THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

4. Schema Design and Entity-Relationship Model

CSCI 2541W
Database Systems & Team Projects

Gabe

Slides adapted from Prof. Bhagi Narahari; and Silberschatz, Korth, and Sudarshan, Wood & Chaufournier

Announcements?

Last time…

SQL DDL & DML

Entity Relationship Model

Normalizatio n

this time…

Design Phases

Initial phase: fully characterize the data needs of the prospective database users

Second phase: choose a data model

- A data model provides a standard way to think about information and how it is related
- Must translate these requirements into a **conceptual schema** of the database
- A fully developed conceptual schema indicates the functional requirements of the enterprise
  - Describes the key pieces of information that must be tracked
  - Describes the kinds of operations (or transactions) that will be performed on the data

Design Phases

Which is harder to fix later?

Final Phase: Moving from an abstract data model to the implementation of the database

- **1. Logical Design** – Deciding on a "good" collection of relation schemas
  - **Business decision** – What attributes should we record in the database?
  - **Computer Science decision** – What relation schemas should we have and how should the attributes be distributed among the various relation schemas?
- **2. Physical Design** – Deciding on the physical layout of the database
  - The DBMS will do some of this for us
  - But we can control things like how indexes are generated to optimize frequent data lookups (later)

Design Alternatives

In designing a database schema, we must ensure that we avoid two major pitfalls:

- **Redundancy**: a bad design may result in repeated information
  - Redundant representation of information may lead to data inconsistency among the various copies of information
- **Incompleteness**: a bad design may make certain aspects of the enterprise difficult or impossible to model

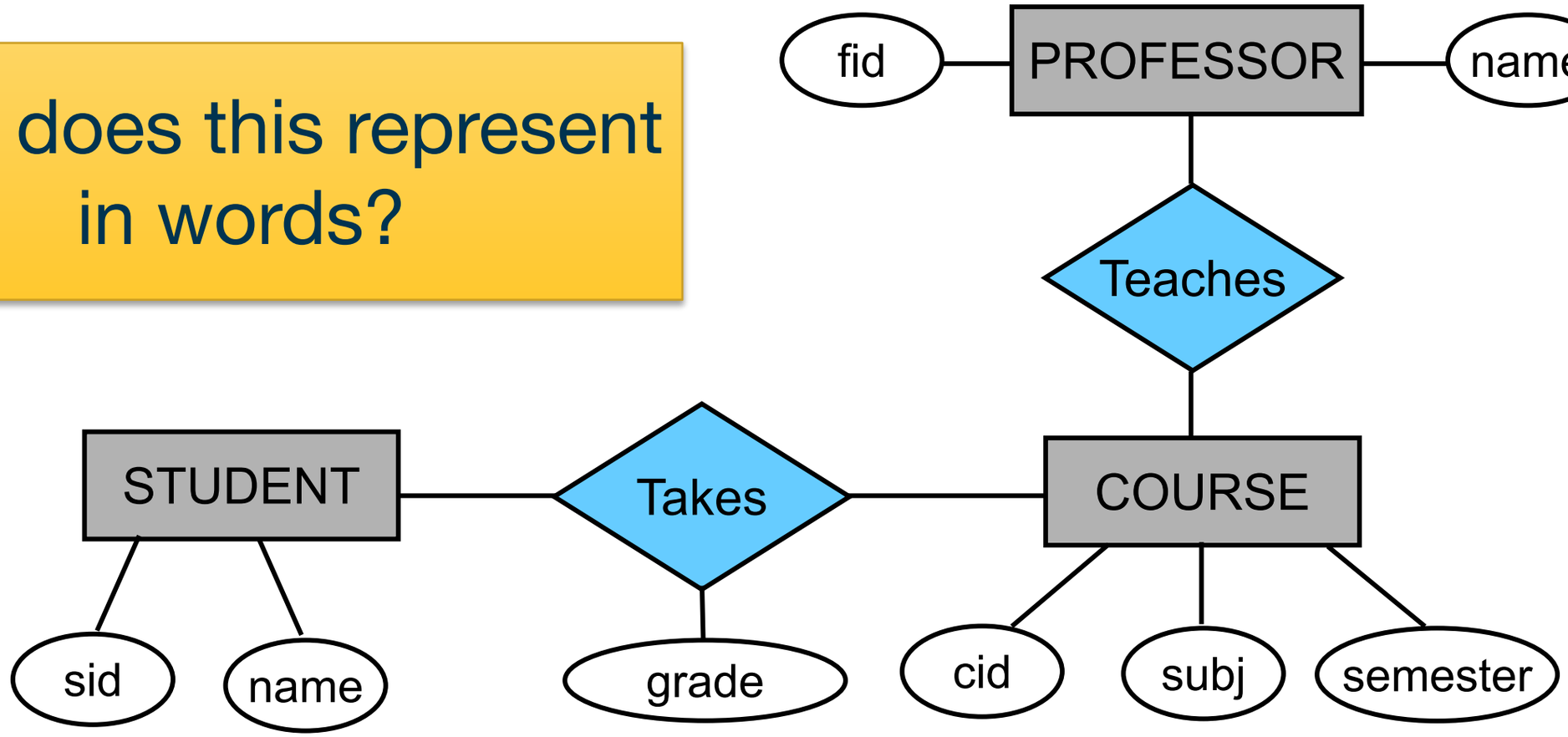
Avoiding bad designs is not enough. There may be a large number of good designs from which we must choose

Entity-Relationship Model

Data model that lets you visualize a conceptual schema based on three simple concepts:

- Entities, Relationships, and Attributes

What does this represent in words?

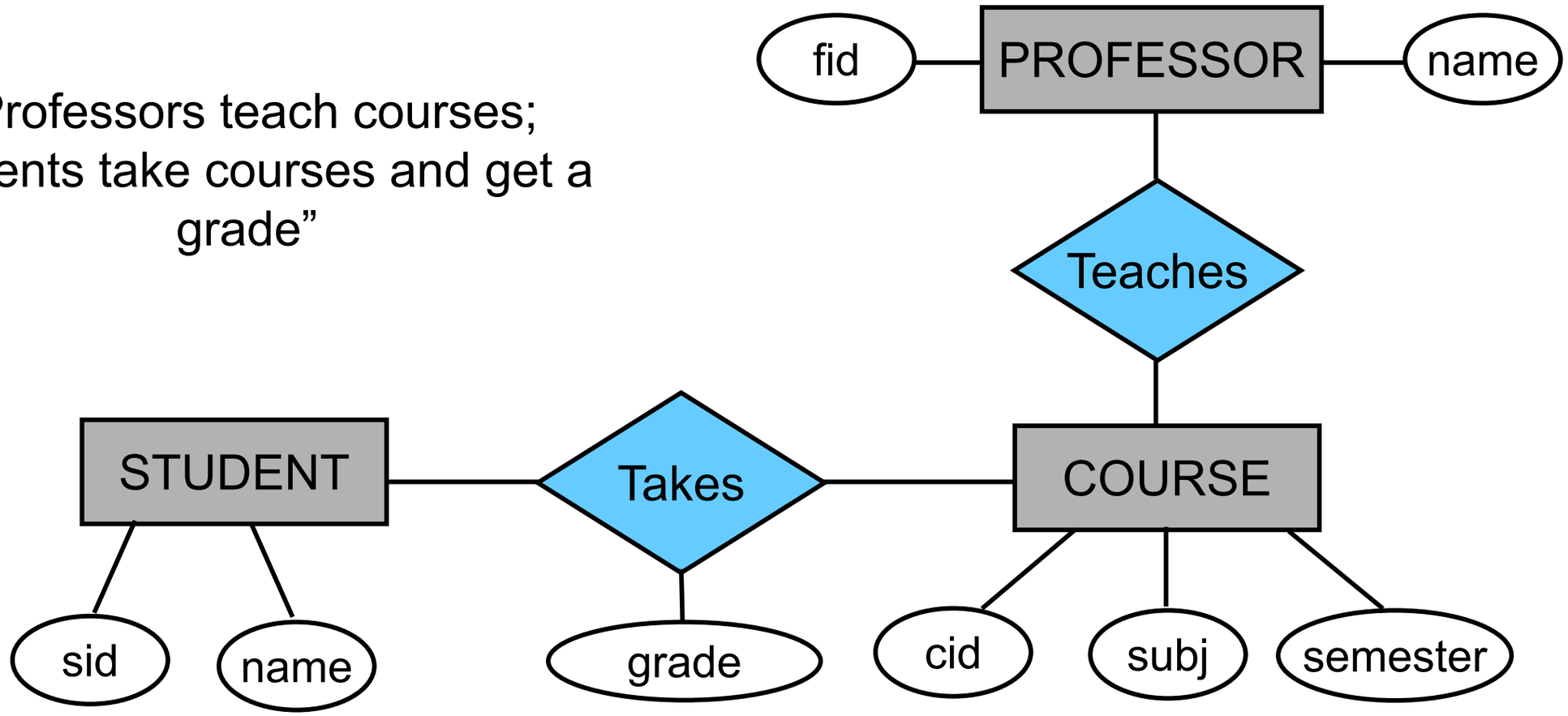


Entity-Relationship Model

Data model that lets you visualize a conceptual schema based on three simple concepts:

- Entities, Relationships, and Attributes

"Professors teach courses; students take courses and get a grade"



One picture provides info on what your system stores and models

ER Model - Entities

Entity: Real-world object distinguishable from other objects

- An entity is described (in DB) using a set of attributes
- Analogy: Nouns (Student, Course,…)

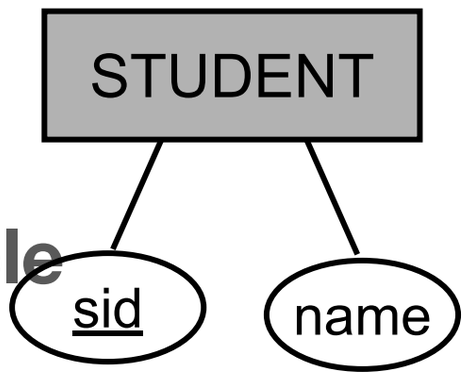
Entity Set: A collection of similar entities. e.g., all employees.

