

# FUNDAMENTALS OF DATABASES

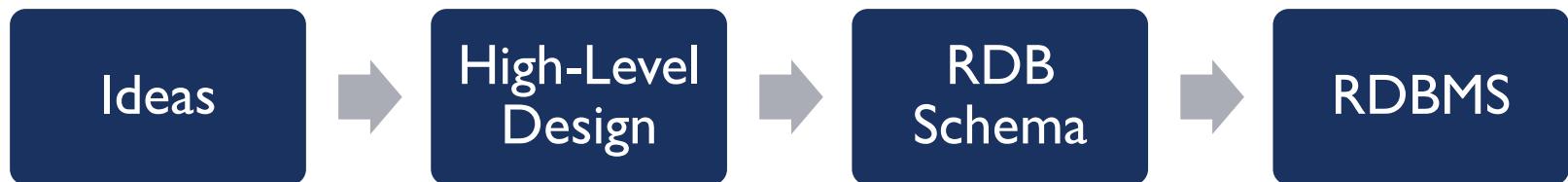
## High level database model – Entity Relationship

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Nguyen Hoang Ha and Le Huu Ton, Fundamentals of Databases, Chapter 5, USTH's textbook, 2025

# DB Modelling and Implementation Process



# How to express High-Level Design

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- There are several options for the notation in which the high-level design is expressed
- The first and oldest method is the “Entity Relationship Diagram”
- A more recent trend is the use of UML (“Unified Modeling Language”)
- We don’t focus on UML in our lessons now but ERD

# Objectives

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- Know or understand
  - Entity Sets
  - Relationship
  - Weak Entity
  - ERD
  - ERD → DB schema

# E/R Model and ERD

- Entity Relationship Model (E/R model) represents the structure of data graphically as an “ERD” using 3-principal element types:
  1. Entity Sets
  2. Attributes
  3. Relationships
- We shall cover all them next

# Framework for E/R

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- Design is a serious business.
- The “boss” knows they want a database, but they don’t know what they want in it.
- Sketching the key components is an efficient way to develop a working database.

# Entity Sets

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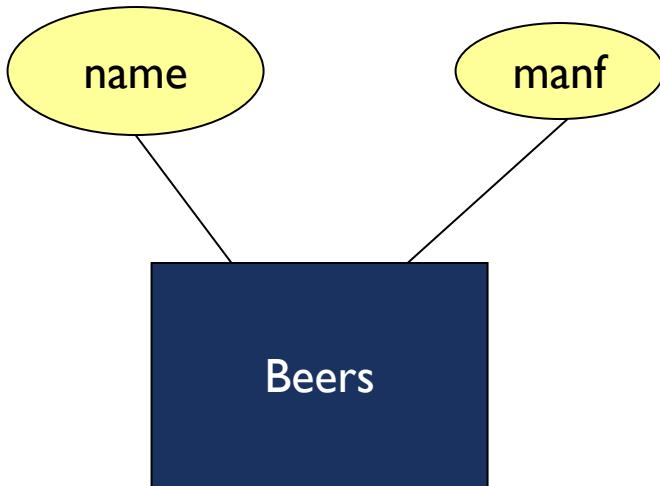
- *Entity* = “thing” or object.
- *Entity set* = collection of similar entities.
  - Similar to a class in object-oriented languages.
- *Attribute* = property of (the entities of) an entity set.
  - Attributes are simple values, e.g. integers or character strings, not structs, sets, etc.

# E/R Diagrams

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- In an entity-relationship diagram:
  - Entity set = rectangle.
  - Attribute = oval, with a line to the rectangle representing its entity set.

# Example:



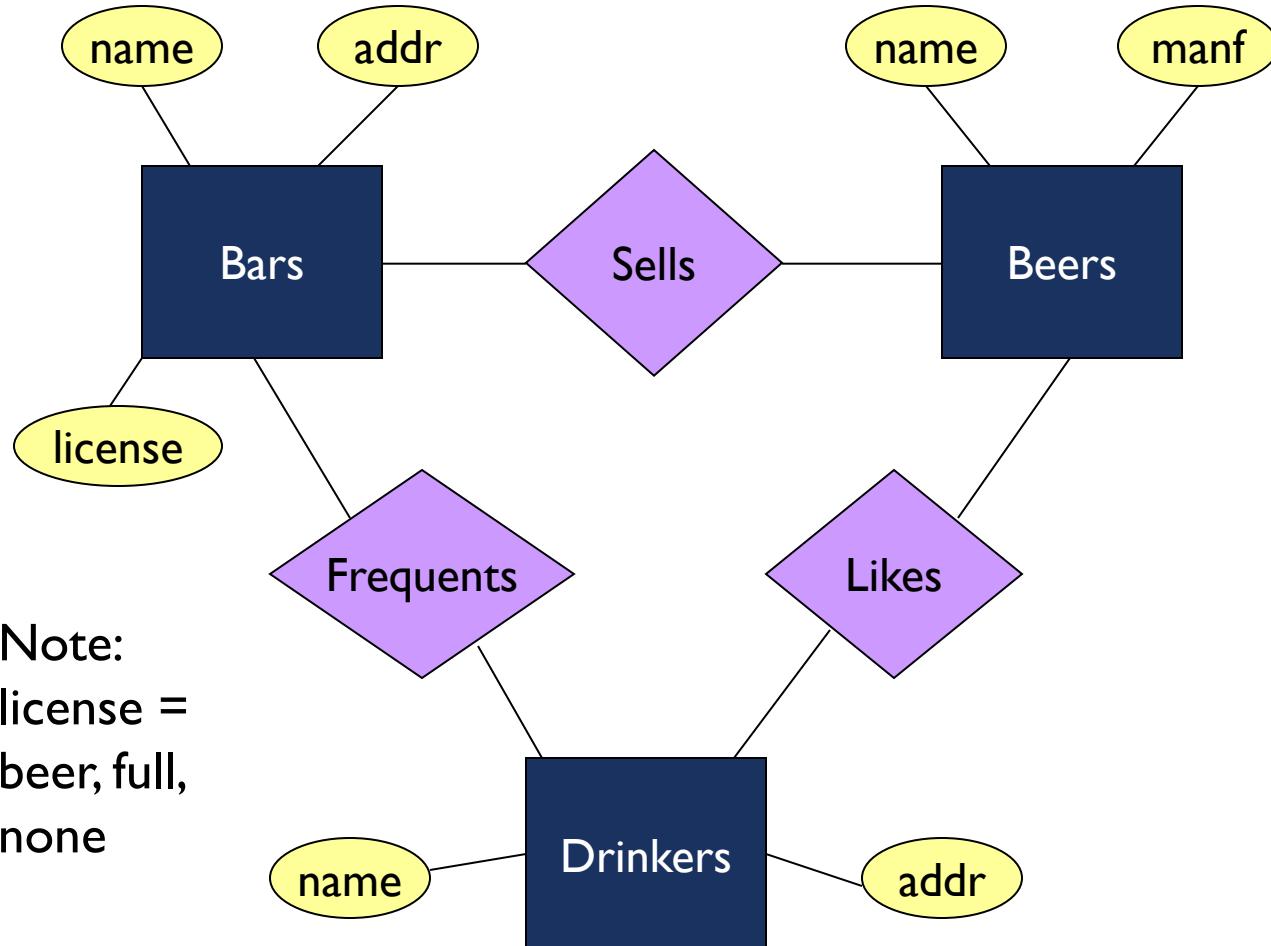
- Entity set **Beers** has two attributes, **name** and **manf** (manufacturer).
- Each **Beers** entity has values for these two attributes, e.g. (Bud, Anheuser-Busch)

# Relationships

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- A **relationship** connects two or more entity sets.
- It is represented by a diamond, with lines to each of the entity sets involved.

# Example: Relationships



Bars sell some beers.

Drinkers like some beers.

