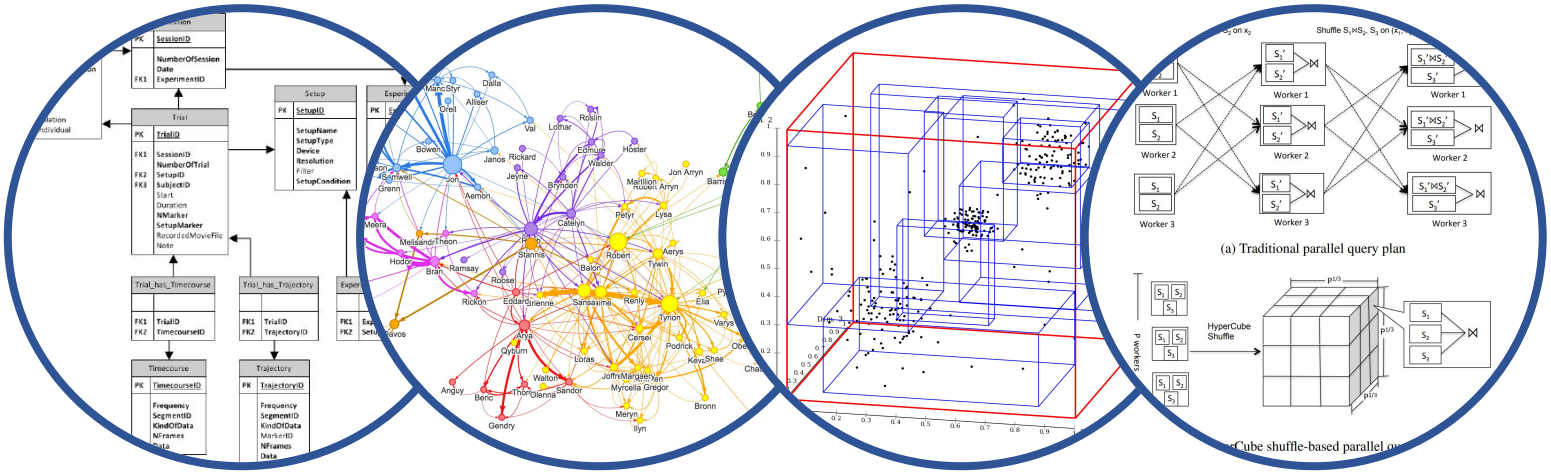


Introduction to Data Management

Entity Relationship Diagrams

Alyssa Pittman
Based on slides by Jonathan Leang, Dan Suciu, et al

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

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

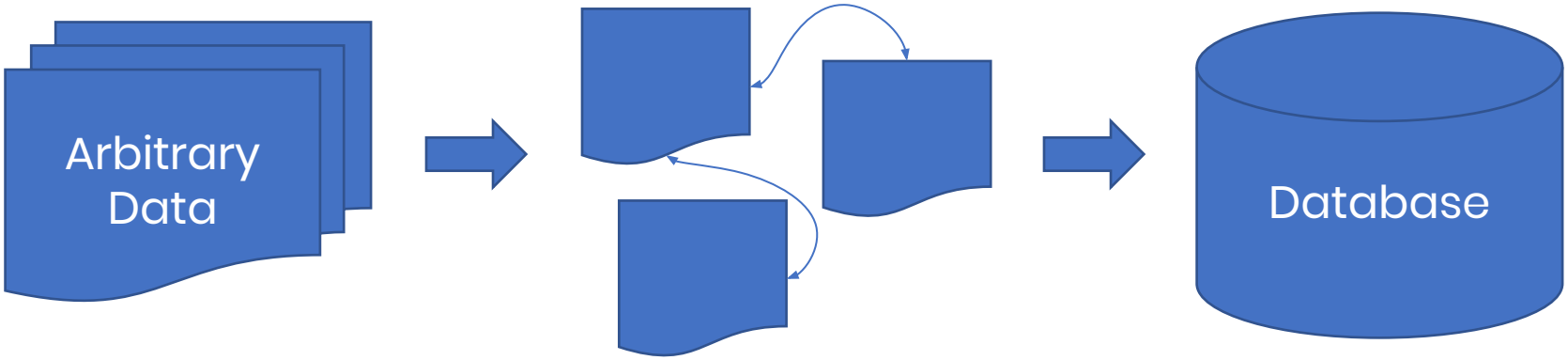
Outline

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

Database Design

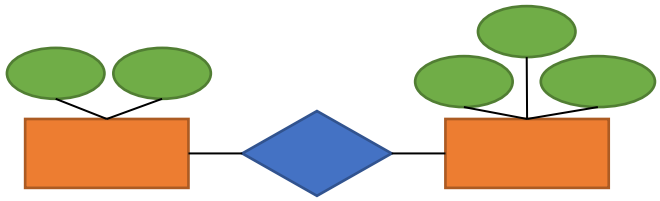
Database Design

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.

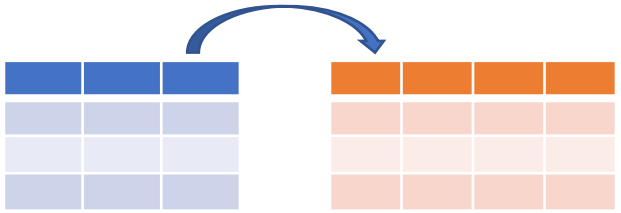


The Database Design Process

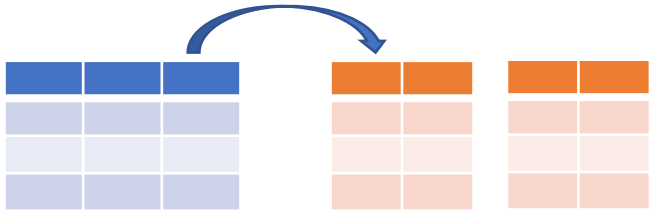
Conceptual Model



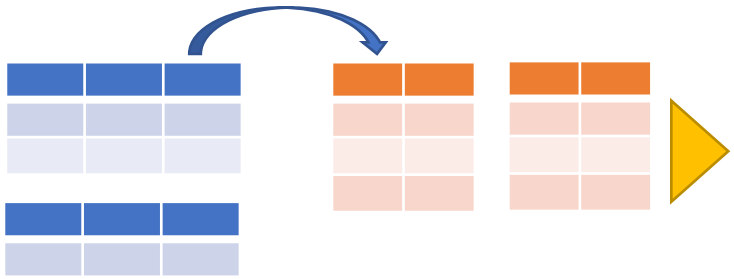
Relational Model
- + Schema
- + Constraints



Conceptual Schema
- + Normalization



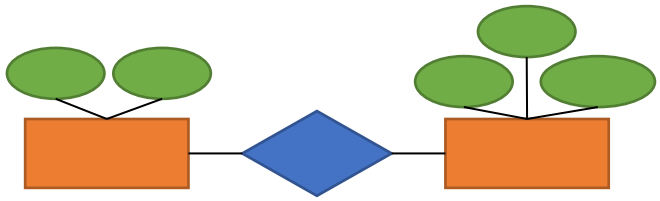
Physical Schema
- + Partitioning
- + Indexing



The Database Design Process

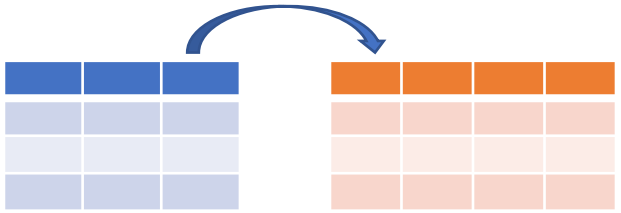
Today

Conceptual Model



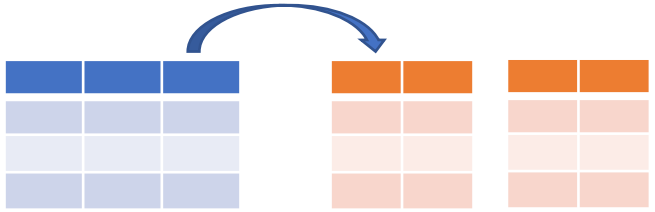
Relational Model

- + Schema
- + Constraints



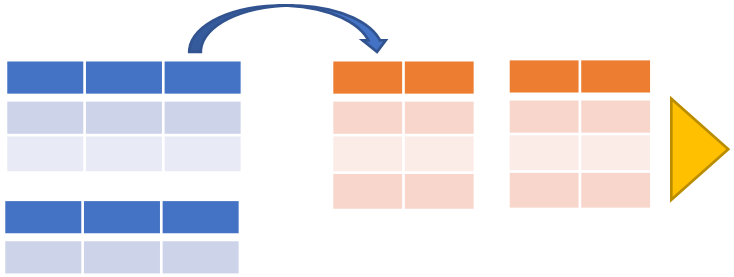
Conceptual Schema

- + Normalization



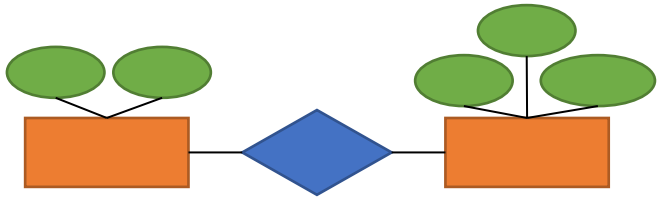
Physical Schema

- + Partitioning
- + Indexing



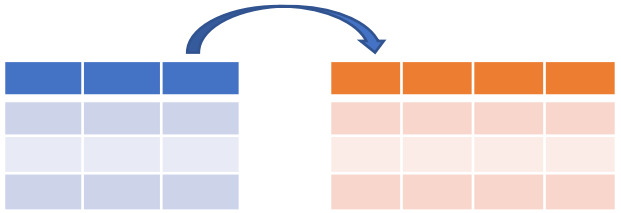
The Database Design Process

Conceptual Model



Relational Model

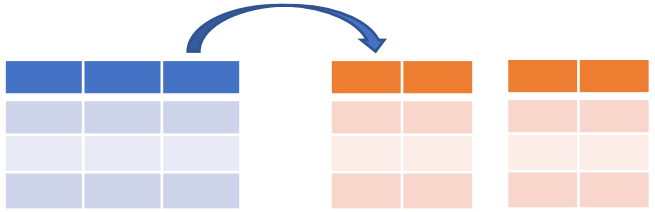
- + Schema
- + Constraints



Monday

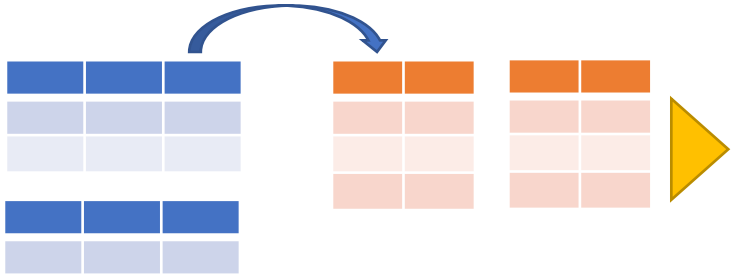
Conceptual Schema

- + Normalization



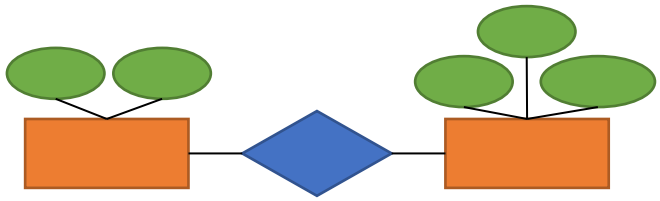
Physical Schema

- + Partitioning
- + Indexing



The Database Design Process

Conceptual Model



Relational Model
- + Schema
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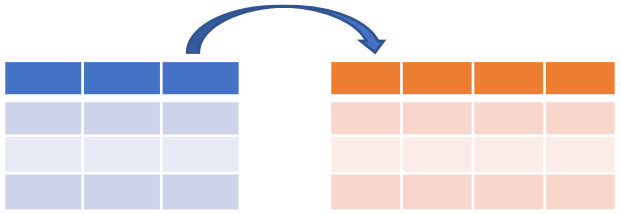
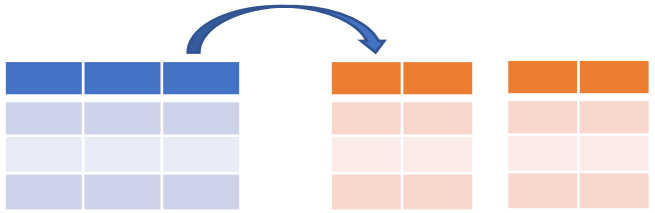
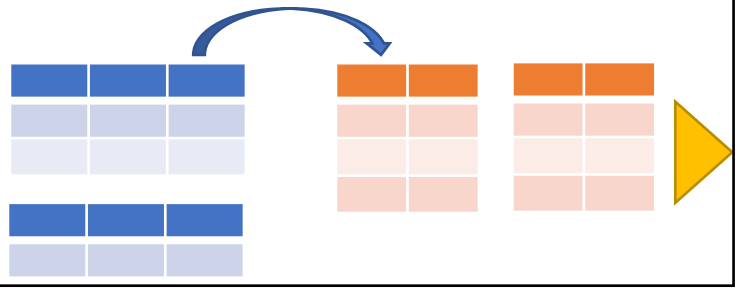


