Relational Database Design

Translation of ER-diagram into Relational Schema

Dr. Sunnie S. Chung

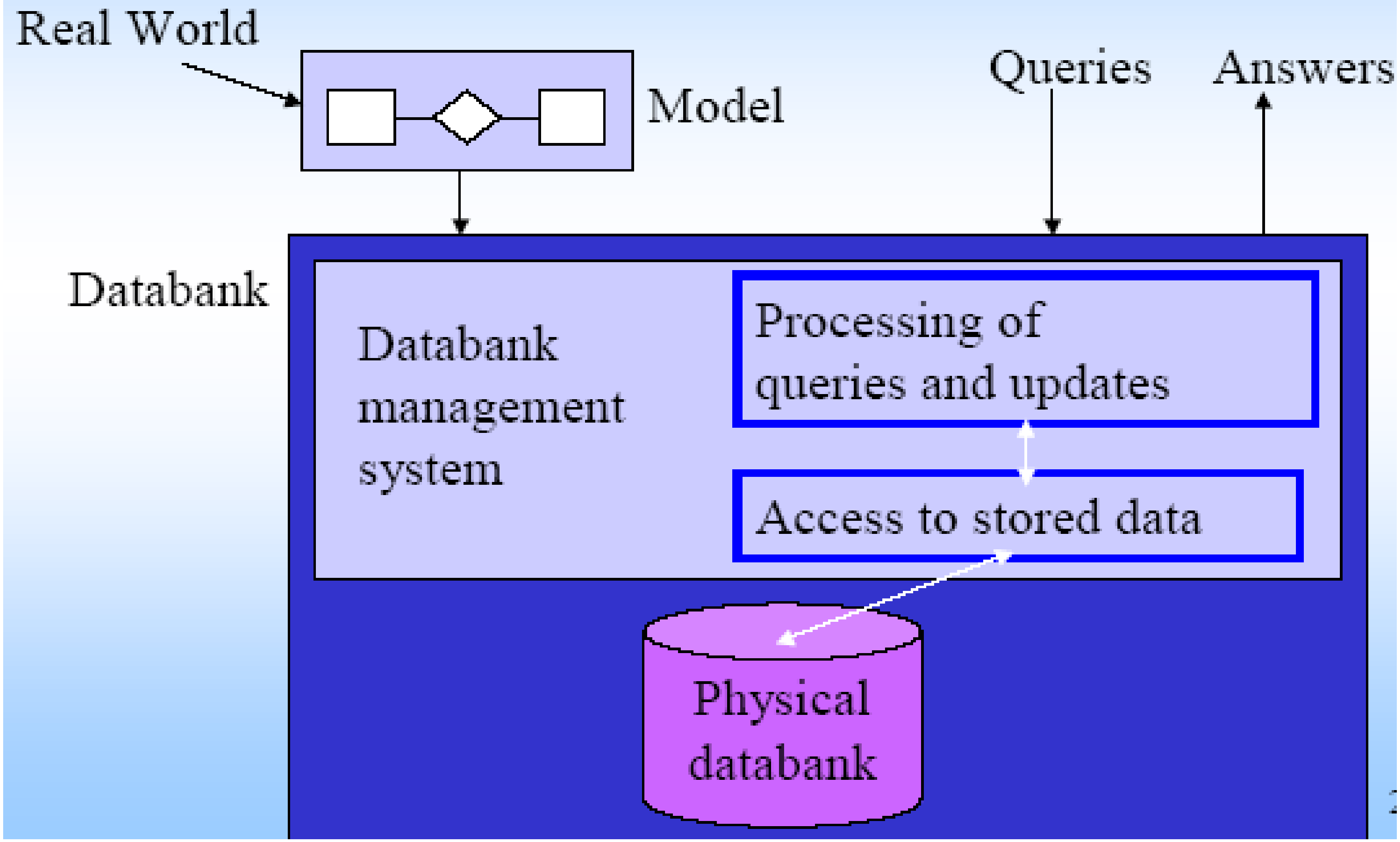
CIS430/530

Learning Objectives

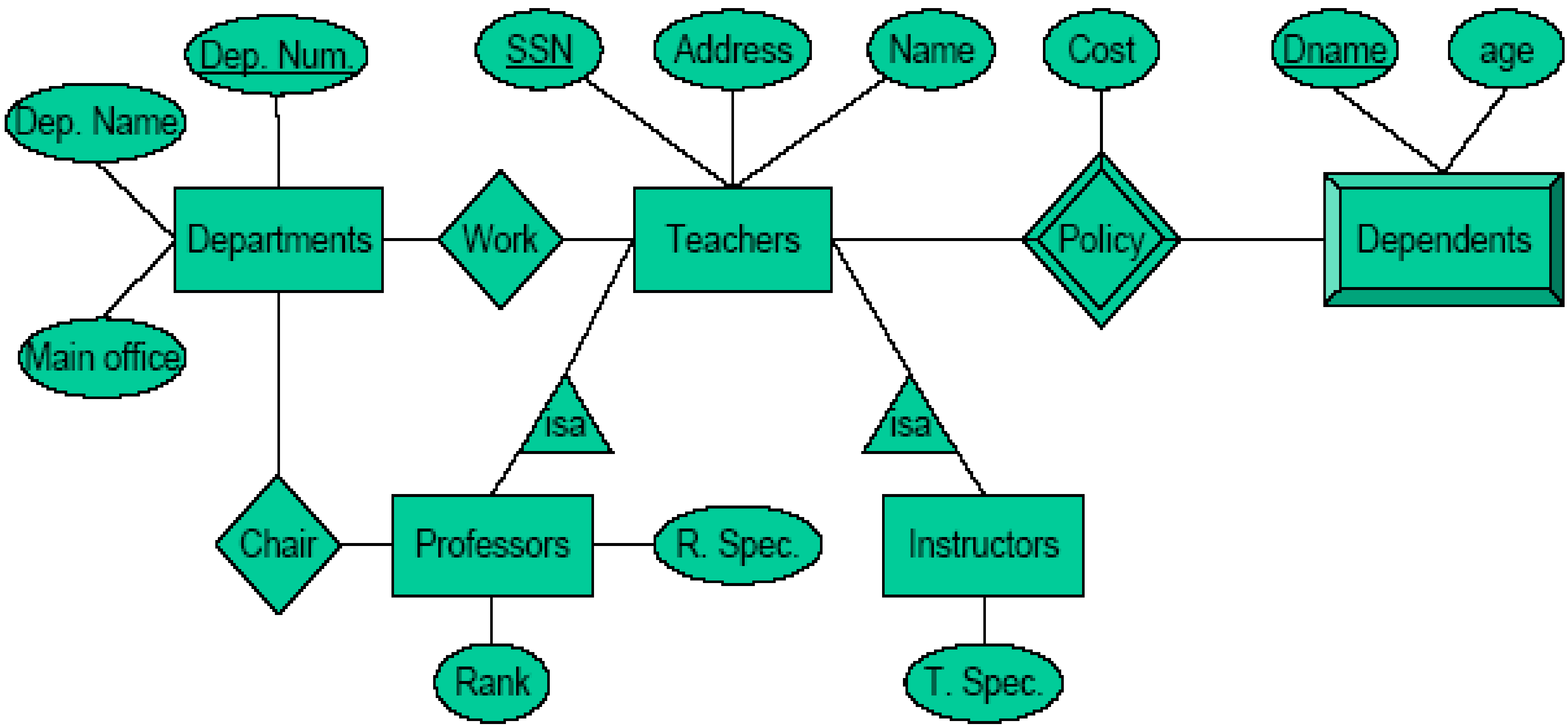
- ✓ Define each of the following database terms
  - ✓ Relation
  - ✓ Primary key
  - ✓ Foreign key
  - ✓ Referential integrity
  - ✓ Field
  - ✓ Data type
  - ✓ Null value
- ✓ Discuss the role of designing databases in the analysis and design of an information system
- ✓ Learn how to transform an entity-relationship (ER) Diagram into an equivalent set of well-structured relations

9.2

Databanks


Real World
Model
Queries
Answers
Databank
Databank management system
Processing of queries and updates
Access to stored data
Physical databank

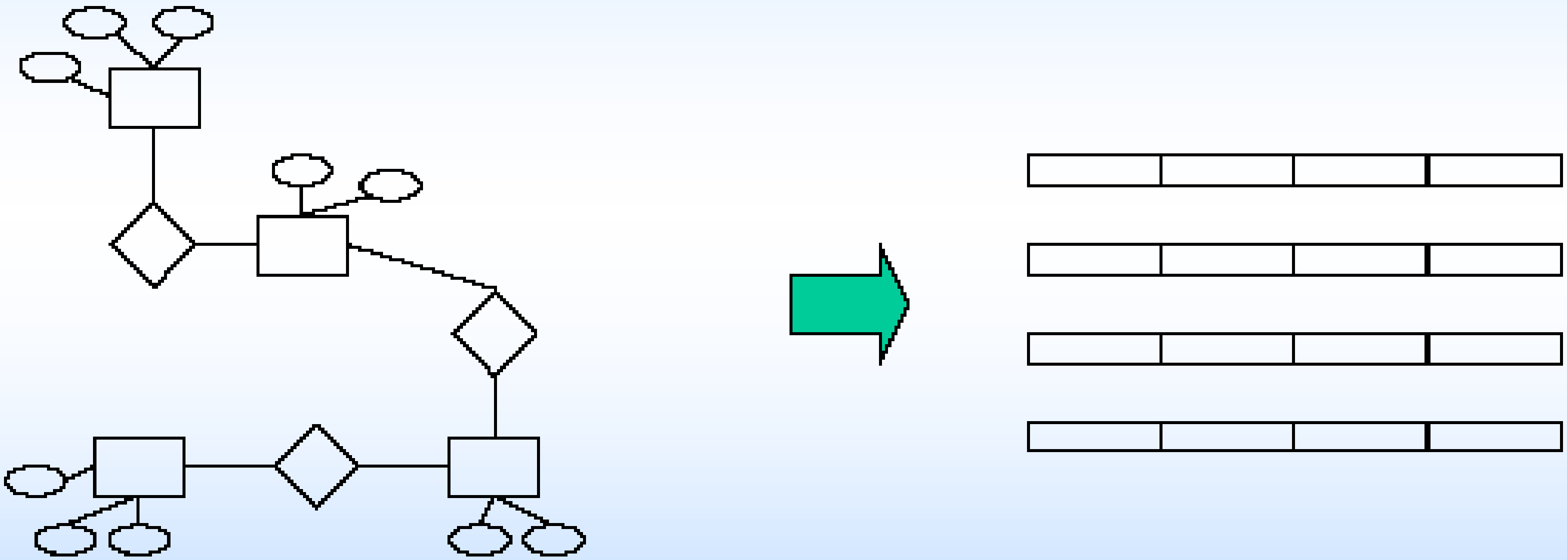
Example



Dep. Num.
Dep. Name
Main office
Departments
Work
SSN
Address
Name
Teachers
Cost
Policy
Dname
age
Dependents
isa
isa
Chair
Professors
R. Spec.
Rank
Instructors
T. Spec.