- All entities in an entity set have the same set of attributes. (Until we consider ISA hierarchies, anyway!)
- Each entity set has a **key**
- Each attribute has a **domain**

An **entity instance** is a particular example or occurrence of an entity type…eg: Faculty Tim Wood

Representation/Syntax:

- **Entity** set represented by **Rectangle**
- **Attribute** represented by **Oval or a Table**
  - Unique (Key) attributes underlined



OR

STUDENT
sid
name

ER Model - Relationships

Relationship: Association among two or more entities. E.g., Dan takes Database Course; Maya works in Research department.

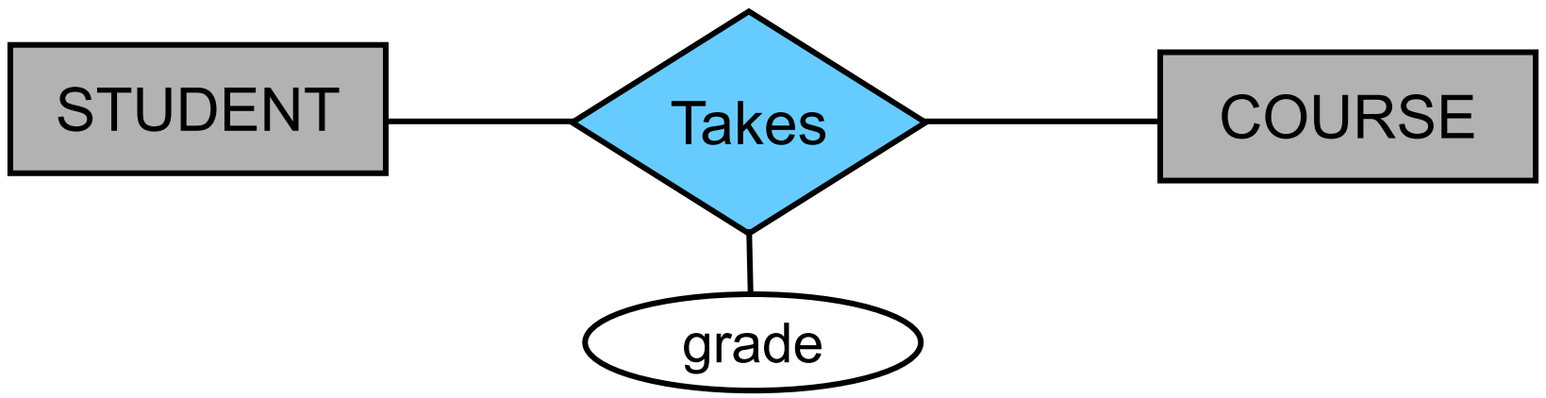
- Relationship can also have attributes (that appear only for this relationship set)
- Analogy: Verb (Takes, Belongs to, Works_On,….)

Relationship Set: Collection of relationships

- An n-ary relationship set R relates n entity sets E1 ... En; each relationship in R involves entities e1 ∈ E1, ..., en ∈ En

Representation/Syntax: a **Diamond** symbol

- Attributes represented by Oval

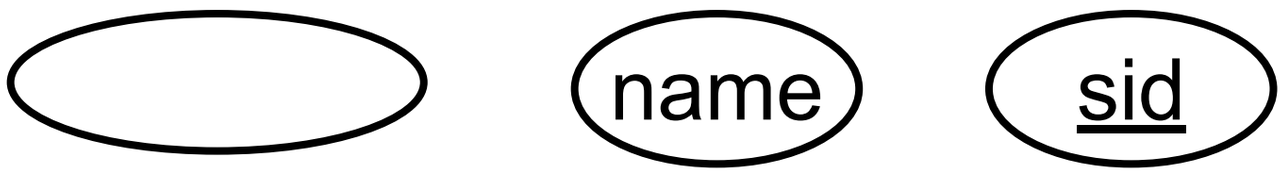


Conceptual Design Process

What are the entities being represented?

What are the relationships?

What info (attributes) do we store about each?



What keys & integrity constraints do we have?

Pet Example

A veterinary clinic wants to track information about its customers (human and animal). Pet owners have a name and account ID. Pets have a name, age, and weight. Whenever a pet comes for an appointment we must record a date, symptoms, and diagnosis.

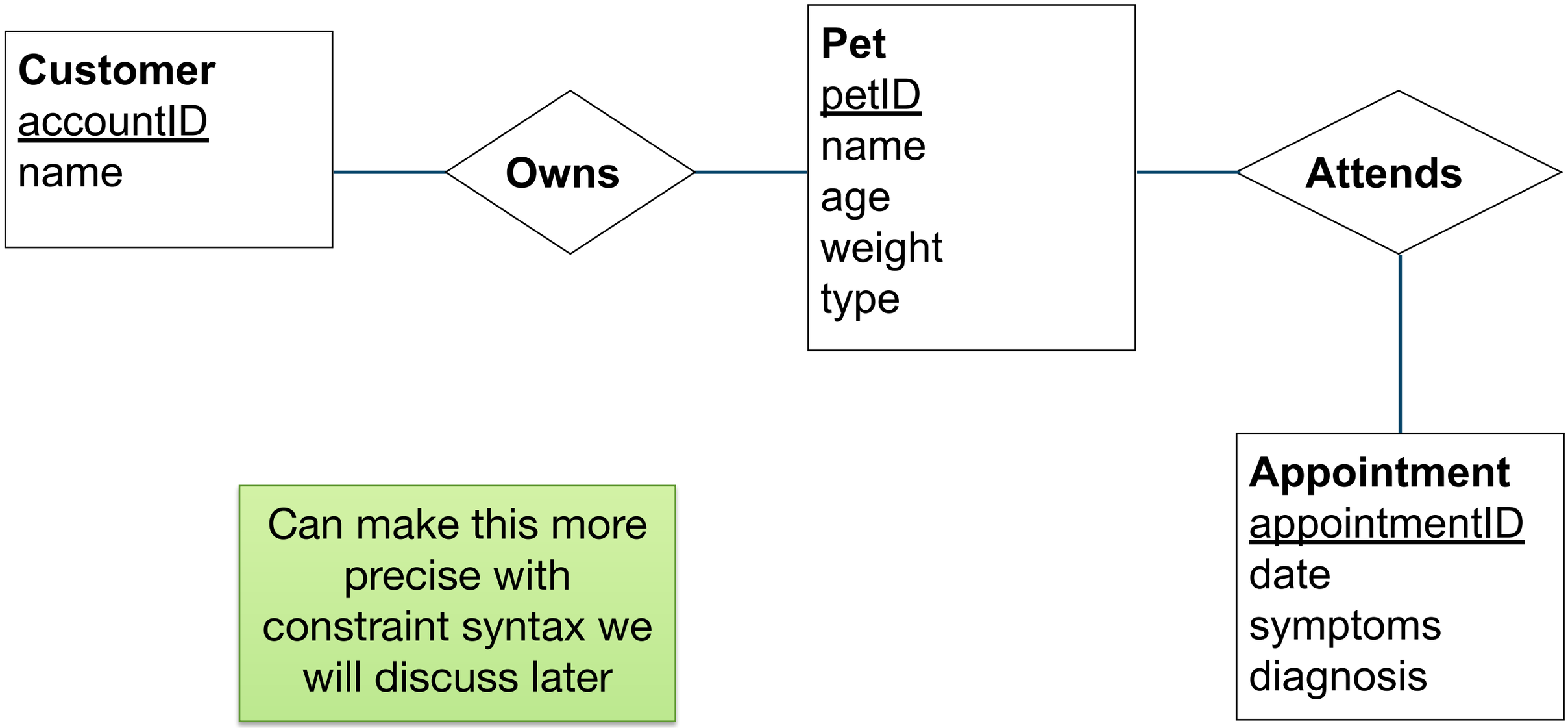
How would we draw this with ER Diagrams?

Pet Example

A veterinary clinic wants to track information about its customers (human and animal). Pet owners have a name and account ID. Pets have a name, age, and weight. Whenever a pet comes for an appointment we must record a date, symptoms, and diagnosis.

Pet Solution

A veterinary clinic wants to track information about its customers (human and animal). Pet owners have a name and account ID. Pets have a name, age, and weight. Whenever a pet comes for an appointment we must record a date, symptoms, and diagnosis.



Can make this more precise with constraint syntax we will discuss later

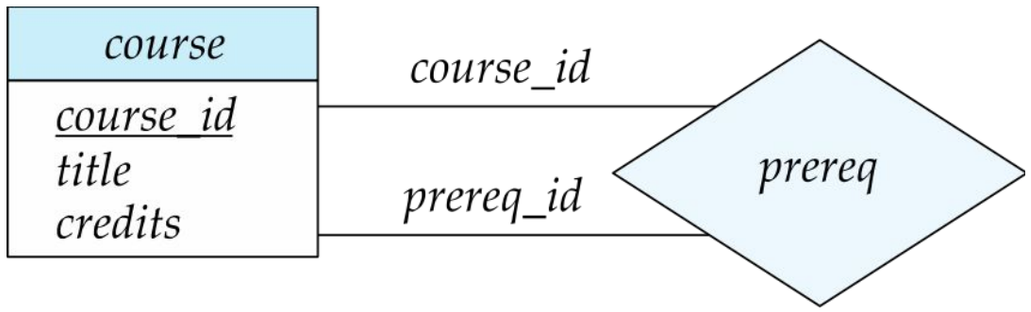
What about these?

A course has a title, ID, number of credits, and may have one or more prerequisite courses

A student is guided on a project by an instructor

What about these?