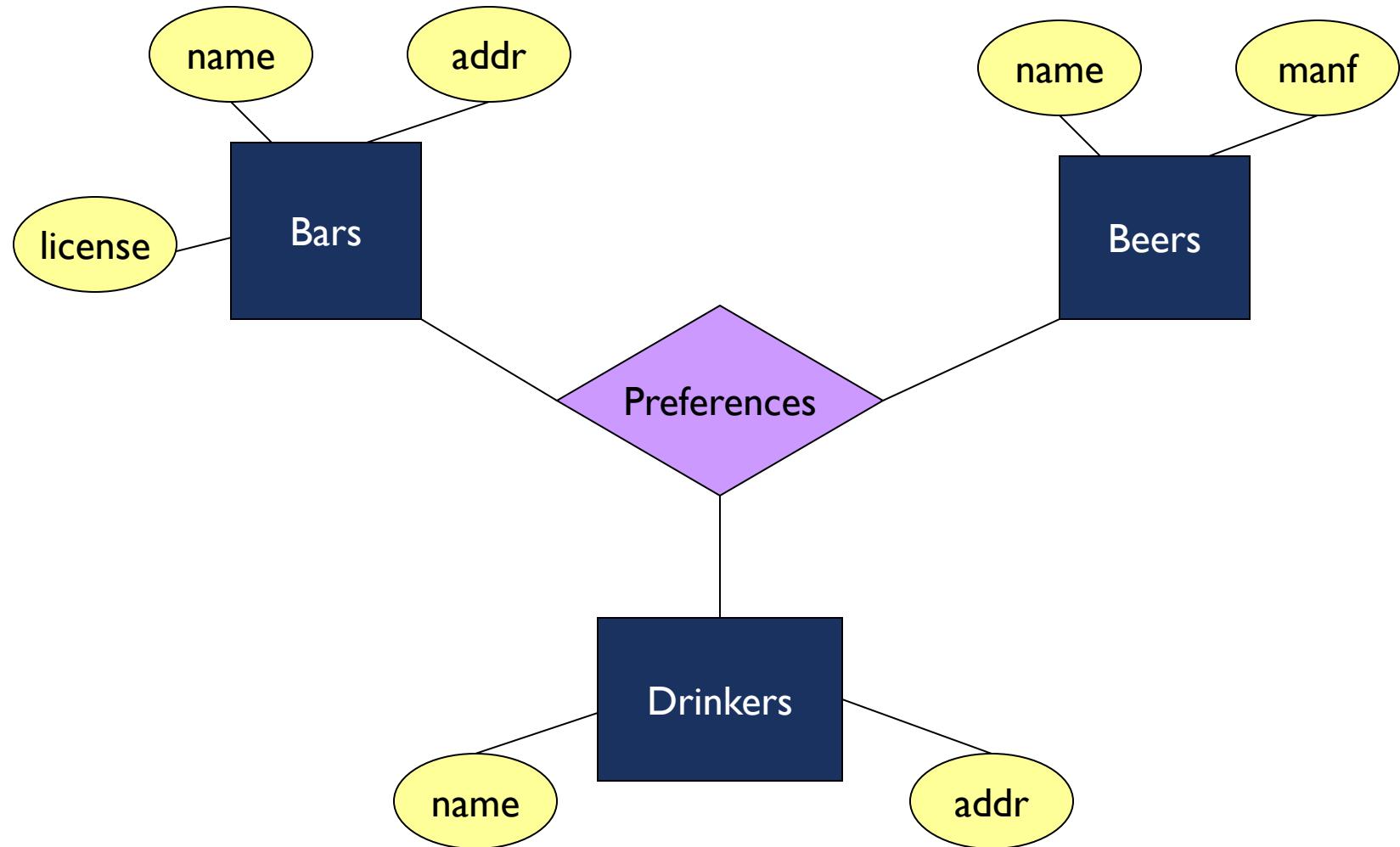
Drinkers frequent some bars.

Note:  
 license =  
 beer, full,  
 none

# Multiway Relationships

- Sometimes, we need a relationship that connects more than two entity sets.
- Suppose that drinkers will only drink certain beers at certain bars.
  - Our three binary relationships **Likes**, **Sells**, and **Frequents** do not allow us to make this distinction.
  - But a 3-way relationship would.

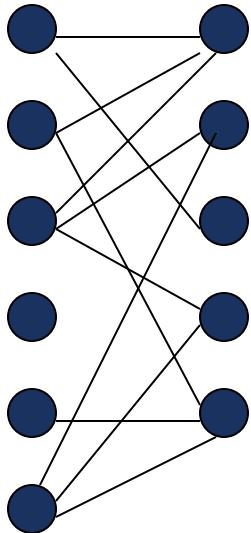
# Example: 3-Way Relationship



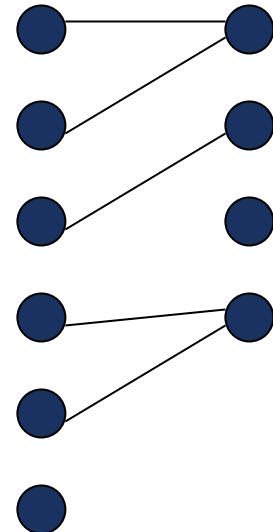
# A Typical Relationship Set

Bar	Drinker	Beer
Joe's Bar	Ann	Miller
Sue's Bar	Ann	Bud
Sue's Bar	Ann	Pete's Ale
Joe's Bar	Bob	Bud
Joe's Bar	Bob	Miller
Joe's Bar	Cal	Miller
Sue's Bar	Cal	Bud Lite

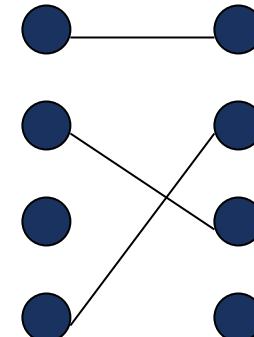
# Multiplicity (cardinality) of Relationships



many-many



many-one



one-one

# Many-Many Relationships

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- Eg: such as **Sells** between **Bars** and **Beers**.
- In a *many-many relationship*, an entity of either set can be connected to many entities of the other set.
  - E.g., a bar sells many beers; a beer is sold by many bars.

# Many-One Relationships

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- Some binary relationships are *many -one* from one entity set to another.
- Each entity of the first set is connected to at most one entity of the second set.
- But an entity of the second set can be connected to zero, one, or many entities of the first set.

# Example: Many-One Relationship

- **Favorite**, from **Drinkers** to **Beers** is many-one.
- A drinker has at most one favorite beer.
- But a beer can be the favorite of any number of drinkers, including zero.

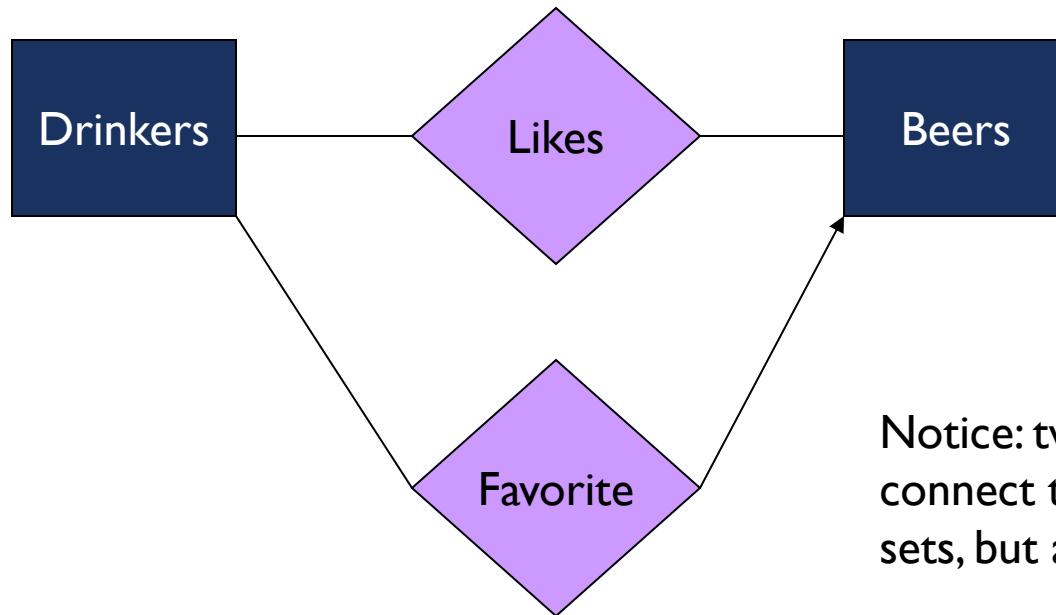
# One-One Relationships

- In a **one-one relationship**, each entity of either entity set is related to at most one entity of the other set.
- **Example:** Relationship **Best-seller** between entity sets **Manfs** (manufacturer) and **Beers**.
  - A beer cannot be made by more than one manufacturer, and no manufacturer can have more than one best-seller (assume no ties).

