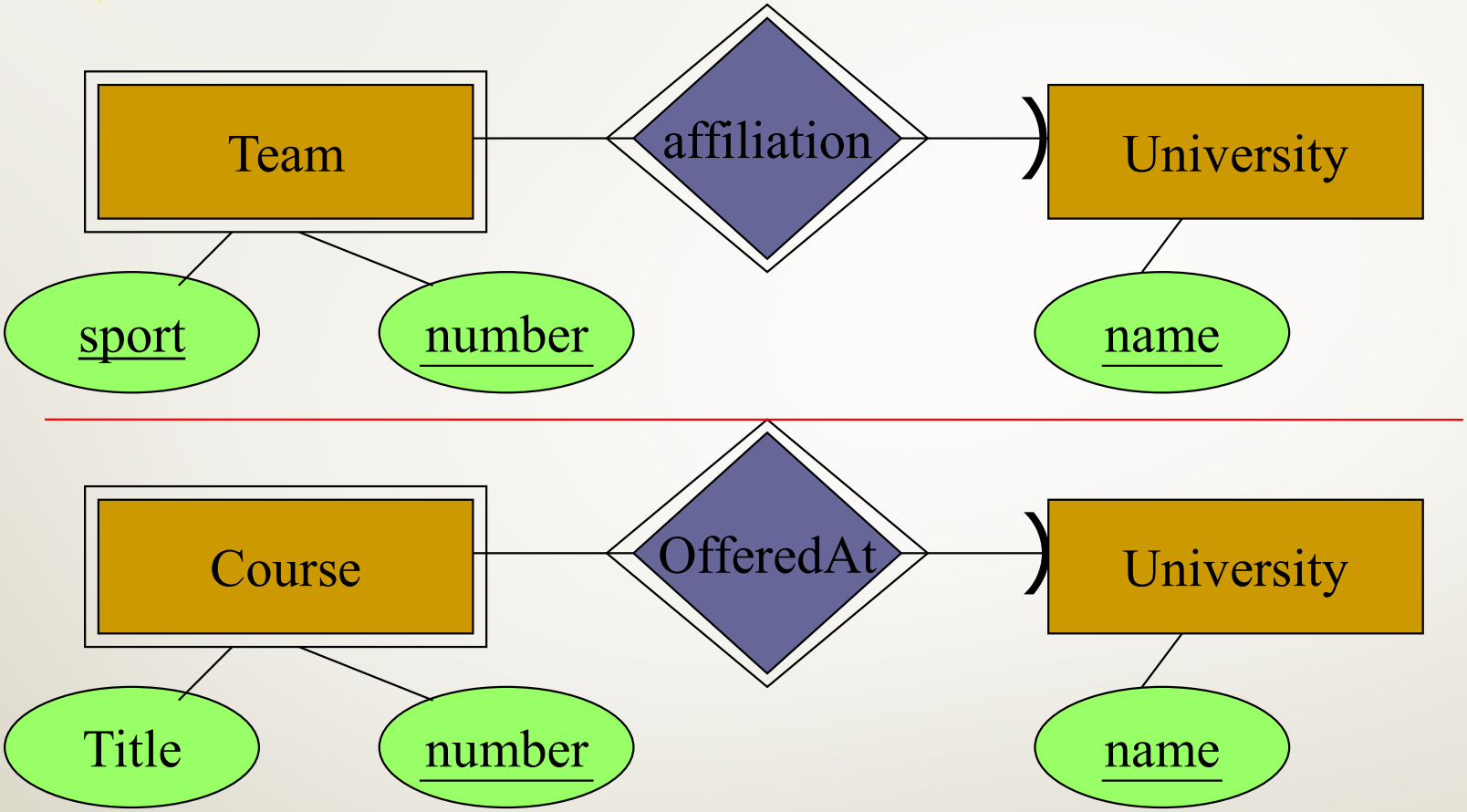
Weak Entity Sets

- Occasionally, entities of an entity set need "help" to identify them uniquely.

- Entity set *E* is *weak* if in order to identify entities of *E* uniquely, we need to follow one or more many-one relationships from *E* and include the key of the related entity sets.

