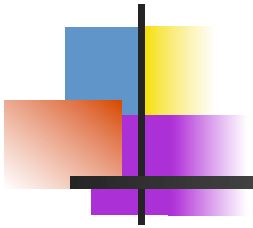


The Entity-Relationship Model

- Chapter 2

Last Time

Database Models

Determine how data can be stored, organized and manipulated in a database system

Common Models?

-
-
-
-
- . . .

Last Time

Database Models

Determine how data can be stored, organized and manipulated in a database system

Common Models:

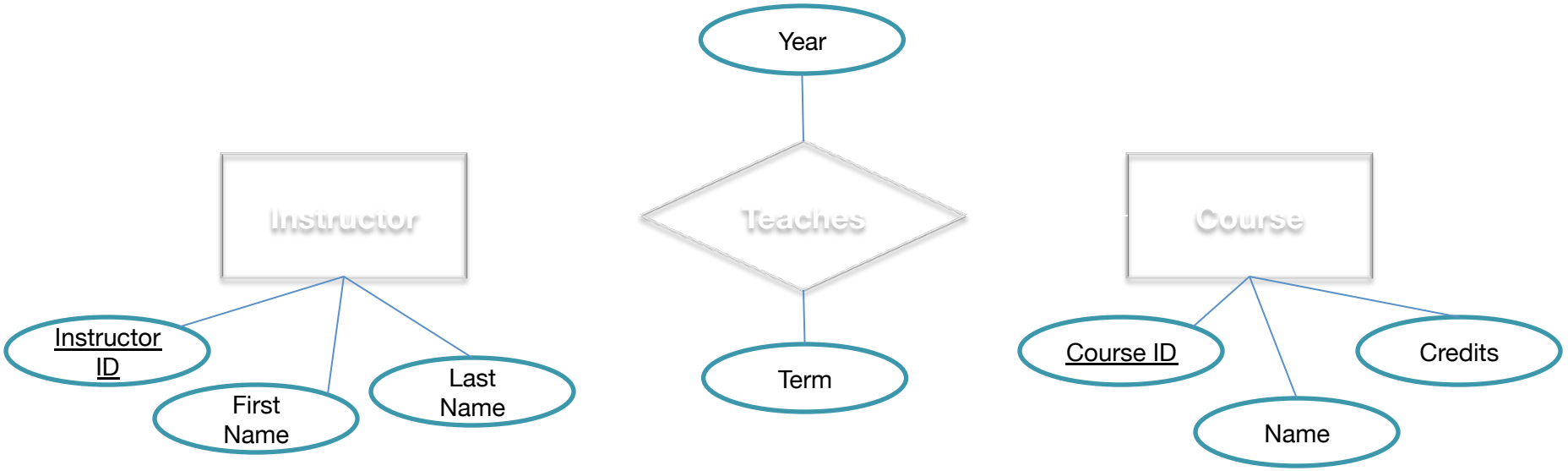
- **Entity Relationship Model** (useful for end-users)
- **Relational Model** (implemented in databases)
- Network Model
- Object Model
- . . .

TODAY

Entity-Relationship Model

entities

relationships



TODAY

We will cover:

- How to design a DB: High-level description of data to be stored
- ER modeling
  - Basic constructs (e.g. entities, relationships)
  - Additional constructs (e.g. hierarchies)
  - Integrity constraints : **capture subtle properties of the data**

Wedsday

Relational Database

- Entities and (most) relationships are translated into Tables

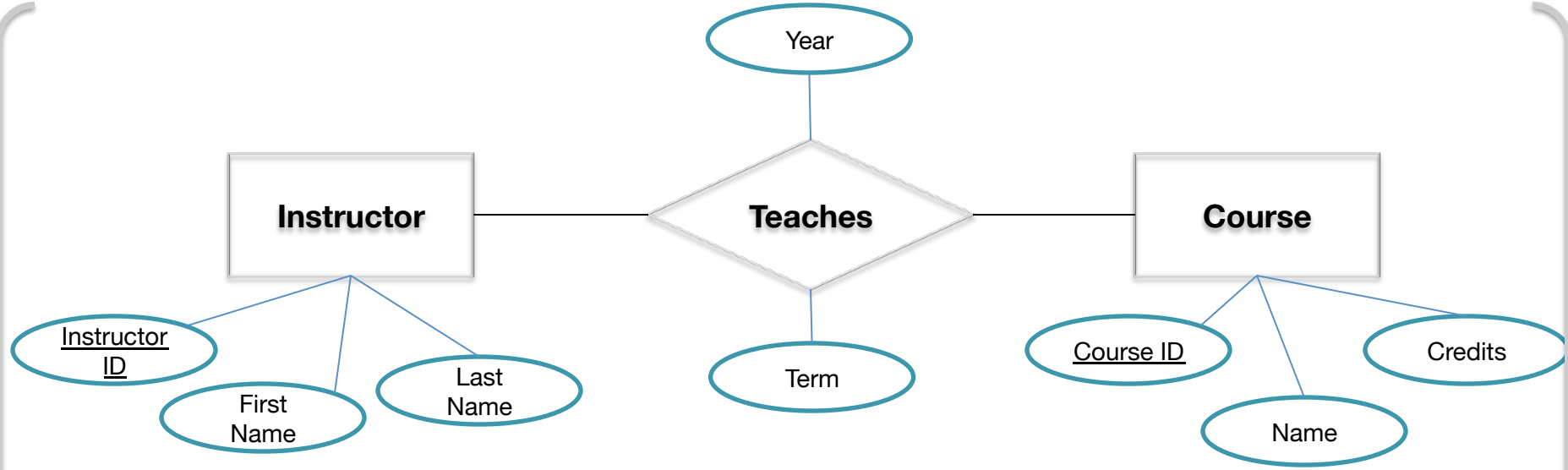
Columns (Fields) (Attributes)

Rows (Records) (Tuples)

Attribute 1	Attribute 2	Attribute 3
.....	.....	.....
.....	.....	.....
.....	.....	.....
.....	.....	.....
.....	.....	.....

Next Monday

Translation from ER Diagrams to Relations



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….	….	….	….
….	….	….	….

Course ID	Name	Credits
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E302	Algorithms	4
….	….	….
….	….	….

Database Design using ER modeling

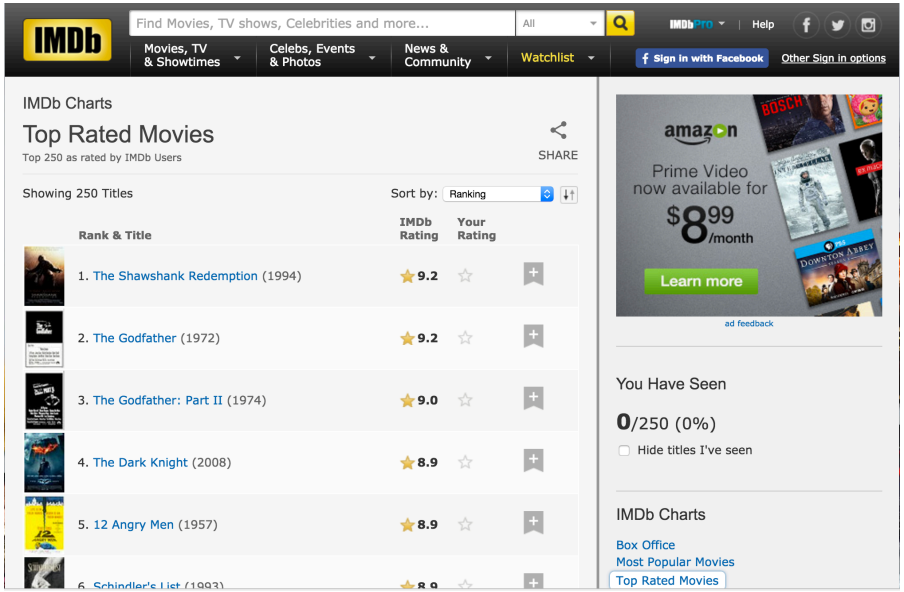
Database Design

- Our goal is to avoid the really bad mistakes and design clean and easily understood databases

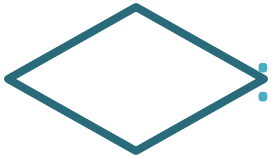
- Database design starts with a picture (E-R diagram)

Scenario 1

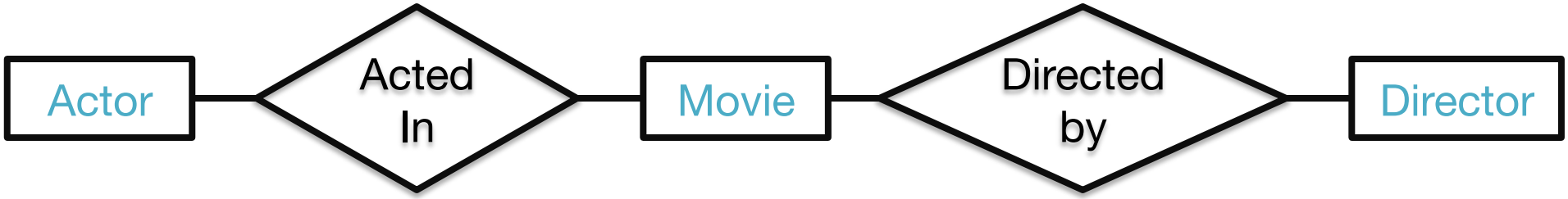
- Create IMDb (Internet Movie Database)
  - i.e., a database to store information about the movies, cast, directors, …



ER Diagram

-  Entities — ‘Actor’ and ‘Movie’
-  Relationships — ‘Acted In’
-  Attributes

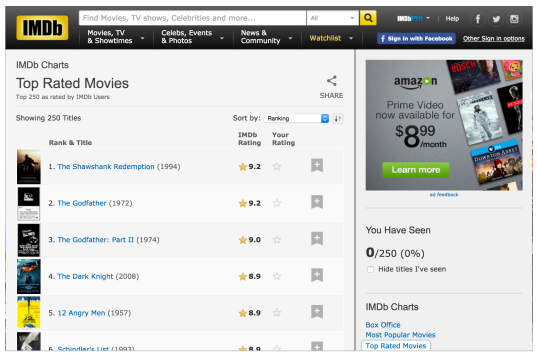
ER Diagram



- Actor *Acted In* Movie
- Movie *Directed by* Director

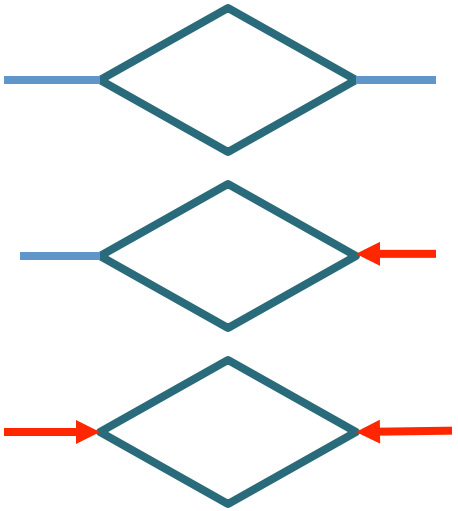
Scenario 1: Update

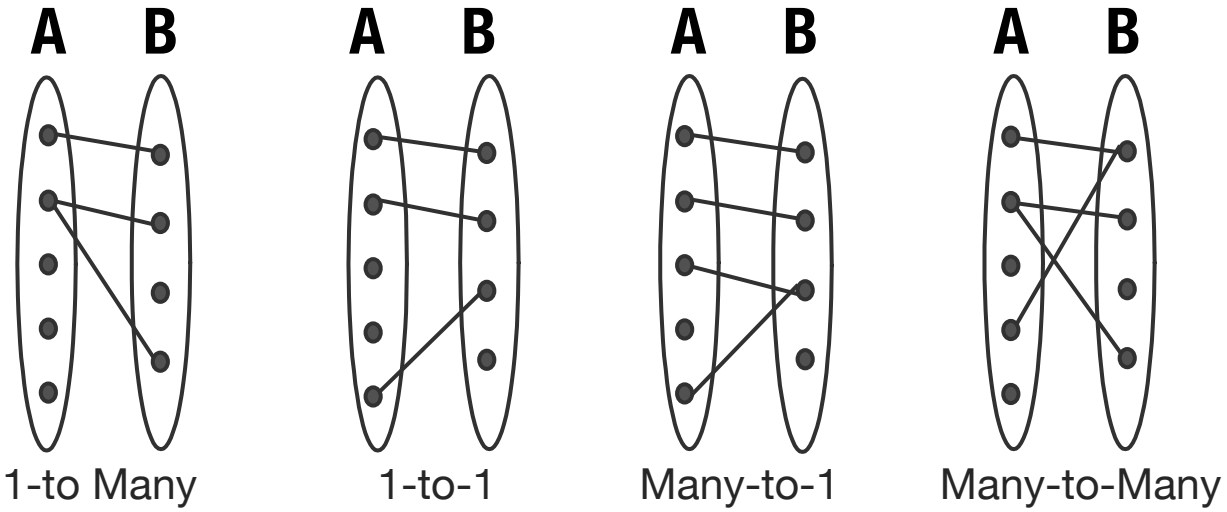
- Create IMDB (Internet Movie Database)
  - i.e., a database to store information about the movies, cast, directors, …
- Constraint (they ask you to impose it)
  - A movie can have AT MOST one director
  - A director can direct MULTIPLE movies