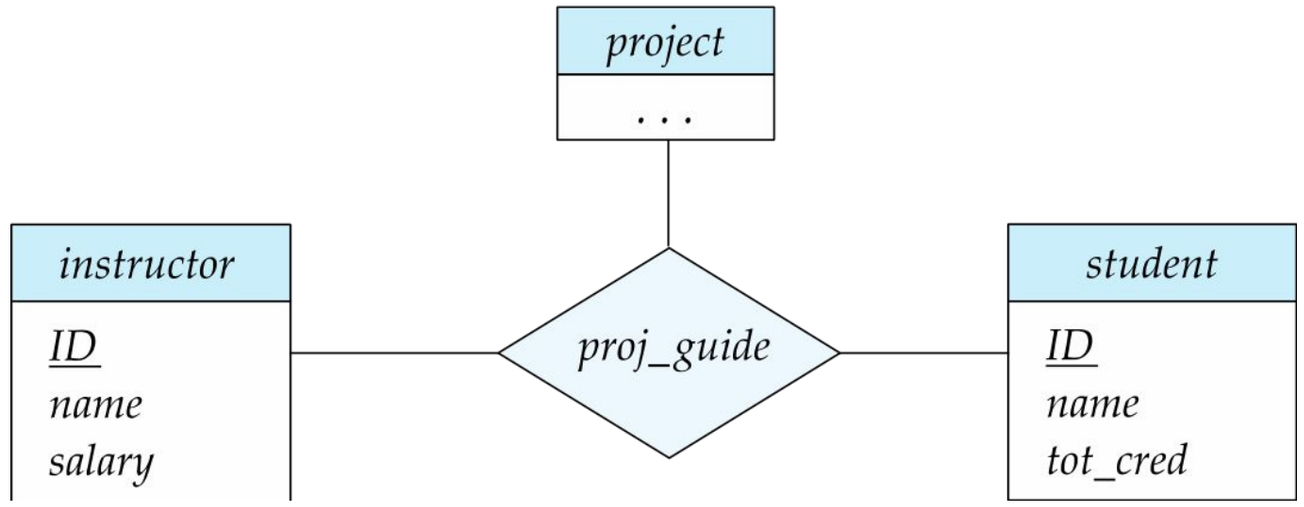
A course has a title, ID, number of credits, and may have one or more prerequisite courses



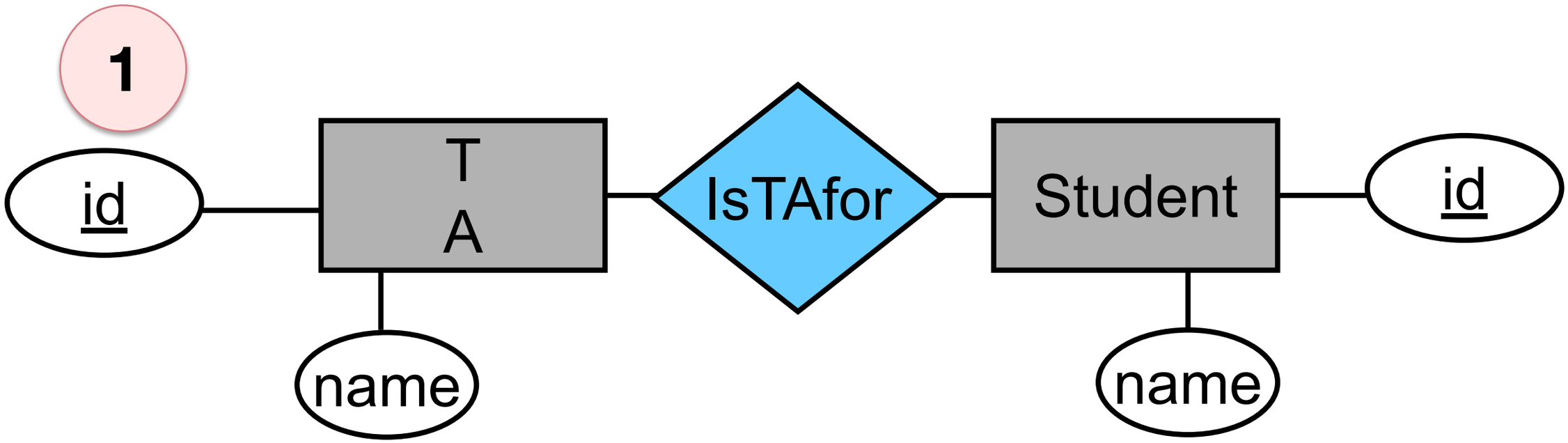
Roles can annotate a connection when a relationship links multiple of the same type of entity

A student is guided on a project by an instructor

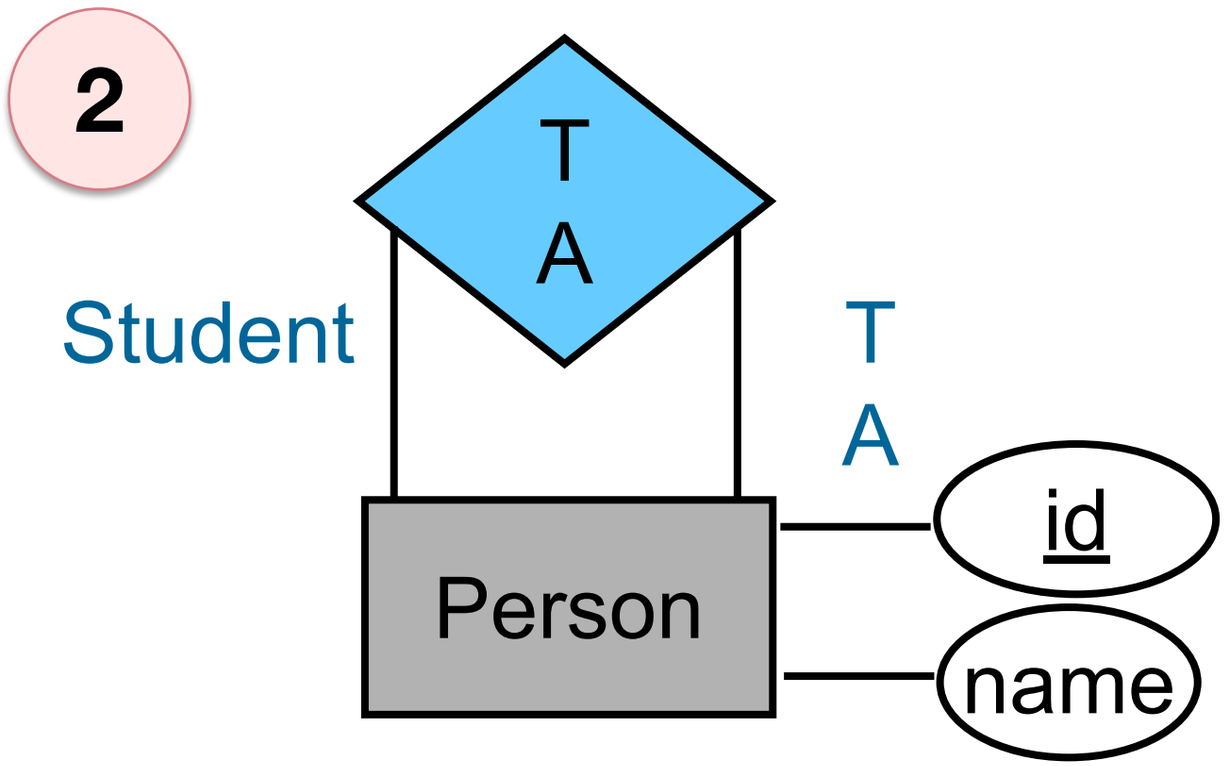
Relationships do not need to be “binary” - can link > 2 entities



Roles or Entities



Are these the same? Which is better?



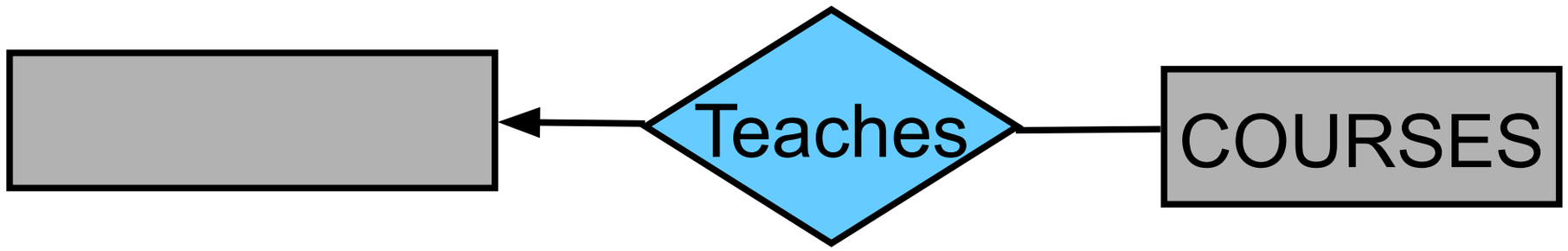
Connectivity in the E-R Diagram

Attributes can **only** be connected to entities or relationships

Entities can **only** be connected to other entities via relationships

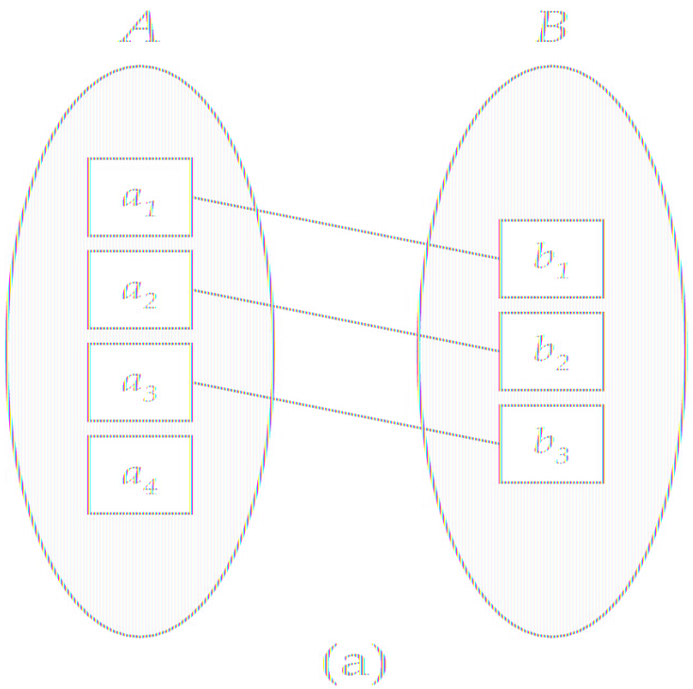
Edges represents **kinds of relationships** and **integrity constraints**

