Database Design: ER and UML Diagrams

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CS411: Database Systems

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CS411 Goals: Two Perspectives of DBMS

- USER PERSPECTIVE
  - **how to use a database system?**
  - conceptual data modeling, the relational and other data models, database schema design, relational algebra, SQL and No-SQL query languages.
- SYSTEMS PERSPECTIVE
  - **how to design and implement a database system?**
  - data representation, indexing, query optimization and processing, transaction processing, and concurrency control.
  - NOT COMPLETE: high-level view of implementation; CS511

Overview of Database Design

Today's lecture

- 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

We'll do this next lecture

- Schema Refinement: (Normalization)
  - 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.

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

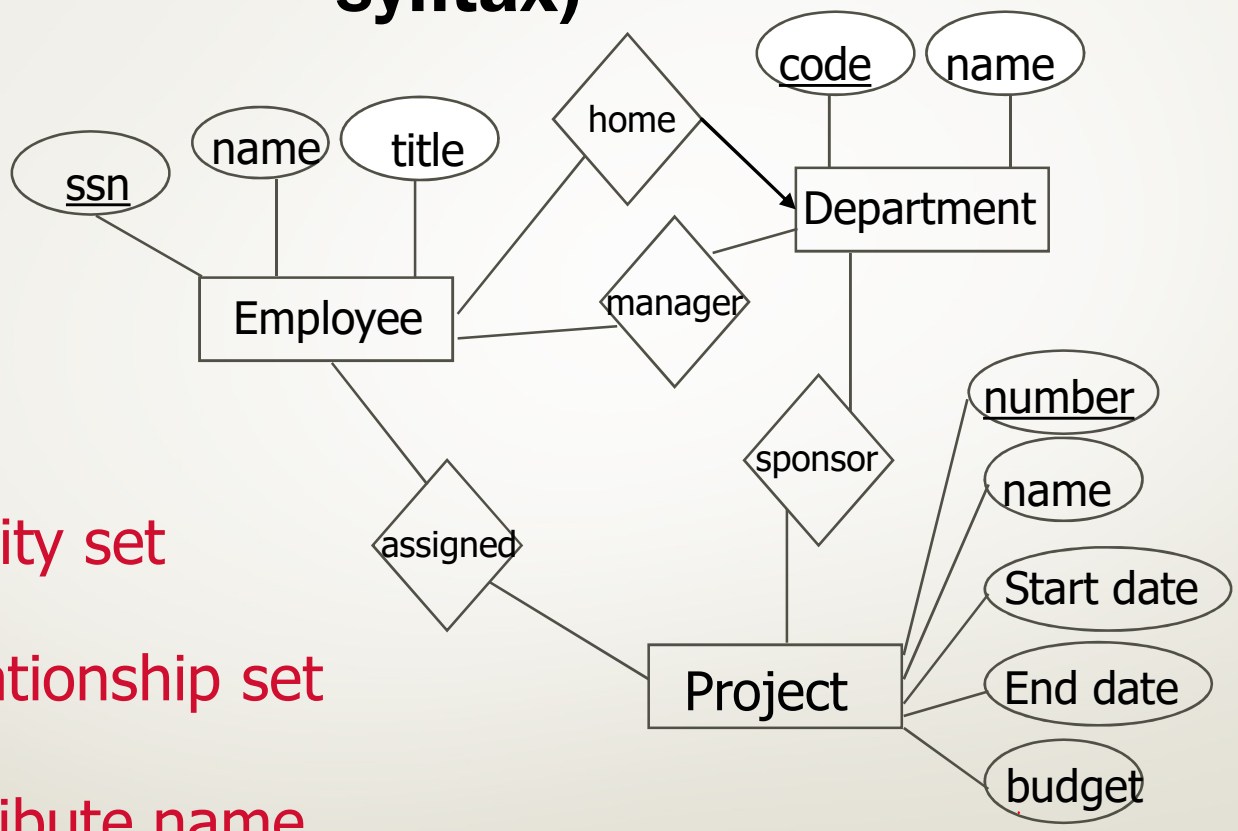
ER Model

- 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)

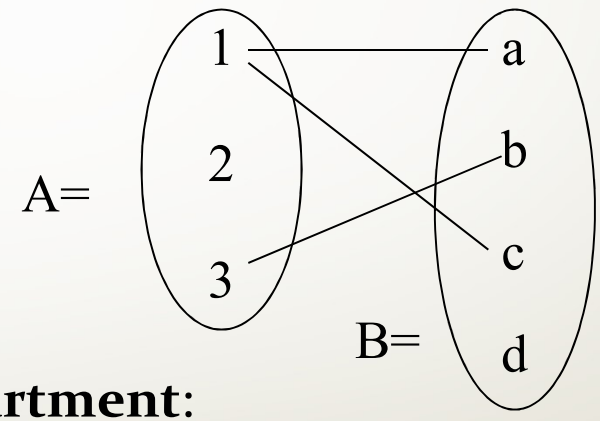
- *Relationship*: Association among 2 or more entities. E.g., Kristin's home department is Research & Development.

- *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)}

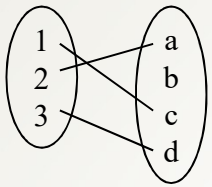


Same story w/ entity sets

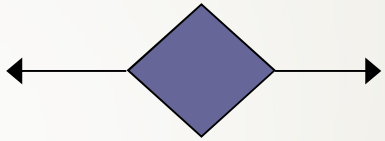
sponsor is a subset of **Project** x **Department**:

Multiplicity of ER Relationships

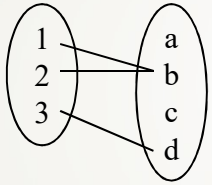
- one-one:



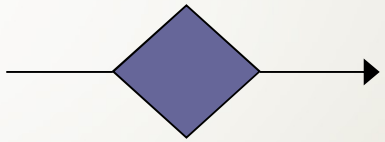
One on LHS/RHS connected to at most one on RHS/LHS



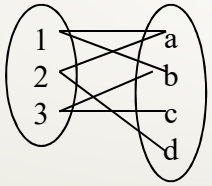
- many-one:



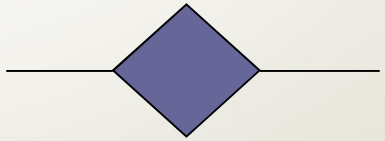
One on LHS connected to at most one on RHS



- many-many:

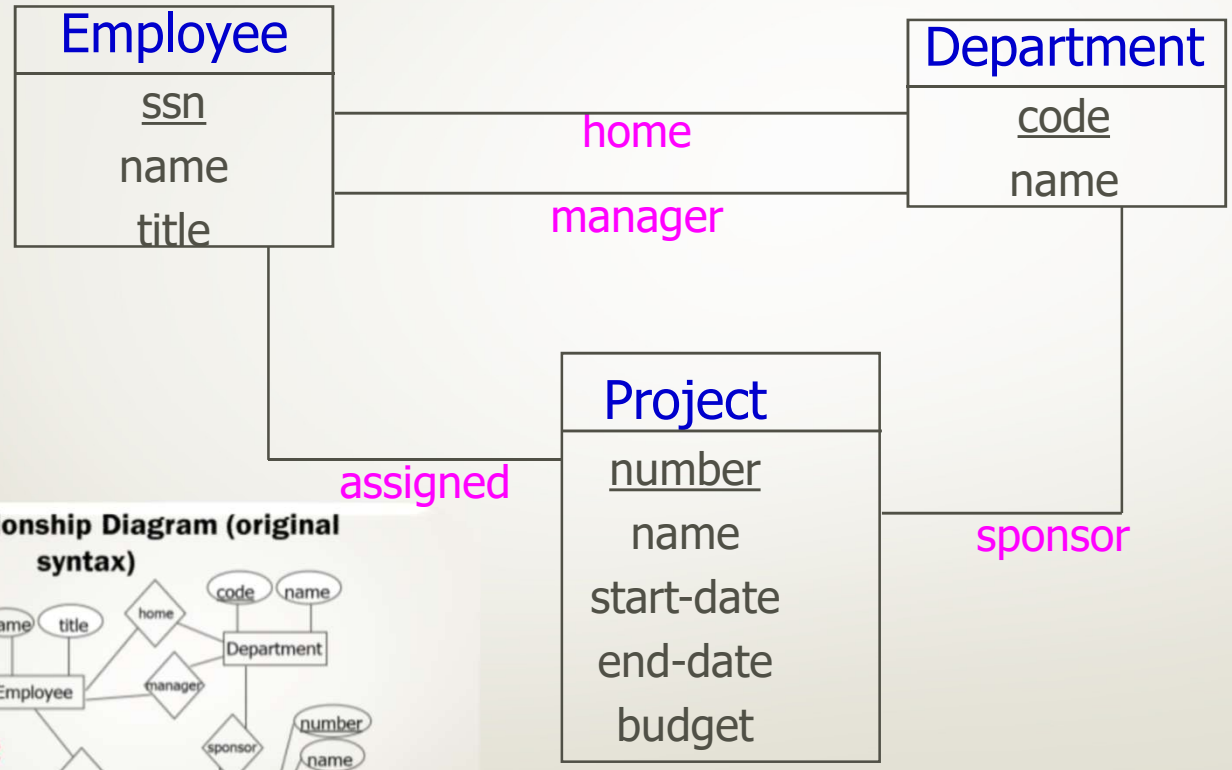


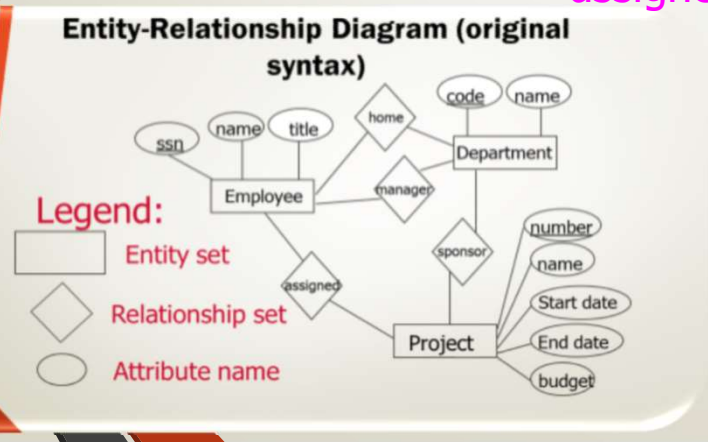
No constraints



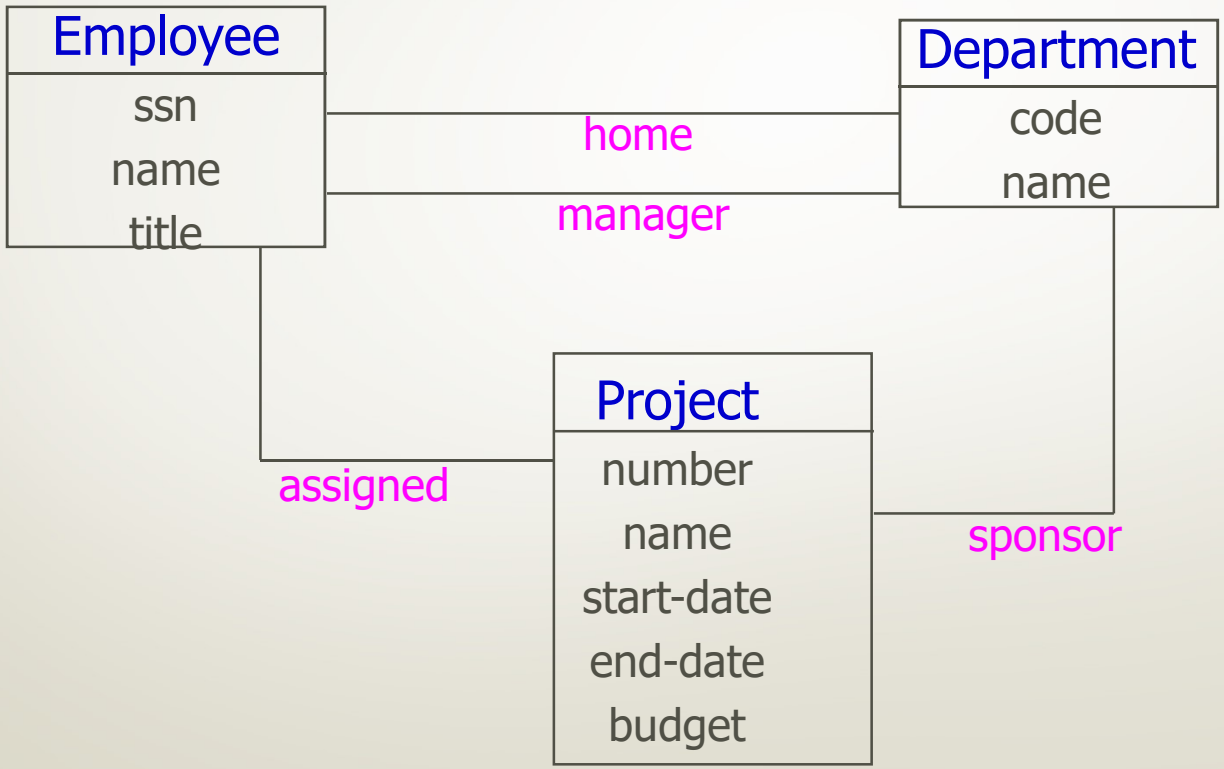
- Multiplicity can be shown with arrows
- Arrow = at most 1

