Logical Database Design: Mapping ER to Relational

Chapter 3, Section 3.5

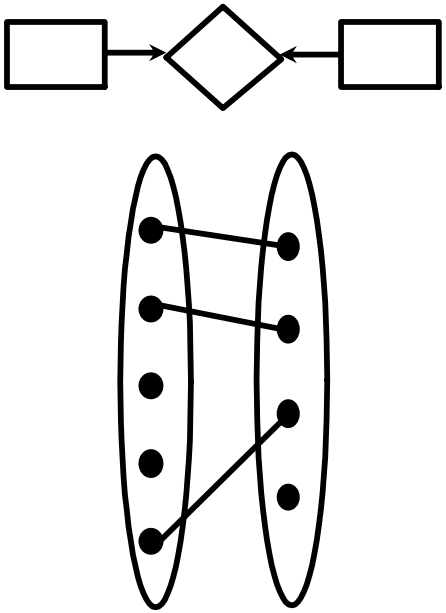
ER Model vs. Relational Model

- ER Model used for conceptual design
- Relational Model implemented by modern DBMS
- Important Step: Translate ER diagram to Relational schema

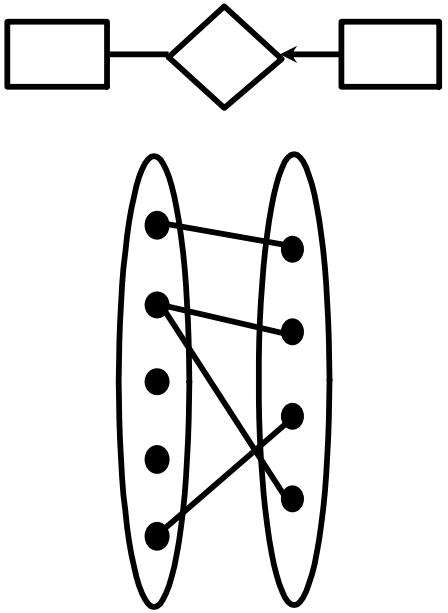
Recall ER Constructs

- Basic Constructs
  - Entity Sets
  - Relationship Sets
  - Attributes (of entities and relationships)
- Additional Constructs
  - ISA Hierarchies
  - Weak Entities
  - Aggregation
- Integrity Constraints
  - Key constraints
  - Participation constraints
  - Overlap / Covering constraints for ISA hierarchies

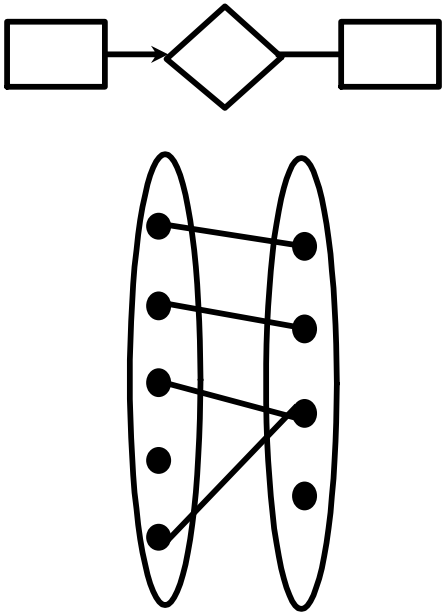
Review: ER relationship types



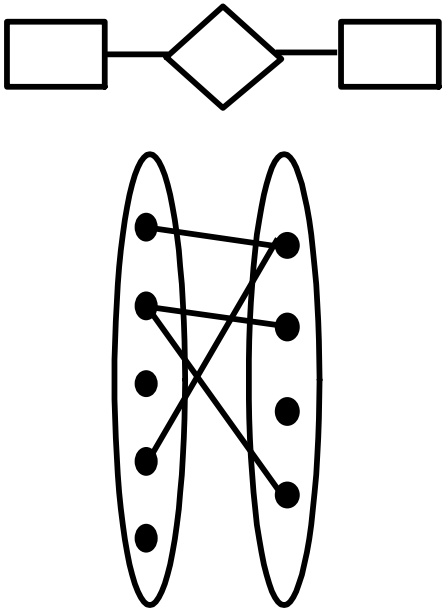
1-to-1



1-to Many
1-to-N



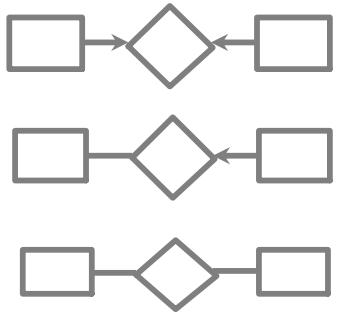
Many-to-1
N-to-1



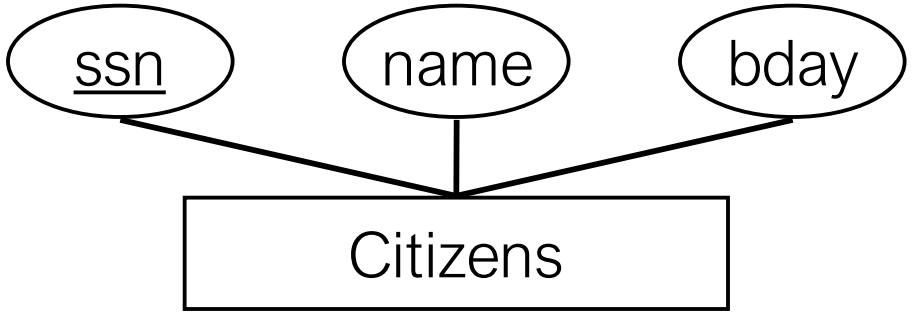
Many-to-Many
M-to-N

ER to Tables: Basics

- **Strong entities:**
  - key = primary key
- **Binary relationships:** keys come from the participating entities
  - **1-to-1:** either key (other = candidate key)
  - **1-to-N:** the key of the 'many' (N) part
  - **M-to-N:** both keys



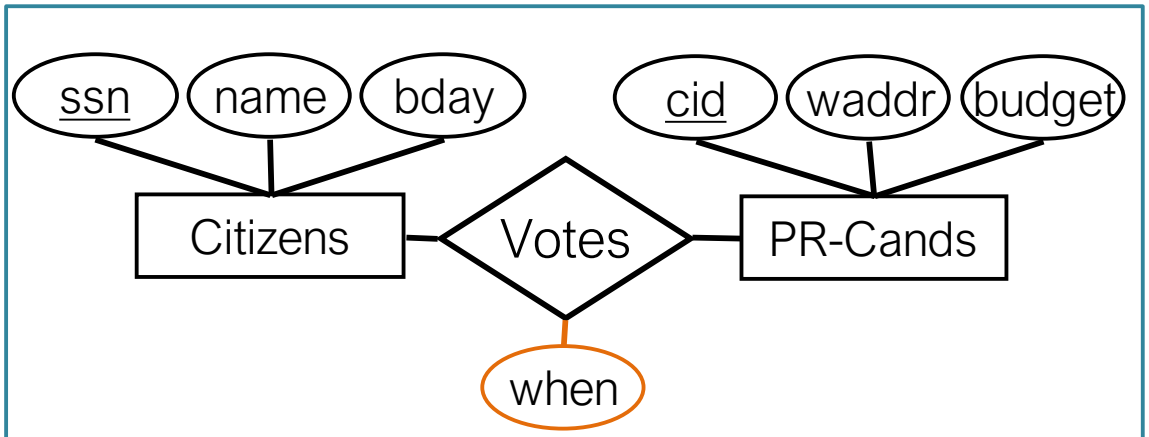
Entity Sets to Tables




```
CREATE TABLE Citizens
    (ssn    CHAR(11),
     name   CHAR(20),
     bday   DATE,
     PRIMARY KEY  (ssn))
```

Can ssn have a null value?

