CSE 344

JULY 30TH

DB DESIGN (CH 4)

ADMINISTRIVIA

- **HW6 due next Thursday**
  - uses Spark API rather than MapReduce
    - (a bit higher level)
  - be sure to **shut down** your AWS cluster when not in use

- **Still grading midterms...**
  - will hand back on Wednesday

REVIEW

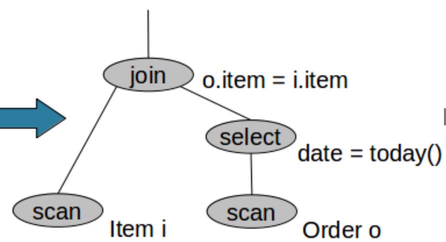
Horizontally partitioned data:

- allows for easy scale-up
    - OLTP is easy!
    - but OLAP becomes harder...
- new problem for query execution: needed data may not be local
- fix by reshuffling: put required data into the same machine

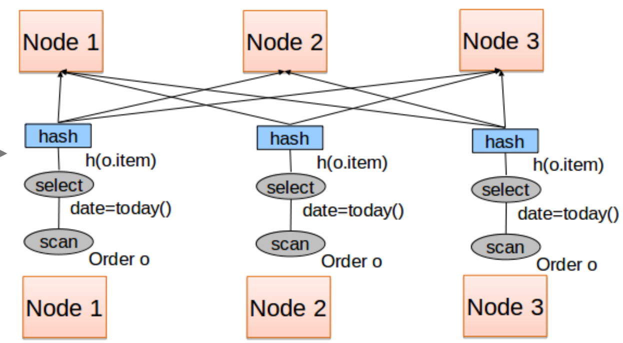
EXAMPLE 1

```
SELECT *
 FROM Order o, Line i
WHERE o.item = i.item
 AND o.date = today()
```

Query



Single Node Plan



Multi-Node Plan

REVIEW

MapReduce

- lower-level API for
- handles networking, I/O, failure, and *straggler* issues
- main piece provided by the API is shuffle
  - read → map → shuffle → reduce → write
  - fits perfectly with what we need above
- one job contains one shuffle
  - complex queries becomes multiple jobs

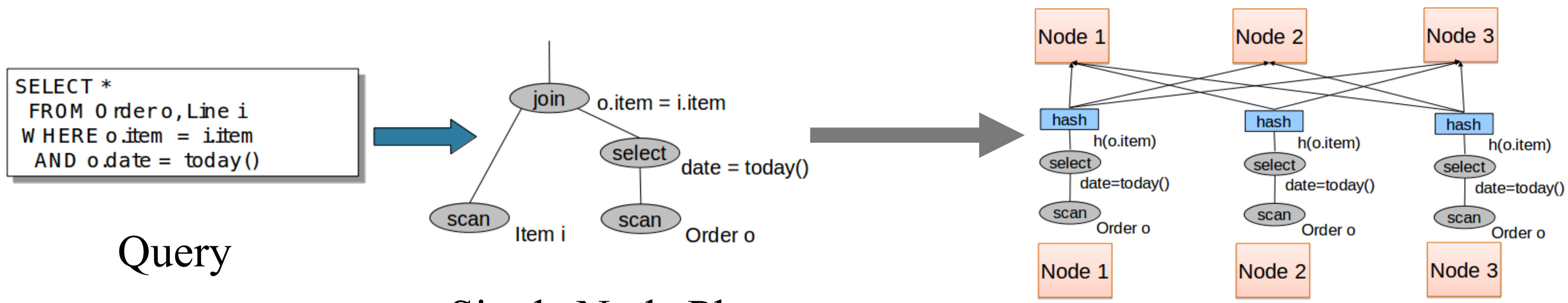
PARALLEL QUERY PLANS

- Split into phases at each reshuffle

- Do as much work as possible within each phase
  - selections never require a reshuffle
  - group by & join may require it
    - (consider what data is *currently* partitioned by)

- In general, n-phase plan can be implemented in (n-1) MapReduce jobs
  - (since it has n-1 shuffles)

EXAMPLE 1



Query

Single Node Plan

Multi-Node Plan

MapReduce

- saw this before in three parts: left side, right side, join
- only 1 reshuffle (for the join), so only 1 job
- mapper does first two parts: input is Item i or Order o
    - left side: output (i.item, ('Item', i))
    - right side: output (o.item, ('Order', o))
- reducer: input is (item, [(table_name, value)])
    - split list into two: items and orders
    - output all combinations (two nested loops)

EXAMPLE 2

Schema:

```
Drug(spec VARCHAR(255), compatibility INT)
Person(name VARCHAR(100) PK, compatibility INT)
```

Query

```
SELECT P.name, count(D.spec)
FROM Person AS P, Drug AS D
WHERE P.compatibility = D.compatibility
GROUP BY P.name;
```

Logical Plan

$\gamma_{\text{name, count(spec)}} (\text{Person} \bowtie \text{Drug})$

EXAMPLE 2

Logical Plan

$\gamma_{\text{name, count(spec)}}$ (Person $\bowtie$ Drug)

Possible Reshuffles

- join: get tuples with same "compatibility" on same machine
- group by: get tuples with same "name" on same machine

EXAMPLE 2

Logical Plan

$\gamma_{\text{name, count(spec)}}(\text{Person} \bowtie \text{Drug})$

Assume

- Drug is block partitioned
- Person is hash partitioned by "compatibility"

Physical Plan

- join: reshuffle Drug by compatibility (not needed for Person)
- group-by: no reshuffle!
  - name is a PK so only one tuple with that name
  - join can produce multiple tuples but all are on same machine with the Person tuple having that name

DB DESIGN

DATABASE DESIGN

What it is:

Starting from scratch, design the database schema: relation, attributes, keys, foreign keys, constraints etc.

Why it's hard

The database will be in operation for a very long time (years). Updating the schema while in production is very expensive

- computer time
- engineering time

DATABASE DESIGN

Consider issues such as:

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

Several formalisms exists

- We discuss E/R diagrams
  - frequently used to communicate schemas in industry
- UML, model-driven architecture

Reading: Sec. 4.1-4.6

DATABASE DESIGN PROCESS

Conceptual Model:

Relational Model:

Tables + constraints

And also functional dep.

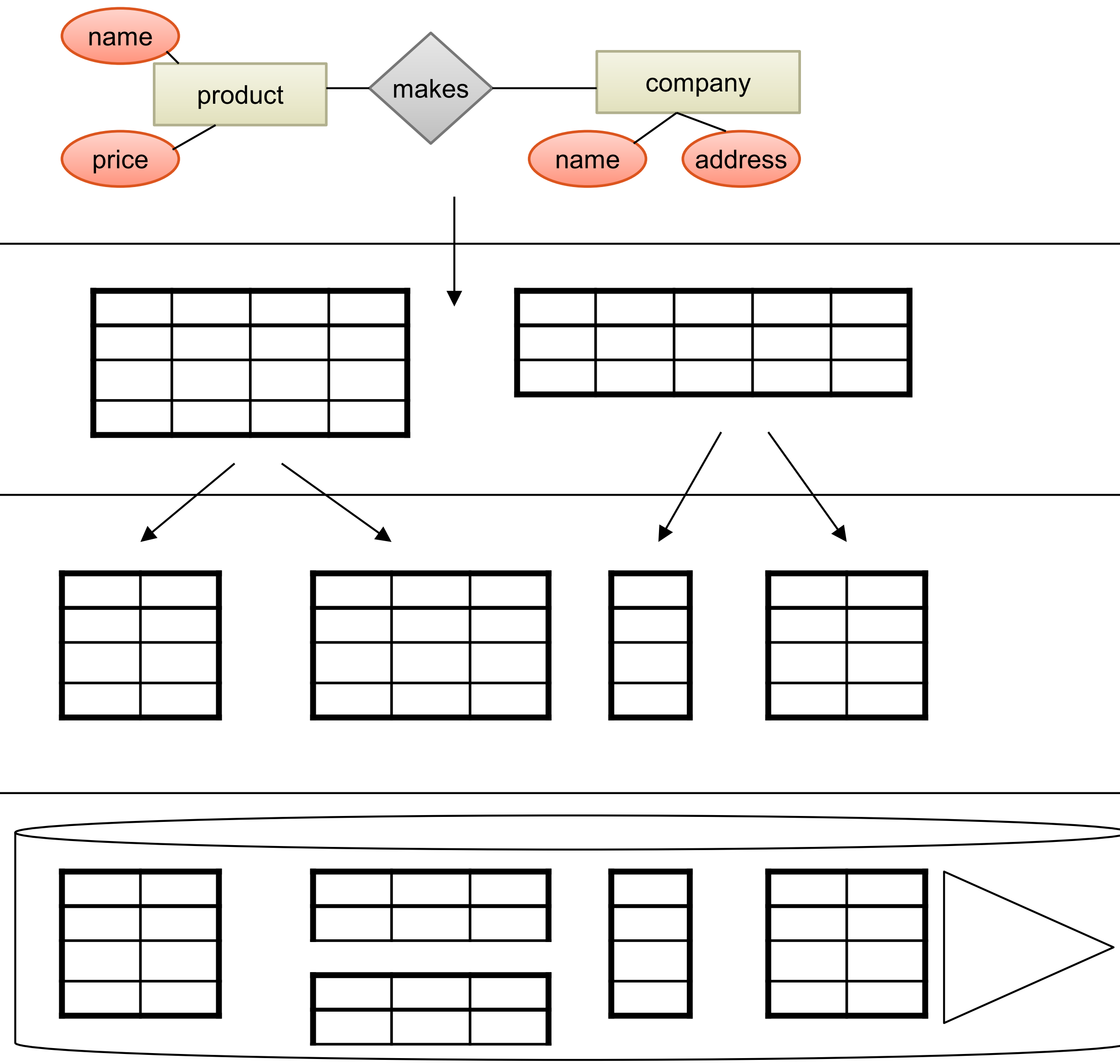
Normalization:

Eliminates anomalies

Conceptual Schema

Physical storage details

Physical Schema

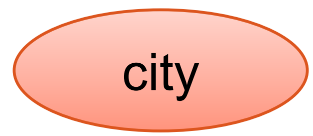


ENTITY / RELATIONSHIP DIAGRAMS

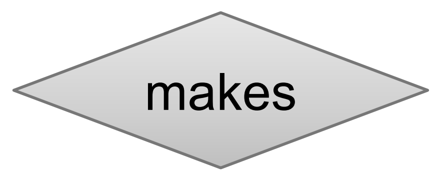
Entity set = a class

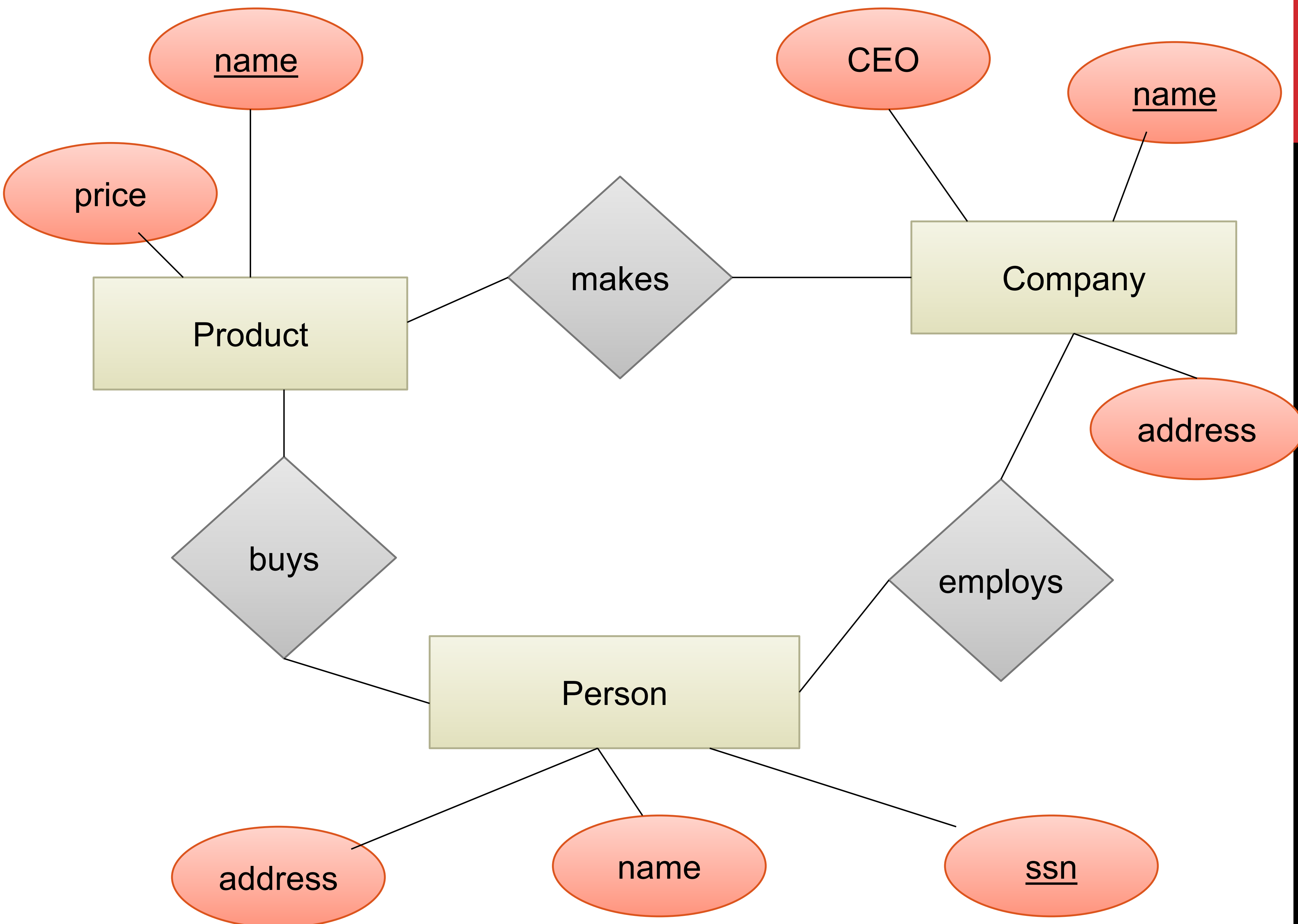
- An entity = an object

Attribute



Relationship

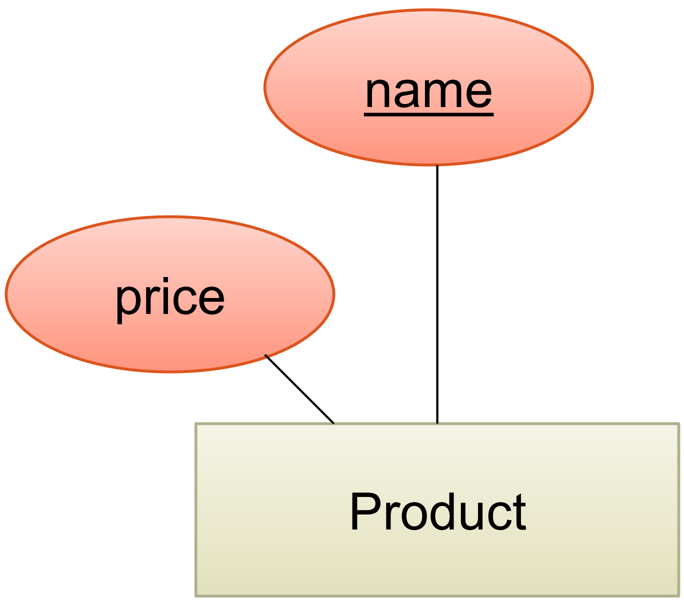




name
price
Product
makes
CEO
name
Company
address
buys
employs
Person
address
name
ssn

