Conceptual Design with ER Model

INF 551

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Lecture Outline

- Steps in building a database application
- Conceptual design with ER model

Steps in Building a DB Application

- Step 0: pick an application domain
  - E.g., course management

- Step 1: conceptual design
  - Decide on what to model in the application domain
    - E.g., instructors, students, courses, etc.
  - need a modeling language to express what you want
  - ER model is the most popular such language
  - output: an ER diagram of the app. domain

Steps in Building a DB Application

- Step 2: pick a type of DBMS
  - Here we use relational DBMS
- Step 3: translate ER design to a relational schema
  - use a set of rules to translate ER to rel. schema
  - use a set of schema refinement rules to transform the above rel. schema into a good rel. schema
- At this point
  - you have a good relational schema on paper

Steps in Building a DB Application

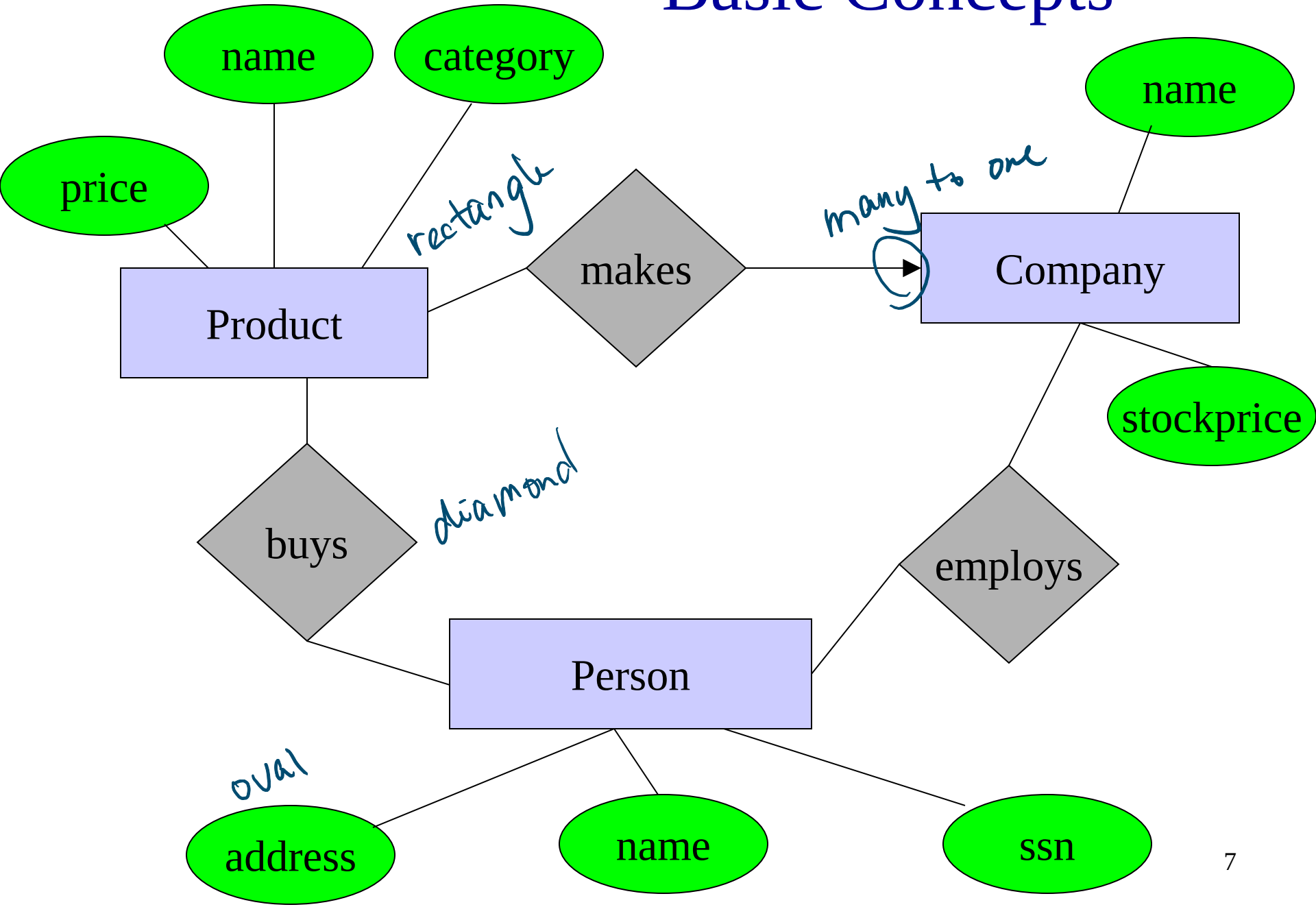
- Subsequent steps include
  - implement your relational DBMS using a "database programming language" called SQL
  - ordinary users cannot interact with the database directly
  - and the database also cannot do everything you want
  - hence write your application program in Php, C++, Java, Python, etc. to handle the interaction and take care of things that the database cannot do
- So, the first thing we should start with is to learn ER model ...

ER Model

- Gives us a language to specify
  - what information the db must hold
  - what are the relationships among components of that information
- Proposed by Peter Chen in 1976
- What we will cover
  - basic stuff
  - subclasses
  - constraints
  - weak entity sets
  - design principles

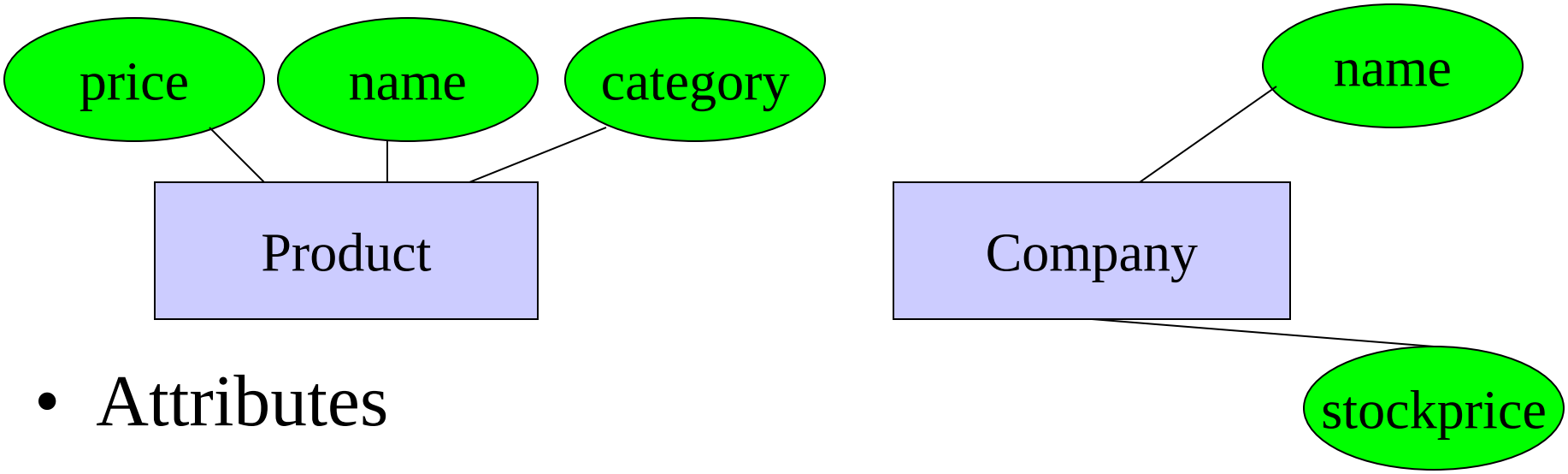
http://www.csc.lsu.edu/~chen/

Basic Concepts



Entities and Attributes

- Entities
  - real-world objects distinguishable from other objects
  - described using a set of attributes

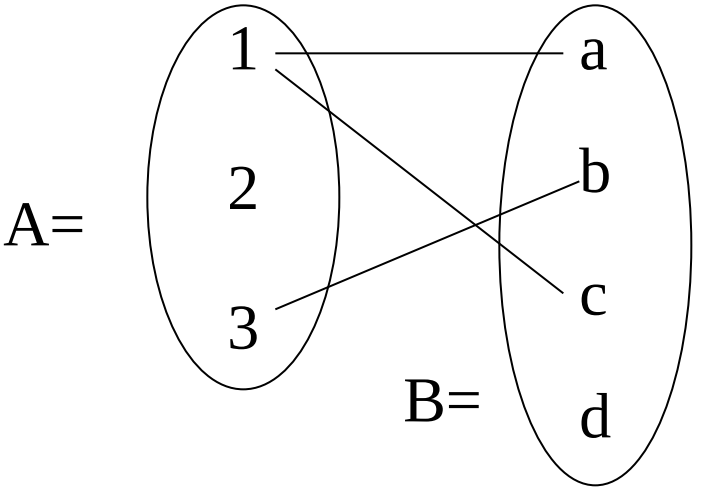


- Attributes
  - each has an atomic domain: string, integers, reals, etc.
- Entity set: a collection of similar entities

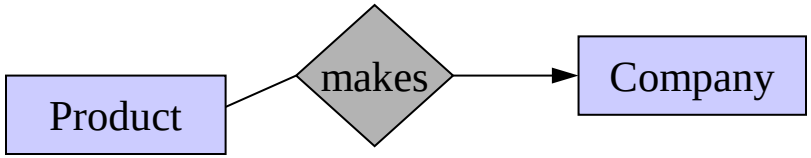
Relationships

- A mathematical definition:
  - if A, B are sets, then a relationship R is a subset of A x B
- A={1,2,3}, B={a,b,c,d},

  R = {(1,a), (1,c), (3,b)}



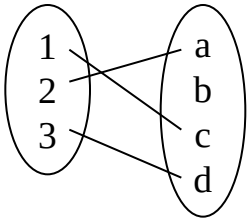
makes is a subset of **Product** x **Company**:

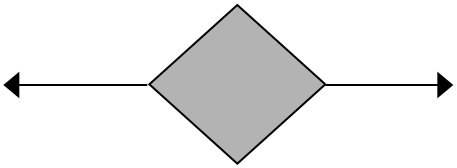


More about relationships ...

