CS 6400 A

Database Systems Concepts and Design

Lecture 4
08/28/24

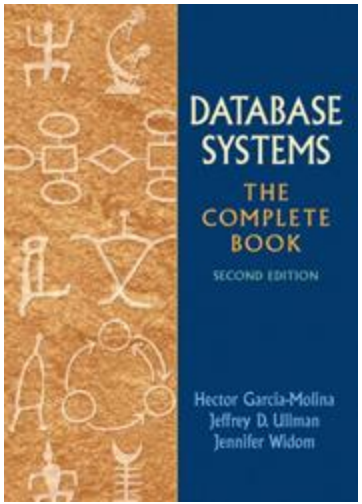
Agenda

1. E/R Basics: Entities & Relations
2. E/R Design considerations
3. E/R Diagram to Relational Schema
4. Advanced E/R Concepts (time permitting)

Reading Materials

Database Systems: The Complete Book (2nd edition)

- Chapter 4: High-Level Database Models (4.1- 4.6)



Notation in this lecture follow this book!

Acknowledgement: The following slides have been adapted from EE477 (Database and Big Data Systems) taught by Steven Whang and CS145 (Intro to Big Data Systems) taught by Peter Bailis.

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:

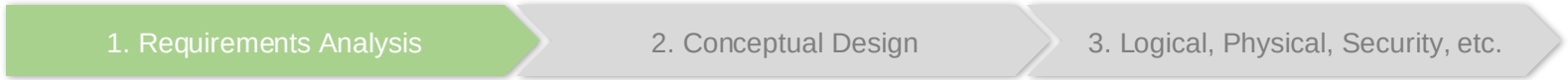
- What entities to model
- How entities are related
- What constraints exist in the domain
- How to achieve good designs

Several formalisms exist

- We discuss one flavor of E/R diagrams

"The Entity-Relationship model – toward a unified view of data" Peter Chen, 1976

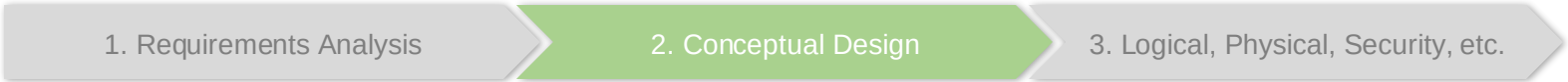
Database Design Process



1. **Requirements analysis**
    - What is going to be stored?
    - How is it going to be used?
    - Who should access the data?

Technical and non-technical people are both involved

Database Design Process

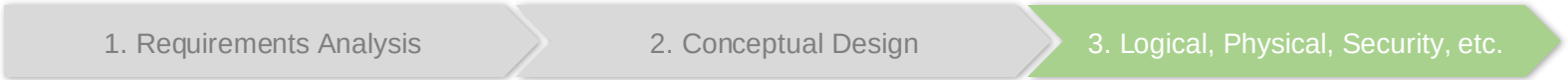


2. Conceptual Design

- 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.

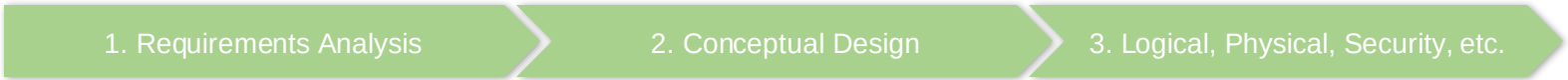
Database Design Process



3. More:

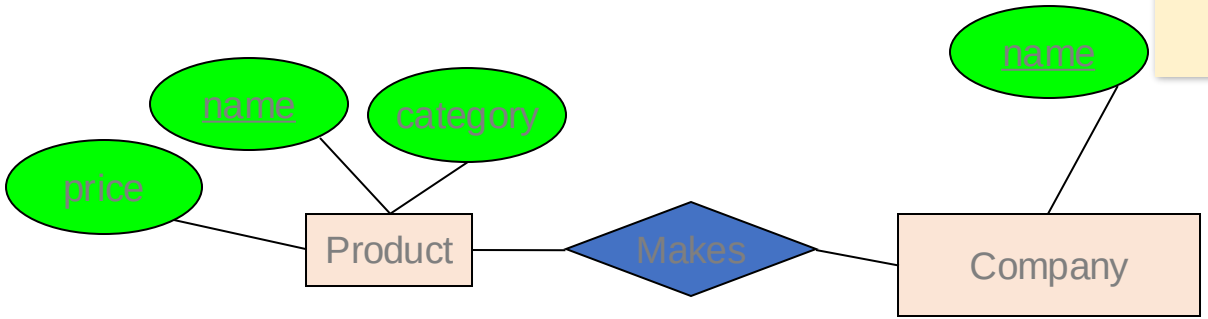
- Logical Database Design
- Physical Database Design
- Security Design

Database Design Process



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

1. E/R Basics: Entities & Relations

The E in E/R: Entities and Entity Set

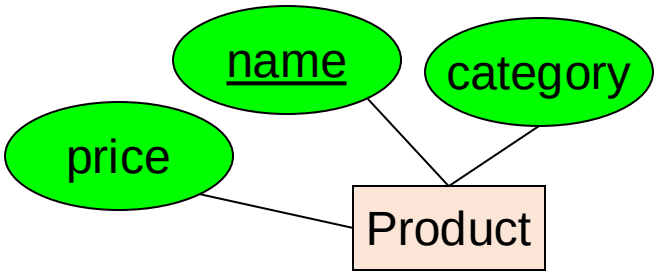
Entities are the individual objects (no associated methods)

Entity sets are collections of similar entities

- Represented by rectangles

An entity set has attributes

- Represented by ovals attached to an entity set

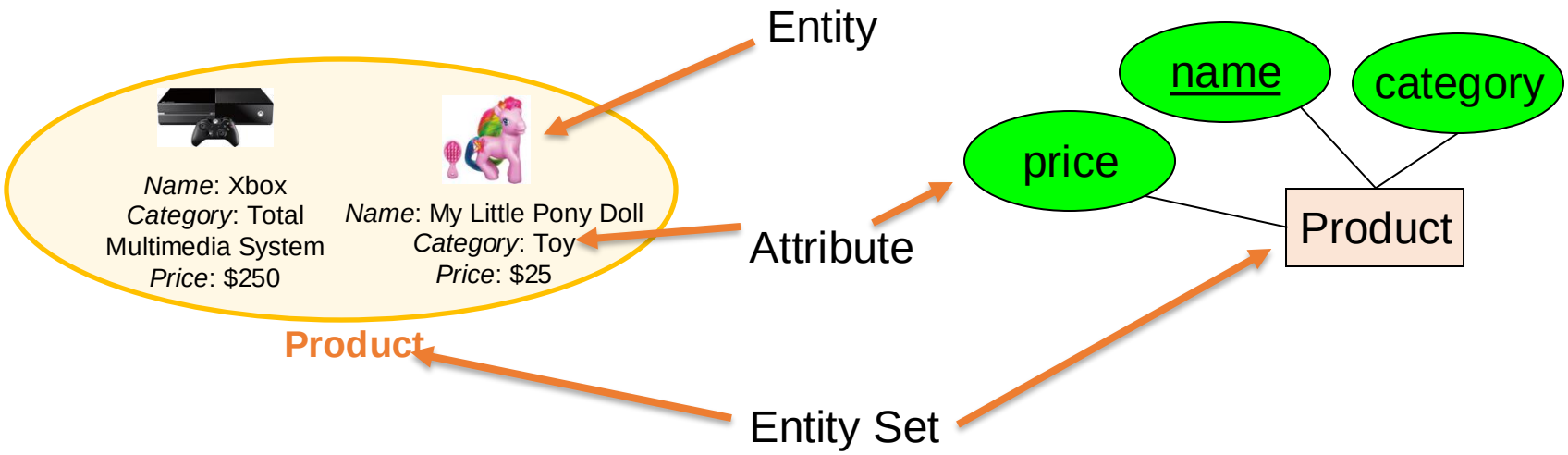


Shapes are important.
Colors are not.

Entities vs. Entity Sets

Entities are not explicitly represented in E/R diagrams!

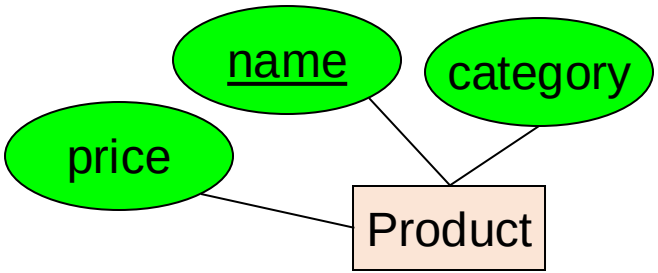
Example:



Keys

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

Denote elements of the primary key by underlining.

