INFO20003 Database Systems

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Lecture 04
Relational Model &
Translating ER diagrams

Semester 1 2018, Week 2

Coverage

- Relational Model
- Keys & Integrity Constraints
- Translating ER to Logical and Physical Model

Readings: Chapter 3, Ramakrishnan & Gehrke, Database Systems

Relational Data Model

- **Data Model** allows us to translate real world things into structures that a computer can store
- Many models: Relational, ER, O-O, Network, Hierarchical, etc.

- **Relational Model:**
  - –Rows & Columns
  - –Keys & Foreign Keys to link Relations

Enrolled

sid	cid	grade
53666	Carnatic101	5
53666	Reggae203	5.5
53650	Topology112	6
53666	History105	5

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	5.4
53688	Smith	smith@eecs	18	4.2
53650	Smith	smith@math	19	4.8

Relational Database: Definitions

- ***Relational database***: a set of *relations*.
- ***Relation***: made up of 2 parts:
  - ***Schema*** : specifies name of relation, plus name and type of each column (attribute).

    Example: Students(*sid*: string, *name*: string, *login*: string, *age*: integer, *gpa*: real)
  - ***Instance*** : a ***table*, **with rows and columns.

    #rows = *cardinality*

    #fields = *degree (or arity)*
- You can think of a relation as a *set* of *rows* or *tuples*.
  - all rows are *distinct*, no order among rows

Example Instance of Students Relation

Students

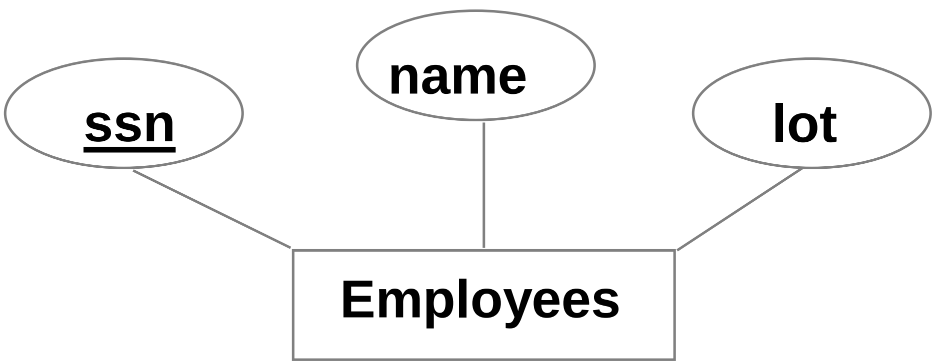
sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

Cardinality = 3, degree (arity) = 5, all rows distinct

Logical Design: ER to Relational Model

In logical design **entity** set becomes a **relation.** Attributes become attributes of the relation.

Conceptual Design:



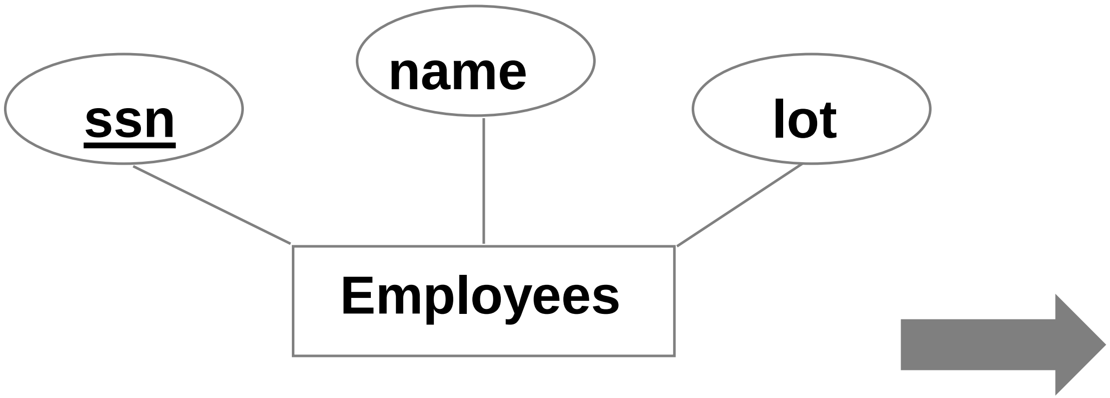
Logical Design:

Employees = (<u>ssn</u>,
name,
lot)

ER to Logical to Physical

In physical design we choose data types

1. Conceptual Design:

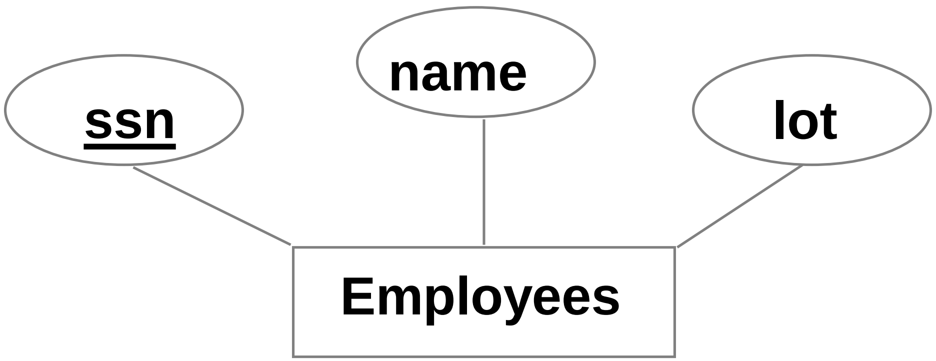


2. Logical Design:
Employees = (<u>ssn</u>,
name,
lot)

3. Physical Design:
Employees
(<u>ssn</u> CHAR(11),
name CHAR(20),
lot INTEGER)

The Entire Cycle

1. Conceptual Design:



2. Logical Design:

Employees = (<u>ssn</u>,
name,
lot)

3. Physical Design:

Employees
(<u>ssn</u> CHAR(11),
name CHAR(20),
lot INTEGER)

4. Implementation:

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

5. Instance:

EMPLOYEES

<u>ssn</u>	name	lot
0983763423	John	10
9384392483	Jane	10
3743923483	Jill	20

Creating Relations in SQL

Example: Creating the Students relation.

```
CREATE TABLE Students
        (sid CHAR(20),
         name CHAR(20),
         login CHAR(10),
         age INTEGER,
         gpa FLOAT)
```

The type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.

Relational Model

- Relational Model & SQL overview
- **Keys & Integrity Constraints**
- Translating ER to Logical and Physical Model

Readings: Chapter 3, Ramakrishnan & Gehrke, Database Systems

Keys

- Keys are a way to associate tuples in different relations
- Keys are one form of **integrity constraint (IC)**

Enrolled

sid	cid	grade
53666	15-101	C
53666	18-203	B
53650	15-112	A
53666	15-105	B

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@cs	18	3.2
53650	Smith	smith@math	19	3.8

FOREIGN Key

PRIMARY Key

Primary Keys

- A set of fields is a ***superkey*** if no two distinct tuples can have same values in all key fields
- A set of fields is a ***key*** for a relation if it is a superkey and no subset of the fields is a superkey (minimal subset)
- Out of all keys *one* is chosen to be the ***primary key*** of the relation**.** Other keys are called ***candidate*** keys.
- Each relation has a primary key.

- **Your turn:**
  1. *Is sid* a key for Students?
  2. What about *name*?
  3. Is the set {*sid, gpa*} a superkey? Is the set {*sid, gpa*} a key?
  4. Find a primary key from this set {sid, login}

Primary and Candidate Keys in SQL

- There are possibly many *candidate keys* (specified using UNIQUE), one of which is chosen as the *primary key*. Keys must be chosen carefully.

Example:

For a given student and course, there is a single grade.

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY (sid,cid))
```

VS.

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY  (sid),
   UNIQUE (cid, grade))
```

"Students can take only one course, and no two students in a course receive the same grade."

Foreign Keys & Referential Integrity

- ***Foreign key*** : A set of fields in one relation that is used to ‘refer’ to a tuple in another relation. Foreign key must correspond to the primary key of the other relation.

- If all foreign key constraints are enforced in a DBMS, we say a ***referential integrity*** is achieved.

Foreign Keys in SQL

Example: Only students listed in the Students relation should be allowed to enroll in courses.

