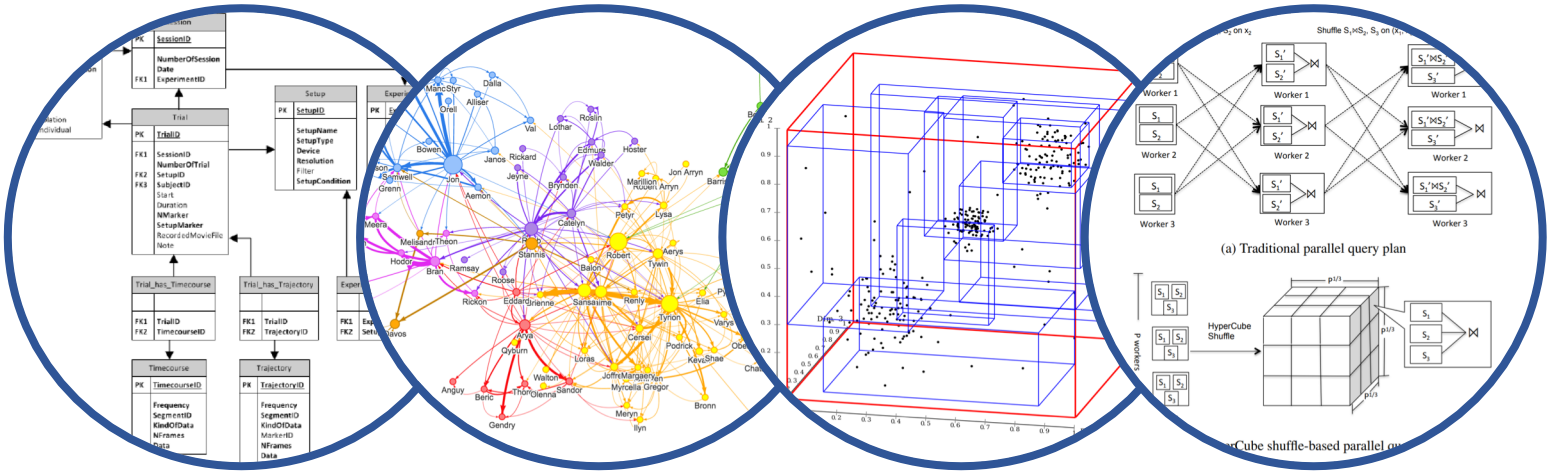


Introduction to Data Management

Database Design

Paul G. Allen School of Computer Science and Engineering
University of Washington, Seattle

Announcements

- HW 3 out
- Azure credits have been issued ($75)
  - Go to this link (posted on message board too):
    - https://portal.azure.com/#blade/Microsoft_Azure_Education/EducationMenuBlade/overview
  - Enter your @uw.edu email in sign-in
- Make sure the setup is working by *yesterday*
- HW 1 grades will be back shortly
- HW 2 grades back by Friday

Recap – Relational Model

- SQL is parsed by the DBMS and translated into an RA plan that is more directly executable
- Both query types work on the assumption that you are **using relational data**
- The relational model specifies mechanics of how data can be organized
  - No prescription of how data should be organized

Goals for Today

- With some application in mind, we can use an entity relationship (ER) diagram to conceptualize and communicate
- And with an ER diagram, we can use SQL to realize the model

Outline

- Introduce Database Design
- ER Diagrams
- ER-to-SQL conversion along the way
- Integrity constraints along the way

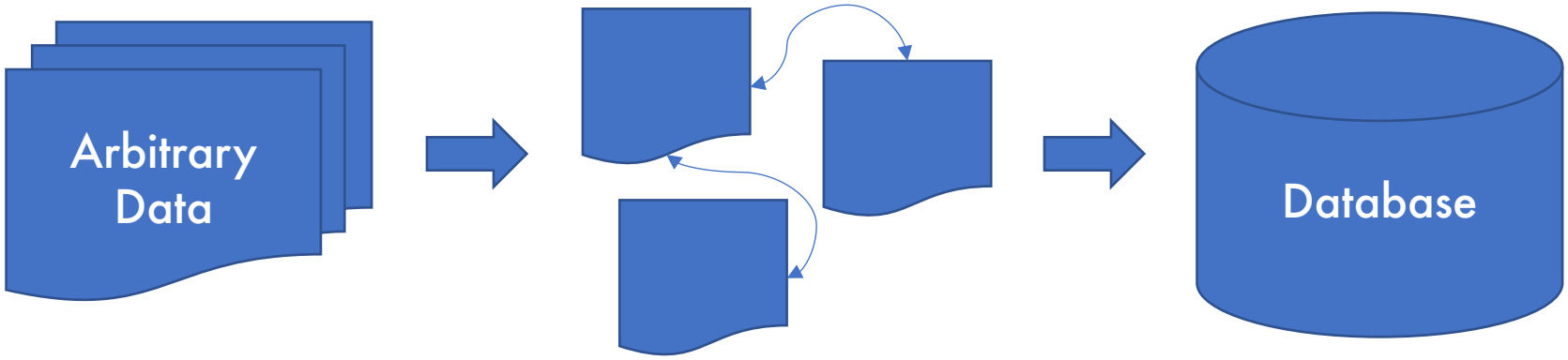
Database Design

- Communication is Key
- Other people are involved in the design process
- Non-computer scientists have to interact with the data too

Database Design

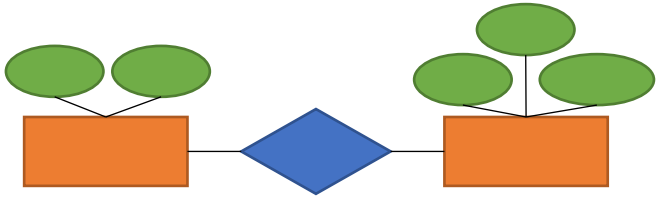
Database Design

Database Design or **Logical Design** or **Relational Schema Design** is the process of organizing data into a database model. This is done by considering what data needs to be stored and the interrelationship of the data.

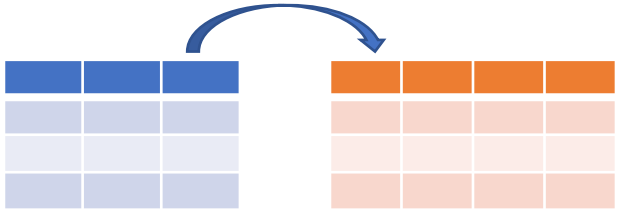


The Database Design Process

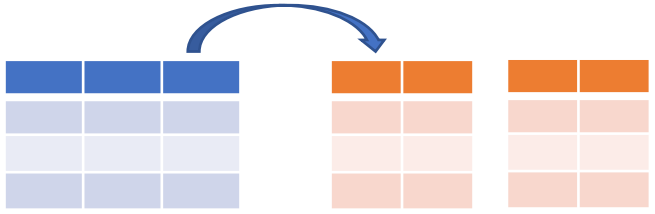
Conceptual Model



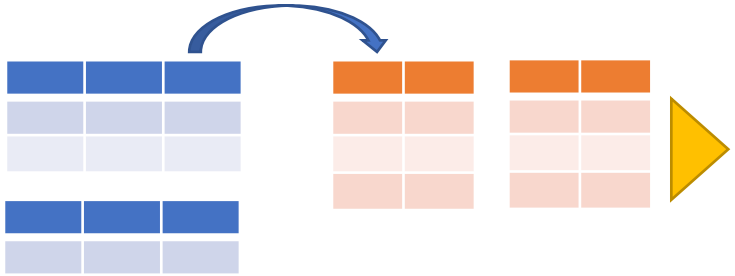
Relational Model
→ + Schema
→ + Constraints



Conceptual Schema
→ + Normalization



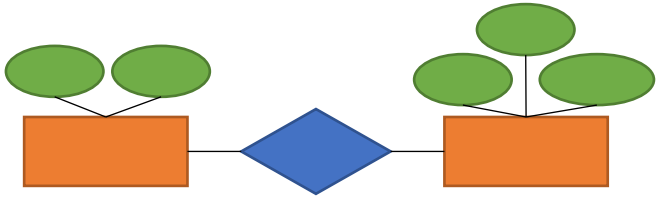
Physical Schema
→ + Partitioning
→ + Indexing



The Database Design Process

Today

Conceptual Model



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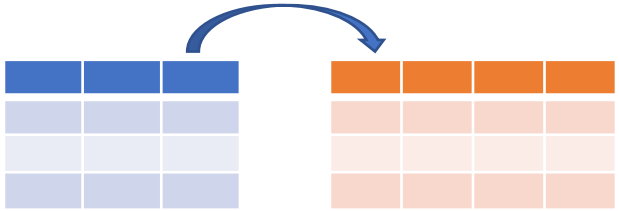
→ + Schema
→ + Constraints



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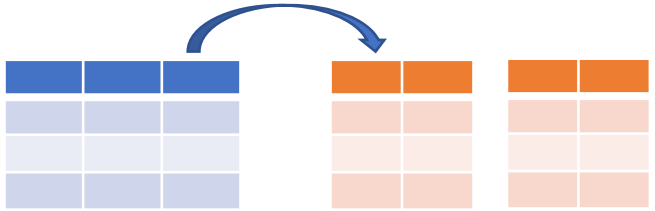

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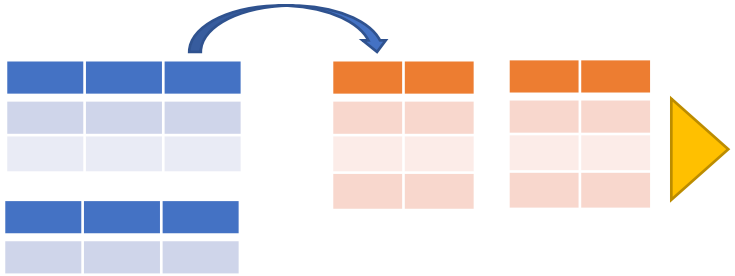
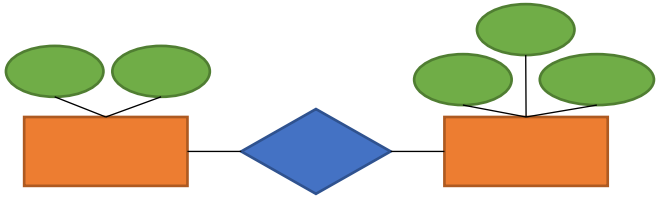


The Database Design Process

Conceptual Model



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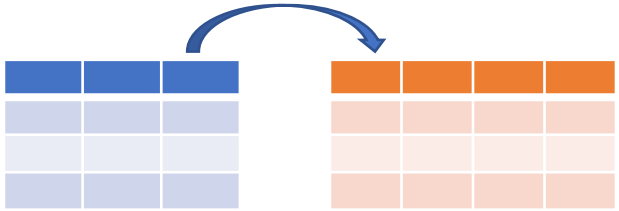

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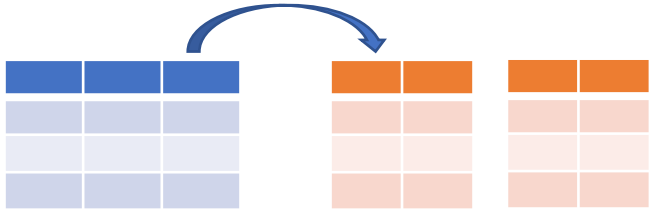

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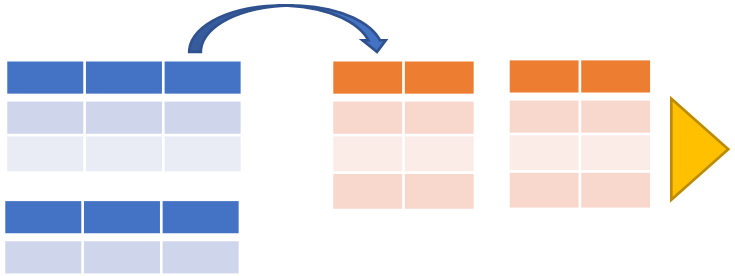

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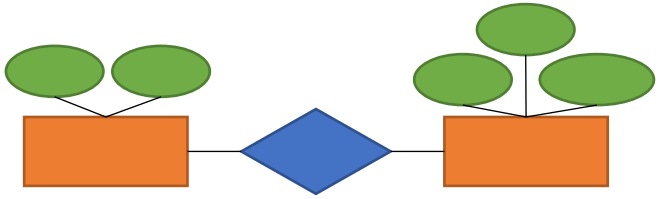