ER Diagram: Relationship Types

- Many-to-Many
- One-to-Many (or Many-to-One)
- One-to-One





Scenario 1: Update

- Create IMDB (Internet Movie Database)
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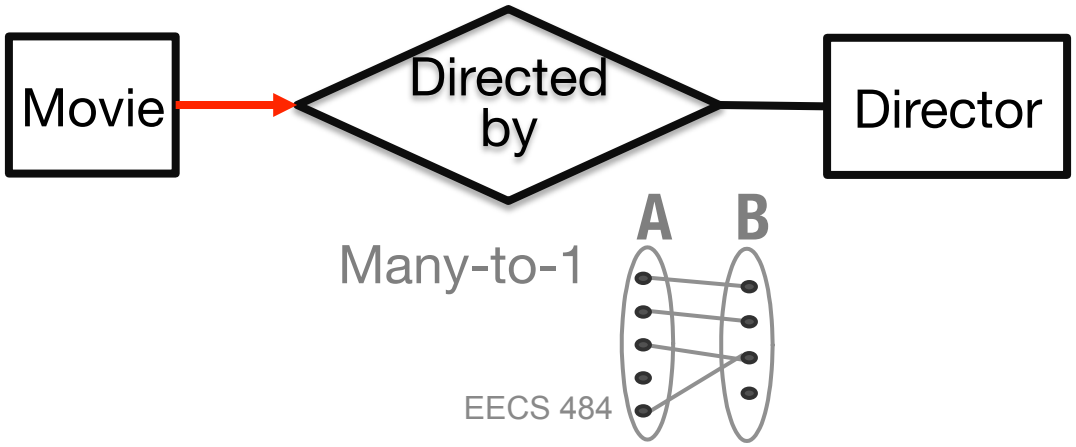
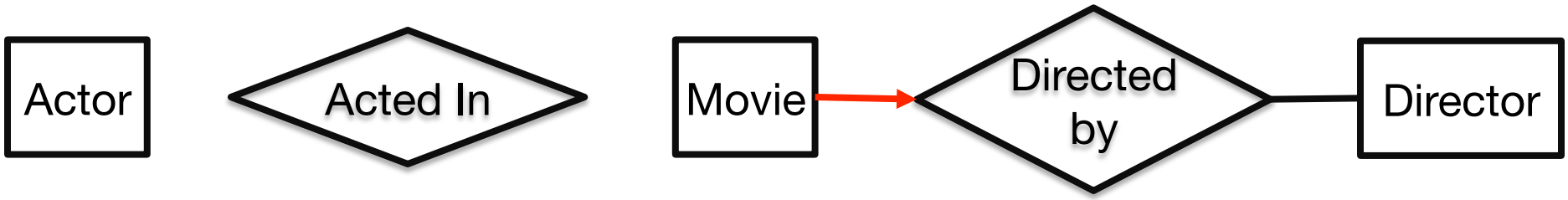


Types of relationships?

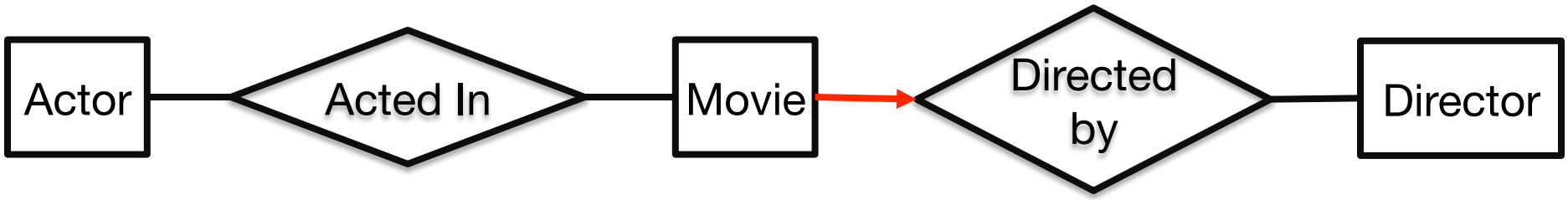
- Acted In:
  - An actor can act in multiple movies and a movie can have multiple actors
- Directed by: Many-to-1
  - **Arrow**: indicates **Key Constraint** on directed-by relationship: a movie in the relationship must be unique (= a movie can map to **at most** one director).



Types of relationships?

IMDb

- Acted In: Many-to-Many
  - An actor can act in multiple movies and a movie can have multiple actors
- Directed by: Many-to-1
  - **Arrow**: indicates **Key Constraint** on directed-by relationship: a movie in the relationship must be unique (= a movie can map to **at most** one director).

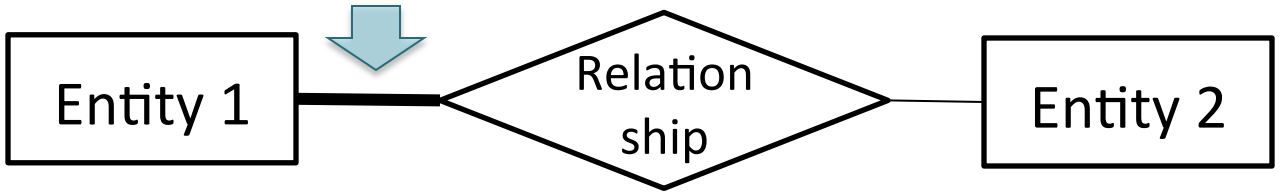


Scenario 1: Update (2)

- Create IMDB (Internet Movie Database)
  - i.e., a database to store information about the movies, cast, directors, …
- Constraint 1 (they ask you to impose it)
  - A movie can have AT MOST one director
  - A director can direct MULTIPLE movies
- Constraint 2
  - Every Movie entity must participate in a relationship with an Actor
    - i.e., every movie must have ***at least*** one actor

Participation constraints

- **Heavy** line

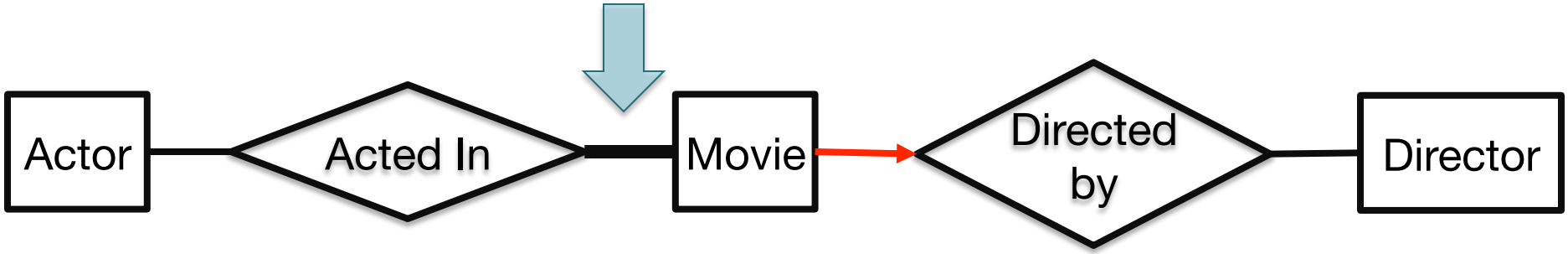


  - Every Entity-1 entity **must participate** in a relationship with an Entity-2 entity.

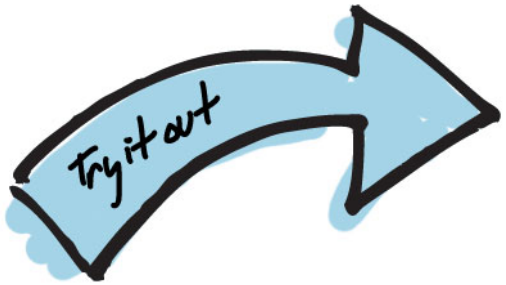
- Light line
  - An Entity-2 can be related to ≥ 0 Entity-1 entities.

Final ER diagram

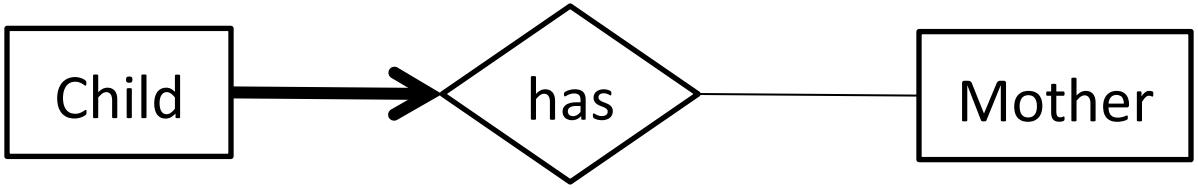
- Participation Constraint
  - Every Movie entity must participate in a relationship with an Actor
    - i.e., every movie must have ***at least*** one actor



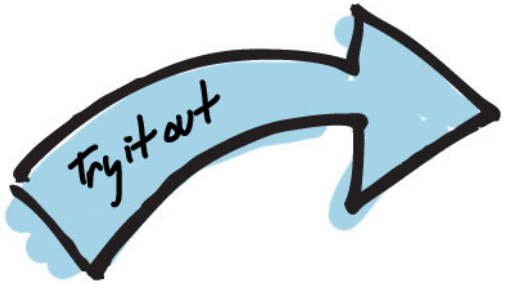
- An Actor can participate in ≥ 0 movies.
- There can be actors who have not yet acted in movies.



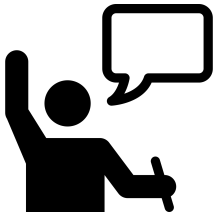
Quiz 1



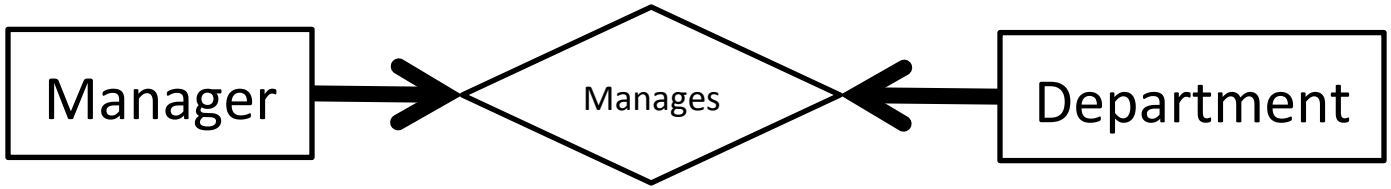
- **Key** Constraint:
  - A child has **at most** one mother but a mother may have several children.
- **Participation** Constraint:
  - Each child must have **at least** one mother
- **Net Result**: Every child has exactly one mother.



Quiz 2



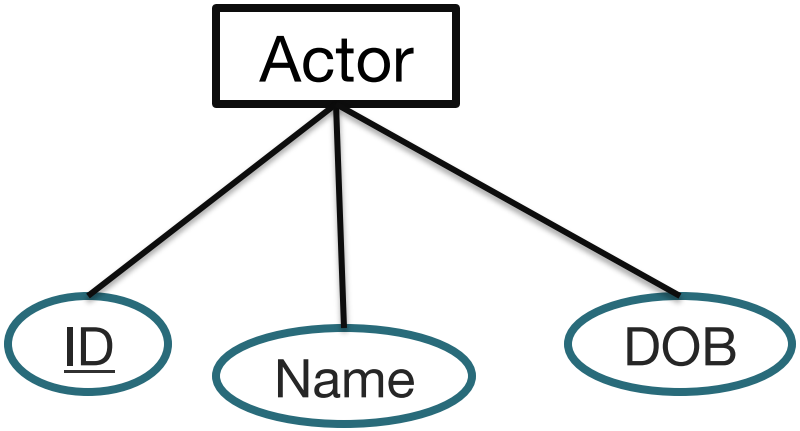
- What is the relationship type here?

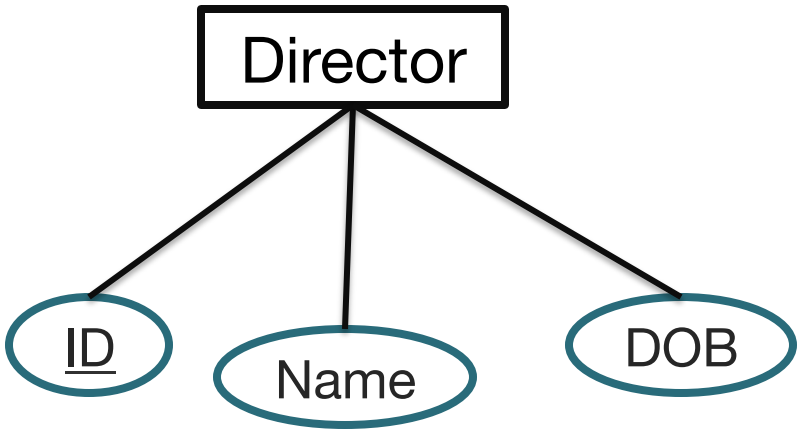


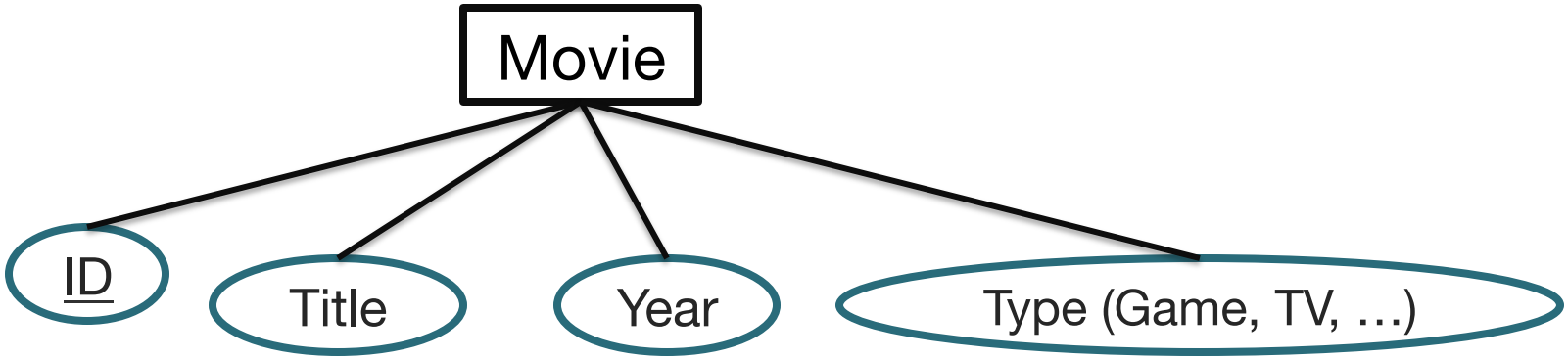
Scenario 1: Update (3)

