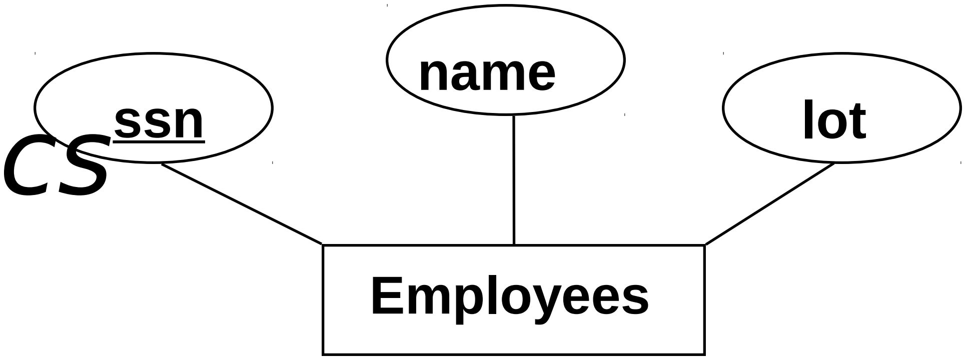
Conceptual Design Using the Entity-Relationship (ER) Model

Module 5, Lectures 1 and 2

Overview of Database Design

- *Conceptual design*: *(ER Model is used at this stage.)*
  - What are the *entities* and *relationships* in the enterprise?
  - What information about these entities and relationships should we store in the database?
  - What are the *integrity constraints* or *business rules* that hold?
  - A conceptual schema in the ER Model can be represented pictorially (*ER diagrams*).
  - Can map an ER diagram into a relational schema.
- *Schema Refinement*: *(Normalization)* Check relational schema for redundancies and related anomalies.
- *Physical Database Design and Tuning*: Consider typical workloads and further refine the database design.