# Representing “Multiplicity”

- Show a many-one relationship by an arrow entering the “one” side.
  - Remember: Like a functional dependency.
- Show a one-one relationship by arrows entering both entity sets.
- Rounded arrow = “exactly one,” i.e., each entity of the first set is related to exactly one entity of the target set.

# Example: Many-One Relationship



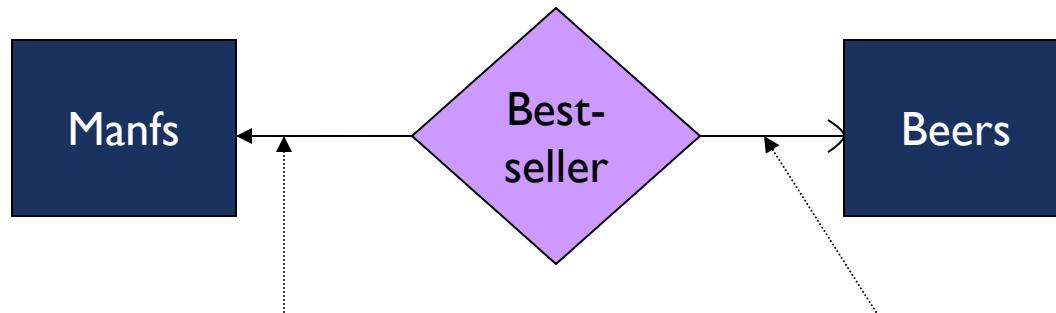
Notice: two relationships connect the same entity sets, but are different.

# Example: One-One Relationship

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- Consider **Best-seller** between **Manfs** and **Beers**.
- Some beers are not the best-seller of any manufacturer, so a rounded arrow to **Manfs** would be inappropriate.
- But a beer manufacturer has to have a best-seller.

# In the E/R Diagram



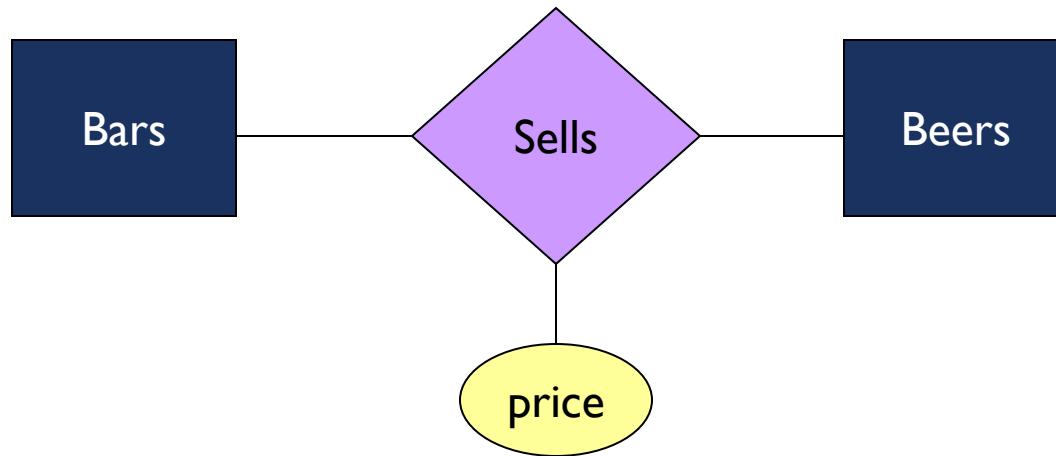
A beer is the best-seller for 0 or 1 manufacturer.

A manufacturer has exactly one best seller.

# Attributes on Relationships

- Sometimes it is useful to attach an attribute to a relationship.
- Think of this attribute as a property of tuples in the relationship set.

# Example: Attribute on Relationship



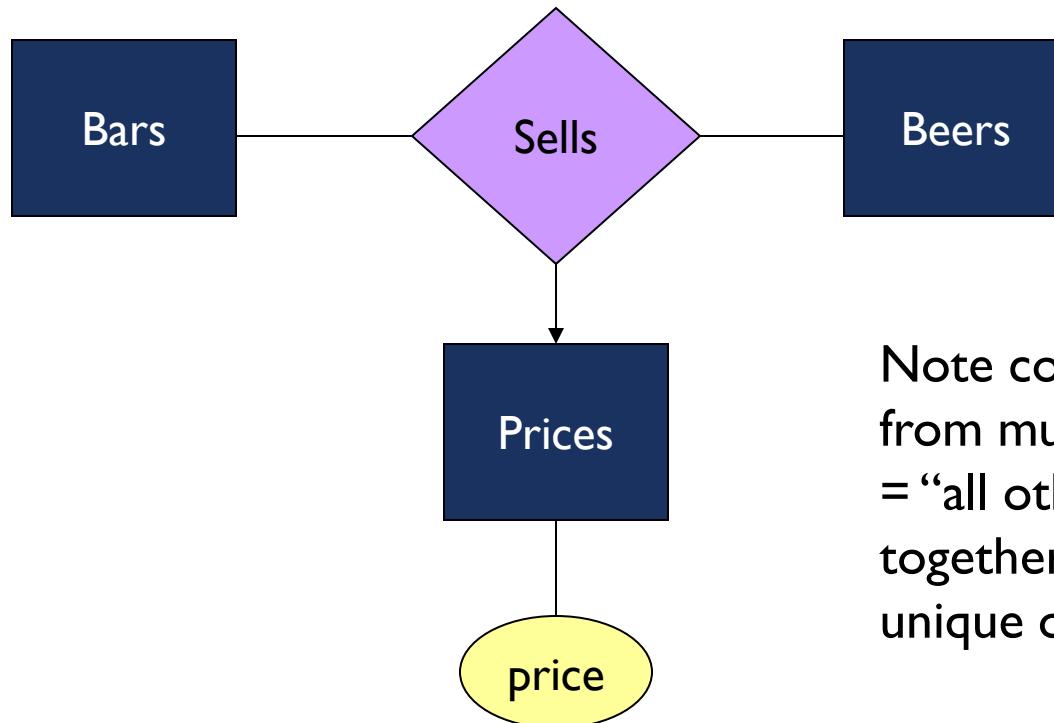
Price is a function of both the bar and the beer,  
not of one alone.

# Equivalent Diagrams Without Attributes on Relationships

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- Create an entity set representing values of the attribute.
- Make that entity set participate in the relationship.

# Example: Removing an Attribute from a Relationship



Note convention: arrow from multiway relationship = “all other entity sets together determine a unique one of these.”

# Roles

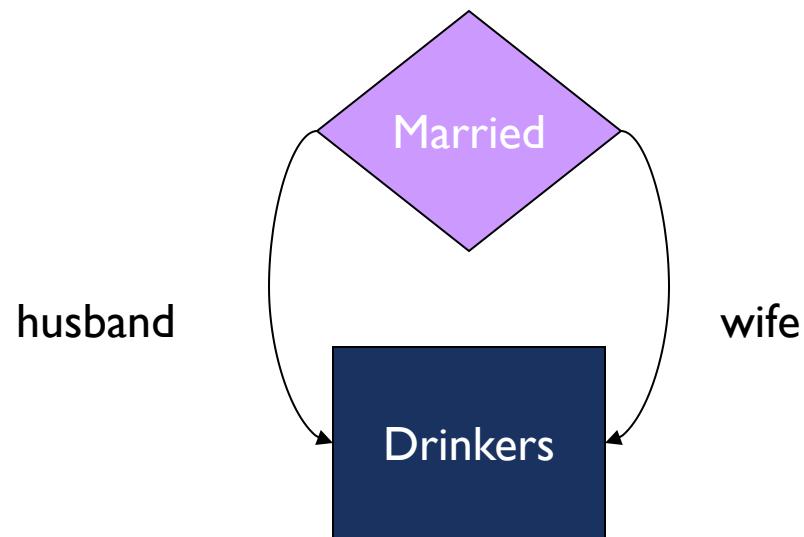
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- Sometimes an entity set appears more than once in a relationship.
- Label the edges between the relationship and the entity set with names called *roles*.

