Conceptual Design.
The Entity-Relationship (ER) Model

CS430/630
Lecture 12

Slides based on "Database Management Systems" 3rd ed, Ramakrishnan and Gehrke

Database Design Overview

- Conceptual design
  - The Entity-Relationship (ER) Model, UML
  - High-level, close to human thinking
  - Semantic model, intuitive, rich constructs
    - Not directly implementable
- Logical Design
  - The relational data model
  - Machine-implementable, fewer and more basic constructs
  - Logical design translates ER into relational model (SQL)
- Physical Design (not in this course)
  - Storage and indexing details

Conceptual Design – ER Model

- What are the *entities* and *relationships* in a typical application?
  - What information about these entities and relationships should we store in the database?

- What are the *integrity constraints* or *business rules*
  - Key constraints
  - Participation constraints

- Representation through *ER diagrams*
  - ER diagrams are then mapped into relational schemas
  - Conversion is fairly mechanical

Entities and Entity Sets

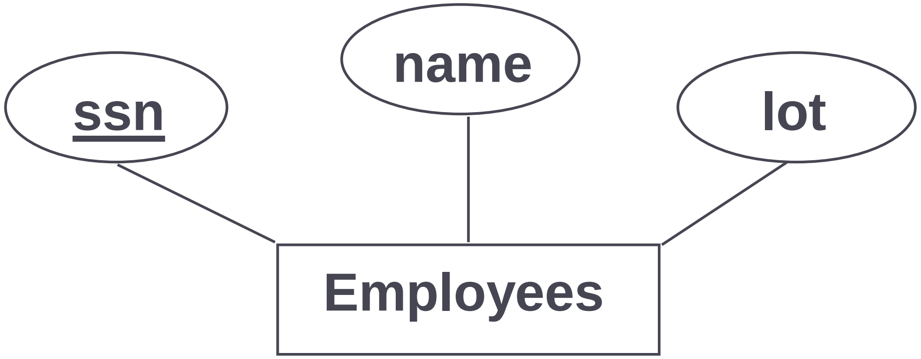
- *Entity:* represents a real-world object
  - Characterized using set of *attributes*
  - Each attribute has a *domain* – similar to variable types

- *Entity Set:* represents collection of similar entities
  - E.g., all employees in an organization
  - All entities in an entity set share same set of attributes

Keys

- Each entity set has a *key*
  - Set of attributes that uniquely identify an entity
  - Multiple *candidate keys* may exist
  - *Primary key* selected among them

Entity Set Representation



Representation Convention:

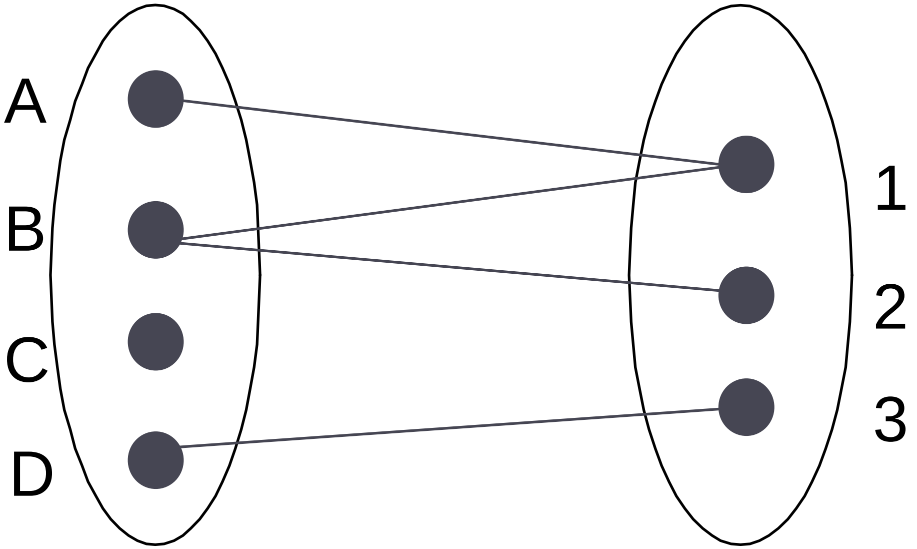
- Entity sets: rectangles
- Attributes: ovals, with key attributes underlined
- Edges connect entity sets to attributes

