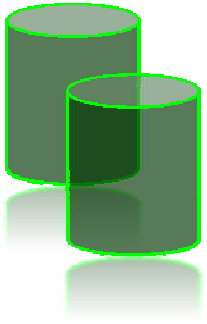

Database Systems
Part-1

Introduction and ER Model

Arijit Khan

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Lecturers

- Arijit Khan
- arijitk@cs.aau.dk
- Teaches till the week of Oct 10 (Week 41)

- Matteo Lissandrini
- matteo@cs.aau.dk
- Teaches after the the week of Oct 10 (Week 41)

Teaching Assistants

- Jan Mackeprang Damgaard Hansen (jmdh19@student.aau.dk)
- Martin Pekár Christensen (mpch@cs.aau.dk)
- Abiram Mohanaraj (abiramm@cs.aau.dk)
- Ghadeer Abuoda (gsmas@cs.aau.dk)

Introduction

- Course website

Moodle:
https://www.moodle.aau.dk/course/view.php?id=44380

- All course materials on Moodle

(slides, exercise, self-study/ mini-project, quiz, . . .)

Textbooks

- Database Systems: The Complete Book

Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom

- Database System Concepts 7th edition

Avi Silberschatz, Henry F. Korth, S. Sudarshan

https://factumbooks.dk/?booklist=3&id=3307

My Teaching Style

- Slides override book
- There will be many **classroom exercises** throughout all lectures
- Questions will be welcomed
- There will be some **study-home slides** throughout most lectures

Quizzes

- One quiz for each lecture on Moodle
- Recommended to do a couple of days after the lecture
- Unlimited number of attempts

Exercise

- Deepen understanding and application of the material covered in the previous week
- Discussions plus training for the written exam
- Mind the notation(!) – avoid losing points in the exam
- TAs will visit you in the group rooms during the scheduled exercise sessions

Questions?

Self-study (mini-project)

- Mini-project divided into 2 parts
  - Database modeling and normalization
  - Loading and querying

- Work in groups of 8-10 students. Register your group to TAs by Sep 23's exercise session.

- Part-1 of self-study to release on Sep 26.

- Complete Part-1 of self-study by Oct 3. Send to peer-group and TA by Oct 3's exercise session.

- Receive feedback by peer-group and TA on Oct 10 (Lecture session).

Questions?

Exam

- Written exam (physical)
- 1 hour
- No books, notes, electronic devices, etc.
- Just brain, pen, and paper
- 100 points
- Passing limit: 50 points

➢ Format might change depending on pandemic, other factors

Schedule for first half

Intro & ER	Sep 5 Monday (12:30-14:15), Lecture - FRB 7H	No exercise
Relation, FD, Keys	Sep 12 Monday (12:30-14:15), Lecture - FRB 7H	Exercise-1 on Intro & ER (14:30-16:30)
Normalization	Sep 19 Monday (12:30-14:15), Lecture - FRB 7H	Exercise-2 on Relation, FD, Keys (14:30-16:30)
Relational Algebra	Exercise-3 on Normalization (8:15-10:00)	Sep 23 Friday (10:15-12:00), Lecture - NOVI8
Release of Self-Study-1	Sep 26 Monday, No lecture, No exercise	
SQL – Part I	Oct 3 Monday (12:30-14:15), Lecture - FRB 7H	Exercise-4 on Relational Algebra (14:30-16:30)
Feedback of Self-Study-1	Oct 10 Monday (12:30-14:15), During lecture - FRB 7H	Exercise-5 on SQL – Part I (14:30-16:30)

Ask Questions!

> The important thing is not to stop questioning.
>
> Albert Einstein

But why should we care?

- We are in the era of “big data”
  - Enormous volumes of data emerge from almost every industry
- We need efficient systems to manage such data

Database and DBMS

- What is a database?
  - A collection of related data, specially organized for efficient retrieval by a computer
- What is a database management system (DBMS)?
  - A piece of software that helps us efficiently manage/retrieve information from databases
- Database System (DBS):

  - A database and a DBMS

DBMS in Practice

- Large web sites rely heavily on DBMS
  - Facebook
  - Twitter
- Many non-web companies, too
  - E.g., Banks
- Even small pieces of software on your computer
  - E.g., Google Chrome

Relational Model

- Numerous DBMS exist on the market
  - Oracle, SQL Server, DB2, MySQL…
- Most of them follow the relational model
- What does it mean?
- Answer: They store all data in relations

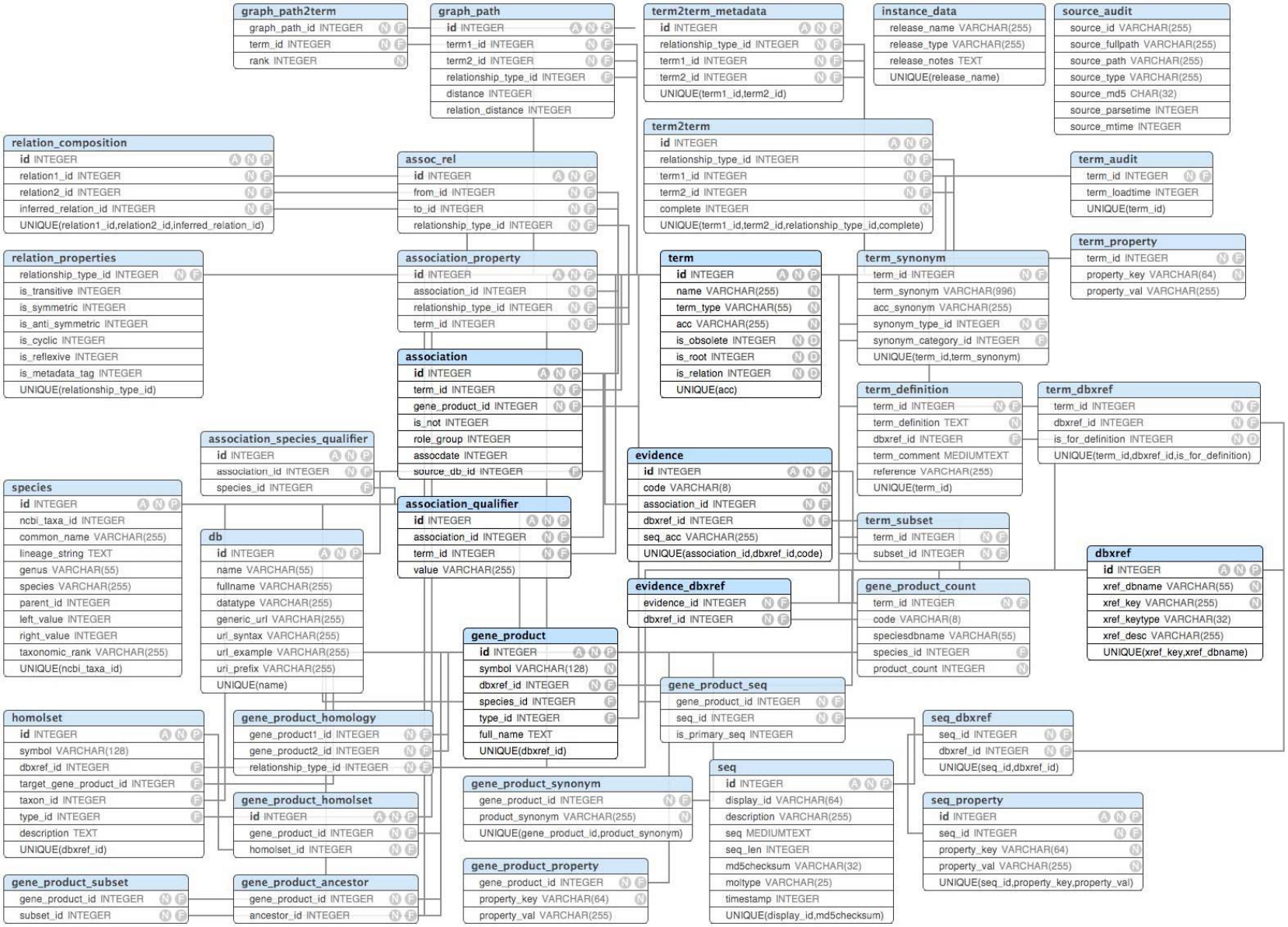
Relation

Product

Name	Price	Category	Manufacturer
iPhone 6	888	Phone	Apple
iPad Air 2	668	Tablet	Apple
Galaxy	798	Phone	Samsung
EOS-1D X	1199	Camera	Canon

- Some jargons:
  - A relation is often referred to as a table
  - A row in a table is also called a tuple or a record
  - A column in a table is also called an attribute of the table

A real database may have a large number of tables...



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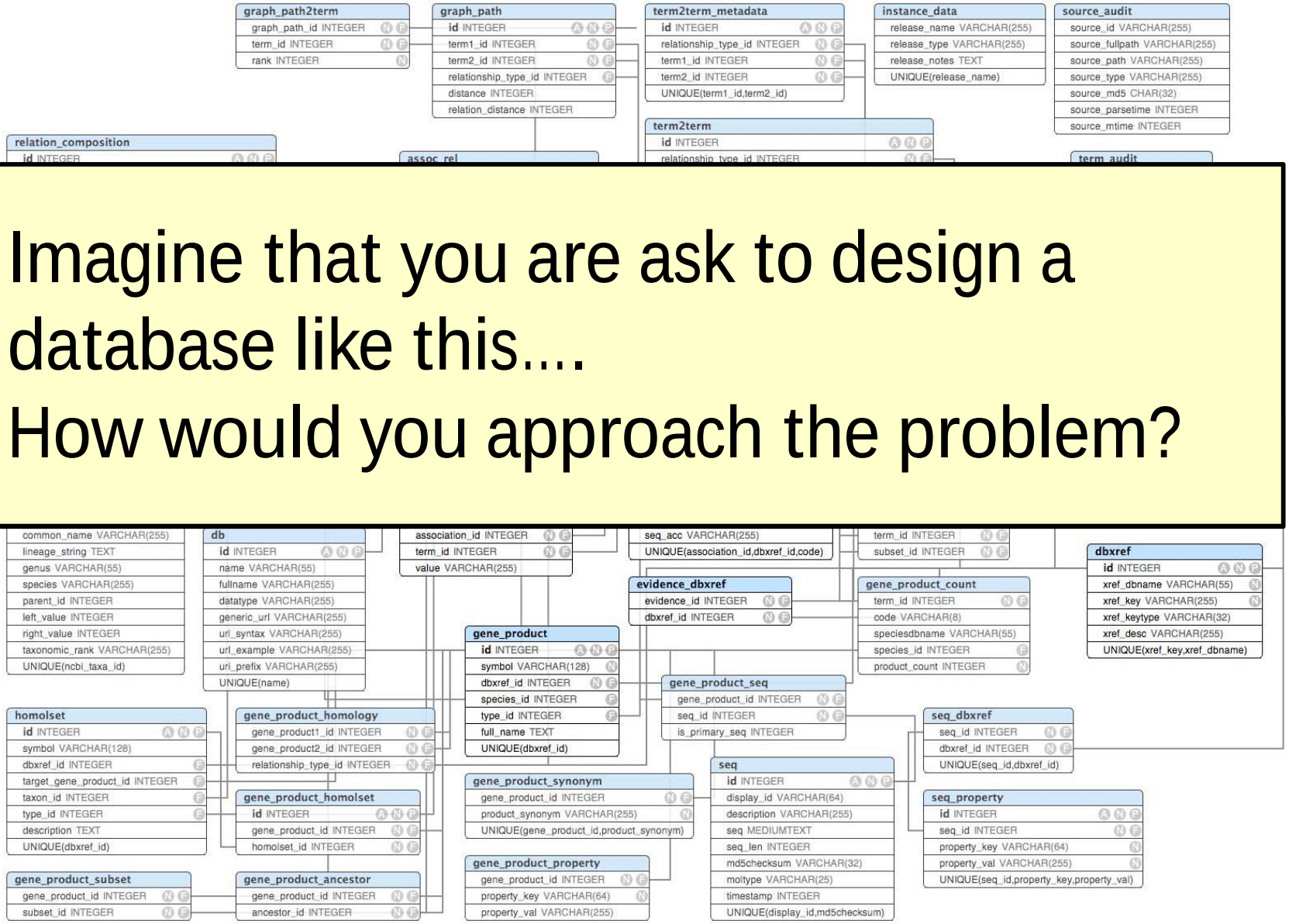


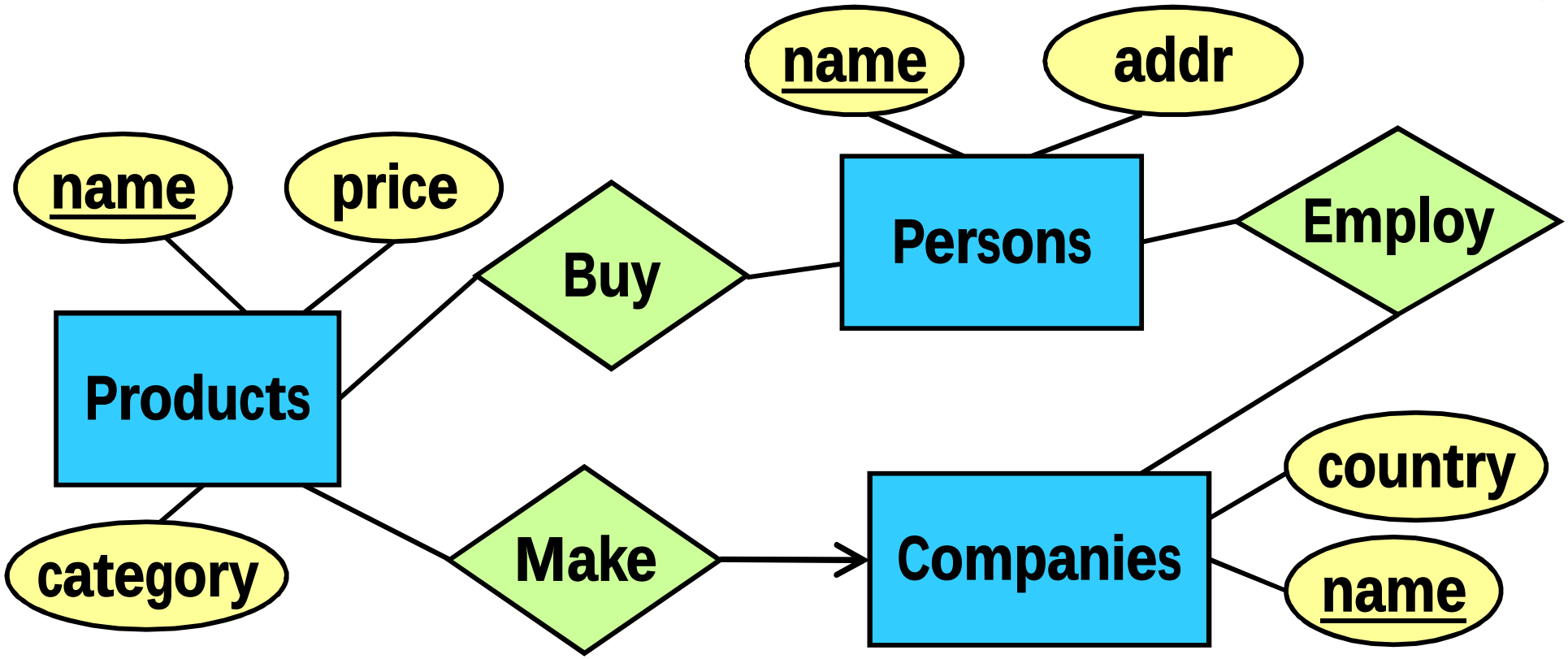
- Imagine that you are ask to design a database like this....
- How would you approach the problem?

