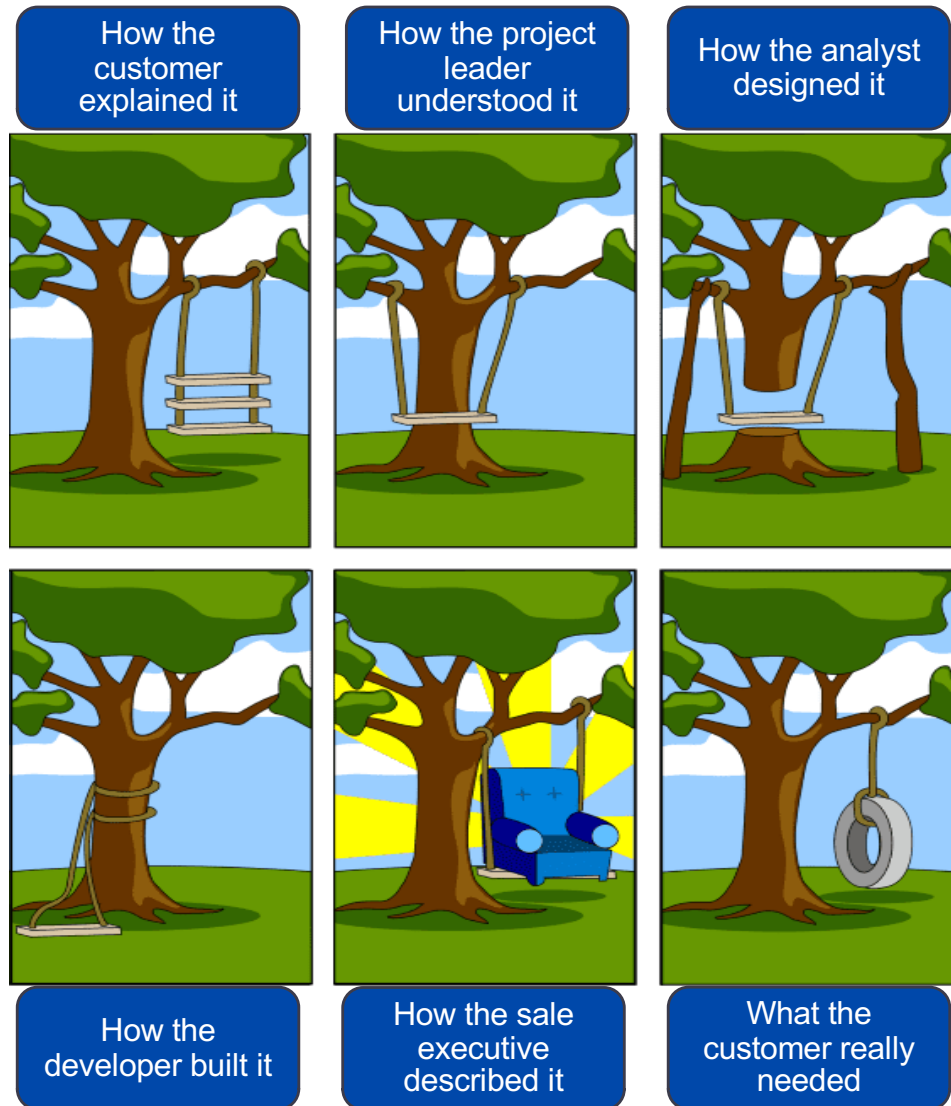# Entity-Relationship (ER) Model

CS 4750
Database Systems

[A. Silberschatz, H. F. Korth, S. Sudarshan, Database System Concepts, Ch.6]
[C.M. Ricardo and S.D. Urban, Database Illuminated, Ch.3]

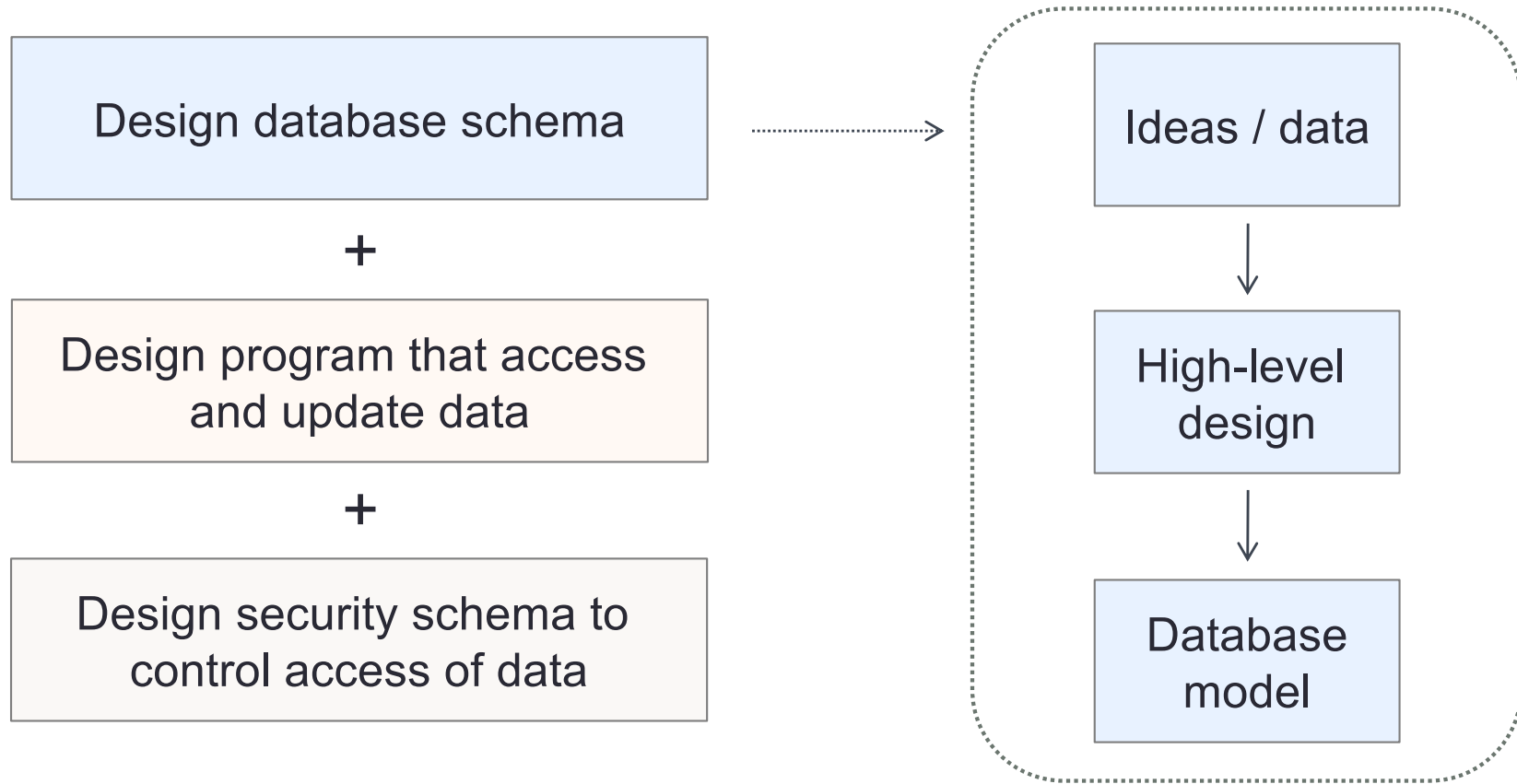# I've Got Great Ideas for An App

- In database design, communication is key

- Many people are involved in the design process

We need a way to communicate our ideas

[modified from image by Janetti, https://www.cleanpng.com/png-project-management-project-manager-architectural-e-5729993/download-png.html]

Overview: Creating DB App

Design database schema

+

Design program that access and update data

+

Design security schema to control access of data

→

Ideas / data

↓

High-level design

↓

Database model

Database design = process of organizing data into a database model by considering data to be stored and the interrelationship of the data

Database Design Process

Interact with users and domain experts to characterize the data

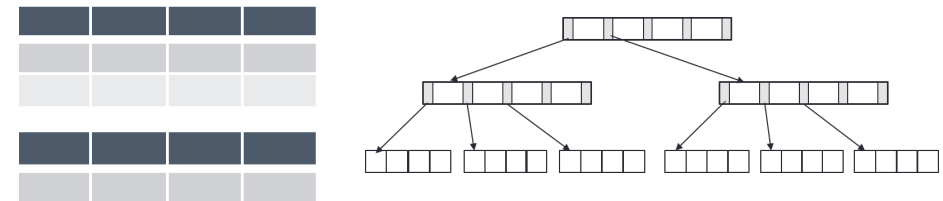Translate requirements into conceptual model (E-R diagrams)
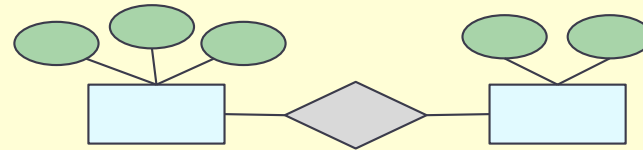
Convert the model to relational model (schema and constraints)