Relationship Sets to Tables



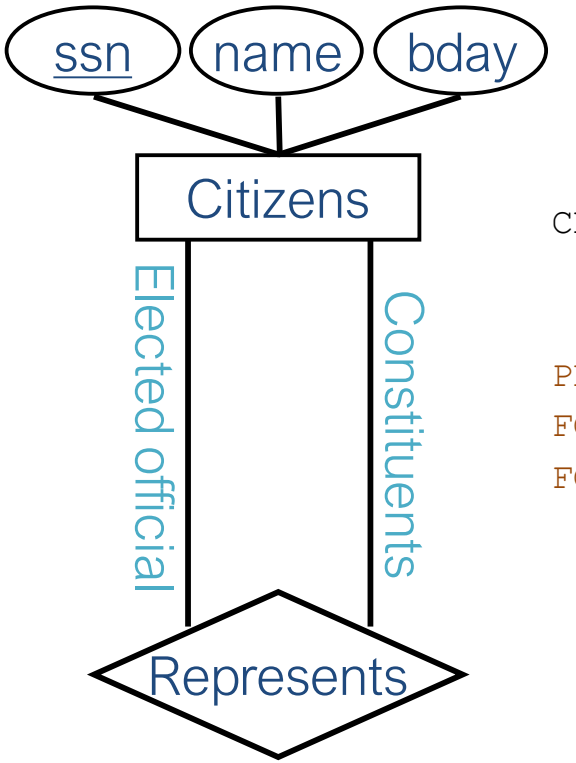

```
CREATE TABLE Votes(
        ssn      CHAR(11),
        cid      INTEGER,
        when     DATE,
PRIMARY KEY (ssn, cid),
FOREIGN KEY (ssn) REFERENCES Citizens,
FOREIGN KEY (cid) REFERENCES PR-Cands)
```

- **Foreign key: keys from** participating entity sets
- Descriptive attributes

Generalizes to n-ary relationships

(we will see example later)

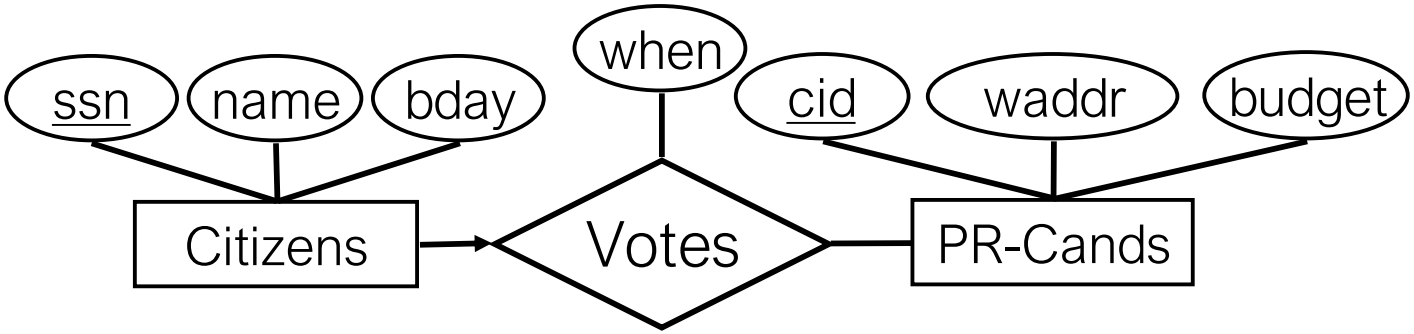
Relationship Sets to Tables




```
CREATE TABLE Represents(
        elected_ssn   CHAR(11),
        cons_ssn      CHAR(11),
PRIMARY KEY (elected_ssn, cons_ssn),
FOREIGN KEY (elected_ssn) REFERENCES Citizens(ssn),
FOREIGN KEY (cons_ssn) REFERENCES Citizens(ssn))
```

Note that you need to specify the column that you are referring to in the `Citizens` table, as `Citizens` does not have "`elected_ssn`" nor "`cons_ssn`".

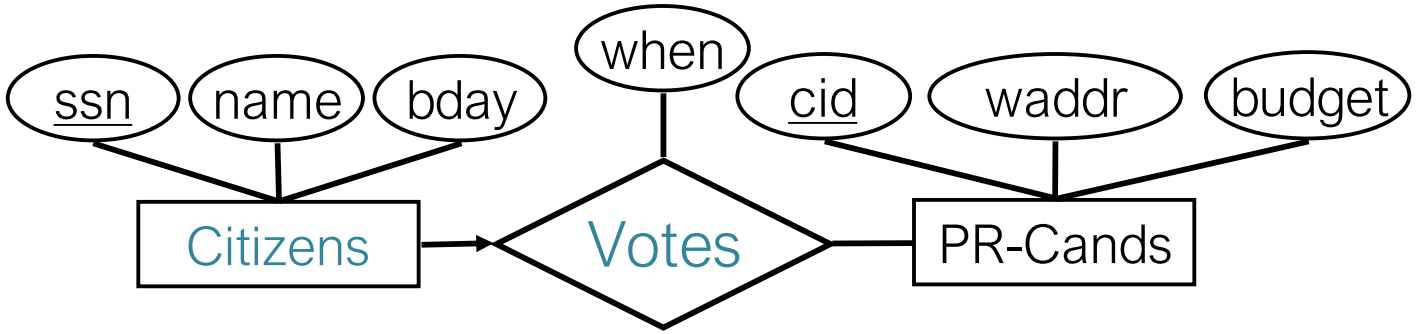
Key Constraints



- Approach 1: **Three** Tables (Citizens, Votes, PR-Cands)

```
CREATE TABLE  Votes
(   ssn     CHAR(11),
    cid     INTEGER,
    when    DATE,
    PRIMARY KEY (ssn),
    FOREIGN KEY (ssn) REFERENCES Citizens,
    FOREIGN KEY (cid) REFERENCES PR-Cands)
```