- *sid* is a foreign key referring to Students

```
CREATE TABLE Enrolled
(sid CHAR(20),
 cid CHAR(20),
 grade CHAR(2),
 PRIMARY KEY (sid,cid),
 FOREIGN KEY (sid) REFERENCES Students )
```

Enrolled

sid	cid	grade
53666	15-101	C
53666	18-203	B
53650	15-112	A
53666	15-105	B

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@cs	18	3.2
53650	Smith	smith@math	19	3.8

Enforcing Referential Integrity

- Consider Students and Enrolled; *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*'.)
- Note: Similar issues arise if primary key of Students tuple is updated.

Integrity Constraints (ICs)

- ***IC***: condition that must be true for *any* instance of the database; e.g., *domain constraints.*
  - –ICs are specified when schema is defined.
  - –ICs are checked when relations are modified.
- A ***legal*** instance of a relation is one that satisfies all specified ICs.
  - –DBMS should not allow illegal instances.

Relational Model

- Relational Model & SQL overview
- Keys & Integrity Constraints
- **Translating ER to Logical and Physical Model**

Readings: Chapter 3, Ramakrishnan & Gehrke, Database Systems

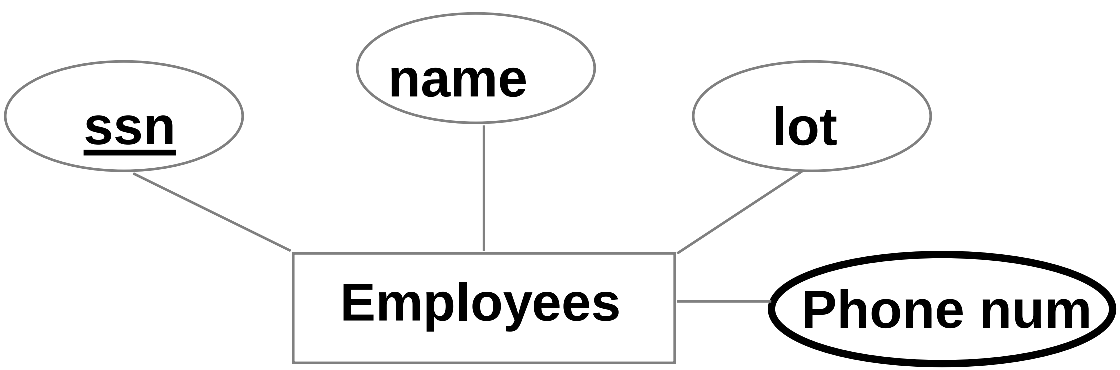
Multi-valued attributes in logical design

- Multi-valued attributes need to be unpacked (flattened) when converting to logical design.

Example:

For employees we need to capture home phone number and work phone number.

Conceptual Design:



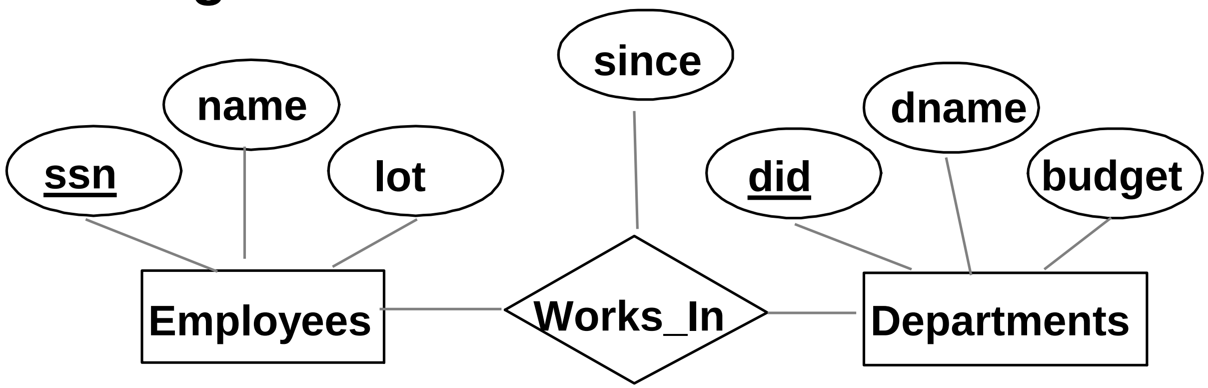
Multi-valued attribute

Logical Design:

Employees = (<u>ssn</u>,
name,
lot,
home_num,
work_num)

ER to Logical Design

Conceptual Design:



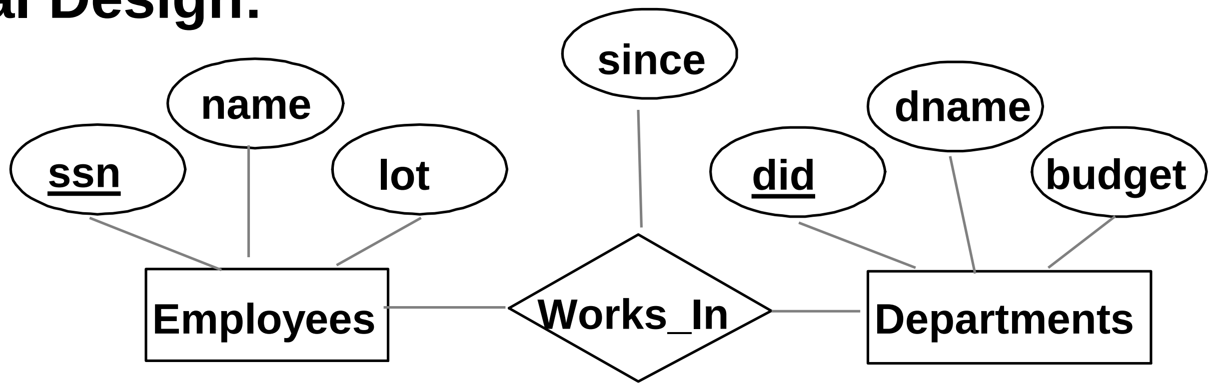
Logical Design:

In translating a **many-to-many** relationship set to a relation, attributes of a *new* relation must include:

1. Keys for each participating entity set (as foreign keys). This set of attributes forms a ***superkey*** of the relation.
2. All descriptive attributes.

ER to Logical Design

Conceptual Design:



Logical Design:

Employees = (<u>ssn</u>,
name
lot)

Departments = (<u>did</u>,
dname,
budget)

Works_In = (<u>**ssn**</u>,
<u>**did**</u>,
since)

Keys from connecting entities become PFK

Note: Underline = PK,
italic and underline = FK,
underline and bold = PFK

Logical to Physical Design

Logical Design:

Employees = (<u>ssn</u>, name, lot)

Departments = (<u>did</u>, dname, budget)

Works_In = (**<u>ssn</u>**, **<u>did</u>**,since)

Note: Underline = PK, italic and underline = FK, underline and bold = PFK

Physical Design:

Employees
(<u>ssn</u> CHAR(11),
name CHAR(20),
lot INTEGER)

Departments
(<u>did</u> INTEGER,
dname CHAR(20),
budget FLOAT)

Works_In(
<u>ssn</u> CHAR(11),
<u>did</u> INTEGER,
since DATE)

Implementation (Create table)

Logical Design:

Employees = (ssn, name, lot)

Departments = (did, dname, budget)

Works_In = (**ssn**, **did**,since)

Note: Underline = PK,
italic and underline = FK,
underline and bold = PFK

Implementation:

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

```
CREATE TABLE Departments
        (did INTEGER,
         dname CHAR(20),
         budget FLOAT,
         PRIMARY KEY  (did))
```

```
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)
```