Designing a Database for an Application

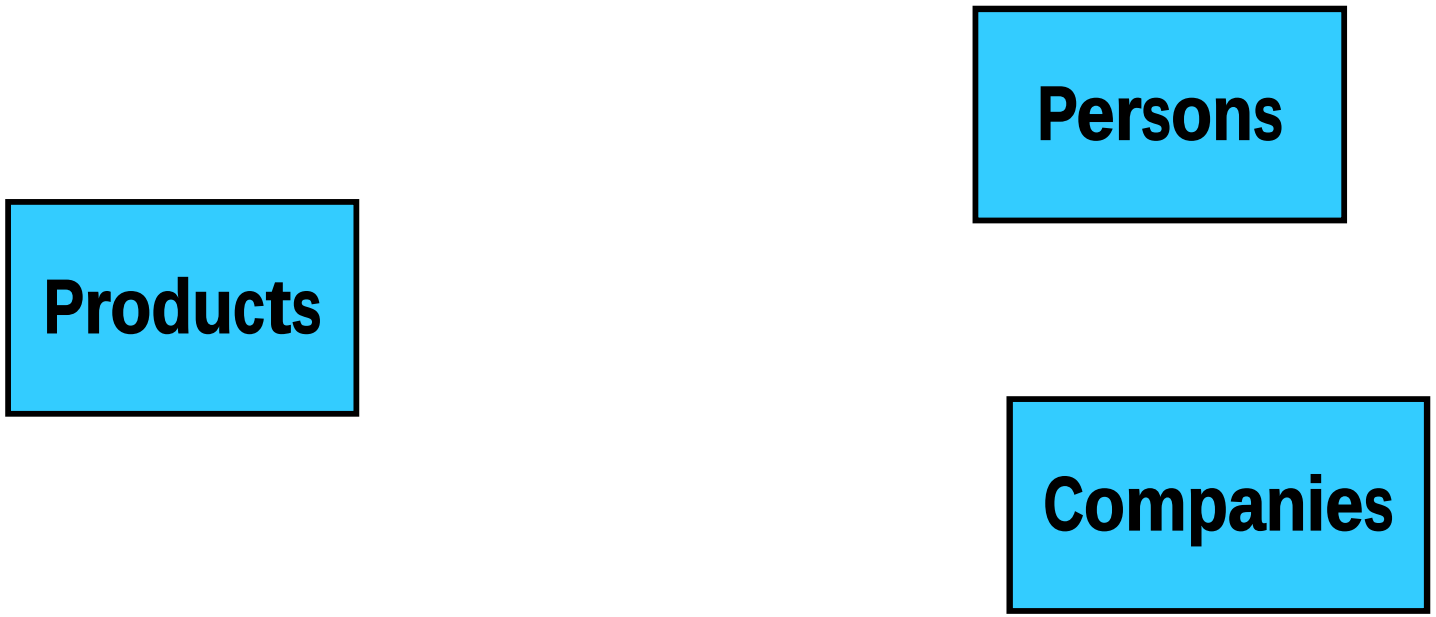
- Conceptually model the requirements of the application
  - What are the things that need to be stored?
  - How do they interact with each other?
- Tool to use: Entity-Relationship (ER) Diagrams
  - A pictorial and intuitive way for modelling
- Translate the conceptual model into a set of tables
- Construct the tables with a DBMS

Questions?

ER Diagram

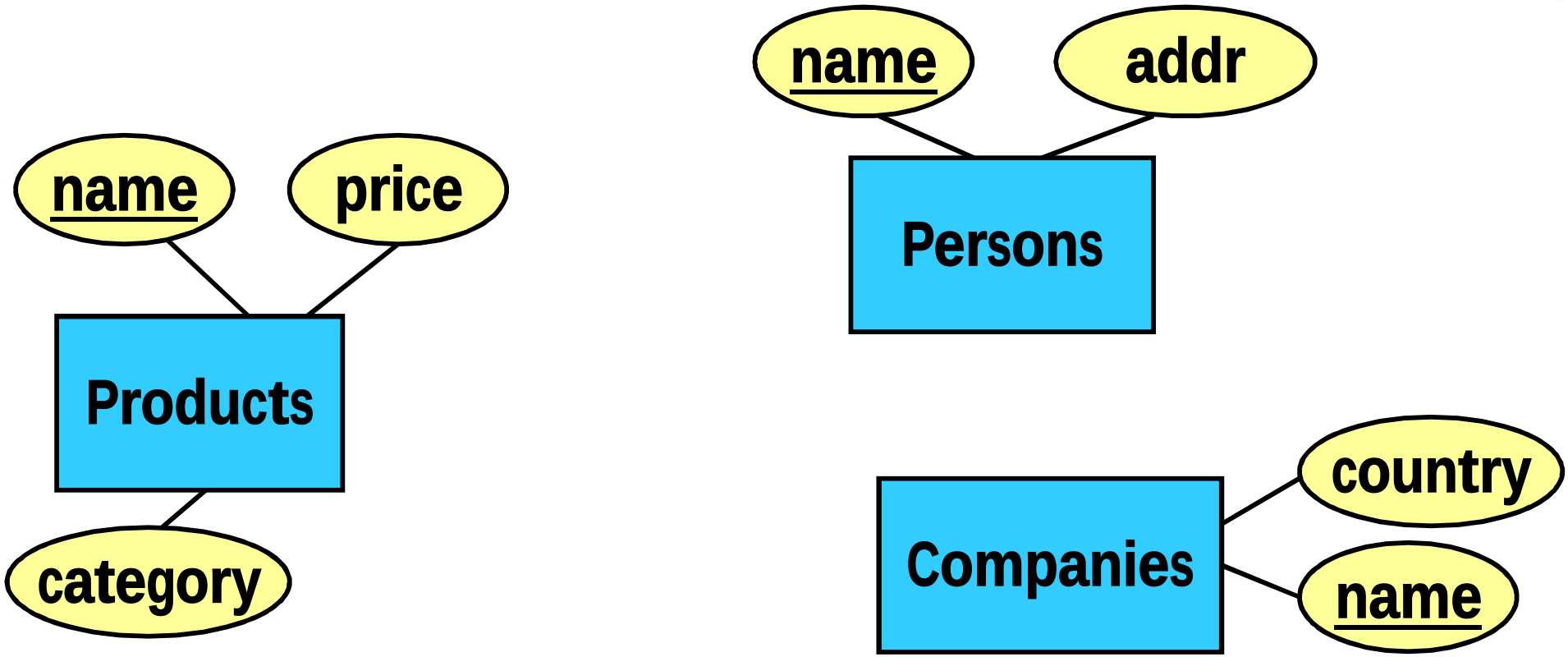

name
addr
name
price
Buy
Persons
Employ
Products
country
Make
Companies
category
name

ER Diagram



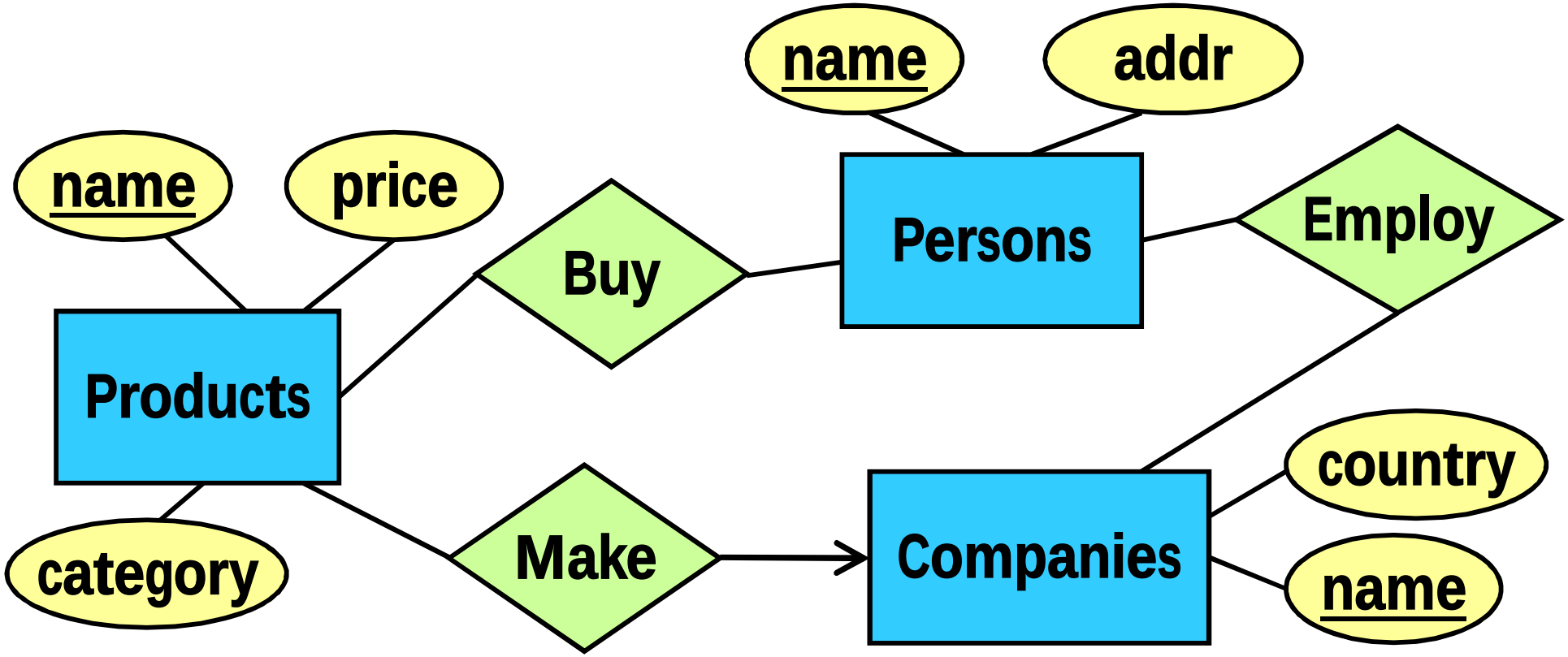
- Rectangle = Entity Set
- Entity = Real-world object (e.g., a bar)
- Entity Set = Collection of similar objects (e.g., a set of bars)
- Analogue: An object class

ER Diagram



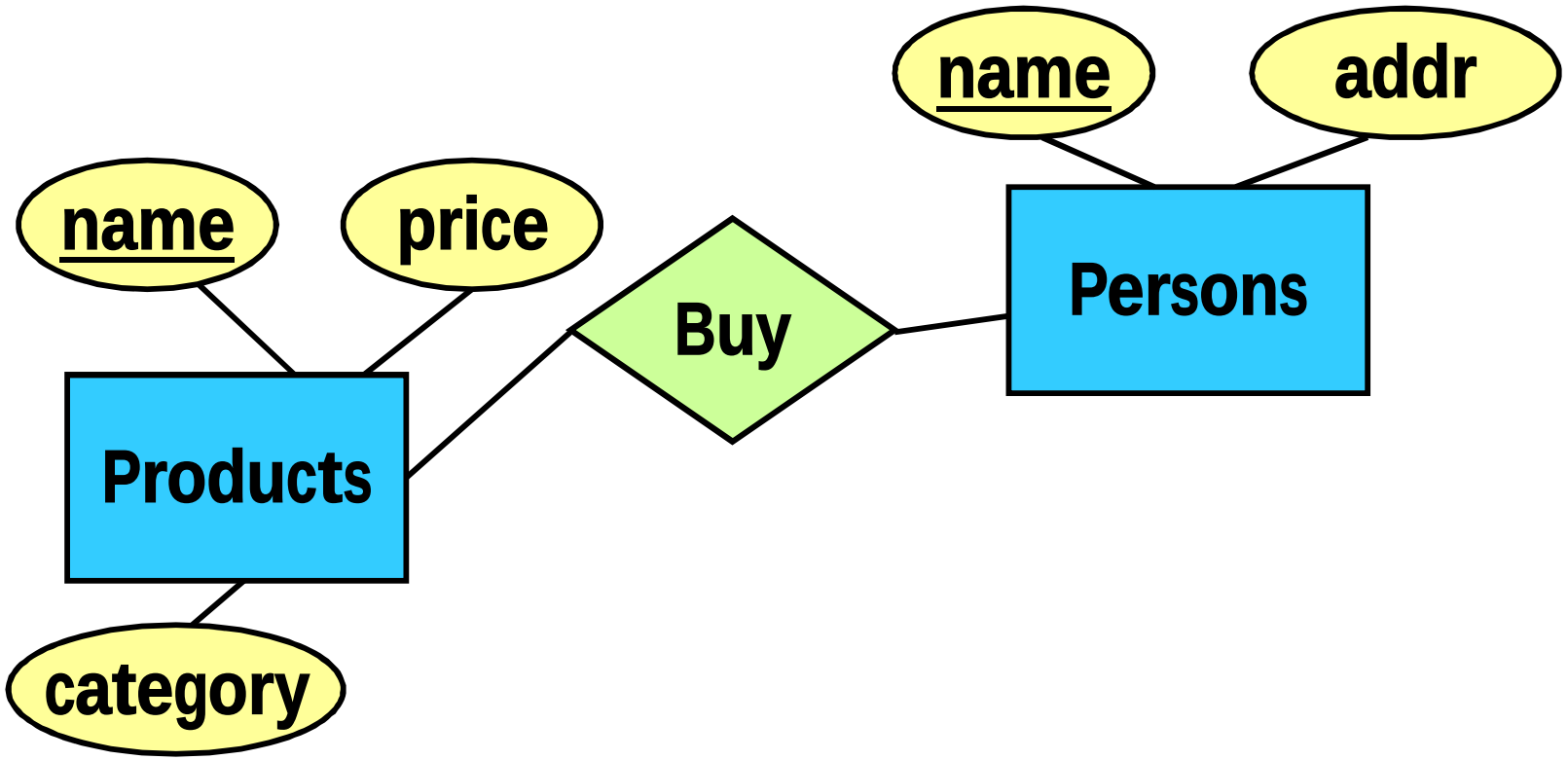
- Oval = Attribute = Property of an entity set