Key Constraints



Each citizen can only vote once, so OK to fold 'Votes' relationship into 'Citizens' entity

- Approach 2: **Two** Tables (Citizen_Votes, PR-Cands)

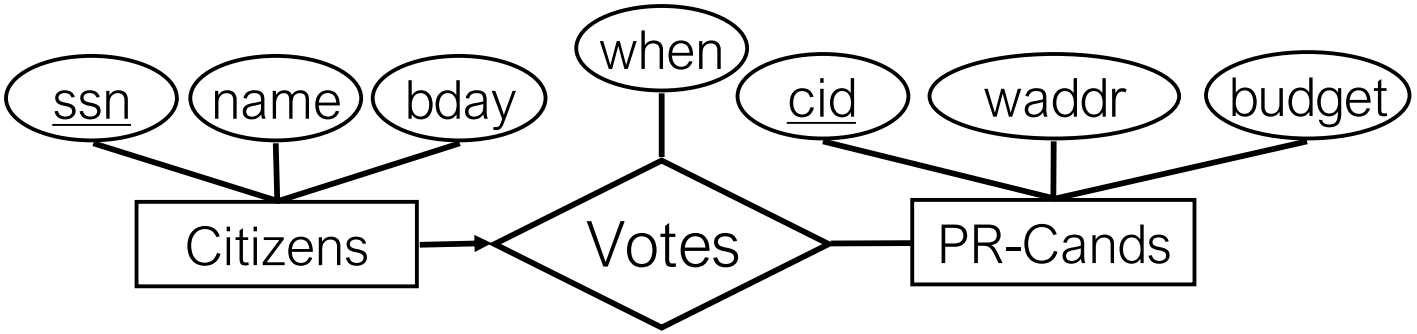
```
CREATE TABLE  Citizen_Votes (
    ssn     CHAR(11),
    name    CHAR(20),
    bday    DATE,
    when    DATE,
    cid     INTEGER,
PRIMARY KEY  (ssn),
FOREIGN KEY (cid) REFERENCES PR-Cands)
```

Q: Can cid be null?

Q: What if many citizens don't vote?

Q: Which approach is better?

Key Constraints



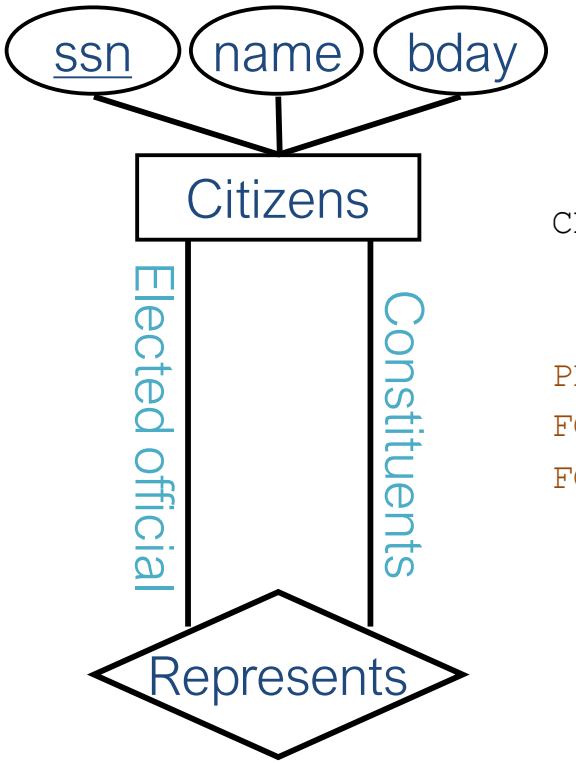
- What about **one** table?
- No! This is bad design.

  e.g., For each citizen that votes for Trump, we have to store Trump's information (cid, waddr, budget) => REDUNDANCY!

Primary Keys and ICs

- In (most) DBMSs the primary key (or any of its parts, if it is composite) cannot get NULL value.
  - In this class, we will stick with this rule (despite the fact that there are exceptions)
- Although you can choose how to handle UPDATE/DELETE actions when there are references (via foreign keys), some options may be in conflict with the primary key (PK) constraints
  - The system will not allow changes that violate the PK constraints.

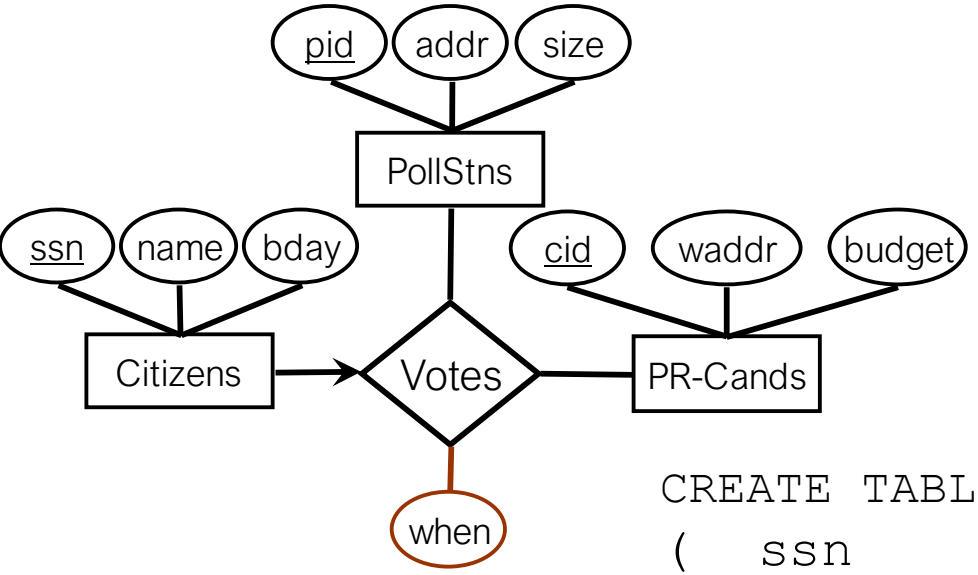
Relationship Sets to Tables




```
CREATE TABLE Represents(
        elected_ssn   CHAR(11),
        cons_ssn      CHAR(11),
PRIMARY KEY (elected_ssn, cons_ssn),
FOREIGN KEY (elected_ssn) REFERENCES Citizens(ssn),
FOREIGN KEY (cons_ssn) REFERENCES Citizens(ssn))
```

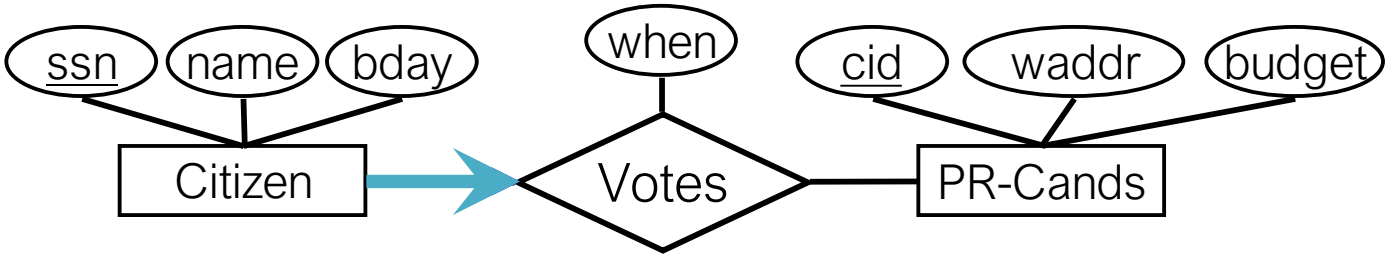
Note that you need to specify the column that you are referring to in the `Citizens` table, as `Citizens` does not have "`elected_ssn`" nor "`cons_ssn`".