UML version of the same E-R Diagram

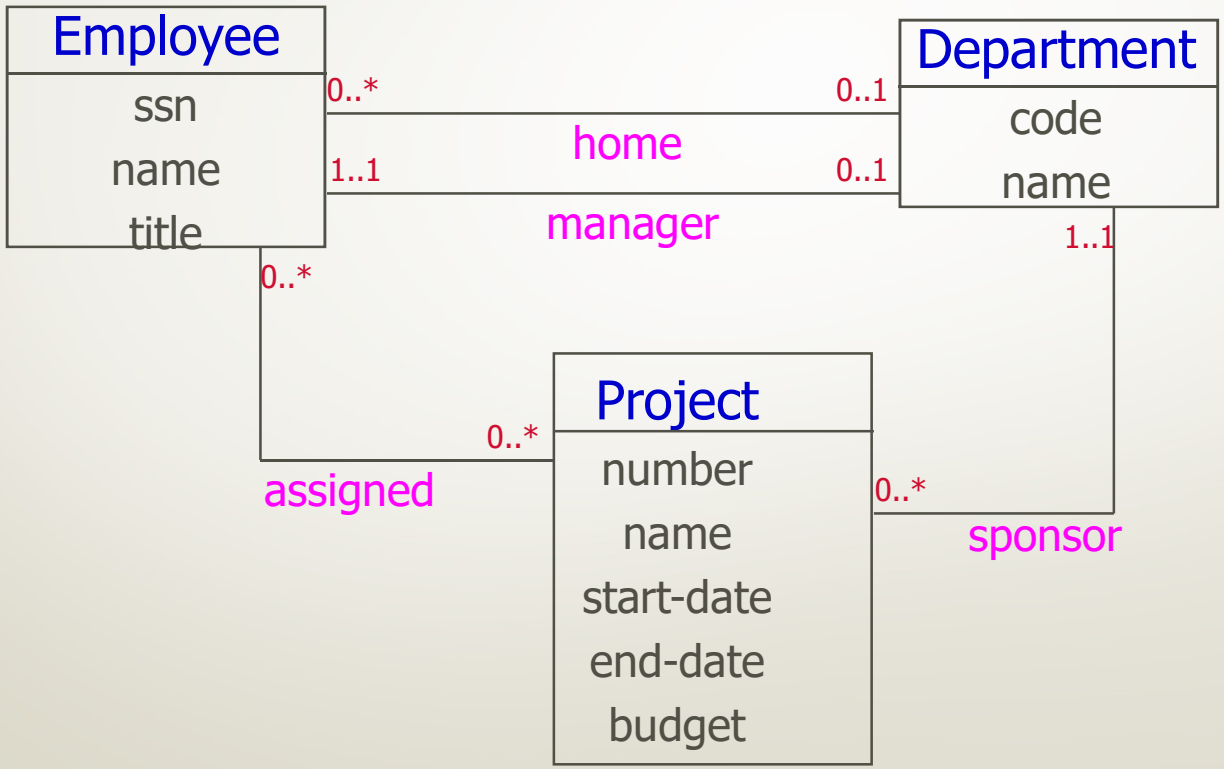




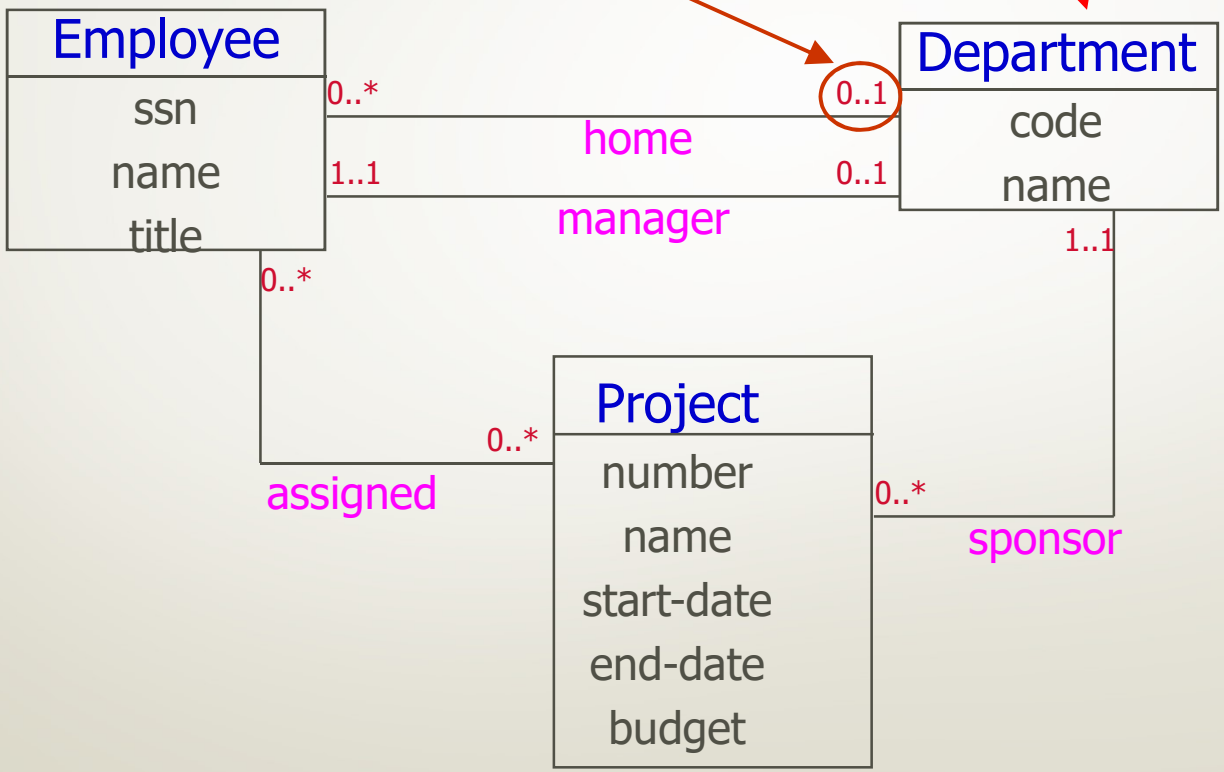
Cardinality Constraints on Relationship sets: How many entities can participate?

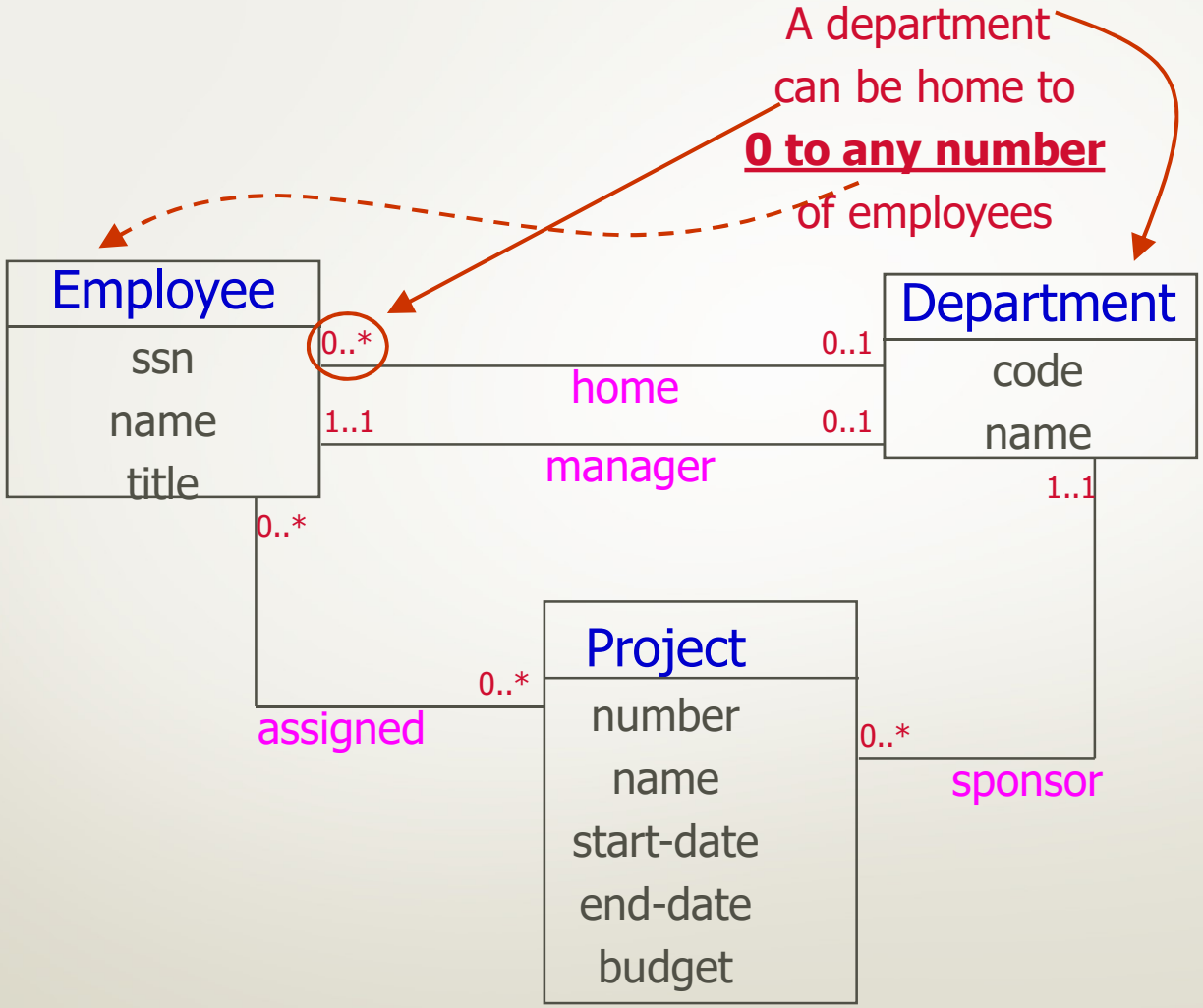


Cardinality Constraints on Relationship sets: How many entities can participate?