ER Diagram



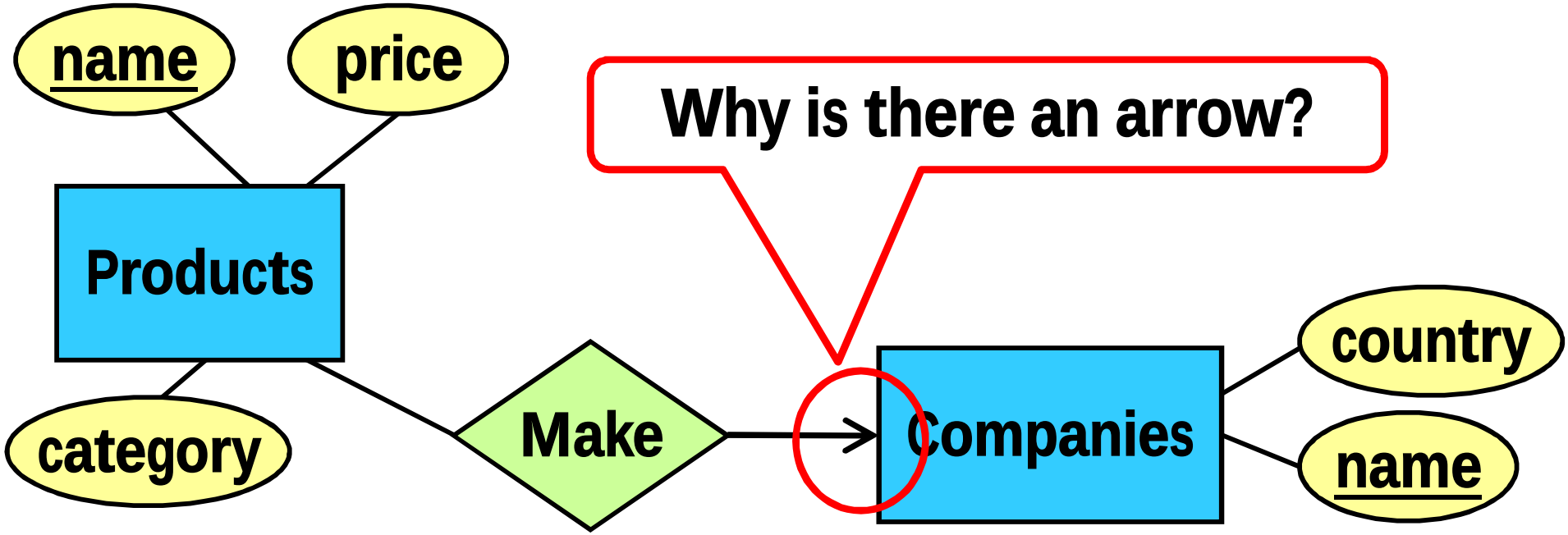
- Diamond = Relationship = Connection between two entity sets

ER Diagram



- Diamond = Relationship = Connection between two entity sets
- Persons buy products

ER Diagram

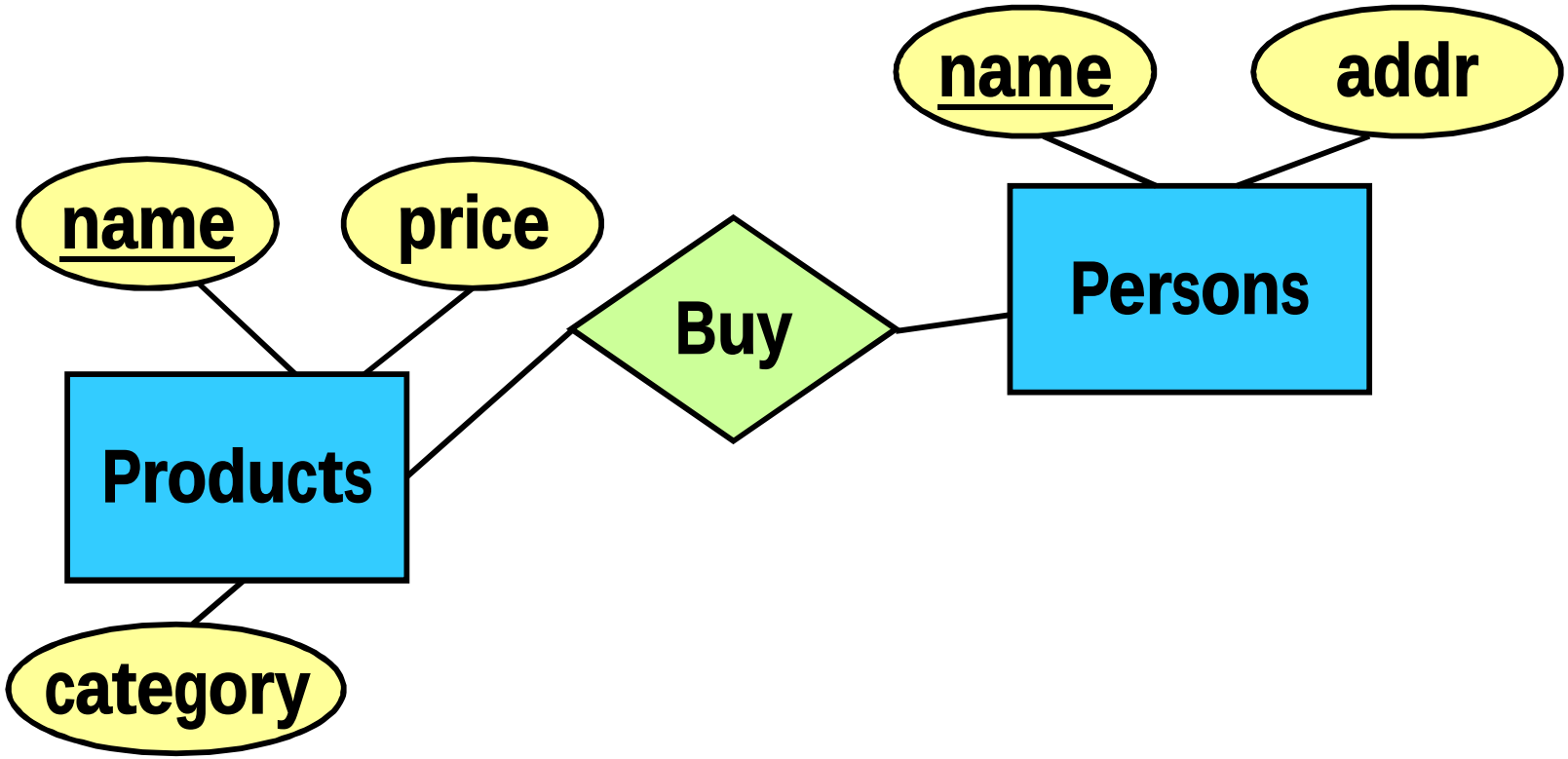


- Diamond = Relationship = Connection between two entity sets
- Companies make products

ER Diagram

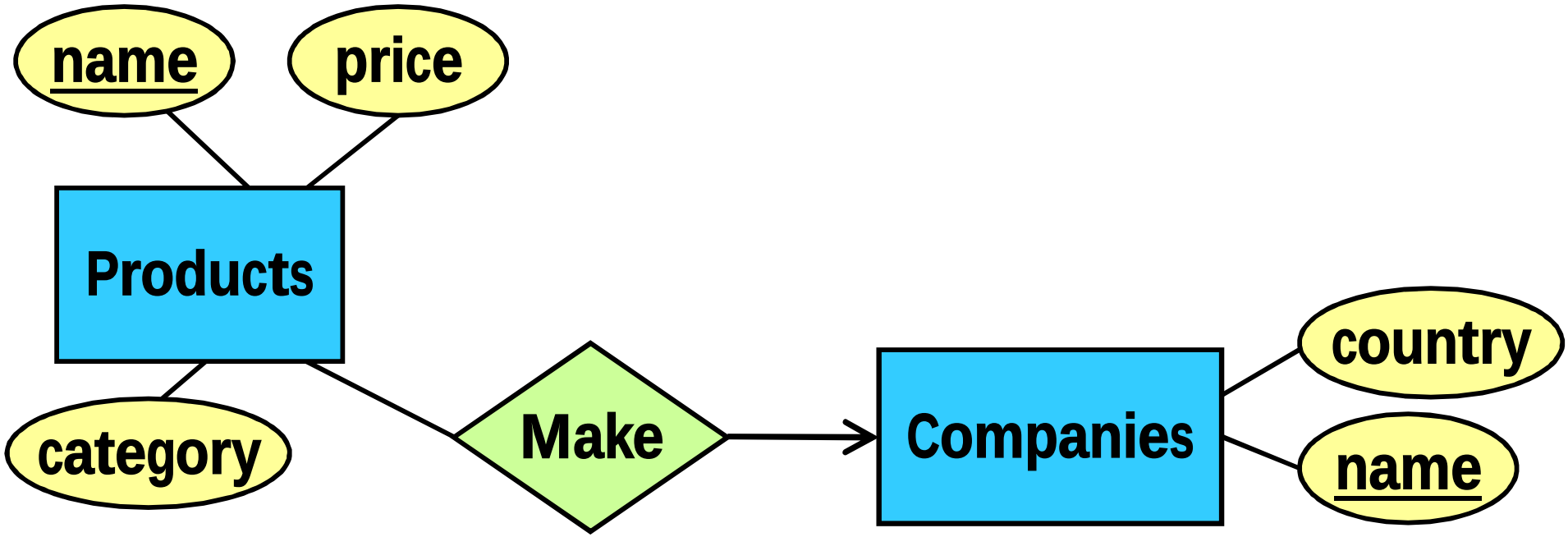
- Many-to-Many Relationships
- Many-to-One Relationships
- One-to-One Relationships

Many-to-Many Relationship



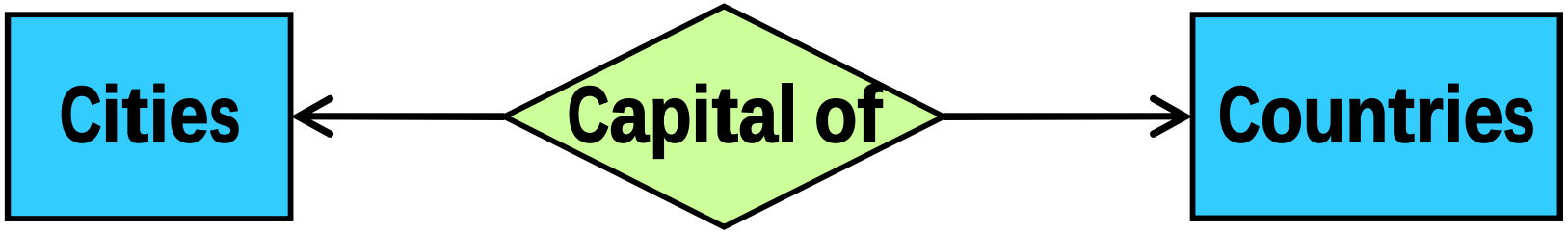
- One person can buy multiple products
- One product can be bought by multiple persons

Many-to-One Relationship



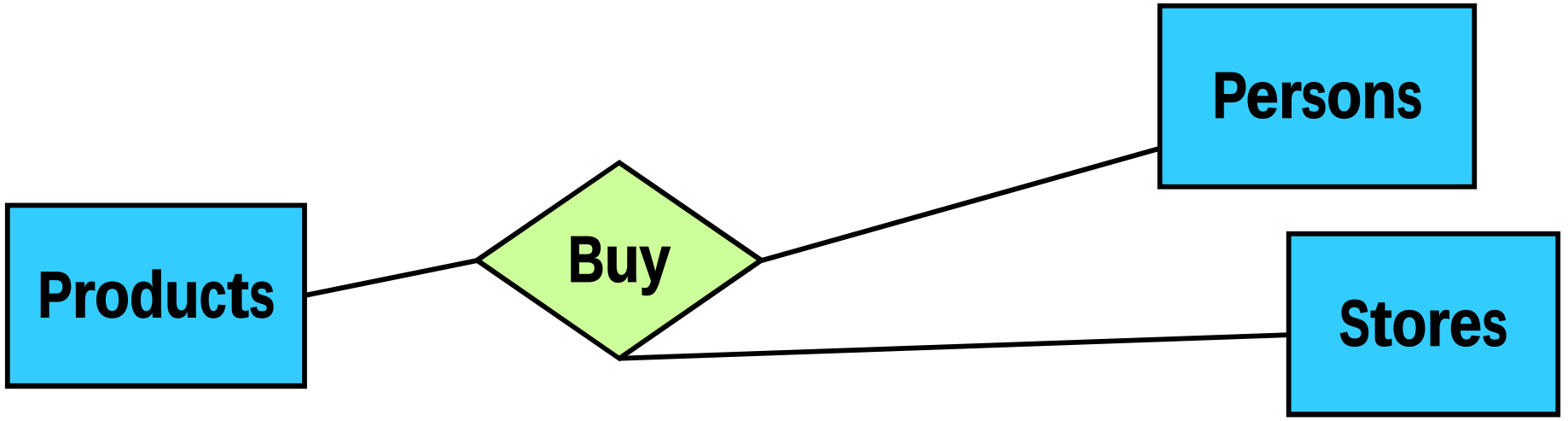
- One company can make multiple products
- But one product can only be made by one company

One-to-One Relationship



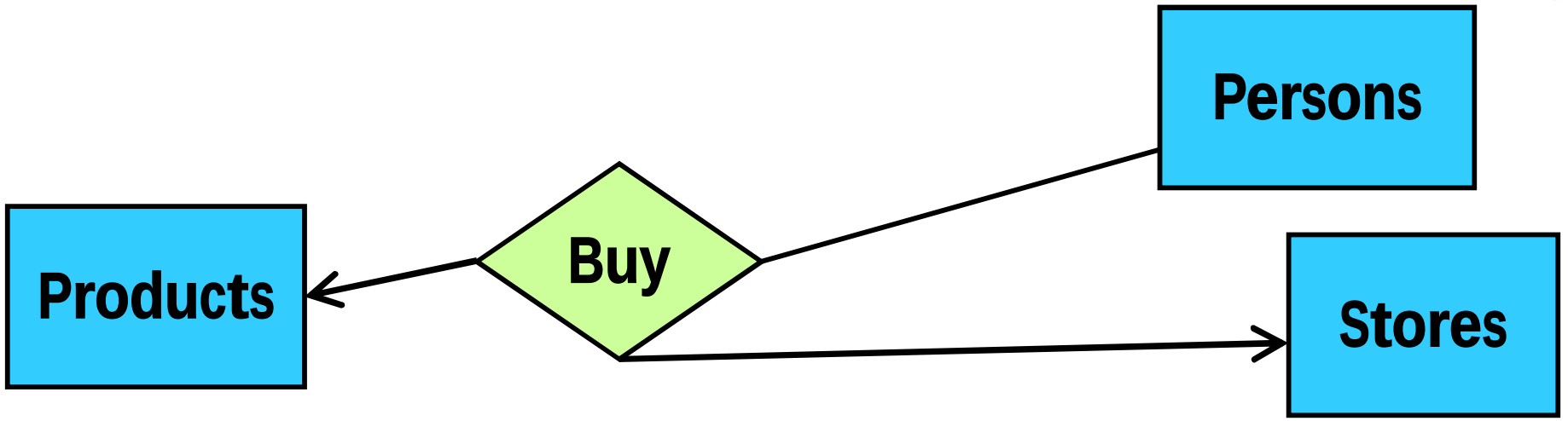
- A city can be the capital of only one country
- A country can have only one capital city

Multi-way Relationships



- What if we want to record the store from which the person buys the product?
- We can use a 3-way relationship
- Drawback: The arrows would be complicated

Multi-way Relationships



- What does this mean?
- From <person, store> to product: many to one
- From <person, product> to store: many to one
- From <product, store> to person: one to many
- Note: arrows with multi-way relation not required in exercise/exam

Questions?