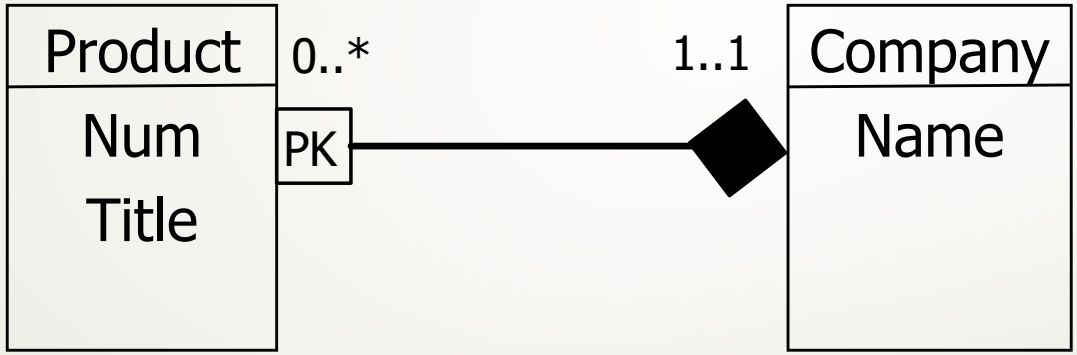
- Note: not an is-a relationship because *E* is not a "subclass" of *F:* Univ and Team

Notations for weak entity set



- "University" is a "supporting entity set" for "Team".
- "Affiliation" is a "supporting relationship".