9.4

ER/EER to database schema



Process of Database Design

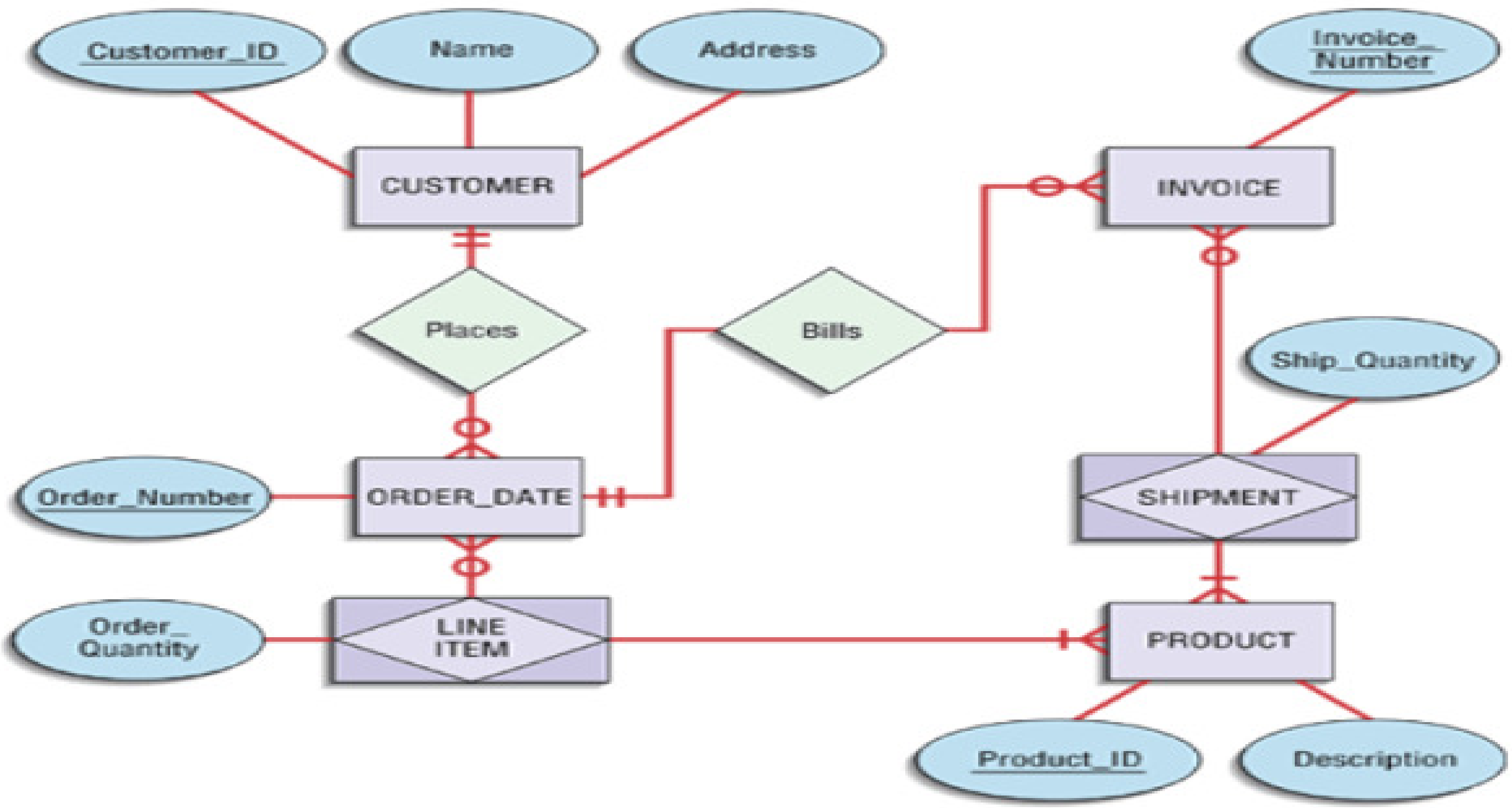
– Steps in translation:
  - Entity sets to tables
  - Relationships to tables
  - Constraints
  - Weak entity sets

- Logical Design

  – Based upon the conceptual data model
  – Four key steps
    1. Develop a logical data model for each known user interface for the application using normalization principles.
    2. Combine normalized data requirements from all user interfaces into one consolidated logical database model
    3. Translate the conceptual E-R data model for the application into normalized data requirements
    4. Compare the consolidated logical database design with the translated E-R model and produce one final logical database model for the application

Entity Sets to Tables

- Each attribute of the E. S. becomes an attribute of the table



Relations:

CUSTOMER(Customer_ID,Name,Address)
PRODUCT(Product_ID,Description)
ORDER(Order_Number,Customer_ID,Order_Date)
LINE ITEM(Order_Number,Product_ID,Order_Quantity)
INVOICE(Invoice_Number,Order_Number)
SHIPMENT(Invoice_Number,Product_ID,Ship_Quantity)

Relational Database Model

- Data represented as a set of related tables or relations
- Relation
  - A named, two-dimensional table of data. Each relation consists of a set of named columns and an arbitrary number of unnamed rows
  - Properties
    - Entries in cells are simple
    - Entries in columns are from the same set of values
    - Each row is unique
    - The sequence of columns can be interchanged without changing the meaning or use of the relation
    - The rows may be interchanged or stored in any sequence

Relational Database Model

- Well-Structured Relation
  - A relation that contains a minimum amount of redundancy and allows users to insert, modify and delete the rows without errors or inconsistencies

EMPLOYEE1

Emp_ID	Name	Dept	Salary
100	Margaret Simpson	Marketing	42,000
140	Allen Beeton	Accounting	39,000
110	Chris Lucero	Info Systems	41,500
190	Lorenzo Davis	Finance	38,000
150	Susan Martin	Marketing	38,500

Transforming E-R Diagrams into Relations

- It is useful to transform the conceptual data model into a set of normalized relations
- Steps
  1. Represent entities
  2. Represent relationships
  3. Normalize the relations
  4. Merge the relations

Refining the ER Design for the COMPANY Database

- Change attributes that represent relationships into relationship types
- Determine cardinality ratio and participation constraint of each relationship type

ER Diagrams, Naming Conventions, and Design Issues

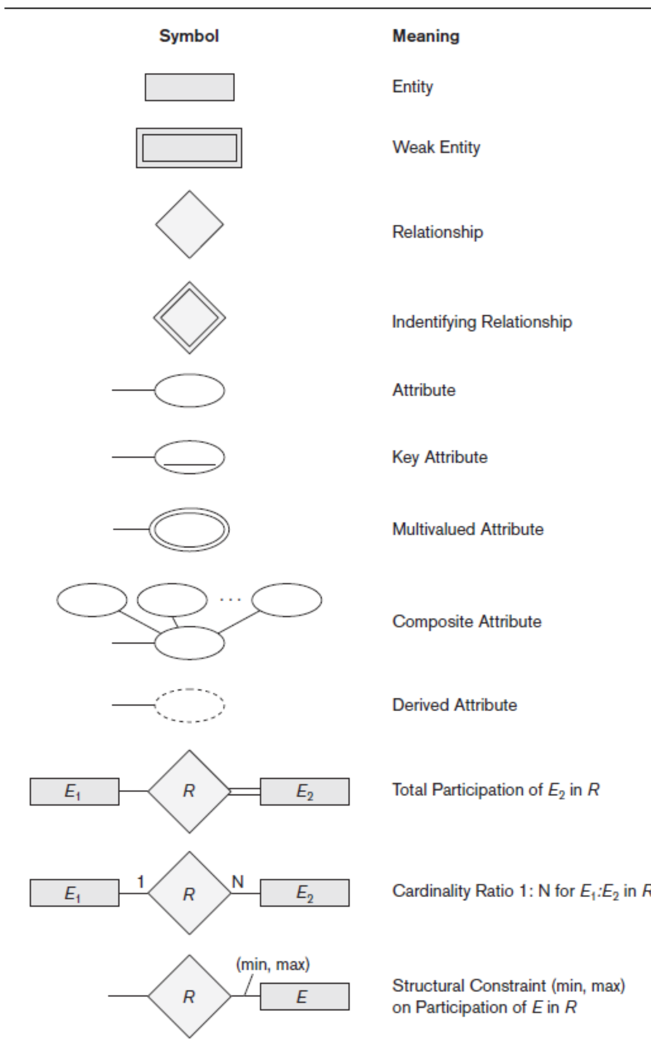


Figure 7.14
Summary of the notation for ER diagrams.

