Computer Science 180: Database Systems

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- Class web page: http://www.cse.ucsc.edu/classes/cmps180
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- Assignments due most Tuesdays; Project Parts due most Thursdays
- T.A. – T.J. Steed

Textbooks

Required:

- *Database Systems: The Complete Book*, by Garcia-Molina, Ullman, and Widom (first edition), Prentice Hall, 2002.

Recommended: (one of these)

- *A Guide to the SQL Standard: A User's Guide to the Standard Database Language SQL*, (fourth edition), by C.J. Date and Hugh Darwen, Addison-Wesley, 2000.
- *SQL: 1999 - Understanding Relational Language Components*, (first edition), by Melton and Simon, Morgan Kaufmann, 2002.
- *PostgreSQL: Introduction and Concepts*, Bruce Momjian, Addison-Wesley, 2001.

You may also want:

- Books on Unix, Perl, PHP, and CGI.

Grading

- Assignments: 8 @ 2% each = 16% of grade.
- Project: 7 @ 5% each = 35% of grade.
- Midterm: Feb. 14 (TH) in class. 14% of grade.
- Final: Mar. 16 (Sa) 12–3PM in class. 35% of grade.

Project

- You will build an application using a relational database system (PostgreSQL) accessed via the web.
- The project has 7 parts (due most Thursdays), starting with design and ending up with a complete application.
- The early programming assignments should be written in C, C++ or Java.
- Some students found it helpful to switch to PHP or Perl for the final project.

Warning

- This class is a lot of work.
- But it is worth it.
- Of all courses you take at UCSC, this may be the one that gets you a job.

Schedule

- Today: Jan. 3 (TH)
  - Intro, Entity-Relationship Model.
  - Read Chapter 1 and Sections 2.1-2.2.
- Jan. 8 (T)
  - Weak Entity Sets, Entity-Relationship Design.
  - Read Sections 2.3-2.4.
- Jan. 10 (TH)
  - Relational Model, Functional Dependencies.
  - Read Sections 3.1-3.5.
- Jan. 15 (T)
  - Normal Forms, Multivalued Dependencies.
  - Read Sections 3.6-3.7. Assignment 1 due.

Syllabus

- The background and history of database management systems.
- The fundamentals of using a database management systems.
- Industry standards used for database management systems.
- Theoretical background of the relational model.
- Queries and Updates.
- Logic databases.
- Transactions and Security.
- Object-oriented, object-relational, semi-structured and XML database systems.
- Mediation and warehousing.

What is a Database Management System?

1. Manages very large amounts of data.
2. Supports efficient access to very large amounts of data.
3. Supports concurrent access to very large amounts of data.
   - Example: bank and its ATM machines.
4. Supports secure, atomic access to very large amounts of data.
   - Contrast two people editing the same UNIX file – last to write "wins" – with the problem if two people deduct money from the same account via ATM machines at the same time – new balance is wrong whichever writes last.

Relational Model

- Based on tables, as:

acct #	name	balance
12345	Sally	1000.21
34567	Sue	285.48
…	…	…

- Today used in *most* DBMS's.

The DBMS Marketplace

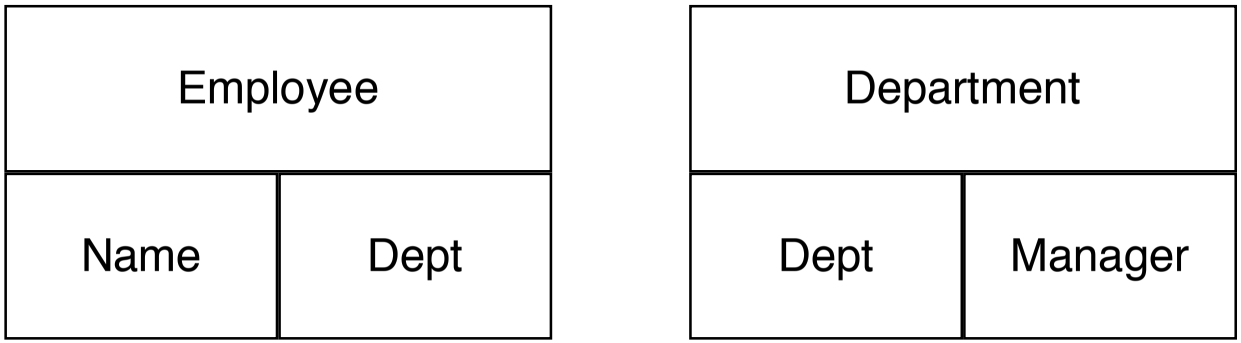
- Relational DBMS companies – Oracle, Sybase – are among the largest software companies in the world.
- IBM offers its relational DB2 system. With IMS, a nonrelational system, IBM is by some accounts the largest DBMS vendor in the world.
- Microsoft offers SQL-Server, plus Microsoft Access for the cheap DBMS on the desktop, answered by "lite" systems from other competitors.
- Relational companies also challenged by "object-oriented DB" companies.
- But countered with "object-relational" systems, which retain the relational core while allowing type extension as in OO systems.

Three Aspects to Studying DBMS's

1. Modeling and design of databases.
   - Allows exploration of issues before committing to an implementation.
2. Programming: queries and DB operations like update.
   - SQL = “intergalactic dataspeak.”
3. DBMS implementation.

CS180 = (1) + (2), while (3) is covered partly in CS277.

