Database Applications (15-415)

The Entity Relationship Model
Lecture 2, January 13, 2015

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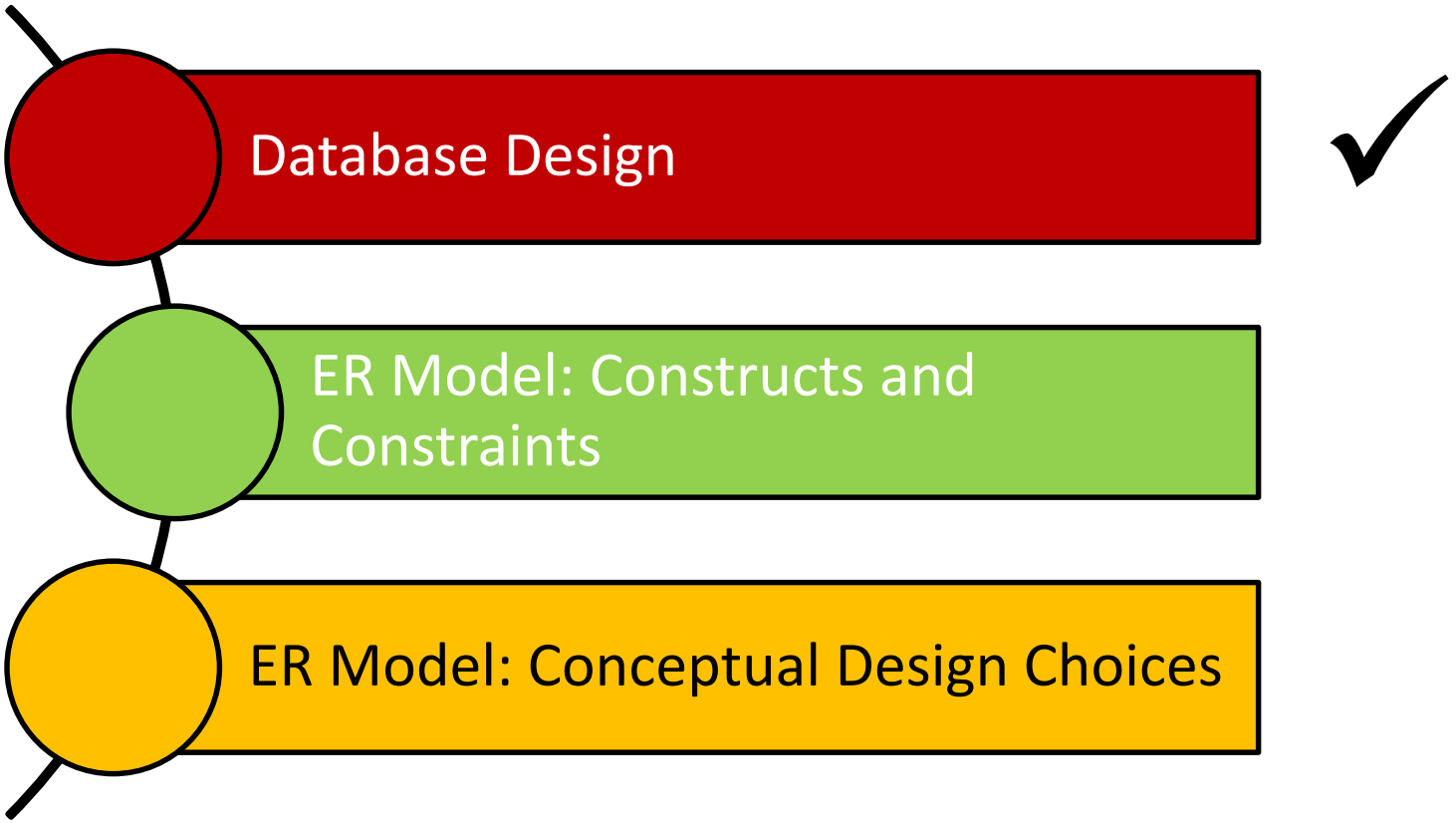
Today…

- Last Session:
  - Course overview and a brief introduction on databases and database systems

- Today's Session:
  - Main steps involved in designing databases
  - Constructs of the entity relationship (ER) model
  - Integrity constrains that can be expressed in the ER model
  - Conceptual design choices

- Announcements:
  - The first Problem Solving Assignment (PS1) is now posted on the course webpage
    - Deadline is Jan 22, 2015 by midnight
  - Thursday, Jan 15 is the first recitation
    - A case study on the ER model will be solved

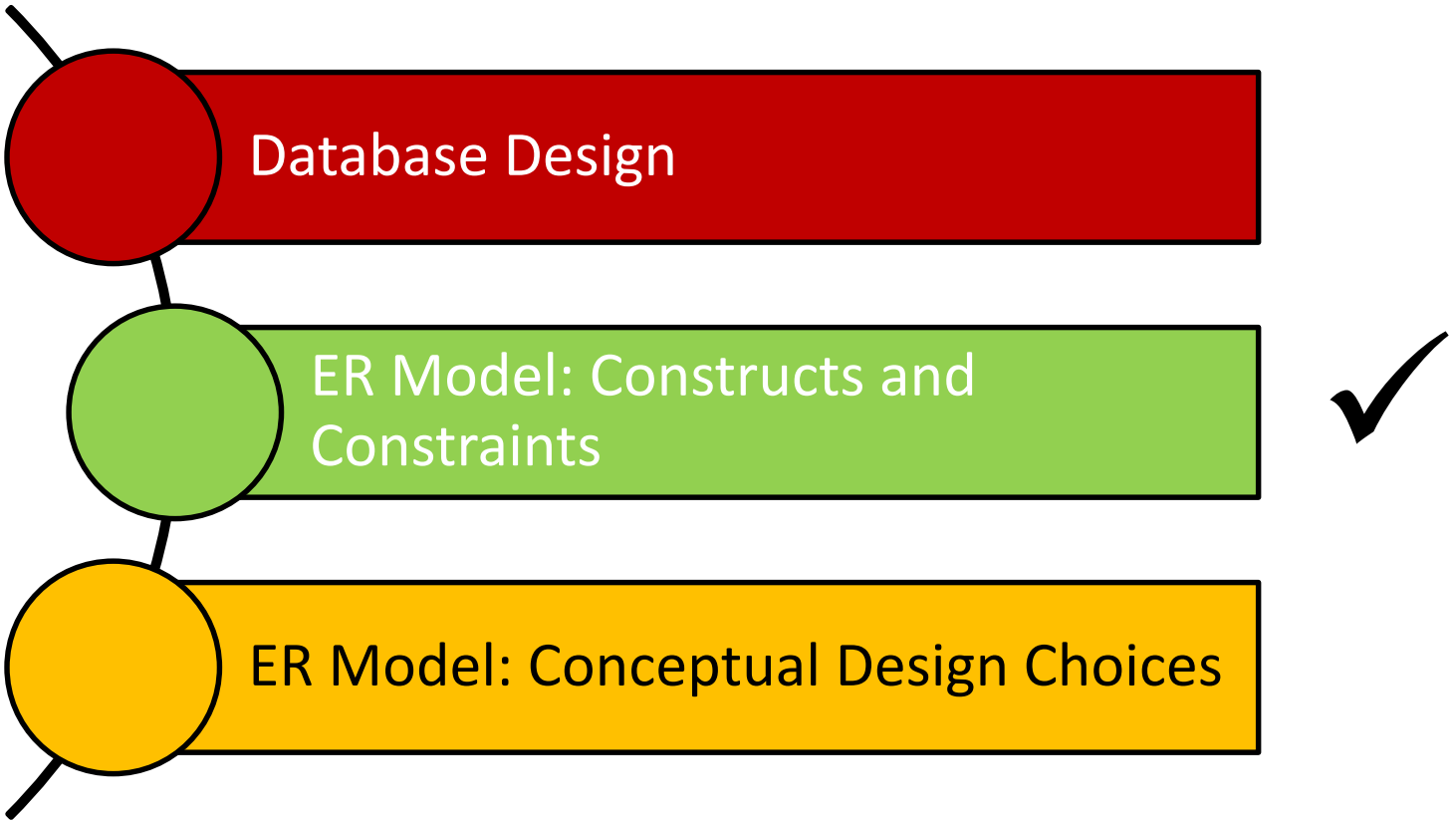
Outline


Database Design
ER Model: Constructs and Constraints
ER Model: Conceptual Design Choices

Database Design

- Requirements Analysis
  - Users needs
- Conceptual Design
  - A high-level description of the data (e.g., using the ER model)
- Logical Design
  - The conversion of an ER design into a relational database schema
- Schema Refinement
  - Normalization (i.e., restructuring tables to ensure some desirable properties)
- Physical Design
  - Building indexes and clustering some tables
- Security Design
  - Access controls

Outline



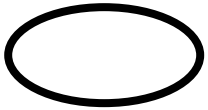
Entities and Entity Sets

- Entity:
  - A real-world object distinguishable from other objects in an enterprise (e.g., University, Students and Faculty)
  - Described using a set of *attributes*

- Entity set:
  - A collection of similar entities (e.g., *all* employees)
  - All entities in an entity set have the same set of attributes (until we consider ISA hierarchies, anyway!)
  - Each entity set has a *key*
  - Each attribute has a *domain*

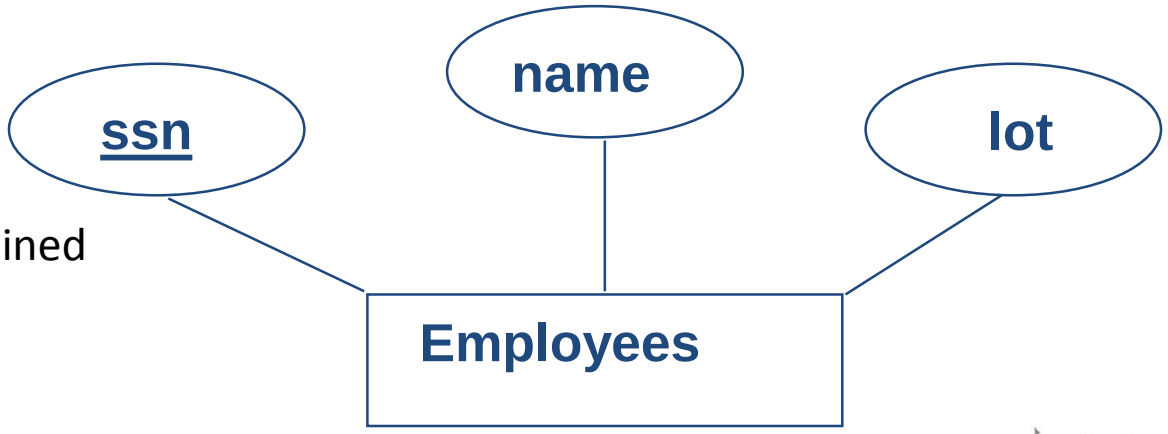
Tools and An ER Diagram

Entities ('Entity Sets')



Attributes

"ssn" is the *primary key*, hence, underlined

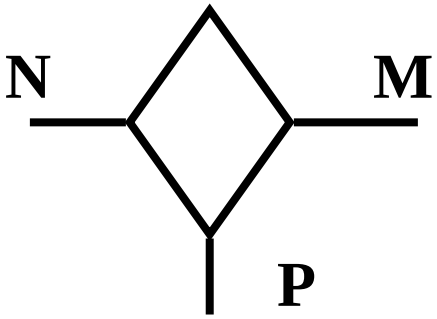


Relationship and Relationship Sets

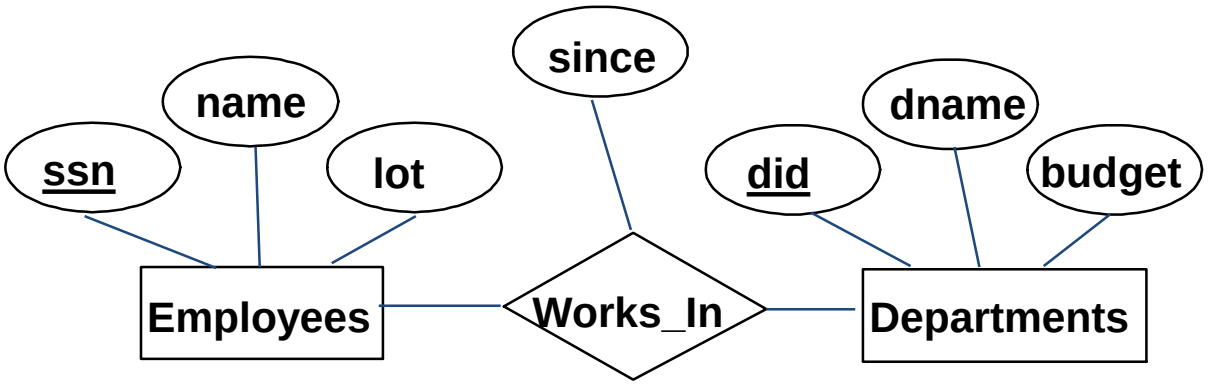
- Relationship:
  - Association among two or more entities (e.g., Mohammad is teaching 15-415)
  - Described using a set of attributes

- Relationship set:
  - Collection of similar relationships
  - Same entity set could participate in different relationship sets, or in different “roles” in the same set