Conceptual Schema
- + Normalization



After Midterm

Physical Schema
- + Partitioning
- + Indexing



Communication is Key

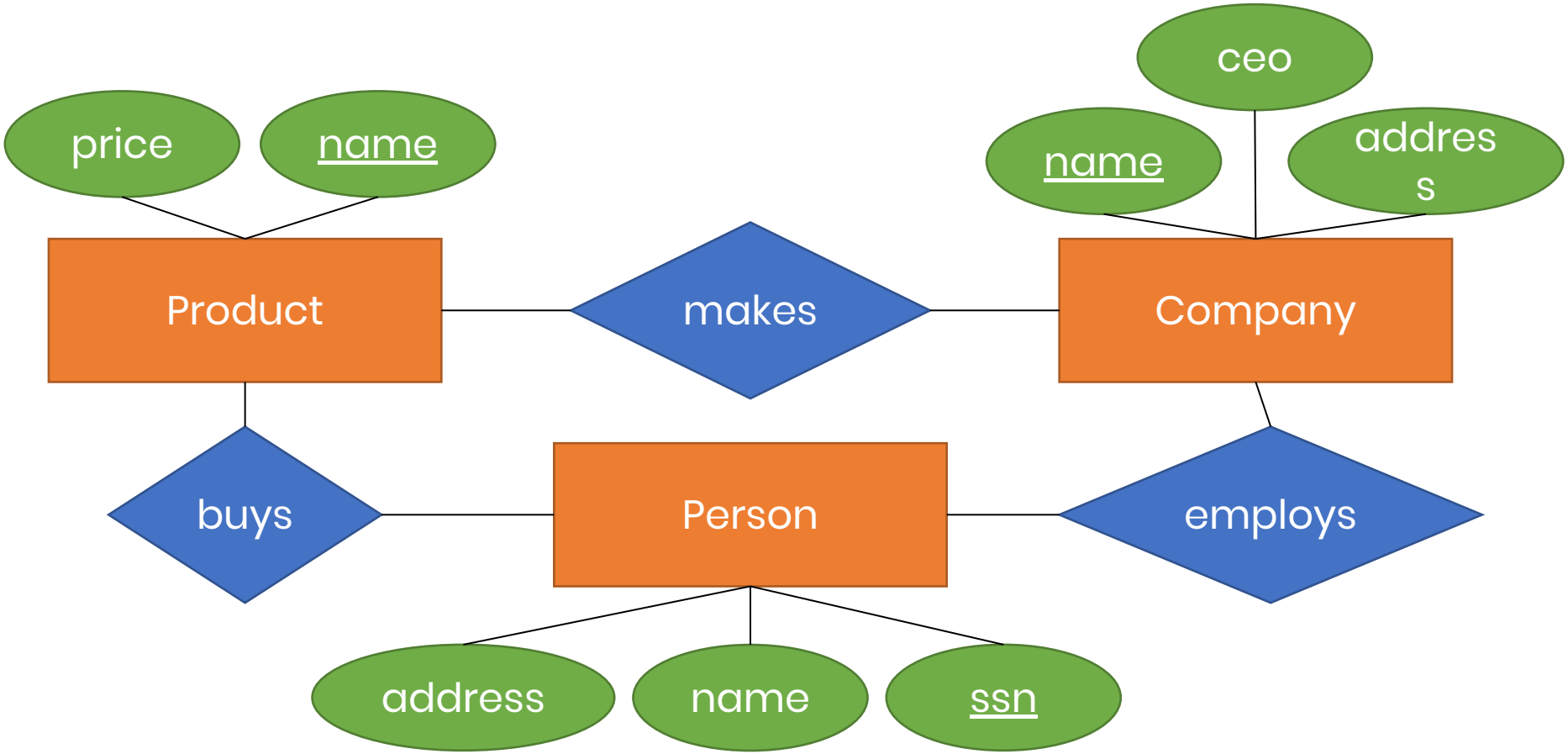
- Other people are involved in the design process
- Non-computer scientists have to interact with the data too
- Future users will also need to understand your data

The Future

- Your database might be around for years
- Updating the schema in production is expensive

ER Diagrams

- Humans tend to be visual creatures so a visual model serves us best



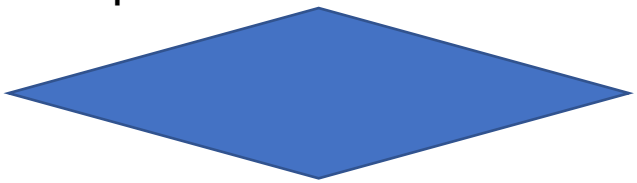
ER Diagram Building Blocks

- These are all the blocks we will learn about

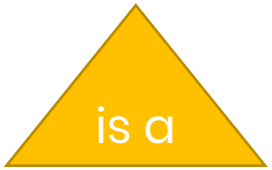
Entity set

Attribute

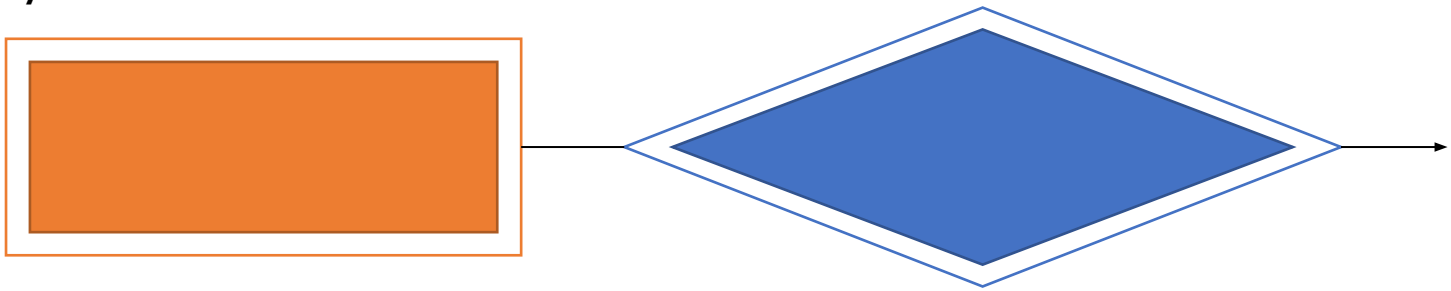
Relationship



Subclass

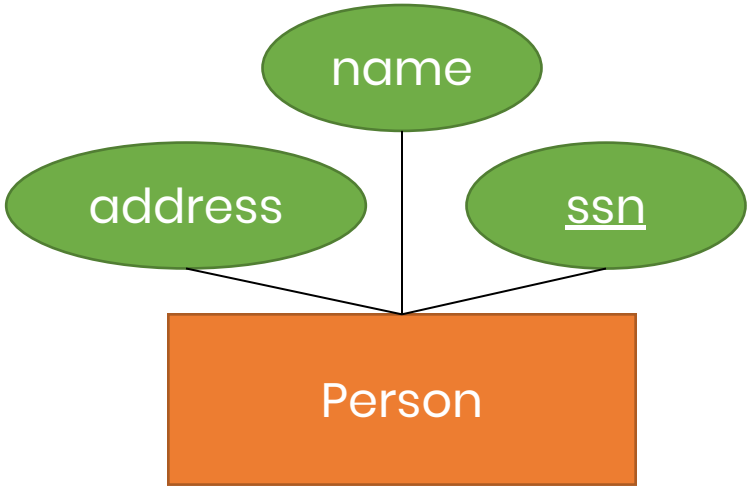


Weak Entity



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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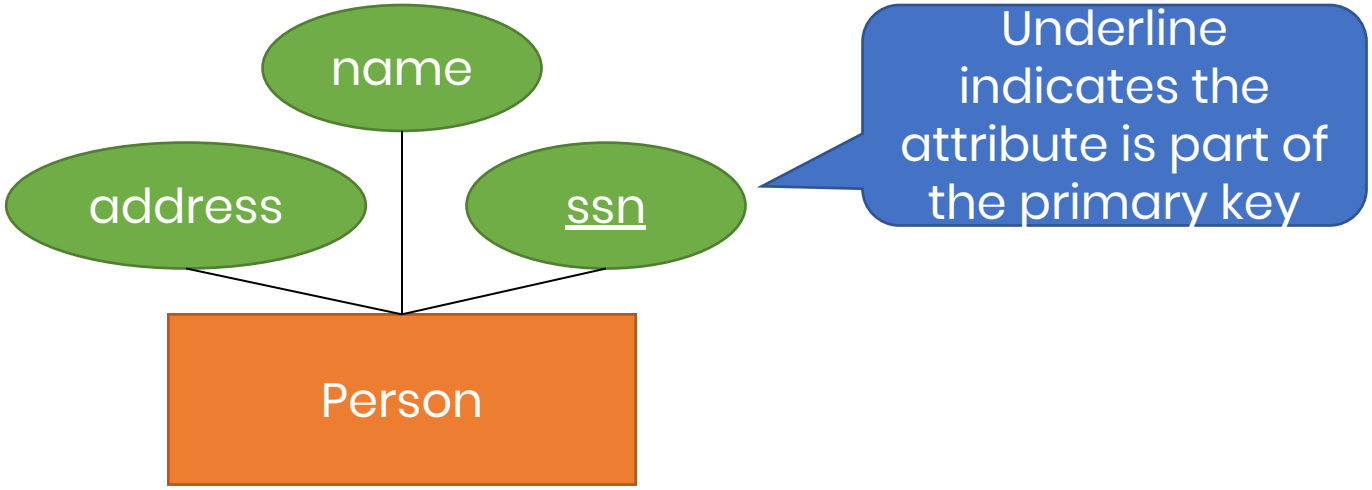

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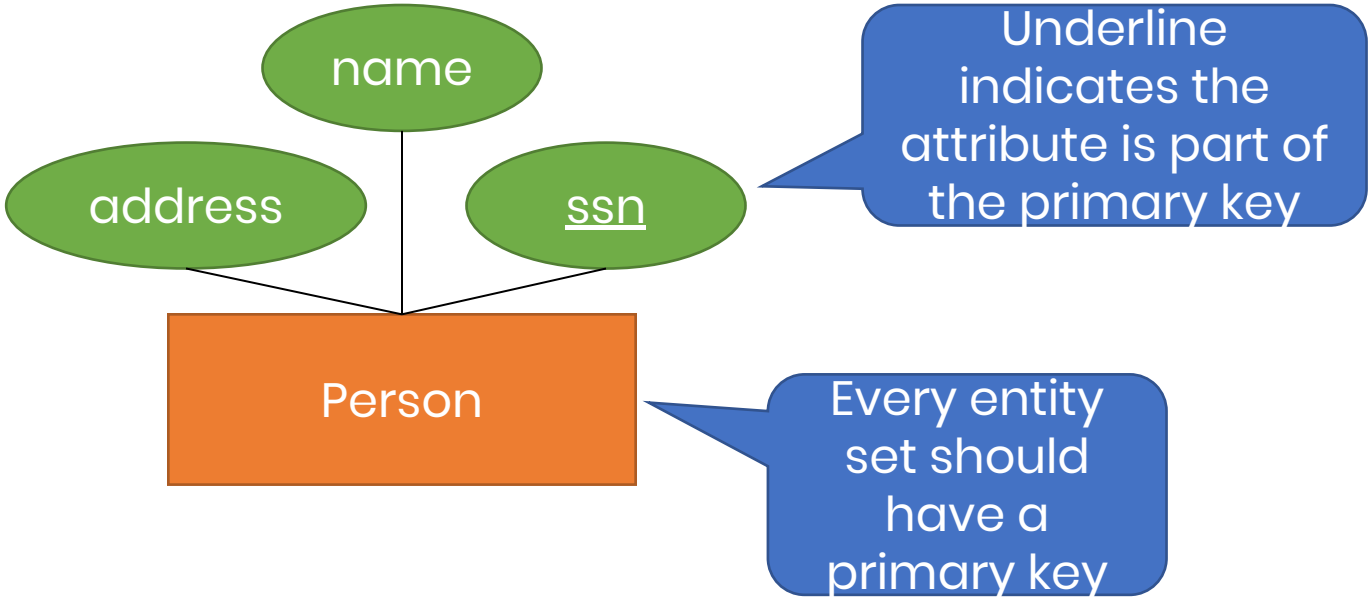