Query Languages



SQL

```
SELECT Manager
FROM Employee, Department
WHERE Employee.name = "Clark Kent”
        AND Employee.Dept = Department.Dept
```

Query Language

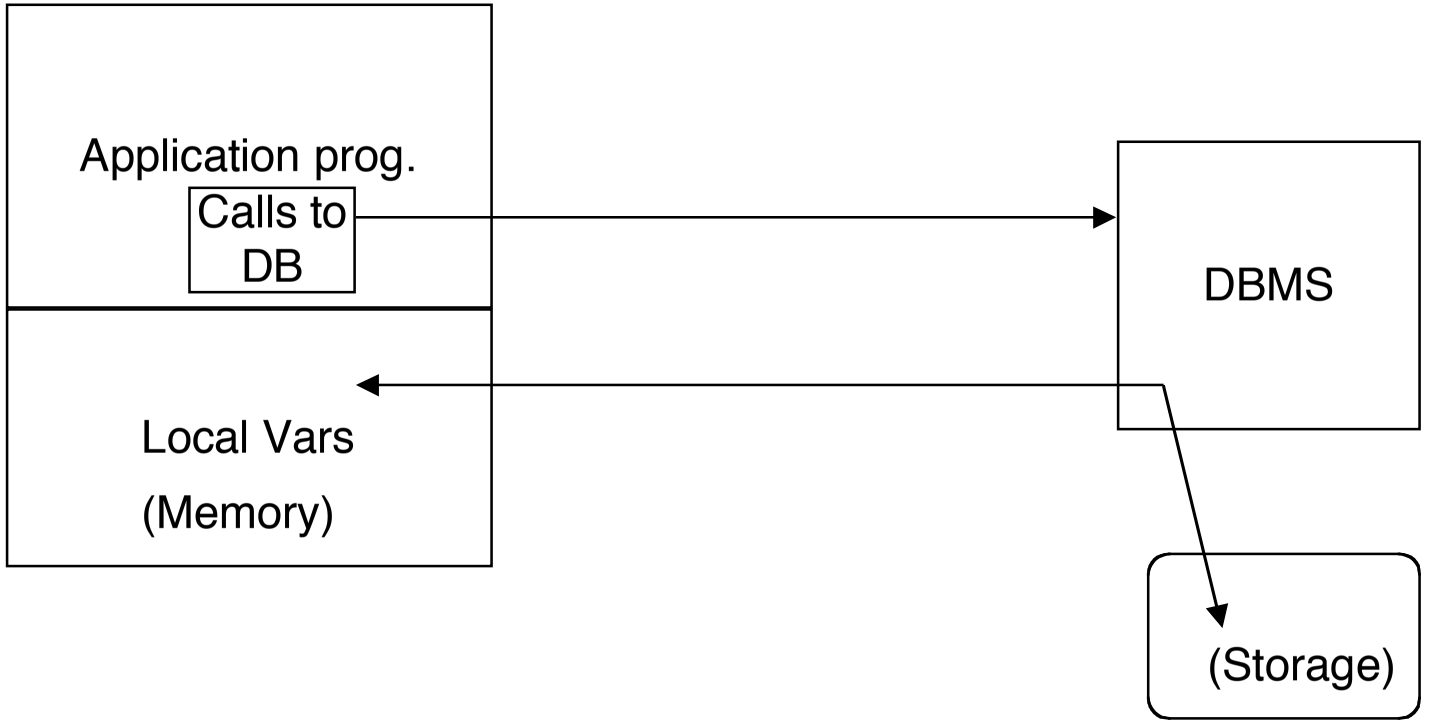
Data definition language (DDL) ~ like type defs in C or Pascal

Data Manipulation Language (DML)

Query (SELECT)
UPDATE < relation name >
SET <attribute> = < new-value>
WHERE <condition>

Host Languages

C, C++, Fortran, Lisp, COBOL



Host language is completely general (Turing complete) but gives you no support

Query language—less general "non procedural" and optimizable

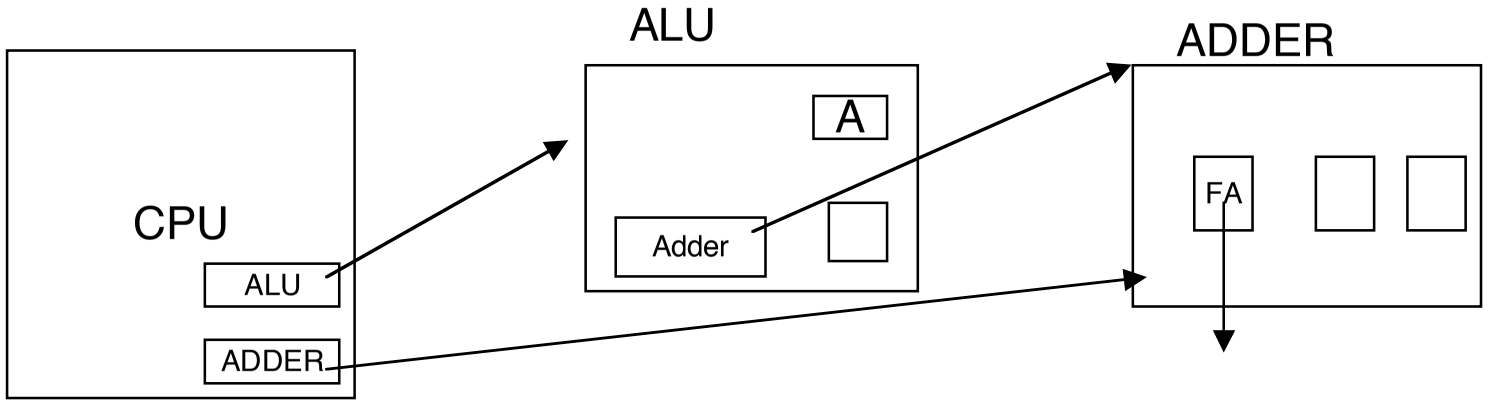
Relational model is good for:

Large amounts of data —> simple operations

Navigate among small number of relations

Difficult Applications for relational model:

- VLSI Design (CAD in general)
- CASE
- Graphical Data



Bill of Materials or
transitive closure

Where number of "relations" is large, relationships are complex

- Object Data Model
- Logic Data Model

OBJECT DATA MODEL

1. Complex Objects – Nested Structure (pointers or references)
2. Encapsulation, set of Methods/Access functions
3. Object Identity
4. Inheritance – Defining new classes like old classes

Object model: usually find objects via explicit navigation
Also query language in some systems

LOGIC (Horn Clause) DATA MODEL

- Prolog, Datalog

if A1 and A2 then B

prolog B:- A1 and A2

Functions s(5) = 6 (successor)