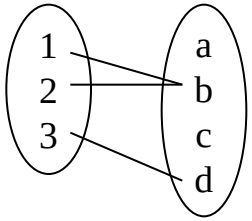
Multiplicity of E/R Relationships

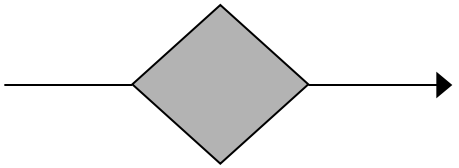
- one-one:
  - One = at most one



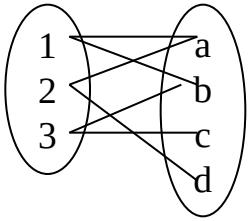


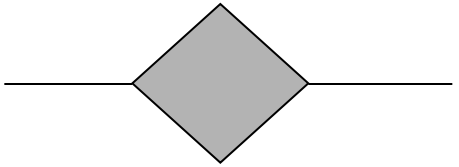
- many-one
  - Here left side = many

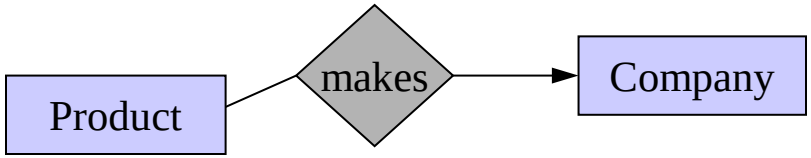




- many-many

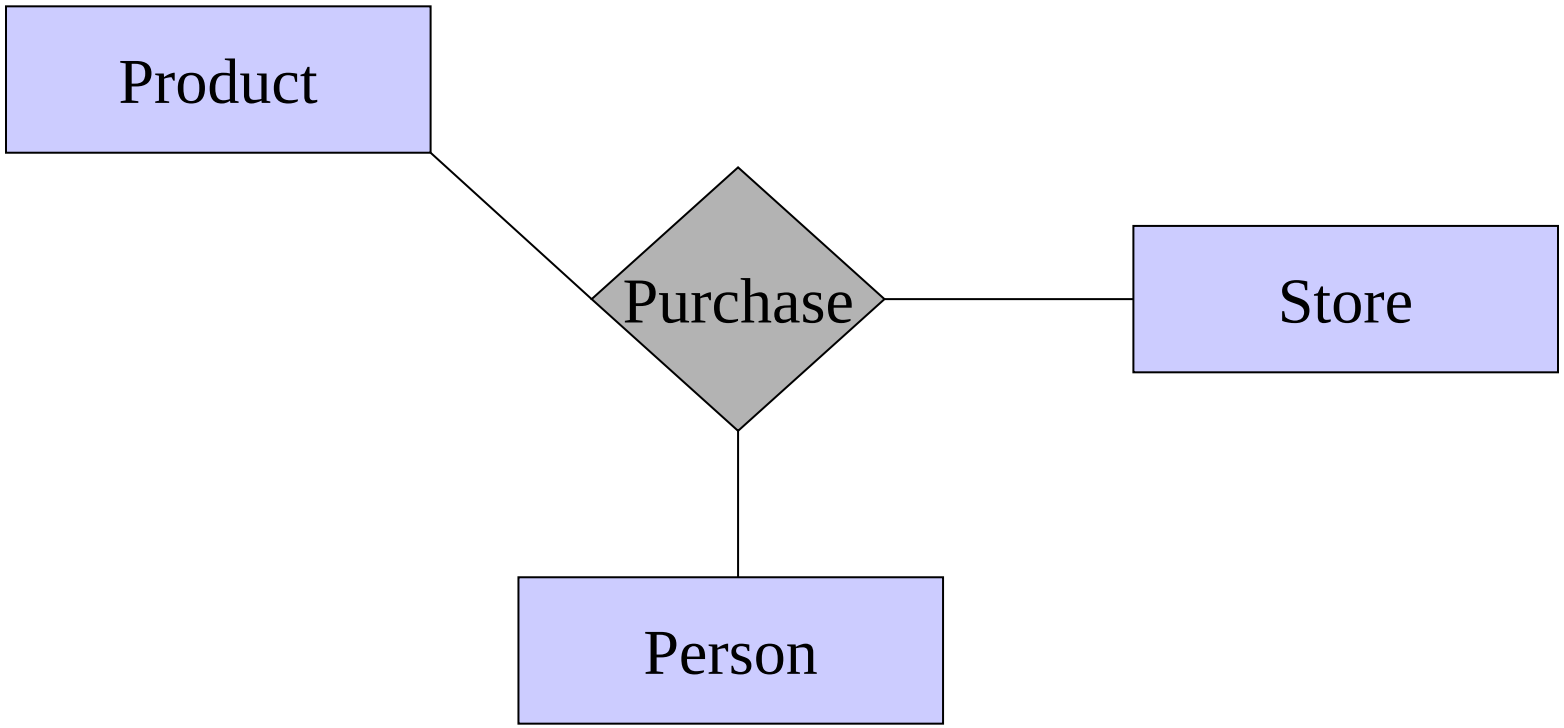






Multiway Relationships

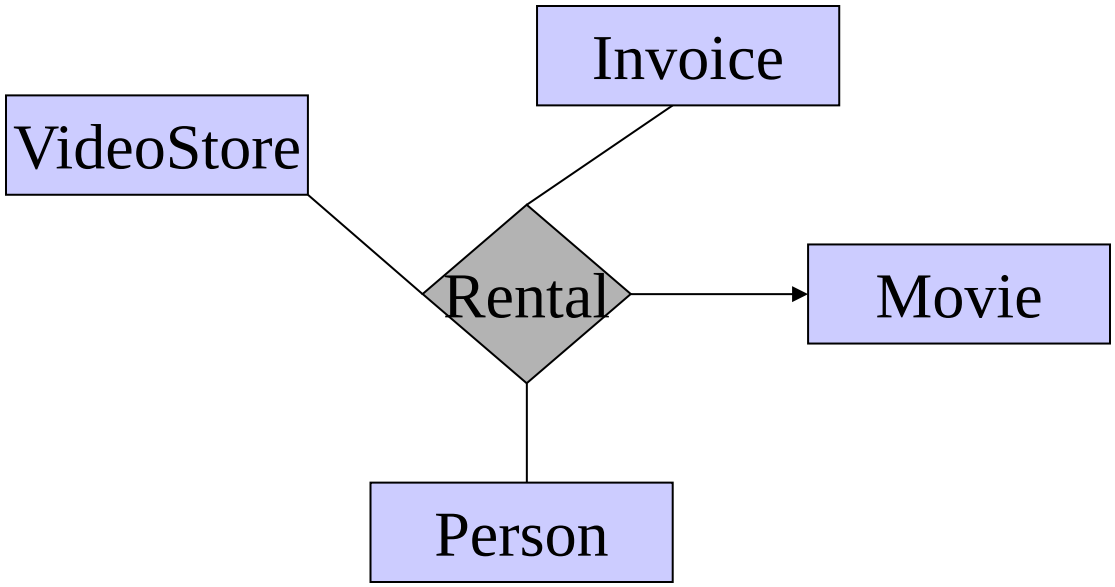
How do we model a purchase relationship between buyers, products and stores?



Can still model as a mathematical set (how ?)

Arrows in Multiway Relationships

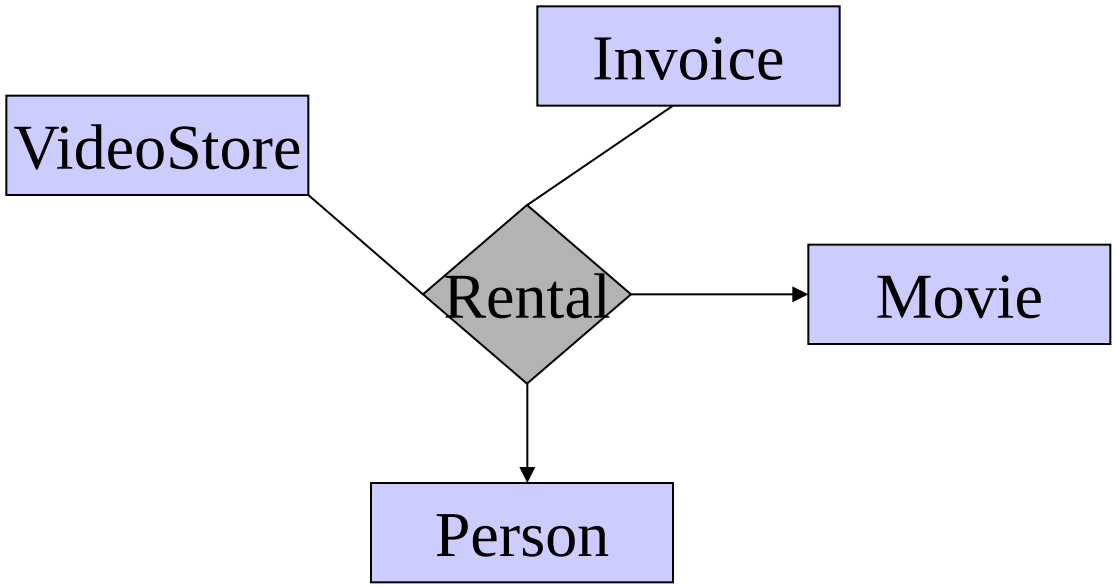
Q: what does the arrow mean?



A: if I know the store, person, invoice, I know the movie too

Arrows in Multiway Relationships

Q: what do these arrows mean?

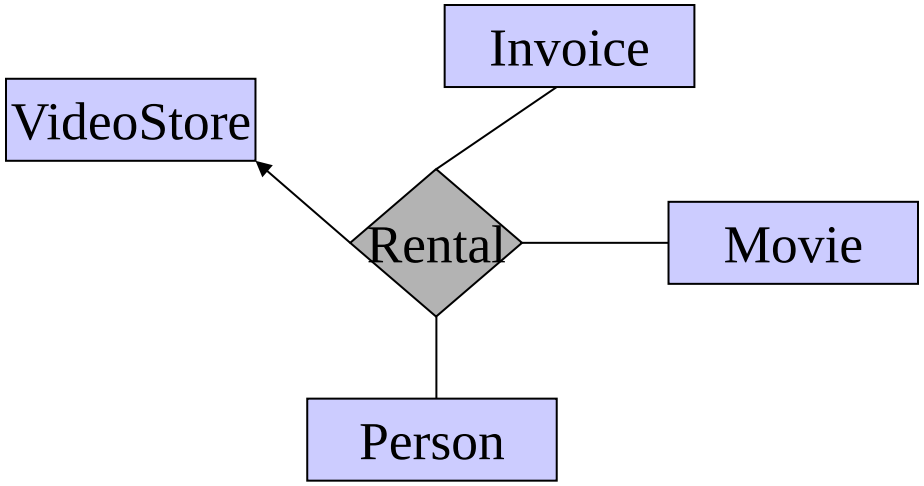


A: store, person, invoice determines movie
and store, invoice, movie determines person

Arrows in Multiway Relationships

Q: how do I say: “invoice determines store” ?