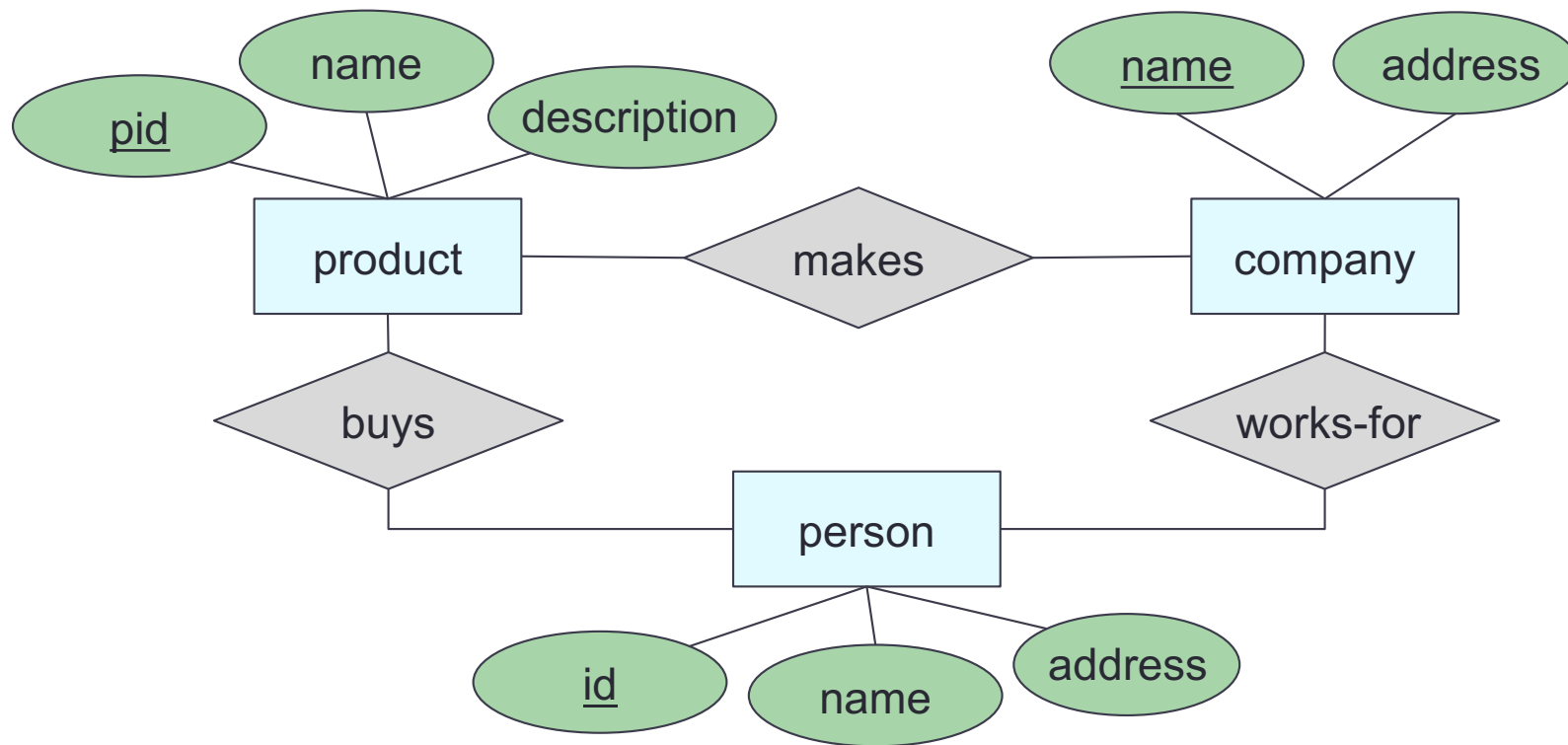Normalize and develop conceptual (logical) schema of the database

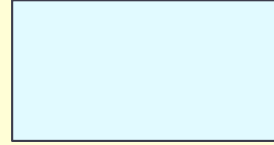Develop physical schema (partitioning and indexing)

Entity-Relationship Model

- **E-R diagram** – high-level design model representing a database as a collection of entities and relationships among entities
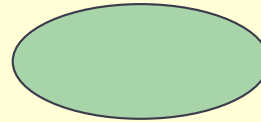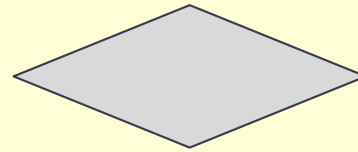
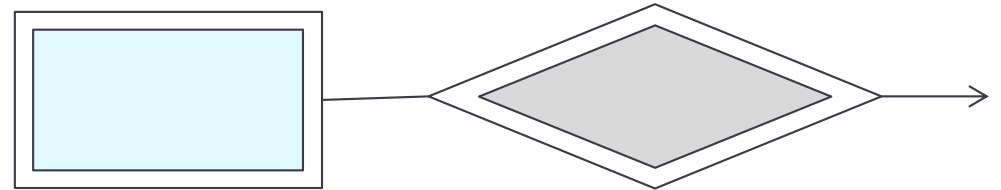# E-R Diagram: Building Blocks

(strong) Entity set

Attribute

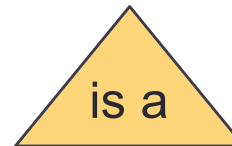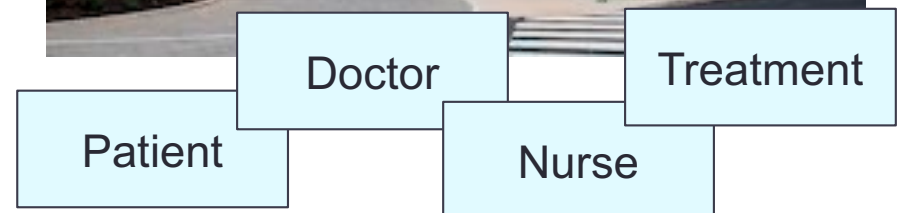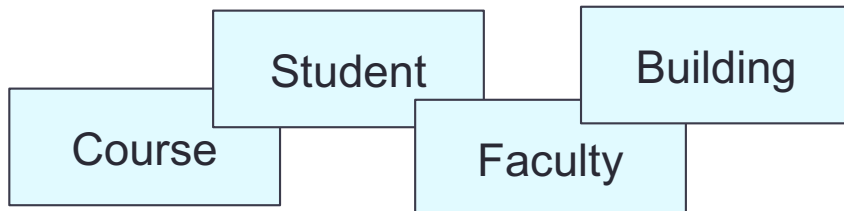Relationship

Weak entity

Subclass

is a

Note: colors are not part of E-R Diagram. They simply are used to increase readability.
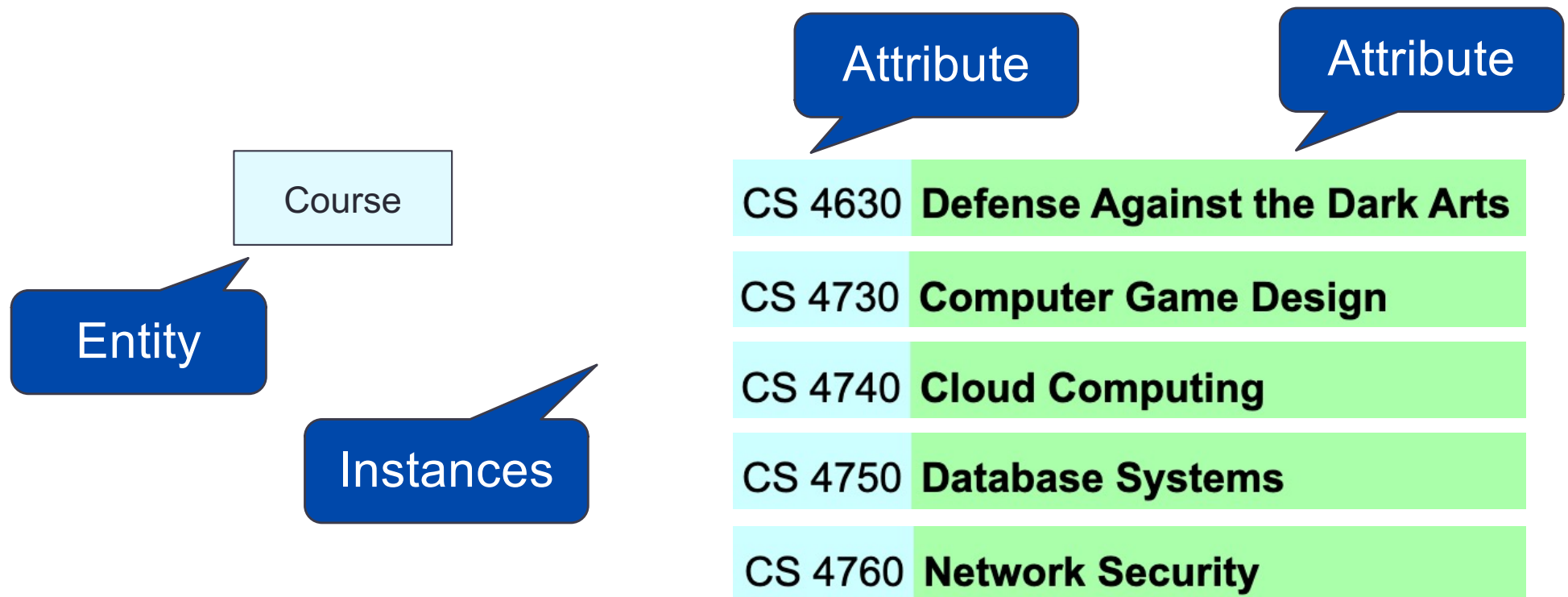
Entity and Entity Sets