Example Instances

Employees

0983763423	John	10
9384392483	Jane	10
3743923483	Jill	20

Departments

101	Sales	10K
105	Purchasing	20K
108	Databases	1000K

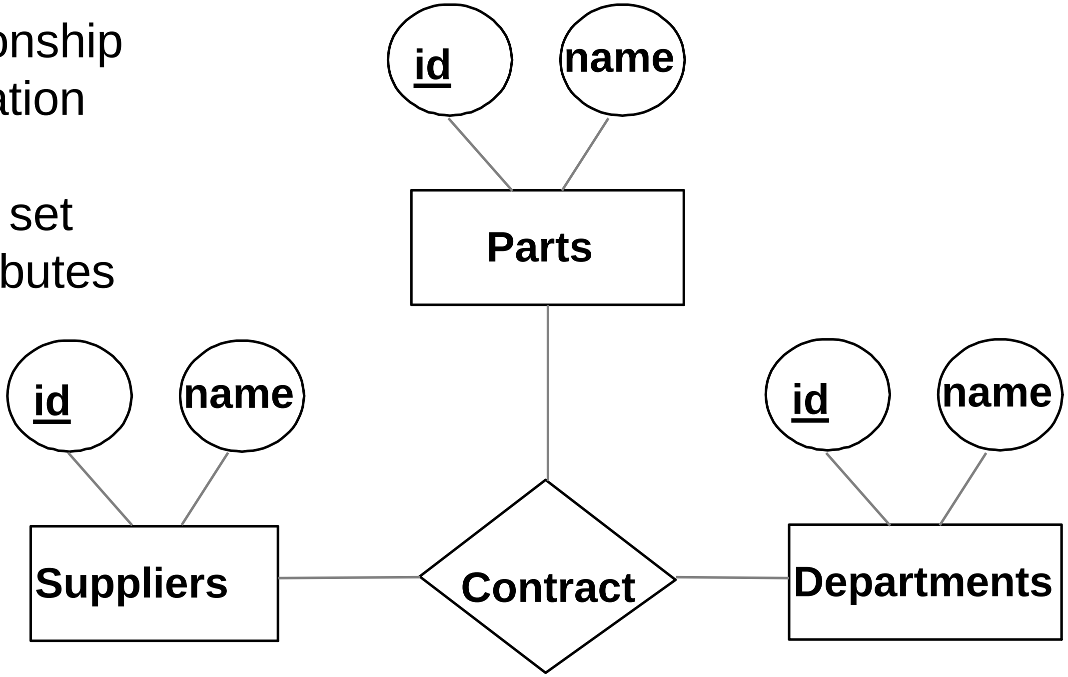
Works_In

0983763423	101	1 Jan 2003
0983763423	108	2 Jan 2003
9384392483	108	1 Jun 2002

ER to Logical Design Example 2

In translating a many-to-many 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.



Logical Design:

Contracts (

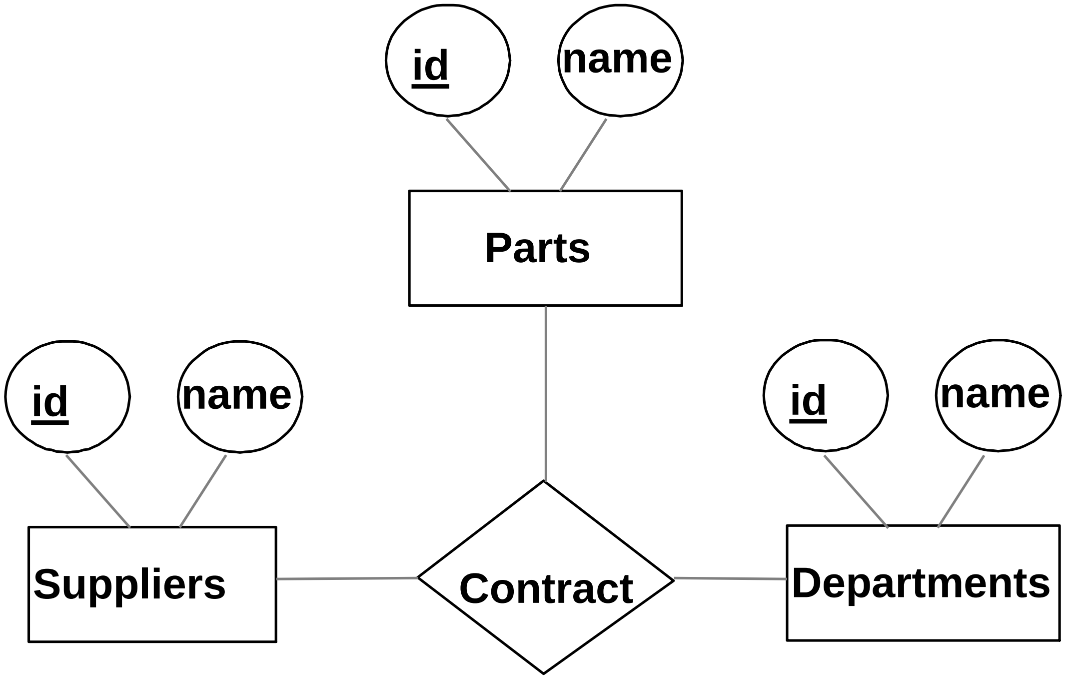
<u>supplier_id</u>,

<u>part_id</u>,

<u>department_id</u>)