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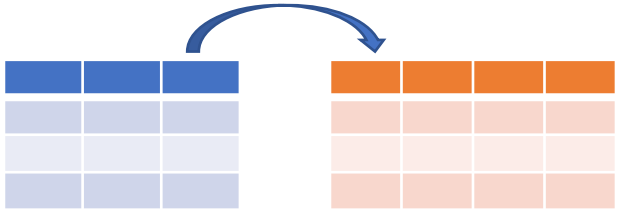

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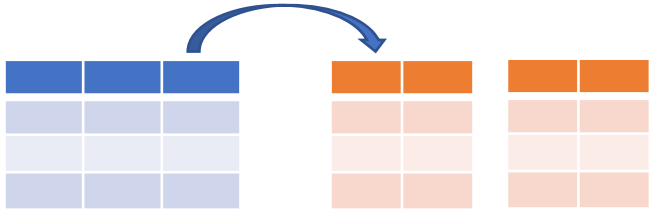
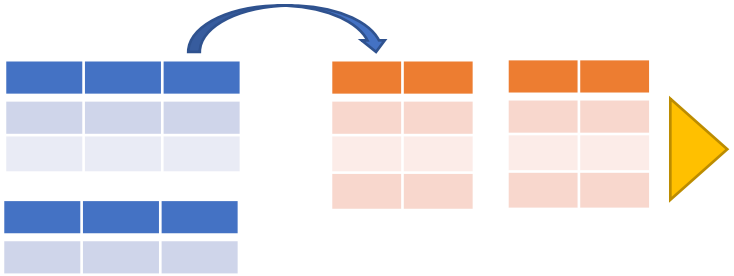


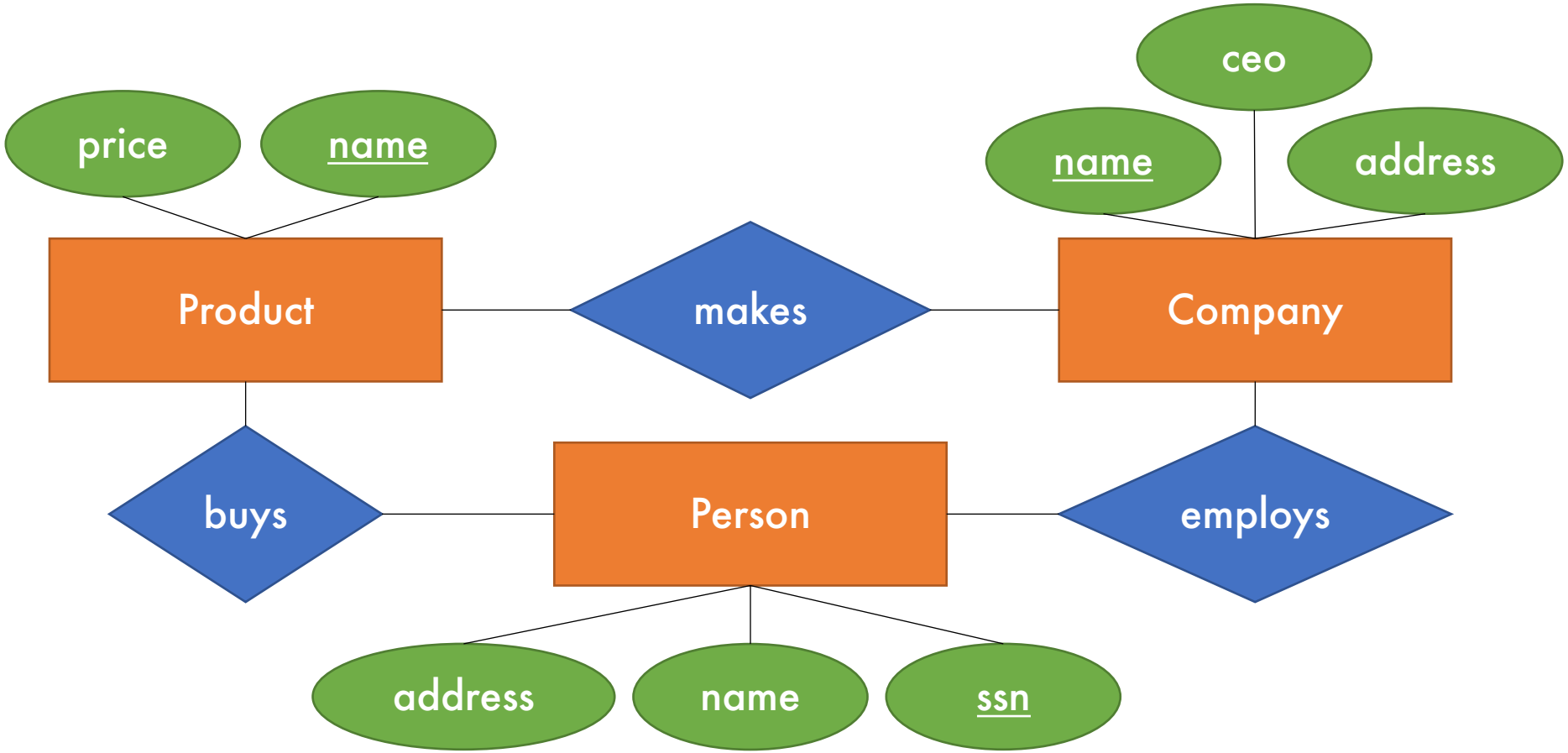
Next Unit

Physical Schema
→ + Partitioning
→ + Indexing



ER Diagrams

- Humans are visual creatures so a visual model serves us best



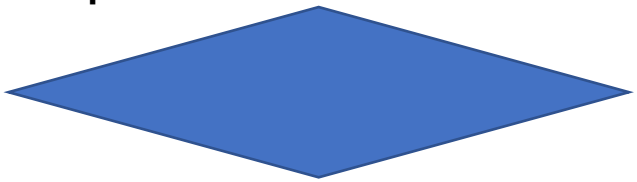
ER Diagram Building Blocks

- These are all the blocks we will learn about

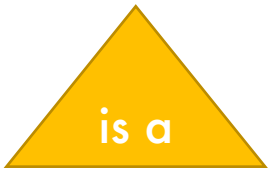
Entity set

Attribute

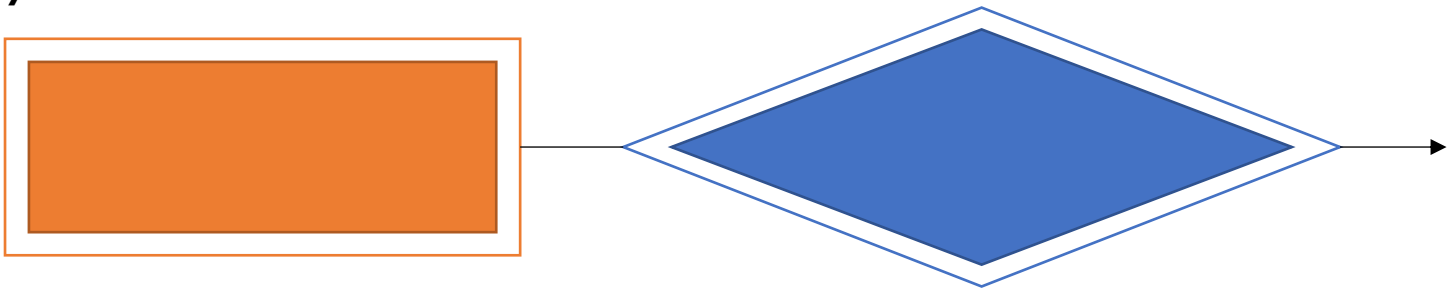
Relationship



Subclass

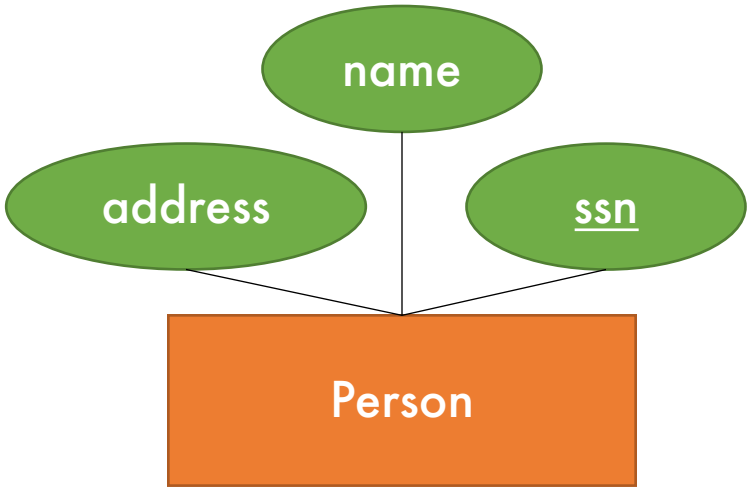


Weak Entity



Entity Sets

- An "**entity set**" is like a **class**
- An **attribute** is like a **field**
- An "**entity**" is like a **object**
  - Corresponds to a row



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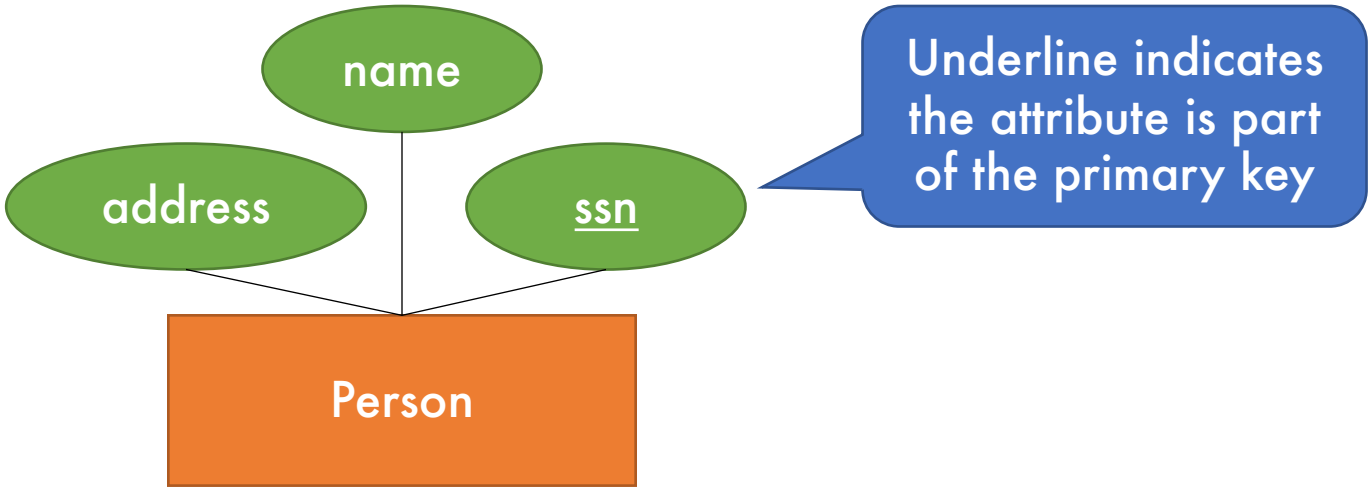

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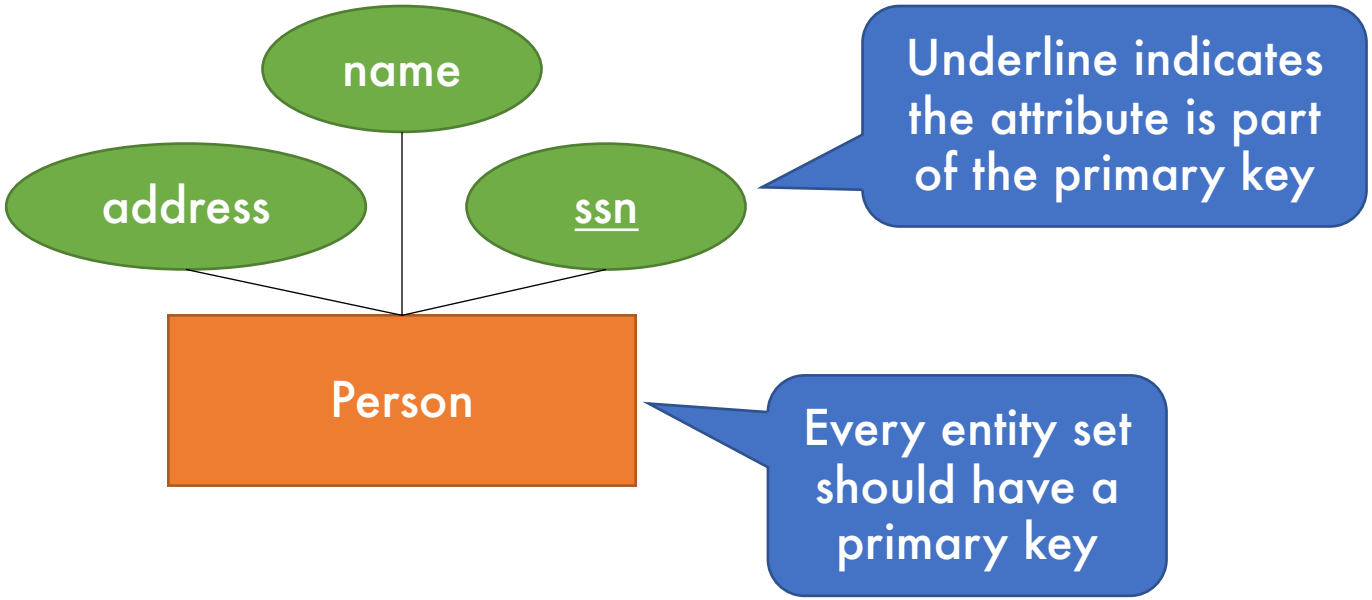

