LASSONDE SCHOOL OF ENGINEERING | YORK UNIVERSITÉ UNIVERSITY

# E/R Modelling:

## *A Conceptual Modelling Language for Schema*

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# Versions

| | |
|---|---|
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# Acknowledgments

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- *Wenxiao Fu*
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# Printable version of talk

- Follow this link:
  *E/R Modelling* [to **pdf**].
- Then *print* to get a **PDF**.

(*This only works correctly in **Chrome** or **Chromium**.*)

# Why a *conceptual* modelling language?

- So we can sketch out database-schema designs more easily, and “see” their *semantics* / *logic* more easily.
  - The relational model just has *relations*. It can be harder to see the schema's *semantics* / *logic*.
- Many conceptual modelling languages are *pictoral*.

*Later*, we'll *convert* E/R designs into relational schema.

# Design Flowchart

ideas / *requirements*

⇓

high-level design / *specification*

⇓

relational schema / *implementation*

⇓

relational database (in RDBMS) / *realization*

# Different conceptual modelling languages

- **E/R** (*the Entity / Relationship Modelling language*)
  - many *dialects*!
- **UML** (*Universal Modelling Language*)
- **ODL** (*Object Definition Language*)
- and many, many more…

We choose E/R here because it is in many ways the simplest for our purposes.

# Schema semantics

## *declarative*

A schema design should specify

- what schema data represents
- how data are related

- **what** data the schema represents, and how the data are related, but
- *not* **how** the data is used or processed (*operational*).

In other words, our schema designs are *not* meant to be *process models*.

Again, this is about *data independence*.

# Design work

Design is *hard* work! And serious business.

- The boss or client may know they need a database, but they do not know *what* they need in it.
- Sketching the key components is an efficient way to develop a working database.
  - A design can be explained to lay people.
  - A design can be *iteratively* refined.

↳ updated / fixed over time

In software engineering, this is called *requirements elicitation*.

# The Entity / Relationship Model

- **entities** (*things*)
- **relationships**: how entities are *related*
- **attributes**: *properties* of an entity
  - attributes are simple values;
    e.g., integers & strings

*Not* structs, sets, lists, etc.

# Types (sets)

We assume we have *types* of entities & of rel-ships.

- For instance, we would have many *students* (entities), many *classes* (entities), and many *enrolled* (rel-ships).
- So, we'll have
  - an *entity set* called *student*,
  - an *entity set* called *class*, and
  - a *rel-ship set* called *enrolled*.
- Entity and rel-ship *instances* of the same *type* (*set*) each has the *same* set of attributes.

# E/R diagrams

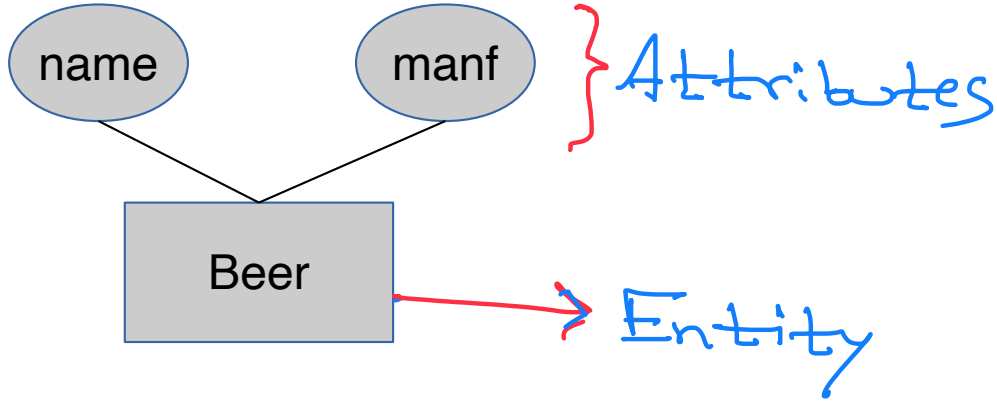
The E/R model is pictoral.

- **entity set**: a labelled *rectangle*
- **rel-ship set**: a labelled *diamond*
- **attribute**: a labelled *oval*, with a line to the entity set or the rel-ship set that *owns* it

Rel-ship sets connect entity sets together that they relate by lines.

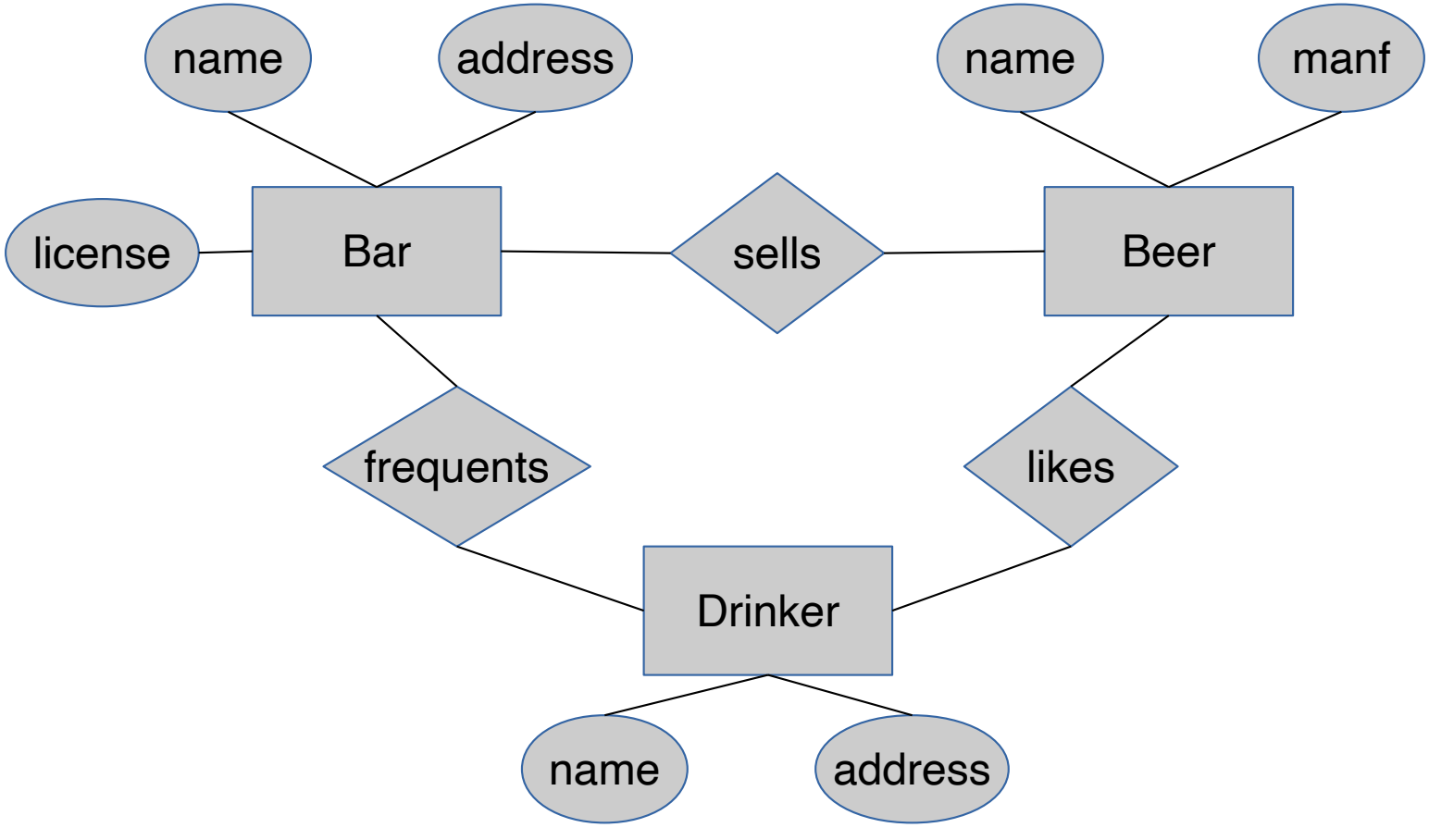
Thus, an E/R diagram is akin to a *bipartite graph* between entity and rel-ship sets.

# Example: entity set




- Entity set **Beer** has two attributes, *name* & *manf*.
- Each *Beer* entity (instance) has values for these two attributes.
  E.g., *Bud* & *Anheuser-Busch*

# Example: relationship sets



# How to read

- Certain **pubs** *sell* certain **beers**.
- Certain **drinkers** *like* certain **beers**.
- Certain **drinkers** *frequent* certain **pubs**.

Values for *license* are intended as *beer only*, *full*, and *none*.

# Value of an entity set or rel-ship set

- The current "value" of an entity set is the set of entities that belong to it.
  - E.g., the set of all **pubs** in our database.
- The "value" of a relationship is the set of relationships that belong to it.
  - The "value" of a relationship is a tuple with one component for *each* related entity set.
  - E.g., ⟨*"Fox & Fiddle"*, *"Molson"*⟩ is a *sells* relationship.

# Example: relationship set value

Thus, an rel-ship value for *sells* might be

| Pub | Beer |
|---|---|
| Fox & Fiddle | Molson |
| Fox & Fiddle | Bud |
| Clintons | Creemore |
| Clintons | Guiness |
| Clintons | Molson |

# Multi-way relationships

Sometimes, we need a relationship that connects more than two entity sets.

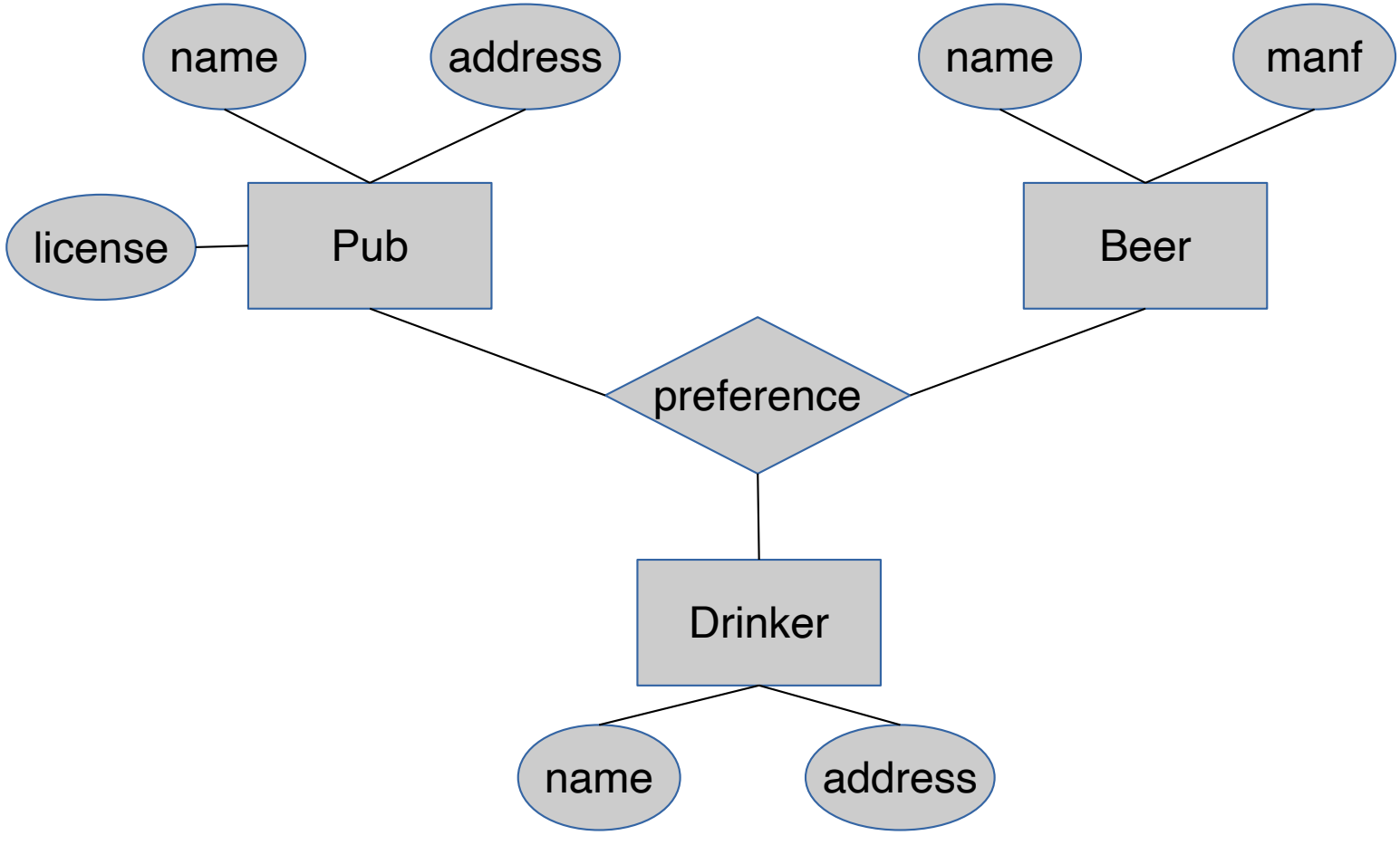
Suppose that drinkers will only drink certain beers at certain pubs.

Our three binary relationships *likes*, *sells*, and *frequents* do not allow us to make this distinction.

But a 3-way relationship would!

→ Multiple connection between attributes and entity.