Classroom Exercise-1

- Each player prefers only one game, but not vice versa
- Many-to-many?
- Many-to-one?
- One-to-one?

Classroom Exercise-1: Solution

- Each player prefers only one game, but not vice versa
- Many-to-many?
- Many-to-one?
- One-to-one?

Classroom Exercise-2

- No two shops sell the same product
- Many-to-many?
- Many-to-one?
- One-to-one?

Classroom Exercise-2: Solution

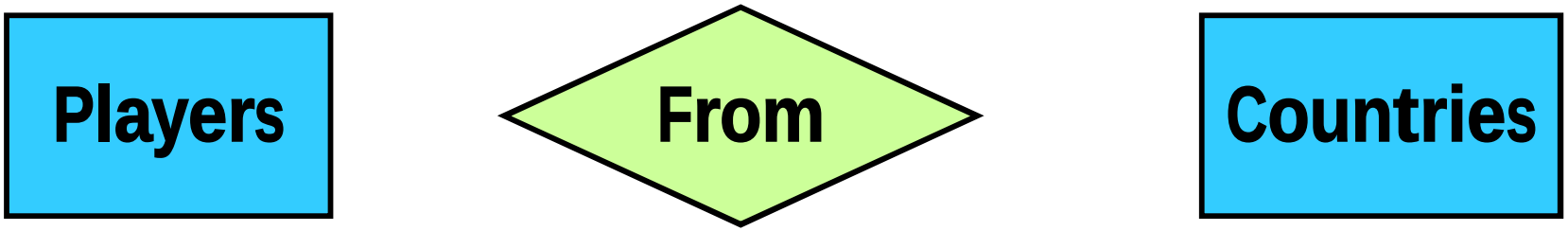
- No two shops sell the same product
- Many-to-many?
- Many-to-one?
- One-to-one?

5 Minutes Interval

The important thing is not to stop questioning.

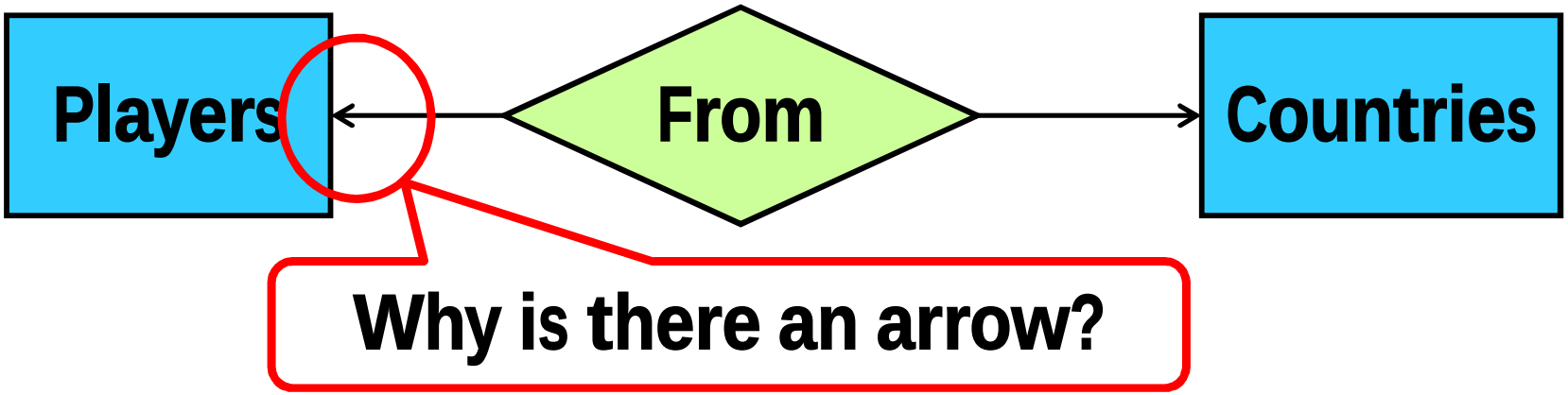
Albert Einstein

Classroom Exercise-3



- No two players are from the same country
- Many-to-many?
- Many-to-one?
- One-to-one?

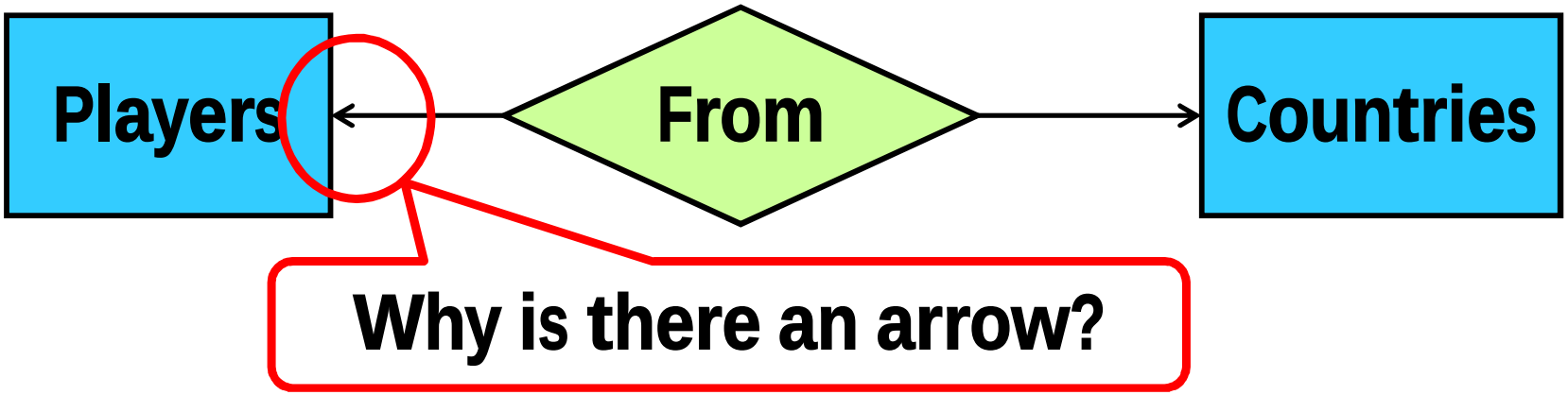
Classroom Exercise-3: Solution



- No two players are from the same country
- Many-to-many?
- Many-to-one?
- One-to-one?

Because we make an assumption: One player cannot be from many countries

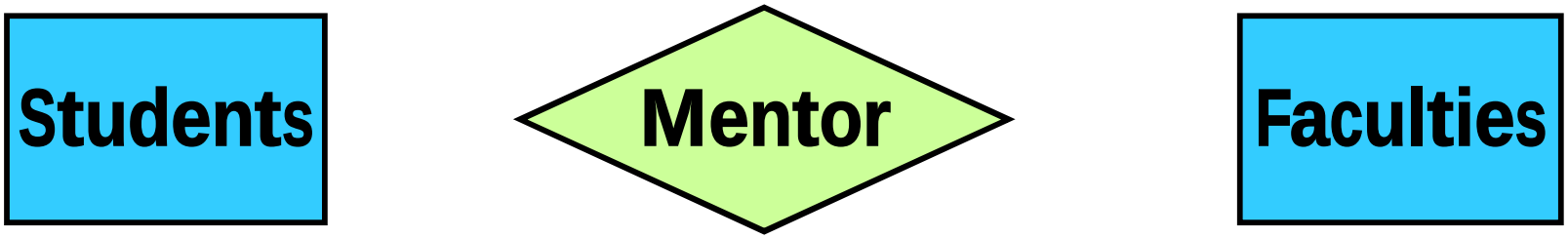
Classroom Exercise-3: Solution



Assumption can be made when it is ambiguous/ unclear in the question without that assumption. However, your assumption must always be a realistic assumption and you must write your assumption together with your answer (e.g., ER diagram).

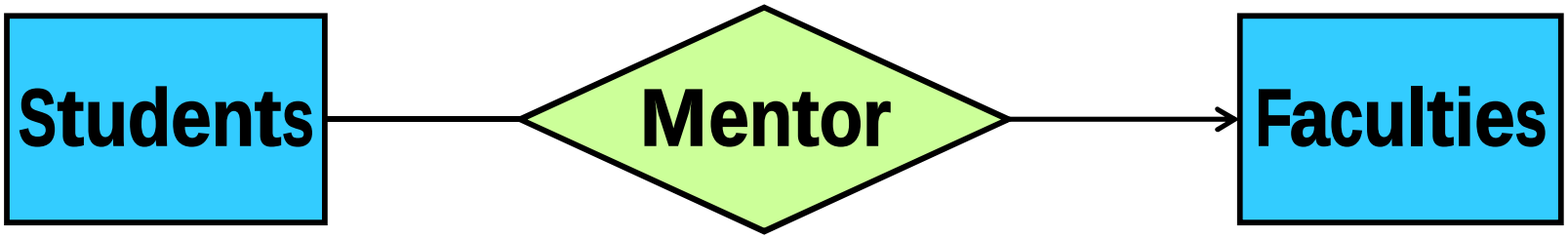
Because we make an assumption: One player cannot be from many countries

Classroom Exercise-4



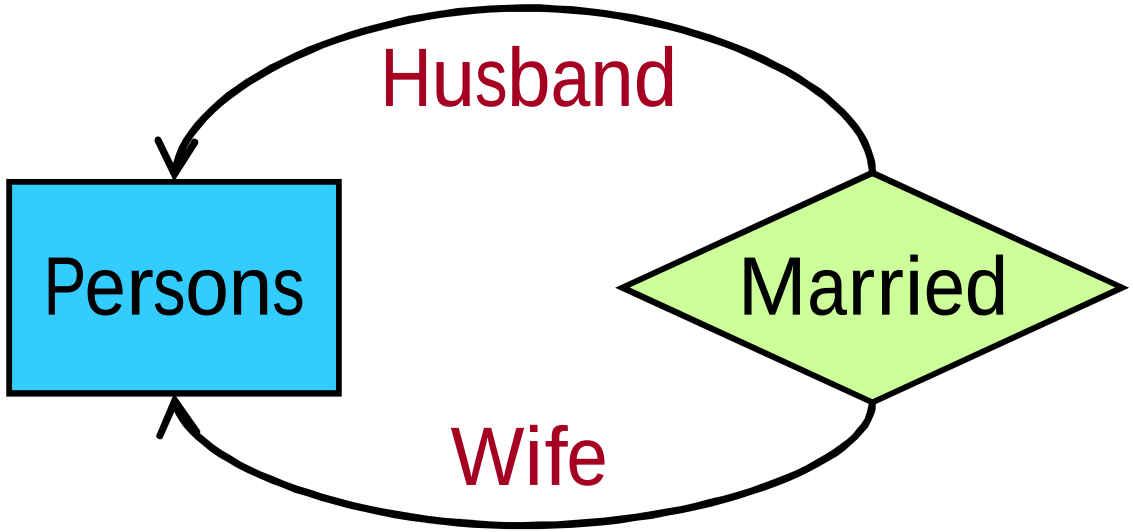
- Each student is mentored by one faculty
- Each faculty can mentor multiple students

Classroom Exercise-4: Solution



- Each student is mentored by one faculty
- Each faculty can mentor multiple students