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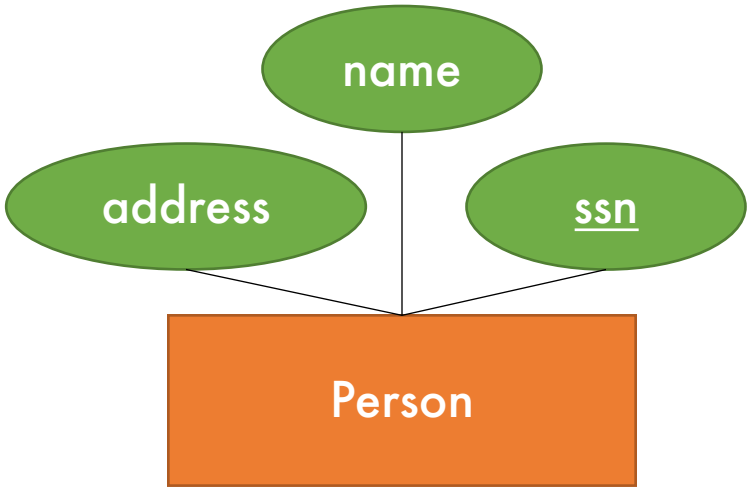
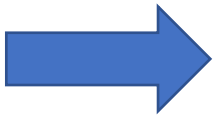


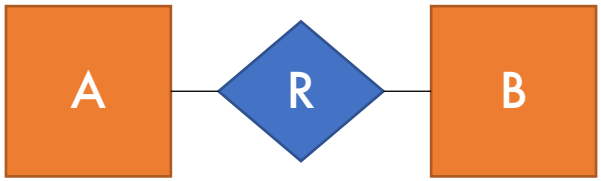


```
CREATE TABLE Person (
    ssn INT PRIMARY KEY,
    name TEXT,
    address TEXT);
```

Relations

Relationship

If A and B are sets, then a relation R is a subset of $A \times B$



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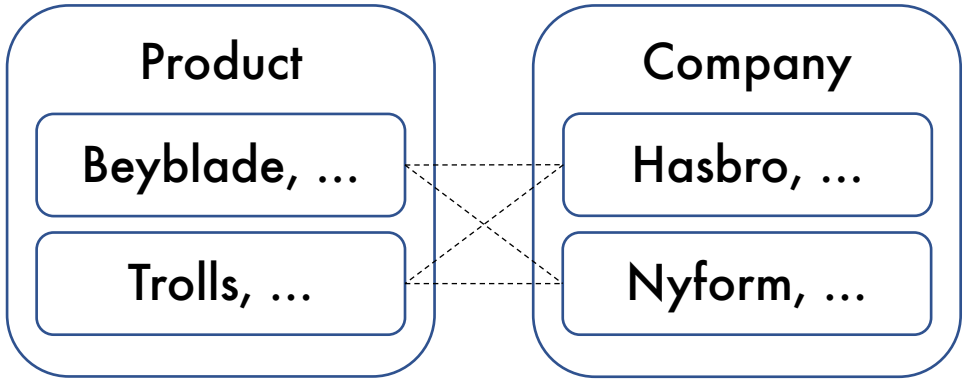

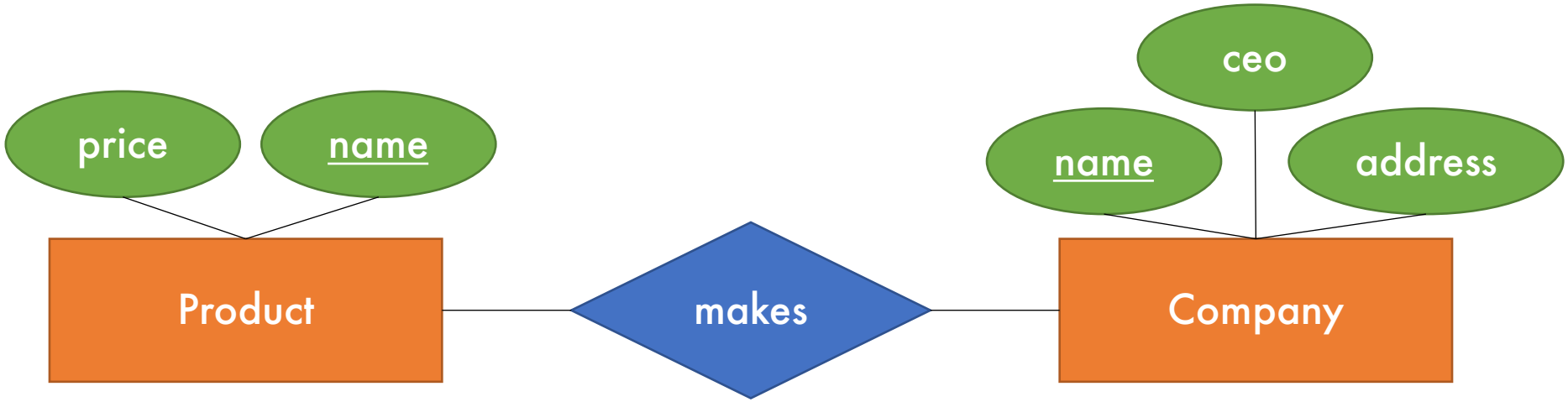

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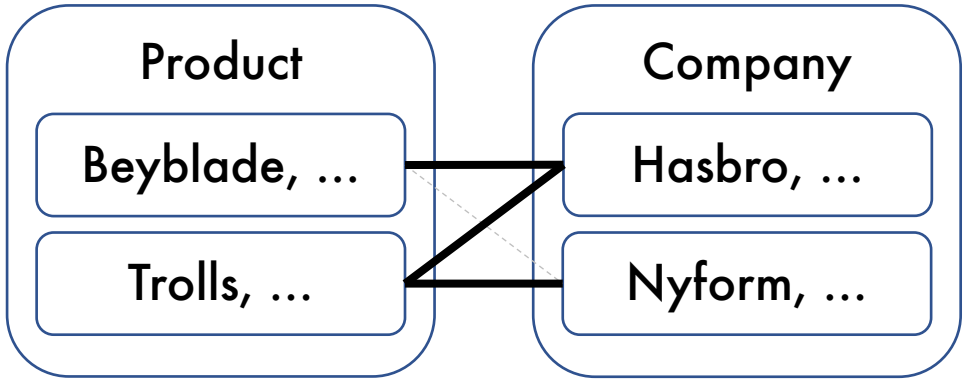
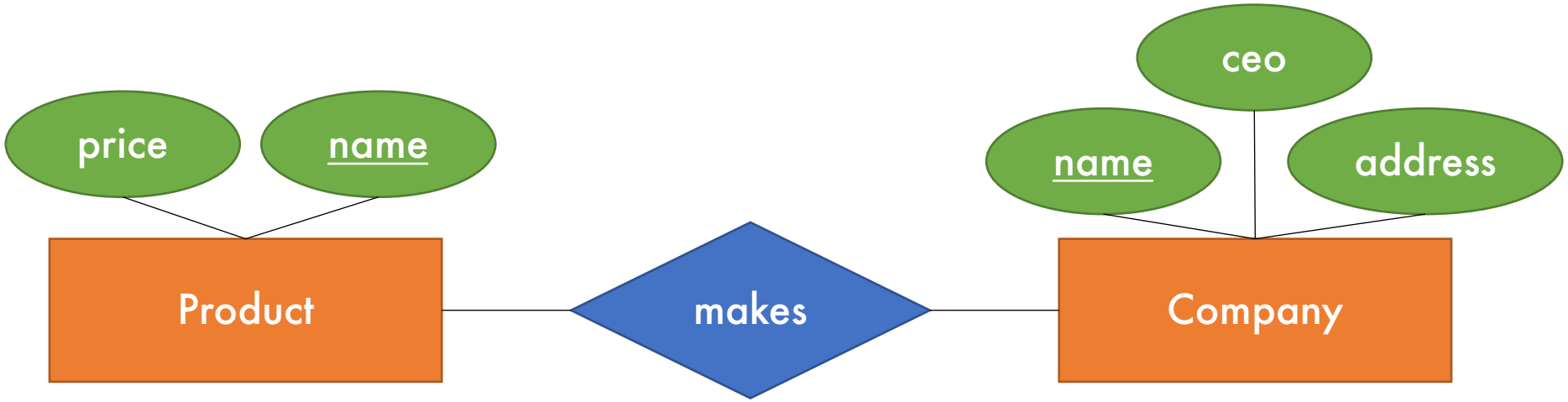
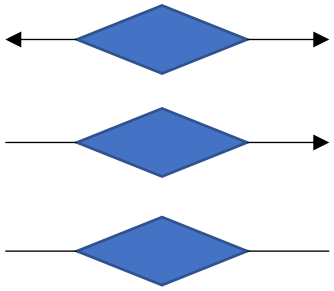
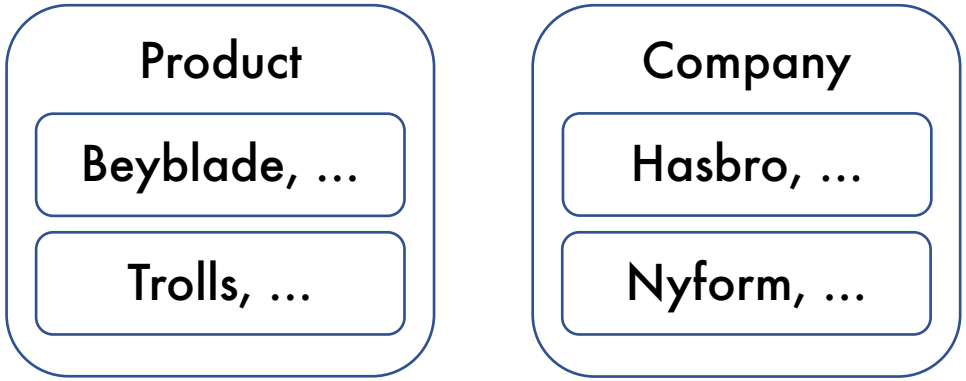




Relation Multiplicity

- One-to-one
- Many-to-one
- Many-to-many





Relation Multiplicity

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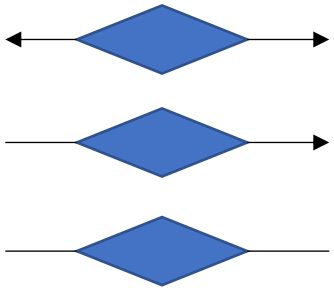
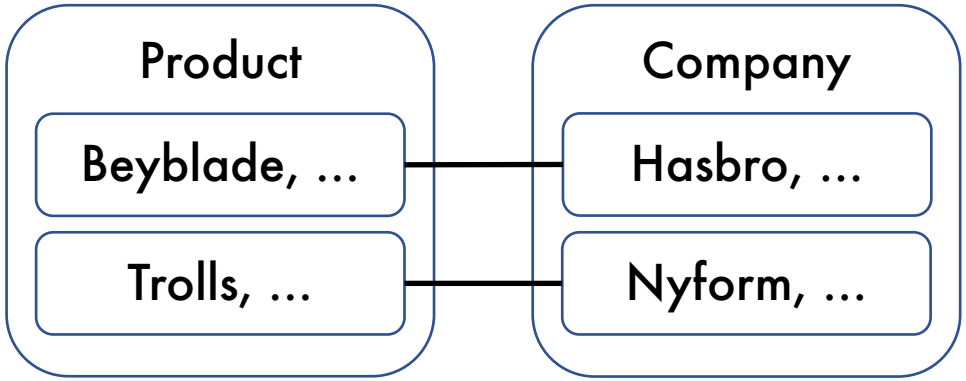
- Many-to-one
- Many-to-many