# Example: 3-way rel-ship



# Example: rel-ship set value

| Pub | Drinker | Beer |
|---|---|---|
| Fox & Fiddle | Franck | Molson |
| Fox & Fiddle | Franck | Bud |
| Fox & Fiddle | Jeff | Bud |
| Clintons | Franck | Molson |
| Clintons | Parke | Creemore |
| Clintons | Jeff | Creemore |
| Clintons | Parke | Guiness |

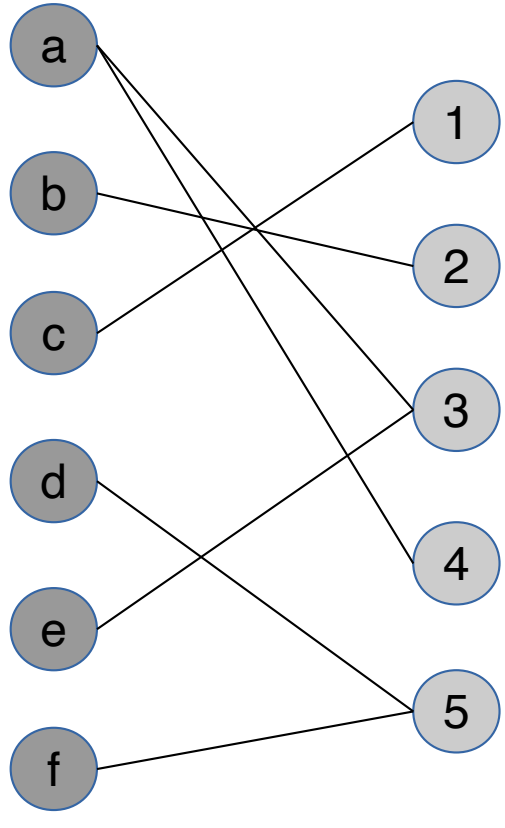
# Many-many rel-ships

**Focus**: binary relationships, such as **sells** between **Pub** and **Beer**.

In a *many-many relationship*, an entity of either set can be connected to many entities of the other set. E.g.,

- a pub sells many beers; and
- a beer is sold by many pubs.

# Many-many



# Many-One rel-ships

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.

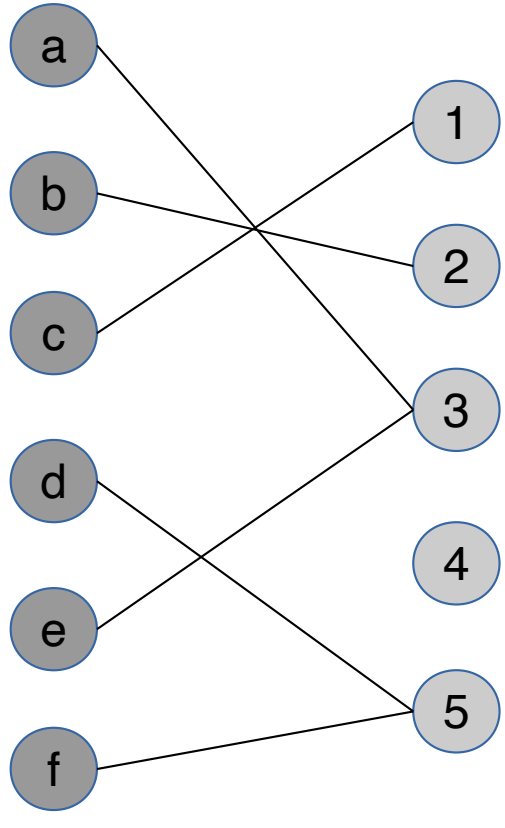
But an entity of the second set can be connected to *zero*, *one*, or *many* entities of the first set.

# Example: many-one rel-ship

Consider a rel-ship **favourite**, from **Drinker** to **Beer**, and that it is *many-one*. That is,

- a drinker has at most one favourite beer, but
- a beer can be the favourite of any number of drinkers (including zero).

# Many-one



# One-one rel-ship

In a *one-one* rel-ship, each entity of either entity set is related to *at most one* entity of the other set.

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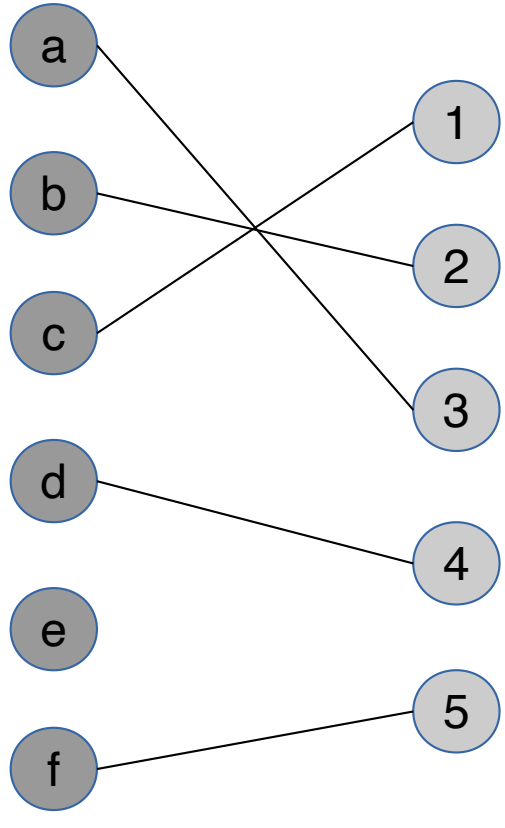
**Example**

Rel-ship **best-seller** between entity sets **Manf** (*manufacturer*) and *Beer*.

- A beer cannot be made by more than one manufacturer, and
- no manufacturer can have more than one best-seller. (Assume no ties.)

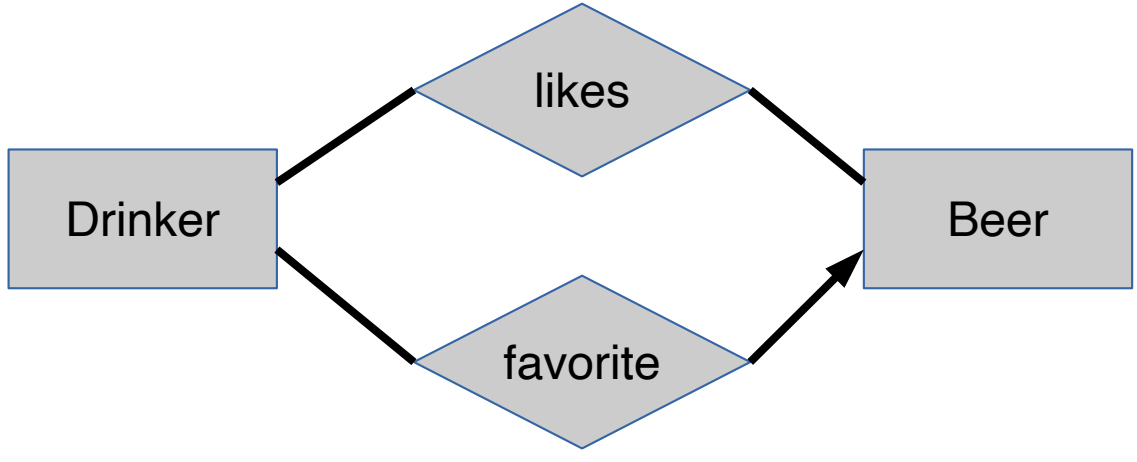
# One-one



# Representing multiplicity

- Show a *many-one* relationship by an arrowhead pointing to the "one" side.
- Show a *one-one* relationship by arrowheads pointing to both entity sets.
- Two types of arrowheads.
  - **plain arrowhead**: *zero* or *one*
    *Each* entity of the first set is related to *no* entity or *one* entity of the target set.
  - **rounded arrowhead**: *exactly one*
    *Each* entity of the first set is related to *exactly one* entity of the target set.

# Favourite: Many-one rel-ship w/ multiplicity




Note that **Drinker** and **Beer** have *two* rel-ships between them. This is fine in E/R.

Thus, an E/R diagram is a *multi-graph*.

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**Q)** How to ensure a *drinker's favourite beer* is actually a *beer* that he or she *likes*?

# Best seller: One-one rel-ship w/ multiplicity


- A beer is the best-seller for 0 or 1 manufacturer.
- A manufacturer has *exactly* one best seller.

# Attributes of rel-ships

- Sometimes a rel-ship needs attributes.
- Such an attribute can be thought of as a property of "tuples" in the rel-ship set.

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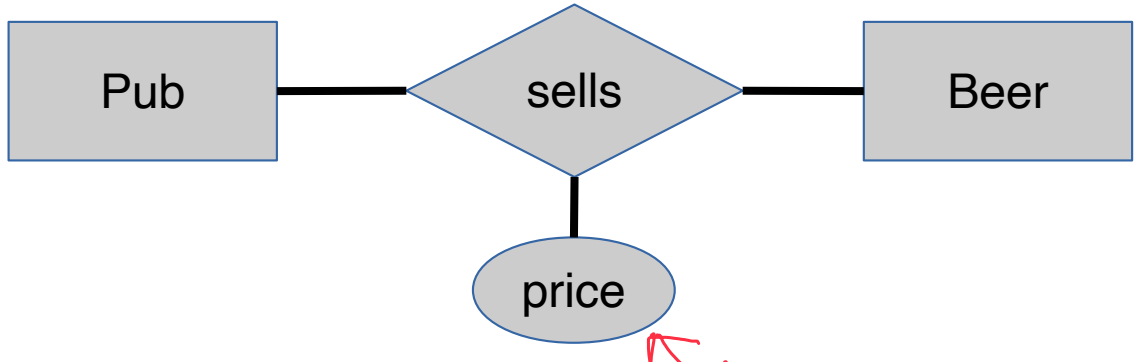
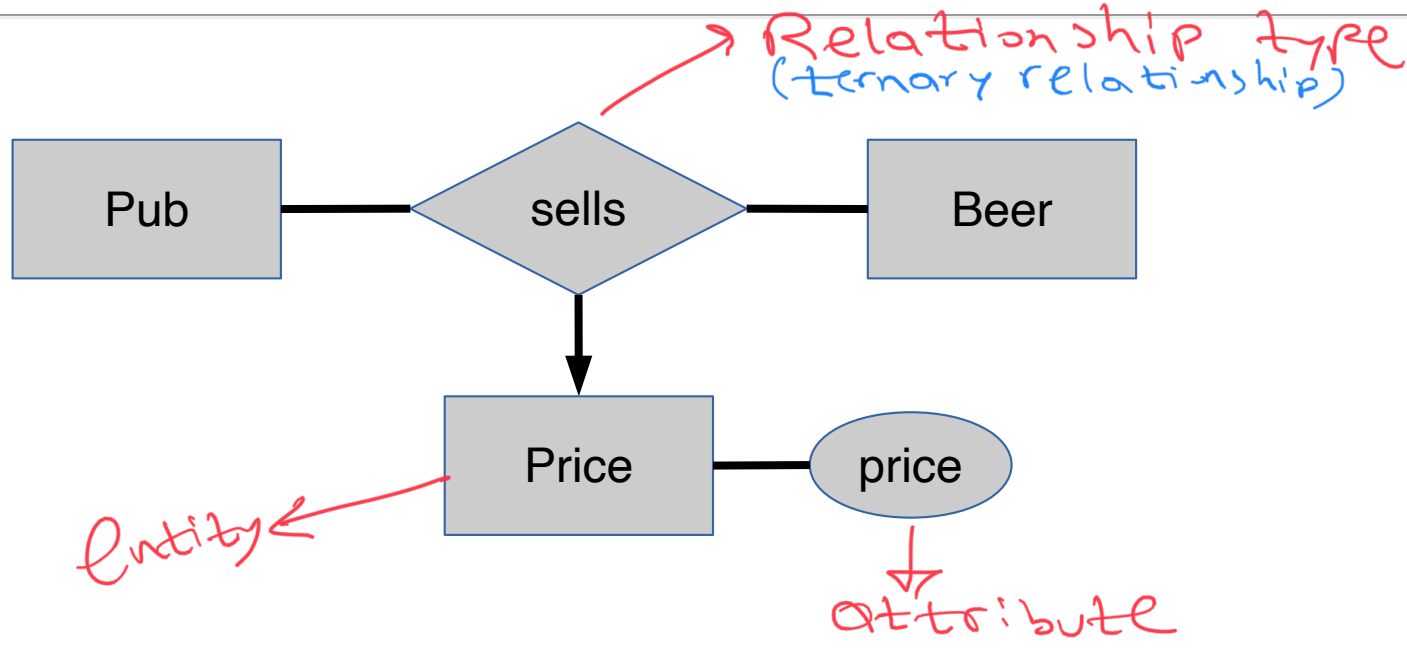



*Price* is a function of both the **Pub** and the **Beer**, not of just one or the other.

# Without attributes on rel-ships

- Instead, could create an entity set representing values of the attribute.
- Then, make that entity set participate in the rel-ship.



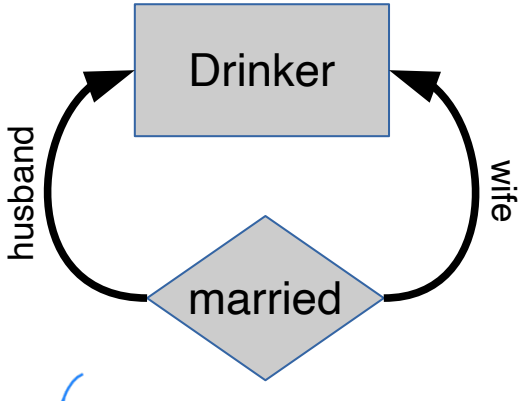

**Convention**: Arrowhead from multiway rel-ship means that all *other* entity sets *together* determine a unique one of these.

ternary → relating 3 things

Recursive relation → relationship between two entities of same type

# "Recursive" rel-ships & roles

- A given entity set may appear more than once in a rel-ship!
- To disambiguate, we label the edges between the rel-ship and the entity set with names called *roles*.