Design Choices for ER Conceptual Design

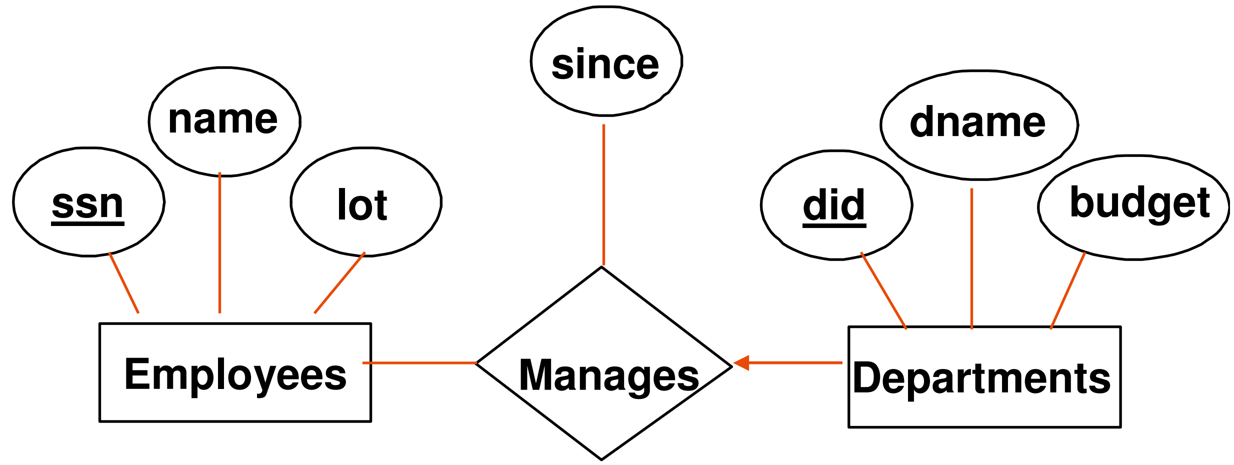
- Model concept first as an attribute
  - Refined into a relationship if attribute is a reference to another entity type
- Attribute that exists in several entity types may be elevated to an independent entity type
  - Can also be applied in the inverse

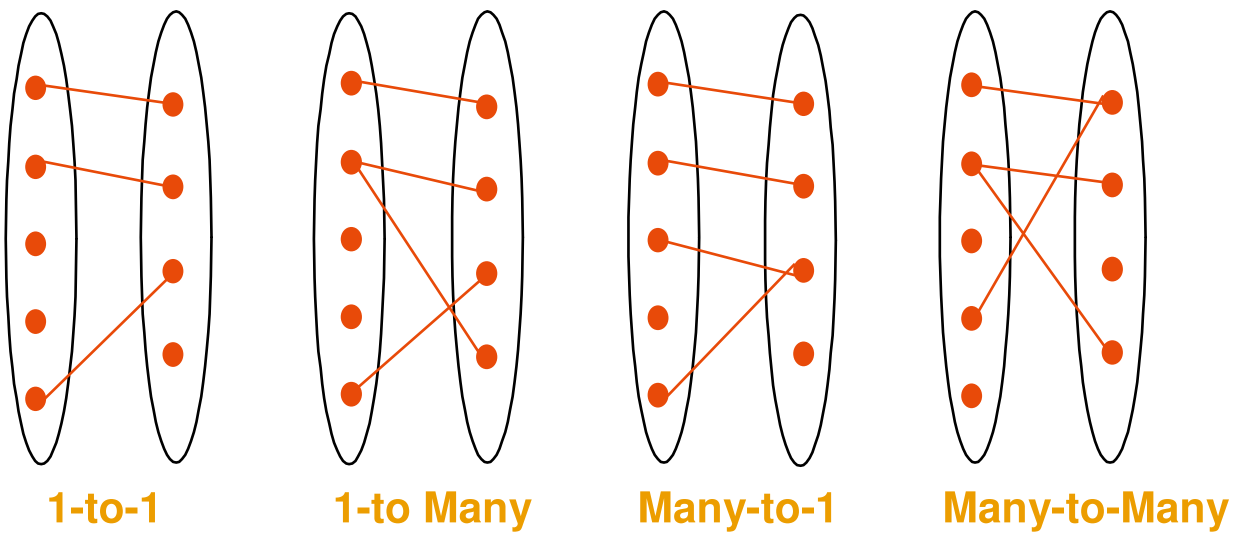
Alternative Notations for ER Diagrams

- Specify structural constraints on Relationships
  - Replaces Cardinality ratio (1:1, 1:N, M:N) and single/double line notation for Participation constraints
  - Associate a pair of integer numbers (min, max) with each participation of an entity type *E* in a relationship type *R*, where $0 \leq \text{min} \leq \text{max}$ and $\text{max} \geq 1$

Cardinality Ratio (1:1, 1:N, M:N)

- 1:N :Each dept has at most one manager on Manages.





Translation to relational model?

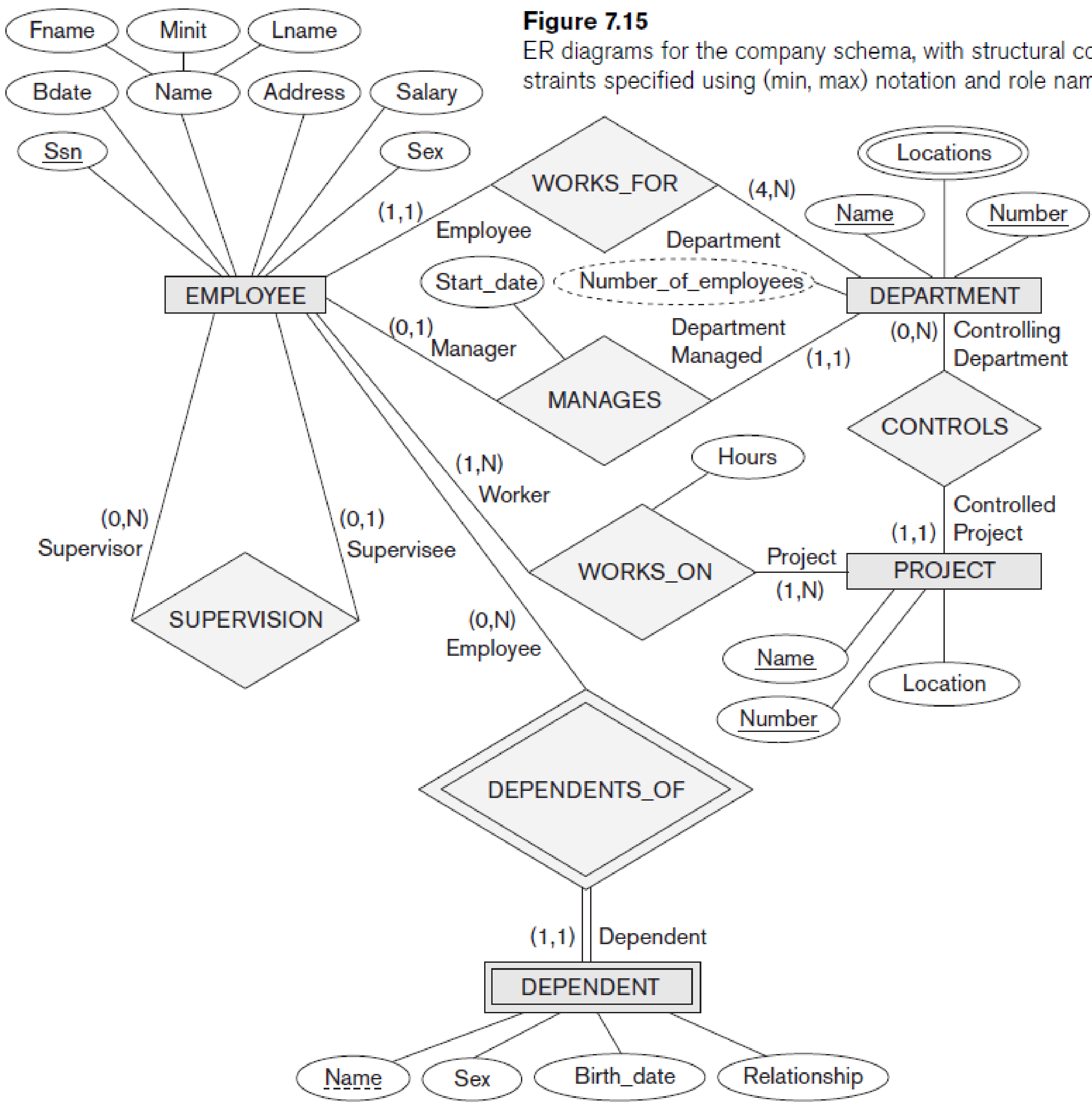
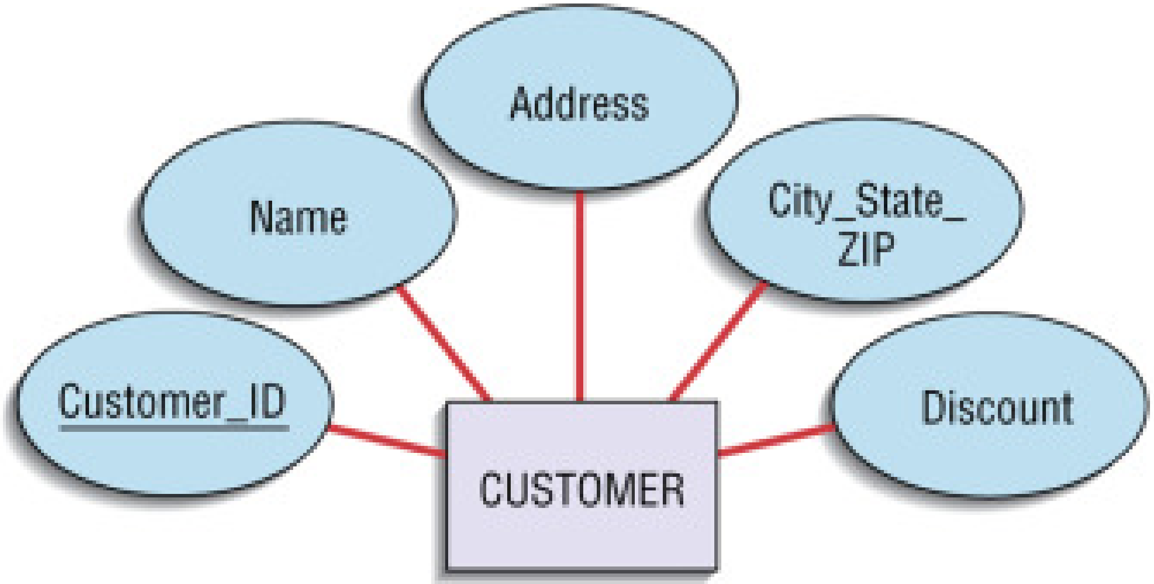


Figure 7.15
ER diagrams for the company schema, with structural constraints specified using (min, max) notation and role names.