ER Model Basics

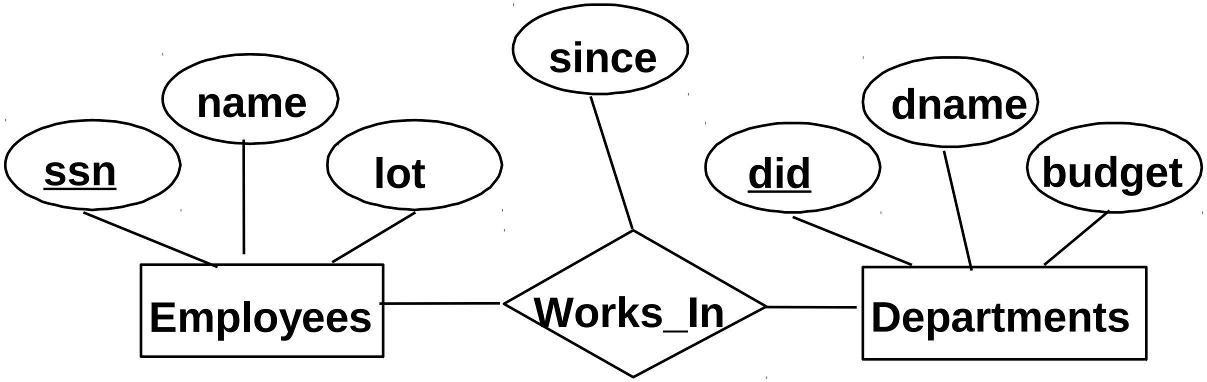


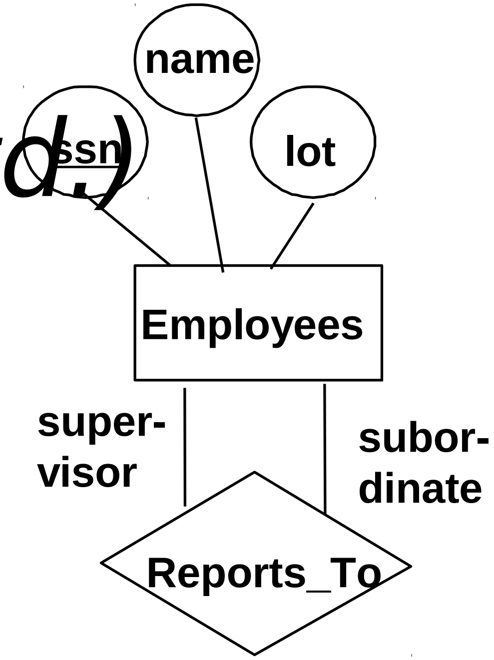
- *Entity:* Real-world object distinguishable from other objects.
  - An entity is described (in DB) using a set of *attributes*.
- *Entity Set*: A collection of similar entities. E.g., all employees.
  - All entities in an entity set have the same set of attributes. (Until we consider ISA hierarchies, anyway!)
  - Each entity set has a *key*.
  - Each attribute has a *domain*.
  - Can map entity set to a relation easily.

ssn	**name**	**lot**
123-22-3666 48	Attishoo	
231-31-5368 22	Smiley	
131-24-3650	Smethust	3

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

ER Model Basics (Contd.)





- *Relationship*: Association among 2 or more entities. E.g., Smith works in Pharmacy department.
- *Relationship Set*: Collection of similar relationships.
  - An n-ary relationship set R relates *n* entity sets E_1 ... E_n; each relationship in R involves entities $e_1 \in E_1, \ldots, e_n \in E_n$
    - Same entity set could participate in different relationship sets, or in different “roles” in same set.

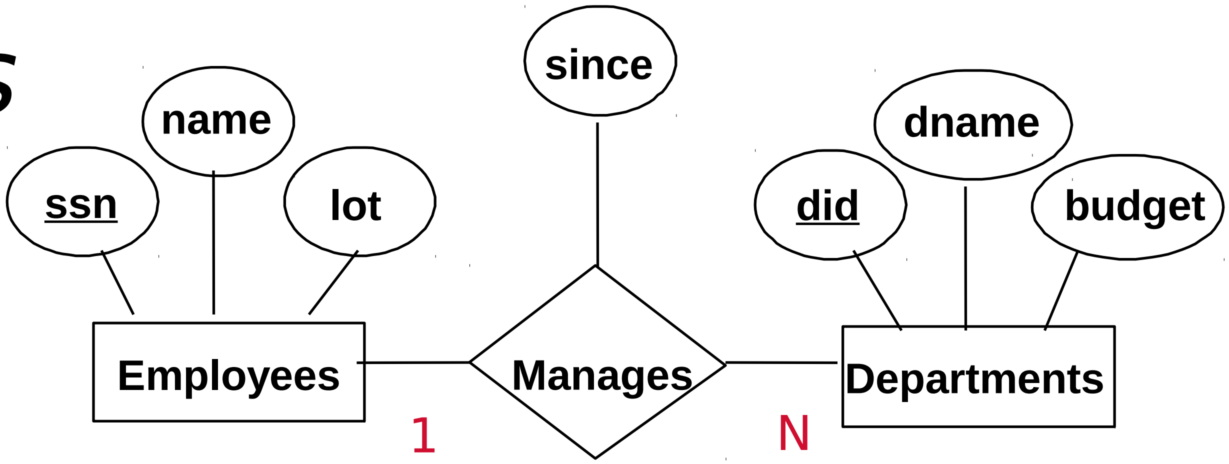
ER Model Basics (Contd.)

- Relationship sets can also have *descriptive attributes* (e.g., the *since* attribute of Works_In).
- In translating a relationship set to a relation, attributes of the relation must include:
  – Keys for each participating entity set (as foreign keys).
    - This set of attributes forms a *superkey* for the relation.
  – All descriptive attributes.