Predicates with Arguments sum(X,Y,Z) X + Y = Z

sum(X,0,X) means X + 0 = X (always true for all X)

sum(X,s(Y),s(Z)):-sum(X,Y,Z)

means X+(Y+1) = (Z+1) if X + Y = Z

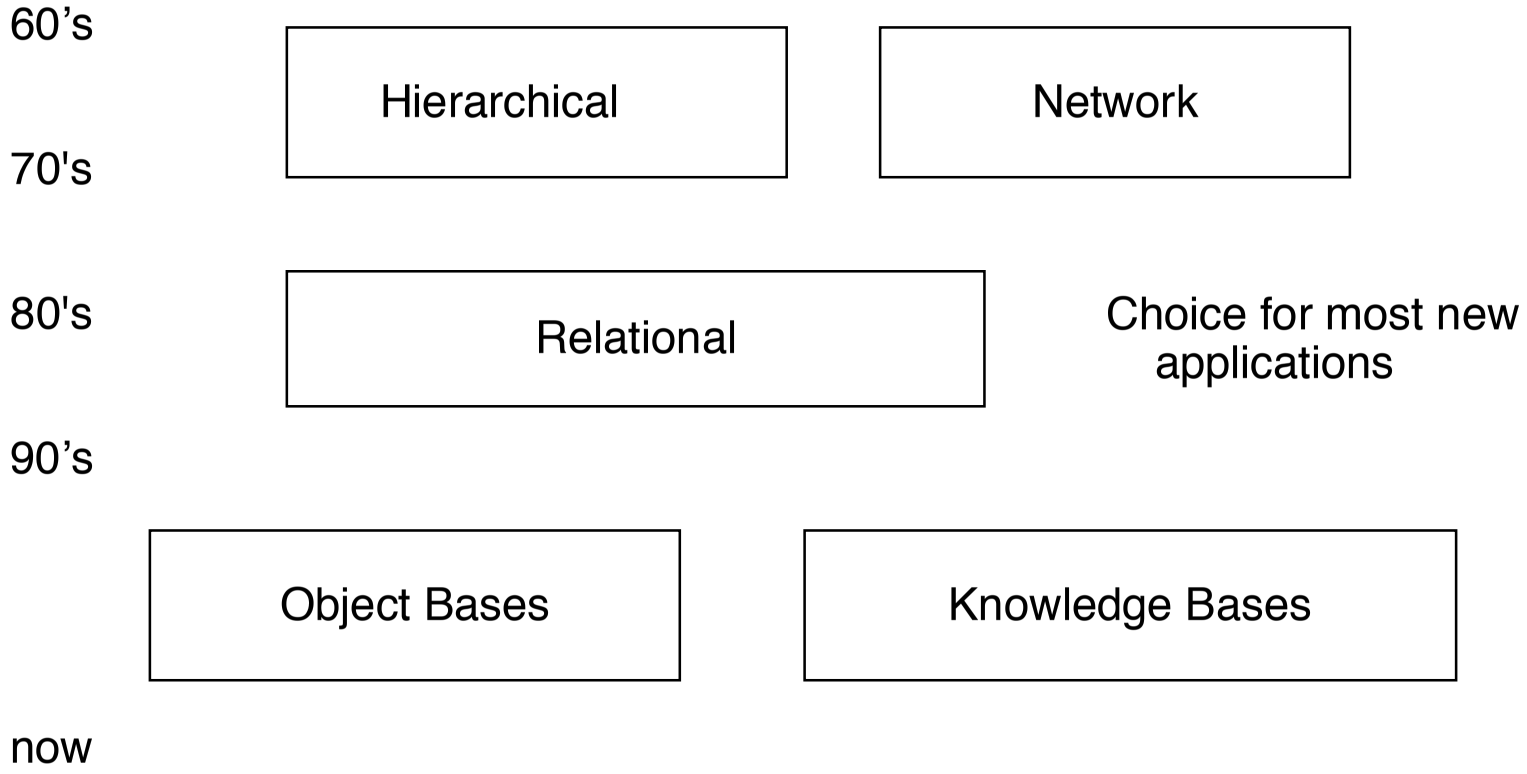
More power than relational

Can Compute Transitive Closure

edge(X,Y)

path(X,Y) :- edge(X,Y)

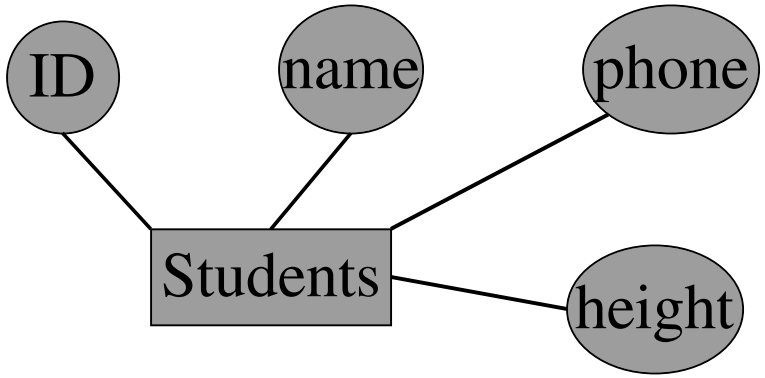
path(X,Z) :- path(X,Y) & edge(Y,Z)


60’s
Hierarchical
Network
70's
80's
Relational
Choice for most new applications
90’s
Object Bases
Knowledge Bases
now

Entity/Relationship Model

Diagrams to represent designs.

- *Entity* like object, = "thing."
- *Entity set* like class = set of "similar" entities/objects.
- *Attribute* = property of entities in an entity set, similar to fields of a struct.
- In diagrams, entity set → rectangle; attribute → oval.



Relationships

- Connect two or more entity sets.
- Represented by diamonds.

Relationship Set

Think of the "value" of a relationship set as a table.

- One column for each of the connected entity sets.
- One row for each list of entities, one from each set, that are connected by the relationship.