- **Entity** ~an object (thing to keep track to run the business)
- **Entity set** ~a class (~table, a collection of things of the same kind)

Some entity set examples

Student
Building
Course
Faculty

Doctor
Treatment
Patient
Nurse

Entity – Instance – Attributes

- **Entity** ~an object (thing to keep track to run the business)
- **Instance** ~actual occurrence of the entity (~row in a table)
- **Attribute** ~ a field (property of the entities in that set)

Attribute

Attribute

Course

Entity

Instances

CS 4630	**Defense Against the Dark Arts**
CS 4730	**Computer Game Design**
CS 4740	**Cloud Computing**
CS 4750	**Database Systems**
CS 4760	**Network Security**

Note: instances do not exist in E-R. The term is mentioned here for completeness. It will be revisited when we discuss data model.

Entity Sets and Attributes

Every entity set should have a primary key

An entity is an object that is distinguishable from other types of objects

person

id   name   address

Underline indicates that the attribute is part of the primary key

An attribute has domain specifying acceptable values
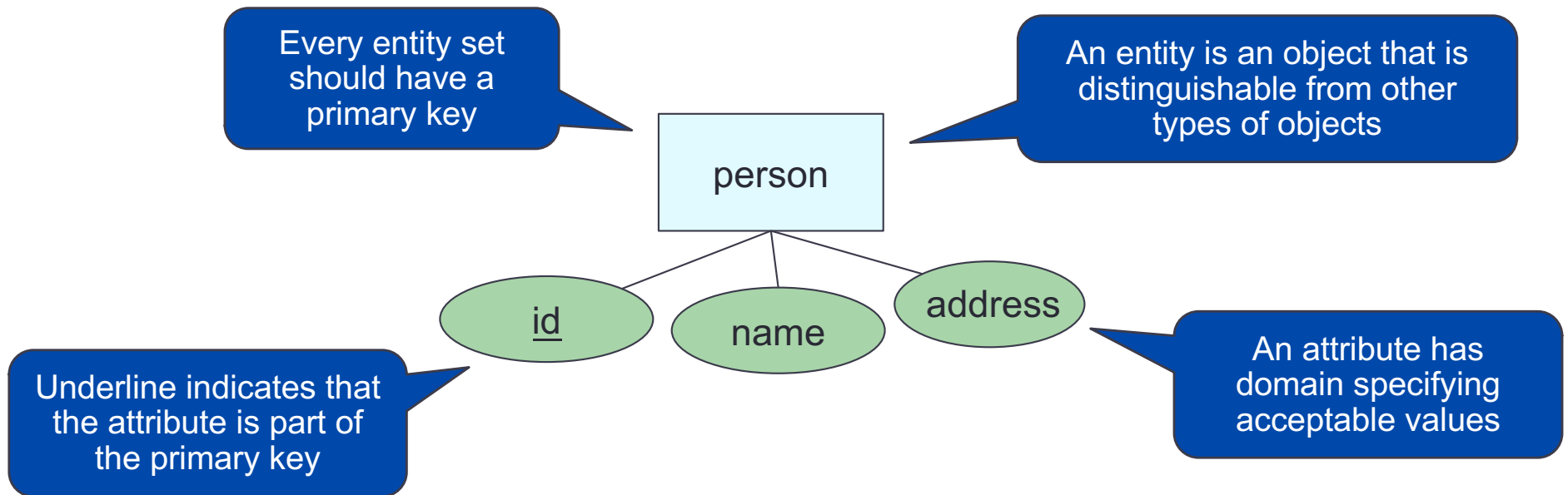
E-R model is a static concept, involving the structure of data and not the operations on data.
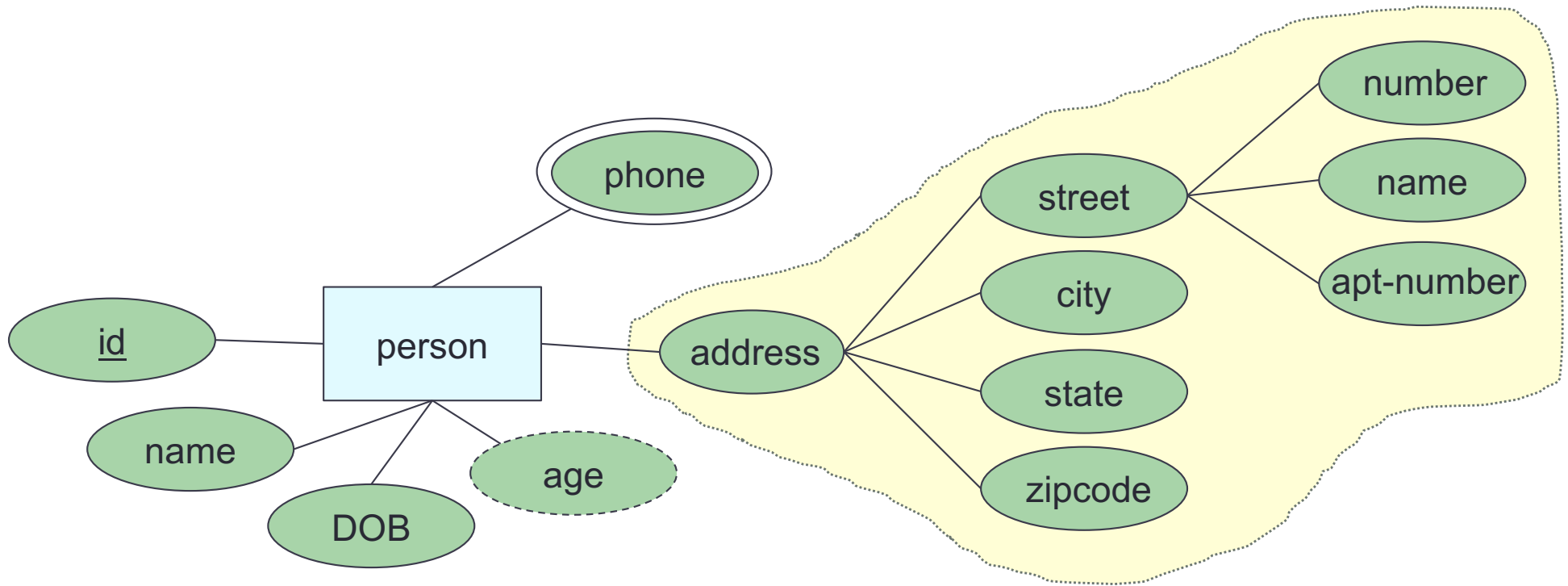Thus, no methods associated with an entity set