Transforming E-R Diagrams into Relations

- In translating a relationship set to a relation, attributes of the relation must include:
  - The primary key for each participating entity set (as foreign keys).
    - This set of attributes forms a *superkey* for the relation.
  - All descriptive attributes of the relationship set
- The **primary key** must satisfy the following two conditions
  a. The value of the key must **uniquely identify** every row in the relation
  b. The key should be **nonredundant**



CUSTOMER

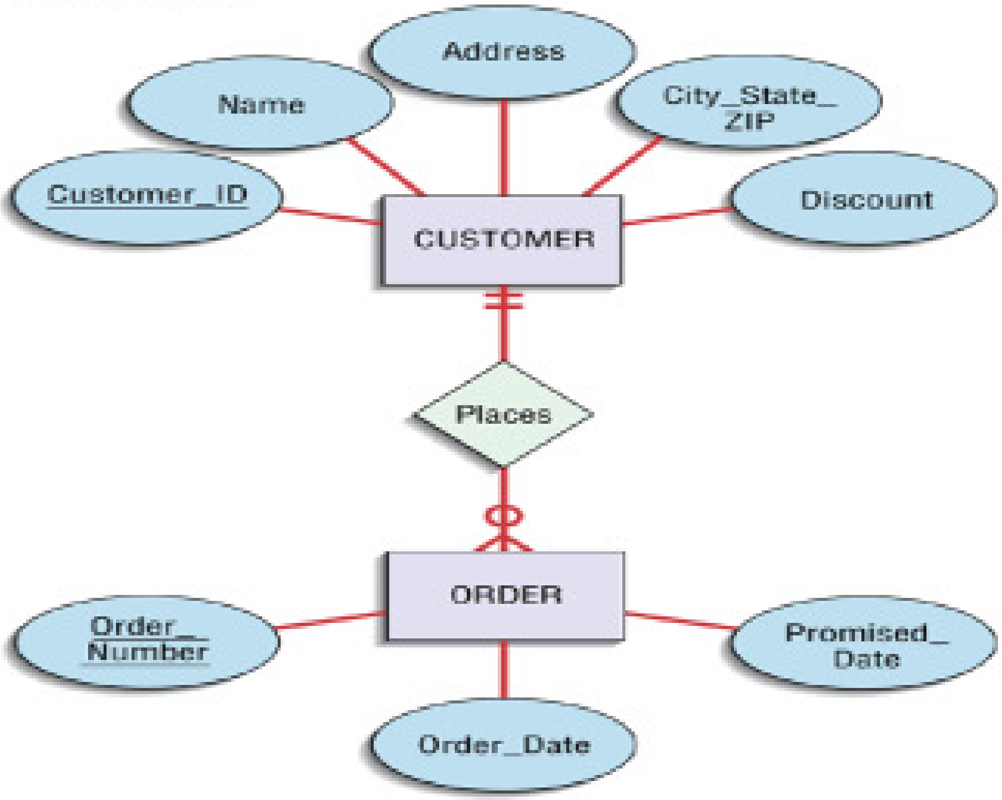
Customer_ID	Name	Address	City_State_ZIP	Discount
1273	Contemporary Designs	123 Oak St.	Austin, TX 28384	5%
6390	Casual Corner	18 Hoosier Dr.	Bloomington, IN 45821	3%

9.18

Transforming E-R Diagrams into Relations

Represent Relationships

- Binary 1:N Relationships
  - Add the **Primary key attribute** (or attributes) of the entity on the one side of the relationship as a **Foreign key** in the relation on the other (N) side
  - The one side *migrates* to the many side



CUSTOMER

Customer_ID	Name	Address	City_State_ZIP	Discount
1273	Contemporary Designs	123 Oak St.	Austin, TX 28384	5%
6390	Casual Corner	18 Hoosier Dr.	Bloomington, IN 45821	3%

ORDER

Order_Number	Order_Date	Promised_Date	Customer_ID
57194	3/15/0X	3/28/0X	6390
63725	3/17/0X	4/01/0X	1273
80149	3/14/0X	3/24/0X	6390

Transforming Binary 1:N Relationships into Relations

- Relationship:

  CUSTOMER Places ORDER(s)
- ORDER Table BEFORE Relationship:

  (Order_Number, Order_Date, Promised_Date)
- ORDER Table AFTER Relationship:

  (Order_Number, Order_Date, Promised_Date, Customer_ID)

```
CREATE TABLE ORDER(
  Order_Number CHAR(1),
  Order_Date DATE,
  Promised_Date DATE,
  Customer_ID CHAR(1),
   PRIMARY KEY
    (Order_Number),
   FOREIGN KEY (Customer_ID)
        REFERENCES
    CUSTOMER);
```

Transforming E-R Diagrams into Relations

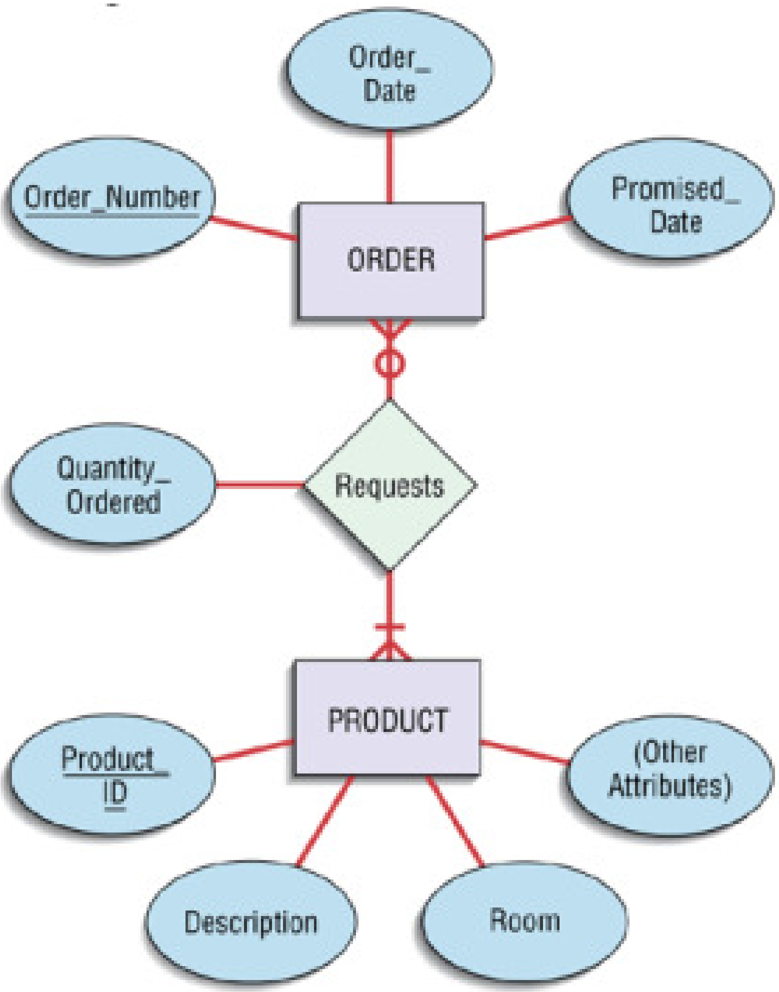
- Binary or Unary 1:1
  - Three possible options
    a. Add the primary key of A as a foreign key of B
    b. Add the primary key of B as a foreign key of A
    c. Both

9.22

Transforming E-R Diagrams into Relations

Represent Relationships

- Binary and higher M:N relationships
  - Create **another relation** and include **primary keys of all relations** as primary key of new relation



ORDER

Order_Number	Order_Date	Promised_Date
61384	2/17/2002	3/01/2002
62009	2/13/2002	2/27/2002
62807	2/15/2002	3/01/2002

ORDER LINE

Order_Number	Product_ID	Quantity_Ordered
61384	M128	2
61384	A261	1

PRODUCT

Product_ID	Description	(Other Attributes)
M128	Bookcase	—
A261	Wall unit	—
R149	Cabinet	—

9.24

Constraints on Binary Relationship Types

- **Cardinality ratio** for a binary relationship
  - Specifies maximum number of relationship instances that entity can participate in
- **Participation Constraint**
  - Specifies whether existence of entity depends on its being related to another entity
  - Types: **total** and **partial**

Attributes of Relationship Types

- Attributes of 1:1 or 1:N relationship types can be migrated to one entity type
- For a 1:N relationship type
  - Relationship attribute can be migrated only to entity type on N-side of relationship
- For M:N relationship types
  - Some attributes may be determined by combination of participating entities
  - Must be specified as relationship attributes

Weak Entity Types

- Do not have key attributes of their own
  - Identified by being related to specific entities from another entity type
- **Identifying relationship**
  - Relates a weak entity type to its owner
- Always has a total participation constraint

Transforming E-R Diagrams into Relations

- Unary 1:N Relationships
  - Relationship between instances of a single entity type
  - Utilize a recursive foreign key
    - A foreign key in a relation that references the primary key values of that same relation
- Unary M:N Relationships
  - Create a separate relation
  - Primary key of new relation is a composite of two attributes that both take their values from the same primary key

Figure 9.13b Two Unary Relations —
Bill-of-Materials Structure (M:N)