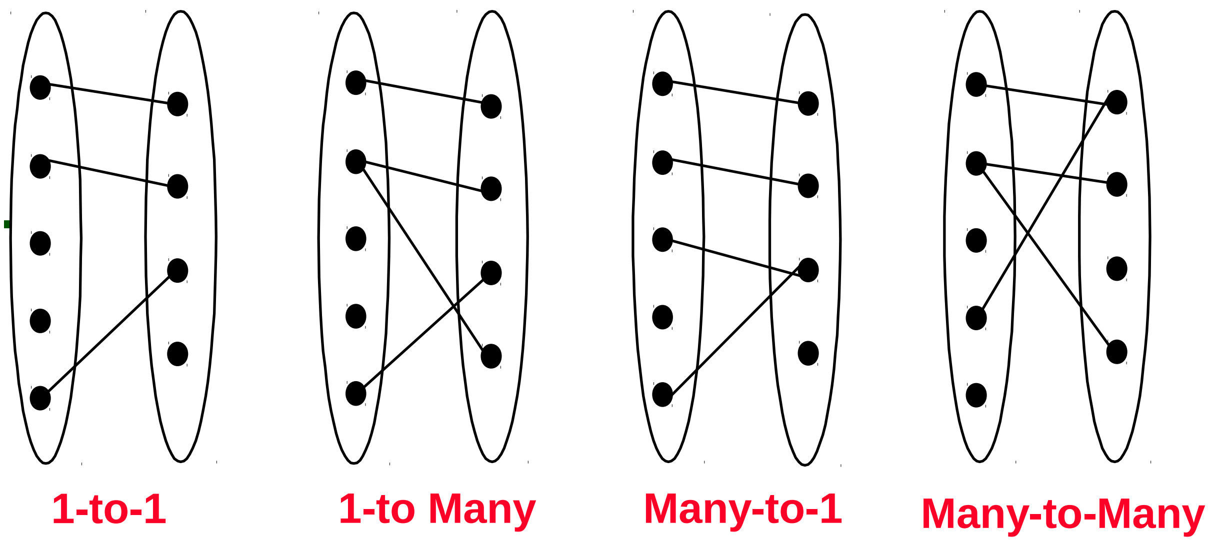
```
CREATE TABLE Works_In(
  ssn  CHAR(1),
  did  INTEGER,
  since  DATE,
  PRIMARY KEY (ssn, did),
  FOREIGN KEY (ssn)
      REFERENCES Employees,
  FOREIGN KEY (did)
      REFERENCES Departments
```

ssn	did	since
123-22-3666	51	1/1/91
123-22-3666	56	3/3/93
231-31-5368	51	2/2/92

Cardinalities



- Consider Works_In: An employee can work in many departments; a dept can have many employees.
- In contrast, each dept has at most one manager, according to the *cardinalities*



