THE E/R MODEL

Today's Lecture

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

1. E/R BASICS: ENTITIES & RELATIONS

- High-level motivation for the E/R model
- Entities
- 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

Technical and non-technical people are involved

- 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?

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.

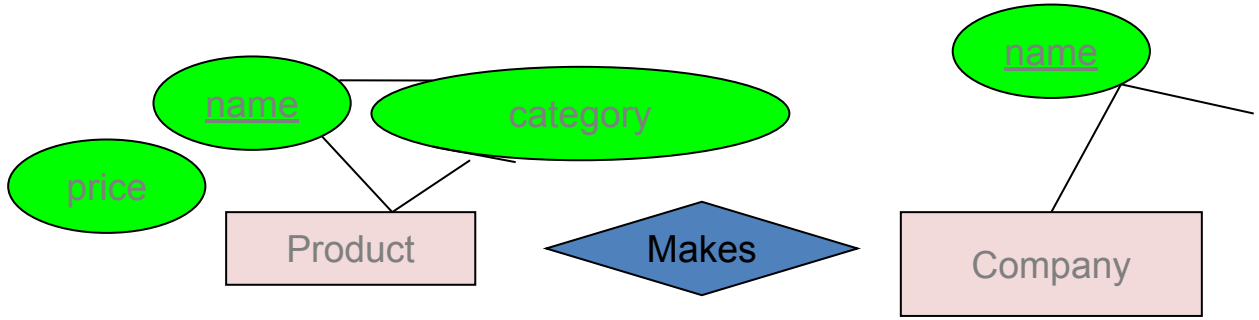
3. More:

- 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

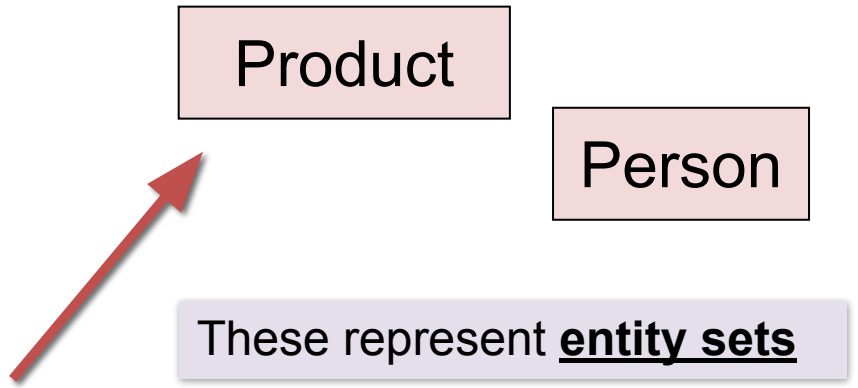
Interlude: Impact of the ER model

- 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

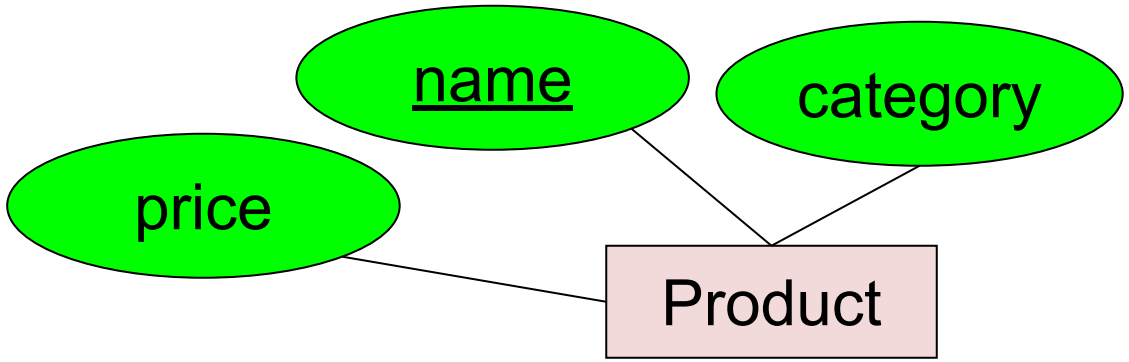
Entities and Entity Sets

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



Entities and Entity Sets

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



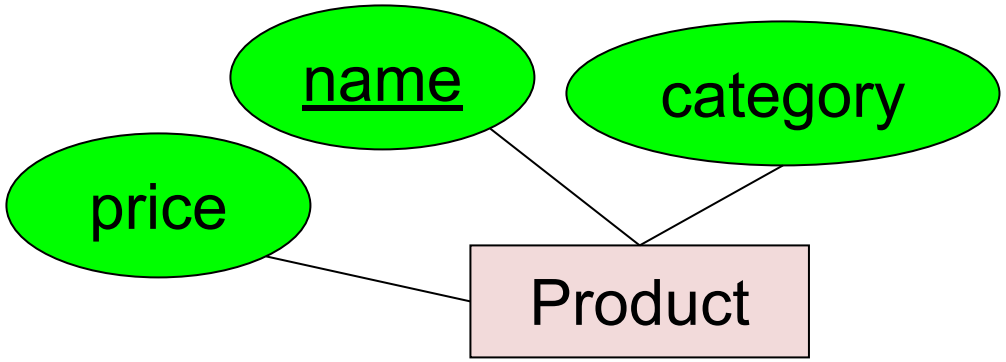
Shapes **are** important.
Colors **are not**.

Keys

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

Denote elements of the primary key by underlining.

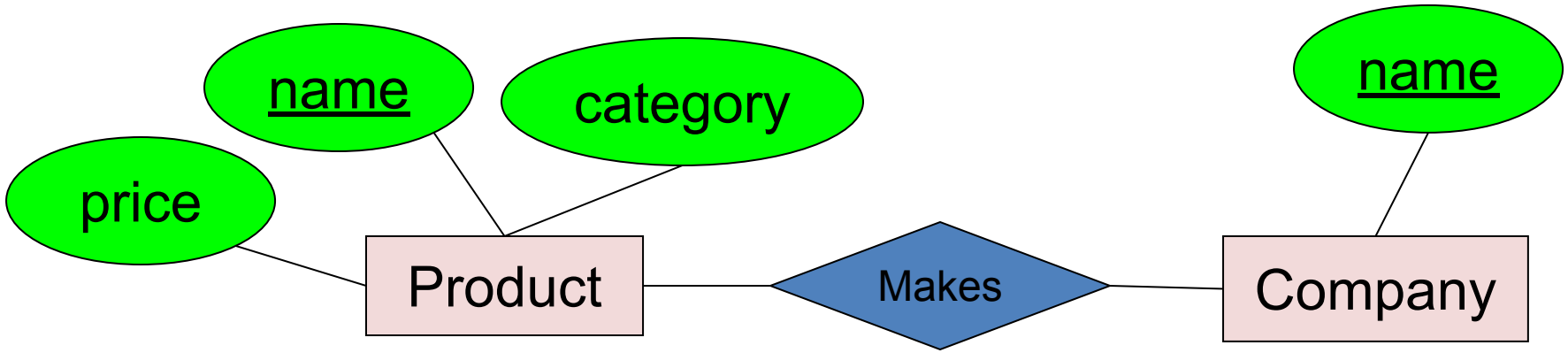
Here, {name, category} is **not** a key (it is not *minimal*).

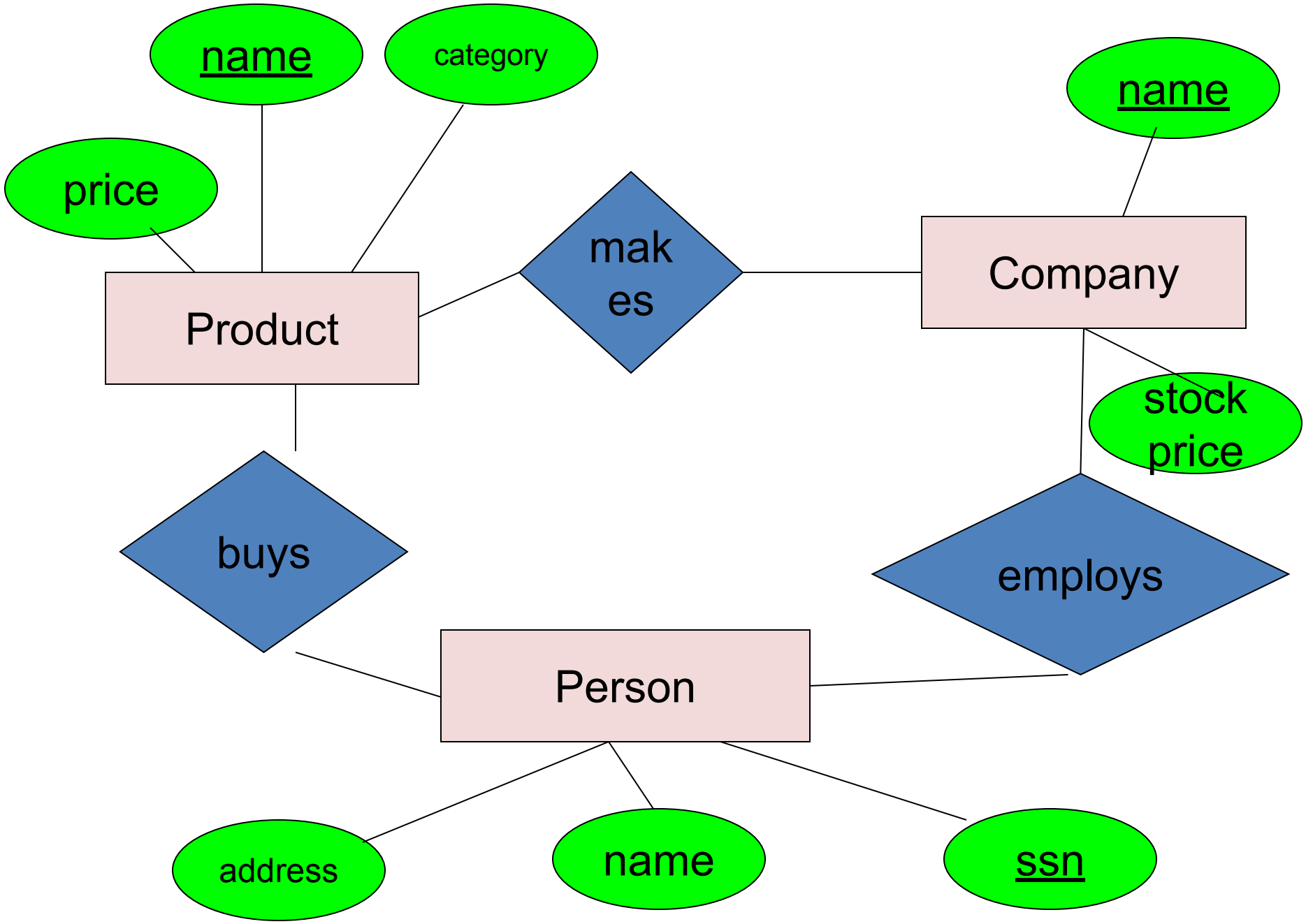


The E/R model forces us to designate a single **primary** key, though there may be multiple candidate keys

The R in E/R: **Relationships**

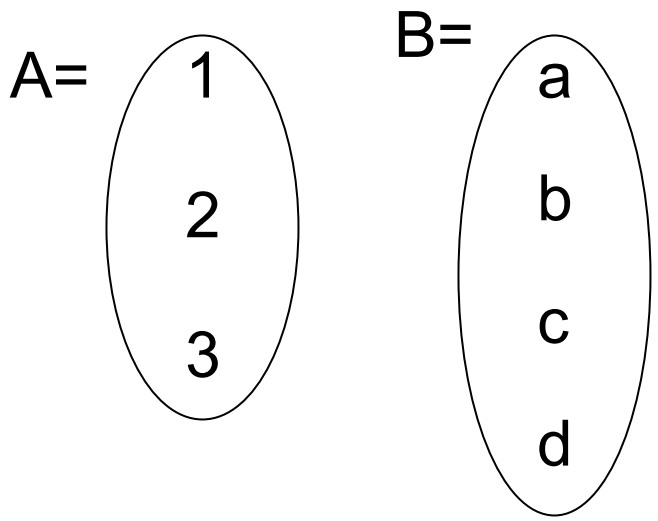
- A **relationship** is between two entities




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

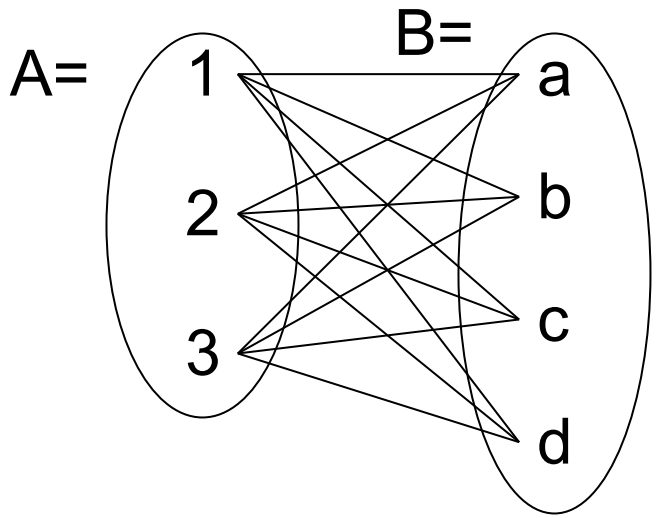
What is a Relationship?