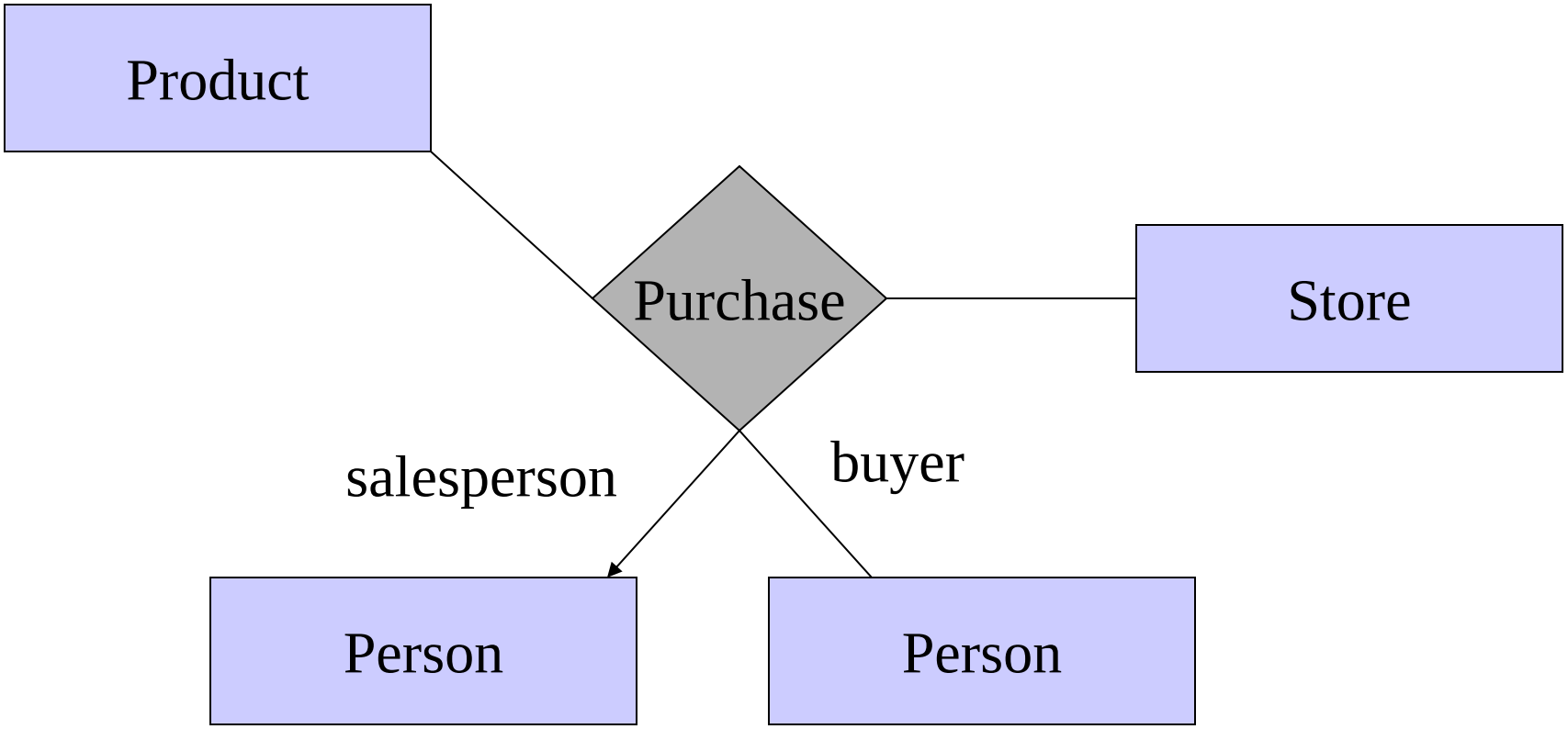
A: no good way; best approximation:



Relational model captures many-one relationships in functional dependencies, e.g., invoice → store

Roles in Relationships

What if we need an entity set twice in one relationship?



Roles in Relationships

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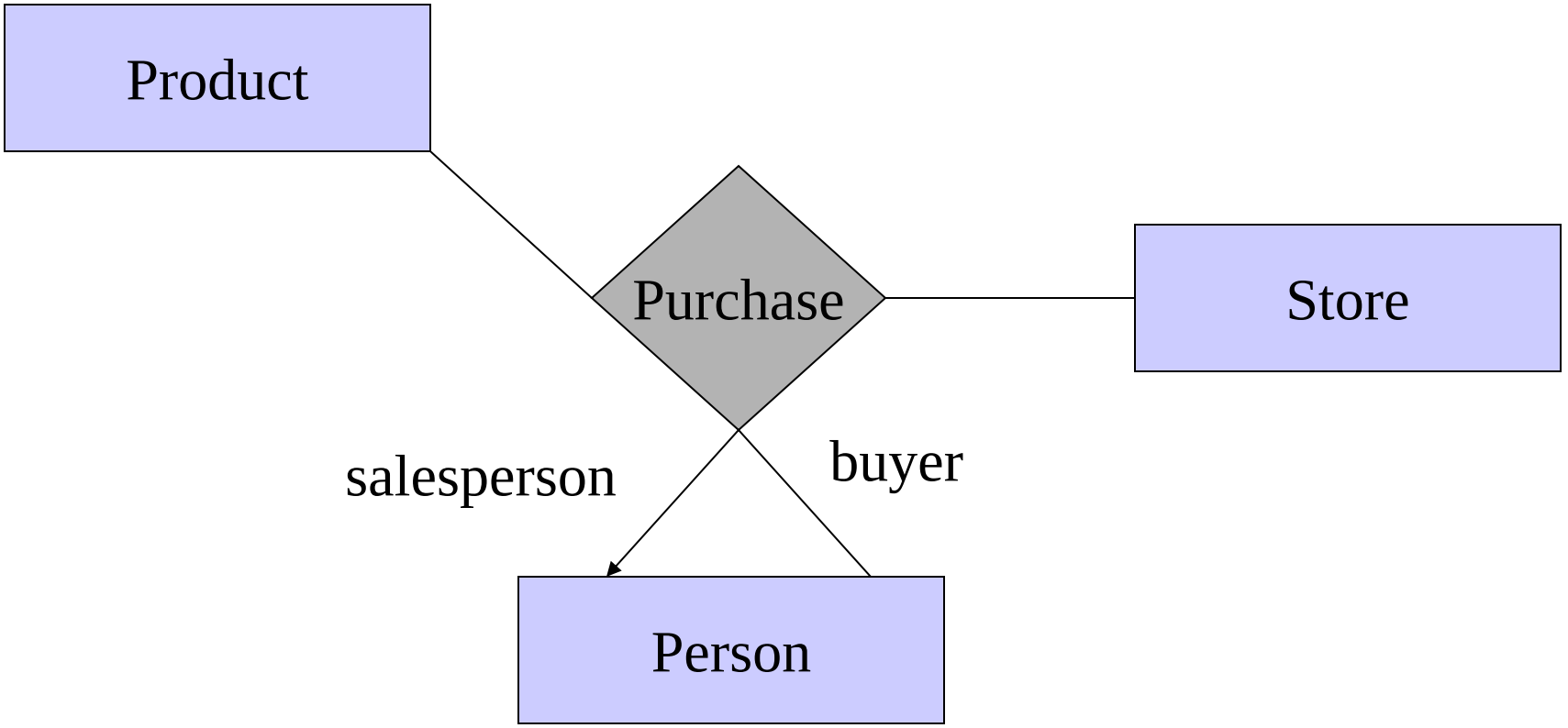
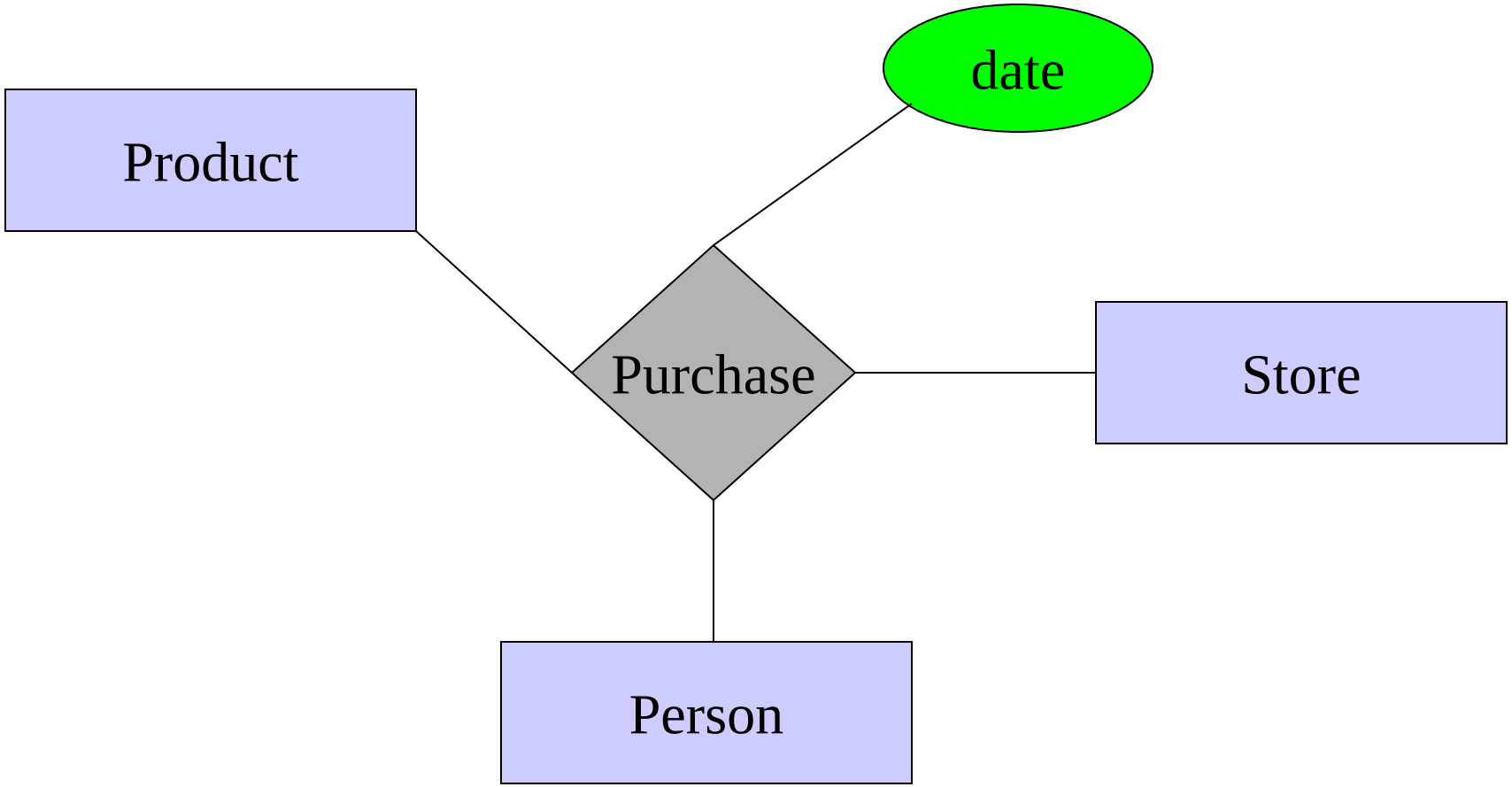
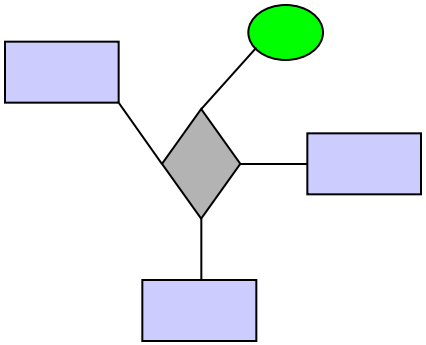
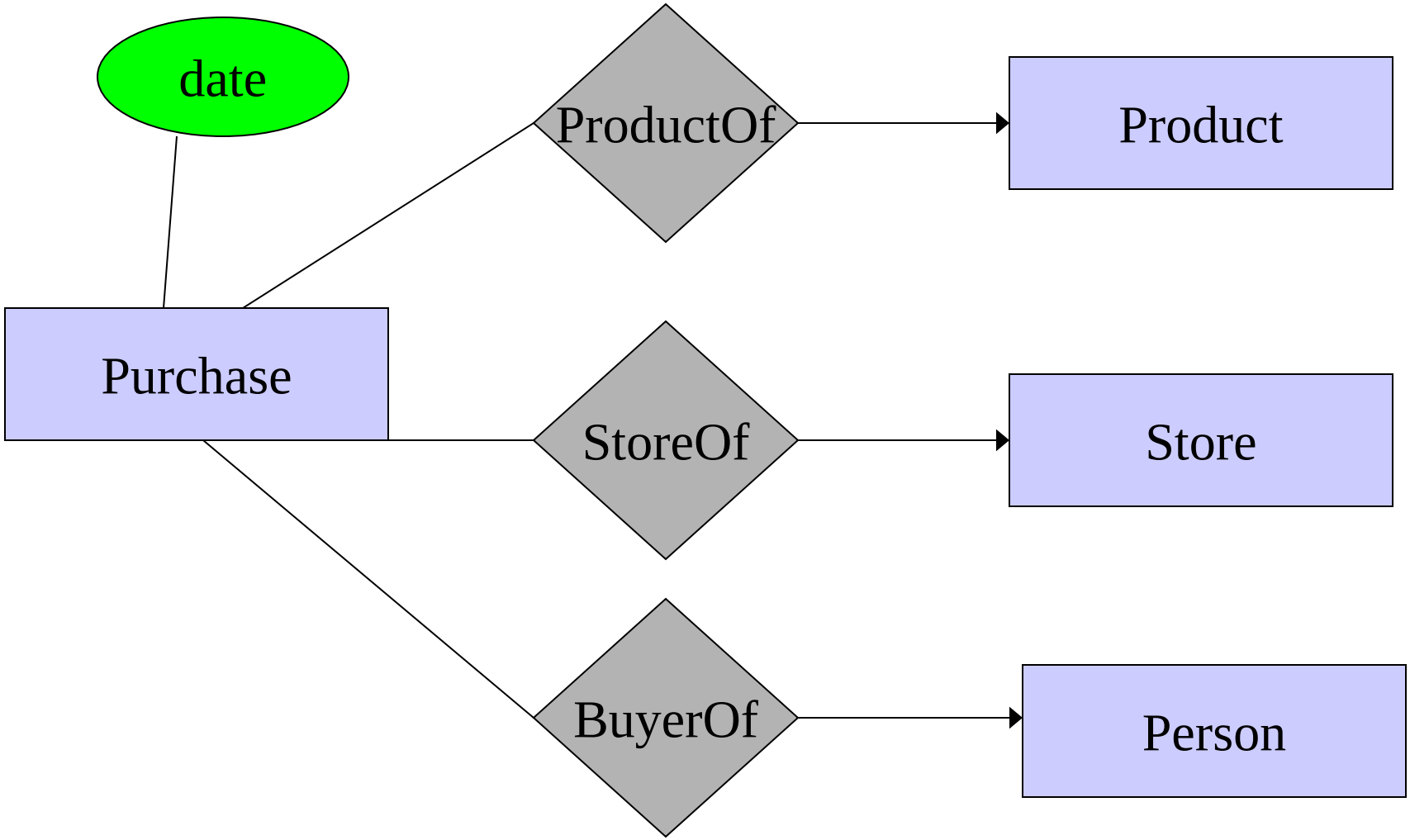