- Use arrows and cardinality annotations

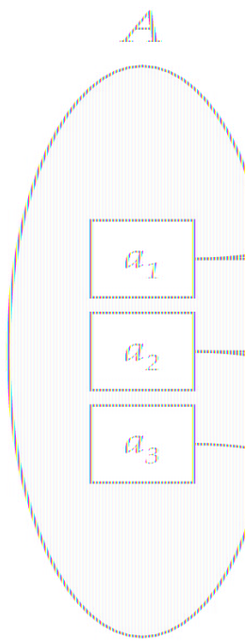


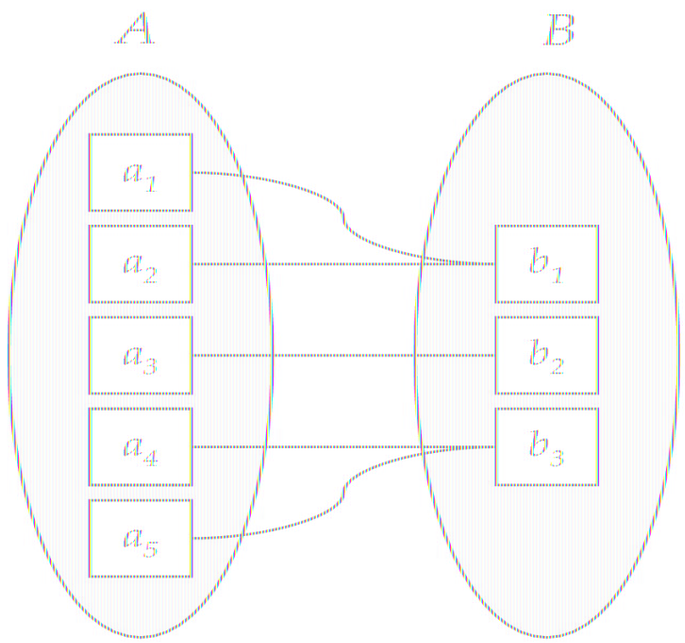
(warning: different ER implementations have slightly different notations!)

Relationship Cardinality

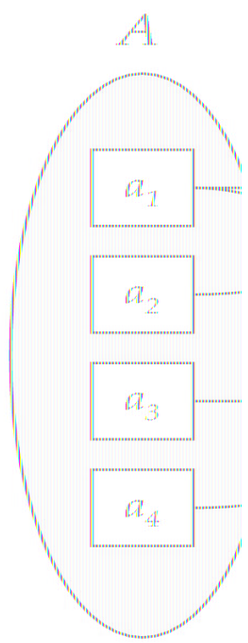


(a)





(c) (a)



(d)

Which represents…

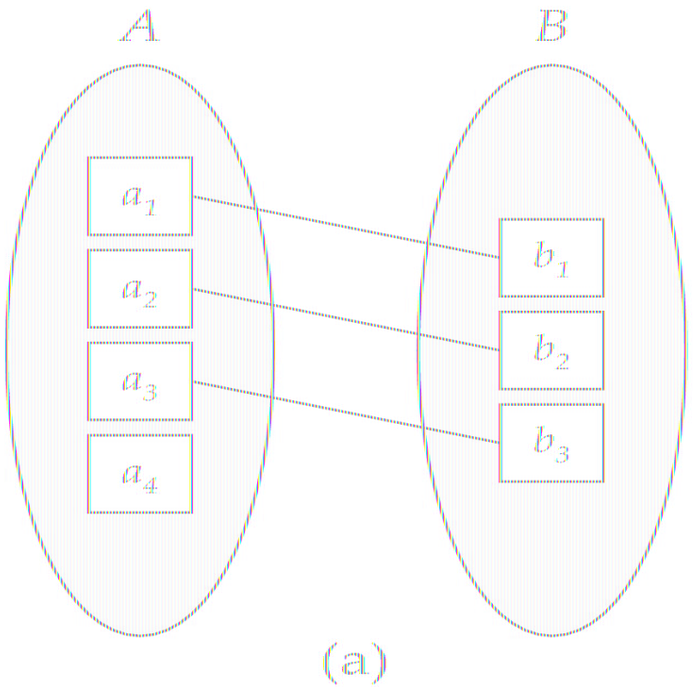
One to Many

One to One

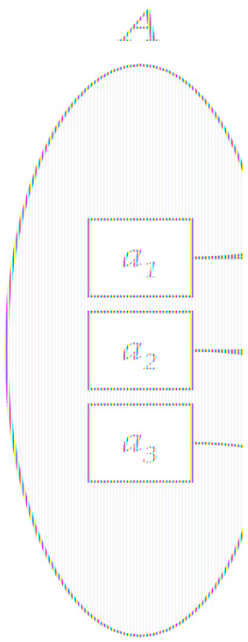
Many to One

Many to Many

Relationship Cardinality



(a)



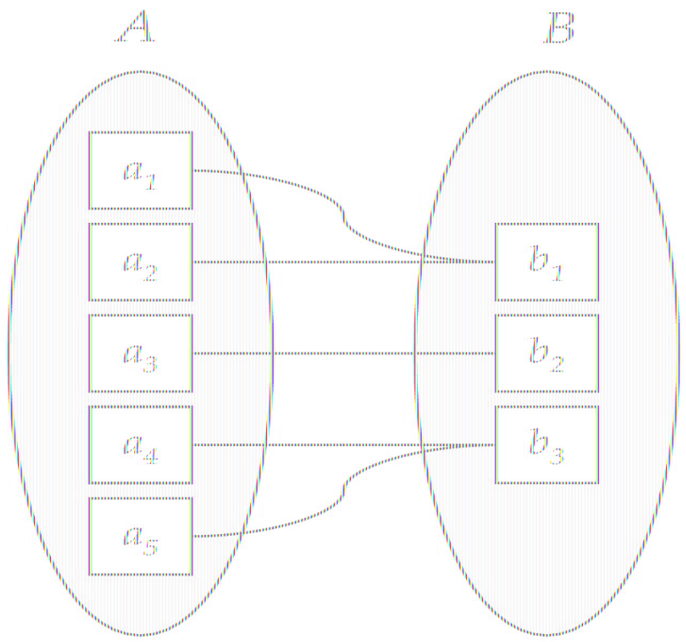
Which represents…

(b) One to Many

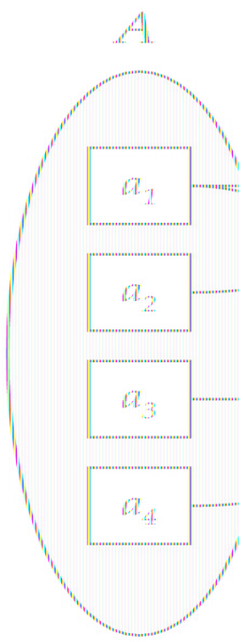
(a) One to One

(c) Many to One

(d) Many to Many



(c) (a)



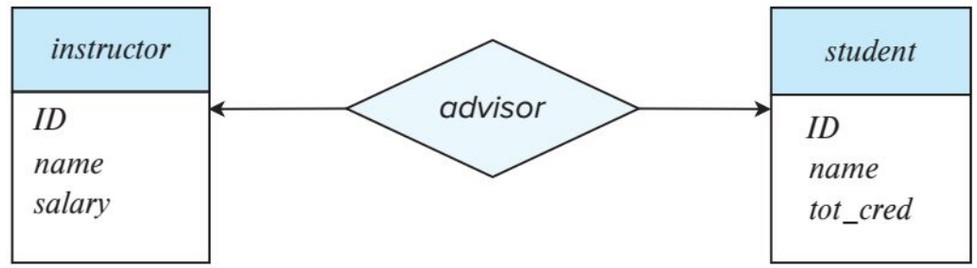
(d)

Relationship Cardinality

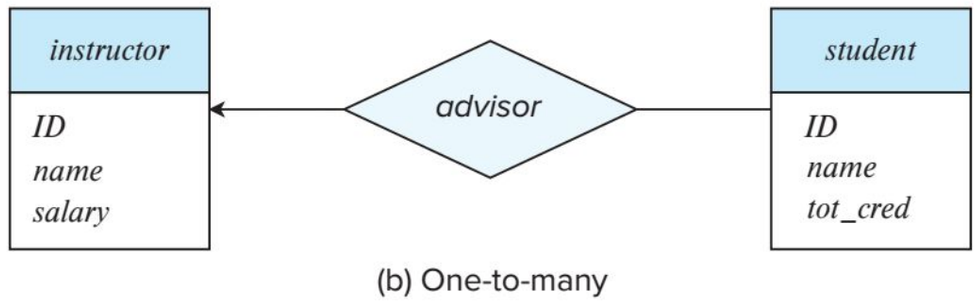
We use **arrows** in ER diagrams to indicate cardinality

- An arrow pointing to an Entity means “one” for that entity
- No arrow means “many” of that entity

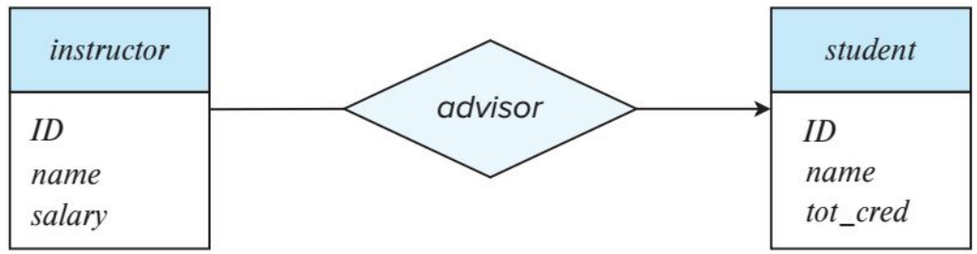
Which relationship best represents undergrad advising at GW? Why?