- *Translation to relational model?*

Translating ER Diagrams with cardinalities

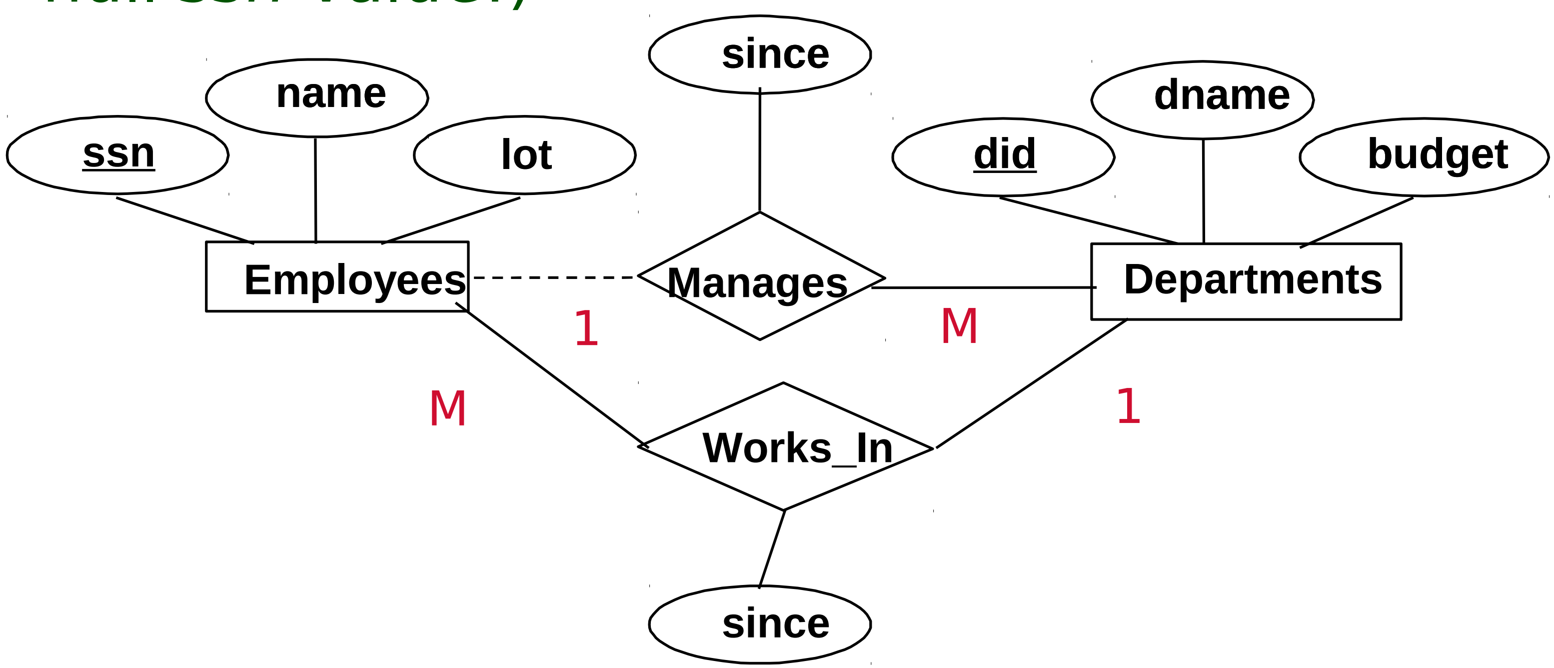
- Map relationship to a table:
  - Note that did is the key now!
  - Separate tables for Employees and Departments.
- Since each department has a unique manager, we could instead combine Manages and Departments.

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

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

Existence dependency

- Does every department have a manager?
  - If so, this is a *existence dependency*: the participation of Departments in Manages is said to be *total* (vs. *partial*).
    - Every *did* value in Departments table must appear in a row of the Manages table (with a non-null *ssn* value!)



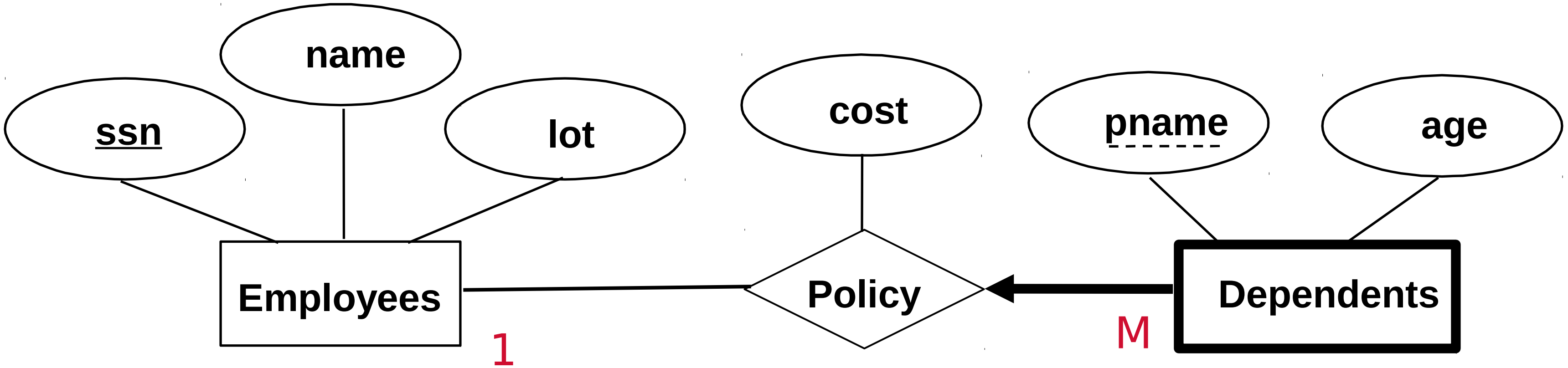
Existence dependency in SQL

- We can capture participation constraints involving one entity set in a binary relationship, but little else (without resorting to CHECK constraints).