Key Constraints: N-ary relationships




```
CREATE TABLE Citizens_Votes
(   ssn      CHAR(11),
    name     CHAR(20),
    bday     DATE,
    when     DATE,
    pid      INTEGER,
    cid      INTEGER,
    PRIMARY KEY  (ssn),
    FOREIGN KEY (cid) REFERENCES PR-Cands,
    FOREIGN KEY (pid) REFERENCES PollStns)
```

Participation Constraints

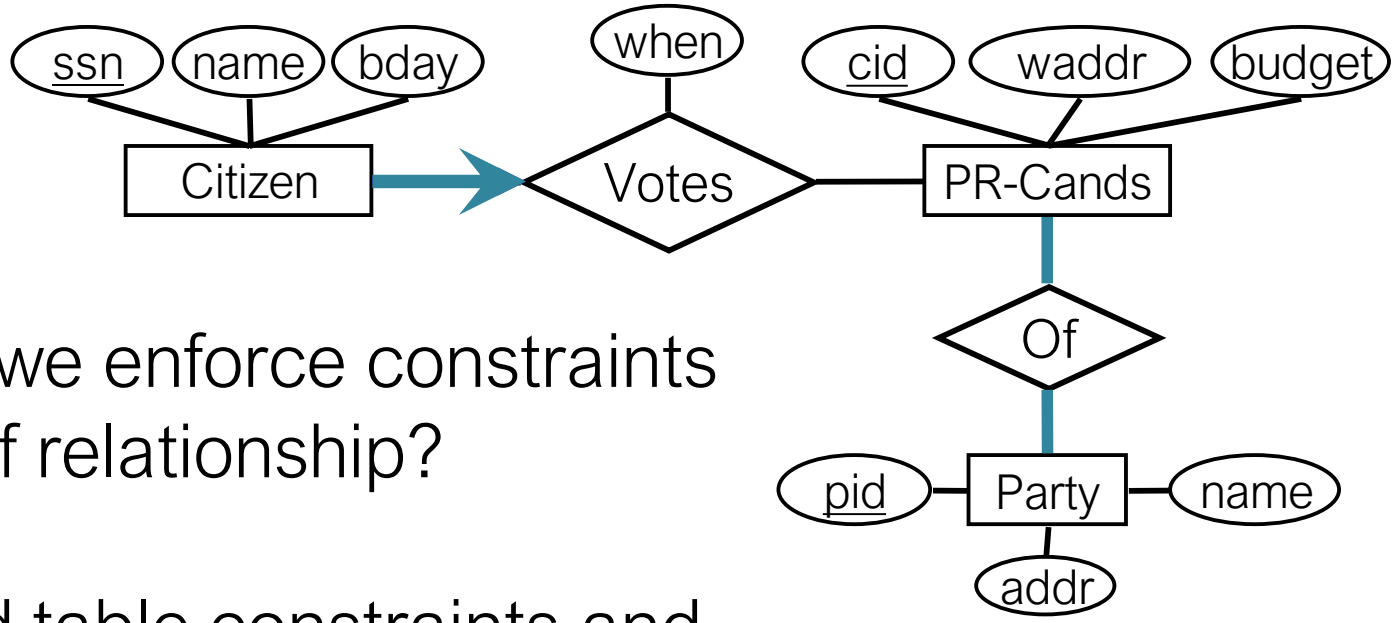


Using Approach 2

```
CREATE TABLE  Citizen_Votes(
    ssn      CHAR(11),
    name     CHAR(20),
    bday     DATE,
    when     DATE,
    cid      INTEGER NOT NULL,
PRIMARY KEY   (ssn),
FOREIGN KEY   (cid) REFERENCES PR_Cands
   ON DELETE NO ACTION);
```

Can we enforce the participation constraint using Approach 1 (three tables) ?

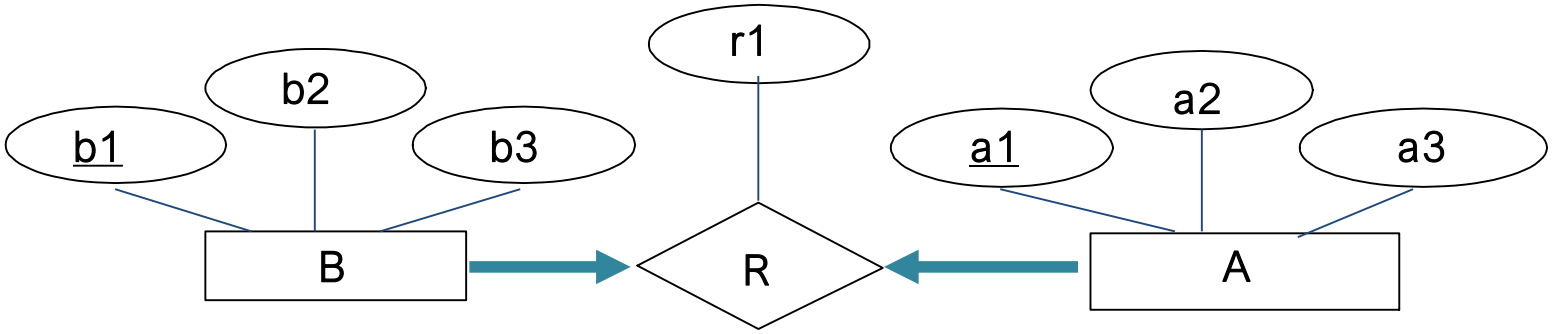
Participation Constraints



Can we enforce constraints on Of relationship?

Need table constraints and assertions (later).

