Relational Databases

BORROWED WITH MINOR ADAPTATION FROM
PROF. CHRISTOS FALOUTSOS, CMU 15-415/615

Roadmap

- Introduction
- Integrity constraints (IC)
- Enforcing IC
- Querying Relational Data
- ER to tables
- Intro to Views
- Destroying/altering tables

Why Study the Relational, a.k.a. "SQL" Model?

- Most widely used model.
  - Vendors: IBM/Informix, Microsoft, Oracle, Sybase, etc.
- "Legacy systems" in older models
  - e.g., IBM's IMS
- Object-oriented concepts have merged in
  - *object-relational model*
    - Informix->IBM DB2, Oracle
- Essentially for up to millions of records (Beyond that, think NoSQL)

Relational Database: Definitions

- *Relational database*: a set of *relations*
- (relation = table)
- specifically

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

Relational Database: Definitions

- *Relation:* made up of 2 parts:
  - *Schema* : specifies name of relation, plus name and type of each column.
  - *Instance* : a *table,* with rows and columns.
    - #rows = *cardinality*
    - #fields = *degree / arity*

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

Relational Database: Definitions

- relation: a *set* of rows or *tuples*.
  - all rows are distinct
  - no order among rows (why?)

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

Ex: Instance of Students Relation

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

- Cardinality = 3, arity = 5 ,
- all rows distinct
- Q: do values in a column need to be distinct?

SQL - A language for Relational DBs

- SQL* (a.k.a. "Sequel"), standard language
- Data Definition Language (DDL)
  - create, modify, delete relations
  - specify constraints
  - administer users, security, etc.
  - E.g.:

```
create table student
        (ssn fixed, name char(20));
```

* Structured Query Language

SQL - A language for Relational DBs

- Data Manipulation Language (DML)
  - Specify *queries* to find tuples that satisfy criteria
  - add, modify, remove tuples

```
select * from student ;

update takes set grade=4
    where name='smith'
    and cid = 'db';
```

SQL Overview

- CREATE TABLE <name> (<field> <domain>, …)
- INSERT INTO <name> (<field names>)
  VALUES (<field values>)
- DELETE FROM <name>
  WHERE <condition>

SQL Overview

- UPDATE <name>
  SET <field name> = <value>
  WHERE <condition>
- SELECT <fields>
  FROM <name>
  WHERE <condition>

Creating Relations in SQL

- Creates the Students relation.

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

Creating Relations in SQL

- Creates the Students relation.
  - Note: the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.

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

Table Creation (continued)

- Another example:

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

Adding and Deleting Tuples

- Can insert a single tuple using:

```
INSERT INTO Students
(sid, name, login, age, gpa)
 VALUES
('53688', 'Smith', 'smith@cs',
18, 3.2)
```

Adding and Deleting Tuples

- ‘mass’ -delete (**all** Smiths!) :

```
DELETE
   FROM Students S
  WHERE S.name = ‘Smith’
```

Roadmap

- Introduction
- Integrity constraints (IC)
- Enforcing IC
- Querying Relational Data
- ER to tables
- Intro to Views
- Destroying/altering tables

Keys

- Keys help 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

(Motivation:)

- In flat files, how would you check for duplicate ssn, in a student file?
- (horror stories, if ssn is duplicate?)

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

Keys

- Keys help 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

FOREIGN Key

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

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 :
  - minimal superkey

```
Student (ssn, name, address)
```

{ssn,name}: superkey
{ssn}: superkey, AND key
{name}: not superkey

Primary Keys

- what if >1 key for a relation?

Primary Keys

- what if >1 key for a relation?
  - one of the keys is chosen (by DBA) to be the ***primary key***. Other keys are called ***candidate*** keys..
  - Q: example of >1 superkeys?

Primary Keys

- what if >1 key for a relation?
  - one of the keys is chosen (by DBA) to be the ***primary key***. Other keys are called ***candidate*** keys..
  - Q: example of >1 superkeys?
  - A1: student: {ssn}, {student-id#},
    {driving license#, state}
  - A2: Employee: {ssn}, {phone#}, {room#}
  - A3: computer: {mac-address}, {serial#}

Primary Keys

- E.g.
  - *sid* is a key for Students.
  - What about *name*?
  - The set {*sid, gpa*} is a superkey.

Syntax:

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

Syntax:


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

PRIMARY KEY == UNIQUE, NOT NULL

Drill:


```
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))
```

Drill:


```
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))
```

Q: what does this mean?

Primary and Candidate Keys in SQL


```
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

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 Keys, Referential Integrity

- *Foreign key*: Set of fields `refering' to a tuple in another relation.
  - Must correspond to the primary key of the other relation.
  - Like a `logical pointer'.
- foreign key constraints enforce *referential integrity* (i.e., no dangling references.)

Foreign Keys in SQL

Example: Only existing students may enroll for courses.

- *sid* is a foreign key referring to 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

Foreign Keys in SQL


```
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

Roadmap

- Introduction
- Integrity constraints (IC)
- Enforcing IC
- Querying Relational Data
- ER to tables
- Intro to Views
- Destroying/altering tables

Enforcing Referential Integrity

- Subtle issues:
- What should be done if an Enrolled tuple with a non-existent student id is inserted?

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

- Subtle issues:
- What should be done if an Enrolled tuple with a non-existent student id is inserted? *(Reject it!)*

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

- Subtle issues, cont'd:
- What should be done if a Student's tuple is deleted?

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

- Subtle issues, cont'd:
- 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'*.)

Enforcing Referential Integrity

- 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.

Integrity Constraints (ICs)

- A *legal* instance of a relation: satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- we prefer that ICs are enforced by DBMS (as opposed to ?)
  - Blocks data entry errors, too!

Where do ICs Come From?

Where do ICs Come From?

- the application!

Where do ICs Come From?

- Subtle point: We can check a database instance to see if an IC is violated, but we can NEVER infer that an IC is true by looking at an instance.
  - An IC is a statement about *all possible* instances!
  - Eg., *name* is not a key,
  - but the assertion that *sid* is a key is given to us.

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

Where do ICs Come From?

- Key and foreign key ICs are the most common; more general ICs supported too.