Roles

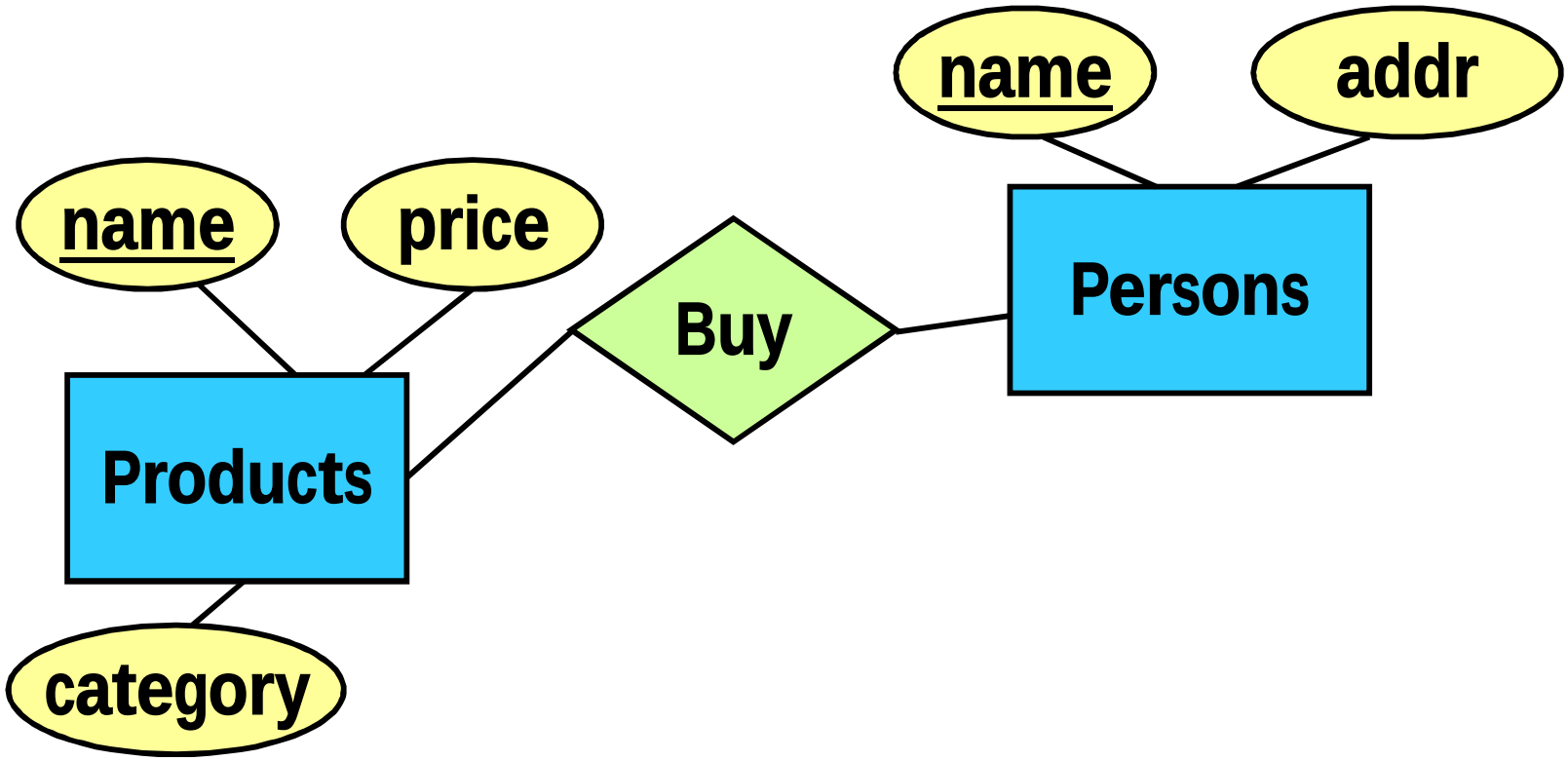


- Sometimes an entity set may appear more than once in a relationship
- Example: some persons are married to each other
- The role of the person is specified on the edge connecting the entity set to the relationship

Husband	Wife
Bob	Alice
David	Cathy
...	...

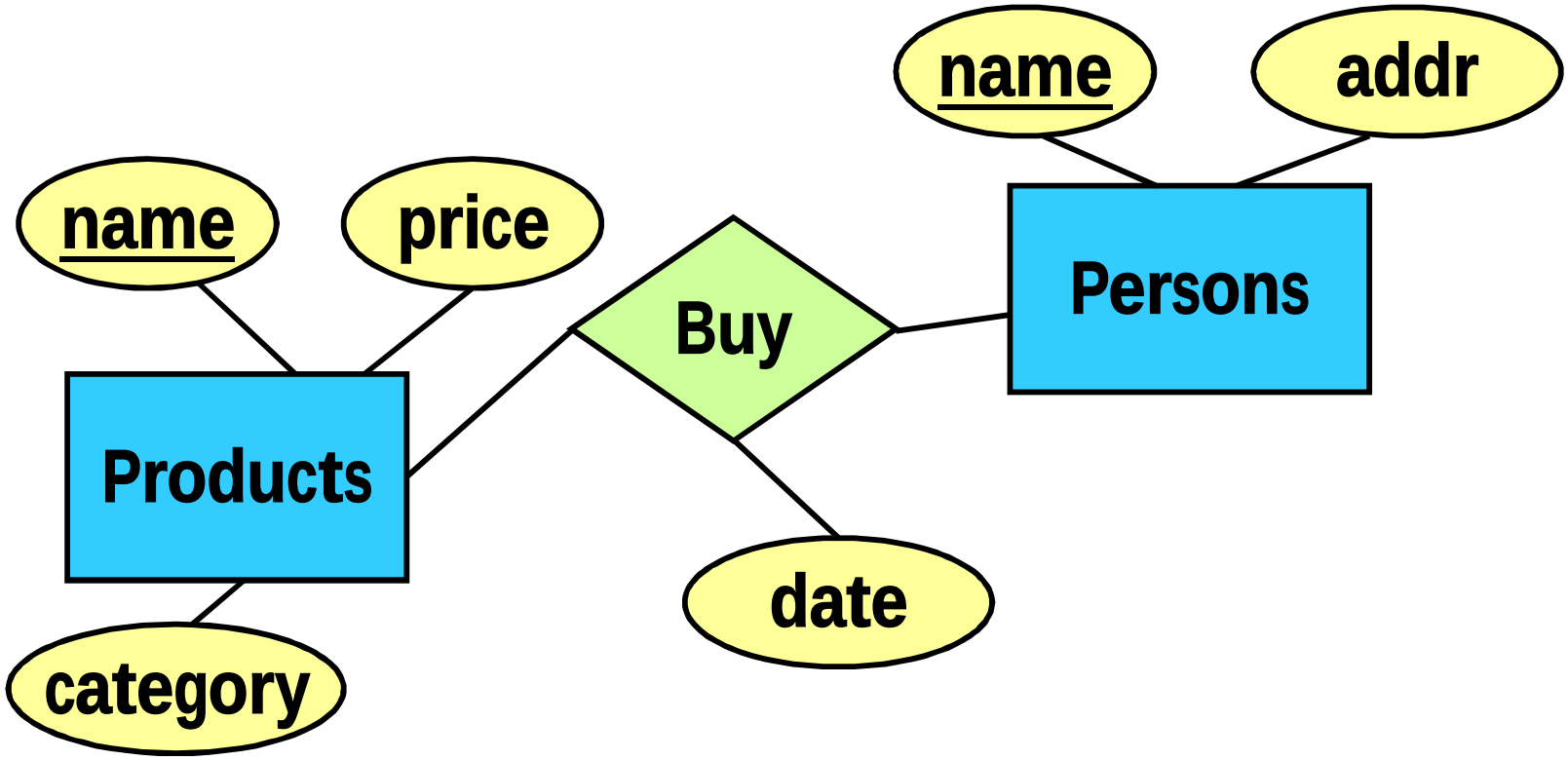
One More Thing about Relationships

- A relationship can have its own attribute



One More Thing about Relationships

- A relationship can have its own attribute
- If we want to record the date of the purchase

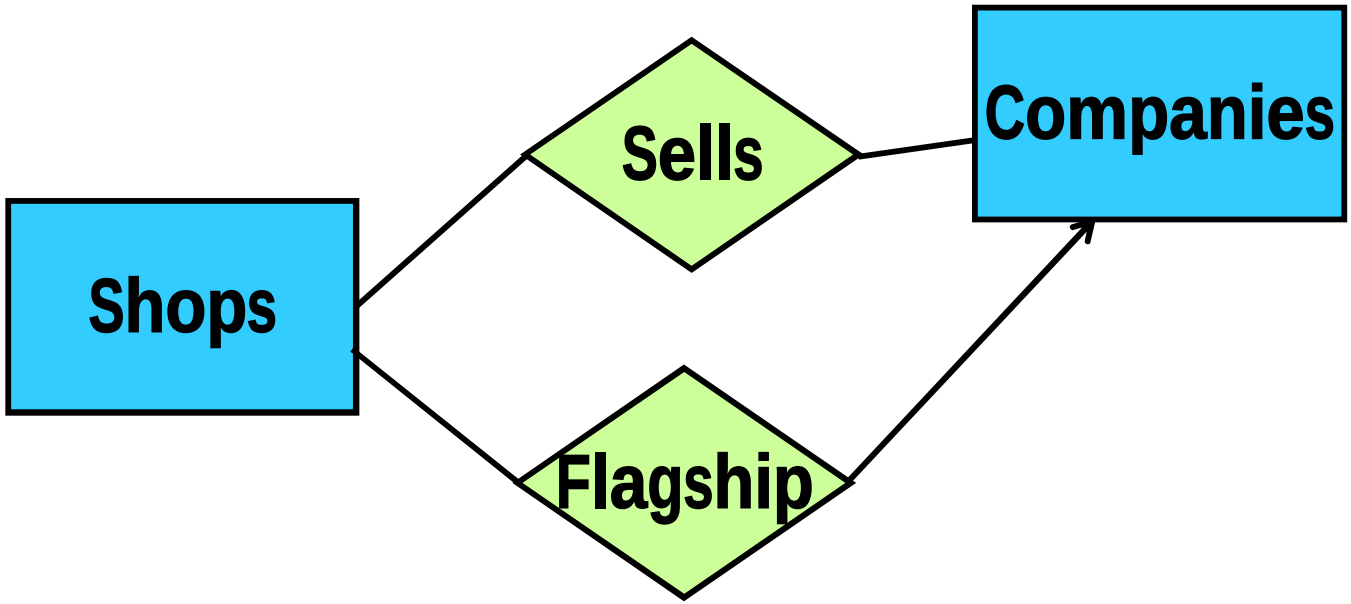


Classroom Exercise-5

- Consider two entity sets, Shops and Companies
- Each shop sells products from at least one company
- Each company has its product sold at least one shop
- A shop may be the flagship shop of at most one company
- Each company has at least one flagship shops
- Draw some relationships between Shops and Companies to capture the above statements

Classroom Exercise-5: Solution

- Consider two entity sets, Shops and Companies
- Each shop sells products from at least one company
- Each company has its product sold at least one shop
- A shop may be the flagship shop of at most one company
- Each company has at least one flagship shops
- Draw some relationships between Shops and Companies to capture the above statements



Classroom Exercise-5: Solution

- Consider two entity sets, Shops and Companies
- Each shop sells products from at least one company
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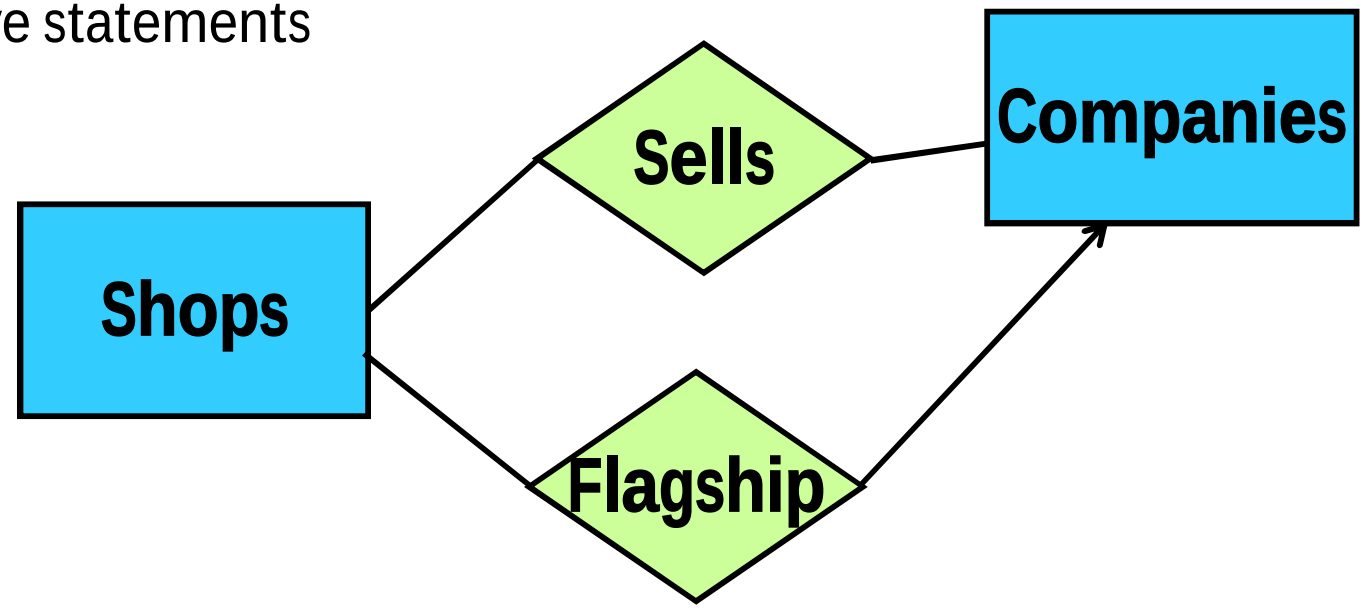
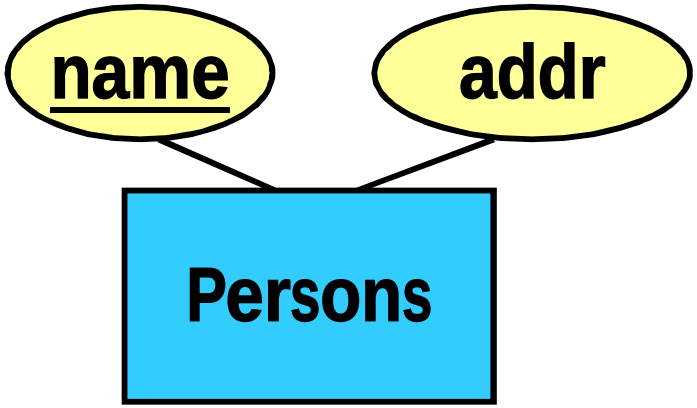


- There can be multiple relationships between two entity sets

Constraints

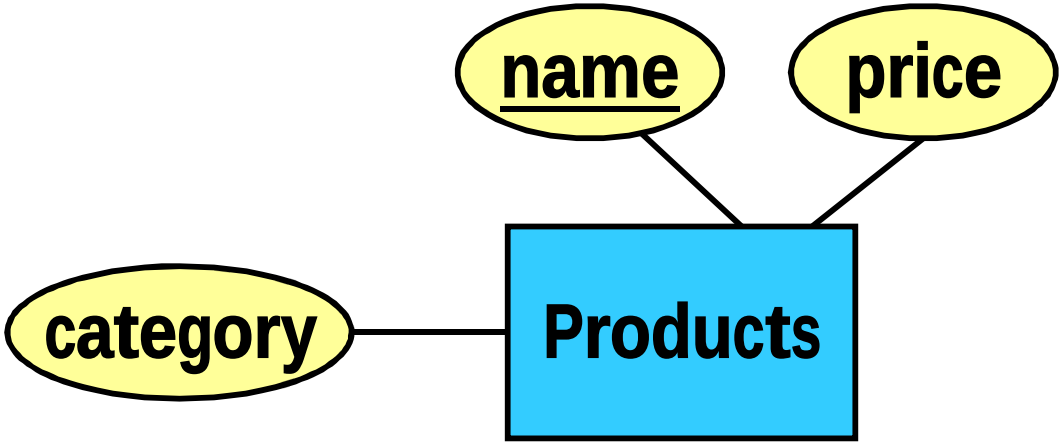
- Some conditions that entity sets and relationships should satisfy
- We will focus on three types of constraints
  - Key constraints
  - Referential integrity constraints
  - Degree constraints