Weak entity set in UML

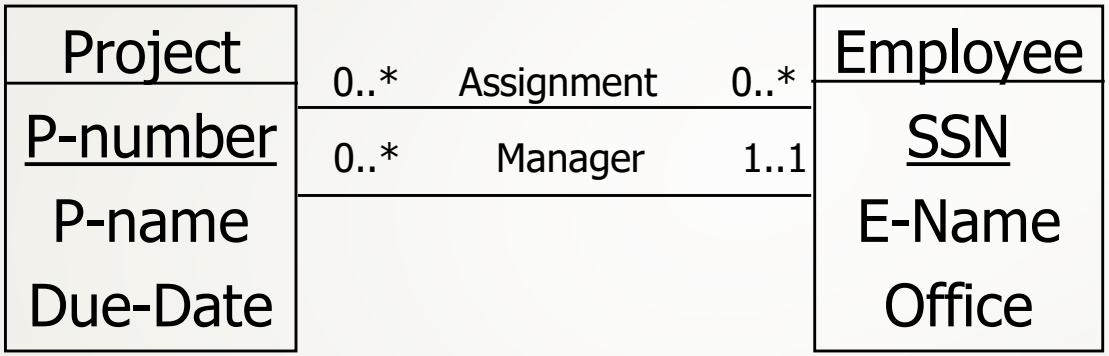


Logical Database Design

From Entity-Relationship Diagrams OR Unified Modeling Language design

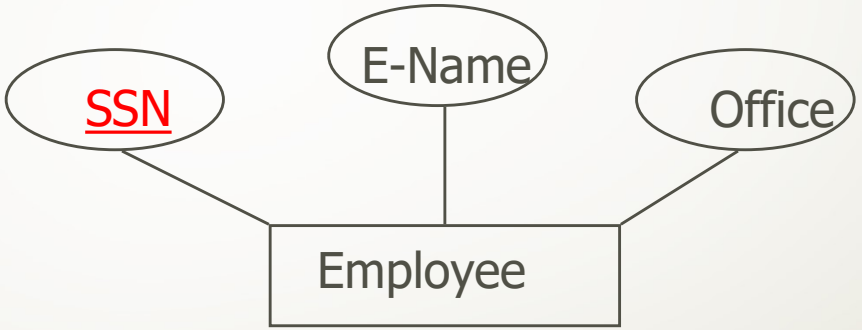
to Relational Database Schema

Converting ER to Relational Schema



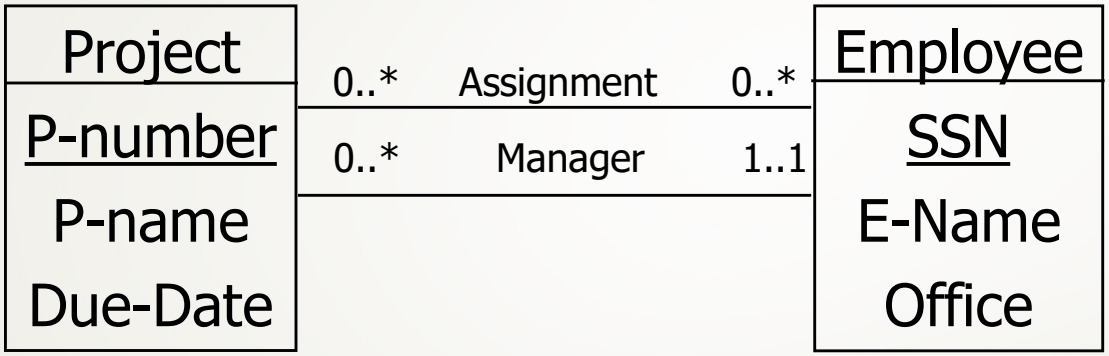
Translate each entity set into a table, with keys.

- Entity set:
  - can be represented as a table in the relational model
  - has a key … which becomes a key for the table




```
CREATE TABLE Employee
      (SSN CHAR(11) NOT NULL,
      E-Name CHAR(20),
      Office  INTEGER,
      PRIMARY KEY  (SSN))
```

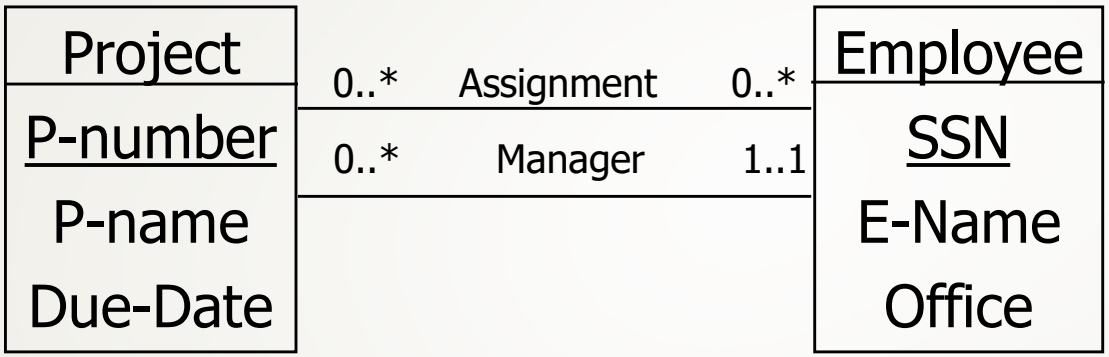
Translate each many-to-many relationship set into a table



What are the attributes and what is the key for Assignment?

Project(P-number, P-name, Due-Date)
Employee(SSN, E-Name, Office)

Translate each many-to-many relationship set into a table



Answer: Assignment(P-Number, SSN)

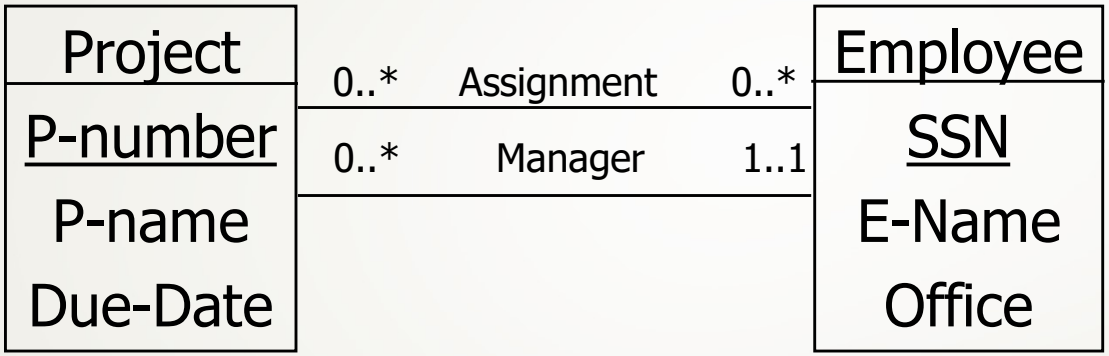
P-Number is a foreign key for Project

SSN is a foreign key for Employee

Project(P-Number, P-Due-Date)

Employee(SSN, E-Name, Office)

What should we do with each one-to-many relationship set?