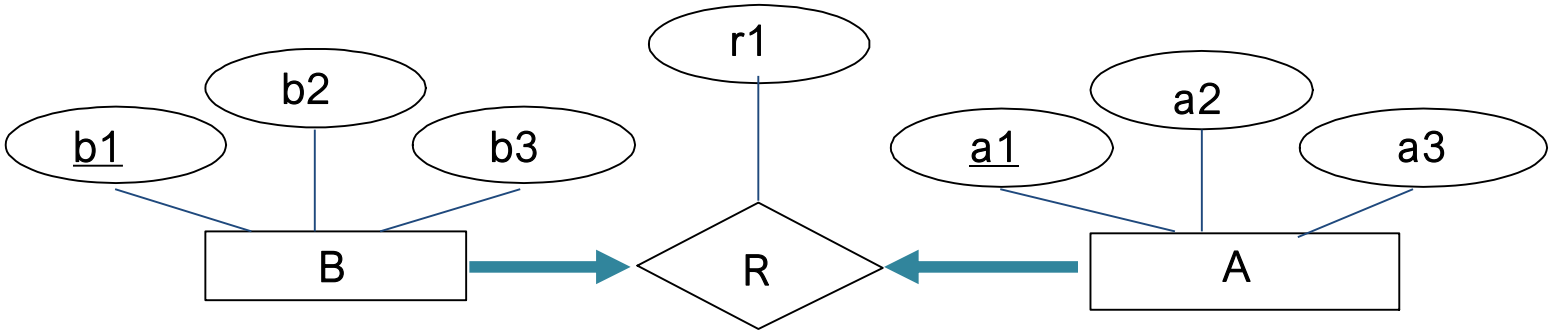
Mapping Participation Constraints (1-to-1)




```
CREATE TABLE  RAB(
        r1 Integer,
        a1 Integer,
        a2 Integer,
        a3 Integer,
        b1 Integer,
        b2 Integer,
        b3 Integer …)
```

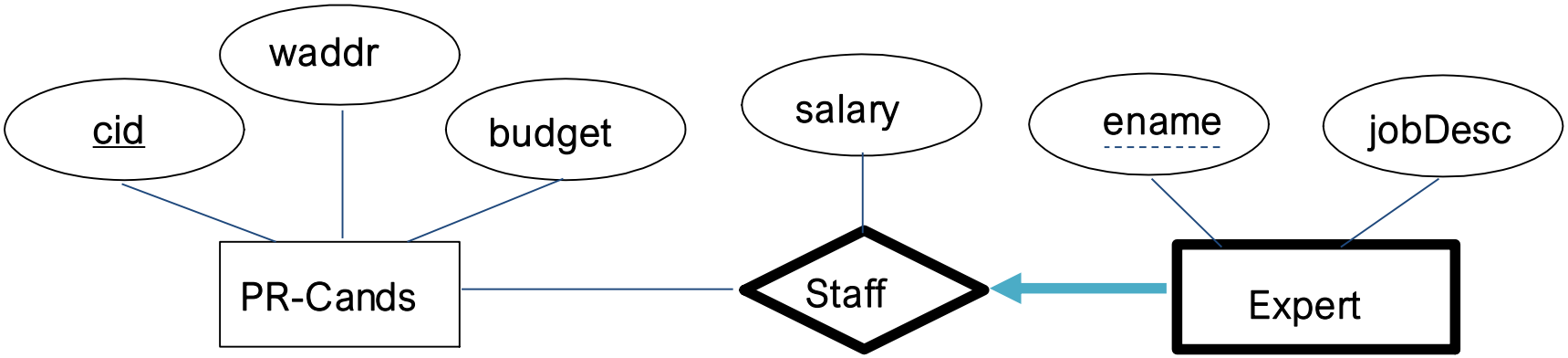
Key constraints?

Mapping Participation Constraints (1-to-1)




```
CREATE TABLE  RAB(
        r1 Integer,
        a1 Integer,
        a2 Integer,
        a3 Integer,
        b1 Integer NOT NULL,
        b2 Integer,
        b3 Integer,
        UNIQUE (b1), PRIMARY KEY (a1))
```

Weak Entities

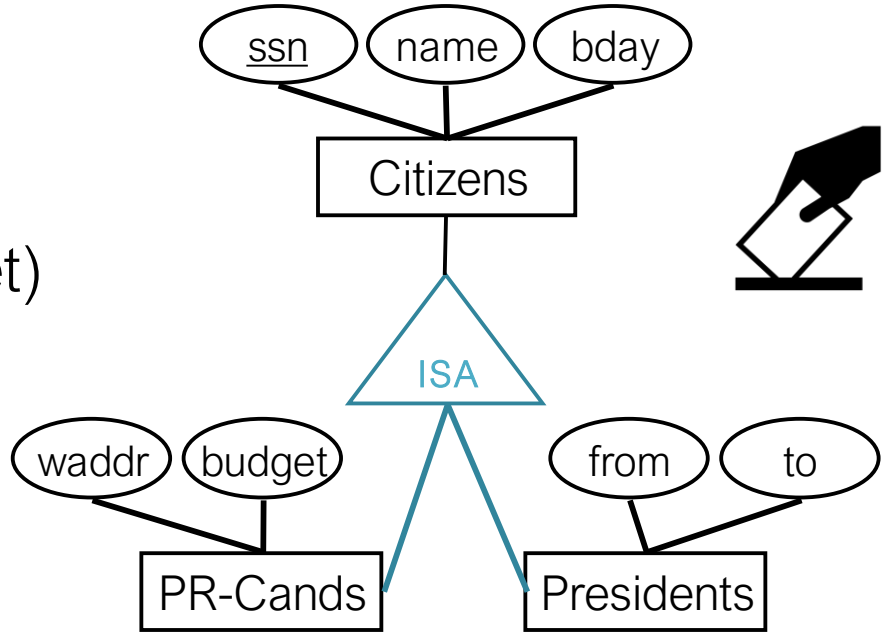


- Approach 2: Combine weak entity and owning relationship into one relation
  - Delete all weak entities when an owner entity is deleted.

```
CREATE TABLE  Expert_Staff  (
    ename       CHAR(20),
    jobDesc     CHAR(40),
    salary      REAL,
    cid         INTEGER,
    PRIMARY KEY   (ename, cid),
    FOREIGN KEY   (cid) REFERENCES PR-Cands
        ON DELETE CASCADE)
```