Key



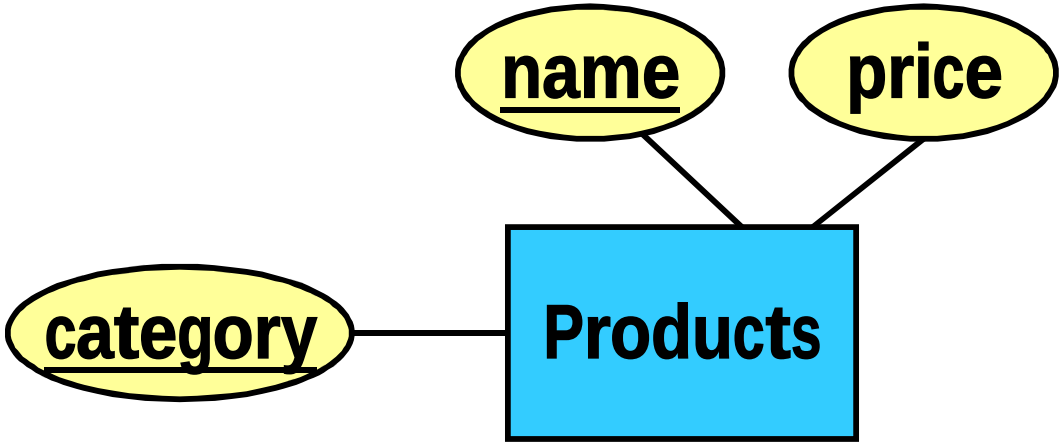
- One or more attributes that are underlined
- Meaning: They uniquely represent each entity in the entity set
- Example: The names uniquely represent the persons
- i.e., each person must have a unique name

Key



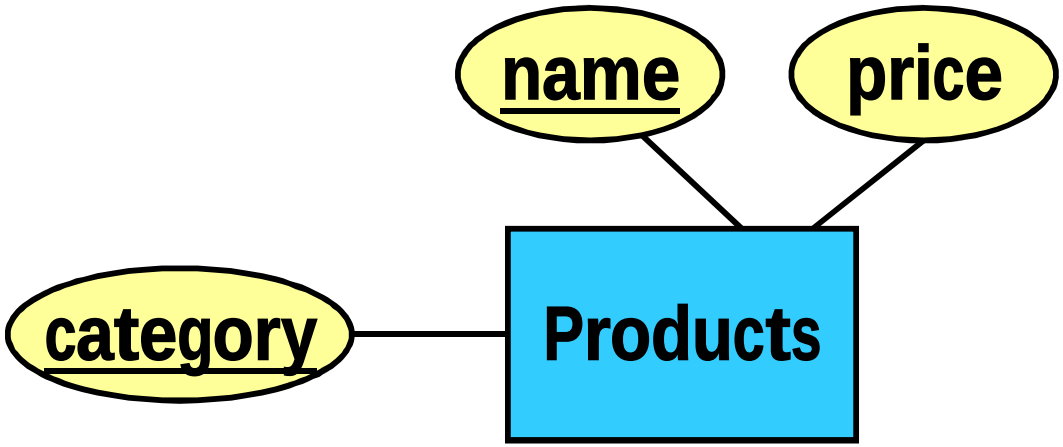
- One or more attributes that are underlined
- Meaning: They uniquely represent each entity in the entity set
- Example: Each product has a unique name

Key



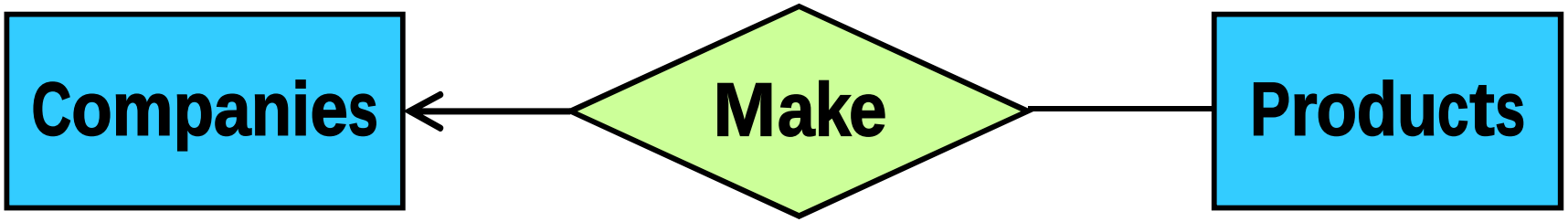
- One or more attributes that are underlined
- What now?
- Each product has a unique <name, category> combination
- But there can be products with the same name, or the same category, but not both
- Example
  - Name = “Apple”, Category = “Fruit”, Price = “1”
  - Name = “Apple”, Category = “Phone”, Price = “888”

Key



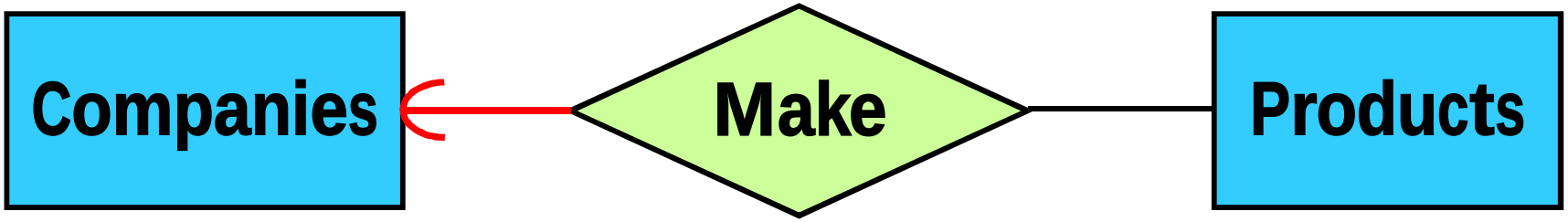
- Rule: Every entity set should have a key
  - So that we can uniquely refer to each entity in the entity set

Referential Integrity



- One company may make multiple products
- One product is made by one company
- Can there be a product that is not made by any company?
- No.
- i.e., every product must be involved in the Make relationship
- This is called a referential integrity constraint.
- How do we specify this in an ER diagram?
- Use a rounded arrow instead of a pointed arrow

Referential Integrity



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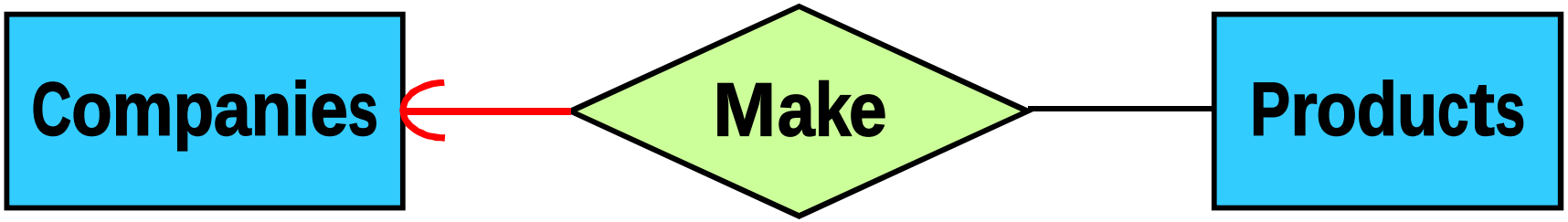
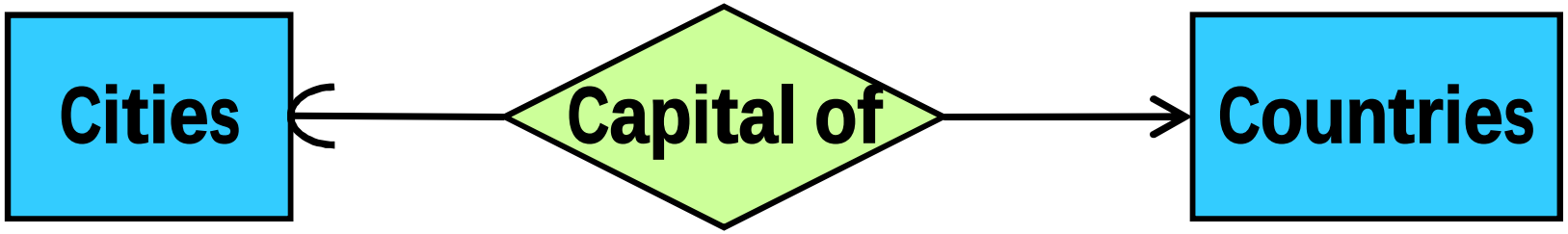
Referential Integrity



- What if every company should make at least one product?
- No arrow there….
- In general, a referential integrity constraint can only apply to the “one” side of
  - A many-to-one relationship, or
  - A one-to-one relationship
- Why? Will be clear later in this course
- For the “many” side, there is another type of constraints to use (will be discussed shortly)

Referential Integrity: Classroom Exercise-6



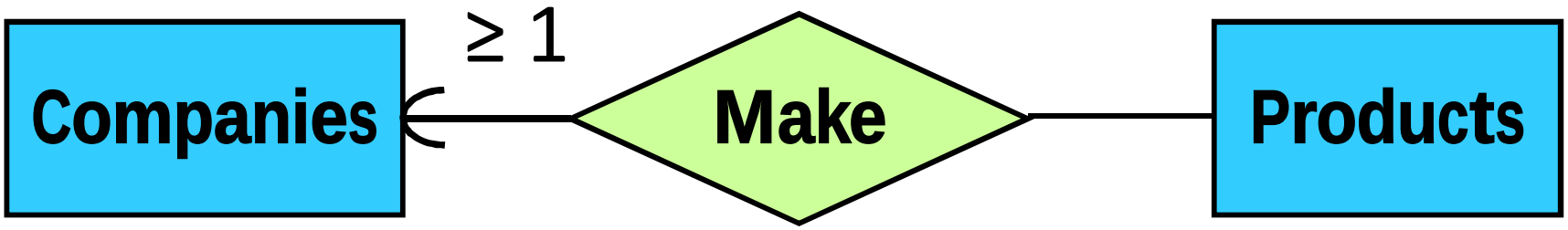
- A city can be the capital of only one country
- A country must have a capital

Referential Integrity: Classroom Exercise-7

- A company must hire at least one person
- A person must be hired by exactly one company

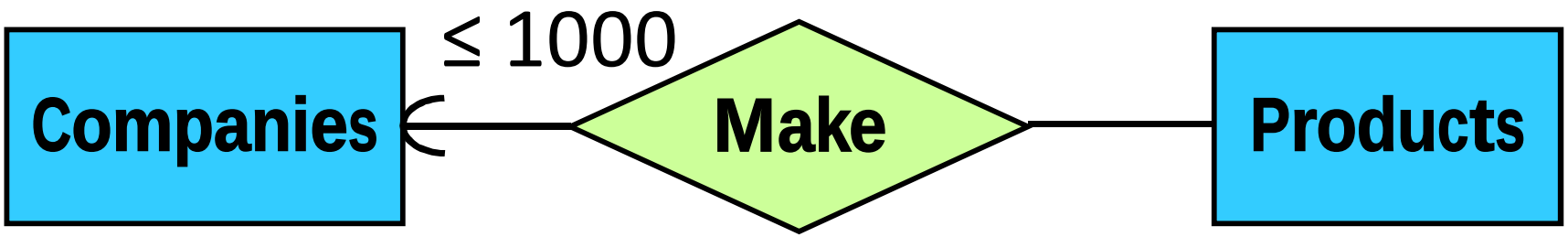
Questions?

Degree Constraint



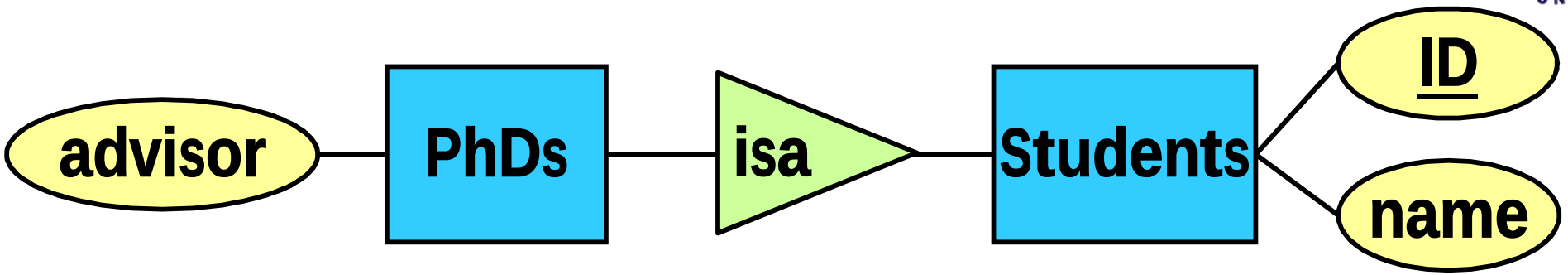
- Each company should make at least 1 product

Degree Constraint



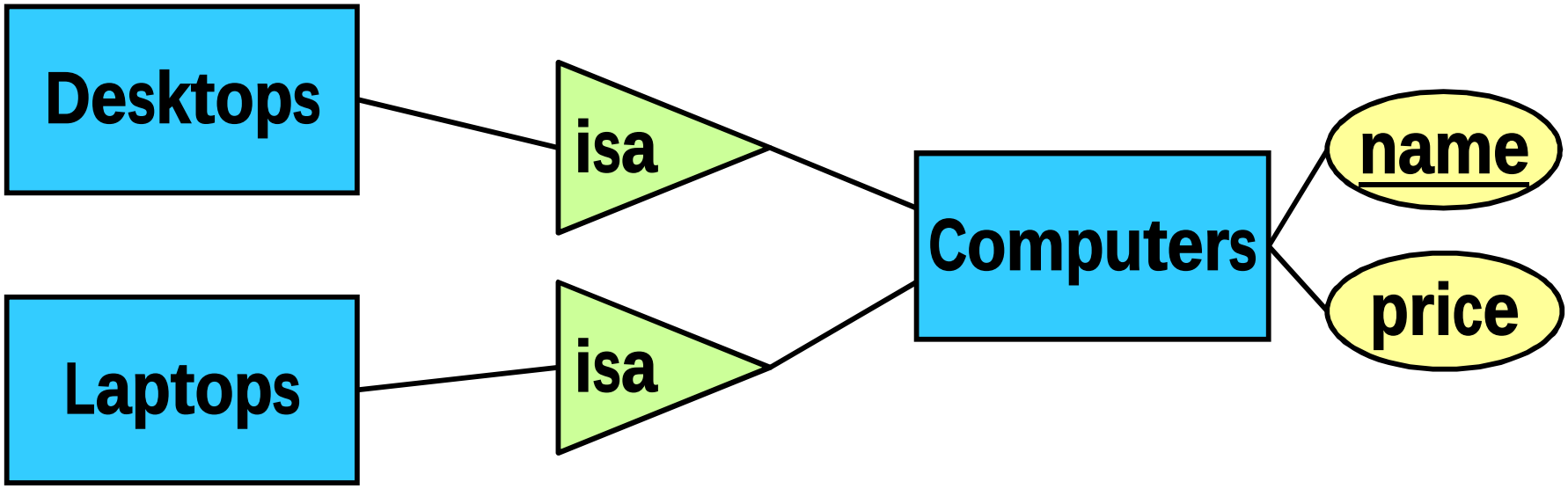
- Each company can make at most 1000 product
- Note
  - Degree constraint not required in the exercise/exam
  - Degree constraints are not easy to enforce in a DBMS
  - Key and referential integrity constraints can be easily enforced