Relationships and Relationship Sets

- *Relationship*: Association among two (or more) entities
  - "Gabriel works in CS department"
  - Can have descriptive attributes: e.g., "since 9/1/2011"
    - But relationship must be fully determined by entities!
  - *Binary*, *ternary* or *multi-way (n-way)* relationships

- *Relationship Set*: Collection of similar relationships
  - Contains *n*-tuples ($e_1, \ldots, e_n$), where e_i belongs to entity set E_i
  - *Instance*: "snapshot" of relationship set at some point in time

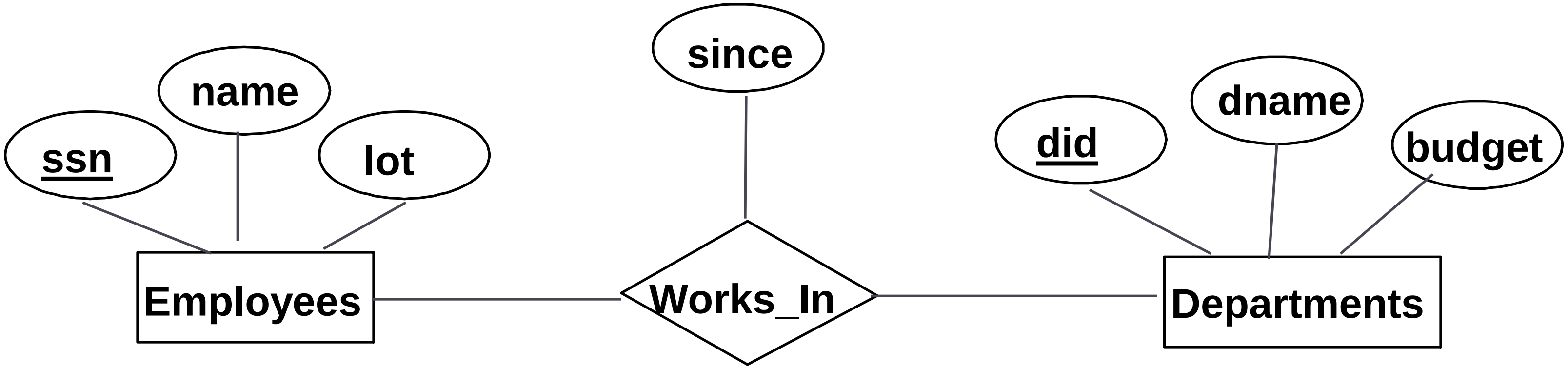
Visualizing Relationships and Rel. Sets



(A, 1)
(B, 1)
(B, 2)
(D, 3)