Attributes

- **Single-valued attribute** – allows a single value
- **Multi-valued attribute** – allows multiple values at the same time
- **Derived attribute** –can be calculated from one or more attributes
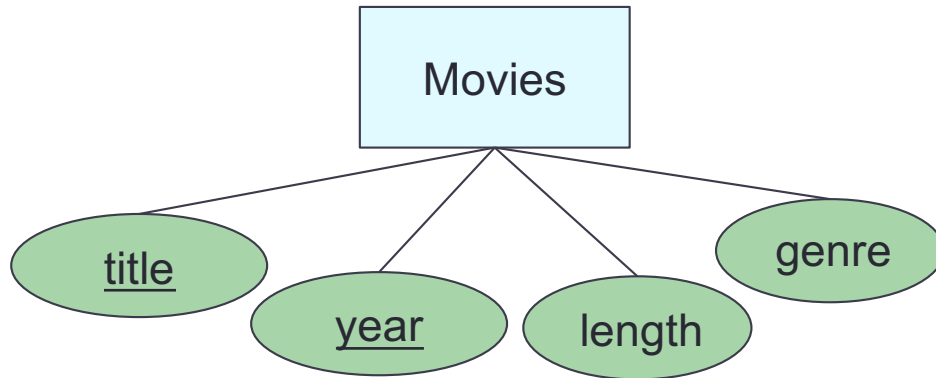- **Composite attribute** – consists of multiple values
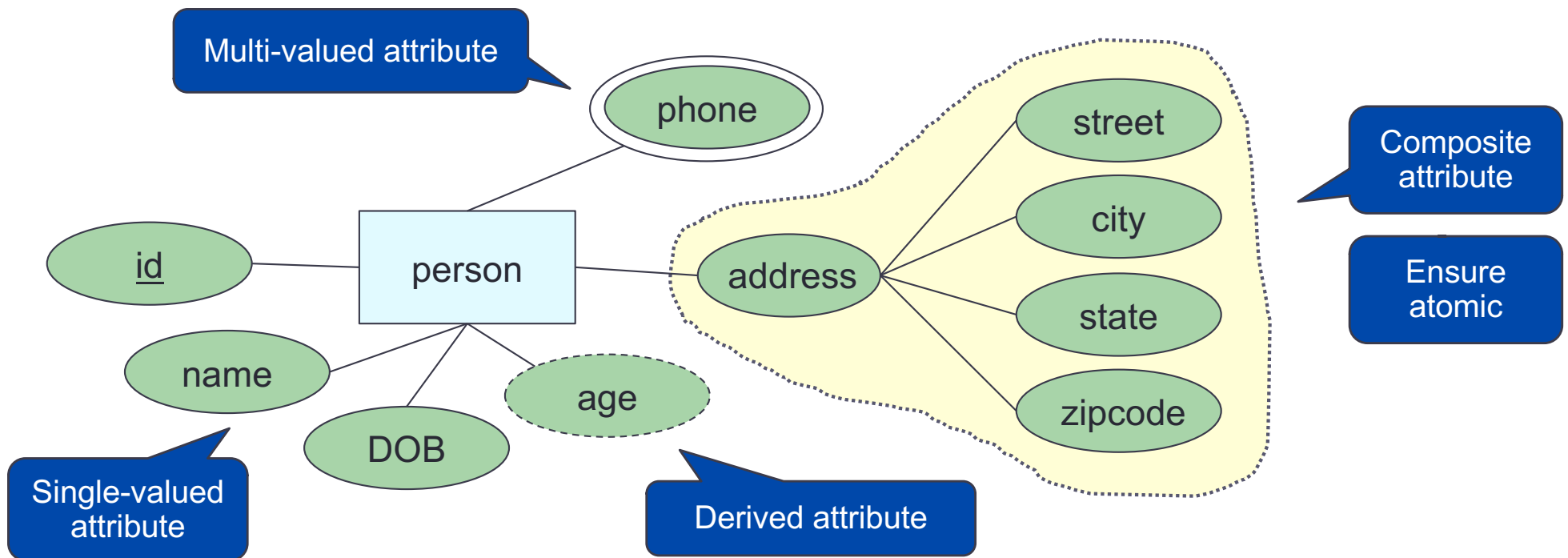
Attributes

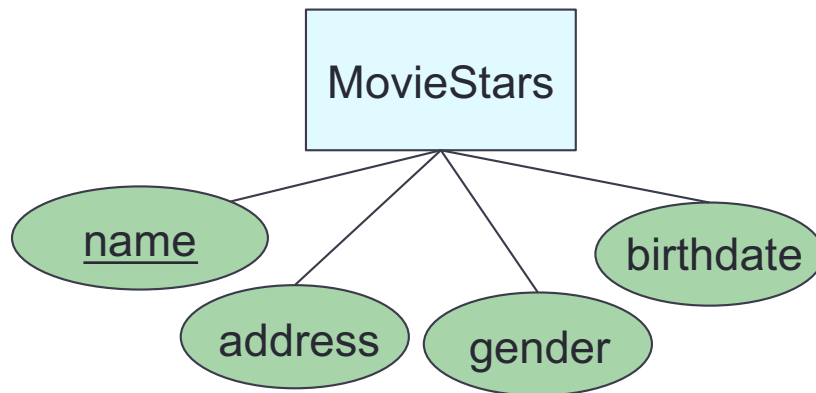- **Composite attribute** – can have as many levels as needed

Let's try: Movie-Database

Movies

Title	Year	Length	Genre
Mickey's Club House	1939	231	drama
Awesome Minnie	1977	124	sciFi
Most wanted	1992	95	comedy

MovieStars

name	address	gender	birthdate
Mickey	11 Somewhere, Charlottesville, VA, 22903	F	01/01/1911
Minnie	22 Another place, Fairfax, VA, 22030	M	02/02/1912
Donald	33 Nowhere, Charlottesville, 22911	F	03/03/1913

Note: instances do not exist in E-R. These tables are only to help visualize the database being designed.

Note: Instances of E-R Diagram

E-R model is used to design a database. The database is not implemented. Therefore, the instance of E-R diagram never exists in the sense that a relation's instances exist in a relational model.

However, it is often useful to visualize the database being designed as if it existed.
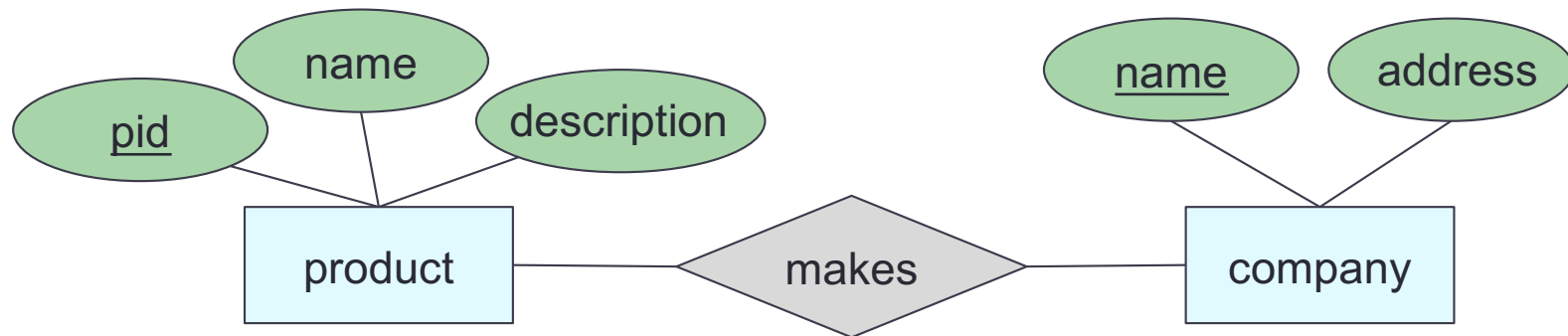
Relationships

- Connections among two or more entity sets

- **Binary relationships** – connections between two entity sets

- **Multi-way relationships** (**u-ary**) – connections involving more than two entity sets

Binary Relationships

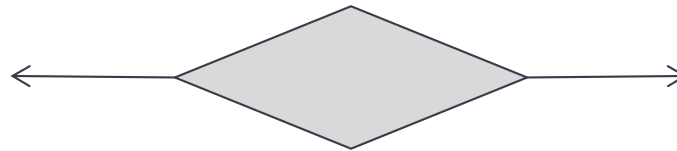If *A* and *B* are sets, a relationship *R* is a subset of *A X B*

Note: instances do not exist in E-R. These tables are only to help visualize the database being designed.
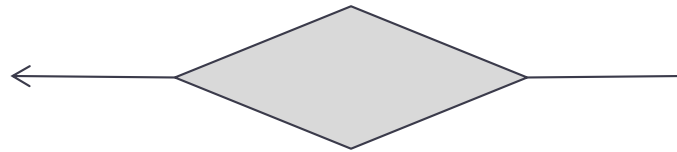
Cardinality (or Multiplicity)