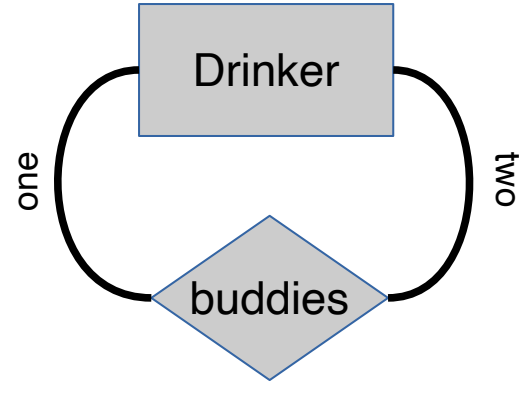



| husband | wife |
|---|---|
| Bob | Ann |
| Joe | Sue |
| ... | ... |

(One-to-one relationship) Can be many-to-many

# Buddies

| one | two |
|---|---|
| Joe | Moe |
| Ann | Sue |
| Ann | Moe |
| … | … |



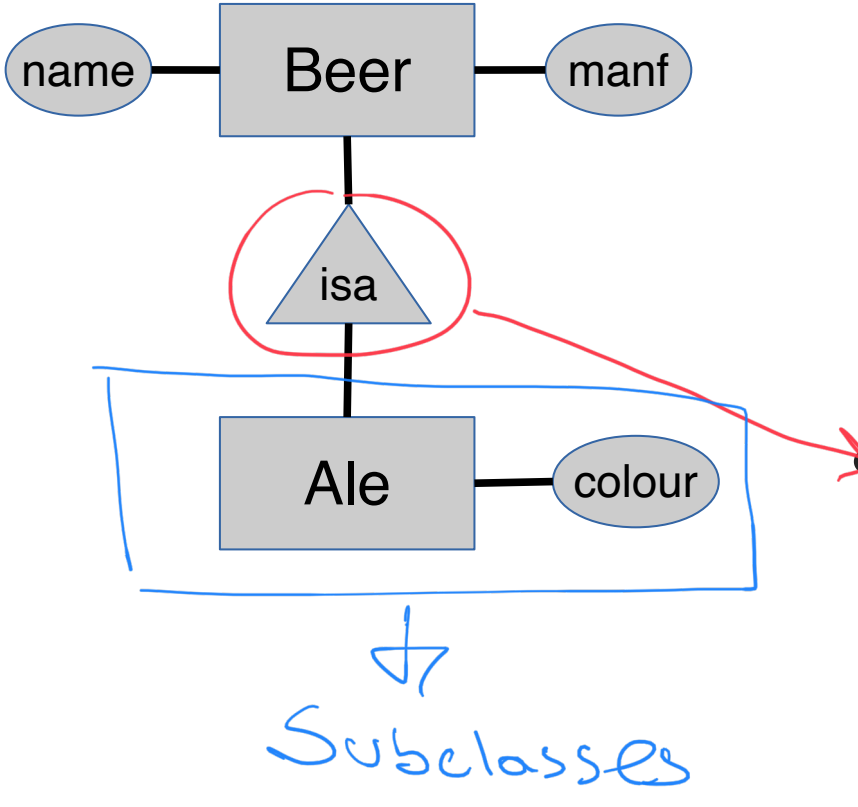

Many - Many relationship

# Subclasses

- A *subclass* is a special case that has more properties.
- E.g., An **Ale** is a kind of **Beer**.
- Not every beer is an ale, but some are.

Let us suppose that, in addition to the properties — attributes and rel-ships — of *beers*, *ales* also have the attribute *colour*.

# Subclasses in E/R




- Assume subclasses form a tree.

  That is, no multiple inheritance.

- An **isa** triangle indicates the subclass “relationship”.

  The triangle “points” to the superclass.

# E/R vs OO

- In OO, objects are in one class only.
  - Subclasses inherit from superclasses.
- In contrast, E/R entities have representatives in all subclasses to which they belong.

**Rule**. If entity *E* is represented in a subclass, then *E* is represented in the superclass. (And recursively up the tree.)

If “Pete's Ale” is an **Ale**, it is also a **Beer**.

# Keys (déjà vu)

A *key* is a set of attributes for one entity set such that *no* two entities in this set agree on *all* the attributes's values of the key.

(Note that two entities may agree on *some*, but not *all*, of the key attributes's values.)

In a *complete* E/R diagram, a key must be designated for every entity set.

# Keys in E/R diagrams

We underline the key attribute(s).

**Note**. In an **isa** hierarchy, only the root entity set has a key; this must serve as the key for all entities in the hierarchy.

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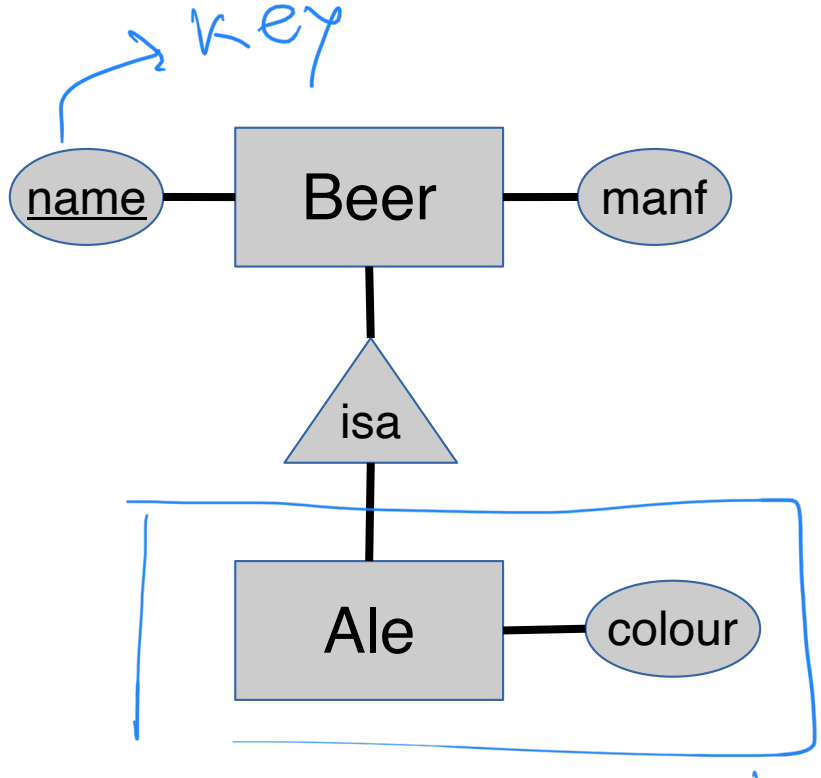
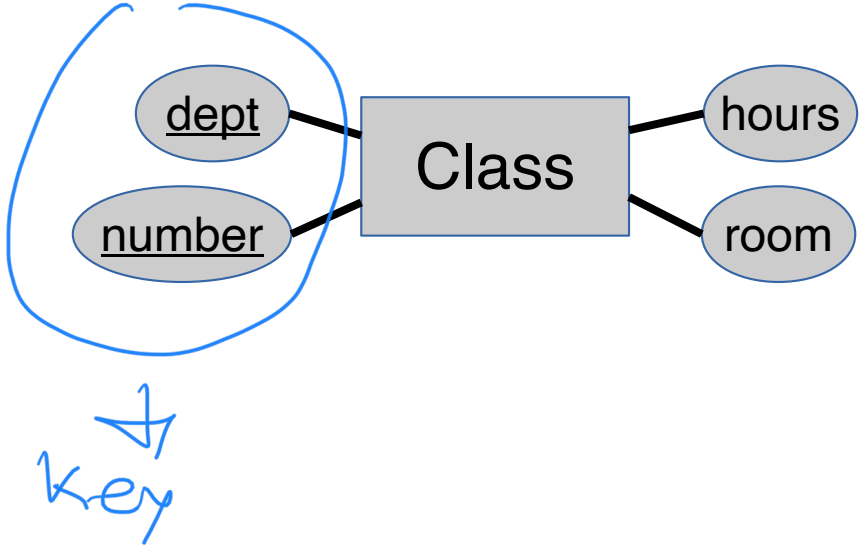
Entity sets have keys.
Rel-ships do *not!*

# Keys in E/R




- *Name* is key for **Beer** *and* for **Ale**.

# A multi-attribute key




- Note that *hours* and *room* could also serve as a key
- But let us limit ourselves to one key. For now.

# Weak entity sets

Entities of entity set might need “help” to *identify* them uniquely.

Entity set **E** is said to be *weak* if, in order to *identify* entities of **E** uniquely,

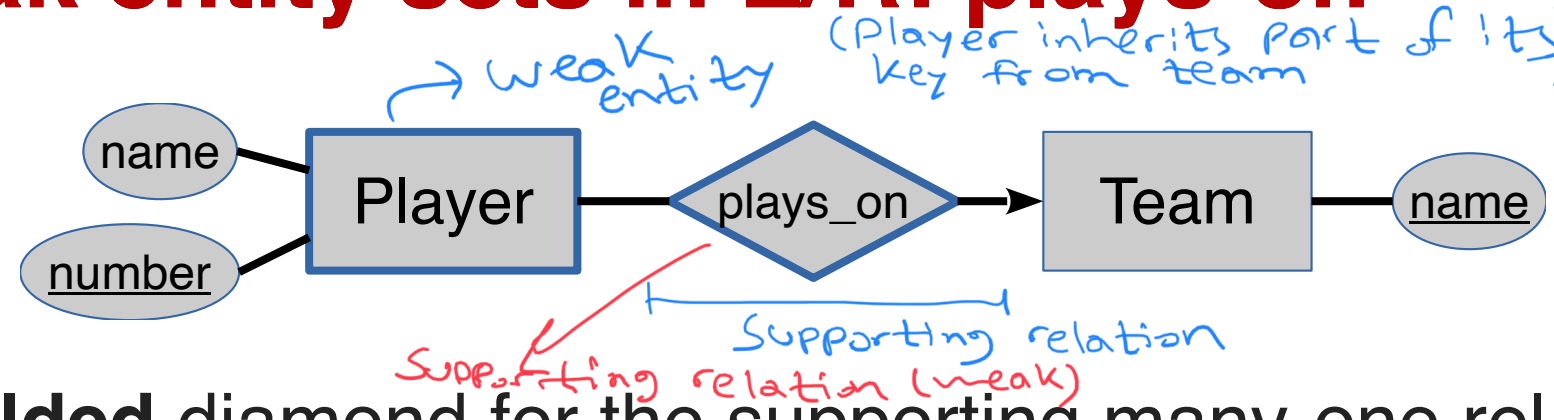
- we need to follow *one or more many-one* rel-ships from **E**, and
- include the *key* of each of the so connected entity sets as part of the weak entity's *key*.

# Example of a weak entity set

- *Name* is “almost” a key for football players; but there can be two with the same name.
- *Number* is certainly not a key, since players on different teams can have the same number.
- But *number* together with the player's team's *name* — as related to the **Player**, say, by a **plays-on** many-one rel-ship — ought to be unique.

Ask Parke, is this a weak relation?

# Weak entity sets in E/R: plays-on




- **Bolded** diamond for the supporting many-one relships.
  (In textbook, double-framed.)
- **Bolded** rectangle for the weak entity set.
  (In textbook, double-framed.)

**Note**. The arrowhead must be *rounded* because each **Player** needs a **Team** to compose his or her *key* value.

# Compositional rules for weak entity sets

- A weak entity set must have *one or more many-one* rel-ships to other *supporting* entity sets.
- Not *every* many-one rel-ship from the weak entity set needs to be *supporting*.
- Each supporting many-one rel-ship must have a *rounded* arrowhead; that is, the entity at the “one” end is guaranteed.
- The *key* for a weak entity set is its own underlined attributes *union* the keys from each of the supporting entity sets.
  - E.g., **Player**'s *number* and **Team**'s *name* is the key for *Player* in the previous example.

# “Recursively” weak

- Can a weak entity set be supported by another weak entity set?
  - Of course.

We do not permit cyclic weak dependencies in E/R diagrams, though; they would not make logical sense.

# When are weak entity sets needed?

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.

# A very powerful modelling tool in E/R

- We can “promote” a rel-ship (set) by replacing it with a weak entity (set).
  - The weak entity's supporting entities are those the rel-ship was relating.
- Why is this useful?
  - The “rel-ship” (as a weak entity) can be related to *other* (non-supporting) entities!

A weak entity set used in this way is called a *connecting entity*.

A connecting entity does *not* contribute any of its *own* attr's to its key.

# Overusing 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. (These are called *surrogate* keys.)
  - Examples include social-security numbers, automobile VIN's etc.

# E/R design principles

1. **fidelity**
2. **brevity**
3. **simplicity**
4. **naturalness**

These guidelines are in order of *precedence*. For example, *brevity* takes precedence over *simplicity*.

See §4.2 (*Design Principles*) in the textbook. Note that these slides is *my* take on design princples; but they align quite nicely with the textbook's.

# 1. Fidelity (to the domain)

## *faithfulness*

- Be logically *true* to the real-world domain that we are modeling.
- Capture all of the real-world properties (*semantics*) of the domain as is possible and “reasonable”.

# 2. Brevity (of the data)

## *avoiding redundancy*

- The design should *not* require that a piece of information be represented more than once.

  This is called the *principle* of *single source of truth*.

  - That is, it should not be possible that the same information appears many times in the same entity set.
  - If information can be logically inferred from other information in the design, it should *not* be kept.

# 3. Simplicity (of the schema)

- **Occam's razor**: Keep the design as *simple* as possible (but no simpler).
  - Should contain no elements — entities, rel-ships, attr's, etc. — that are not necessary.
  - Should have as few connections as possible.
  - **Precedence**: Use attributes before entities, and relationships before entities.

# 4. Naturalness (of the model)

- Model as *naturally* as possible the domain.
  - Entities ought to correspond to real things.
  - Rel-ships should be understandable.

# Requirements to specifications

What is your *domain*?

- **queries**. What questions does the database need to be able to answer?
- **transactions**. What data-processing *activities* does the database need to support?

# Modelling the domain

## What is your design?

1. Choose your entities, attr's, and keys.

   What are the important rel-ships among them?

2. Any logical problems; anything missing?

   If so, then *refine* the design.

3. Can the design accommodate the questions (*queries*) and activities (*transactions*)?
   - If not, then *refine* the design.

4. Can we violate any real-world constraints?
   - If so, re-design — if *possible* and if *practical!* — so that we cannot.