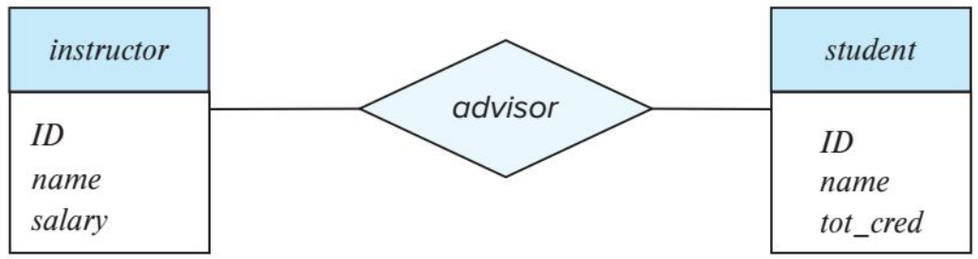
(a) One-to-one



(b) One-to-many



(c) Many-to-one

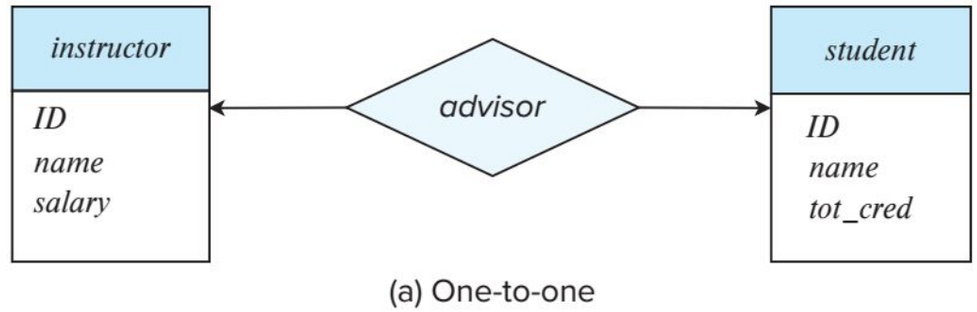


(d) Many-to-many

Relationship Cardinality

One-to-One

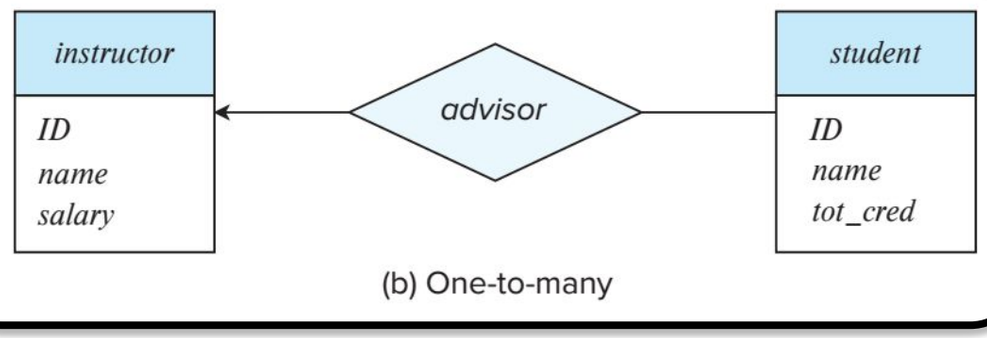
- An instructor can only advise one student and a student can only have one advisor



(a) One-to-one

One-to-Many

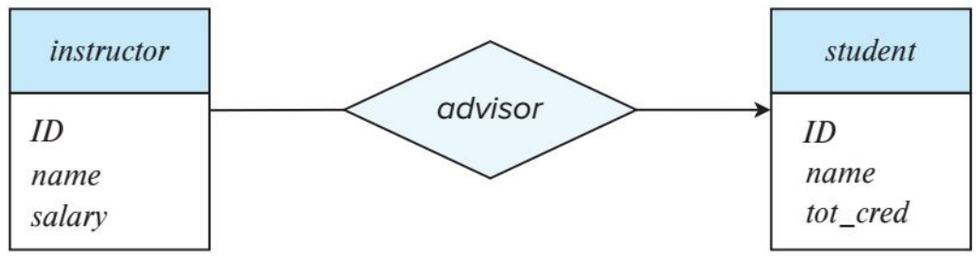
- An instructor can advise many students, but each student only has one advisor



(b) One-to-many

Many-to-One

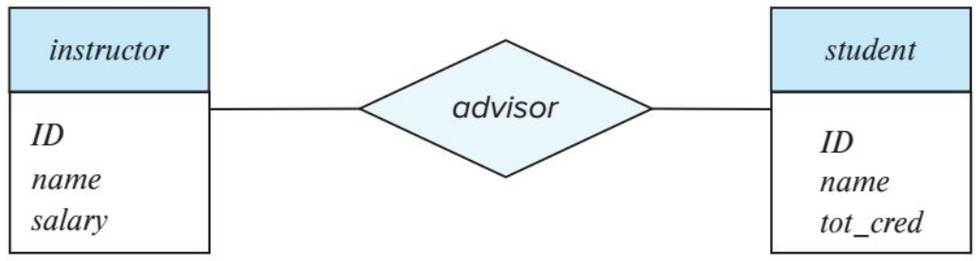
- An instructor can only advise one student, but each student can have many advisors



(c) Many-to-one

Many-to-Many

- An instructor can advise many students and each student can have multiple advisors



(d) Many-to-many

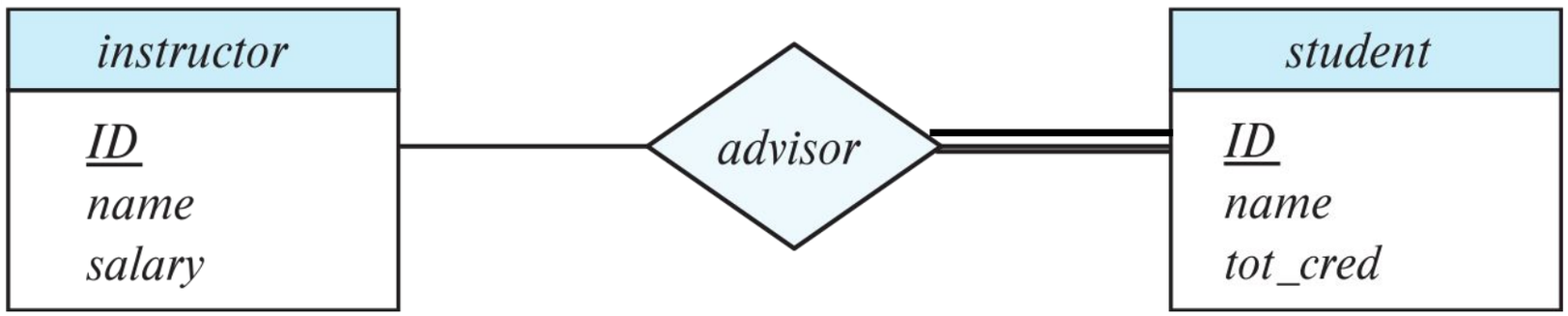
Participation Constraints

Cardinality constraints are upper bound limits

- Limits the maximum number of entities referenced by a relation

Participation Constraints

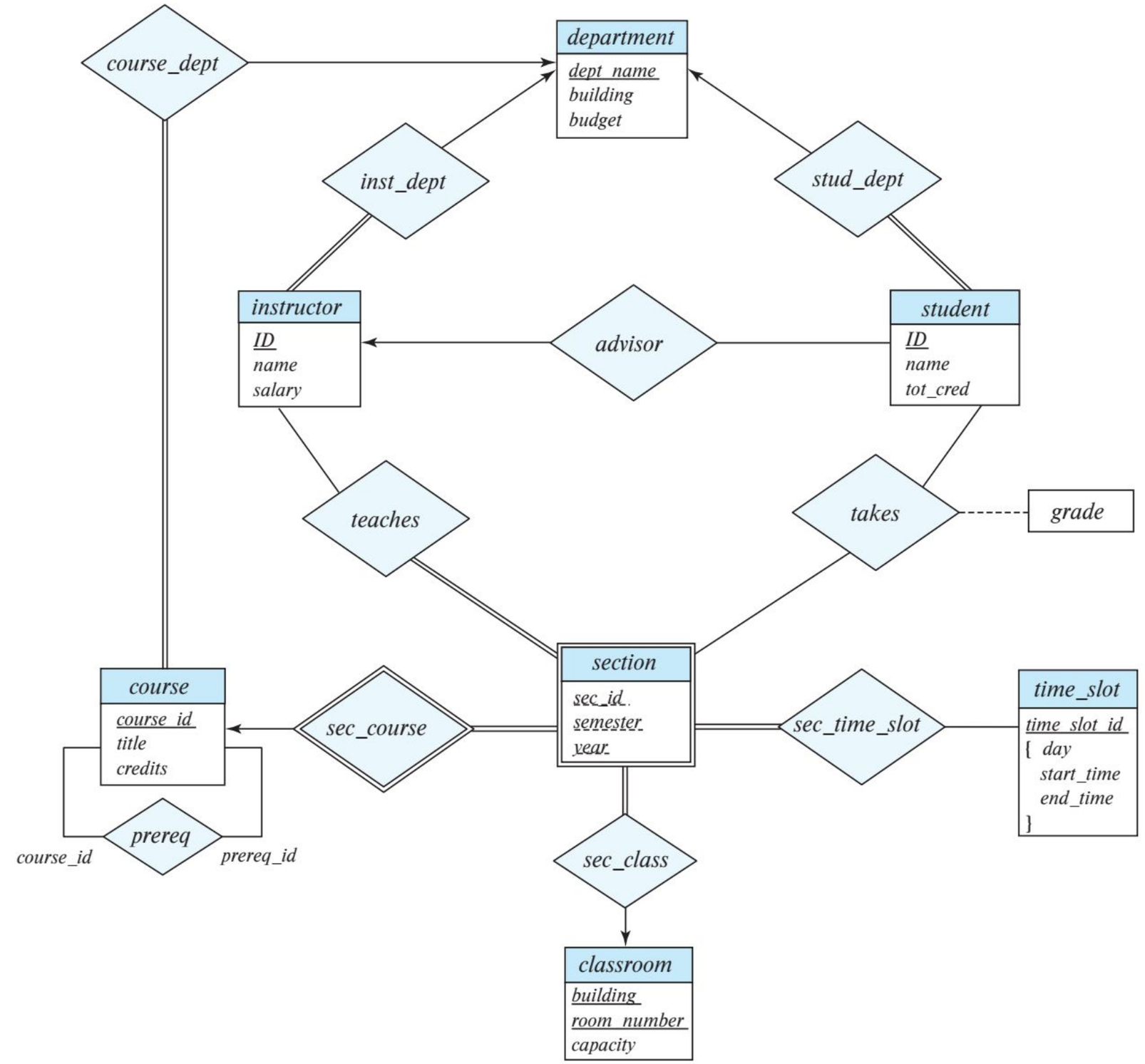
- **Total participation**: all elements from an Entity Set must appear in the Relationship Set (Syntax: double line)
  - Example: “Every student needs an advisor” -> Total participation of Student and Advisor relation
- **Partial participation**: relationship is optional (Syntax: single line)
  - Example: “Not all instructors advise students”