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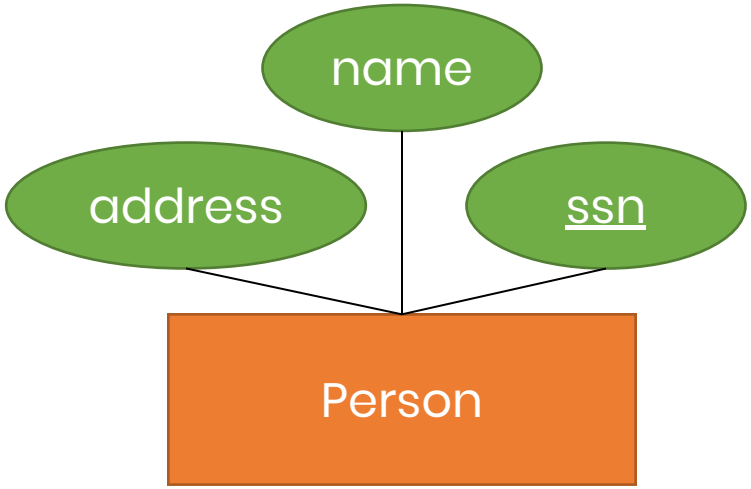



```
CREATE TABLE Person (
    ssn INT PRIMARY KEY,
    name TEXT,
    address TEXT);
```

Integrity Constraints

Integrity Constraints

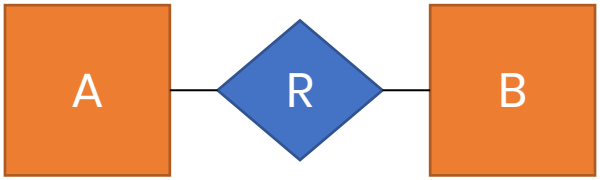
An **integrity constraint** is a condition specified on a database schema that restricts the data that can be stored in an instance of the database.

- Why?
  - Want our application data to be consistent with our design
- How?
  - The DBMS checks and enforces constraints during updates

Relations

Relationship

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



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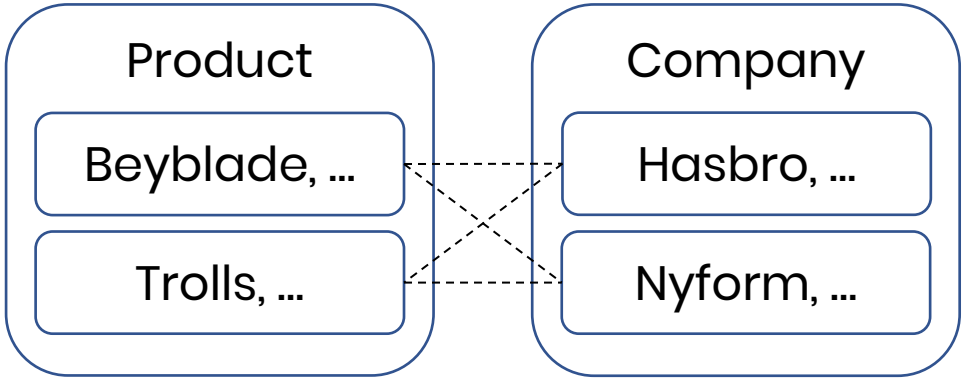

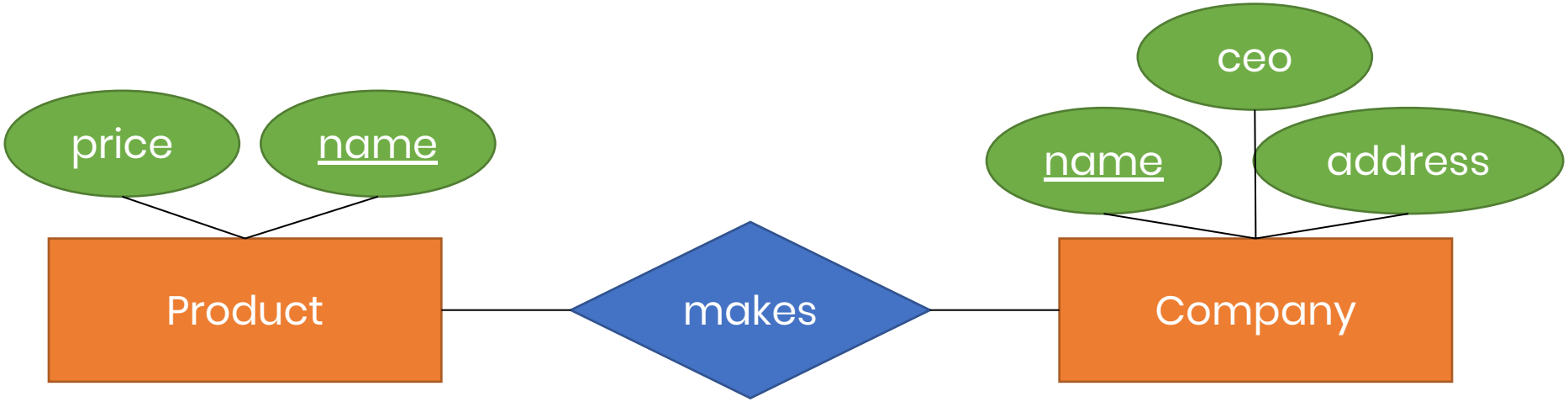

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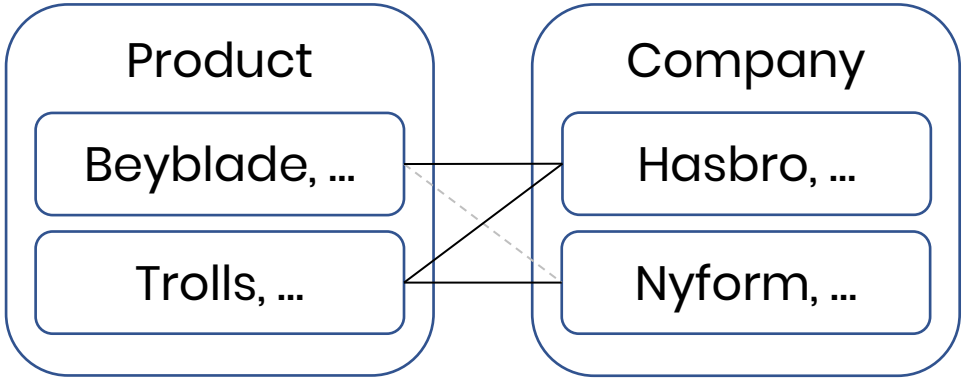
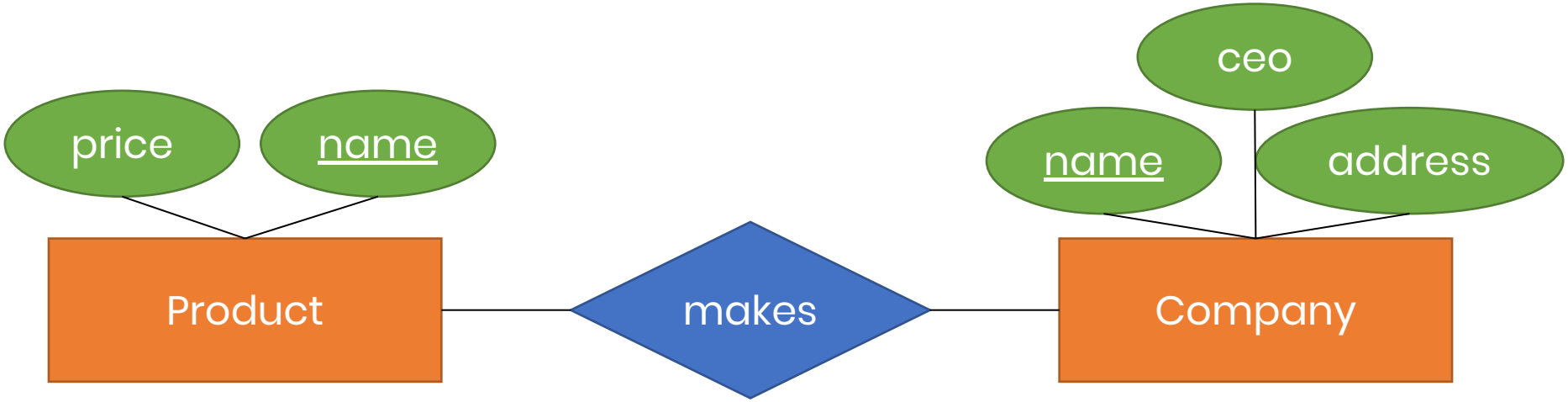
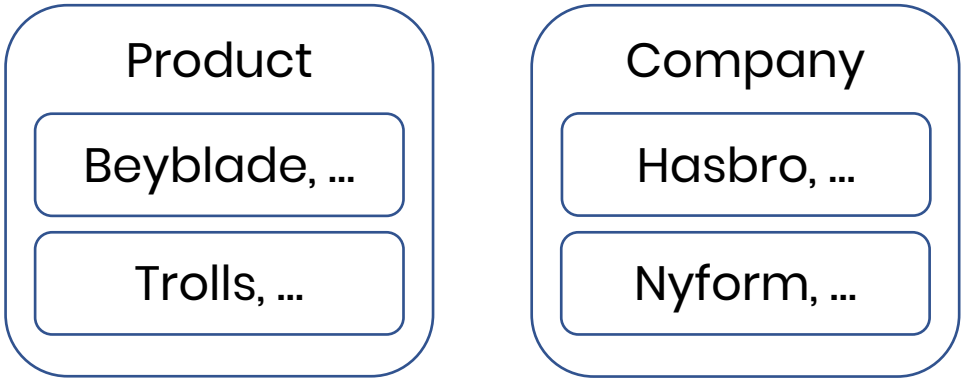




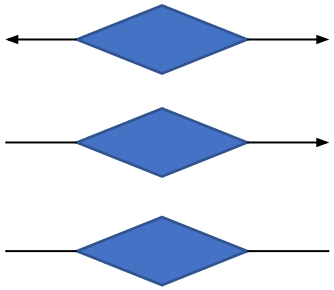
Relation Multiplicity

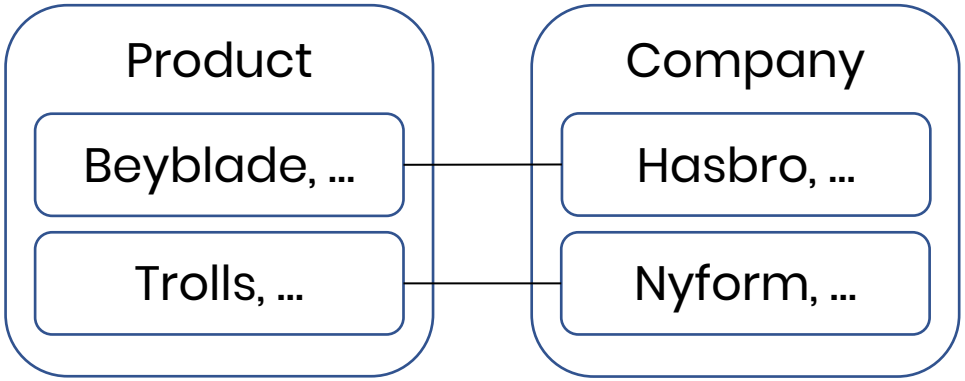
- One-to-one 
- Many-to-one 
- Many-to-many 