Subclass



- PhDs are a special type of Students
- Subclass = Special type
- The connection between a subclass and its superclass is captured by the isa relationship, which is represented using a triangle
- Key of a subclass = key of its superclass
- Example: Key of Phds = Students.ID
- Students is referred to as the superclass of PhDs

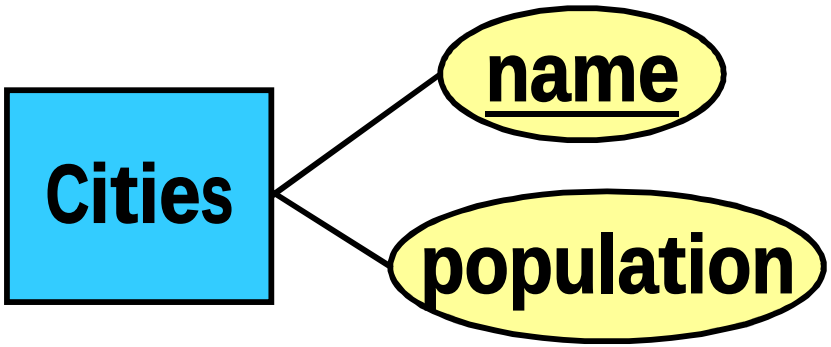
Subclass



- An entity set can have multiple subclasses
- Example
  - Superclass: Computers
  - Subclass 1: Desktop
  - Subclass 2: Laptop

Weak Entity Sets

- Weak entity sets are a special type of entity sets that
  - cannot be uniquely identified by their own attributes
  - needs attributes from other entities to identify themselves
- Example: Cities in USA
- Problem: there are cities with identical names



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Madison

From Wikipedia, the free encyclopedia

Madison may refer to:

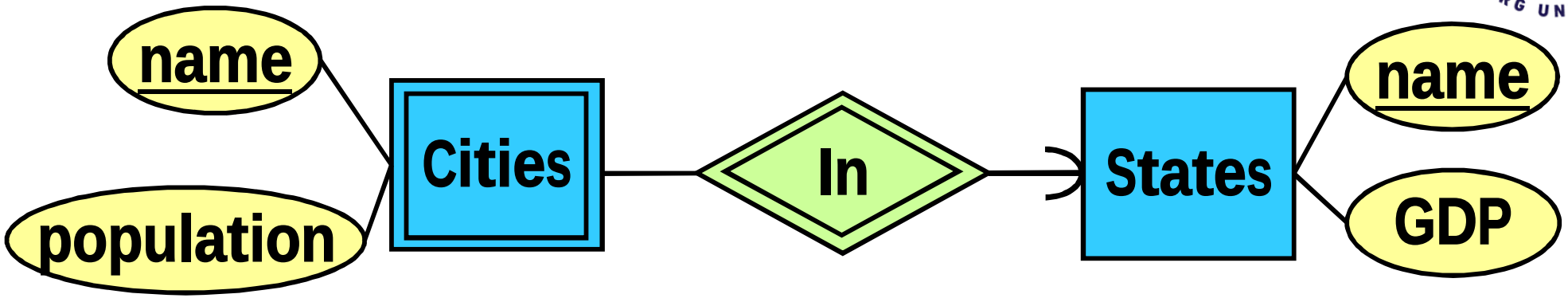
People

- Madison (name), a given name and a surname

Place names

- Madison, Wisconsin, the largest city by the name and the state capital of Wisconsin
- Madison, Alabama
- Madison, Arkansas
- Madison, California
- Madison, Connecticut
- Madison, Florida
- Madison, Georgia
- Madison, Illinois
- Madison, Indiana
- Madison, Kansas
- Madison, Maine
  - Madison (CDP), Maine, census-designated place within the town of Madison
- Madison, Minnesota
- Madison, Mississippi
- Madison, Missouri
- Madison, Nebraska
- Madison, New Hampshire
- Madison, New Jersey
- Madison (town), New York
  - Madison (village), New York, within the town of Madison
- Madison, North Carolina
- Madison, Ohio
- Madison, Pennsylvania
- Madison, South Dakota
- Madison, Tennessee
- Madison, Virginia
- Madison, West Virginia
- Madison (town), Wisconsin, adjacent to the city of Madison
- Madison Lake, Minnesota
- Madison Park, Seattle, Washington State

Weak Entity Sets



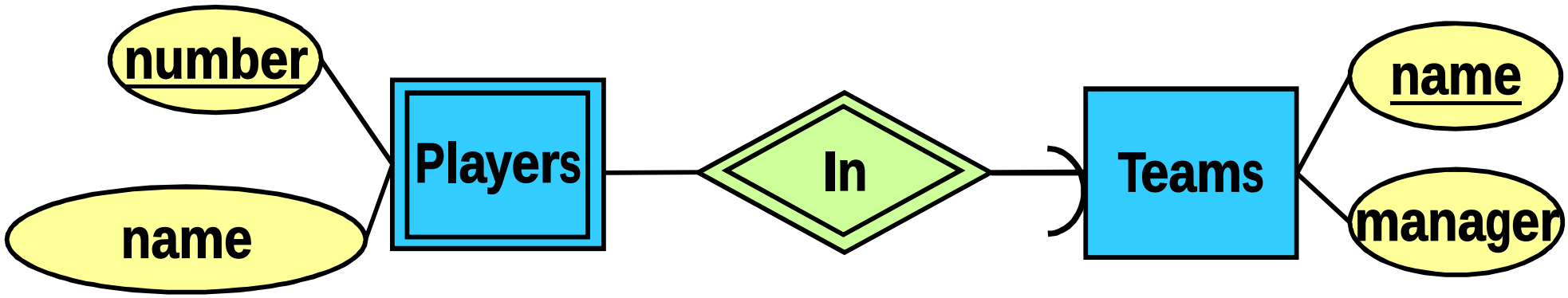
- Problem: there are cities with identical names
- Observation: cities in the same state would have different names
- Solution: make Cities a weak entity set associated with the entity set States
- The relationship In is called the supporting relationship of Cities
- Weak entity set = Double-lined rectangle
- Supporting relationship = Double-lined diamond
- The key of Cities = (State.name, Cities.name)

Classroom Exercise-8

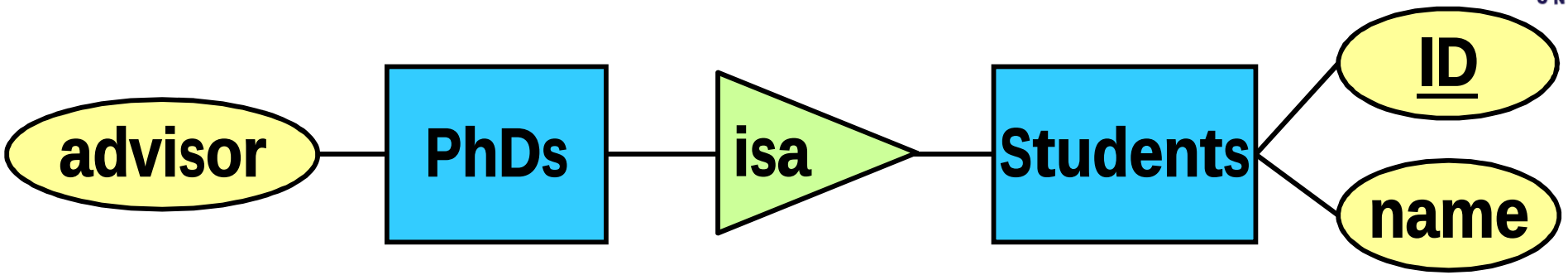
- Consider two entity sets: Players and Teams
- Each player has a name and a number
- Each team has a name and a manager
- Each player plays for exactly one team, and is uniquely identified within the team by his/her number
- Each team is uniquely identified by its name
- Different players may have the same name
- Draw a ER diagram that captures the above statements
- What is the key of Players?

Classroom Exercise-8: Solution

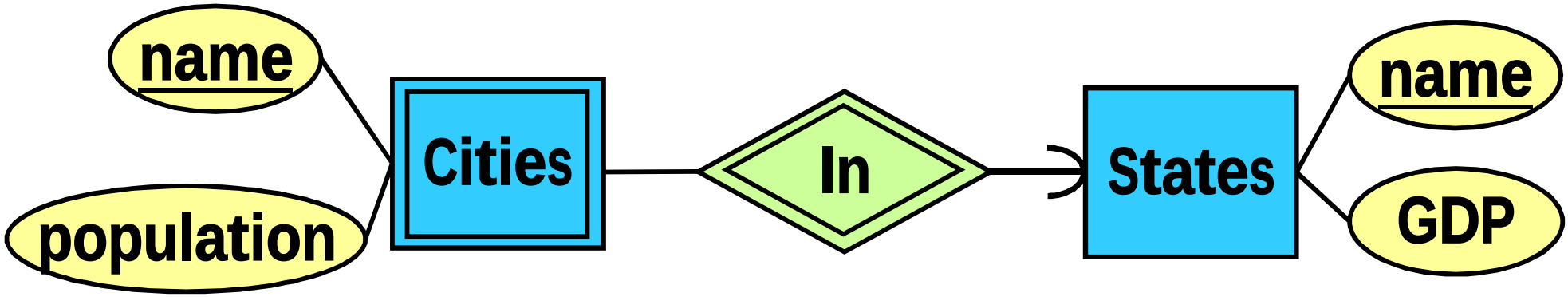
- Consider two entity sets: Players and Teams
- Each player has a name and a number
- Each team has a name and a manager
- Each player plays for exactly one team, and is uniquely identified within the team by his/her number
- Each team is uniquely identified by its name
- Different players may have the same name
- Draw a ER diagram that captures the above statements
- What is the key of Players? (Players.number, Teams.name)



Subclass vs. Weak Entity Sets



- PhDs are a special type of Students



- Cities are NOT a special type of States

Questions?

Summary

- Introduction 
- Entity-relationship diagram 

Study-at-Home Slides

ER Design Principles

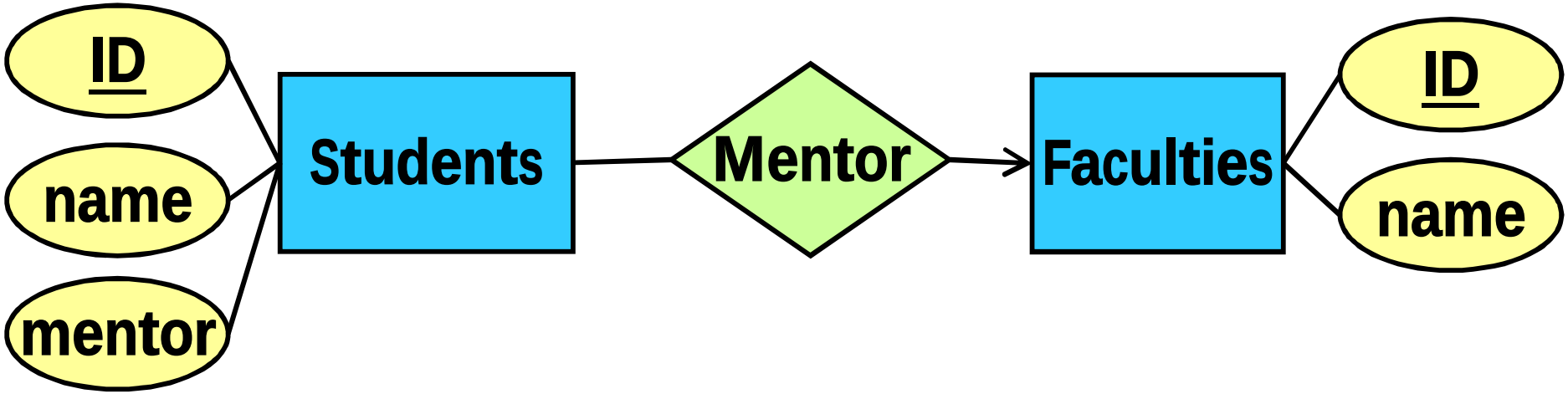
Will be in the syllabus of Exercise, self-study, and Exam

Design Principle 1: Be Faithful

- Be faithful to the specifications of the application
- Capture the requirements as much as possible