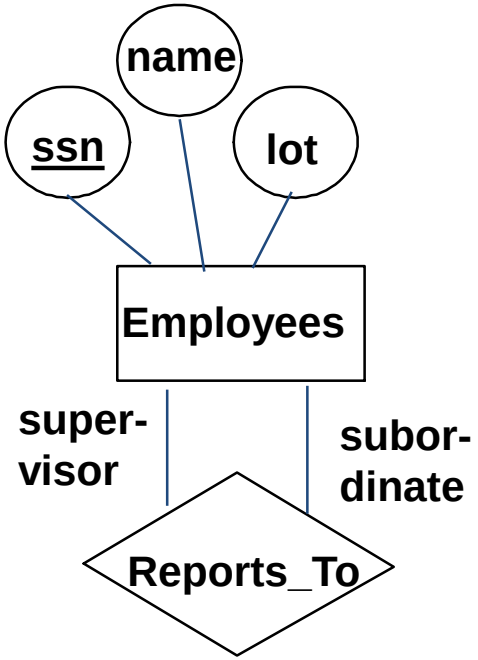
More Tools and ER Diagrams



Relationships ('rel. sets') and mapping constraints



A Binary Relationship

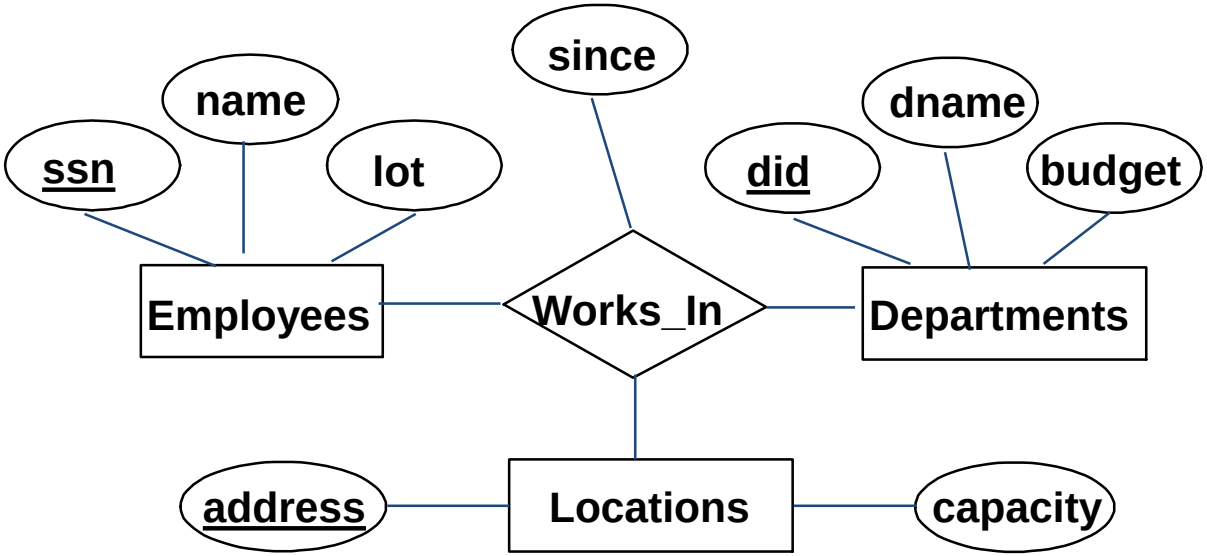


A Self-Relationship

Ternary Relationships

- Suppose that departments have offices at different locations and we want to record the locations at which each employee works

- Consequently, we must record an association between an employee, a department and a location

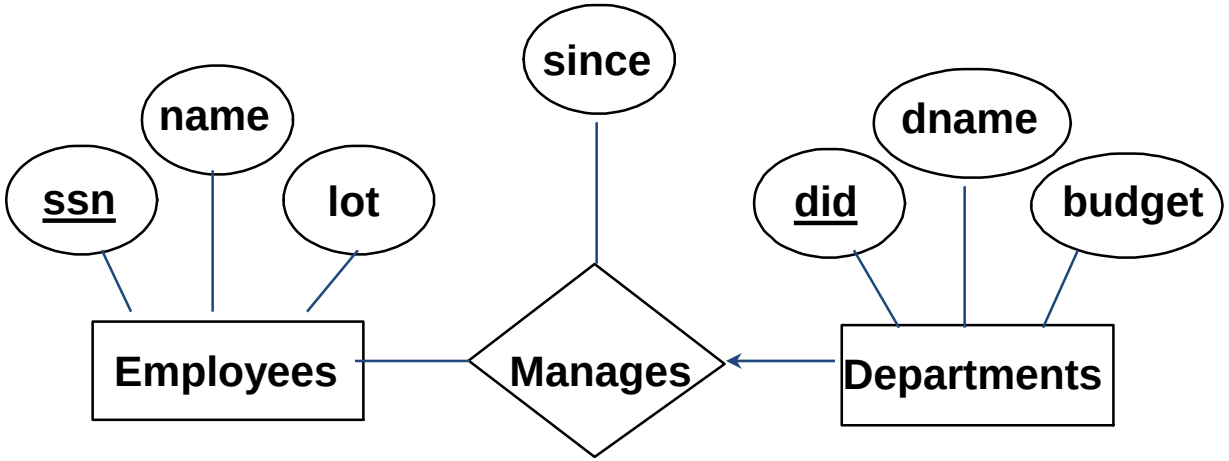


This is referred to as a "Ternary Relationship" (vs. Self & Binary Relationships)

Key Constraints

- Consider the “Employees” and “Departments” entity sets with a “Manages” relationship set
  - An employee can work in *many* departments
  - A department can have *many* employees
  - Each department can have only one manager

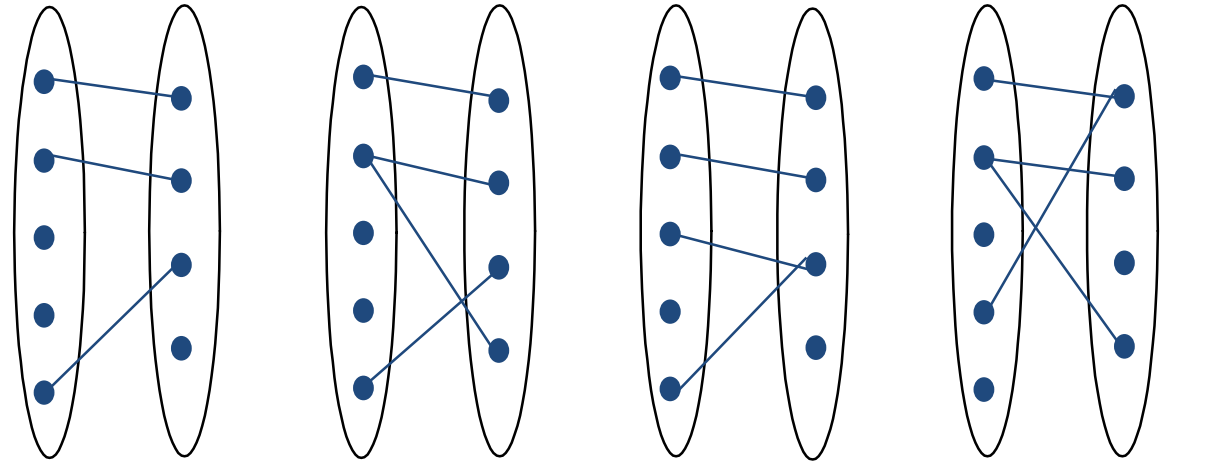
This restriction is an example of a “key constraint”

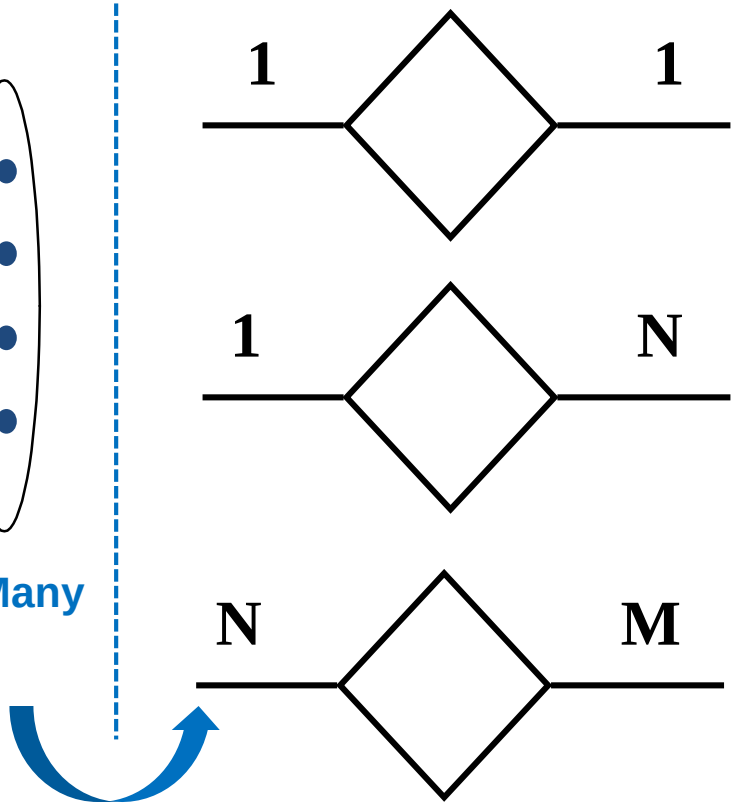


Key constraints are denoted by *thin arrows*

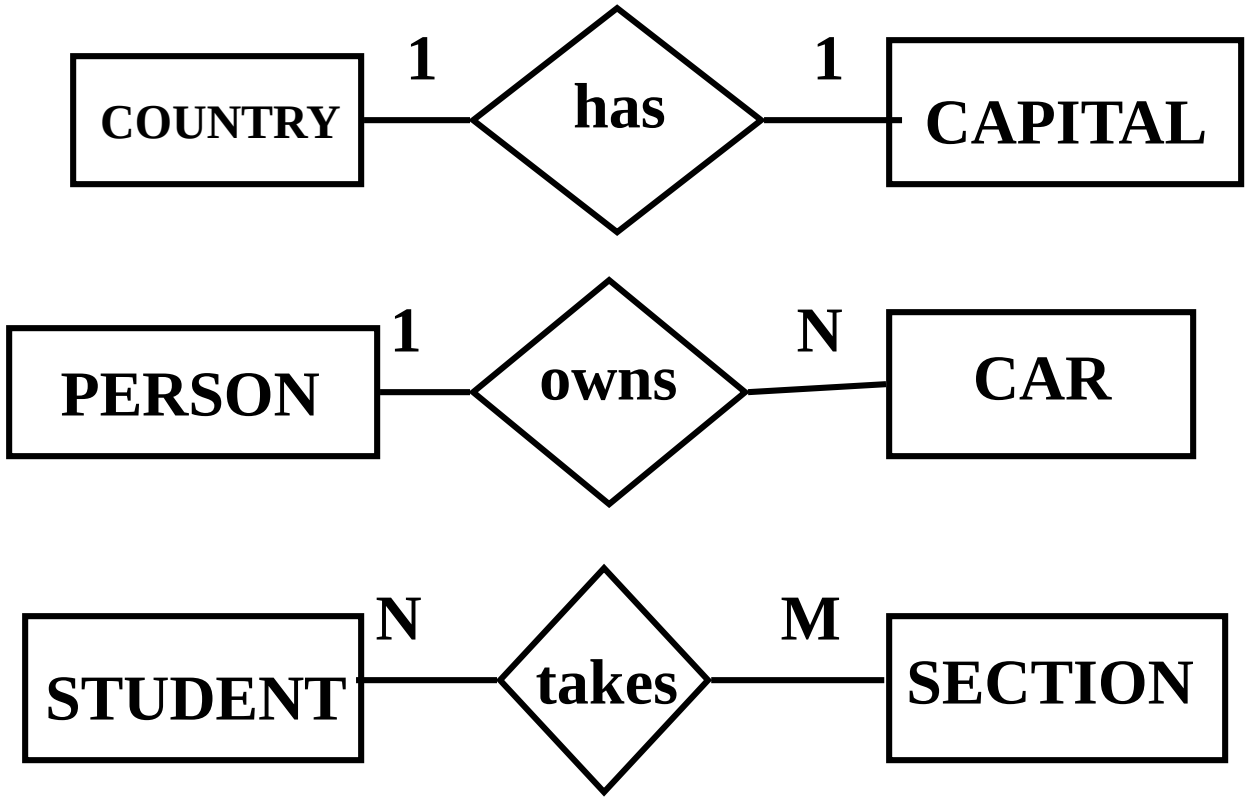
Cardinalities

- Entities can be related to one another as “one-to-one”, “one-to-many” and “many-to-many”
  - This is said to be the cardinality of a given entity in relation to another



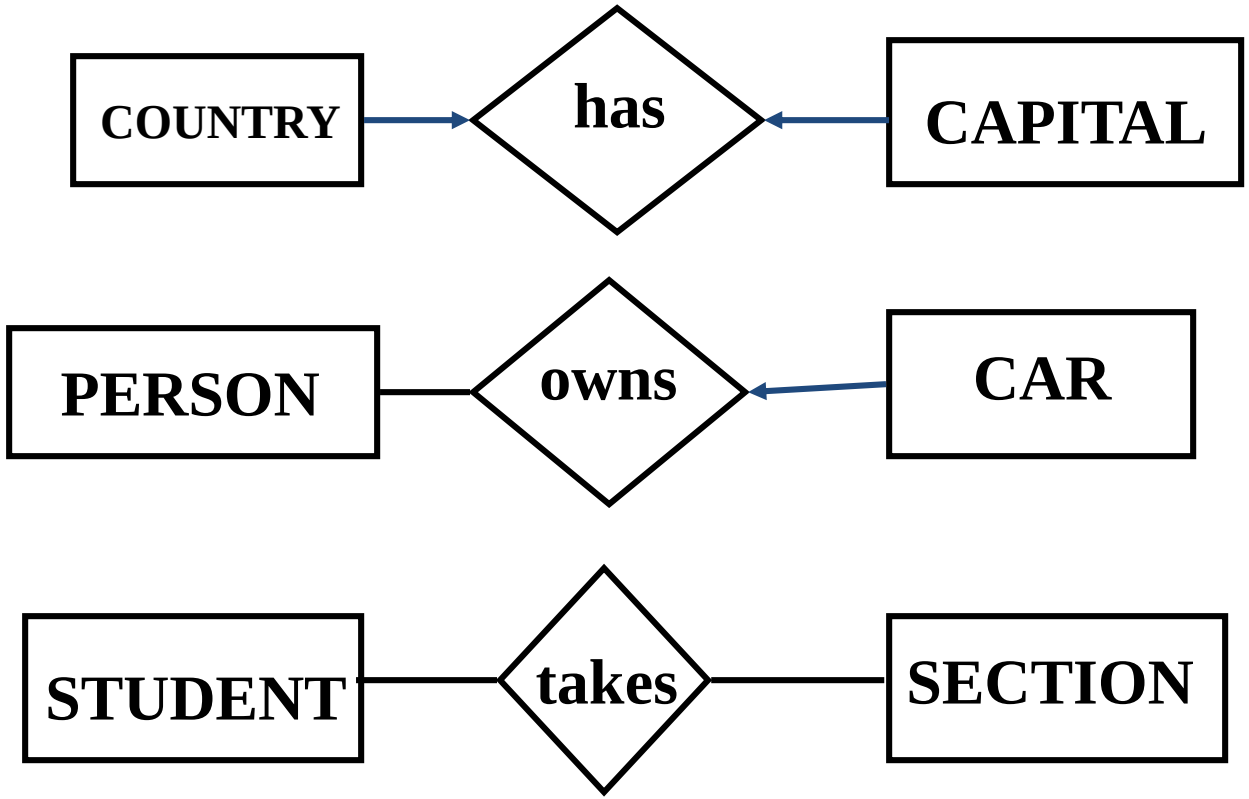


Cardinalities: Examples



Cardinalities: Examples

Book's notation:

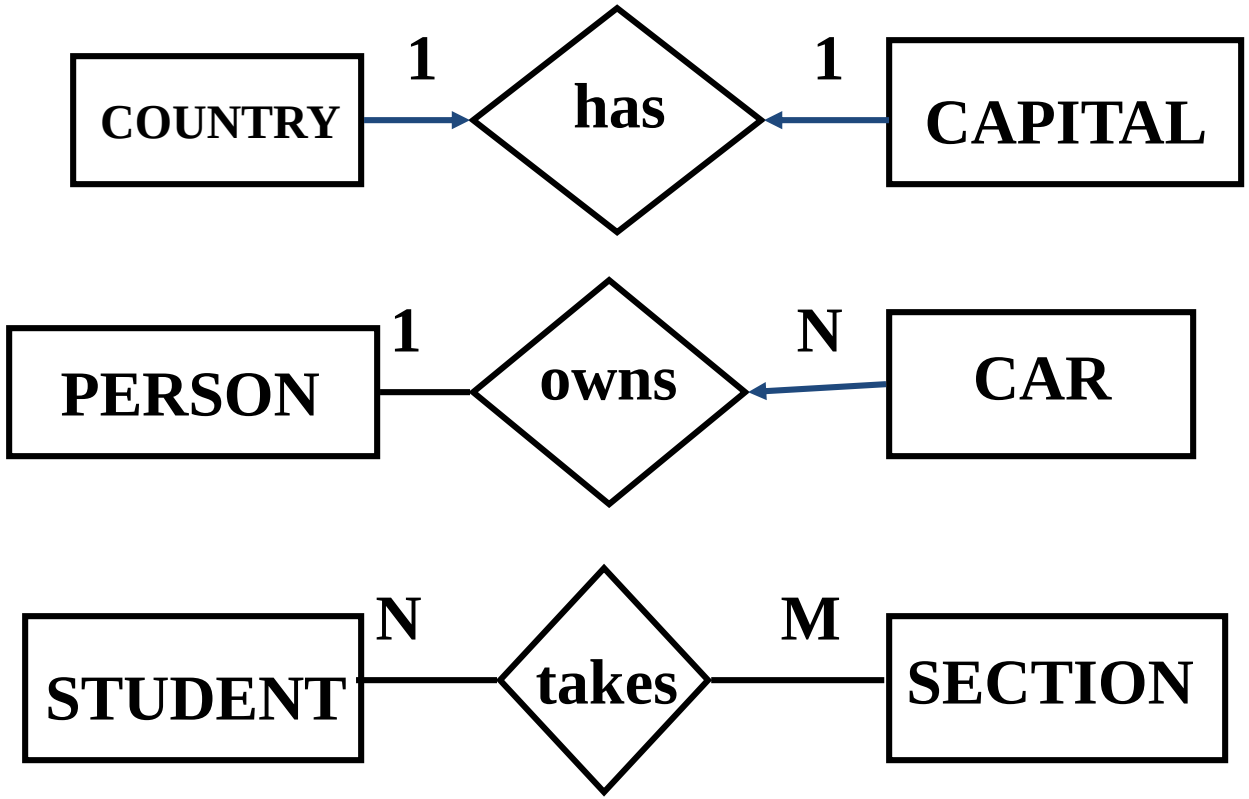


Cardinalities: Examples

Book's notation

vs

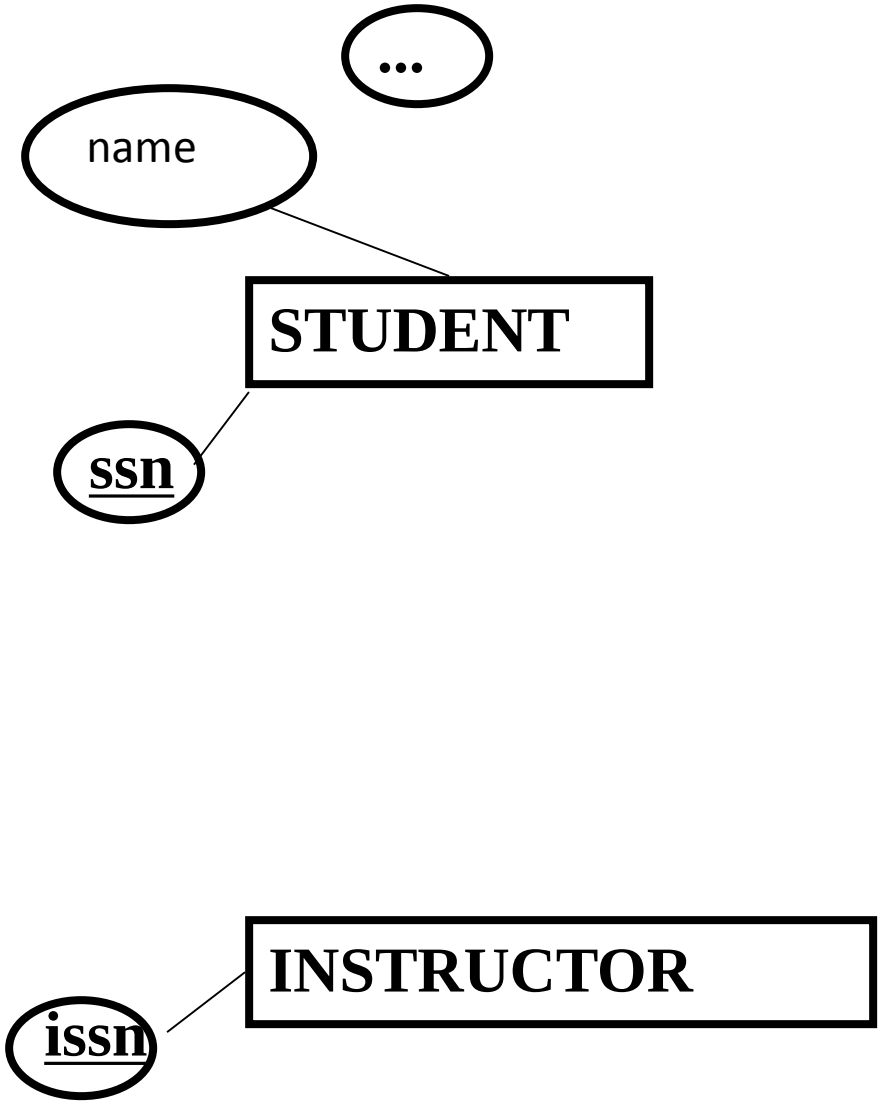
***1 to N* notation**



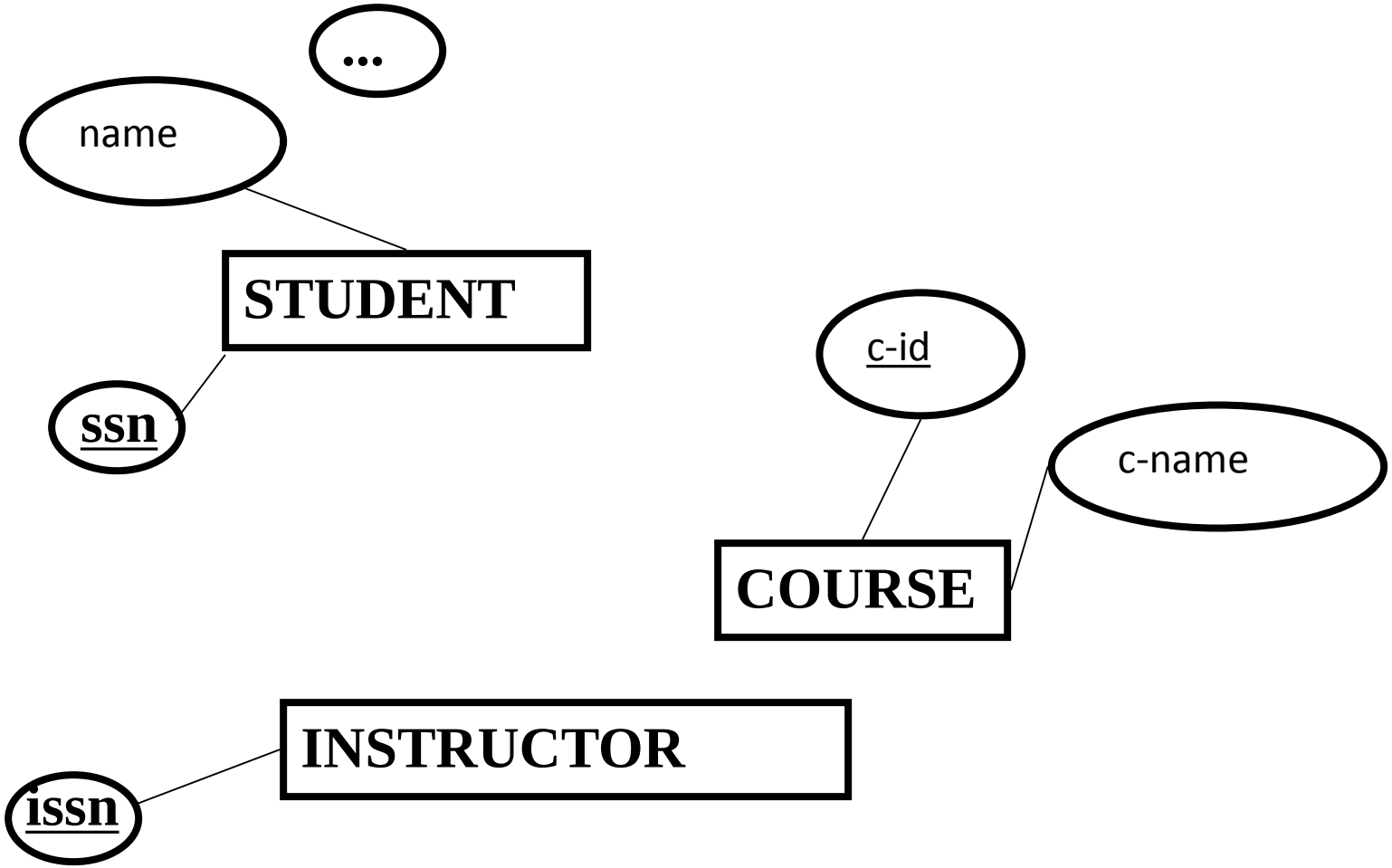
A Working Example

- Requirements: Students take courses offered by instructors; a course may have multiple sections; one instructor per section

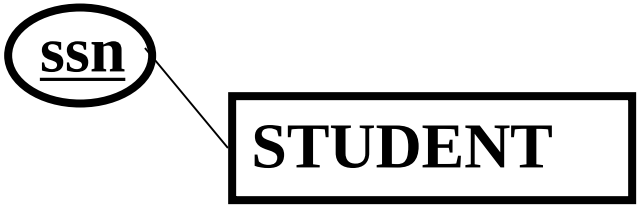
- How to start?
  - Nouns -> entity sets
  - Verbs -> relationship sets

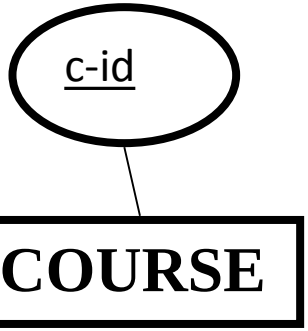


Primary key = unique identifier → underline

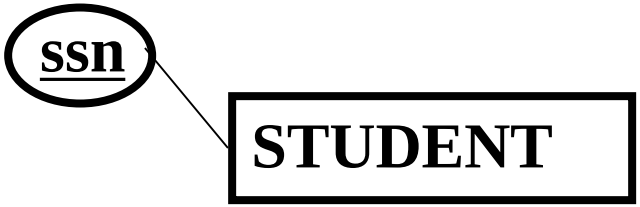


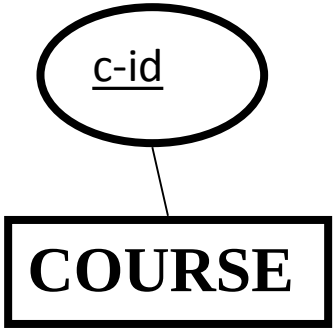
But: sections of a course (with different instructors)?