Relation Multiplicity

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





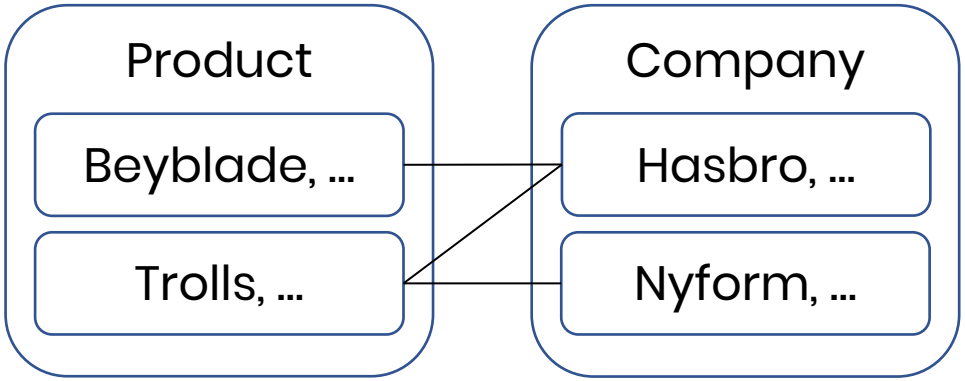
Relation Multiplicity

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

```
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** 



Relation Multiplicity

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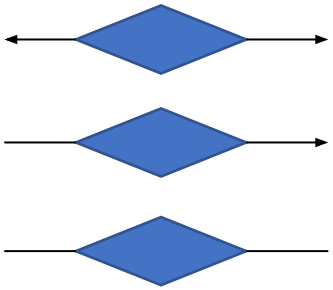
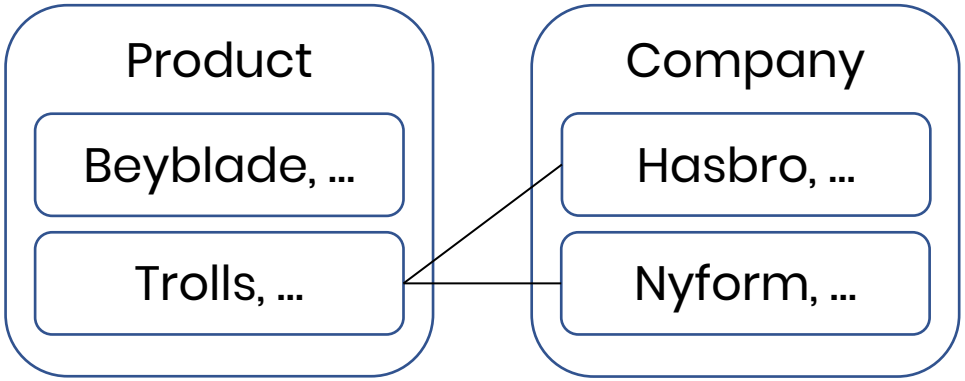
    ...);
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY KEY,
    ...);
CREATE TABLE Makes (
    cname VARCHAR(100) UNIQUE REFERENCES Company,
    pname VARCHAR(100) UNIQUE REFERENCES Product,
    PRIMARY KEY (cname, pname),
    ...);
```

Relation Multiplicity

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





Relation Multiplicity

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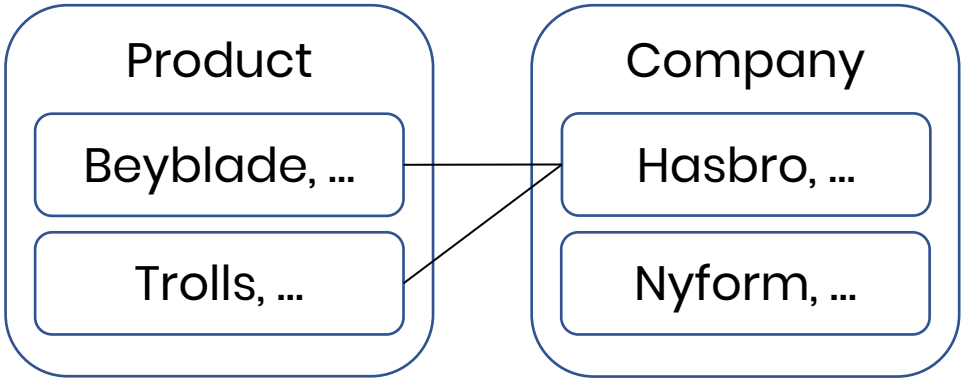
- Many-to-many 



Relation Multiplicity

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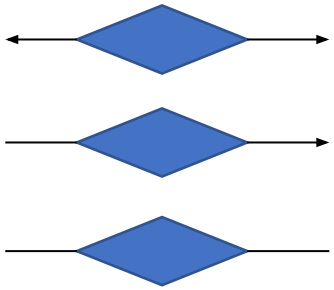
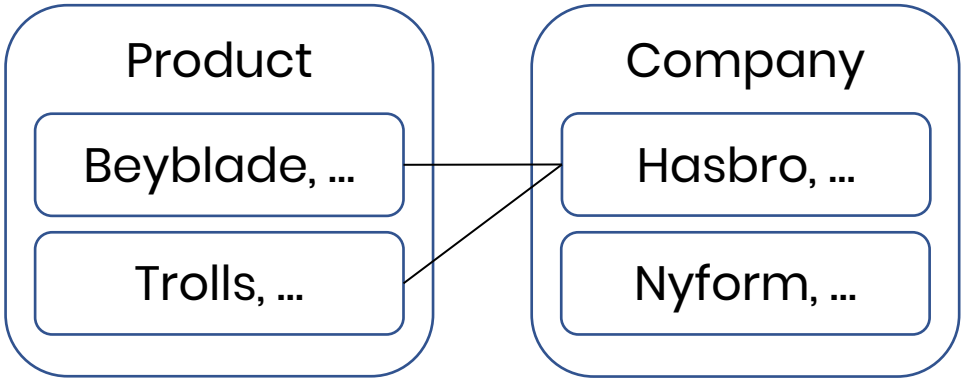


Do I need a Makes table?



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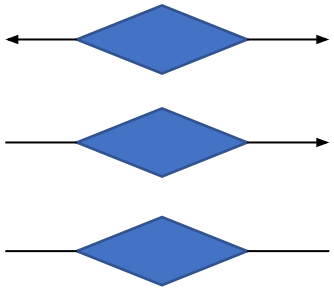
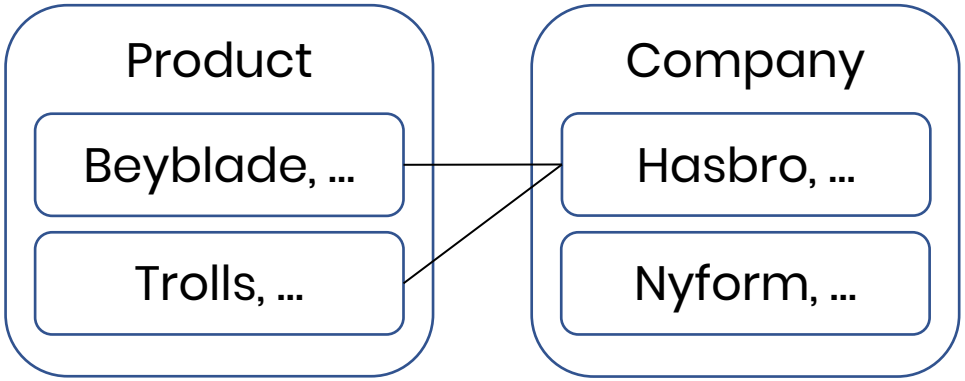


Do I need a Makes table? Key observation: In this many-to-one relationship, each company can make many products, but **each product can only be made by one company**



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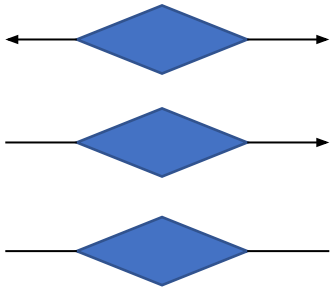

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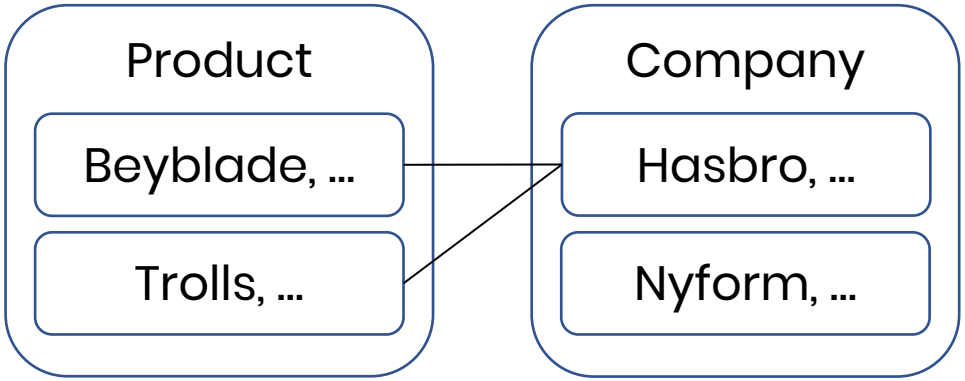
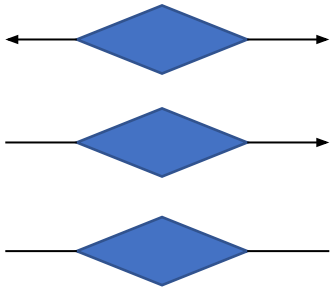


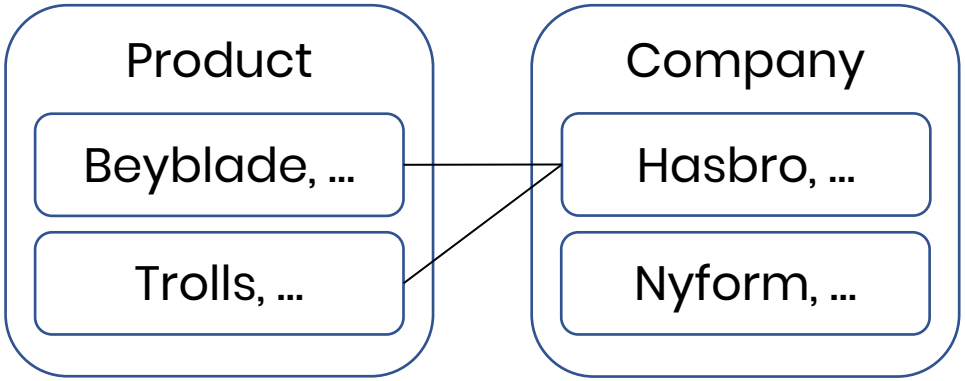
If we allow products to be made by multiple companies, we would have a many-to-many relationship

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
    ...);
```



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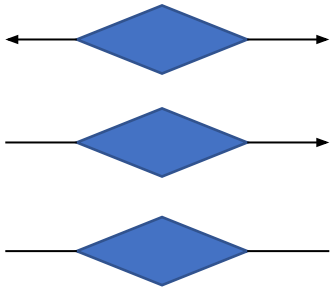

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    ...);
CREATE TABLE Product (
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KEY,
    cname VARCHAR(100)
      REFERENCES Company
    ...);
```
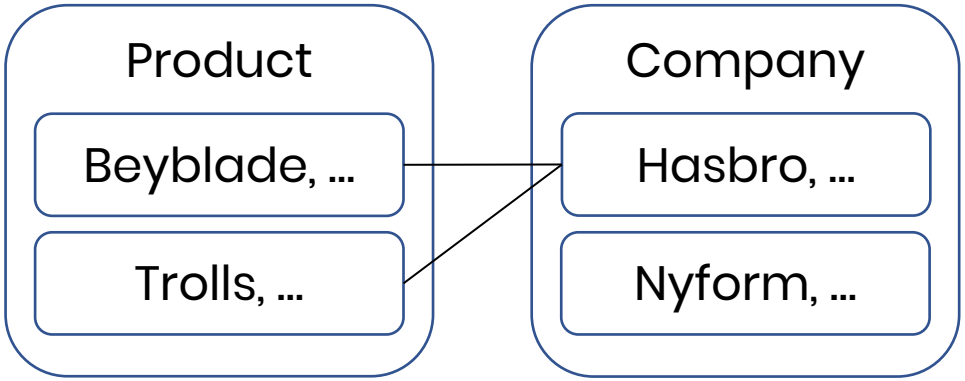
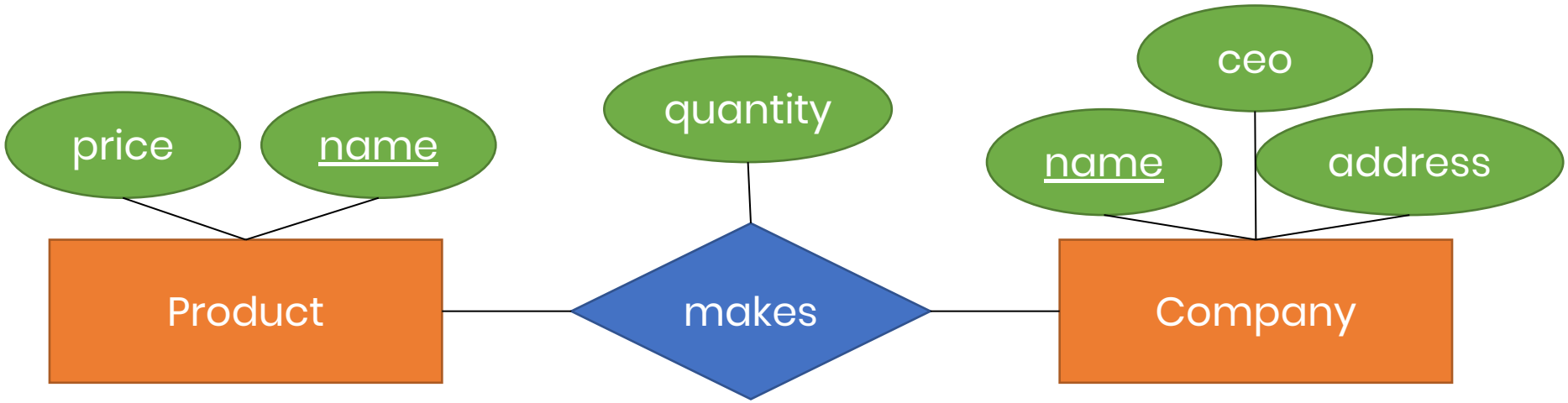