Edge = Relationship
Set of Edges = Relationship Set

Relationship Set Representation



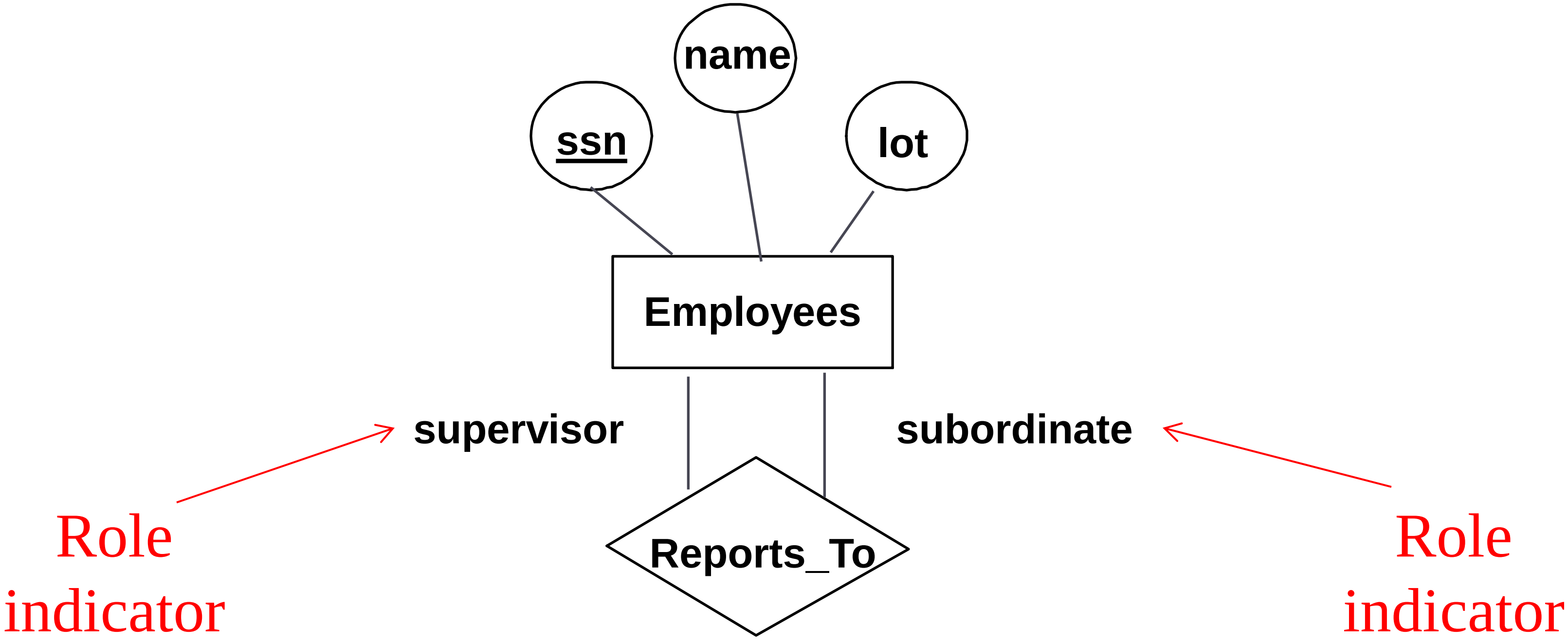
Representation Convention:

- Relationship sets: diamonds

- Edges connect relationship sets to entity sets, and relationship sets to relationship set attributes

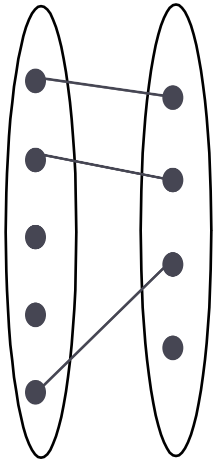
A Special Case of Relationship

- An entity set can participate in a relationship set with itself
  - Entities in same set play different ***roles*** in the relationship
  - ***Role indicators*** express the role

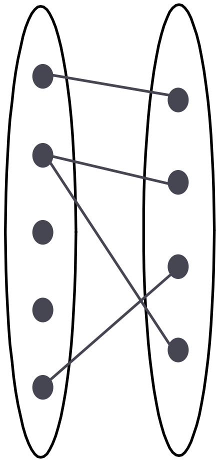


Key Constraints

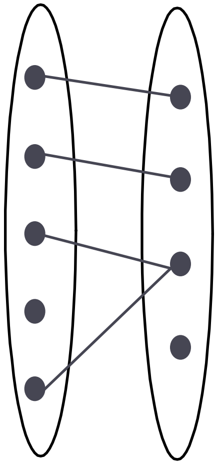
- How many other entities can an entity have a relationship with?
    - Also referred to as relationship *multiplicity*