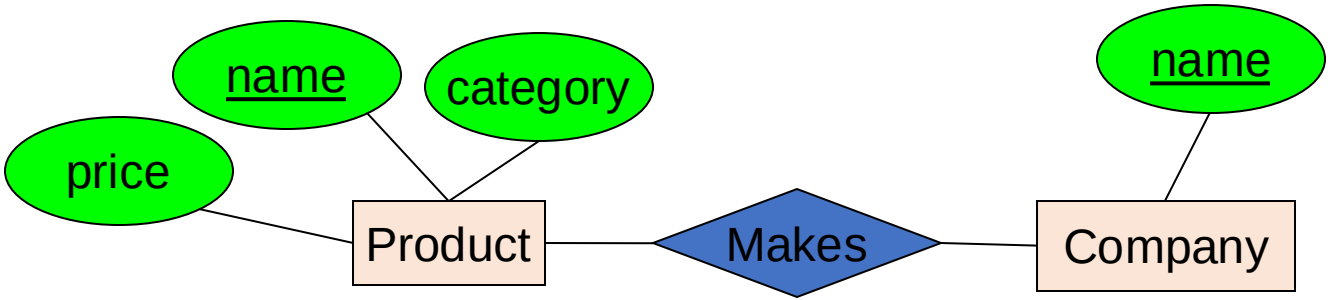


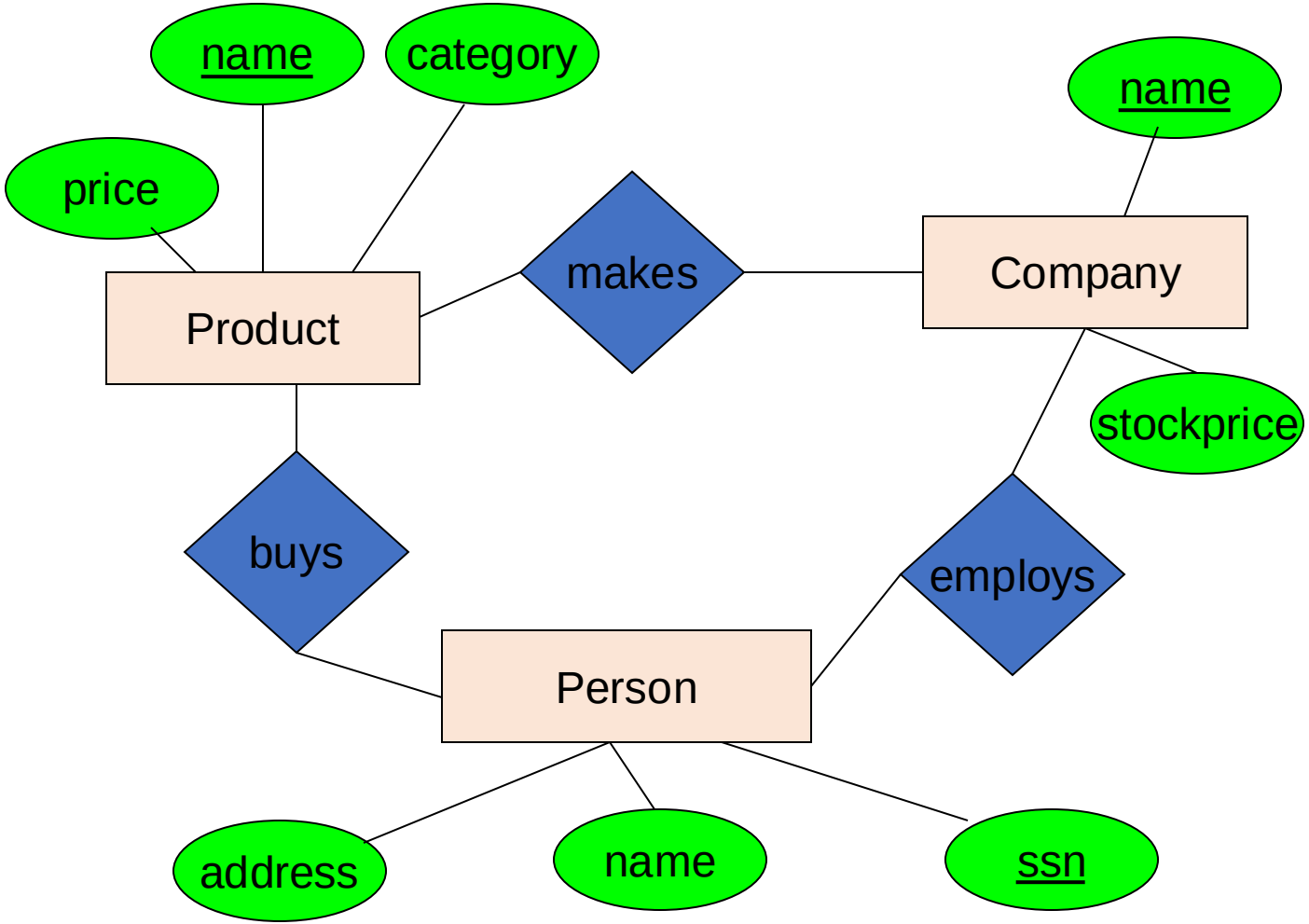
The E/R model forces us to designate a single primary key, though there may be multiple candidate keys

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

A **relationship** is between two entities

- Represented by diamonds

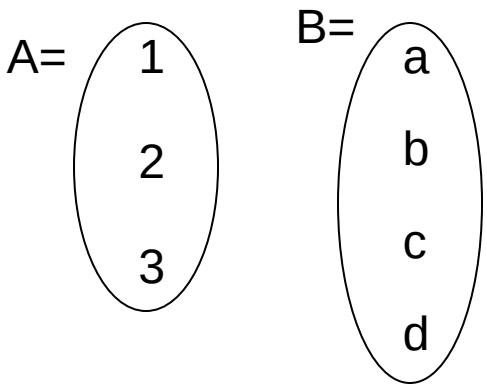



name
category
price
Product
makes
Company
name
stockprice
buys
employs
Person
address
name
ssn

What is a Relationship?

A mathematical definition:

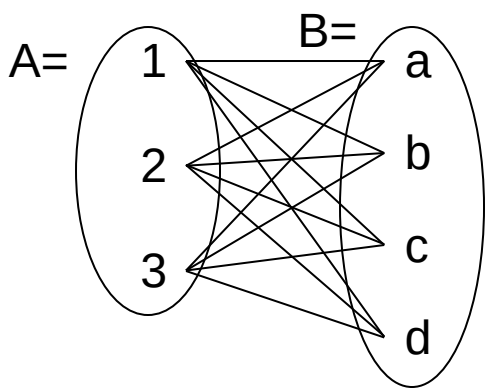
- Let A, B be sets
  - *A={1,2,3}, B={a,b,c,d}*



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)}*



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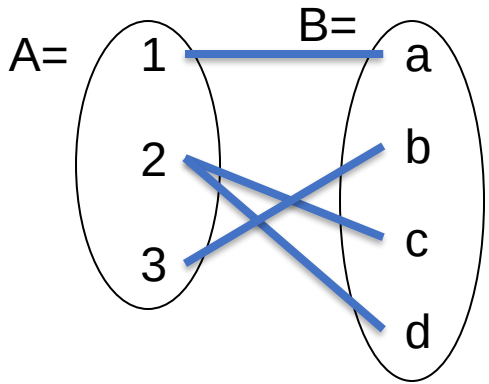
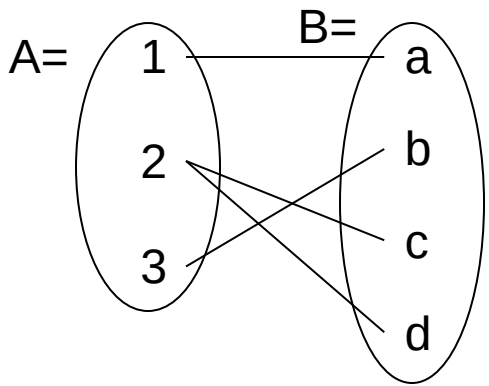
  - *A × B = {(1,a), (1,b), (1,c), (1,d), (2,a), (2,b), (2,c), (2,d), (3,a), (3,b), (3,c), (3,d)}*
- **We define a relationship to be a subset of A x B**
  - *R = {(1,a), (2,c), (2,d), (3,b)}*



What is a Relationship?

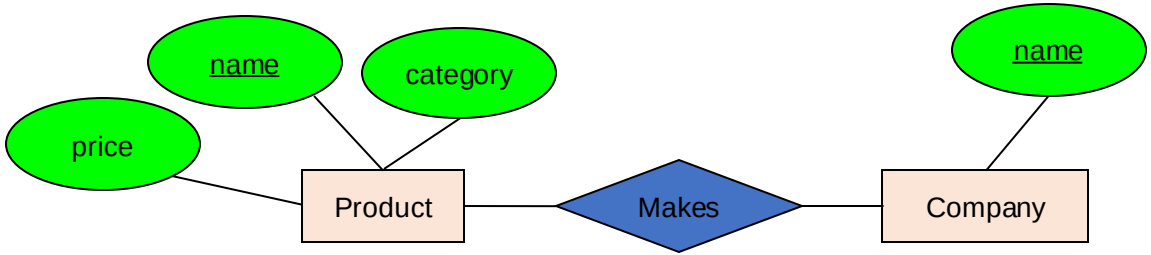
A mathematical definition:

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

What is a Relationship?



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

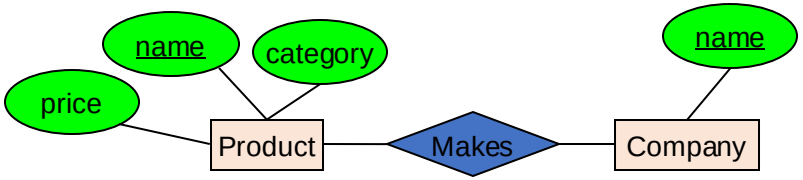
What is a Relationship?

Company

name
GizmoWorks
GadgetCorp

Product

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



Company C × Product P

C.name	P.name	P.category	P.price
GizmoWorks	Gizmo	Electronics	$9.99
GizmoWorks	GizmoLite	Electronics	$7.50
GizmoWorks	Gadget	Toys	$5.50
GadgetCorp	Gizmo	Electronics	$9.99
GadgetCorp	GizmoLite	Electronics	$7.50
GadgetCorp	Gadget	Toys	$5.50

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

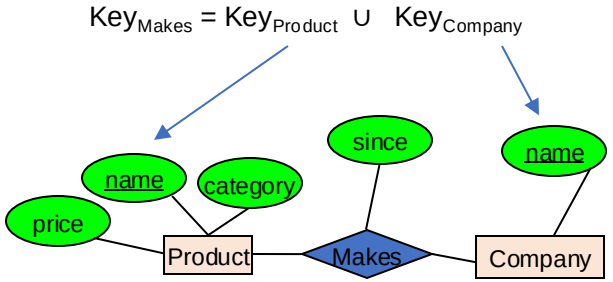
What is a Relationship?

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**

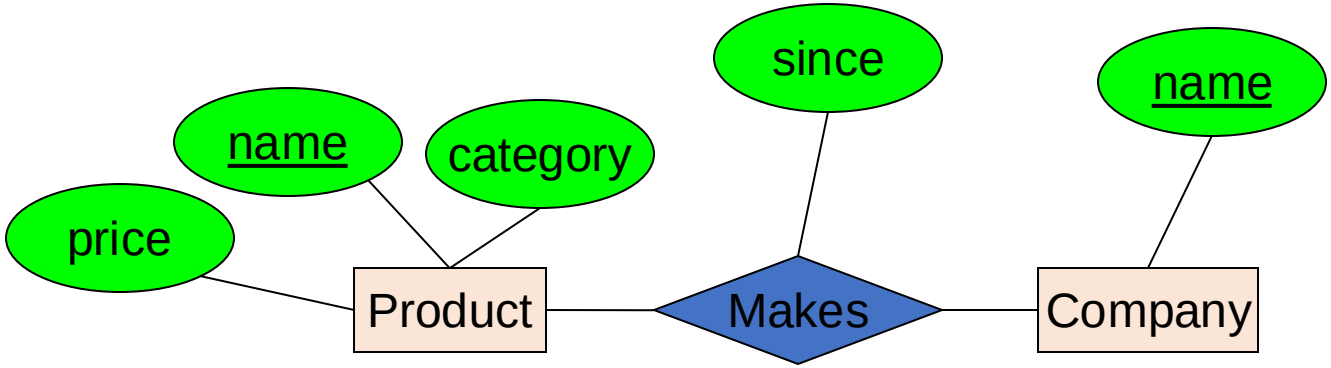
Example: the "key" for Makes (to right) is {Product.name, Company.name}

This follows from our mathematical definition of a relationship- it's a SET!