Design Principle 2: Avoid Redundancy

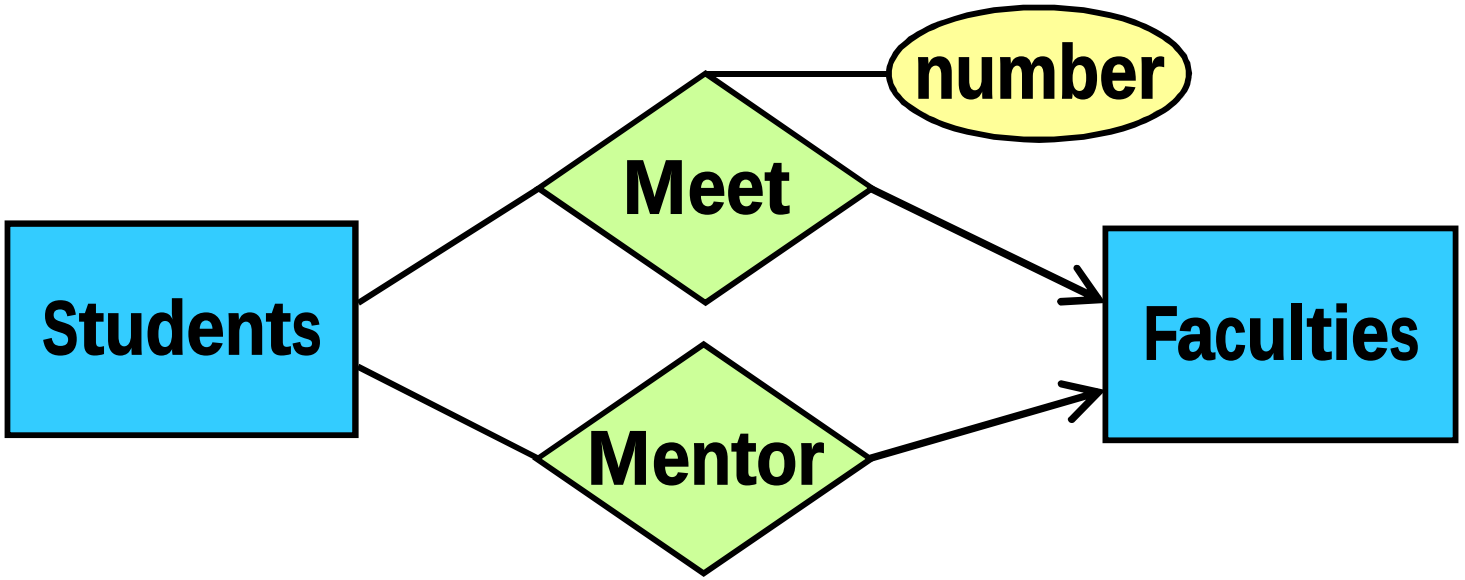
- Avoid repetition of information
- Example



- Problems that can be caused by redundancy
  - Waste of space
  - Possible inconsistency

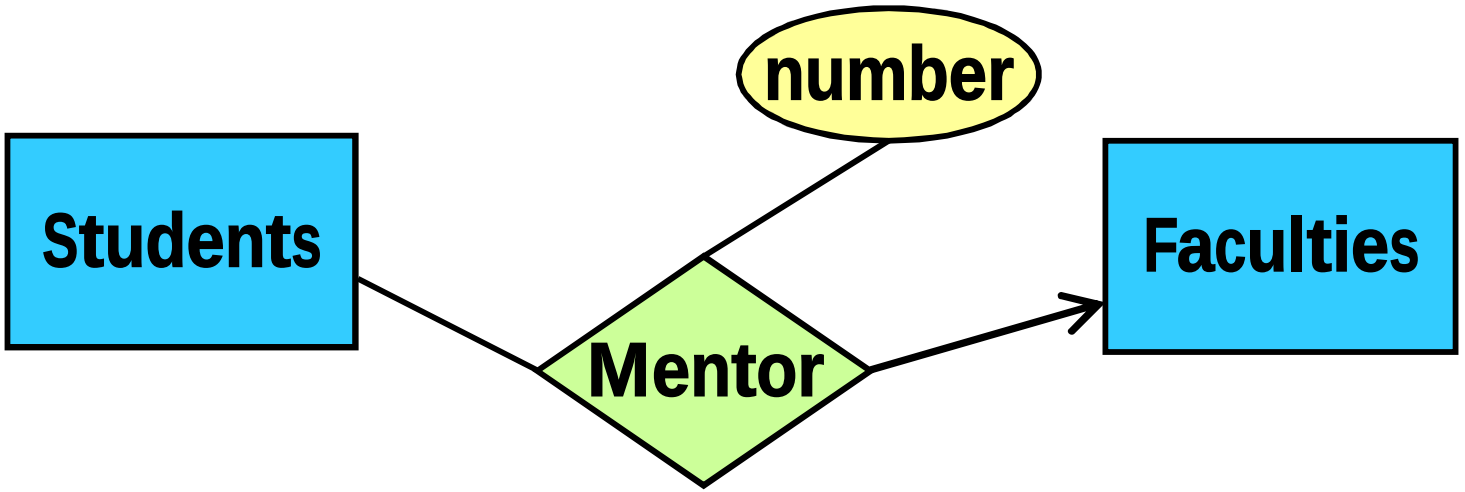
Design Principle 3: Keep It Simple

- Each student is mentored by one faculty
- One faculty can mentor multiple students
- We also record the number of times that a mentee meets with his/her mentor
- Design below: Not wrong, but can be simplified



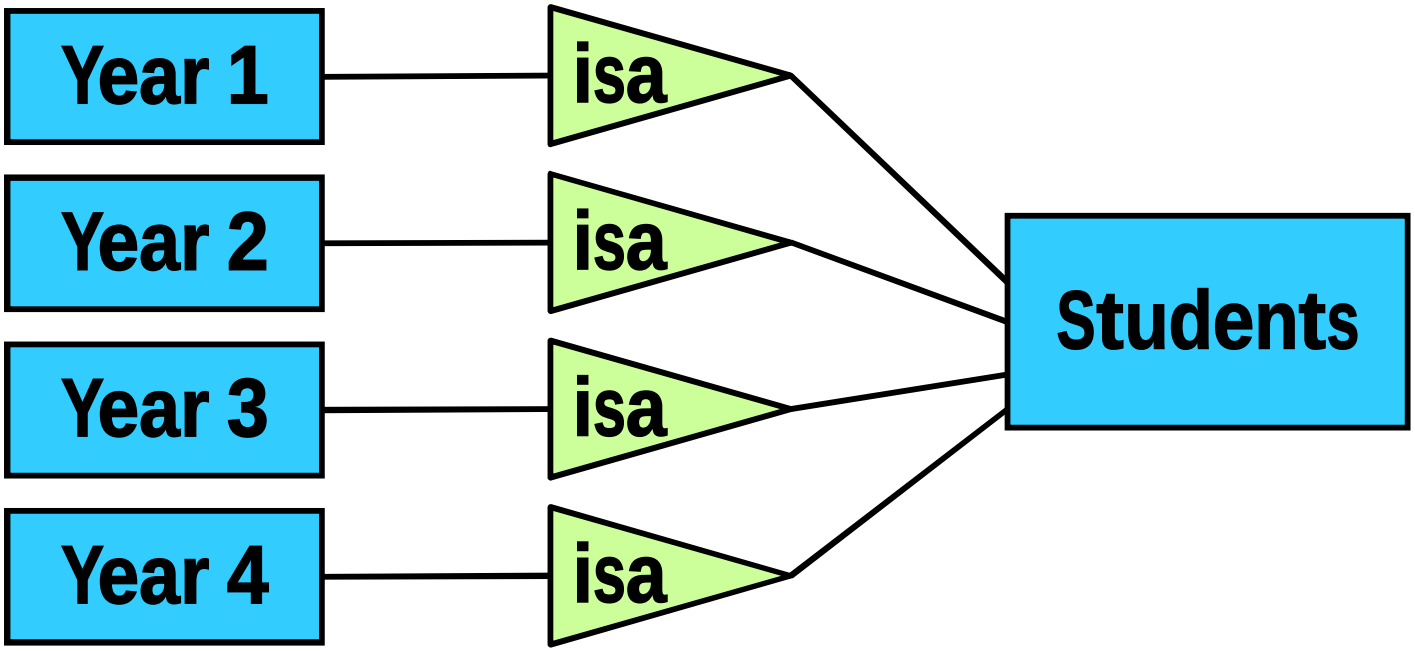
Design Principle 3: Keep It Simple

- Each student is mentored by one faculty
- One faculty can mentor multiple students
- We also record the number of times that a mentee meets with his/her mentor
- Better Design:



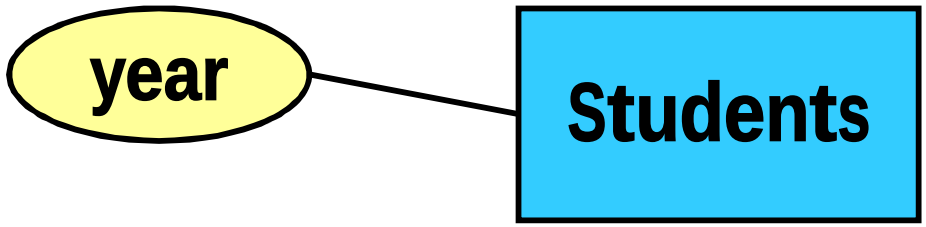
Design Principle 3: Keep It Simple

- There are four types of students: Year 1, Year 2, Year 3, Year 4
- Design below: Not wrong, but can be simplified



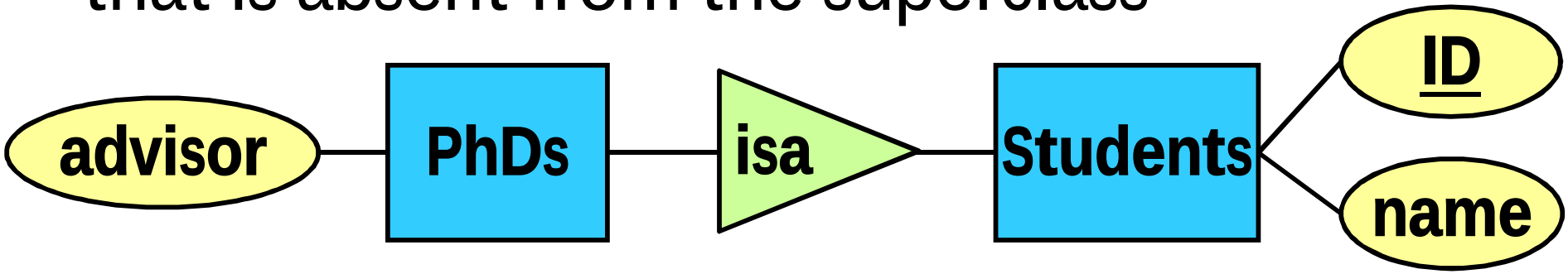
Design Principle 3: Keep It Simple

- There are four types of students: Year 1, Year 2, Year 3, Year 4
- Better Design

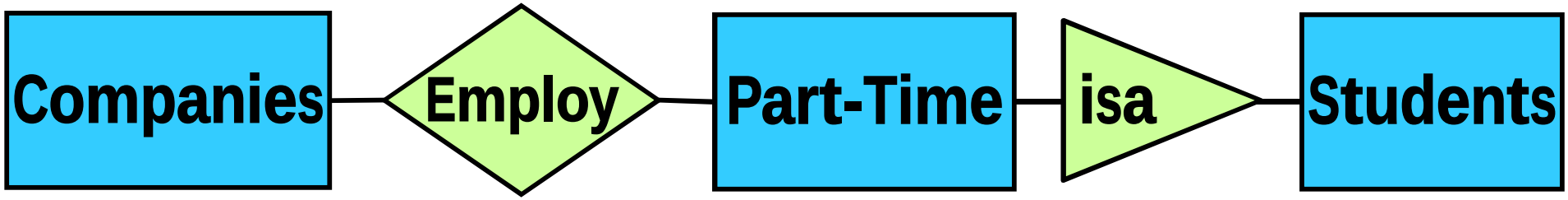


Tips: When to Use Subclasses

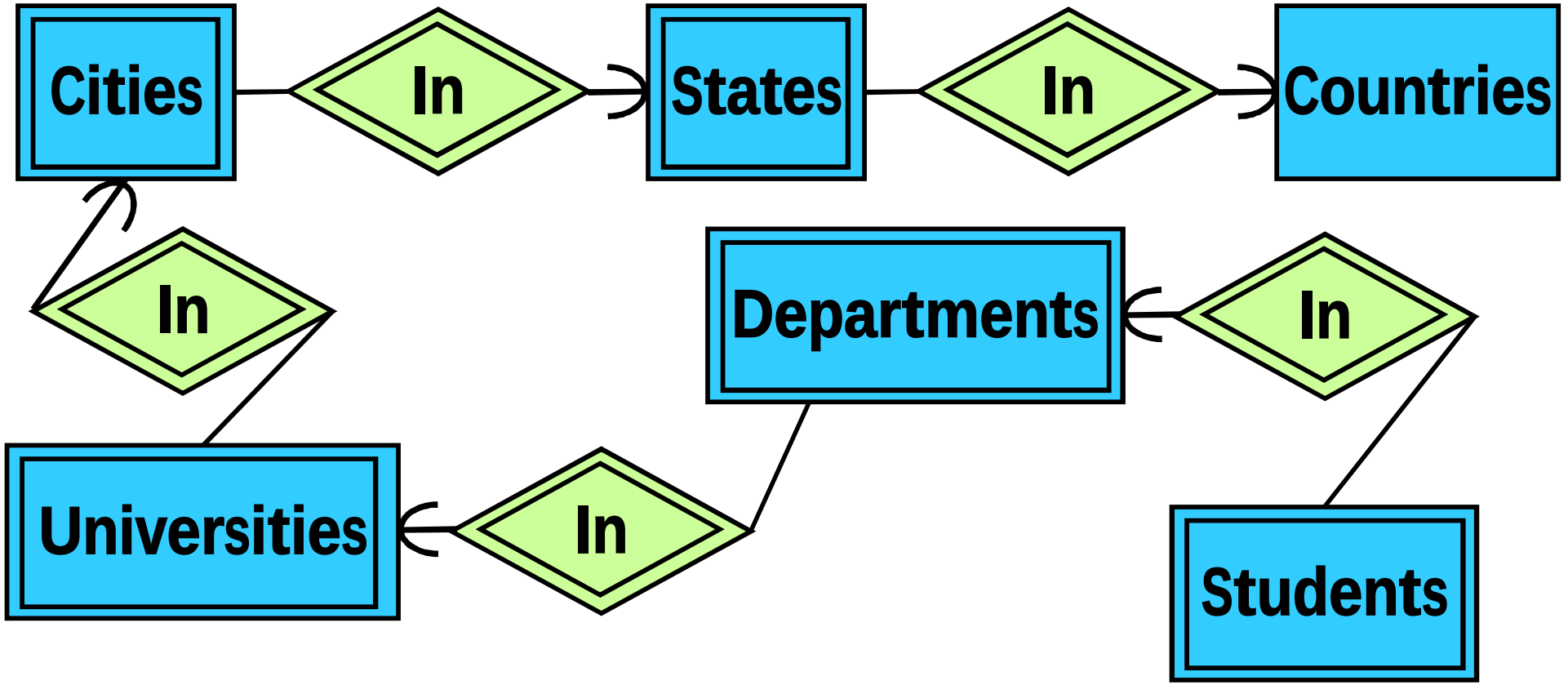
- Case 1: When a subclass has some attribute that is absent from the superclass



- Case 2: When a subclass has its own relationship with some other entity sets



Design Principle 4: Don't Over-use Weak Entity Sets



- Too many entity sets that should not be "weak"

Questions ??

Thank You !