Complete ER University

Making an ER diagram can…

- Help you understand what constraints are important
- Eliminate redundant data fields across Entities
- Think about important edge cases



From ER to SQL

Once we have an ER model, we can transform it into a SQL (or other) format

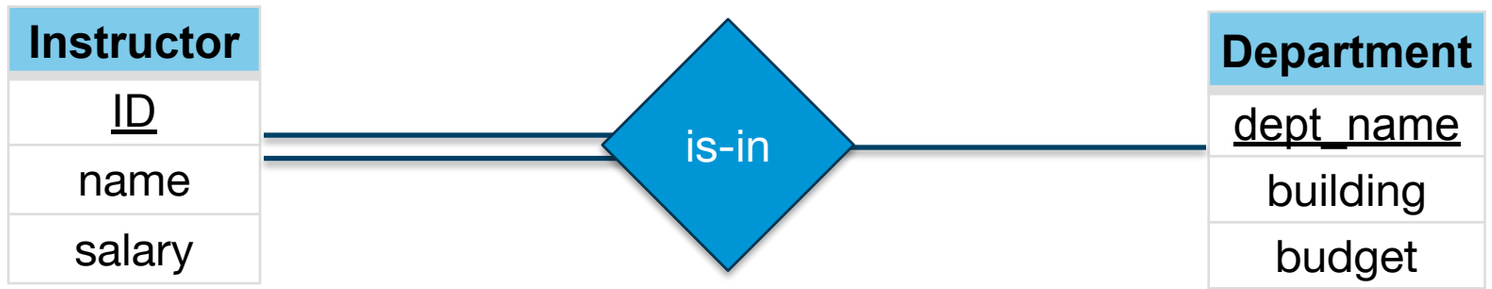
- ER gives us a principled way to define our SQL schema

Relationships map to tables and/or foreign key constraints

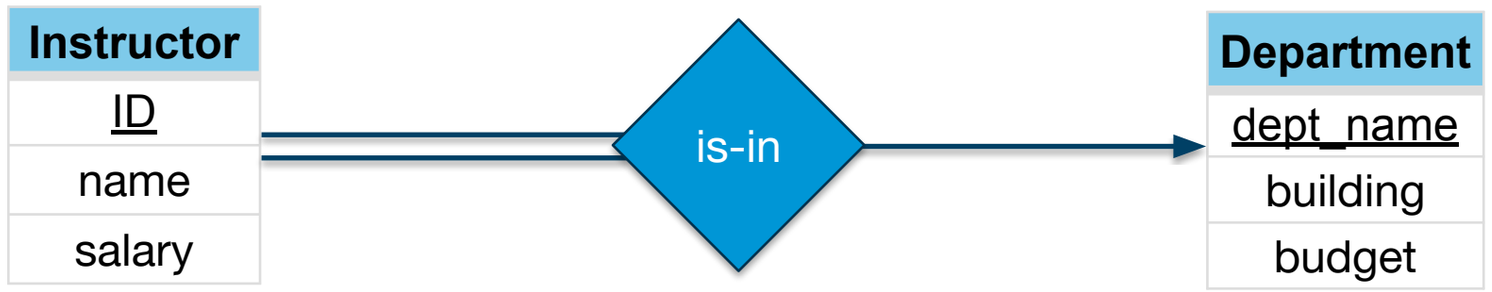
- Simplest approach is every Entity and every Relationship becomes a new Table in SQL
- But *-1 relationships can then be merged with another table, eliminating redundancy

Instructors and Departments

TOP



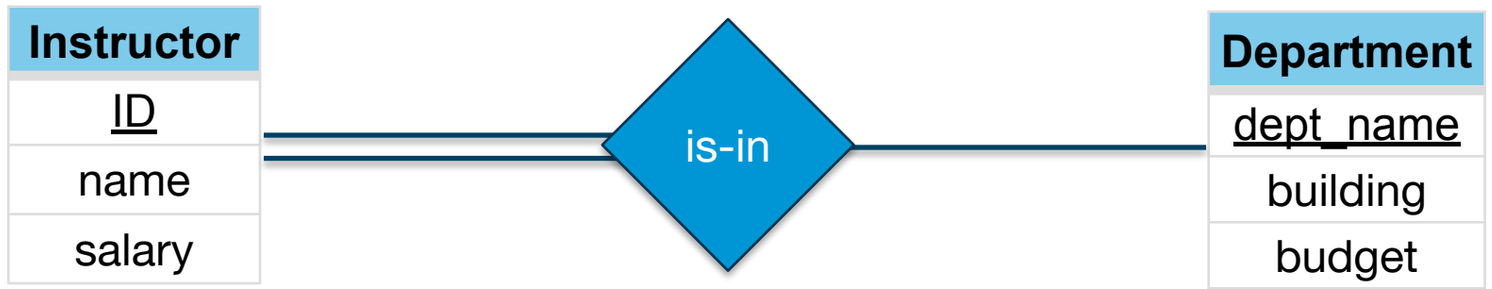
BOTTOM



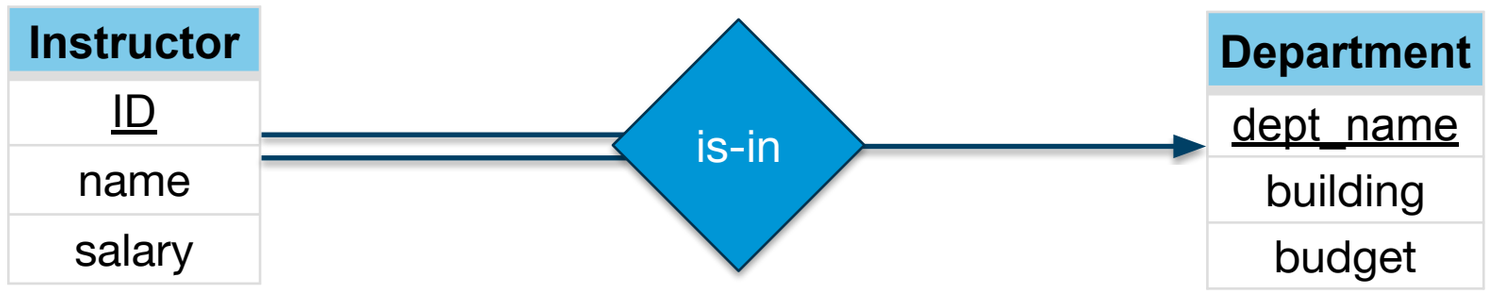
What do each of these mean?