Roadmap

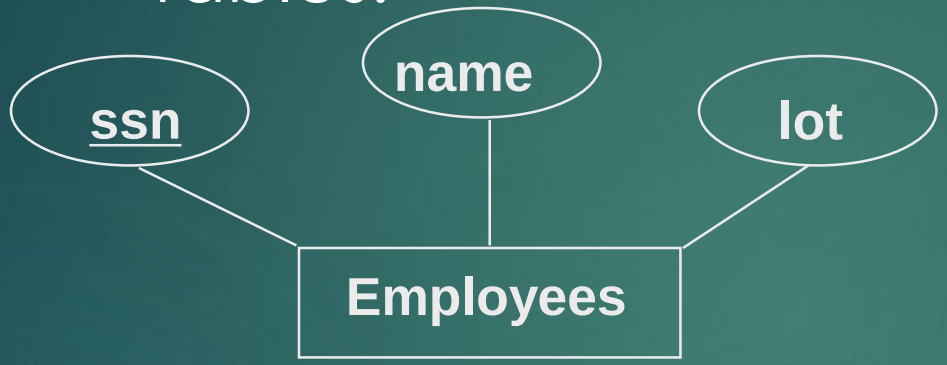
- Introduction
- Integrity constraints (IC)
- Enforcing IC
- Querying Relational Data
- ER to tables
- Intro to Views
- Destroying/altering tables

ER to tables outline:

- strong entities
- weak entities
- (binary) relationships
  - 1-to-1, 1-to-many, etc
  - total/partial participation
- ternary relationships
- ISA-hierarchies
- aggregation

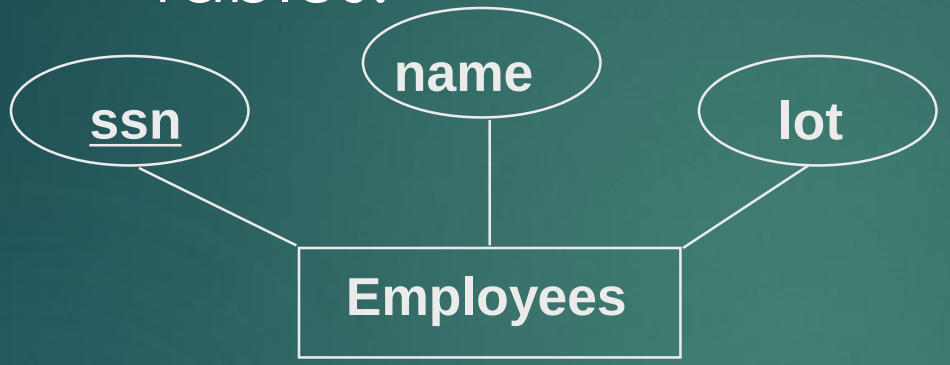
Logical DB Design: ER to Relational

- (strong) entity sets to tables.



Logical DB Design: ER to Relational

- (strong) entity sets to tables.

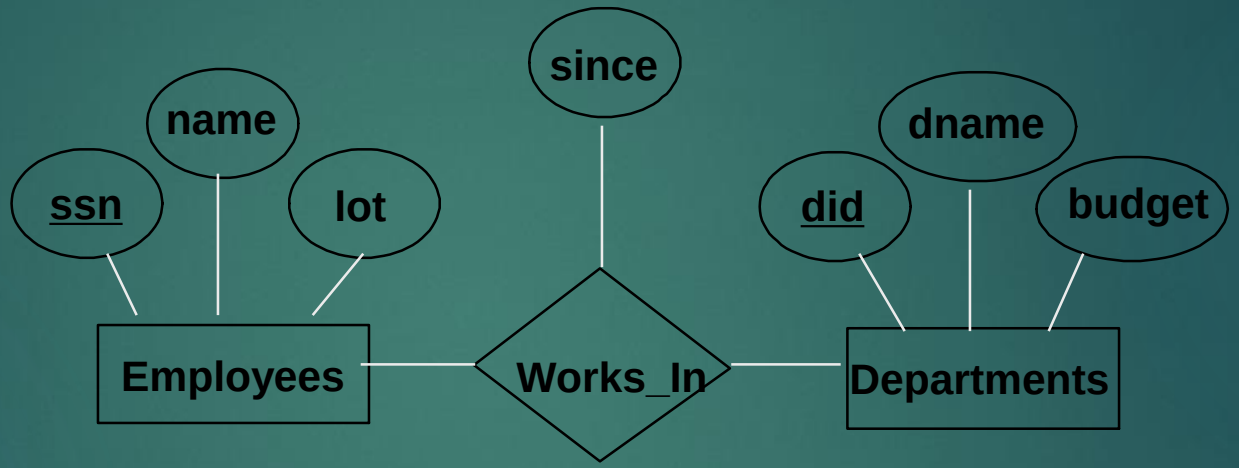


Ssn	Name	Lot
123-22-6666	Attishoo	48
233-31-5363	Smiley	22
131-24-3650	Smethurst	35

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

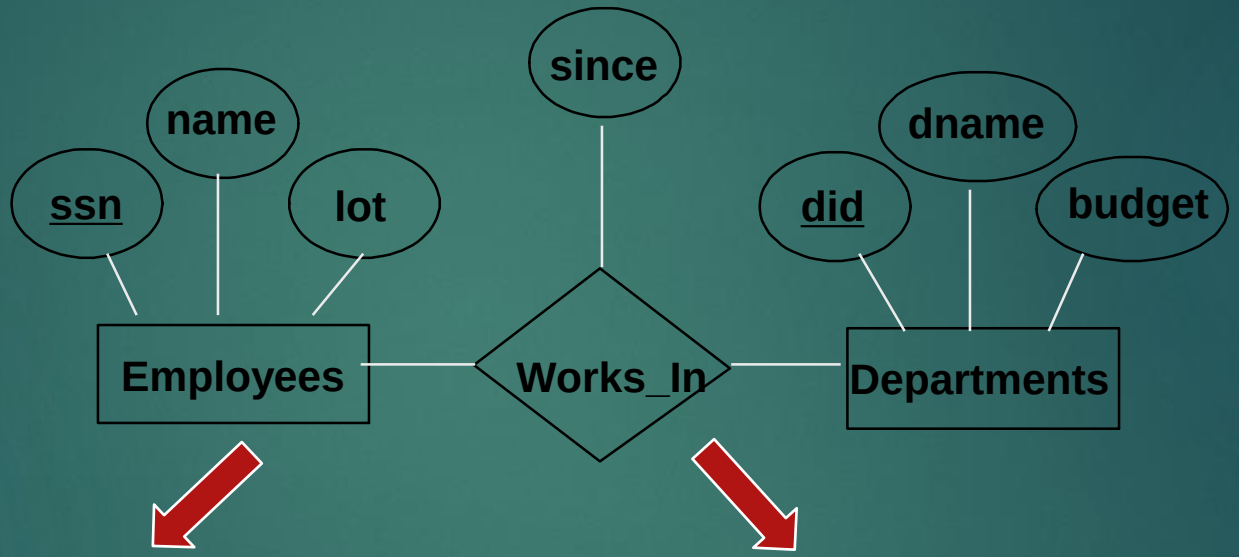
Relationship Sets to Tables

Many-to-many:



Relationship Sets to Tables

Many-to-many:



Ssn	Name	Lot
123-22-6666	Attishoo	48
233-31-5363	Smiley	22
131-24-3650	Smethurst	35

Ssn	did	since
123-22-6666	51	1/1/91
123-22-6666	56	3/3/93
233-31-5363	51	2/2/92

Relationship Sets to Tables

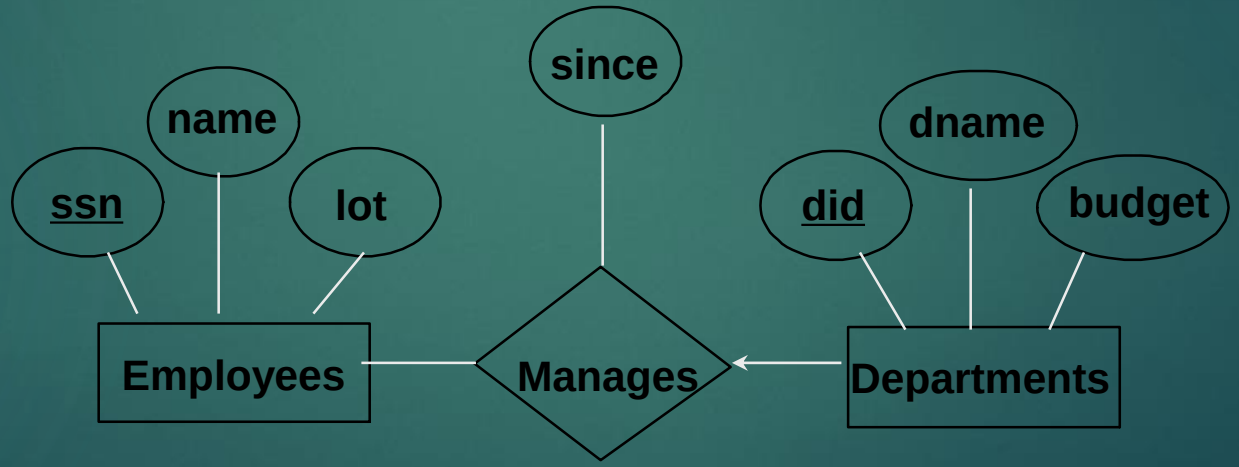
- key of many-to-many relationships:
  - Keys from participating entity sets (as foreign keys).

```
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)
```

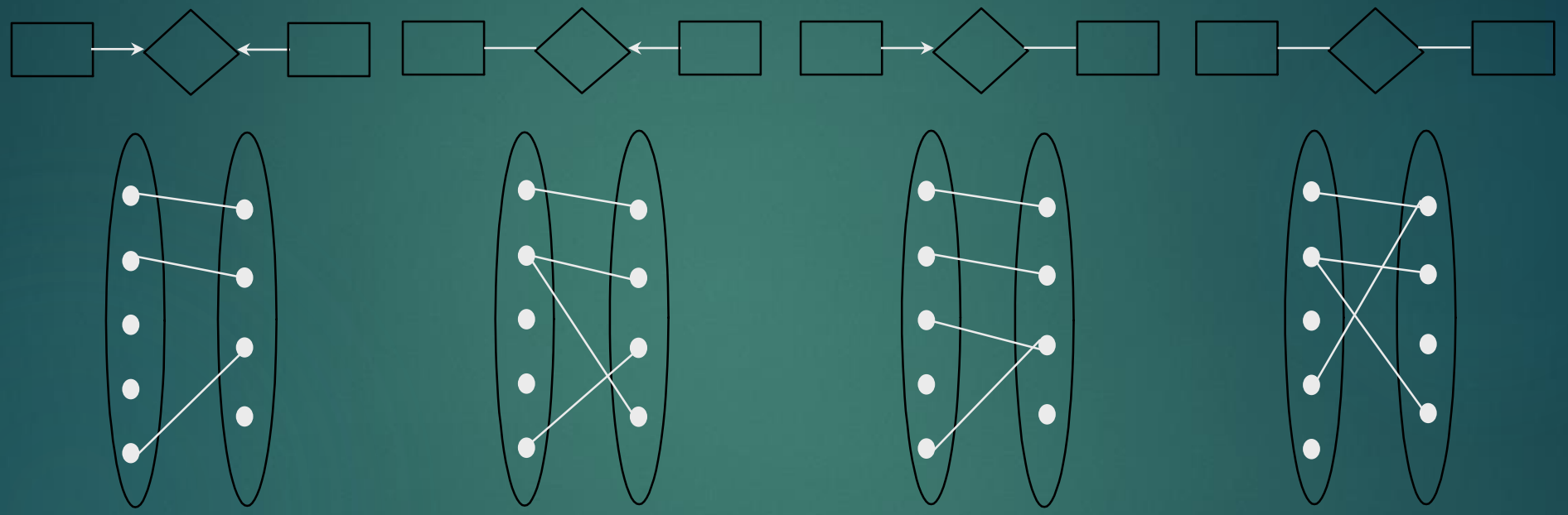
Ssn	did	since
123-22-6666	51	1/1/91
123-22-6666	56	3/3/93
233-31-5363	51	2/2/92

Review: Key Constraints in ER

- 1-to-many:



(Reminder: Key Constraints in ER)