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



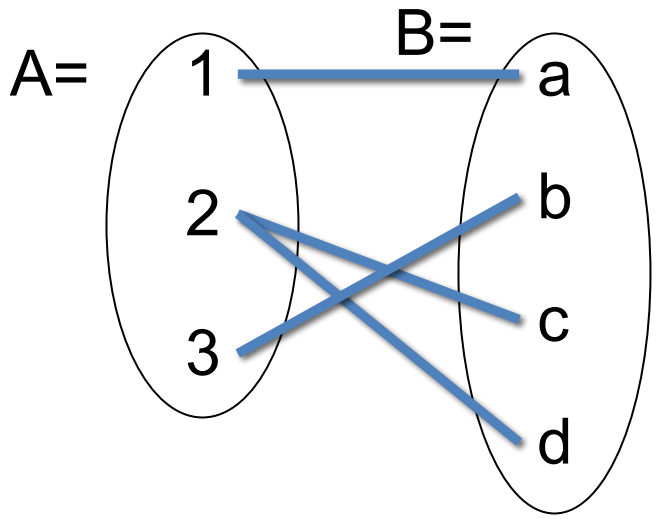
What is a Relationship?

- ***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 × 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)}*



What is a Relationship?

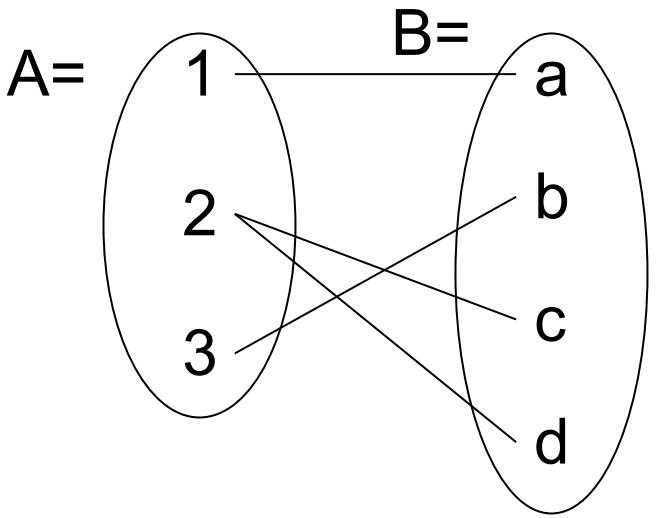
- ***A mathematical definition:***
  - Let A, B be sets
    - *A={1,2,3}, B={a,b,c,d},*
  - A x B (the ***cross-product***) is the set of all pairs (a,b)
    - *A × B = {(1,a), (1,b), (1,c), (1,d), (2,a), (2,b), (2,c), (2,d), (3,a), (3,b), (3,c), (3,d)}*
  - **We define a relationship to be a subset of A x B**
    - *R = {(1,a), (2,c), (2,d), (3,b)}*

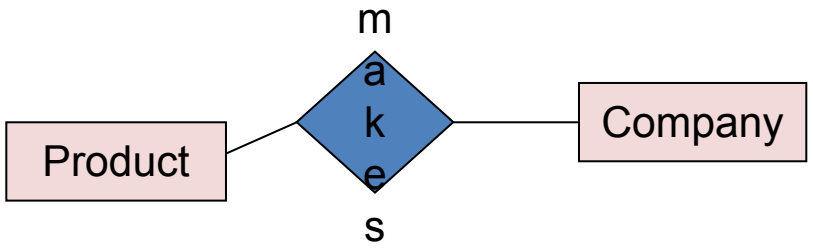


What is a Relationship?

- ***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

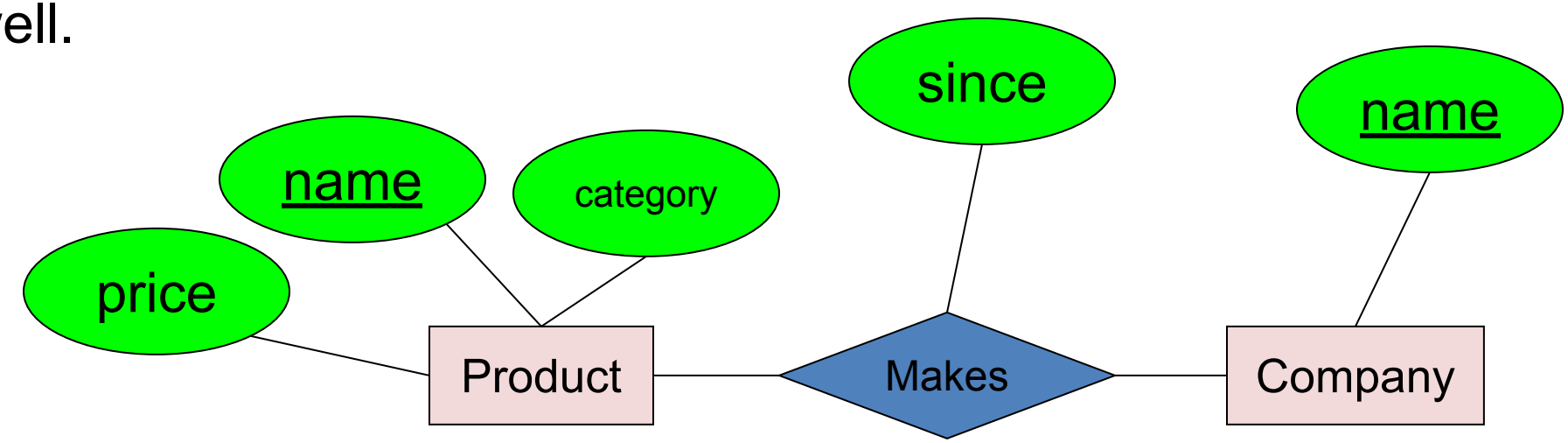
- **Makes** is a relationship- it is a ***subset*** of **Product × Company**:





Relationships and Attributes

- Relationships may have attributes as well.



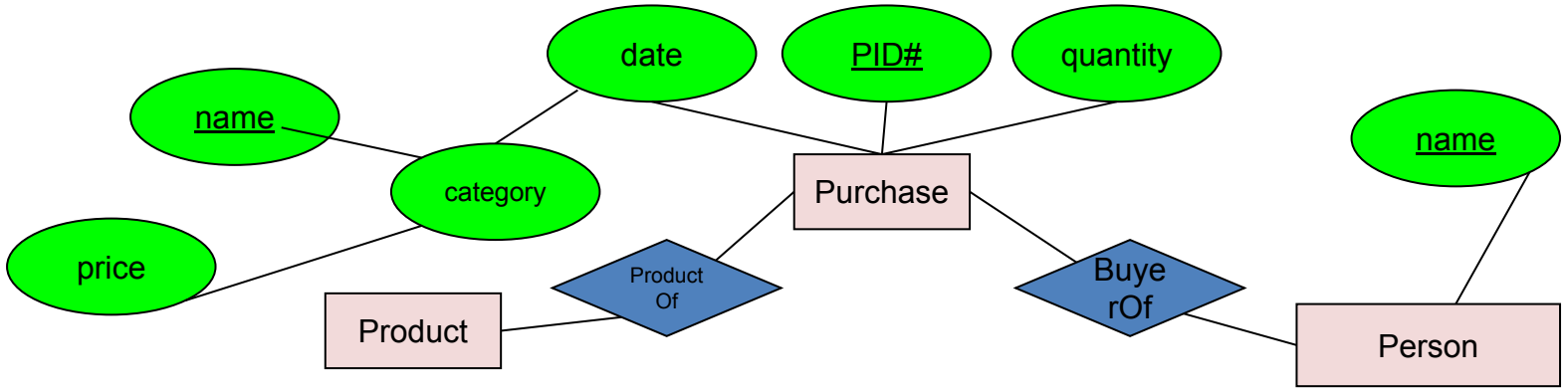
For example: "since" records when company started making a product

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

Note #2: Why not "how long"?

Decision: Relationship vs. Entity?

- What about this way?

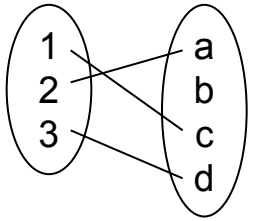


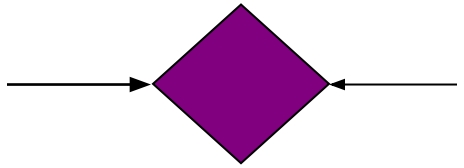
- *Now we can have multiple purchases per product, person pair!*

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

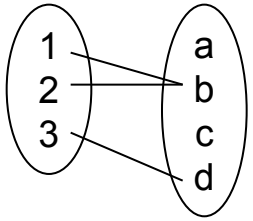
Multiplicity of E/R Relationships

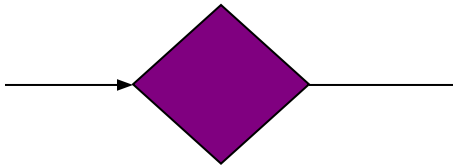
One-to-one:



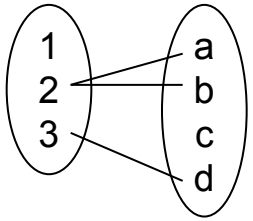


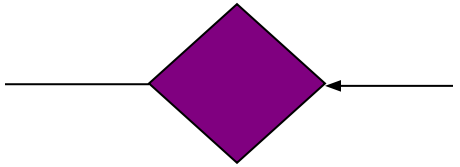
Many-to-one:



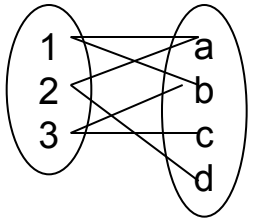


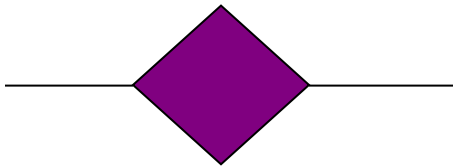
One-to-many:





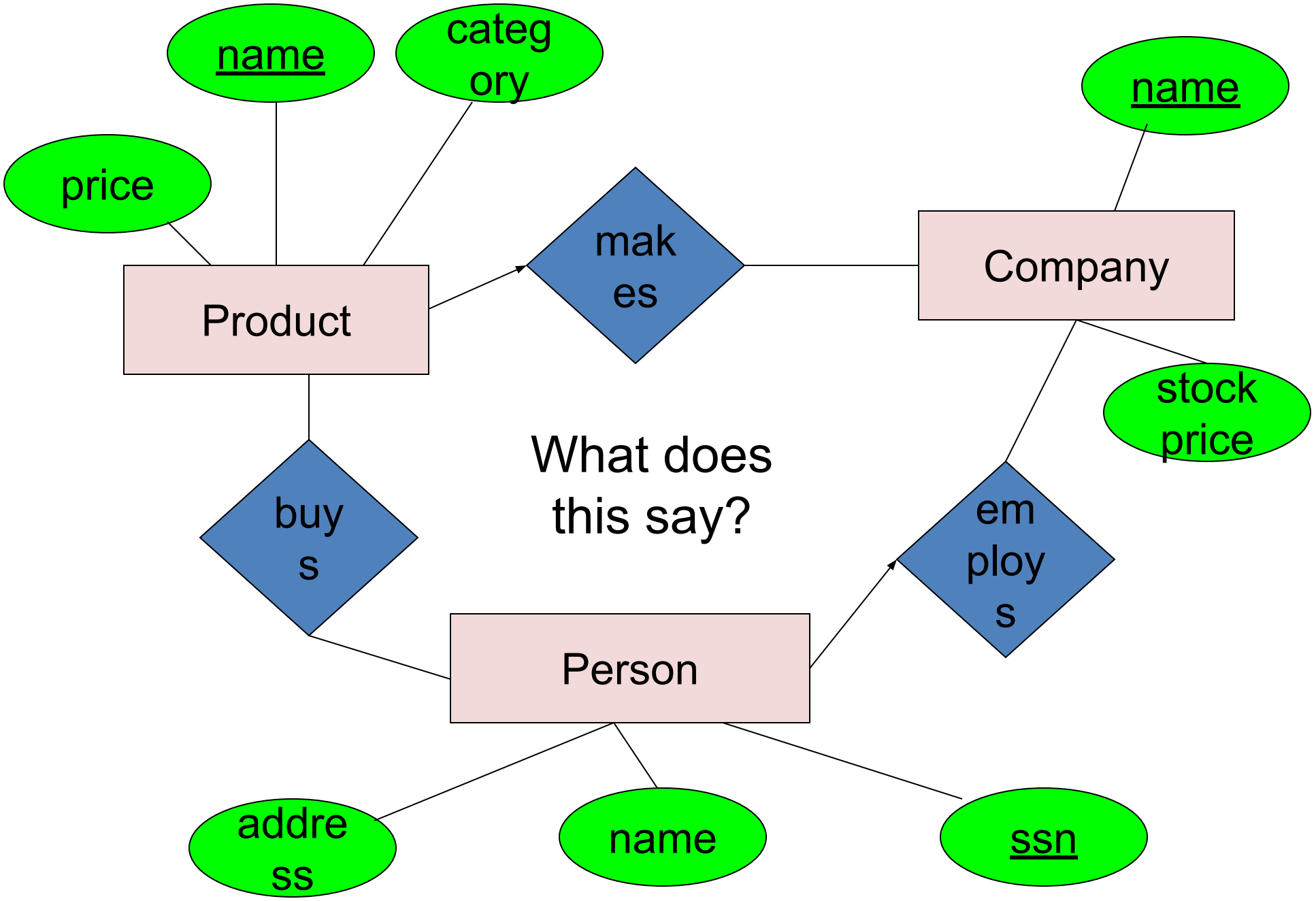
Many-to-many:





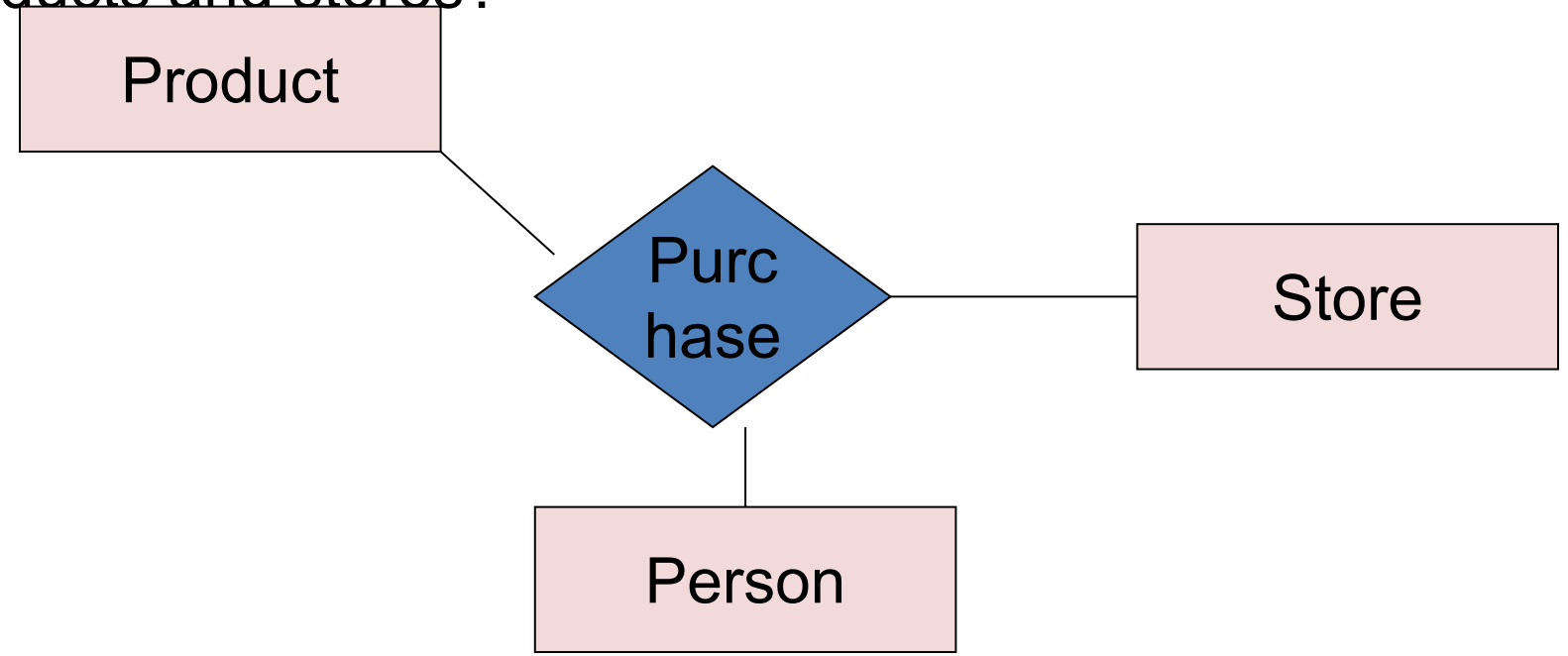
Indicated using arrows

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


name
categ
ory
price
Product
mak
es
Company
name
stock
price
What does
this say?
buy
s
em
ploy
s
Person
addre
ss
name
ssn

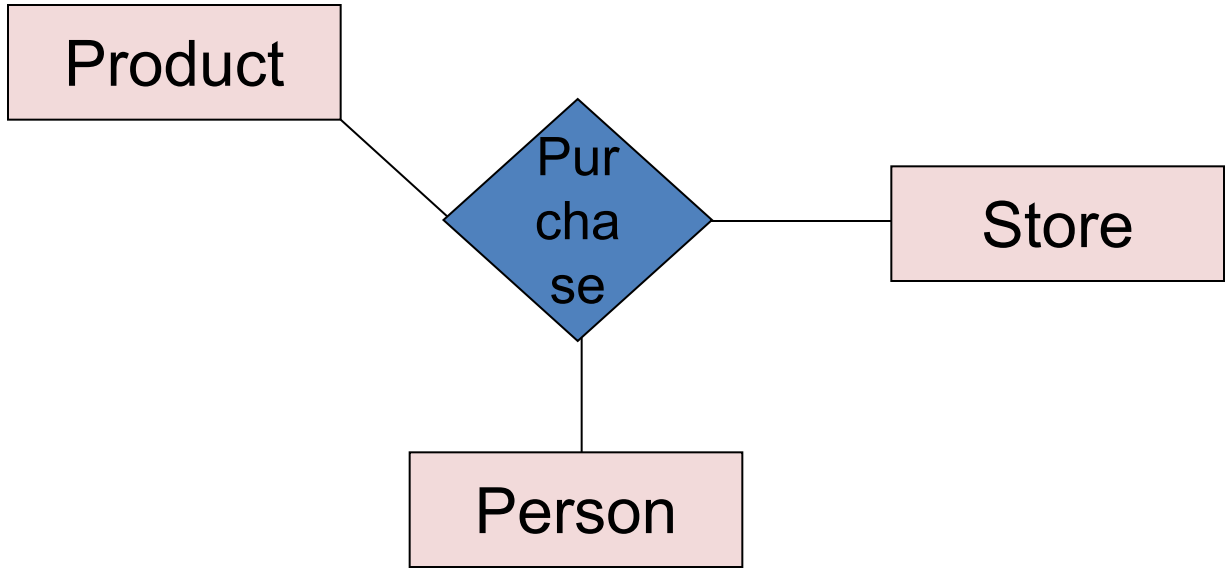
Multi-way Relationships

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



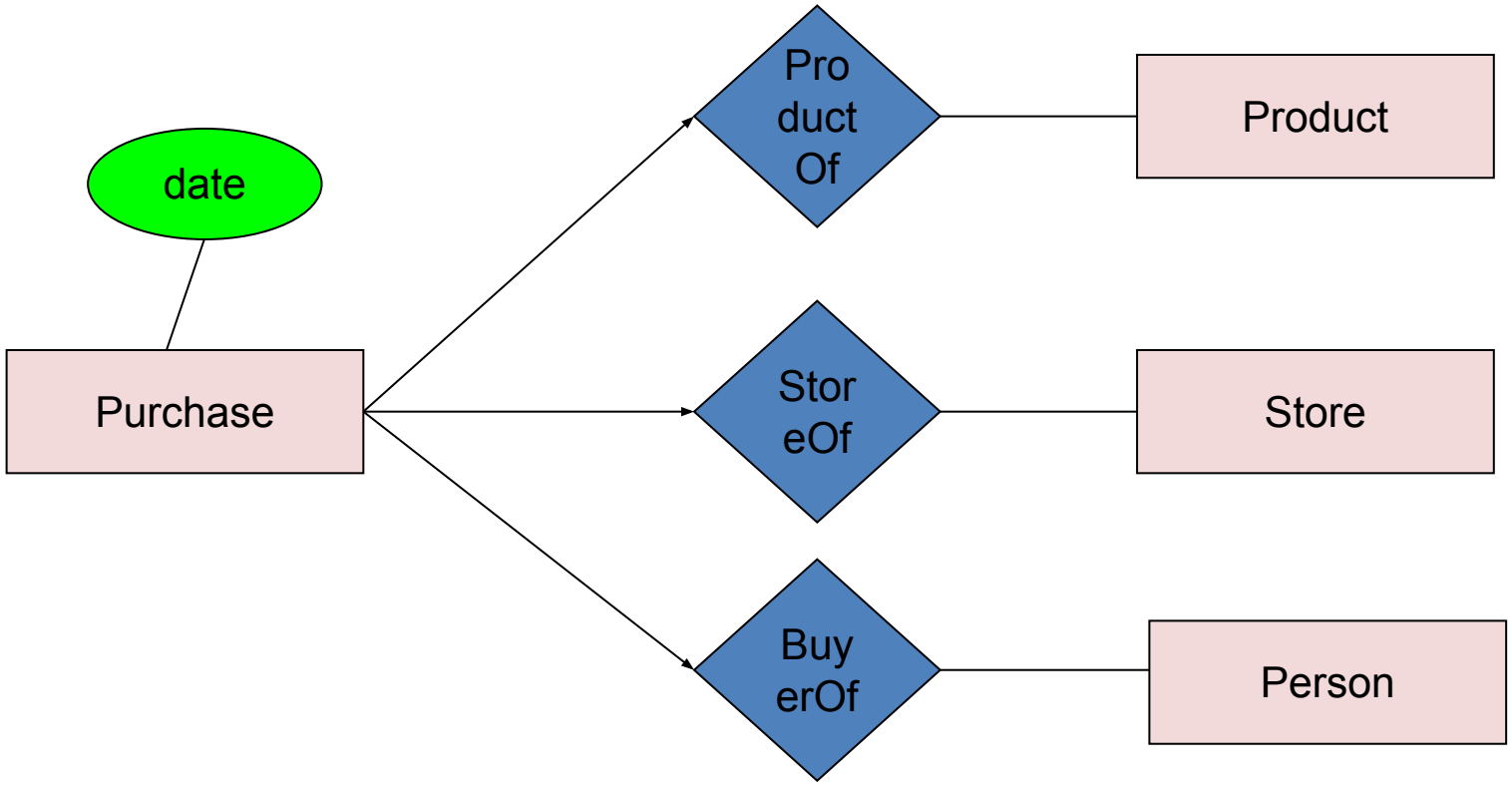
Arrows in Multiway Relationships

Q: How do we say that every person shops in at most one store ?