5. Simplify. Repeat.

# E/R to relational

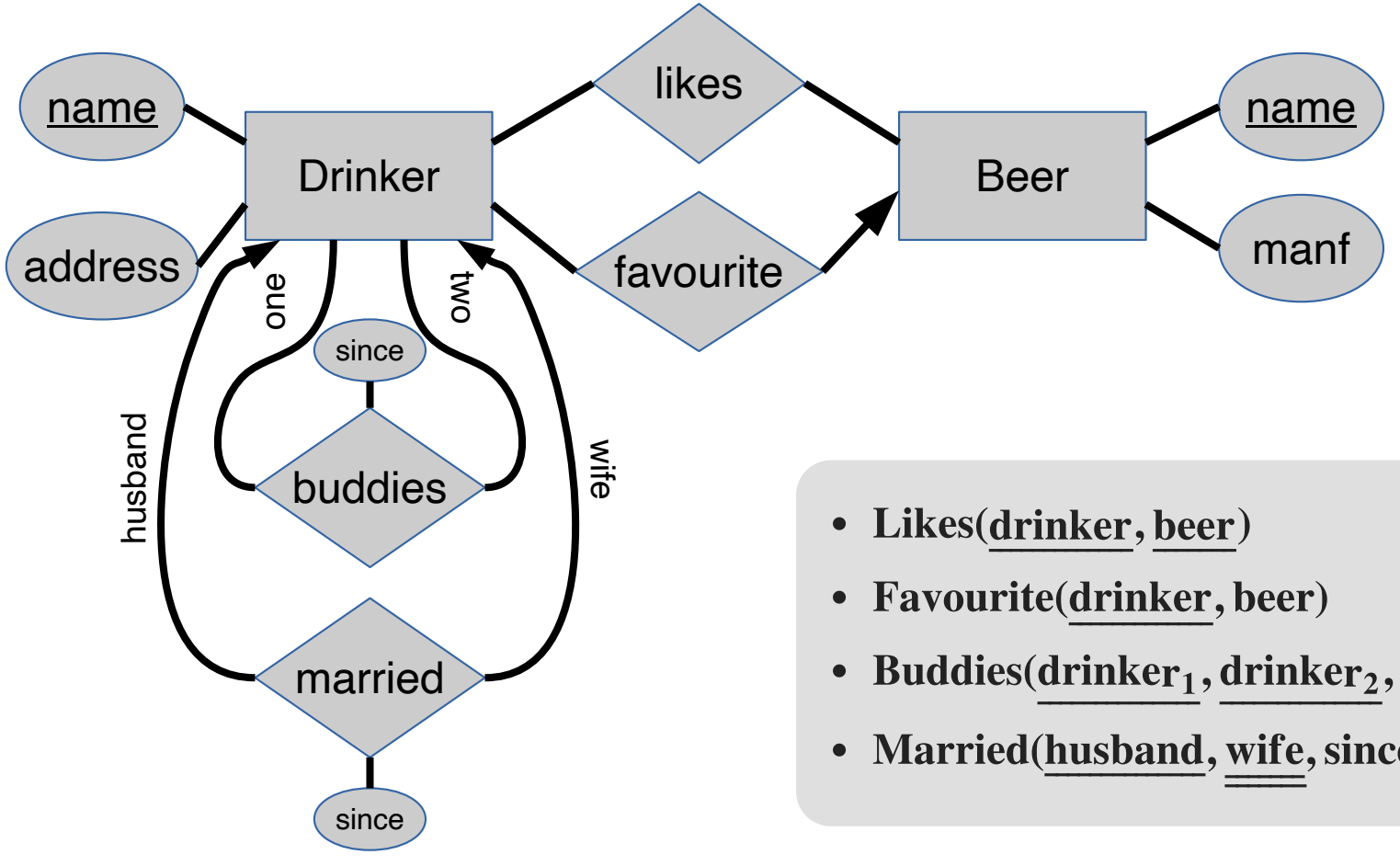
- *Entity set* ⇒ *relation* (table)
  - *Attributes* ⇒ *attributes* (columns)
  - key's *Attributes* ⇒ key's *attributes*
- *Rel-ship set* -> *relation* ⇒ for which the attr's are only
  - *Attributes* ⇒ attr's of the rel-ship itself.
  - key's *Attributes* ⇒ all the keys's attr's of the “many” connected entity sets (but not the “one”'s!)

We may *rename* attr's to disambiguate!

# Entity set ⇒ relation


Relation: **Beer(<u>name</u>, manf)**

# Rel-ship ⇒ relation




- Likes(<u>drinker</u>, <u>beer</u>)
- Favourite(<u>drinker</u>, beer)
- Buddies(<u>drinker$_1$</u>, <u>drinker$_2$</u>, since)
- Married(<u>husband</u>, <u>wife</u>, since)

# Combining many-one relations

Okay to combine into one relation

- the relation for an entity-set **E** *and*
- the relations for *many-one* rel-ships for which **E** is the "many".

**Example**: **Drinker(<u>name</u>, addr)** and **Favourite(<u>drinker</u>, beer)** combine to make $\mathbf{Drinker_1}(\underline{\mathbf{name}}, \mathbf{addr}, \mathbf{favBeer})$.

# Combining many-one relations

This is *compulsory* whenever the *many-one* is "mandatory participation"; that is, the "one" arrowhead is rounded, meaning *exactly* one (as opposed to zero or one).

# Do not combine many-many rel-ships!

Combining **Drinker** and **Likes** would be a mistake.

It leads to *redundancy*. E.g.,

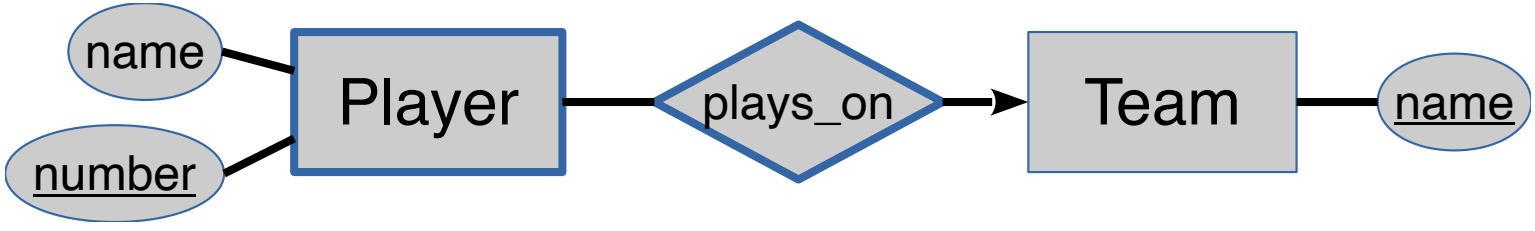
| **name** | **addr** | **beer** |
|---|---|---|
| Sally | 123 Maple | Bud |
| Sally | 123 Maple | Miller |

Plus, would we combine **Likes** with **Drinker** or with **Beer**? It would not make sense.

# Handling weak entity sets

- Relation for a *weak entity set* must include attr's for its complete key — including those of the other entity sets upon which it is *weak* — as well as its own, non-key attr's.
- The same applies for *connecting entities*; these simply add no attr's of their own to the key.

# Weak entity set ⇒ relation




- **Team(name)**
- **Player(team, number, name)**

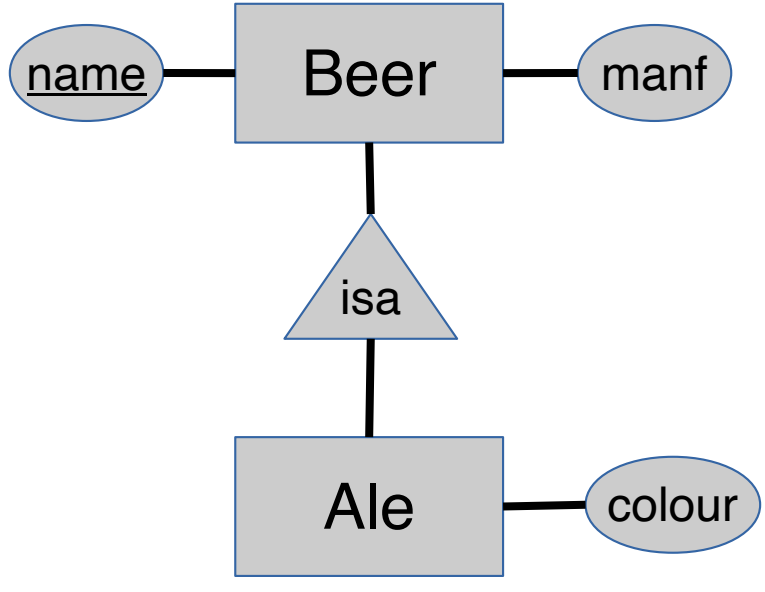
Note this is the same we did for a compulsory *many-one* before.

The addition here is the additional attr's in the key of the relation resulting from the weak entity on the “many“ side of the connectiong rel-ship.

# Subclasses: Three approaches

1. **object-oriented**: a relation per *subset* of subclasses, with all relevant attributes.
2. **E/R style**: a relation for each subclass, with
   - key attribute(s)
   - attributes of that subclass
3. **using nulls**: one relation; “entities” have a *null* “value” in attributes that do not belong to them.

# Subclass ⇒ relations



# Object-oriented

**Beer**

| name | manf |
|---|---|
| Bud | Anheuser Busch |

---

**Ale**

| name | manf | colour |
|---|---|---|
| Summerbrew | Pete's | dark |

Good for queries like, “Find the color of ales made by Pete's.”

# E/R style

**Beer**

| name | manf |
|---|---|
| Bud | Anheuser Busch |
| Summerbrew | Pete's |

---

**Ale**

| name | manf | colour |
|---|---|---|
| Summerbrew | Pete's | dark |

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

# Using nulls

**Beer**

| name | manf | type | colour |
|---|---|---|---|
| Bud | Anheuser Busch | beer | *null* |
| Summerbrew | Pete's | ale | dark |

Saves space, unless there are *lots* of attr. values that will be *null*.

And only a *single* relation, which is simpler.

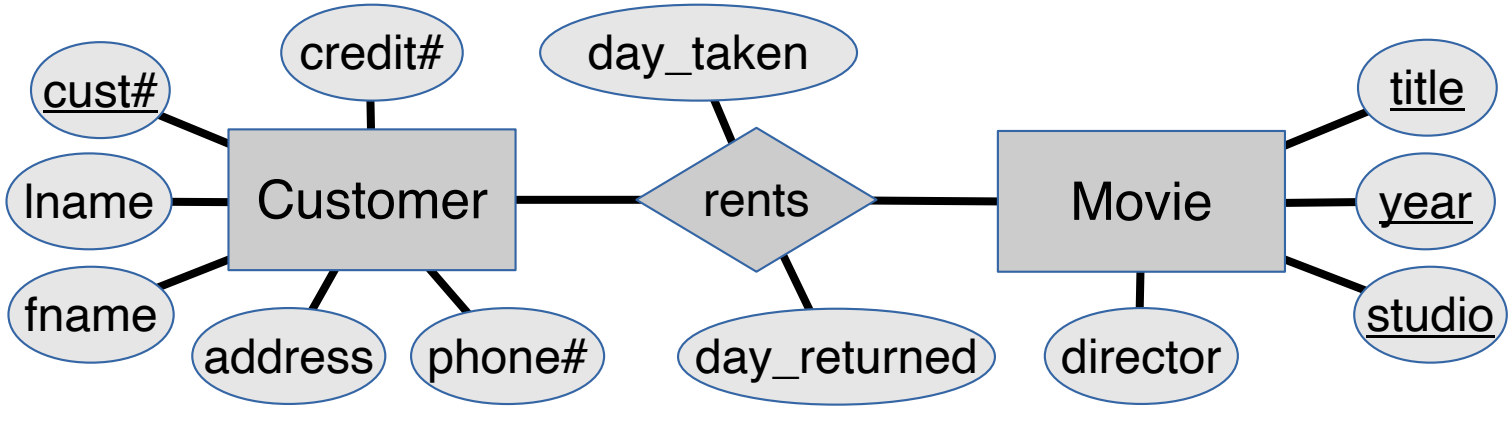
# An Example Domain

## “Previously”: Parke's Retro Video Shop

# A movie rental domain


**Scenario**: We are running a movie rental store.

- We have *movies*.
- We have *customers*. (We hope!)
- Customers *rent* movies from us.



# A good design?

- Any logical problems? Anything missing?
- Can the design accommodate the *questions* and *activities*?
- Can the design violate any real-world constraints?

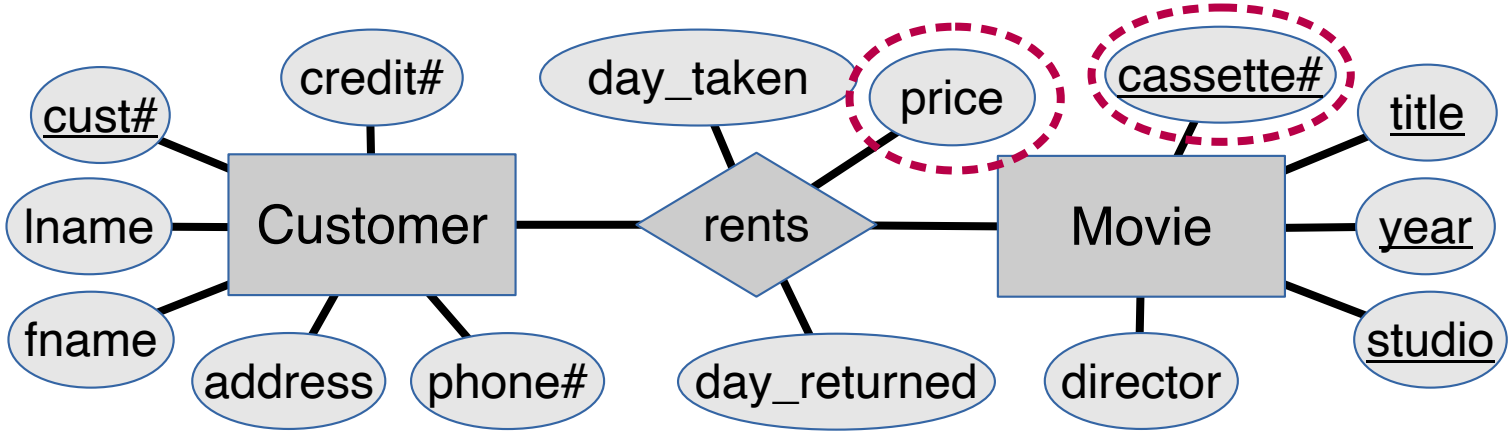
**Anything missing?**

Can add attr's, rel-ships, or entities.