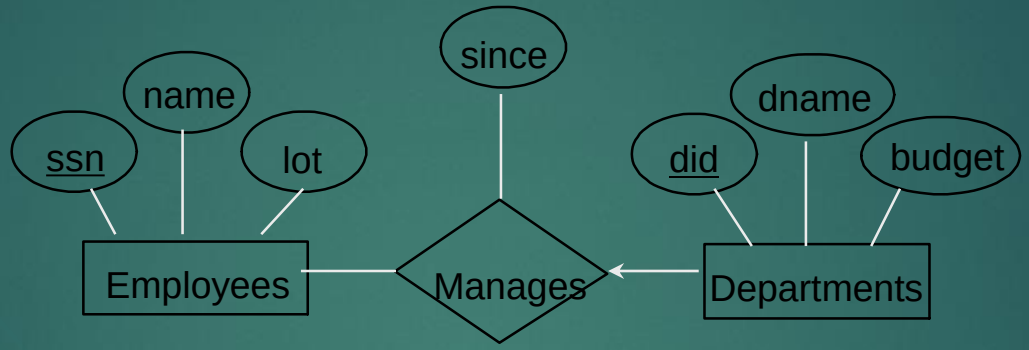


1-to-1 | 1-to Many | Many-to-1 | Many-to-Many

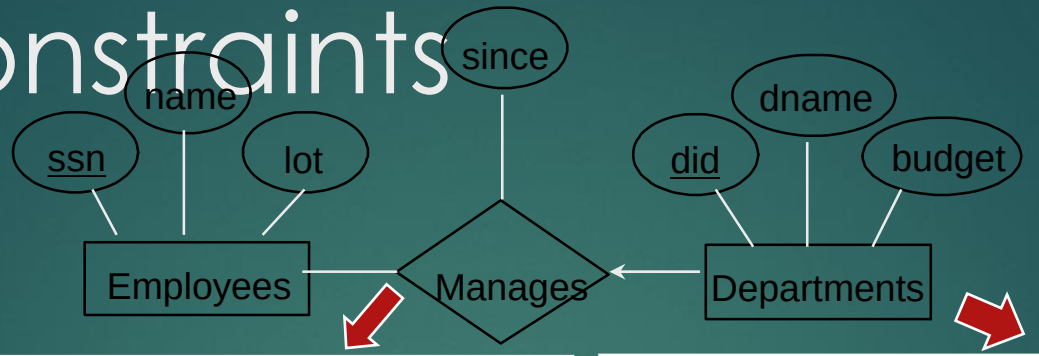
ER to tables - summary of basics

- strong entities:
  - key -> primary key
- (binary) relationships:
  - get keys from all participating entities - pr. key:
  - 1-to-1 -> either key (other: ‘cand. key’)
  - 1-to-N -> the key of the ‘N’ part
  - M-to-N -> both keys

A subtle point (1-to-many)



Translating ER with Key Constraints



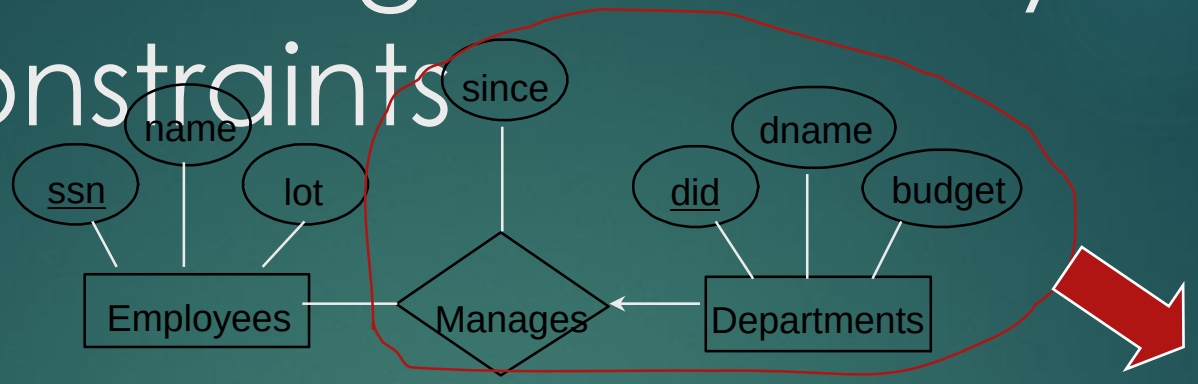

```
CREATE TABLE  Manages(
  ssn      CHAR(11),
  did      INTEGER,
  since    DATE,


  PRIMARY KEY  (did),
  FOREIGN KEY (ssn)
REFERENCES Employees,
  FOREIGN KEY (did)
REFERENCES Departments)
```

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

Two-table-solution

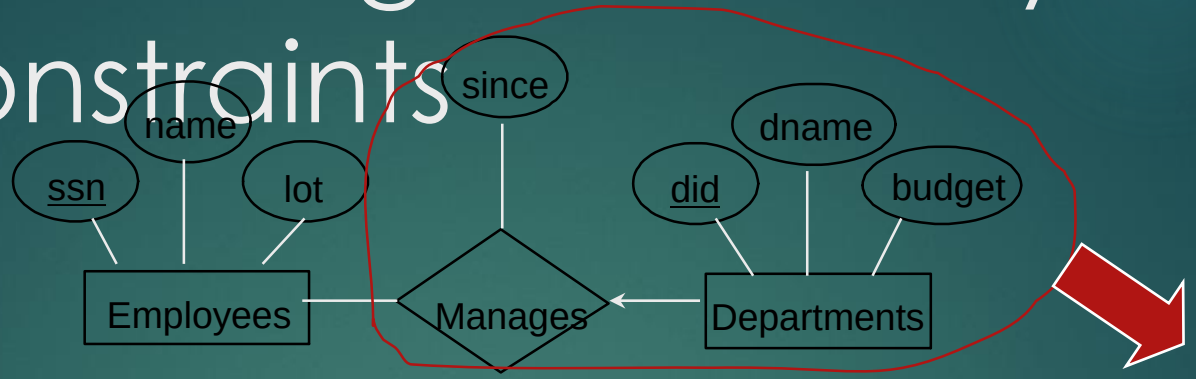
Translating ER with Key Constraints




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

Single-table-solution

Translating ER with Key Constraints




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

Pros and cons?

Drill:

What if the toy department has no manager (yet) ?

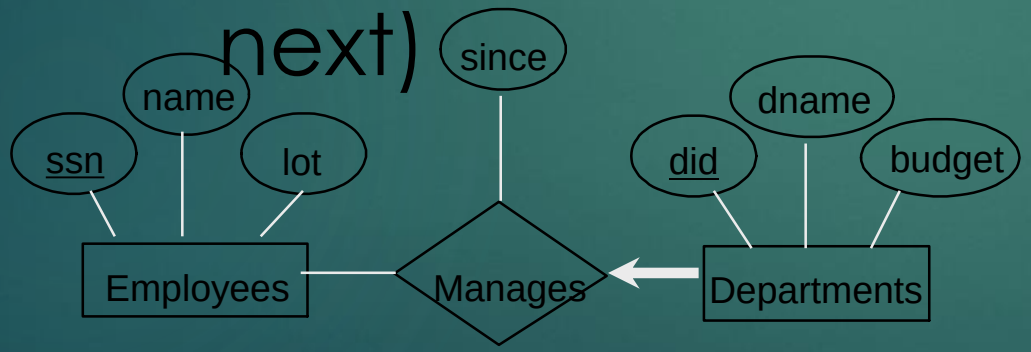
```
CREATE TABLE  Dept_Mgr(
 did     INTEGER,
 dname   CHAR(20),
 budget  REAL,
 ssn     CHAR(11),
 since   DATE,
 PRIMARY KEY  (did),
 FOREIGN KEY (ssn)
  REFERENCES Employees)
```

Drill:

What if the toy department has no manager (yet) ?

A: one-table solution can not handle that.