Relationships and Attributes

Relationships may have attributes as well.



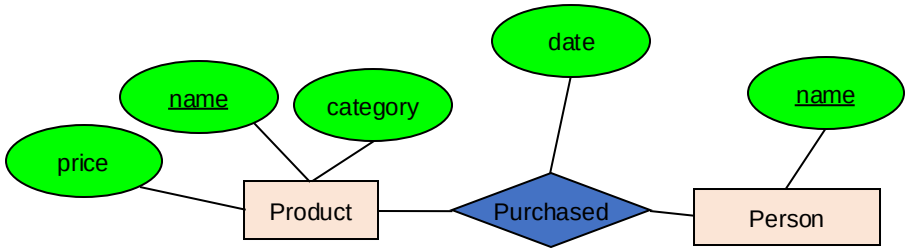
For example: “since” records when company started making a product

Note: “since” is implicitly unique per pair here! Why?

Note #2: Why not “how long”?

Decision: Relationship vs. Entity?

Q: What does this say?

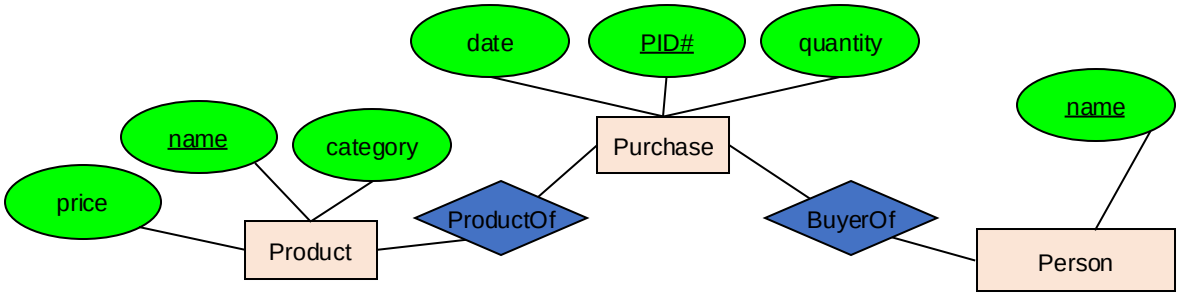


A: A person can only buy a specific product once (on one date)

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!

2. E/R Design Considerations

Multiplicity of binary relationships

Relationships can be one-one, one-many, or many-many

An arrow indicates “related to at most one entity”

- Different than “exactly one”

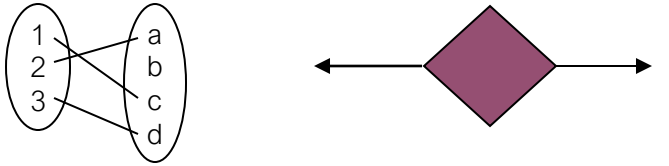
A product has at most one company

A product has at most one company, and a company has at most one product

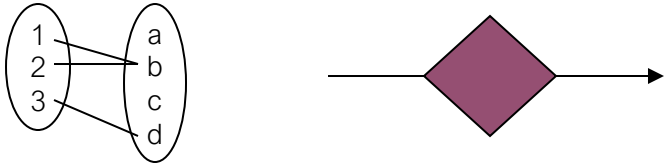
What kind of relationship does the bottom diagram imply?

Multiplicity of binary relationships

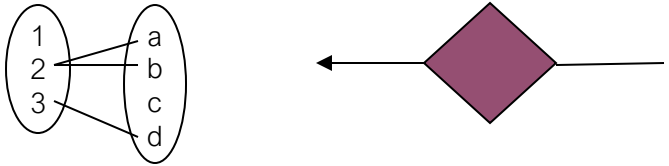
One-to-one:



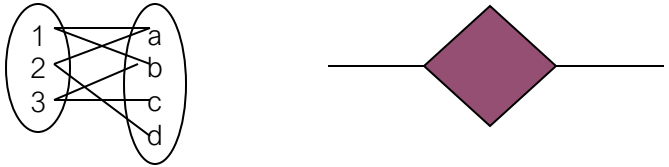
Many-to-one:



One-to-many:

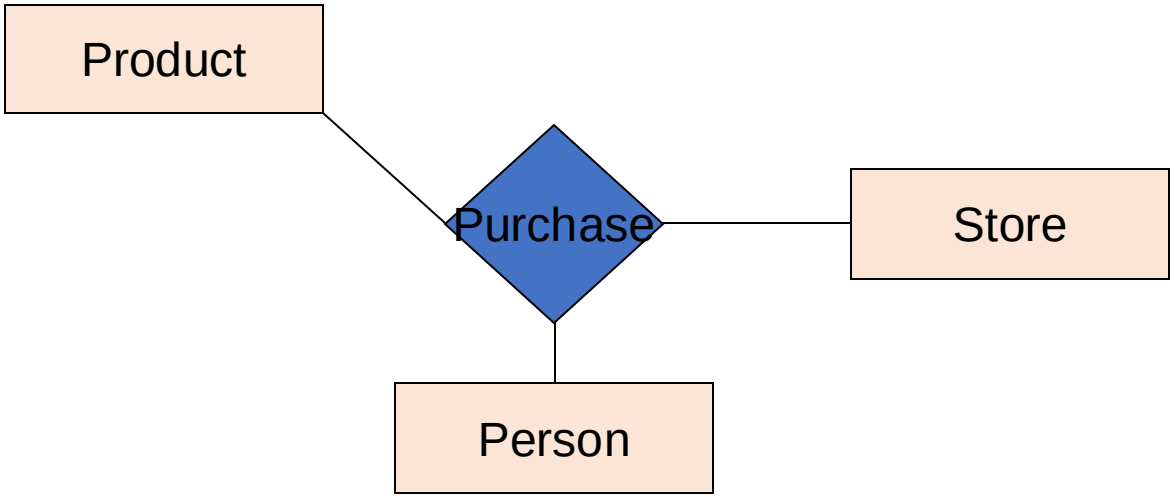


Many-to-many:



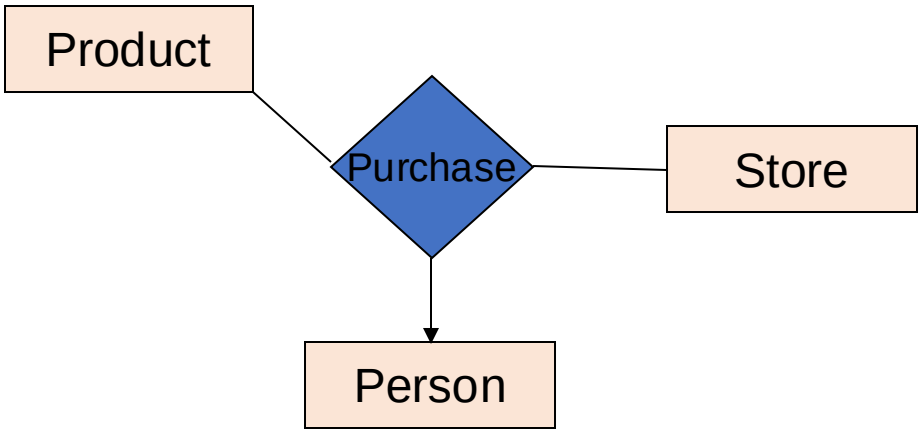
Multiway relationships

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



Arrows in Multiway Relationships

Q: What does the arrow mean ?



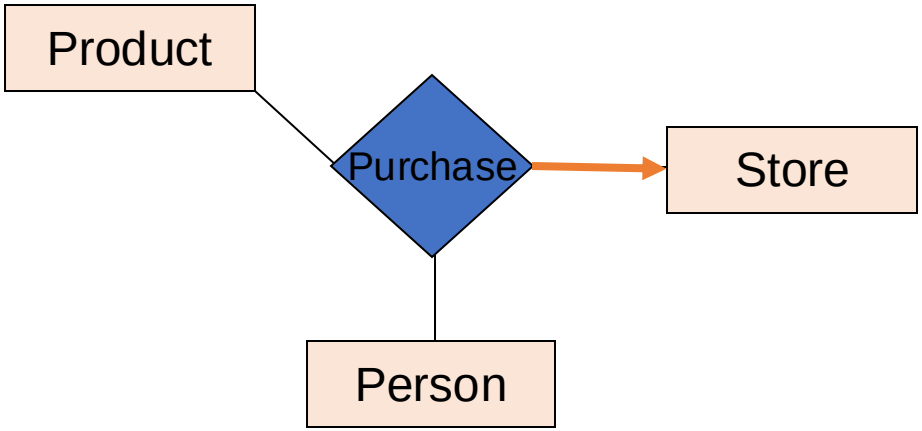
Arrow: if we select one entity from each of the other entity sets in the relationship, those entities are related to at most one entity in E.

For each (product, store), there is at most one person who have made that purchase

Q: Can a person purchase two different products the same store?
Q: Can a person purchase the same product at two different stores?

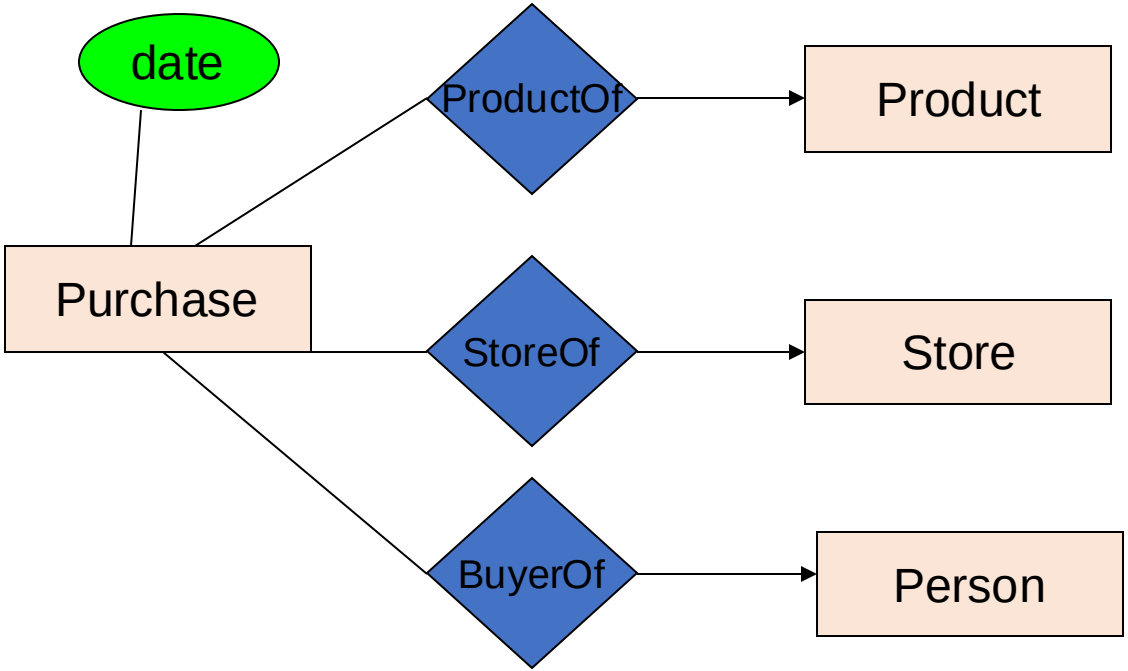
Arrows in Multiway Relationships

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

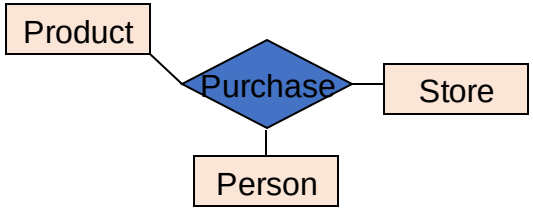


A: Cannot. This is the best approximation.
(Why only approximation ?)