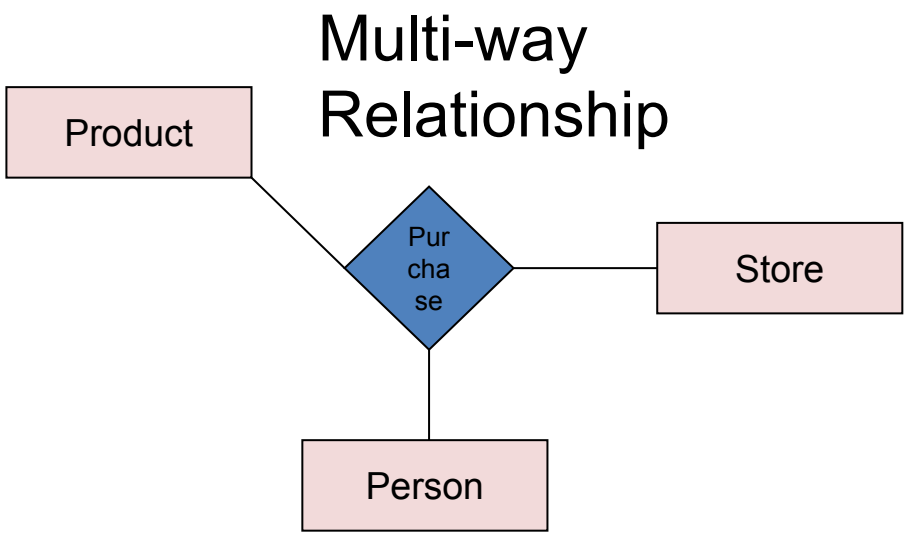


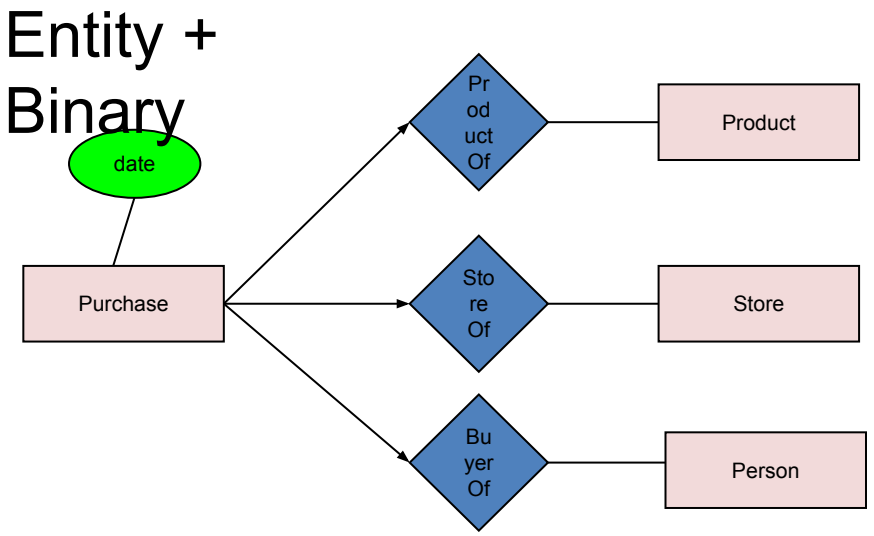
A: Cannot. This is the best approximation.
(Why only approximation ?)

Converting Multi-way Relationships to New Entity + Binary Relationships



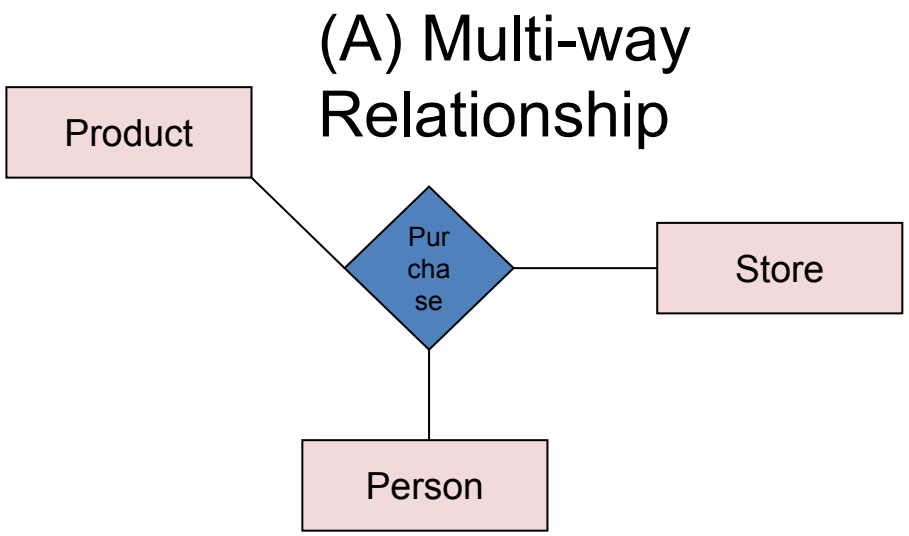
Decision: Multi-way or New Entity + Binary?

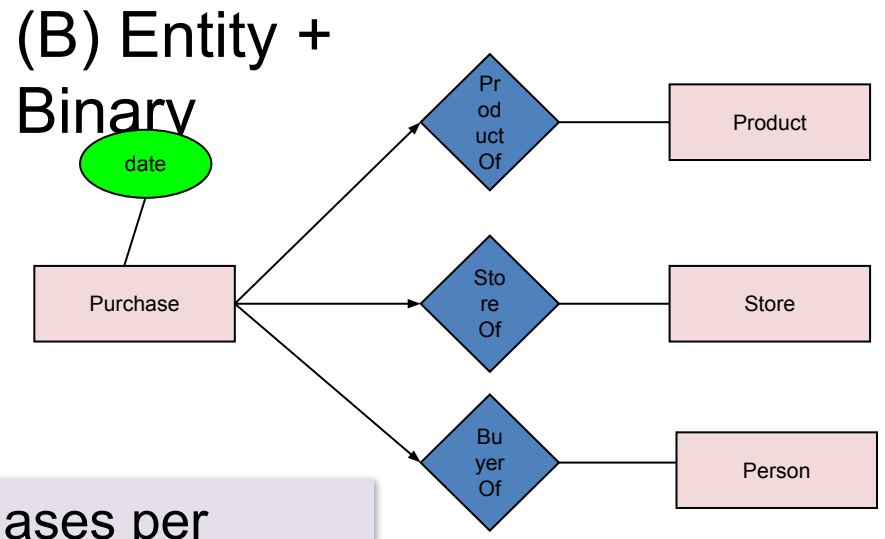




Should we use a single **multi-way relationship** or a ***new entity with binary relations?***

Decision: Multi-way or New Entity + Binary?



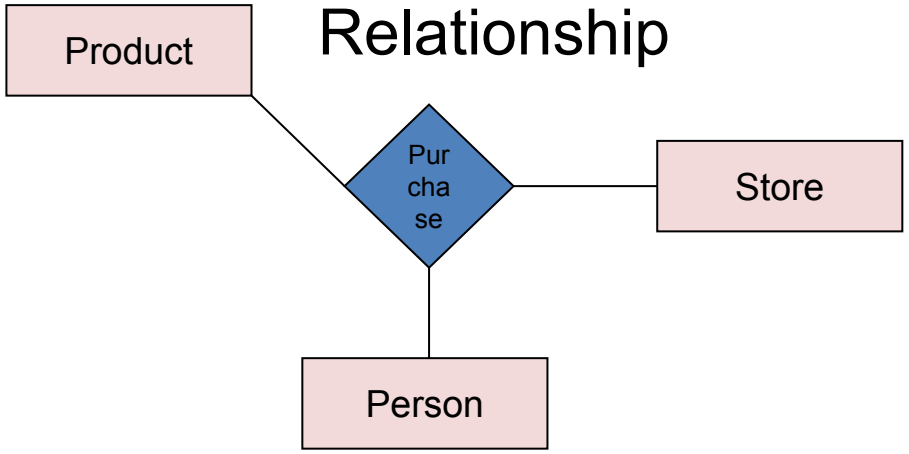


Multiple purchases per (product, store, person) combo possible here!

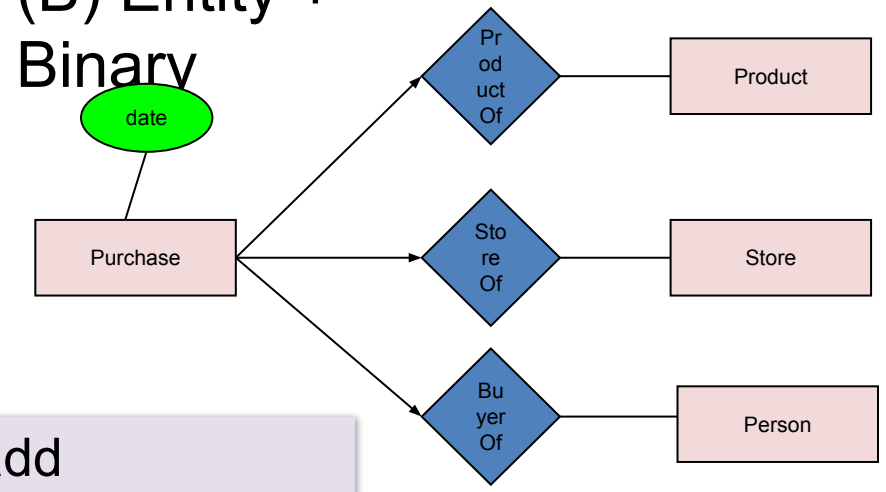
- *Covered earlier:* (B) is useful if we want to have multiple instances of the "relationship" per entity combination

Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



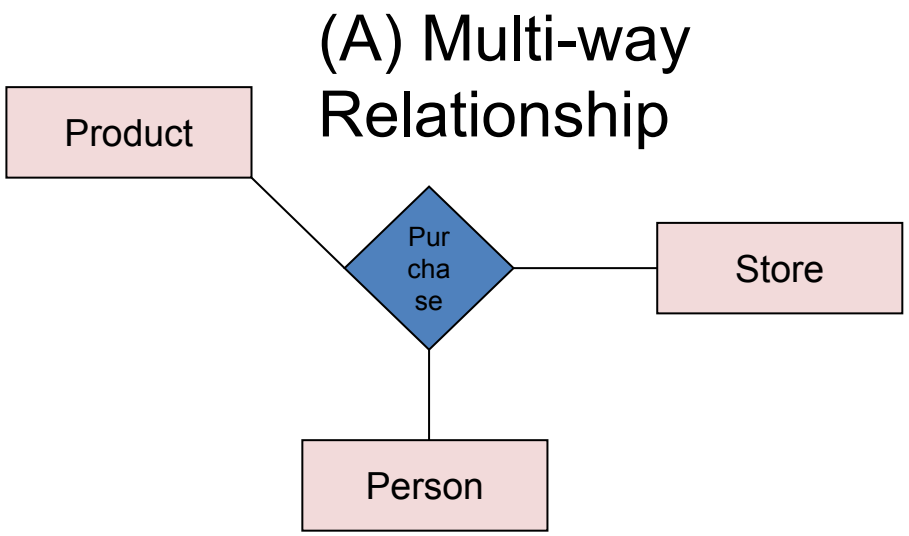
(B) Entity + Binary

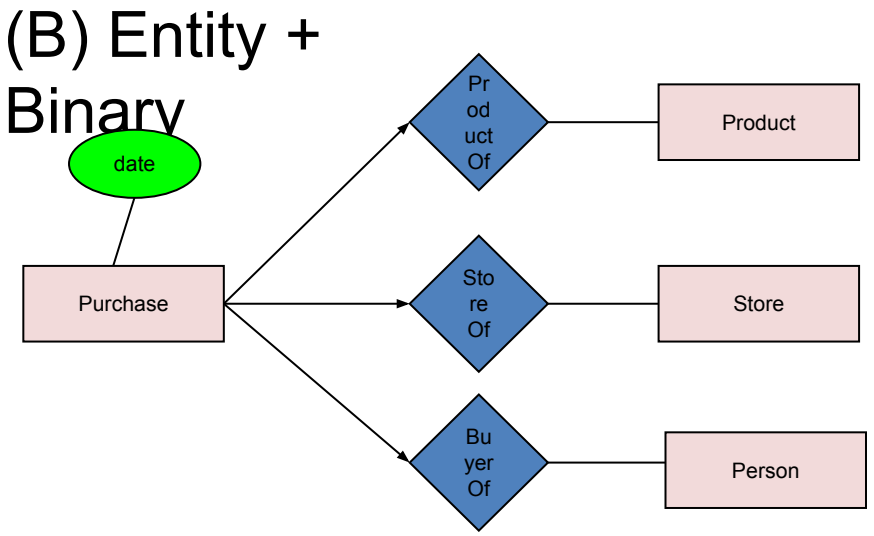


We can add more-fine-grained constraints here!