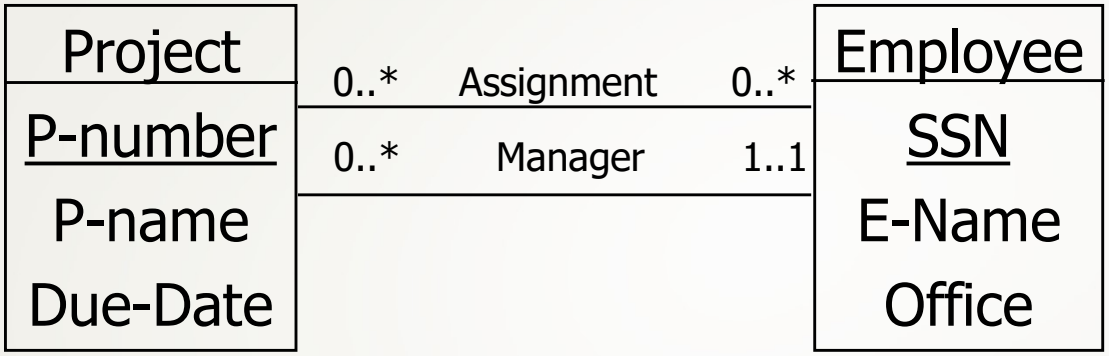


Manager (?)

Project(P-number, P-name, Due-Date)

Employee(SSN, E-Name, Office)

Create a foreign key for a 1-to-many relationship set.



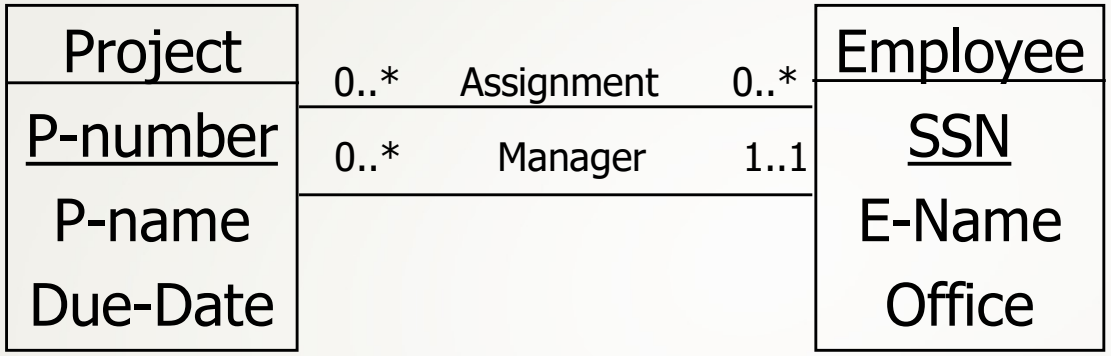
Project(P-number, P-name, Due-Date, MgrSSN)

Employee(SSN, E-Name, Office)

MgrSSN is a foreign key (referencing the Employee relation)

value of Manager must match an SSN

Create a foreign key for a 1-to-many relationship set.



Project(P-number, P-name, Due-Date, MgrSSN)

Employee(SSN, E-Name, Office)

vs.