Foreign key alone is able to encode the Makes relationship



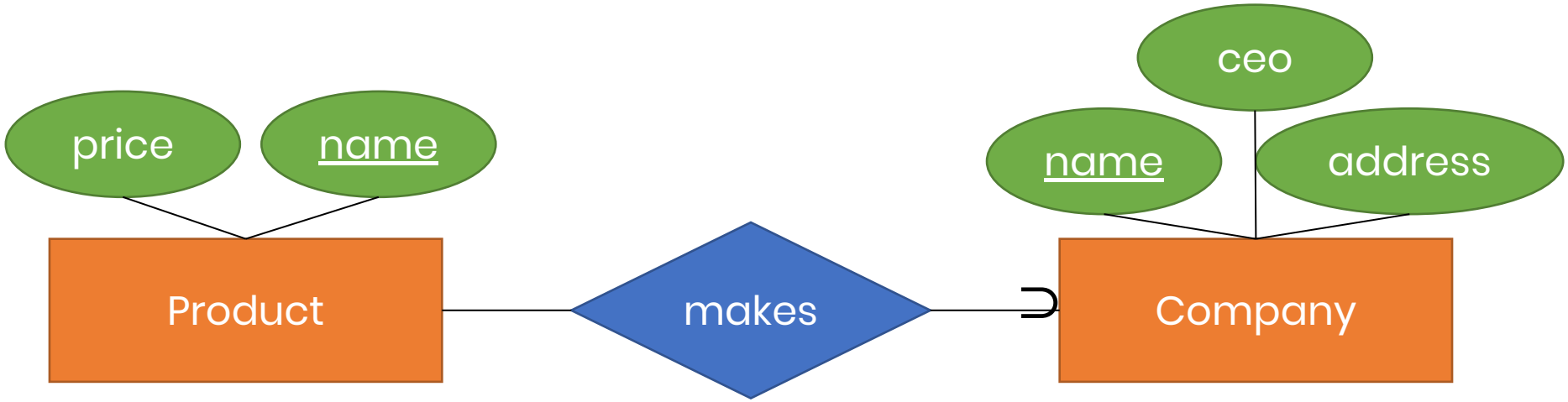
Relation Attributes

- Relations can have attributes too!



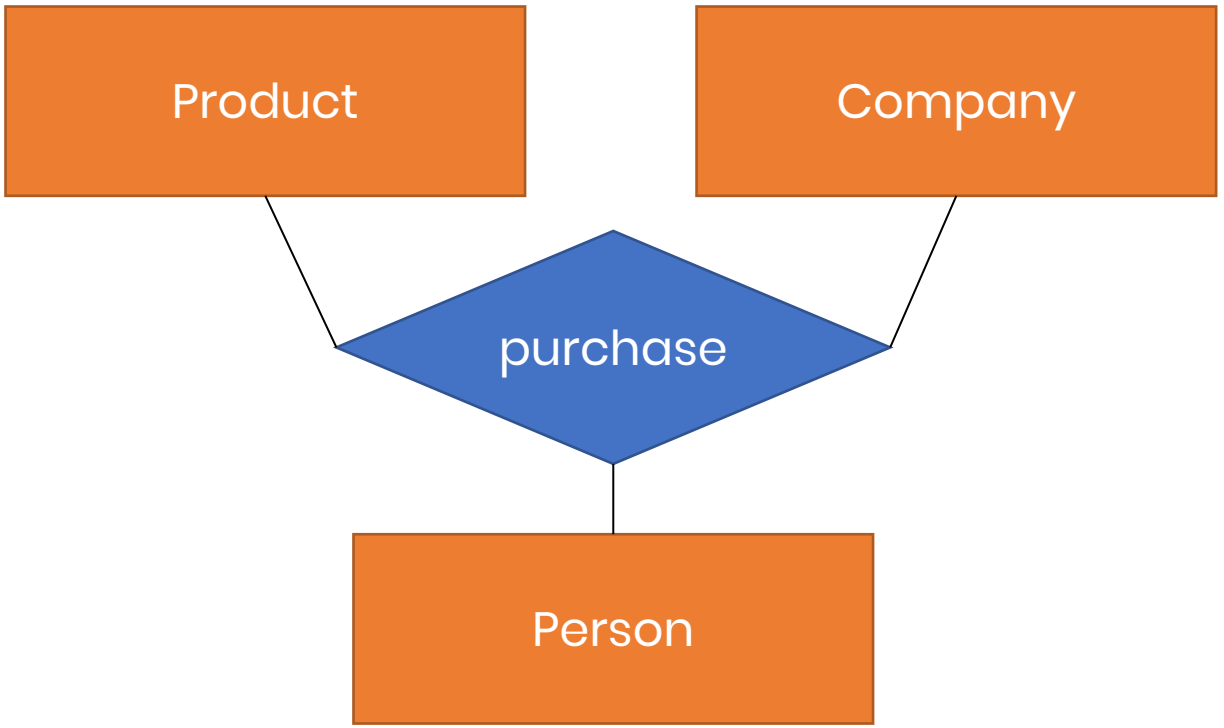
Exactly-One Reference

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

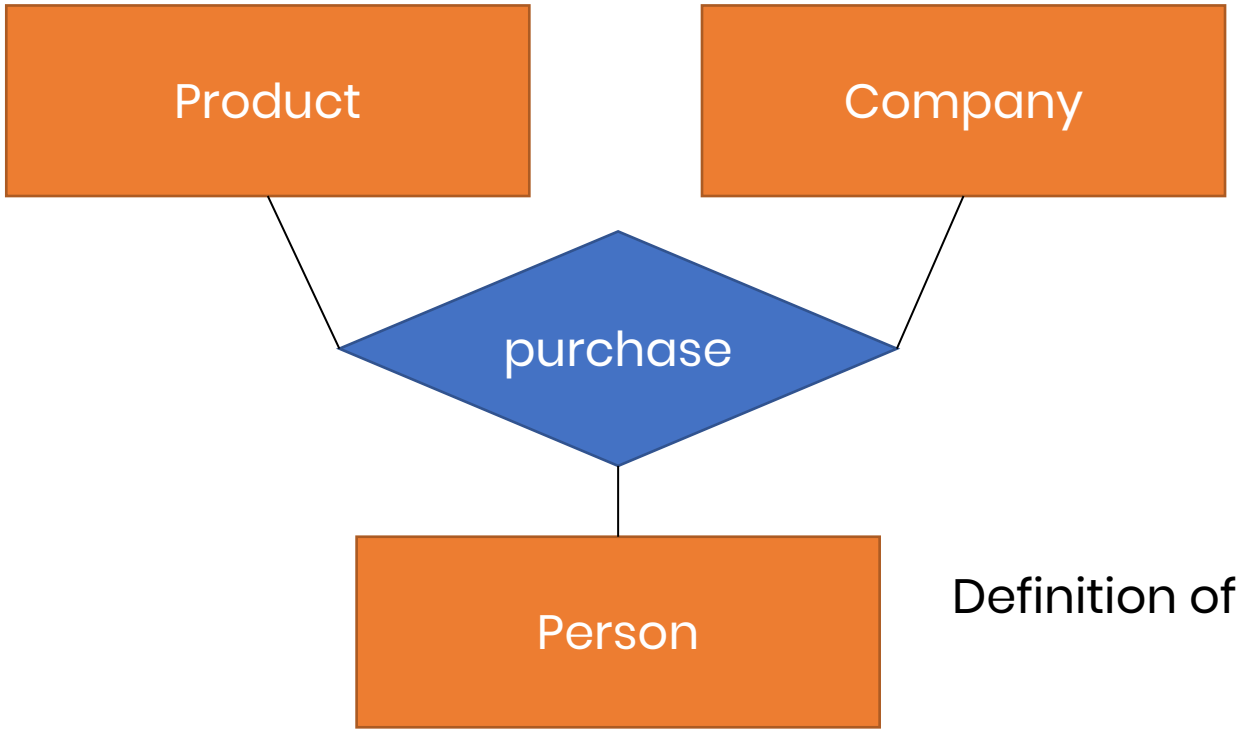



```
CREATE TABLE Company (
    name VARCHAR(100) PRIMARY
KEY,
    ...);
CREATE TABLE Product (
    name VARCHAR(100) PRIMARY
KEY,
    cname VARCHAR(100) NOT NULL
      REFERENCES Company
    ...);
```

Multi-Way Relations



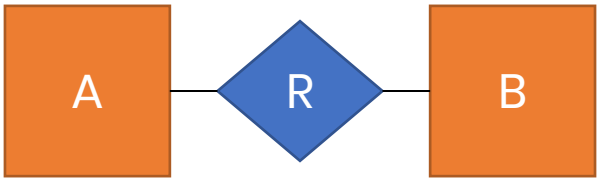
Multi-Way Relations



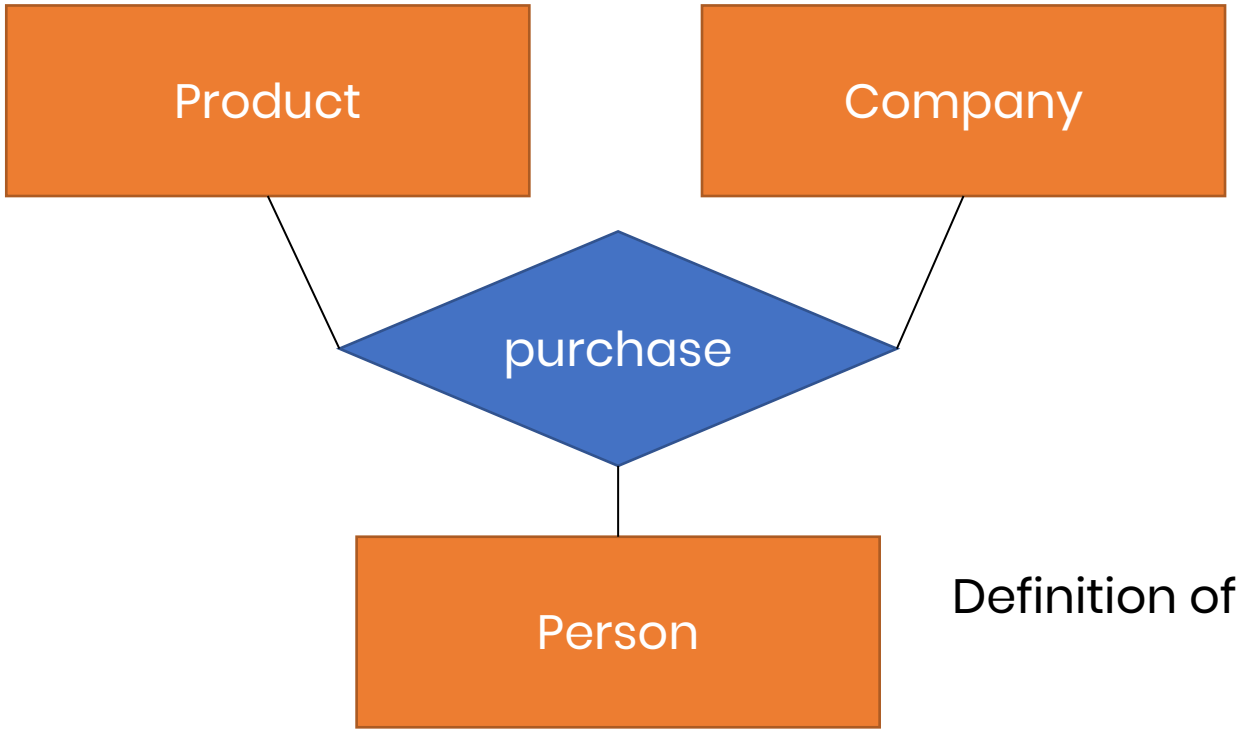
Definition of a relation generalizes!

