The E/R Model

Prof. Hyuk-Yoon Kwon
https://sites.google.com/view/seoultech-bigdata

Most parts are based on slides used in Stanford (http://web.stanford.edu/class/cs145)

Today's Lecture

1. E/R Basics: Entities & Relations
2. E/R Design considerations
3. Advanced E/R Concepts

What you will learn about in this section

1. High-level motivation for the E/R model

2. Entities

3. Relations

Database Design

- **Database design: Why do we need it?**
  - Agree on structure of the database before deciding on a particular implementation

- **Consider issues such as:**
  - What entities to model
  - How entities are related
  - What constraints exist in the domain
  - How to achieve good designs

- **Several formalisms exist**
  - We discuss one flavor of E/R diagrams

Database Design Process

1. Requirements Analysis → 2. Conceptual Design → 3. Logical, Physical, Security, etc.

1. **Requirements analysis**

- What is going to be stored?
- How is it going to be used?
- What are we going to do with the data?
- Who should access the data?

Technical and non-technical people are involved

Database Design Process

1. Requirements Analysis → **2. Conceptual Design** → 3. Logical, Physical, Security, etc.

2. Conceptual Design

- A high-level description of the database
- Sufficiently precise that technical people can understand it
- But, not so precise that non-technical people can't participate

This is where E/R fits in.

Database Design Process

1. Requirements Analysis → 2. Conceptual Design → 3. Logical, Physical, Security, etc.

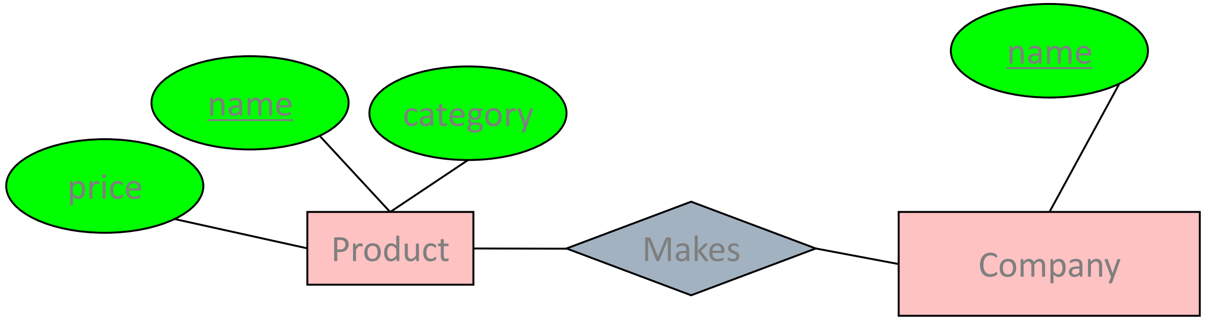
3. More:

- Logical Database Design
- Physical Database Design
- Security Design

Database Design Process

1. Requirements Analysis
2. Conceptual Design
3. Logical, Physical, Security, etc.

E/R Model & Diagrams used



This process is iterated **many** times

E/R is a *visual syntax* for DB design which is ***precise enough*** for technical points, but ***abstracted enough*** for non-technical people

Impact of the ER model

- **The E/R model is one of the most cited articles in Computer Science**
  - *"The Entity-Relationship model – toward a unified view of data"* Peter Chen, 1976

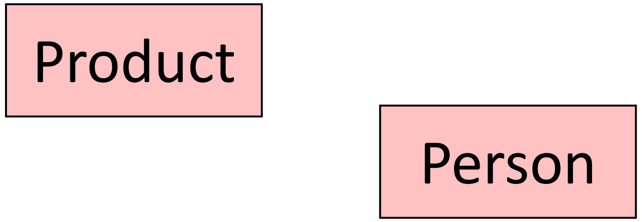
- **Used by companies big and small**
  - You'll know it soon enough

Entities and Entity Sets

■ Entities & entity sets are the primitive unit of the E/R model

- Entities are the individual objects, which are members of entity sets
  - Ex: A specific person or product

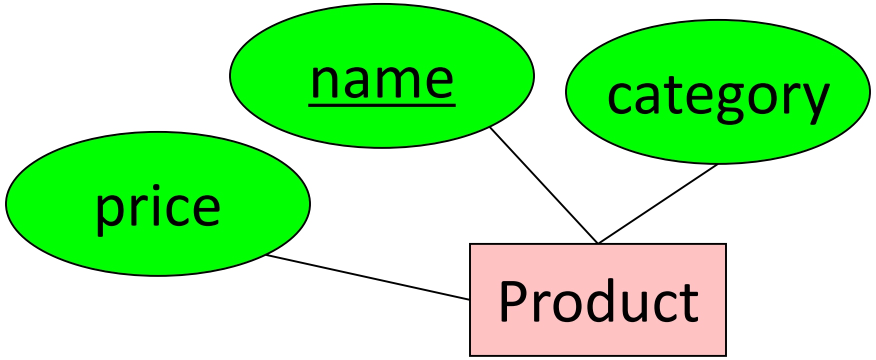
- Entity sets are the *classes* or *types* of objects in our model
  - *Entity sets represent the sets of all possible entities*
  - Ex: Person, Product
  - *These are what is shown in E/R diagrams - as rectangles*



These represent **entity sets**

Entities and Entity Sets

- **An entity set has attributes**
  - Represented by ovals attached to an entity set

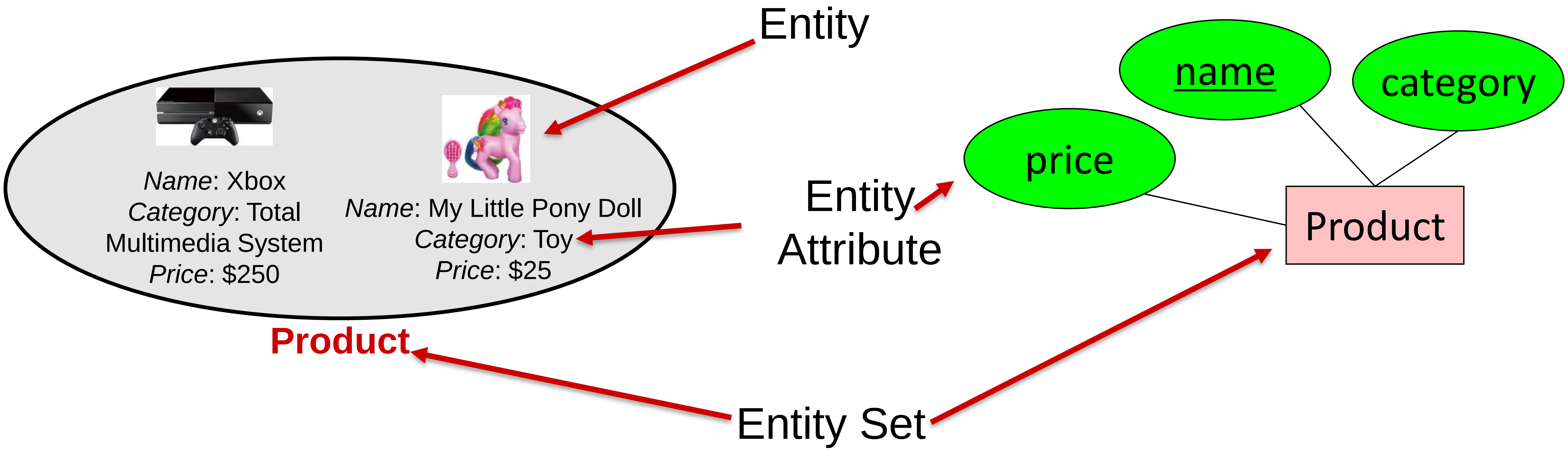


Shapes **are** important.
Colors **are not.**

Entities vs. Entity Sets

Example:

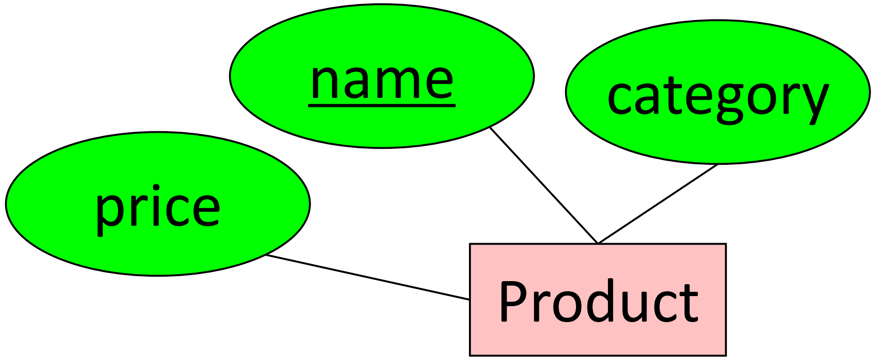
Entities are **not** explicitly represented in E/R diagrams!



Keys

- **A *key* is a minimal set of attributes that uniquely identifies an entity.**

Denote elements of the primary key by underlining.



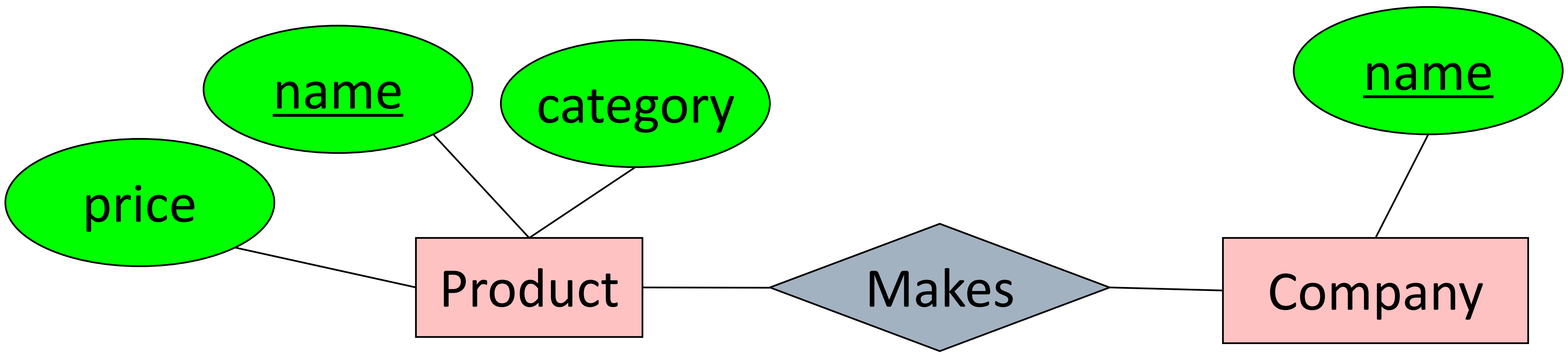
Here, {name, category} is **not** a key (it is not *minimal*).

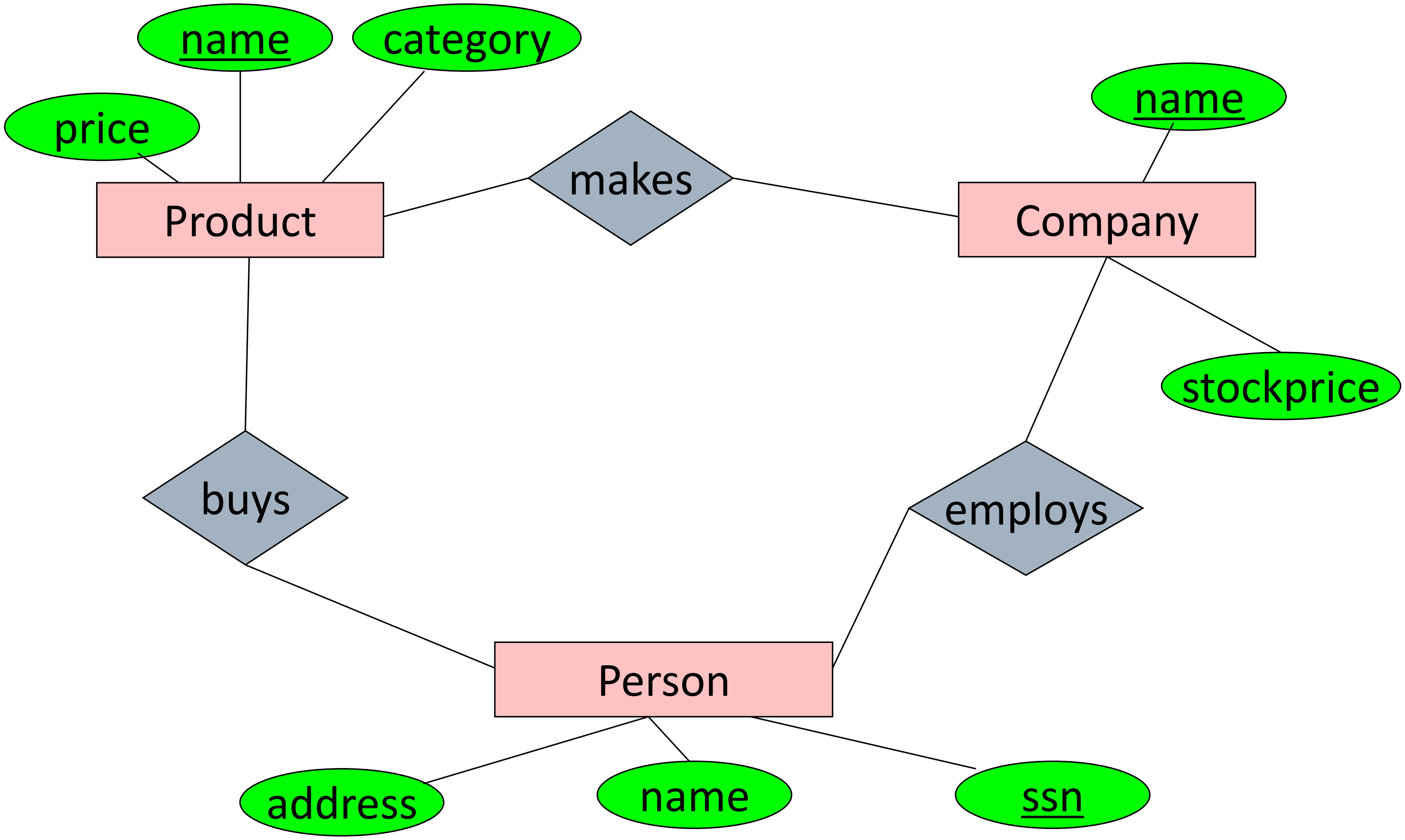
If it were, what would it mean?

The E/R model forces us to designate a single **primary** key, though there may be multiple candidate keys

The R in E/R: Relationships

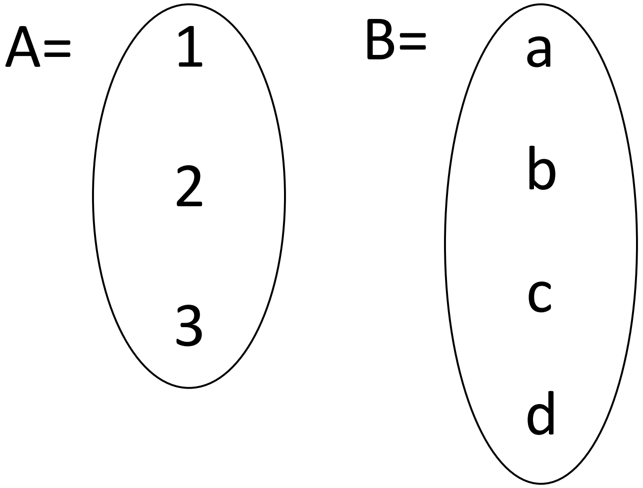
- A relationship is between two entities




name
category
price
name
makes
Product
Company
buys
stockprice
employs
Person
address
name
ssn

What is a Relationship?