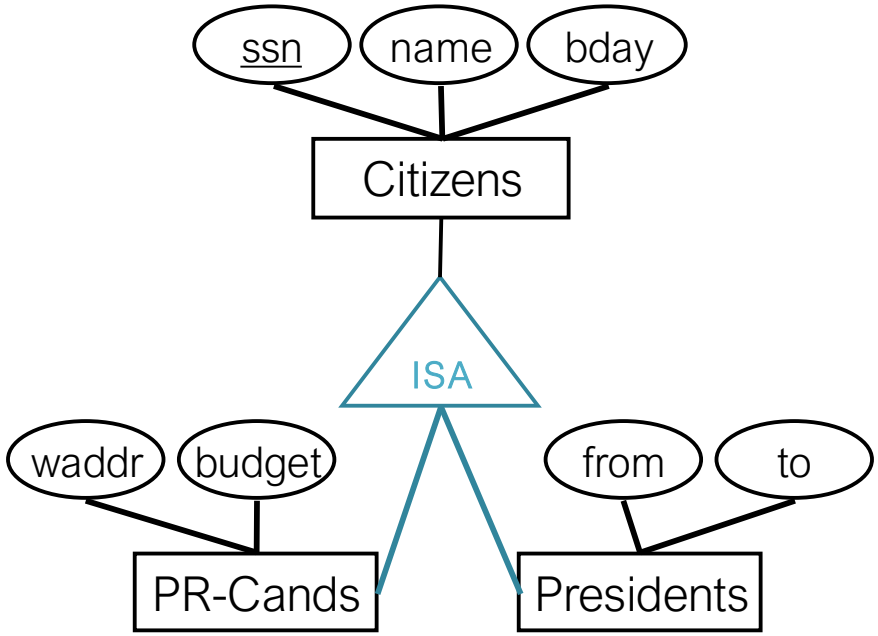
ISA Hierarchies: General Approach

- Three relations:
  - Citizens (ssn, name, bday)
  - PR-Cands (ssn, waddr, budget)
  - Presidents (ssn, from, to)
- Queries:
  - Involving all citizens => Easy
  - Involving just PR-Cands => need to join PR-cands with Citizens to get some attributes



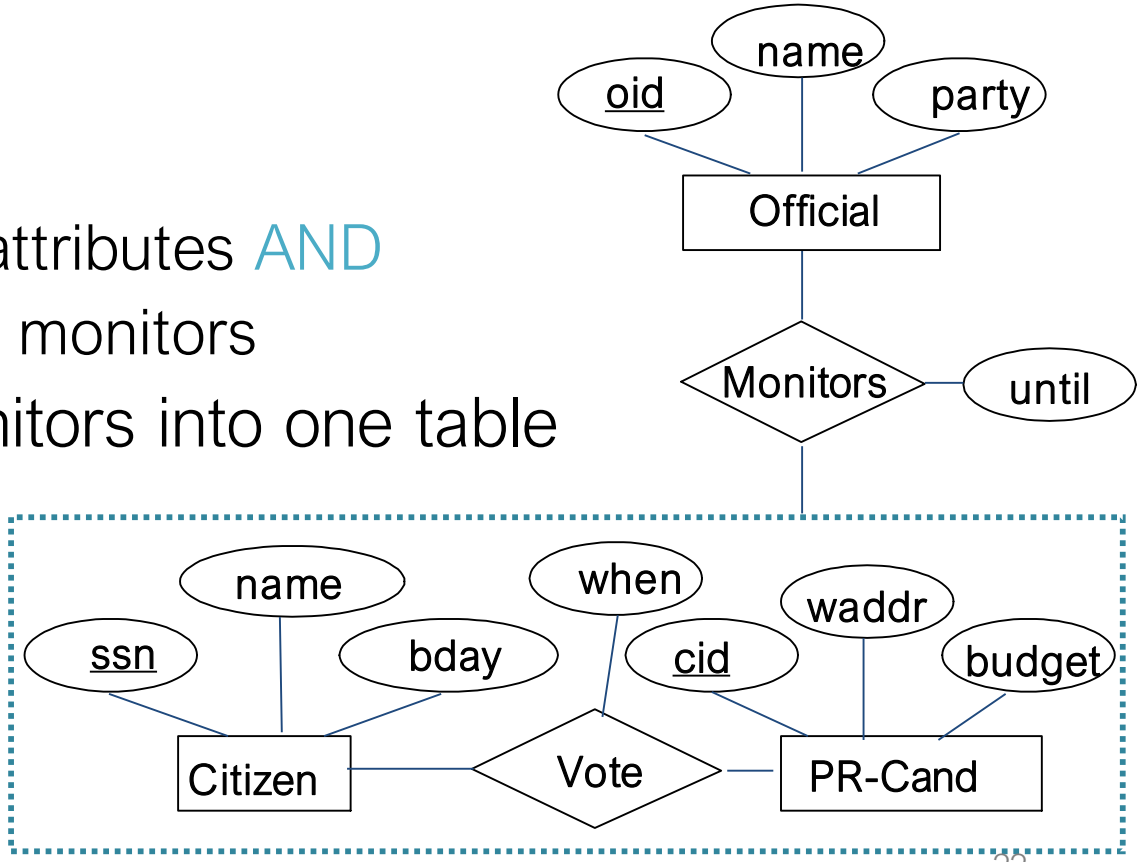
ISA Hierarchies: Alternative

- Two relations:
  - PR-Cands (<u>ssn</u>, name, bday, waddr, budget)
  - Presidents (<u>ssn</u>, name, bday, from, to)
- Problems:
  - What if citizen is both?
    - Redundancy
  - What if citizen is neither?
    - Use General approach



Aggregation

- Keep keys of **all** participating entity sets; decide primary
- Keys for Monitors
  - oid
  - (ssn, cid)
- Q: What if Vote:
  - has no descriptive attributes AND
  - total participation in monitors
- A: Fold Vote and Monitors into one table