Note: Underline = PK, italic and underline = FK, underline and bold = PFK

ER to Logical to Implementation Example 2



Logical Design:

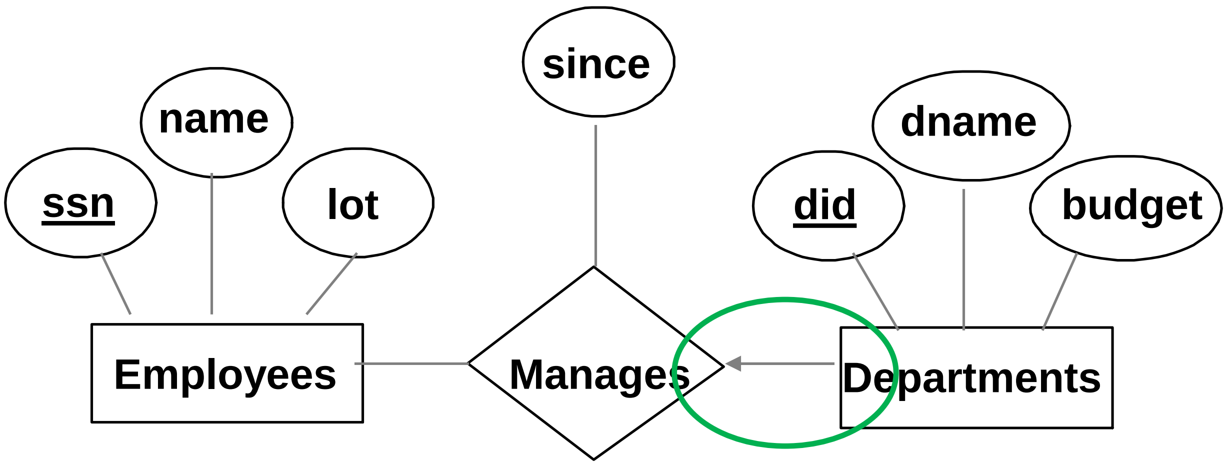
Contracts (
supplier_id,
part_id,
department_id)

Implementation:

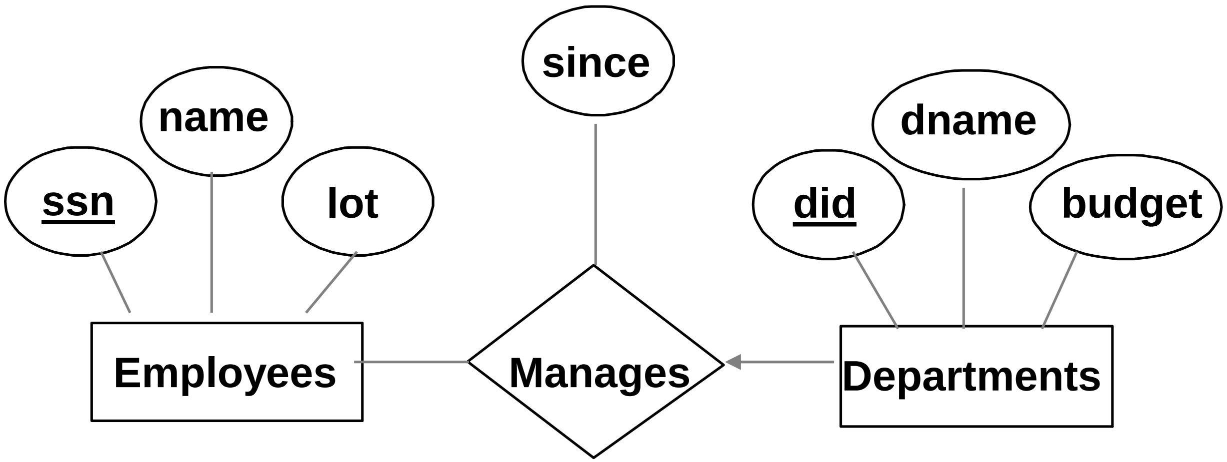
```
CREATE TABLE Contracts (
    supplier_id  INTEGER,
    part_id  INTEGER,
    department_id  INTEGER,
    PRIMARY KEY (supplier_id, part_id, department_id),
    FOREIGN KEY (supplier_id) REFERENCES Suppliers,
    FOREIGN KEY (part_id) REFERENCES Parts,
    FOREIGN KEY (department_id) REFERENCES Departments)
```

Review: Key Constraints in ER

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



Key Constraints: Logical design



Logical Design:

Employees = (<u>ssn</u>,name, lot)

Departments = (<u>did</u>,dname, budget)

Manages = (<u>*ssn*</u>, <u>did</u>, since)

VS.