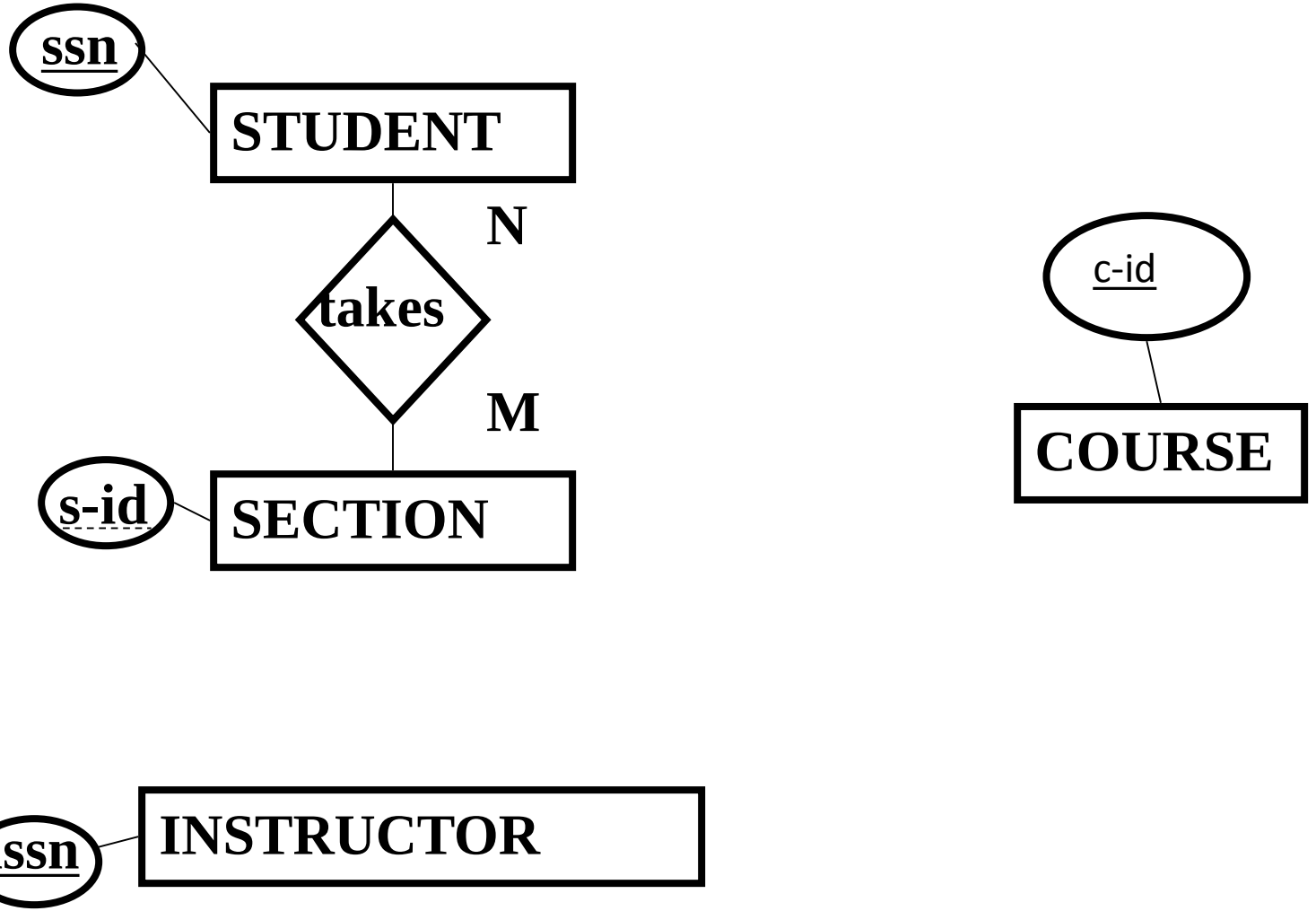


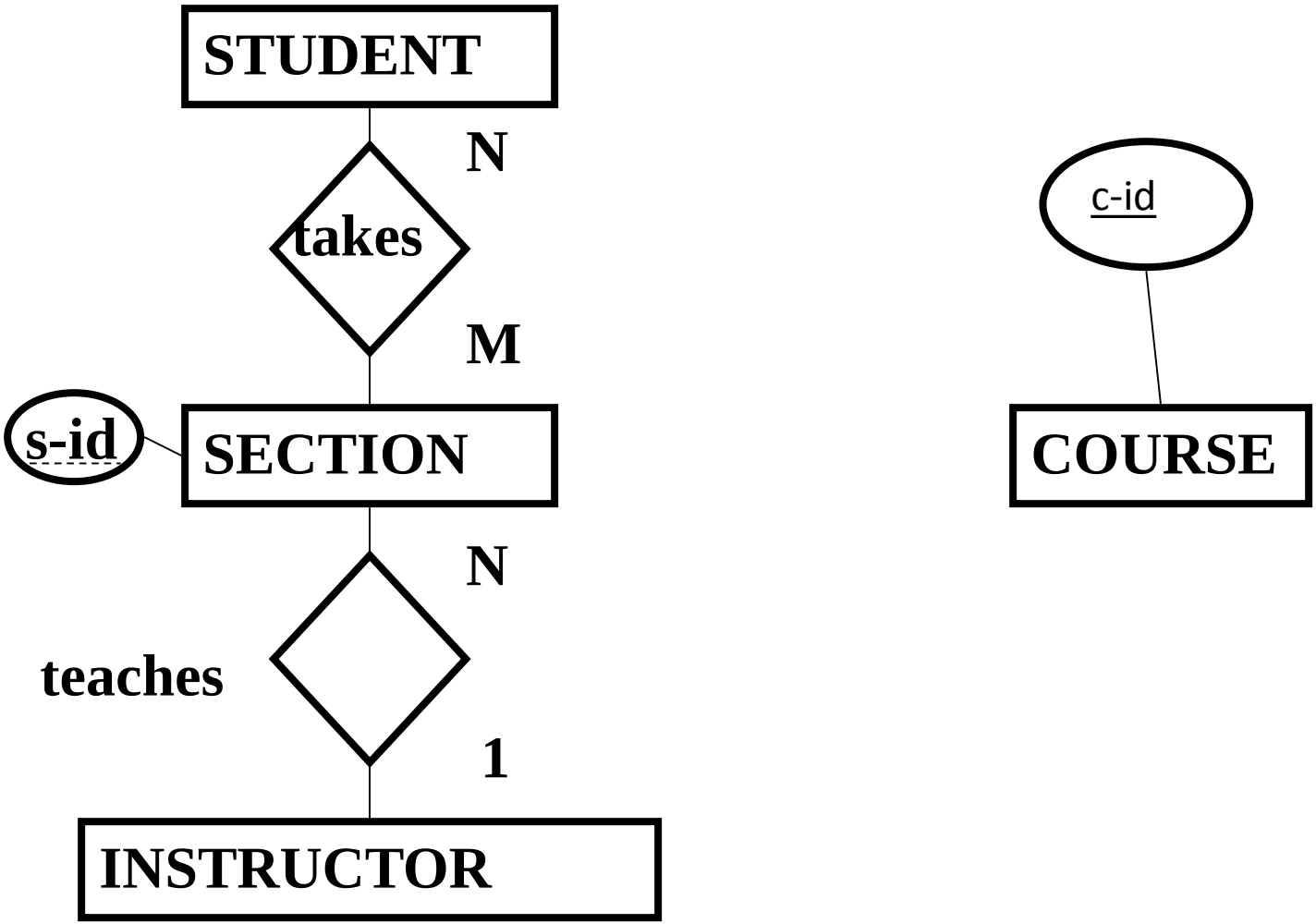
But: s-id is not unique... (see later)

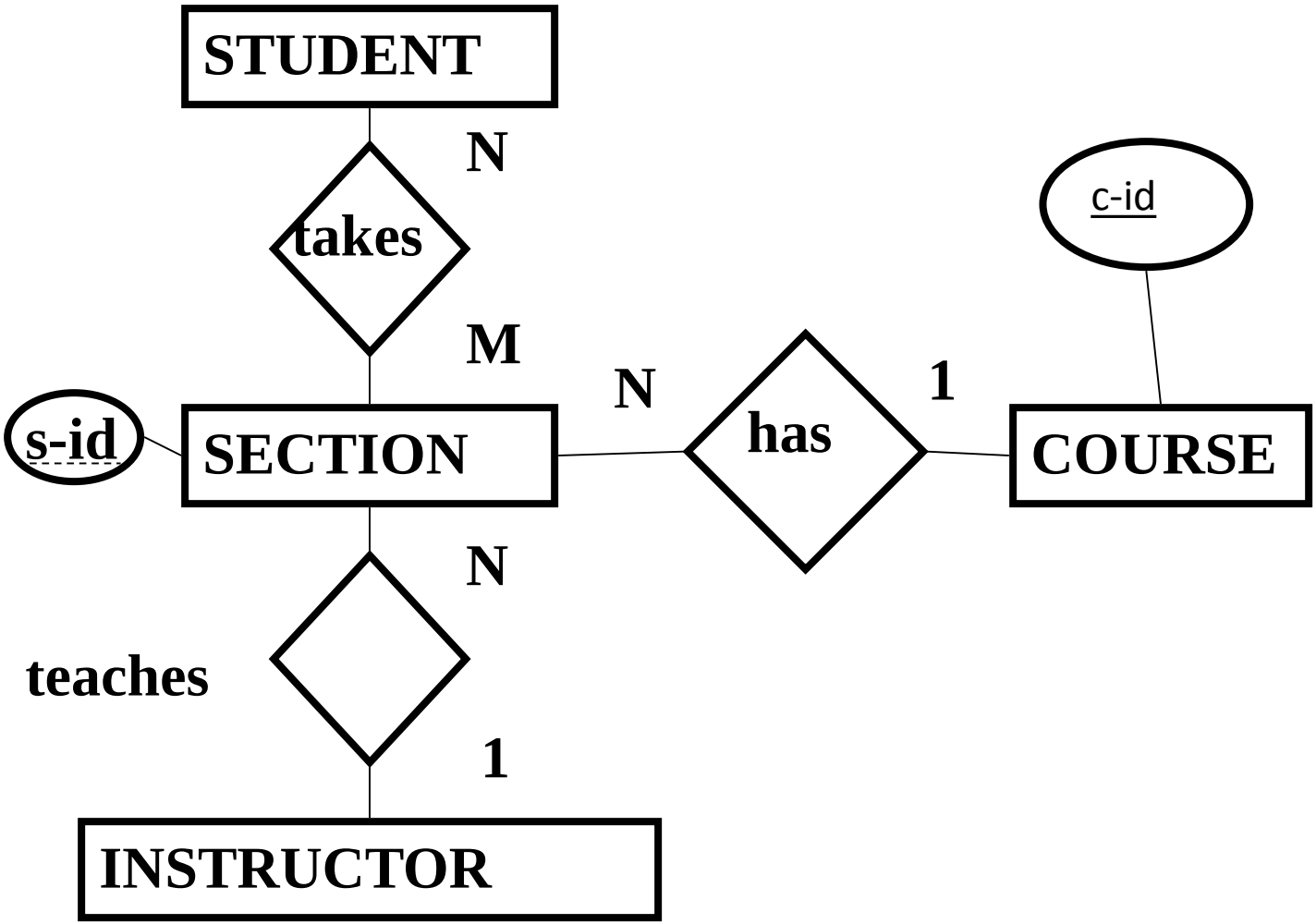




Q: how to record that students take courses?

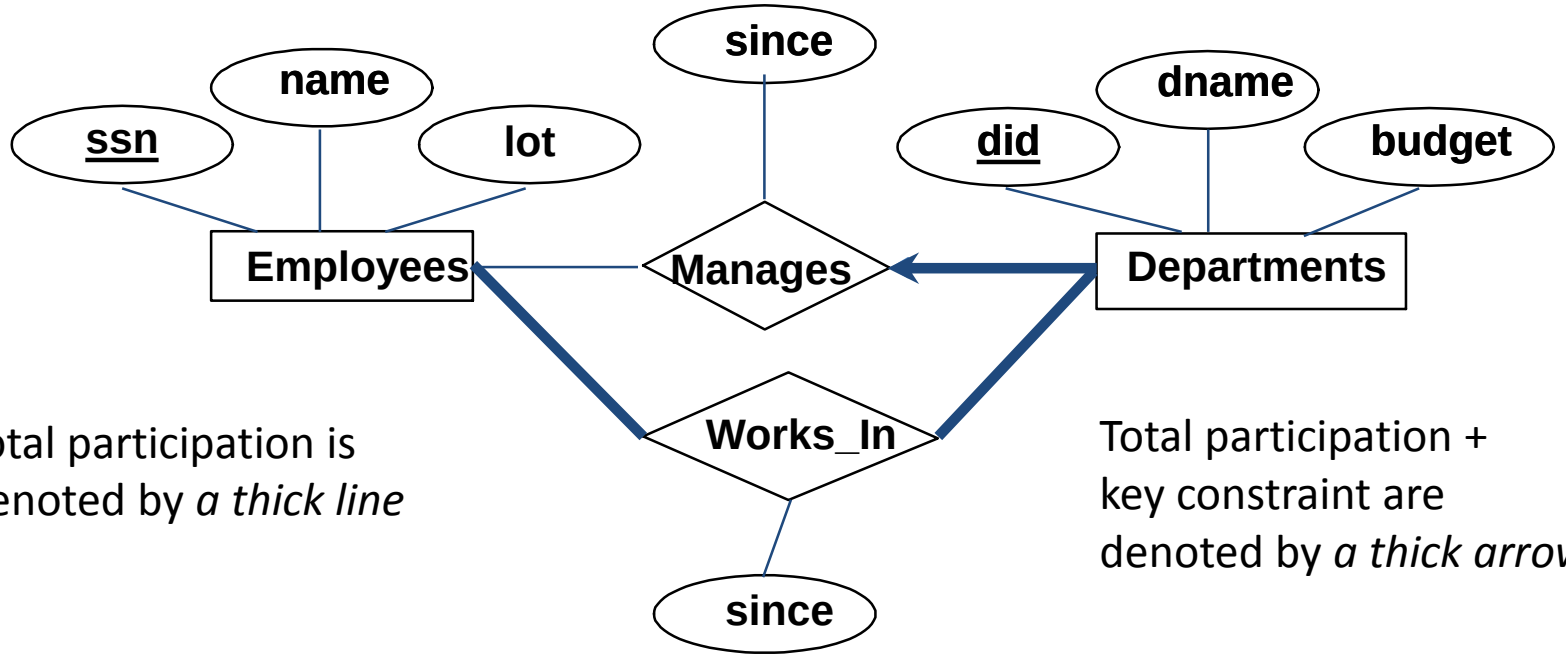






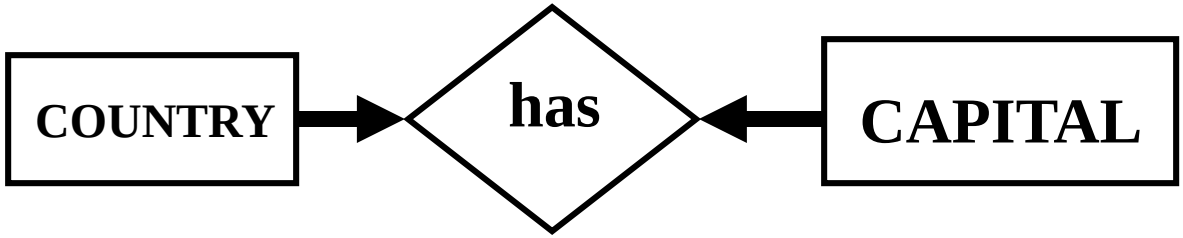
Participation Constraints

- Consider again the “Employees” and “Departments” entity sets as well as the “Manages” relationship set
  - Should every department have a manager?
  - If so, this is a participation constraint
  - Such a constraint entails that every Departments entity must appear in an instance of the Manages relationship
  - The participation of Departments in Manages is said to be total (vs. partial)



Total vs. Partial Participations

Total, Total



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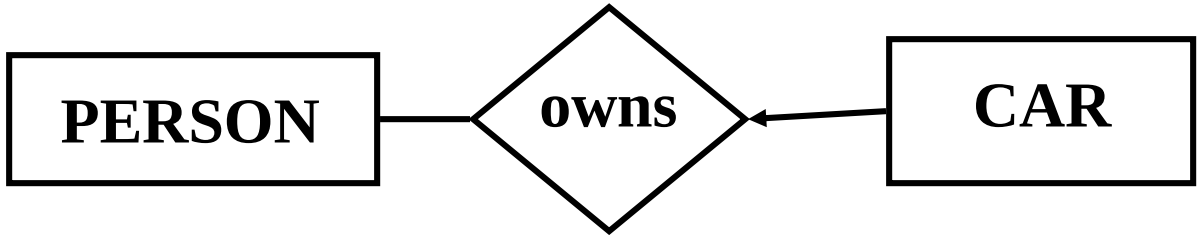