# Problem: multiple copies

We may have several copies of a given movie.

- More than one *copy* might be rented at the same time.
- We need to *know* which customer has which copy.



# Attribute vs Entity

## When to promote an attr. to an entity?

1. It needs to participate in rel-ships itself.
    - Then it must be an entity.
2. The values of the attr. in its entity would be repeated *often*, or there are other attr's associated with this one. (**Brevity**)

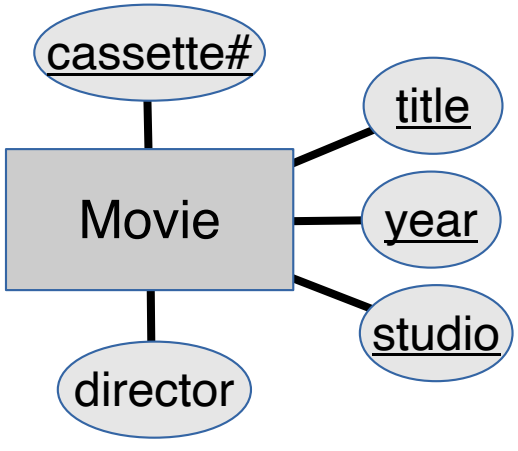
   E.g., **Professor** has *office#*.
    - It probably should be an entity.
3. The values that the attr. may take are restricted. (*strong typing*)
    - Can accomplish this by making it an entity.

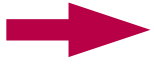
# Movies and *copies*

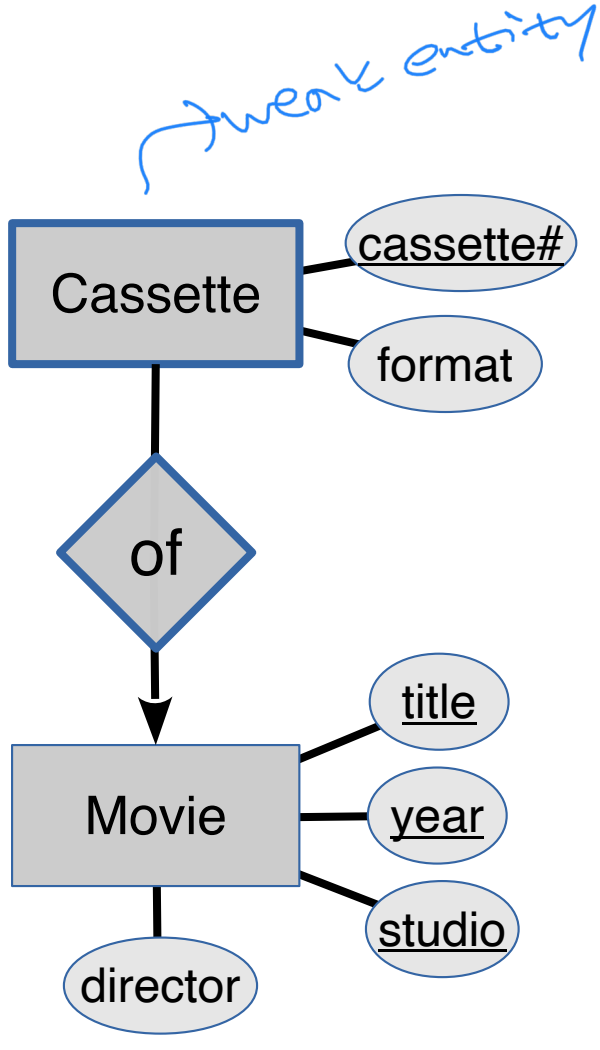
- The information about a movie is *repeated* for as many copies of that movie we have. This seems awkward…
  - Soon, we will formalize *why* this *redundancy* is actually problematic, and not just inelegant.
  - What if we want to *catalog* a movie, but we have no copies yet?
- To fix this, we separate the notion of a *copy of a movie* — call this a *cassette* — and the *movie itself* (the "listing" of the movie).

  So, we add an entity **Cassette**.

# Cassettes



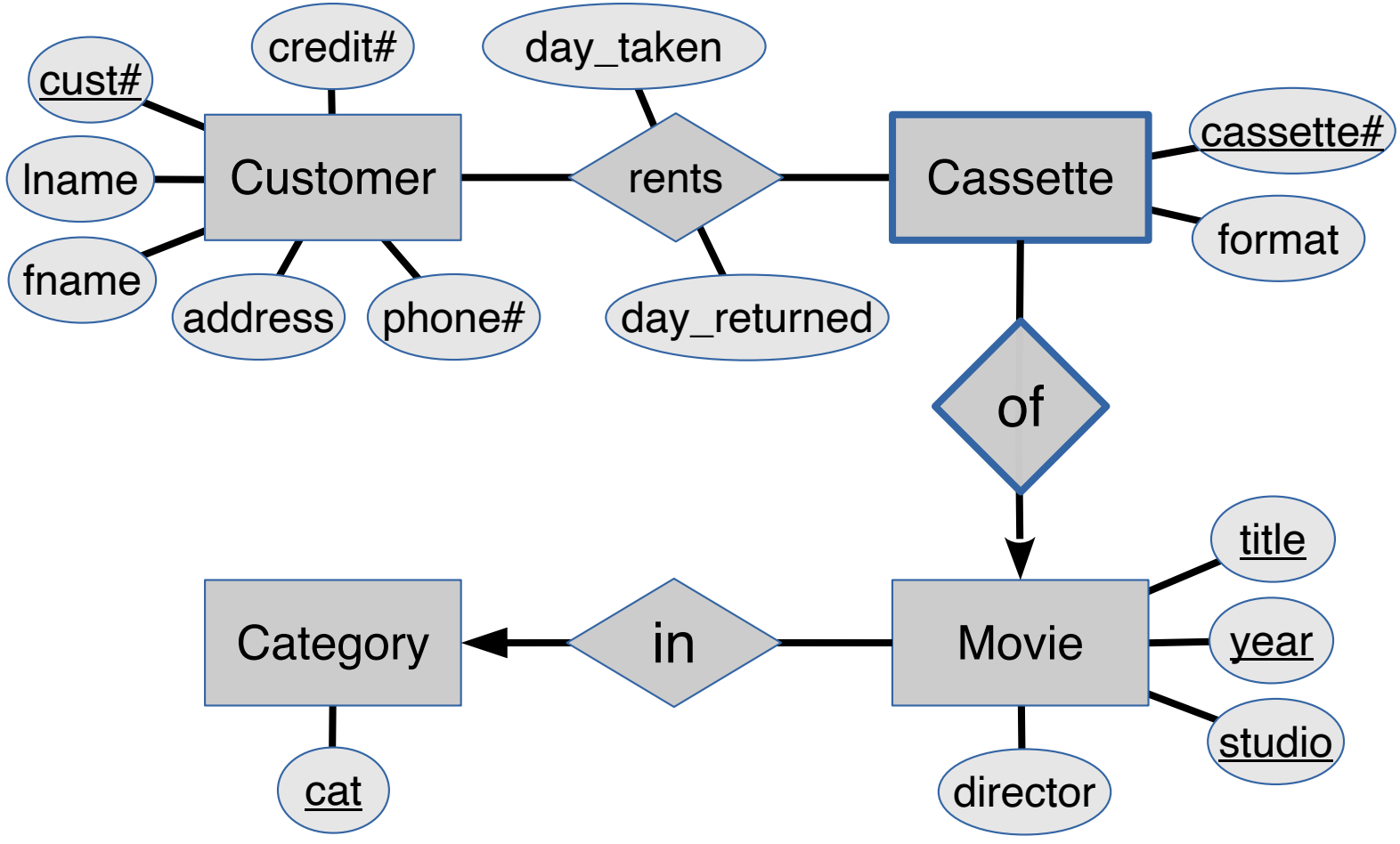






- A *weak entity* for **Cassette** can be used.
- But we could use a regular entity too.
- What are the differences?

# A better design?

→ Customer rents cassete not movie




Cassete → related movie → related catagory

# A better design? (2)

- I also added an entity **Category** for movies (e.g., *comedy*, *drama*, *scifi*).

  This strongly types the *category* a movie can be in.

Are we done yet? Can we stop?

Not even close!

# New Relationships

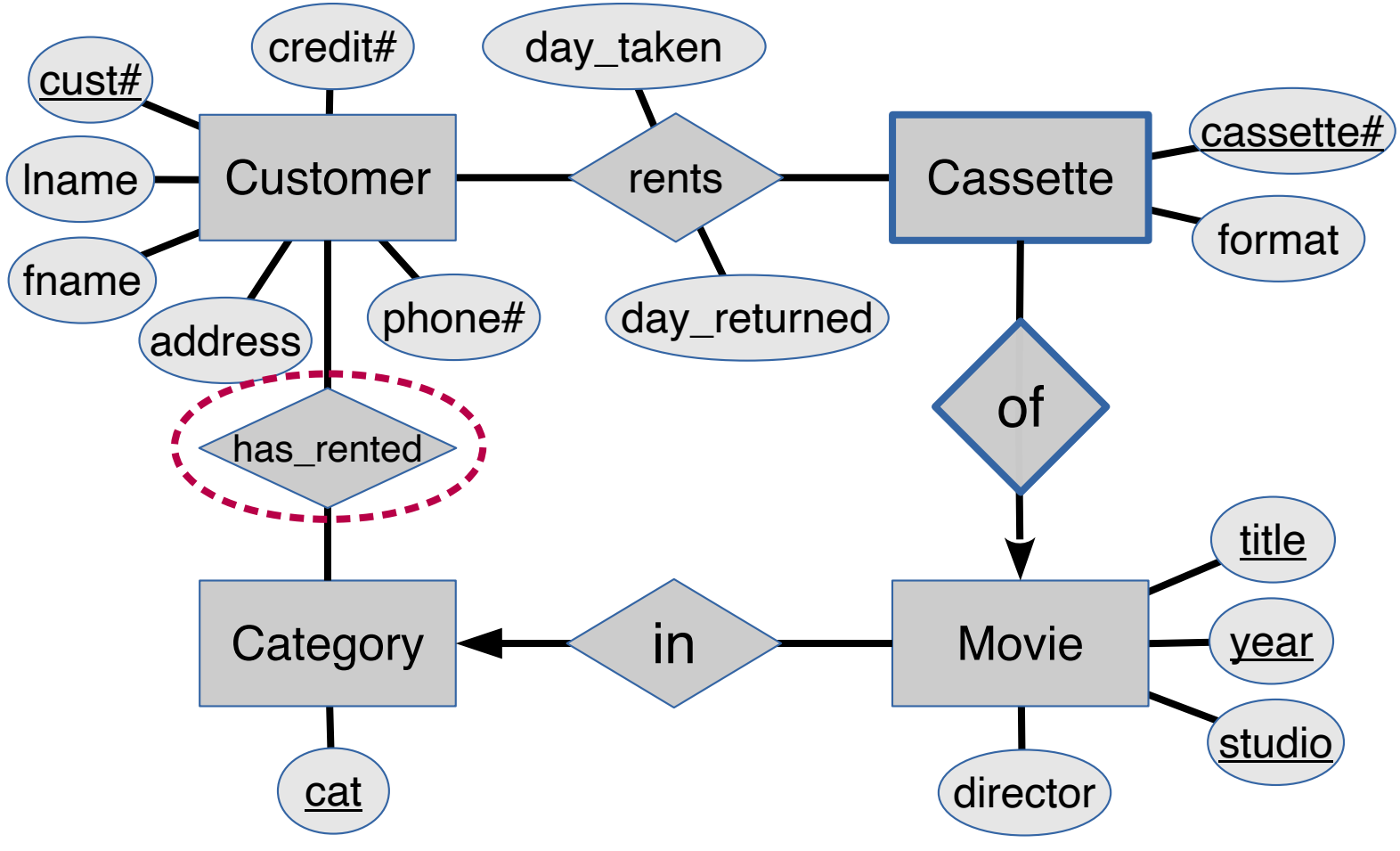
## *Careful for redundancy!*

A requirement for our movie rental database is that we can determine *which* categories of movies a customer has rented (for promotions and such).

**Q**. Have we overlooked this?

# Adding “has rented”…

This is redundant



# That's redundant!

**No!** We had not overlooked this. Which categories a customer has rented is *derivable* from which movies he or she has rented.

Thus, the rel-ship **has_rented** would be *redundant*. It represents a new rel-ship that could be populated with completely *unrelated* data.

So, **has_rented** should *not* be added.