A binary relationship can connect any member of one of its entity sets to any number of members of the other entity set
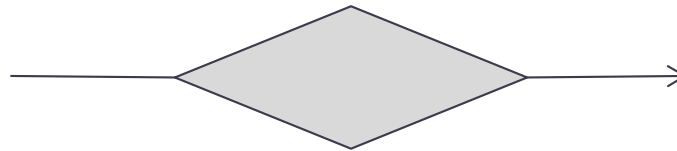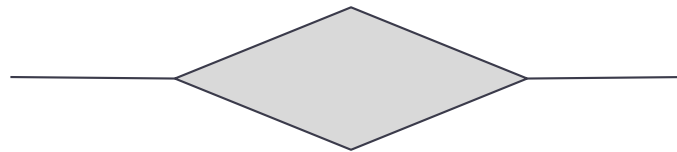
- One-to-one

- One-to-many
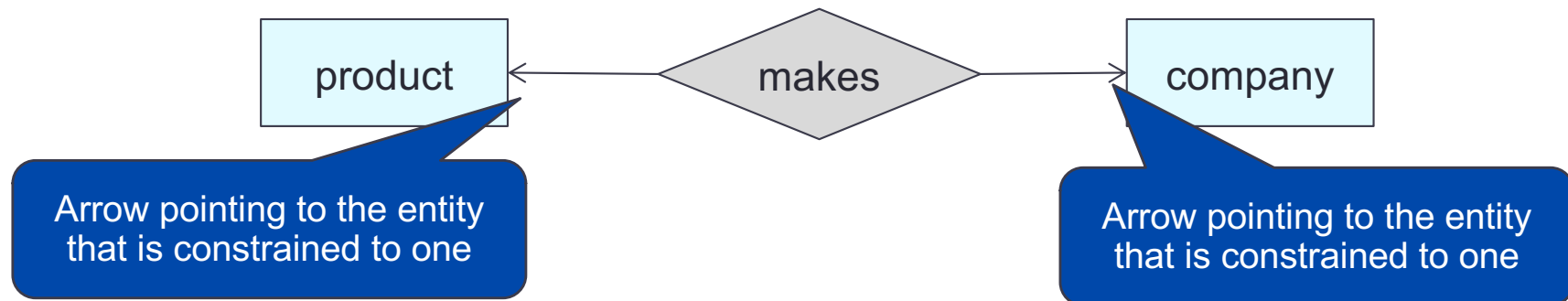
- Many-to-one

- Many-to-many

Cardinality: One-to-One

product

pid	name	description
11	Chocolate	...
22	Biscuits	...
...	...	...

company

Name	Address
Dabur India Ltd	...
Nestle India Ltd	...
Britannia Industries Ltd	...

product ← makes → company

Arrow pointing to the entity that is constrained to one

Arrow pointing to the entity that is constrained to one

Each product can be made by at most one company.
Each company can make at most one product.

"at most one" – Guarantee existence?

Note: instances do not exist in E-R. These tables are only to help visualize the database being designed.
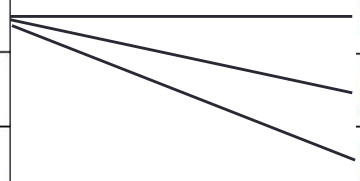
Cardinality: One-to-Many

product

pid	name	description
11	Chocolate	...
22	Biscuits	...
...	...	...

company

Name	Address
Dabur India Ltd	...
Nestle India Ltd	...
Britannia Industries Ltd	...

product ← makes — company
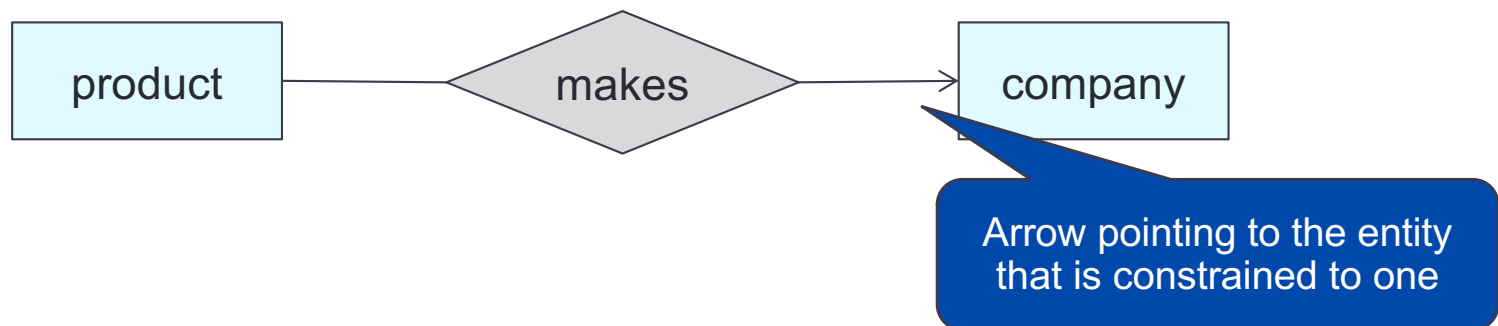
Arrow pointing to the entity that is constrained to one

Each product can be made by many companies.
Each company can make at most one product.

"at most one" and "many" – Guarantee existence?

Note: instances do not exist in E-R. These tables are only to help visualize the database being designed.

Cardinality: Many-to-One

product

pid	name	description
11	Chocolate	...
22	Biscuits	...
...	...	...

company

Name	Address
Dabur India Ltd	...
Nestle India Ltd	...
Britannia Industries Ltd	...

product → makes → company

Arrow pointing to the entity that is constrained to one

Each product can be made by at most one company.
Each company can make many products.

"at most one" and "many" – Guarantee existence?

Note: instances do not exist in E-R. These tables are only to help visualize the database being designed.
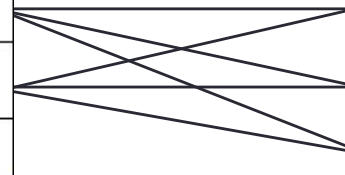
Cardinality: Many-to-Many

product

pid	name	description
11	Chocolate	...
22	Biscuits	...
...	...	...

company

| Name	Address
Dabur India Ltd	...
Nestle India Ltd	...
Britannia Industries Ltd	...

product — makes — company

Each product can be made by many companies.
Each company can make many products.

"many" – Guarantee existence?

Note: instances do not exist in E-R. These tables are only to help visualize the database being designed.
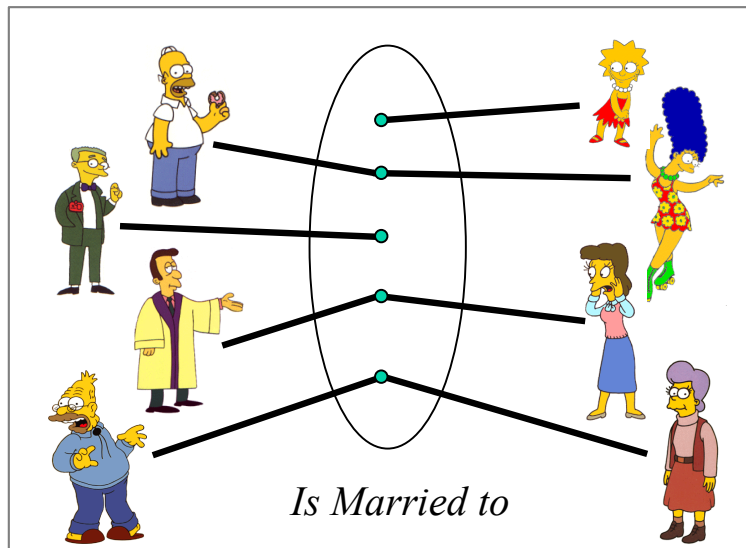
Let's try: Cardinality (1)

Draw an E-R diagram to model the given image sample data. Specify the cardinality. Interpret the E-R diagram.
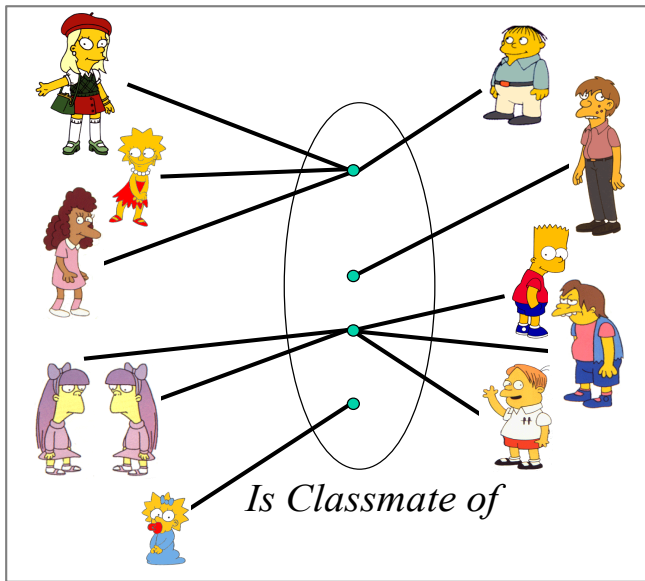