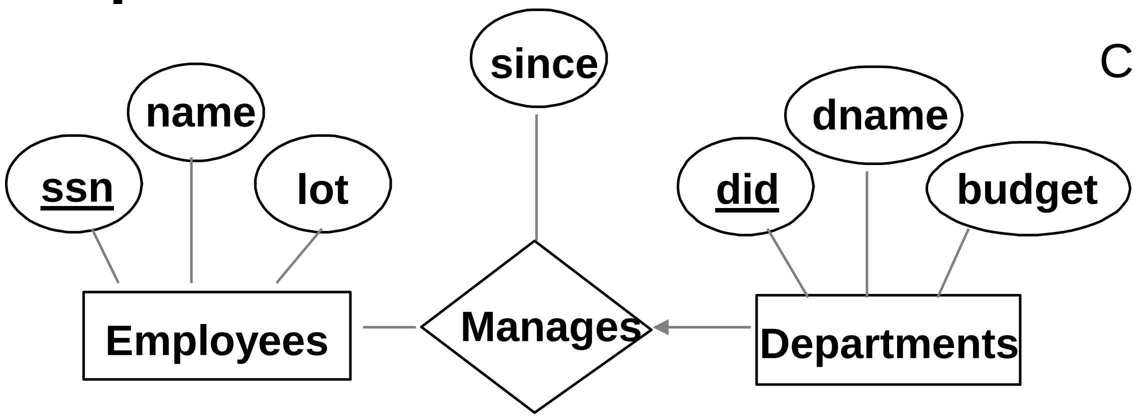
Employees = (<u>ssn</u>,name, lot)

Departments = (<u>did</u>,dname, budget, <u>*ssn*</u>, since)

Note: Underline = PK, italic and underline = FK, underline and bold = PFK

Key Constraints in SQL

Implementation:



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

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

VS.

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

Which one is better?

Key Constraints rule

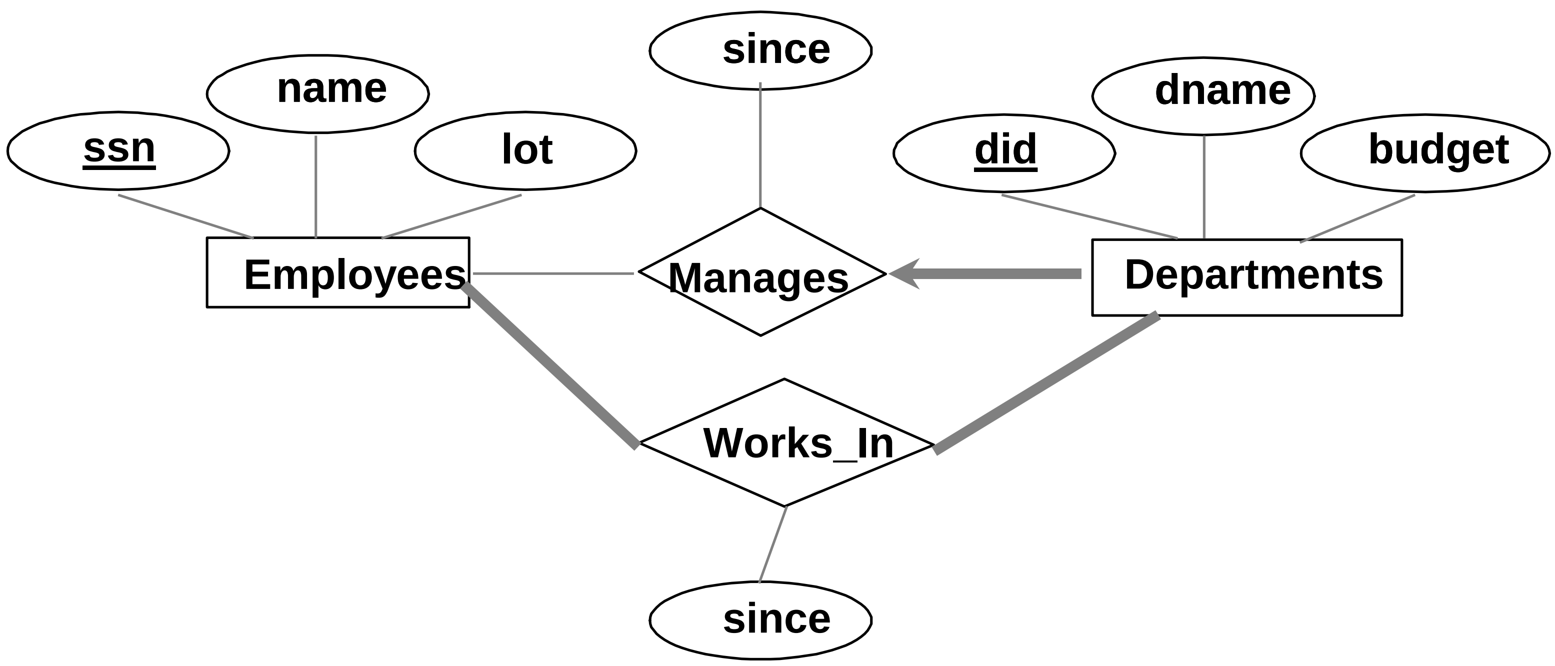
- Primary key from the many side becomes a foreign key on the one side
- This is the way to ensure that the key constraint holds