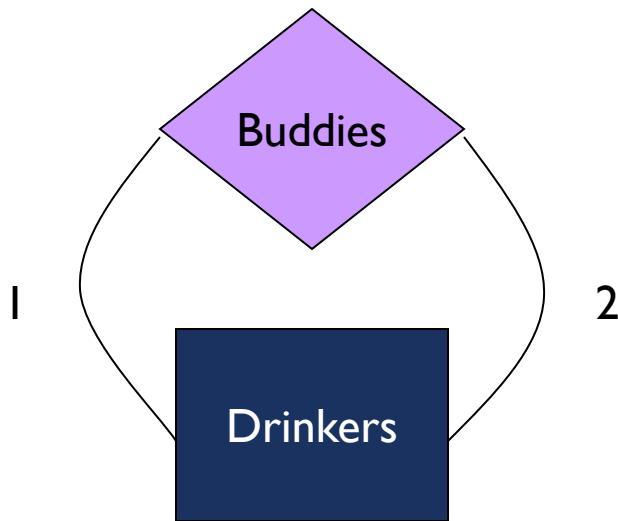
# Example: Roles

Relationship Set

Husband	Wife
Bob	Ann
Joe	Sue
...	...



# Example: Roles



Relationship Set

Buddy1	Buddy2
Bob	Ann
Joe	Sue
Ann	Bob
Joe	Moe
...	...

# Subclasses

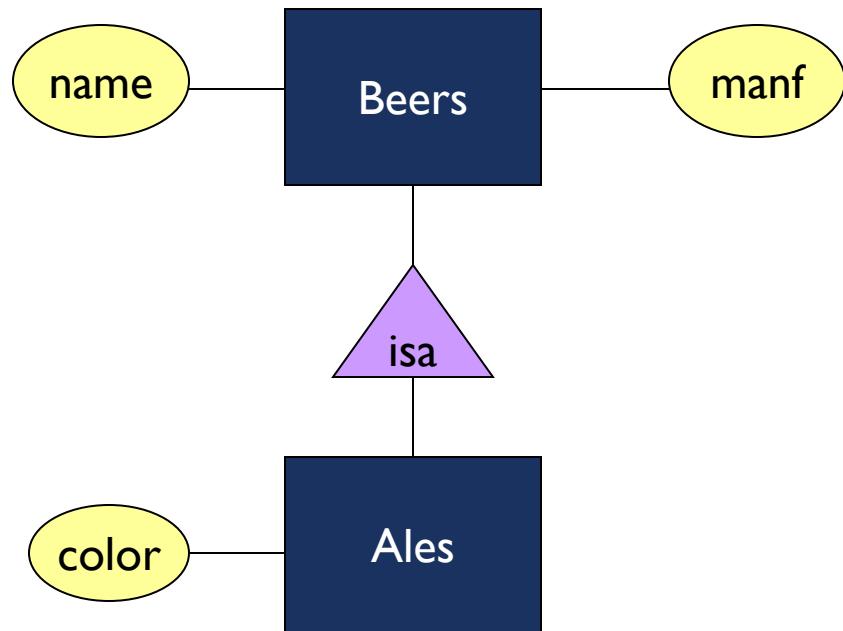
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- **Subclass** = special case = fewer entities = more properties.
- **Example:** Ales are a kind of beer.
  - Not every beer is an ale, but some are.
  - Let us suppose that in addition to all the *properties* (attributes and relationships) of beers,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

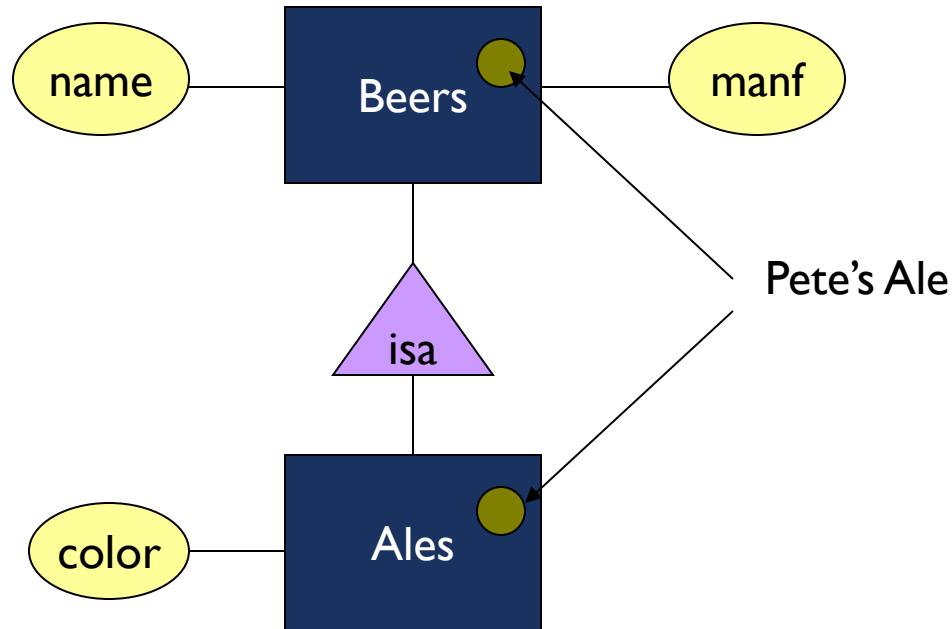
# Subclasses in E/R Diagrams

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

# Example: Subclasses



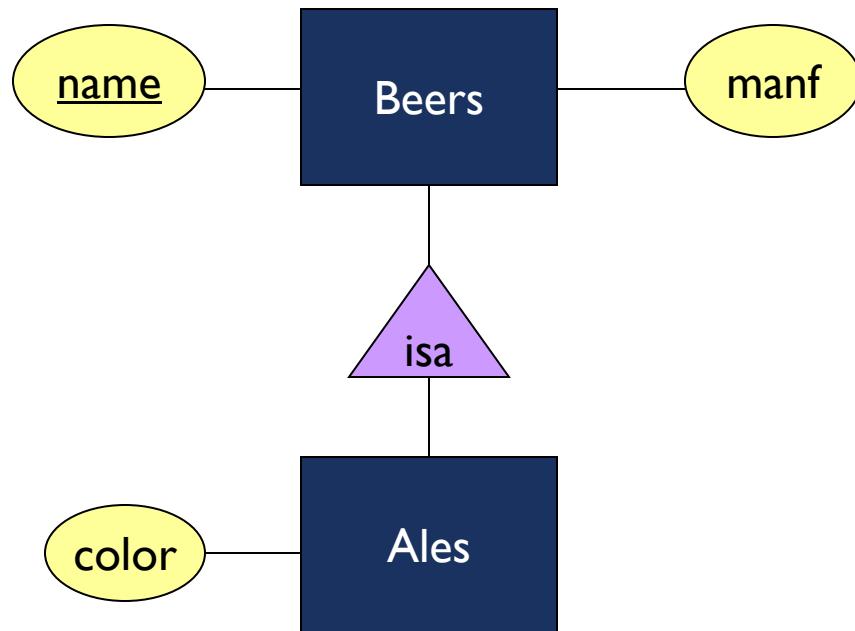
# Example: Representatives of Entities



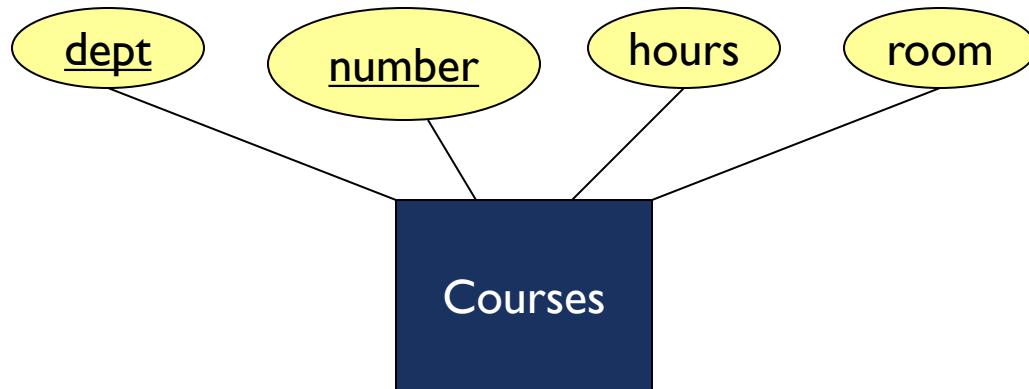
# Keys

- A **key** is a set of attributes for one entity set such that no two entities in this set agree on all the attributes of the key.
  - It is allowed for two entities to agree on some, but not all, of the key attributes.
- We must designate a key for every entity set.
- Keys in E/R Diagrams
  - Underline the key attribute(s).
  - In an Isa hierarchy, only the root entity set has a key, and it must serve as the key for all entities in the hierarchy.