Attributes on Relationships



Converting Multiway Relationships to Binary





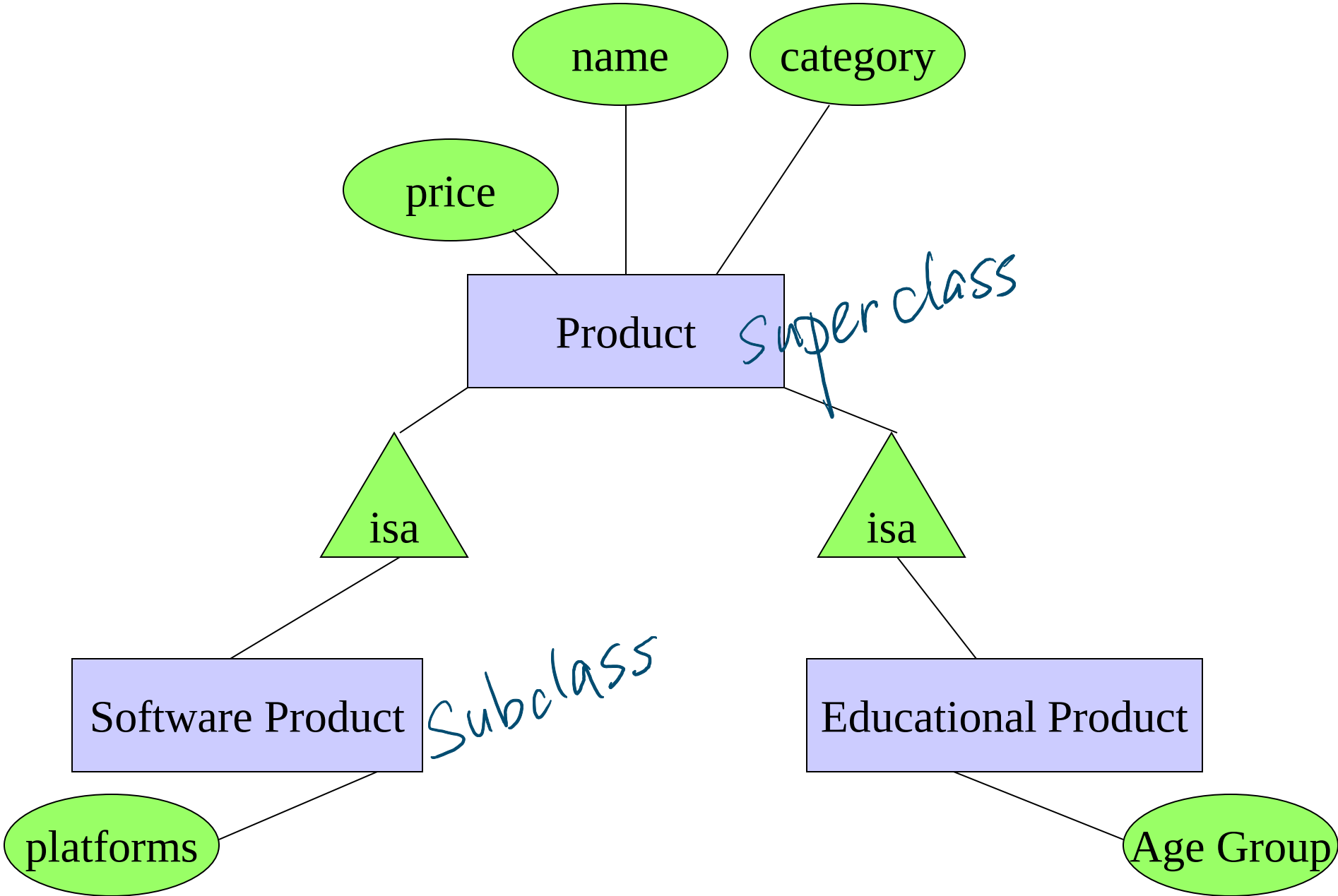
Relationships: Summary

- Modeled as a mathematical set
- Binary and multiway relationships
- Converting a multiway one into many binary ones
- Constraints on the degree of the relationship
  - many-one, one-one, many-many
  - limitations of arrows
- Attributes of relationships
  - not necessary, but useful

Roadmap

- What we will cover
  - basic stuff
  - subclasses 
  - constraints
  - weak entity sets
  - design principles

Subclasses in ER Diagrams



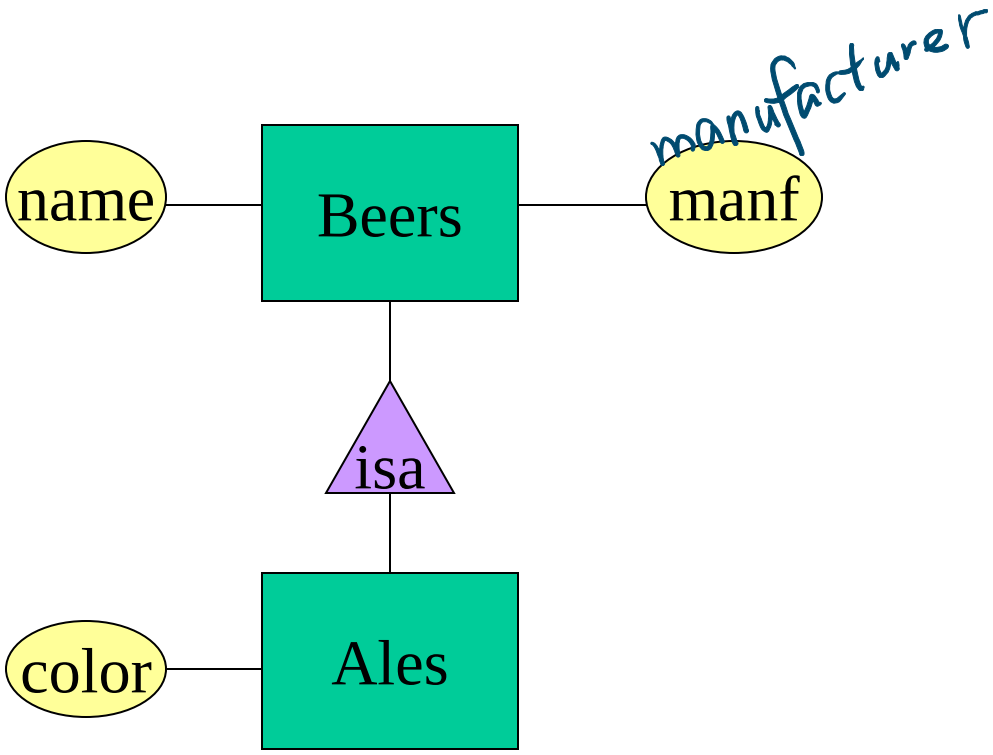
Subclasses in ER Diagrams

- Assume subclasses form a tree.
  - I.e., no multiple inheritance.
- Isa triangles indicate the subclass relationship.
  - Point to the superclass.

Subclasses

- Subclass = special case = fewer entities = more properties.
- Example: Ales are a kind of beer.
  - Not every beer is an ale, but some are.
  - Let us suppose that in addition to all the *properties* (attributes and relationships) of beers, ales also have the attribute *color*.

Example



ER vs. Object Oriented Subclasses

- In the object-oriented world, objects are stored in one class only.
  - Subclasses inherit all properties from superclasses.
  - All properties of the object are stored together.
- In contrast, in the E/R view, entities may have components in all subclasses to which they belong.
  - Matters when we convert to relations.