(ie., helps enforce 'thick arrow' see next)

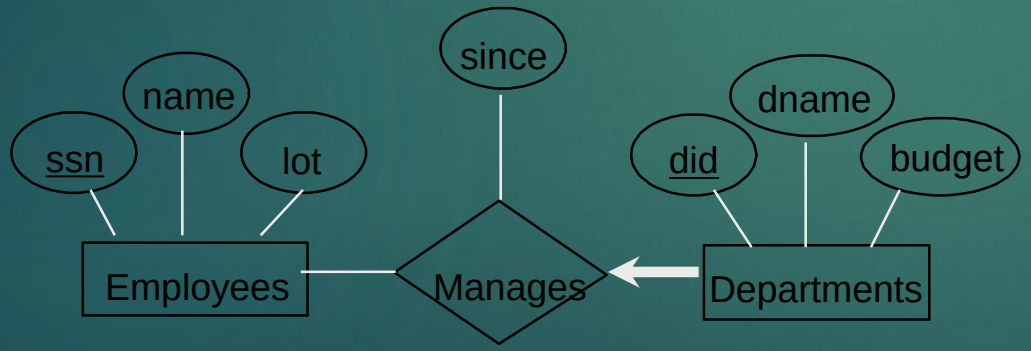



```
CREATE TABLE Dept_Mgr(
 did     INTEGER,
 dname   CHAR(20),
 budget  REAL,
 ssn     CHAR(11),
 since   DATE,
 PRIMARY KEY  (did),
 FOREIGN KEY (ssn)
  REFERENCES Employees)
```

Rules:

- Thick arrow -> one-table solution
- Thin arrow -> two-table solution

(More rules: next)



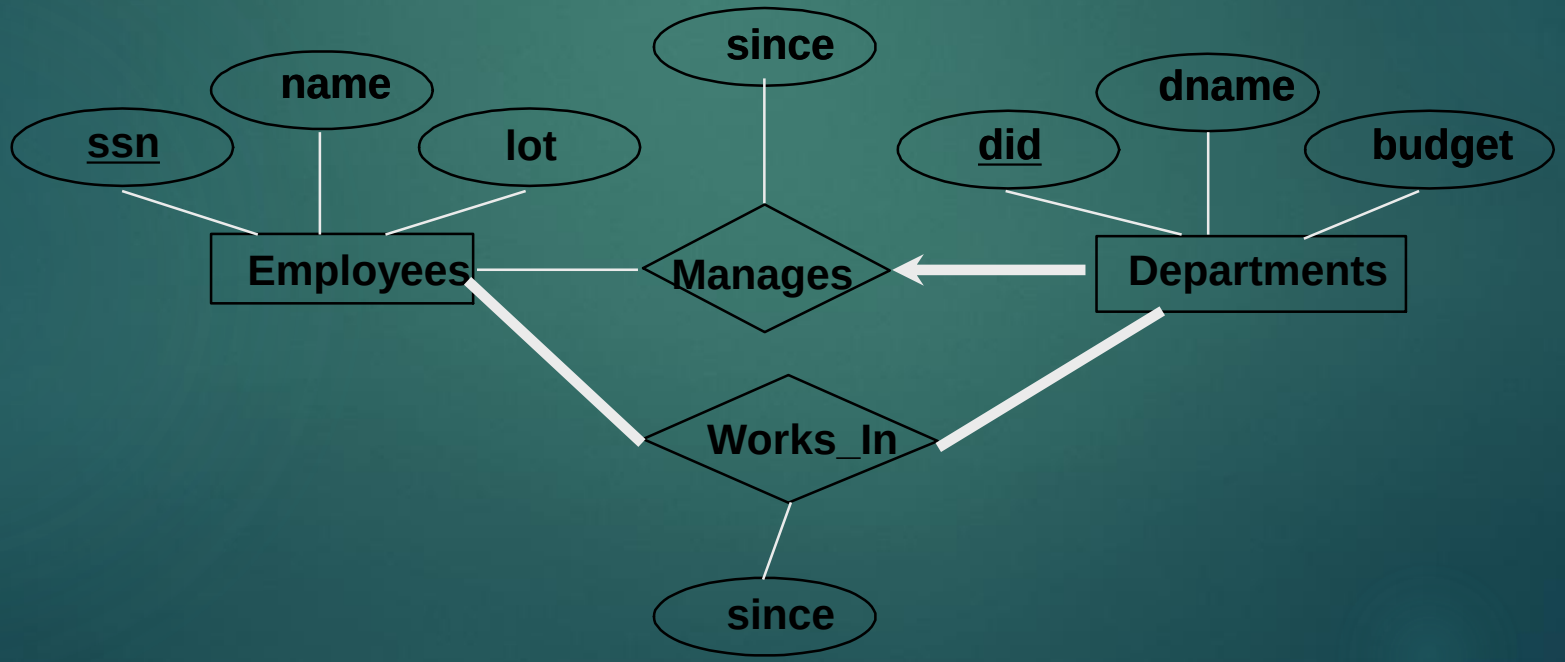

```
CREATE TABLE  Dept_Mgr(
 did     INTEGER,
 dname   CHAR(20),
 budget  REAL,
 ssn     CHAR(11),
 since   DATE,
 PRIMARY KEY  (did),
 FOREIGN KEY (ssn)
  REFERENCES Employees)
```

ER to tables outline:

- strong entities
- weak entities
- (binary) relationships
  - 1-to-1, 1-to-many, etc
  - total/partial participation
- ternary relationships
- ISA-hierarchies
- aggregation

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)
```

Participation Constraints in SQL

- Total participation ('no action' -> do NOT do the delete)
- Ie, a department MUST have a nanager

```
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)
```

Participation Constraints in SQL

- Partial partipation, ie, a department may be headless