# Example: name is Key for Beers



# Example: a Multi-attribute Key



- Note that **hours** and **room** could also serve as a key, but we must select only one key.

# Weak Entity Sets

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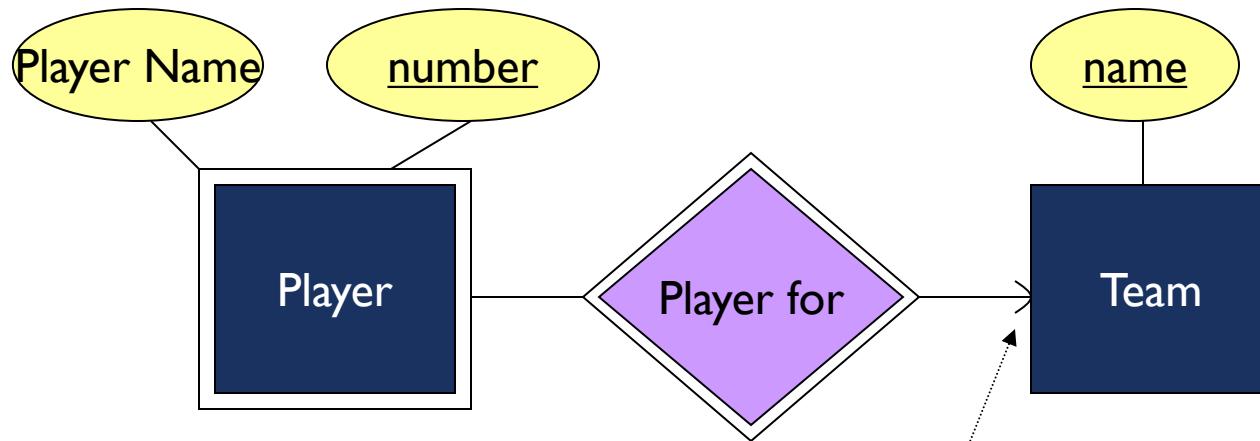
- Occasionally, entities of an entity set need “help” to identify them uniquely.
- Entity set  $E$  is said to be **weak** if in order to identify entities of  $E$  uniquely, we need to follow one or more many-one relationships from  $E$  and include the key of the related entities from the connected entity sets.

# Example: Weak Entity Set

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- **name** is almost a key for football players, but there might be two with the same name.
- **number** is certainly not a key, since players on two teams could have the same number.
- But **number**, together with the team **name** related to the player by **Plays-on** should be unique.

# In E/R Diagrams



Note: must be rounded  
because each player needs  
a team to help with the key.

- Double diamond for *supporting* many-one relationship.
- Double rectangle for the weak entity set.

# Weak Entity-Set Rules

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- A weak entity set has one or more many-one relationships to other (supporting) entity sets.
  - Not every many-one relationship from a weak entity set need be supporting.
  - But supporting relationships must have a rounded arrow (entity at the “one” end is guaranteed).
- The key for a weak entity set is its own underlined attributes and the keys for the supporting entity sets.

# Design Techniques

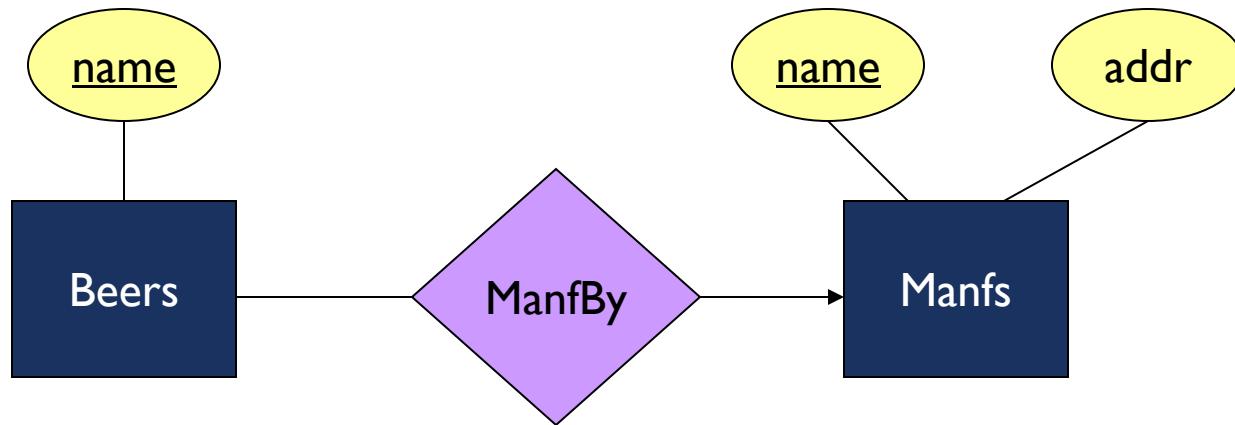
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1. Avoid redundancy.
2. Limit the use of weak entity sets.
3. Don't use an entity set when an attribute will do.

# Avoiding Redundancy

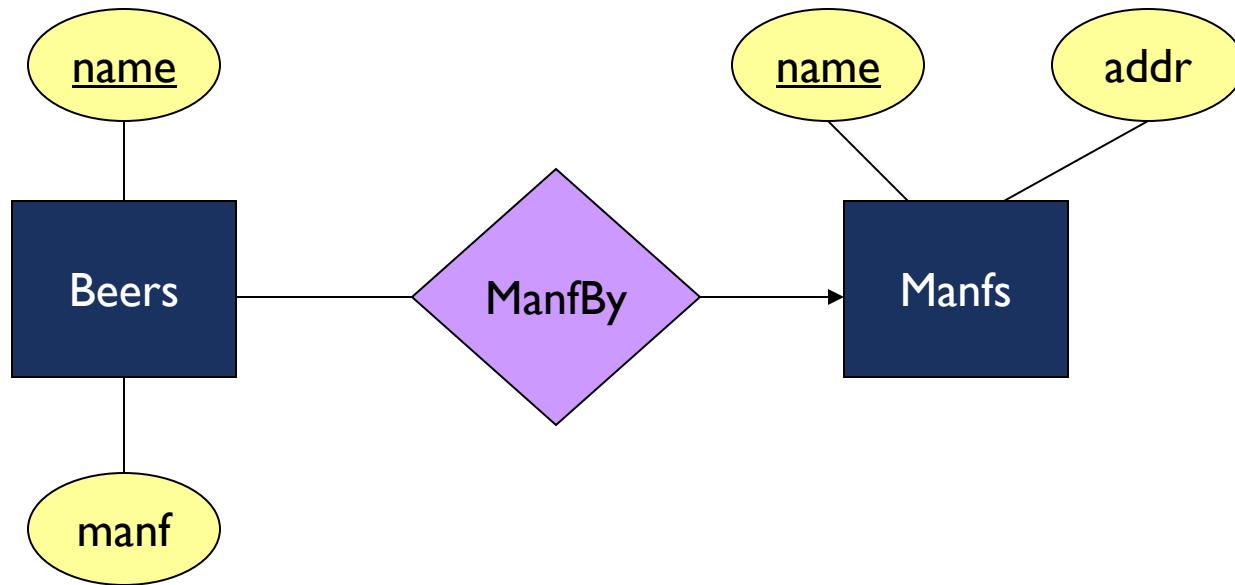
- *Redundancy* = saying the same thing in two (or more) different ways.
- Wastes space and (more importantly) encourages inconsistency.
  - Two representations of the same fact become inconsistent if we change one and forget to change the other.
  - Recall anomalies due to FD's.