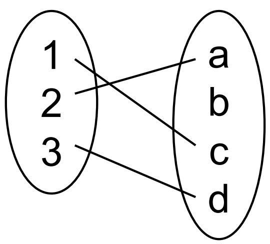
KEYS IN E/R DIAGRAMS

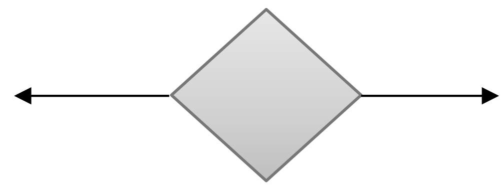
Every entity set must have a key



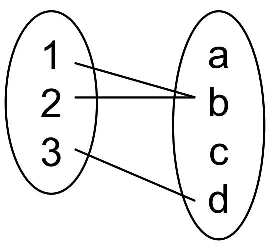
MULTIPLICITY OF E/R RELATIONS

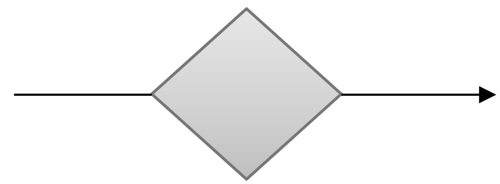
one-one:



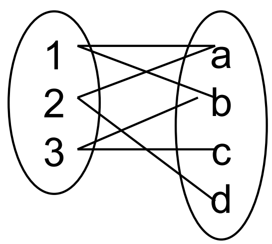


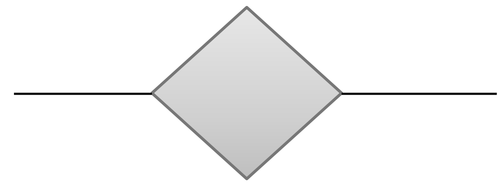
many-one

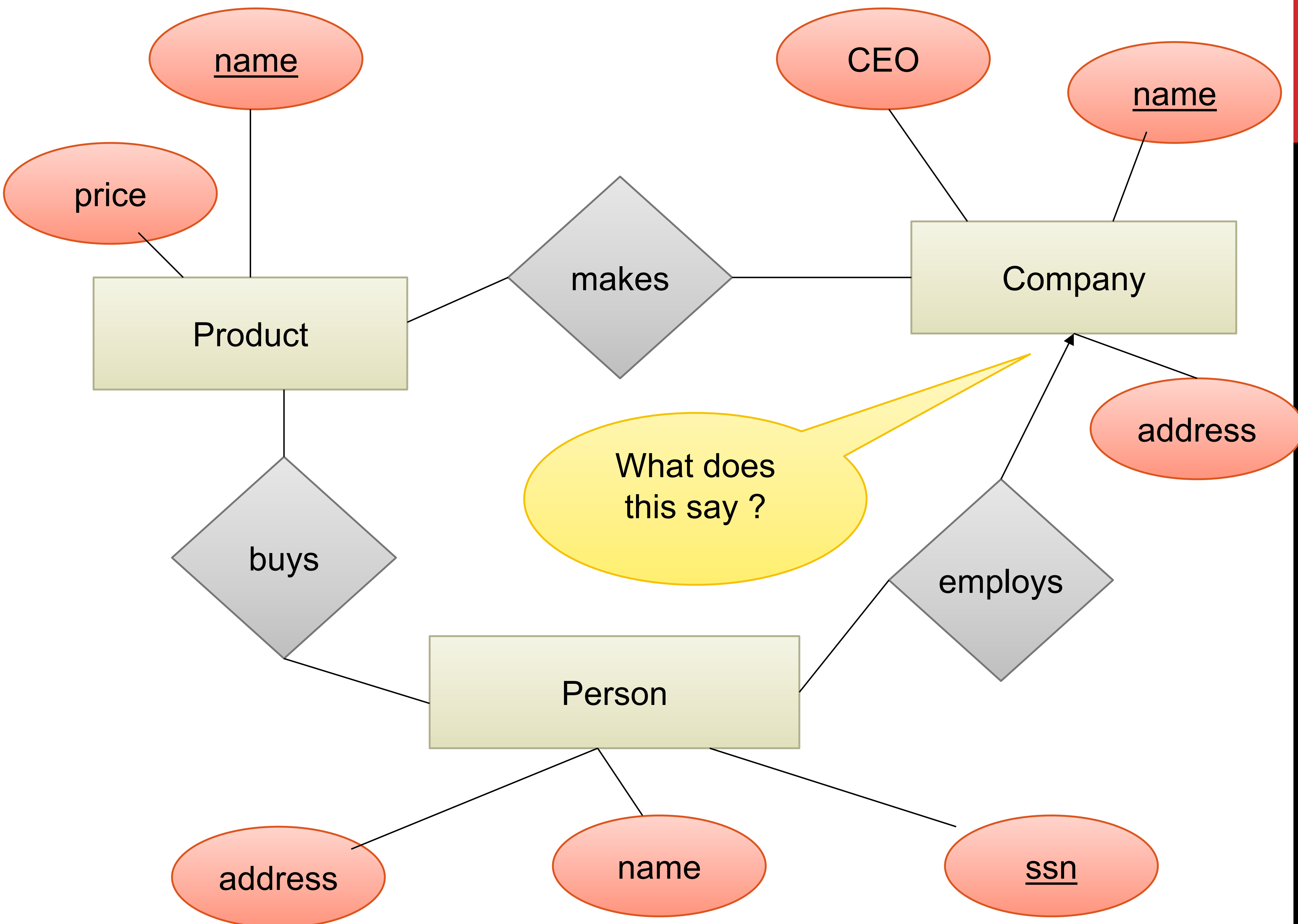




many-many

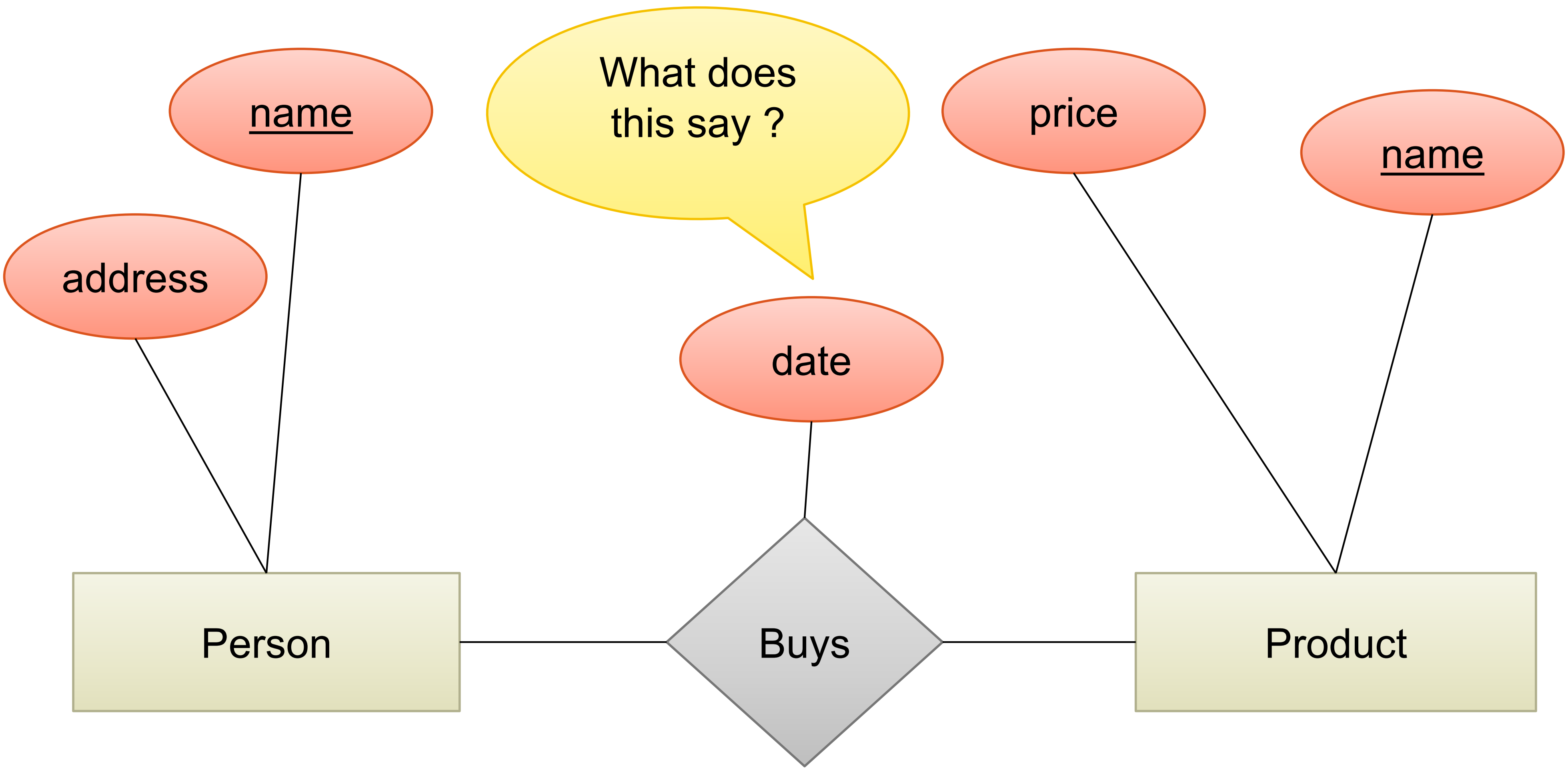






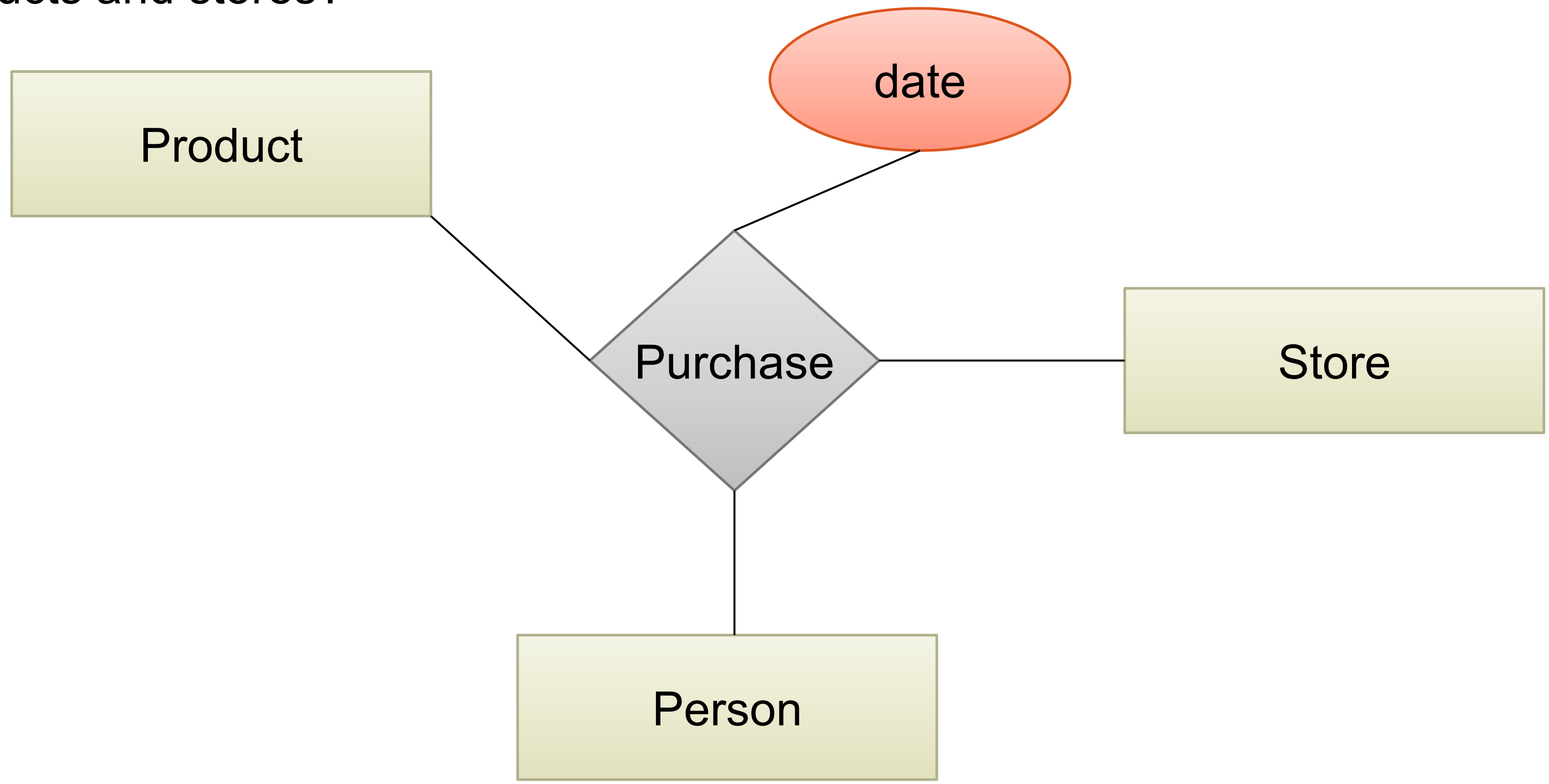
name
price
Product
makes
CEO
name
Company
address
What does this say ?
buys
employs
Person
address
name
ssn