Instructors and Departments

TOP



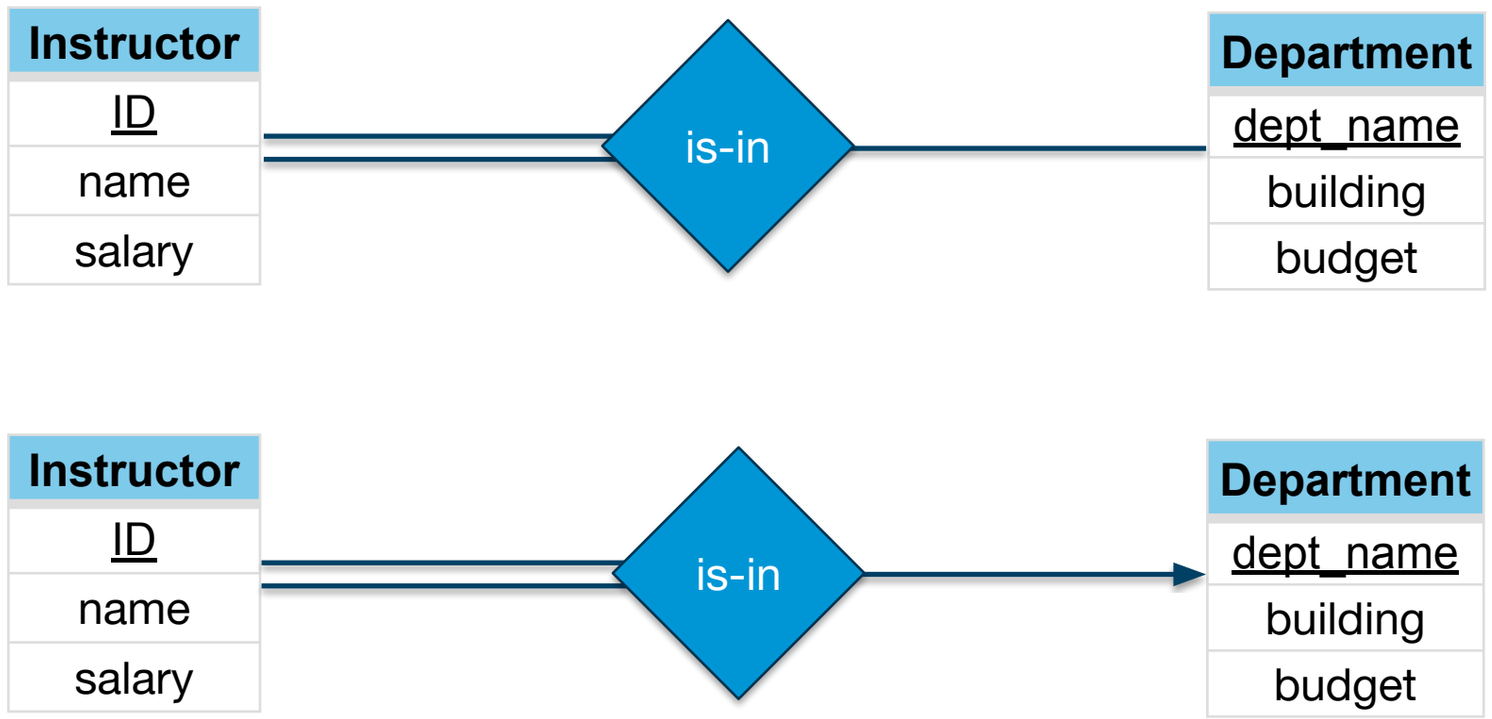
BOTTOM



TOP: Every instructor is in at least one department

BOTTOM: Every instructor is in one department

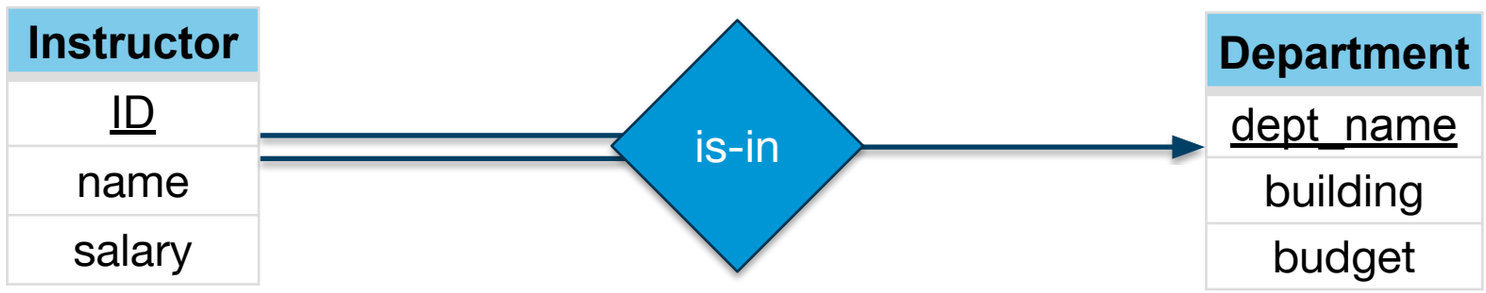
Instructors and Departments



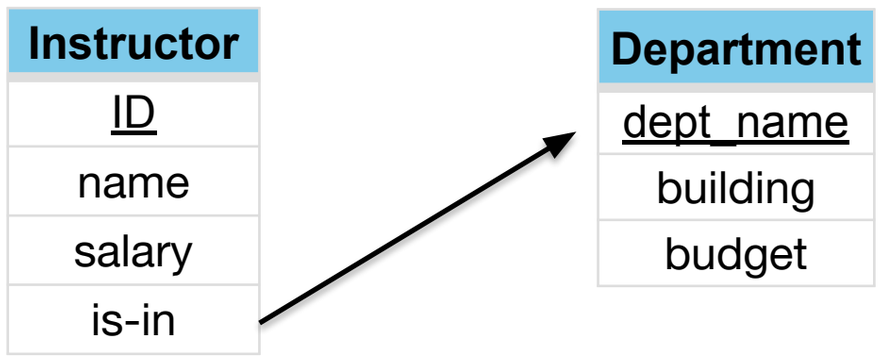
How would you implement each of these in SQL?

Many to One Relations

BOTTOM



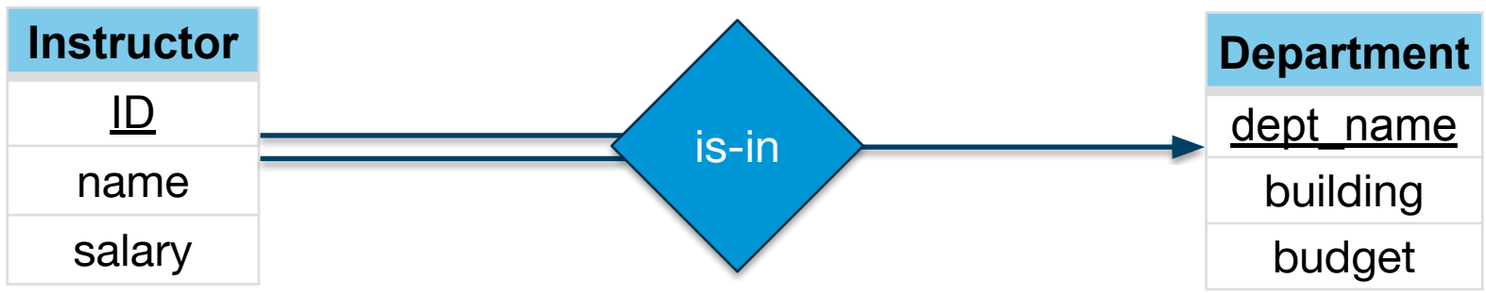
Foreign keys easily represent Many to One relations



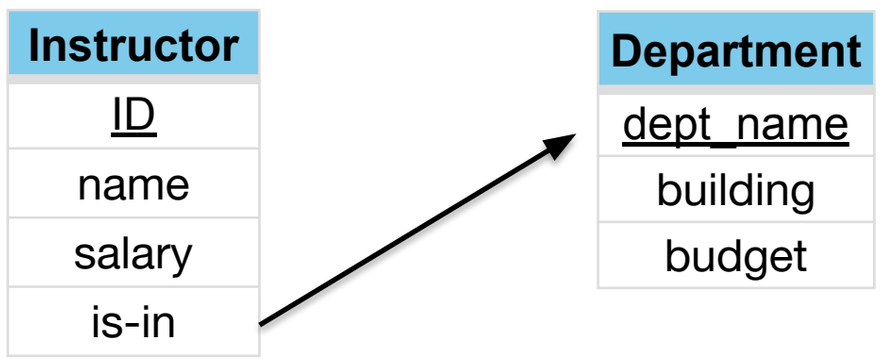
What else do we need for this ER?

Many to One Relations

BOTTOM



Foreign keys easily represent X to One relations



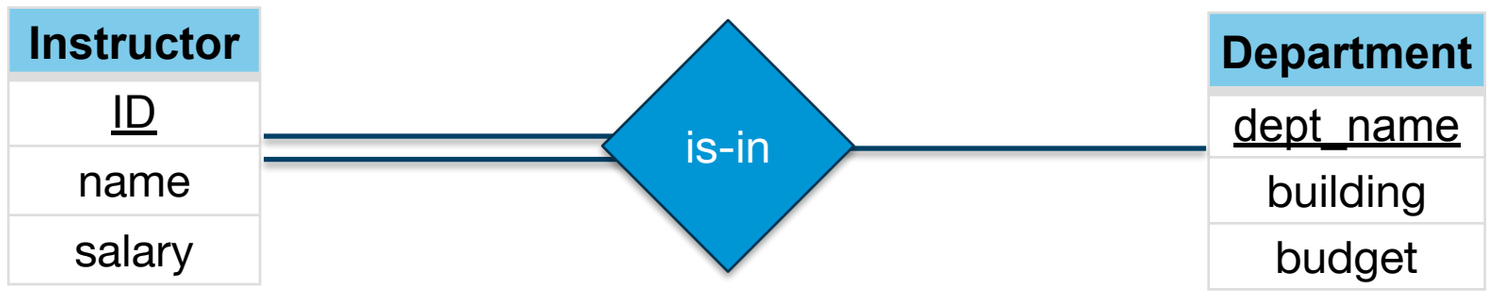

```
CREATE TABLE Instructor (
  ID INTEGER PRIMARY KEY AUTOINCREMENT,
  name VARCHAR(40),
  salary INTEGER,
  in_dept VARCHAR(40) NOT NULL,
  FOREIGN KEY (in_dept) REFERENCES
    Department(dept_name)
);
CREATE TABLE Department (
  dept_name VARCHAR(4),
  building  VARCHAR(4),
  budget INTEGER
);
```

What else do we need?