Was born in
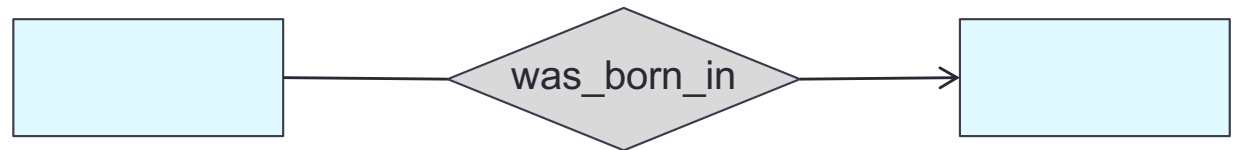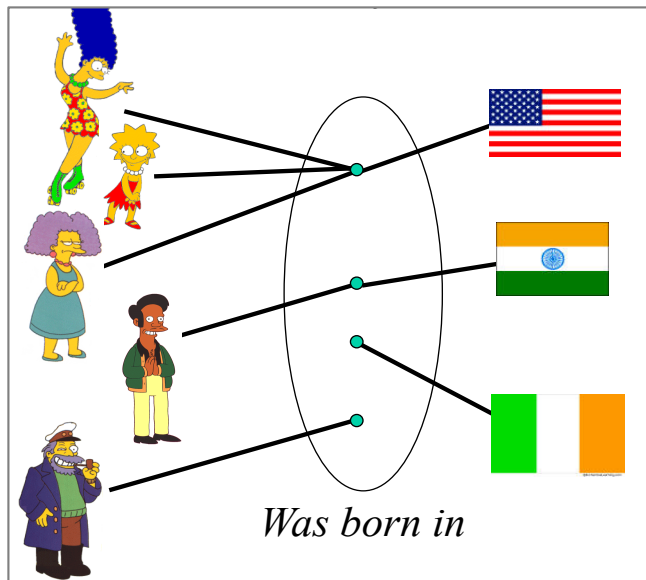
(many-to-one)

Let's try: Cardinality (2)

Draw an E-R diagram to model the given image sample data. Specify the cardinality. Interpret the E-R diagram.

Is Married to

is_married_to

(one-to-one)

Let's try: Cardinality (3)

Draw an E-R diagram to model the given image sample data. Specify the cardinality. Interpret the E-R diagram.

Is Classmate of

is_clasmate_of

(many-to-many)

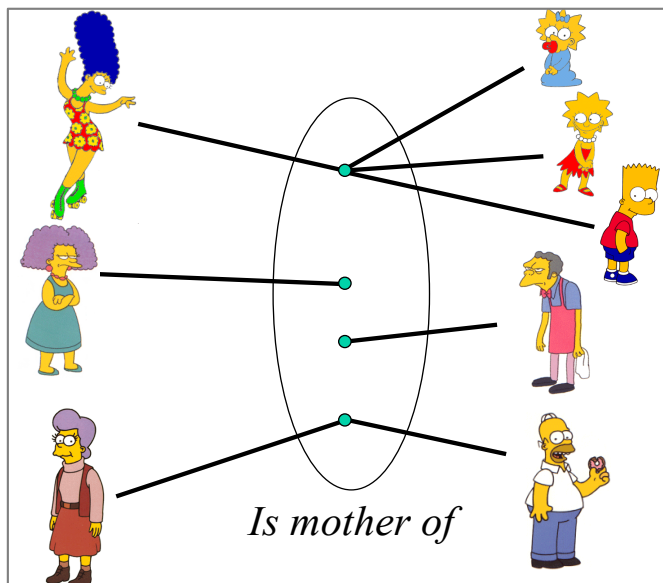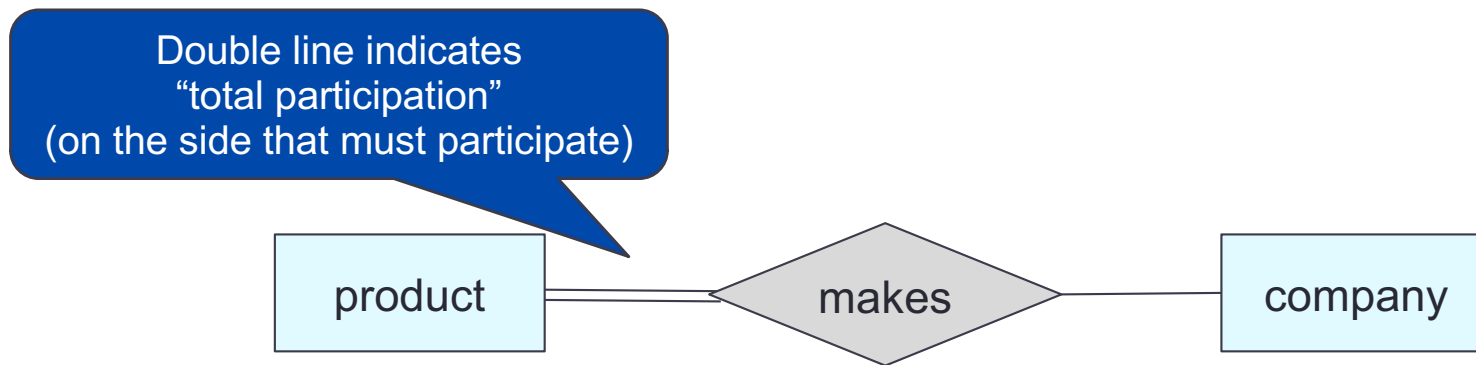**Draw an E-R diagram to model the given image sample data. Specify the cardinality. Interpret the E-R diagram.**


is_mother_of

(one-to-many)

Total Participation

Total participation – all entities in an entity set must participate in the relationship

Double line indicates "total participation" (on the side that must participate)

product — makes — company

Every product must be made by at least one company.

Each product can be made by many companies.

Each company can make many products.

Some companies may not make any product.
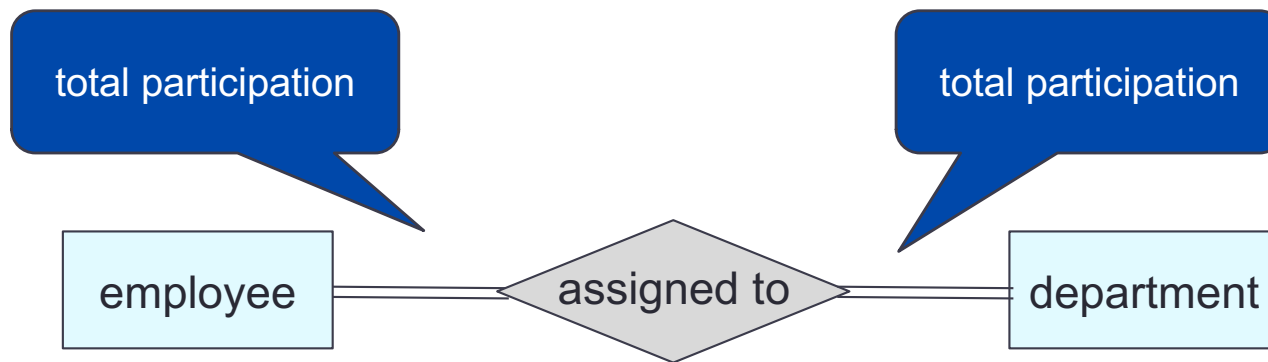
Let's try: Participation (1)

Interpret the E-R diagram.
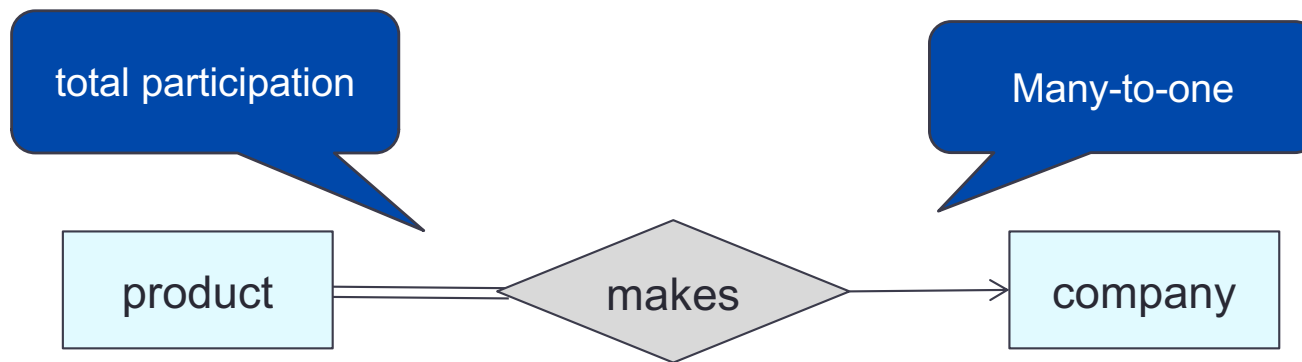
Every product **must** be made by exactly one company.