ATTRIBUTES ON RELATIONSHIPS



MULTI-WAY RELATIONSHIPS

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

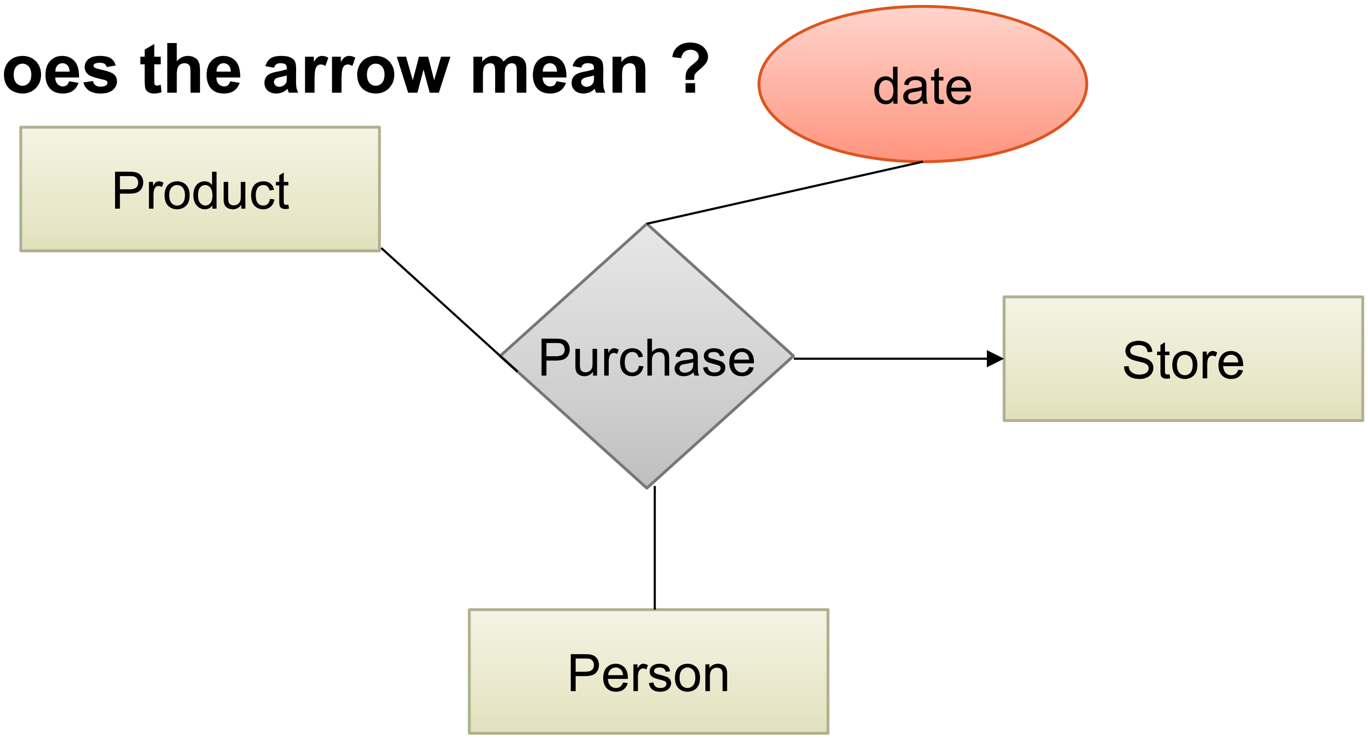


Can still model as a mathematical set (How?)

As a set of triples $\subseteq$ Person $\times$ Product $\times$ Store

ARROWS IN MULTIWAY RELATIONSHIPS

Q: What does the arrow mean ?

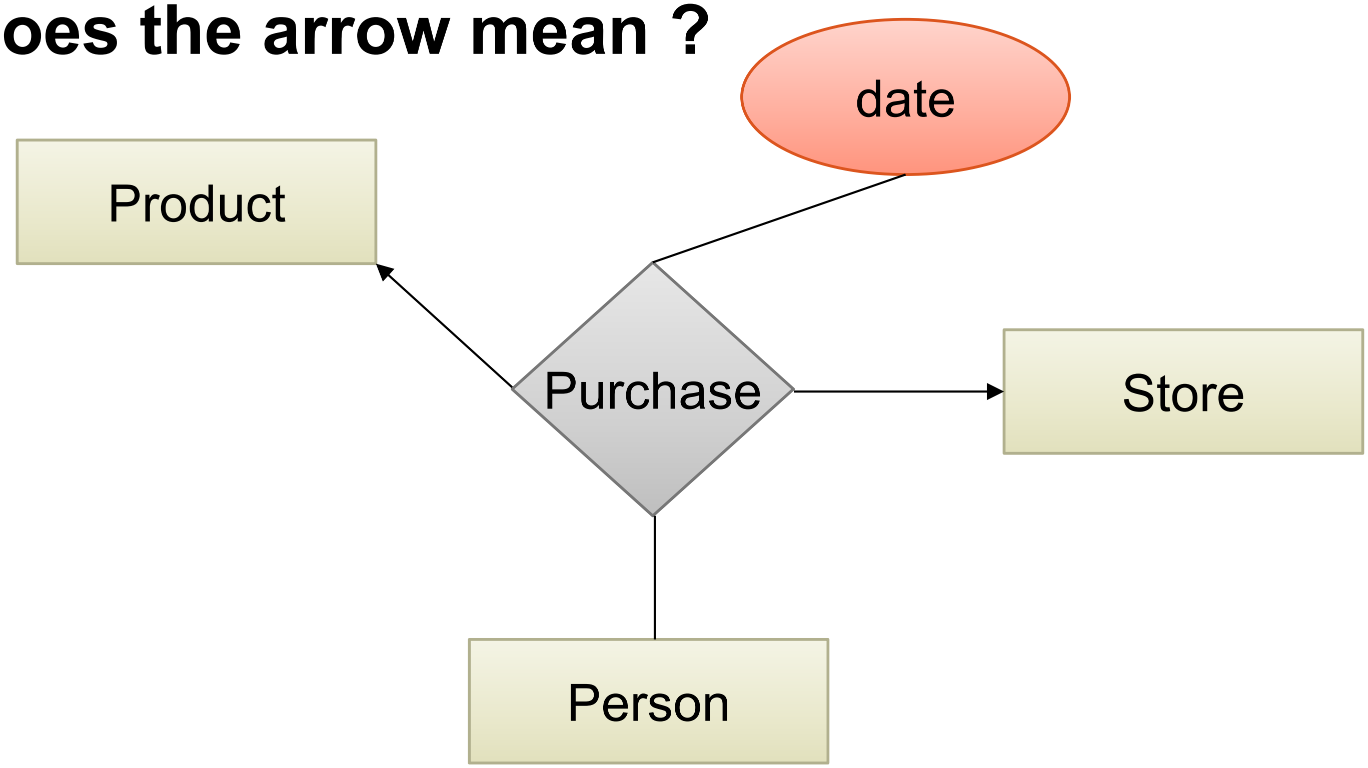


A: Any person buys a given product from at most one store

[Fine print: Arrow pointing to E means that 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]

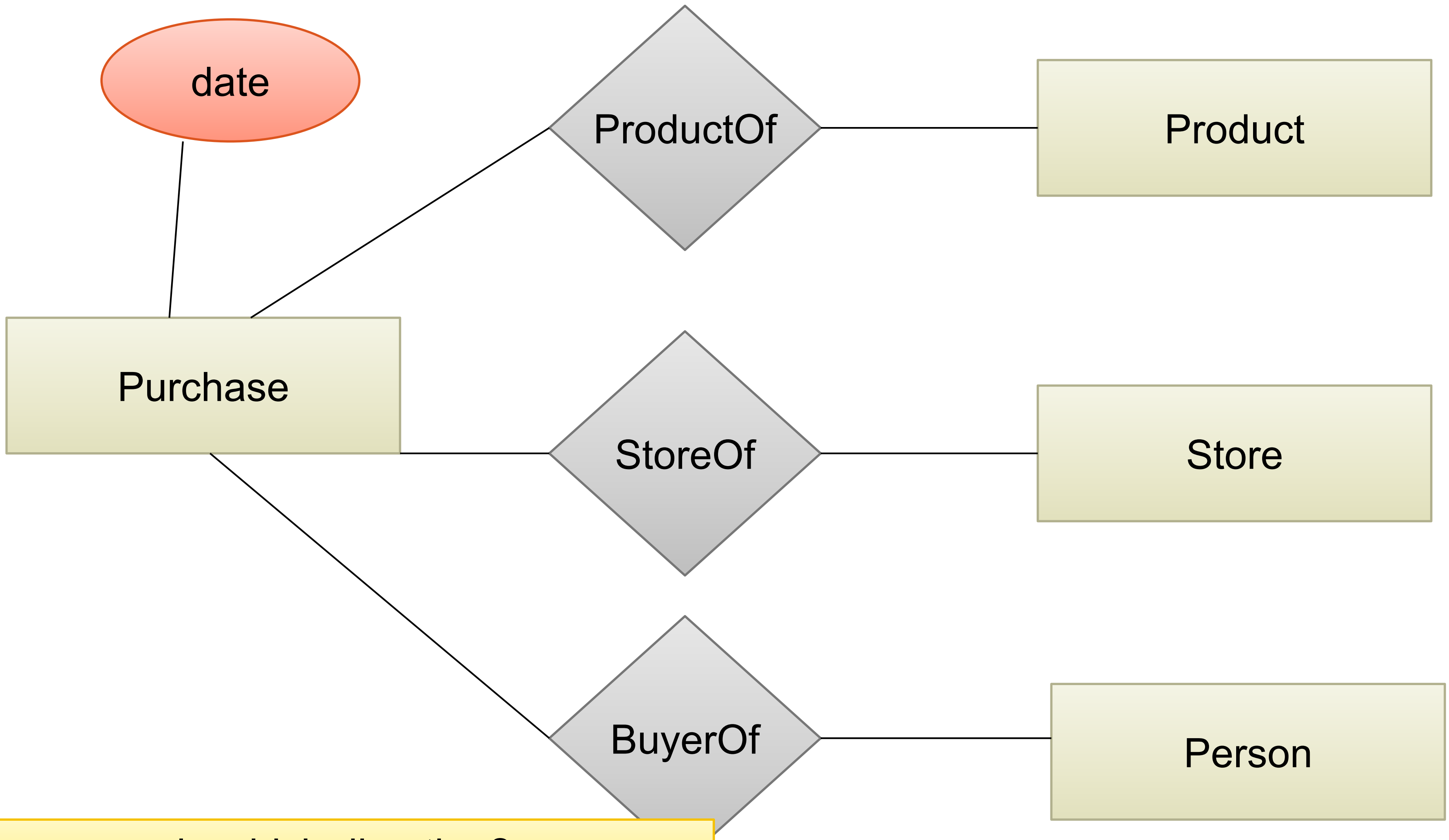
ARROWS IN MULTIWAY RELATIONSHIPS

Q: What does the arrow mean ?



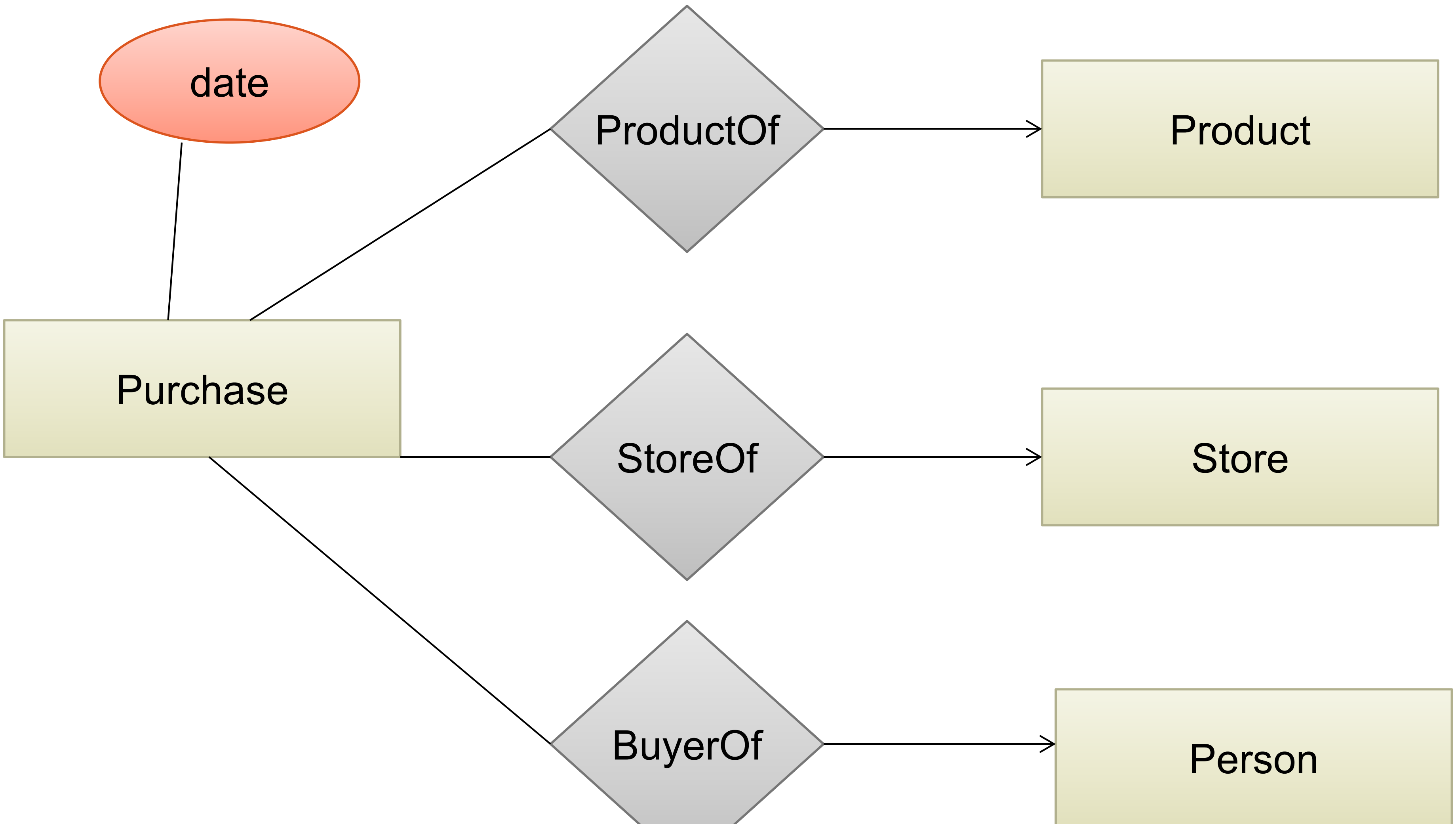
A: Any person buys a given product from at most one store AND every store sells to every person at most one product