- ***A mathematical definition:***
  - Let A, B be sets
    - *A={1,2,3},   B={a,b,c,d}*

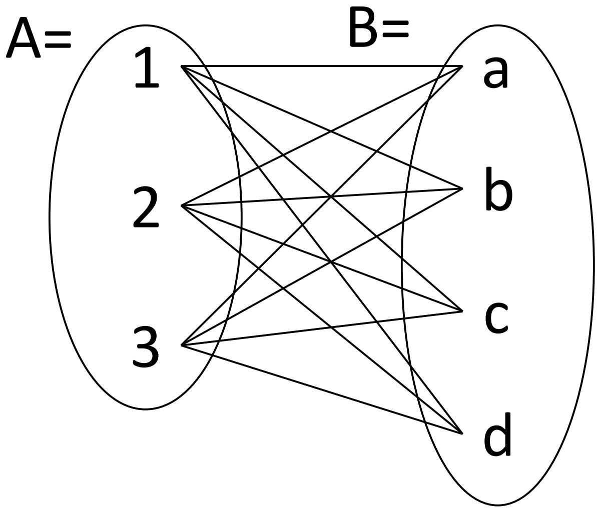


What is a Relationship?

- ***A mathematical definition:***

  - Let A, B be sets
    - *A={1,2,3},   B={a,b,c,d}*

  - A x B (the ***cross-product***) is the set of all pairs (a,b)
    - $A \times B$ = *{(1,a), (1,b), (1,c), (1,d), (2,a), (2,b), (2,c), (2,d), (3,a), (3,b), (3,c), (3,d)}*



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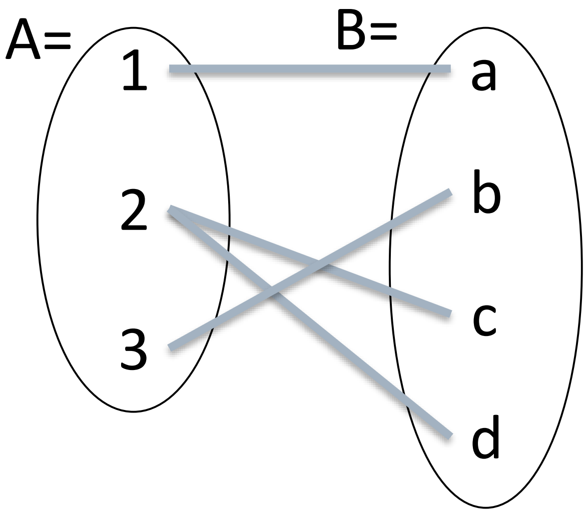
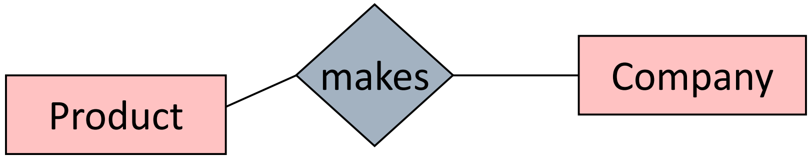
  - **We define a <u>relationship</u> to be a subset of A x B**
    - *R = {(1,a), (2,c), (2,d), (3,b)}*

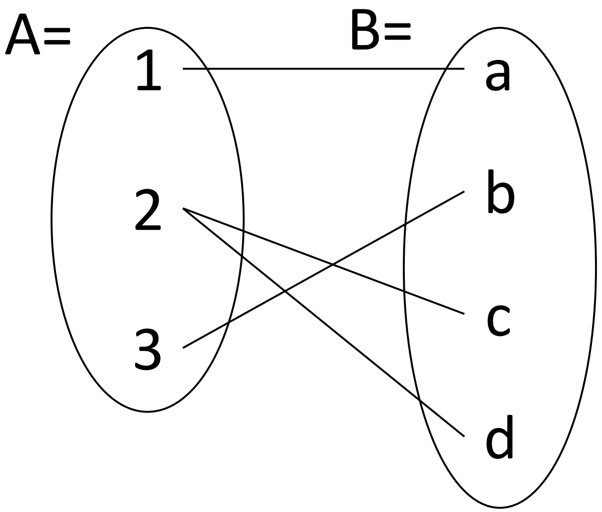


What is a Relationship?

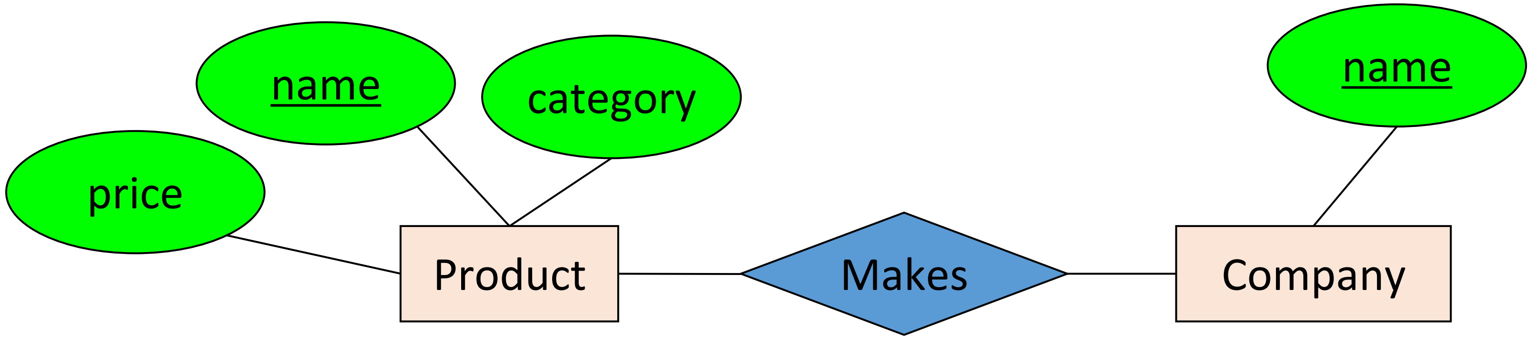
- ***A mathematical definition:***
  - Let A, B be sets
  - A x B (the ***cross-product***) is the set of all pairs
  - A relationship is a subset of A x B

- **Makes is relationship- it is a *subset* of Product × Company:**





What is a Relationship?



A **<u>relationship</u>** between **entity sets P and C** is a ***subset of all possible pairs of entities in P and C***, with tuples uniquely identified by ***P and C's keys***

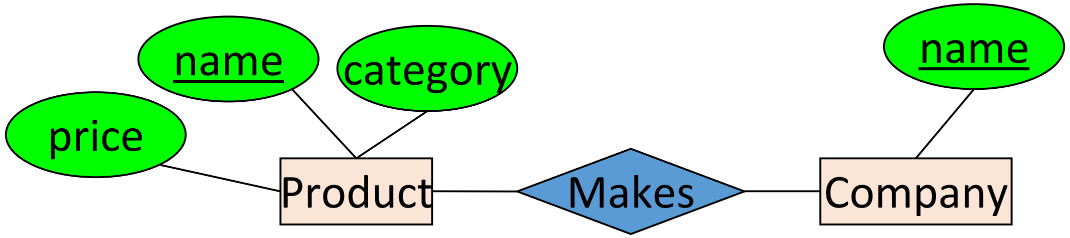
What is a Relationship?

Company

name
GizmoWorks
GadgetCorp

Product

name	category	price
Gizmo	Electronics	$9.99
GizmoLite	Electronics	$7.50
Gadget	Toys	$5.50



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Company C × Product P

C.name	P.name	P.category	P.price
GizmoWorks	Gizmo	Electronics	$9.99
GizmoWorks	GizmoLite	Electronics	$7.50
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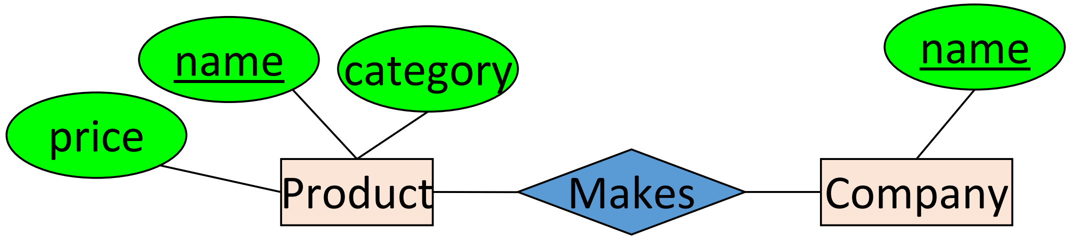

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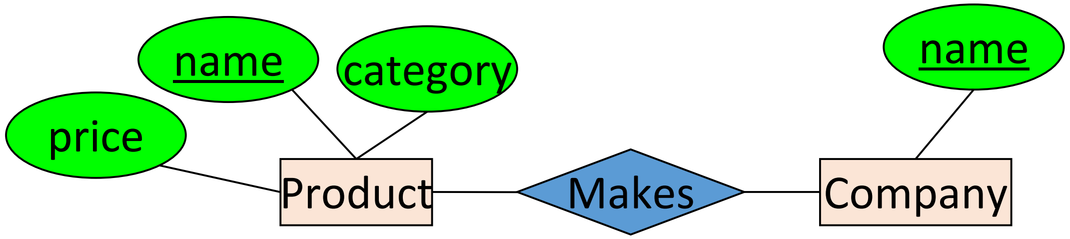
Makes

C.name	P.name
GizmoWorks	Gizmo
GizmoWorks	GizmoLite
GadgetCorp	Gadget



A relationship between **entity sets P and C** is a ***subset of all possible pairs of entities in P and C***, with tuples uniquely identified by ***P and C's keys***

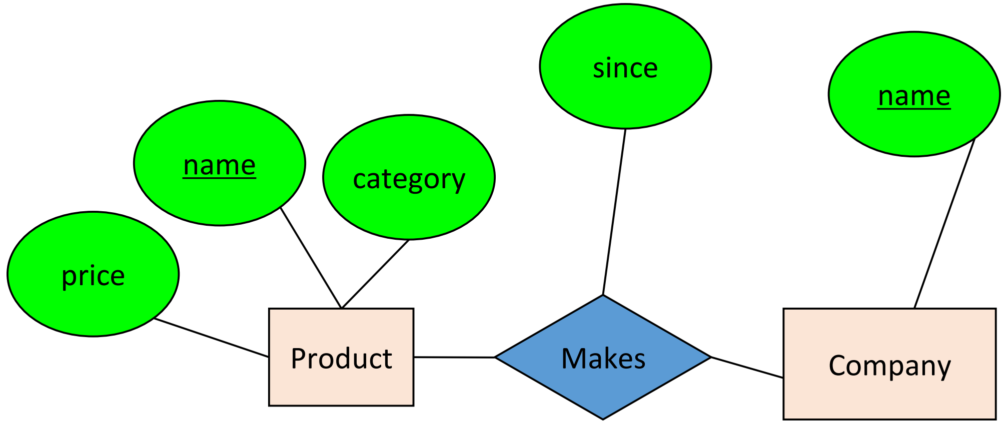
What is a Relationship?

- There can only be one relationship for every unique combination of entities

- This also means that the relationship is uniquely determined by the keys of its entities

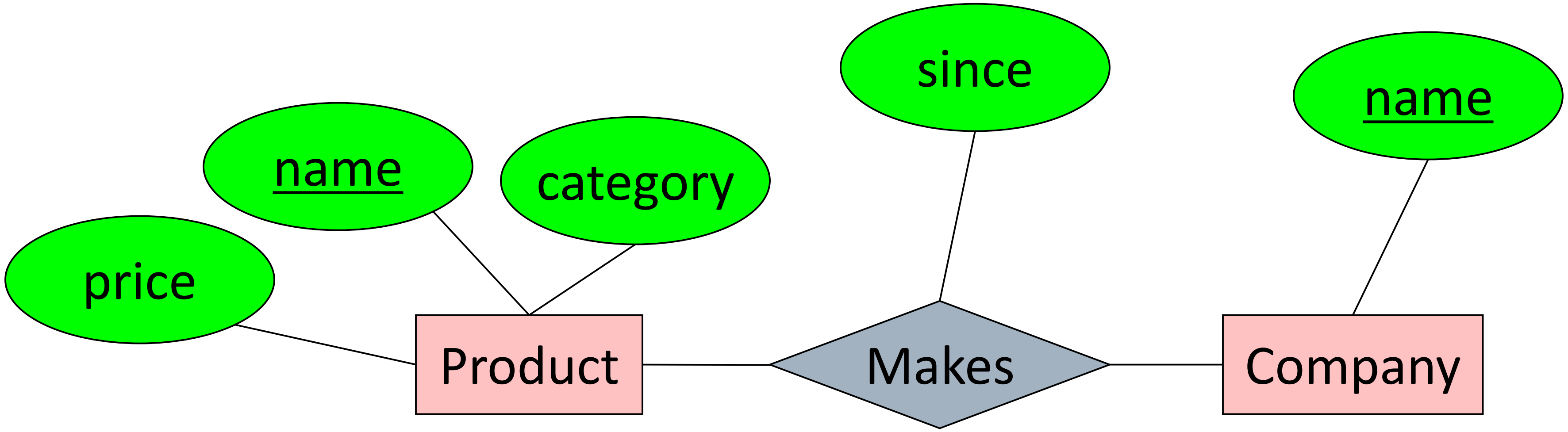
- *Example: the "key" for Makes (to right) is*

  {Product.name, Company.name}



Relationships and Attributes

- **Relationships may have attributes as well.**



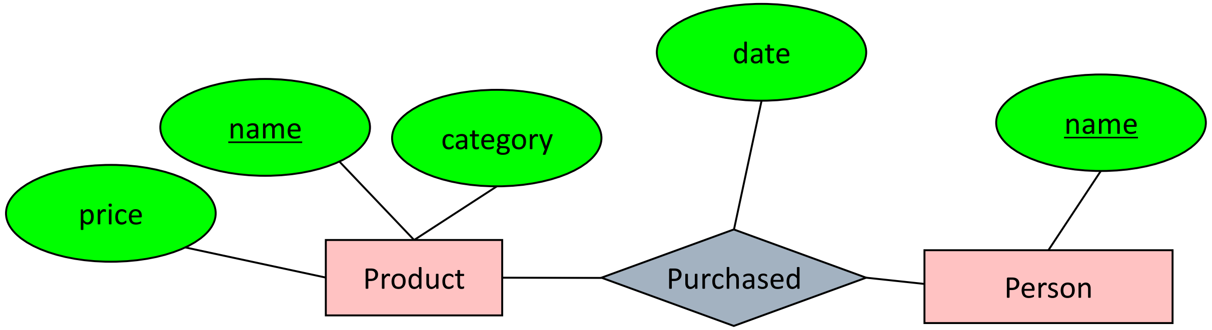
For example: "since" records when company started making a product

Note: "*since*" is implicitly unique per pair here! Why?

Note #2: Why not "how long"?

Decision: Relationship vs. Entity?

- **Q: What does this say?**

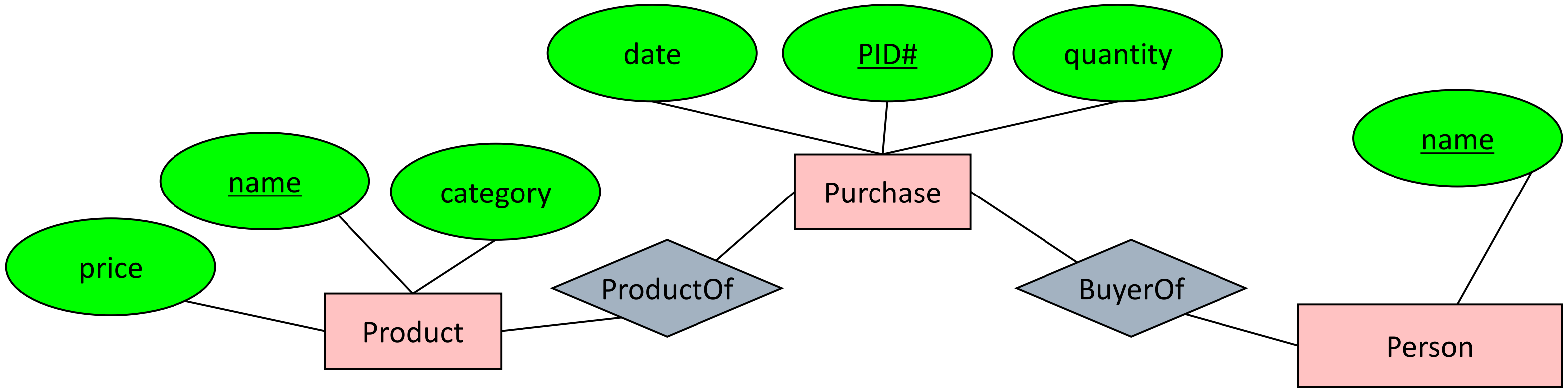


- **A: A person can only buy a specific product once (on one date)**

Modeling something as a relationship makes it unique; what if not appropriate?