Converting Multi-way Relationships to Binary

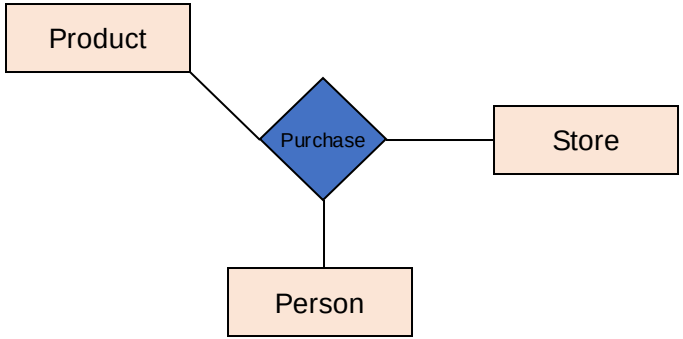


- Create a connecting entity set
- Introduce many-one relationships

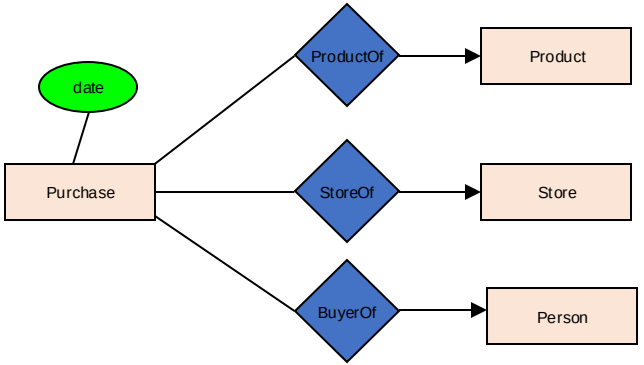


Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



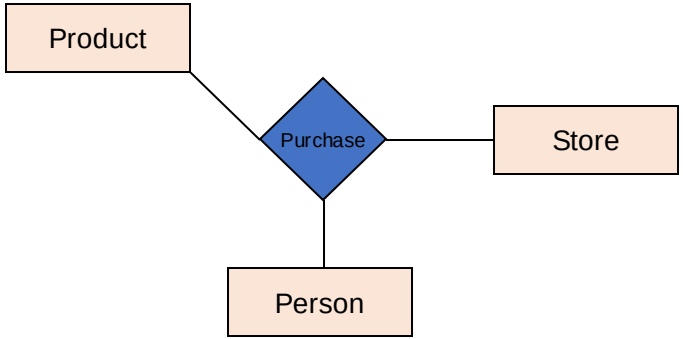
(B) Entity + Binary



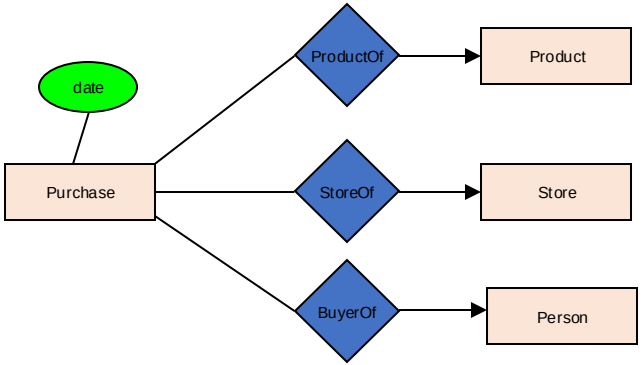
Should we use a single multi-way relationship or a new entity with binary relations?

Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



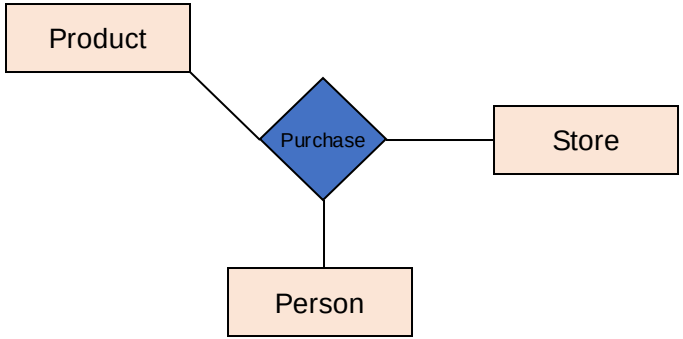
(B) Entity + Binary



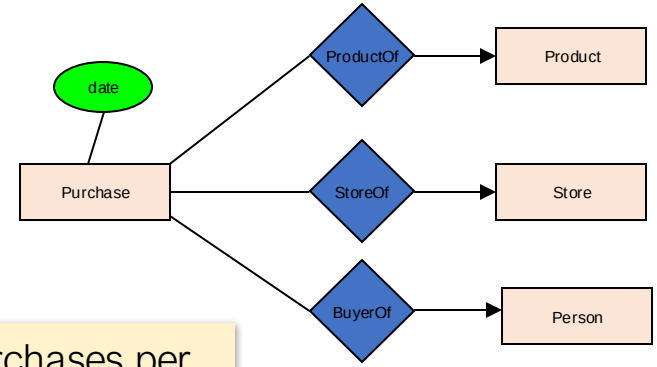
- (A) is useful when a relationship really is between multiple entities
  - Ex: A three-party legal contract

Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



(B) Entity + Binary

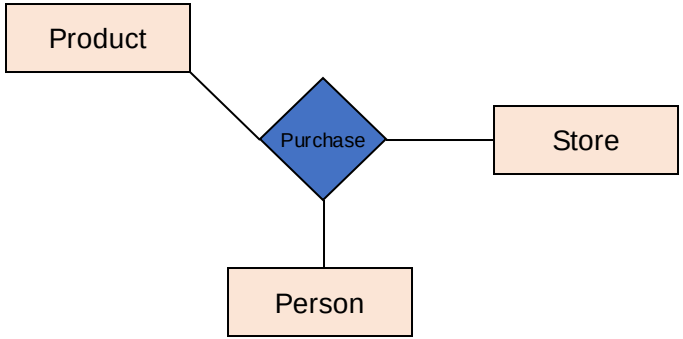


Multiple purchases per (product, store, person) combo possible here!

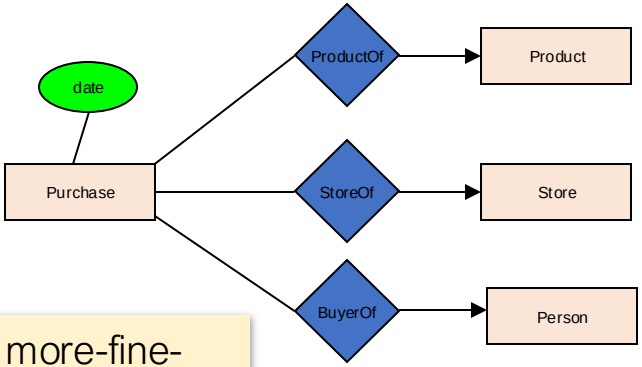
- Covered earlier: (B) is useful if we want to have multiple instances of the "relationship" per entity combination

Decision: Multi-way or New Entity + Binary?

(A) Multi-way Relationship



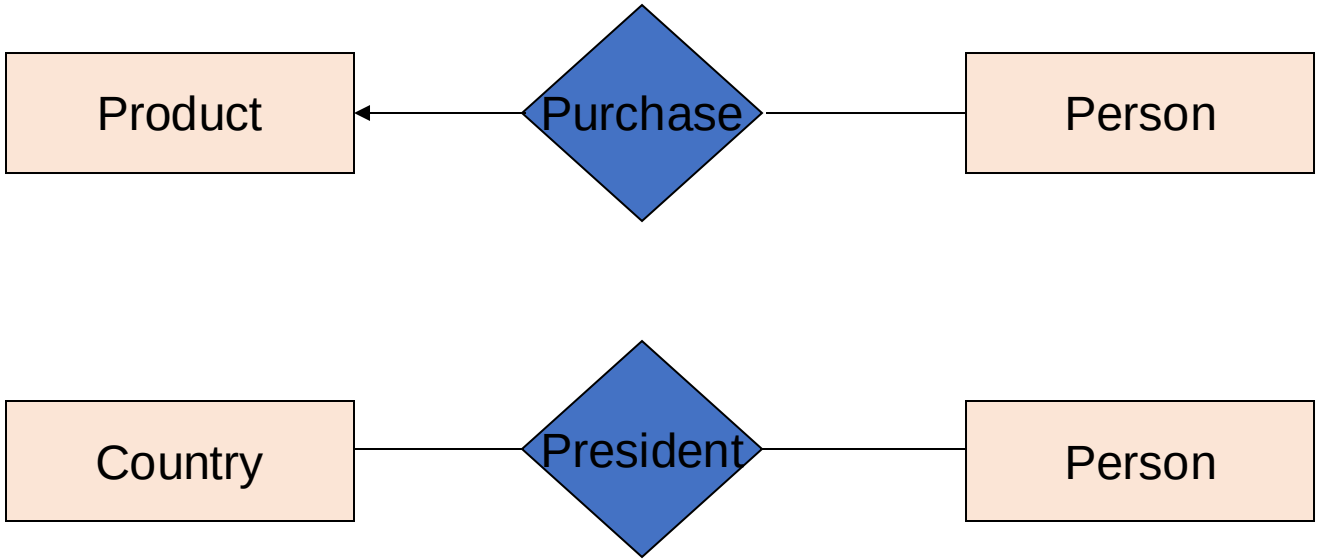
(B) Entity + Binary



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"

Exercises:
What's Wrong?