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

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 (1 owner, many weak entities).
  - Weak entity set must have total participation in this *identifying* relationship set.

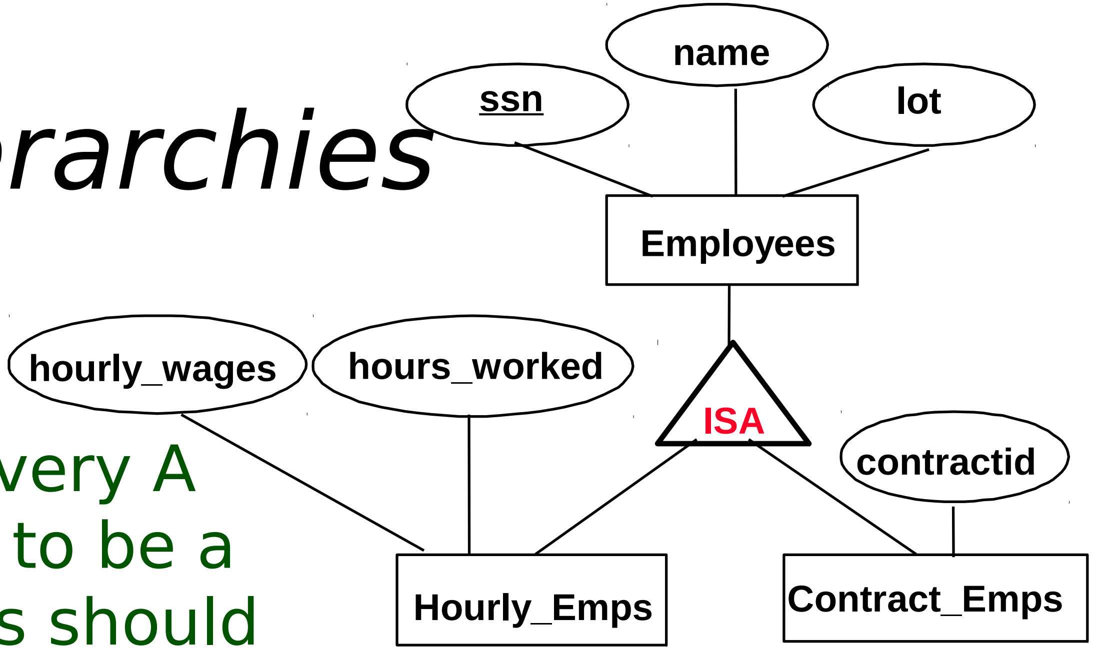


Translating Weak Entity Sets

- Weak entity set and identifying relationship set are translated into a single table.
  - When the owner entity is deleted, all owned weak entities must also be deleted.

```
CREATE TABLE Dep_Policy (
  pname CHAR(20),
  age INTEGER,
  cost REAL,
  ssn CHAR(11) NOT NULL,
  PRIMARY KEY (pname, ssn),
  FOREIGN KEY (ssn) REFERENCES Employees,
    ON DELETE CASCADE)
```

ISA (`is a') Hierarchies



- As in C++, or other PLs, attributes are inherited.
- If we declare A **ISA** B, every A entity is also considered to be a B entity. (Query answers should reflect this: unlike C++!)