Each company can make many products.

Some companies may not make any product.
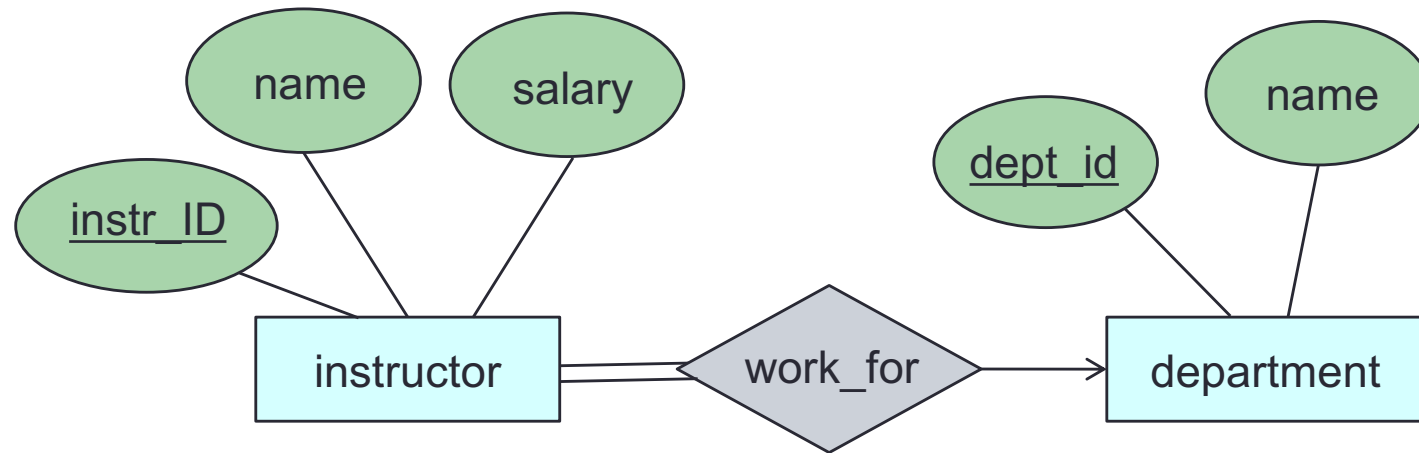
Let's try: Participation (2)

Interpret the E-R diagram.

Every employee must be assigned to at least one department.
Each employee can be assigned to many departments.
Each department can have many employees.
Every department must have at least one employee.

Let's try: Participation (3)

Interpret the E-R diagram.

Each instructor must work for at least 1 department *(double lines on the instructor)*
Each instructor can work for at most 1 department *(arrow points to the department)*.
Thus, each instructor works for exactly 1 department.

Each department has 0..many instructors *(no arrow points to the instructor)*.

(read 1 direction at a time until reaching the other end)

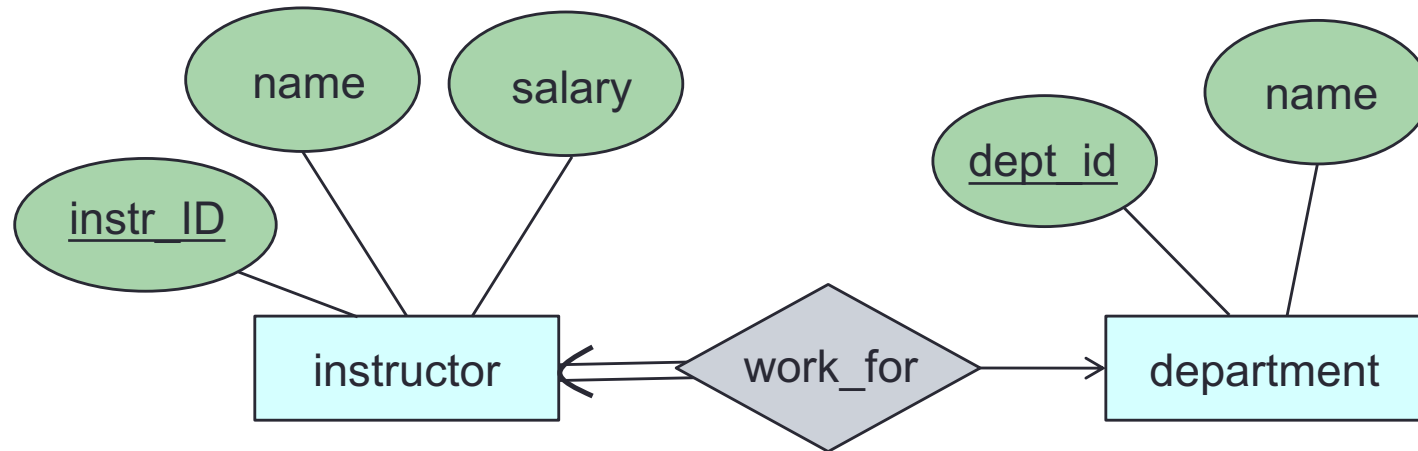# Let's try: Participation (4)
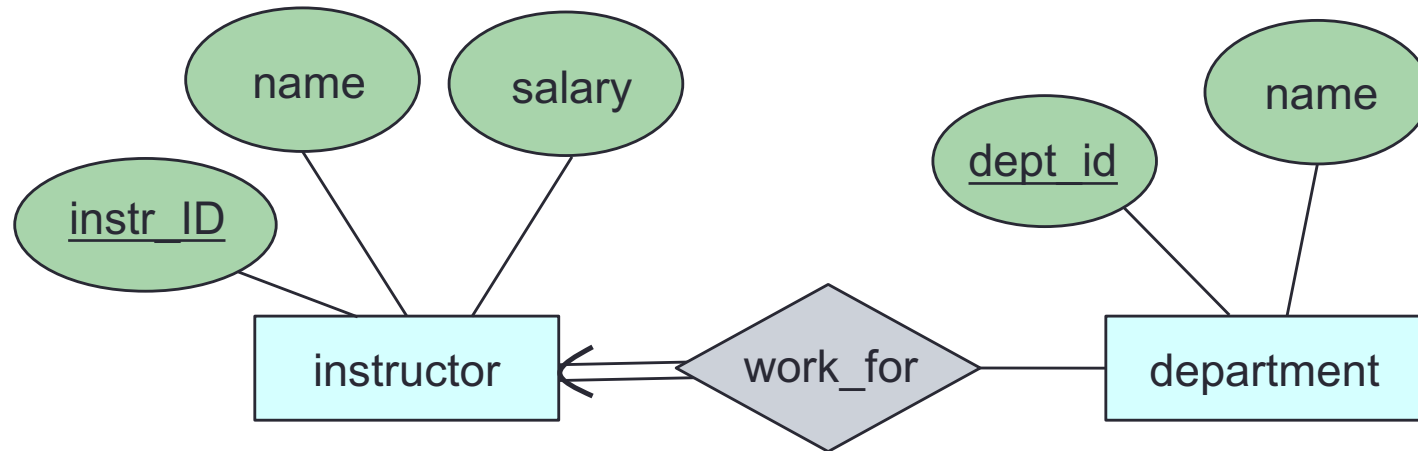
Interpret the E-R diagram.

Each instructor must work for at least 1 department *(double lines on the instructor).*
Each instructor can work for at most 1 department *(arrow points to the department).*
Thus, each instructor works for exactly 1 department.