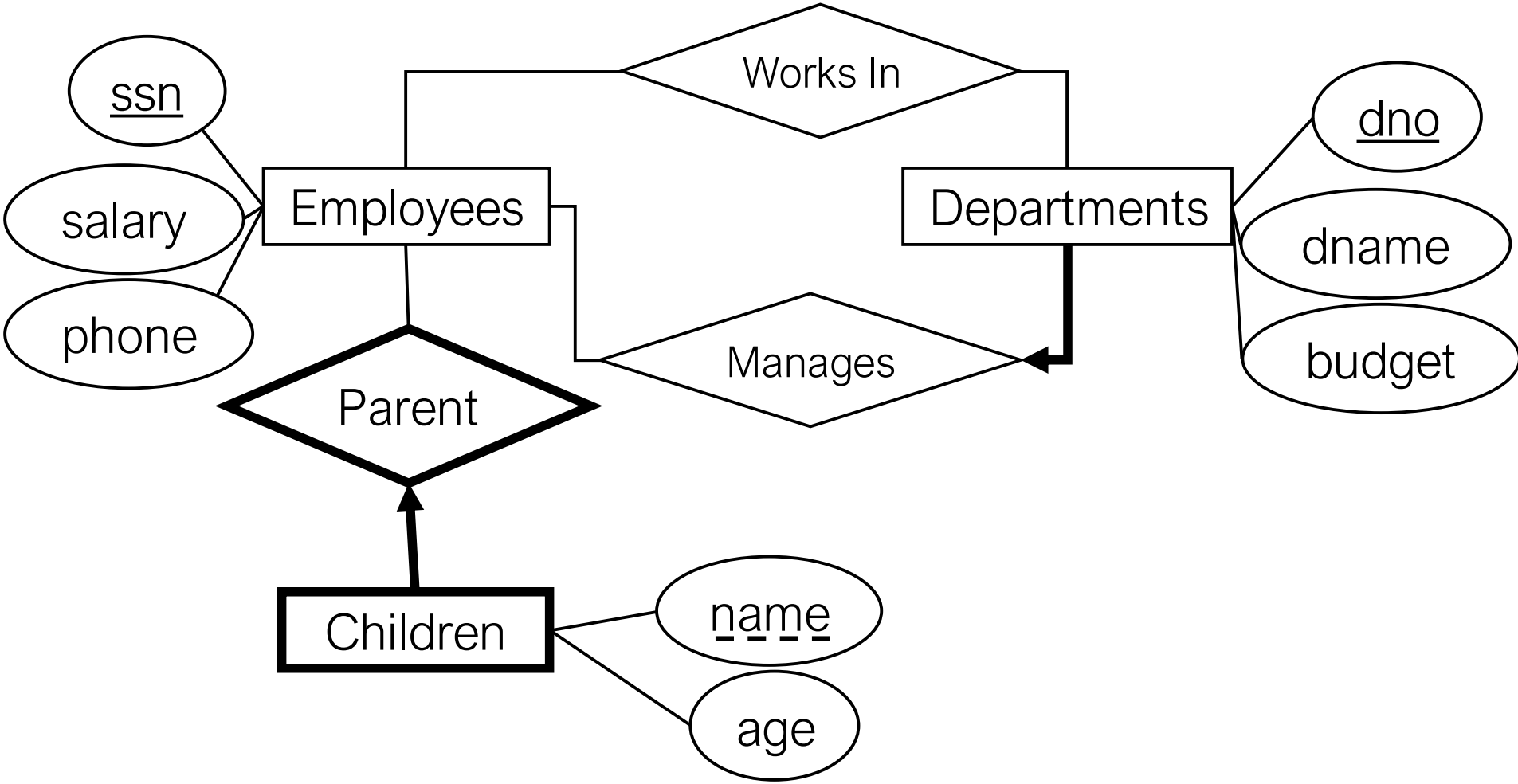


On your own

Exercise – Part 1

- A **company database** needs to store information about
  - **employees** (identified by ssn, with salary and phone attributes),
  - **departments** (identified by dno, with dname and budget attributes), and
  - **children of employees** (with name and age attributes).
- Employees work in (zero or more) departments
- Each department is managed by exactly one employee
- A child must be identified uniquely by name when the parent (who is an employee; assume only one parent works for the company) is known.
- We are not interested in information about a child once the parent leaves the company.
- Draw an ER diagram that captures this information

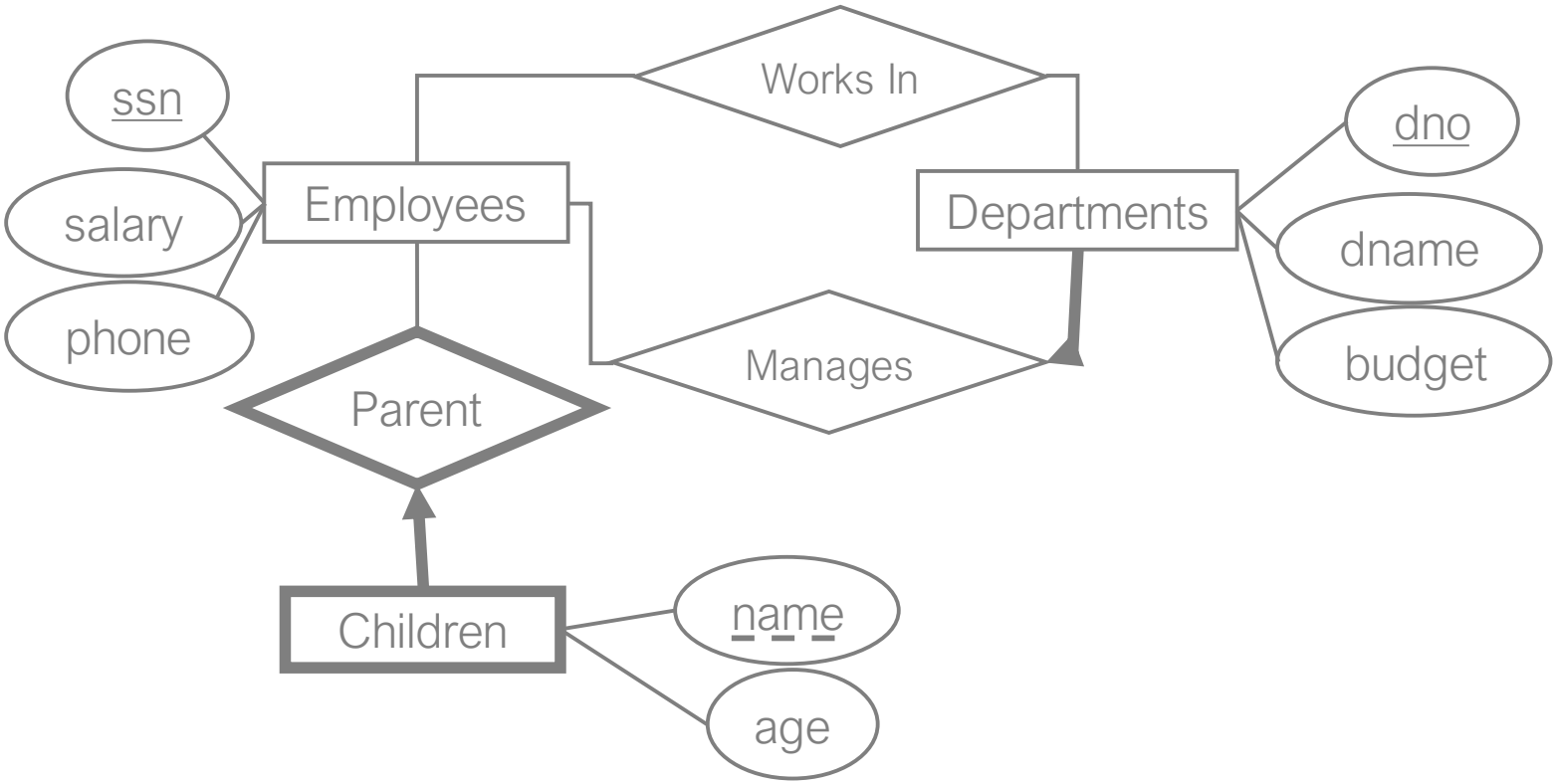
ER Diagram (one solution)



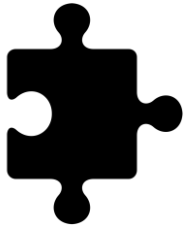
On your own

Exercise – Part 2

- Write SQL statements to create the corresponding relations, and to capture as many of the constraints as possible.