- Create IMDB (Internet Movie Database)
  - i.e., a database to store information about the movies, cast, directors, …
- Constraint 1 (they ask you to impose it)
  - A movie can have AT MOST one director
  - A director can direct MULTIPLE movies
- Constraint 2
  - Every Movie entity must participate in a relationship with an Actor
    - i.e., every movie must have ***at least*** one actor
- The actors & directors have attributes: ID, Name, DOB
- The movies have: ID, title, year, type

ER Diagram: Attributes







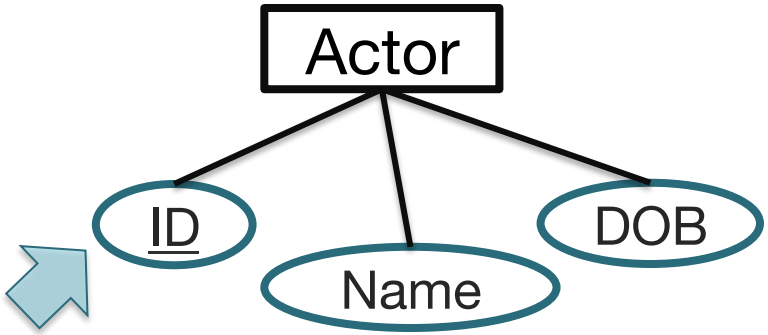
Keys

Key: A minimal set of one or more attributes that has unique value for each record.

- **Candidate keys:** potential keys

- Students in a student database have multiple **potential keys** (they must be unique to be a key):
  - Student ID
  - Login name
  - SSN
  - (Name, address)

Primary Key

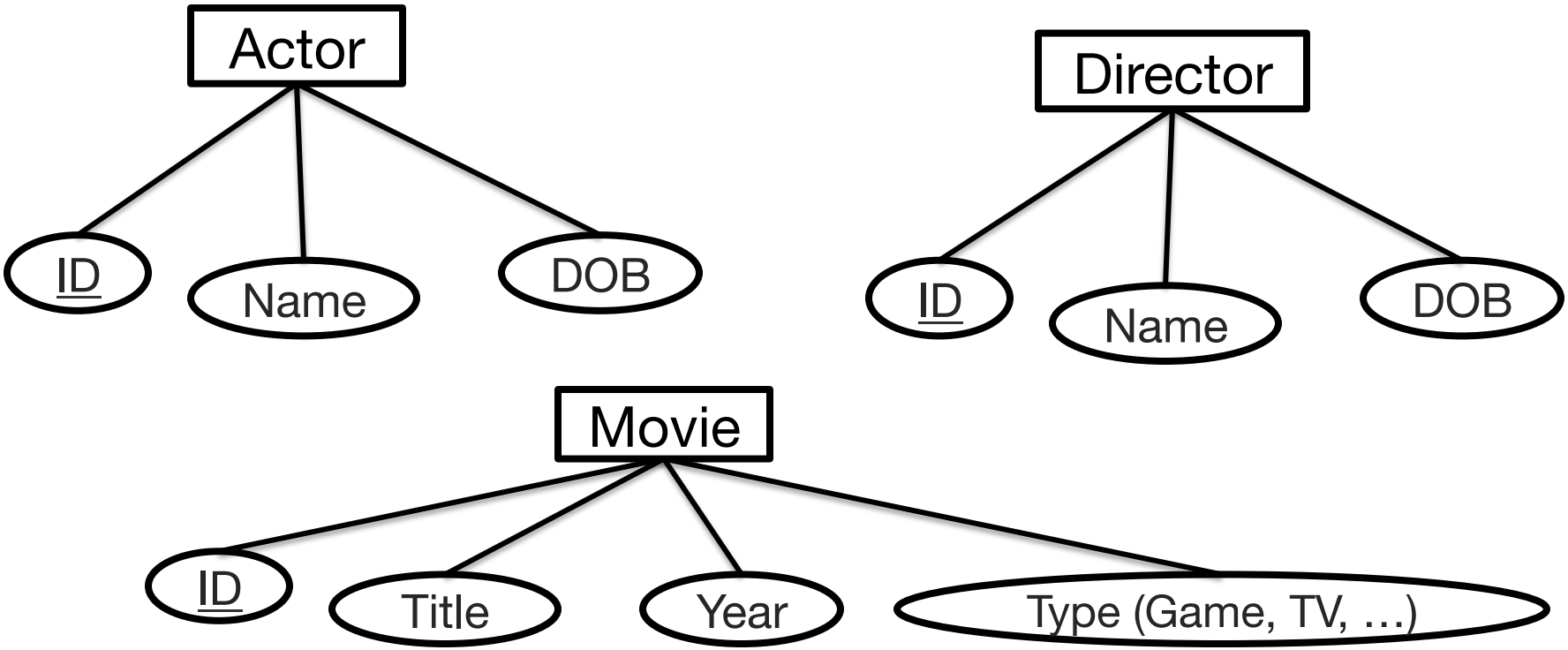


- **Primary Key:** One of the candidate keys
- The primary key attribute(s) is (are) underlined in the ER diagram

- When you design a database, the **primary** key is **cross-referenced** in other tables to represent relationships.
  - e.g., For students, Student ID is a good primary key

Primary Keys

- Often each Entity is assigned a unique ID, which serves as a primary key



What are the Primary Keys for Instructor? Course? Teaches?

Instructor ID	First Name	Last Name
394953	John	Smith
454544	Sara	King
439849	Alex	Dee
….	….	….
….	….	….

Instructor ID	Course ID	Year	Term
454544	E302	2009	F
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….	….	….	….
….	….	….	….

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Practice ER Modeling Problem

Scenario 2

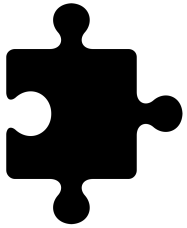
ER Modeling Problem

- Citizens vote on initiatives at polling stations.
- Polling stations have a location and size.
  - Citizen info: SSN, name, bday (SSN is unique)
  - Initiatives info: ID, name, description (Id is unique)
- Citizens are represented by an elected official, who is also a citizen.

Exercise:

1. Identify entities (objects), relationships between entities
2. Attach attributes
3. Keys: something that uniquely identifies an entity

ER Modeling Problem
STEP 1a



- **Citizens** vote on **initiatives** at **polling stations**.
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Exercise:

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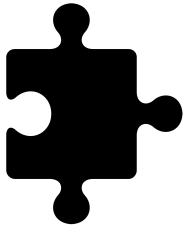
ER Modeling Problem
STEP 1b



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Exercise:

1. **Identify** entities (objects), **relationships** between entities
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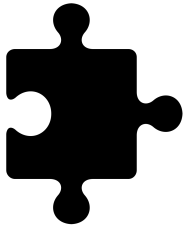
3. Keys: something that uniquely identifies an entity

ER Modeling Problem
STEP 2



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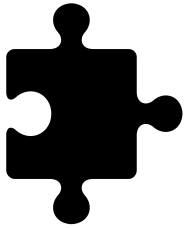
Exercise:

1. **Identify entities** (objects), relationships between entities
2. Attach attributes
3. Keys: something that uniquely identifies an attribute

ER Modeling Problem
STEP 3



- **Citizens vote** on **initiatives** at **polling stations**.
- **Polling stations** have a location and size. + pid
  - Citizen info: SSN, name, bday (SSN is unique)
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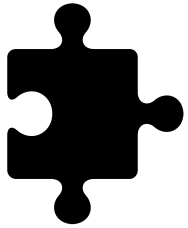
Entities



Citizen

Initiative

Poll Stn

- **Citizens** vote on **initiatives** at **polling stations**.
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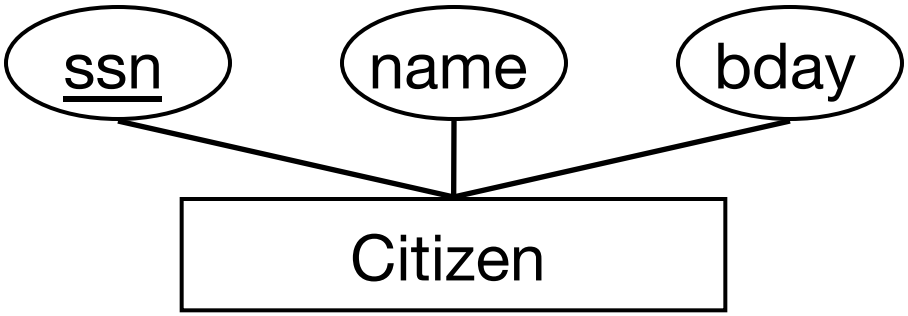
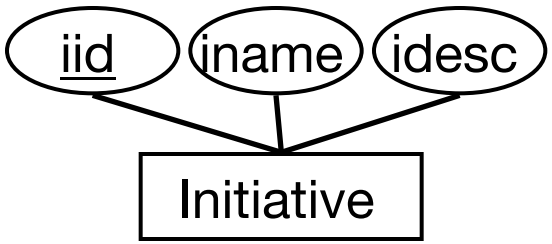
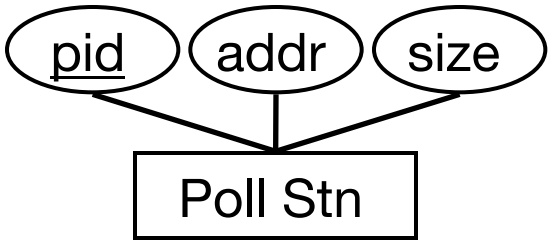
Add attributes and underline keys







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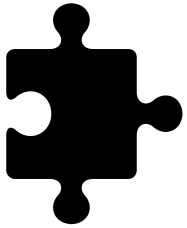
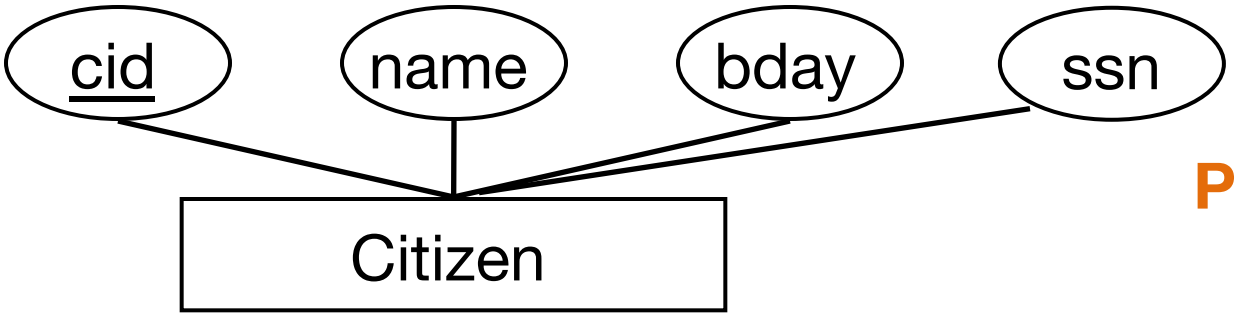
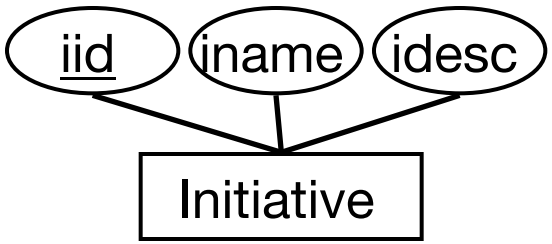
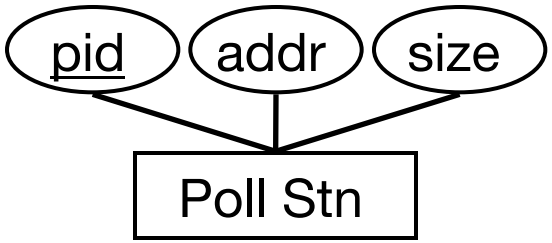
Alternate key for Citizen





Pros and cons?