# New rel-ships

## *But if not redundant…*

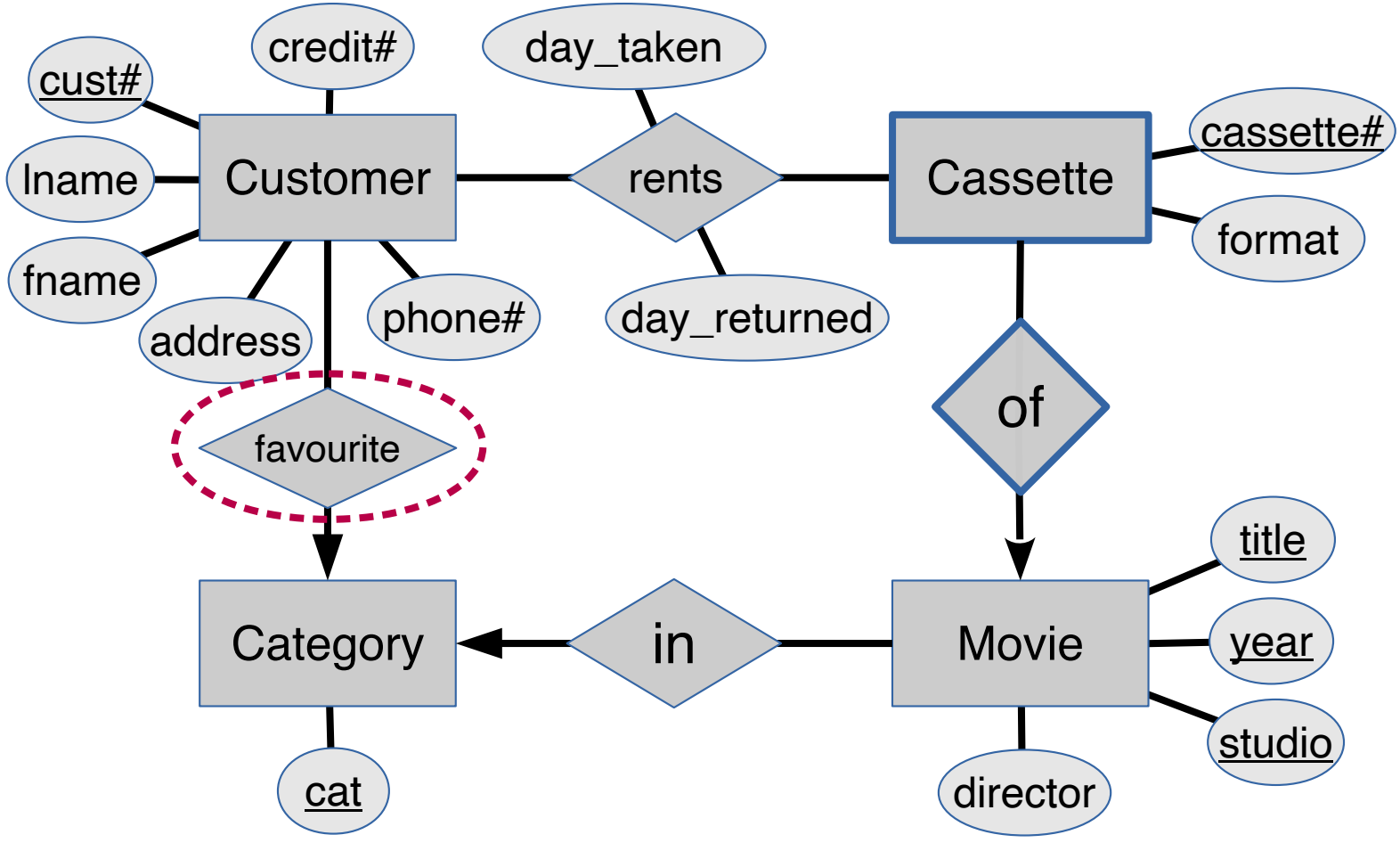
However, if a new rel-ship represents *new* information which is

- *not derivable* from what we already have, and
- which is needed for our intended *queries* and *applications*

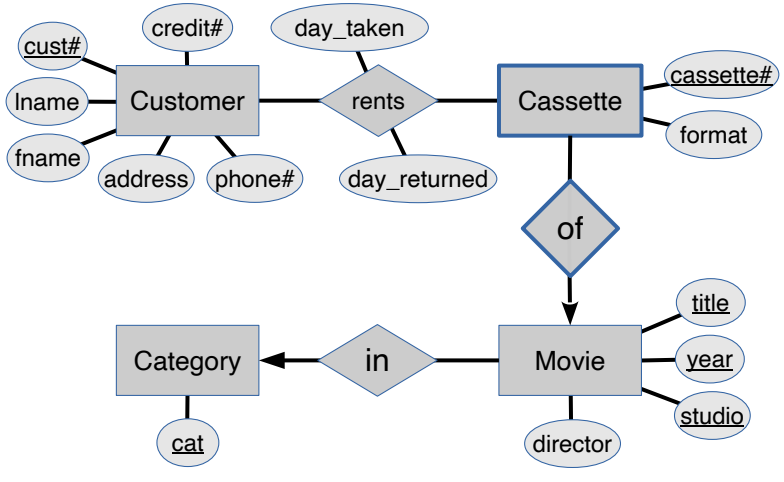
then we should added it.

For example, say we want to know a customer's favourite category (e.g., *romance*) for promotional purposes.

# Favourite category



# Ambiguity / missing “logic”

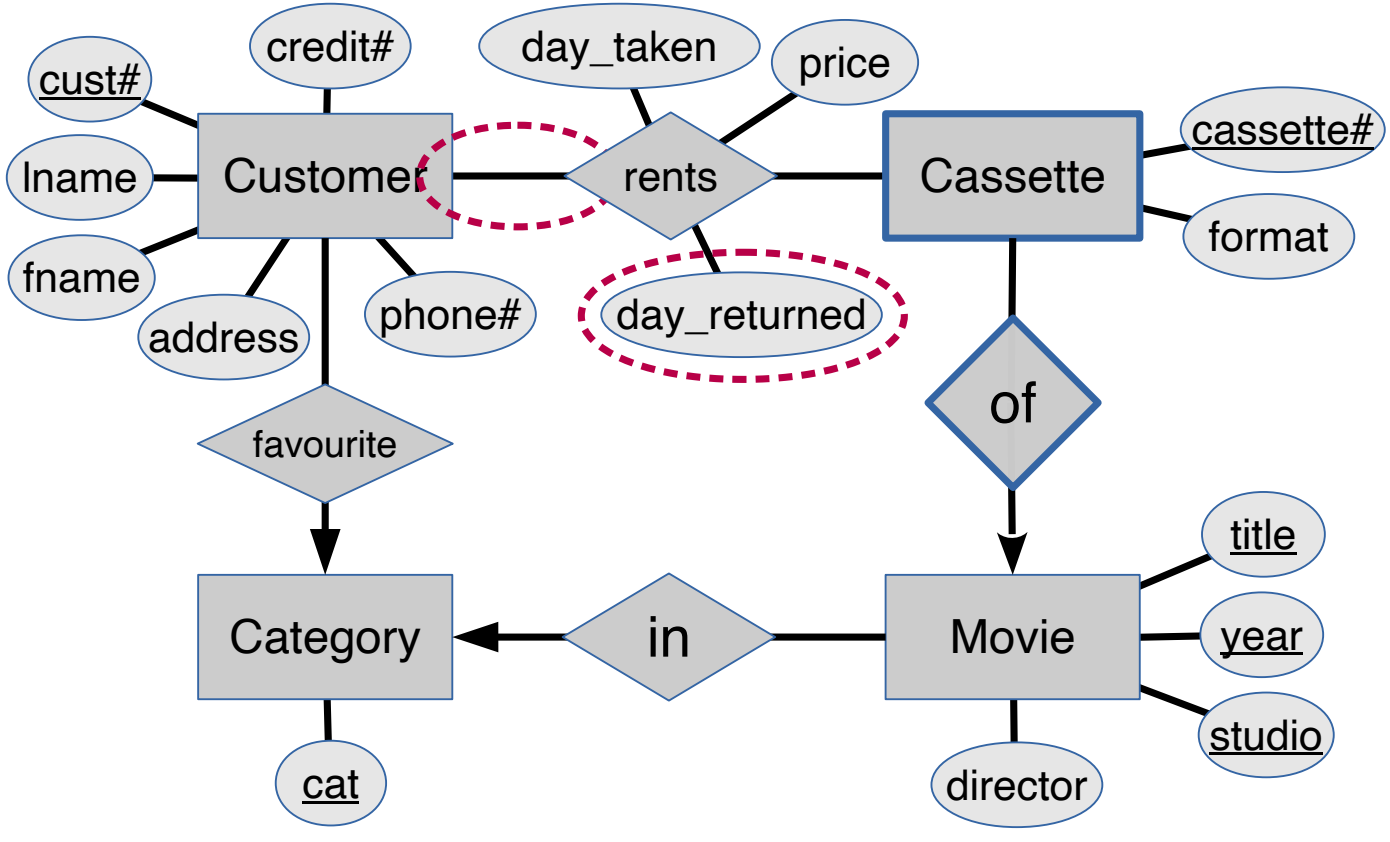



**Missing**

- A given copy cannot be rented at the same time by two or more customers.
- A given customer may rent the same copy of a movie more than one time.

Which do we miss? I don't know, but we do miss at least one of these!

# One needs changing!

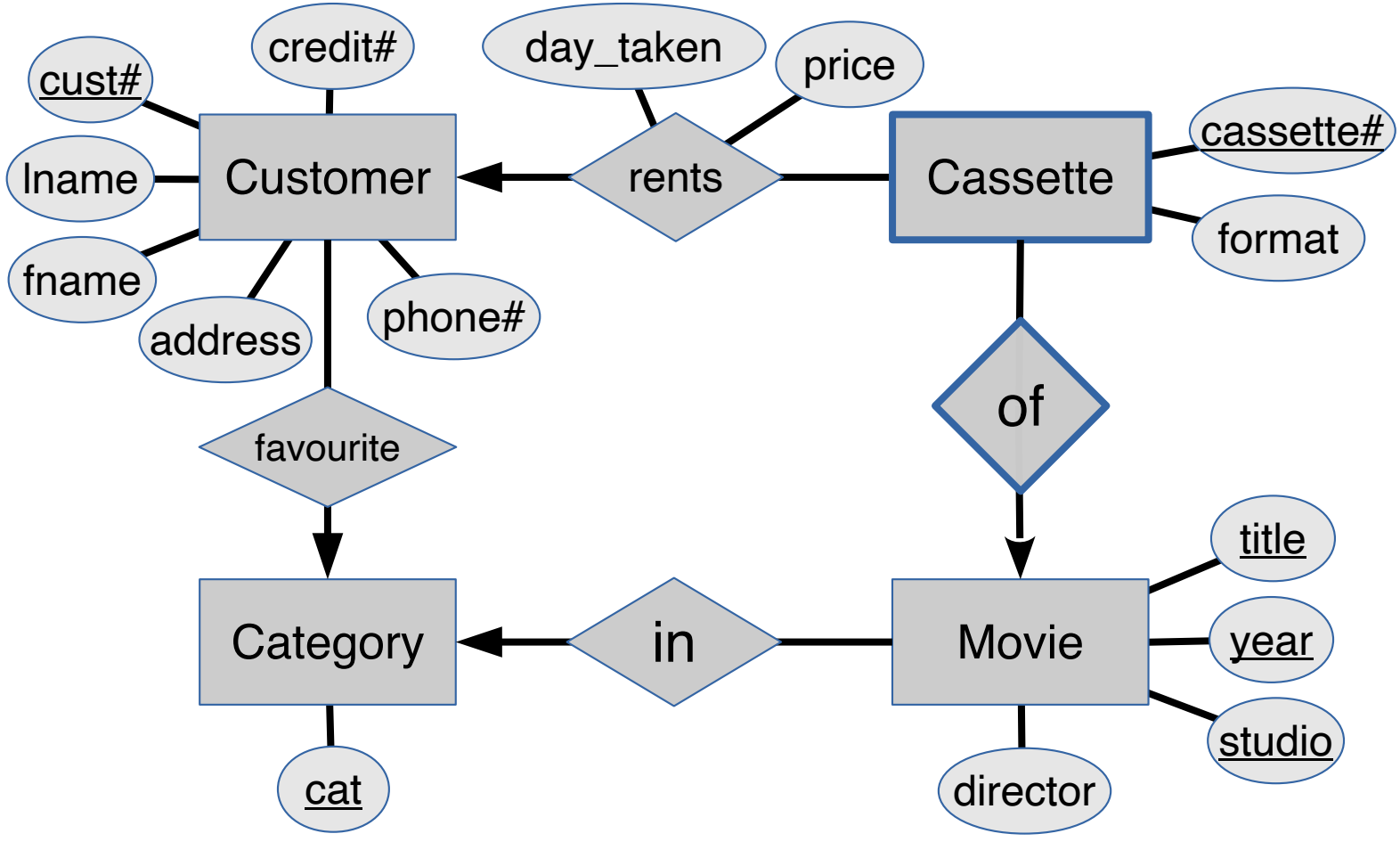



Which to change?

Upto here

# Interpretation #1

## *Only track movies that are out*



# Interpretation #2

## *Record all rentals forever*

Once a rental is recorded in the database, it stays.