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

Each department will have a *single* manager

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*).



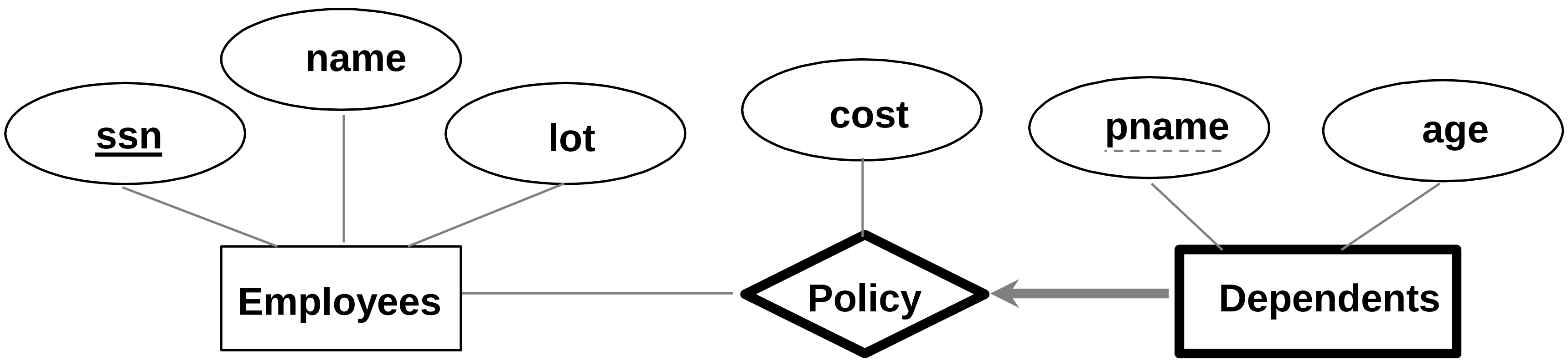
Participation Constraints in SQL

- We specify total participation with key words NOT NULL
  - NOT NULL = this field cannot be empty

```
CREATE TABLE Departments(
   did  INTEGER NOT NULL,
   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.



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.

Logical Design:

Dependents = (pname, age, cost, **ssn**)

Note: Underline = PK, italic and underline = FK, underline and bold = PFK

Implementation:

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

Relational Model: Summary

- A tabular representation of data.
- Simple and intuitive, currently the most widely used.
- Integrity constraints can be specified based on application semantics. DBMS checks for violations.
  - Two important ICs: primary and foreign keys
  - In addition, we *always* have domain constraints.
- Rules to translate ER to logical design (relational model)

What's examinable

- Translate conceptual (ER) into logical & physical design
- Understand integrity constraints
- Use DDL of SQL to create tables with constraints

Next Lecture

- ER Modelling Example with MySQL Workbench
  - You will need this for workshops/labs (and assessment)