SQL DDL – One solution



```
CREATE TABLE Employees (
ssn INTEGER,
salary REAL,
phone CHAR(10),
PRIMARY KEY(ssn))
```

```
CREATE TABLE Works (
ssn INTEGER,
dno INTEGER,
PRIMARY KEY (ssn, dno),
FOREIGN KEY (ssn)
   REFERENCES employees,
FOREIGN KEY (dno)
   REFERENCES departments)
```

```
CREATE TABLE Departments (
dno INTEGER,
dname CHAR(20),
budget real,
manager INTEGER NOT NULL,
PRIMARY KEY (dno),
FOREIGN KEY (manager)
      REFERENCES employees)
```

```
CREATE TABLE Children (
name CHAR(20),
age REAL,
parent INTEGER NOT NULL,
PRIMARY KEY(name, parent),
FOREIGN KEY(parent)
   REFERENCES employees
   ON DELETE CASCADE)
```

Integrity Constraints

- Describe conditions that must be satisfied by every legal instance
- Types of integrity constraints
  - Domain constraints
  - Primary key constraints
  - Foreign key constraints
  - General constraints

Table Constraints (5.7 in book)

- More general than key constraints
- Can use a query to express constraint
  - Constraints checked each time table updated
  - CHECK constraint always true for empty relation

```
CREATE TABLE   Sailors
     (  sid      INTEGER,
        sname    CHAR(10),
        rating   INTEGER,
        age      REAL,
        PRIMARY KEY  (sid),
        CHECK   ( rating >= 1
                AND rating <= 10)
      );
```

Try it out in sqlplus or sqlite

```
CREATE TABLE Sailors
    ( sid      INTEGER,
      sname    CHAR(10),
      rating   INTEGER,
      age      REAL,
      PRIMARY KEY  (sid),
      CHECK (rating >= 1 AND rating <= 10));

INSERT INTO Sailors VALUES (1, 's1', 11, 25);
```

Do you get a constraint violation error?

Try it out in sqlplus or sqlite

```
CREATE TABLE Sailors
     ( sid      INTEGER,
       sname    CHAR(10),
       rating   INTEGER,
       age      REAL,
       PRIMARY KEY  (sid),
       CHECK (rating >= 1 AND rating <= 10));

INSERT INTO Sailors VALUES (1, 's1', 11, 25);
```

Do you get a constraint violation error?

```
> Error: CHECK constraint failed: Sailors
```

More general CHECK

- Interlake boats cannot be reserved.
- Note: these are not supported in Oracle or SQLite

```
CREATE TABLE  Reserves
   ( sname  CHAR(10),
     bid    INTEGER,
     day    DATE,
     PRIMARY KEY (bid,day),
     CONSTRAINT  noInterlakeRes
     CHECK  ('Interlake' NOT IN
               ( SELECT  B.bname
                 FROM  Boats B
                 WHERE  B.bid=bid)))
```

Constraints Over Multiple Relations

- For general constraint over multiple tables, use an assertion
- Number of boats plus number of sailors is < 100

```
CREATE ASSERTION smallClub
CHECK
((SELECT COUNT (S.sid) FROM Sailors S) +
  (SELECT COUNT (B.bid) FROM Boats B) < 100)
```

Practical Considerations

- CHECK with subqueries and ASSERTIONS
  - Part of SQL standard (since 1992?)
  - But, they are not supported in many major databases
  - **Main concern**: Performance issues; CHECK or ASSERTION constraints over multiple are very slow
- Instead: Triggers
  - Most major database systems require them
  - Triggers are procedural

Active Databases & Triggers (5.8 in the book)

Trigger: Procedure that starts automatically if specified changes occur to the DBMS

- Three parts:
  - Event (activates the trigger)
  - Condition (test that is run when the trigger is activated)
  - Action (what happens if the trigger runs)
    - Before and After Triggers
- Trigger Execution
  - Row-level Triggers: Once per modified row
  - Statement-level Triggers: Once per SQL statement

Oracle Trigger Example

- First trigger executed before the activating statement, second executes after the activating statement.
- In combination with:
  - `FOR EACH ROW` - execute once per modified record
  - (default) - execute once per activating statement
- Activating statements:
  - `INSERT`
  - `DELETE`
  - `UPDATE`

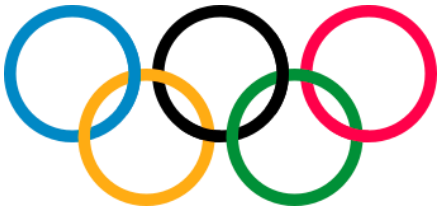
```
CREATE TRIGGER init_count
BEFORE INSERT ON Student          /* Event */
    DECLARE
          count INTEGER;
                        BEGIN
    /* Action */
          count := 0
    END;


CREATE TRIGGER incr_count
AFTER INSERT ON Student           /* Event */
    FOR EACH ROW
    WHEN (new.age >= 18)          /* Condition
    */
    BEGIN                         /* Action */
          count := count + 1;
    END;
```

Recall CASCADE constraints

```
CREATE TABLE Athlete
(aid INTEGER PRIMARY KEY,
 name CHAR(30),
 country CHAR(20),
 sport CHAR(20));
```

```
CREATE TABLE Olympics
(oid INTEGER PRIMARY KEY,
 year INTEGER,
 city CHAR(20));
```



```
CREATE TABLE Compete
    (aid INTEGER,
     oid INTEGER,
     PRIMARY KEY  (aid, oid),
     FOREIGN KEY (aid) REFERENCES Athlete
        ON DELETE CASCADE
     FOREIGN KEY (oid) REFERENCES Olympics
     );
```

CASCADE Using Triggers

```
CREATE TABLE Compete
    (aid INTEGER,
     oid INTEGER,
     PRIMARY KEY  (aid, oid),
     FOREIGN KEY (aid) REFERENCES Athlete
     FOREIGN KEY (oid) REFERENCES Olympics);

CREATE OR REPLACE TRIGGER cascade_on_delete
AFTER  DELETE ON Athlete
FOR EACH ROW
BEGIN
  DELETE FROM Compete
  WHERE Compete.aid = :OLD.aid;
END;
```

Trying out triggers

- Try out the file athlete_trigger_cascade.sql in sqlplus
- Also try it out in sqlite to see if it supports triggers the same way
- Try removing a row from athlete. Does it cascade to Compete via the trigger?
- Try dropping the trigger:
  - `DROP TRIGGER triggername;`
- What happens now on deleting a row from Athlete?

Triggers: Pitfalls and Pain

- Triggers can be recursive!
  - Chain of triggers can be hard to predict, which makes triggers difficult to understand and debug
- Errors with "mutating" table
  - A table that is currently being modified by an UPDATE, DELETE, or INSERT statement, or a table that might be updated by the effects of a DELETE CASCADE constraint
  - The session that issued the triggering statement cannot query or modify a mutating table
  - Used to prevent a trigger from seeing **inconsistent data**