- (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"

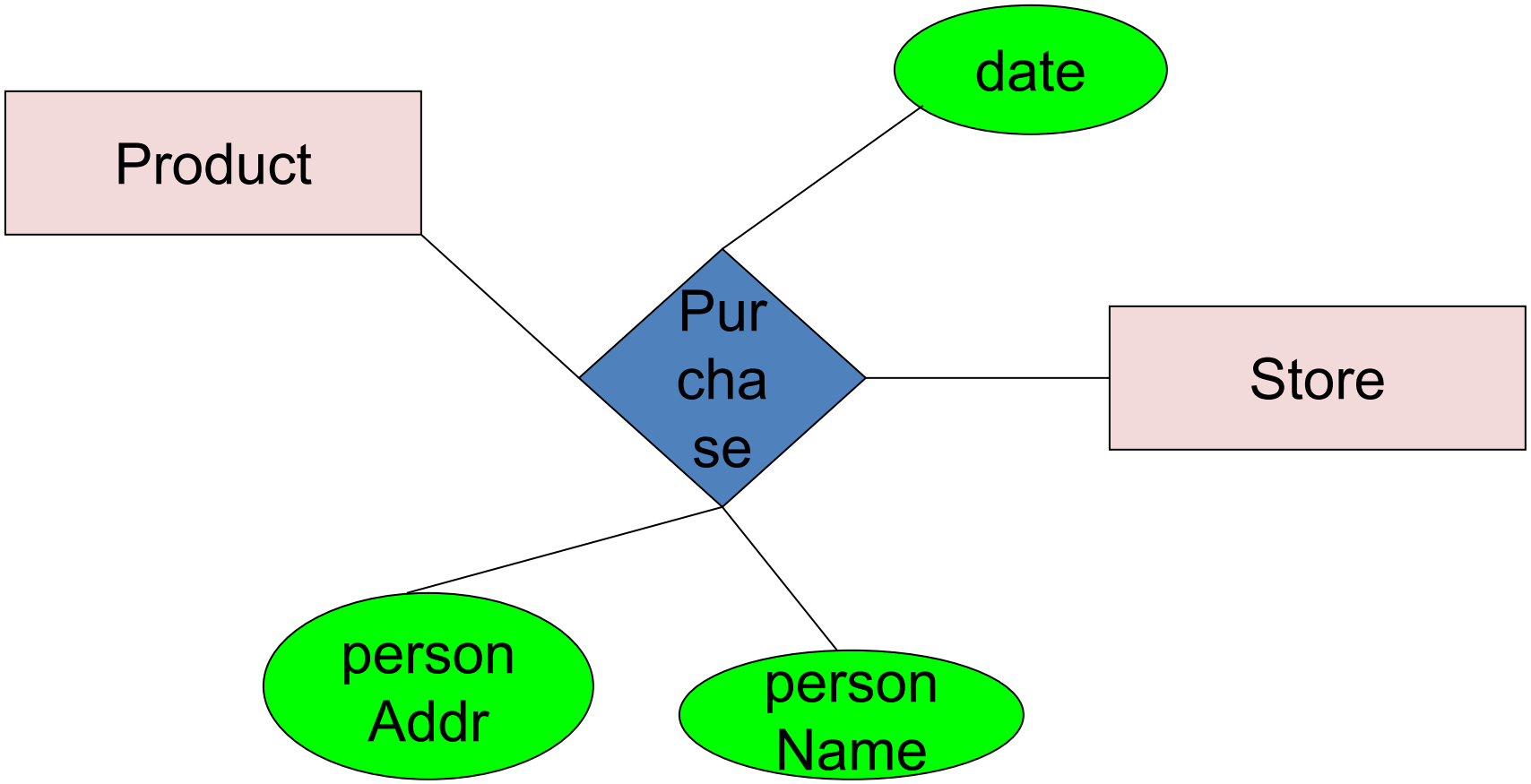
Decision: Multi-way or New Entity + Binary?



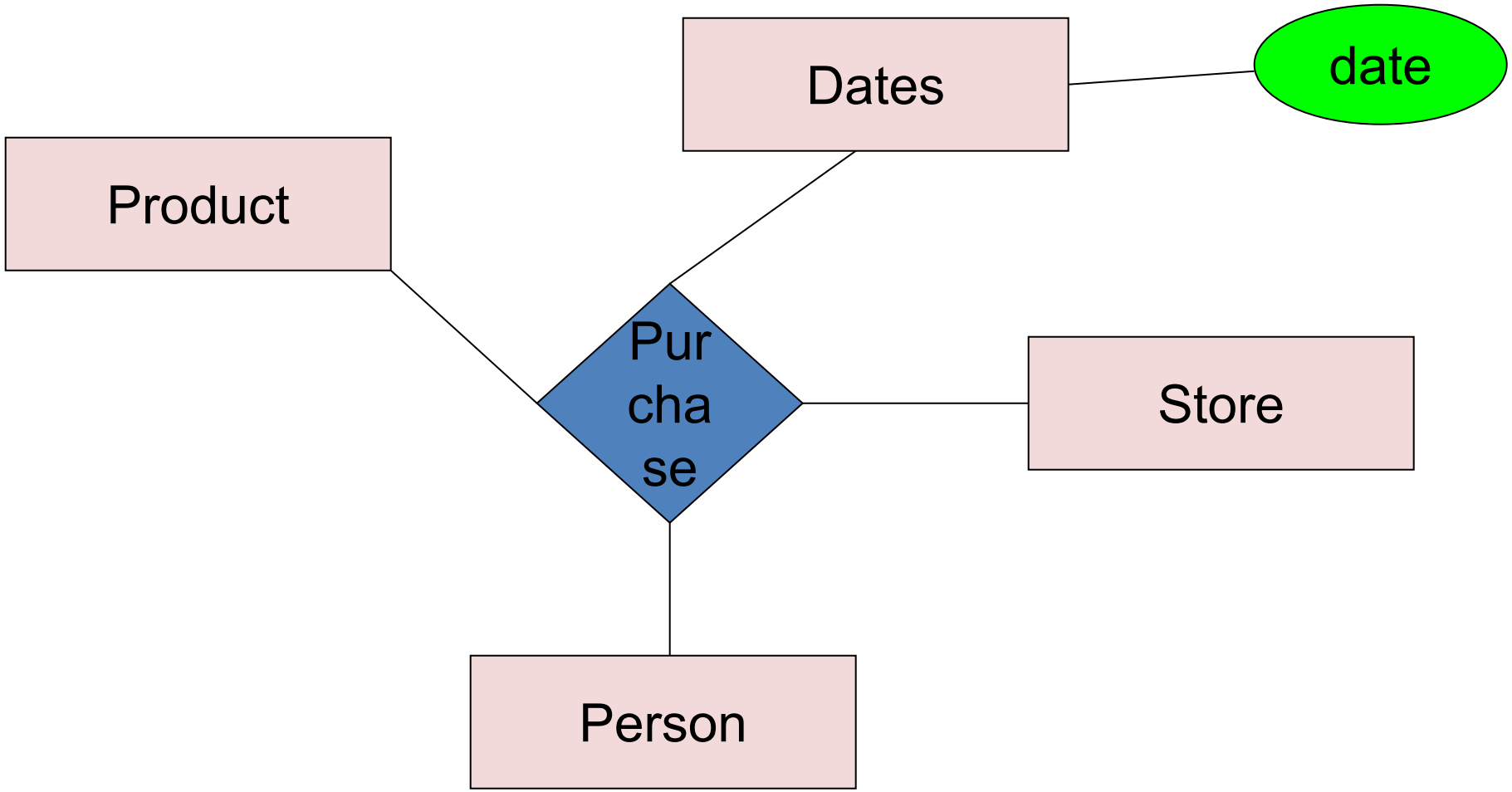


- (A) is useful when a relationship really is between multiple entities
  - *Ex: A three-party legal contract*

Design Principles: What's Wrong?

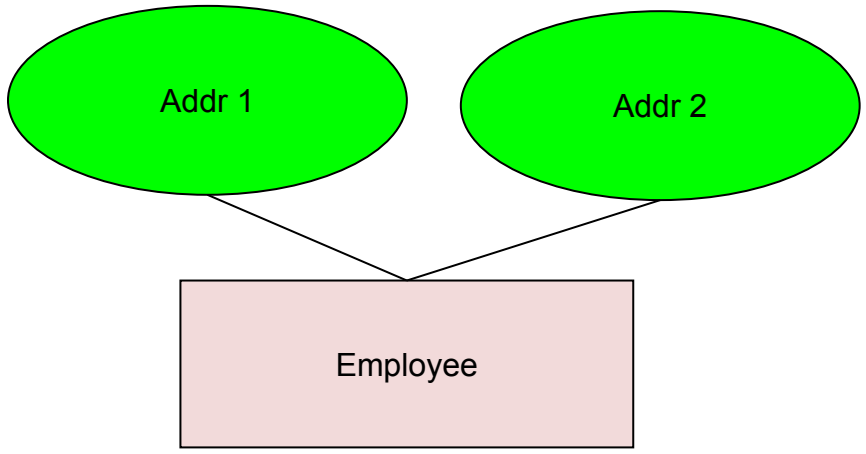


Design Principles: Better?

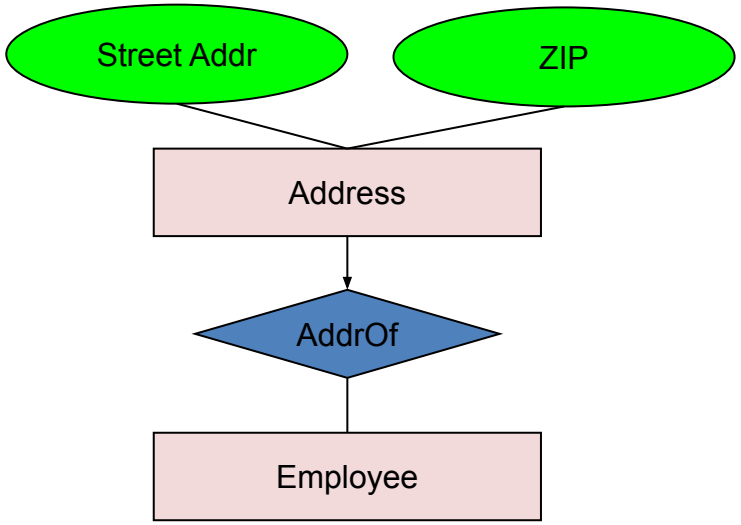


Examples: Entity vs. Attribute

Should address (A) be an attribute?

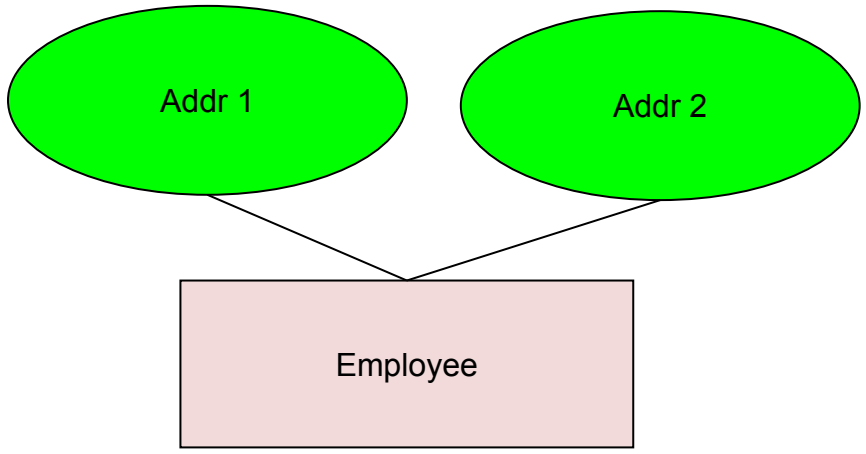


Or (B) be an entity?



Examples: Entity vs. Attribute

Should address (A) be an attribute?

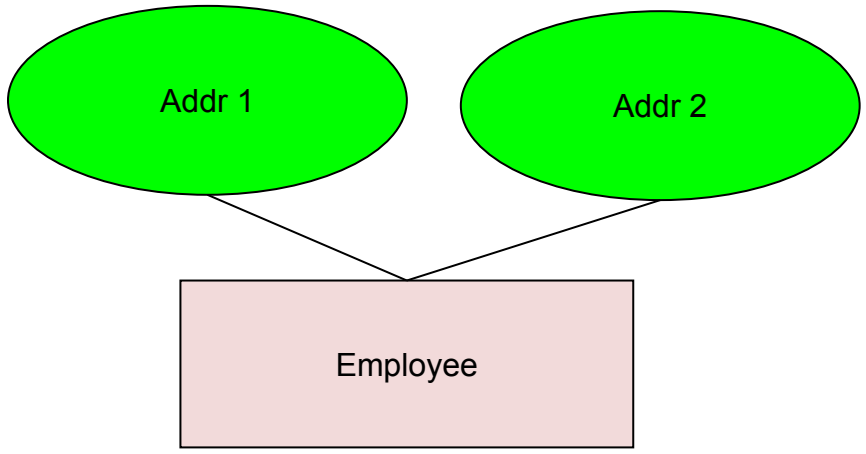


How do we handle employees with multiple addresses here?

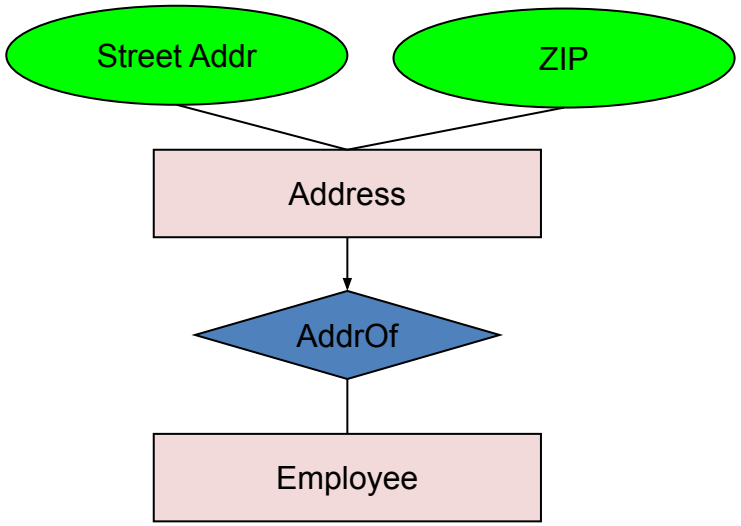
How do we handle addresses where internal structure of the address (e.g. zip code, state) is useful?