# Example: Good



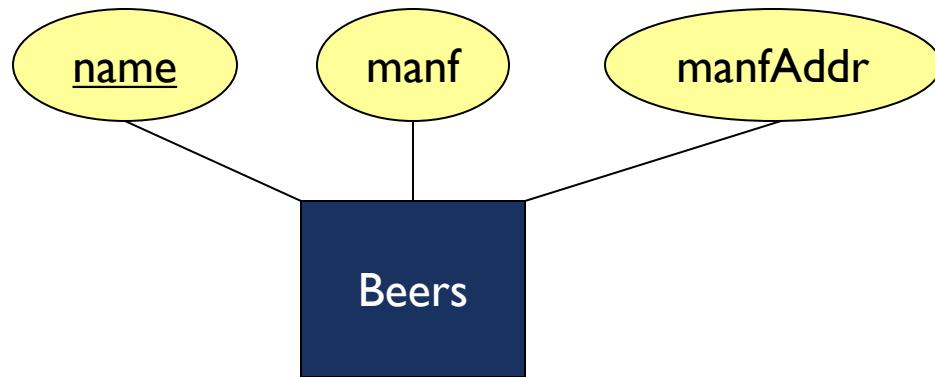
This design gives the address of each manufacturer exactly once.

# Example: Bad



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

# Example: Bad



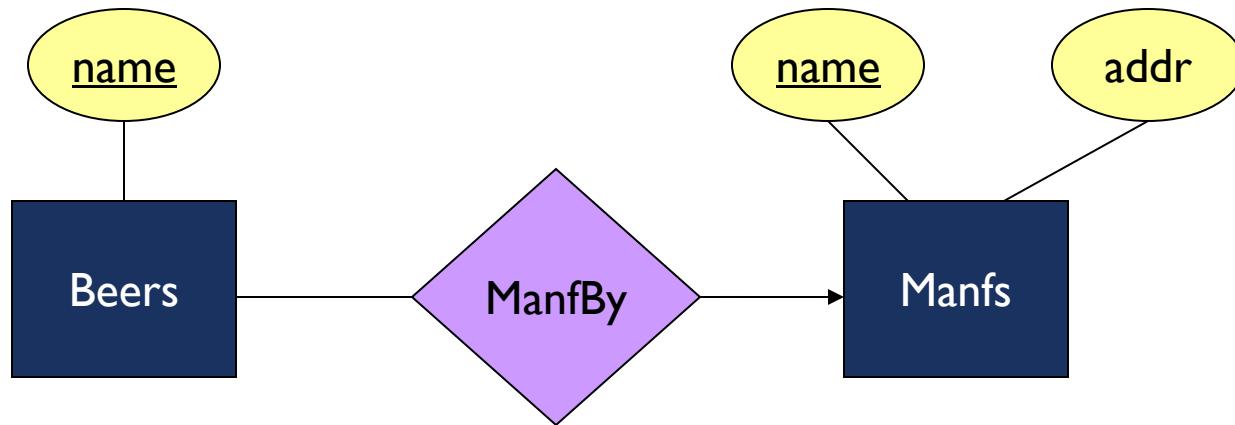
This design repeats the manufacturer's address once for each beer and loses the address if there are temporarily no beers for a manufacturer.

# 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.

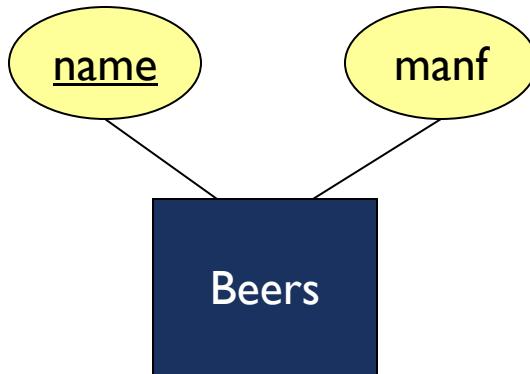
or
  - It is the “many” in a many-one or many-many relationship.

# Example: Good



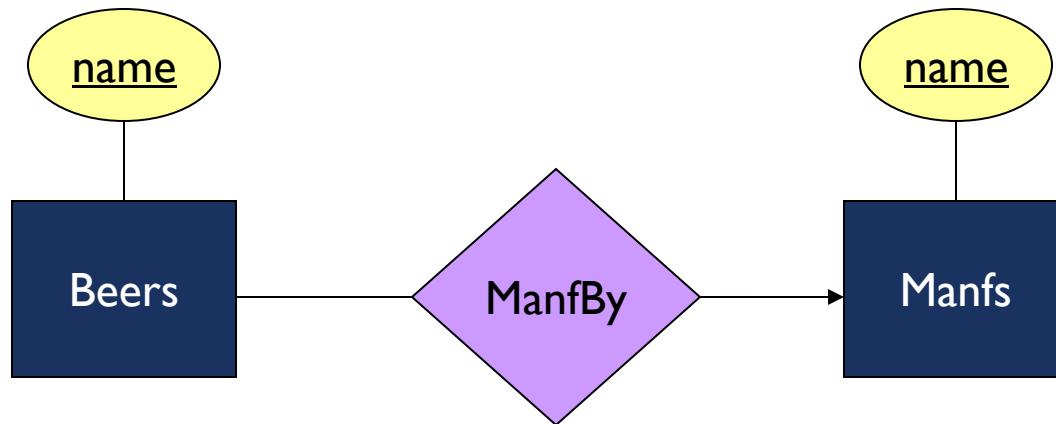
- **Manfs** deserves to be an entity set because of the nonkey attribute **addr**.
- **Beers** deserves to be an entity set because it is the “many” of the many-one relationship **ManfBy**.

# Example: Good



There is no need to make the manufacturer an entity set, because 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.

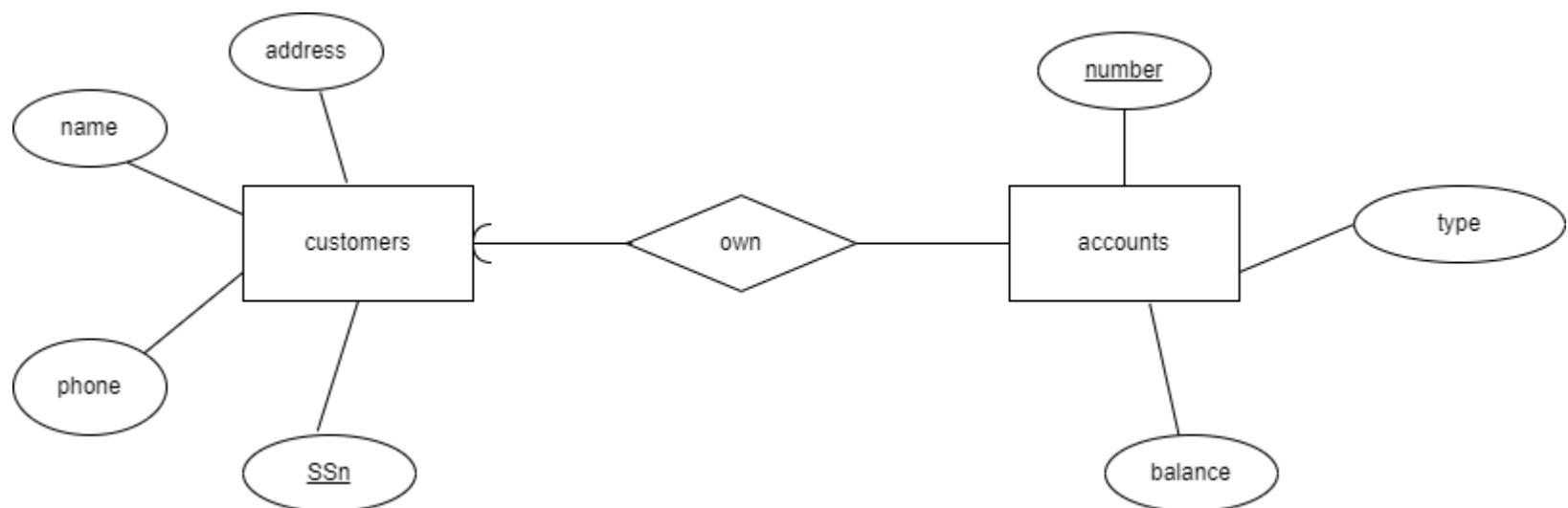
# Don't Overuse Weak Entity Sets

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- 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.