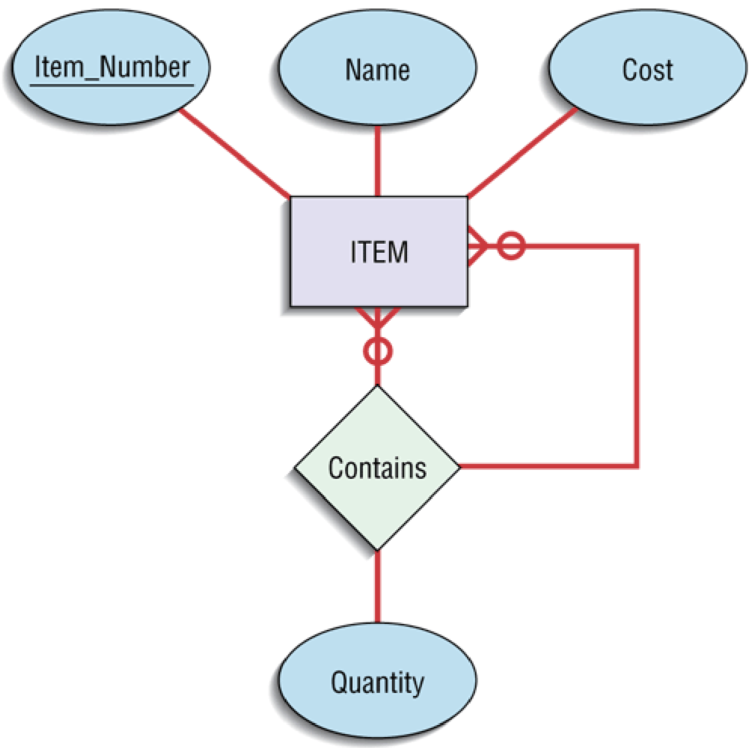
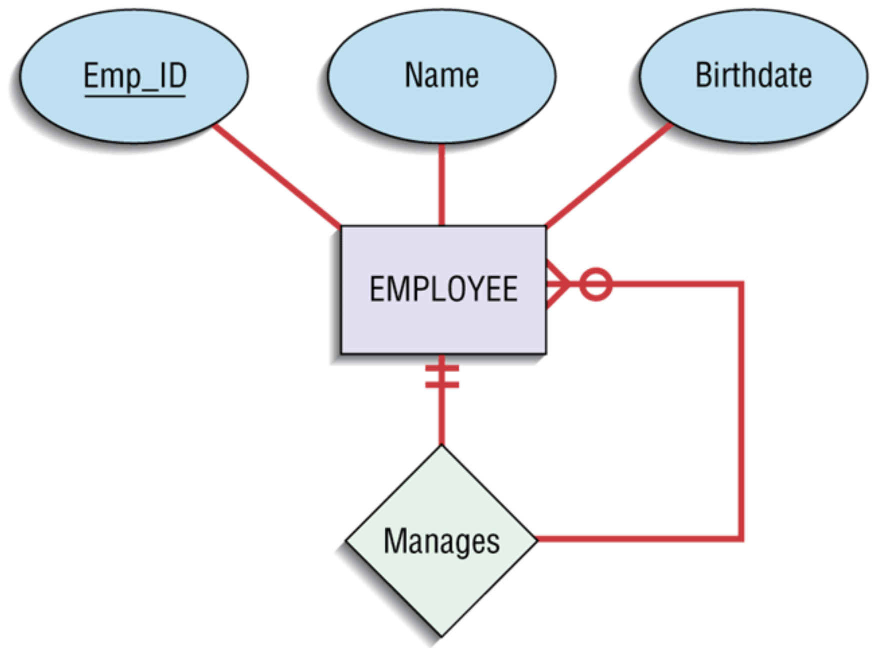


Figure 9-13a Two Unary Relations —
EMPLOYEE with Manages Relationship (1:N)



9.29

Transforming Unary 1:N Relationships into Relations

- Relationship:

  EMPLOYEE (Manager) Manages EMPLOYEE

- EMPLOYEE Table BEFORE Relationship:

  (Emp_ID, Name, Birthday)

- EMPLOYEE Table AFTER Relationship:

  (Emp_ID, Name, Birthday, Mgr_ID)

```
CREATE TABLE
  EMPLOYEE(
   Emp_ID CHAR(1),
   Name   Varchar(30),
   Birthday  DATE,
   Mgr_ID CHAR(1),
   PRIMARY KEY (Emp_ID),
   FOREIGN KEY (Mgr_ID)
       REFERENCES
  EMPLOYEE);
```

Transforming Unary M:N Relationships into Relations

- Relationship Contains:

  ITEM Contains ITEM

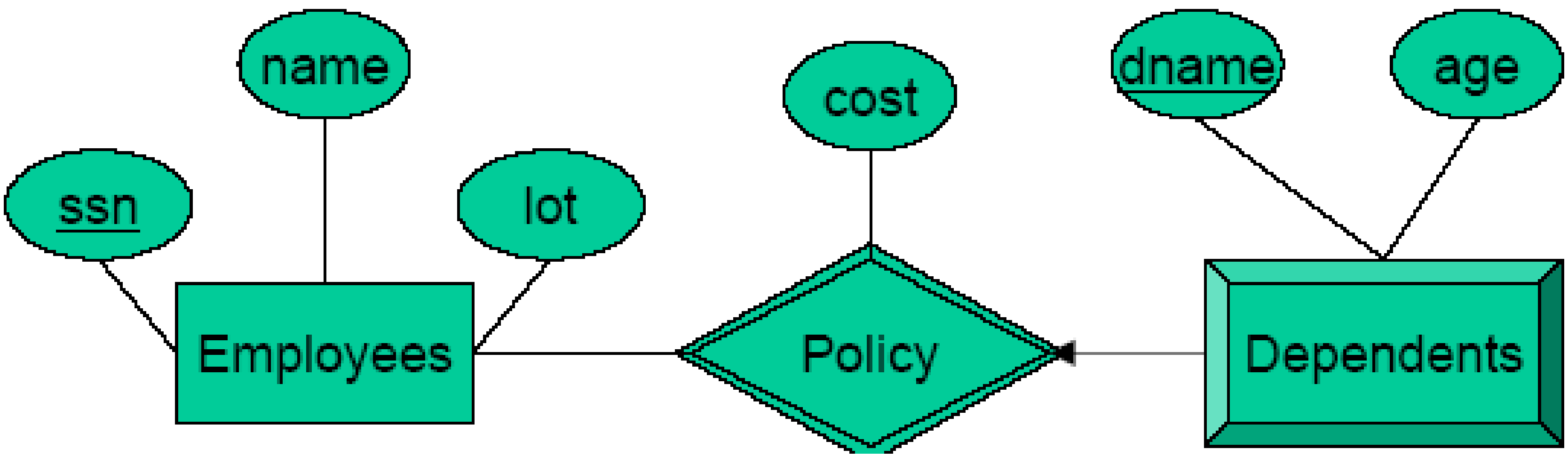
1. Create Table for Relationship CONTAINS
2. Add PK of each side of Tables (ITEM, ITEM) as Foreign Keys
3. Make composite of both attributes as Primary Key of the Table CONTAINS:

   CONTAINS
   (Containing_Item_Num, Contained_Item_Num, Quantity)

```
CREATE TABLE CONTAINS (
 Containing_Item_Num   CHAR(10),
 Contained_Item_Num    CHAR(10),
 Quantity  Integer,
  PRIMARY KEY
   (Containing_Item_Num,
   Contained_Item_Num),
  FOREIGN KEY
   (Containing_Item_Num)
        REFERENCES ITEM,
  FOREIGN KEY
   (Contained_Item_Num)
        REFERENCES ITEM);
```

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.



9.32

Primary Key Constraints

- A set of fields is a ***key*** for a relation if :
  1. No two distinct tuples can have same values in all key fields, and
  2. This is not true for any subset of the key. – Key is minimal.
  - However, 2 does not hold (so false) for *superkey – which is not minimal.*
  - If there's more than one keys for a relation, one of the keys is chosen (by DBA) to be the *primary key*.
- E.g., customer_id is a key for Customer. (What about *name*?) The set {customer_id, *name*} could be a superkey.

Primary key can not have null value

Domain Constraint

- The value of each Attribute *A* with Domain Type D(A_i) must be a atomic value from the domain type D(A_i).

Definitions of Keys and Attributes Participating in Keys

- A **superkey** of a relation schema R = {A1, A2, ..., An} is a set of attributes S, *subset-of* R, with the property that **No two tuples t1 and t2 in any legal relation state r of R will have t1[S] = t2[S].**

  That is, for any given two tuples t1, t2 in data (extensions) of Relation schema R, t1[S] is not identical to t2[S].

- A **key** K is a superkey with the *additional property* that removal of any attribute from K will cause K not to be a superkey any more; **Key is minimal**.

Definitions of Keys and Attributes Participating in Keys

- If a relation schema has more than one key, each is called a **candidate** key.
- One of the candidate keys is *arbitrarily* designated to be the **primary key**, and the others are called **secondary keys**.
- *A* **Prime attribute** must be a member of any (candidate) key
- *A* **Nonprime attribute** is not a prime attribute—that is, it is not a member of any (candidate) key.

Foreign Keys, Referential Integrity

- **Foreign key** : Set of fields in one relation that is used to `refer' to a tuple in another relation. (Must correspond to primary key of the second relation.) Like a `logical pointer'.
- E.g. customer_id in Order is a foreign key referring to Customer:

Order (*order_number*, order_date, promised_date, customer_id)

Foreign Keys, Referential Integrity

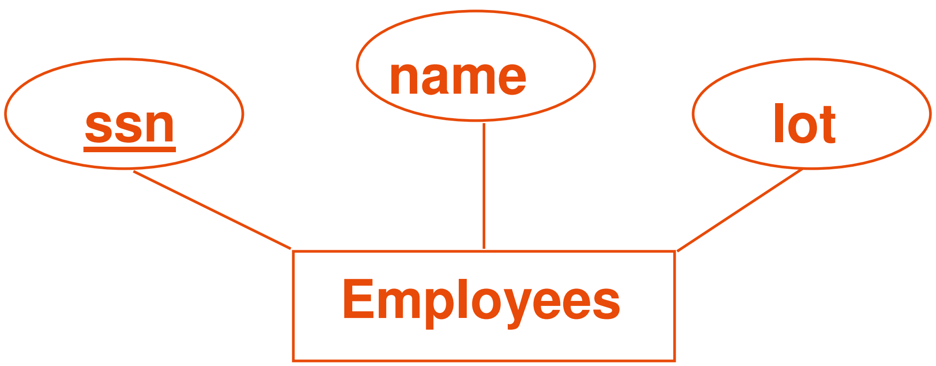
- If all foreign key constraints are enforced, **referential integrity** is achieved; all foreign key values should refer to existing values, i.e., no dangling references.
- Can you name a data model w/o referential integrity?
  - Links in HTML!