Decision: Relationship vs. Entity?

- **What about this way?**



- ***Now we can have multiple purchases per product, person pair!***

We can always use **a new entity** instead of a relationship. For example, to permit multiple instances of each entity combination!

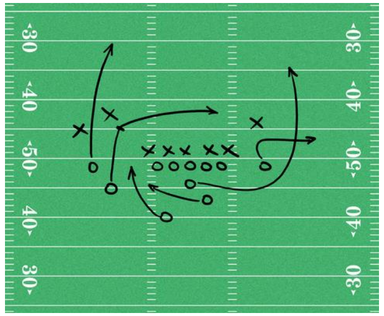
Practice1

Draw an E/R diagram for football

Use the following simplified model of a football season
<u>(concepts to include are underlined):</u>

<u>Teams</u> play each other in **<u>Games</u>**. Each pair of teams can play each other multiple times

<u>Players</u> belong to Teams (assume no trades / changes).



A Game is made up of **<u>Plays</u>** that result in a yardage gain/loss, and potentially a touchdown

A Play will contain either a **<u>Pass</u>** from one player to another, or a **<u>Run</u>** by one player

Today’s Lecture

1. E/R Basics: Entities & Relations
2. **E/R Design considerations**
3. Advanced E/R Concepts

What you will learn about in this section

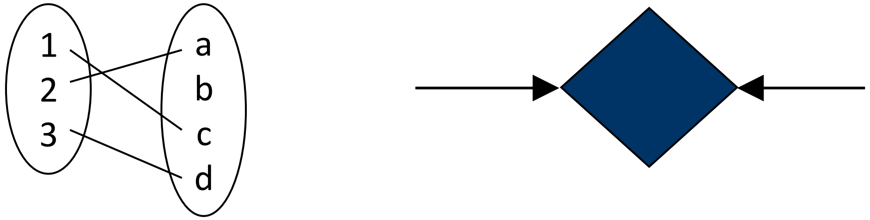
1. **Relationships cont'd: multiplicity, multi-way**

2. **Design considerations**

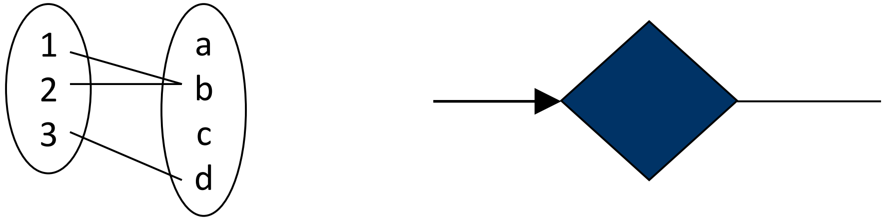
3. **Conversion to relational schema**

Multiplicity of E/R Relationships

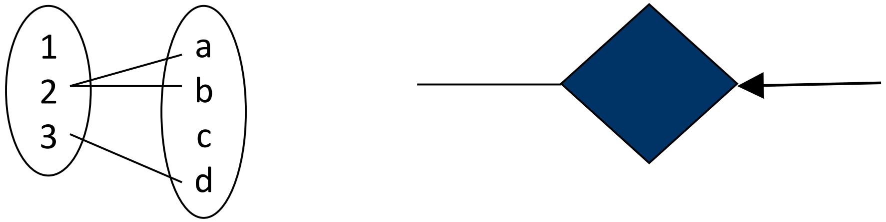
One-to-one:



Many-to-one:



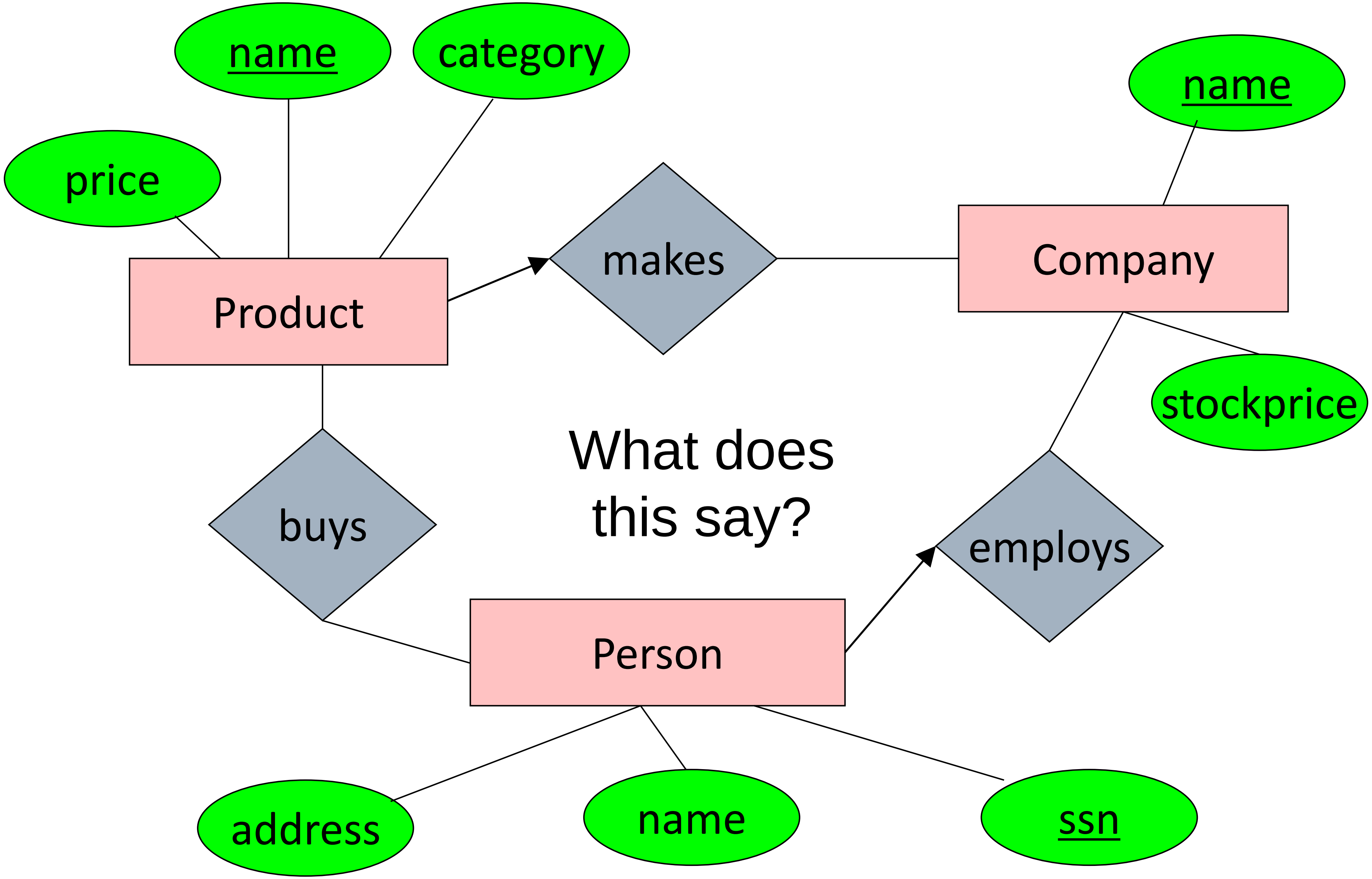
One-to-many:



Many-to-many:

Indicated using arrows

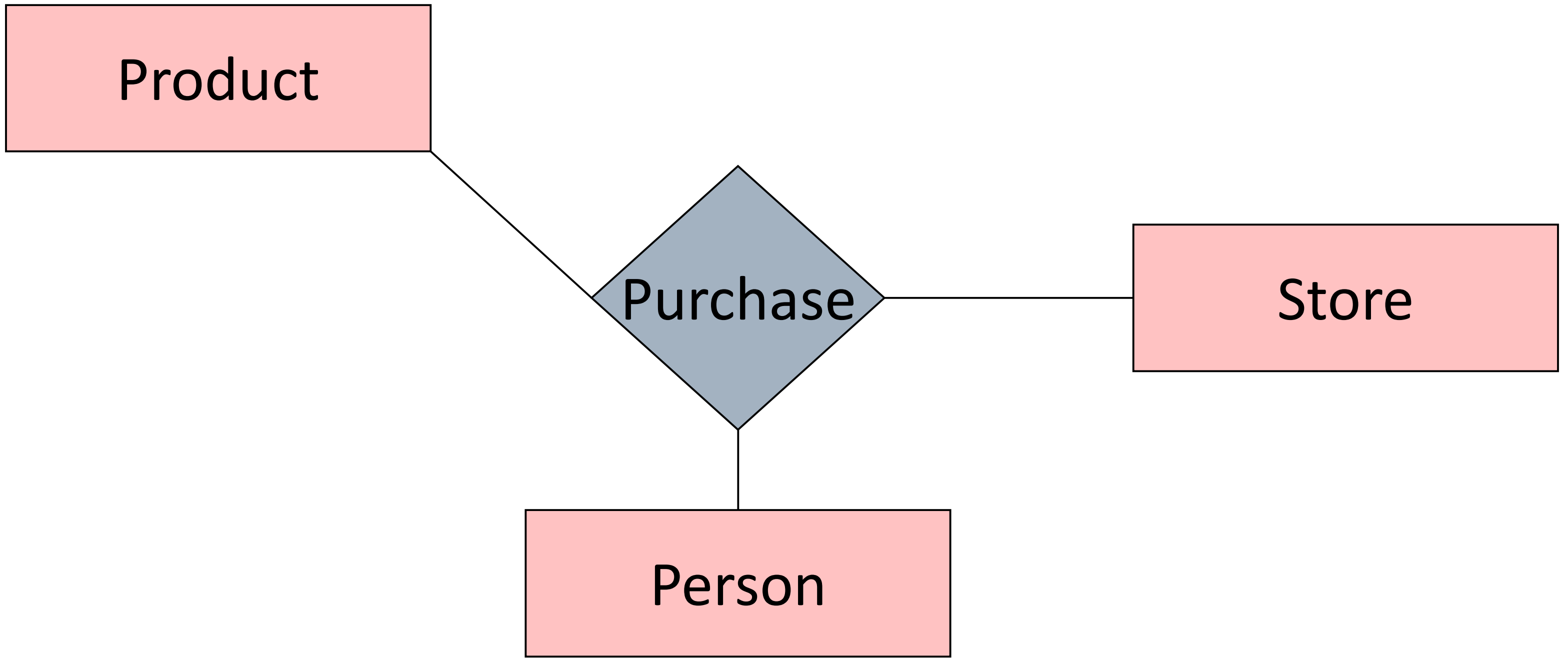
X -> Y means **<u>there exists a function mapping from X to Y</u>** (*recall the definition of a function)*



What does this say?

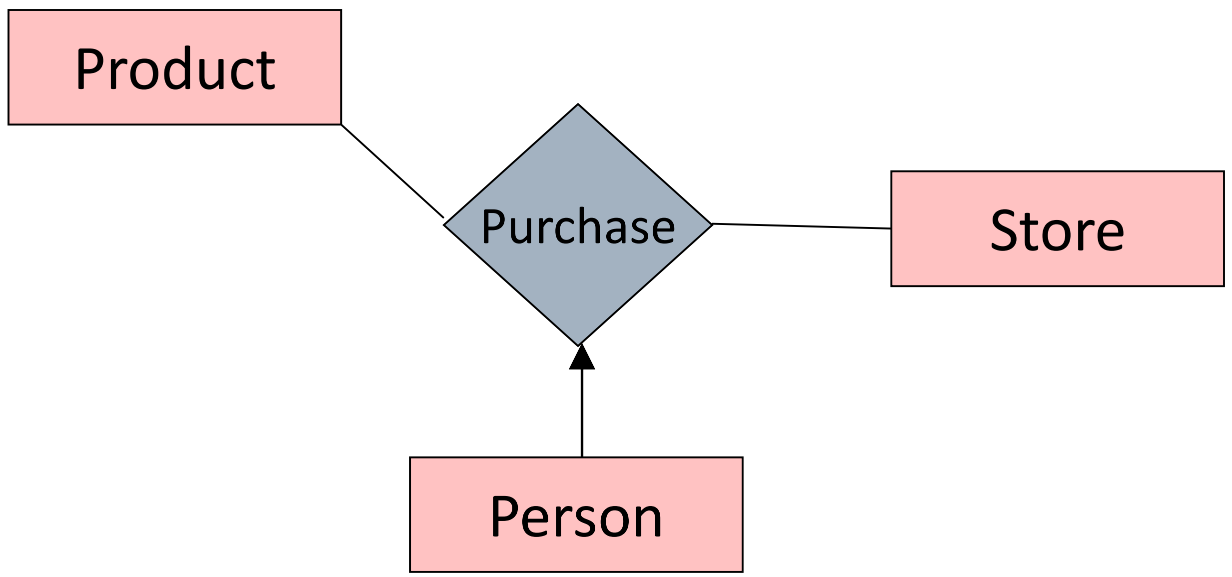
Multi-way Relationships

- **How do we model a purchase relationship between buyers, products and stores?**



Arrows in Multiway Relationships

Q: What does the arrow mean ?