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

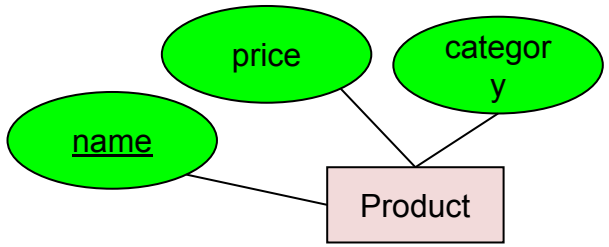
From E/R Diagrams to Relational Schema

- Key concept:

  Both ***Entity sets*** and ***Relationships*** become relations (tables 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

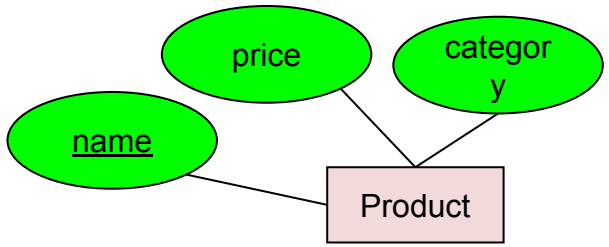


Produc
t

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)
)
```

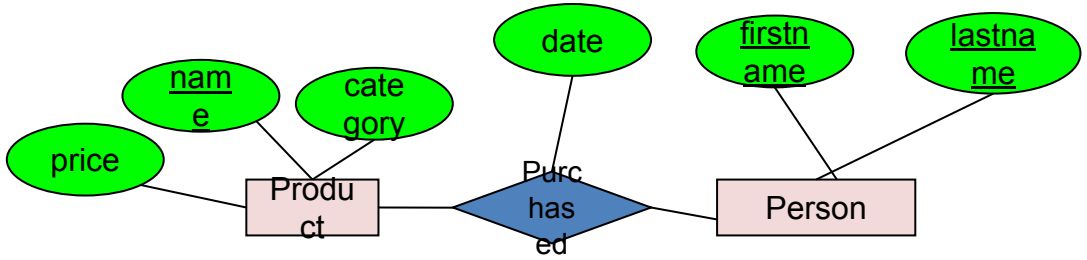


Produc
t

name	price	category
Gizmo1	99.99	Camera
Gizmo2	19.99	Edible

From E/R Diagrams to Relational Schema

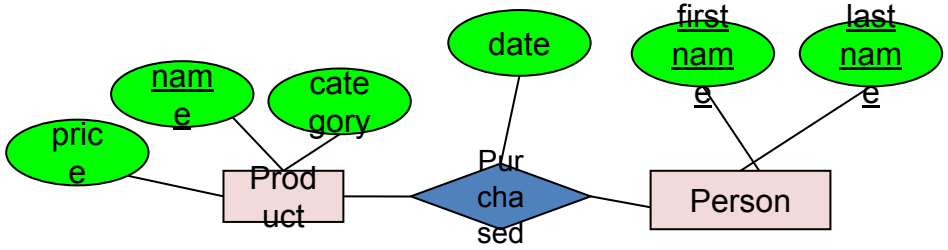
- A relation between entity sets $A_1, \ldots, A_N$ *also* becomes a multiset of tuples / a table
  - Each row/tuple is one relation, i.e. one unique combination of entities $(a_1,\ldots,a_N)$
  - Each row/tuple is
    - composed of the **union of the entity sets' keys**
    - has the entities' primary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



Purchased

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

From E/R Diagrams to Relational Schema

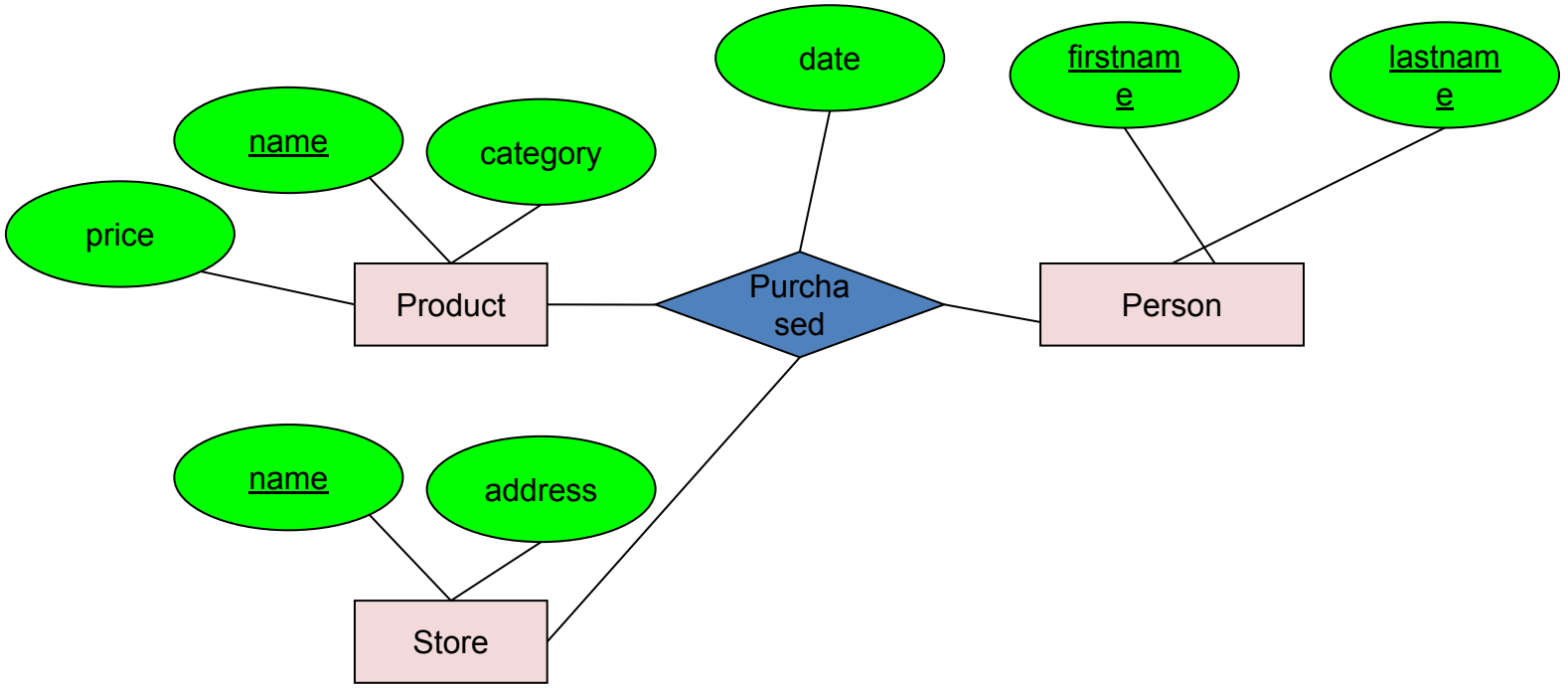


Purchased

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

From E/R Diagrams to Relational Schema

How do we represent this
as a relational schema?

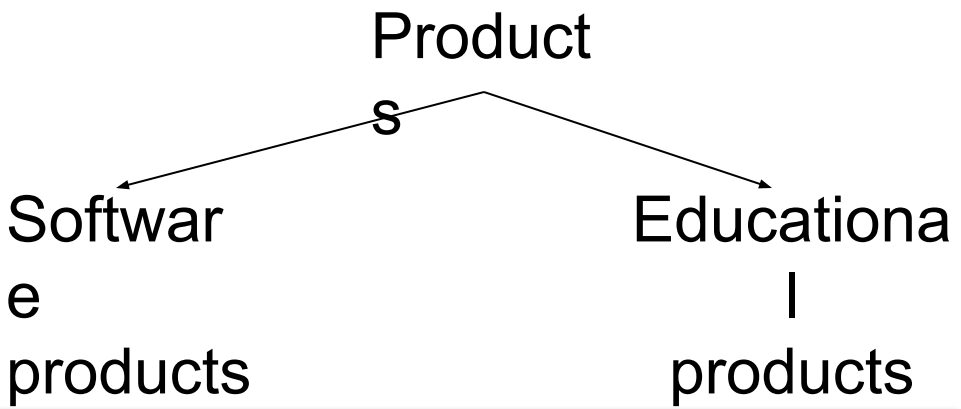


3. ADVANCED E/R CONCEPTS

1. Subclasses
2. Constraints
3. Weak entity sets