```
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 SET NULL)
```

Participation Constraints in SQL

- Partial partipation, ie, a department may be headless
- OR (better): use the two-table solution

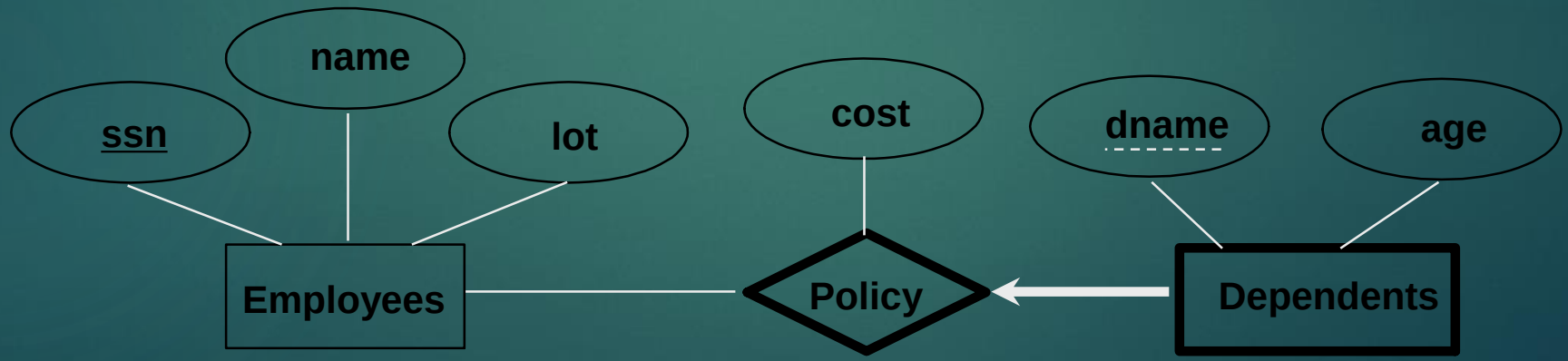
```
CREATE TABLE  Dept_Mgr(
    did     INTEGER,
    dname   CHAR(20),
    budget  REAL,
    ssn     CHAR(11) NOT NULL,
    since   DATE,
    PRIMARY KEY  (did),
    FOREIGN KEY  (ssn) REFERENCES Employees,
       ON DELETE SET NULL)
```

ER to tables outline:

- strong entities
- weak entities
- (binary) relationships
  - 1-to-1, 1-to-many, etc
  - total/partial participation
- ternary relationships
- ISA-hierarchies
- aggregation

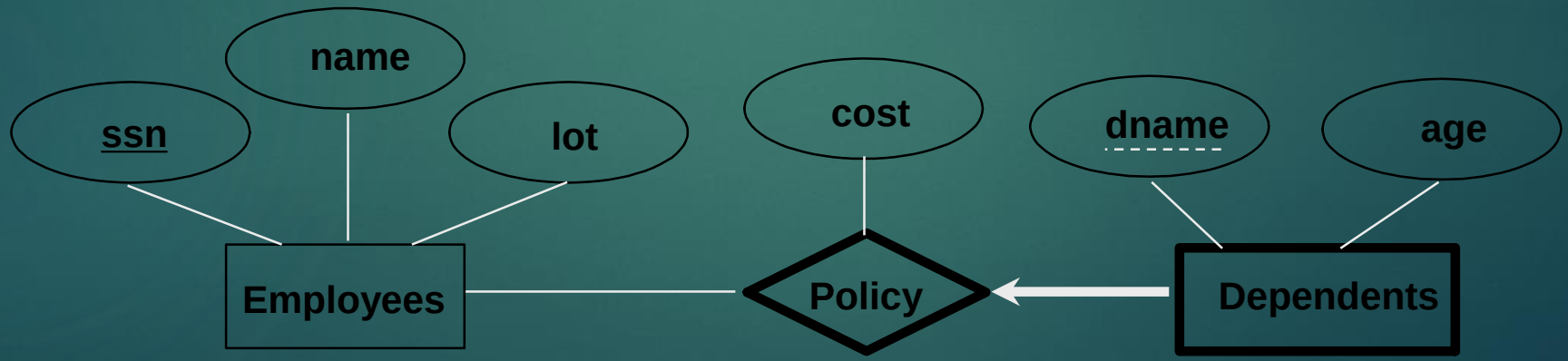
Review: Weak Entities

- 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.



Review: Weak Entities

How to turn ‘Dependents’ into a table?



Translating Weak Entity Sets

- Weak entity set and identifying relationship set are translated into a single table (== 'total participation')


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

Translating Weak Entity Sets

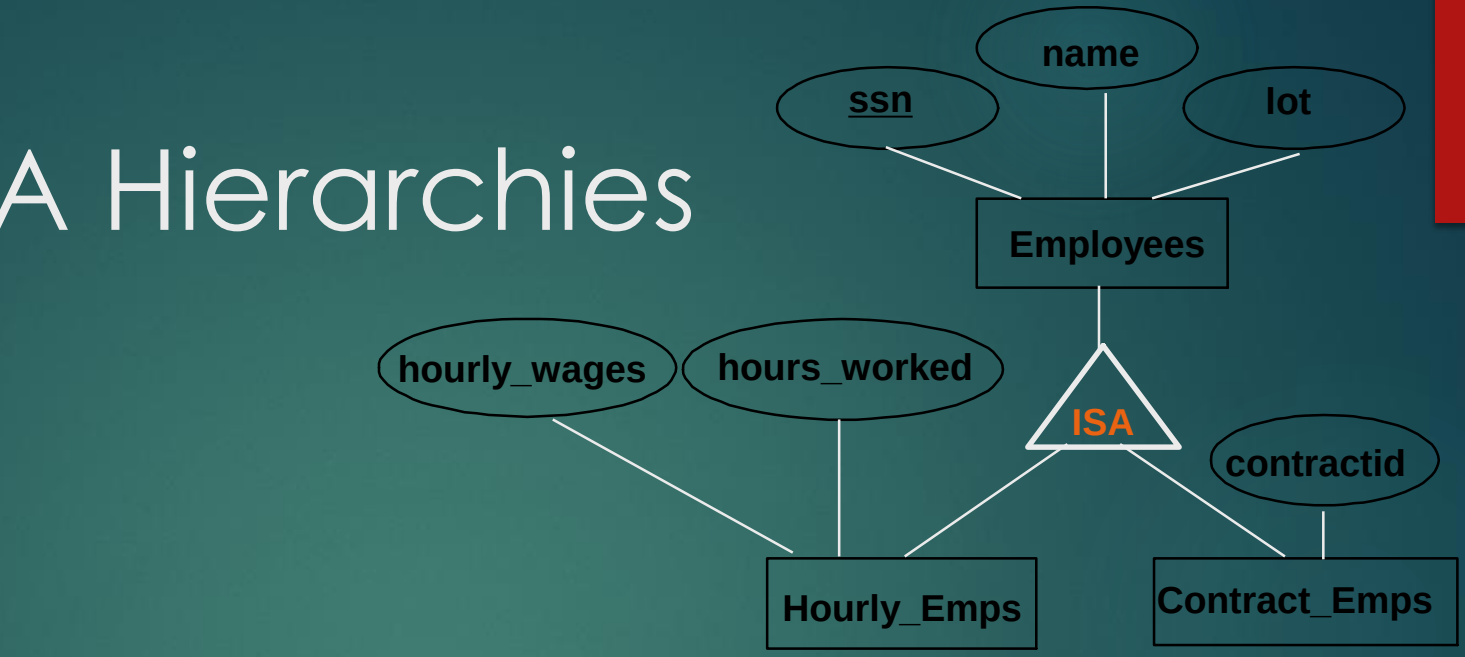
- Weak entity set and identifying relationship set are translated into a single table.
  - When the owner entity is deleted, all owned weak entities must also be deleted (-> 'CASCADE')


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

ER to tables outline:

- strong entities
- weak entities
- (binary) relationships
  - 1-to-1, 1-to-many, etc
  - total/partial participation