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- **Polling stations** have a location and size. + pid
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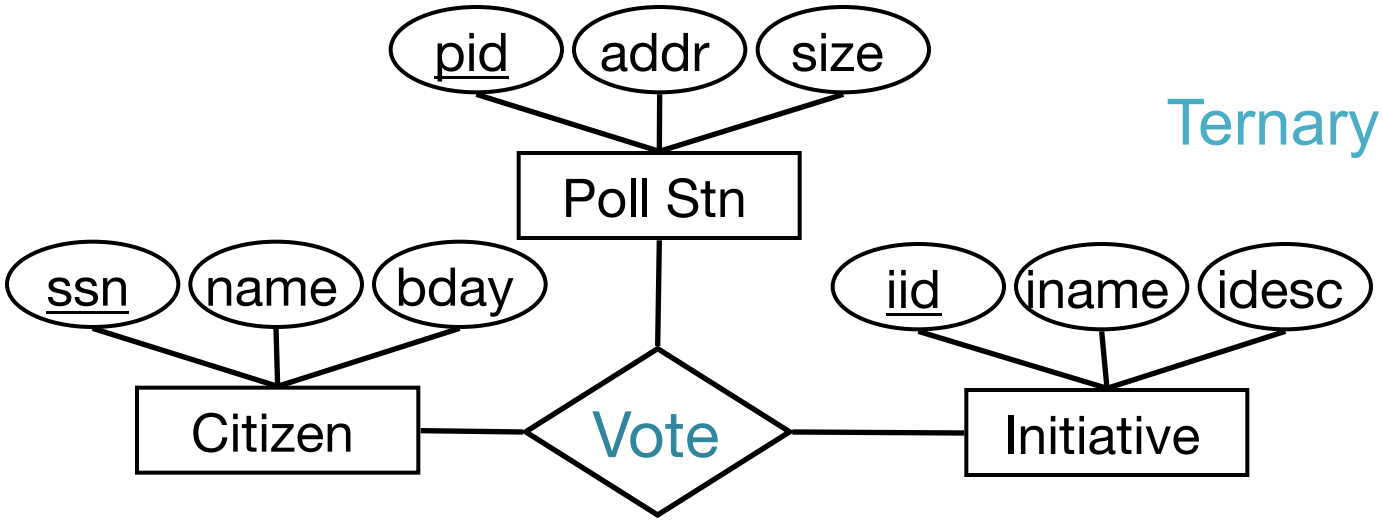
- **Citizens** are represented by an elected official, who is also a **citizen**.

+cid

Add in the relationships



Ternary relationship

- **Relationship set**: $\{(e_1, e_2, \ldots, e_n) \mid e_1 \in E_1, e_2 \in E_2, \ldots, e_n \in E_n\}$

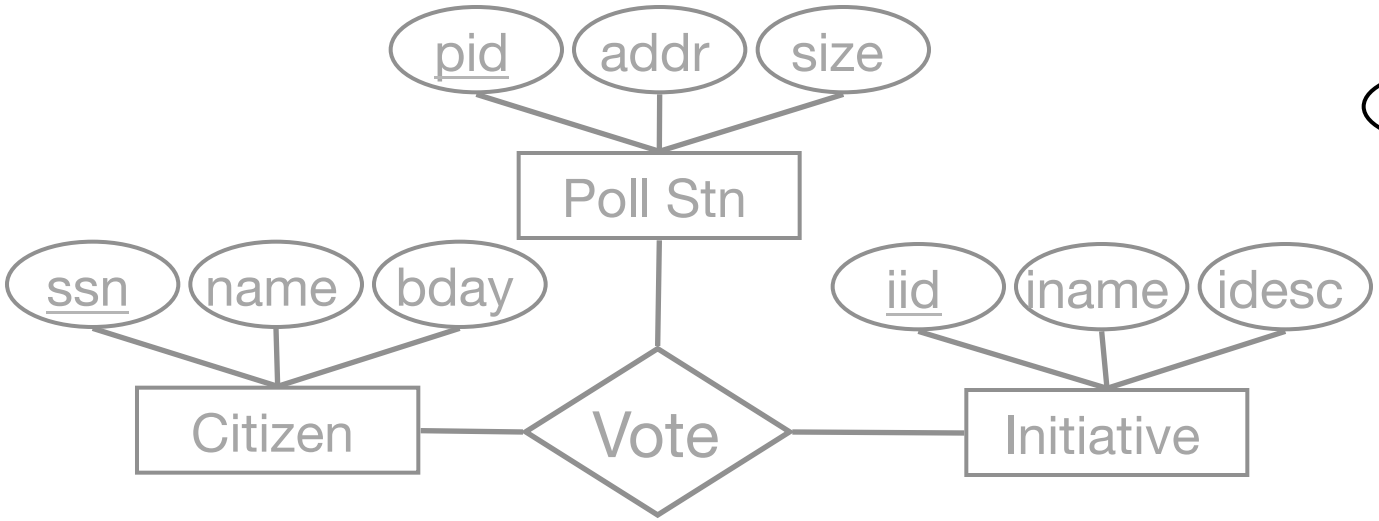
  e.g., Vote: {(c1, p, i), (c2, p, i), …}

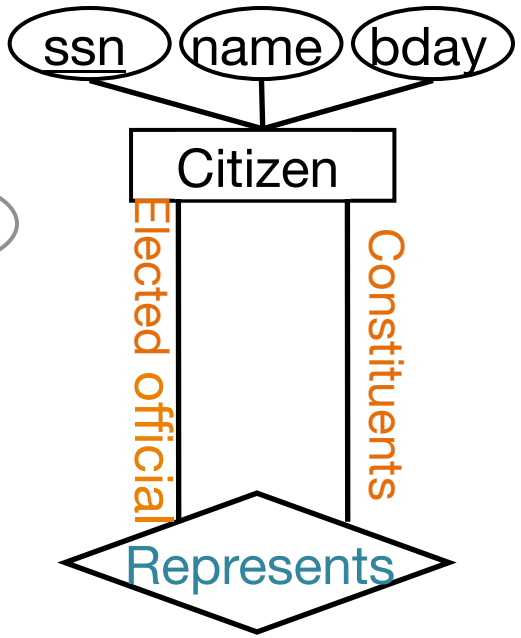
- **Entity sets**: Collection of entity instances

  e.g., set of citizens

- **Citizens vote** on **initiatives** at **polling stations**.
- **Polling stations** have a location and size. + pid
  - Citizen info: SSN, name, bday (SSN is unique)
  - Initiatives info: Id, name, description (Id is unique)
- **Citizens** are **represented by** an elected official, who is also a **citizen**.

Add in the relationships





Different roles
In the same entity

- **Relationship set**:

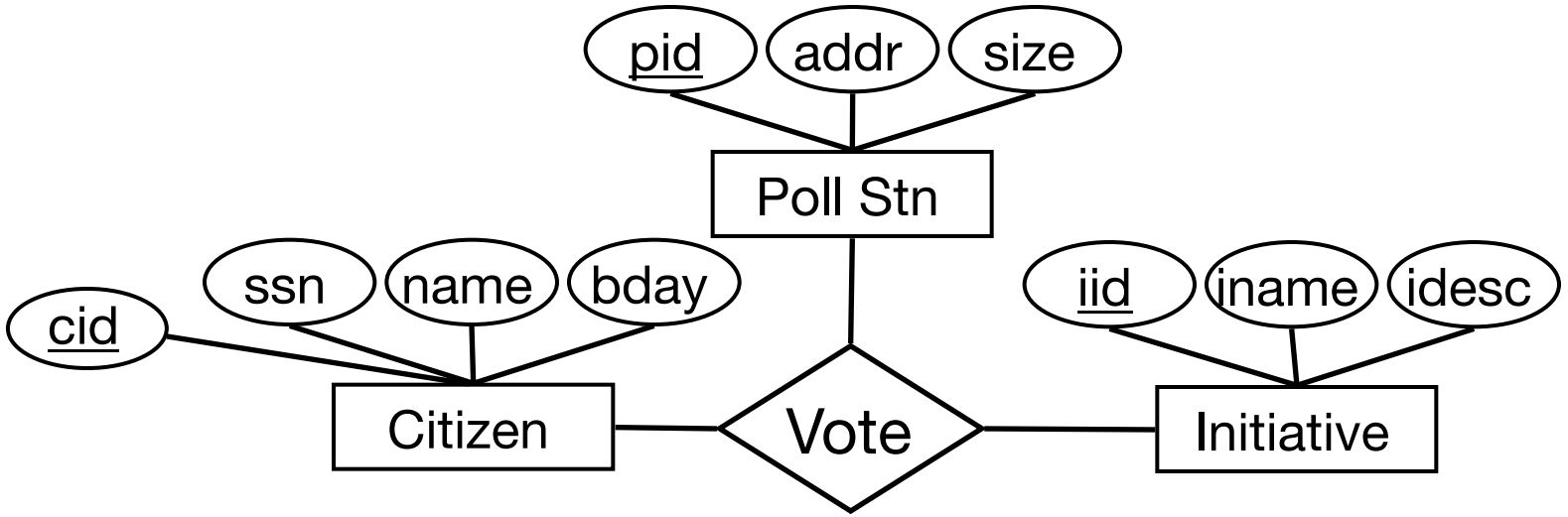
  e.g. Vote: {(c1, p, i), (c2, p, i), …}

- **Entity sets**: Collection of entity instances

  e.g. set of citizens

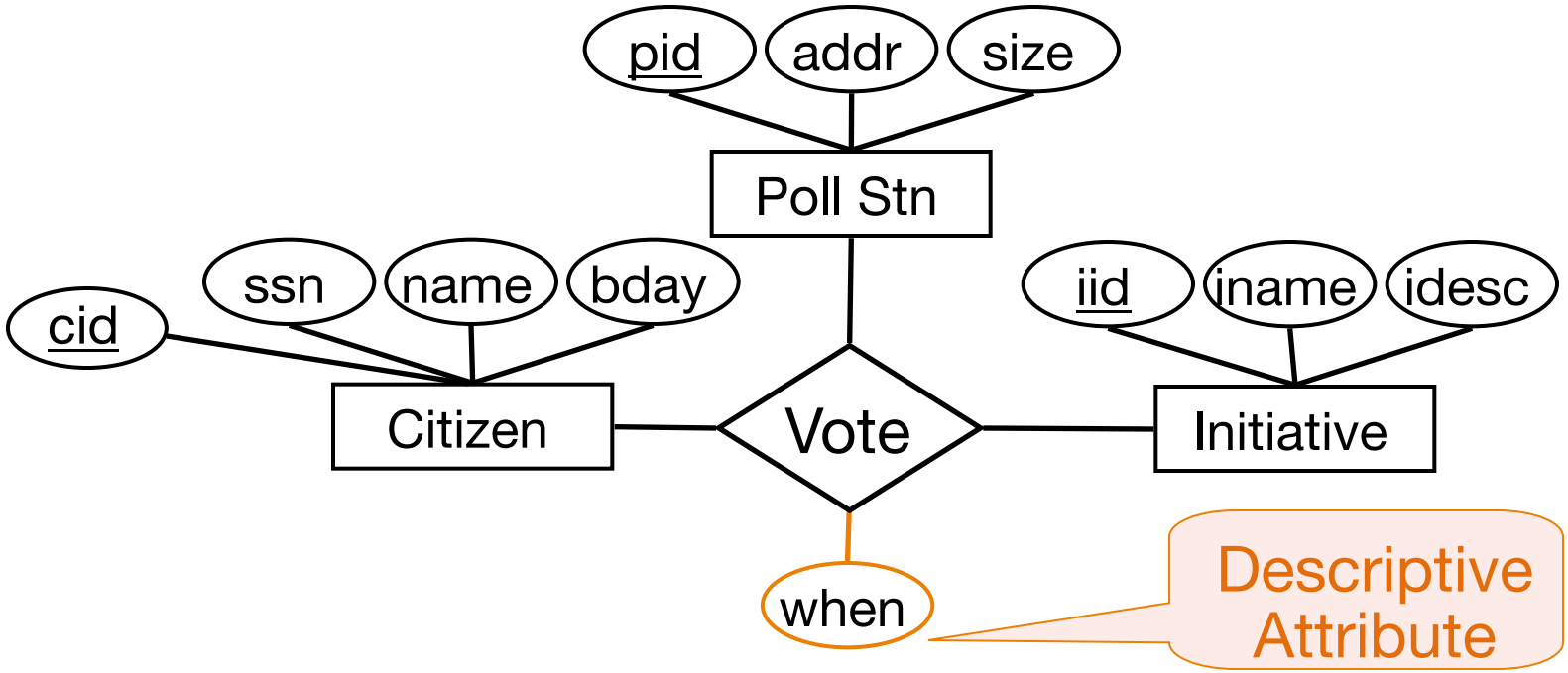
- **Citizens** vote on **initiatives** at **polling stations**.
- **Polling stations** have a location and size. + pid
  - Citizen info: SSN, name, bday (SSN is unique)
  - Initiatives info: Id, name, description (Id is unique)
- **Citizens** are **represented by** an elected official, who is also a **citizen**.

Additional requirement 1



- Suppose we want to also record *when* a Citizen voted.
- How should we represent that?

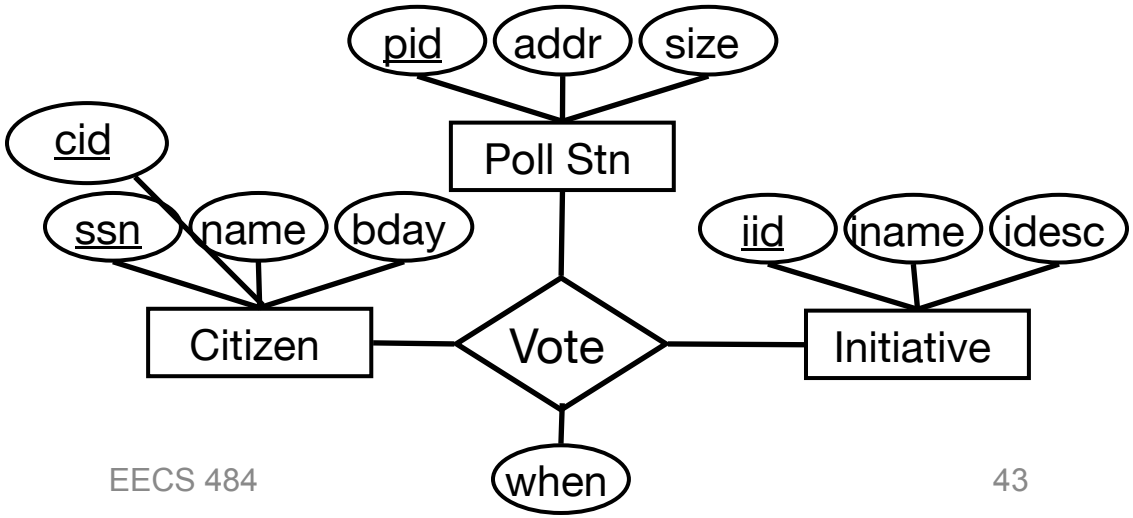
Attributes on Relationships



Additional Requirement 2

- A citizen also votes (PR-vote) for a candidate.
- He can vote at most once for a candidate, and we record the date of the vote.
- A candidate is also a citizen and has a work address (waddr).