Relationship

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



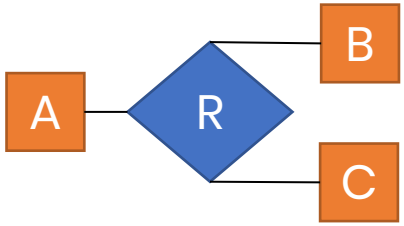
Multi-Way Relations



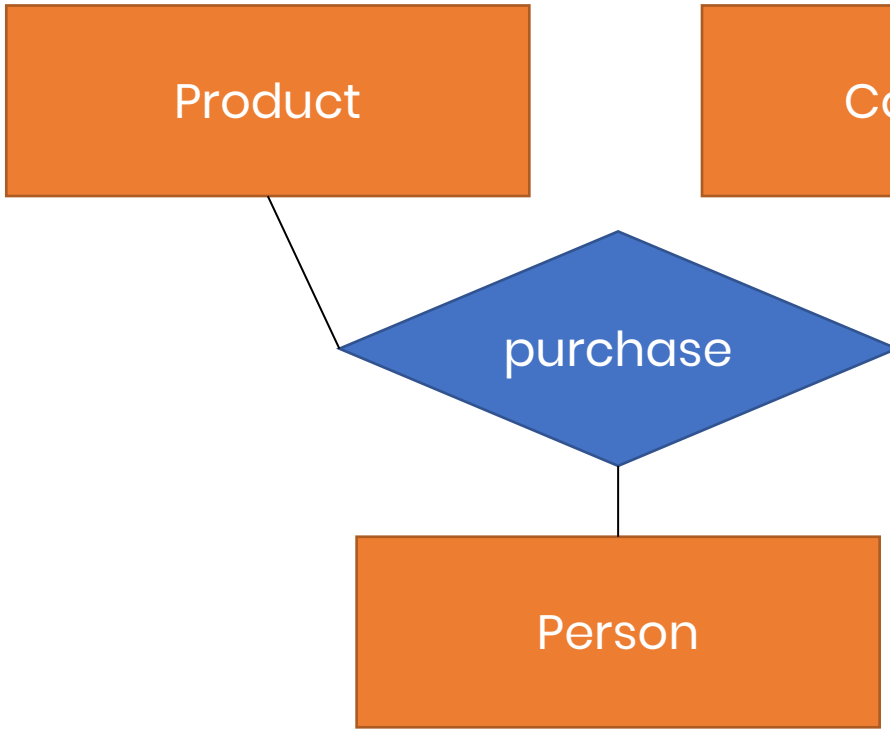
Definition of a relation generalizes!