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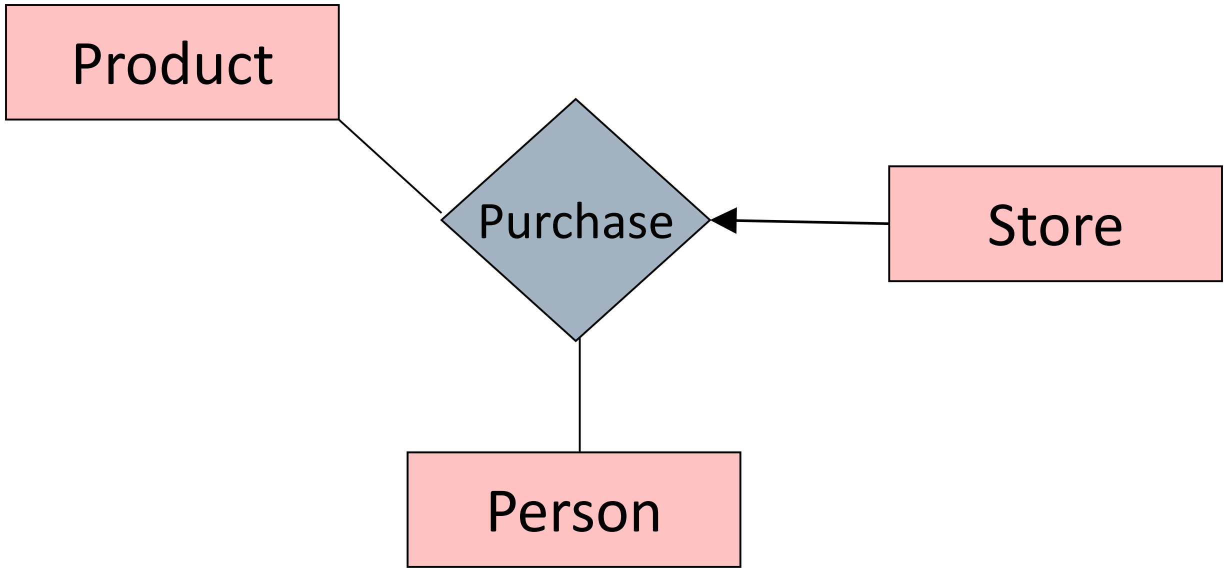
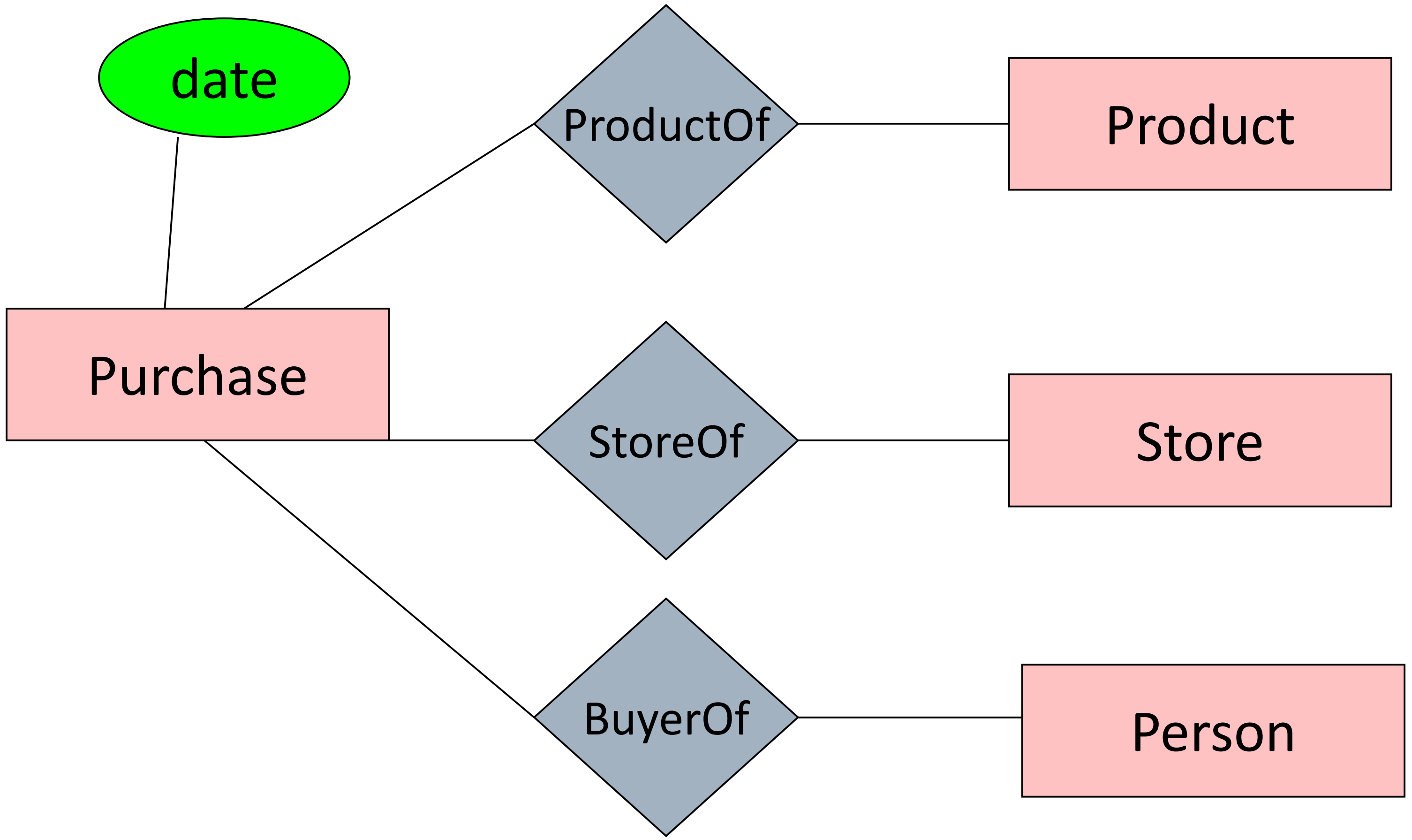
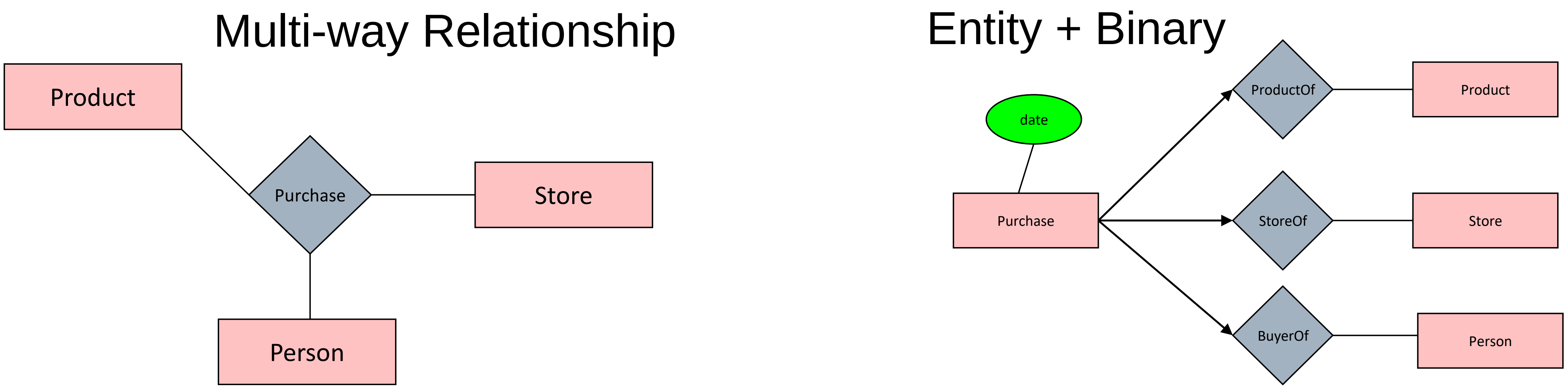


Converting Multi-way Relationships to Binary



From what we had on previous slide to this - what did we do?

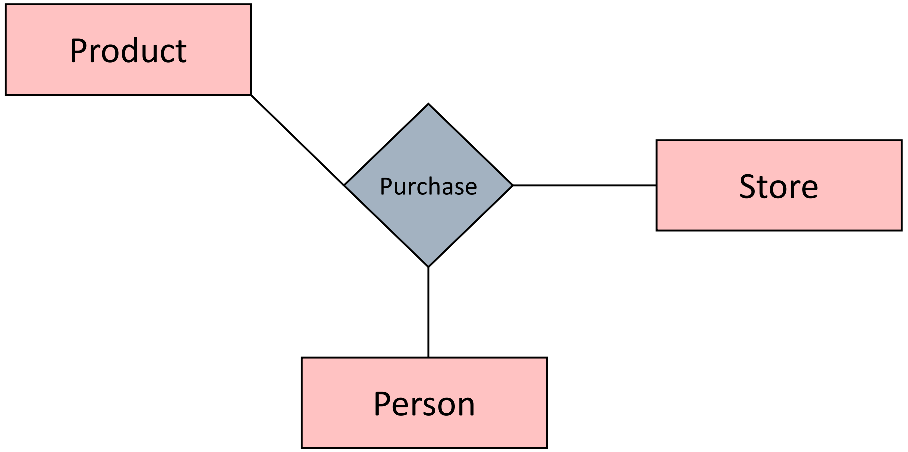
Decision: Multi-way or New Entity + Binary?



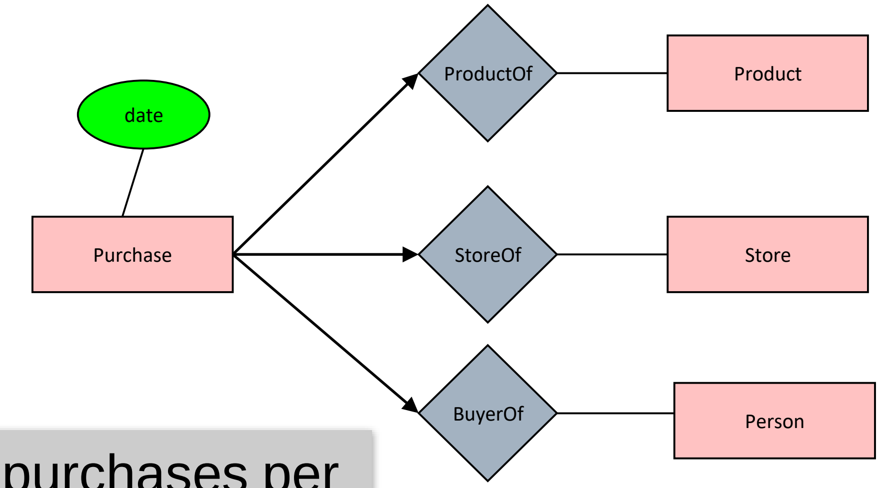
Should we use a single **multi-way relationship** or a ***new entity with binary relations?***

Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



(B) Entity + Binary

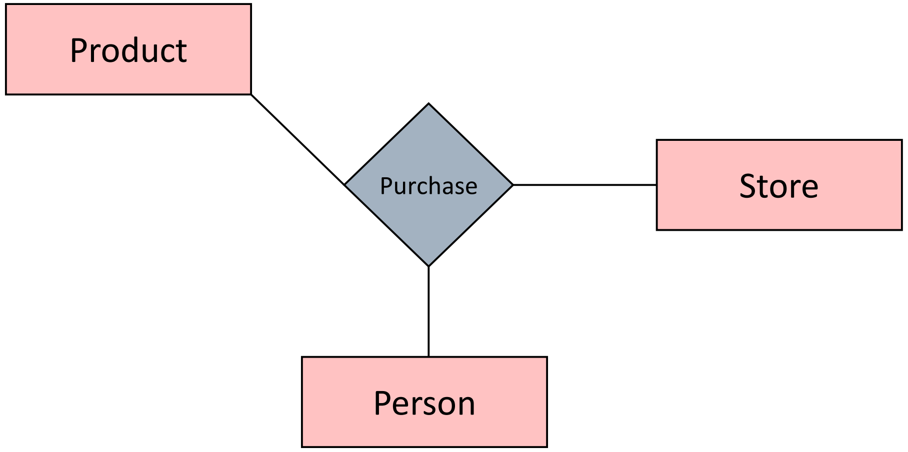


Multiple purchases per (product, store, person) combo possible here!

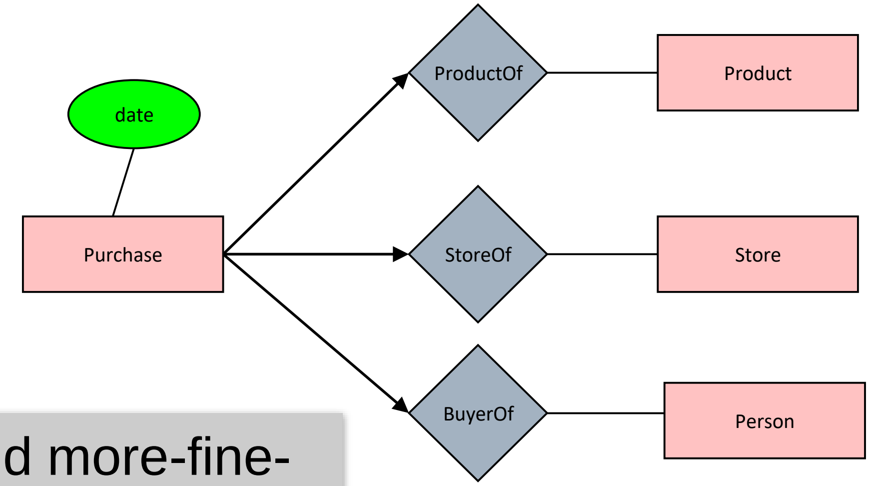
- *Covered earlier:* (B) is useful if we want to have multiple instances of the "relationship" per entity combination

Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



(B) Entity + Binary

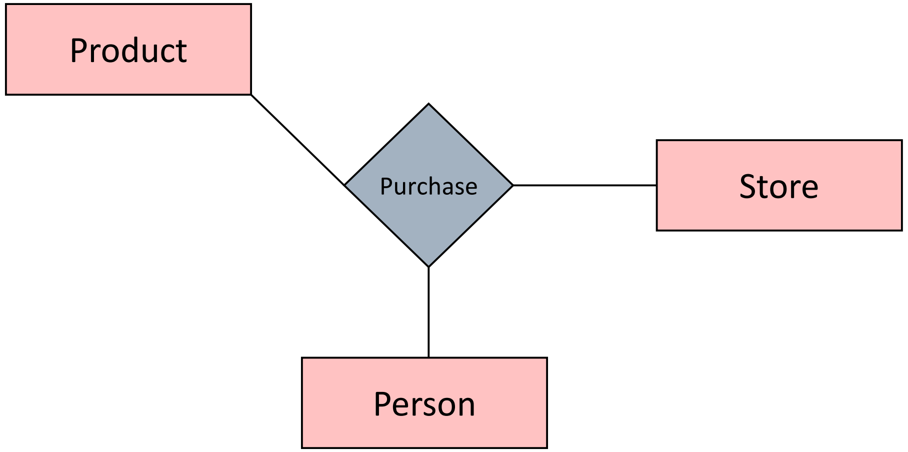


We can add more-fine-grained constraints here!

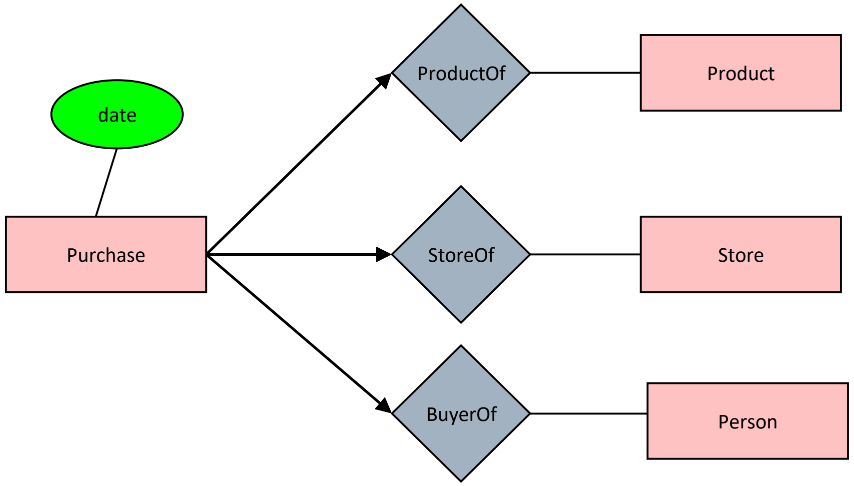
- (B) is also useful when we want to add details (constraints or attributes) to the relationship
  - “A person who shops in only one store”
  - “How long a person has been shopping at a store”

Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



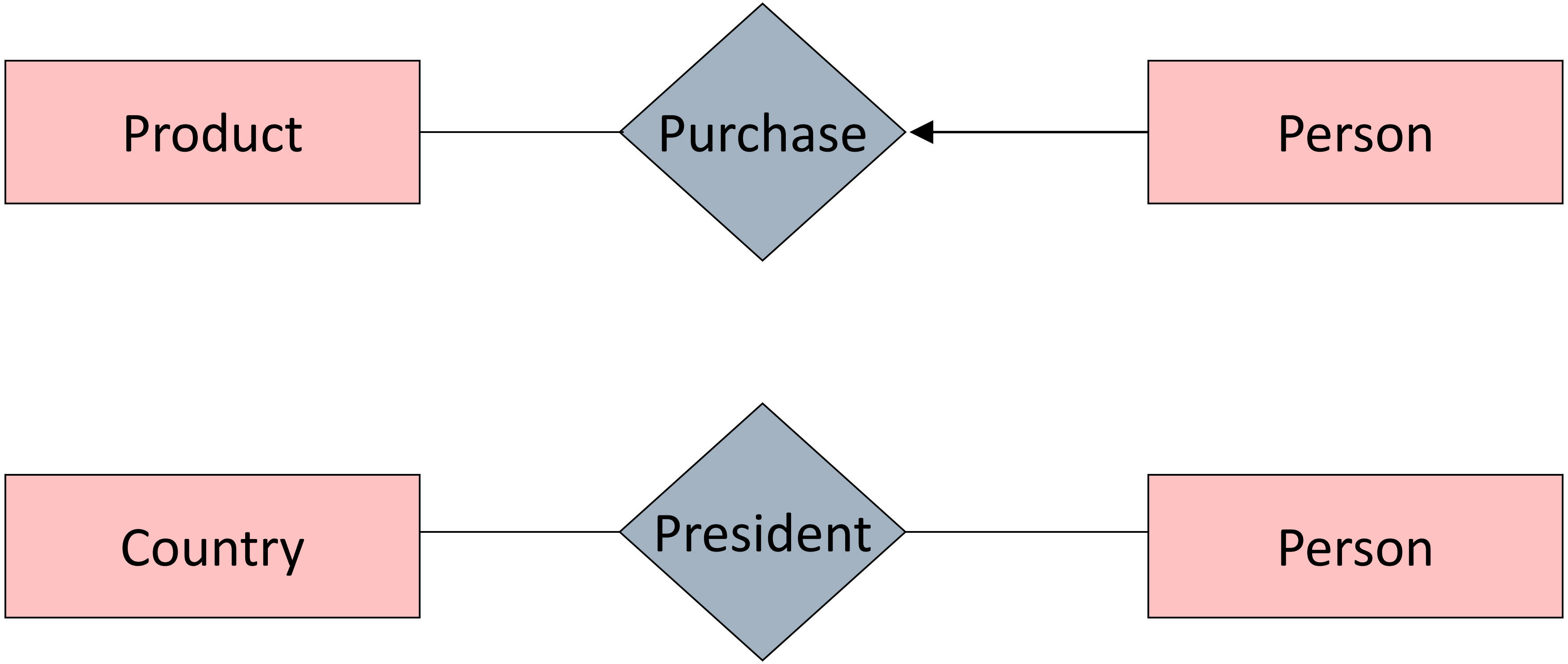
(B) Entity + Binary



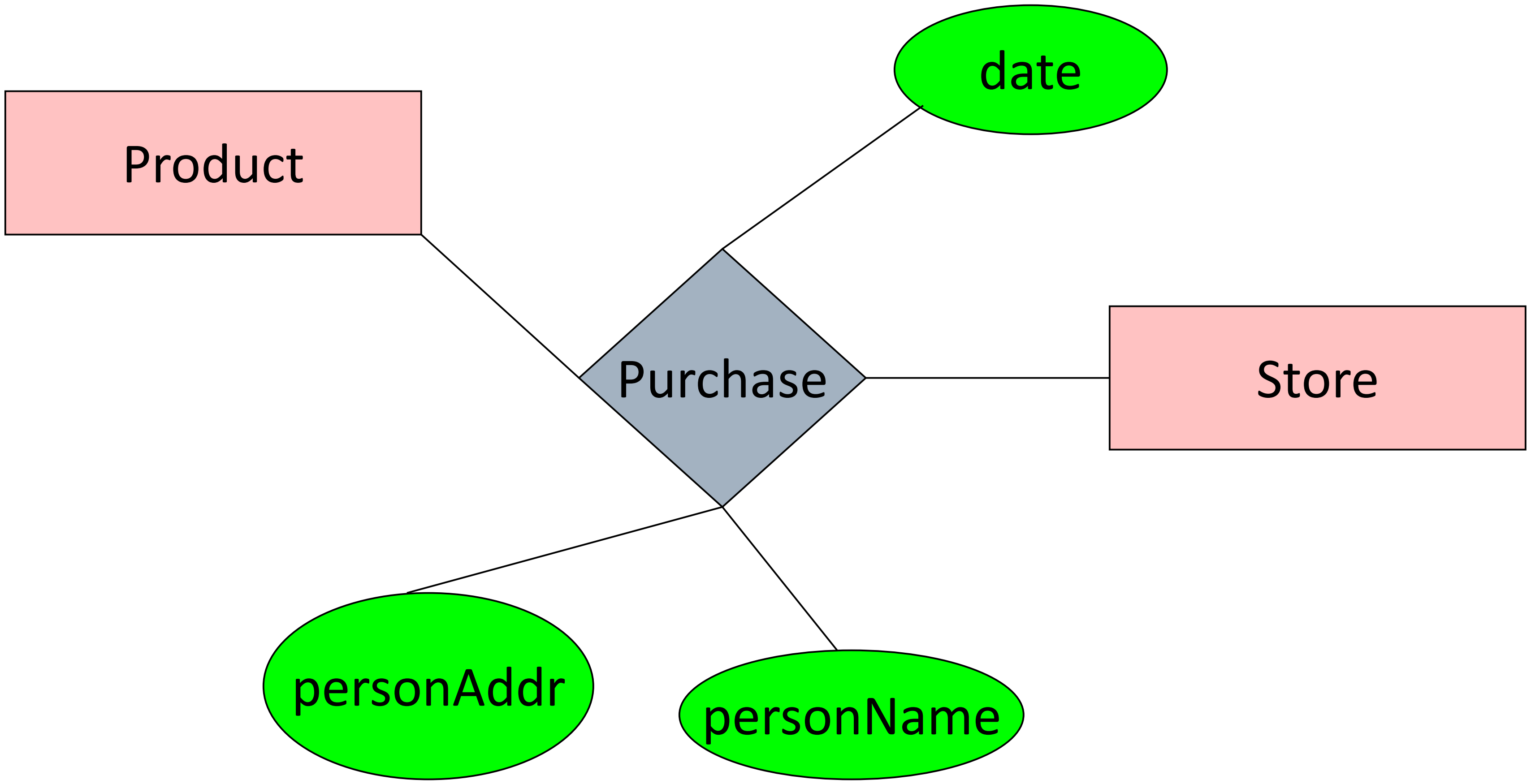
- (A) is useful when a relationship really is between multiple entities
    - *Ex: A three-party legal contract*

Design Principles

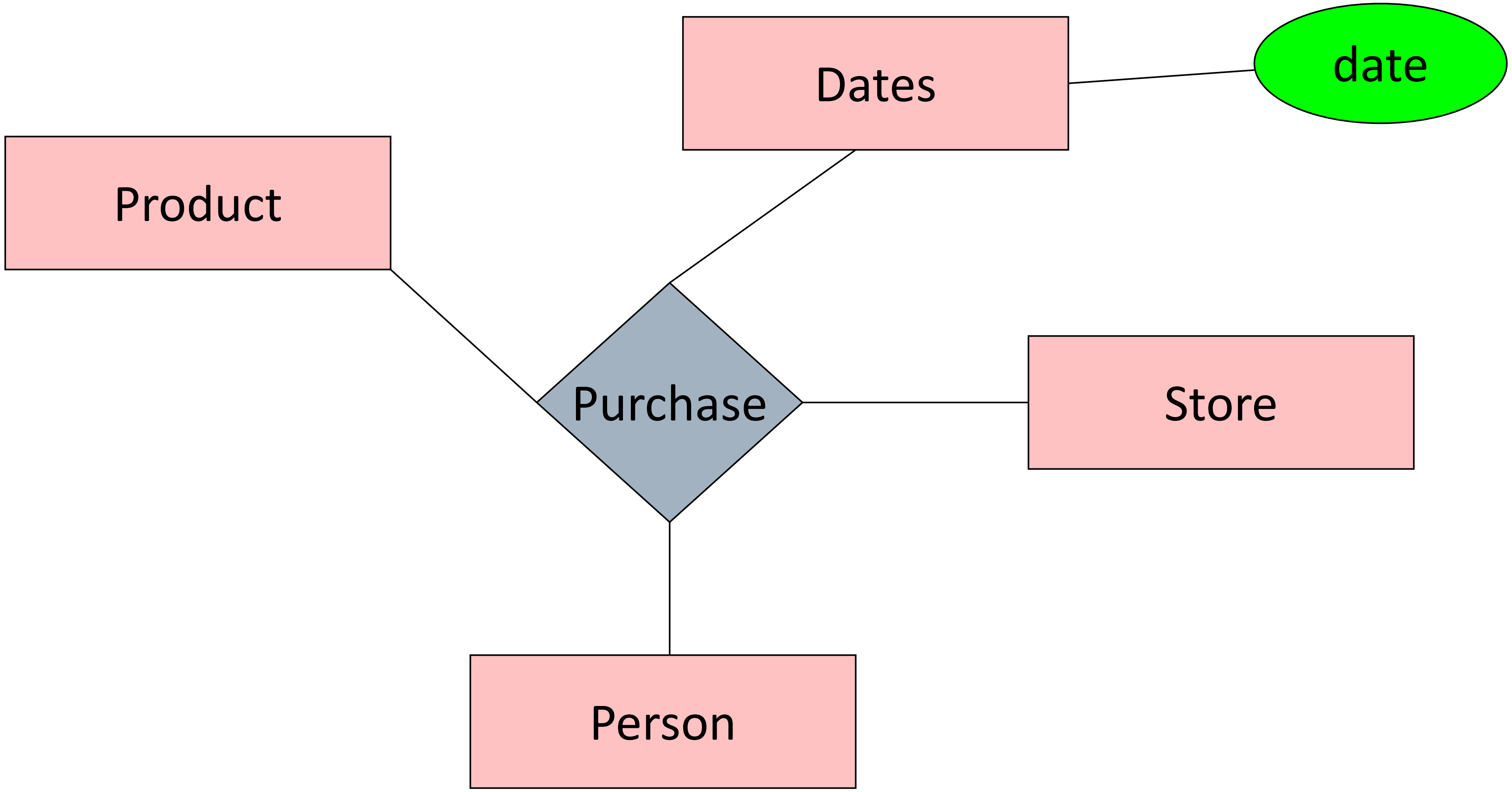
What's wrong with these examples?



Design Principles: What’s Wrong?

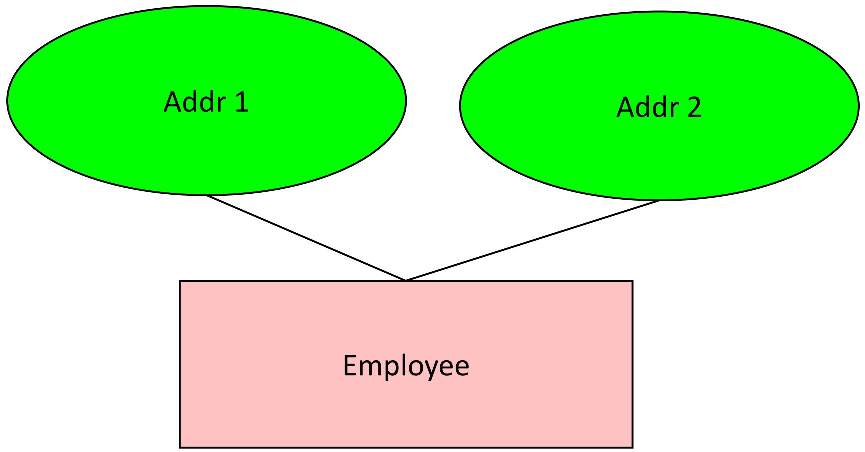


Design Principles: What's Wrong?

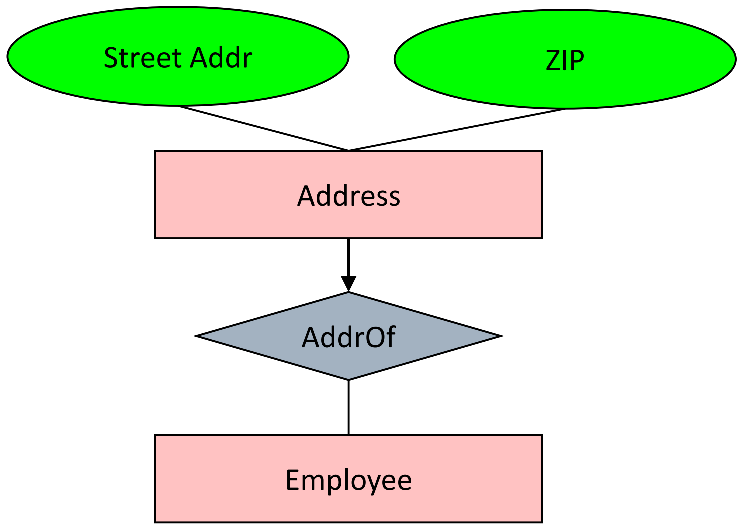


Examples: Entity vs. Attribute

Should address (A) be an attribute?



Or (B) be an entity?



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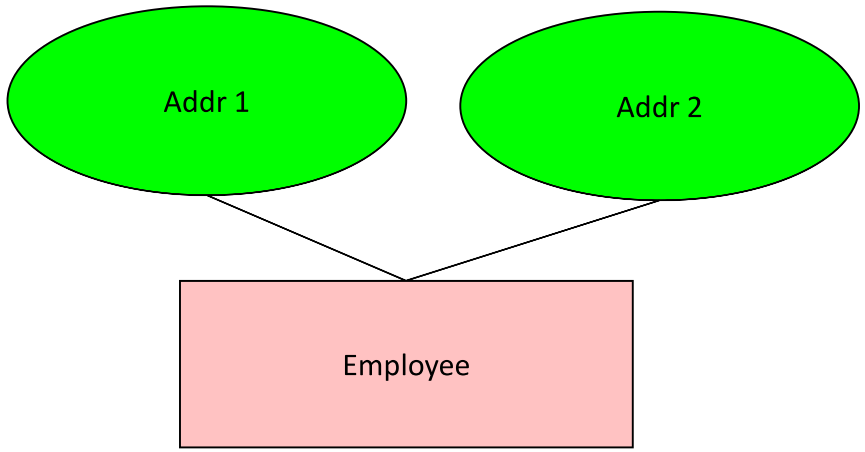
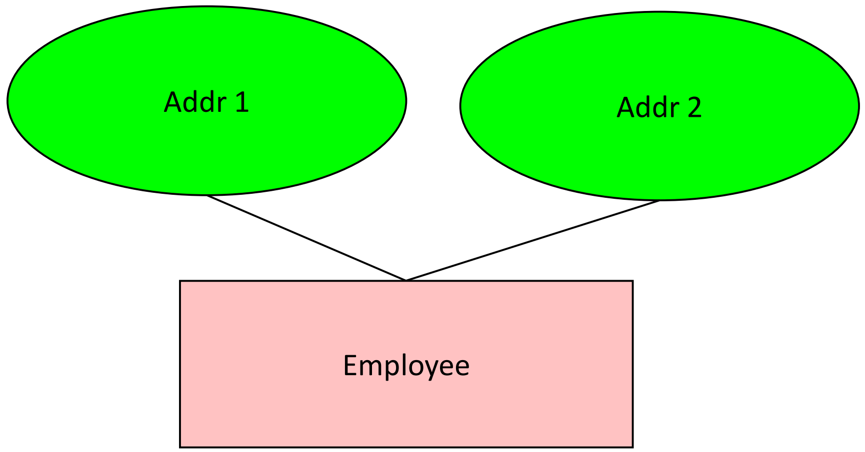


How do we handle employees with multiple addresses here?

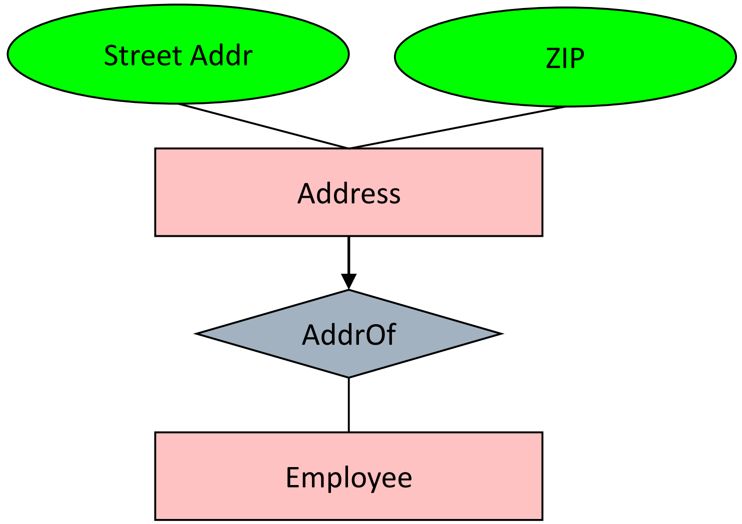
How do we handle addresses where internal structure of the address (e.g. zip code, state) is useful?

Examples: Entity vs. Attribute

Should address (A) be an attribute?



Or (B) be an entity?