Note: *For simplicity, we only focus on the PR-vote relationship in the next slides (and drop Vote).*



Additional Requirement 2: Key Constraints

- A citizen also votes for a candidate.
- He can vote **at most once for a candidate**, and we record the date of the vote.
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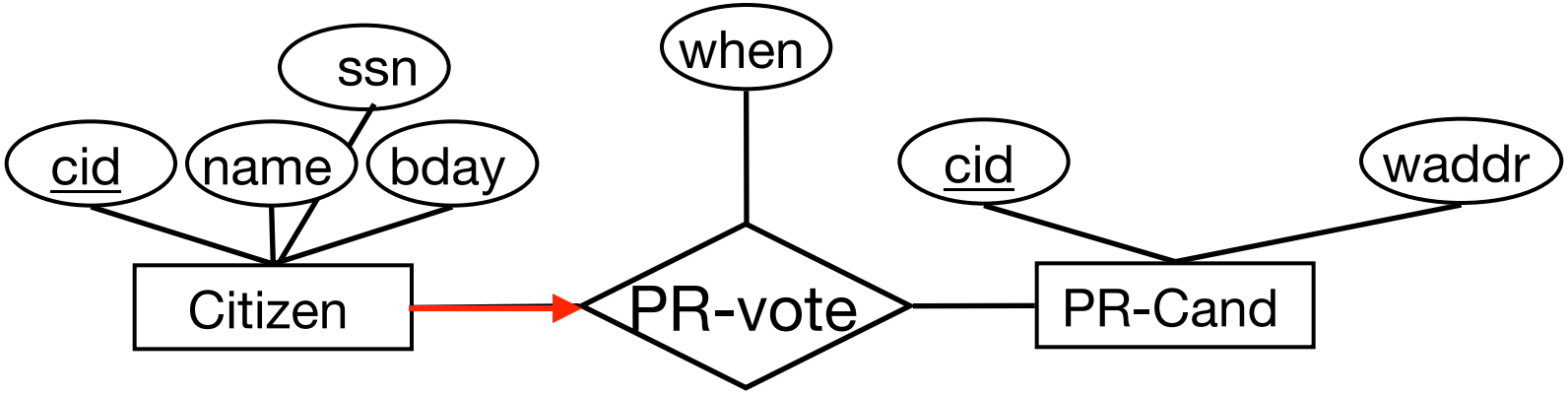
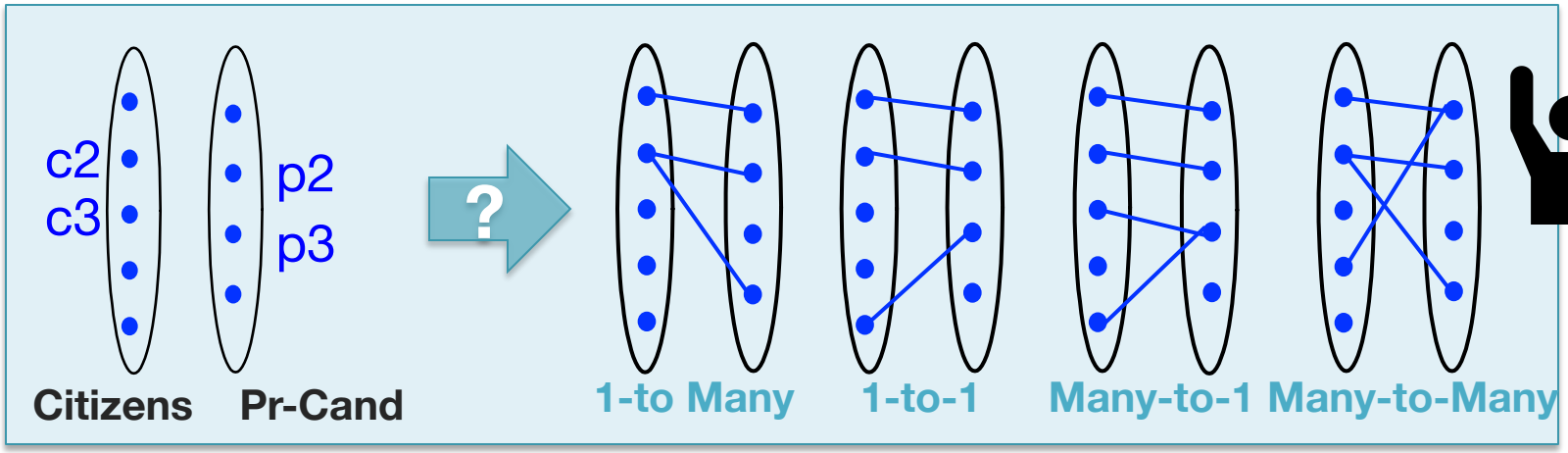
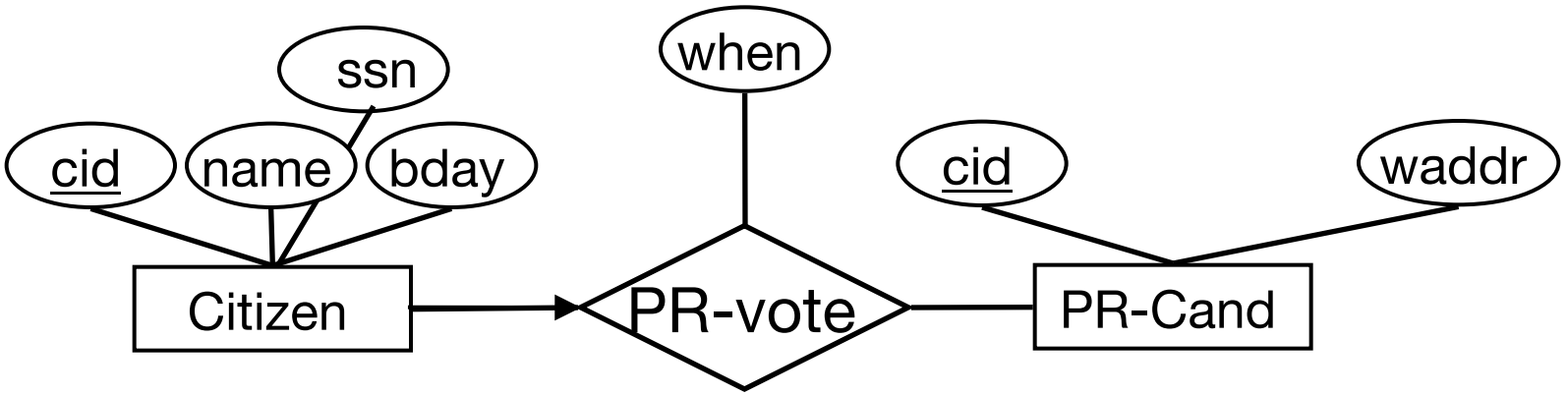


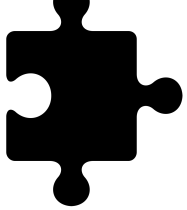
Additional Requirement 2: Key Constraints

- Relationship type between Citizen & PR-Cand?





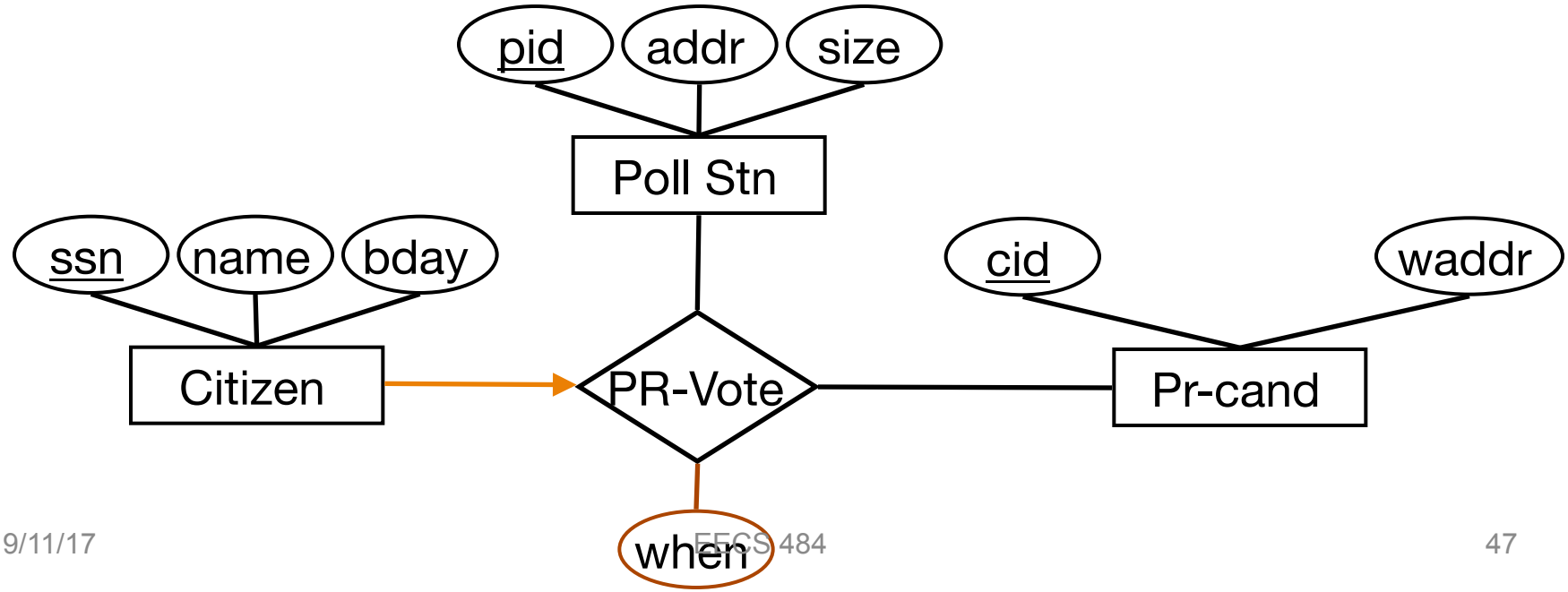
Key Constraints: Generalize



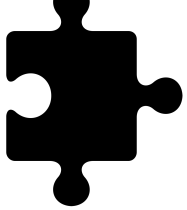
- Each voter votes at most once (for one candidate) and at a polling location.
- A given citizen can appear at most once in (citizen, polling station, candidate) sets

Key Constraints: Generalize

- Each voter votes at most once (for one candidate) and at a polling location.
- A given citizen can appear at most once in (citizen, polling station, candidate) sets



Additional requirements 3



- Every citizen MUST vote for a candidate
- Each candidate belongs to a party. Parties have a name and address
- Each party has exactly one candidate