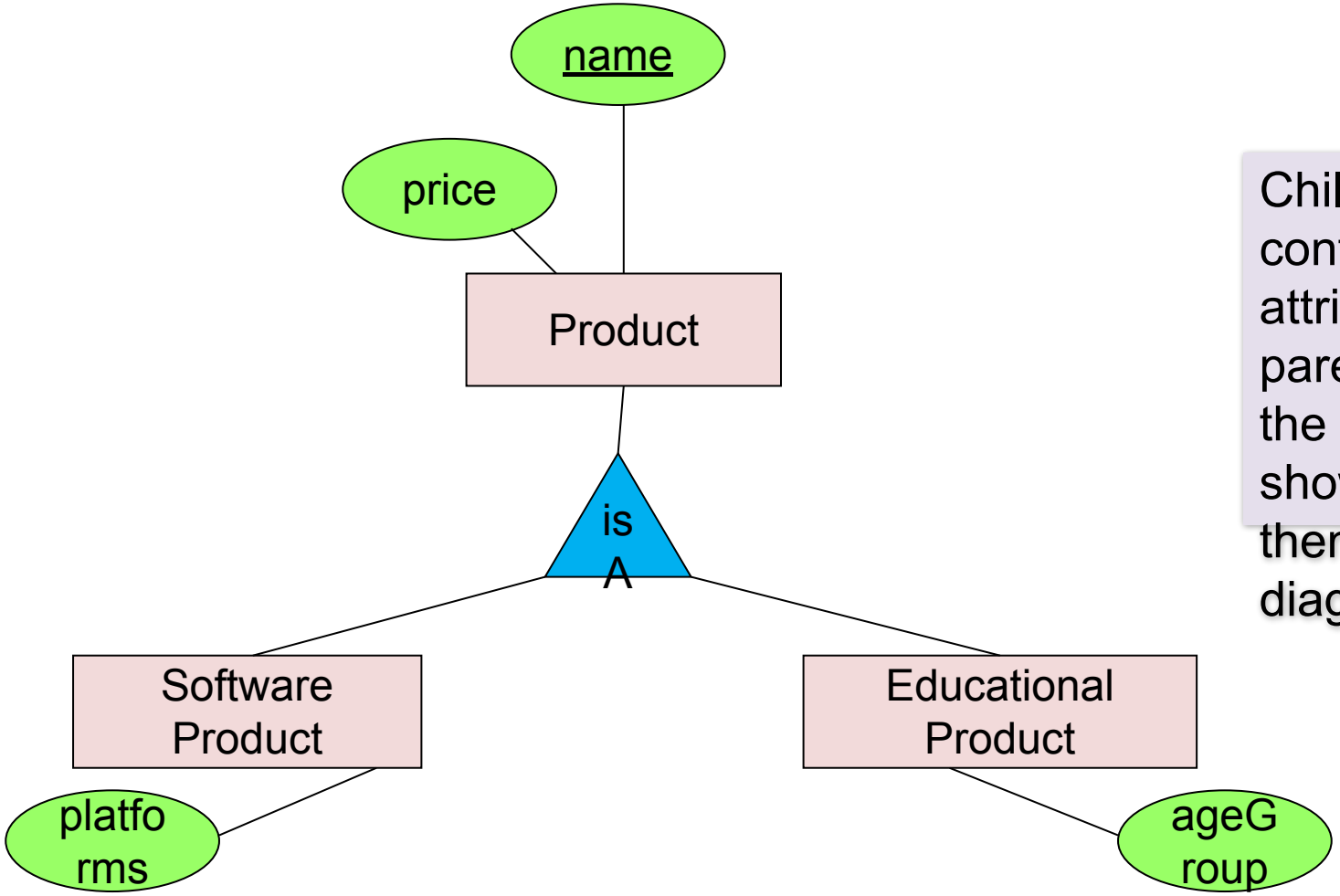
Modeling Subclasses

- 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?*
  - Better: define a *subclass*
    - *Ex:*



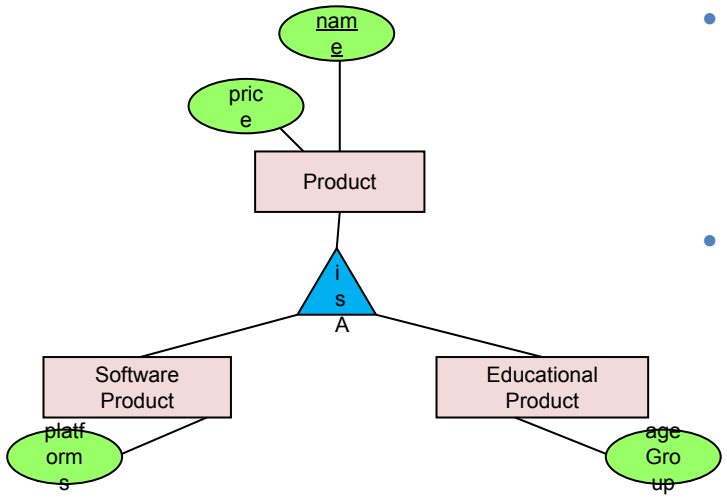
We can define **subclasses** in E/R!

Modeling Subclasses

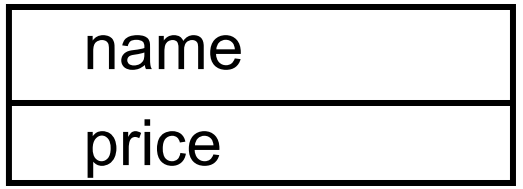


Child subclasses contain all the attributes of *all* of their parent classes **plus** the new attributes shown attached to them in the E/R diagram

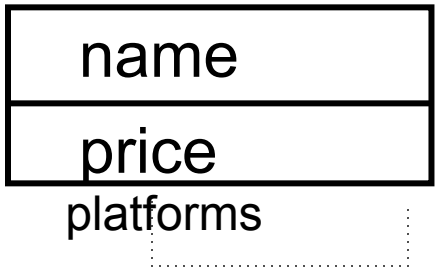
Understanding Subclasses



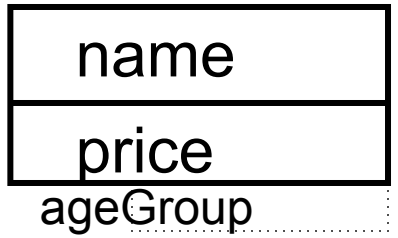
- Think in terms of records; ex:
  - Product



  - SoftwareProduct

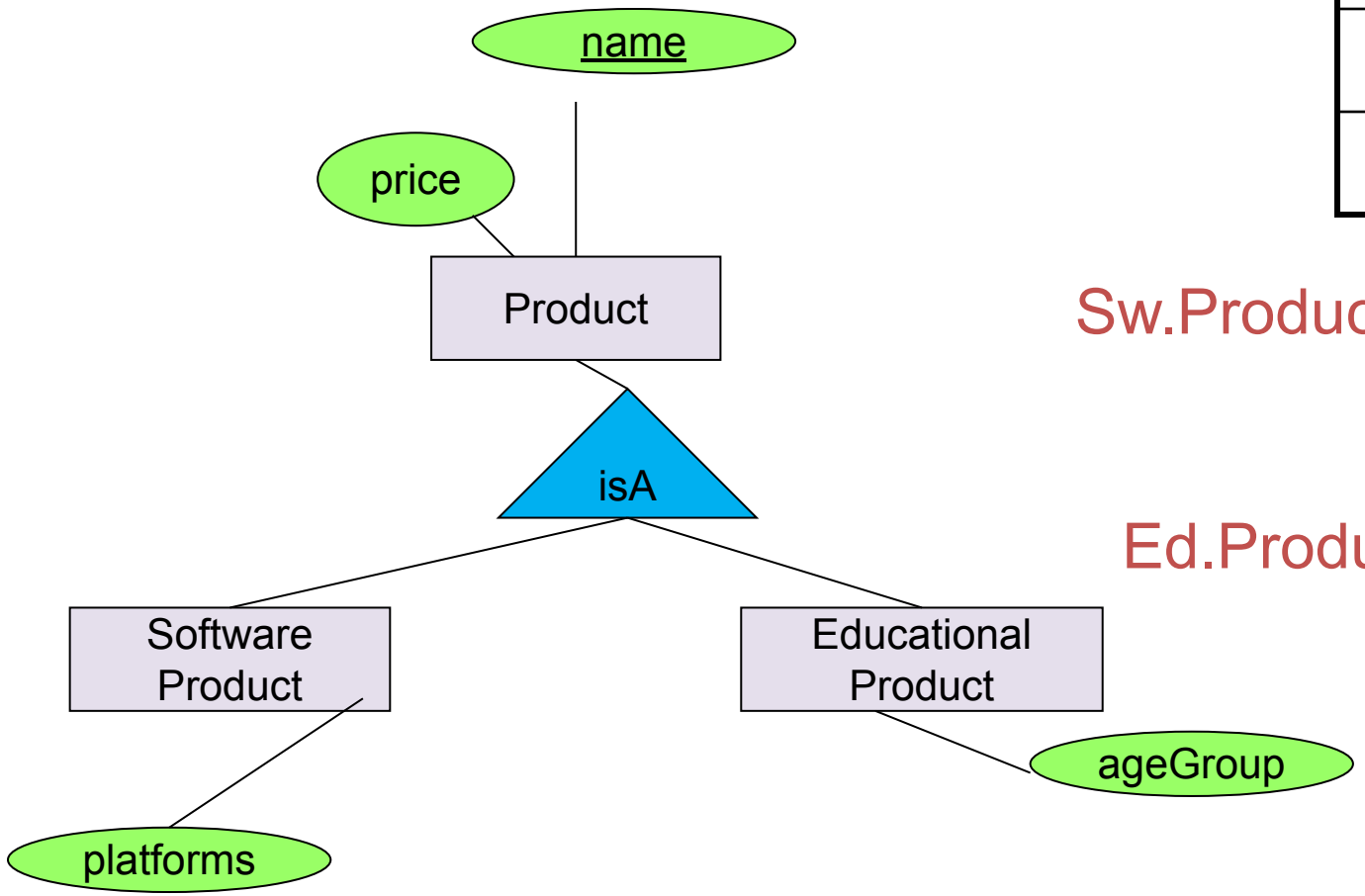


  - EducationalProduct



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

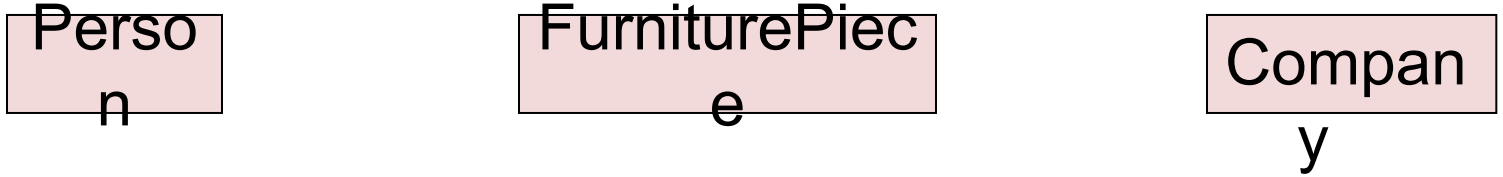
Ed.Product

name	ageGroup
Gizmo	todler
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
  - To identify entities that participate in a relationship
- **No need for multiple inheritance**

Modeling UnionTypes With Subclasses

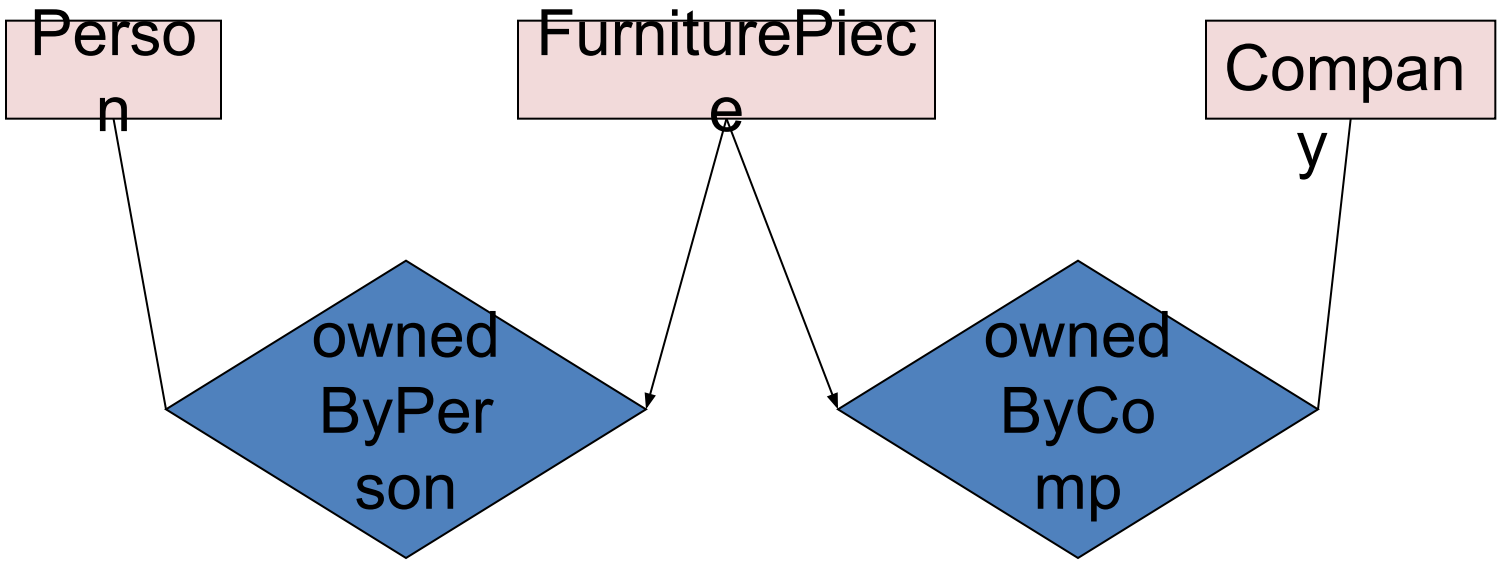


Suppose each piece of furniture is owned either by a person, or by a company.
How do we represent this?

Modeling Union Types with Subclasses

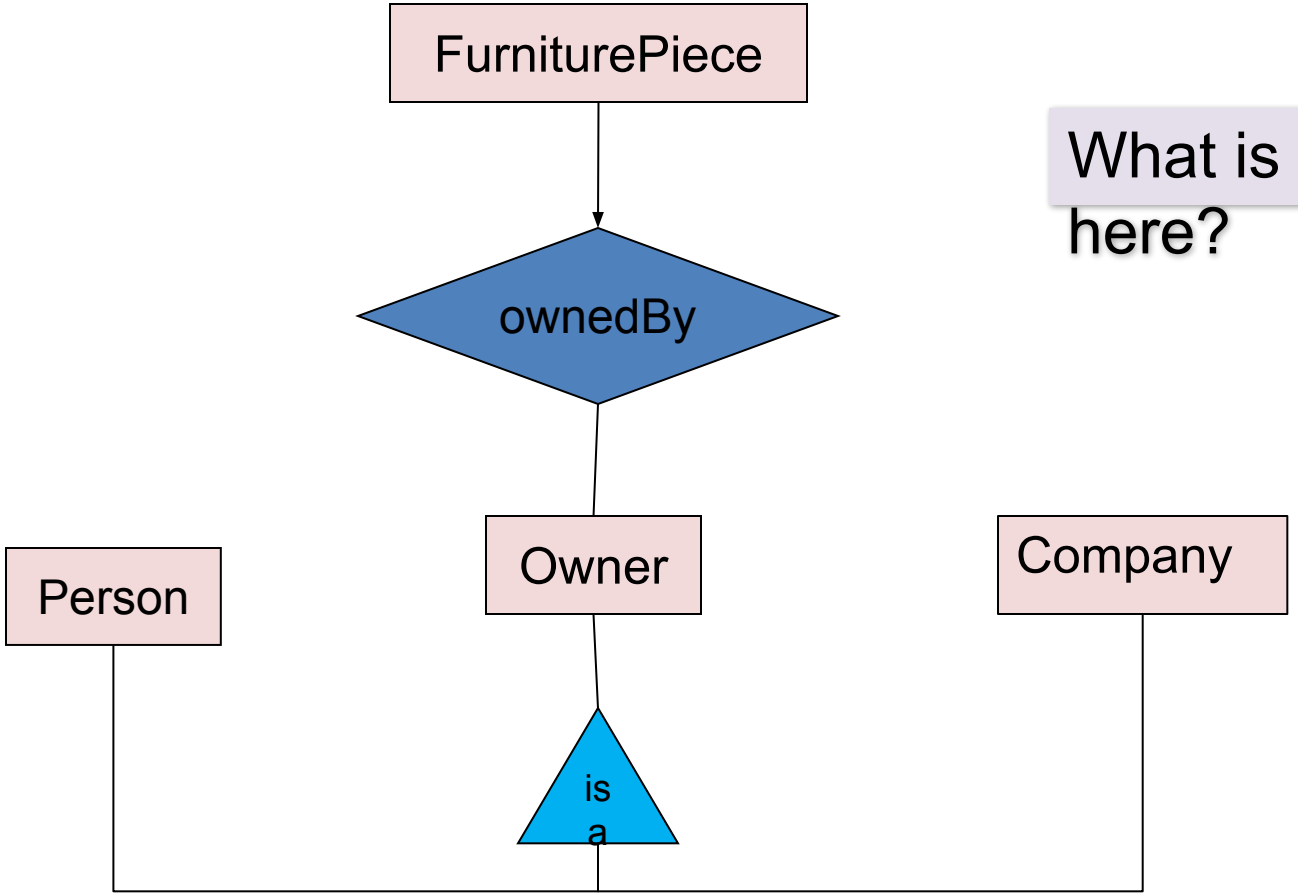
Say: each piece of furniture is owned either by a person, or by a company

Solution 1. Acceptable, but imperfect (What's wrong ?)