An employee can have **0 or 1** home departments

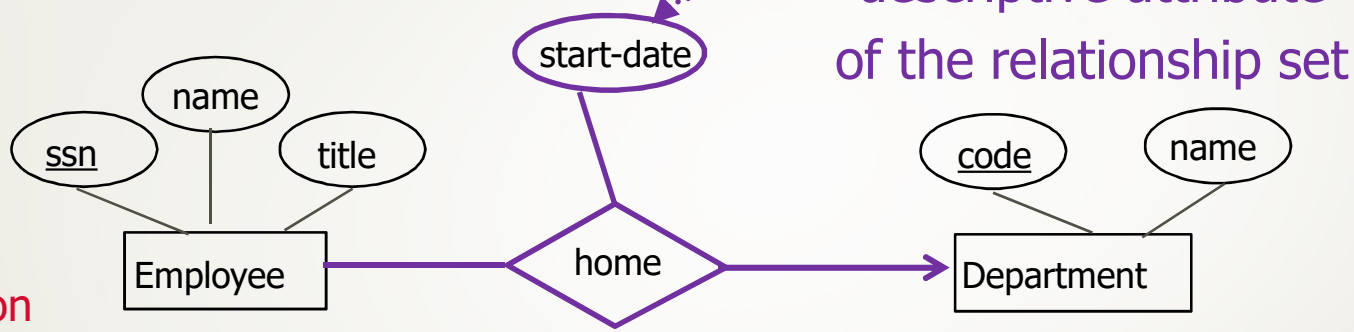




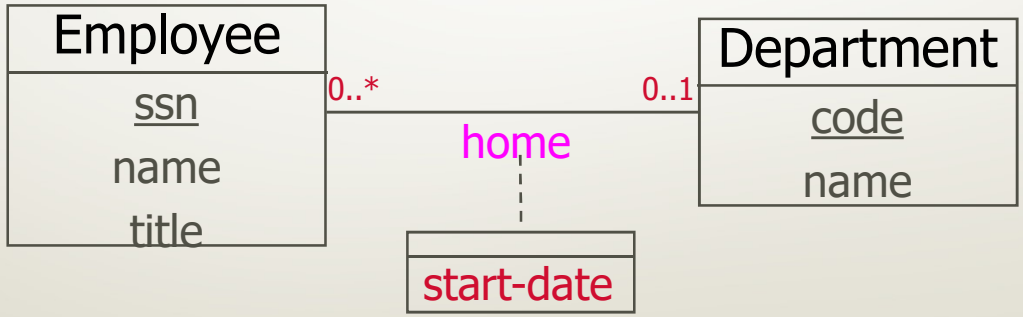
Relationship sets can have attributes

descriptive attribute of the relationship set

E-R notation

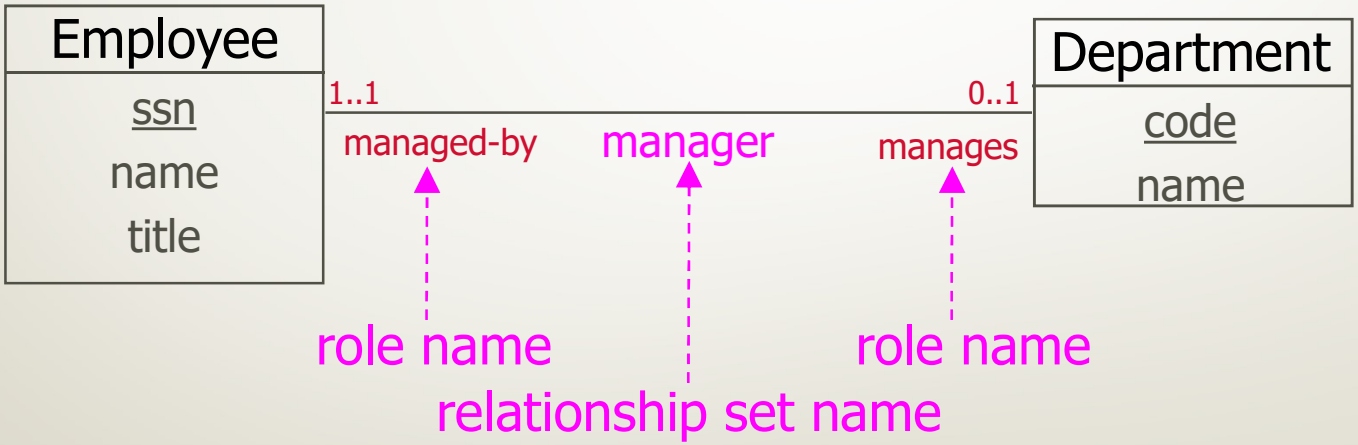


UML notation



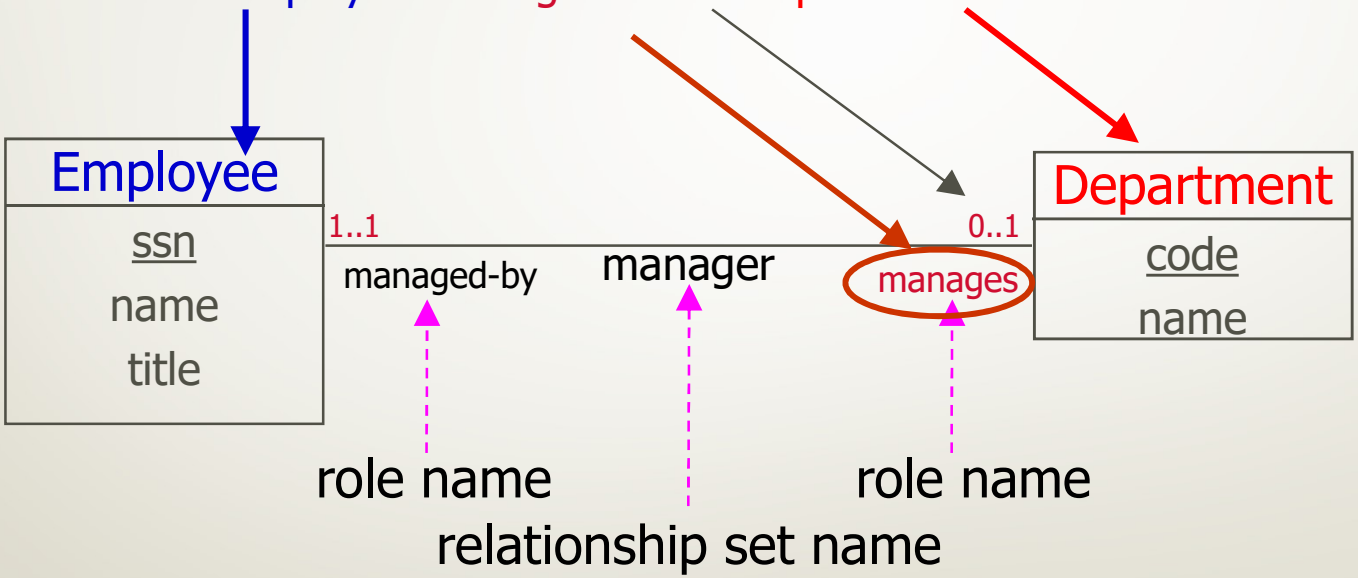
Relationship sets can have role names

(in addition to the name of the relationship set)



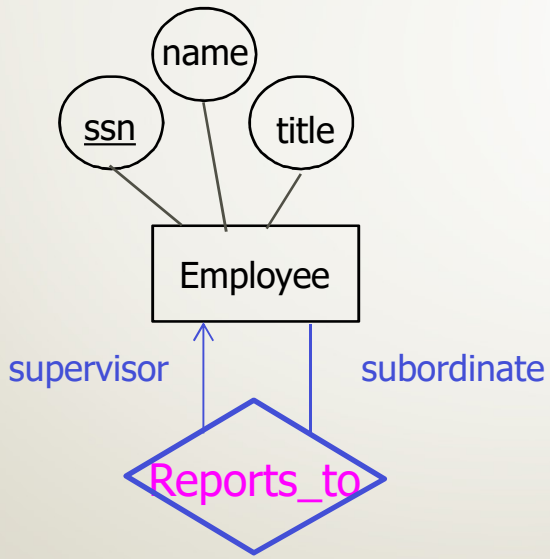
Example: reading role names

"An employee manages 0 or 1 departments"

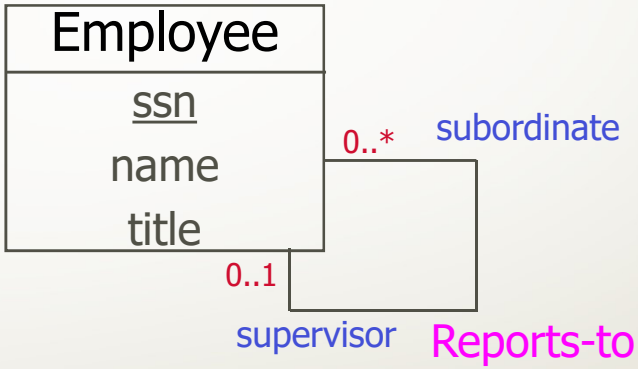


Same entity sets can participate in different "roles" for the same relationship set

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:

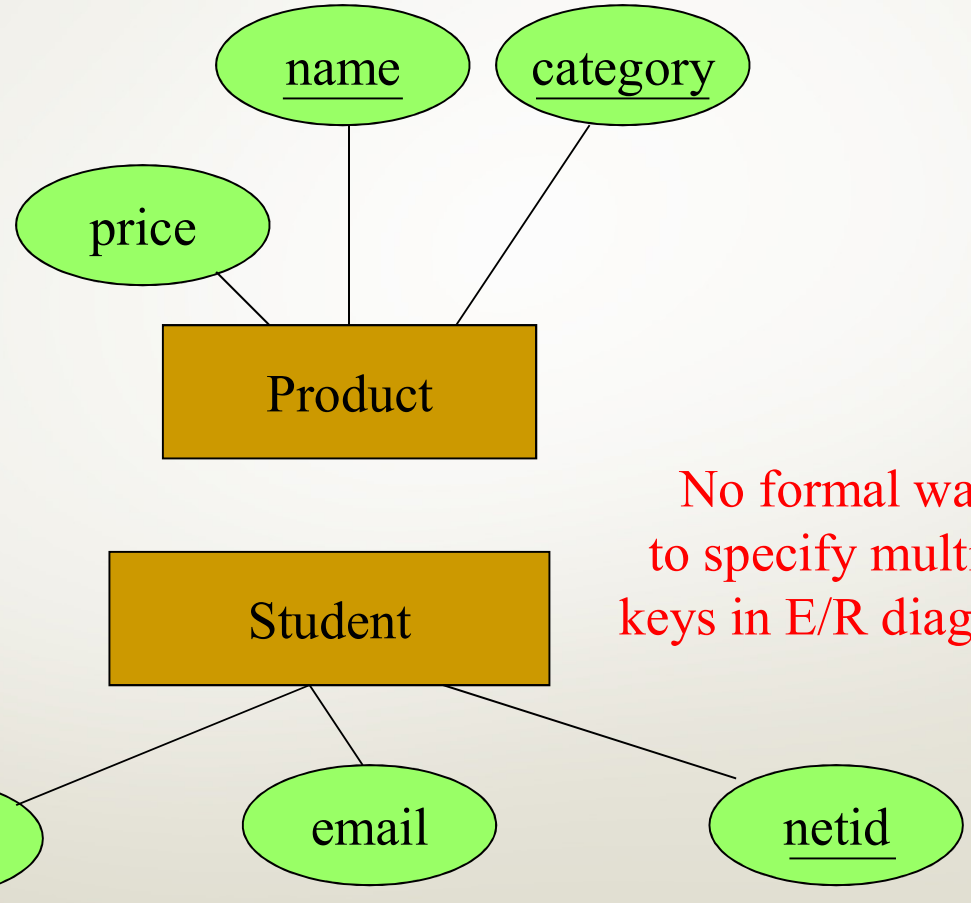
- Keys: attributes that identify entities in an entity set
  e.g., social security number uniquely identifies a person.