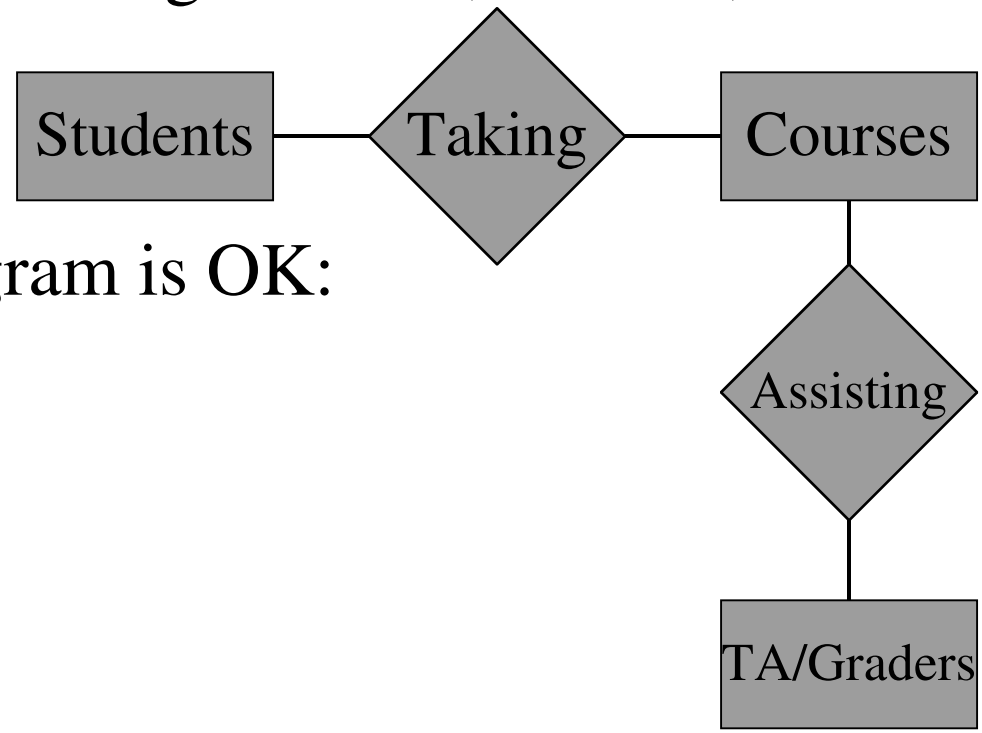
Students	Courses
Sally	CS180
Sally	CS111
Joe	CS180
…	…

Multiway Relationships

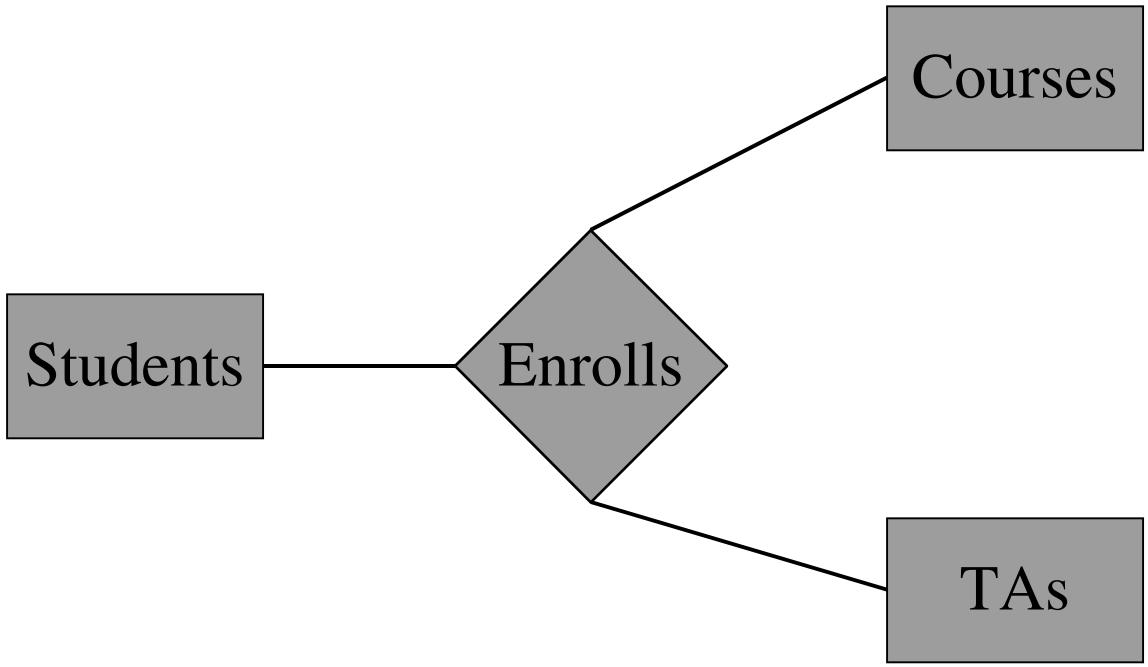
Usually binary relationships (connecting two E.S.) suffice.

- However, there are some cases where three or more E.S. must be connected by one relationship.
- Example: relationship among students, courses, TA's (and graders).

Possibly, this E/R diagram is OK:



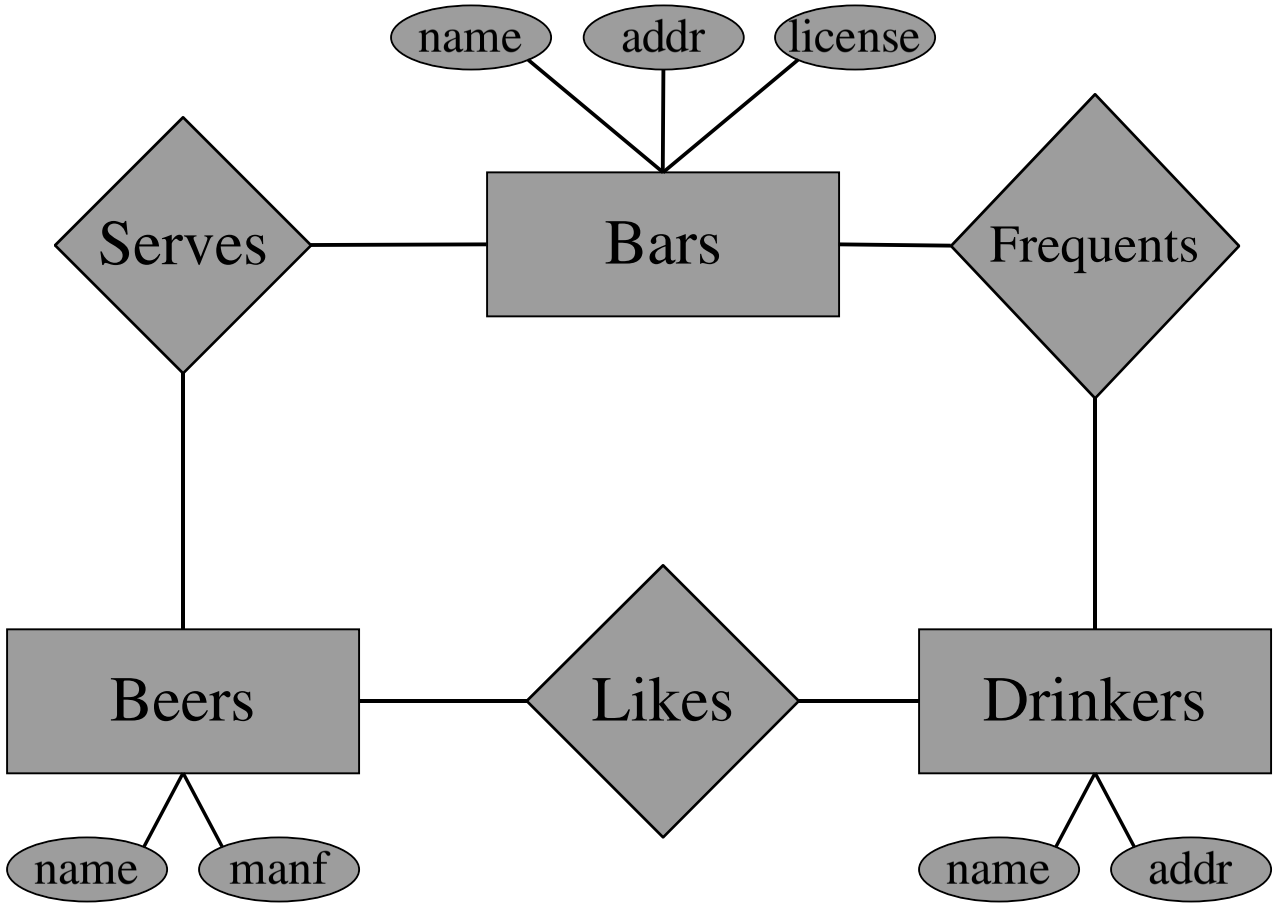
- Works in CS180, because each TA (or grader) is a TA of all students. Connection student-TA is *only* via the course.
- But what if students were divided into sections, each headed by a TA?
  - Then, a student in CS180 would be related to only one of the TA's for CS180. Which one?
- Need a 3-way relationship to tell.



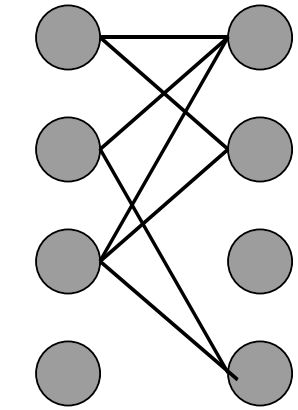
Students	Courses	TAs
Ann	CS180	Jan
Sue	CS180	Pat
Bob	CS180	Jan
…	…	…

Beers-Bars-Drinkers Example

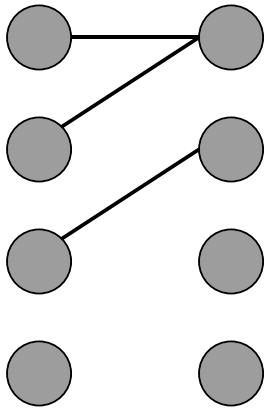
- Our running example for the course.