CONVERTING MULTI-WAY RELATIONSHIPS TO BINARY



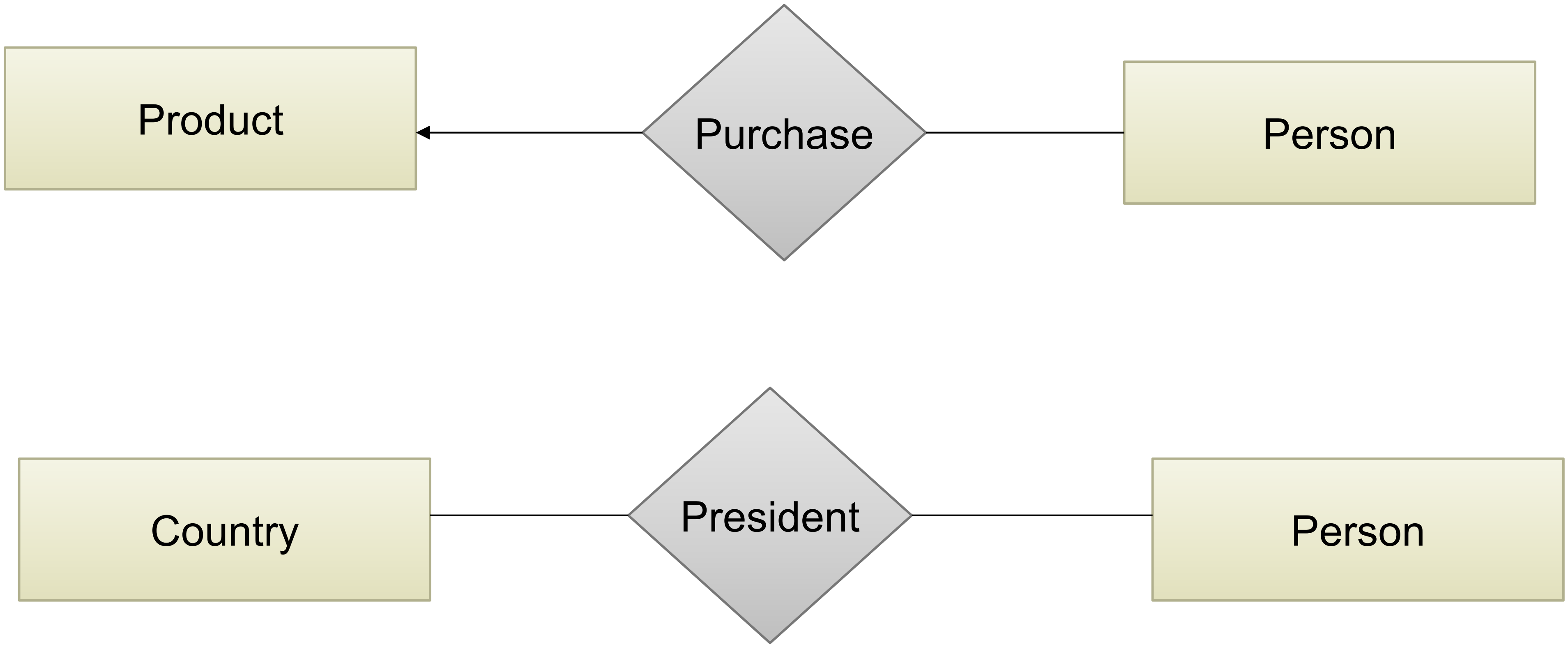
Arrows go in which direction?

CONVERTING MULTI-WAY RELATIONSHIPS TO BINARY



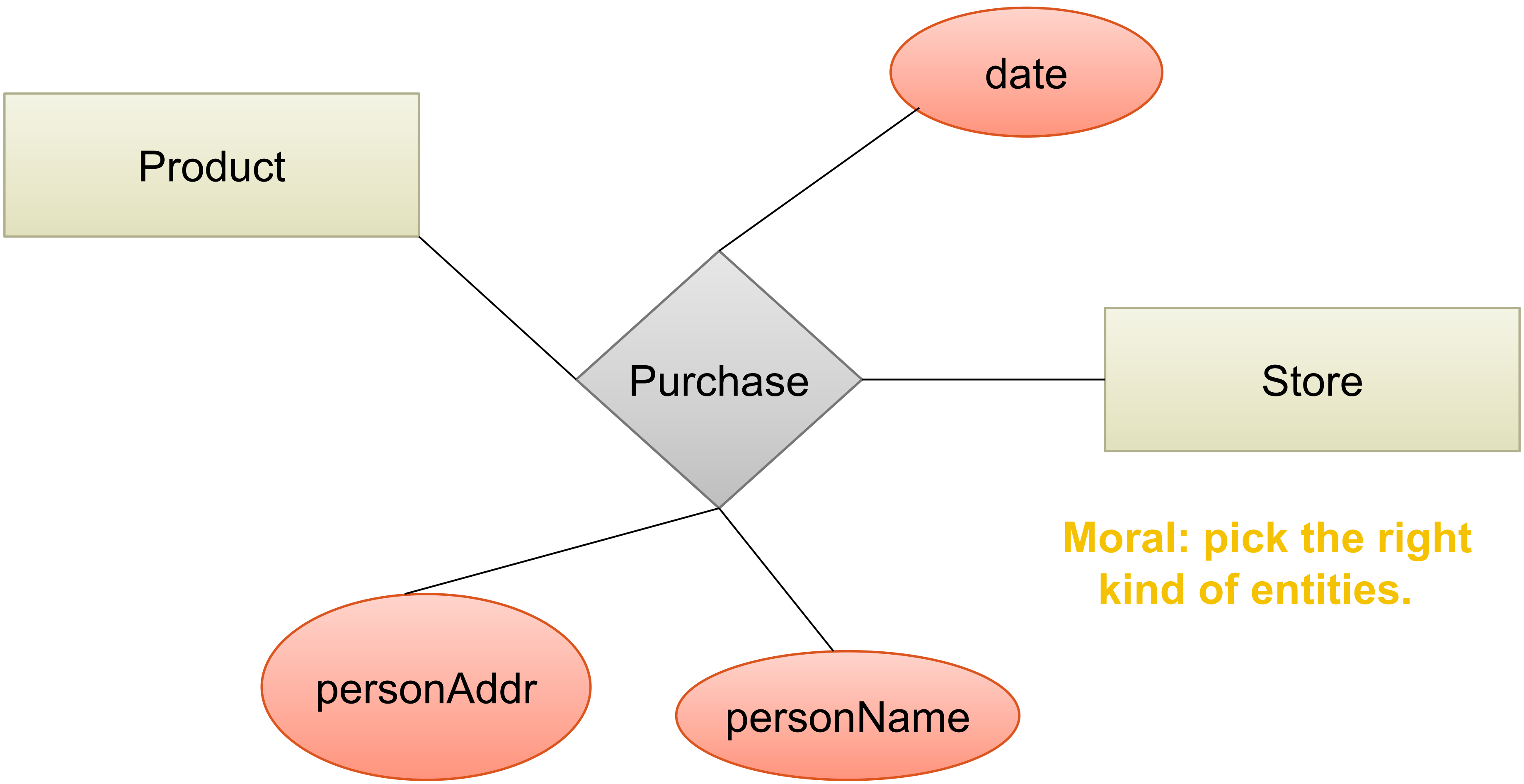
Make sure you understand why!

DESIGN PRINCIPLES: WHAT'S WRONG?



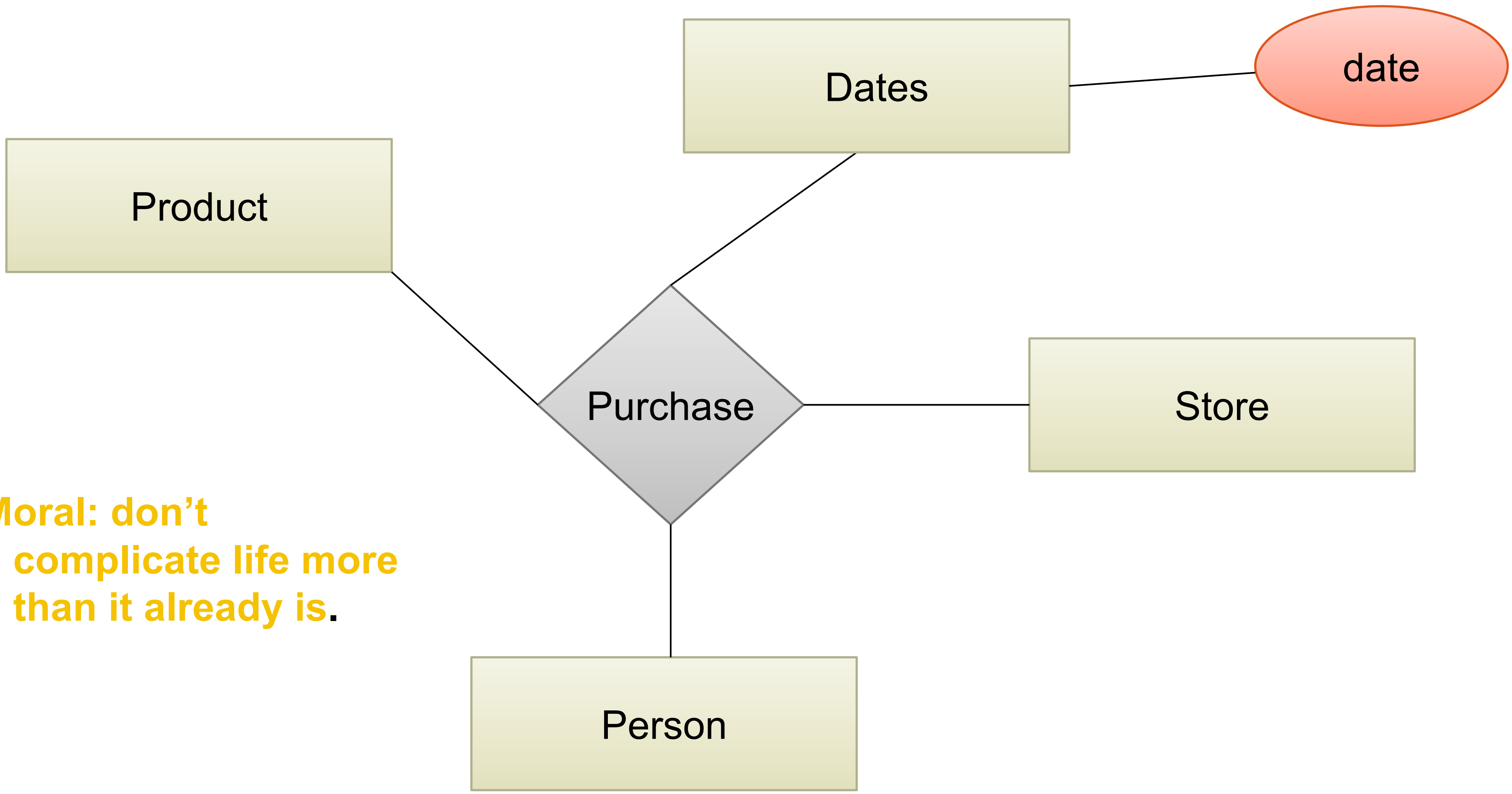
Moral: Be faithful to the specifications of the application!

DESIGN PRINCIPLES: WHAT'S WRONG?



Moral: pick the right kind of entities.

DESIGN PRINCIPLES: WHAT'S WRONG?



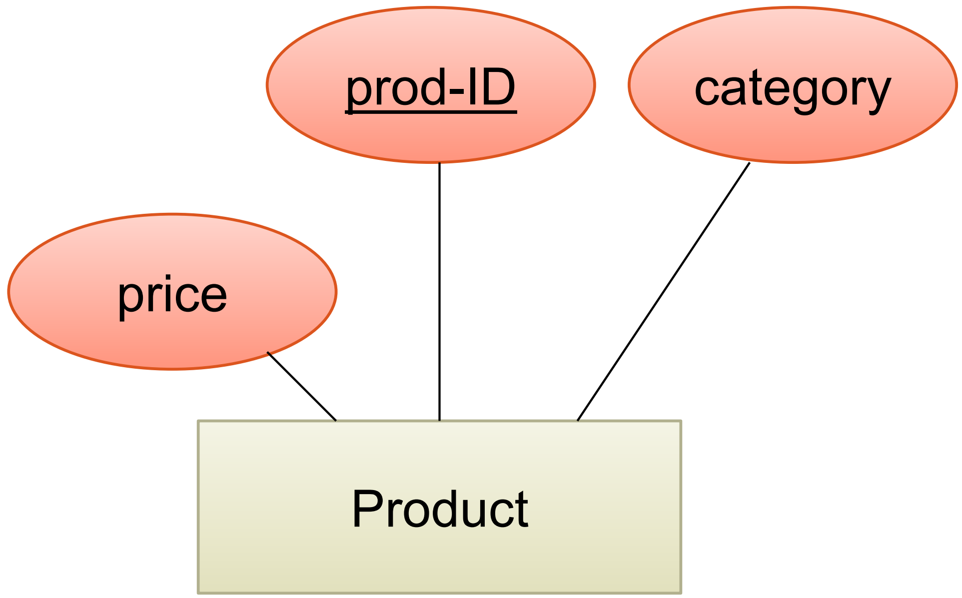
Moral: don't complicate life more than it already is.