In general, when we want to record several values, we choose new entity

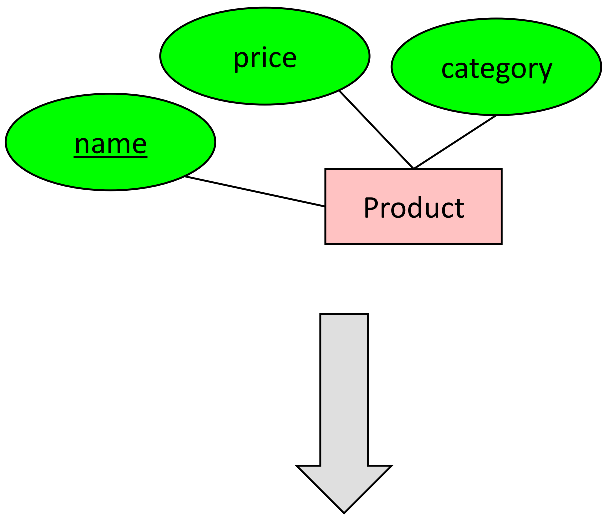
From E/R Diagrams to Relational Schema

Key concept:

Both ***Entity sets*** and ***Relationships*** become relations (tabl
es in RDBMS)

From E/R Diagrams to Relational Schema

- An entity set becomes a relation (multiset of tuples / table)
  - Each tuple is one entity
  - Each tuple is composed of the entity's attributes, and has the same primary key

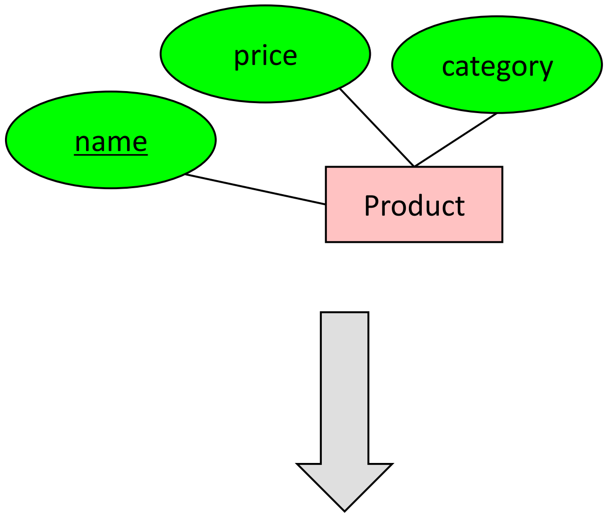


Product

name	price	category
Gizmo1	99.99	Camera
Gizmo2	19.99	Edible

From E/R Diagrams to Relational Schema

```
CREATE TABLE Product(
  name     CHAR(50) PRIMARY KEY,
  price    DOUBLE,
  category VARCHAR(30)
)
```

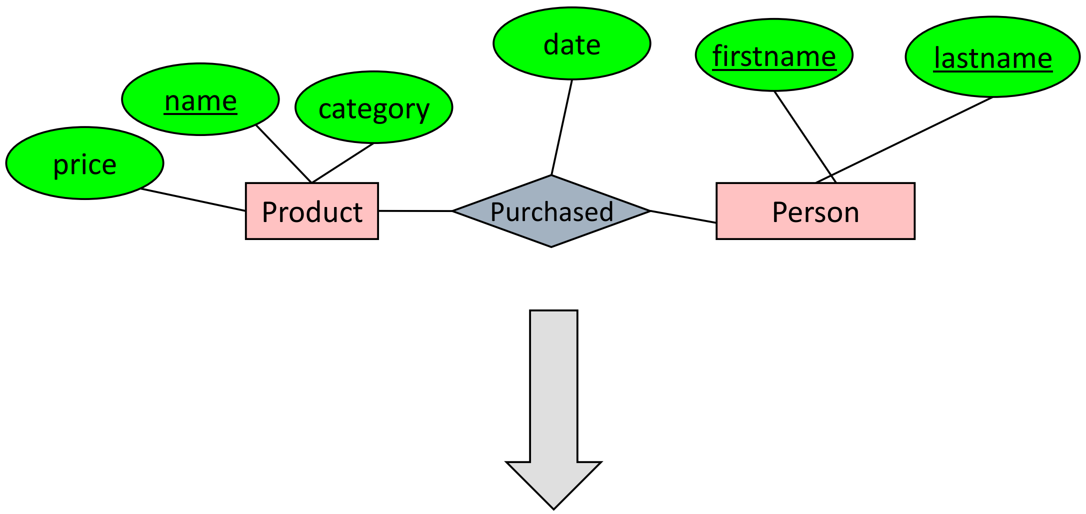


Product

<u>name</u>	price	category
Gizmo1	99.99	Camera
Gizmo2	19.99	Edible

From E/R Diagrams to Relational Schema

- A relation between entity sets $A_1, \ldots, A_N$ *also* becomes a multiset of tuples / a table
  - Each row/tuple is one relation, i.e. one unique combination of entities $(a_1,\ldots,a_N)$
  - Each row/tuple is
    - composed of the **union of the entity sets' keys**
    - has the entities' primary keys as foreign keys
    - has the union of the entity sets' keys as primary key

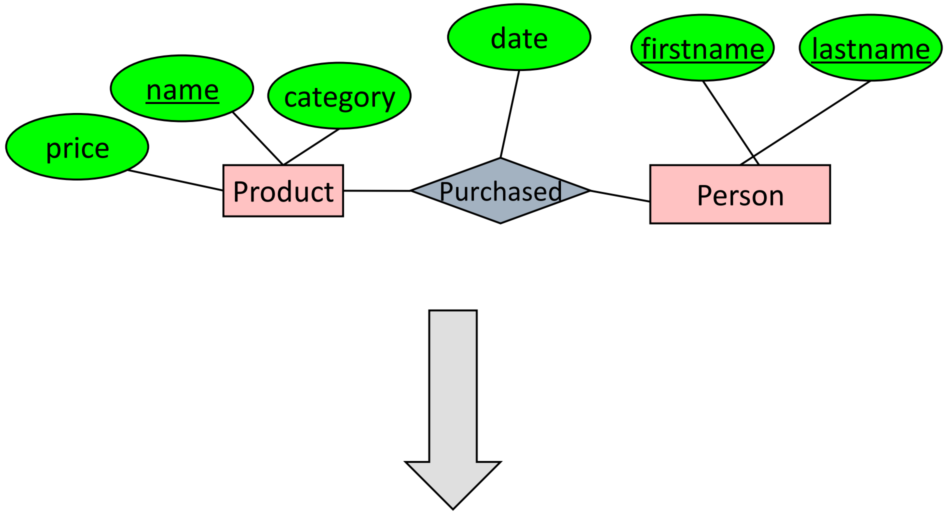


Purchased

name	firstname	lastname	date
Gizmo1	Bob	Alice	01/01/15
Gizmo2	Alice	Bob	01/03/15
Gizmo1	Joe	Smith	01/05/15

From E/R Diagrams to Relational Schema

```
CREATE TABLE Purchased(
  name      CHAR(50),
  firstname CHAR(50),
  lastname  CHAR(50),
  date      DATE,
  PRIMARY KEY (name, firstname, lastname),
  FOREIGN KEY (name)
           REFERENCES Product,
  FOREIGN KEY (firstname, lastname)
           REFERENCES Person
)
```

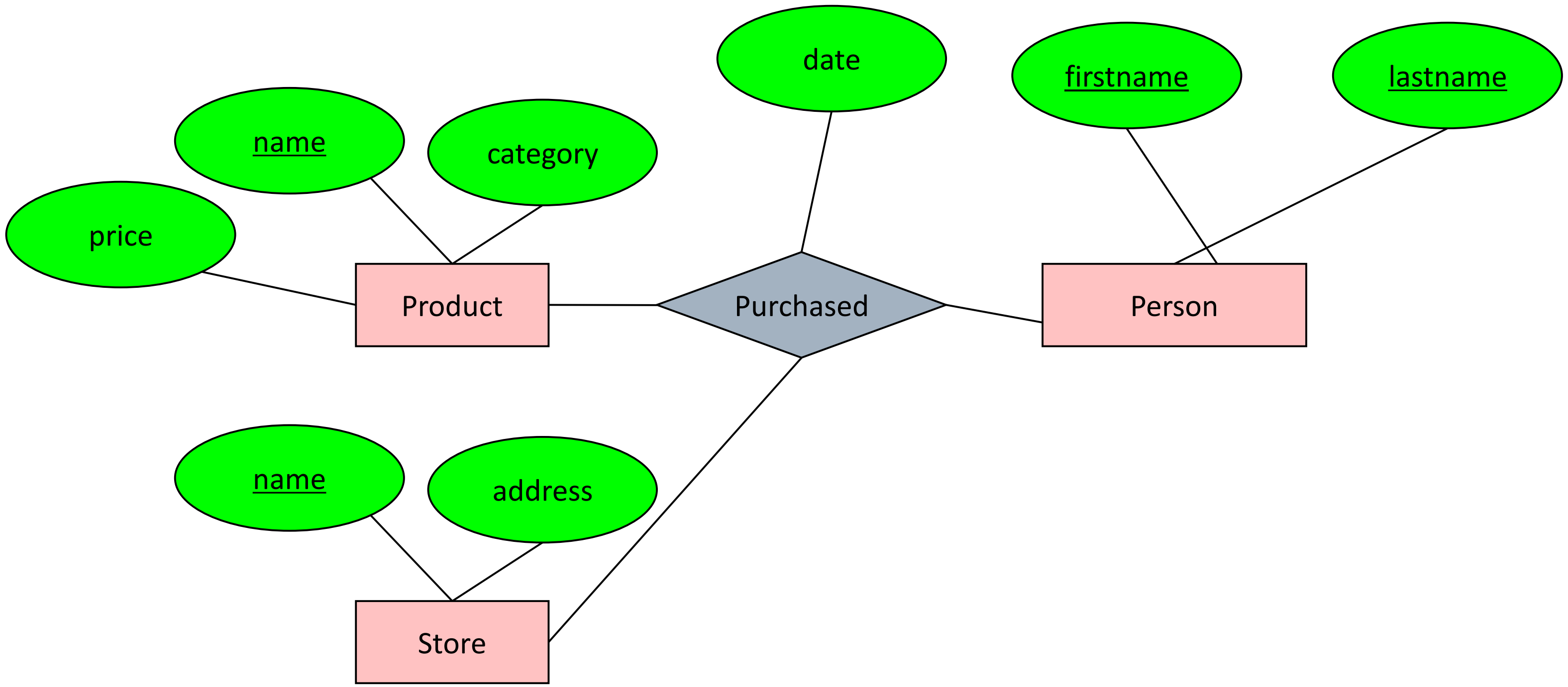


Purchased

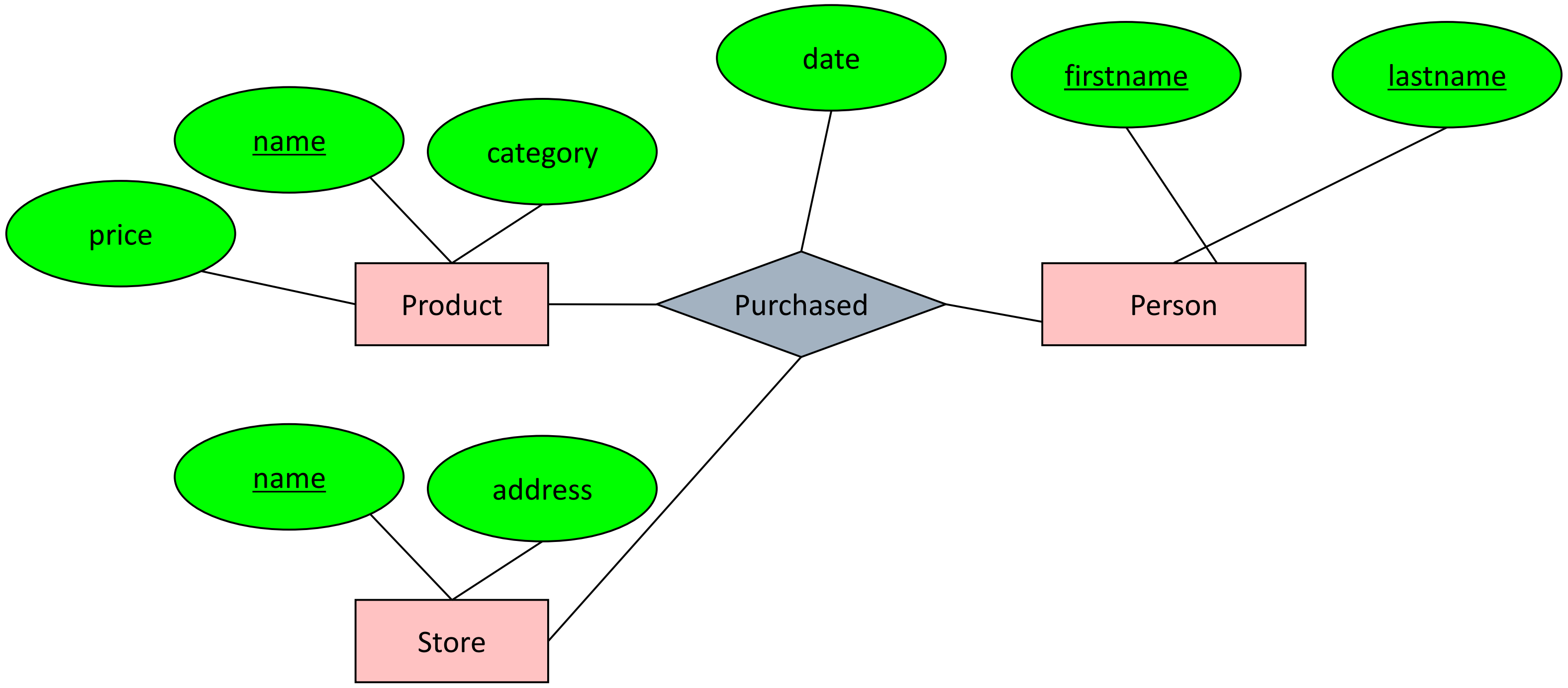
name	firstname	lastname	date
Gizmo1	Bob	Alice	01/01/15
Gizmo2	Alice	Bob	01/03/15
Gizmo1	Joe	Smith	01/05/15

From E/R Diagram to Relational Schema

How do we represent this as a relational schema?



From E/R Diagram to Relational Schema



Product

Name	Price	Category
Gizmo1	99.99	Camera
Gizmo2	19.99	Edible

Purchased

Pname	Firstname	Lastname	Date
Gizmo1	Bob	Alice	01/01/15
Gizmo2	Alice	Bob	01/03/15
Gizmo1	Joe	Smith	01/05/15

Practice 2

Add arrows to your E/R diagram!

Also make sure to add **(new concepts underlined):**

A player can only belong to one team, a play can only be in one game, a pass/run..?