Project(P-number, P-name, Due-Date)

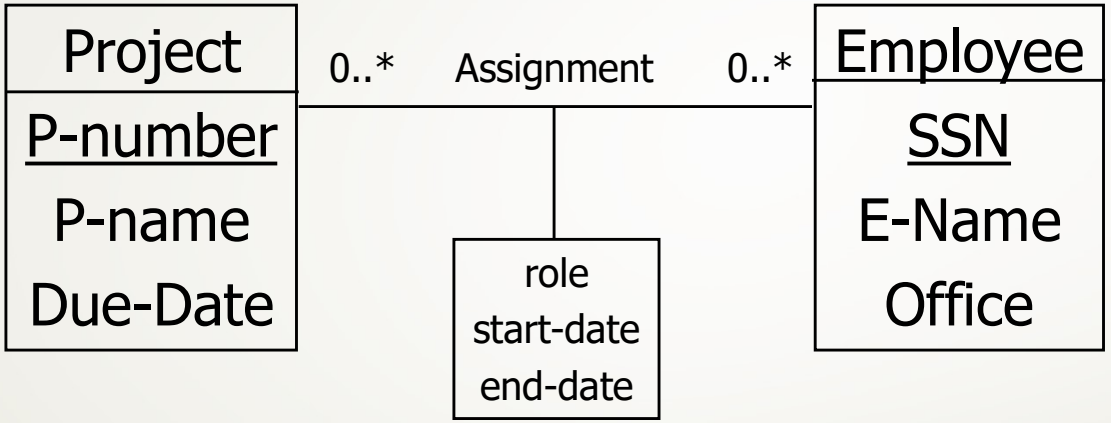
Employee(SSN, E-Name, Office)

Manager(P-number, SSN)

What are the tradeoffs between these two?

Note:
P-number
is the key
for Manager

What do we do when a many-to-many relationship set has an attribute?

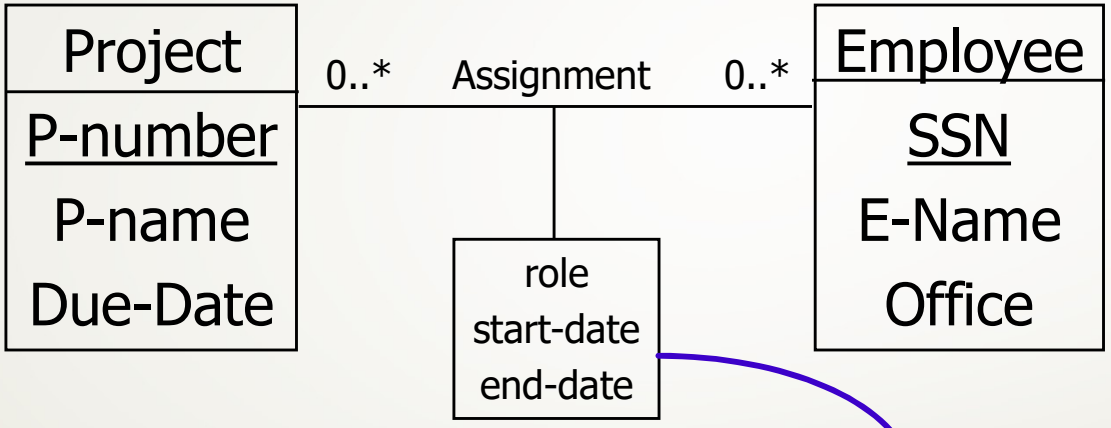


Assignment(P-number, SSN)

Project(P-number, P-name, Due-Date)

Employee(SSN, E-Name, Office)

What do we do when a many-to-many relationship set has an attribute?

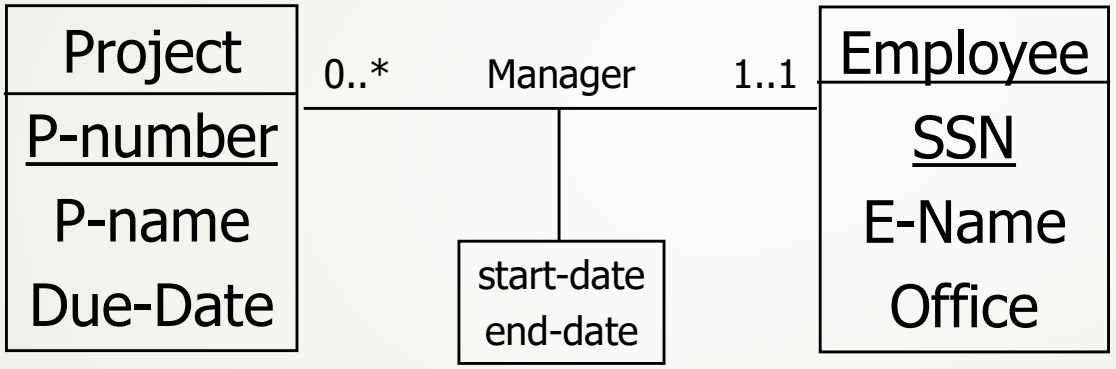


Assignment(P-number, SSN, role, start-date, end-date)