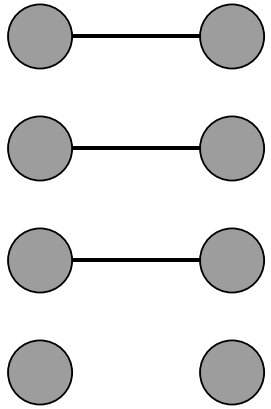
Multiplicity of Relationships



Many-many



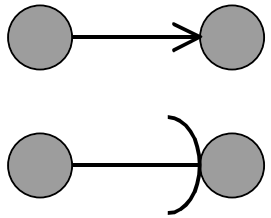
Many-one



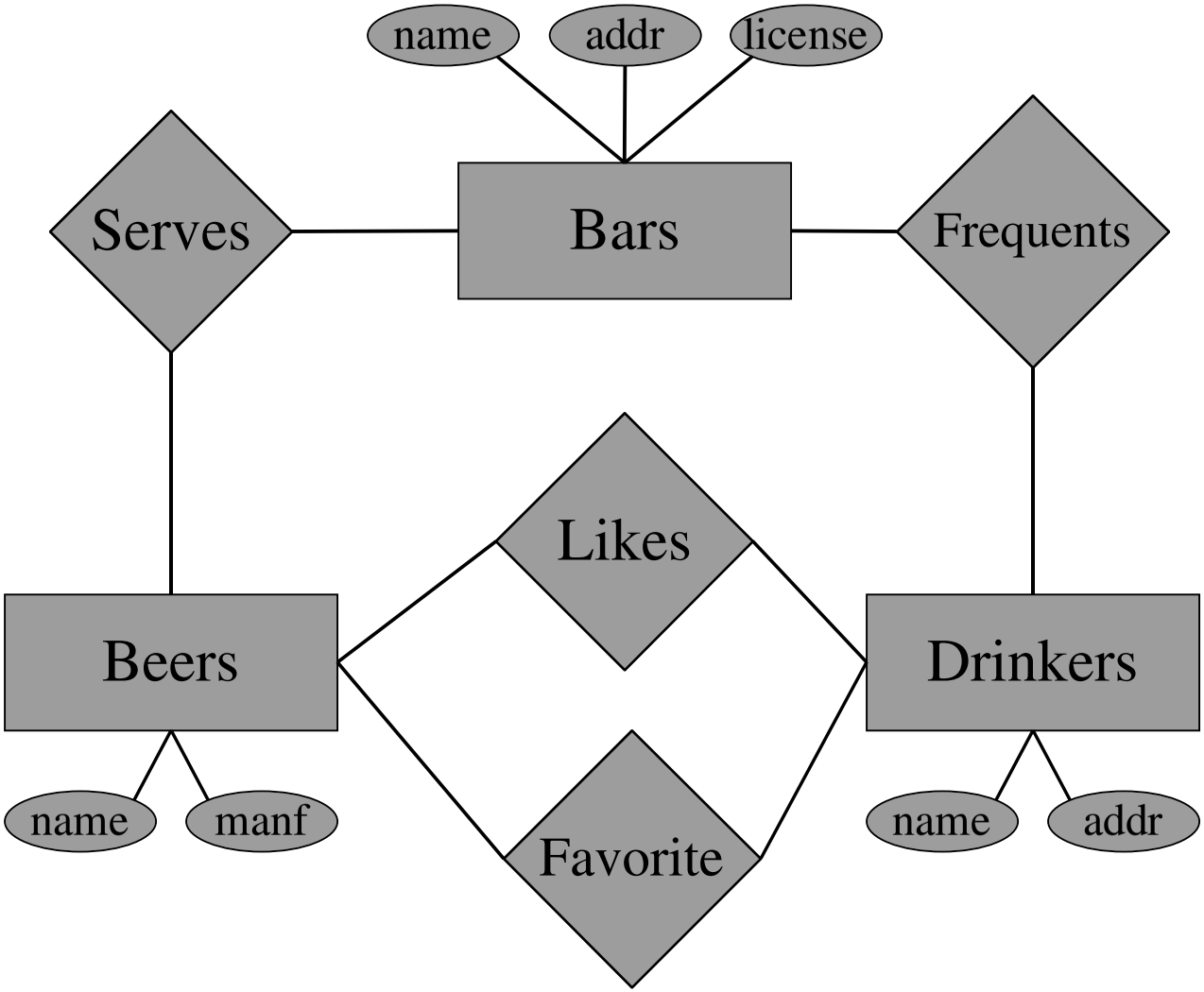
One-one

Representation of Many-One

- E/R: arrow pointing to "one."
  - Rounded arrow = "exactly one."



Example: Drinkers Have Favorite Beers



One-One Relationships

Put arrows in both directions.

Design Issue:

Is the rounded arrow justified?

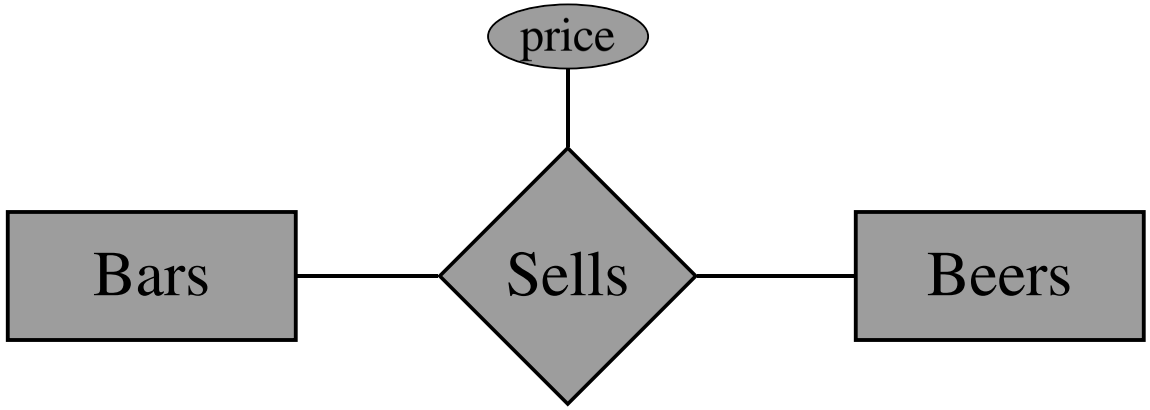
Design Issue:

Here, manufacturer is an E.S.

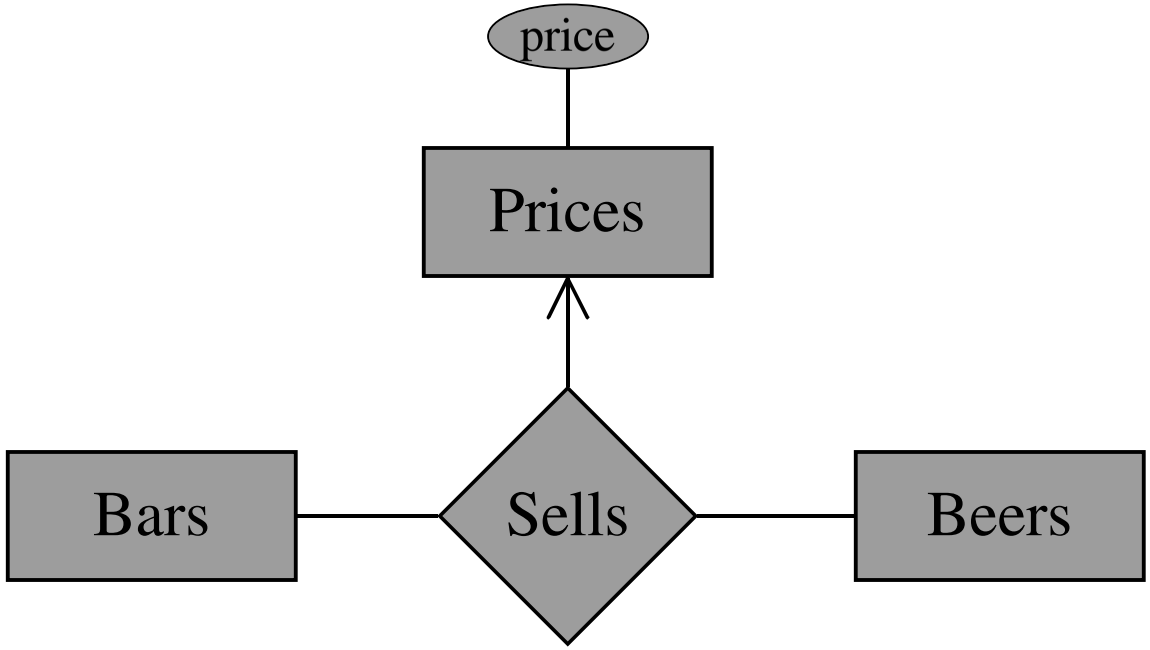
In earlier diagrams it is an attribute.