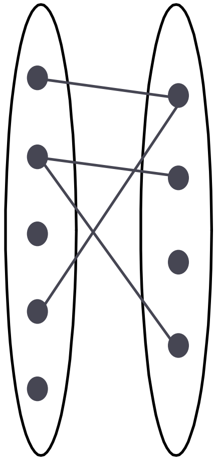
1-to-1



1-to-Many



Many-to-1

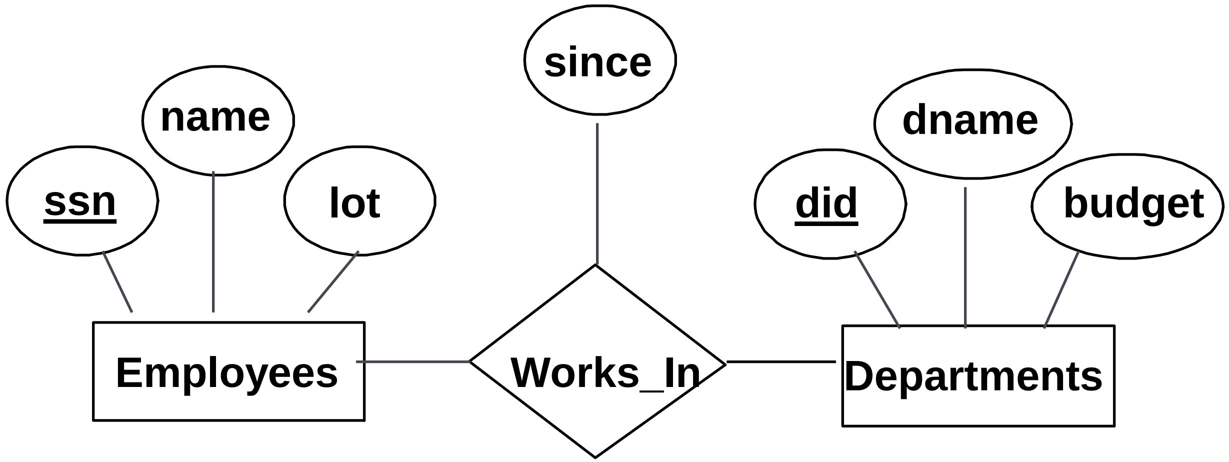


Many-to-Many

Example 1

- Works_In relationship: an employee can work in many departments; a dept can have many employees.

many-to-many



Example 2

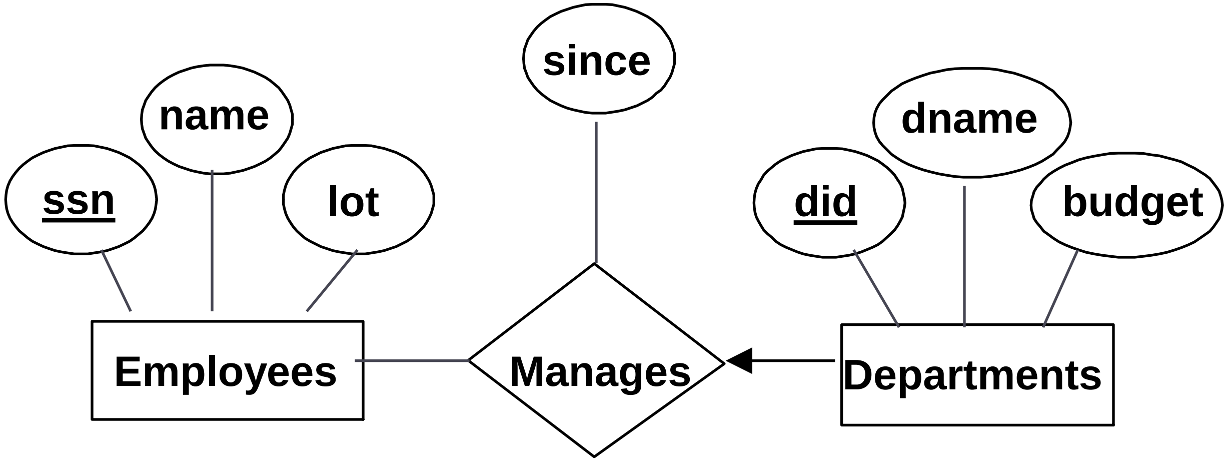
- Manages relationship: each dept has *at most one* manager