Additional requirements

- Every citizen MUST vote for a candidate
- Each candidate belongs to a party. Parties have a name and address
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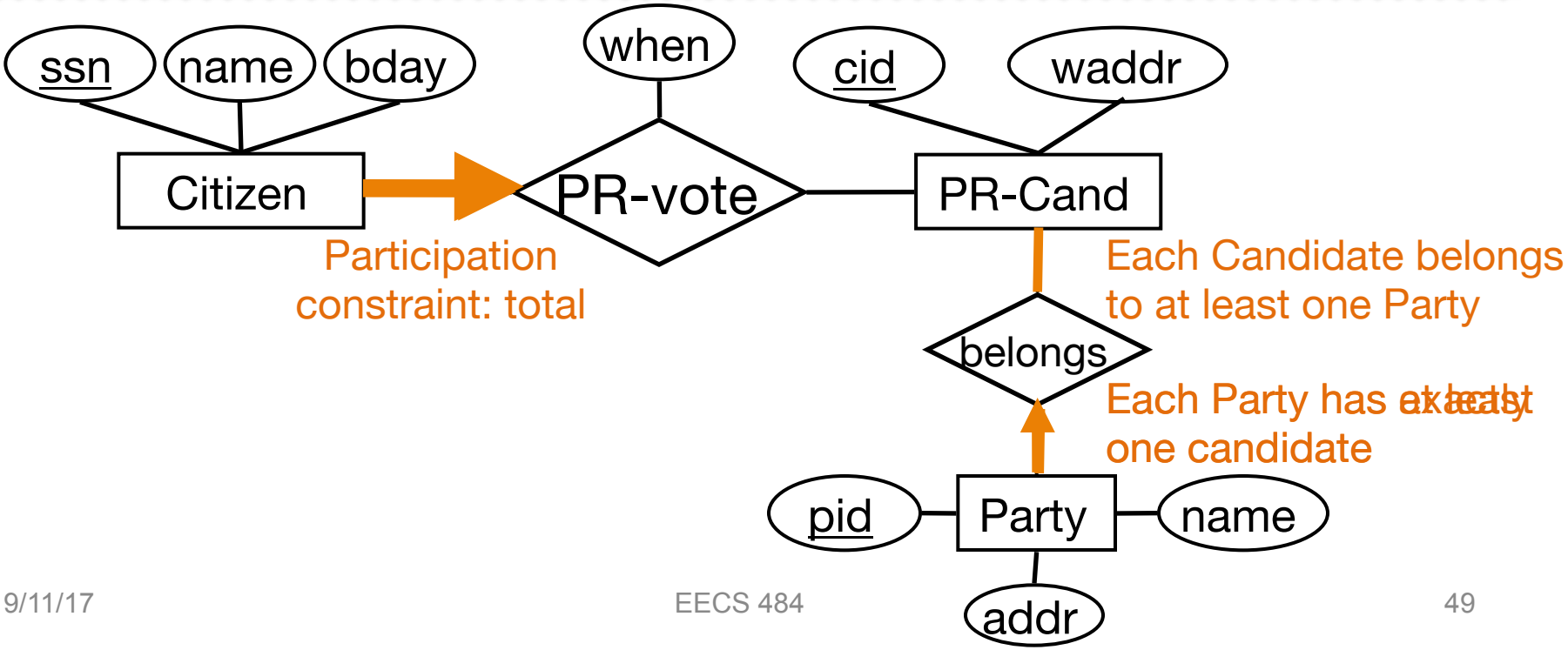
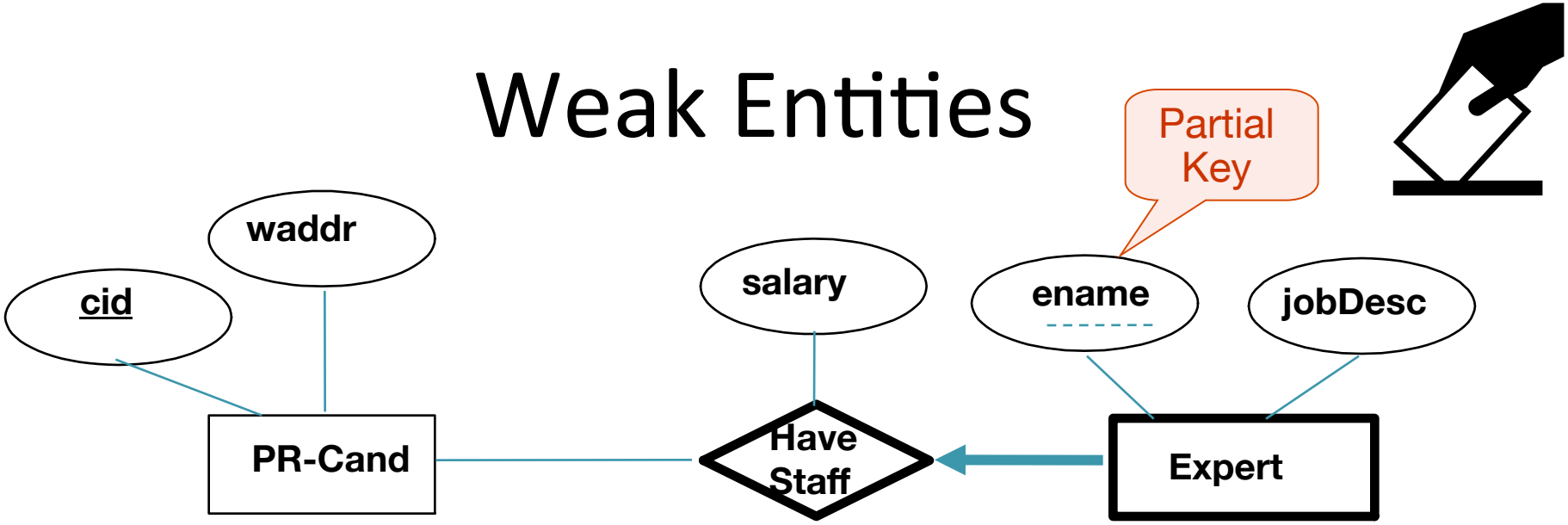
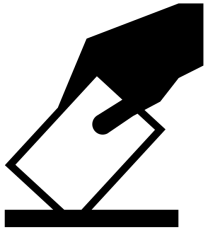


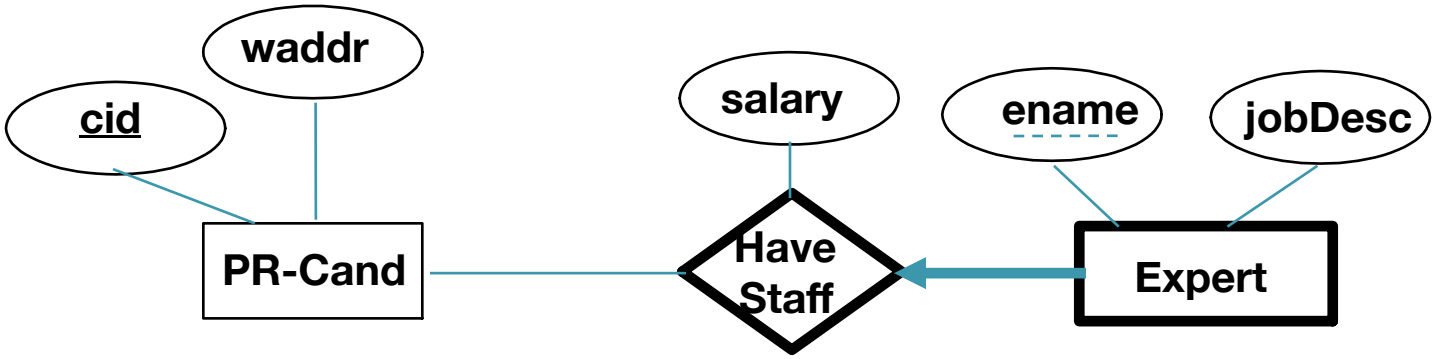
Weak Entities



- **Example**: Candidates have experts on their staff, identified by their name.
- Experts should be modeled as weak entities
- Expert names are not globally unique. To identify an expert, we need candidate's ID + expert's name.

Weak Entities





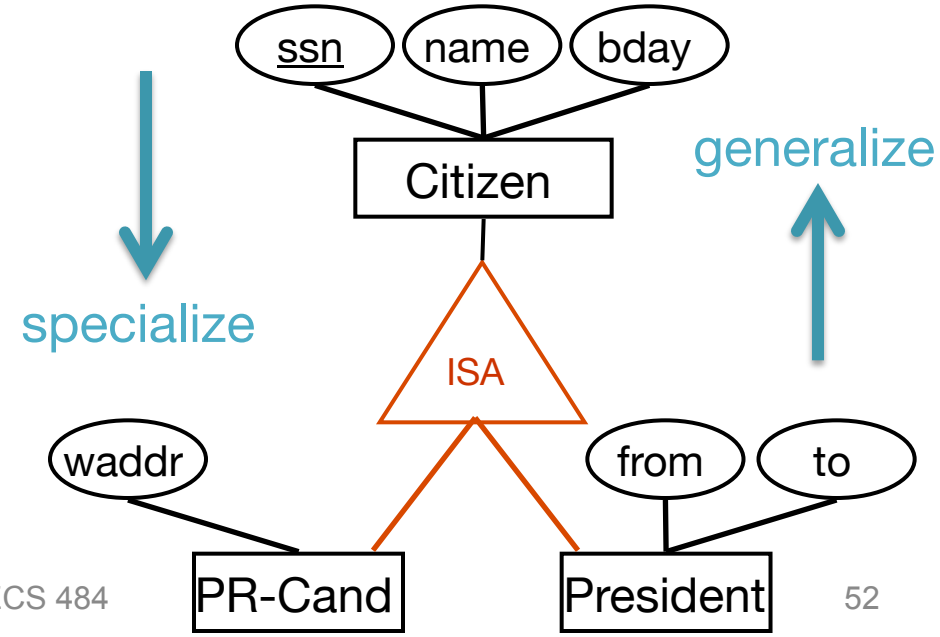
- A weak entity can be identified uniquely only by considering *some of its attributes in conjunction with* the *primary key* of the another entity (**identifying owner**)
- **Rules:**
  - Weak entity has a single owner (**one-to-many relationship**)
  - Weak entity must have **total participation** in the above identifying relationship set.

ISA ('is a') Hierarchies

- ✓ As in C++ attributes are inherited
- ✓ If A **ISA** B, every A entity is also a B entity
- ✓ Specialize superclass (top-down design)
- ✓ Generalize subclasses (bottom-up design)

Example

- Superclass: Citizen
- Subclasses: PR-Cand, President



ISA ('is a') Hierarchies

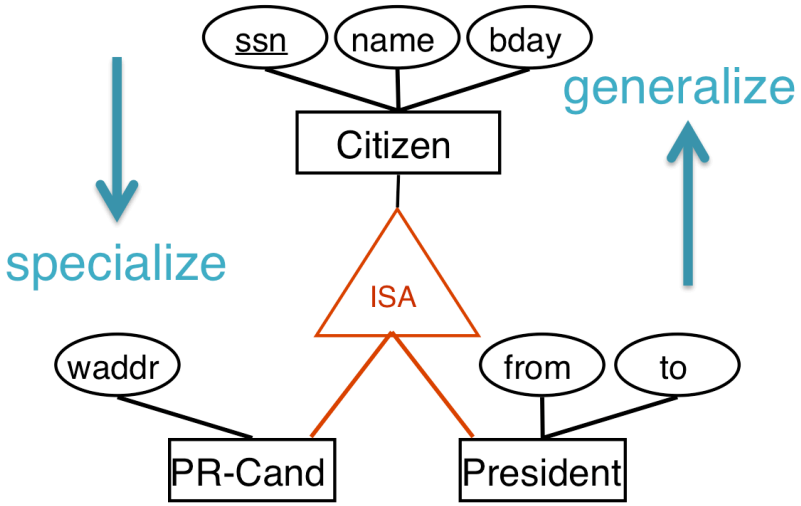
- Do not overuse them!
- Constraint types:
  - **Overlap**: Can >=2 subclasses contain the same entity?
    - Overlapping vs. Disjoint (default)
  - **Covering**: Do the entities in the subclasses include ALL the entities in the superclass?

    i.e., union of subclass entities = the set of superclass entities?
    - Total vs. Partial (default)