- *Overlap constraints*: Can Joe be an Hourly_Emps as well as a Contract_Emps entity? (*Allowed/disallowed*)
- *Covering constraints*: Does every Employees entity also have to be an Hourly_Emps or a Contract_Emps entity? *(Yes/no)*
- Reasons for using ISA:
  - To add descriptive attributes specific to a subclass.
  - To identify entities that participate in a relationship.

Translating ISA Hierarchies to Relations

- ***General approach:***
  - 3 relations: Employees, Hourly_Emps and Contract_Emps.
    - *Hourly_Emps*: Every employee is recorded in Employees. For hourly emps, extra info recorded in Hourly_Emps (*hourly_wages*, *hours_worked*, *ssn)*; must delete Hourly_Emps tuple if referenced Employees tuple is deleted).
    - Queries involving all employees easy, those involving just Hourly_Emps require a join to get some attributes.
- Alternative: Just Hourly_Emps and Contract_Emps.
  - *Hourly_Emps*: *ssn, name, lot, hourly_wages, hours_worked.*
  - Each employee must be in one of these two subclasses.

Conceptual Design Using the ER Model

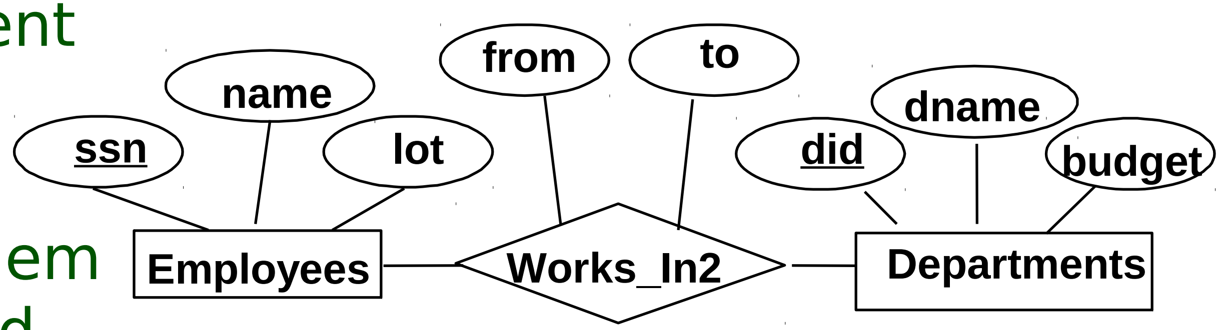
- Design choices:
  - Should a concept be modelled as an entity or an attribute?
  - Should a concept be modelled as an entity or a relationship?
  - Identifying relationships: Binary or ternary? Aggregation?
- Constraints in the ER Model:
  - A lot of data semantics can (and should) be captured.
  - But some constraints cannot be captured in ER diagrams.
- Need for further refining the schema:
  - Relational schema obtained from ER diagram is a good first step. But ER design subjective & can’t express certain constraints; *so this relational schema may need refinement.*

Entity vs. Attribute

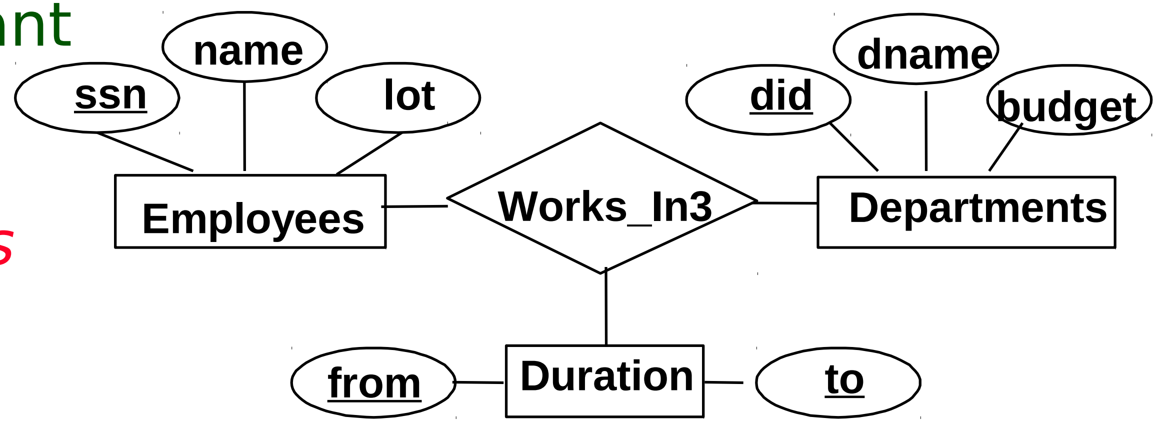
- Should *address* be an attribute of Employees or an entity (connected to Employees by a relationship)?
- Depends upon the use we want to make of address information, and the semantics of the data:
    - If we have several addresses per employee, *address* must be an entity (since attributes cannot 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 modelled as an entity (since attribute values are atomic).