one-to-many

from *Employees* to *Departments* , *or*

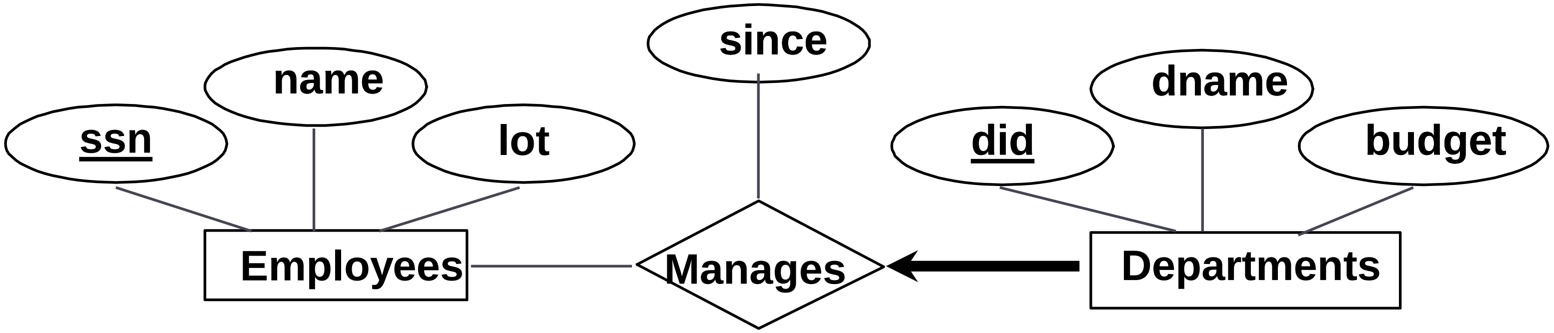
many-to-one

from *Departments* to *Employees*



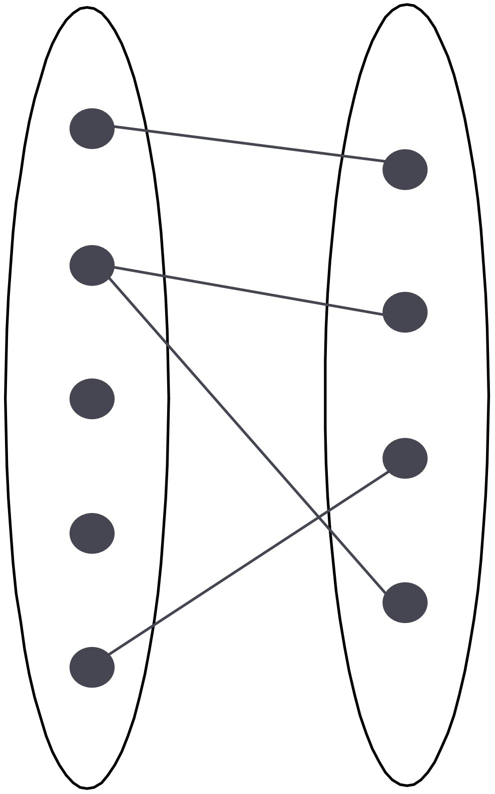
Participation Constraints

- *Total* vs *Partial* Participation
  - Total: every department must have a manager
    - "Departments" entity set has total participation in relationship
    - Represented as thickened line (there is a key constraint as well)
  - Partial: not every employee is a manager
    - "Employees" entity set has partial participation



Participation Constraints

Partial
Participation



Total
Participation

Example

Design a database for a bank, including information about customers and their accounts. Information about customers includes their name, address, phone and SSN. Accounts have numbers, types (e.g., savings/checking) and balances.

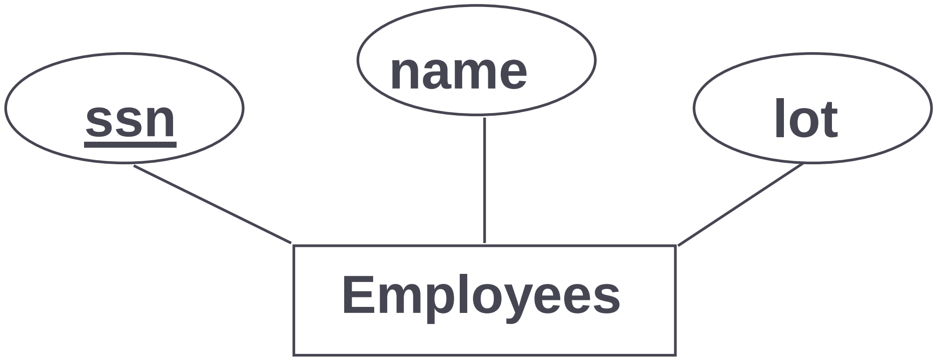
1. Draw the E/R diagram for this database.
2. Modify the E/R diagram such that each customer must have at least one account.
3. Modify the E/R diagram further such that an account can have at most one customer.