FROM E/R DIAGRAMS
TO RELATIONAL SCHEMA

Entity set → relation

Relationship → relation

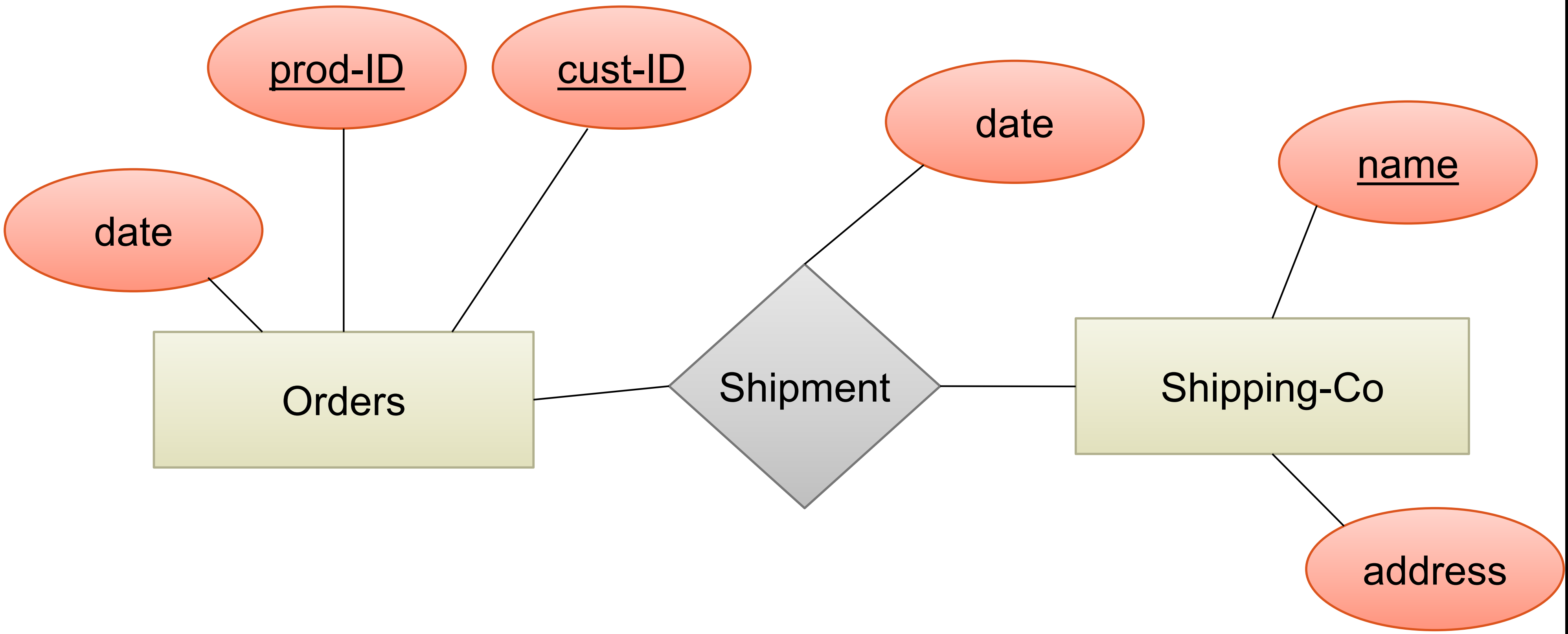
ENTITY SET TO RELATION



Product(<u>prod-ID</u>, category, price)

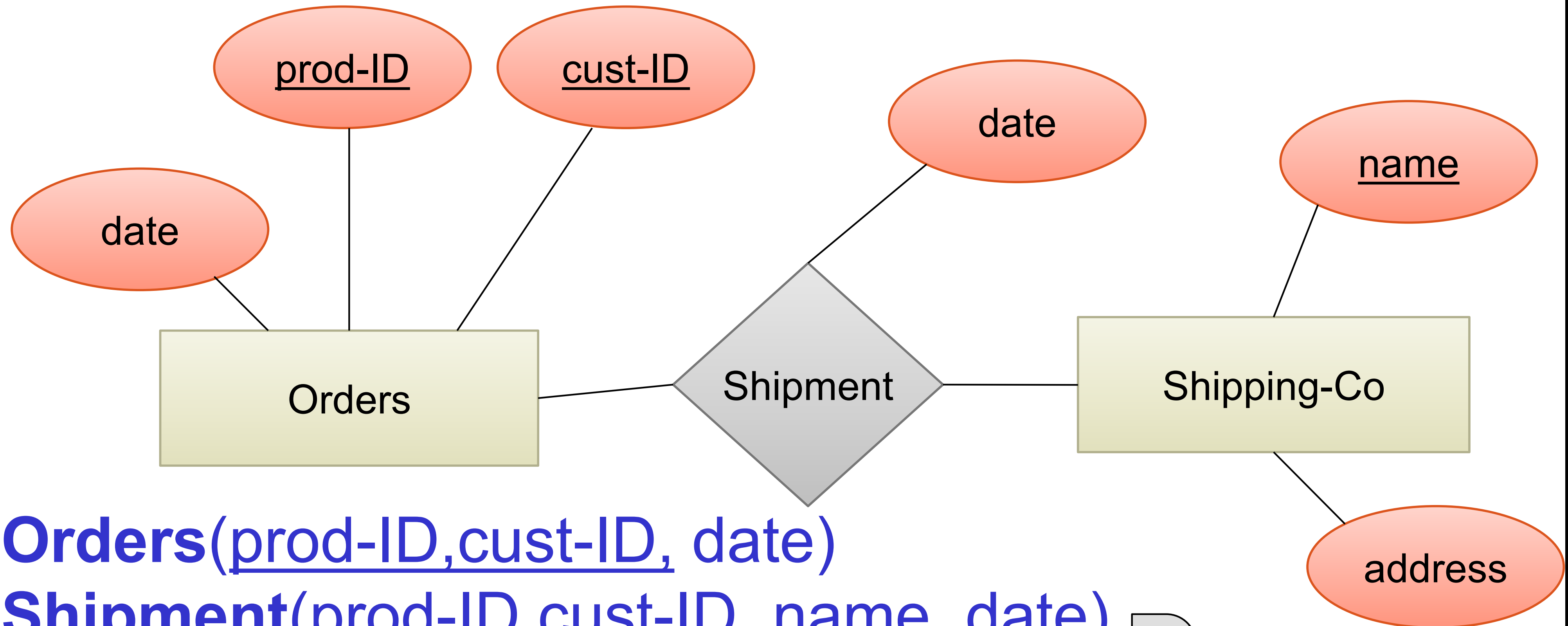
<u>prod-ID</u>	category	price
Gizmo55	Camera	99.99
Pokemn19	Toy	29.99

N-N RELATIONSHIPS TO RELATIONS



How to represent Shipment in relations?

N-N RELATIONSHIPS TO RELATIONS



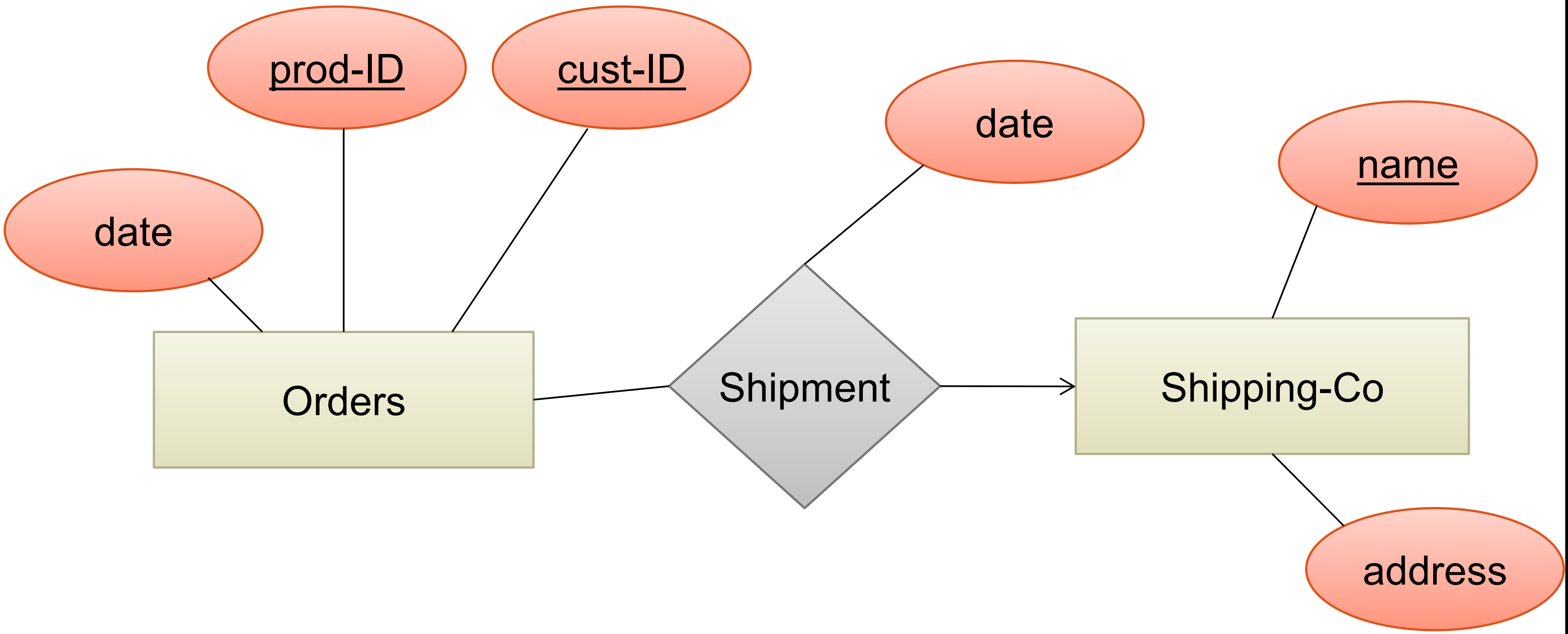
Orders(prod-ID,cust-ID, date)

Shipment(prod-ID,cust-ID, name, date)

Shipping-Co(name, address)

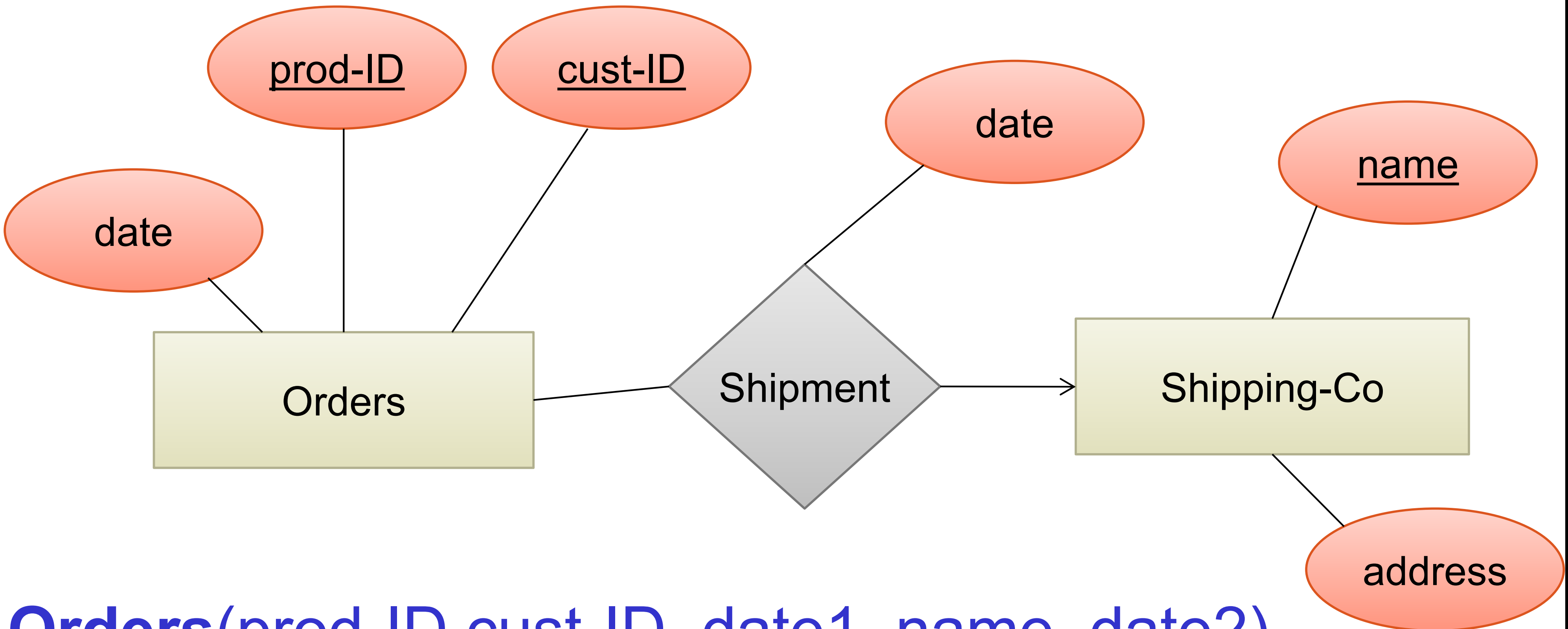
prod-ID	cust-ID	name	date
Gizmo55	Joe12	UPS	4/10/2011
Gizmo55	Joe12	FEDEX	4/9/2011

N-1 RELATIONSHIPS TO RELATIONS



How to represent Shipment in relations?