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- **One-to-one**
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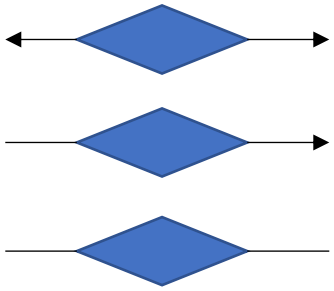
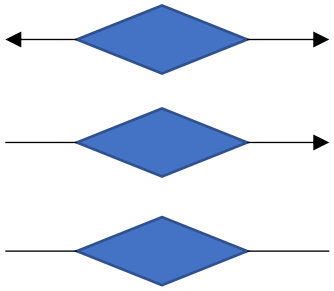
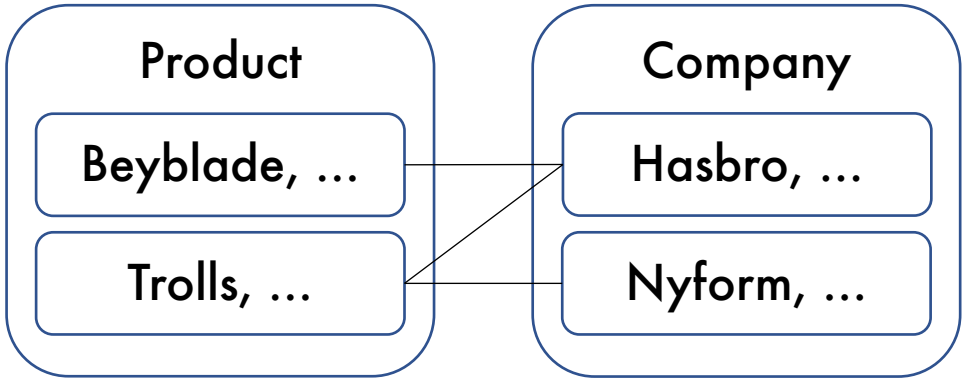


```
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Makes (
    cname VARCHAR(100) UNIQUE REFERENCES Company,
    pname VARCHAR(100) UNIQUE REFERENCES Product,
    ...);
```

Relation Multiplicity

- One-to-one
- Many-to-one
- **Many-to-many**





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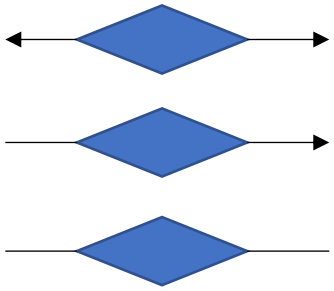

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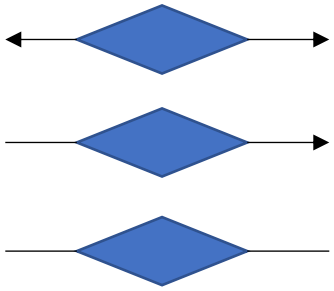

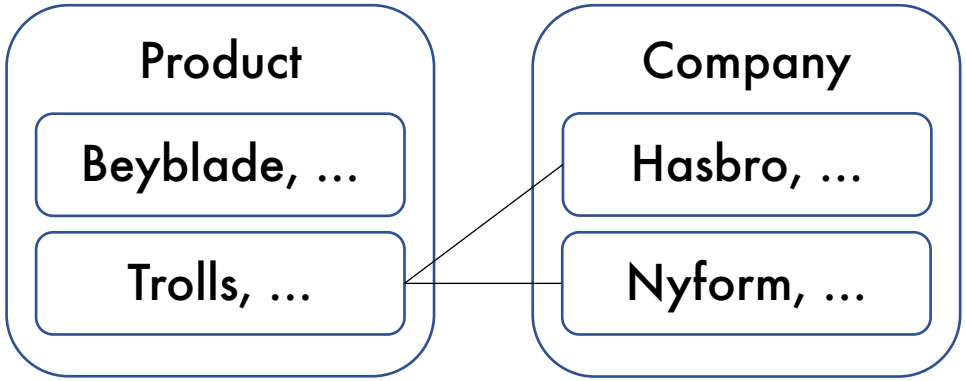

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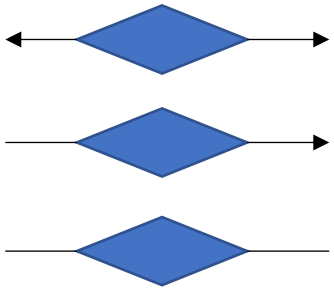

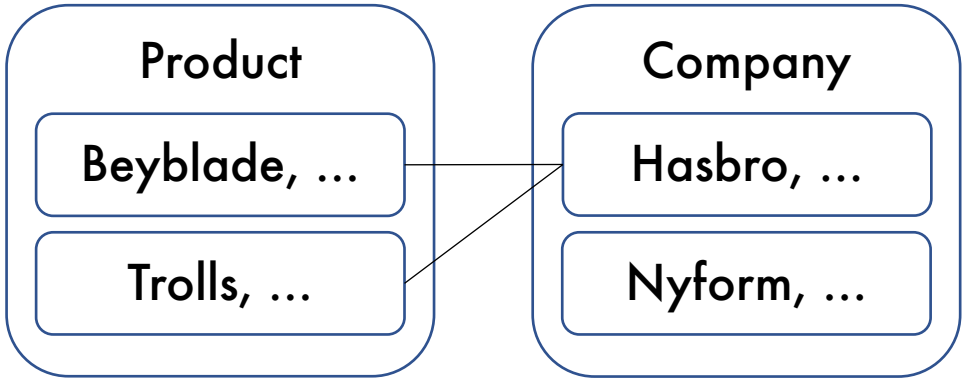

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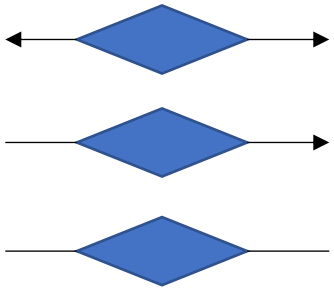
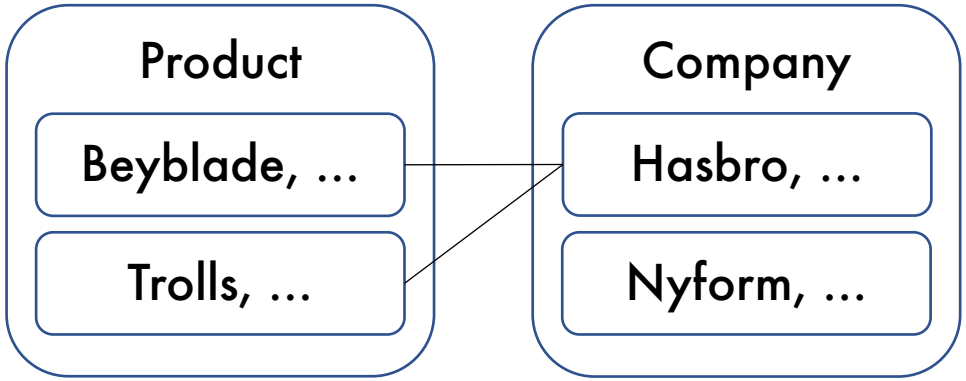


Do I need a Makes table?



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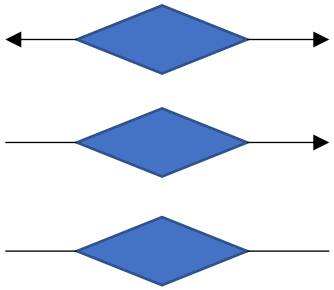
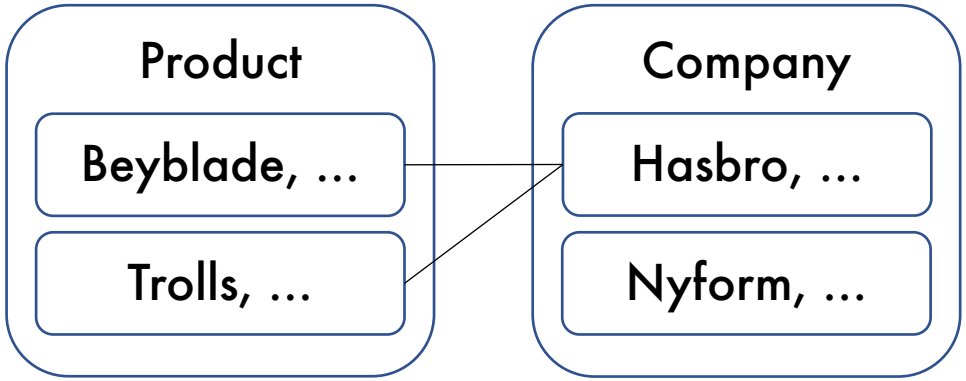


Do I need a Makes table? Key observation: In this many-to-one relationship, each company can make many products, but **each product can only be made by a one company**



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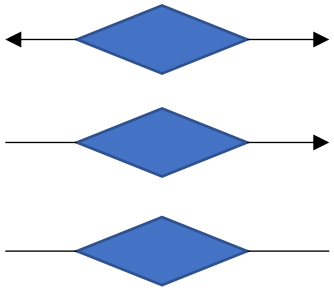

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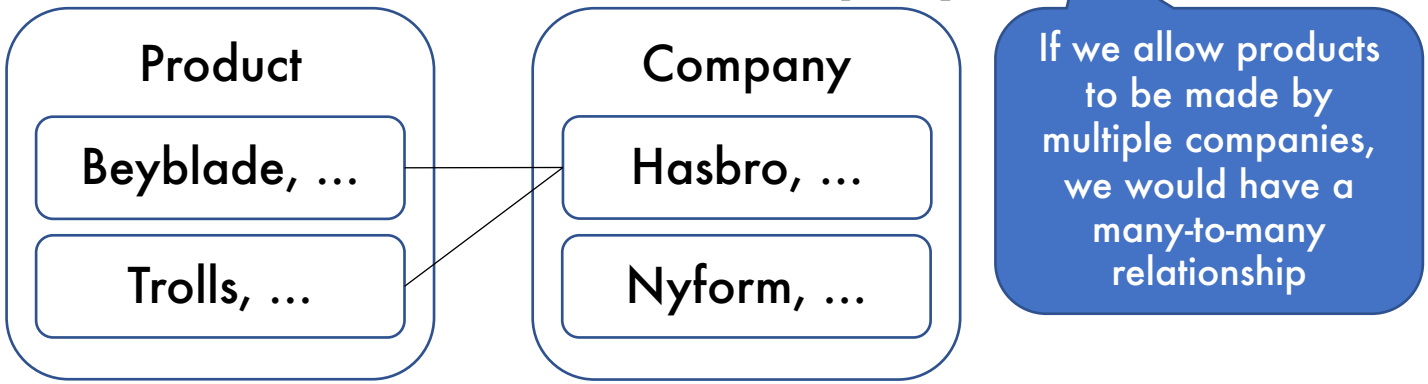

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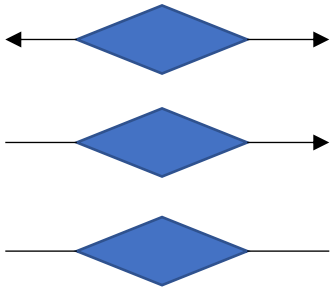
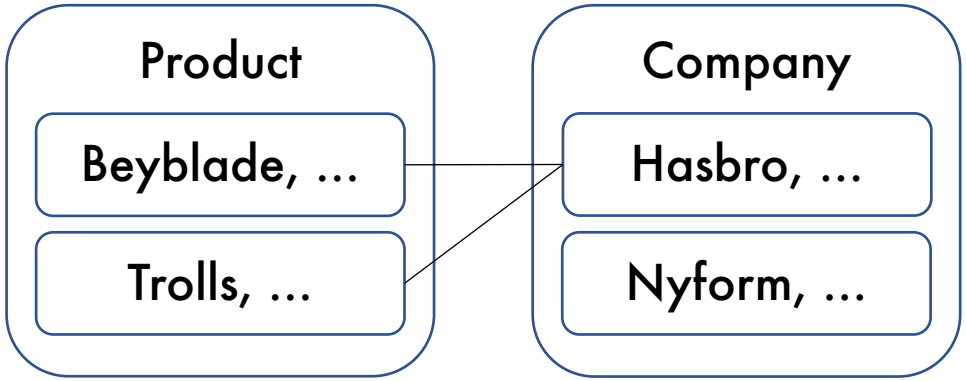
- **Many-to-one**
- Many-to-many