- ternary relationships
- ISA-hierarchies
- aggregation

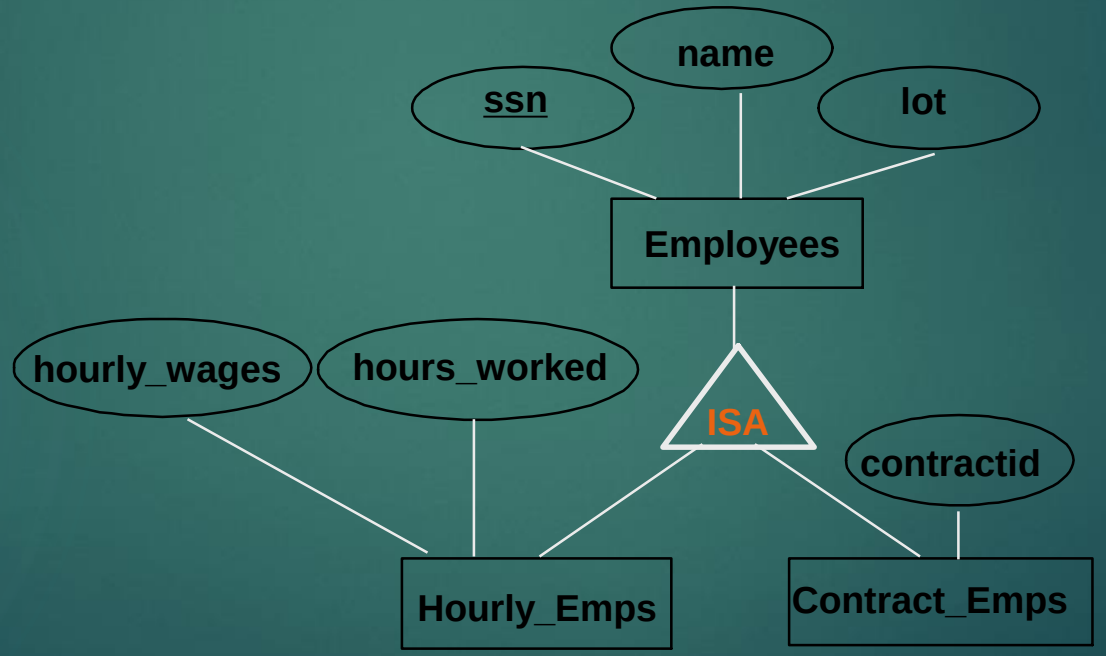
Review: ISA Hierarchies



- *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)*

Drill:

- What would you do?



Translating ISA Hierarchies to Relations

- General approach: 3 relations: Employees, Hourly_Emps and Contract_Emps.
  - how many times do we record an employee?
  - what to do on deletion?
  - how to retrieve all info about an employee?

EMP(ssn, name, dob)

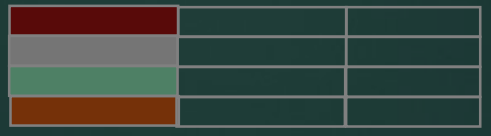
H_EMP(ssn, h_wg, h_wk)

CONTR(ssn, cid)

Translating ISA Hierarchies to Relations

- 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.

EMP (ssn, name, lot)

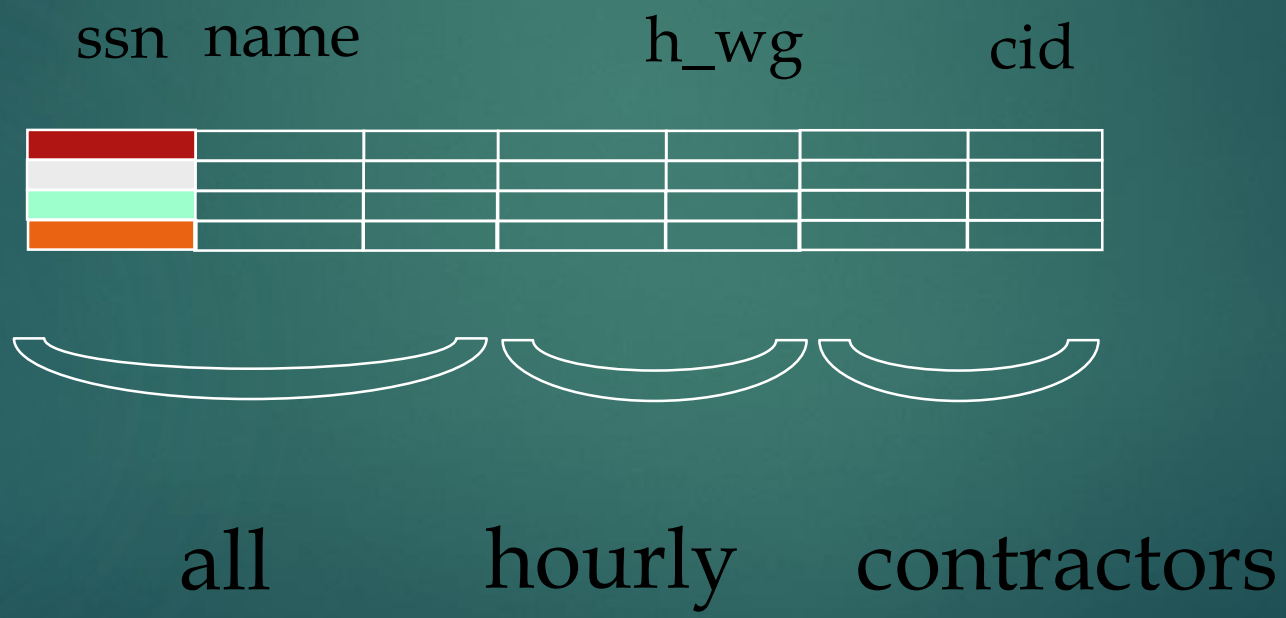


H_EMP(ssn, h_wg, h_wk, name, lot)

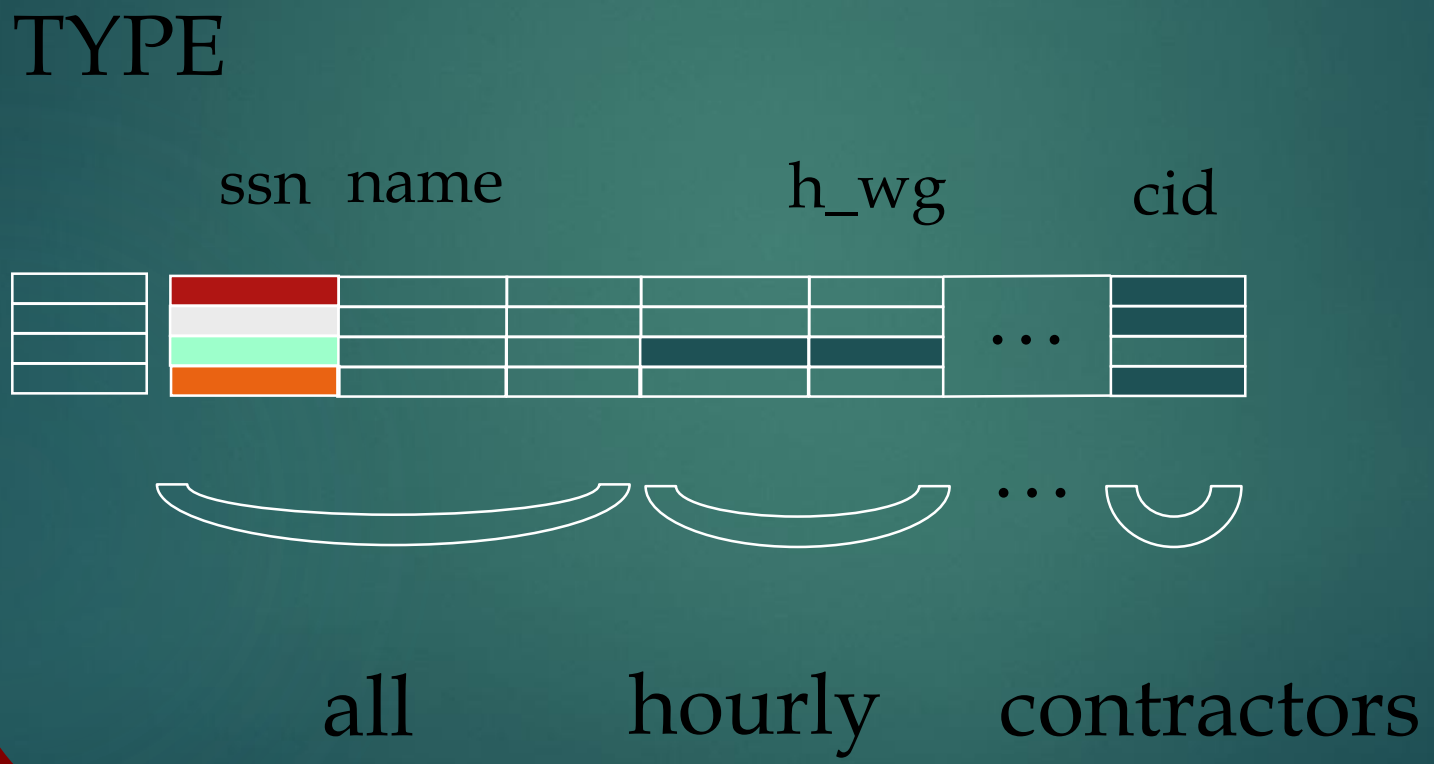
CONTR(ssn, cid, name, lot)

Notice: 'black' is gone!

Not in book – why NOT 1 table + nulls?



Not in book – why NOT 1 table + nulls?



ER to tables outline:

- strong entities
- weak entities
- (binary) relationships
  - 1-to-1, 1-to-many, etc
  - total/partial participation
- ternary relationships
- ISA-hierarchies
- aggregation

Ternary relationships; aggregation

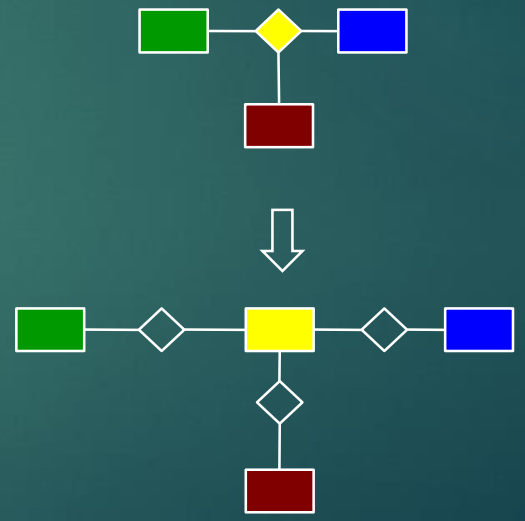
- rare
- keep keys of all participating entity sets

(or: avoid such situations:

break into 2-way relationships or

add an auto-generated key

)



Roadmap

- Introduction
- Integrity constraints (IC)
- Enforcing IC
- Querying Relational Data
- ER to tables
- Intro to Views
- Destroying/altering tables

Views

- Virtual tables