N-1 RELATIONSHIPS TO RELATIONS

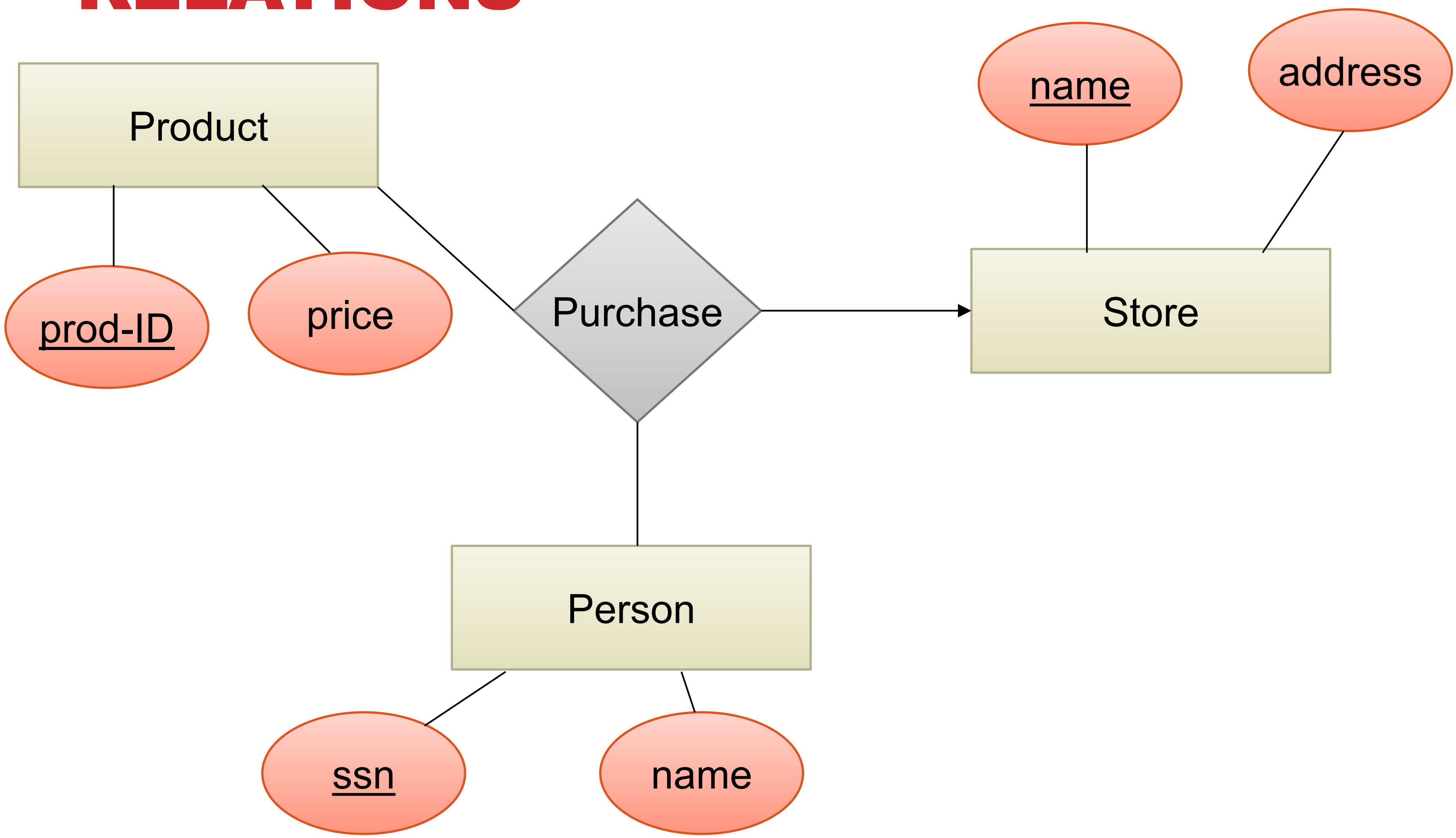


Orders(<u>prod-ID,cust-ID,</u> date1, name, date2)

Shipping-Co(<u>name</u>, address)

Remember: no separate relations for many-one relationship

MULTI-WAY RELATIONSHIPS TO RELATIONS

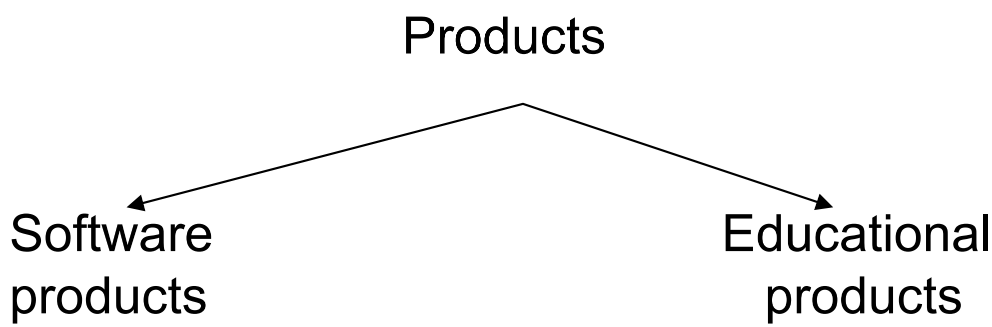


Purchase(prod-ID, ssn, name)

MODELING SUBCLASSES

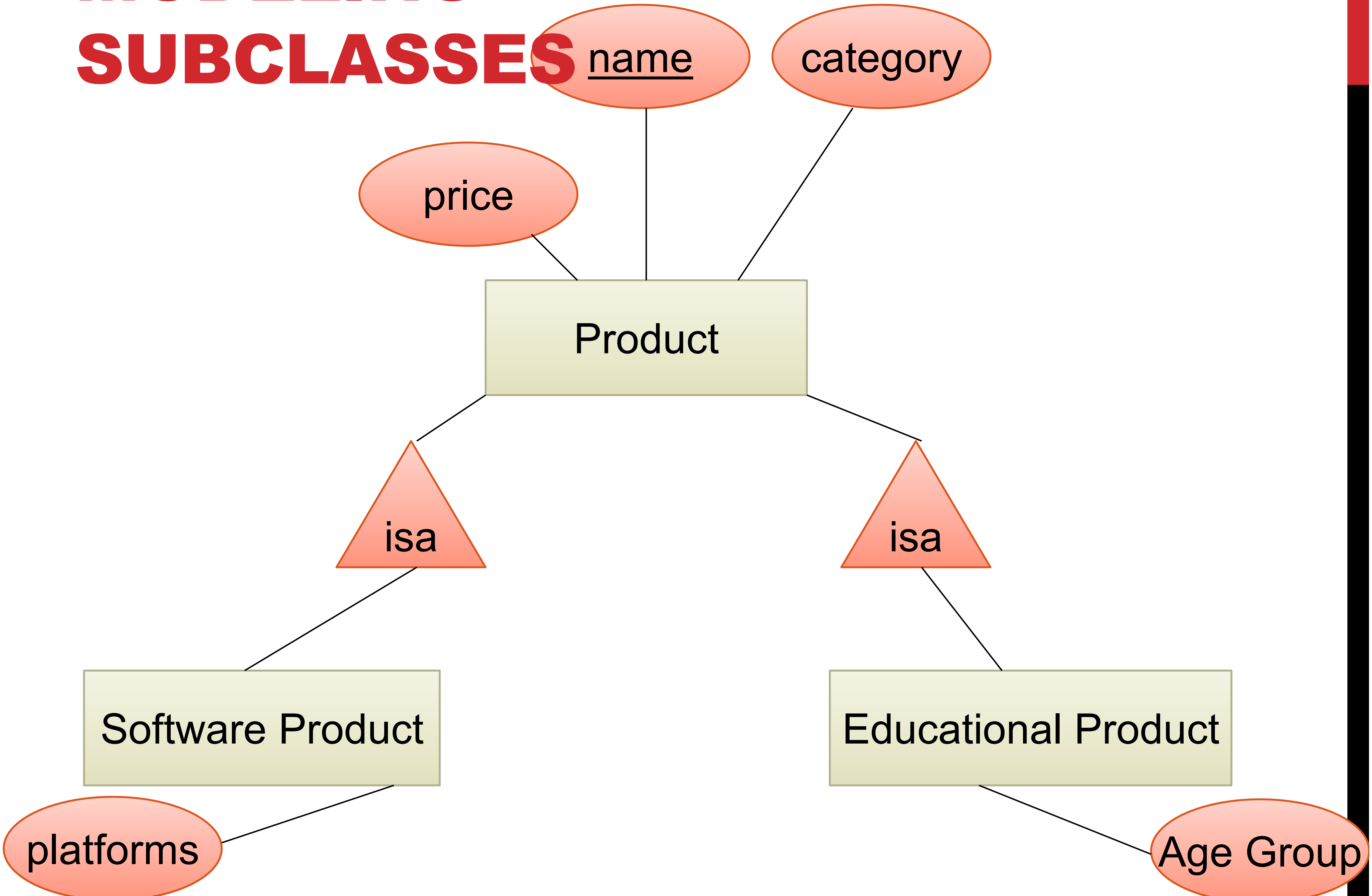
Some objects in a class may be special

- define a new class
- better: define a *subclass*

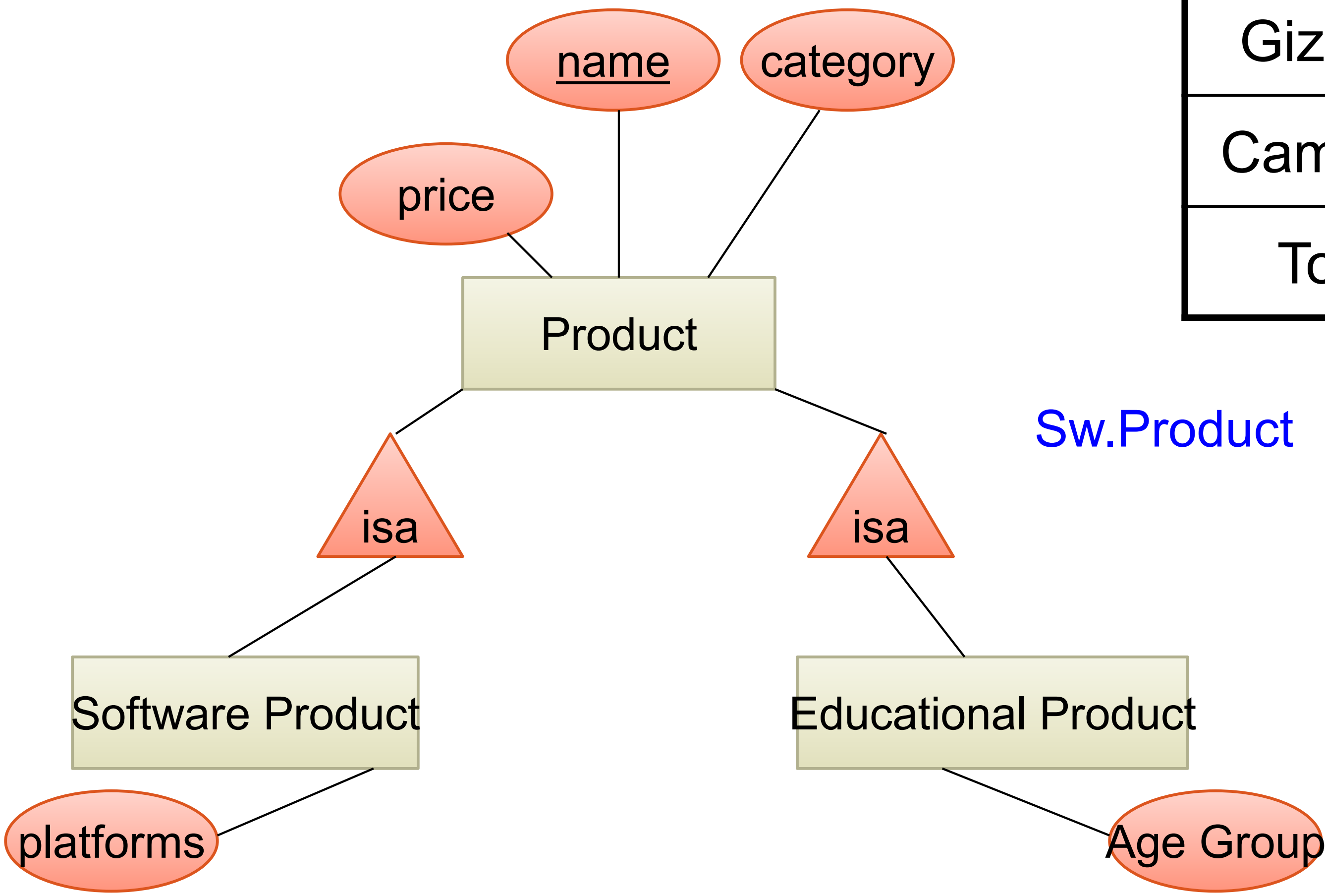


So --- we define subclasses in E/R

MODELING SUBCLASSES



MODELING SUBCLASSES



Product

Name	Price	Category
Gizmo	99	gadget
Camera	49	photo
Toy	39	gadget

Sw.Product

Name	platforms
Gizmo	unix

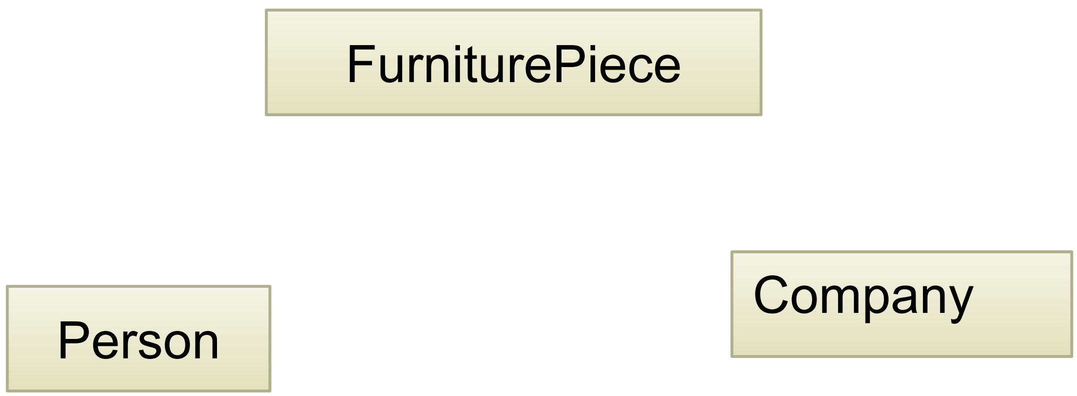
Ed.Product

Name	Age Group
Gizmo	toddler
Toy	retired

Other ways to convert are possible...