Mapping ER to Relational Schemas

- For most part, process is mechanical
  - Some special cases arise in the presence of constraints

- Translation from ER to SQL requires:
  - Mapping entity sets to tables
  - Mapping relationship sets to tables
  - Capturing key constraints
  - Capturing participation constraints

Entity Sets to Tables



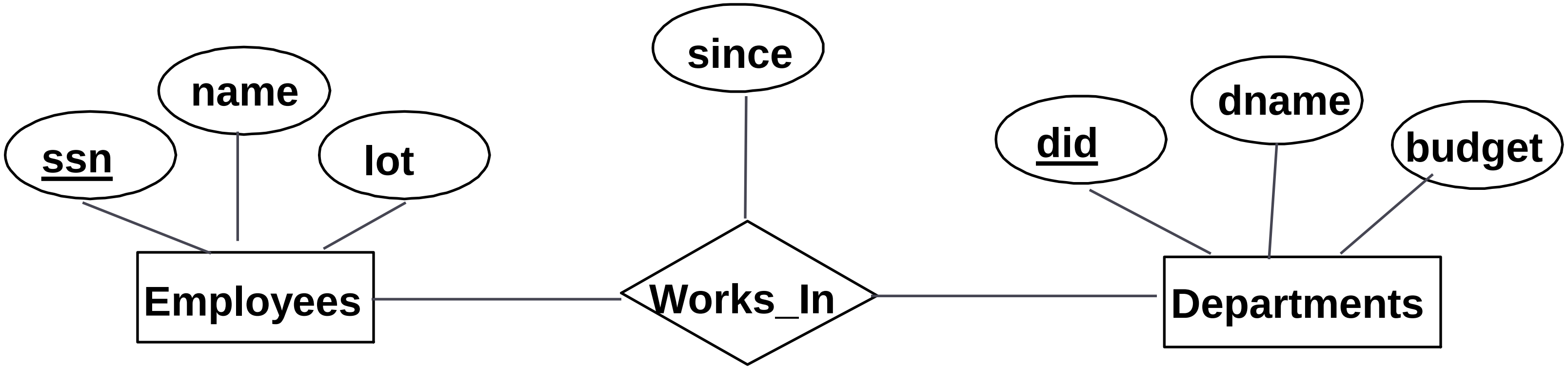
```
CREATE TABLE Employees
        (ssn CHAR(11),
        name CHAR(20),
        lot  INTEGER,
        PRIMARY KEY  (ssn))
```

Relationship Sets to Tables

- “No-constraints” case follows simple rules

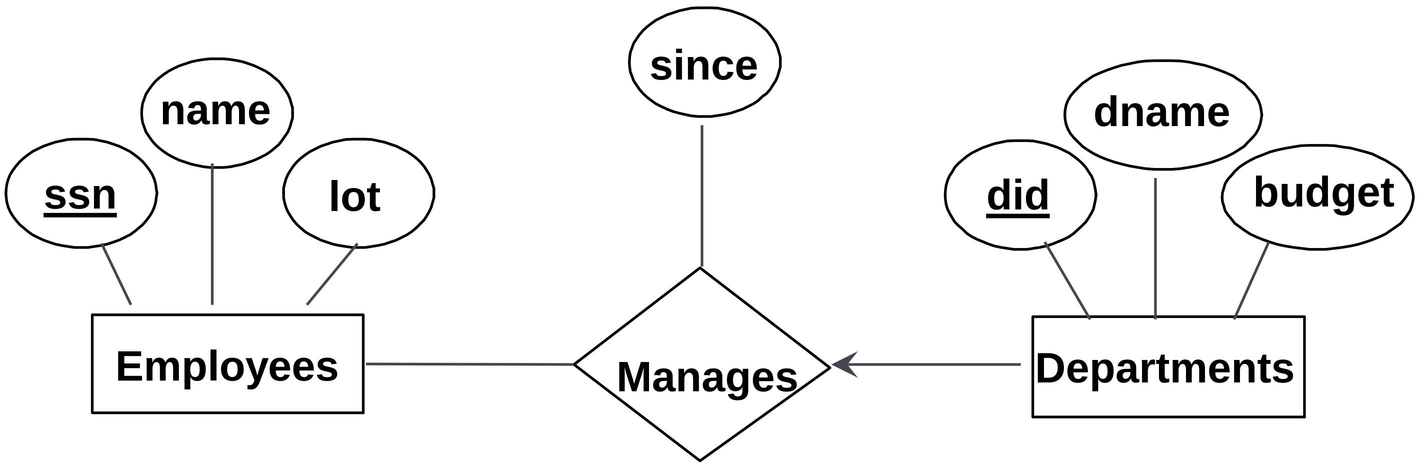
- Relationship set becomes a relation, attributes include:
  - Keys for each participating entity set (as foreign keys pointing to respective entity table)
  - All descriptive attributes for relationship
  - Primary key of relationship set table is the concatenation of primary keys for the entity sets