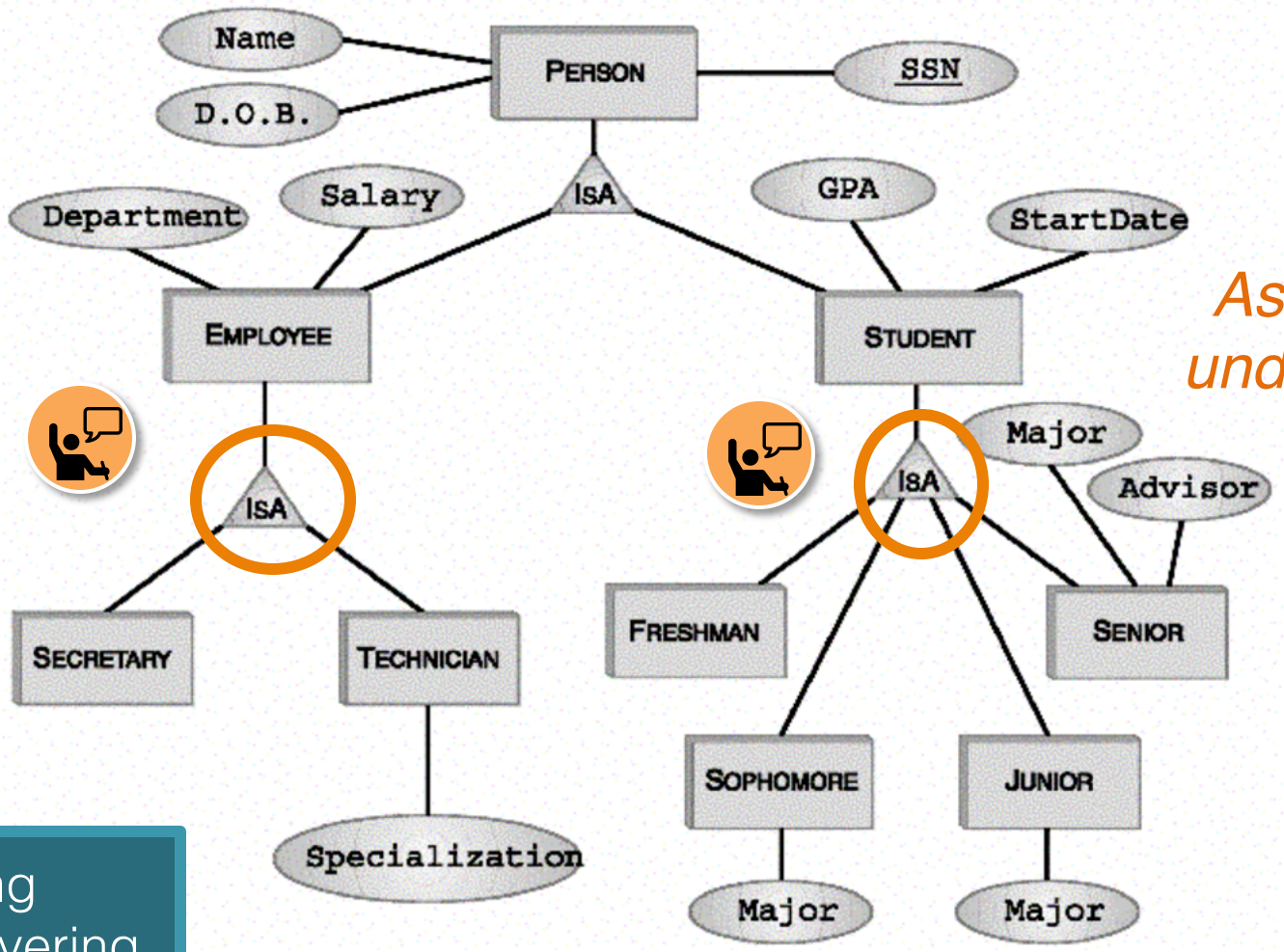
Example

Superclass: Citizen

Subclasses: PR-Cand, President



ISA Overlap and Covering Constraints: Example

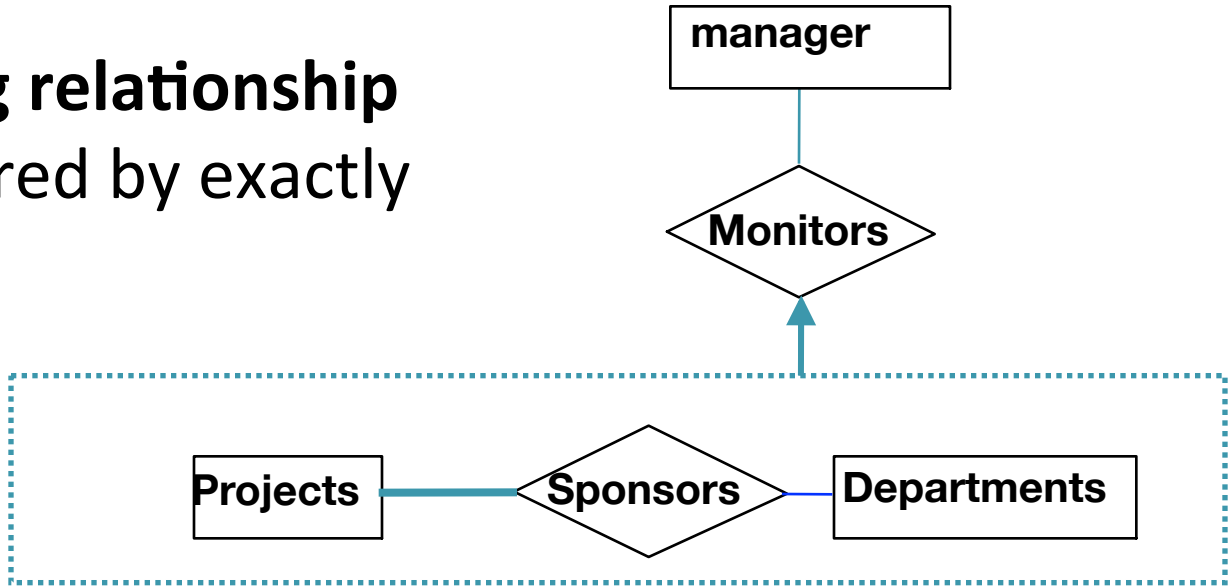


Assume undergrad

(A) Covering
(B) Non-covering
(C) Overlapping
(D) Disjoint

Relationship with relationships

- Each **Project** must be sponsored by at least one **Department**
- Each **sponsoring relationship** must be monitored by exactly one **manager**

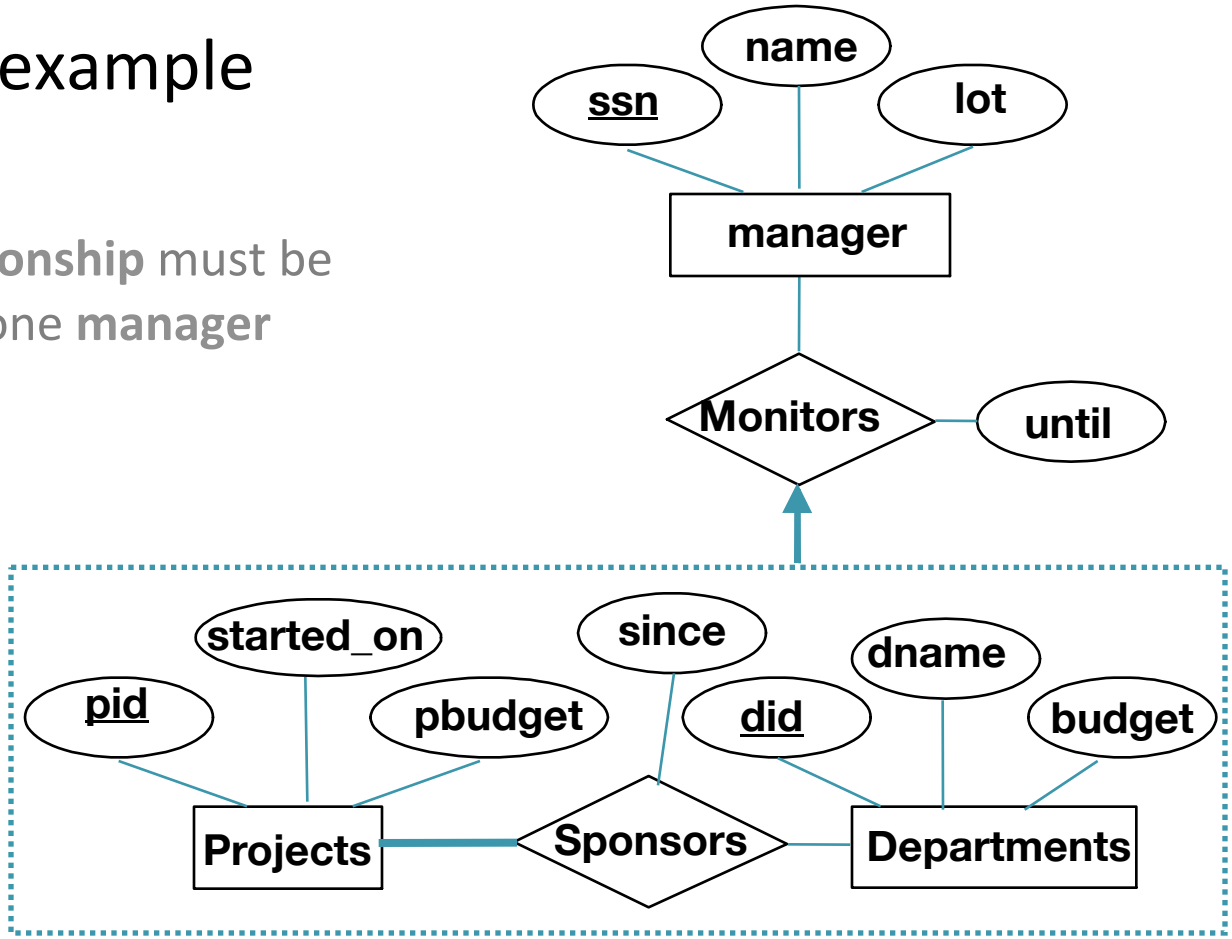


Treating a relationship as an entity for another relationship is called **aggregation.**

Aggregation

- More complete example

- Each **sponsoring relationship** must be monitored by exactly one **manager**

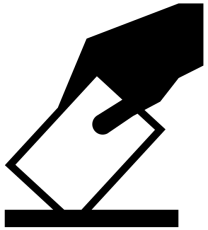


Conceptual Design Using the ER Model

- Design choices:

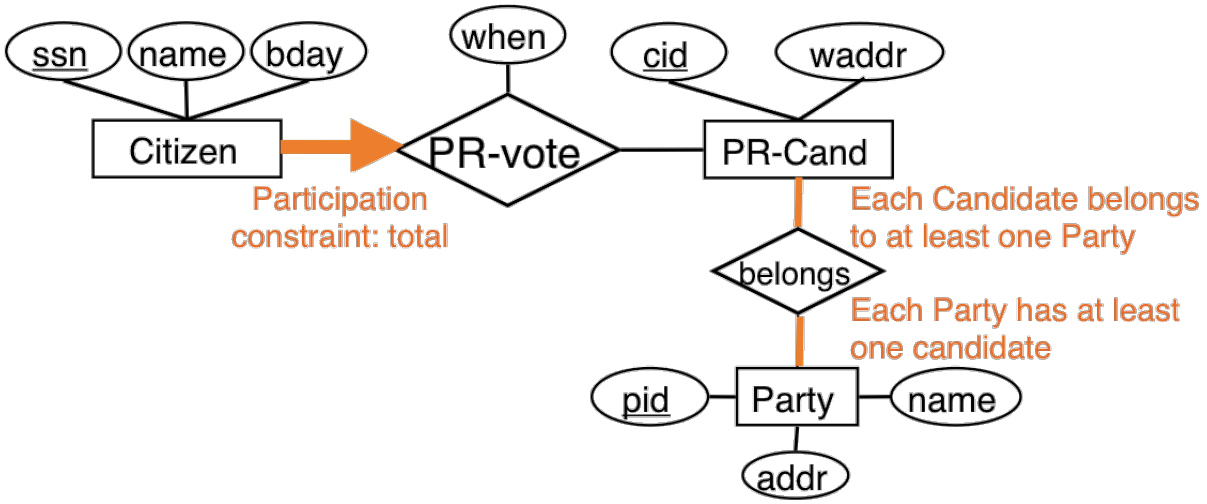
  1. Model a concept as an **entity** or an **attribute**?
  2. Model a concept as an **entity** or a **relationship**?
  3. **Binary** or **ternary** relationship? **Aggregation**?

1. Entity vs. Attribute



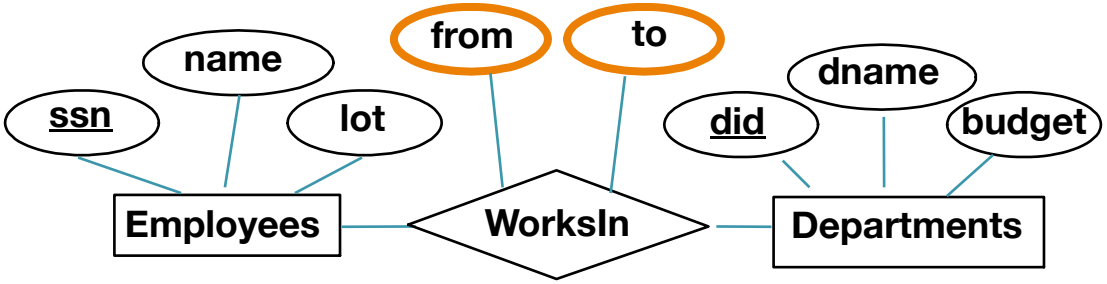
- Address of a Party: entity or attribute?
- Go with **entity** IF you want to:
  - Store several addresses per Party

  or
  - Encode the structure of address (city, street, etc.)

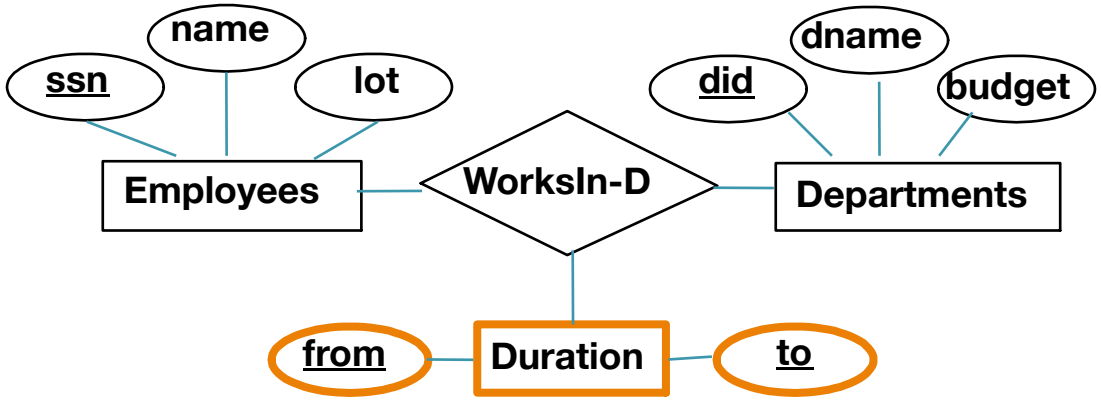


1. Entity vs. Attribute

- Can employee work in a given dept. for two or more periods?

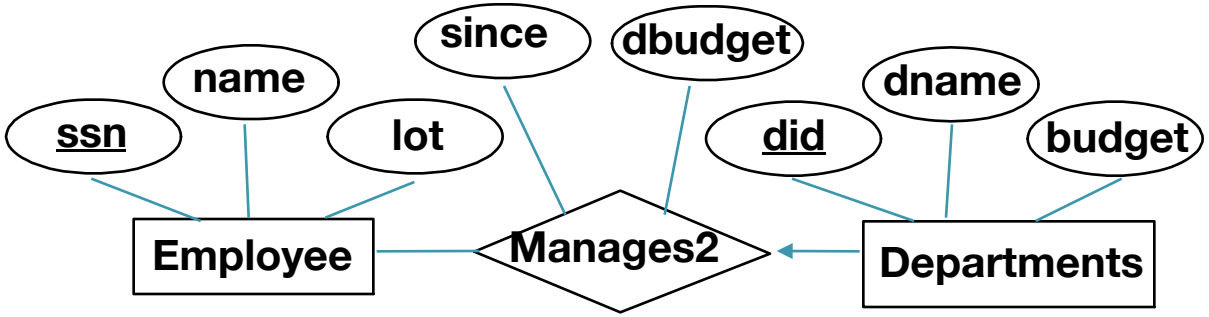


- Now?