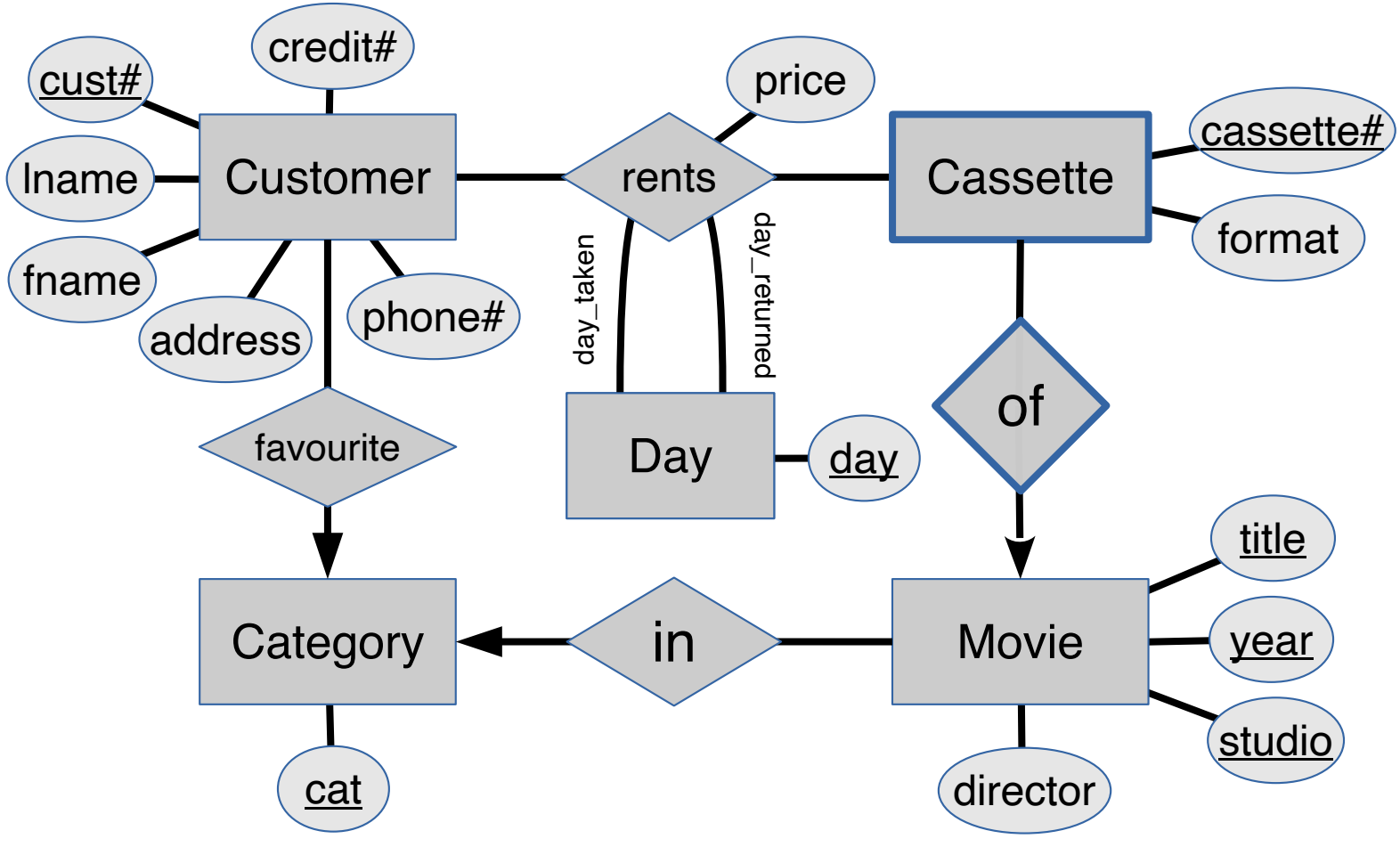
---

**First Problem**. A customer may rent (the same copy of) a movie more than one time. The rel-ship **rents** does not allow for this!

**Solutions?**

1. Have more entities participate in **rents** to fix this. (*a ternary rel-ship*)
2. Promote **rents** to be an entity. (**Rental**)

# Ternary rel-ship attempt #1



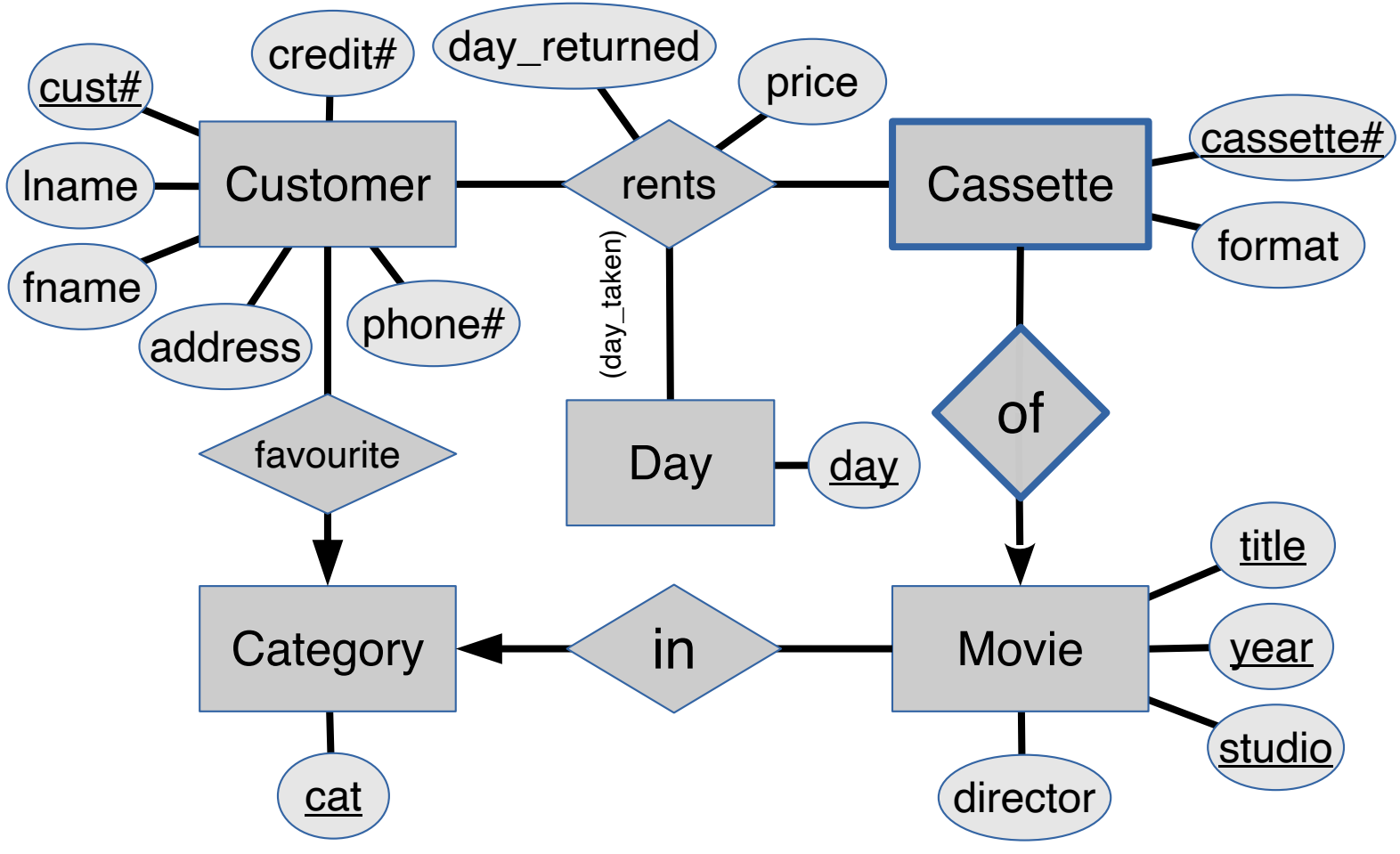
# Ternary rel-ship attempt #1 (2)

## Problems

1. Should **Day** be an entity? Do we really want to "store" days explicitly? (We wouldn't *actually* have to. But, still seems awkward!)
2. Rel-ship **rents** is **Customer** $\times$ **Cassette** $\times$ **Day** (*day_taken*) $\times$ **Day** (*day_returned*). But is *day_returned always* filled in? **No!**

This does *not* work because of #2.

# Ternary rel-ship attempt #2



# Ternary rel-ship attempt #2 (2)

This fixes the problematic — **fatal**! — aspect that the *returned day* is not known for any copies that are currently rented out by making it an attribute again.

---

But two customers still can rent the same copy of a movie on the same day!

- Why did the previous design (Ternary #1) not handle this?
- Why does this design (Ternary #2) not handle this?
- Can you fix it?

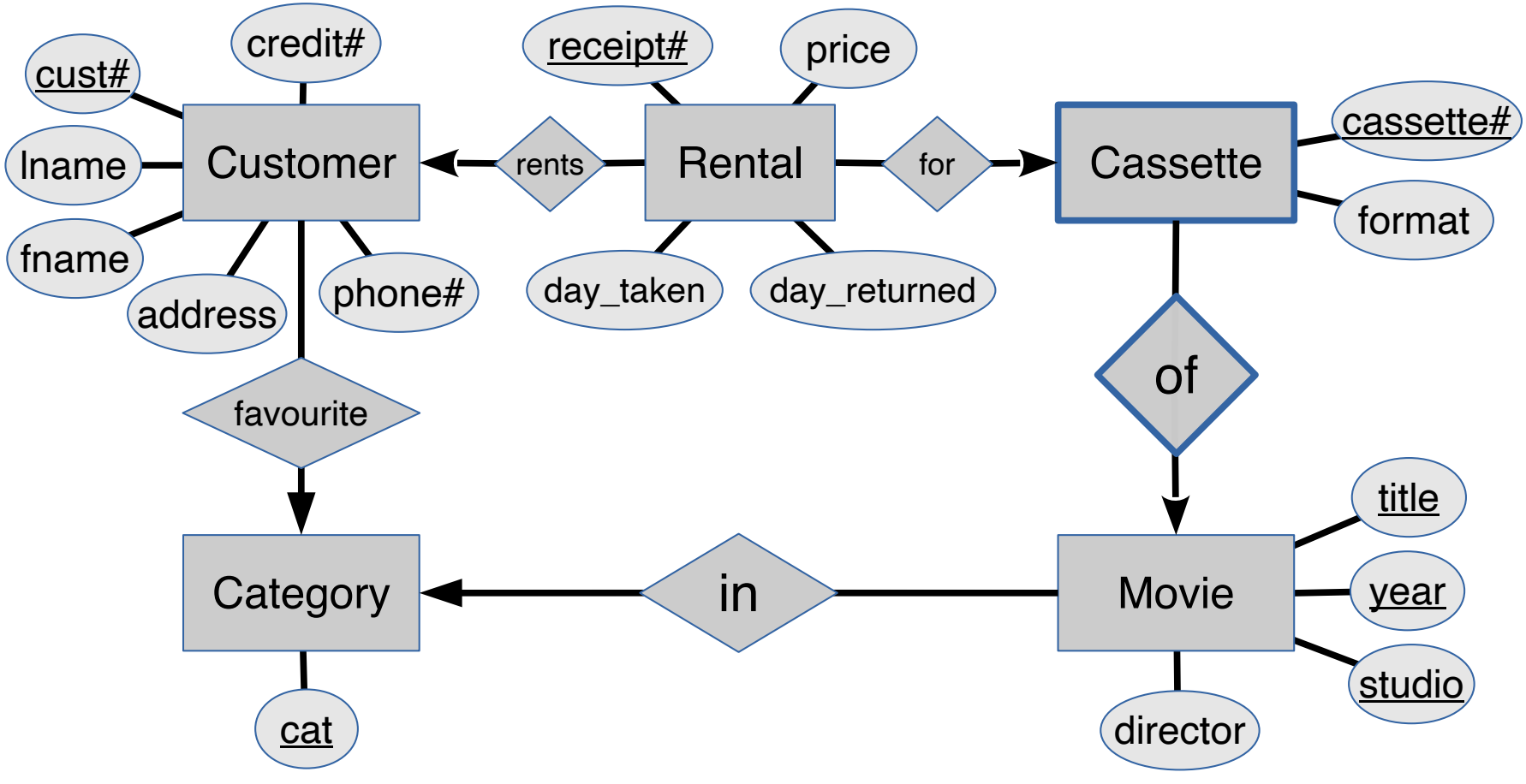
And still, overall, an awkward design anyway.

# Rel-ship vs Entity

## *When to promote a rel-ship to an entity?*

1. When the “key” of the rel-ship is too restrictive
    - Can promote the rel-ship to be an entity instead. Then it has a key.
    - *Or* the rel-ship should involve more entities so that its “key” is adequate. (Like in the *ternary* examples above.)
2. When it seems we need this rel-ship to be involved itself in other rel-ships.
    - Promote the rel-ship to be a *connecting* entity. Then it can participate in rel-ships with other entities.

# Rental: Entity solution #1



# Rental: Entity solution #1 (2)

## One problem down, one remains

Handles *Problem #1*: A customer can now rent the same cassette a second time.

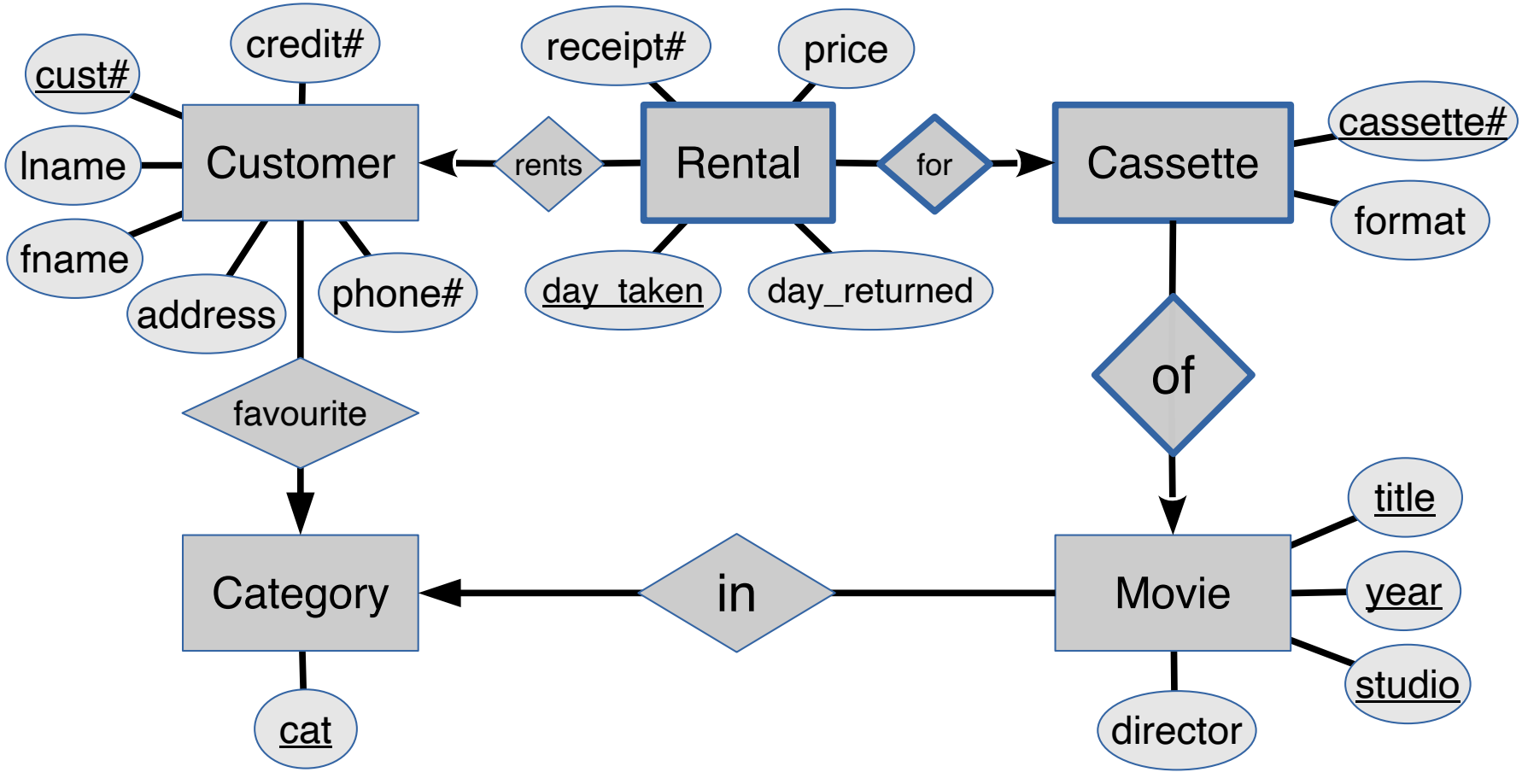
Still does not handle *Problem #2*: Two customers may rent the same cassette at the same time!