Example

OO

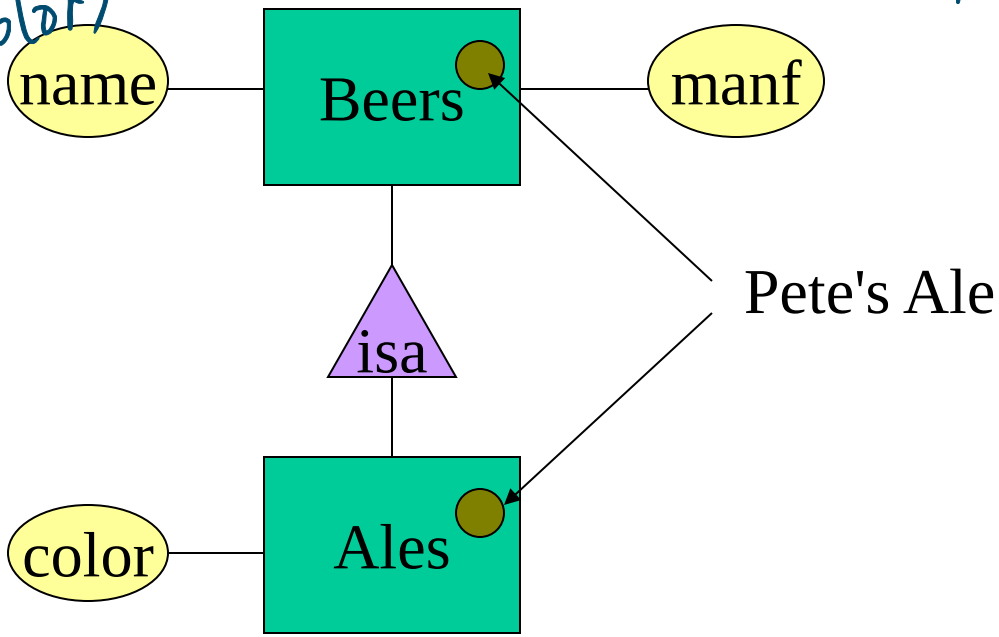
Beers(name, manf)

Ales(name, manf, color)

E/R

Beers(name, manf)

Ales(name, color)



Roadmap

- What we will cover
  - basic stuff
  - subclasses
  - constraints 
  - weak entity sets
  - design principles

Constraints

- A constraint = an assertion about the data in the database that must be true at all times
- Part of the database schema
- Very important in database design
  - To ensure data integrity

Modeling Constraints

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

primary key, foreign key

Keys: social security number uniquely identifies a person.

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

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

1 byte
4 byte
8 byte

int

tiny int
int
large int

Domain constraints: peoples' ages are between 0 and 150.

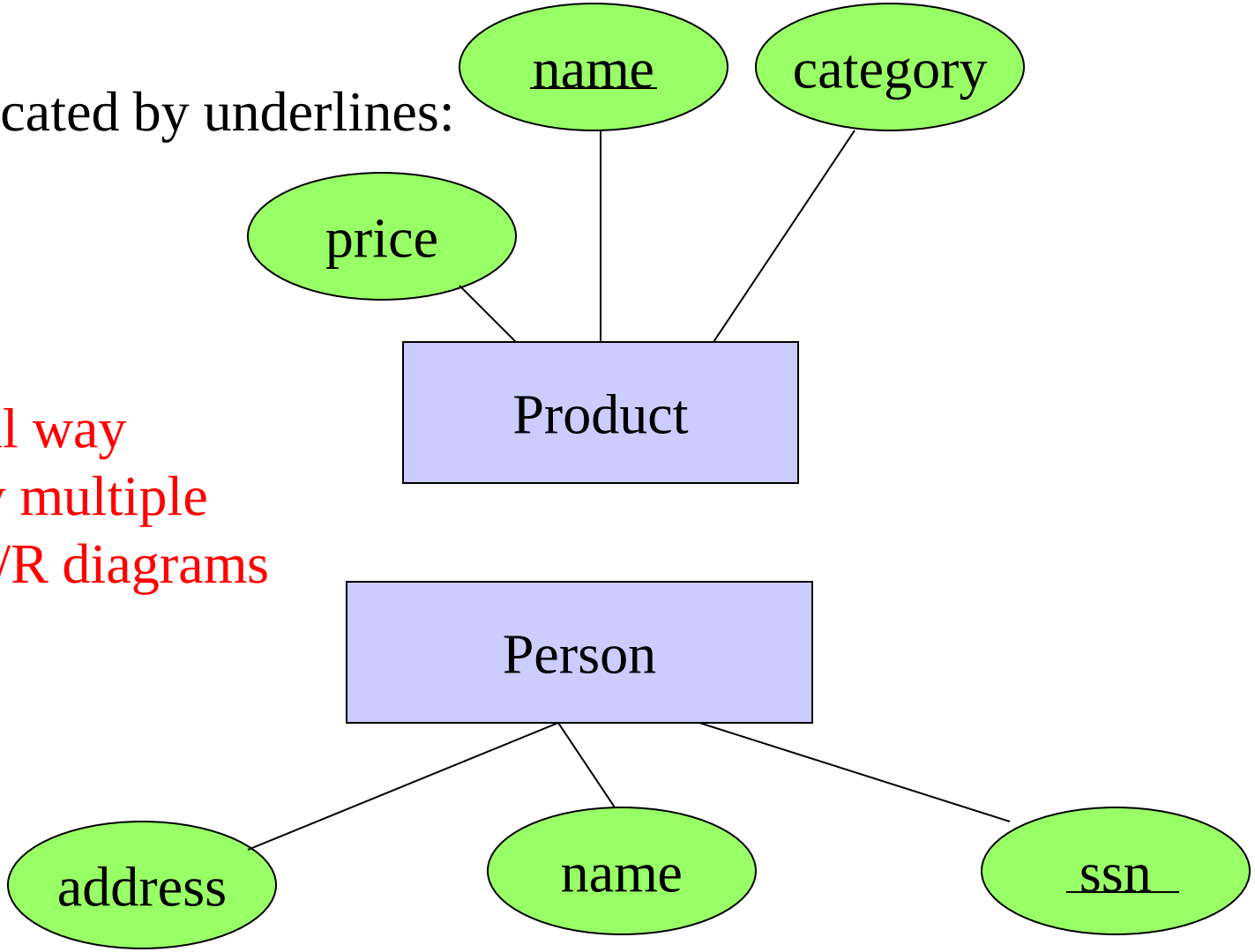
General constraints: all others (e.g., at most 50 students can enroll in a class)

Why Constraints are Important?

- Give more semantics to the data
  - help us better understand it
- Allow us to refer to entities (e.g, using keys)
- Enable efficient storage
  - E.g., store ages as tiny integer (1 byte for example)
- Enable efficient lookup
  - E.g., creating an index on key

Keys in E/R Diagrams

Indicated by underlines:

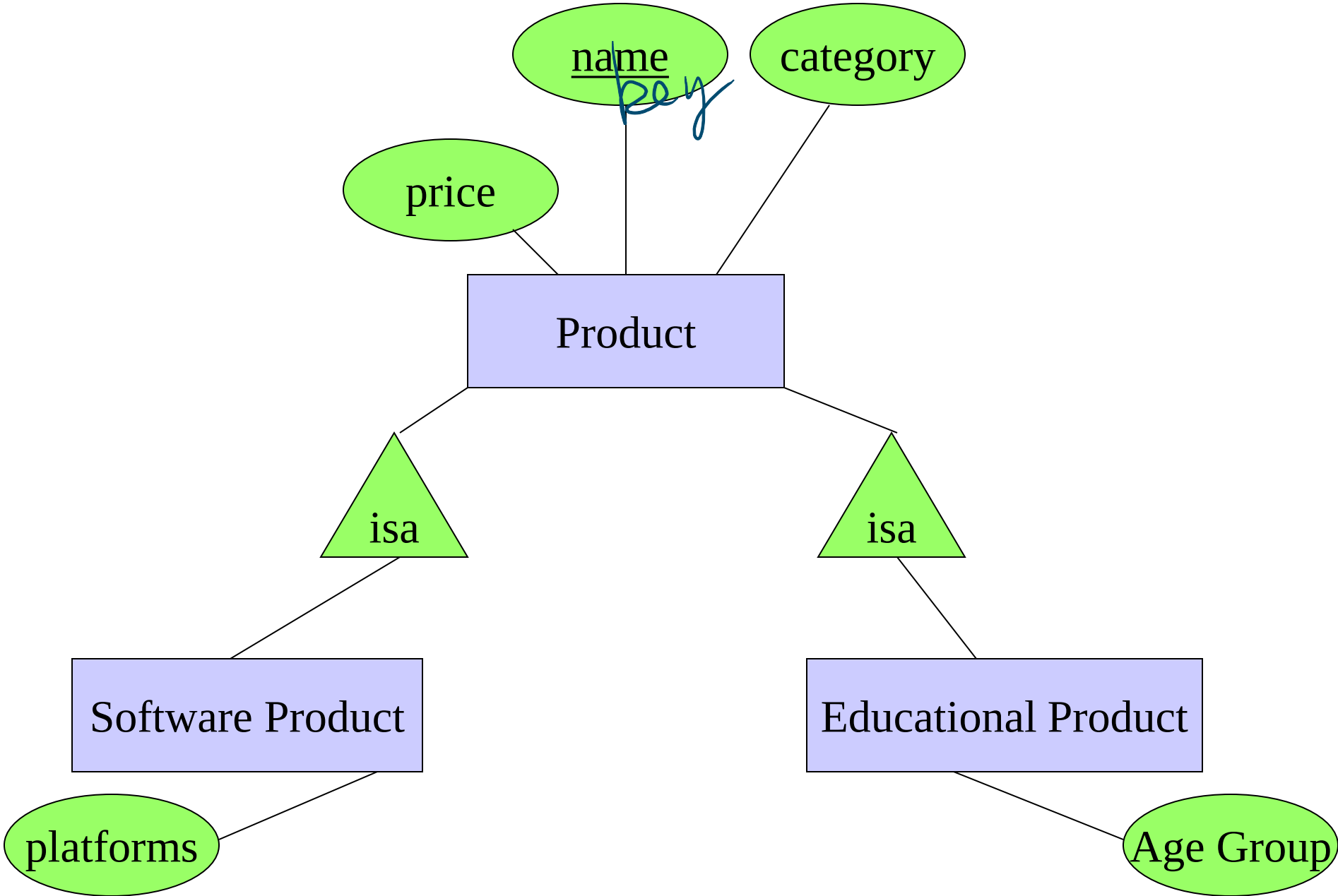


No formal way
to specify multiple
keys in E/R diagrams

More about Keys

- Every entity set must have a key
  - why?
- A key can consist of more than one attribute
- There can be more than one key for an entity set
  - one key will be designated as primary key
- Requirement for key in an isa hierarchy
  - Root entity set has all attributes needed for a key

Subclasses in ER Diagrams

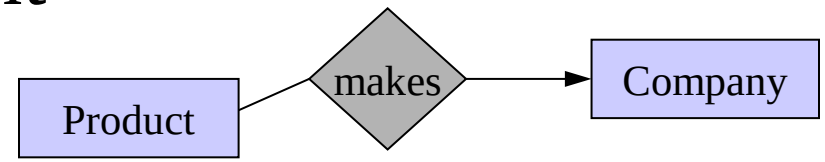


Single Value Constraint

- An entity has at most one value for a given attribute or relationship

- An attribute of an entity set has a single value or NULL
  - i.e., the value may be missing