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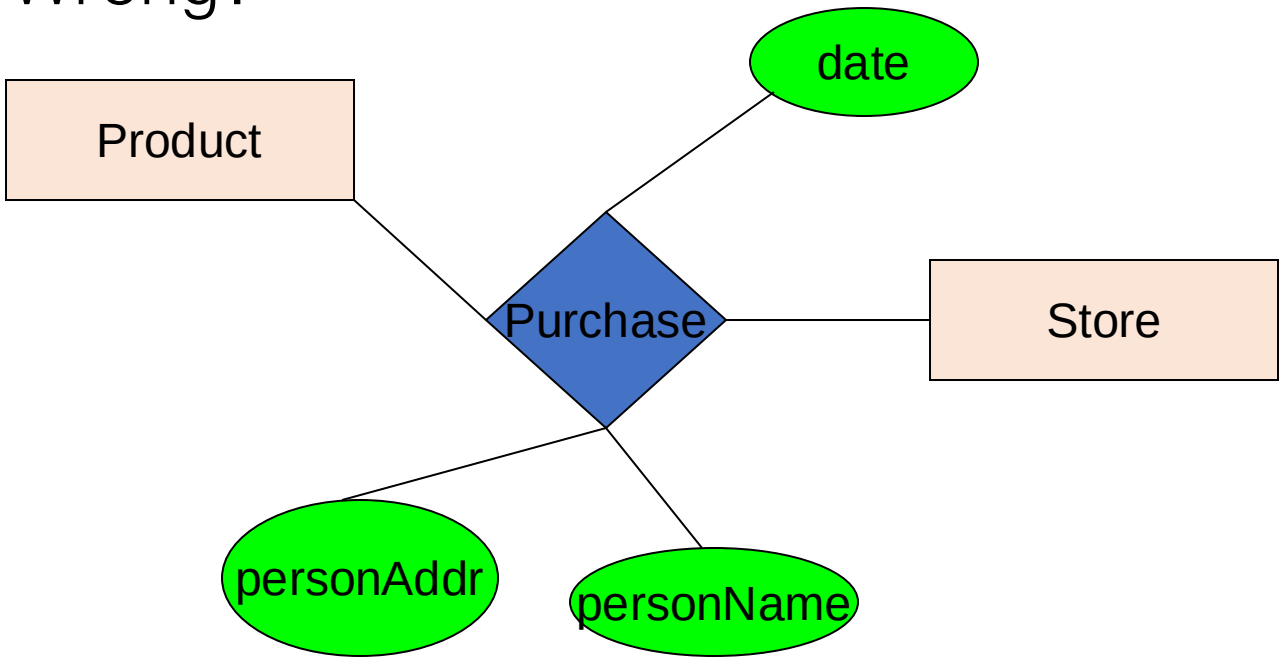
What's Wrong?



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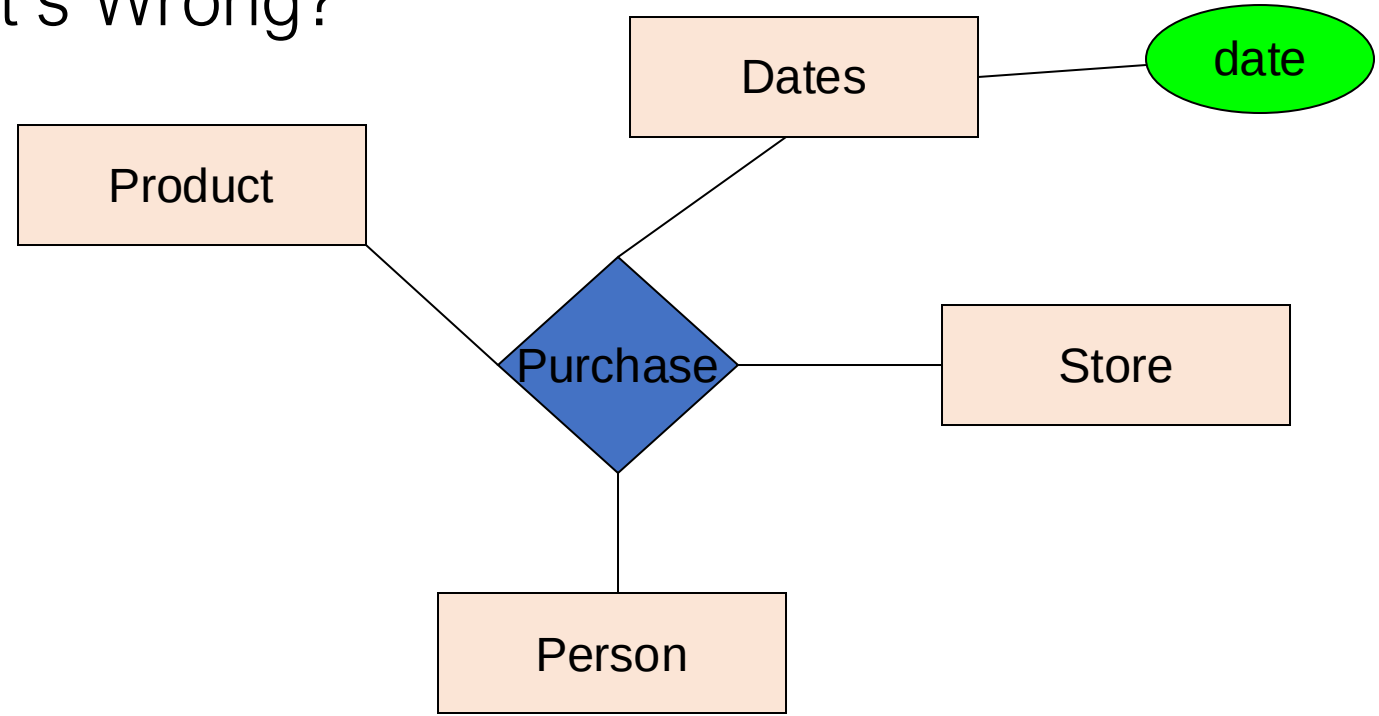
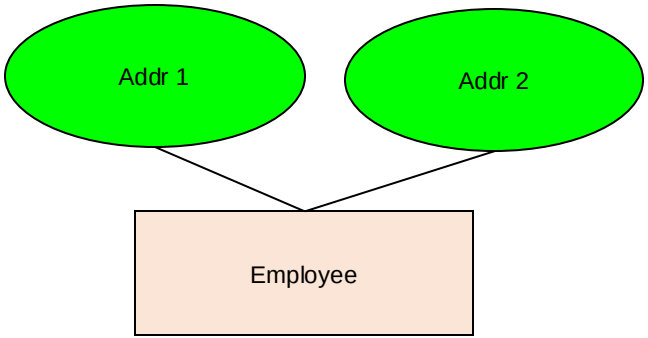
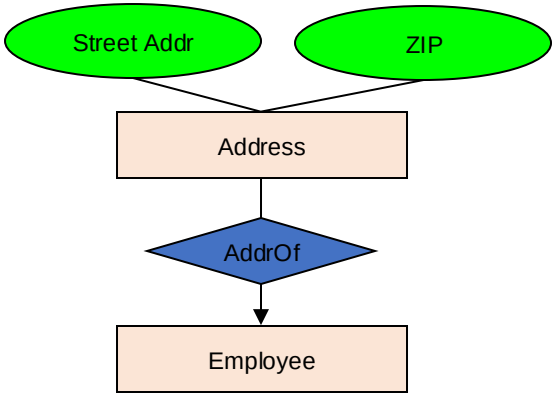


Examples: Entity vs. Attribute

Should address (A) be an attribute?



Or (B) be an entity?



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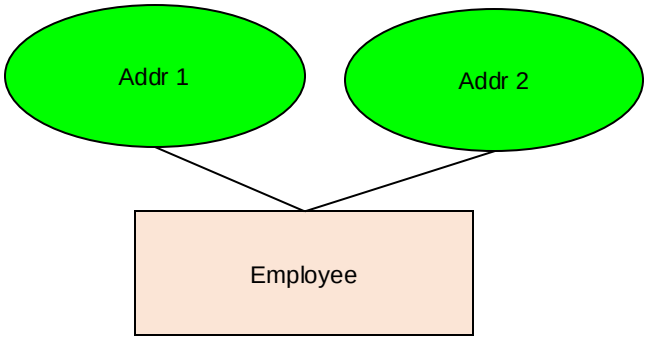
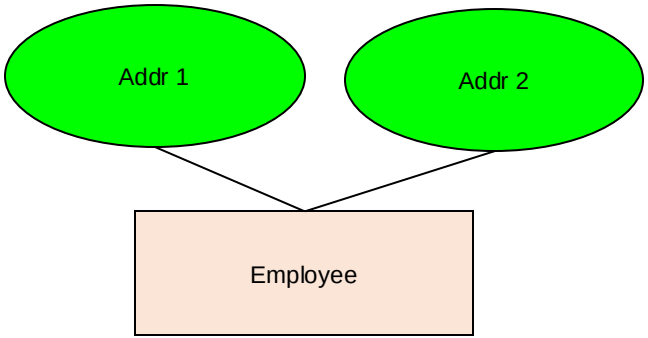


How do we handle employees with multiple addresses here?

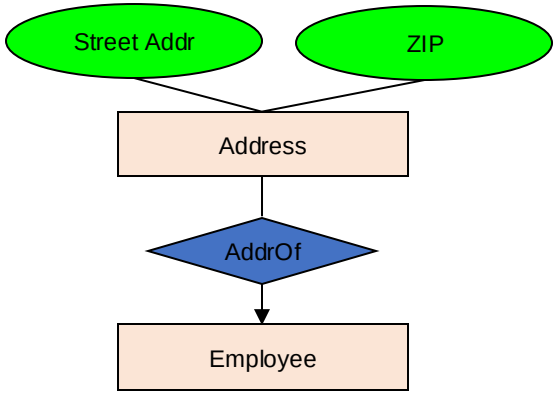
How do we handle addresses where internal structure of the address (e.g. zip code, state) is useful?