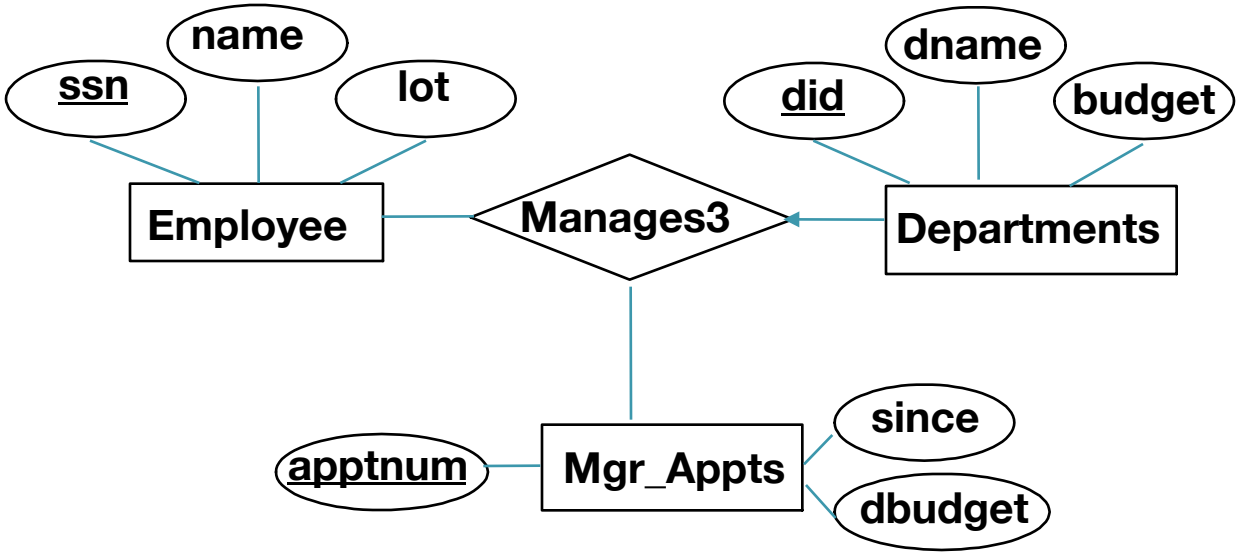
2. Entity vs. Relationship

- Manager (also an employee) gets a separate discretionary budget for each dept.



- What if we want Manager to get a discretionary budget that covers all managed depts?
  - Redundancy of dbudget, in each Manages2 relationship.
  - Misleading: suggests dbudget tied to relationship, not mngr

One Solution



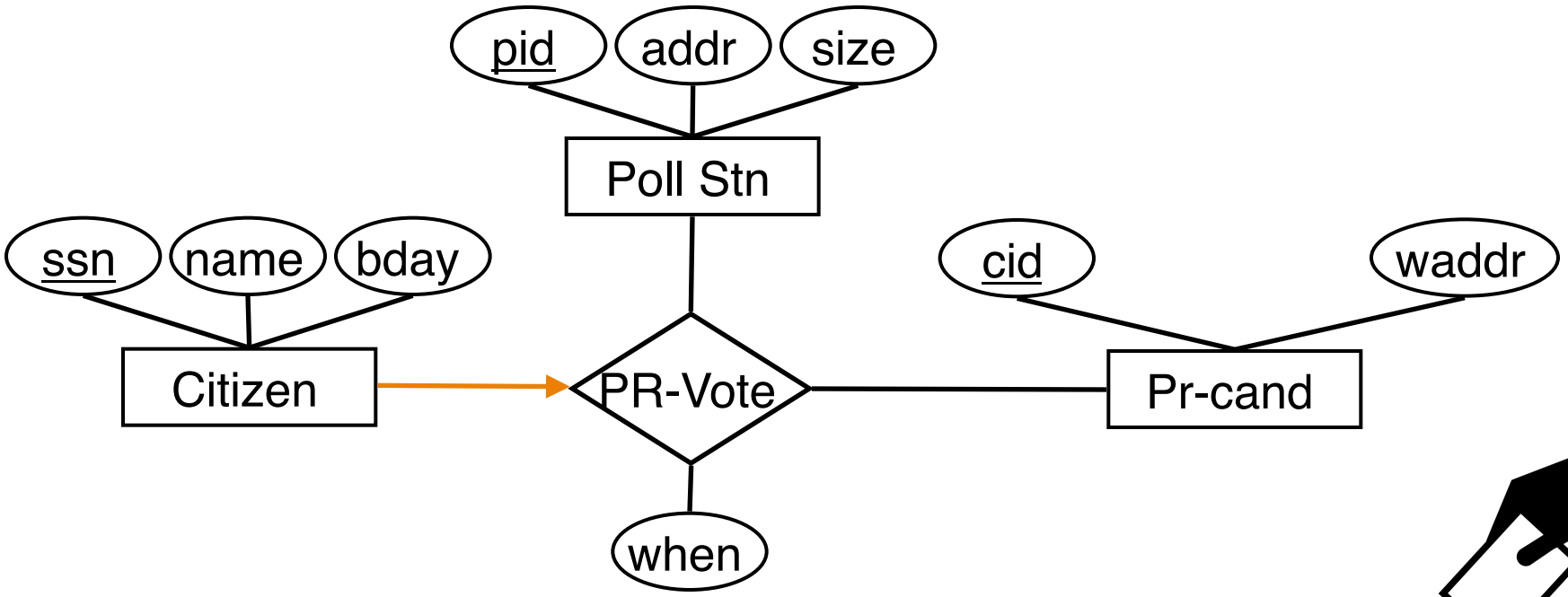
There is another way to do this.
Left as an exercise.

Think ISA hierarchy

- What if we want Manager to get a discretionary budget that covers all managed depts?

Participation constraint in a ternary relationship?

- A citizen votes at most once and at only one polling location (on a specific date)



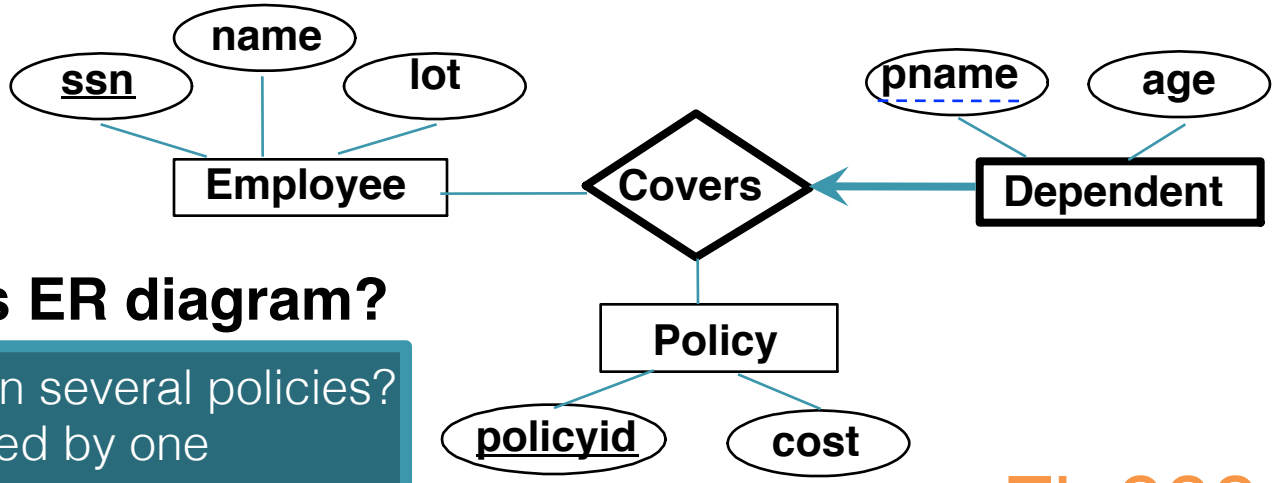
Later, on your own ☺

Try it out!

1. An insurance policy cannot be owned by multiple employees
2. Every policy must be owned by an employee
3. Dependents is a weak entity set, identified by the conjunction of pname with policyid.

Incorrect Design Example

1. An insurance policy cannot be owned by multiple employees
2. Every policy must be owned by an employee
3. Dependents is a weak entity set, identified by the conjunction of pname with policyid.



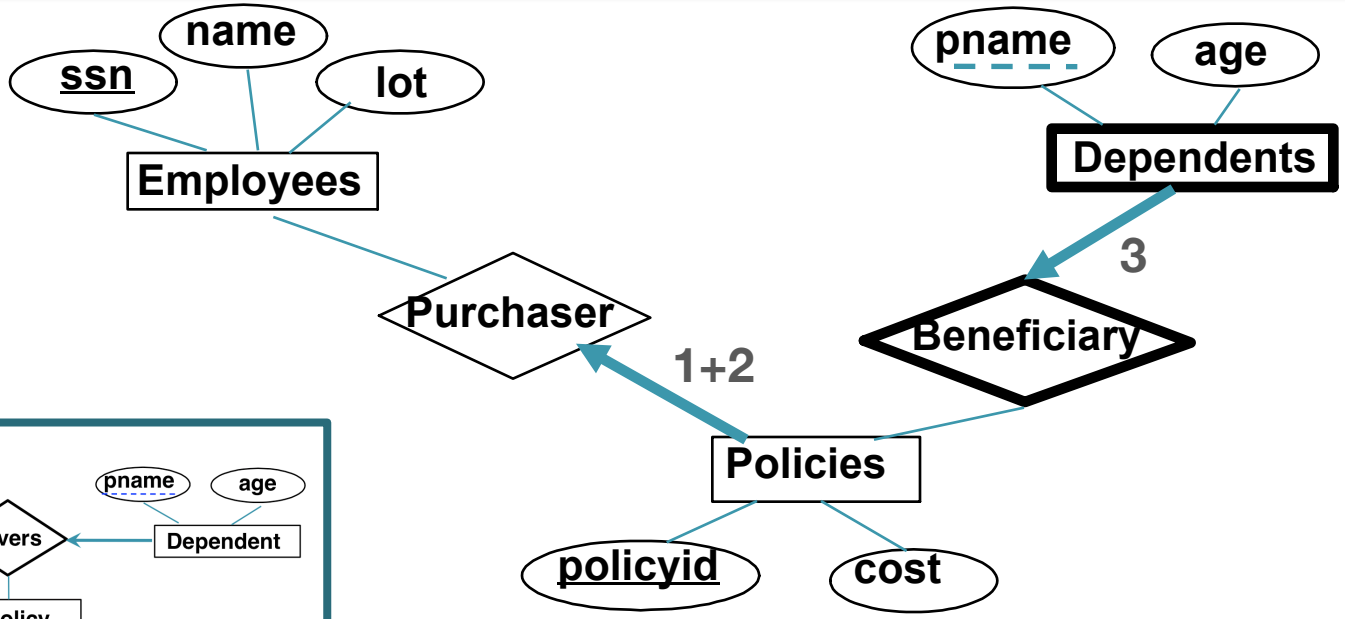
What is true in this ER diagram?

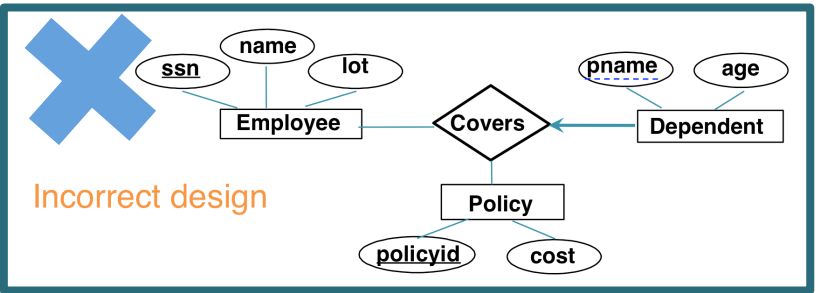
(A) Employees can own several policies?
(B) Each policy is owned by one employee?
(C) Each dependent can be covered by several policies?

Fix???

Better Design

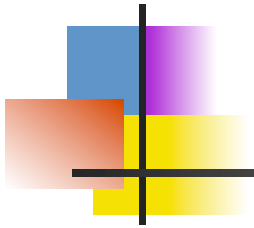
1. An insurance policy cannot be owned by multiple employees
2. Every policy must be owned by an employee
3. Dependents is a weak entity set, identified by the conjunction of pname with policyid.





Questions to think about

- Does the ER diagram allow a citizen to vote for multiple initiatives?
  - If so, how can the design be changed for the answer to become No?
- Does the ER diagram allow a citizen to vote for the same initiative at multiple polling stations? (i.e., cast two votes for an initiative)
  - If so, how can the design be changed for the answer to become No, while allowing vote on multiple initiatives? And what if we wanted to require those votes by a particular citizen to be on at most one polling station?



Binary vs. Ternary Relationships

- An example in the other direction: a ternary relation Contracts relates entity sets Parts, Departments and Suppliers, and has descriptive attribute qty.
- Can we use binary relationships? E.g.,
  - Supplier S1 supplies Part P1
  - Department D1 buys Part P1
  - Department D1 has a contract with S1
- Does the above imply that D1 has agreed to buy P1 from S1?
  - How do we record qty?

Summary of Conceptual Design

- High-level description of data to be stored
- ER model popular for conceptual design
  - Constructs are expressive and natural
  - Basic constructs: **entities, relationships, and attributes** (of entities and relationships).
  - Additional constructs: **weak entities, ISA, aggregation**.
  - Integrity constraints: **key constraints and participation constraints.**
- Note: There are many variations on ER model
- ER designing is subjective!

What's Next?

- Relational Model
  - Chapter 3
- Suggested exercises (ungraded)
  - 1.3
  - 2.1,2.3,2.5,2.7