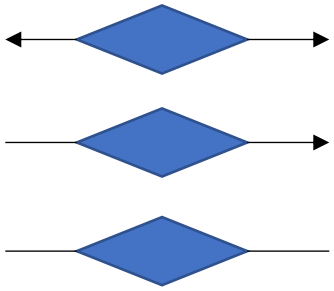


```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100)
      REFERENCES Company(name)
    ...);
```



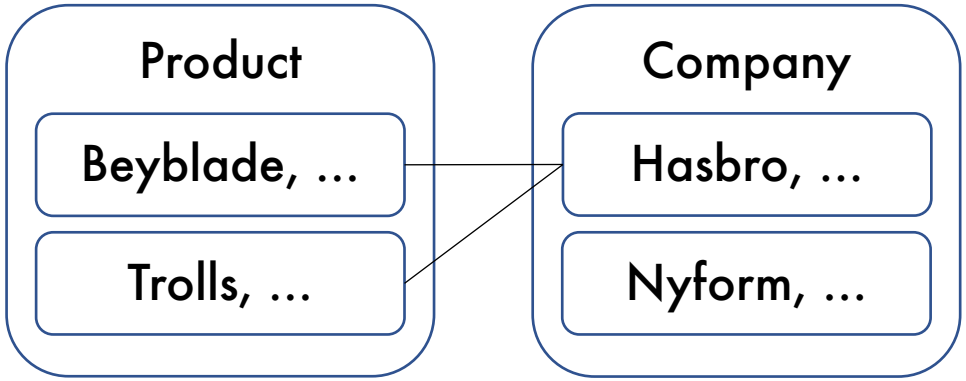
Relation Multiplicity

- One-to-one
- **Many-to-one**
- Many-to-many



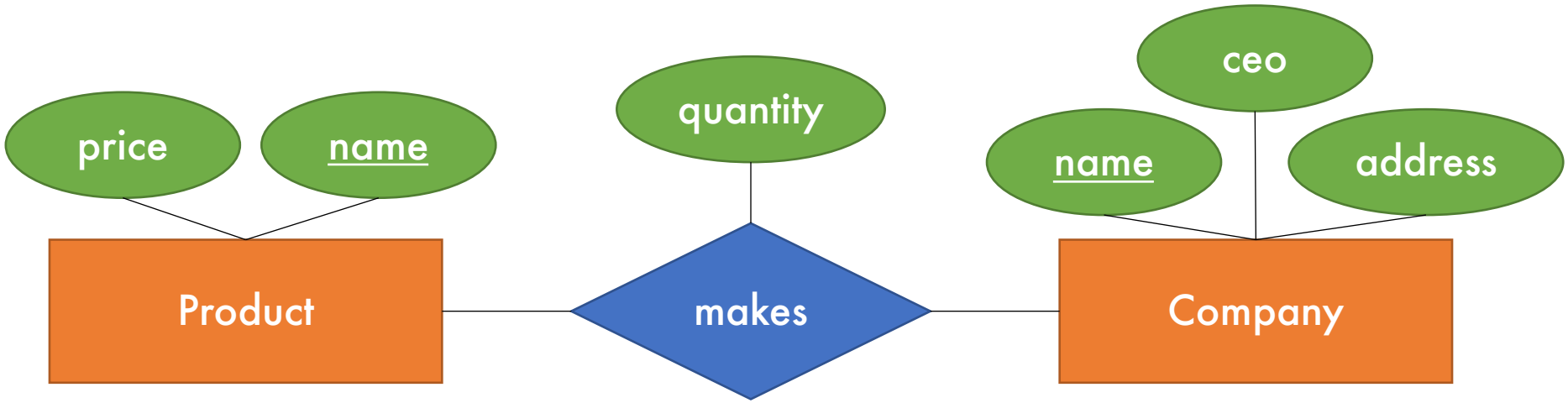
```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100)
      REFERENCES Company
    ...);
```

Foreign key alone is able to encode the Makes relationship



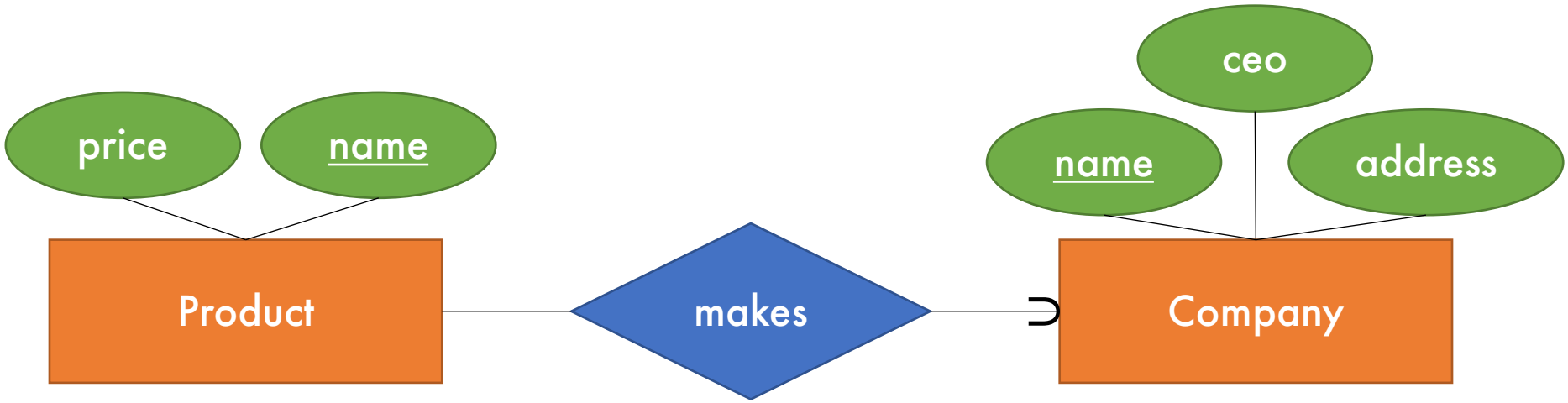
Relation Attributes

- Relations can have attributes too!



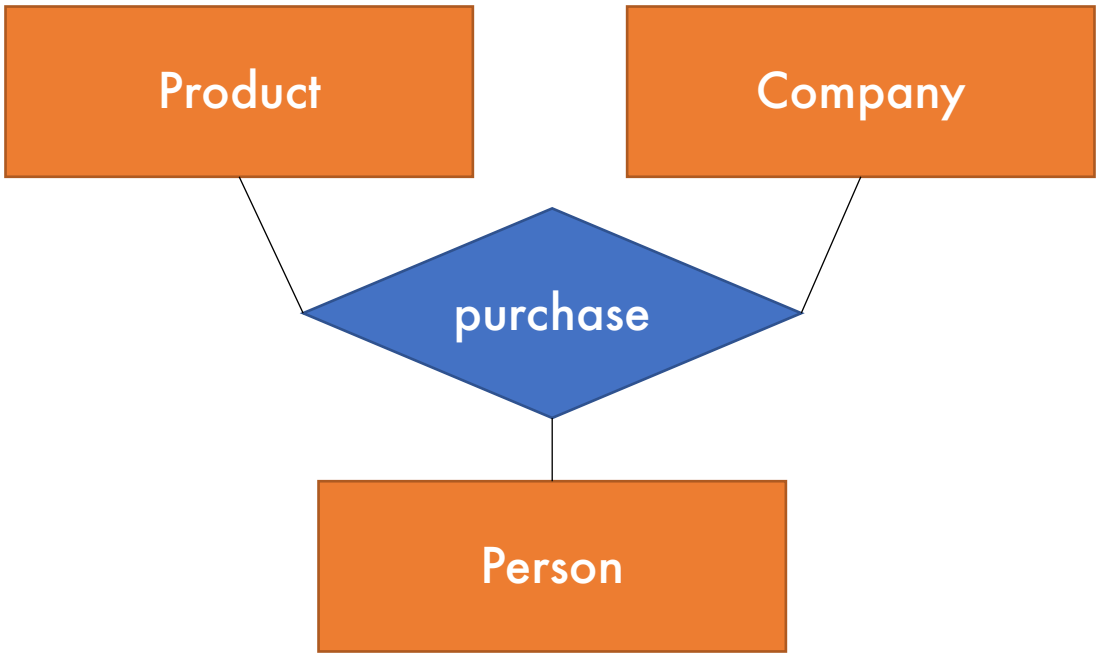
Exactly-One Reference

- Rounded arrow means the relationship is not optional (exactly one vs. at most one)

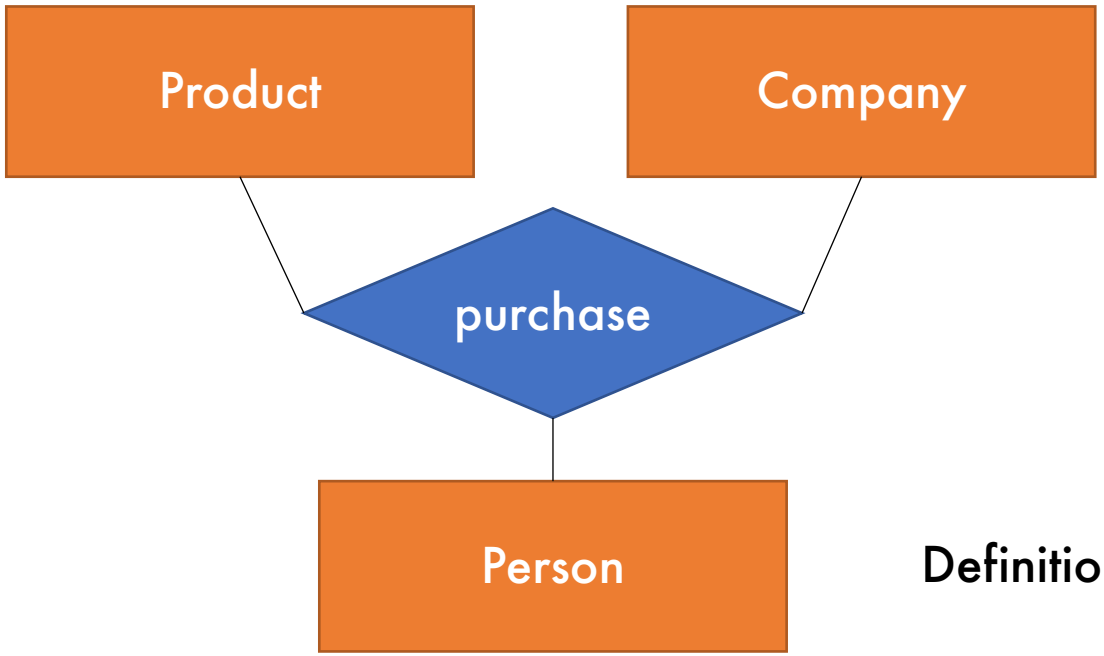



```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100) NOT NULL
      REFERENCES Company
    ...);
```

Multi-Way Relations



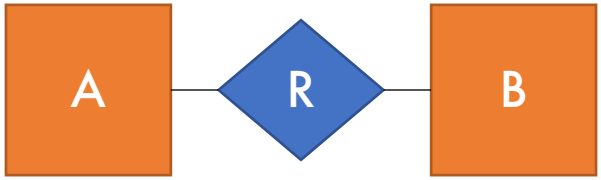
Multi-Way Relations



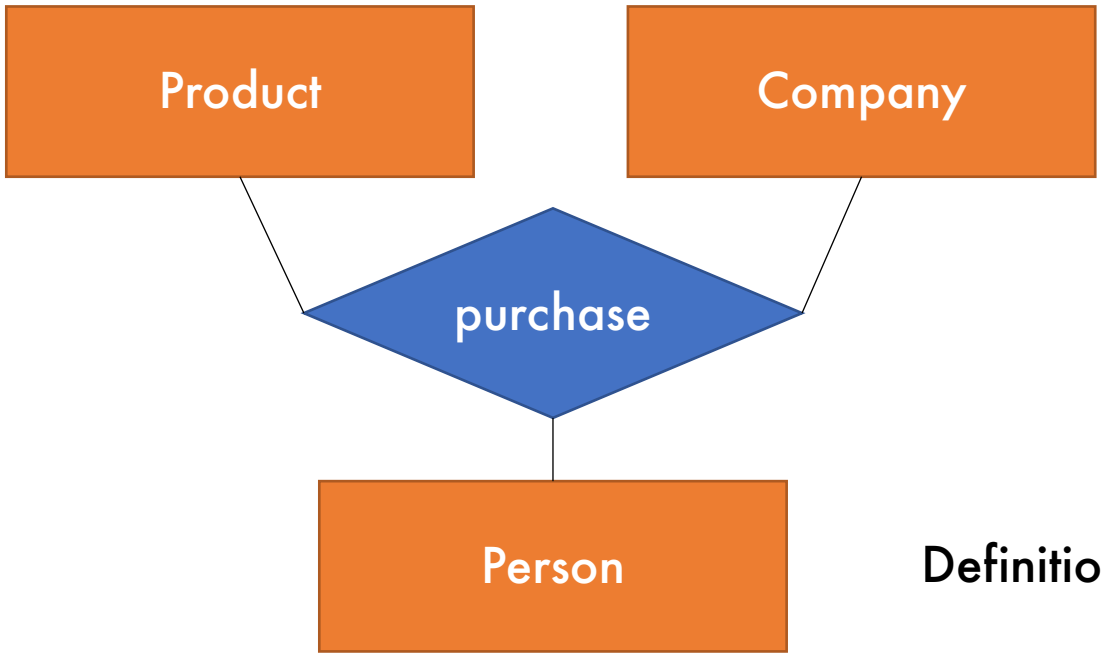
Definition of a relation generalizes!