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

Constraints in E/R Diagrams

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

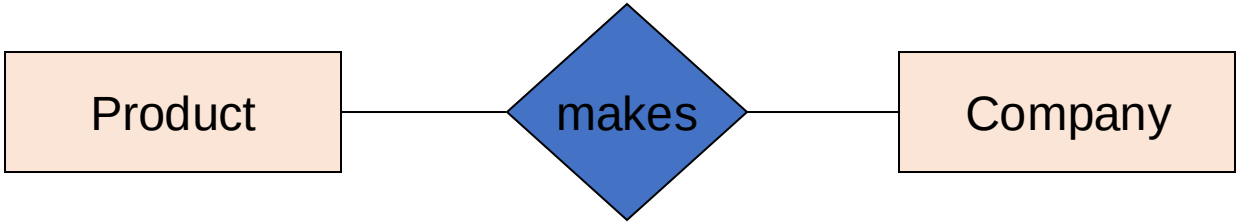
Referential integrity constraints: Referenced entities must exist
- Ex: if you work for a company, it must exist in the database

Participation constraints:
- Ex: every student must enroll in a class

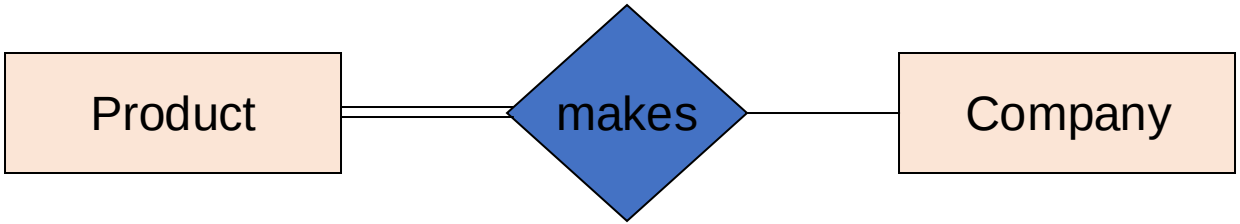
Other constraints:
- Ex: peoples' ages are between 0 and 150

Recall FOREIGN KEYs!

Participation Constraints: Partial v. Total



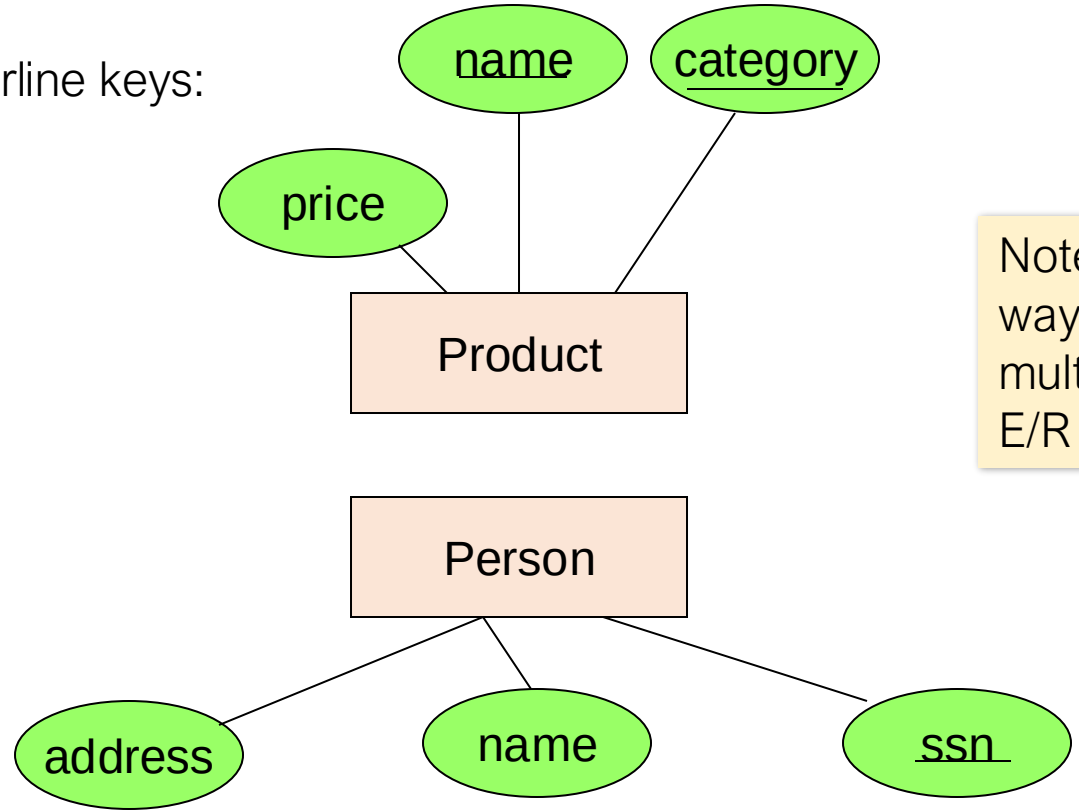
Are there products made by no company?
Companies that don't make a product?



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

Key Constraints

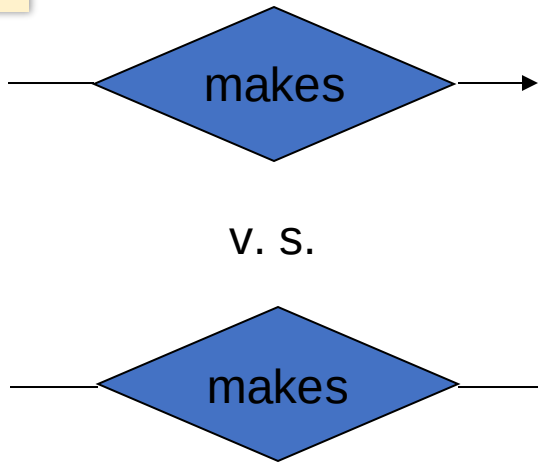
Underline keys:



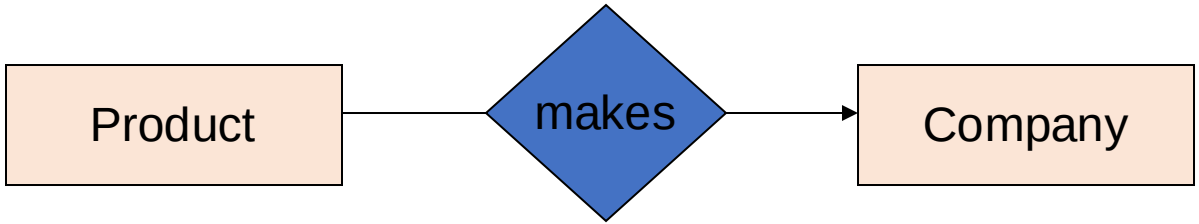
Note: no formal way to specify multiple keys in E/R diagrams…

Single Value Constraints

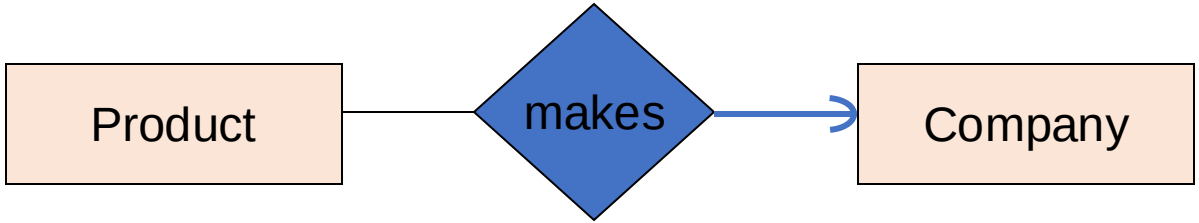
See previous section!



Referential Integrity Constraints



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

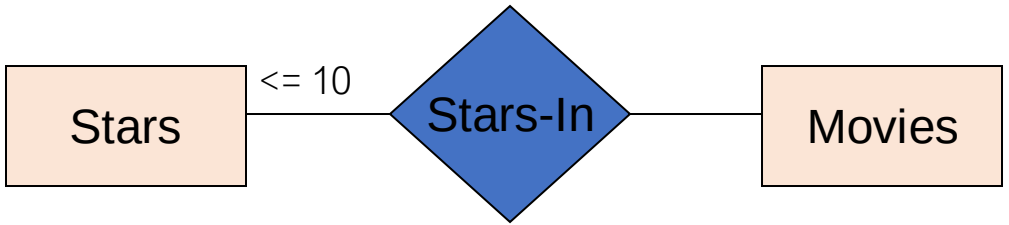


Each product made by <u>exactly one</u> company.

A rounded arrow to F means
- The relationship is many-one and
- The entity of set F related to an entity of E must exist

Degree constraints

- Limit the number of entities connected to any one entity of the related entity set
  - Arrow is same as “<=1” constraint
  - Rounded arrow is same as “=1” constraint



Every movie can be connected to at most 10 stars

3. E/R Diagram to Relational Schema

From E/R Diagrams to Relational Schema

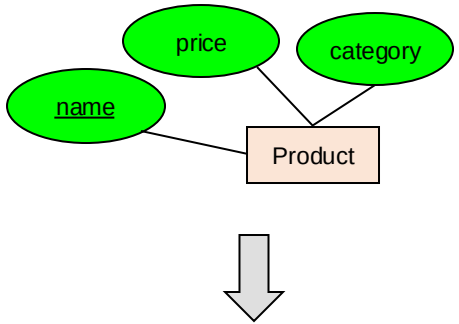
- Key concept:

  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

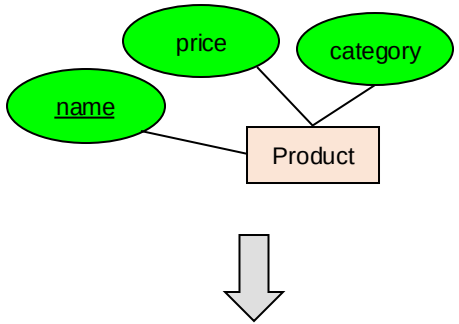


Product

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)
)
```

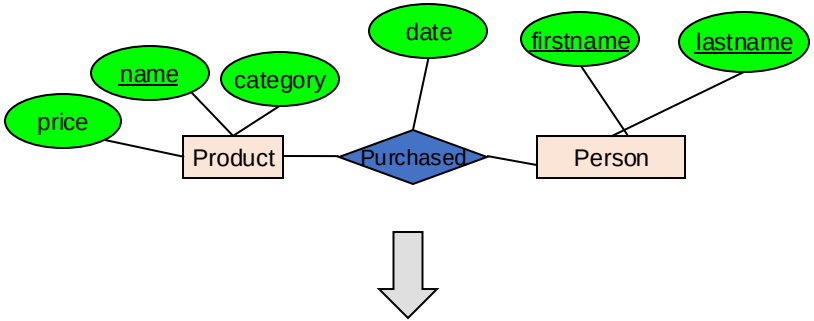


Product

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 $(a_1,\ldots,a_N)$

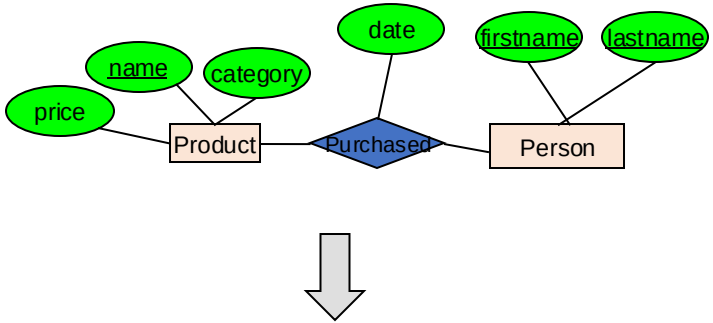
- Each row/tuple is
  - composed of the **union of the entity sets' keys**
  - has the union of the entity sets' keys as primary key
  - has the entities' primary keys as foreign keys

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