- 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:



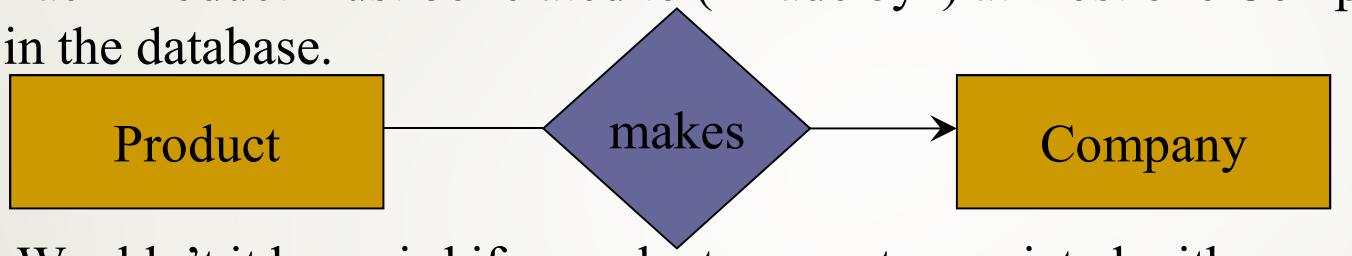
This means "name" and "category" together uniquely determine product

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

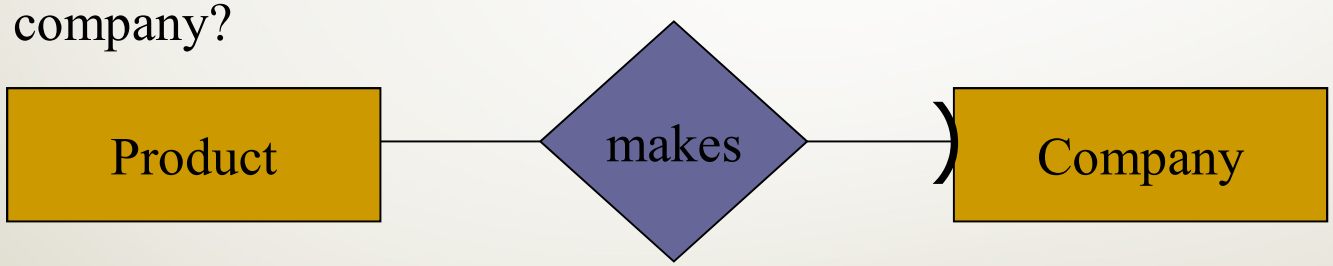
Referential Integrity Constraints

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".

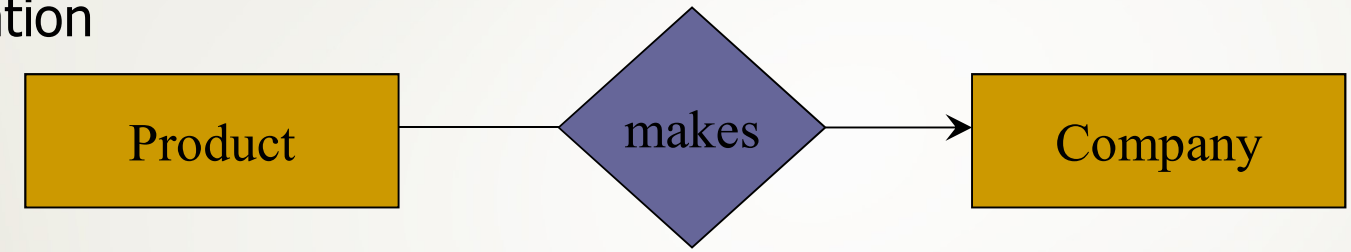
Each Product must be related to ("made by") exactly one Company in the database.

Arrow = at most 1

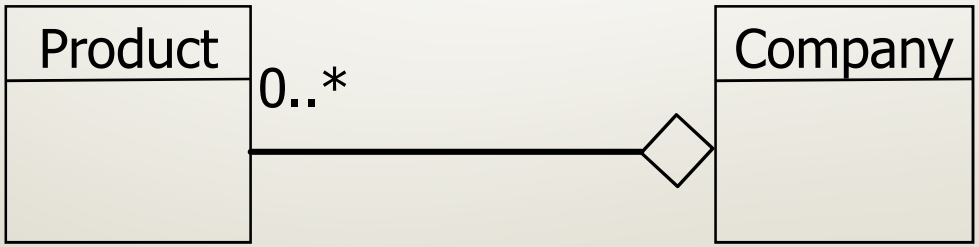
Semicircle = exactly 1

Referential Integrity Constraints
UML: Aggregation

ER Notation

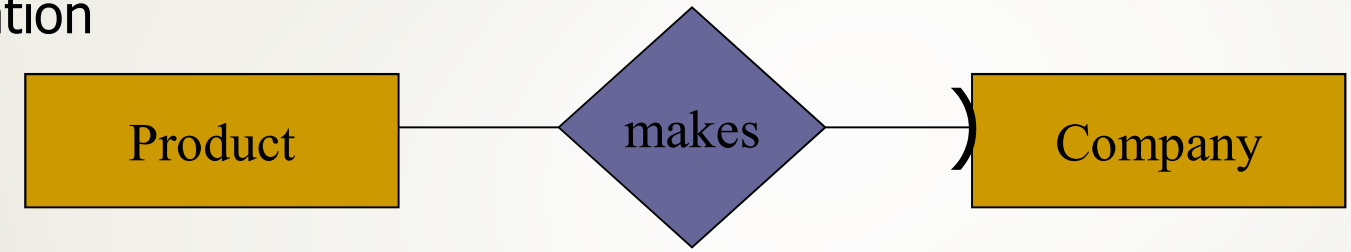


UML Notation



Referential Integrity Constraints
UML: Composition

ER Notation



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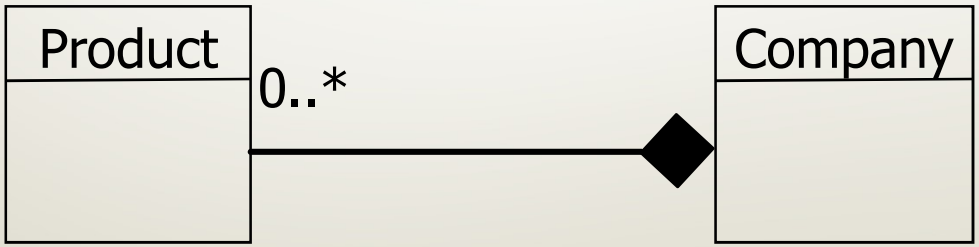
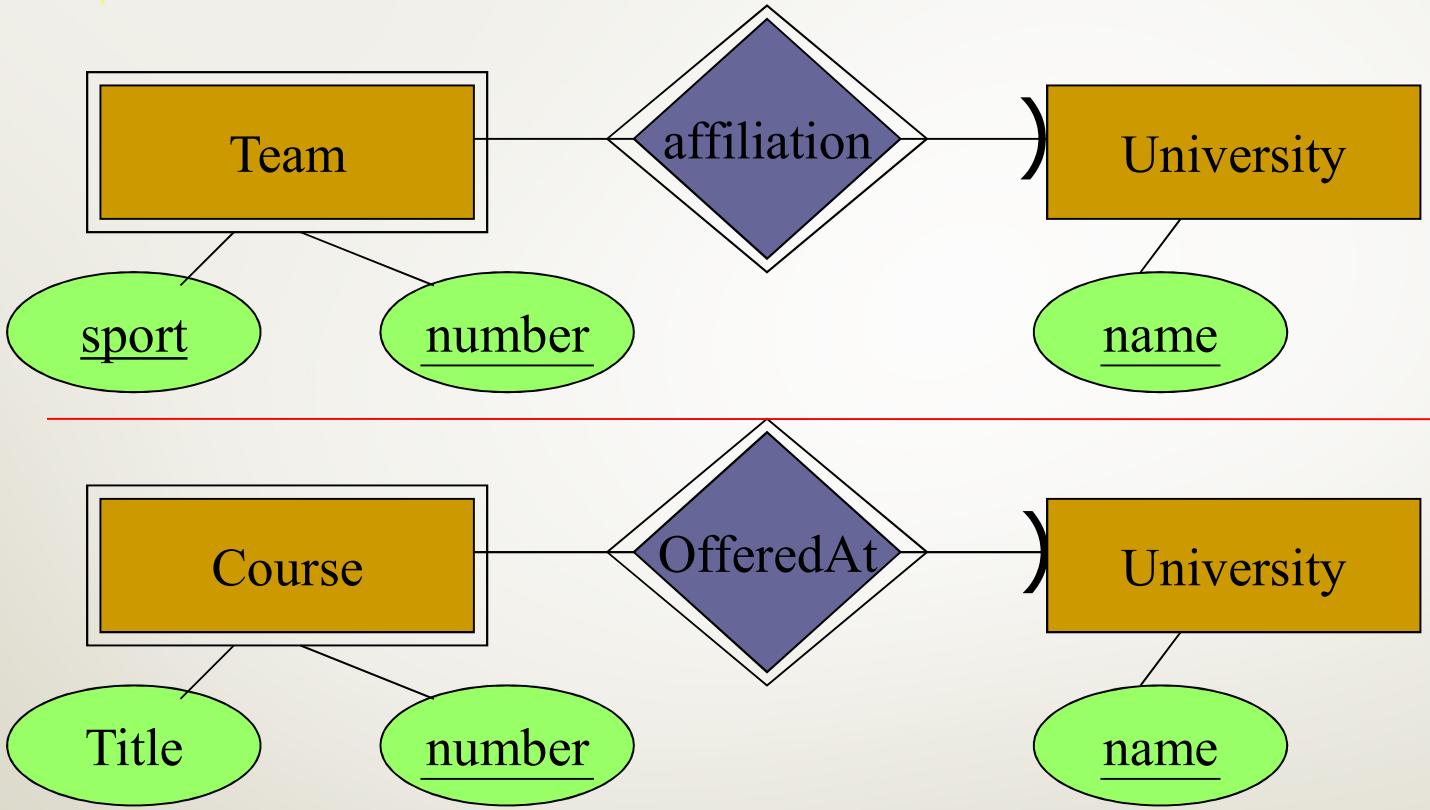


Weak Entity Sets

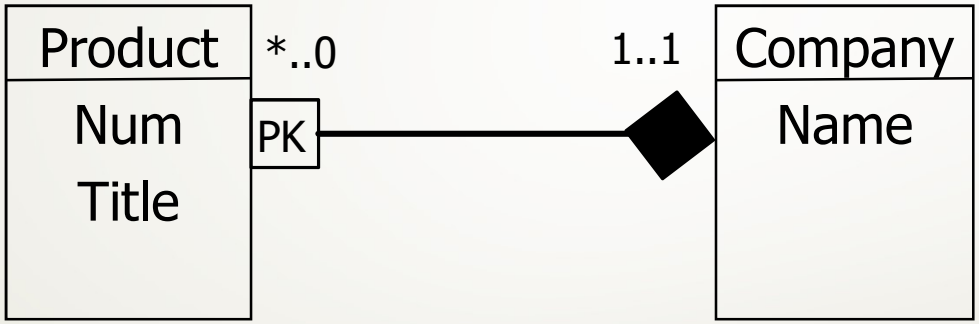
- Occasionally, entities of an entity set need "help" to identify them uniquely.
- Entity set *E* is *weak* if in order to identify entities of *E* uniquely, we need to follow one or more many-one relationships from *E* and include the key of the related entity sets.
- Note: not an is-a relationship because *E* is not a "subclass" of *F:* Univ and Team