# Exercise

**Exercise 4.1.1:** Design a database for a bank, including information about **customers** and **their accounts**. Information about a customer includes their **name**, **address**, **phone**, and **Social Security number**. Accounts have **numbers**, **types** (e.g., savings, checking) and **balances**. Also record the customer(s) who **own** an account. Draw the E/R diagram for this database. Be sure to include arrows where appropriate, to indicate the multiplicity of a relationship.

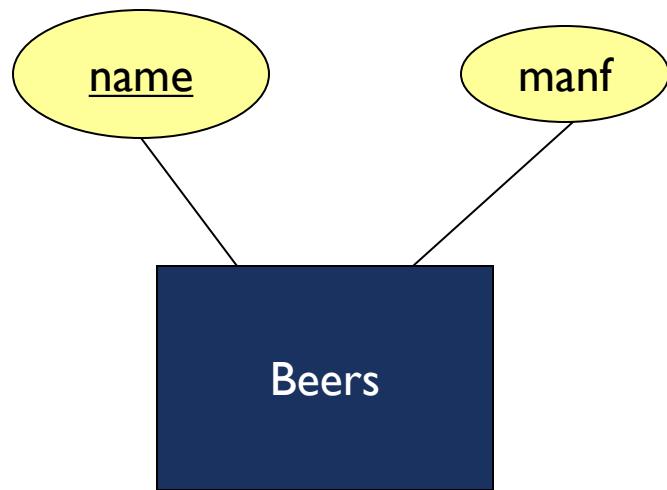


# From E/R Diagrams to Relations

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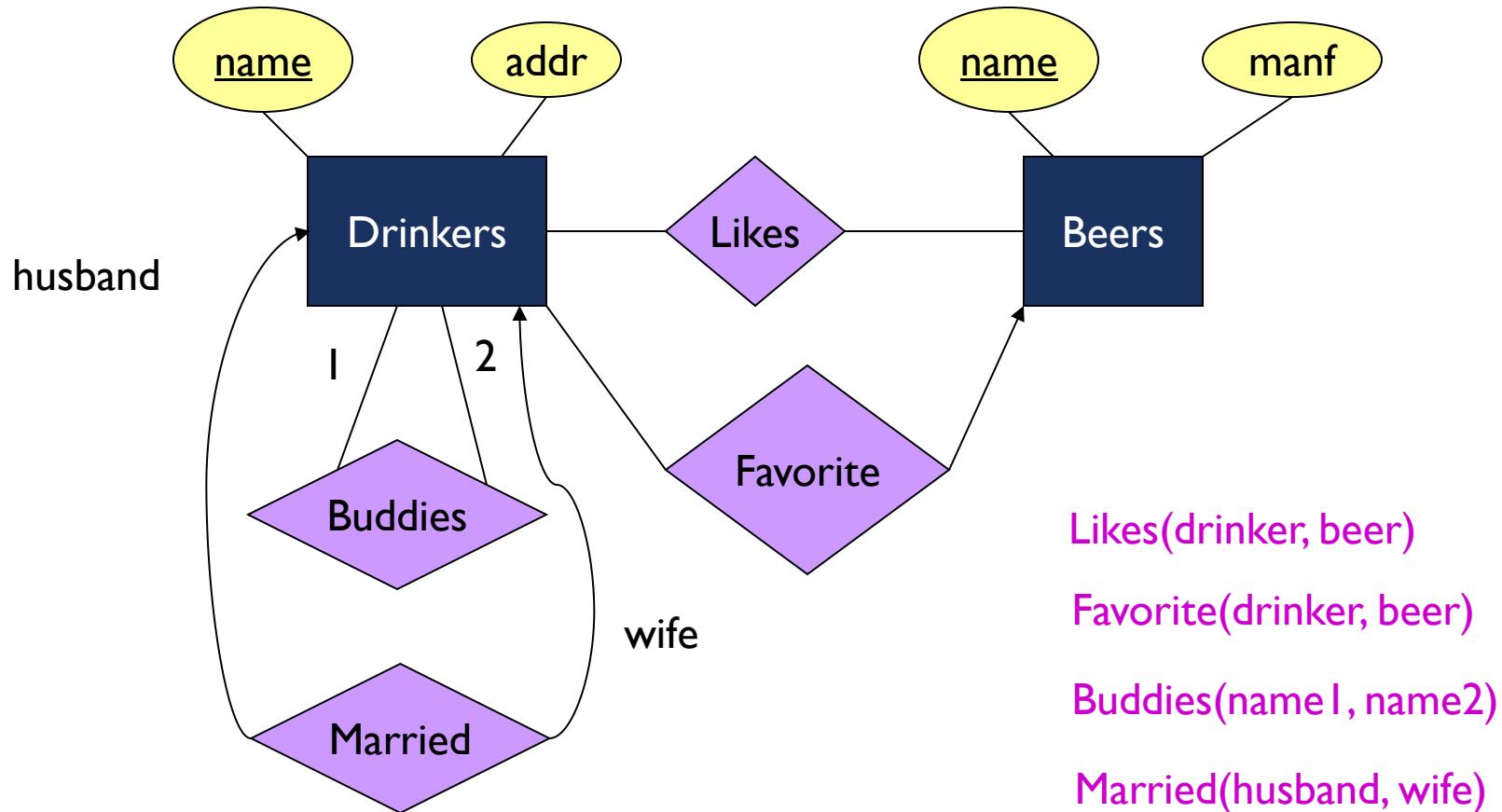
- Entity set → relation.
  - Attributes → attributes.
- Relationships -> relations whose attributes are only:
  - The keys of the connected entity sets.
  - Attributes of the relationship itself.

# Entity Set → Relation



Relation: Beers(name, manf)

# Relationship → Relation



# Combining Relations

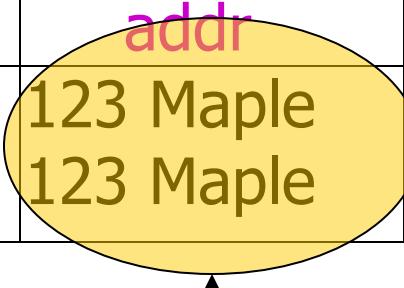
- OK to combine into one relation:
  1. The relation for an entity-set  $E$
  2. The relations for many-one relationships of which  $E$  is the “many.”
- Example:  $\text{Drinkers}(\text{name}, \text{addr})$  and  $\text{Favorite}(\text{drinker}, \text{beer})$  combine to make  $\text{Drinker I}(\text{name}, \text{addr}, \text{favBeer})$ .