Players can achieve a **Personal Record** linked to a specific Game and Play

Players have a **weight** which changes in on vs. off-season

Today's Lecture

1. E/R Basics: Entities & Relations
2. E/R Design considerations
3. **Advanced E/R Concepts**

What you will learn about in this section

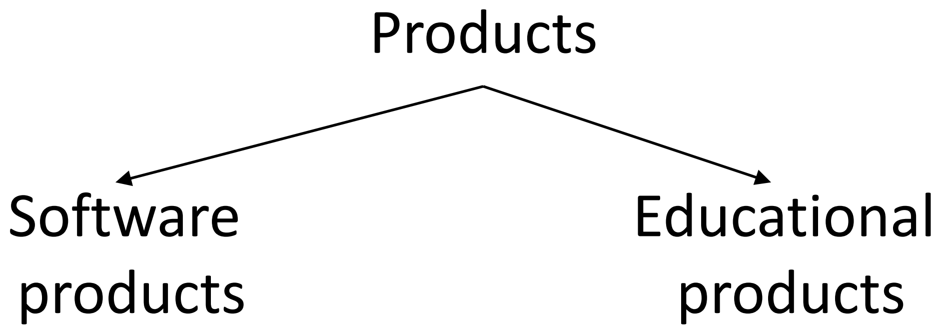
1. **Subclasses**

2. **Constraints**

3. **Weak entity sets**

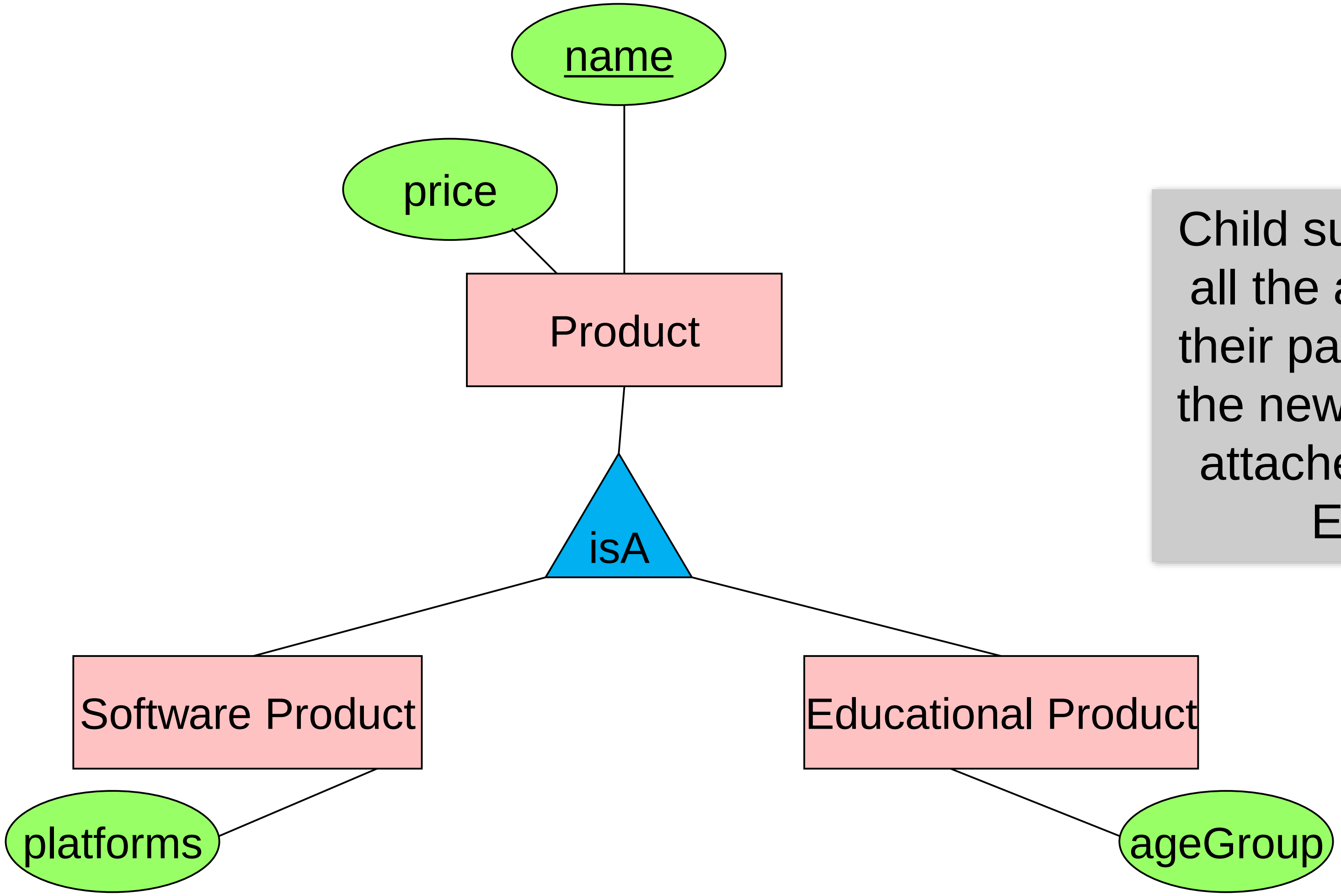
Modeling Subclasses

- Some objects in a class may be special, i.e. worthy of their own class
    - Define a new class?
        - *But what if we want to maintain connection to current class?*
    - <u>Better: define a *subclass*</u>
        - *Ex:*



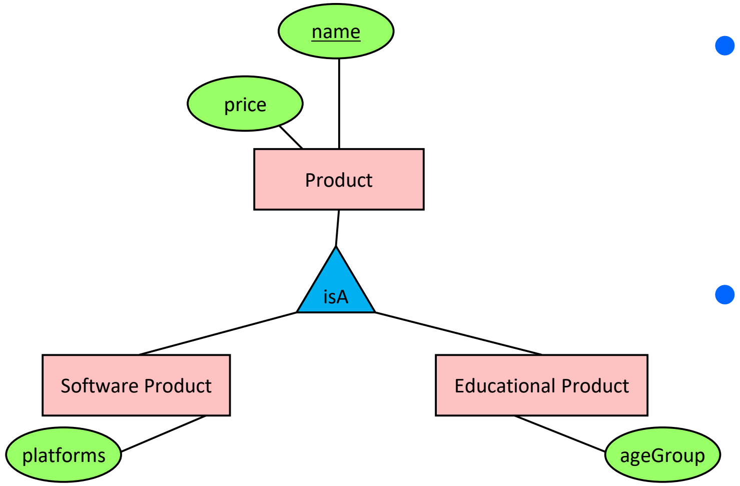
We can define **subclasses** in E/R!

Modeling Subclasses



Child subclasses contain all the attributes of *all* of their parent classes **plus** the new attributes shown attached to them in the E/R diagram

Understanding Subclasses



- **Think in terms of records; ex:**
  - Product

name
price

  - SoftwareProduct

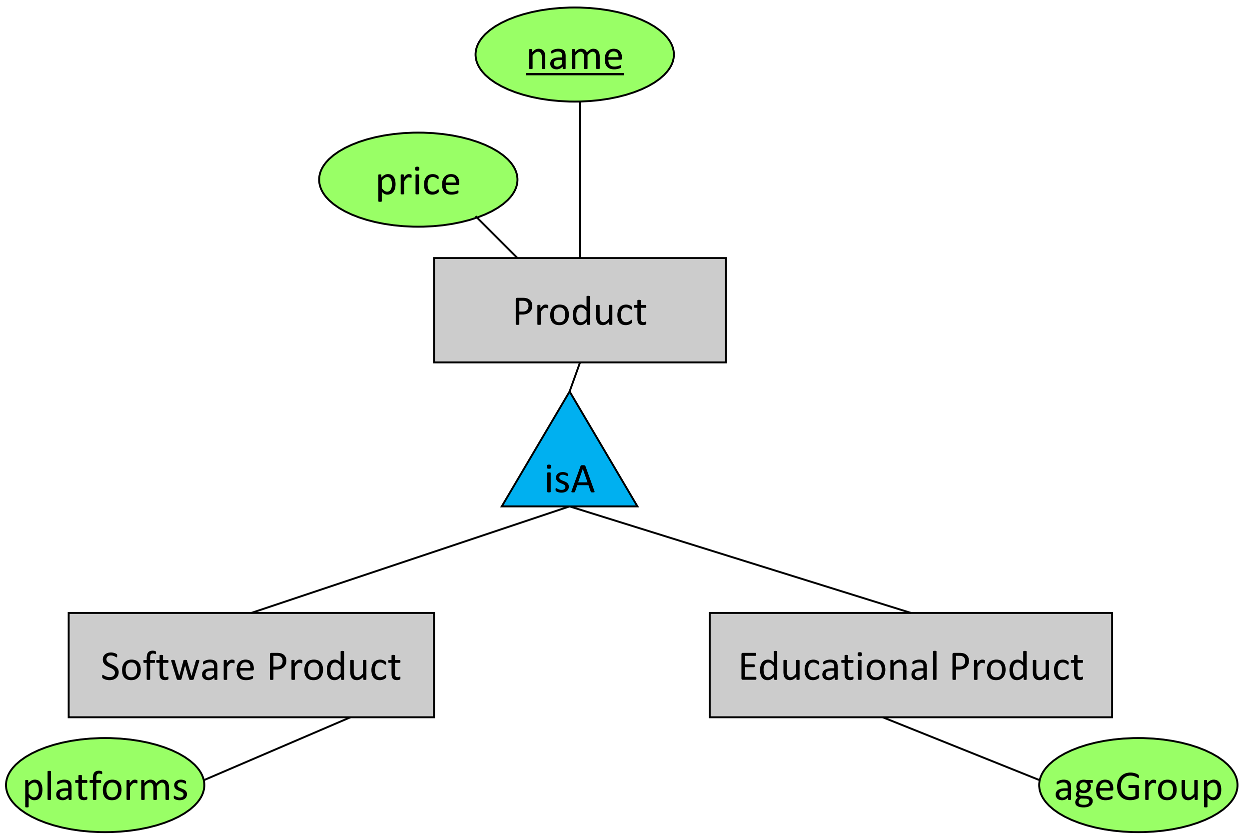
name
price
platforms

  - EducationalProduct

name
price
ageGroup

Child subclasses contain all the attributes of *all* of their parent classes **plus** the new attributes shown attached to them in the E/R diagram

Think like tables…



Product

name	price	category
Gizmo	99	gadget
Camera	49	photo
Toy	39	gadget

Sw.Product

name	platforms
Gizmo	unix

Ed.Product

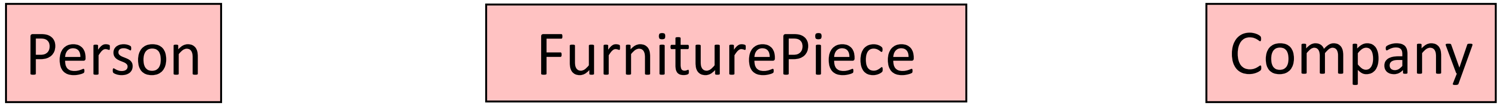
name	ageGroup
Gizmo	toddler
Toy	retired

IsA Review

- If we declare *A IsA B* then every A is a B

- We use IsA to Add descriptive attributes to a subclass

Modeling UnionTypes With Subclasses

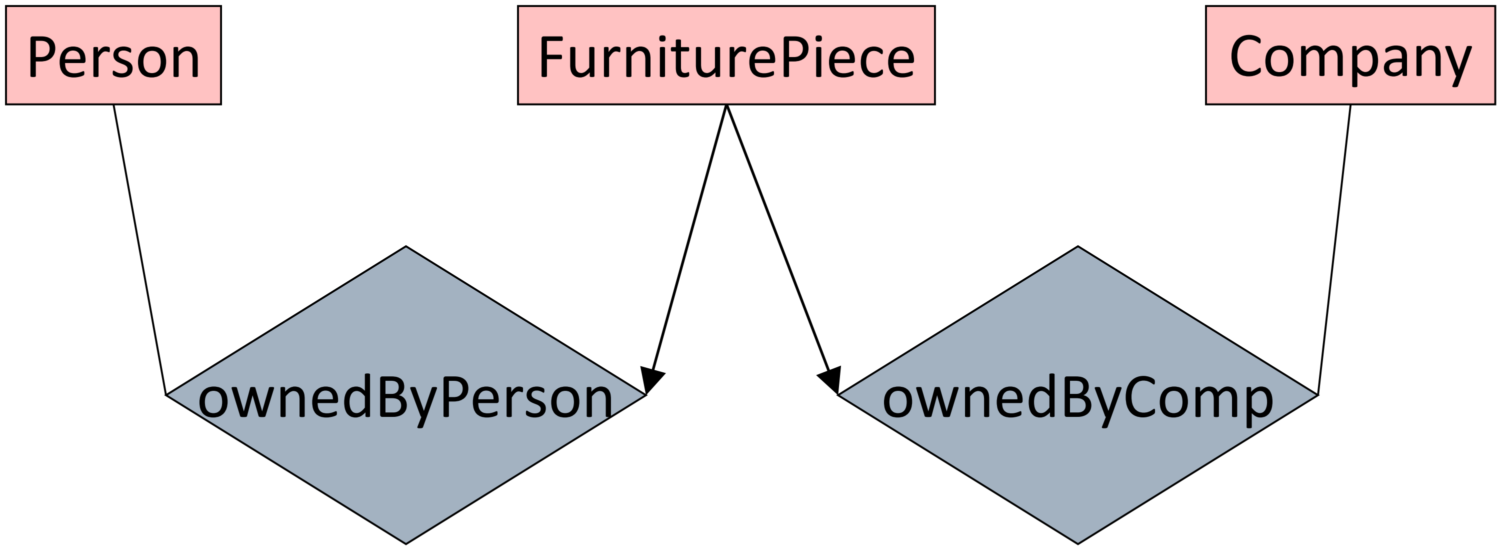


Suppose each piece of furniture is owned either by a person, or by a company. *How do we represent this?*

Modeling Union Types with Subclasses

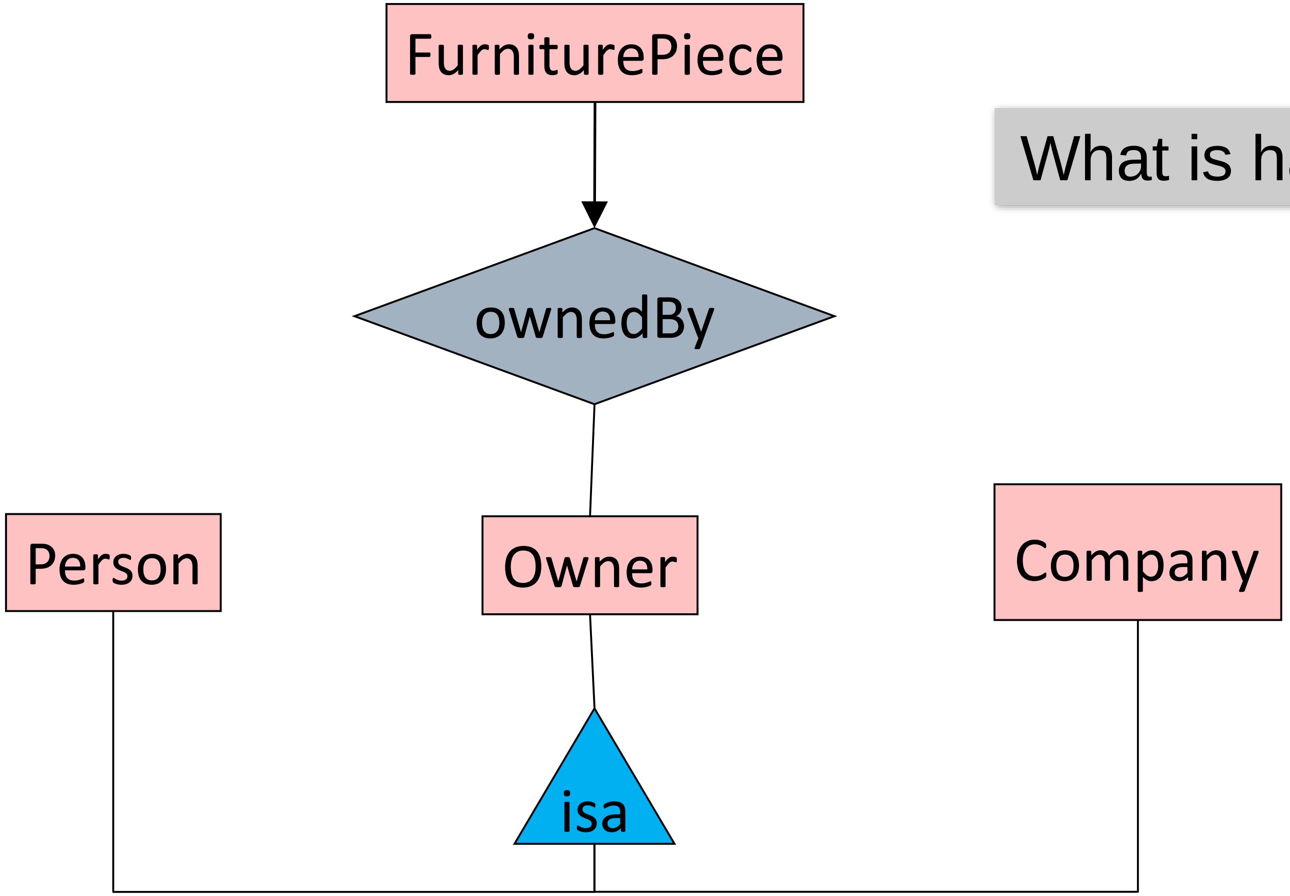
Say: each piece of furniture is owned either by a person, or by a company

<u>Solution 1.</u> Acceptable, but imperfect (What's wrong ?)