Relationship Sets to Tables



```
CREATE TABLE Works_In(
  ssn  CHAR(11),
  did  INTEGER,
  since  DATE,
  PRIMARY KEY (ssn, did),
  FOREIGN KEY (ssn)
        REFERENCES Employees,
  FOREIGN KEY (did)
        REFERENCES Departments)
```

What if there are Key Constraints?



- Each department has at most one manager, according to the key constraint on Manages

Variant 1

- Map relationship to a table:
  - Note that did is the key now!
  - Separate table for Manages relationship.

```
CREATE TABLE  Manages(
   ssn  CHAR(11),
   did  INTEGER,
   since  DATE,
   PRIMARY KEY  (did),
   FOREIGN KEY (ssn) REFERENCES Employees,
   FOREIGN KEY (did) REFERENCES Departments)
```

Variant 2

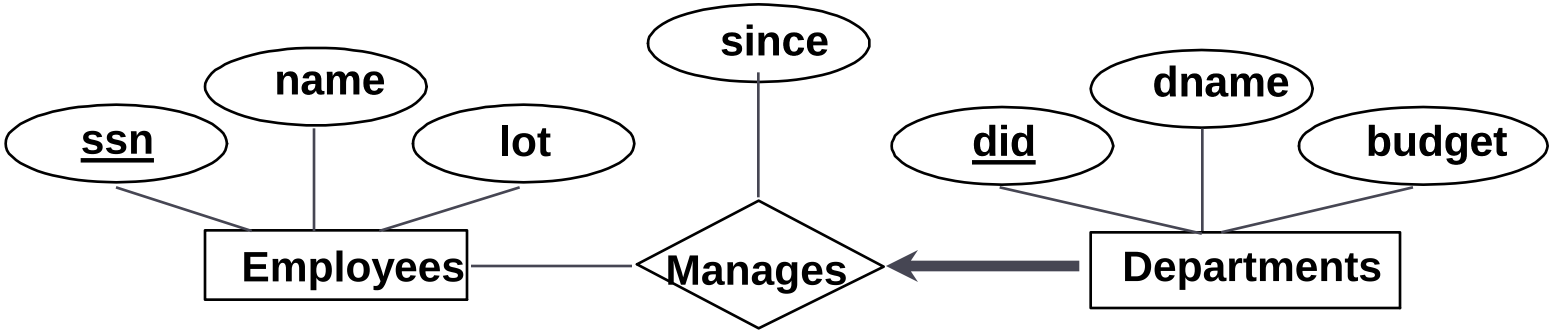
- Since each department has a unique manager, we could instead combine Manages and Departments.

```
CREATE TABLE  Dept_Mgr(
   did  INTEGER,
   dname  CHAR(20),
   budget INTEGER,
   ssn  CHAR(11),
   since  DATE,
   PRIMARY KEY  (did),
   FOREIGN KEY (ssn) REFERENCES Employees)
```

Review: Participation Constraints

- Does every department have a manager?
  - If yes, the participation of Departments in Manages is *total*
  - Every *did* value in Departments table must appear in a row of the Manages table (with a non-null *ssn* value!), but this cannot be controlled in SQL (unless we use complex constraints)
- Turns out that it is NOT possible to capture this with the two-tables mapping
  - Foreign key mechanism does not allow to check if there is a reference to every tuple in the referenced table
  - The Dept_Mgr variant is the only way!