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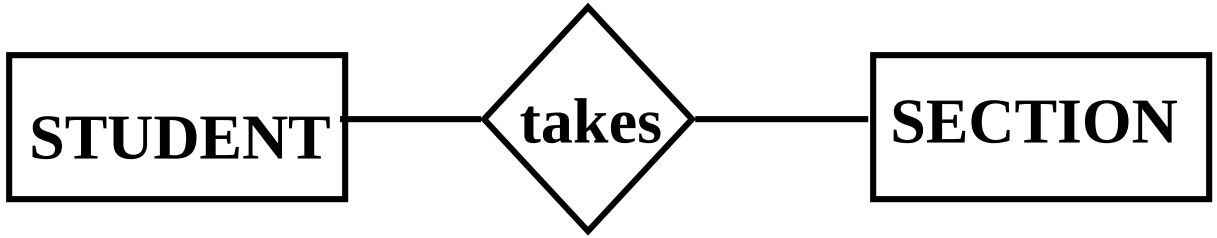
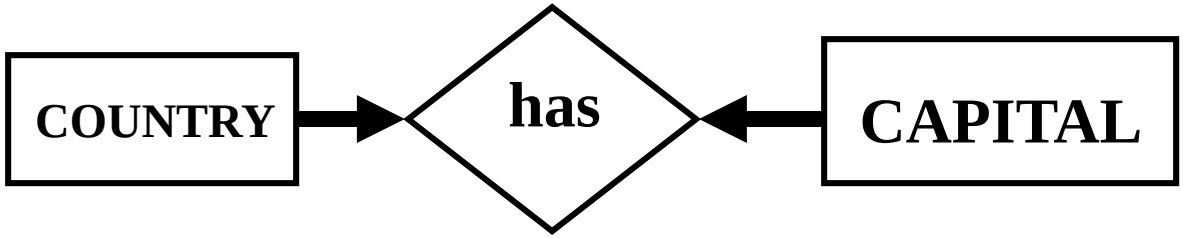
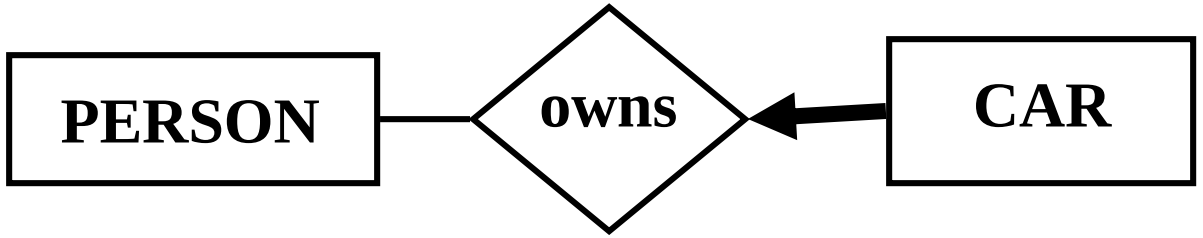


Total vs. Partial Participation

Total, Total



Partial, Total



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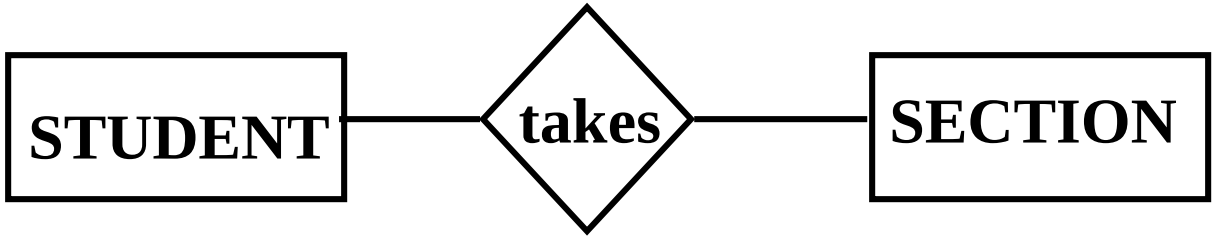
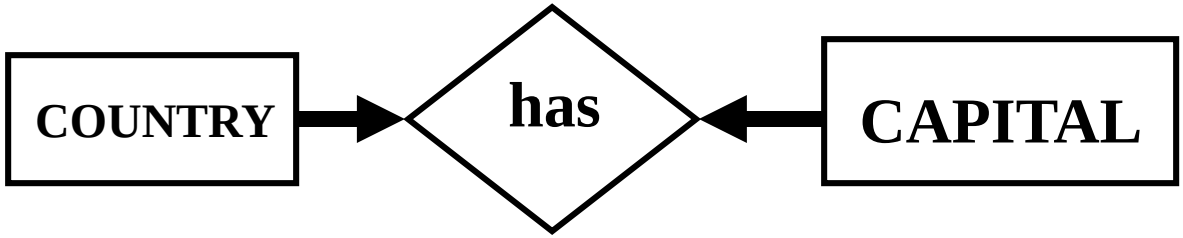
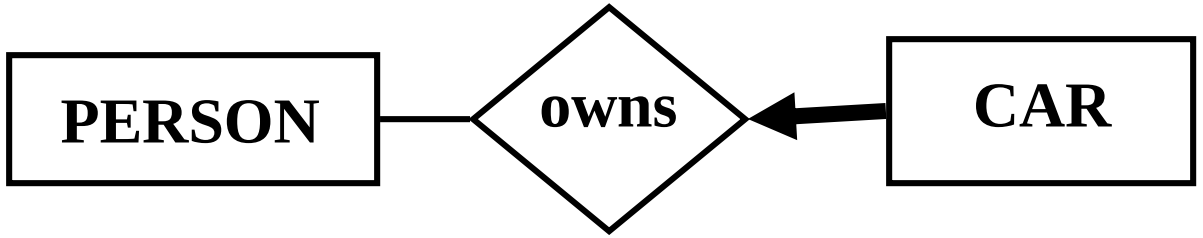


Total vs. Partial Participation

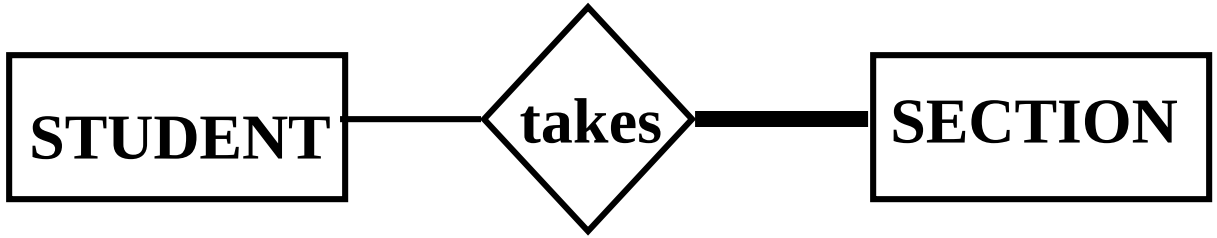
Total, Total



Partial, Total



Partial, Total



Weak Entities

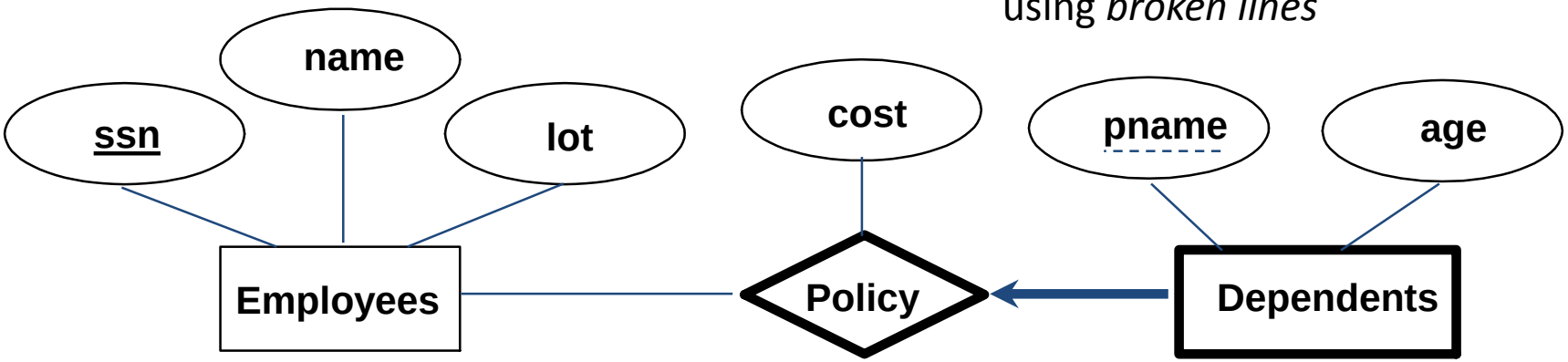
- A weak entity can be identified uniquely only by considering the primary key of another (*owner*) entity
  - Owner entity set and weak entity set must participate in a one-to-many relationship set (one owner, many weak entities)
  - Weak entity set must have total participation in this identifying relationship set

- The set of attributes of a weak entity set that uniquely identify a weak entity for a given owner entity is called partial key

Weak Entities: An Example

- "Dependents" has no unique key of its own
  - "Dependents" is a weak entity with partial key "pname"
  - "Policy" is an identifying relationship set
  - "pname" + "ssn" are the primary key of "Dependents"

Partial keys are underlined using *broken lines*

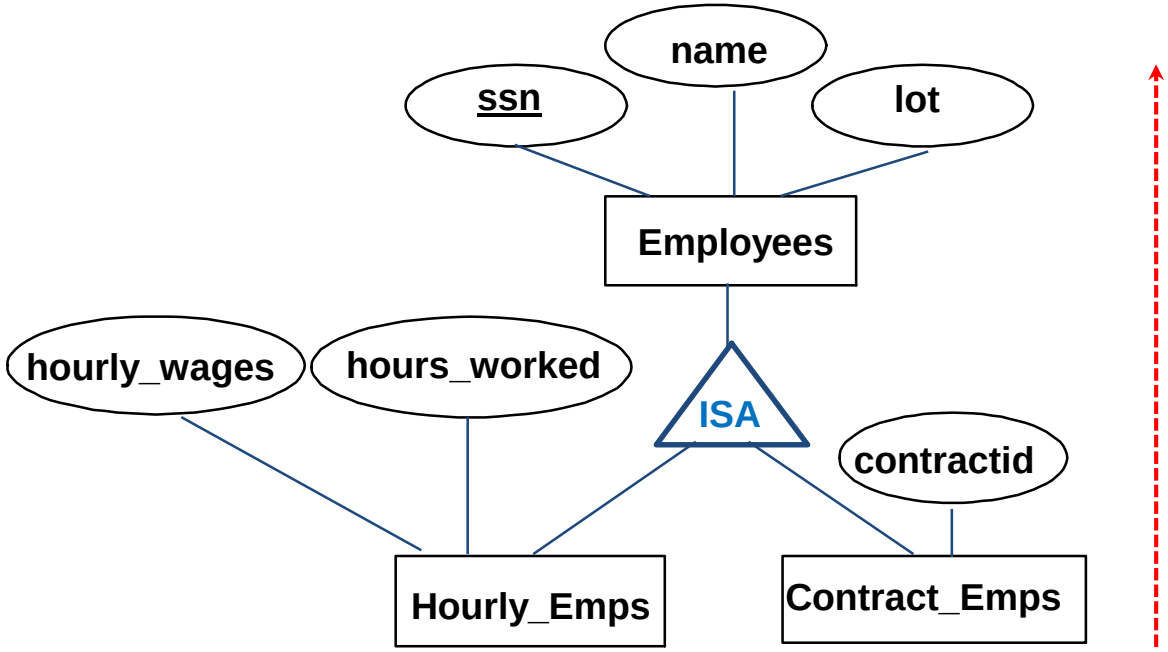


Weak entities and identifying relationships are drawn using *thick lines*

ISA (`is a') Hierarchies

- Entities in an entity set can sometimes be classified into subclasses (this is "kind of similar" to OOP languages)

- If we declare B **ISA** A, every B entity is also considered to be an A entity

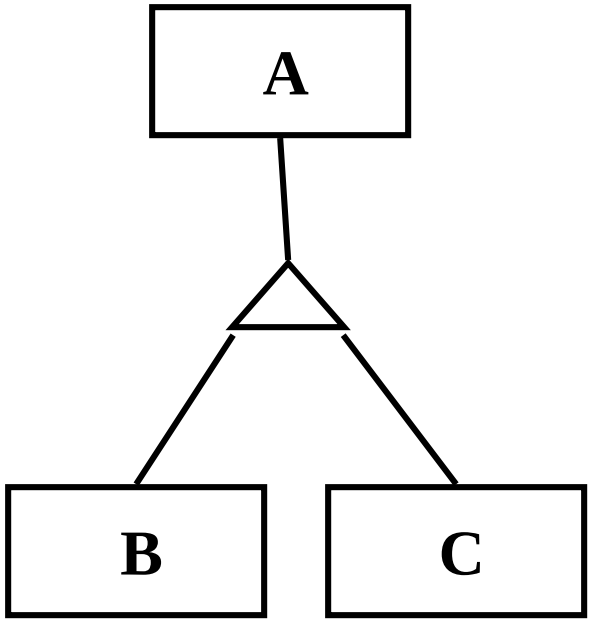


"Employees" is specialized into subclasses

"Hourly_Emps" and "Contract_Emps" are generalized by "Employees"

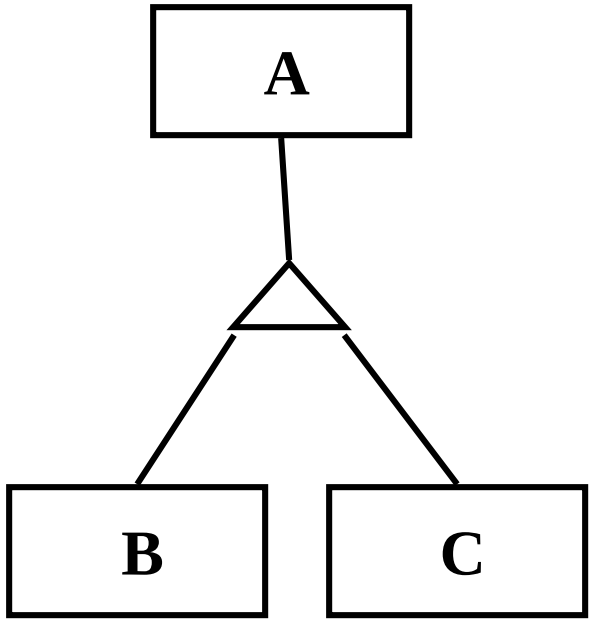
Overlap and Covering Constraints

- Overlap constraints
  - Can an entity belong to both ‘B’ and ‘C’?
- Covering constraints
  - Can an ‘A’ entity belong to neither ‘B’ nor ‘C’?