Modeling Union Types with Subclasses

Solution 2: better (though more laborious)



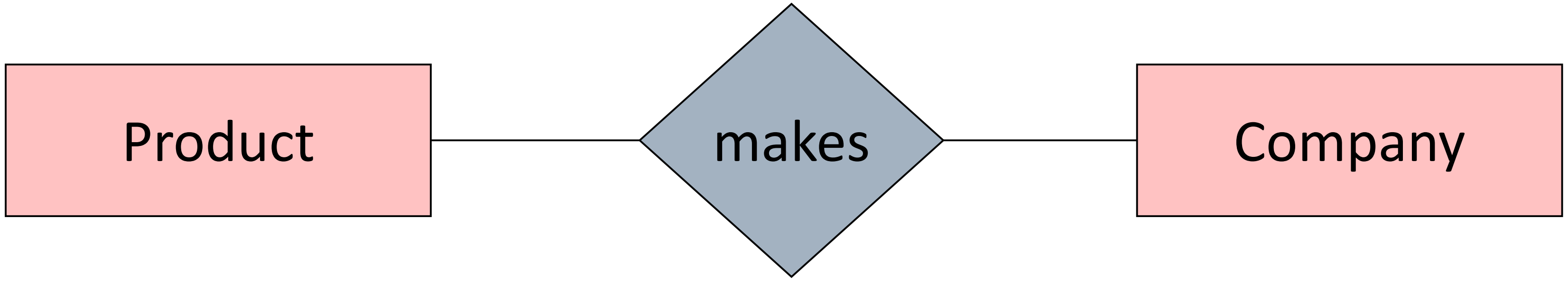
What is happening here?

Constraints in E/R Diagrams

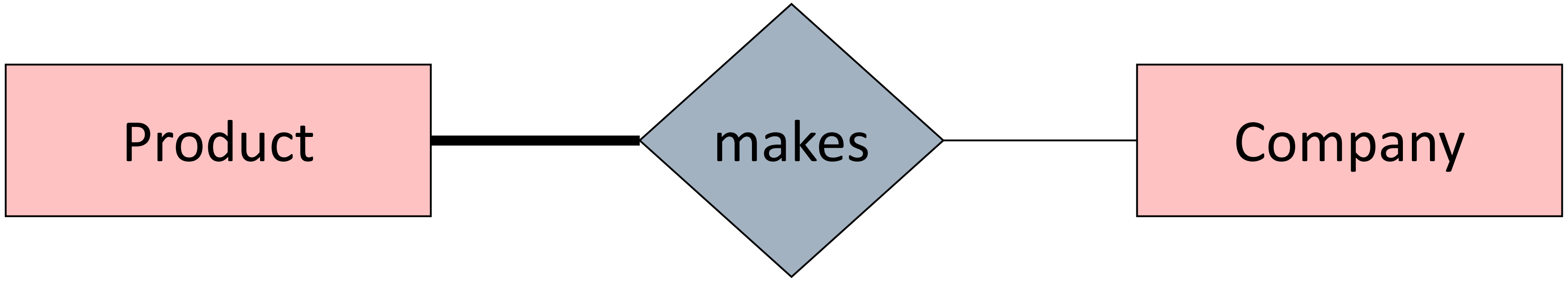
- **Finding constraints is part of the E/R modeling process. Commonly used constraints are:**
  - Keys: Implicit constraints on uniqueness of entities
    - *Ex: An SSN uniquely identifies a person*
  - Single-value constraints:
    - *Ex: a person can have only one father*
  - Referential integrity constraints: Referenced entities must exist
    - *Ex: if you work for a company, it must exist in the database*
  - Other constraints:
    - *Ex: peoples' ages are between 0 and 150*

Recall FOREIGN KEYs!

Participation Constraints: Partial v. Total



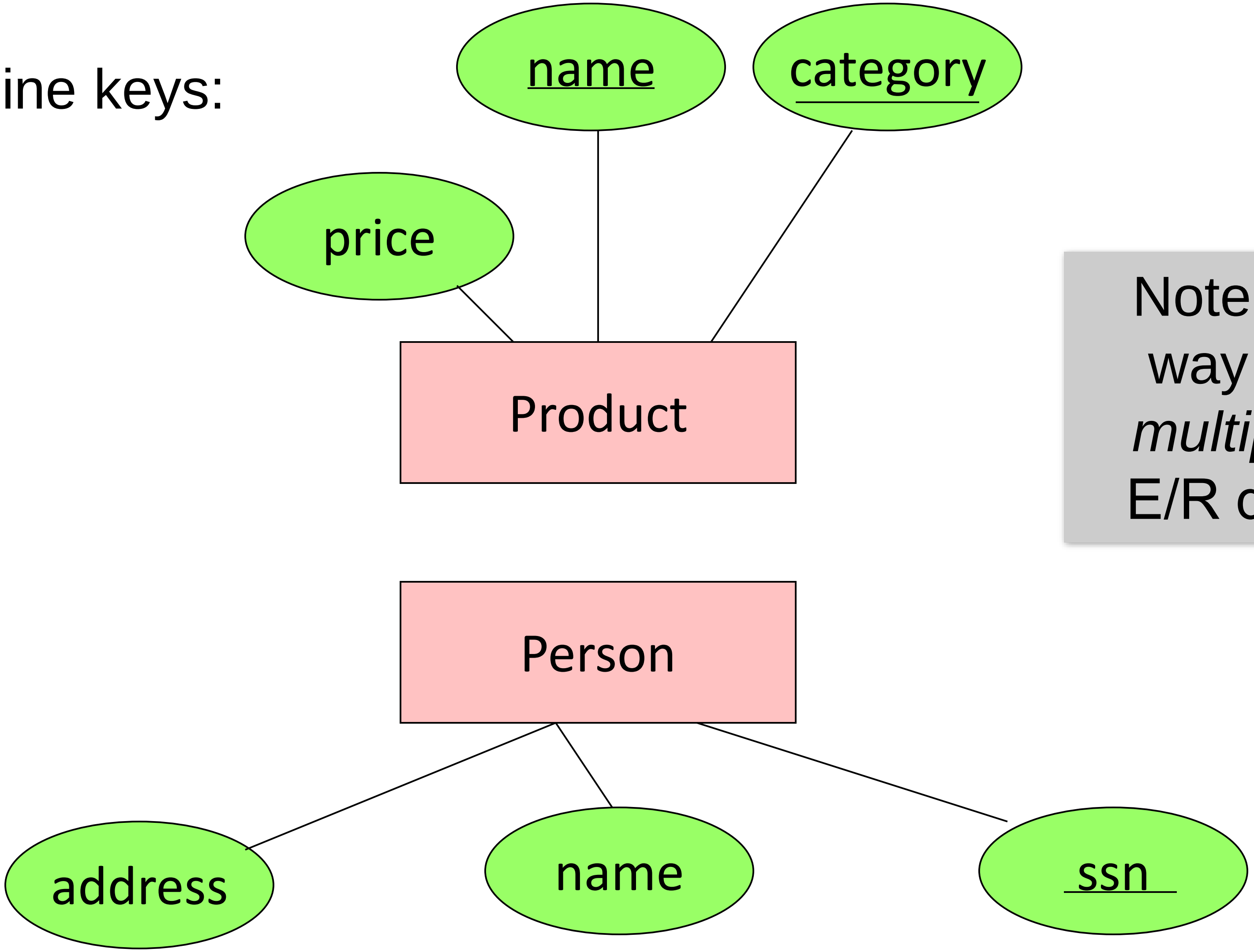
Are there products made by no company?
Companies that don't make a product?



Bold line indicates *total participation* (i.e. here: all products are made by a company)

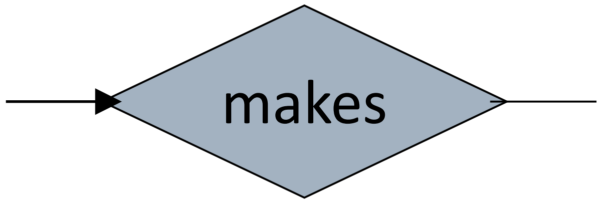
Keys in E/R Diagrams

Underline keys:

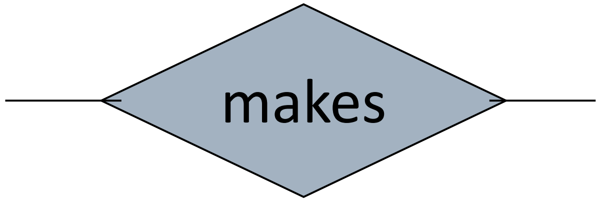


Note: no formal way to specify *multiple* keys in E/R diagrams…

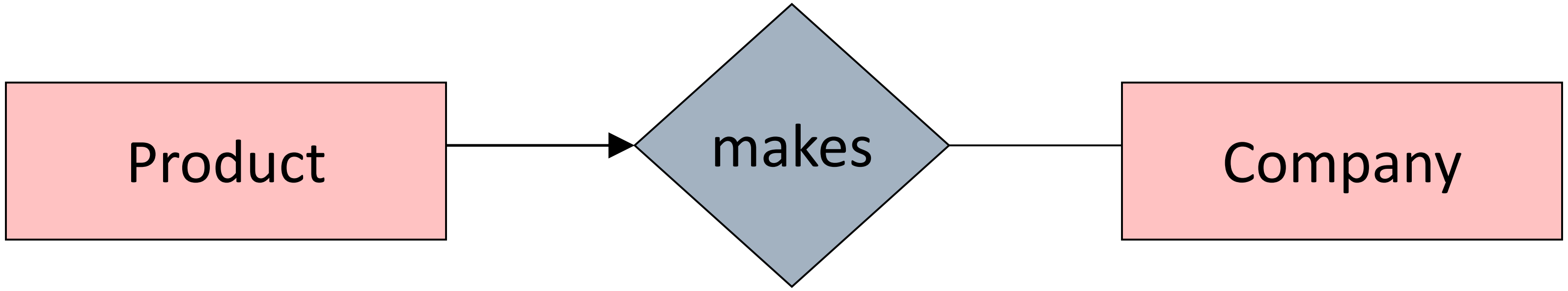
Single Value Constraints



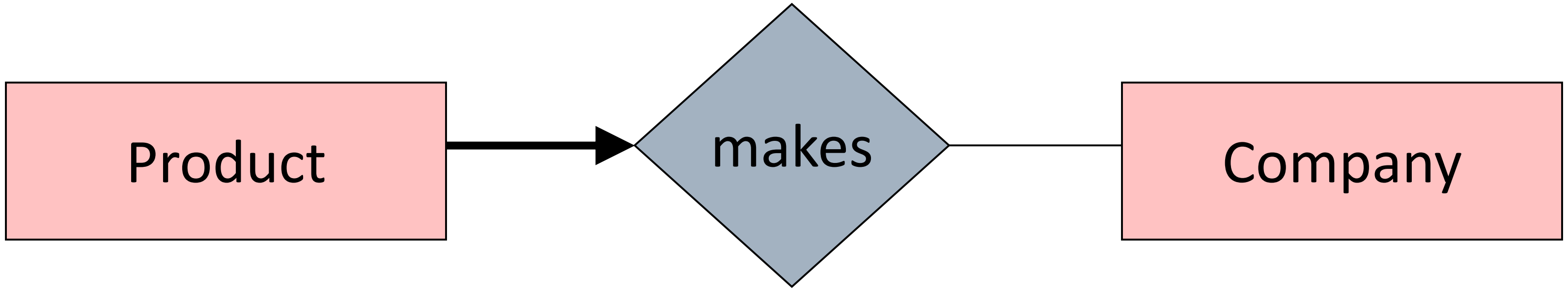
v. s.



Referential Integrity Constraints



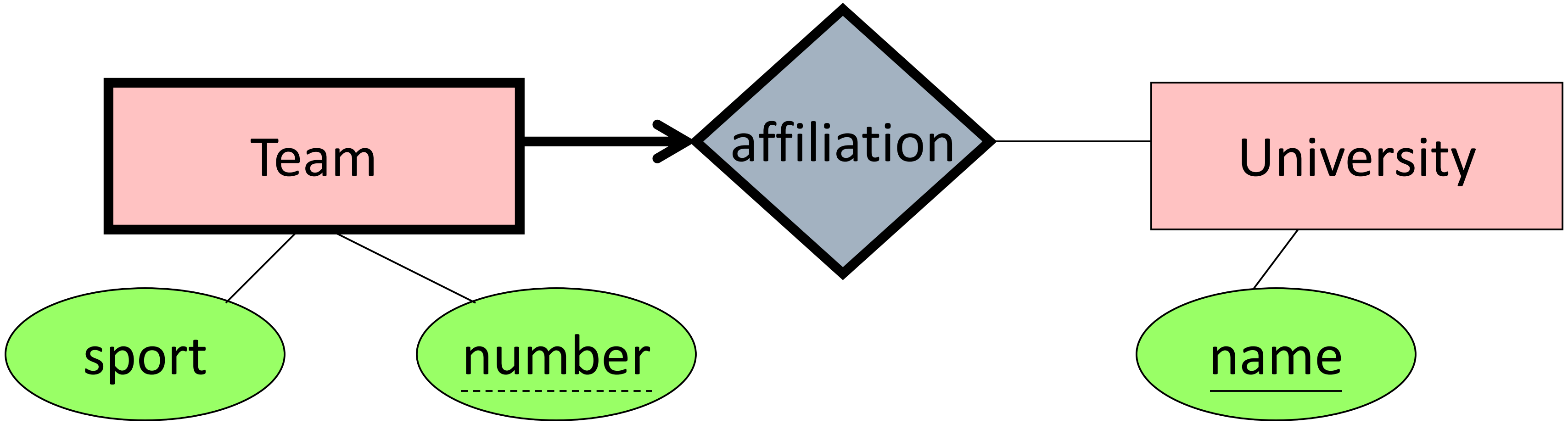
Each product made by at most one company.
Some products made by no company?



Each product made by *exactly* one company.

Weak Entity Sets

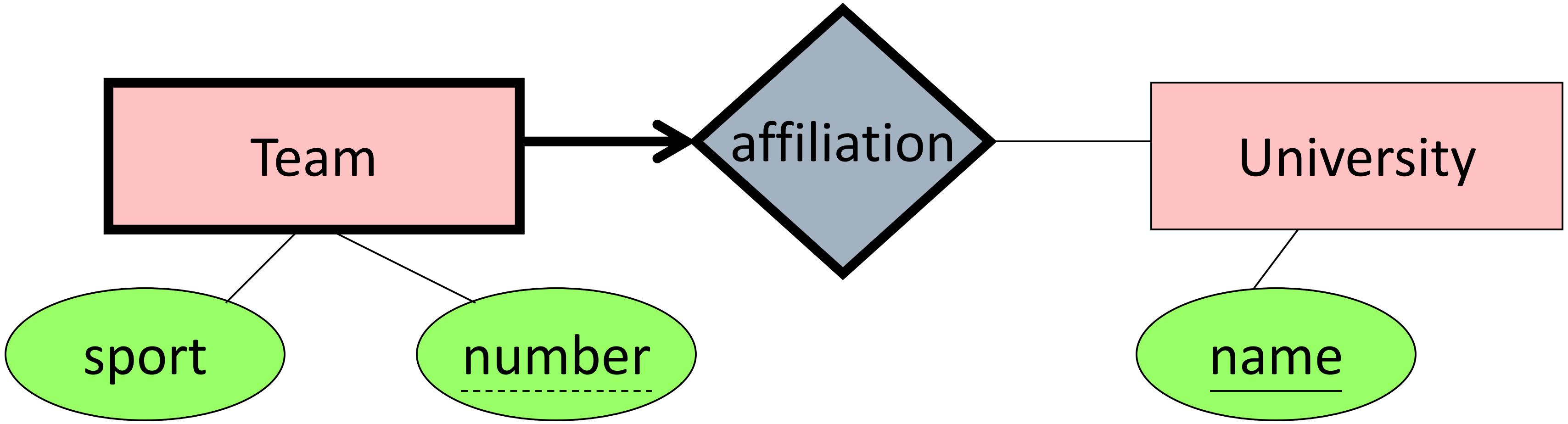
Entity sets are *weak* when their key comes from other classes to which they are related.



“Football team” v. “***The Stanford*** Football team” *(E.g., Berkeley has a football team too, sort of)*

Weak Entity Sets

Entity sets are *weak* when their key comes from other classes to which they are related.



- number is a *partial key*. (denote with dashed underline).
- University is called the *identifying owner*.
- Participation in affiliation must be total. Why?

Practice 3

Weak entity sets / Subclasses

Concepts to include / model:

Teams belong to cities- model as ***weak entity sets***

Players are either on Offense or Defense, and are of types (QB, RB, WR, TE, K, Farmer*…)

E/R Summary

- **E/R diagrams are a visual syntax that allows technical and non-technical people to talk**
  - For conceptual design
- **Basic constructs: entity, relationship, and attributes**
- **A good design is faithful to the constraints of the application**