```
CREATE VIEW YoungActiveStudents(name,grade)
 AS SELECT S.name, E.grade
 FROM Students S, Enrolled E
 WHERE S.sid=E.sid and S.age<21
```

- DROP VIEW

Views and Security

- DBA: grants authorization to a view for a user
- user can only see the view - nothing else

Roadmap

- Introduction
- Integrity constraints (IC)
- Enforcing IC
- Querying Relational Data
- ER to tables
- Intro to Views
- Destroying/altering tables

Table changes

- DROP TABLE
- ALTER TABLE, e.g.

```
ALTER TABLE students
   ADD COLUMN maiden-name CHAR(10)
```

Relational Model: Summary

- A tabular representation of data.
- Simple and intuitive; widely used
- Integrity constraints can be specified by the DBA, based on customer specs. DBMS checks for violations.
  - Two important ICs: **primary** and **foreign** keys
  - also: not null, unique
  - In addition, we *always* have domain constraints.
- Mapping from ER to Relational is (fairly) straightforward:

ER to tables - summary of basics

- strong entities:
  - key -> primary key
- (binary) relationships:
  - get keys from all participating entities - pr. key:
  - 1:1 -> either key
  - 1:N -> the key of the ‘N’ part
  - M:N -> both keys
- weak entities:
  - strong key + partial key -> primary key
  - ..... ON DELETE CASCADE

ER to tables - summary of advanced

- total/partial participation:
  - NOT NULL; ON DELETE NO ACTION
- ternary relationships:
  - get keys from all; decide which one(s) -> prim. key
- aggregation: like relationships
- ISA:
  - 2 tables (‘total coverage’)
  - 3 tables (most general)