Relationship

If A and B are sets, then a relation R is a subset of $A \times B$



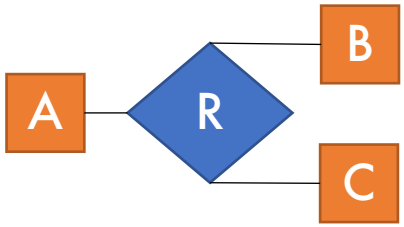
Multi-Way Relations



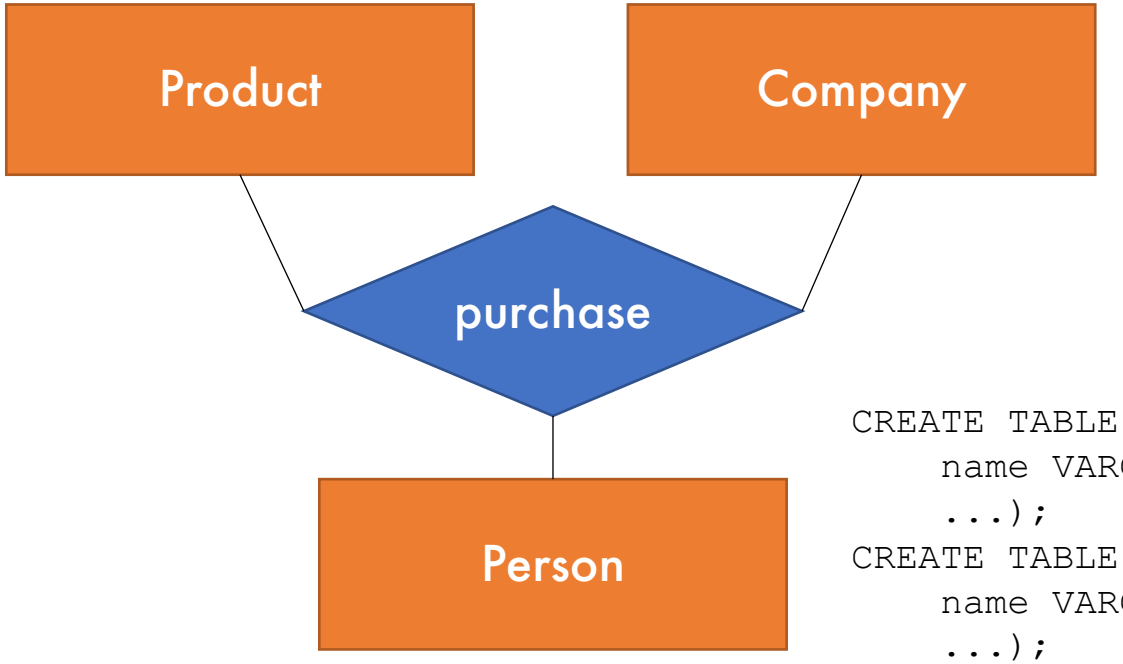
Definition of a relation generalizes!

Relationship

If A, B, and C are sets, then a relation R is a subset of $A \times B \times C$



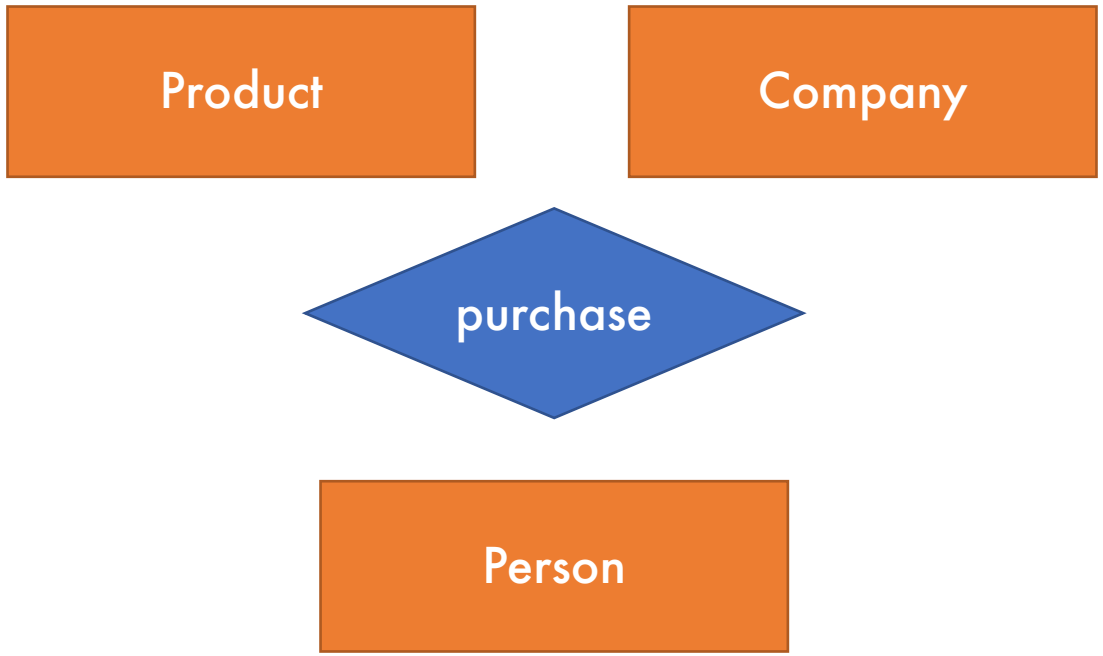
Multi-Way Relations




```
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Person (
    ssn INT PRIMARY KEY,
    ...);
CREATE TABLE Purchase (
    cname VARCHAR(100) REFERENCES Company,
    pname VARCHAR(100) REFERENCES Product,
    ssn INT REFERENCES Person,
    PRIMARY KEY (cname, pname, ssn),
    ...);
```

It's Your Turn!

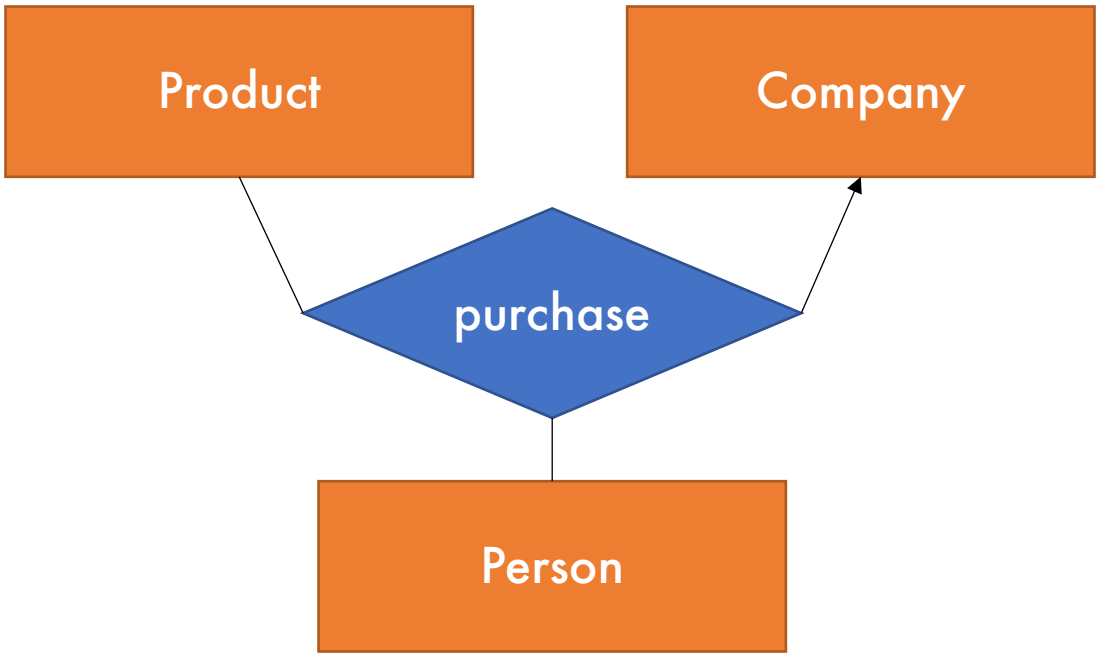
I want purchases to be such that a person will only buy each product from a single company.



How would you draw it?
Remember that the arrows read like an implication/function
Discuss!

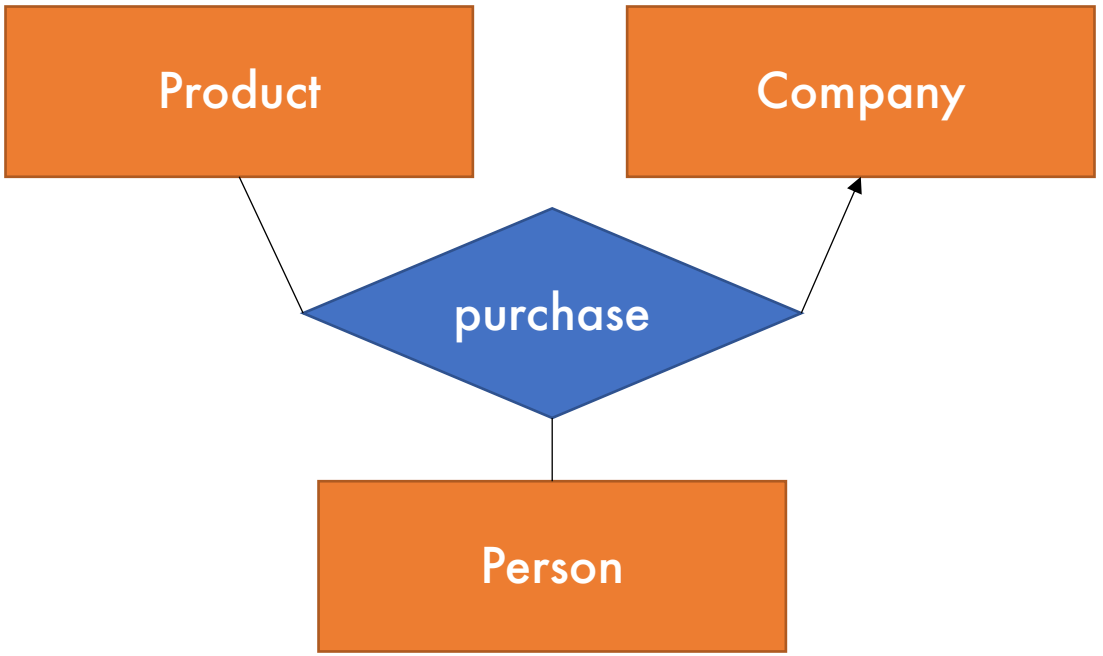
Multi-Way Relations

I want purchases to be such that a person will only buy each product from a single company.