Relationship

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



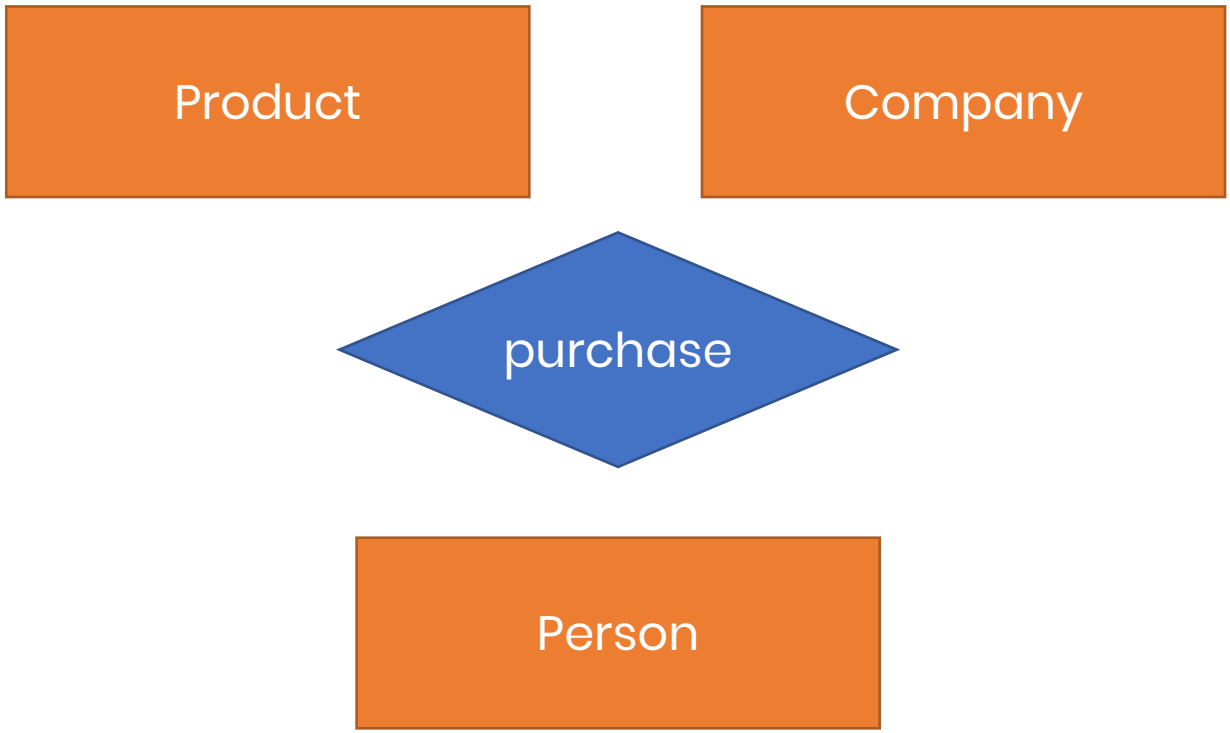
Multi-Way Relations




```
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!

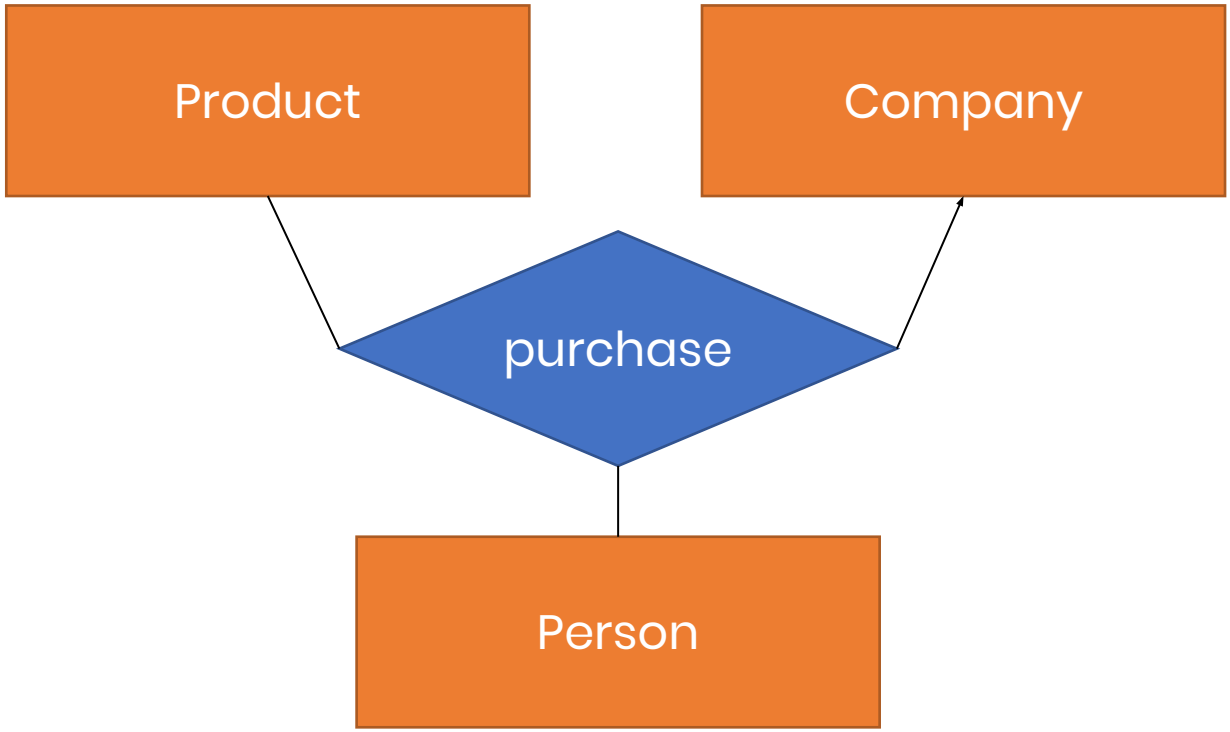
I want purchases to be such that a person will only buy each product from a single company.



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

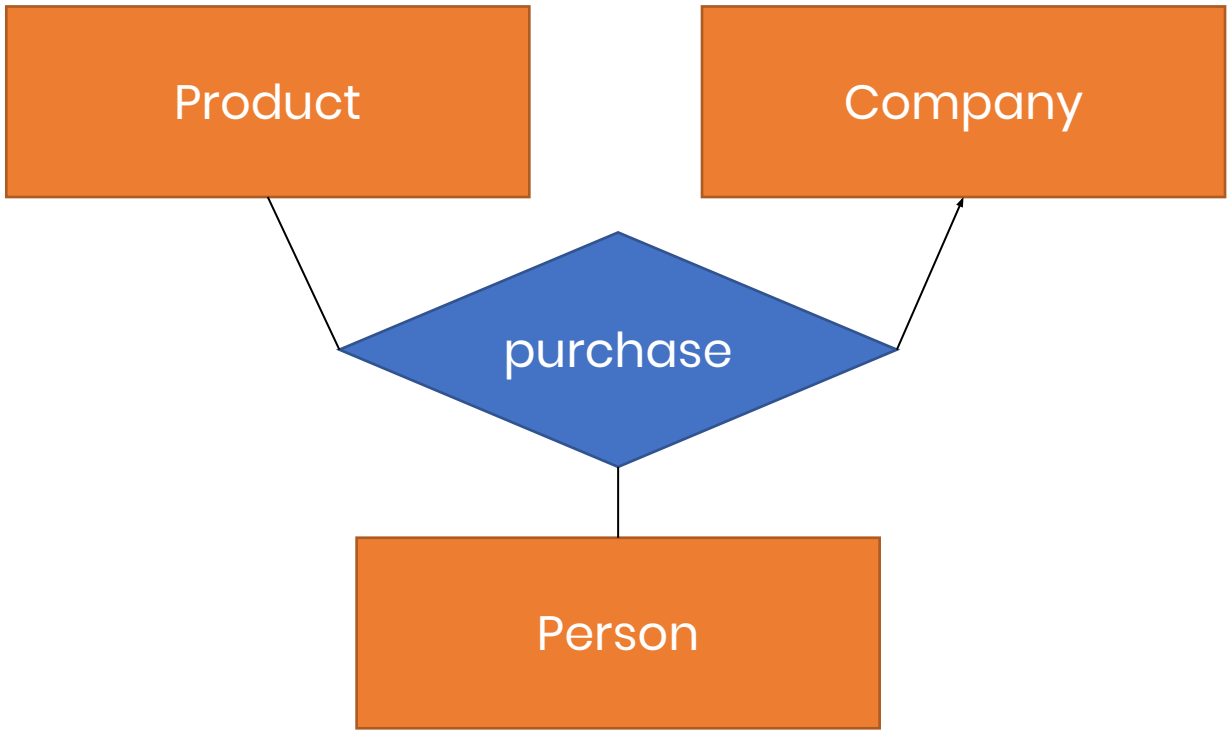
Multi-Way Relations

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



Multi-Way Relations

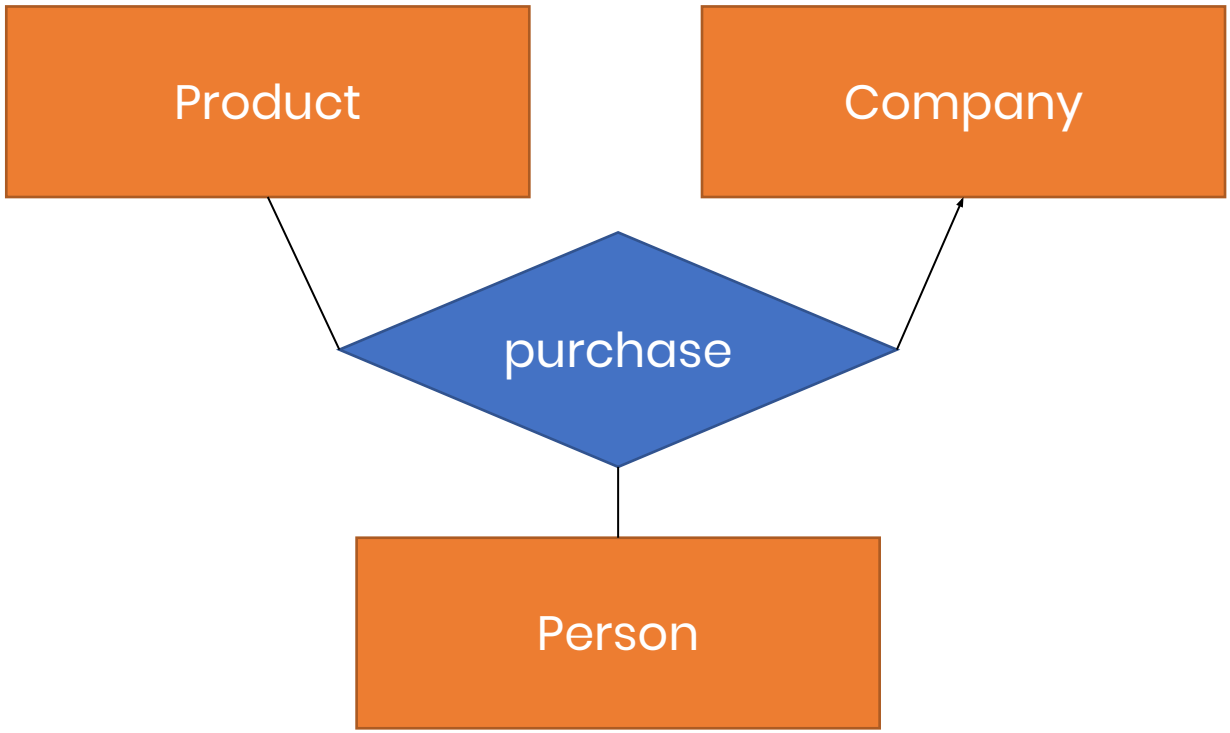
Do I need a Purchase table?



Multi-Way Relations

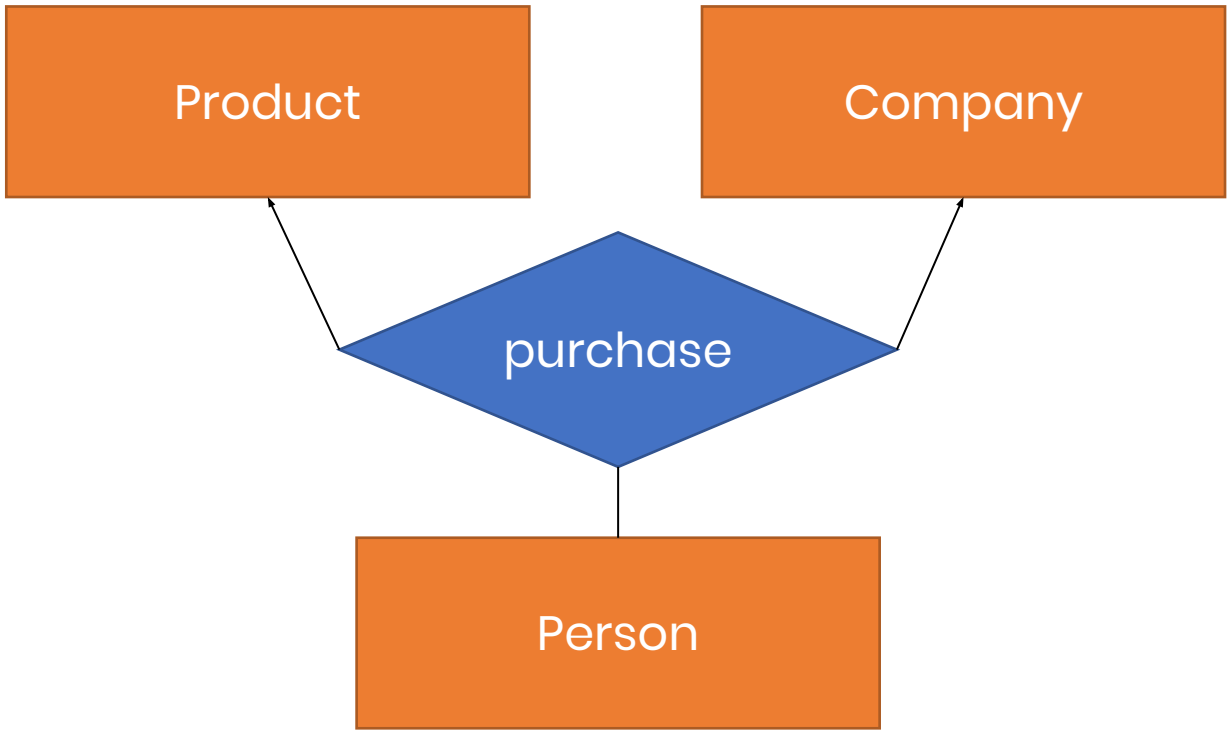
Do I need a Purchase table?

Probably a good idea



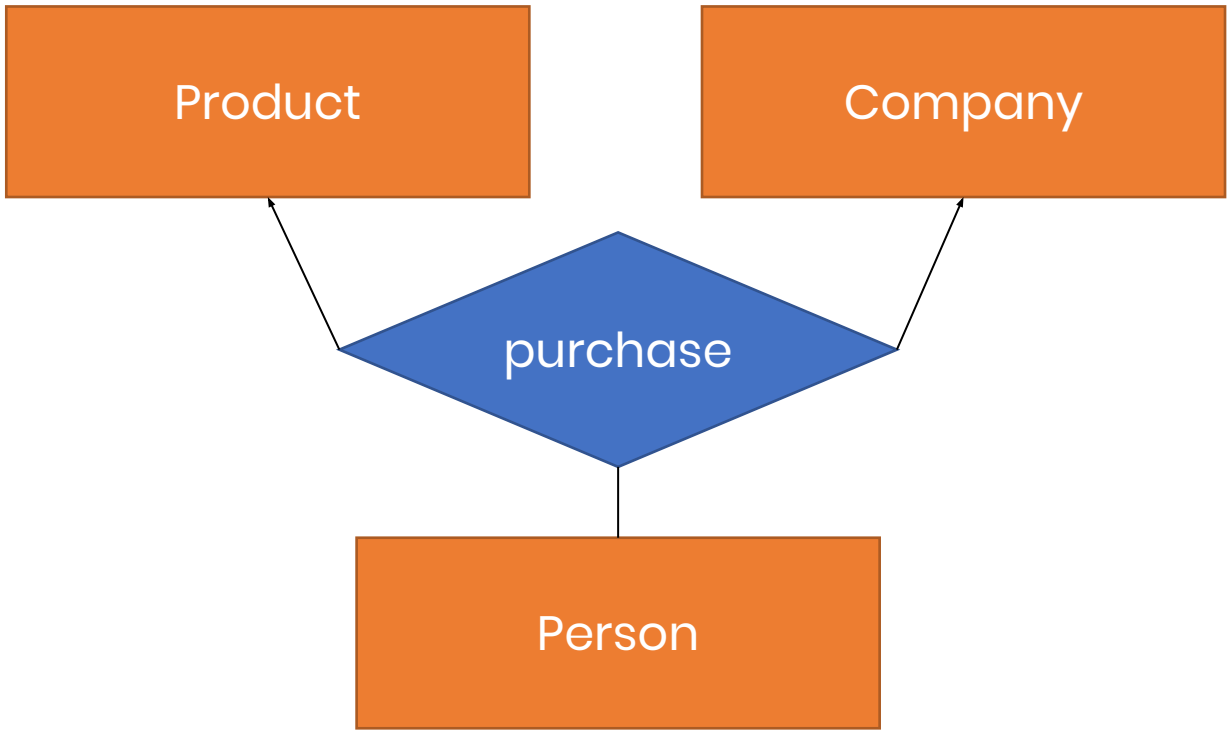
Multi-Way Relations

Now do I need a Purchase table?



Multi-Way Relations

Now do I need a Purchase table?
Nope.



Rules of Thumb in Database Design

Design Principles (common sense):

- Pick the right entities
- Don't overcomplicate things
- Follow the application spec

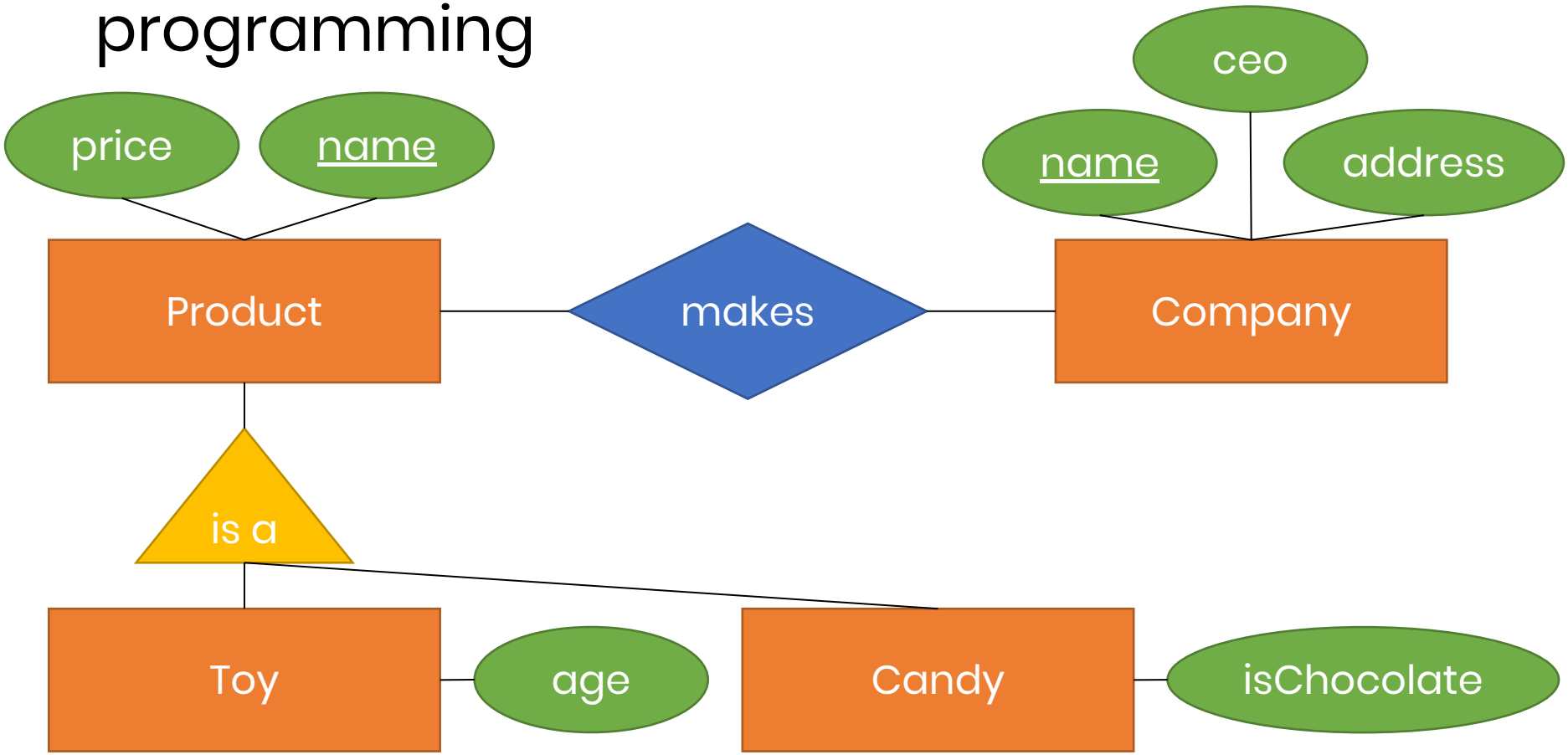
Weak Entity Set