Enforcing Referential Integrity

- Consider Students(sid, name, gpa) and Enrolled (rid, semester, sid);
- *sid* in Enrolled is a foreign key that references Students.
- What should be done if an Enrolled tuple with a non-existent student id is **inserted**? **Reject it !**
- What should be done if a Students tuple is **deleted**?
  - Also delete all Enrolled tuples that refer to it.
  - Disallow deletion of a Students tuple that is referred to.
  - Set sid in Enrolled tuples that refer to it to a *default sid*.
  - (In SQL, also: Set sid in Enrolled tuples that refer to it to a special value *null*, denoting `*unknown*' or `*inapplicable*'.)
- Similar if primary key of Students tuple is **updated**.

Logical DB Design: ER to Relational

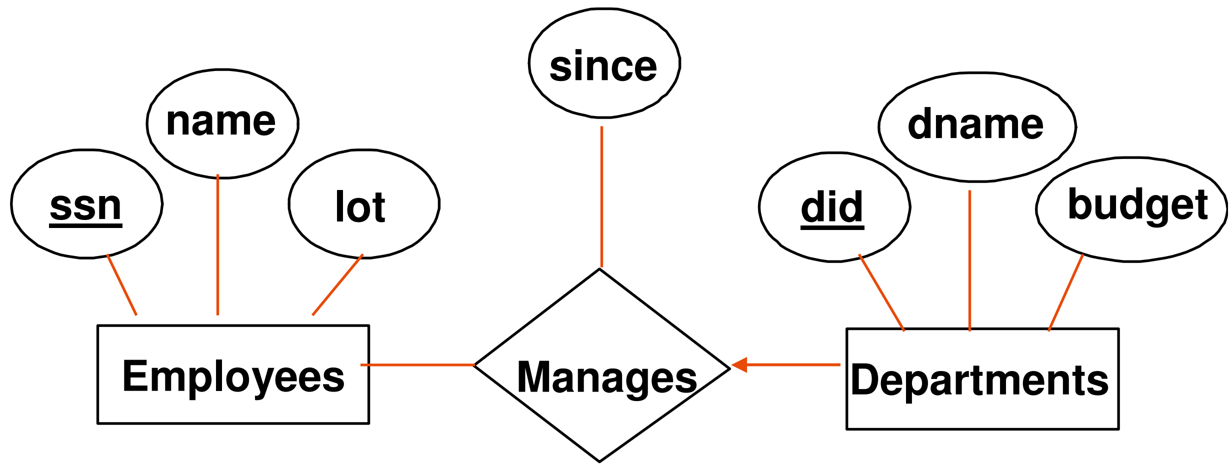
- Entity sets to tables.

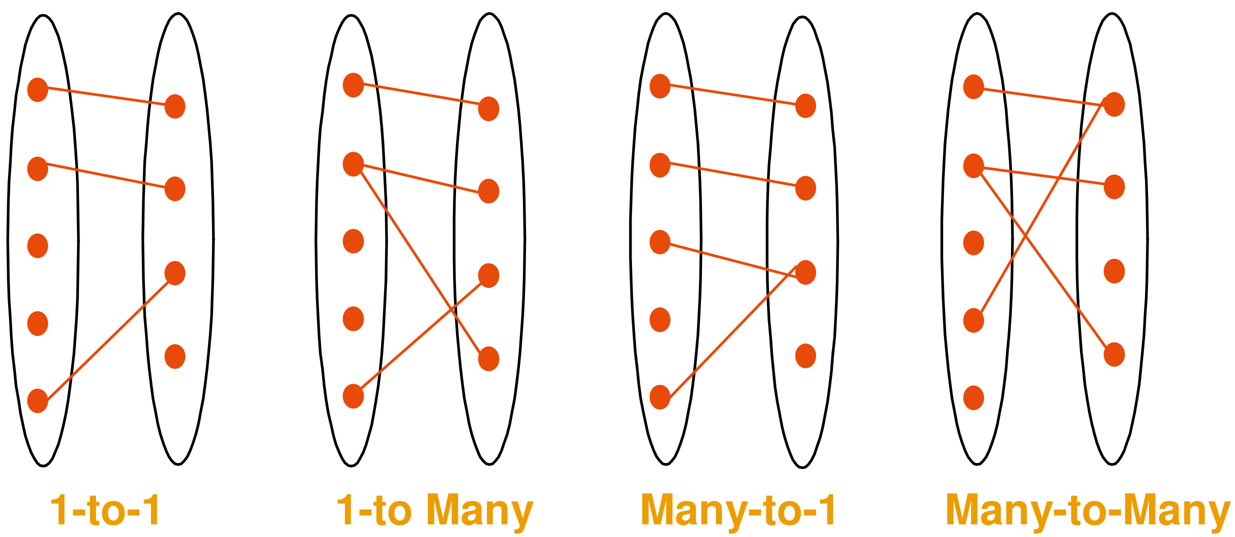



```
CREATE TABLE Employees
      (ssn CHAR(11),
      name CHAR(20),
      lot  INTEGER,
      PRIMARY KEY  (ssn))
```

Review: Key Constraints

- Each dept has at most one manager, according to the ***key constraint*** on Manages.

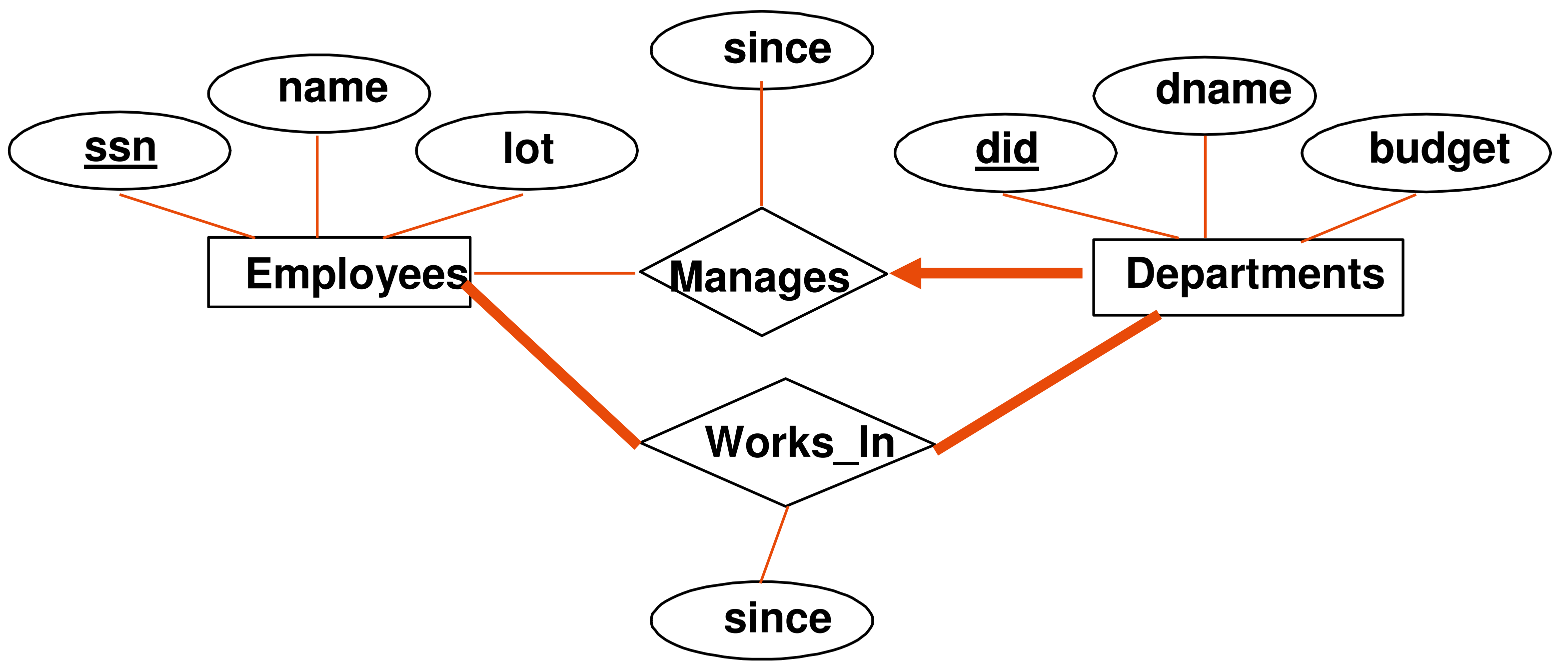




Translation to relational model?