Which is right?

Attributes on Relationships



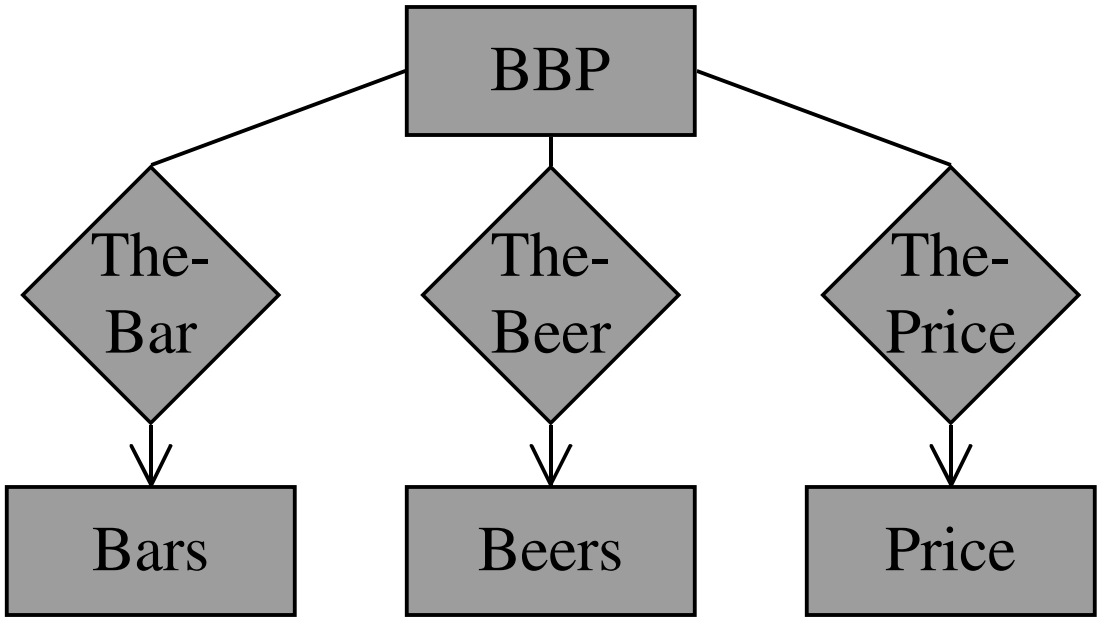
- Shorthand for 3-way relationship:



- A true 3-way relationship.
  - Price depends jointly on beer and bar.
- Notice arrow convention for multiway relationships: “all other E.S. determine one of these.”
  - Not sufficiently general to express any possibility.
  - However, if price, say, depended only on the beer, then we could use two 2-way relationships: price-beer and beer-bar.
  - Or better: just make price an attribute of beer.

Converting Multiway to 2-Way

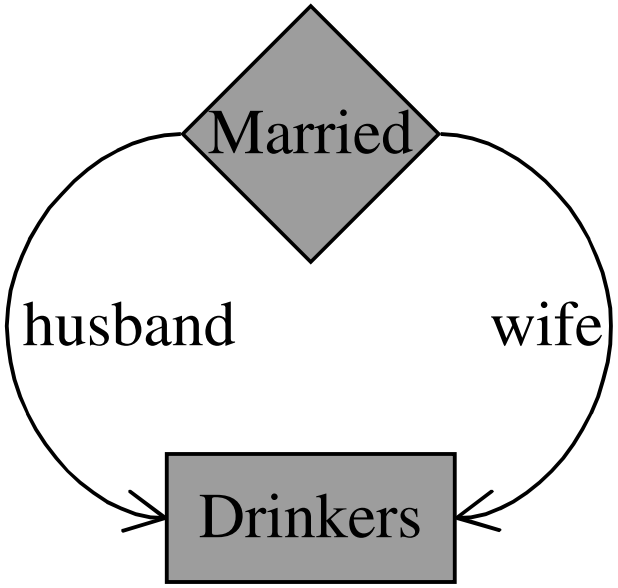
- Baroque in E/R, but necessary in certain "object-oriented" models.
- Create a new connecting E.S. to represent rows of a relationship set.
  - E.g., (Joe's Bar, Bud, $2.50) for the *Sells* relationship.
- Many-one relationships from the connecting E.S. to the others.



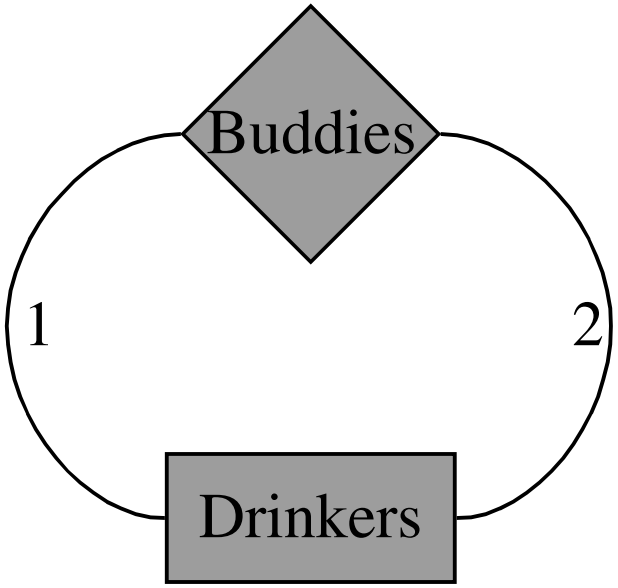
Roles

Sometimes an E.S. participates more than once in a relationship.