Modeling Union Types with Subclasses

Solution 2: better (though more laborious)



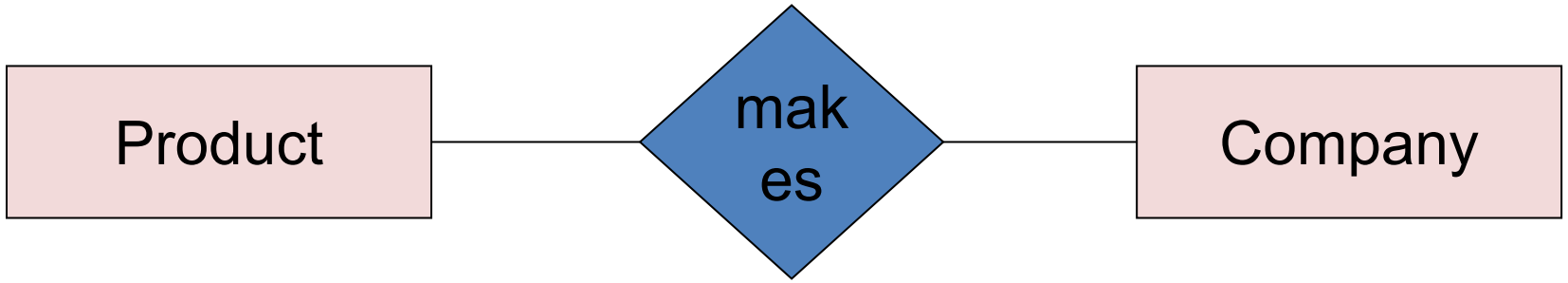
What is happening here?

Constraints in E/R Diagrams

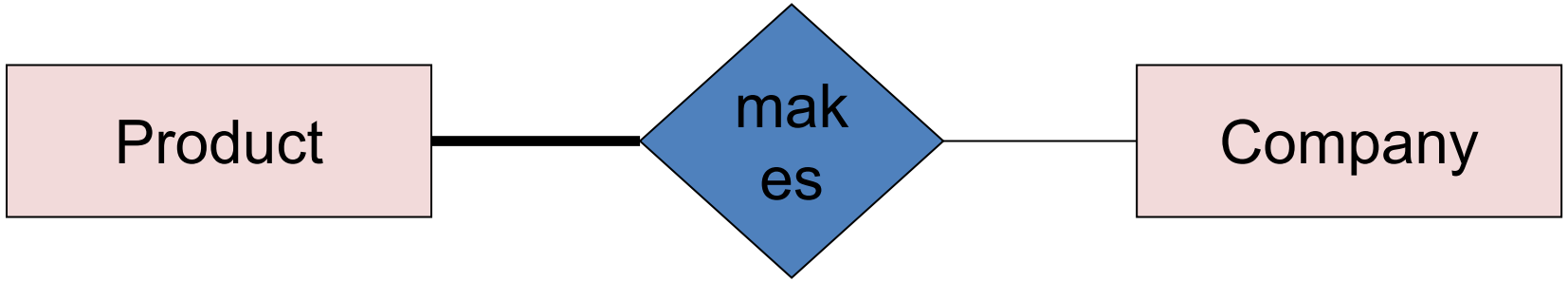
- Finding constraints is part of the E/R modeling process. Commonly used constraints are:
  - Keys: Implicit constraints on uniqueness of entities
    - *Ex: An SSN uniquely identifies a person*
  - Single-value constraints:
    - *Ex: a person can have only one father*
  - Referential integrity constraints: 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

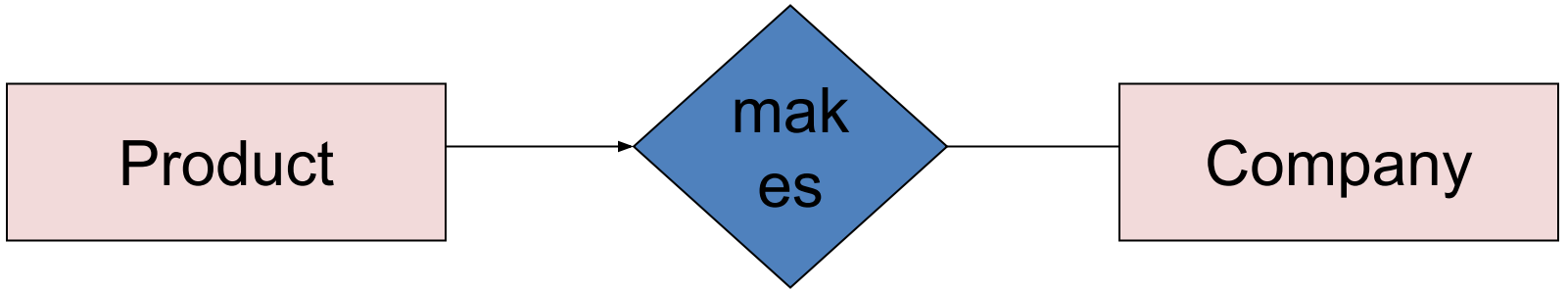


Are there products made by no company?
Companies that don't make a product?

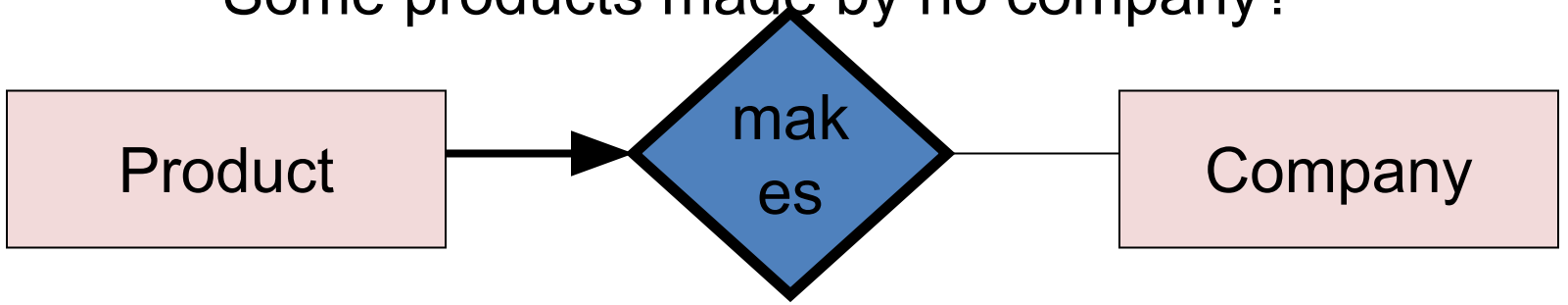


Bold line indicates *total participation* (i.e. here: all products are made by a company)

Referential Integrity Constraints



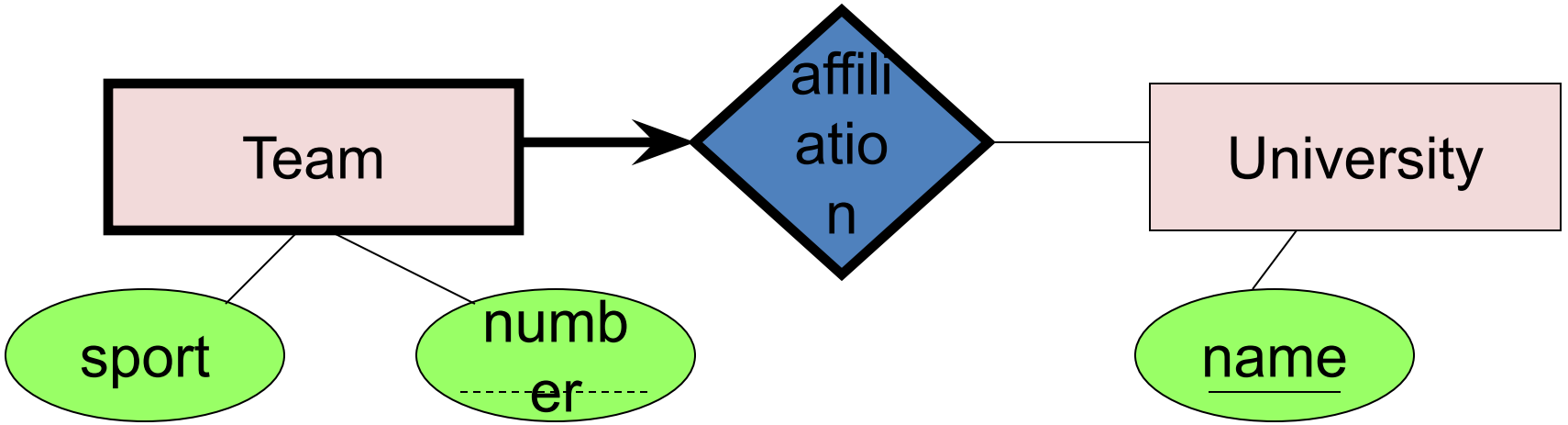
Each product made by at most one company.
Some products made by no company?



Each product made by *exactly* one company.

Weak Entity Sets

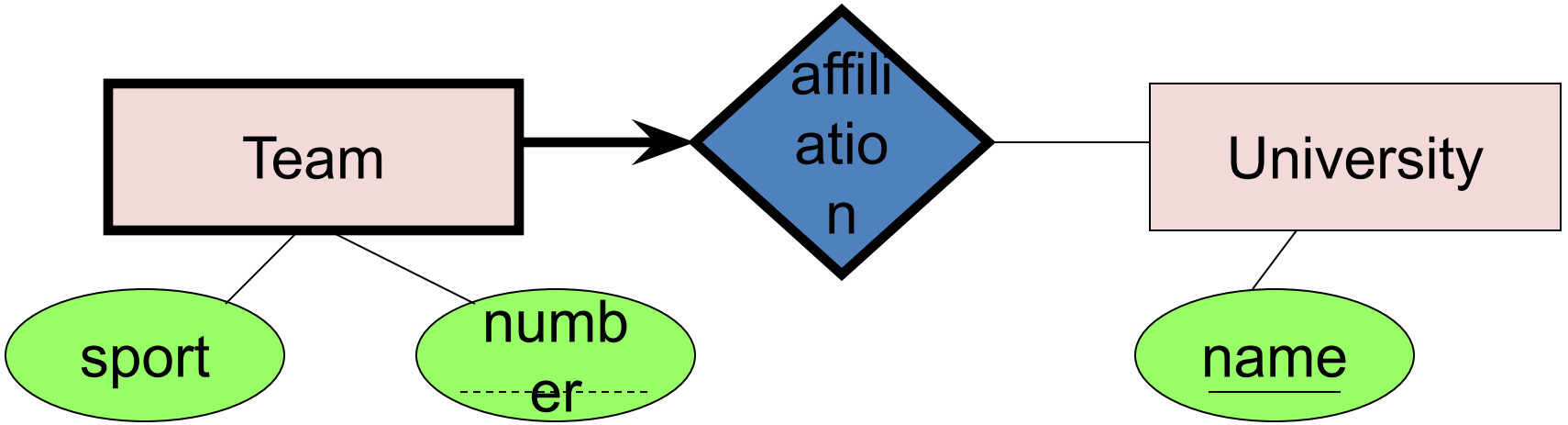
Entity sets are *weak* when their key comes from other classes to which they are related.



"Football team" v. "***The UW*** Football team"

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?

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, but not overzealous