Multi-Way Relations

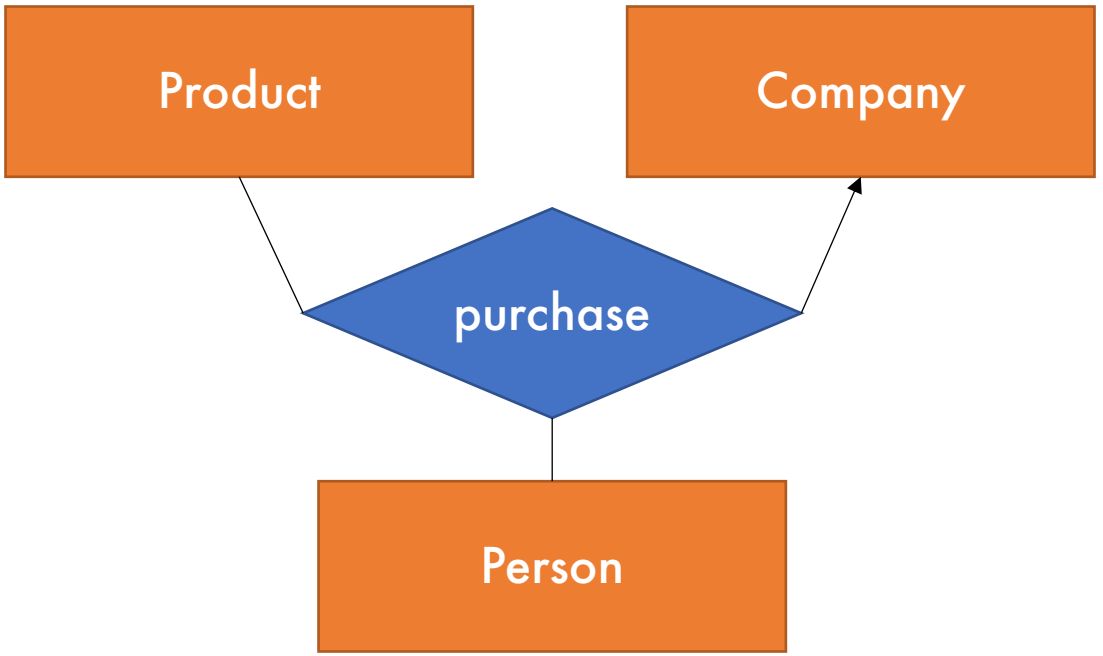
Do I need a Purchase table?



Multi-Way Relations

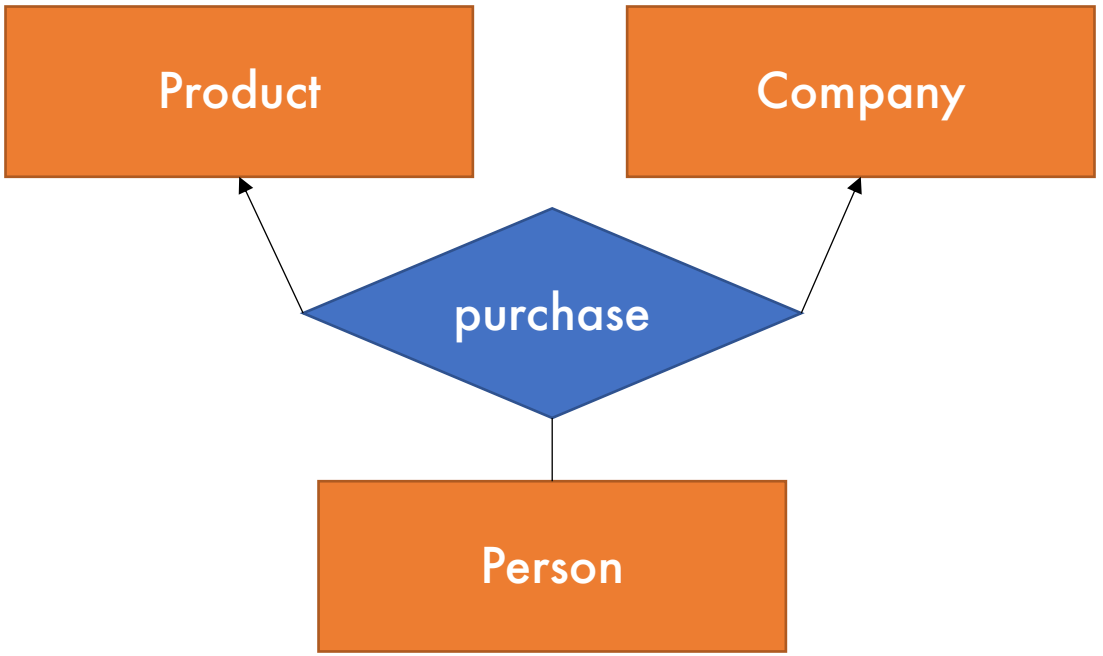
Do I need a Purchase table?

Probably a good idea



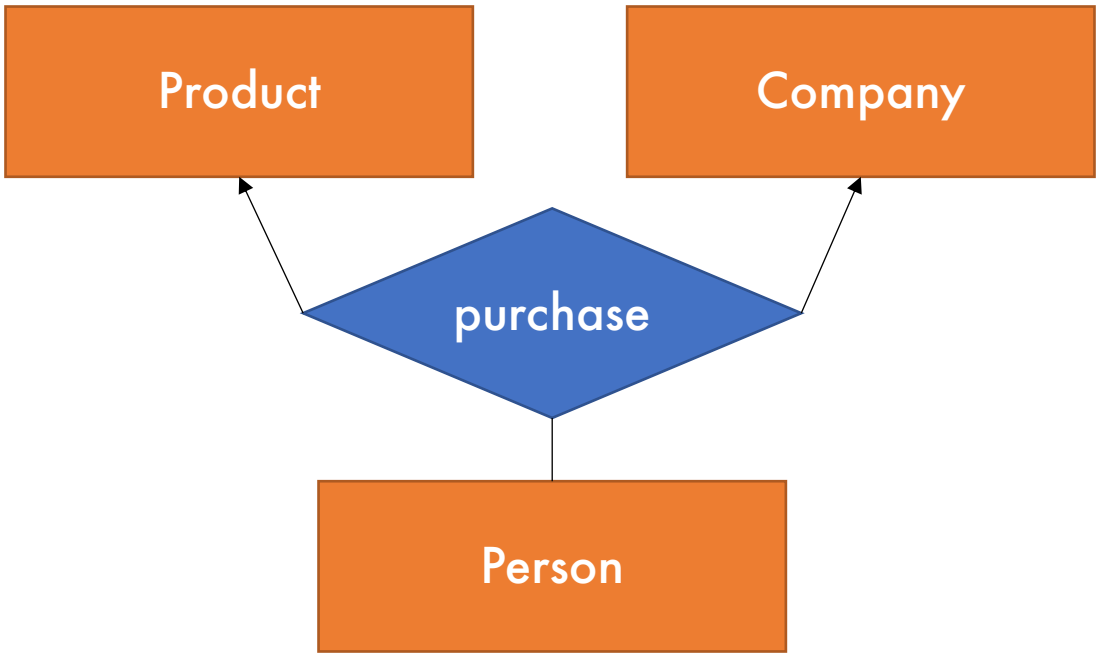
Multi-Way Relations

Now do I need a Purchase table?



Multi-Way Relations

Now do I need a Purchase table?
Nah



Rules of Thumb in Database Design

Design Principles (common sense):

- Pick the right entities
- Don't over complicate things
- **Follow the application spec**