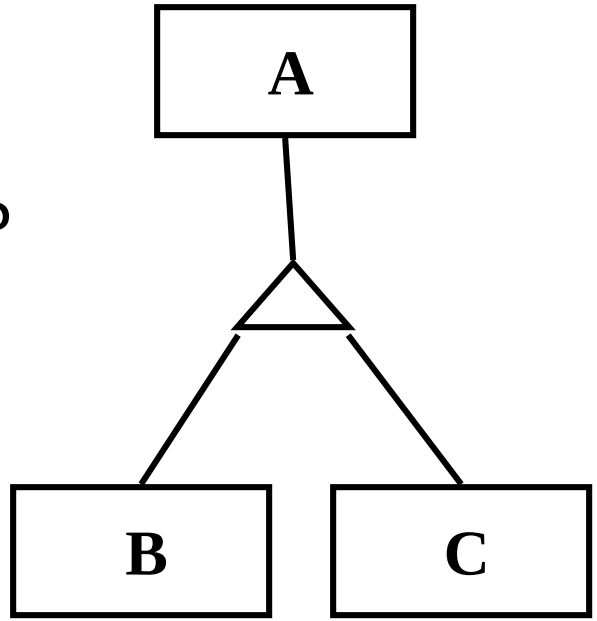
Overlap Constraints: Examples

- Overlap constraints
  - Can John be in Hourly_Emps and Contract_Emps? Intuitively, *no*
  - Can John be in Contract_Emps and in Senior_Emps? Intuitively, *yes* ➔ "Contract_Emps OVERLAPS Senior_Emps"



Covering Constraints: Examples

- Covering constraints
  - Does every one in Employees belong to a one of its subclasses? Intuitively, *no*



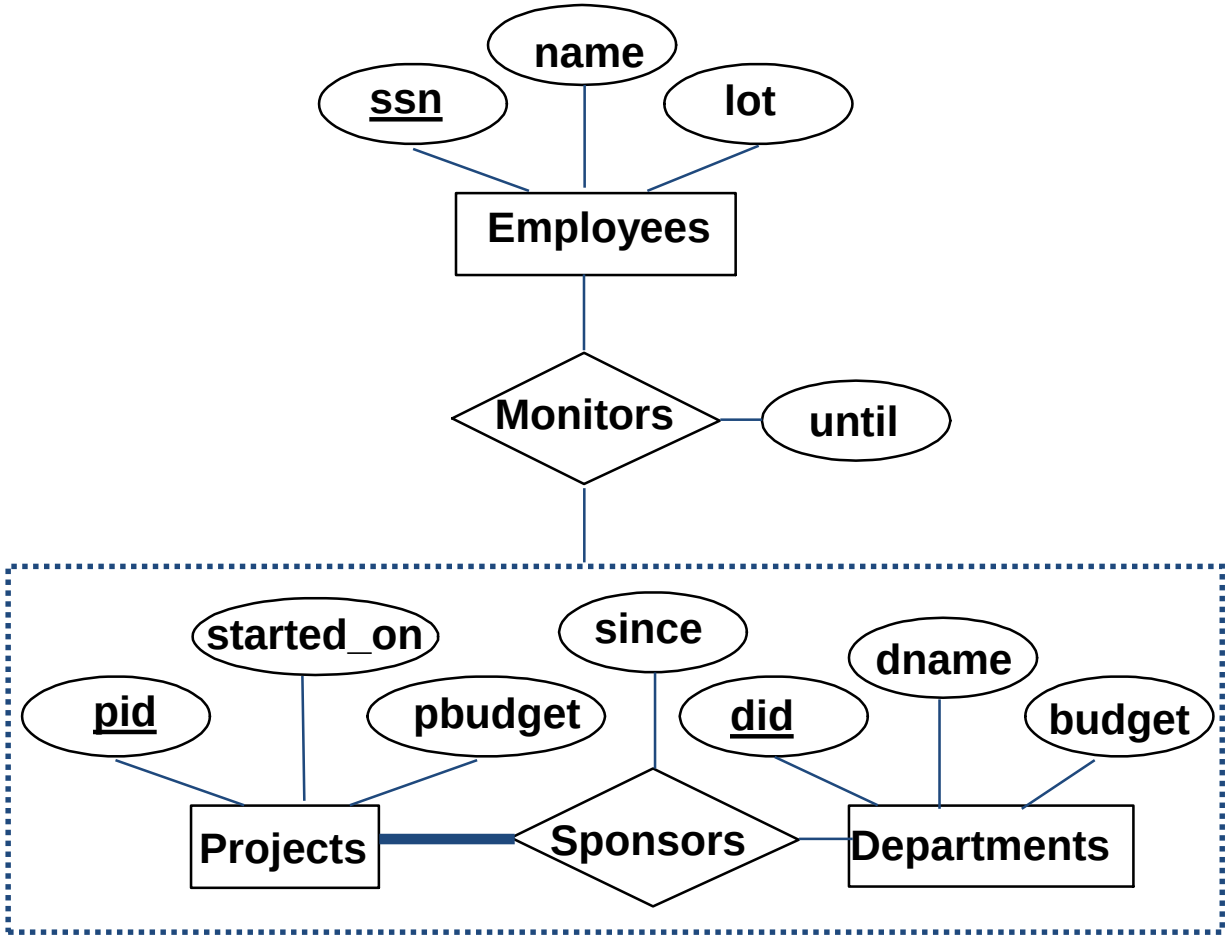
  - Does every Motor_Vehicles entity have to be either a Motorboats entity or a Cars entity? Intuitively, *yes* ➔ "Motorboats AND Cars COVER Motor_Vehicles"

More Details on ISA Hierarchies

- Attributes are *inherited* (i.e., if B ISA A, the attributes defined for a B entity are the attributes for A *plus* B)
- We can have ***many*** levels of an ISA hierarchy
- Reasons for using ISA:
  - To add descriptive attributes specific to a subclass
  - To identify entities that participate in a relationship

Aggregation

- Aggregation allows indicating that a relationship set (identified through a *dashed box*) participates in another relationship set



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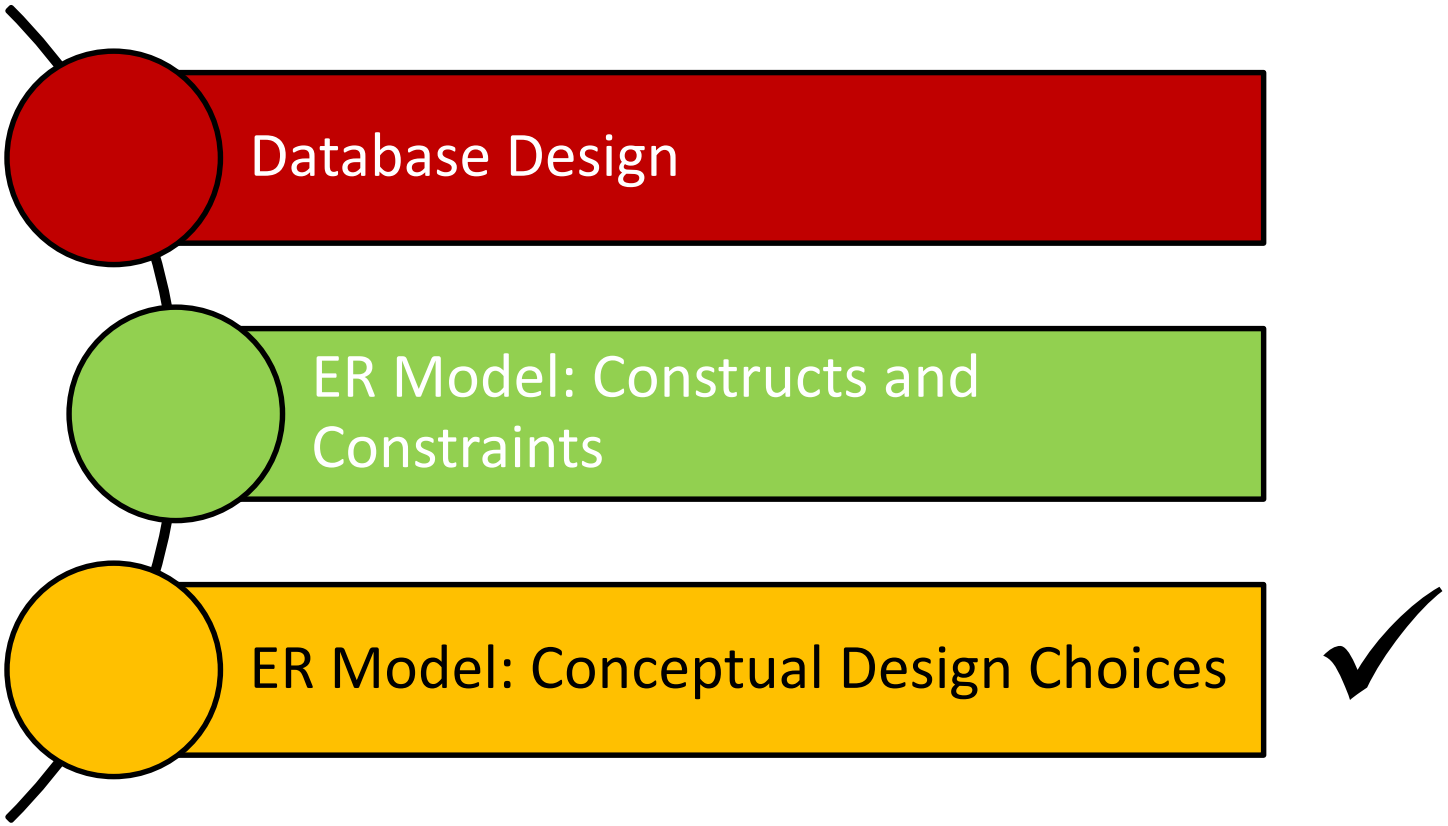


Conceptual Design Choices

- Should a concept be modeled as an *entity* or an *attribute*?
- Should a concept be modeled as an *entity* or a *relationship*?
- How should we identify relationships?
  - *Binary* or *ternary*?
  - *Ternary* or *aggregation*?
- Constraints in the ER Model:
  - A lot of data semantics can (and should) be captured
  - But some constraints cannot be captured in ER diagrams

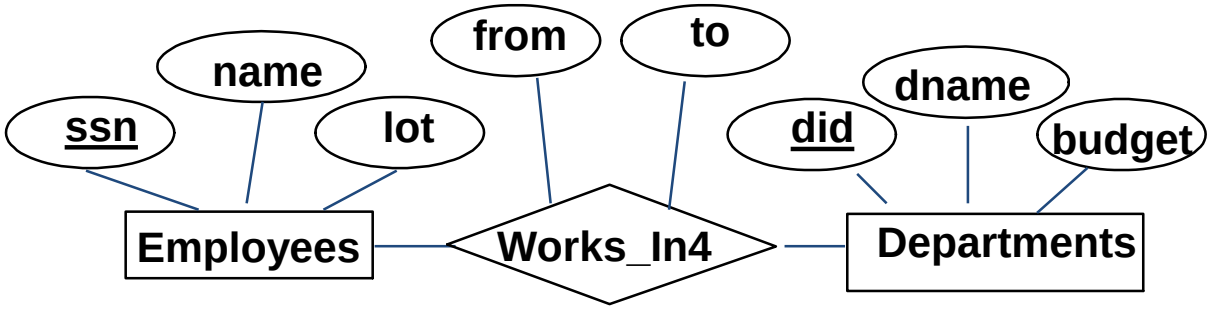
Entity vs. Attribute

- Should *address* be an attribute of Employees or an entity (connected to Employees by a relationship)?

- This depends upon the use we want to make of address information, and the semantics of the data
  - If we have several addresses per an employee, *address* must be an entity (since attributes cannot be set-valued)
  - If the structure (city, street, etc.) is important (e.g., we want to retrieve employees in a given city), *address* must be modeled as an entity

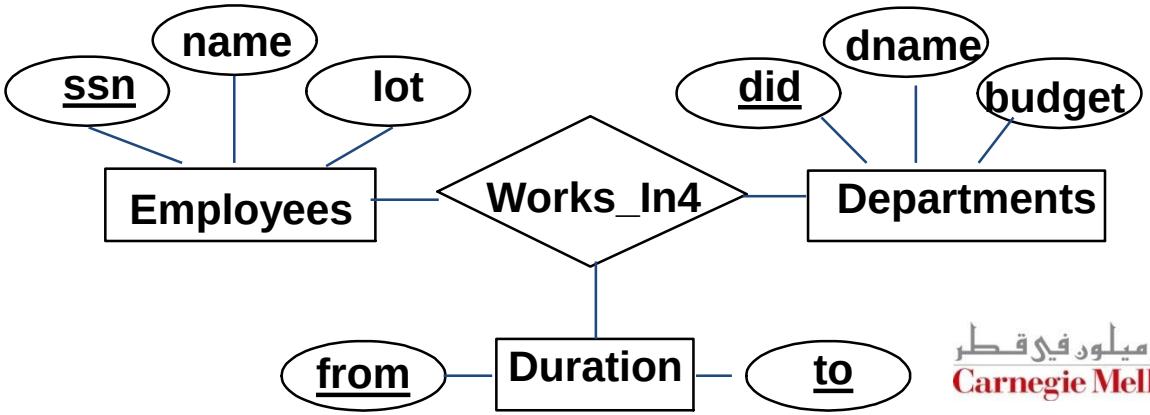
Entity vs. Attribute (Cont'd)

- Consider the following ER diagram:



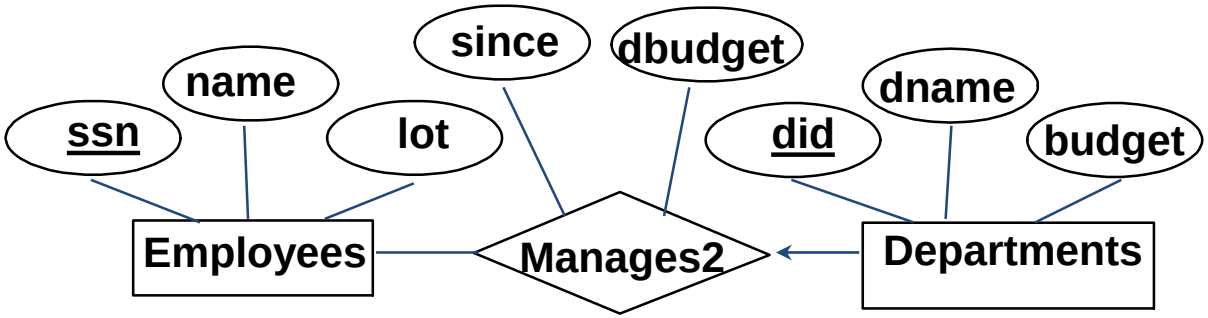
- A problem: Works_In4 does not allow an employee to work in a department for two or more periods