Notations for weak entity set



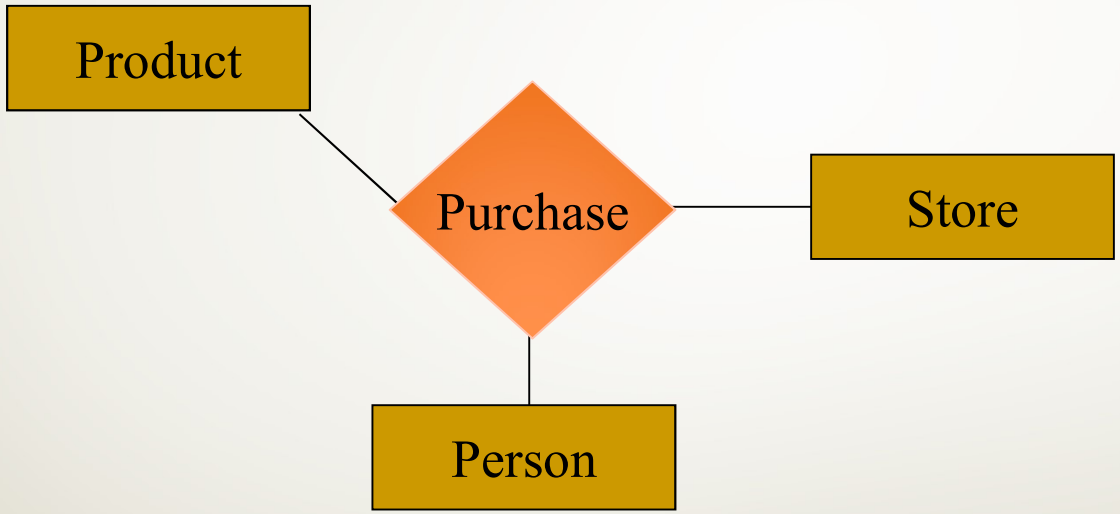
- "University" is a "supporting entity set" for "Team".
- "Affiliation" is a "supporting relationship".

Weak entity set in UML



Multiway Relationships

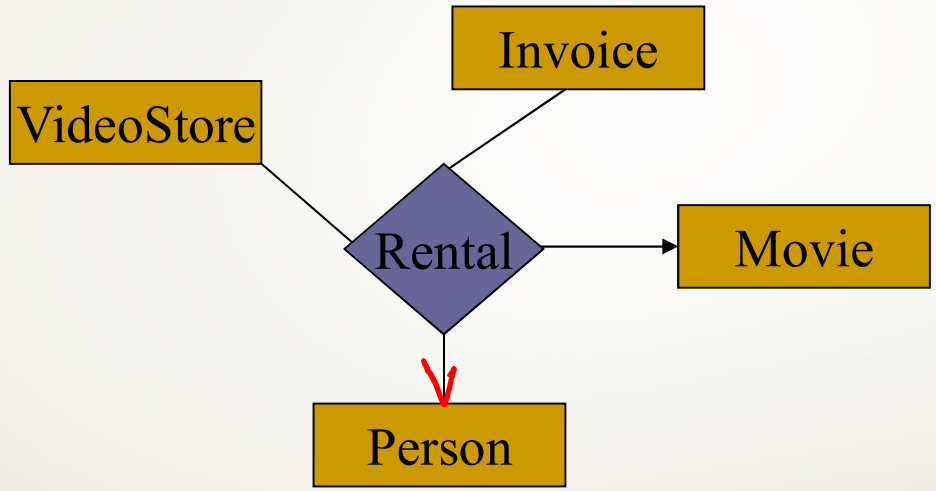
How do we model a purchase relationship between buyers, products and stores?



- Can still model as a mathematical set (how ?)
  - Yes: As a subset of product x store x person

Arrows in Multiway Relationships

Q: what does the arrow mean ?



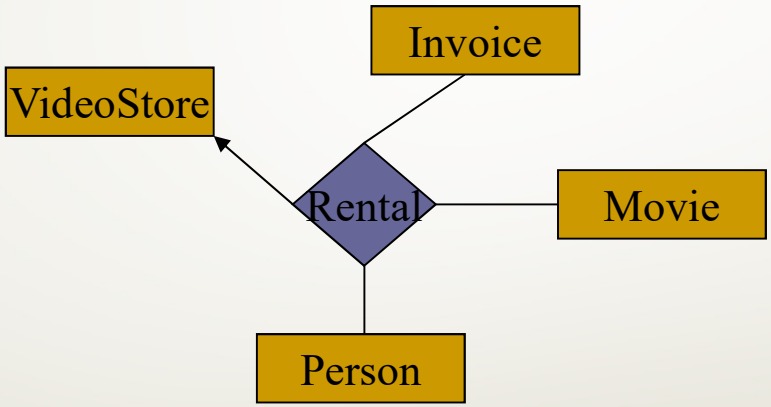
A: "At most one". That is, a specific combination of videostore, invoice and person can correspond to at most one movie.

Q: What if I had an arrow into Person?

Arrows in Multiway Relationships

Q: how do I say: "invoice determines store" ?

A: no good way; best approximation:



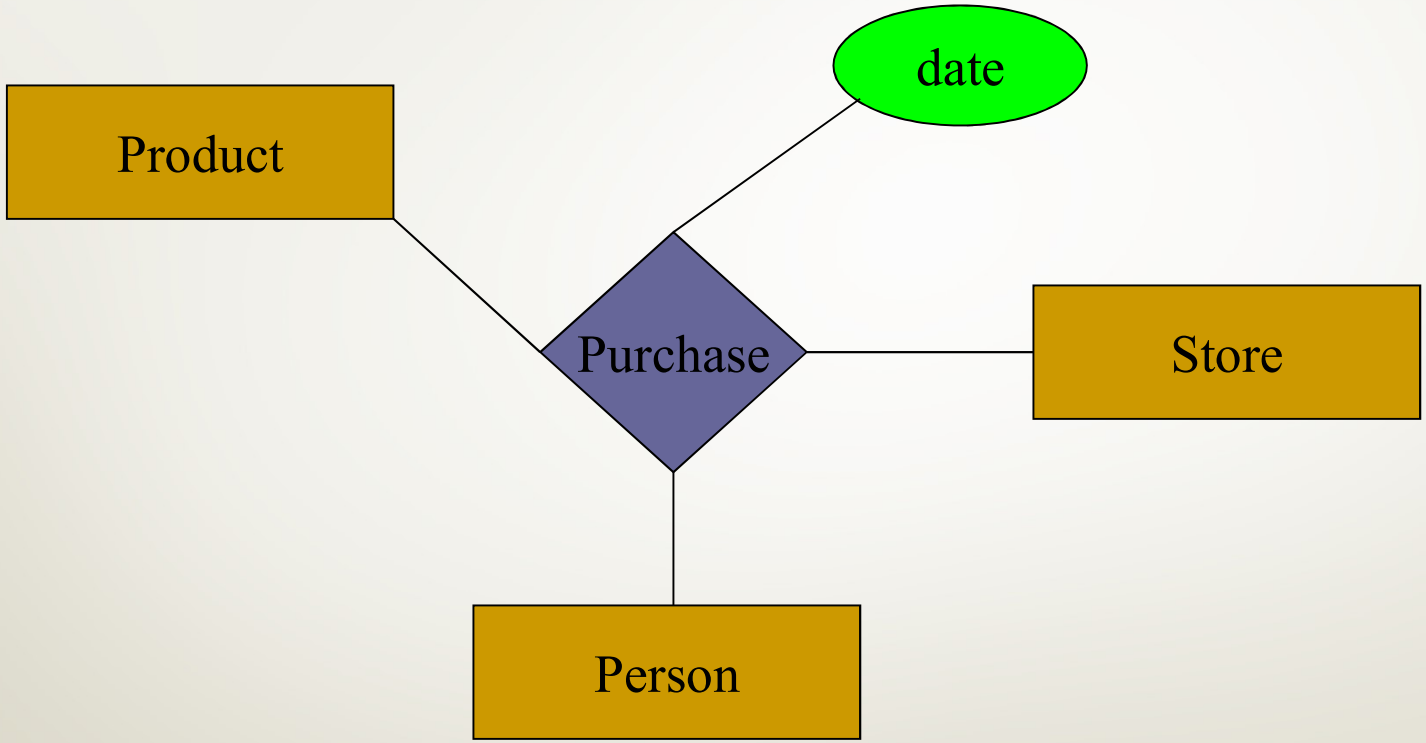
Q: Why is this bad ?

A: We aren't clarifying that the store is a function of the invoice only

Some ER Modeling Tools Require 2-way Relationships

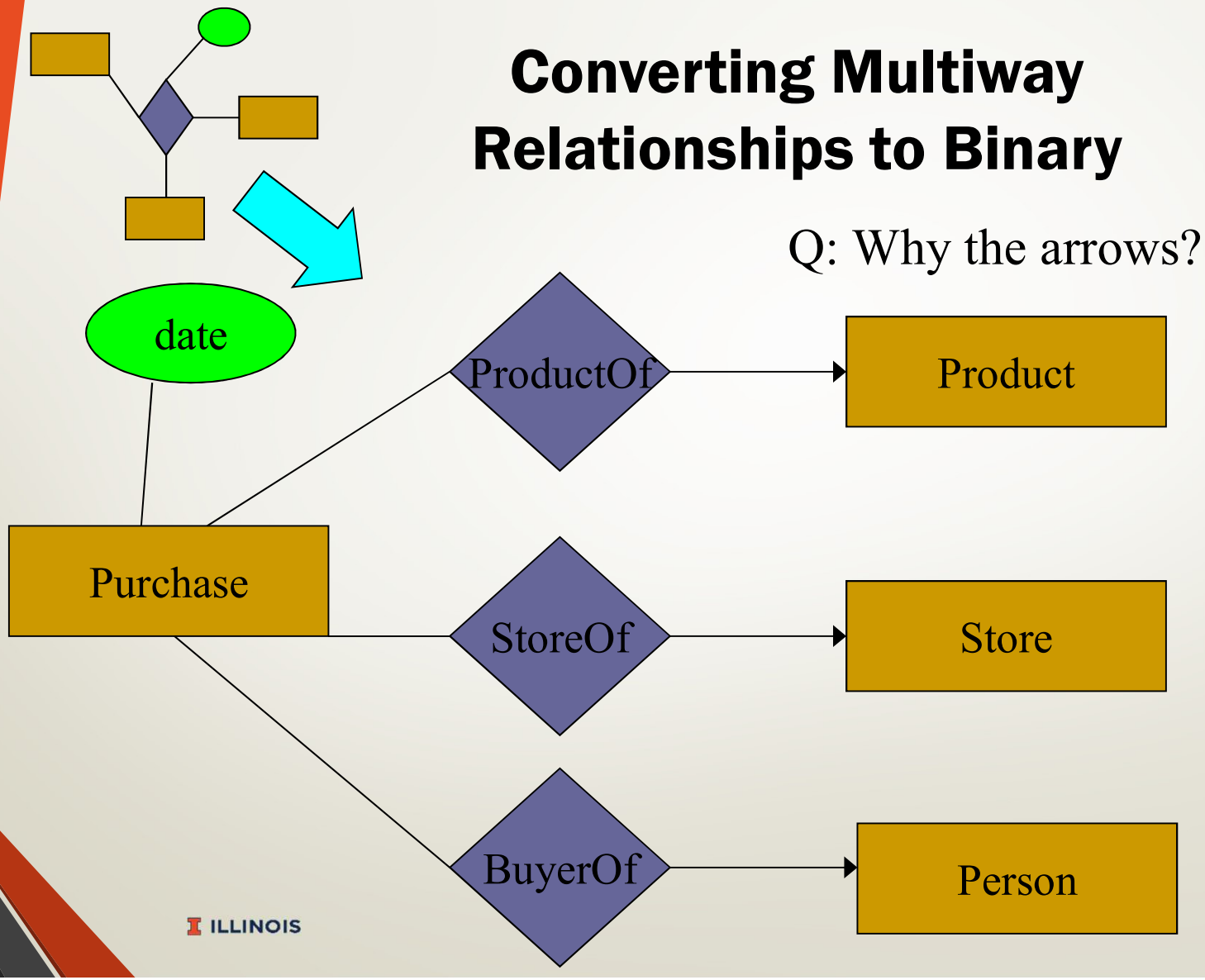
Do we need multi-way relationships or do 2-way (binary) relationships suffice?