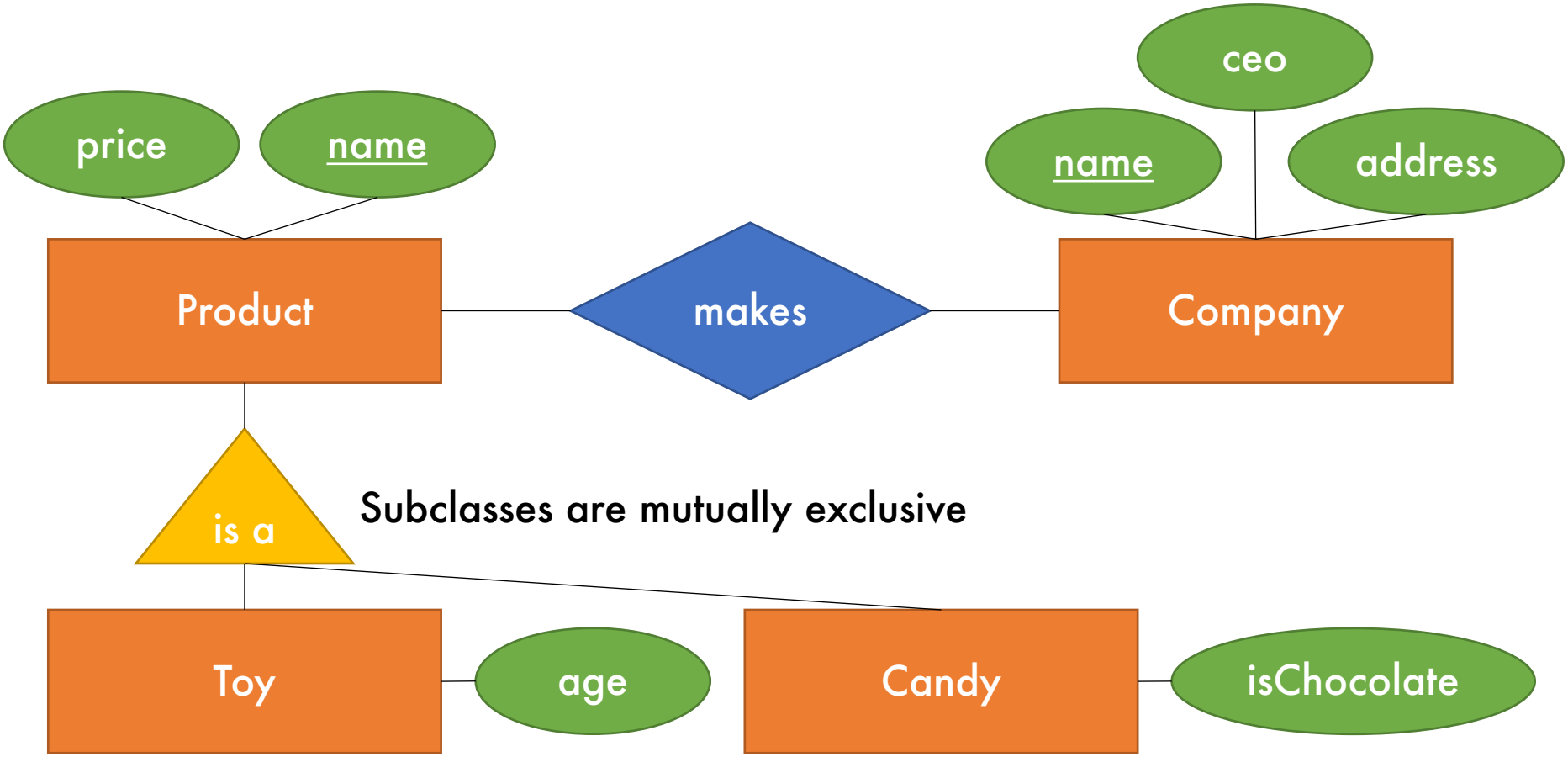
Weak Entity Set

- A weak entity set has a key that is from another entity set

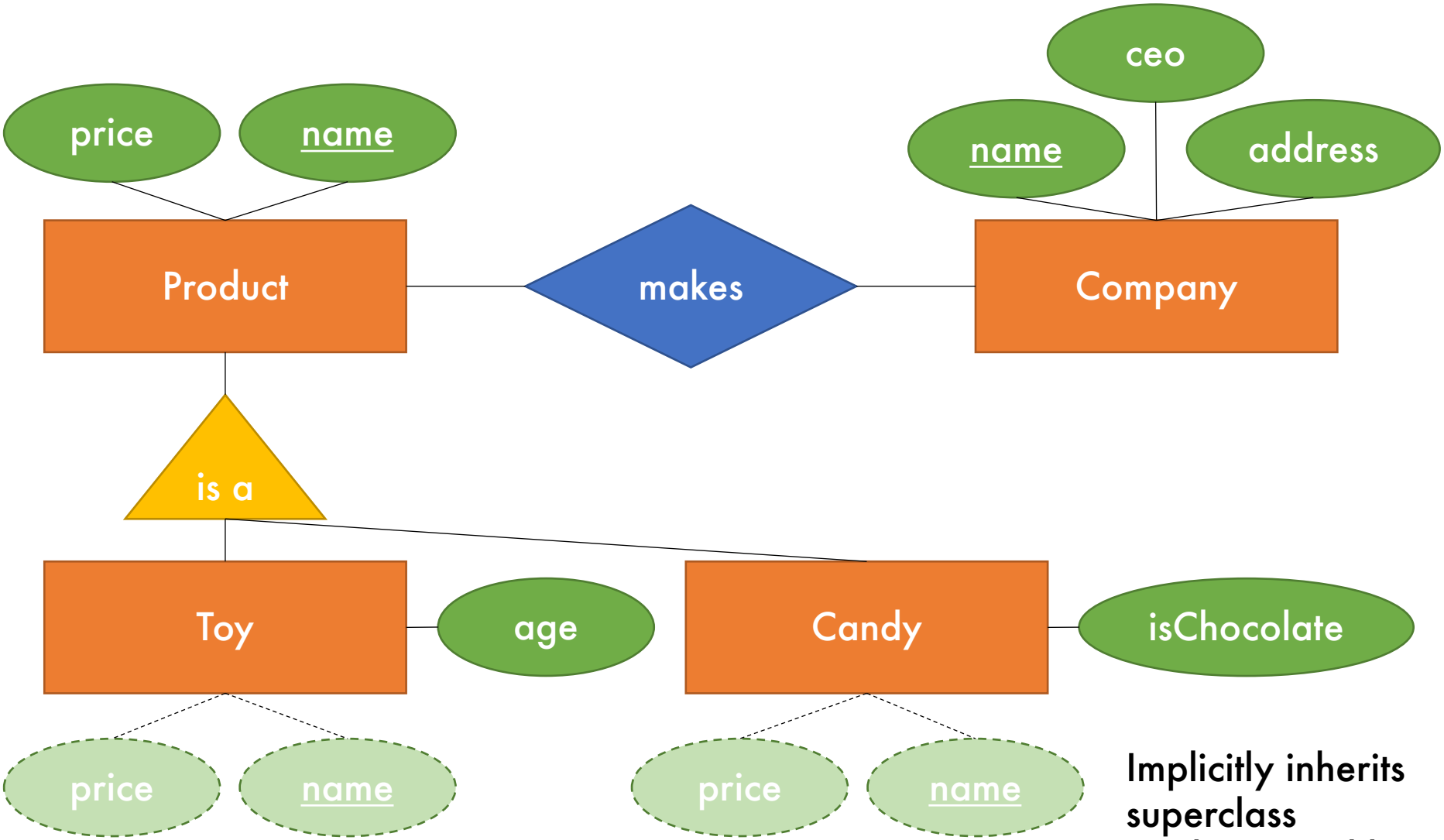
University(size, <u>name</u>)
Team(sport, <u>name</u>, <u>uname</u>)

Subclassing

- Distinguish special entities in an entity set
- Mimics heuristics in object oriented programming

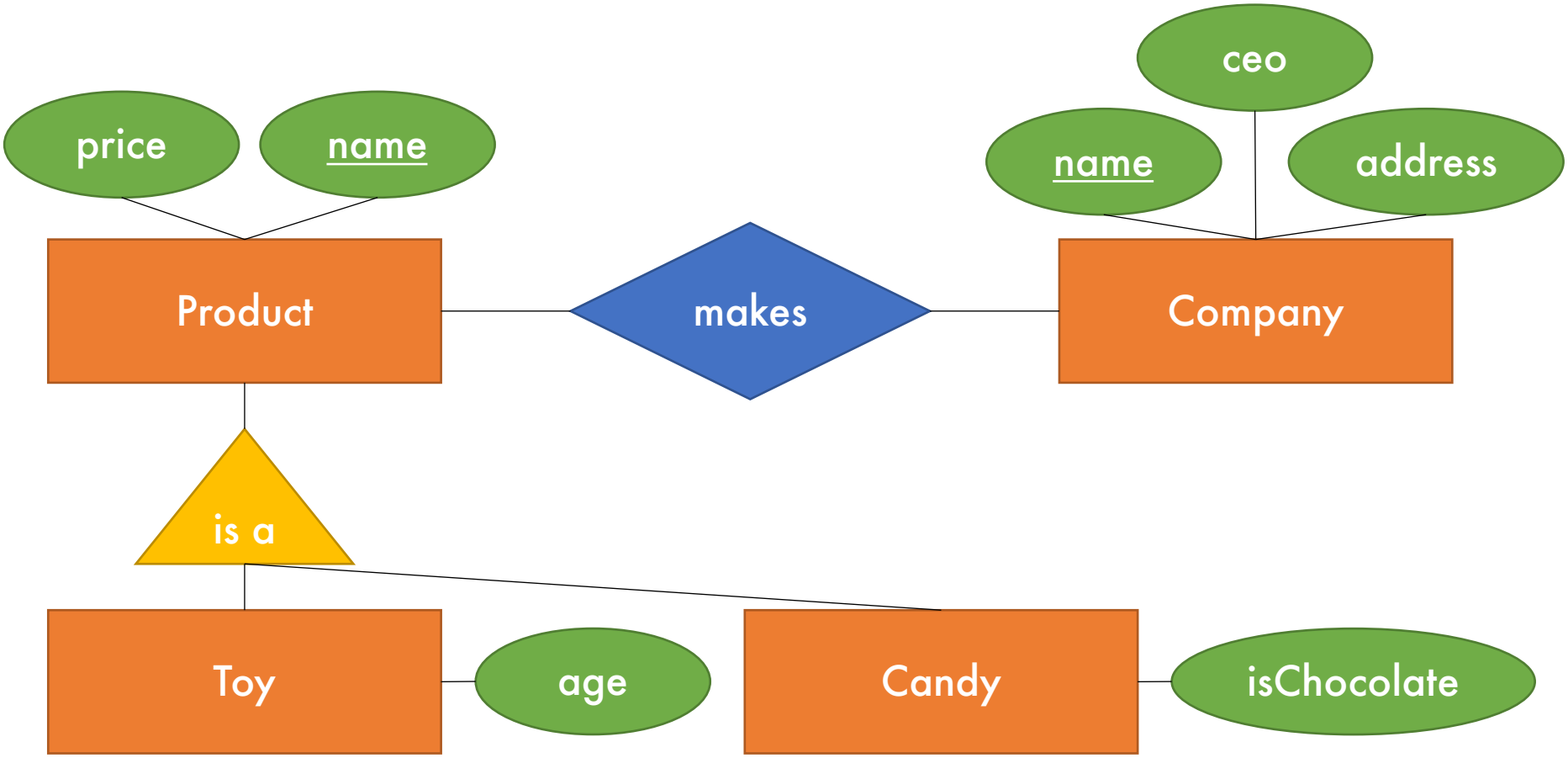


Subclassing



Implicitly inherits superclass attributes and key

Subclassing

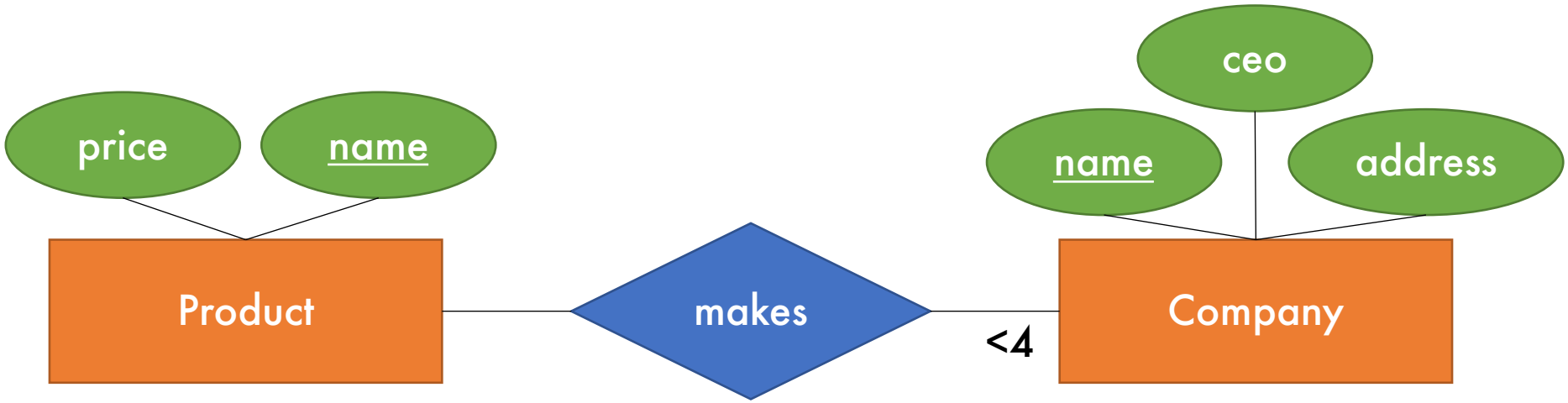


Company(…)
Makes(…)
Product(price, name)

Toy(name, age)
Candy(name, isChocolate)

Misc Constraints

- Normal arrows are shorthand versions of (<=1)
- Rounded arrows are shorthand versions of (=1)



Each product can be made by, at most, 3 companies

Other Constraints

- `CHECK (condition)`
  - **Single attribute**
  - **Single tuples**

```
CREATE TABLE User (
    uid INT PRIMARY KEY,
    firstName TEXT,
    lastName TEXT,
    age INT CHECK (age > 12 AND age < 120),
    email TEXT,
    phone TEXT,
    CHECK (email IS NOT NULL OR phone IS NOT NULL)
);
```

Referential Constraint Maintenance

`ON UPDATE/ON DELETE`

- `NO ACTION` → (default) error out
- `CASCADE` → update/delete referencers
- `SET NULL` → set referencers' field to NULL
- `SET DEFAULT` → set referencers' field to default
  - Assumes default was set, e.g.

```
CREATE TABLE Table (
   id INT DEFAULT 42 REFERENCES OtherTable,
   ...
);
```

Referential Constraint Maintenance

```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100)
      REFERENCES Company
      ON UPDATE CASCADE
      ON DELETE SET NULL);
```

Company

name
Hasbro
Nyform

Product

name	cname
Beyblade	Hasbro
Troll	Hasbro

Referential Constraint Maintenance

```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100)
      REFERENCES Company
      ON UPDATE CASCADE
      ON DELETE SET NULL);
```

Company

name
Hasbro
Nyform

Product

name	cname
Beyblade	Hasbro
Troll	Hasbro

```
UPDATE Company
   SET name = 'lmao'
 WHERE name = 'Hasbro';
```

Referential Constraint Maintenance

```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100)
      REFERENCES Company
      ON UPDATE CASCADE
      ON DELETE SET NULL);
```

Company

name
lmao
Nyform

Product

name	cname
Beyblade	lmao
Troll	lmao

```
UPDATE Company
   SET name = 'lmao'
 WHERE name = 'Hasbro';
```

Referential Constraint Maintenance

```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100)
      REFERENCES Company
      ON UPDATE CASCADE
      ON DELETE SET NULL);
```

Company

name
lmao
Nyform

Product

name	cname
Beyblade	lmao
Troll	lmao

```
DELETE FROM Company
 WHERE name = 'lmao';
```

Referential Constraint Maintenance

```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY KEY,
    cname VARCHAR(100)
      REFERENCES Company
      ON UPDATE CASCADE
      ON DELETE SET NULL);
```

Company

name
Nyform

Product

name	cname
Beyblade	NULL
Troll	NULL

```
DELETE FROM Company
 WHERE name = 'lmao';
```

Assertions

- Hard to support
- Usually impractical
- Usually not supported
  - Simulated with triggers

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

Triggers

- Triggers activate on a specified event

```
CREATE TRIGGER LowCredit ON Purchasing.PurchaseOrderHeader
AFTER INSERT AS
  IF (ROWCOUNT_BIG() = 0) RETURN;
  IF EXISTS (SELECT *
             FROM Purchasing.PurchaseOrderHeader AS p
             JOIN inserted AS i
             ON p.PurchaseOrderID = i.PurchaseOrderID
             JOIN Purchasing.Vendor AS v
             ON v.BusinessEntityID = p.VendorID
             WHERE v.CreditRating = 5
            )
    BEGIN
      RAISERROR ('A vendor''s credit rating is too
                  low to accept new purchase orders.', 16, 1);
      ROLLBACK TRANSACTION;
      RETURN
    END;
GO
```

= you don't need to study this for the class

Takeaways

- ER diagrams can sketch out **high-level designs**
- Certain rules of thumb for ER-to-SQL conversions help **preserve design semantics**
- SQL allows you to make **rules specific to your application**