- Solution: introduce "Duration" as a new entity set

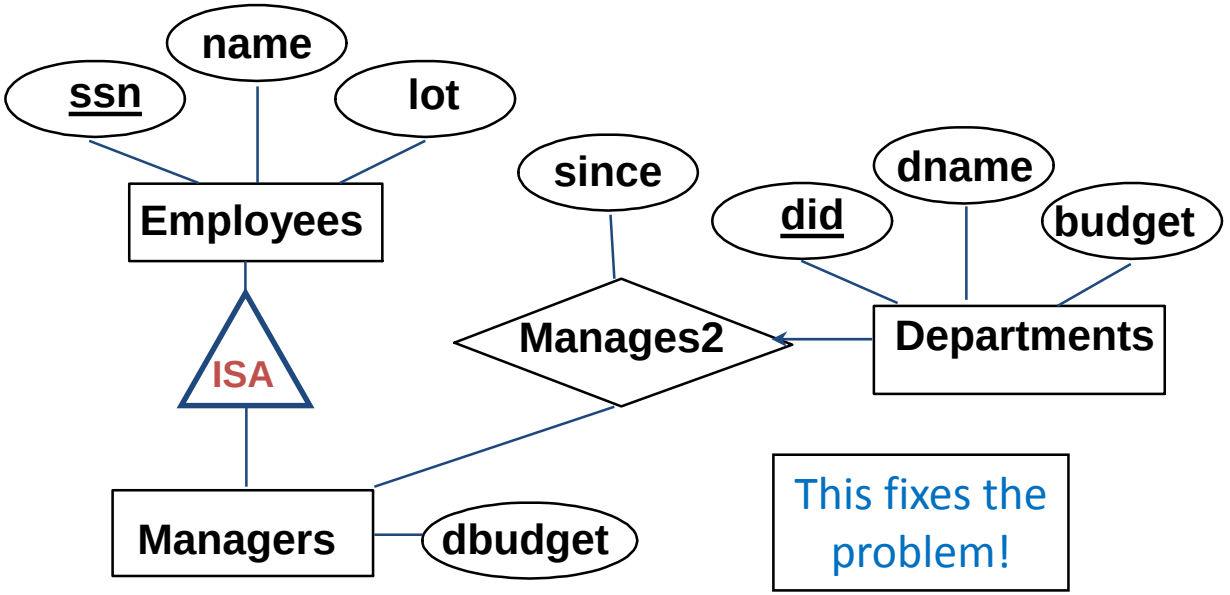


Entity vs. Relationship

- Consider the following ER diagram whereby a manager gets a separate discretionary budget for each department

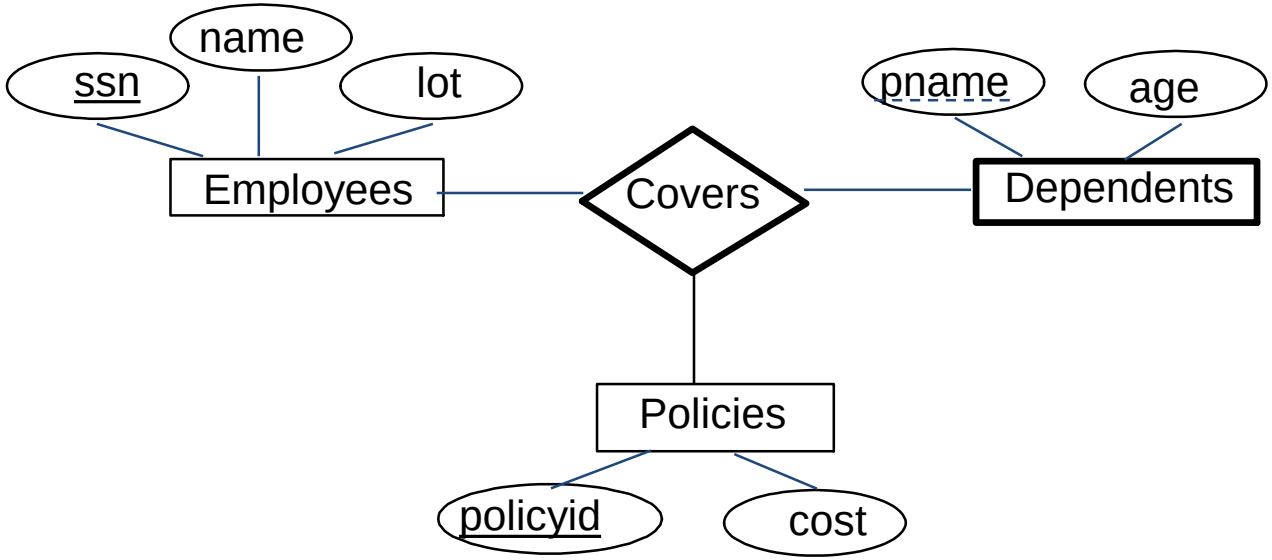


- What if a manager gets a discretionary budget that covers *all* managed departments?
  - Redundant data
  - Misleading



Binary vs. Ternary Relationships

If each policy is
owned by just 1
employee:



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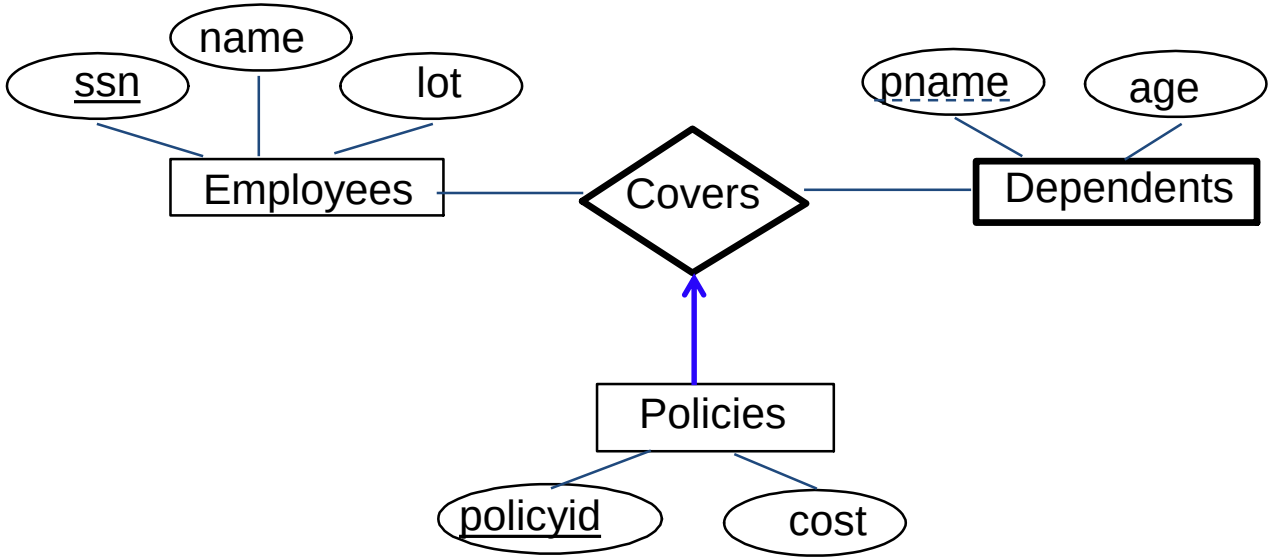
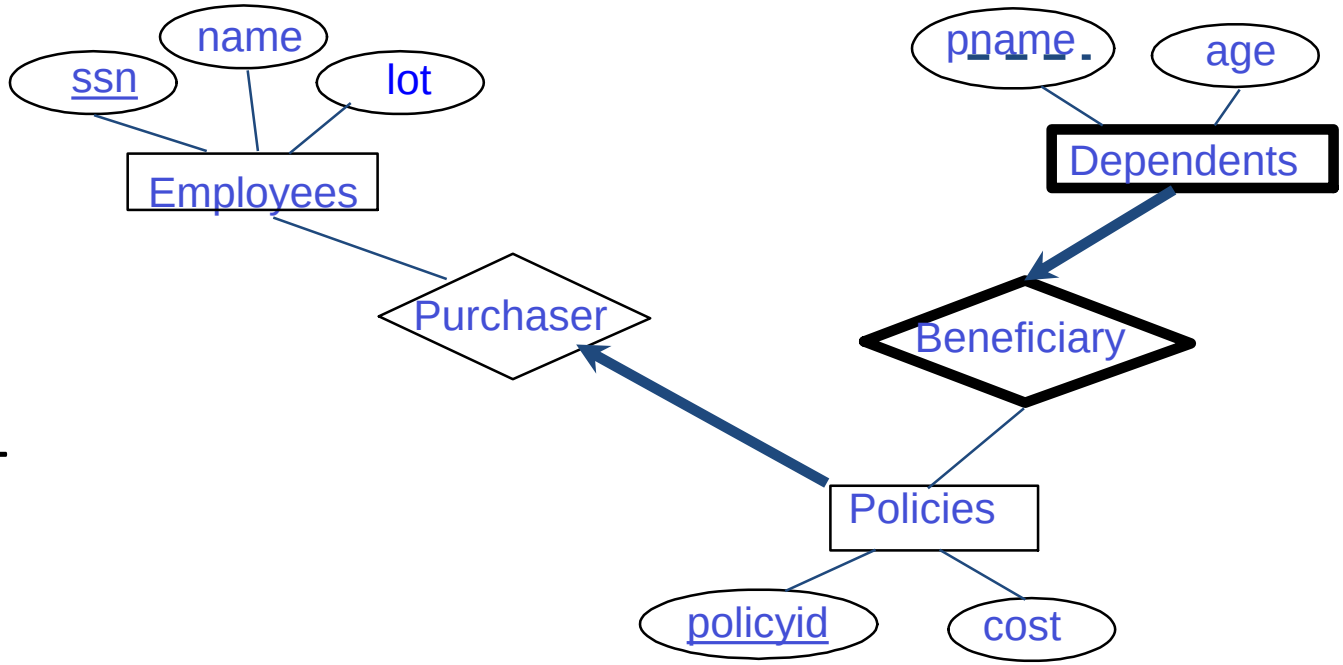


Bad design!

Key constraint on Policies would mean policy can only cover 1 dependent!

Binary vs. Ternary Relationships

If each policy is owned by just 1 employee:



Better design!

What are the additional constraints?

Binary vs. Ternary Relationships

- But sometimes ternary relationships cannot be replaced by a set of binary relationships

Binary vs. Ternary Relationships

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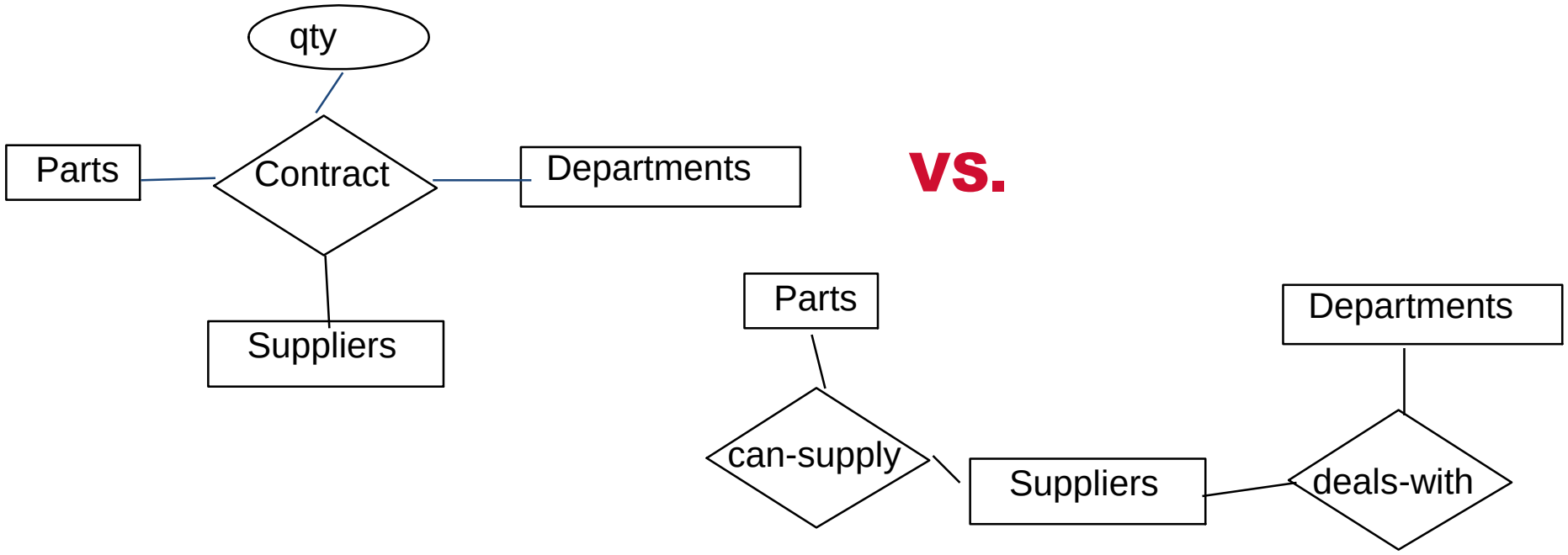

Binary vs. Ternary Relationships

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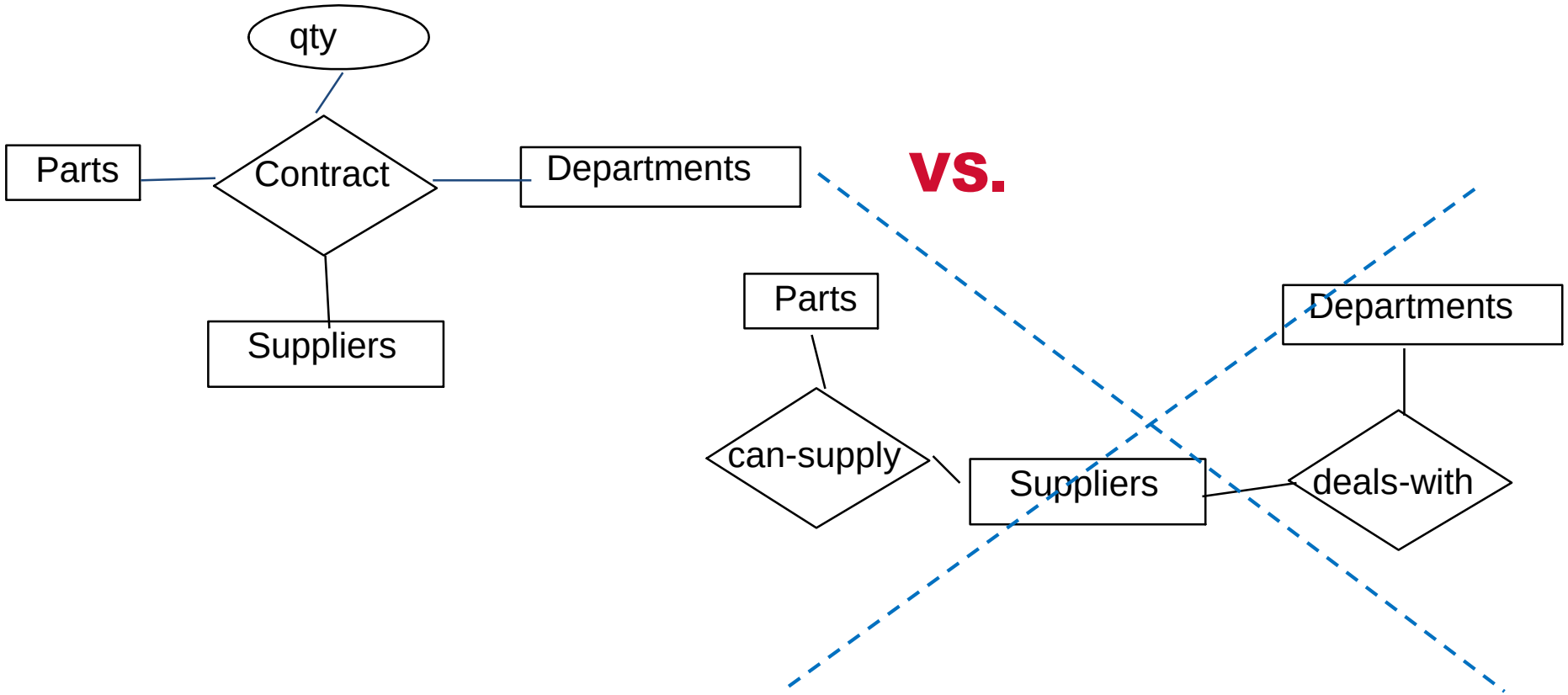