```
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
)
```

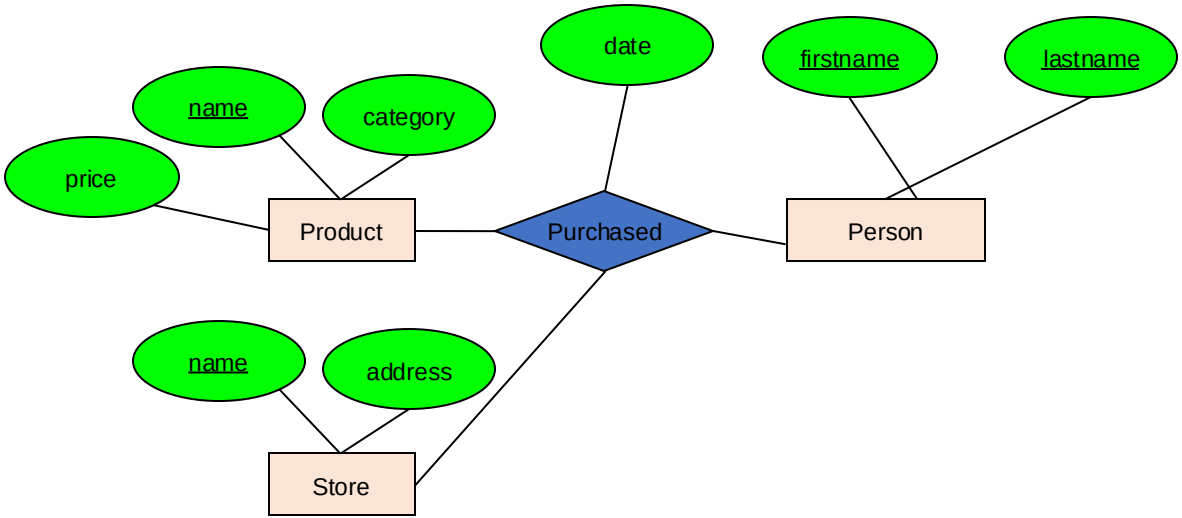


Purchased

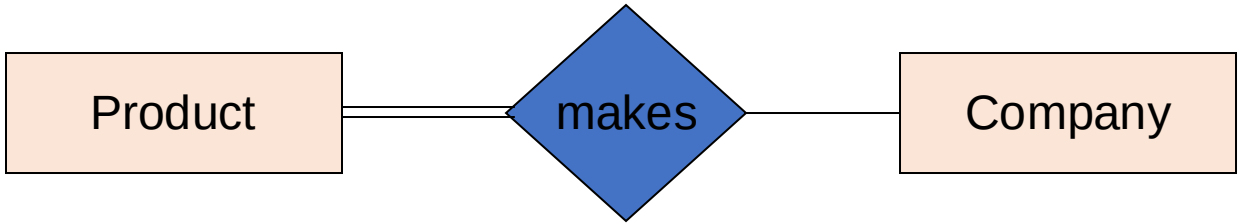
name	firstname	lastname	date
Gizmo1	Bob	Joe	01/01/15
Gizmo2	Joe	Bob	01/03/15
Gizmo1	JoeBob	Smith	01/05/15

Exercise

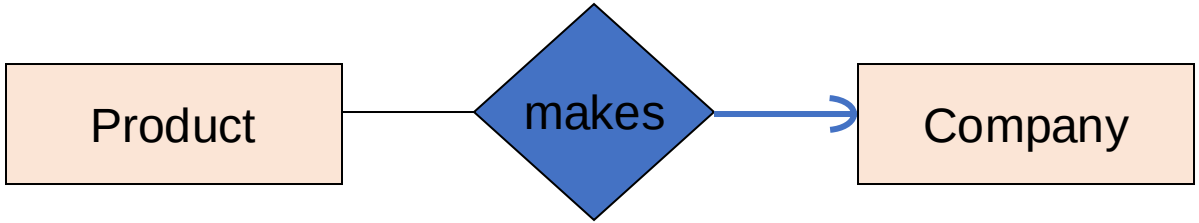
How do we represent **Purchased** as a relational schema?



Note: total participation vs. referential integrity



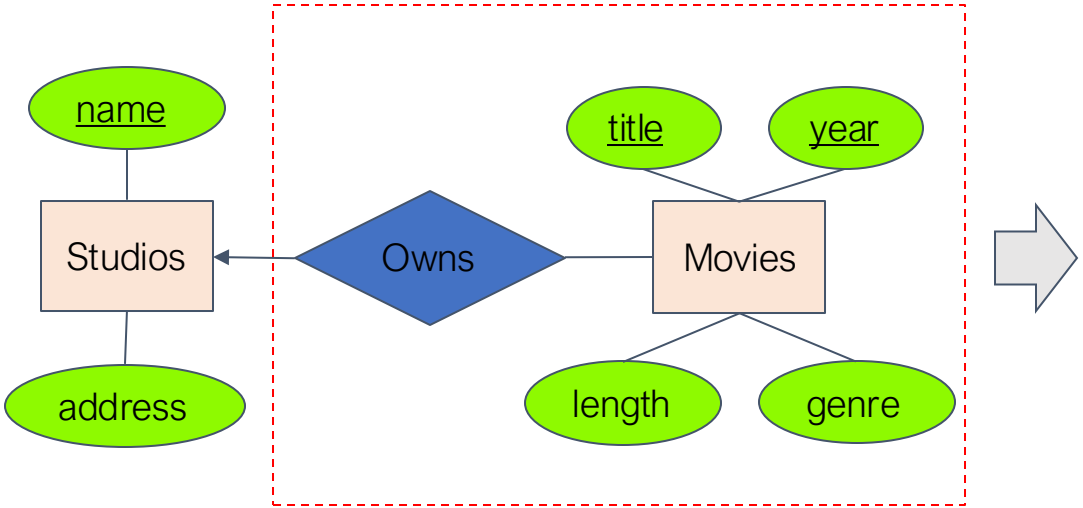
All products need to be in the makes relationship



Each product made by exactly one company;
the company involved must exist in our database.

Combining relations

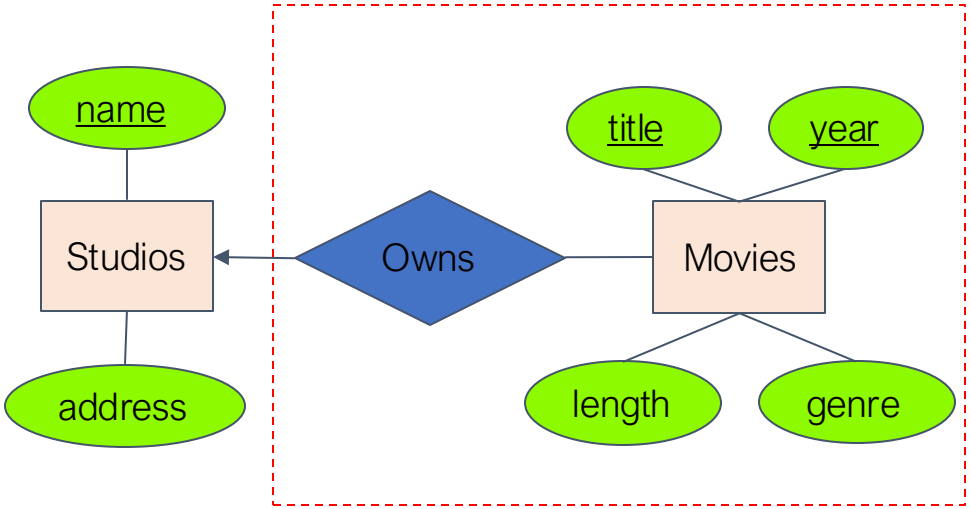
- If E is connected to F through a many-one relationship R, combine E and R
  - Attributes of E and R, and the key attributes of F
- Advantage: querying one relation is faster than querying several relations