- A many-one relationship also implies a single value constraint



Referential Integrity Constraint

- Ref. int. constraint: exactly one value exists in a given role

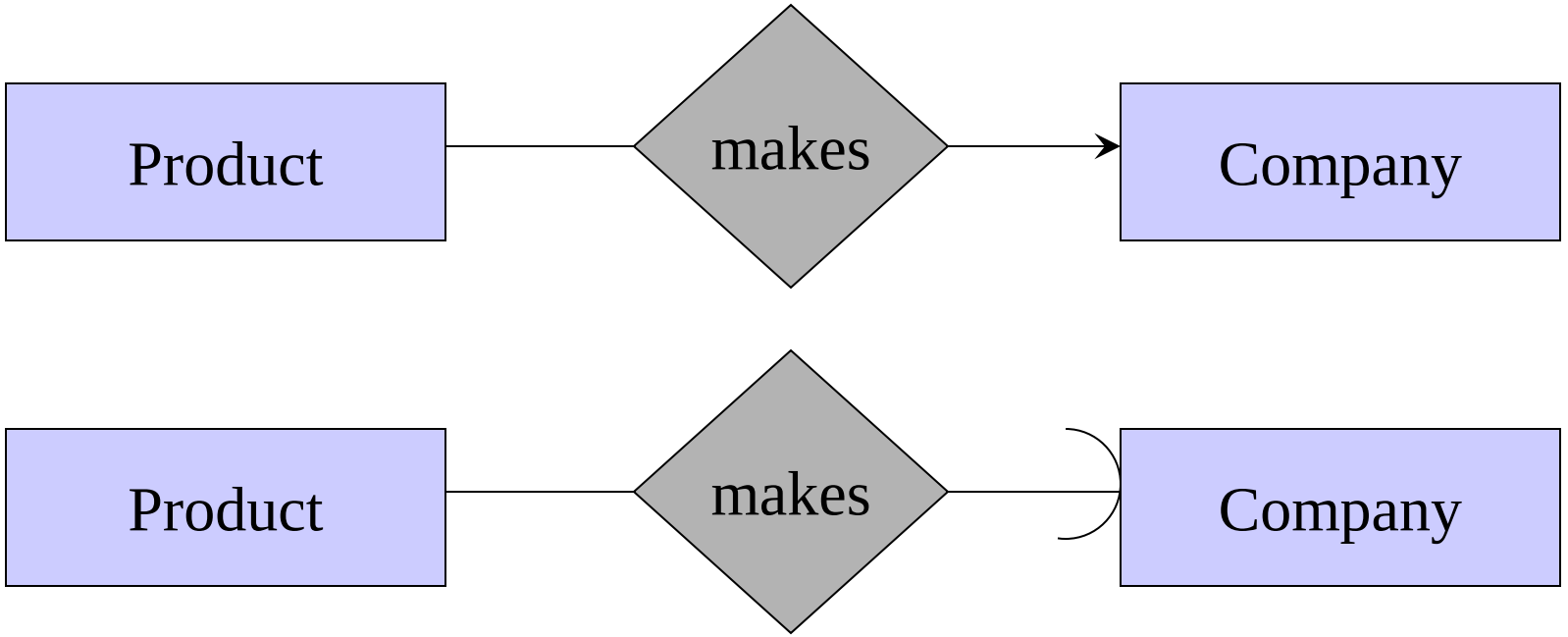
- An attribute has a non-null, single value
  - this can be considered a kind of ref. int. constraint

- However, we more commonly use such constraints to refer to relationships

Referential Integrity Constraints

- In some formalisms we may refer to other object but get garbage instead
  - e.g. a dangling pointer in C/C++
- The Referential Integrity Constraint on relationships explicitly requires a reference to exist

Referential Integrity Constraints



- This will be even clearer once we get to relational databases

Roadmap

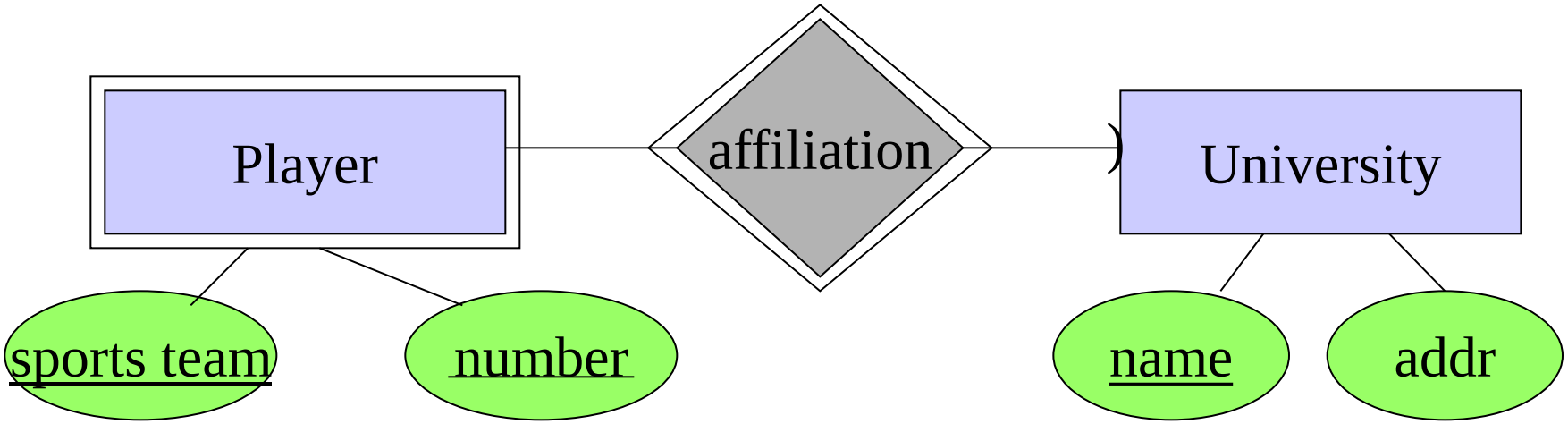
- What we will cover
  - basic stuff
  - subclasses
  - constraints
  - weak entity sets 
  - design principles

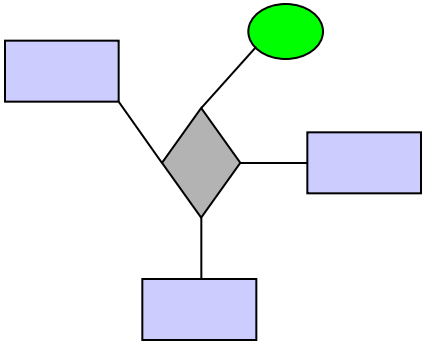
Weak Entity Sets

Entity sets are weak when (some or all of) their key attributes come from other entity sets to which they are related.

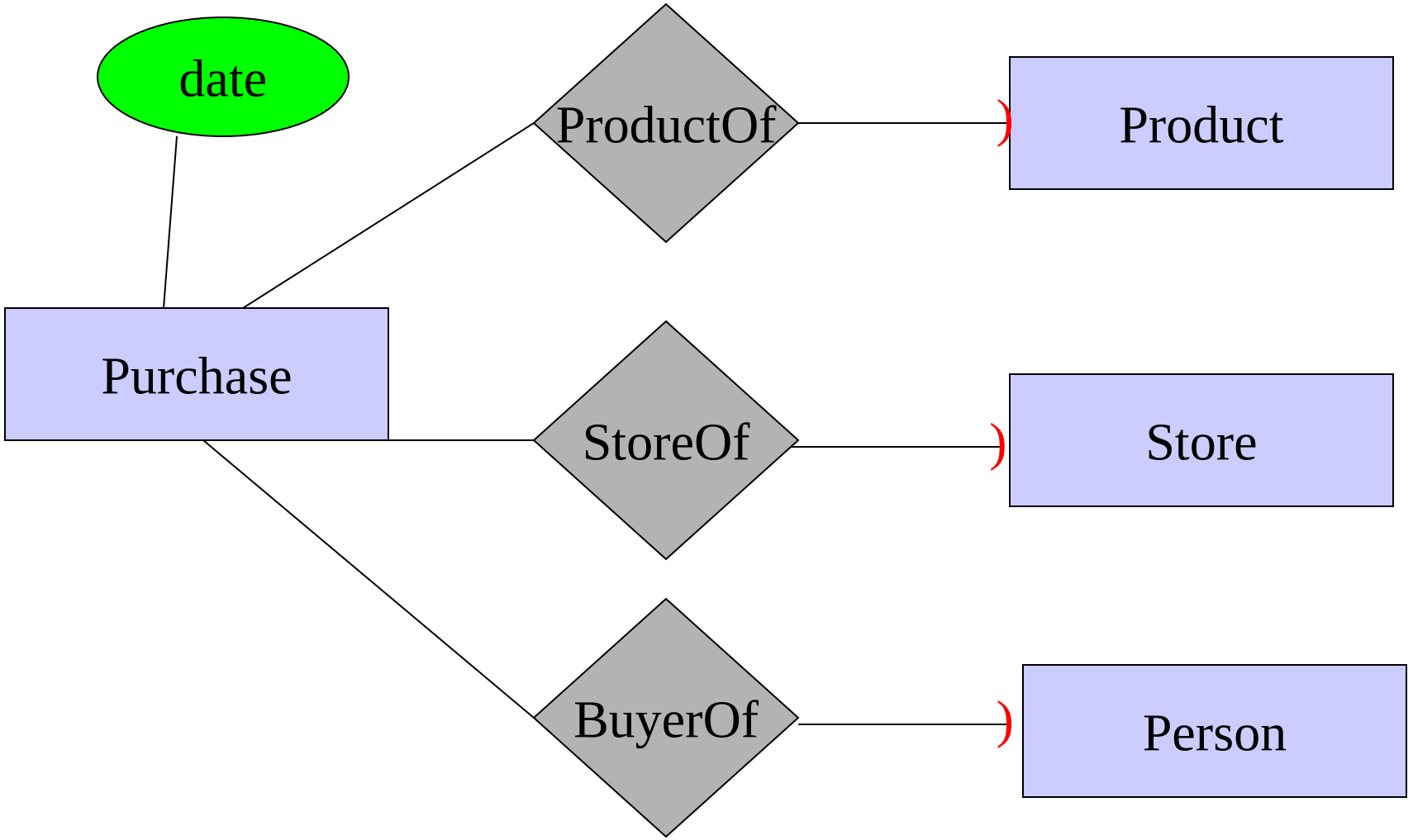
This happens when:

- part-of relationships
- splitting n-ary relationships to binary.