Binary vs. Ternary Relationships

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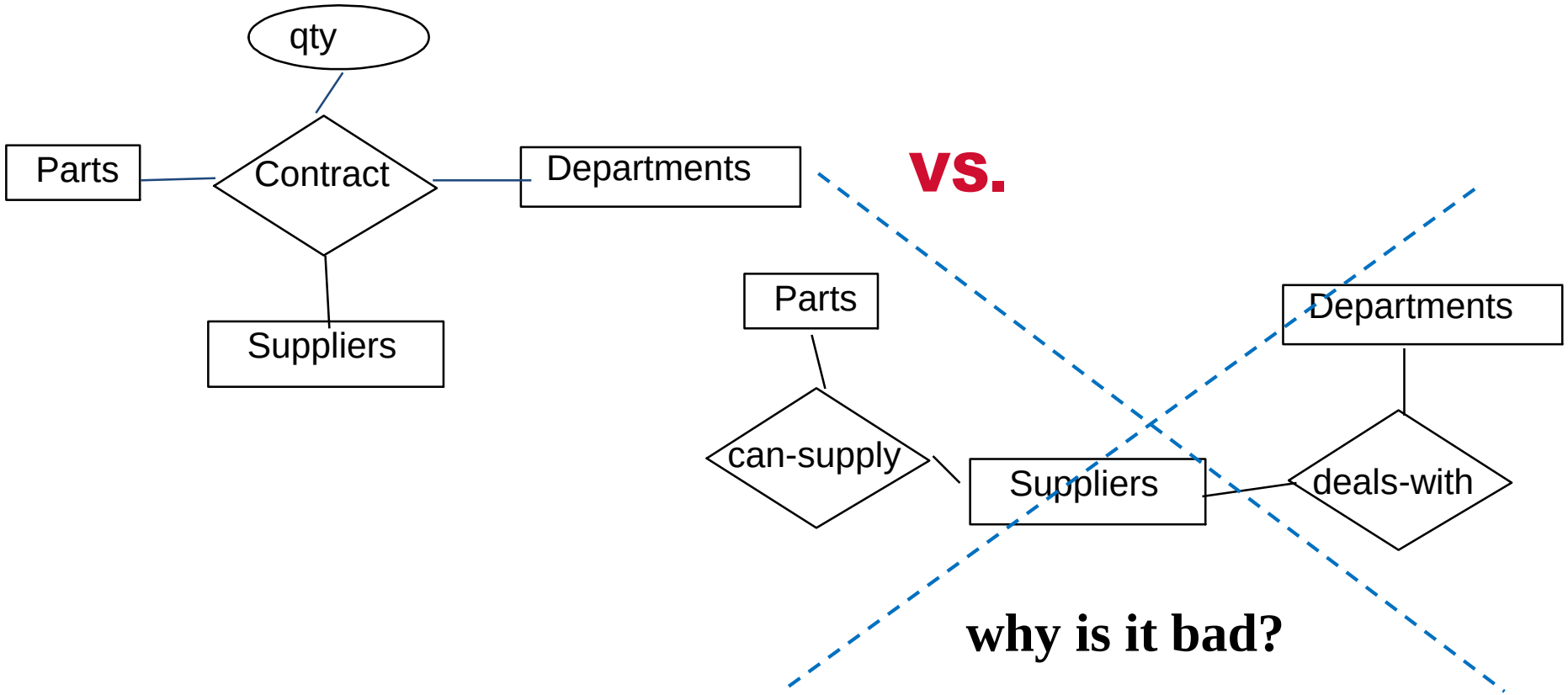
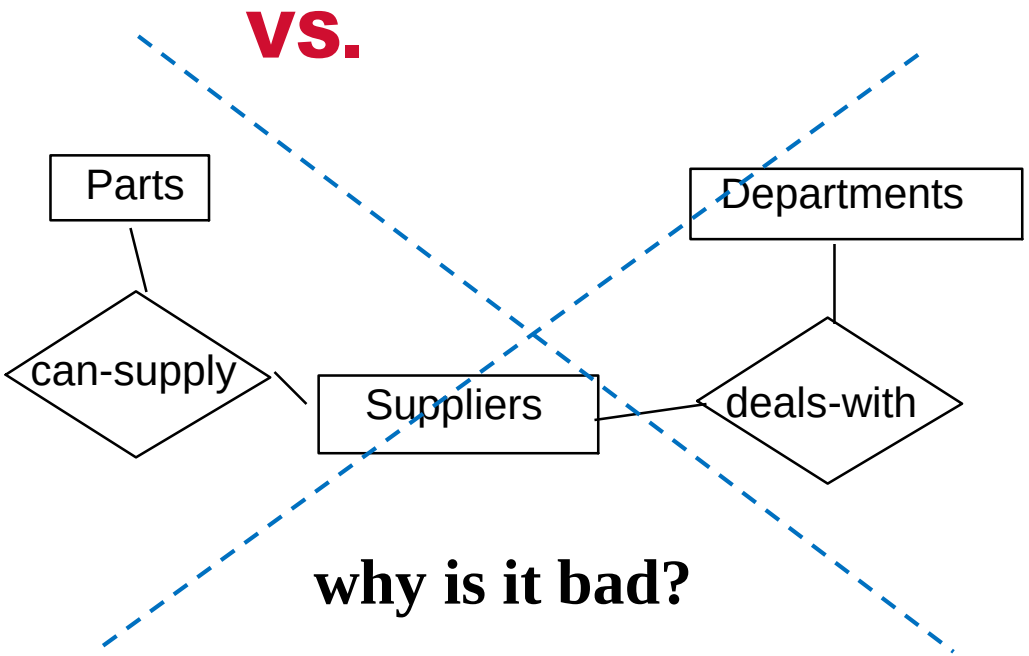


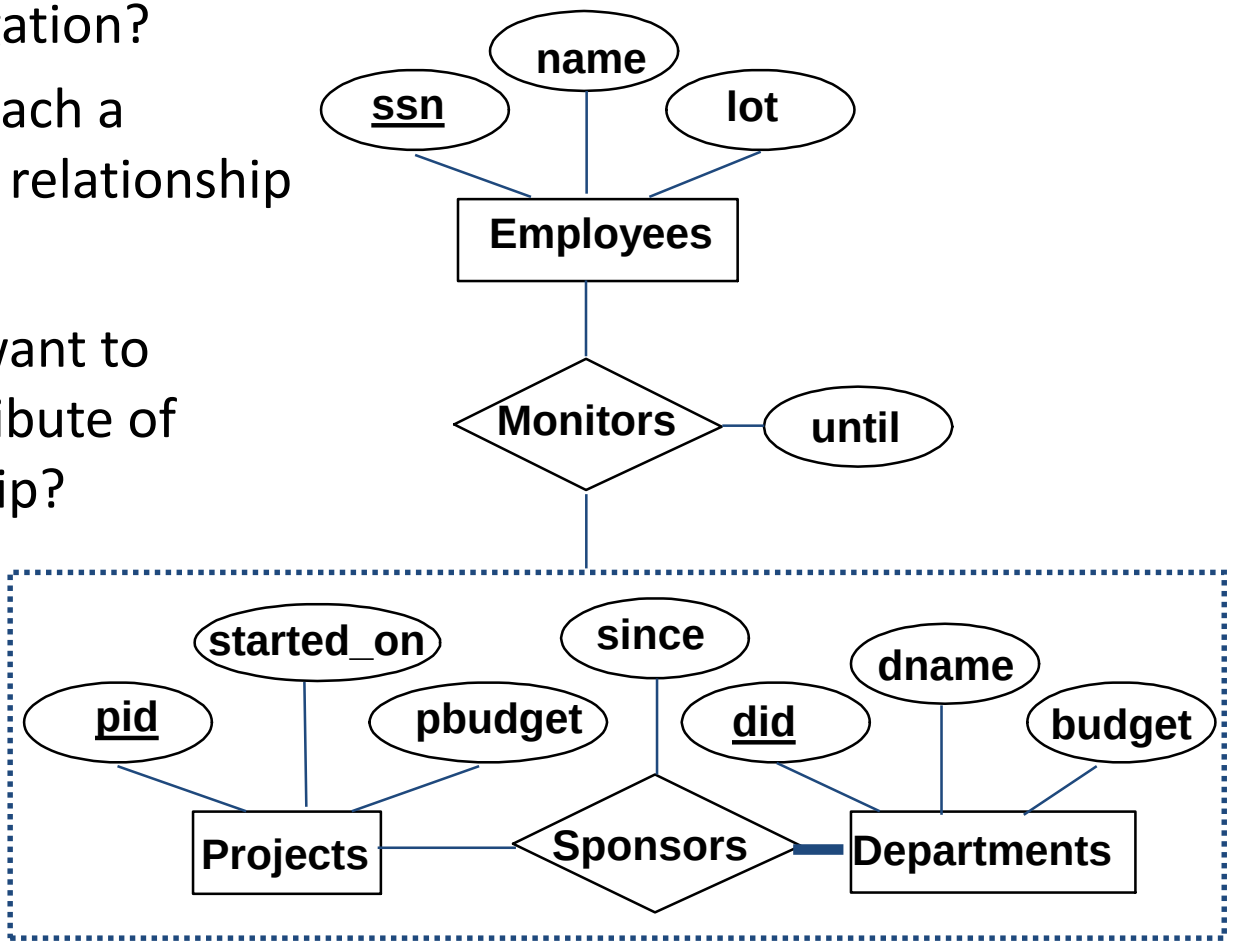
Binary vs. Ternary Relationships

- But sometimes ternary relationships cannot be replaced by a set of binary relationships
  - ***S*** "can-supply" ***P***, ***D*** "needs" ***P***, and ***D*** "deals-with" ***S*** does not imply that ***D*** has agreed to buy ***P*** from ***S***
  - How do we record *qty*?



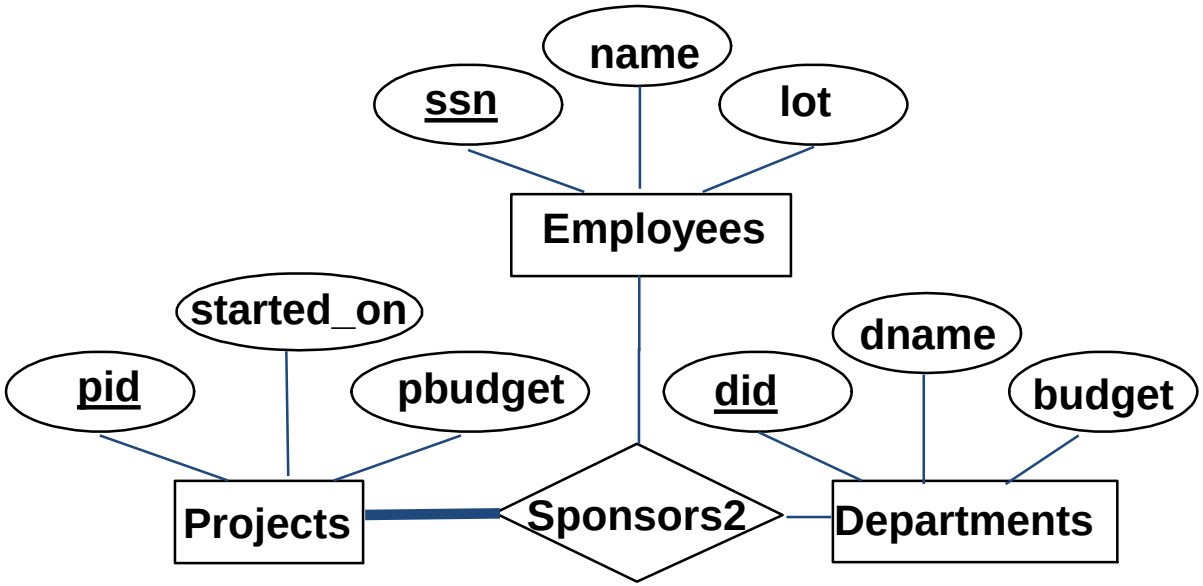
Ternary vs. Aggregation Relationships

- When to use aggregation?
  - If we want to attach a relationship to a relationship
- What if we do not want to record the *until* attribute of Monitors relationship?



Ternary vs. Aggregation Relationships (Cont'd)

- We might reasonably use a ternary relationship instead of an aggregation



What if each sponsorship (of a project by a department) is to be monitored by at most one employee?

Summary

- *Conceptual design* follows *requirements analysis*
  - Yields a high-level description of data to be stored
- The ER model is popular for conceptual design
  - Its constructs are expressive, close to the way people think about their applications
- The basic constructs of the ER model are:
  - *Entities*, *relationships*, and *attributes* (of entities and relationships)

Summary

- Some additional constructs of the ER model are:
  - *Weak entities*, *ISA hierarchies*, and *aggregation*
- Several kinds of integrity constraints can be expressed in the ER model
  - *Key constraints*, *participation constraints*, and *overlap/covering constraints* for ISA hierarchies
- Note: there are many variations on the ER model

Summary

- ER design is *subjective*
  - There are often many ways to model a given scenario!
  - Analyzing alternatives can be tricky, especially for a large enterprise
  - Common choices include:
    - Entity vs. attribute
    - Entity vs. relationship
    - Binary or *n-ary* relationship (e.g., ternary)
    - Whether or not to use ISA hierarchies
    - Whether or not to use aggregation

Next Class

The relational Model