How would you convert this into binary?



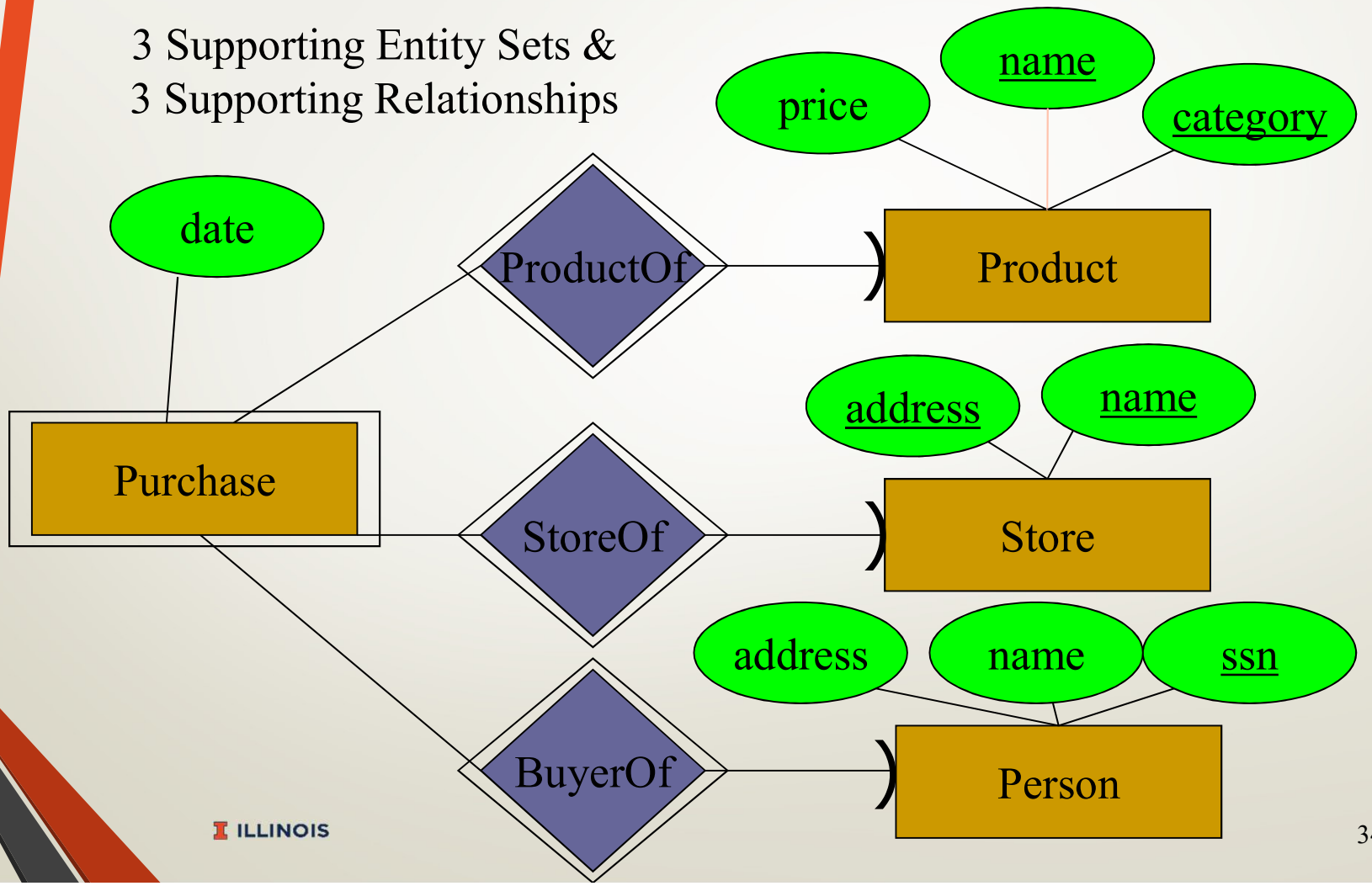
Converting Multiway Relationships to Binary

Q: Why the arrows?

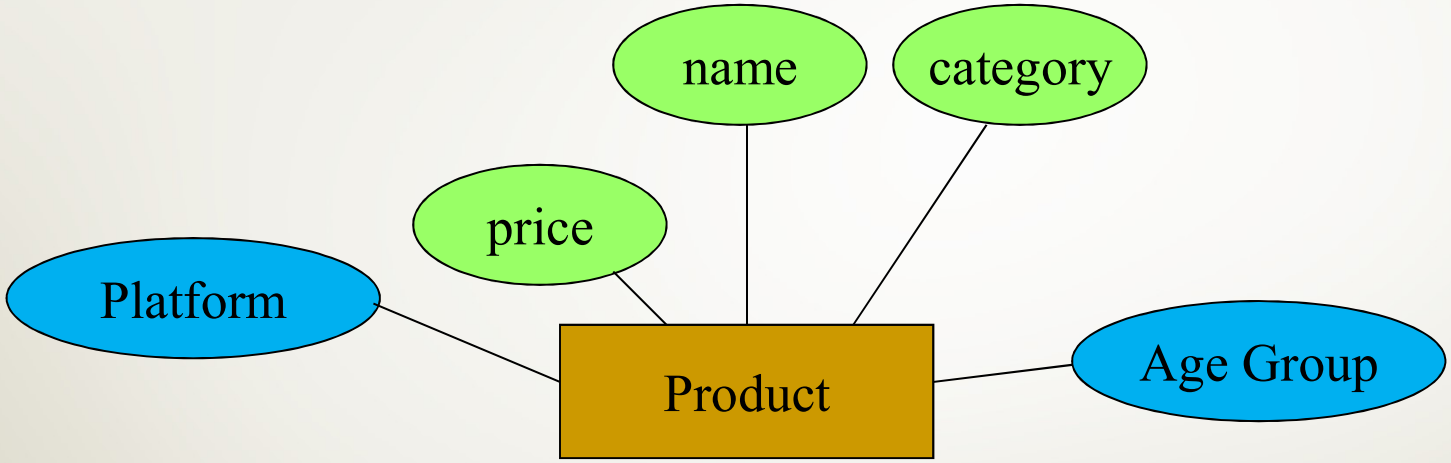


Another scenario where weak e.s. arises

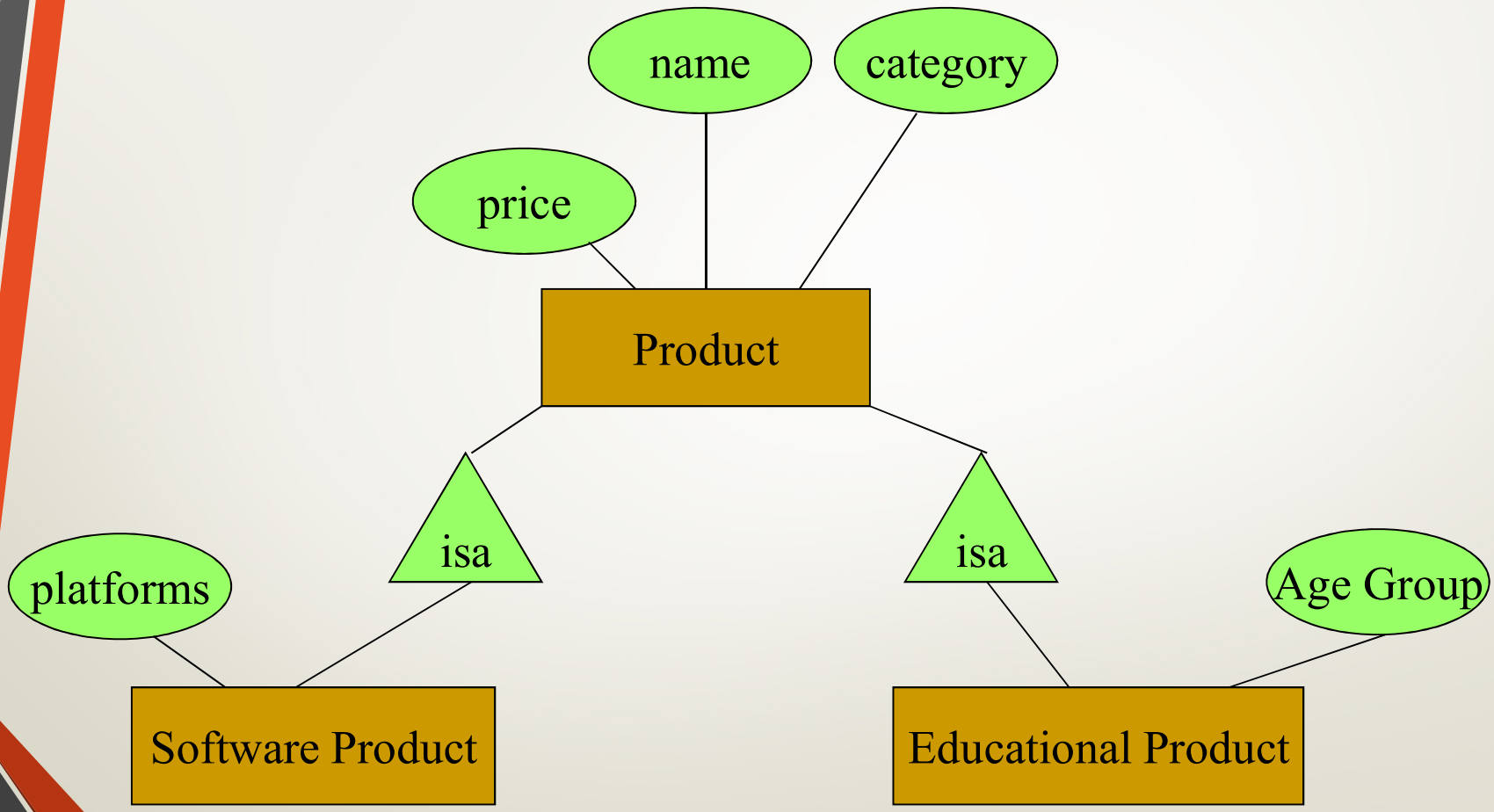
3 Supporting Entity Sets &
3 Supporting Relationships