- NOT NULL enforces Total Participation

Many to Many Relations

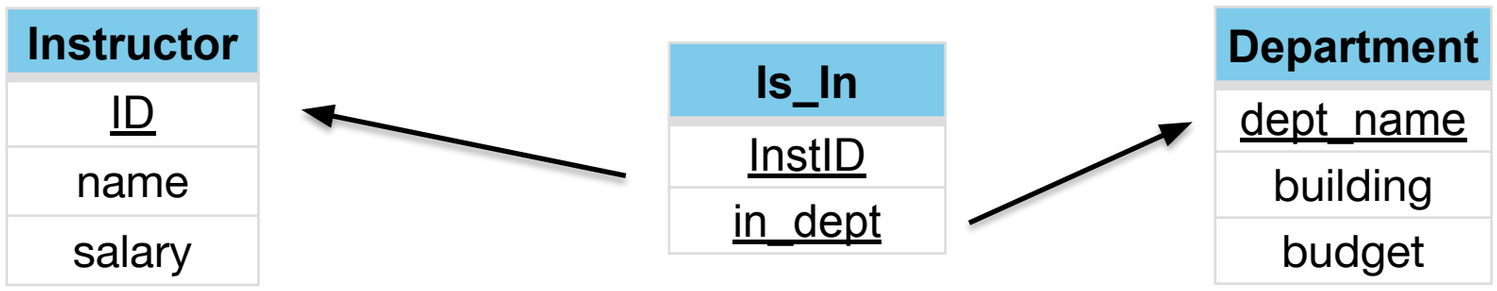
TOP



Using a foreign key is too restrictive

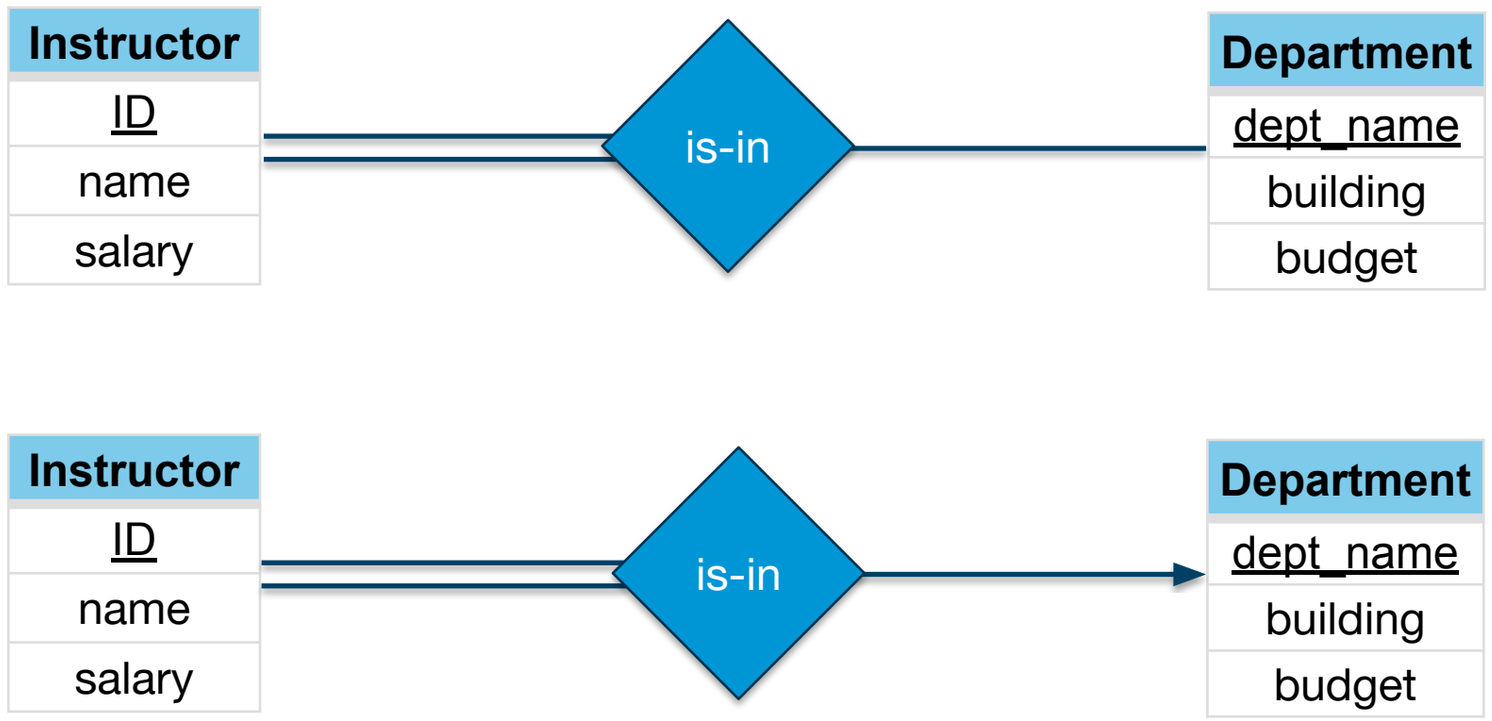
- Couldn't have an Instructor in multiple departments

Instead we will need a 3rd table to connect



Not possible to enforce total participation

Instructors and Departments



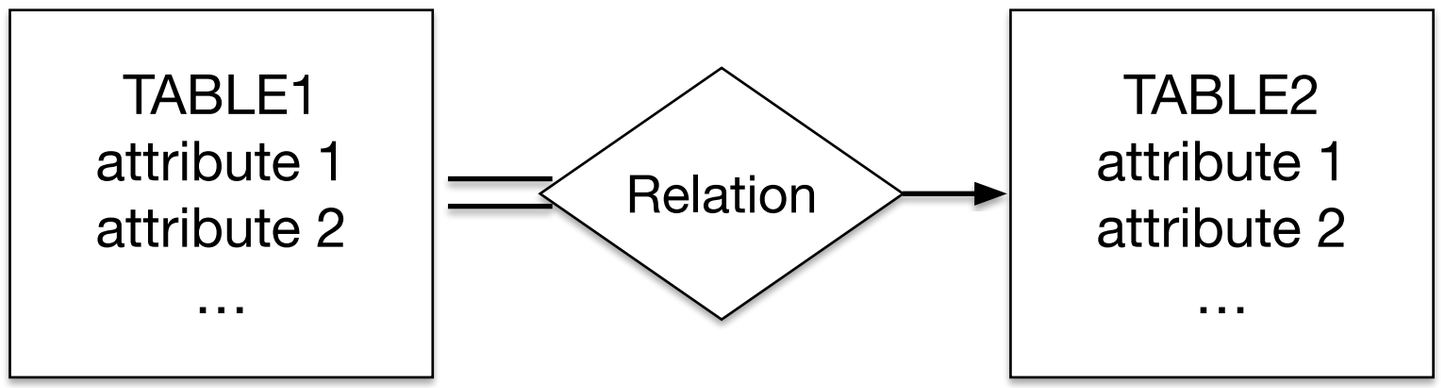
TOP: We would need a third table that would connect each instructor to one or more departments

BOTTOM: We could add dept_name as a foreign key in Instructor

Exercise

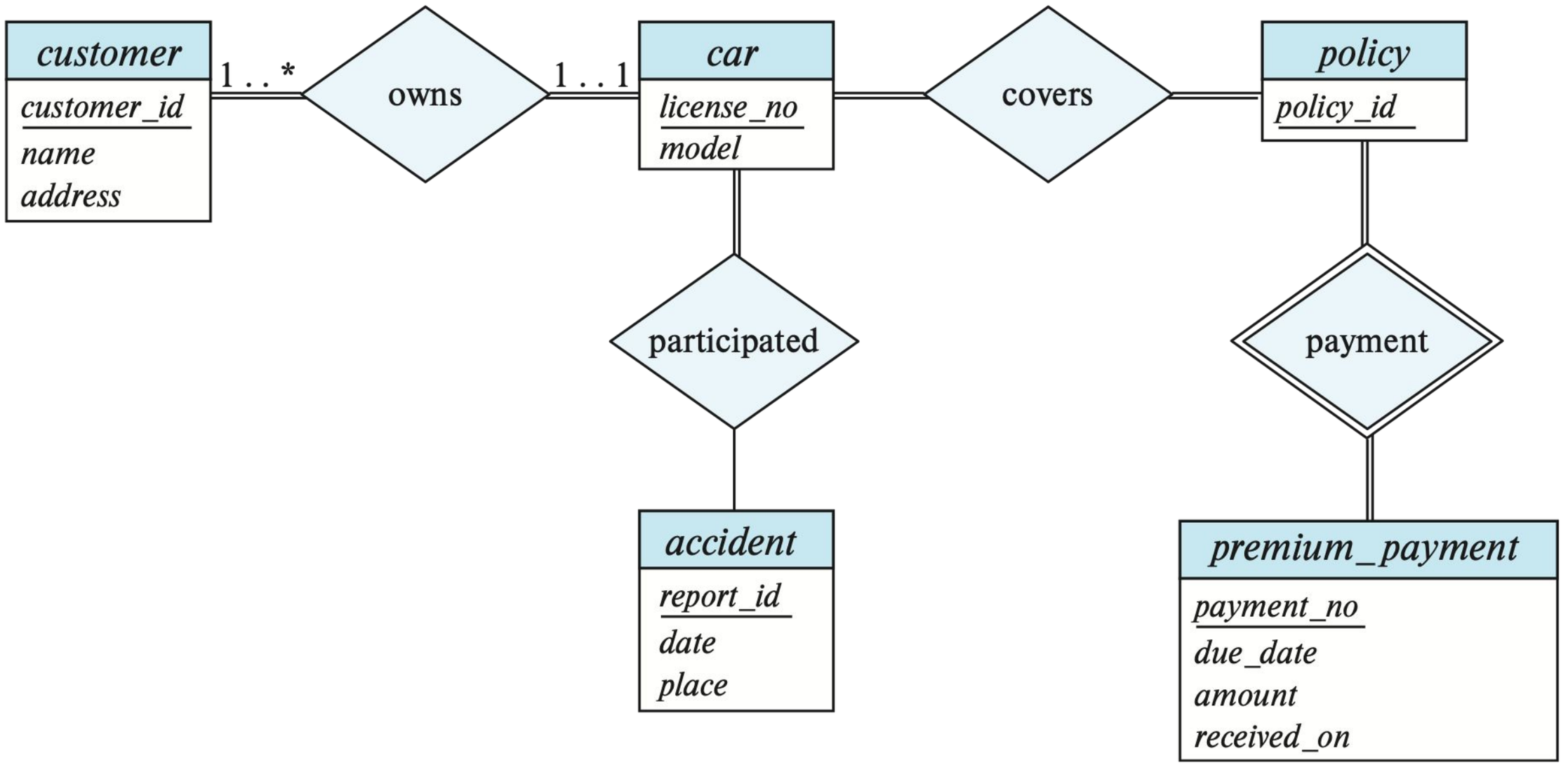
Design an ER diagram for a car insurance company whose customers own one or more cars each. Each car may be associated with a recorded accident. Each insurance policy covers one or more cars and has one or more premium payments associated with it. Each payment is for a particular time period and has an associated due date, and the date when the payment was received.

Sample Syntax



Exercise Sample Answer

Note: this uses some extra syntax / annotations we haven't discussed



Summary - Conceptual Design

E-R model defines a formal approach for translating business requirements into a data model

Helps identify redundant information and the appropriate ways to link entities

After ER, still need to translate into a DBMS implementation

How can we judge goodness?

Final Phase: Moving from an abstract data model to the implementation of the database

- **1. Logical Design** – Deciding on a "good" collection of schemas
  - **Business decision** – What attributes should we record in the database?
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- **2. Physical Design** – Deciding on the physical layout of the database
  - The DBMS will do some of this for us
  - But we can control things like how indexes are generated to optimize frequent data lookups (later)