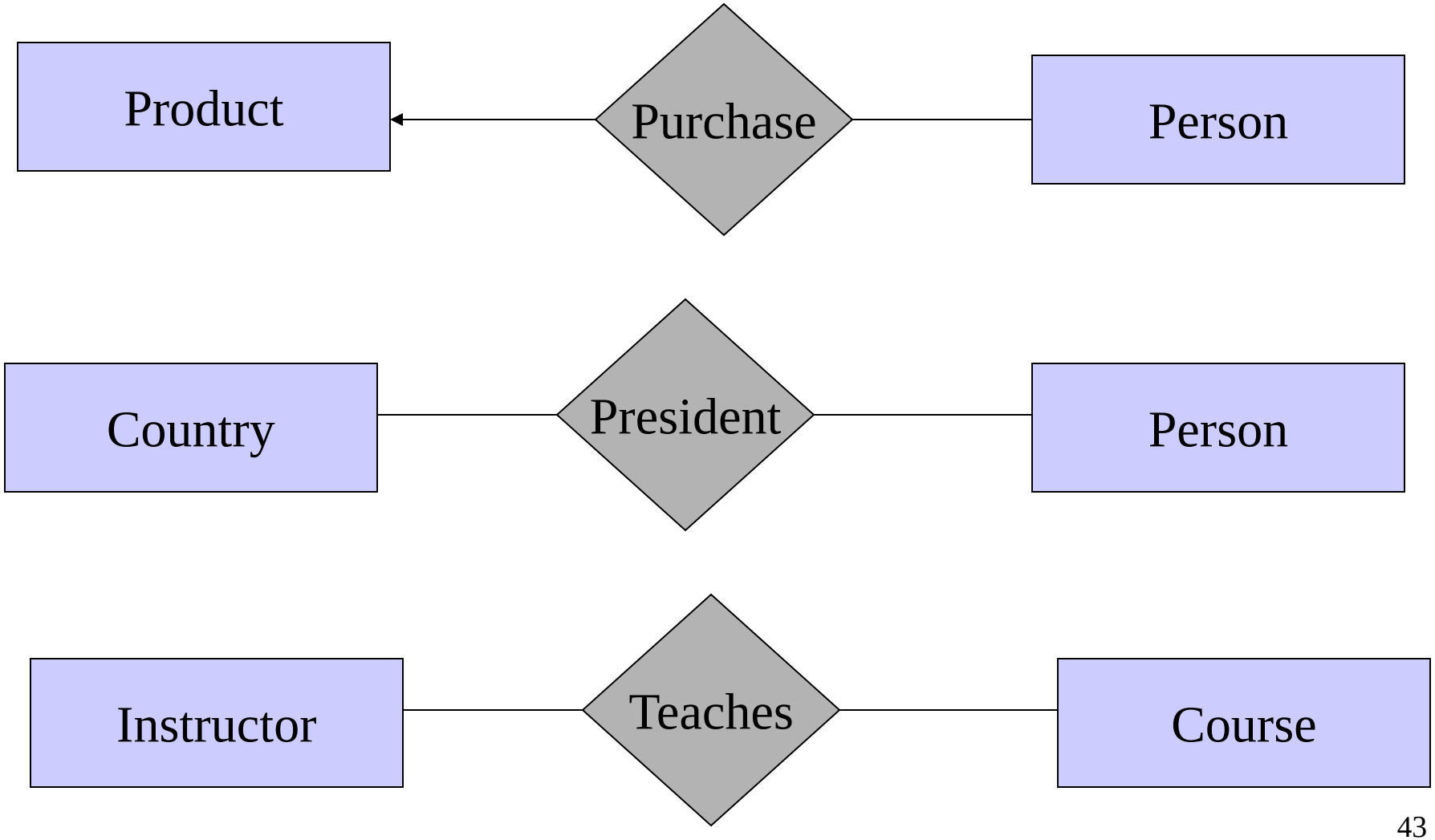


Converting Multiway Relationships to Binary

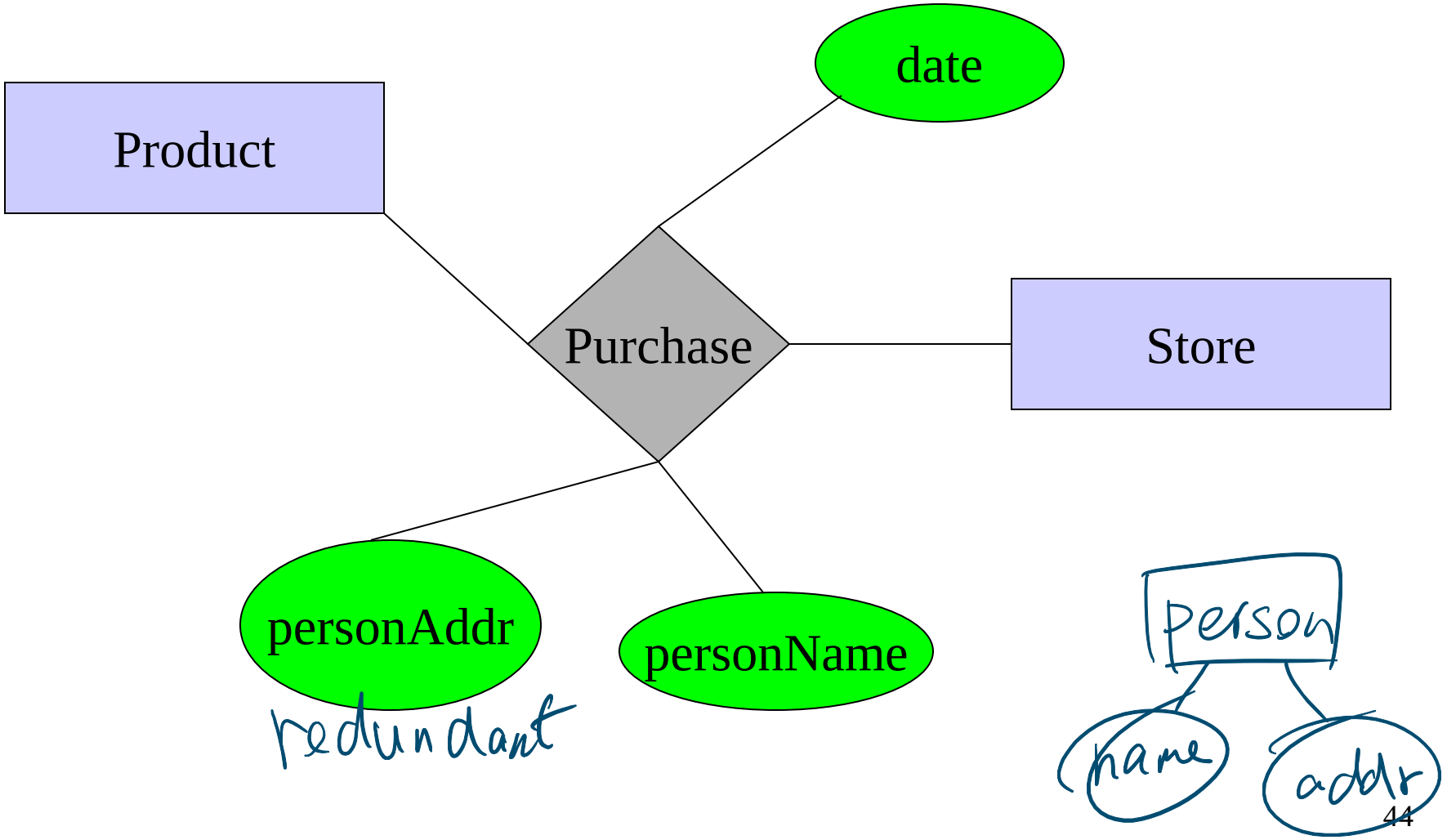


Now, about design techniques ...

Design Principle 1: Be Faithful



Design Principle 2: Avoid Redundancy

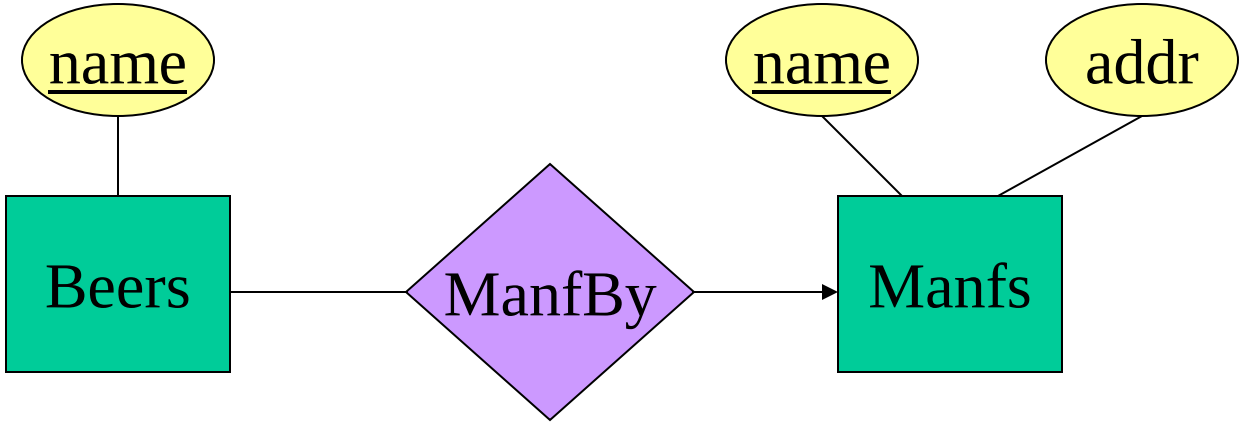


Avoiding Redundancy

- Redundancy occurs when we say the same thing in more than one way.

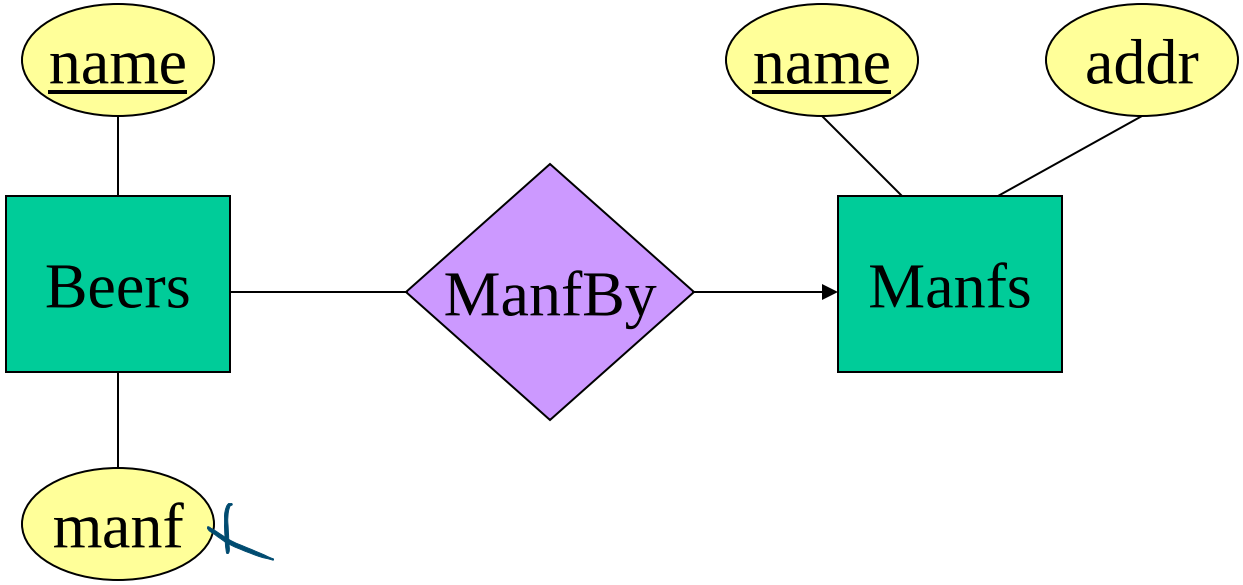
- Redundancy wastes space and (more importantly) encourages inconsistency.
  - Multiple instances of the same fact may become inconsistent if we change one and forget to change the other, related version.