Is this representation subclassing in Java sense?

MODELING UNION TYPES WITH SUBCLASSES

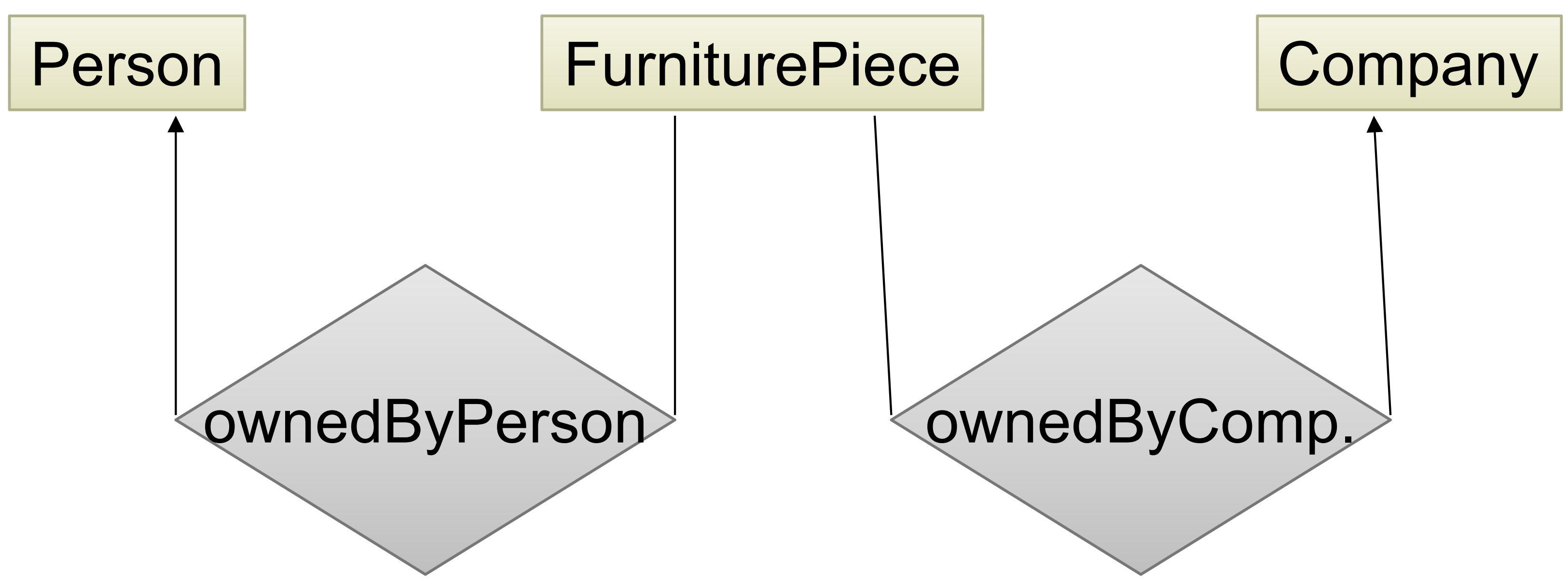


Say: each piece of furniture is owned either by a person or by a company

MODELING UNION TYPES WITH SUBCLASSES

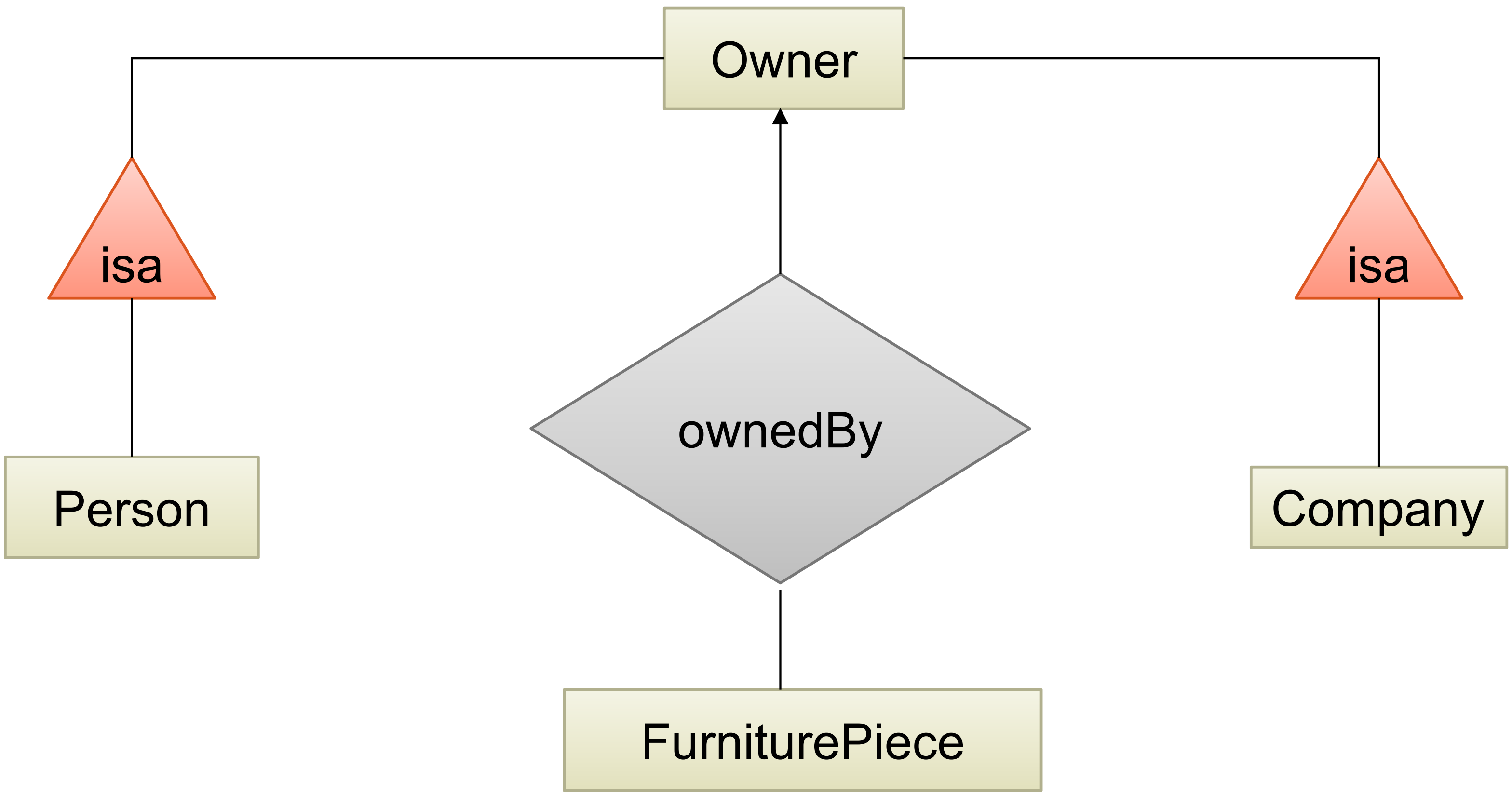
Say: each piece of furniture is owned either by a person or by a company

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



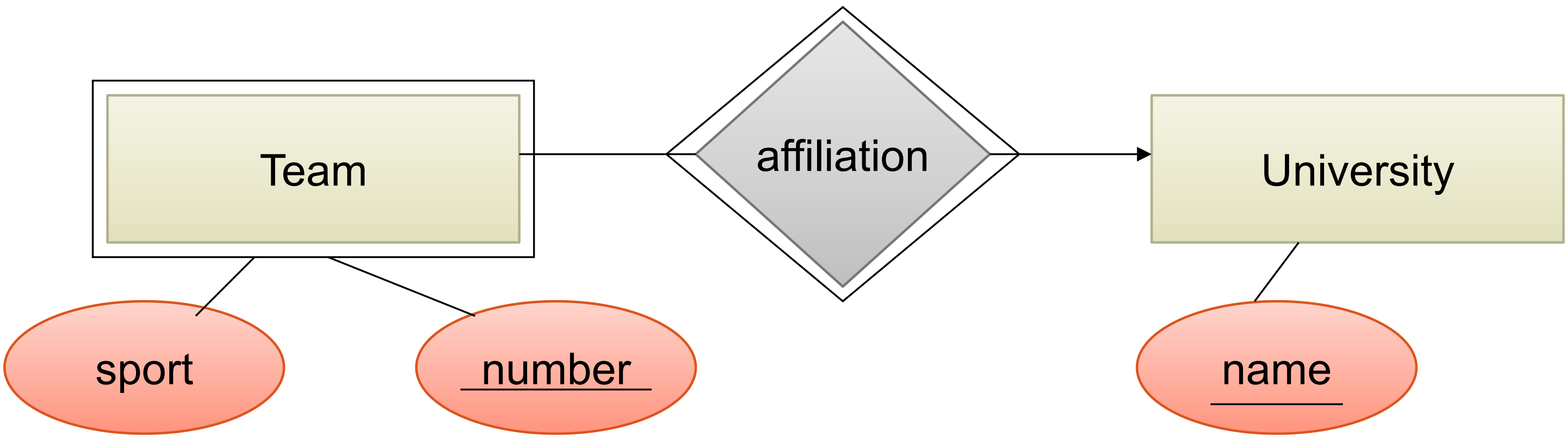
MODELING UNION TYPES WITH SUBCLASSES

Solution 2: better, more laborious



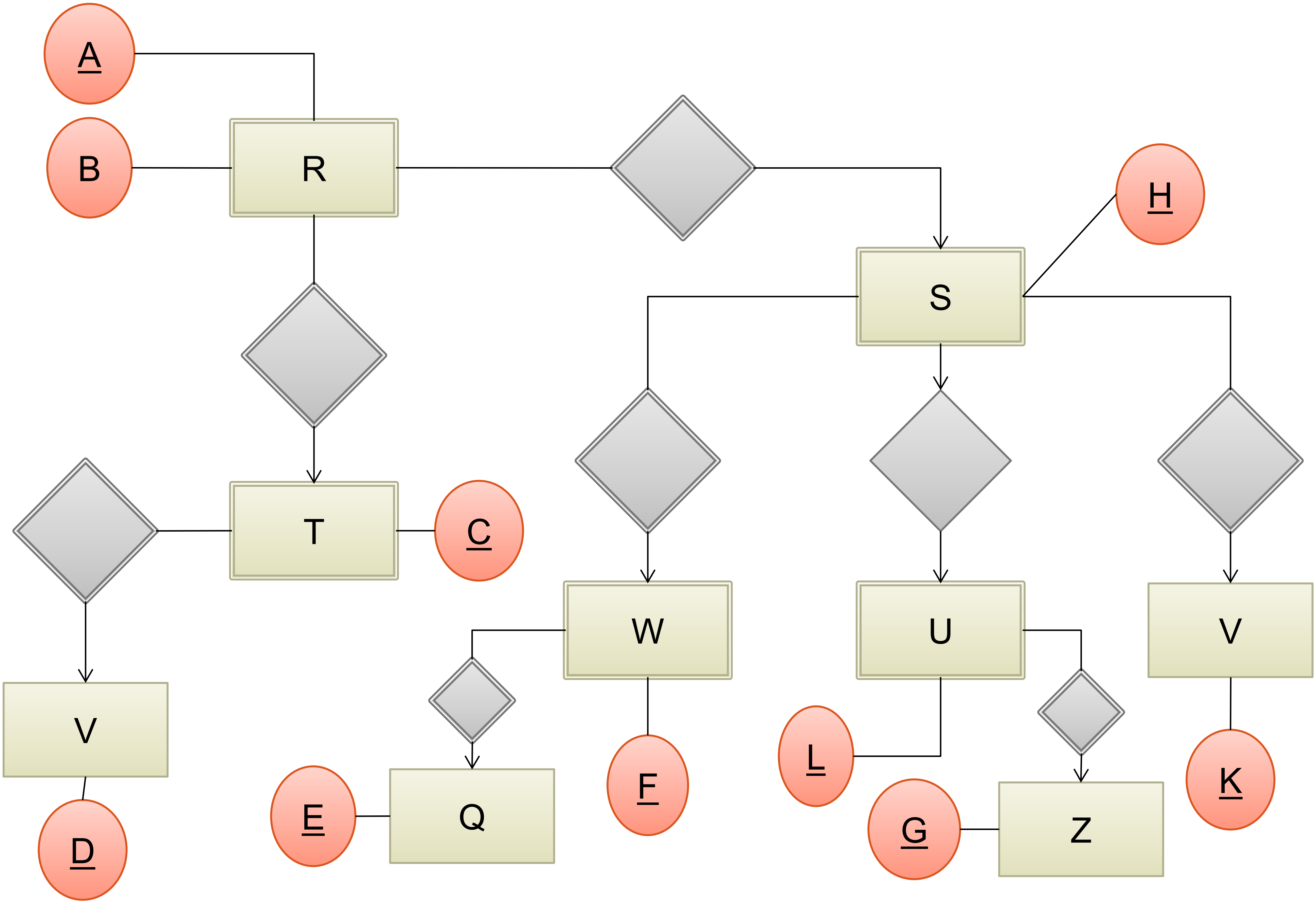
WEAK ENTITY SETS

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



Team(sport, number, universityName)
University(name)

WHAT ARE THE KEYS OF R ?



INTEGRITY CONSTRAINTS MOTIVATION

An integrity constraint is a condition specified on a database schema that restricts the data that can be stored in an instance of the database.

ICs help prevent entry of incorrect information

How? DBMS enforces integrity constraints

- Allows only legal database instances (i.e., those that satisfy all constraints) to exist
- Ensures that all necessary checks are always performed and avoids duplicating the verification logic in each application

CONSTRAINTS IN E/R DIAGRAMS

Finding constraints is part of the modeling process.
Commonly used constraints:

Keys: social security number uniquely identifies a person.