Transforming 1:N, M:N Relationships with Key Constraints

ER Diagram:



Translating ER Diagrams with Key Constraints

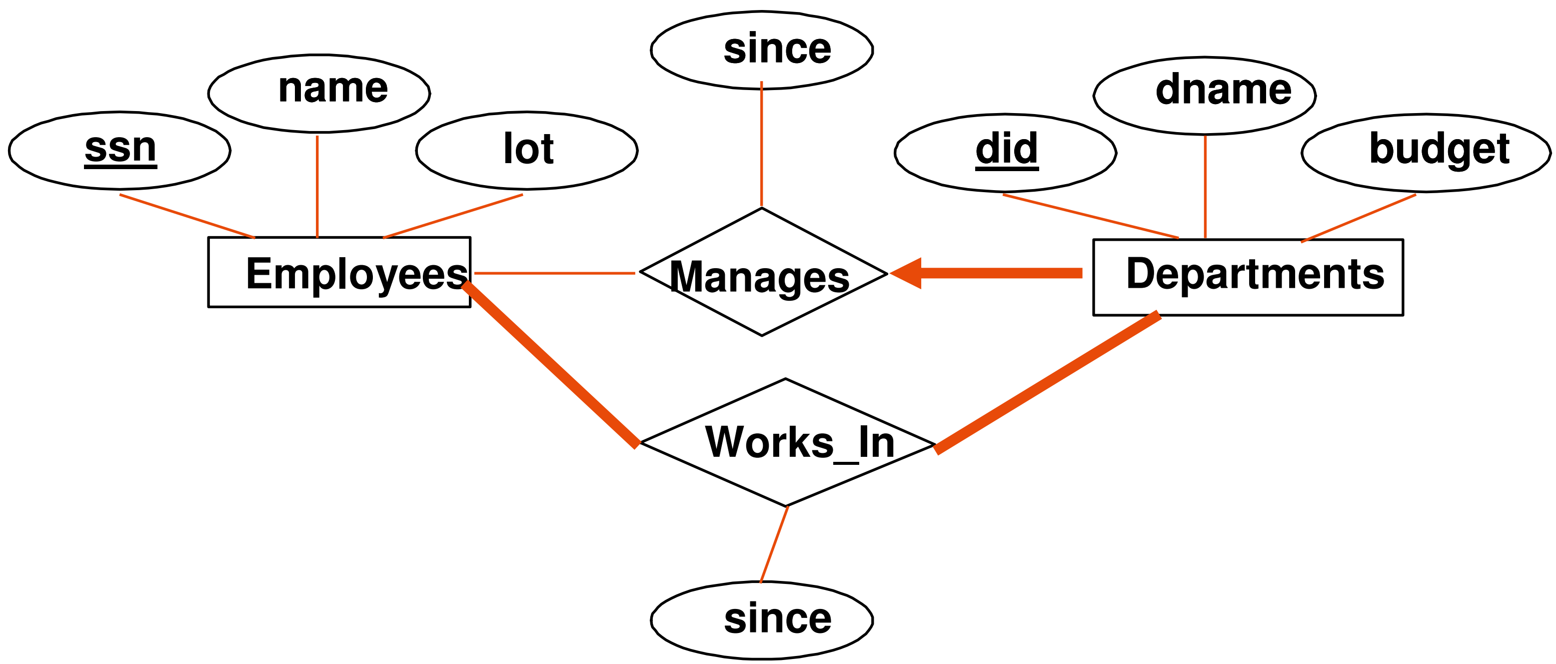
- Map relationship to a table:
  - Note that did is the key here!
  - Separate tables for Employees and Departments.
- Since each department has a unique manager, we could instead combine Manages and Departments.

```
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)
```

Transforming Realtionship to Tables

Example E-R diagram:



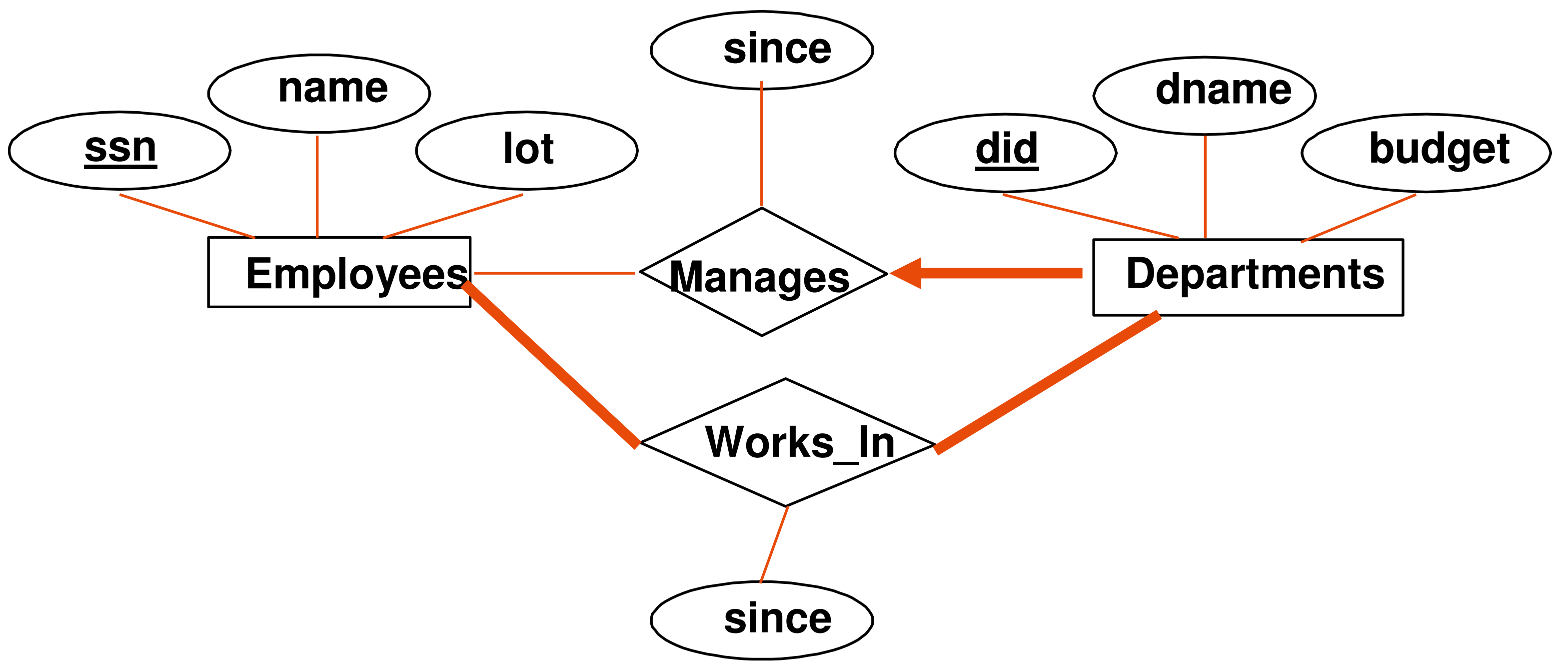
Relationship Sets to Tables

- In translating a relationship Works_In (M-N) 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)
```

Review: Participation Constraints

- Does every department have a manager?
  - If so, this is a *participation constraint*: 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!)



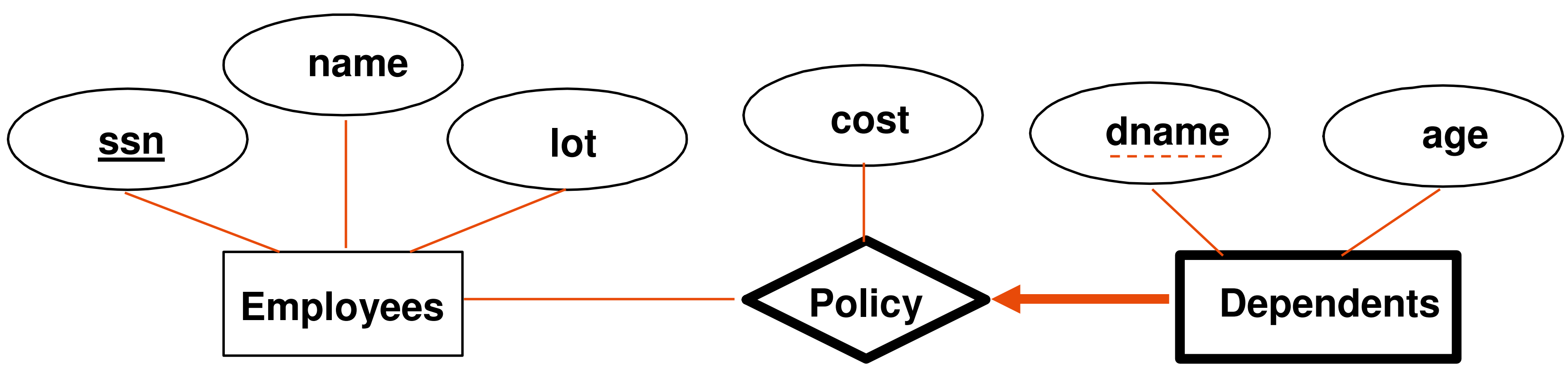
Participation Constraints in SQL

- 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)
```

Review: 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 entities

- Weak entity set and identifying relationship set are translated into a single table --- it has a (1,1) cardinality constraint.

```
CREATE TABLE  Dep_Policy (
   dname  CHAR(20),
   age  INTEGER,
   cost  REAL,
   parent_ssn  CHAR(9) NOT NULL,
   PRIMARY KEY  (dname, parent_ssn),
   FOREIGN KEY  (parent_ssn) REFERENCES Employees,
      ON DELETE CASCADE)
```

- When an owner entity is deleted all owned entity should also be deleted.