# Risk with Many-Many Relationships

- Combining Drinkers with Likes would be a mistake. It leads to redundancy, as:

name	addr	beer
Sally	123 Maple	Bud
Sally	123 Maple	Miller

Redundancy

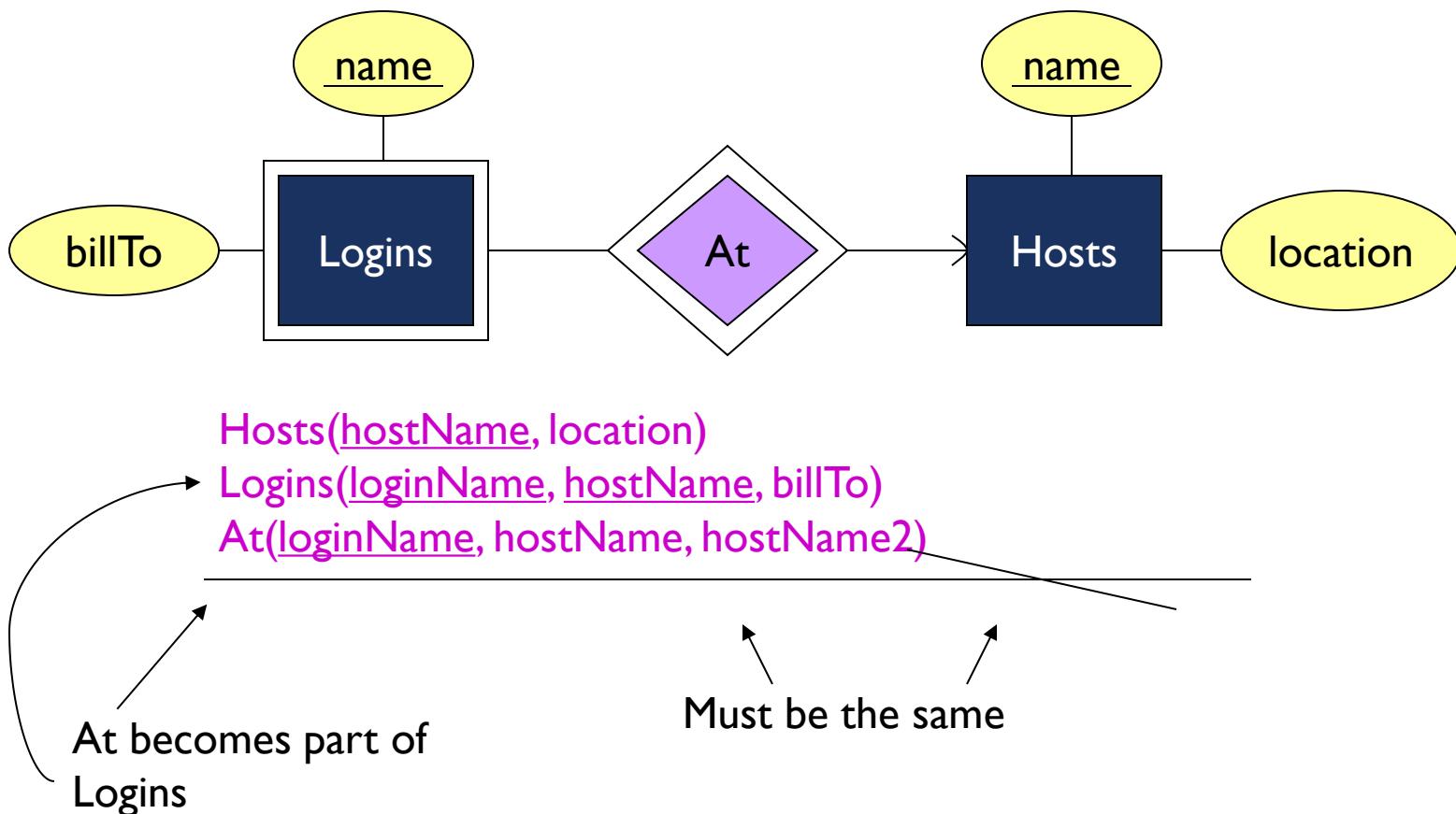


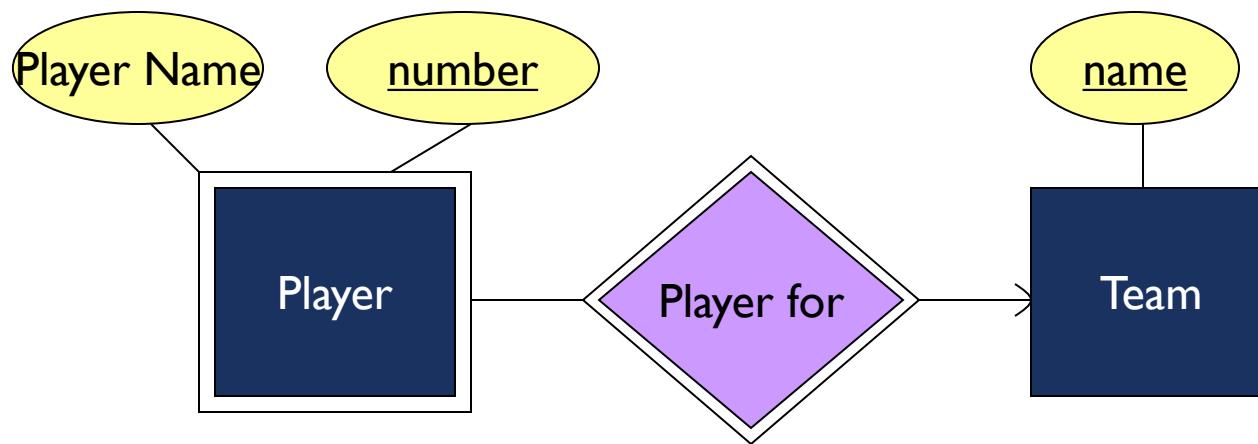
# Handling Weak Entity Sets

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- Relation for a weak entity set must include attributes for its complete key (including those belonging to other entity sets), as well as its own, nonkey attributes.
- A supporting relationship is redundant and yields no relation (unless *it* has attributes).

# Example: Weak Entity Set -> Relation





Team (name)

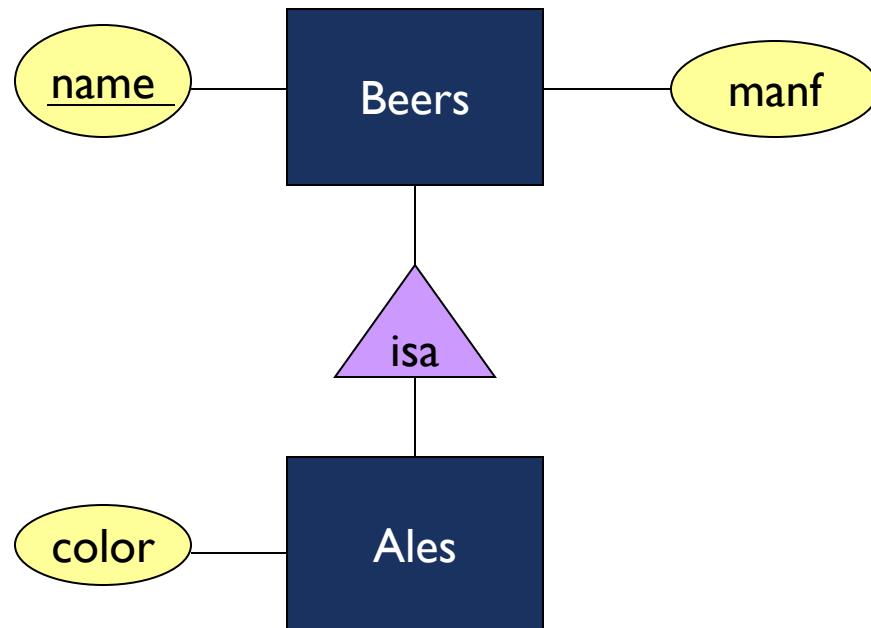
Player (number, team, playerName)

PlayerFor(teamName, playerNumber) → many-one relationship so it can be combined with Player

# Subclasses: Three Approaches

1. *Object-oriented* : One relation per subset of subclasses, with all relevant attributes.
2. *Use nulls* : One relation; entities have NULL in attributes that don't belong to them.
3. *E/R style* : One relation for each subclass:
  - Key attribute(s).
  - Attributes of that subclass.

# Example: Subclass -> Relations



# Object-Oriented

name	manf
Bud	Anheuser-Busch
Beers	

name	manf	color
Summerbrew	Pete's	dark
Ales		

Good for queries like “find the color of ales made by Pete’s.”

# E/R Style

## Beers

name	manf
Bud	Anheuser-Busch
Summerbrew	Pete's

## Ales

name	color
Summerbrew	dark

Good for queries like  
 “find all beers (including  
 ales) made by Pete's.”

# Using Nulls

name	manf	color
Bud Summerbrew	Anheuser-Busch Pete's beer	NULL dark

Saves space unless there are *lots* of attributes that are usually NULL.