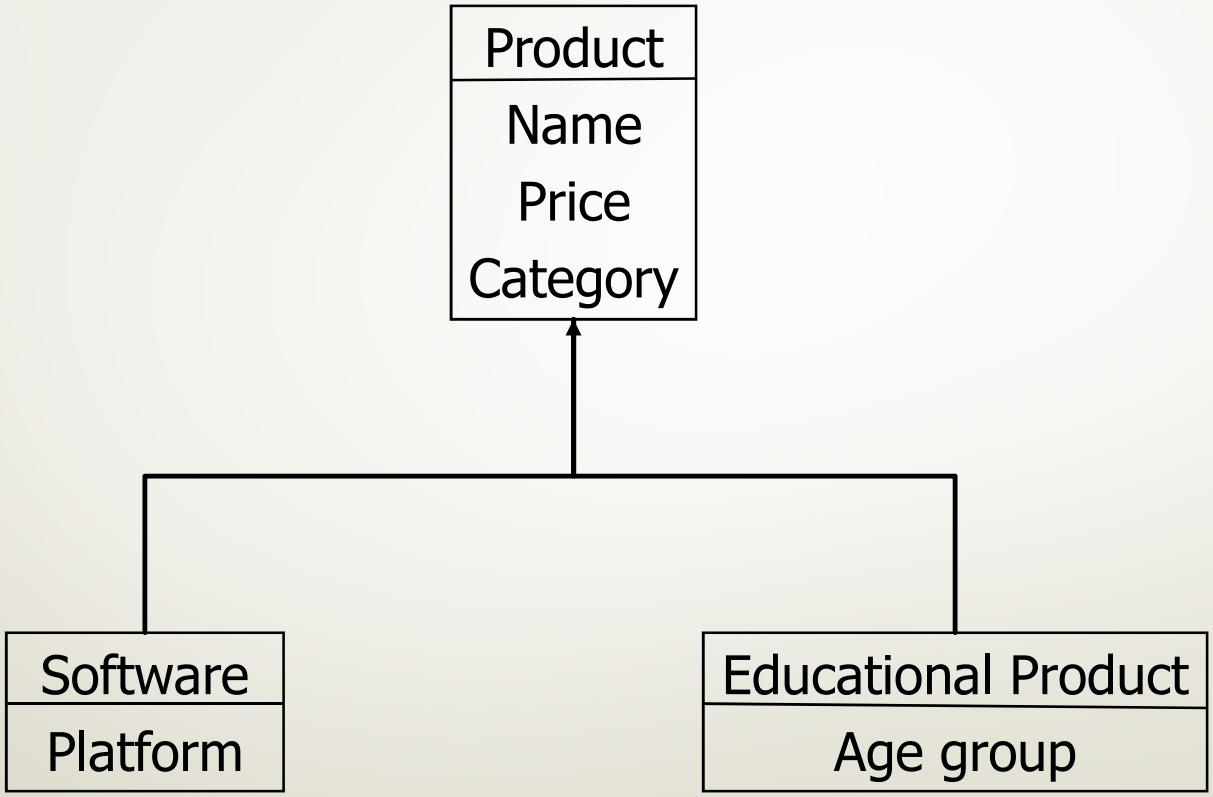
Subclasses in ER Diagrams



Subclasses in ER Diagrams



Subclasses in UML



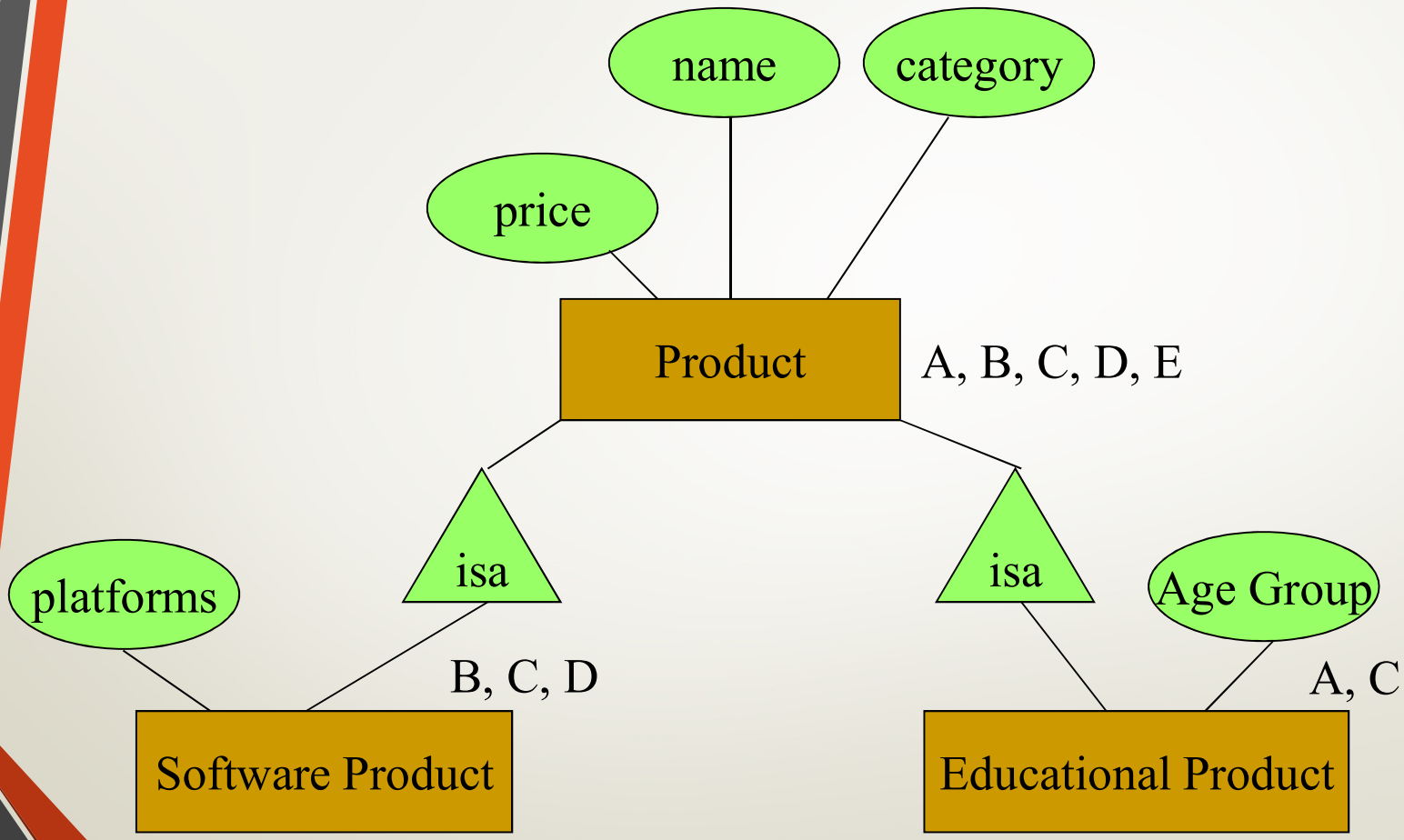
Subclasses

- "Isa" triangles indicate the subclass relationship.
  - Point to the superclass.
- Subclasses form a tree.
  - I.e., no "multiple inheritance".
- Why subclasses?
  - Unnecessary to add redundant properties to the root entity set that don't apply to many of the entities

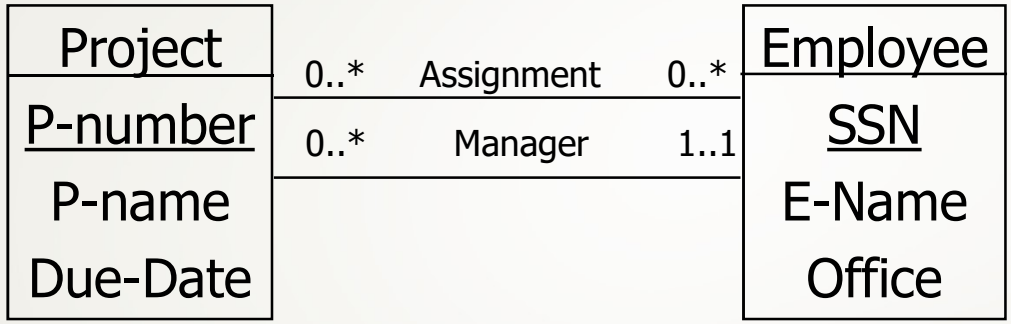
ER Vs. Object Oriented Subclasses

- In the object-oriented world, objects are in one class only.
  - Subclasses inherit properties from superclasses.
- In contrast, E/R entities have components in all subclasses to which they belong.
  - Matters when we convert to relations.

Subclasses in ER Diagrams

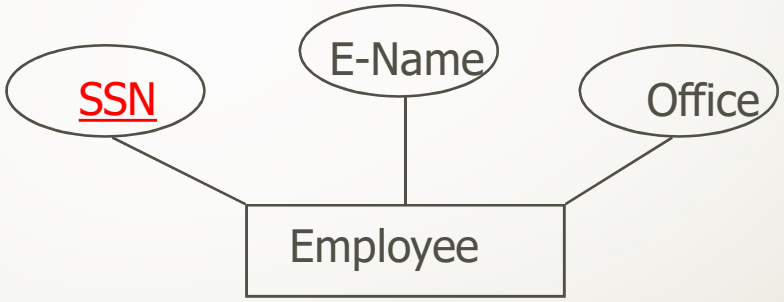


Converting ER to Relational Schema



1. 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

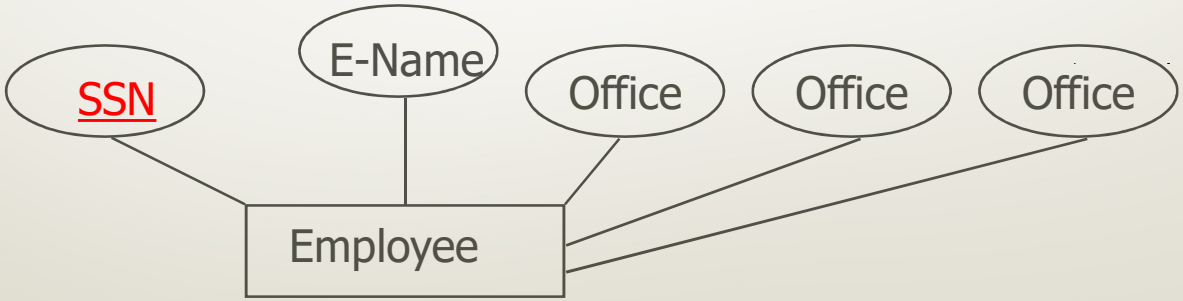



```
CREATE TABLE Employee
    (SSN CHAR(11) NOT NULL,
    E-Name CHAR(20),
    Office  INTEGER,
    PRIMARY KEY  (SSN))
```

Multi-valued Attribute

Didn't see this case when discussing ER diagrams

One or more values of same attribute for an entity



2. Create a table for the multi-valued attribute.

Most relational DBMSs do not allow multi-valued attributes.

How many offices can one employee have?

Just one

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

vs.