- 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>)

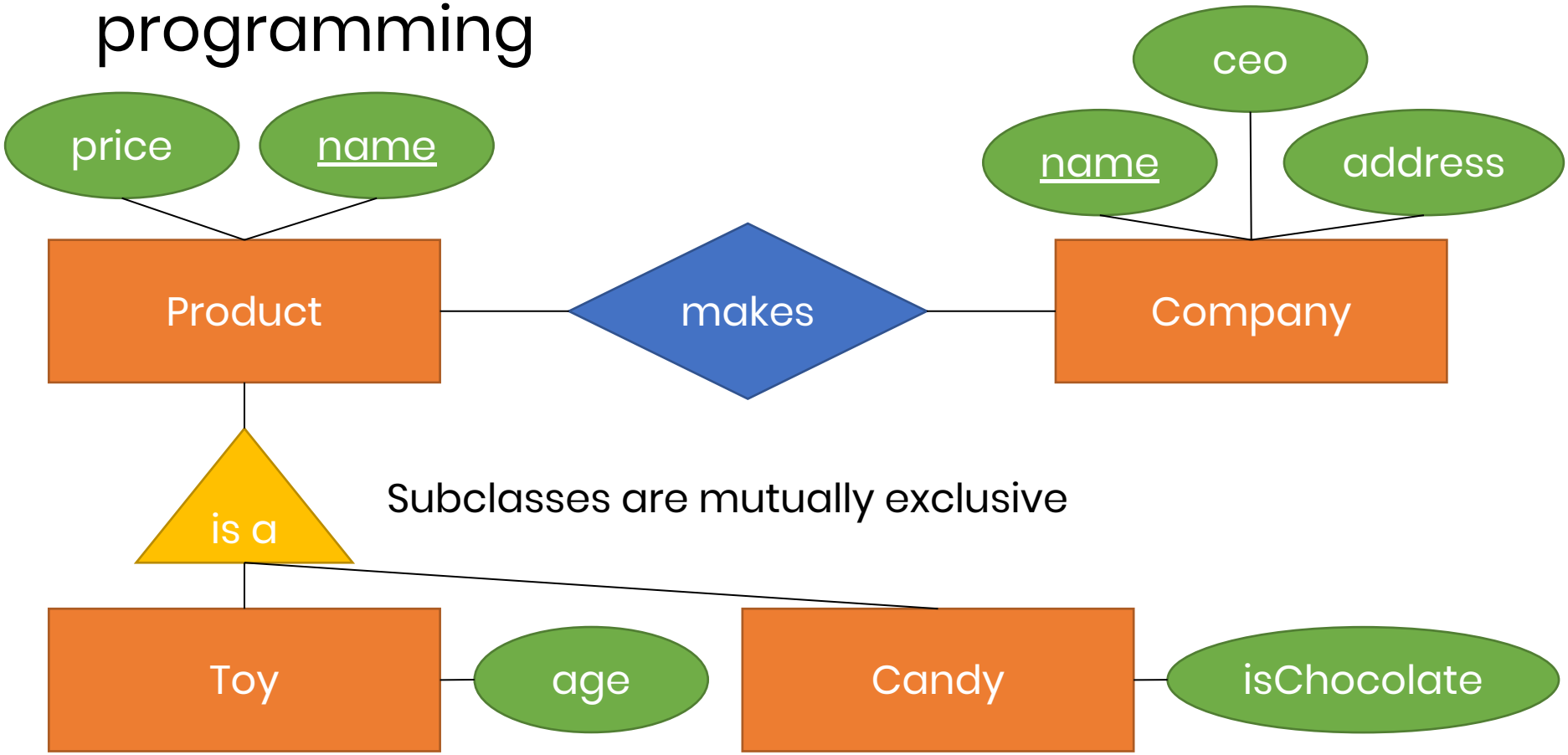
Subclassing

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

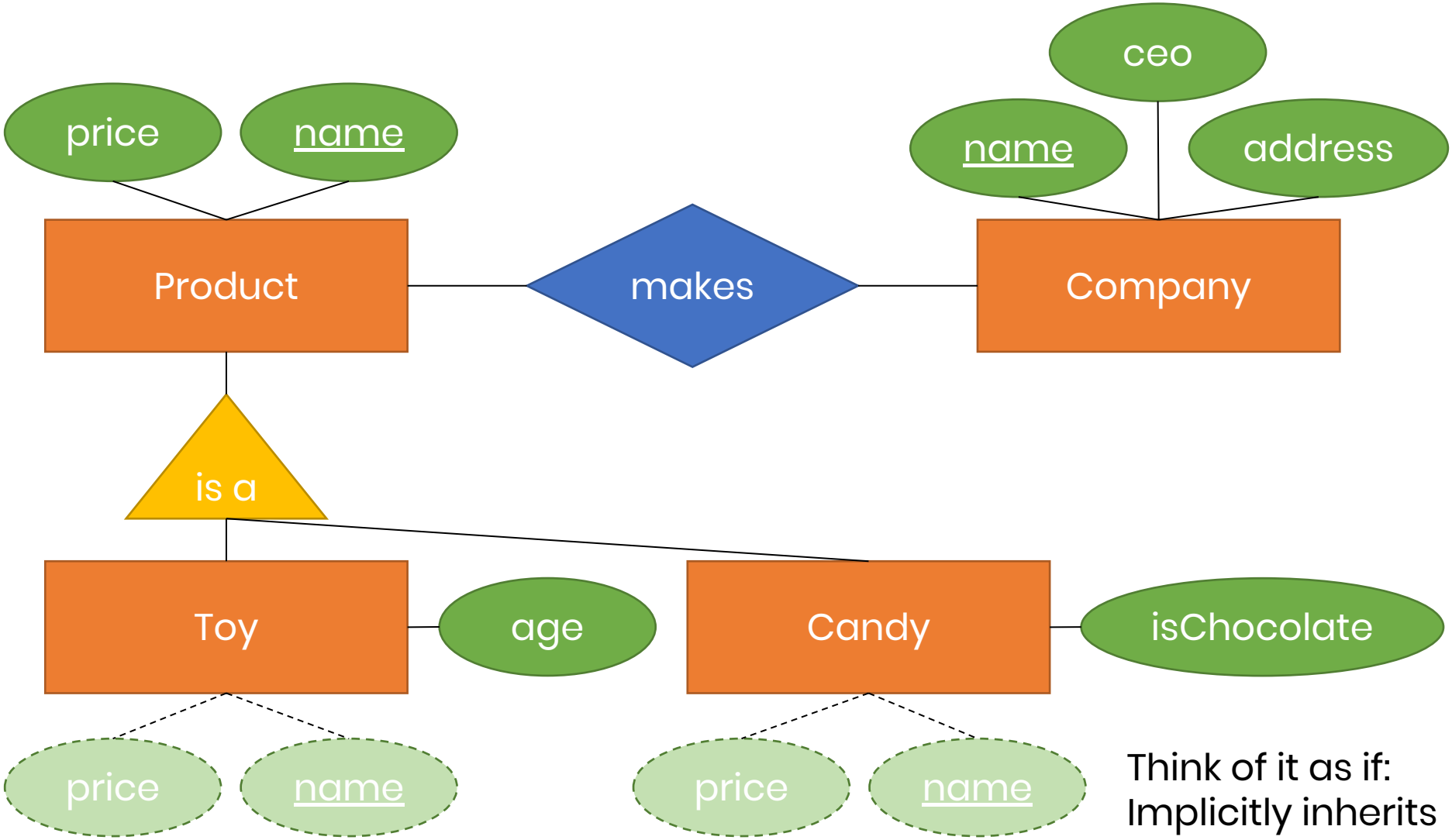


Subclassing

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

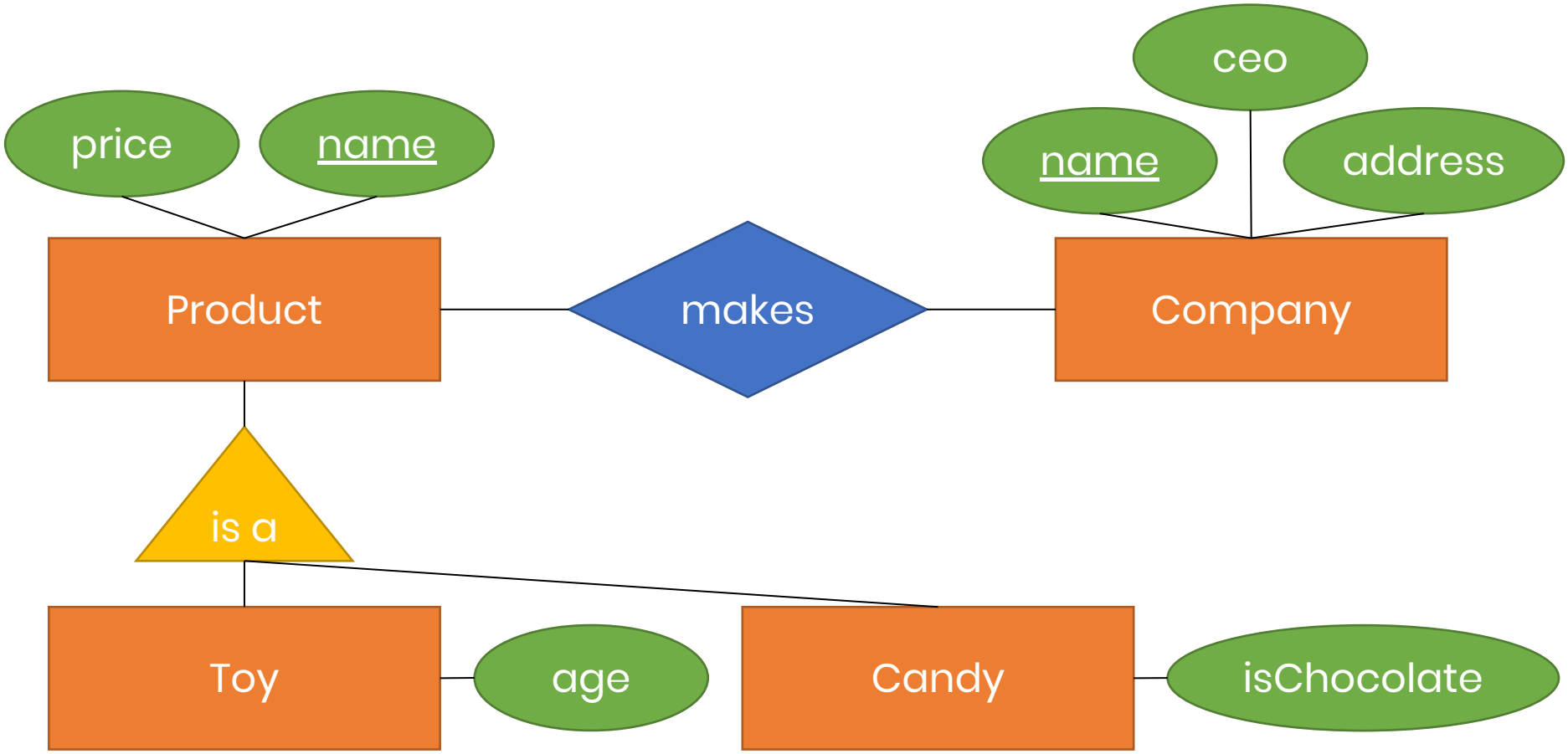


Subclassing



Think of it as if: Implicitly inherits superclass attributes and key

Subclassing

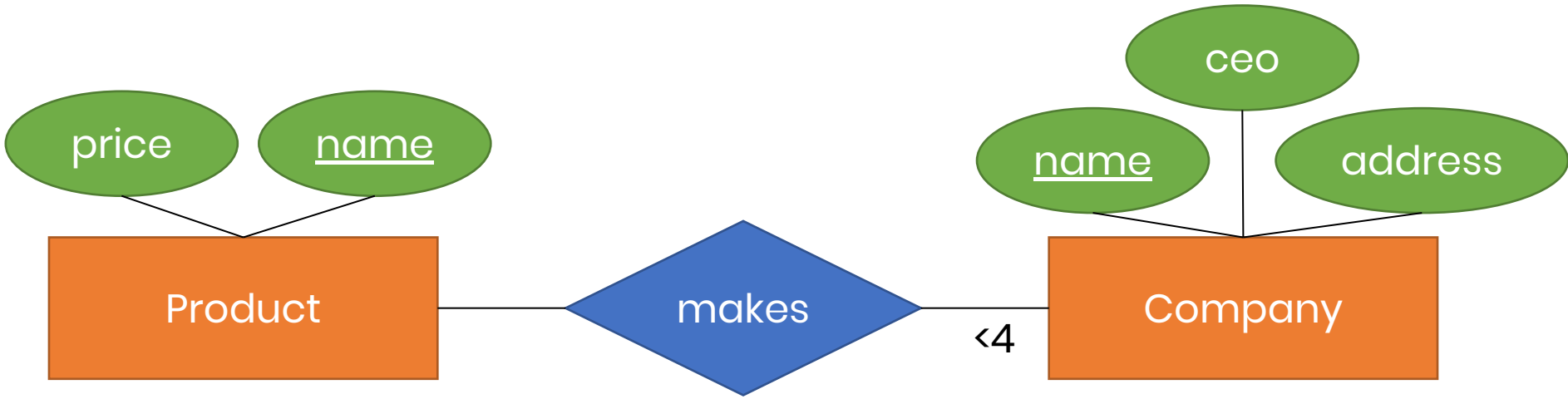


Company(…)
Makes(…)
Product(price, name)

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 = 'foo'
 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
foo
Nyform

Product

name	cname
Beyblade	foo
Troll	foo

```
UPDATE Company
   SET name = 'foo'
 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
foo
Nyform

Product

name	cname
Beyblade	foo
Troll	foo

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

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 = 'foo';
```

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));
```

you don't need to study this for the class

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**