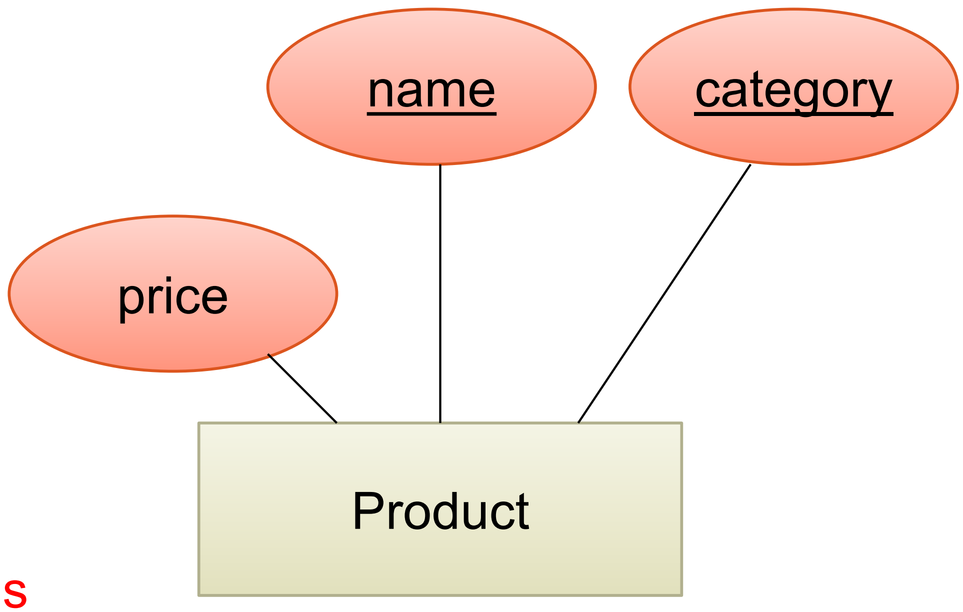
Single-value constraints: a person can have only one biological father.

Referential integrity constraints: if you work for a company, it must exist in the database.

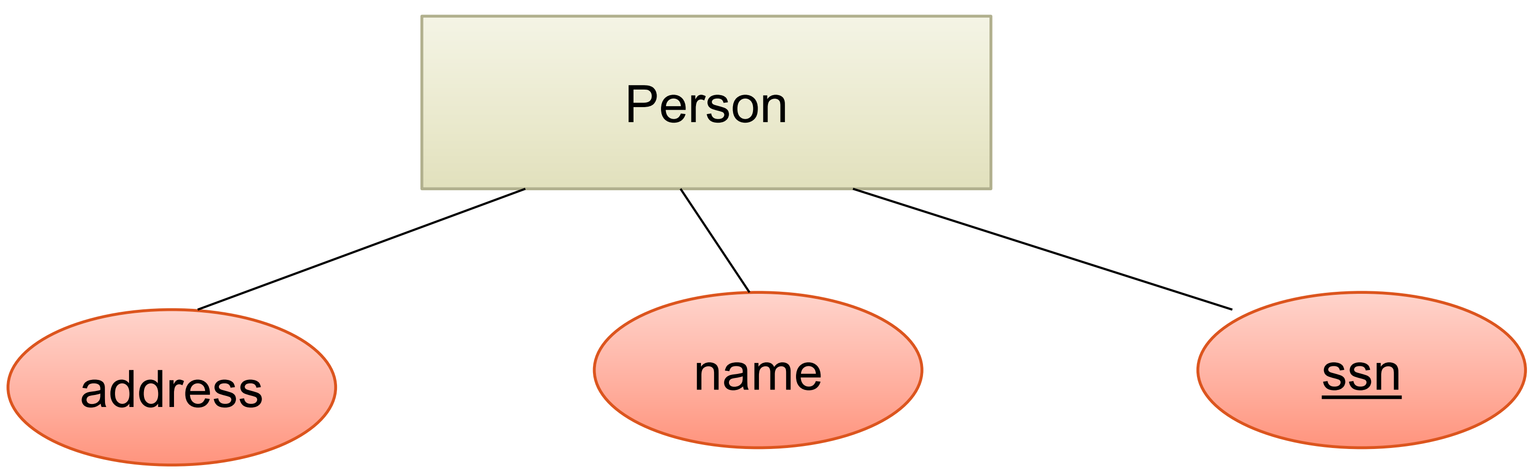
Other constraints: peoples' ages are between 0 and 120

KEYS IN E/R DIAGRAMS

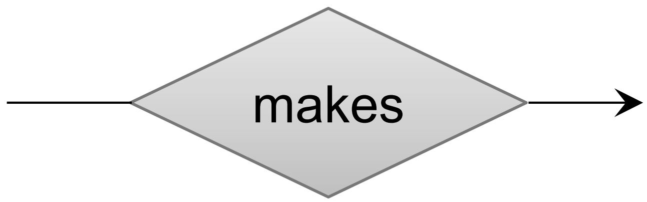
Underline:



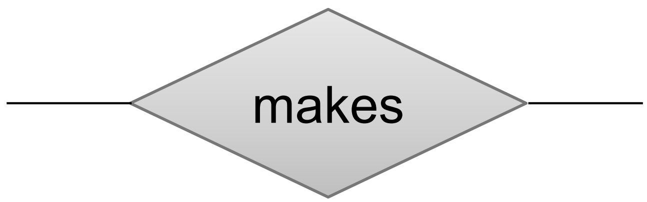
No formal way
to specify multiple
keys in E/R diagrams



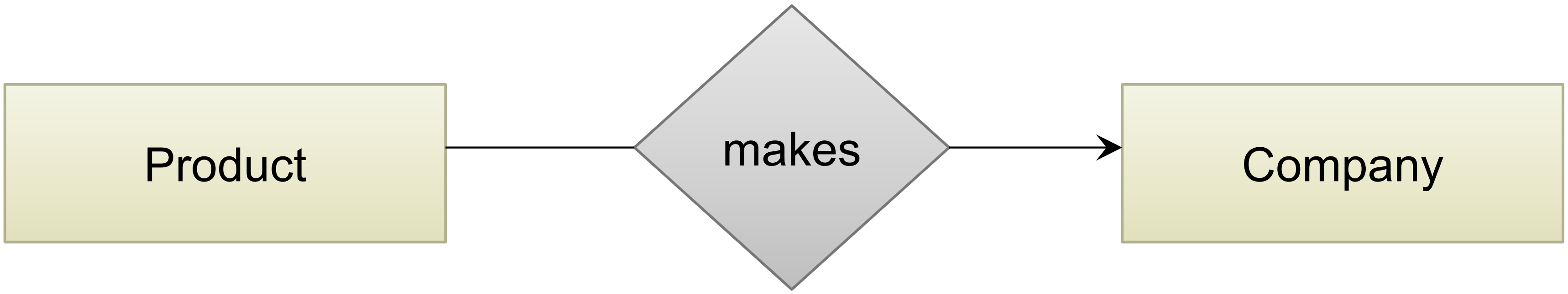
SINGLE VALUE CONSTRAINTS



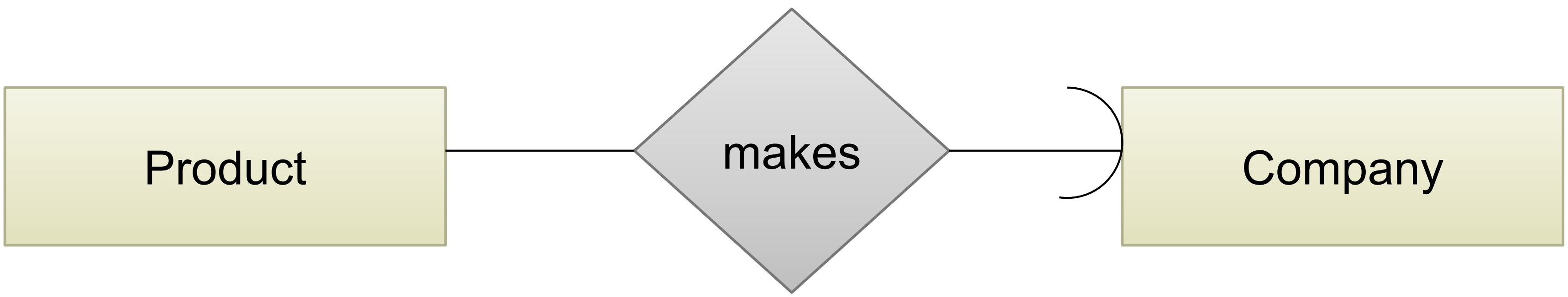
vs.



REFERENTIAL INTEGRITY CONSTRAINTS

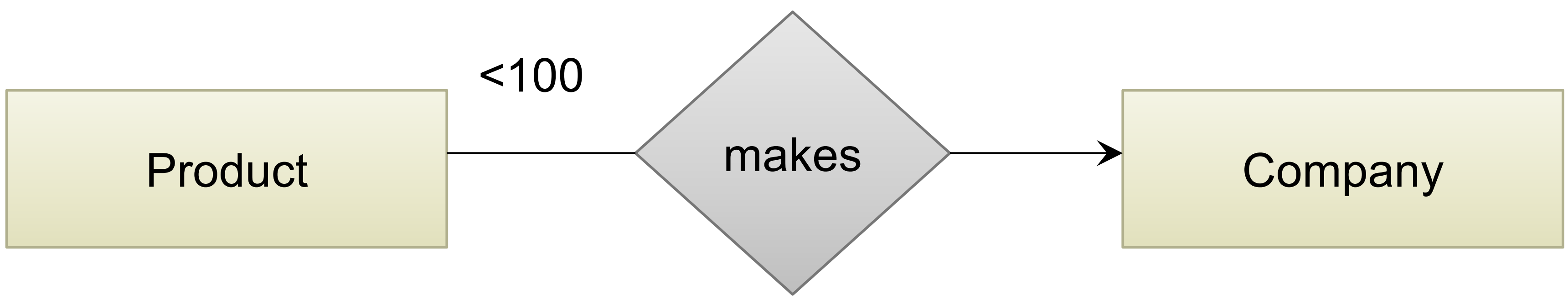


Each product made by at most one company.
Some products made by no company



Each product made by *exactly* one company.

OTHER CONSTRAINTS



Q: What does this mean ?
A: A Company entity cannot be connected
by relationship to more than 99 Product entities

CONSTRAINTS IN SQL

Constraints in SQL:

Keys, foreign keys

simplest

Attribute-level constraints

Tuple-level constraints

Global constraints: assertions

Most complex

The more complex the constraint, the harder it is to check and to enforce

KEY CONSTRAINTS

Product(<u>name</u>, category)

```
CREATE TABLE Product (
      name CHAR(30) PRIMARY KEY,
      category VARCHAR(20))
```

OR:

```
CREATE TABLE Product (
      name CHAR(30),
      category VARCHAR(20),
      PRIMARY KEY (name))
```

KEYS WITH MULTIPLE ATTRIBUTES

Product(<u>name, category</u>, price)

```
CREATE TABLE Product (
        name CHAR(30),
        category VARCHAR(20),
        price INT,
   PRIMARY KEY (name, category))
```

Name	Category	Price
Gizmo	Gadget	10
Camera	Photo	20
Gizmo	Photo	30
~~Gizmo~~	~~Gadget~~	~~40~~

OTHER KEYS

```
CREATE TABLE Product (
        productID  CHAR(10),
        name CHAR(30),
        category VARCHAR(20),
        price INT,
        PRIMARY KEY (productID),
        UNIQUE (name, category))
```

There is at most one PRIMARY KEY;
there can be many UNIQUE

FOREIGN KEY CONSTRAINTS

```
CREATE TABLE Purchase (
        prodName CHAR(30)
        REFERENCES Product(name),
        date DATETIME)
```

Referential integrity constraints

May write just Product if name is PK

prodName is a **foreign key** to Product(name)
name must be a **key** in Product

FOREIGN KEY CONSTRAINTS

Example with multi-attribute primary key

```
CREATE TABLE Purchase (
        prodName CHAR(30),
        category VARCHAR(20),
        date DATETIME,
        FOREIGN KEY (prodName, category)
                REFERENCES  Product(name, category)
```

(name, category) must be a KEY in Product

WHAT HAPPENS WHEN DATA CHANGES?

Types of updates:

In Purchase: insert/update

In Product: delete/update

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

WHAT HAPPENS WHEN DATA CHANGES?

SQL has three policies for maintaining referential integrity:

NO ACTION reject violating modifications (default)

CASCADE after delete/update do delete/update

SET NULL set foreign-key field to NULL

SET DEFAULT set foreign-key field to default value

- need to be declared with column, e.g.,
  `CREATE TABLE Product (pid INT DEFAULT 42)`

MAINTAINING REFERENTIAL INTEGRITY

```
CREATE TABLE Purchase (
        prodName CHAR(30),
        category VARCHAR(20),
        date DATETIME,
        FOREIGN KEY (prodName, category)
                REFERENCES  Product(name, category)
           ON UPDATE CASCADE
           ON DELETE SET NULL     )
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Category
Gizmo	Gizmo
Snap	Camera
EasyShoot	Camera

CONSTRAINTS ON ATTRIBUTES AND TUPLES

Constraints on attributes:

NOT NULL -- obvious meaning...

CHECK condition -- any condition !

Constraints on tuples

CHECK condition

CONSTRAINTS ON ATTRIBUTES AND TUPLES

```
CREATE TABLE R (
        A int NOT NULL,
        B int CHECK (B > 50 and B < 100),
        C varchar(20),
      D int,
        CHECK (C >= 'd' or D > 0))
```

CONSTRAINTS ON ATTRIBUTES AND TUPLES

```
CREATE TABLE Product (
        productID  CHAR(10),
        name CHAR(30),
        category VARCHAR(20),
        price INT CHECK (price > 0),
        PRIMARY KEY (productID),
        UNIQUE (name, category))
```

Constraints on Attributes and Tuples

What does this constraint do?

```
CREATE TABLE Purchase (
      prodName CHAR(30)
            CHECK (prodName IN
                        (SELECT Product.name
                         FROM Product),
      date DATETIME NOT NULL)
```

What is the difference from Foreign-Key ?

GENERAL ASSERTIONS

```
CREATE ASSERTION myAssert CHECK
  (NOT EXISTS(
      SELECT Product.name
      FROM Product, Purchase
      WHERE Product.name = Purchase.prodName
      GROUP BY Product.name
      HAVING count(*) > 200) )
```

But most DBMSs do not implement assertions
Because it is hard to support them efficiently
Instead, they provide triggers