More than one

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

Sample Data

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

Employee(SSN, E-Name, **Office**)

Just one

12	Smith	O-105
15	Wei	O-110

More than one

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

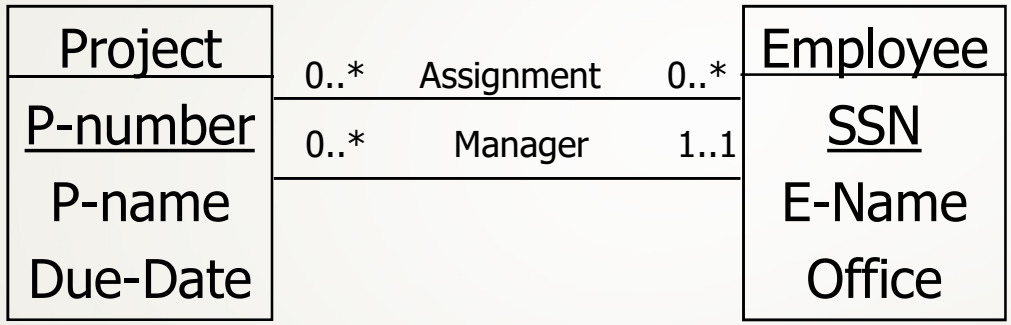
Employee(SSN, E-Name)

12	Smith
15	Wei

Office-Assignment(SSN, Office)

12	O-105
12	O-106
15	O-110

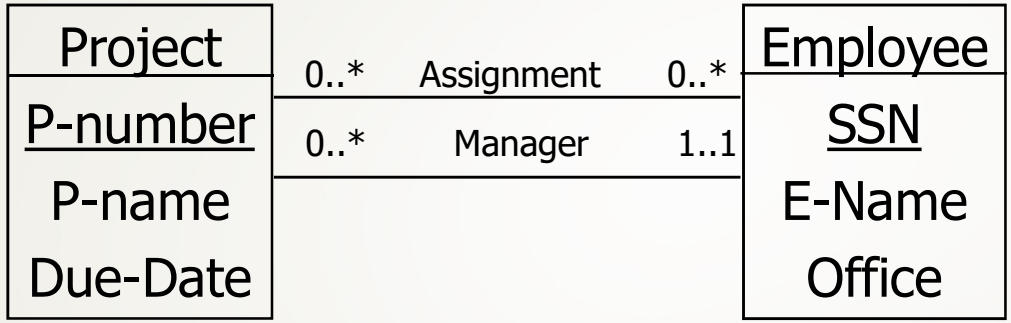
3. Translate each many-to-many relationship set into a table



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

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

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



Answer: Assignment(P-Number, SSN)

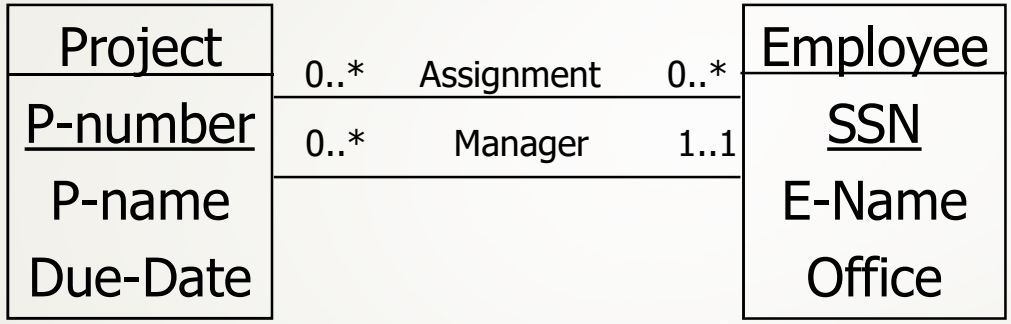
P-Number is a foreign key for Project

SSN is a foreign key for Employee

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

Employee(SSN, E-Name, Office)

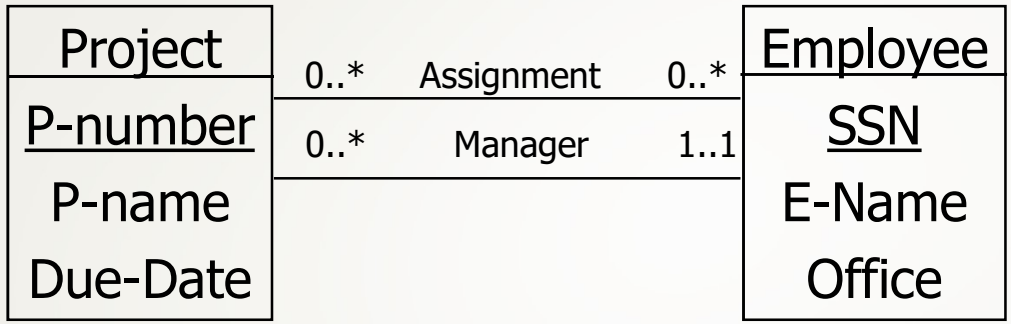
What should we do with each one-to-many relationship set?



Manager (?)

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

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

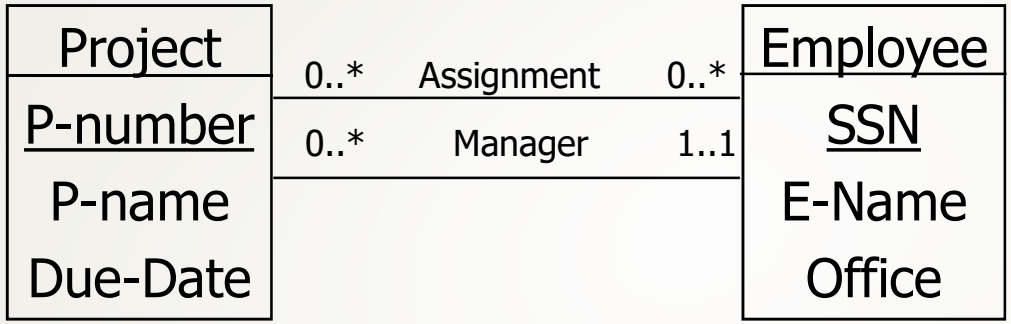


Project(P-number, P-name, Due-Date, MgrSSN)
Employee(SSN, E-Name, Office)

MgrSSN is a foreign key (referencing the Employee relation)

value of Manager must match an SSN

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



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

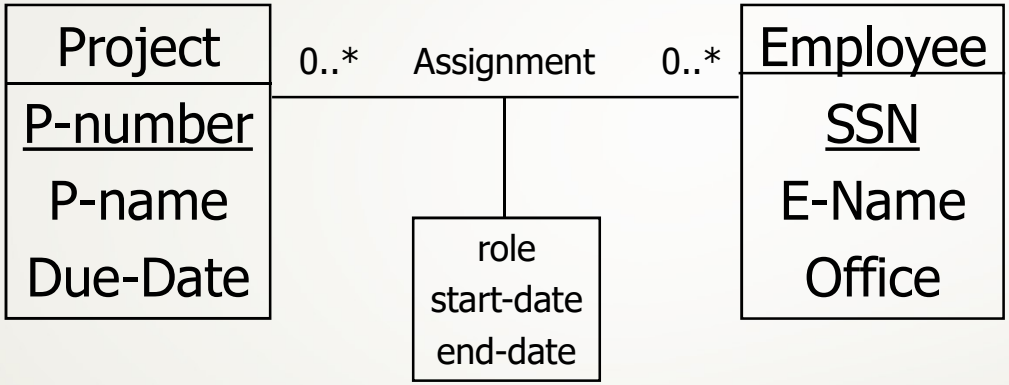
vs.

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?

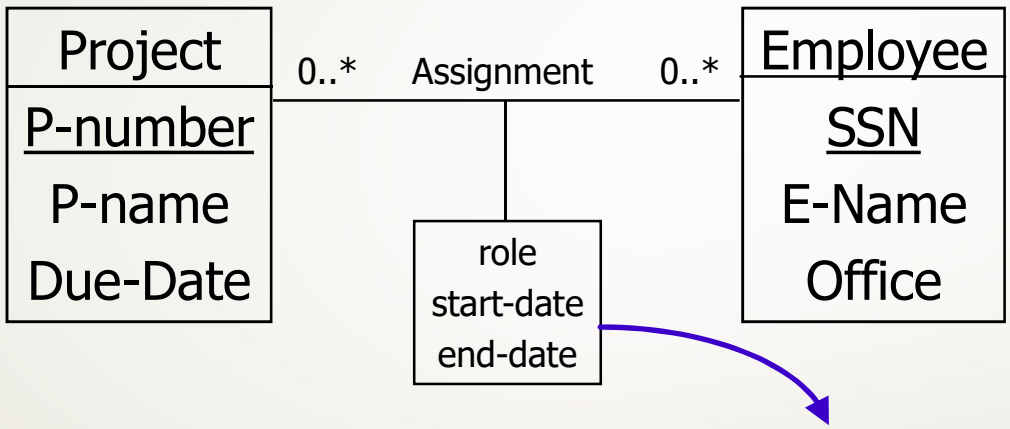


Assignment(P-number, SSN)

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?

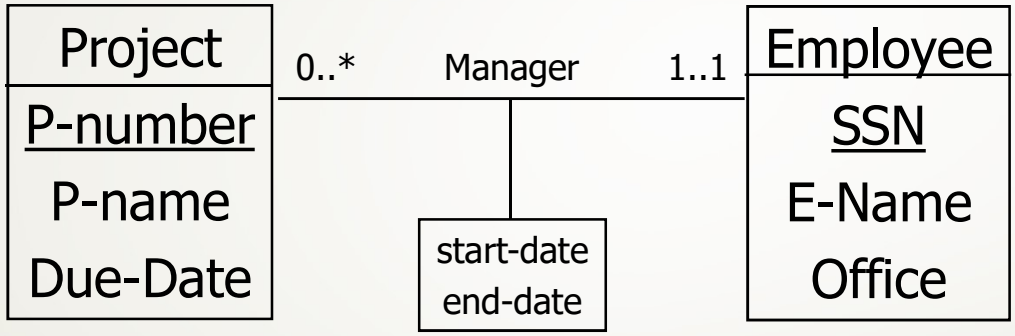


Assignment(P-number, SSN, role, start-date, end-date)

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

Employee(SSN, E-Name, Office)

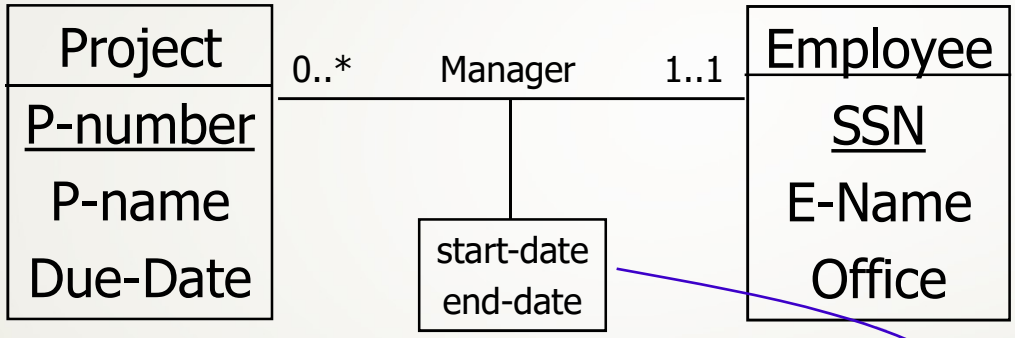
What do we do when a 1-to-many relationship set has an attribute?



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

Employee(SSN, E-Name, Office)

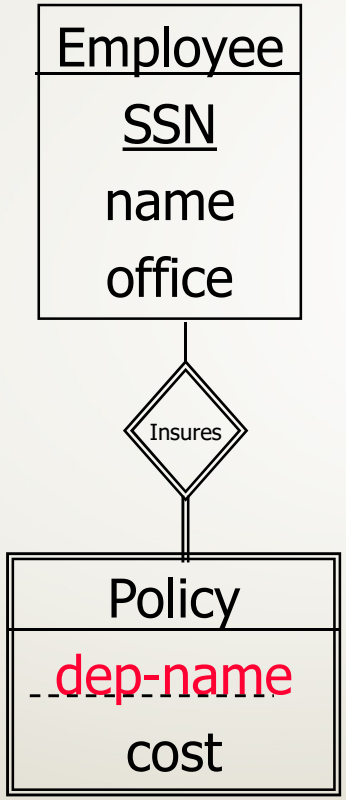
What do we do when a 1-to-many relationship set has an attribute?



Project(P-number, P-name, Due-Date, MgrSSN, start-date, end-date)

Employee(SSN, 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)
```

Converting Subclass Structures to Relations

Three approaches:

1. ***Follow the E /R viewpoint.***
   - For each entity set *E* in the hierarchy, create a relation that includes the key attributes from the root and any attributes belonging to *E*.
2. ***Treat entities as objects belonging to a single class.***
   - For each possible subtree that includes the root, create one relation, whose schema includes all the attributes of all the entity sets in the subtree.
3. ***Use null values.***
   - Create one relation with all the attributes of all the entity sets in the hierarchy.
   - Each entity is represented by one tuple, and that tuple has a null value for whatever attributes the entity does not have.

Read textbook section 4.6
for examples and comparison of approaches