Example: Good



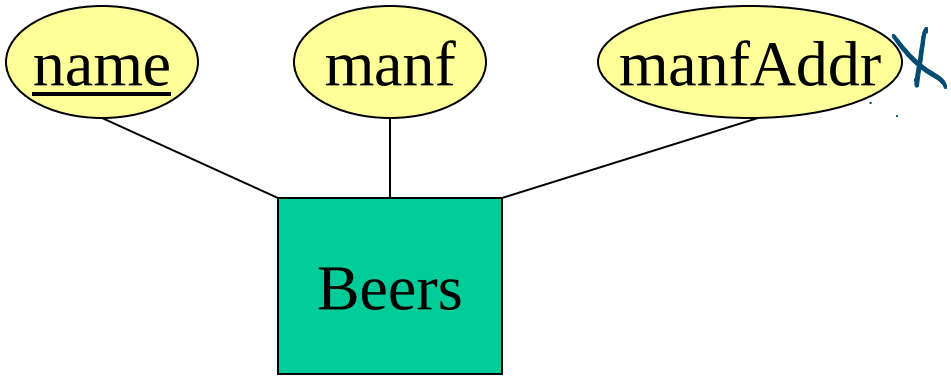
This design gives the address of each manufacturer exactly once.

Example: Bad



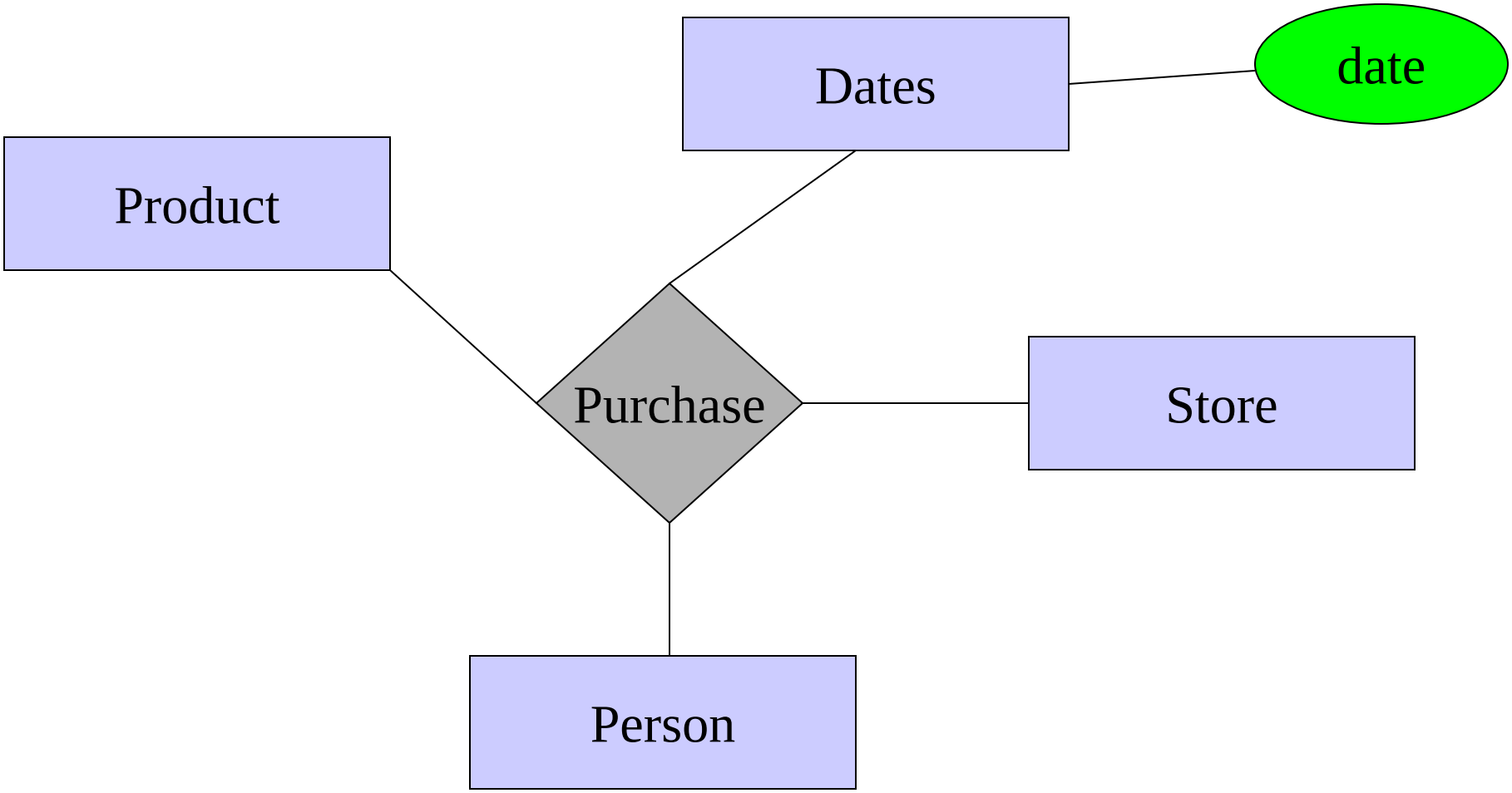
This design states the manufacturer of a beer twice: as an attribute and as a related entity.

Example: Bad



This design repeats the manufacturer's address once for each beer; loses the address if there are temporarily no beers for a manufacturer.

Design Principle 3: KISS



More on Design Techniques

1. Don't use an entity set when an attribute will do.
2. Limit the use of weak entity sets.

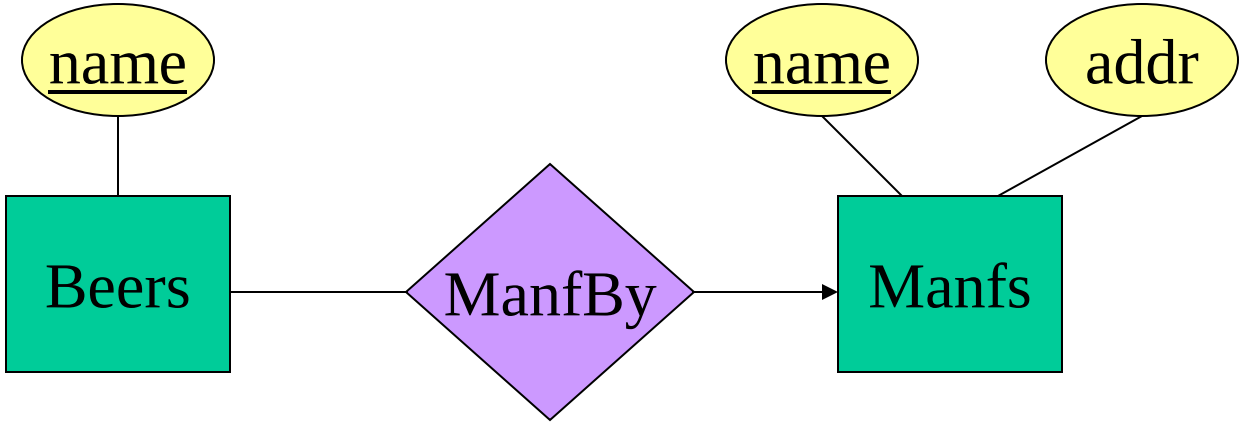
Entity Sets Versus Attributes

- An entity set should satisfy at least one of the following conditions:
  - It is more than the name of something; it has at least one nonkey attribute.

    or

  - It is the “many” in a many-one or many-many relationship. (why?)

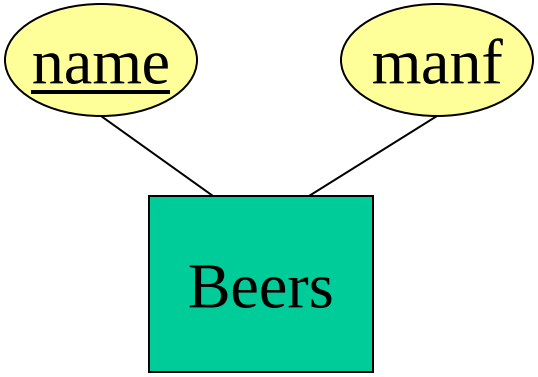
Example: Good



- *Manfs* deserves to be an entity set because of the nonkey attribute *addr*.

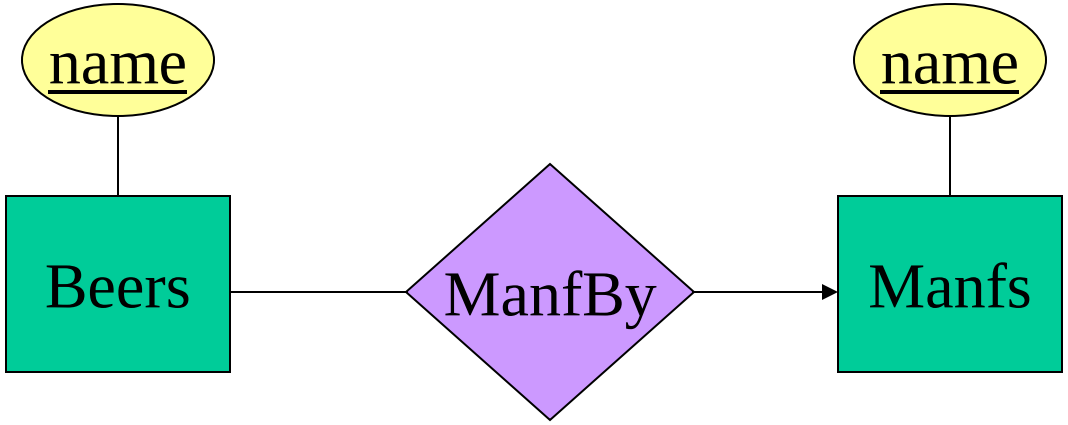
- *Beers* deserves to be an entity set because it is the “many” of the many-one relationship *ManfBy*.

Example: Good



There is no need to make the manufacturer an entity set, if we record nothing about manufacturers besides their name.

Example: Bad



Since the manufacturer is nothing but a name, and is not at the “many” end of any relationship, it should not be an entity set.

Don't Overuse Weak Entity Sets

- Beginning database designers often doubt that anything could be a key by itself.
  - They make all entity sets weak, supported by all other entity sets to which they are linked.
- In reality, we usually create unique ID's for entity sets.
  - Examples include social-security numbers, automobile VIN's etc.

When Do We Need Weak Entity Sets?

- The usual reason is that there is no global authority capable of creating unique ID's.
- Example: it is unlikely that there could be an agreement to assign unique player numbers across all football teams in the world.

ER Review

- Basic stuff
  - entity, attribute, entity set
  - relationship: binary, multiway, converting from multiway
  - relationship roles, attributes on relationships
- Subclasses (is-a)
- Constraints
  - multiplicity of relationships
    - many-one, one-one, many-many
    - limitations of arrows
  - keys, single-valued, ref integrity, domain & general constraints

ER Review

- Weak entity set

- Design principles
  - be faithful
  - avoid redundancy
  - KISS