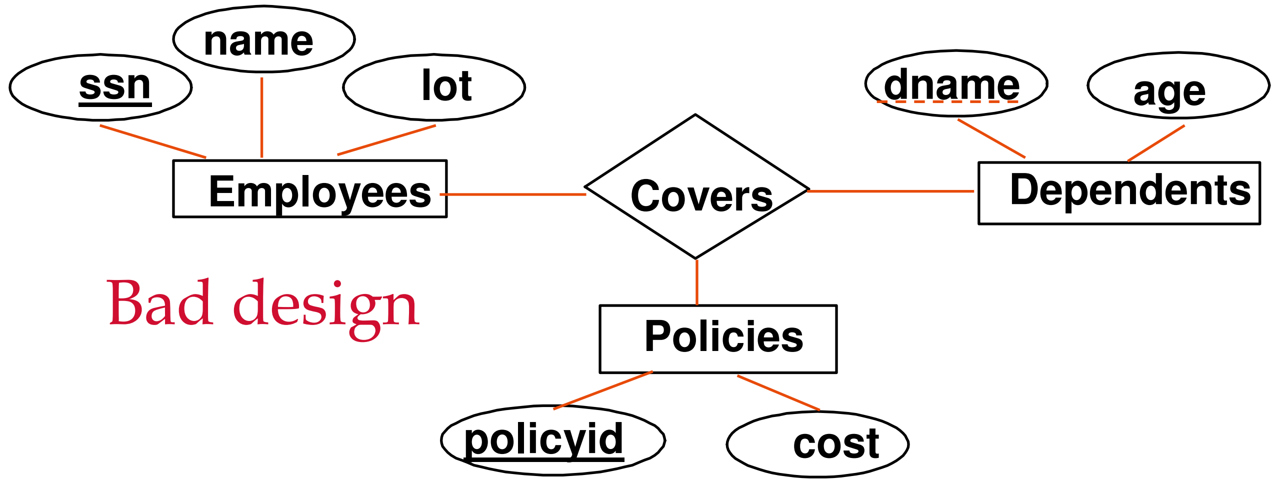
Translating Weak Entity Sets

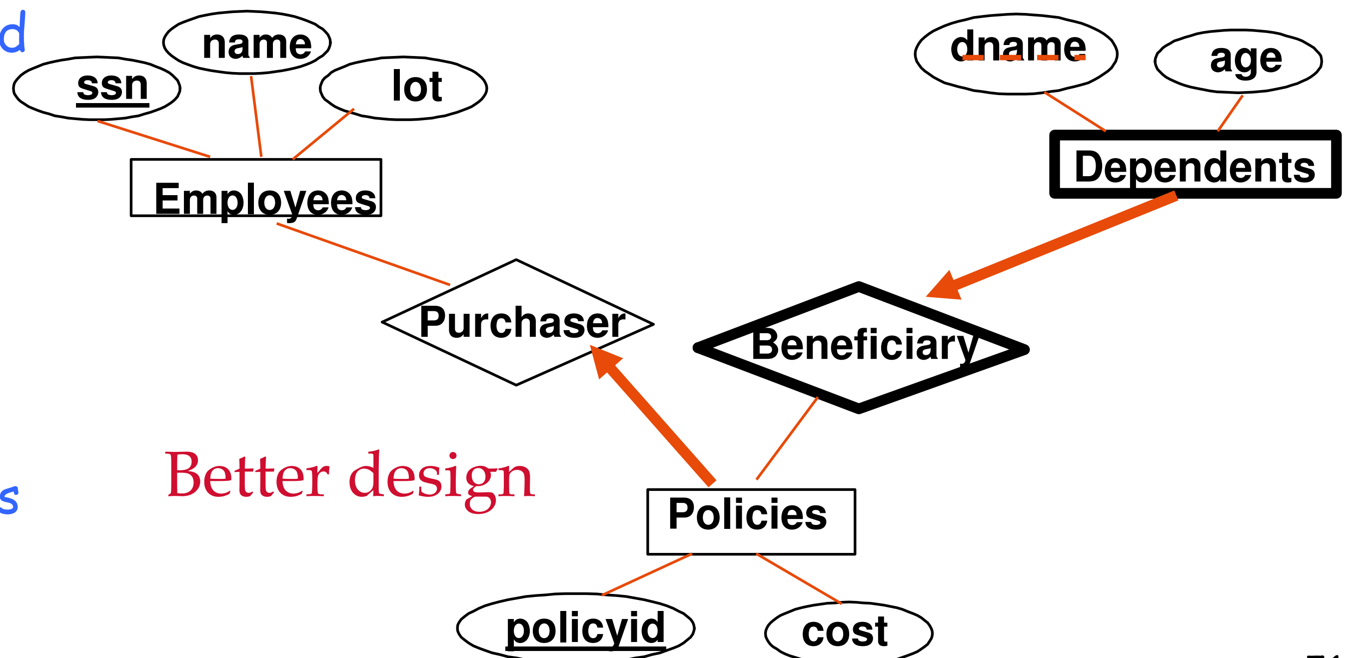
- Weak entity set and identifying relationship set are translated into a single table.
  - When the owner entity is deleted, all owned weak entities must also be deleted.

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

Review: Binary vs. Ternary Relationships

- If each policy is owned by just 1 employee:
  - Key constraint on Policies would mean policy can only cover 1 dependent!
- 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?

  PK of Policies: (policyid, ssn)

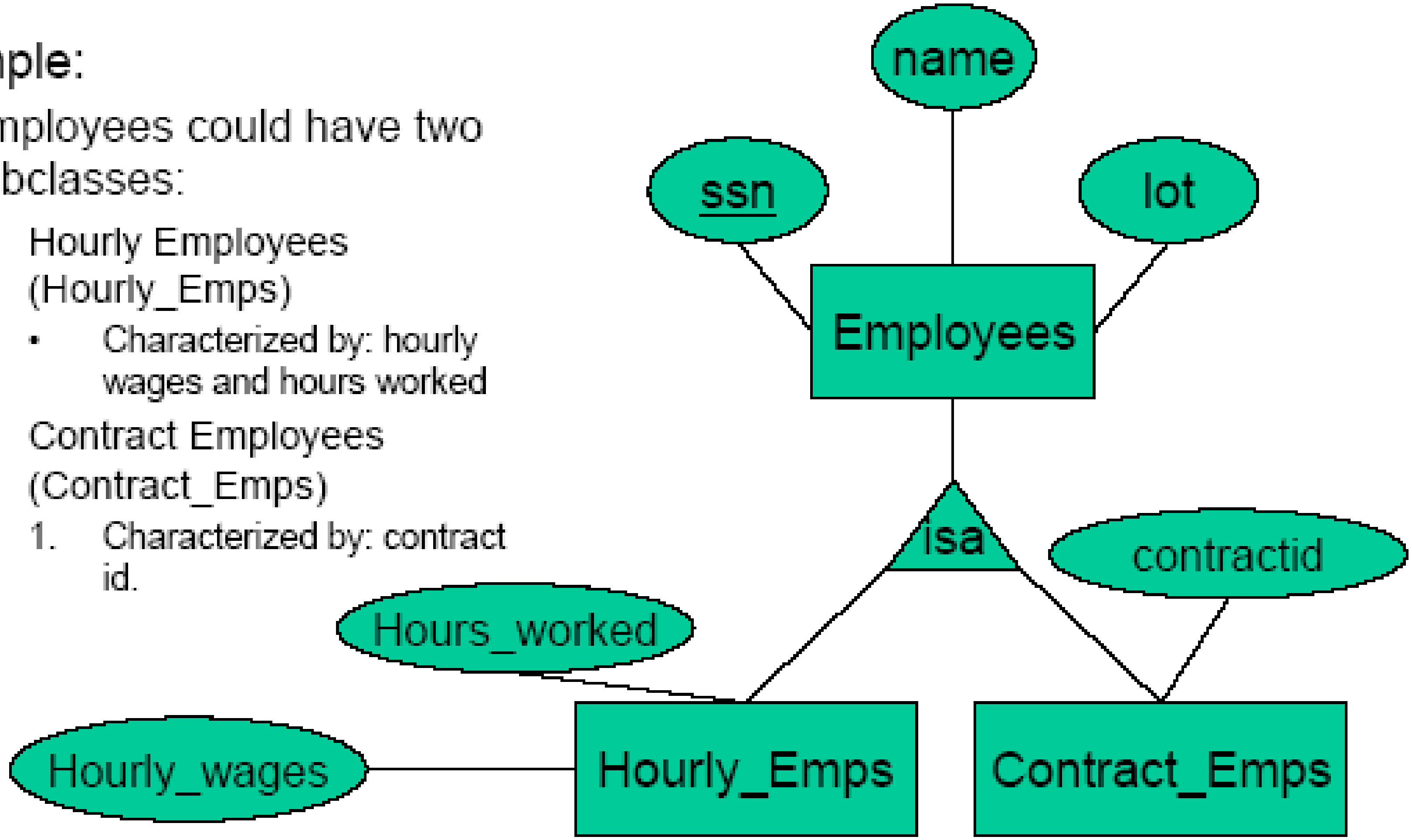
  PK of Dependents: (dname, policyid, ssn)

```
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 (
  dname CHAR(20),
  age INTEGER,
  policyid INTEGER,
  PRIMARY KEY (dname, policyid).
  FOREIGN KEY (policyid) REFERENCES Policies
    ON DELETE CASCADE);
```

Translating Class Hierarchies

- Example:
  - Employees could have two subclasses:
    1. Hourly Employees (Hourly_Emps)
       - Characterized by: hourly wages and hours worked
    2. Contract Employees (Contract_Emps)
       1. Characterized by: contract id.



Translating Class Hierarchies

- Two approaches
  - Three tables: 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*);
    - We 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.

An Example

```
CREATE TABLE Student (
        ID          NUMBER,
        Fname       VARCHAR2(20),
        Lname       VARCHAR2(20),
);
```

Constraints in Create Table

- Adding constraints to a table enables the database system to enforce data integrity.
- Different types of constraints:

  * Not Null
  * Default Values
  * Unique
  * Primary Key
  * Foreign Key
  * Check Condition

Not Null Constraint

```
CREATE TABLE Student (
        ID          NUMBER,
        Fname       VARCHAR2(20) NOT NULL,
        Lname       VARCHAR2(20) NOT NULL,
);
```

Primary Key Constraint

```
CREATE TABLE Student (
        ID          NUMBER      PRIMARY KEY,
        Fname       VARCHAR2(20) NOT NULL,
        Lname       VARCHAR2(20) NOT NULL,
);
```

- Primary Key implies: * NOT NULL * UNIQUE.
- There can only be one primary key.

Primary Key Constraint (Syntax 2)

```
CREATE TABLE Students (
        ID          NUMBER,
        Fname       VARCHAR2(20) NOT NULL,
        Lname       VARCHAR2(20) NOT NULL,
        PRIMARY KEY(ID)
);
```

Needed when the primary key is made up of two or more attributes (fields)

Foreign Key Constraint

```
CREATE TABLE Studies(
      Course        NUMBER,
      Student       NUMBER,
      FOREIGN KEY (Student) REFERENCES
            Students(ID)
);
```

NOTE: ID must be unique (or primary key) in Students table