Project(P-number, P-name, Due-Date)

Employee(SSN, E-Name, Office)

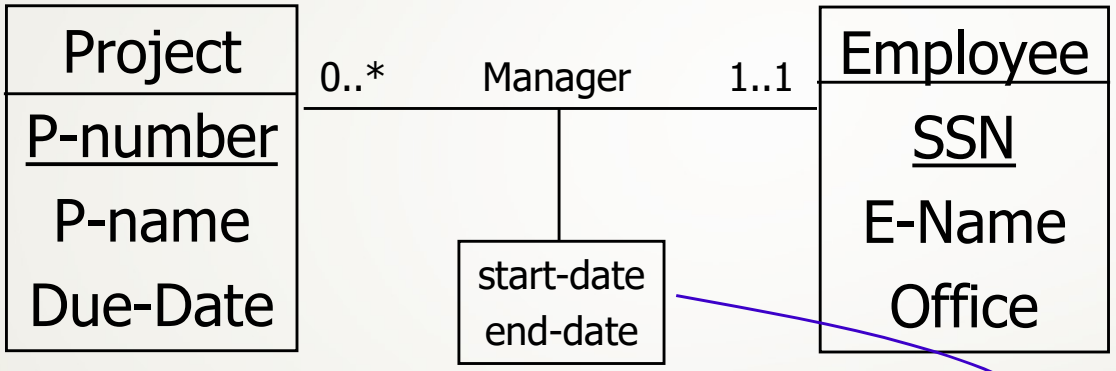
What do we do when a 1-to-many relationship set has an attribute?



Project(P-number, P-name, Due-Date, MgrSSN)

Employee(SSN, E-Name, Office)

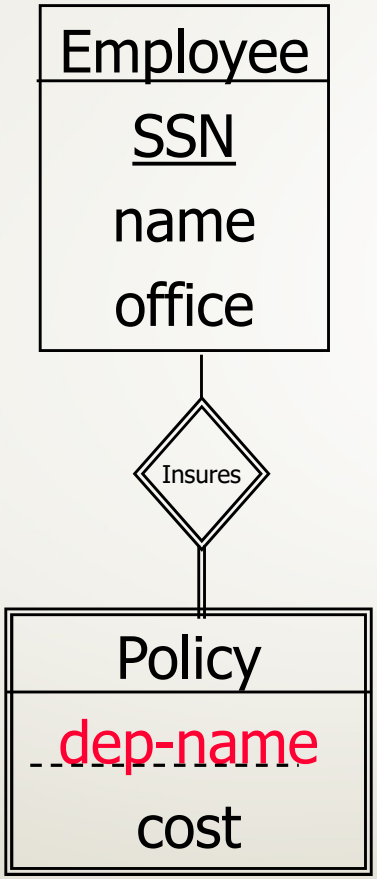
What do we do when a 1-to-many relationship set has an attribute?



Project(<u>P-number</u>, P-name, Due-Date, MgrSSN,
start-date, end-date)

Employee(<u>SSN</u>, E-Name, Office)

Weak Entity Sets



supporting entity set

supporting relationship set

weak Entity set

Translating Weak Entity Sets

- Weak entity sets and supporting relationship sets are translated into a single table. Must include key of supporting entity set, as a foreign key.
- When the owner entity is deleted, all owned weak entities must also be deleted.

```
CREATE TABLE  Insurance_Policy (
  dep-name          CHAR(20),
   cost             REAL,
   ssn              CHAR(11) NOT NULL,
   PRIMARY KEY  (dep-name, ssn),

   FOREIGN KEY (ssn) REFERENCES Employee,
      ON DELETE CASCADE)
```