How to fix this second problem?

# Rental: Entity solution #2

→ Every entity is a table

## *Better keys*




upto here on 24 sept

# Rental: Entity solution #2 (2)

Handles both problems now! (*Caveat*: Two customers cannot *take out* the same cassette on the same day.)

Can an entity have more than one key?

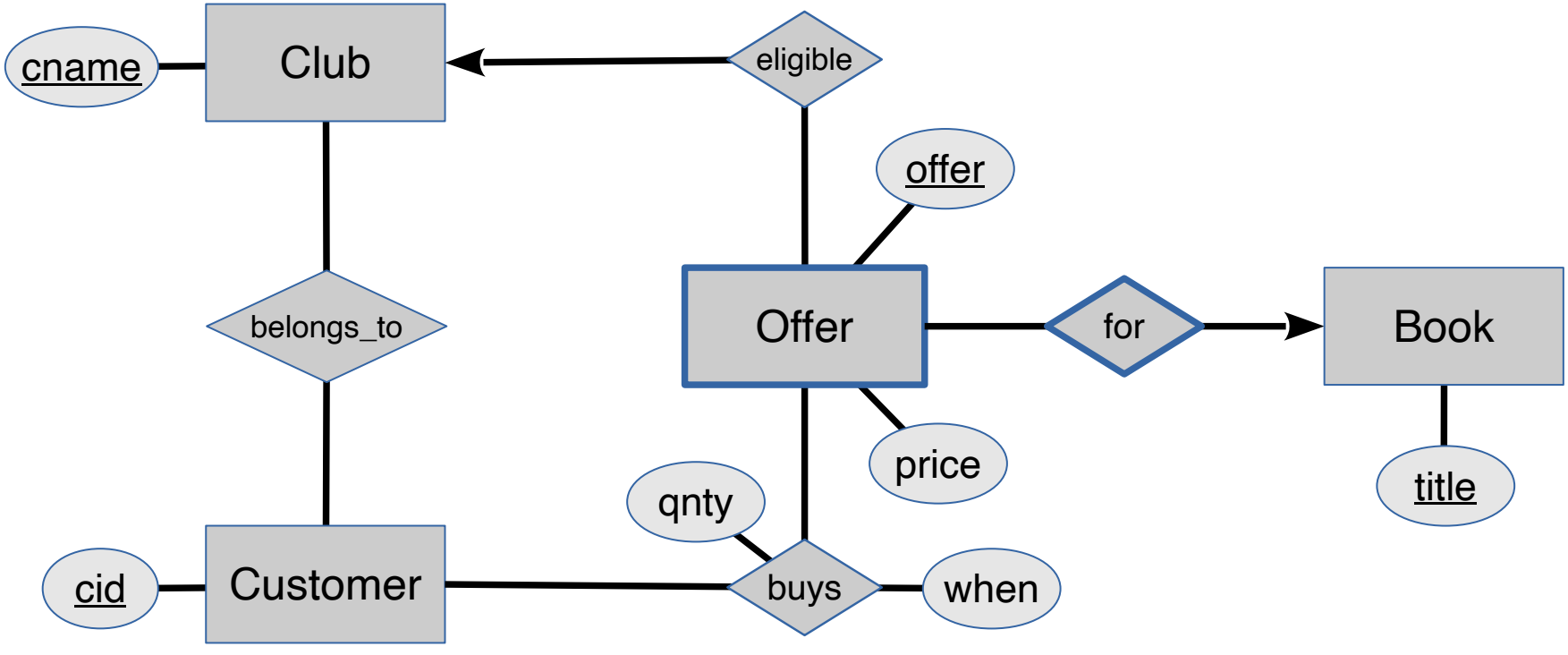
Of course!

We certainly could make **receipt#** a *second* key of the **Rental** table (relation) in our relational schema.

# An Example Domain #2

## *StLoB: Saint Lawrence Online Bookshop*

# A online book purchase domain

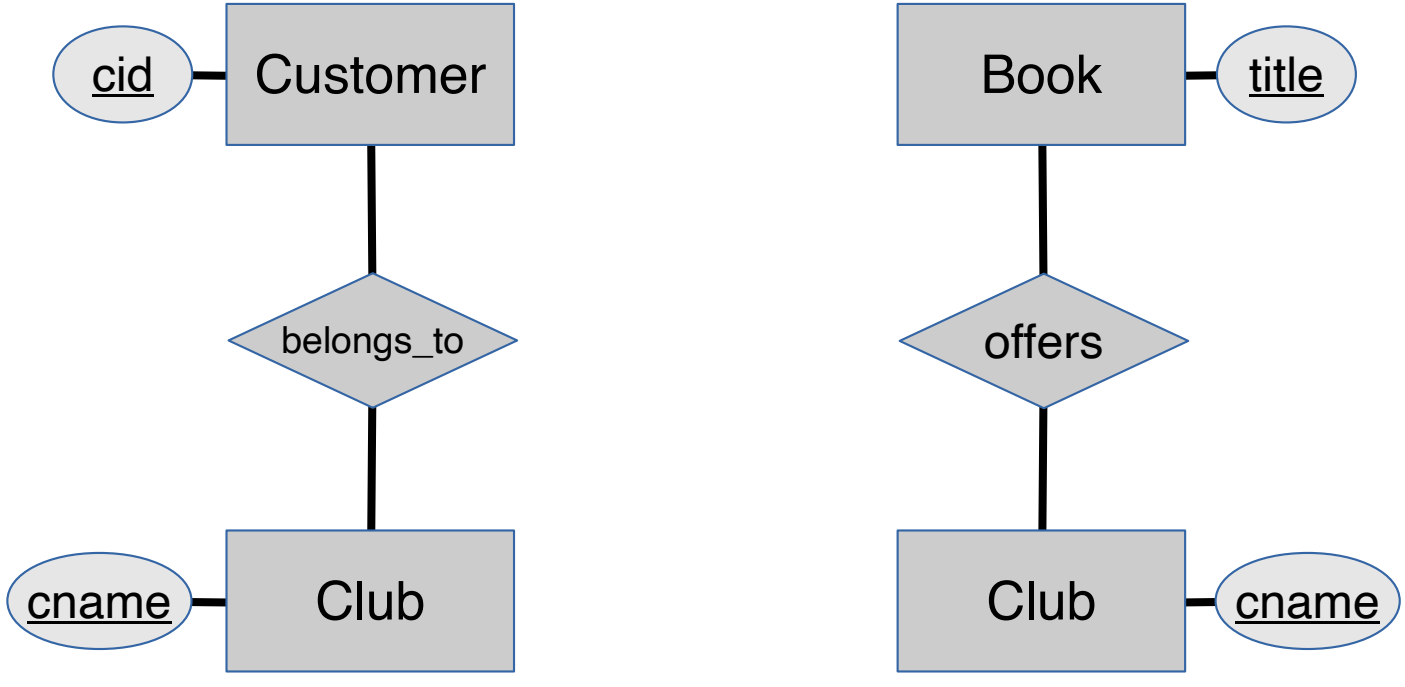



- **Gimmick**:
  - Customers belong to clubs.
  - Via clubs, there are offers on books.

# Problems with our initial design?

1. Can a customer buy a book via an offer with a club a *second* time?
   - **No**.
2. Is *every* book *offered* by *every* club?
   - **No**. This does not have to be the case.
   - But say we do not want this.
3. Are we ensured that, when a customer *buys* a book via an offer, that he or she belongs to the club that the offer is through?
   - **No**.
   - This is my business model! I want to enforce this.

# Back to the fundamentals




- **Customers** *belong to* **Clubs**
- **Books** *are offered by* **Clubs**

# “buys”

We need to *relate* — a rel-ship — *belongs_to* and *offers*.

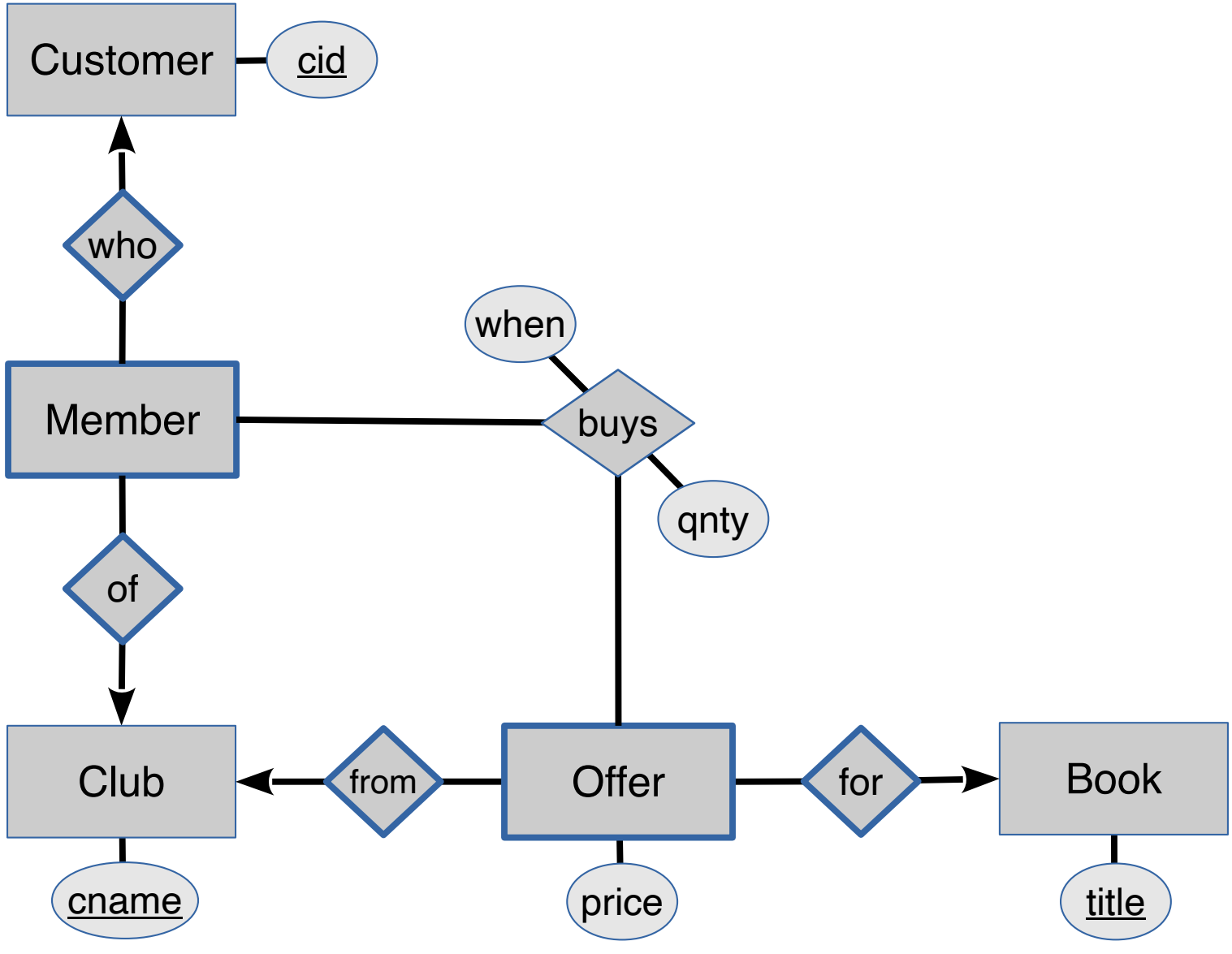
But that is not legal in E/R!

Okay… Let's promote them to entities, then!

- *belongs_to* ⇒ **Member**
- *offers* ⇒ **Offer**

# And put it all together…

- How to *implement* “buys”?
- We have a choice.
  - **restrictive**: one *cname*
  - **unrestrictive**: two *cnames*
- I intend **restrictive** here.


Customer
cid
who
when
Member
buys
qnty
of
Club
from
Offer
for
Book
cname
price
title

# To relational

- **Customer(cid)**
- **Club(cname)**
- **Member(cid, cname)**
- **Book(title)**
- **Offer(cname, title, price)**
- **Buys(cid, title, cname, when, qnty)**

**Foreign keys**: Add §7.1.1 & §7.1.2 (pp.313–315) to your reading!

# To relational w/ foreign keys

- **Customer(cid)**
- **Club(cname)**
- **Member(cid, cname)**
  - FK (**cid**) refs **Customer**
  - FK (**cname**) refs **Club**
- **Book(title)**
- **Offer(cname, title, price)**
  - FK (**cname**) refs **Club**
  - FK (**title**) refs **Book**
- **Buys(cid, title, cname, when, qnty)**
  - FK (**cid, cname**) refs **Member**
  - FK (**cname, title**) refs **Offer**