Each department has at most 1 instructor (0..1) *(arrow points to the instructor).*

(read 1 direction at a time until reaching the other end)

Let's try: Participation (5)
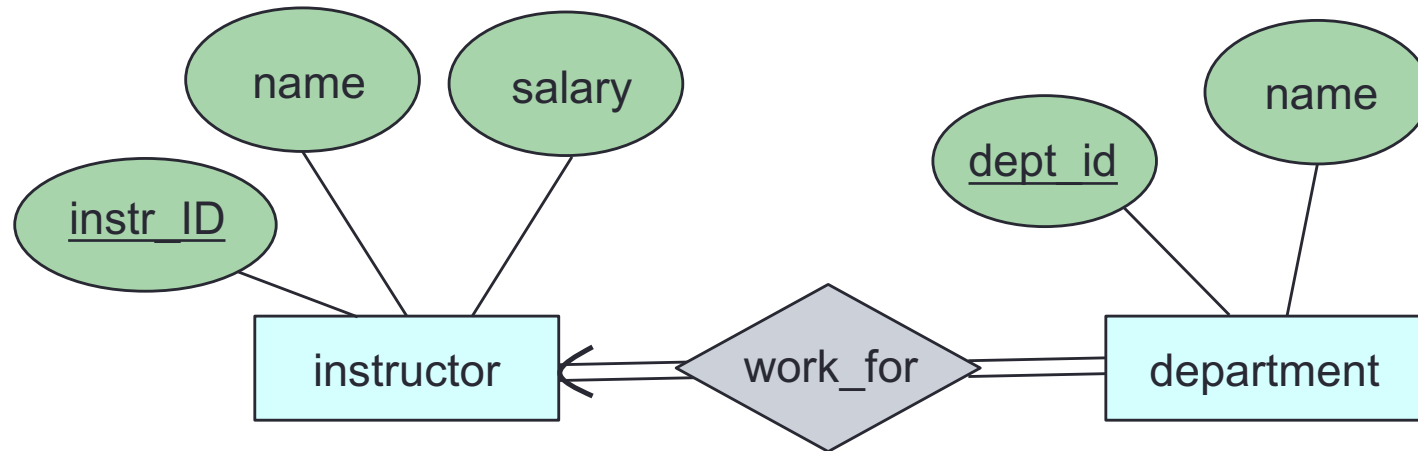
Interpret the E-R diagram.

Each instructor must work for at least 1 department *(double lines on the instructor)*.
Each instructor can work for many departments *(no arrow points to the department)*.
Thus, each instructor works for 1..many department.

Each department has at most 1 instructor (0..1) *(arrow points to the instructor)*.

(read 1 direction at a time until reaching the other end)

Let's try: Participation (6)
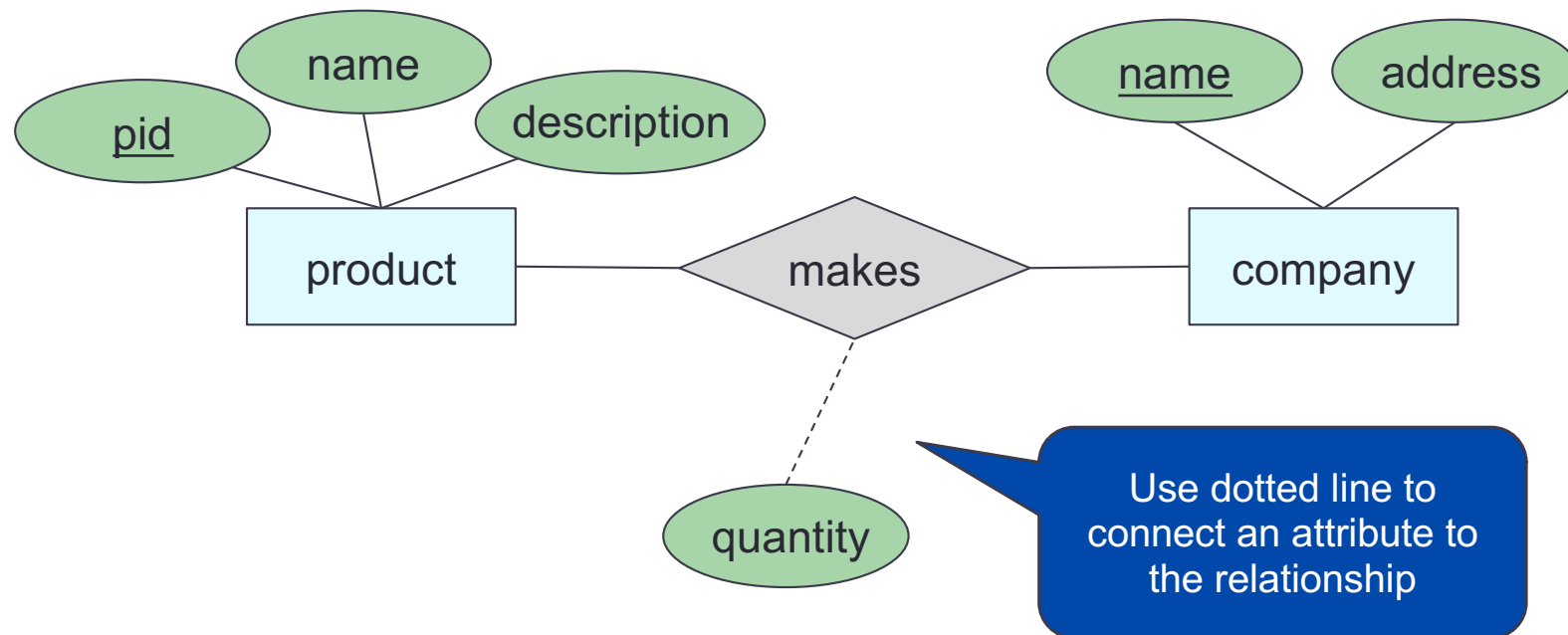
Interpret the E-R diagram.

Each instructor must work for at least 1 department *(double lines on the instructor)*.
Each instructor can work for many departments *(no arrow points to the department)*.
Thus, each instructor works for 1..many department.

Each department must have at least 1 instructor *(double lines on the department)*.
Each department has at most 1 instructor *(arrow points to the instructor)*.
Thus, each department has exactly 1 instructor.

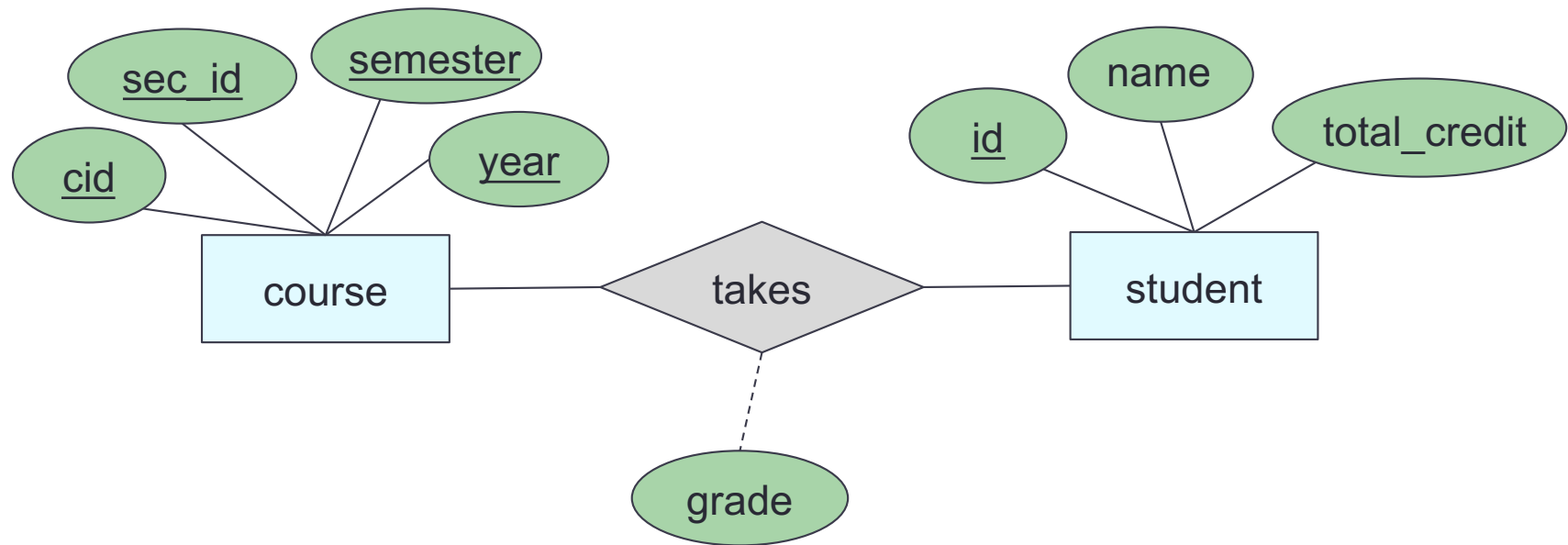(read 1 direction at a time until reaching the other end)

Attributes on Relationships

- Relationships can have attributes

- The attributes have values only when the relationship occurs

Let's try: Attributes - Relationships

Interpret the E-R diagram.

Each student can take many courses.
Each course can be taken by many students.
A grade exists only when the student takes a course.

Wrap-Up

- Database design process
- Intro to E-R model
- Entities and entity sets
- Attributes: single-valued, multi-valued, derived, composite
- Cardinality and participation

What's next?

- Roles in relationships
- Relationships: binary, multi-way
- Weak entity