```
Owns(title, year, length,
     genre, studioName)
```

Combining relations

- Why only consider many-one relationships?
  - Otherwise, the combined relation is not good design and may contain anomalies



This information is redundant, and updating one tuple may leave the other one incorrect (update anomaly)

Owns

title	year	length	genre	studioName
t1	y1	l1	g1	n1
t1	y1	l1	g1	n2
t2	y2	l2	g2	n2

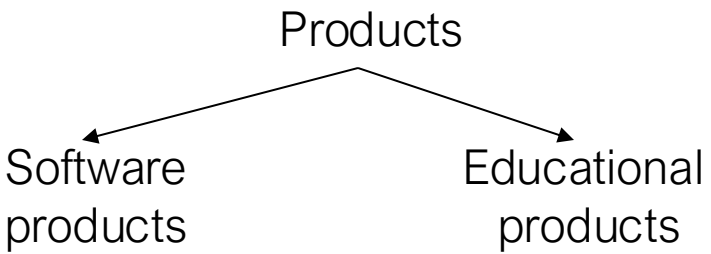
4. Advanced E/R Concepts

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?

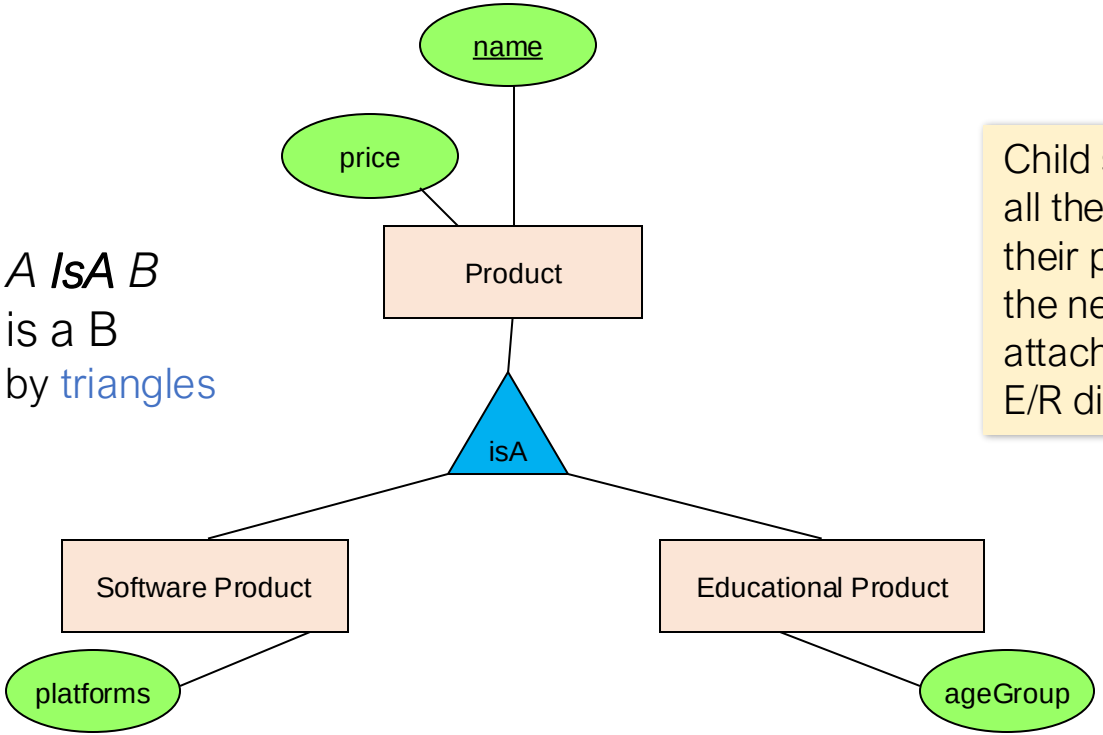
Better: define a subclass



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

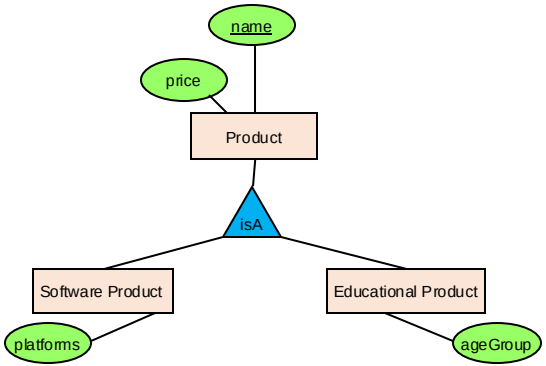
Modeling Subclasses

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



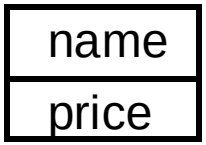
Child subclasses contain all the attributes of all of their parent classes plus the new attributes shown attached to them in the E/R diagram

Understanding Subclasses

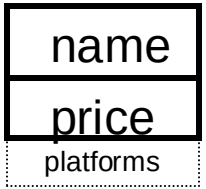


Think in terms of records; ex:

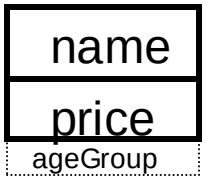
- Product



- SoftwareProduct

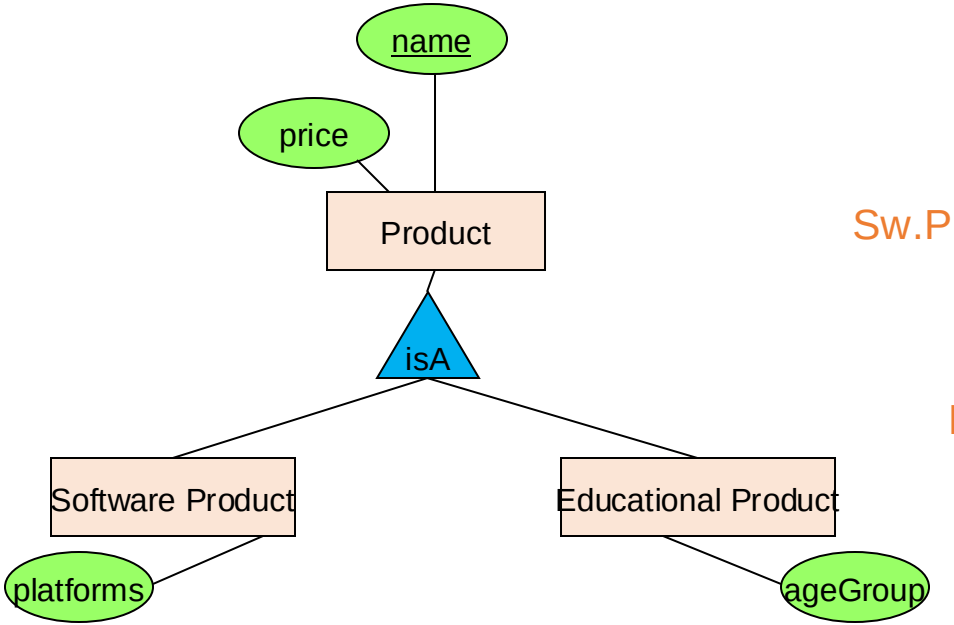


- EducationalProduct



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

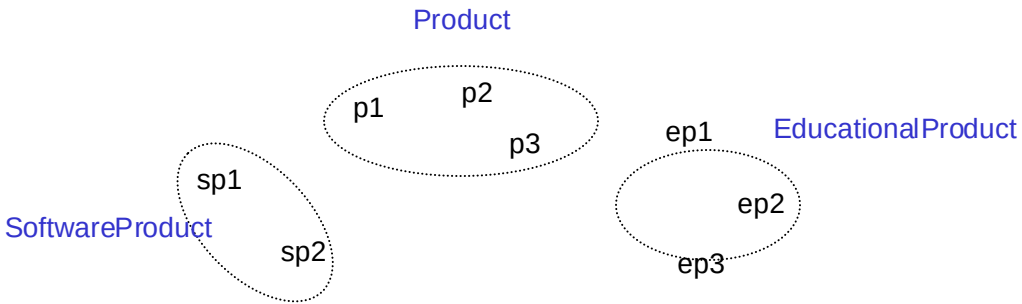
name	platforms
Gizmo	unix

Ed.Product

name	ageGroup
Gizmo	toddler
Toy	retired

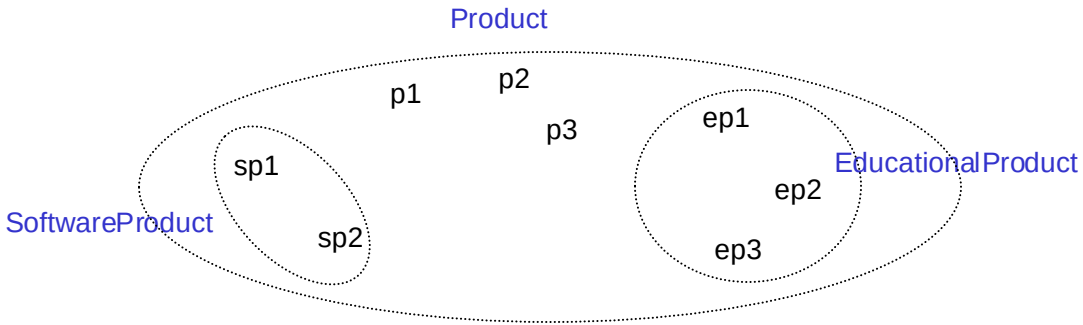
Difference between OO and E/R inheritance

OO: Classes are disjoint (same for Java, C++)



Difference between OO and E/R inheritance

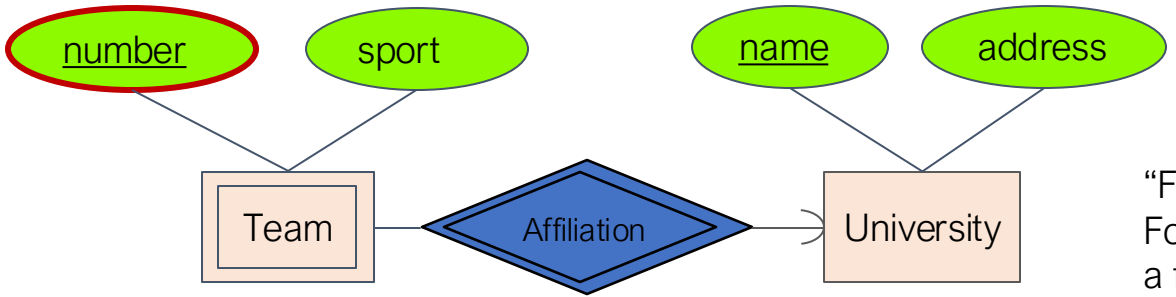
E/R: entity sets overlap



Weak entity set

Different from an isa relationship

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

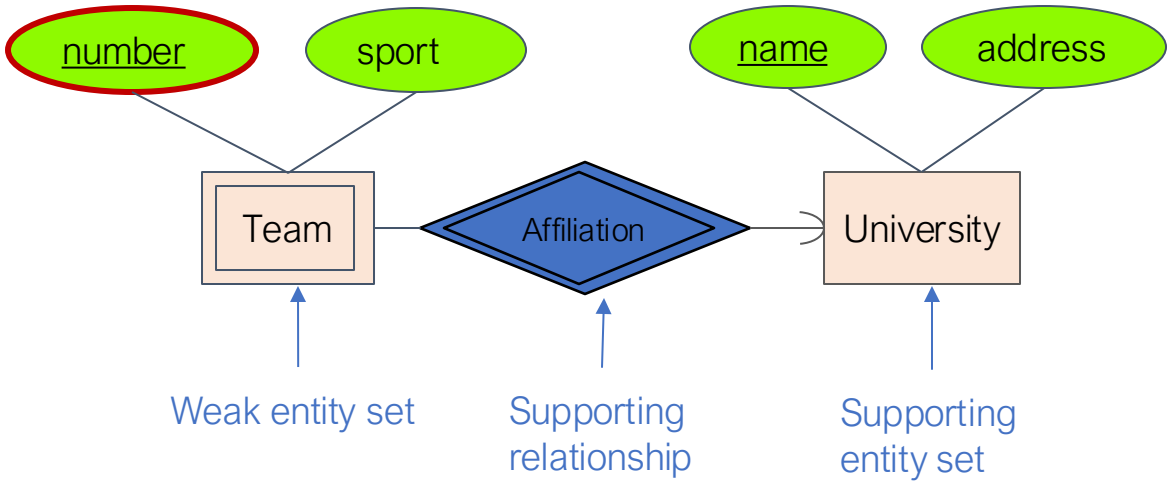


"Football team" v. "The GT Football team" (E.g., UGA has a football team too)

- number is a *partial key.*
- The key also contains keys of the University entity set
- Affiliation must have referential integrity from Team to University

Weak entity set notation

- A weak entity set is shown as a rectangle with a double border
- Supporting many-one relationships are diamonds with a double border
- Any attributes that form a key are underlined



Additional Reading

Requirements for weak entity set
- 4.4.2

Combining relationship
- 4.5.3

Converting weak entity set to relations
- 4.5.4

Converting subclasses to relations
- 4.6