Entity vs. Attribute (Contd.)

- Works_In2 does not allow an employee to work in a department for two or more periods.

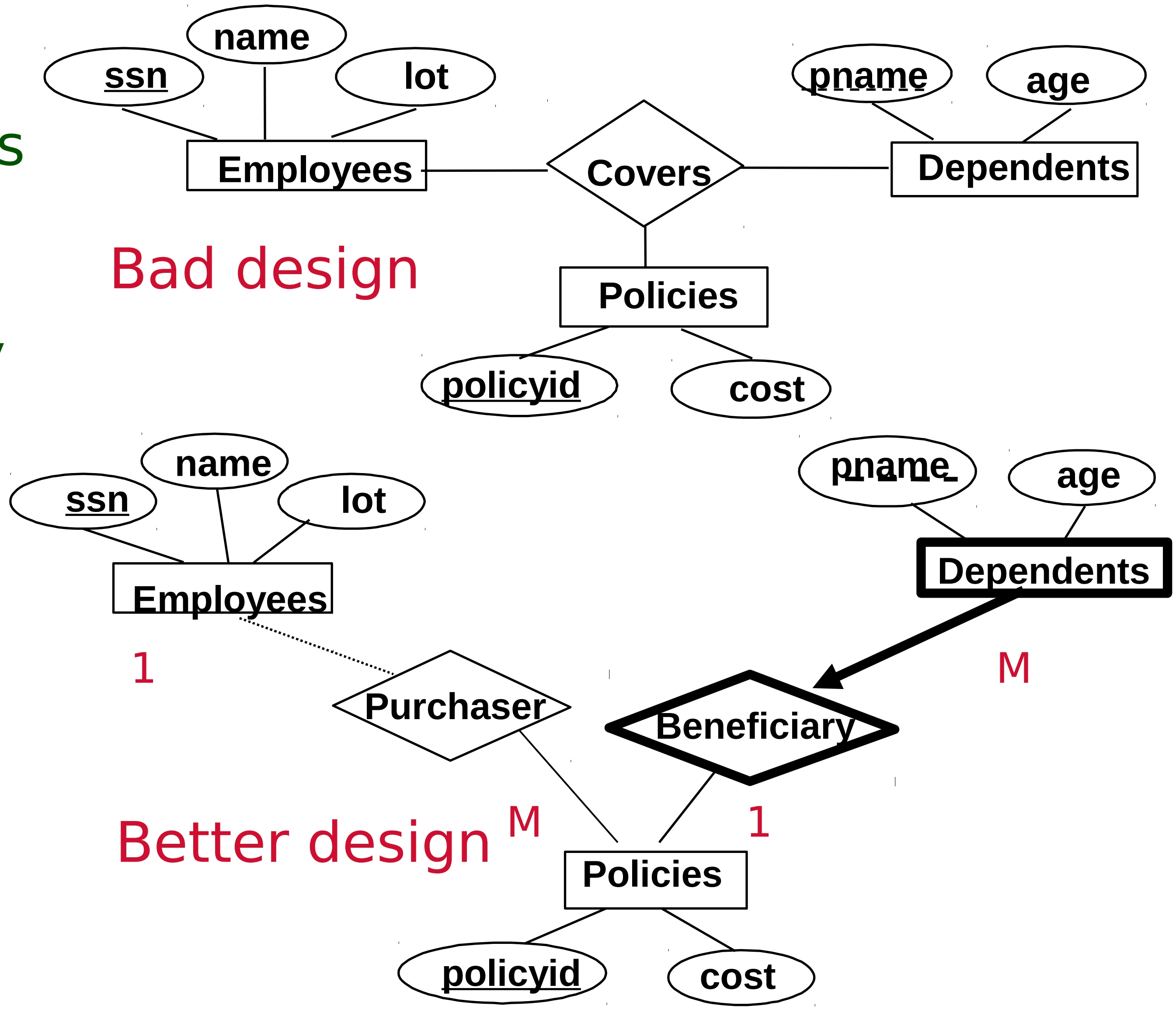


- Similar to the problem of wanting to record several addresses for an employee: we want to record *several values of the descriptive attributes for each instance of this relationship.*



Binary vs. Ternary Relationships

- If each policy is owned by just 1 employee:
  - 1:N cardinality
- What are the additional constraints in the 2nd diagram?



Binary vs. Ternary Relationships (Contd.)

- The key constraints allow us to combine Purchaser with Policies and Beneficiary with Dependents.
- Participation constraints lead to NOT NULL constraints.
- What if Policies is a weak entity set?

```
CREATE TABLE  Policies (
   policyid  INTEGER,
   cost  REAL,
   ssn  CHAR(11)  NOT NULL,
   PRIMARY KEY (policyid).
   FOREIGN KEY (ssn) REFERENCES Employees,
      ON DELETE CASCADE)
```

```
CREATE TABLE Dependents (
   pname  CHAR(20),
   age  INTEGER,
   policyid  INTEGER,
   PRIMARY KEY (pname, policyid).
   FOREIGN KEY (policyid) REFERENCES Policies,
      ON DELETE CASCADE)
```

Binary vs. Ternary Relationships (Contd.)

- Previous example illustrated a case when 2 binary relationships were better than a ternary relationship.
- An example in the other direction: a ternary relation Contracts relates entity sets Parts, Departments and Suppliers, and has descriptive attribute *qty*. No combination of binary relationships is an adequate substitute:
  - 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*?

Constraints Beyond the ER Model

- Functional dependencies:
  - *e.g., A dept can't order two distinct parts from the same supplier*.
    - Can't express this wrt ternary Contracts relationship.
  - Normalization refines ER design by considering FDs.