Participation Constraints in SQL



```
CREATE TABLE  Dept_Mgr(
  did  INTEGER,
  dname  CHAR(20),
  budget INTEGER,
  ssn CHAR(11) NOT NULL,
  since  DATE,
  PRIMARY KEY  (did),
  FOREIGN KEY  (ssn) REFERENCES Employees
    ON DELETE NO ACTION)
```

Participation Constraints Summary

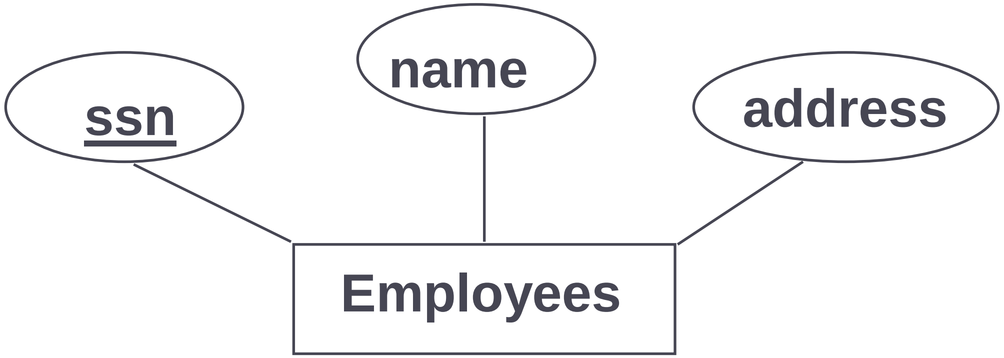
- General case
  - Total participation cannot be enforced unless we use complex constraints
- What if there is also a key constraint in place?
  - If the entity set with total participation also has a key constraint, then it is possible to capture total participation
  - But only if "combined" table construction is used!

Design Choices in the ER Model

- Should a concept be modeled as an entity or an attribute?

- Should a concept be modeled as an entity or a relationship?
  - Considers hierarchies and inheritance
  - Outside the scope of this class

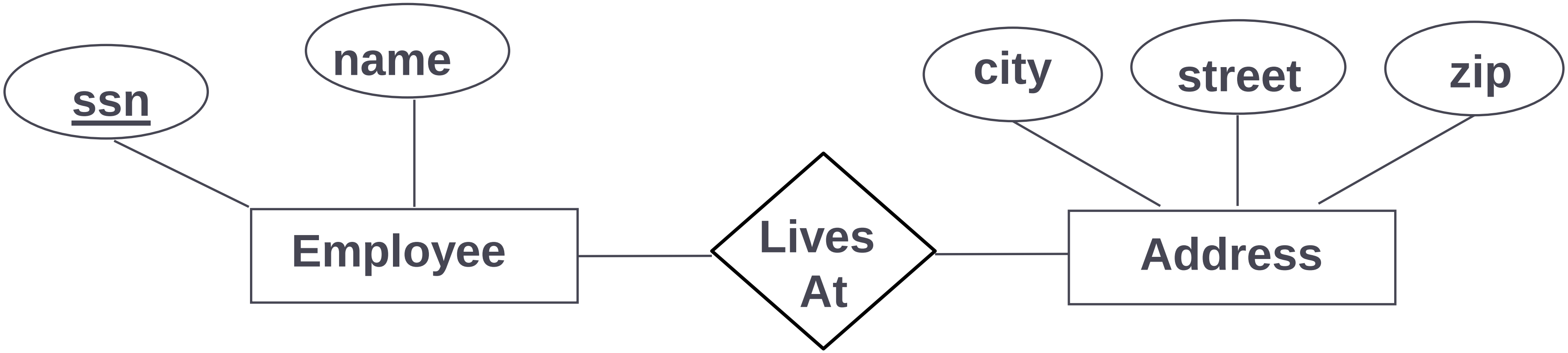
Entity vs. Attribute



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

Entity vs. Attribute

- Sometimes address may have to be an entity:
  - If we have several addresses per employee (since attributes cannot be set-valued)
  - If the structure (city, street, etc.) is important, e.g., retrieve employees in a given city (attribute values are atomic!)


ssn
name
Employee
Lives At
Address
city
street
zip