- Inclusion dependencies:
  - Special case: Foreign keys (ER model can express these).
  - *e.g., At least 1 person must report to each manager.* (Set of *ssn* values in Manages must be subset of *supervisor_ssn* values in Reports_To.) Foreign key? Expressible in ER model?
- General constraints:
  - *e.g., Manager's discretionary budget less than 10% of the combined budget of all departments he or she manages*.

Summary of Conceptual Design

- *Conceptual design* follows *requirements analysis*,
  - Yields a high-level description of data to be stored
- ER model popular for conceptual design
  - Constructs are expressive, close to the way people think about their applications.
- Basic constructs: *entities*, *relationships*, and *attributes* (of entities and relationships).
- Some additional constructs: *weak entities*, and *ISA hierarchies*.
- Note: There are many variations on ER model.

Summary of ER (Contd.)

- Several kinds of integrity constraints can be expressed in the ER model: *key constraints*, *participation constraints*, and *overlap/covering constraints* for ISA hierarchies. Some *foreign key constraints* are also implicit in the definition of a relationship set.
  - Some of these constraints can be expressed in SQL only if we use general CHECK constraints or assertions.
  - Some constraints (notably, *functional dependencies*) cannot be expressed in the ER model.
  - Constraints play an important role in determining the best database design for an enterprise.

Summary of ER (Contd.)

- 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, whether or not to use ISA hierarchies.
- Ensuring good database design: resulting relational schema should be analyzed and refined further. FD information and normalization techniques are especially useful.