- Label edges with *roles* to distinguish.



Husband	Wife
d_1	d_2
d_3	d_4
…	…



Buddy1	Buddy2
d_1	d_2
d_1	d_3
d_2	d_1
d_2	d_4
…	…

- Notice *Buddies* is symmetric, Married not.
  - ◆ No way to say "symmetric" in E/R.

Design Question

Should we replace *husband* and *wife* by one relationship *spouse*?

More Design Issues

1. Subclasses.
2. Keys.
3. Weak entity sets. (Next class.)

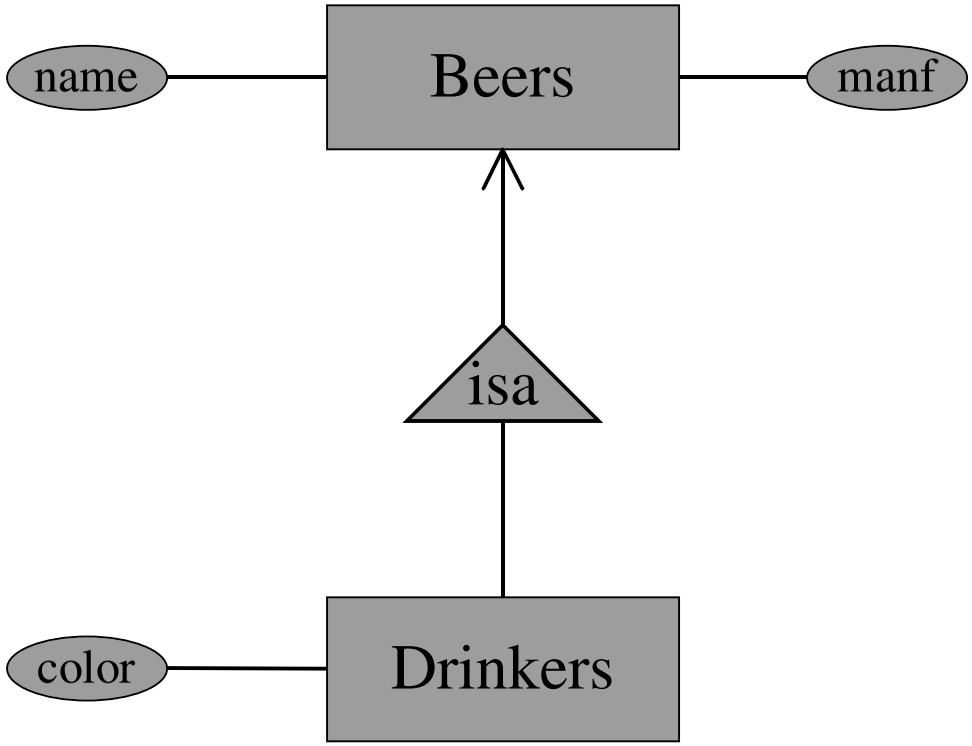
Subclasses

Subclass = special case = fewer entities = more properties.

- Example: Ales are a kind of beer. In addition to the *properties* (= attributes and relationships) of beers, there is a "color" attribute for ales.

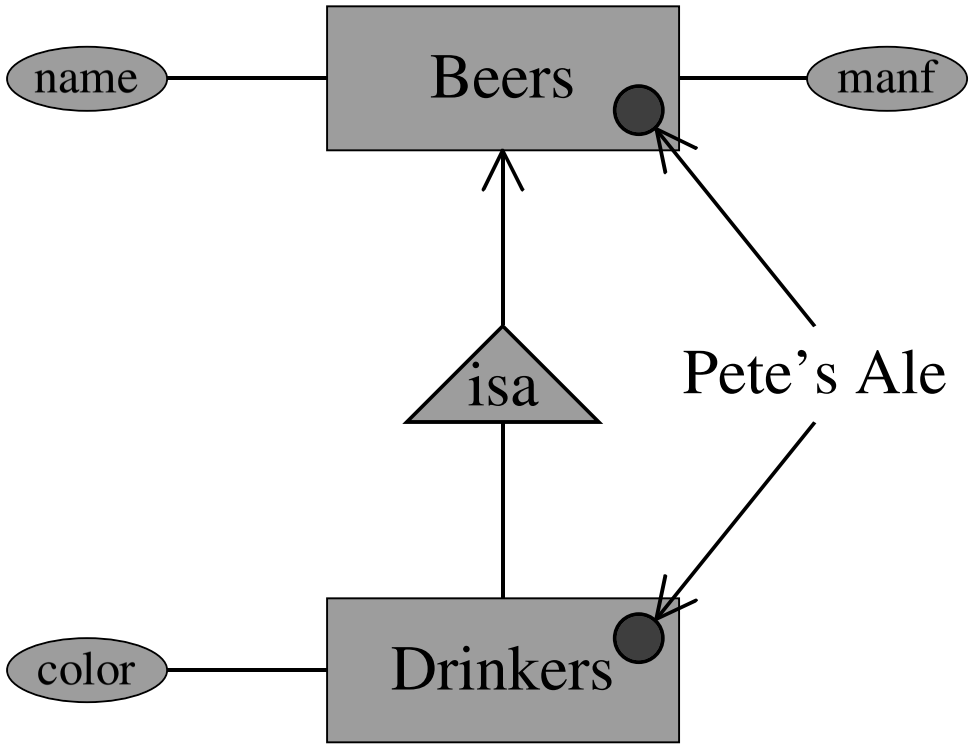
E/R Subclasses

- Assume subclasses form a tree (no multiple inheritance).
- *isa* triangles indicate the subclass relation.



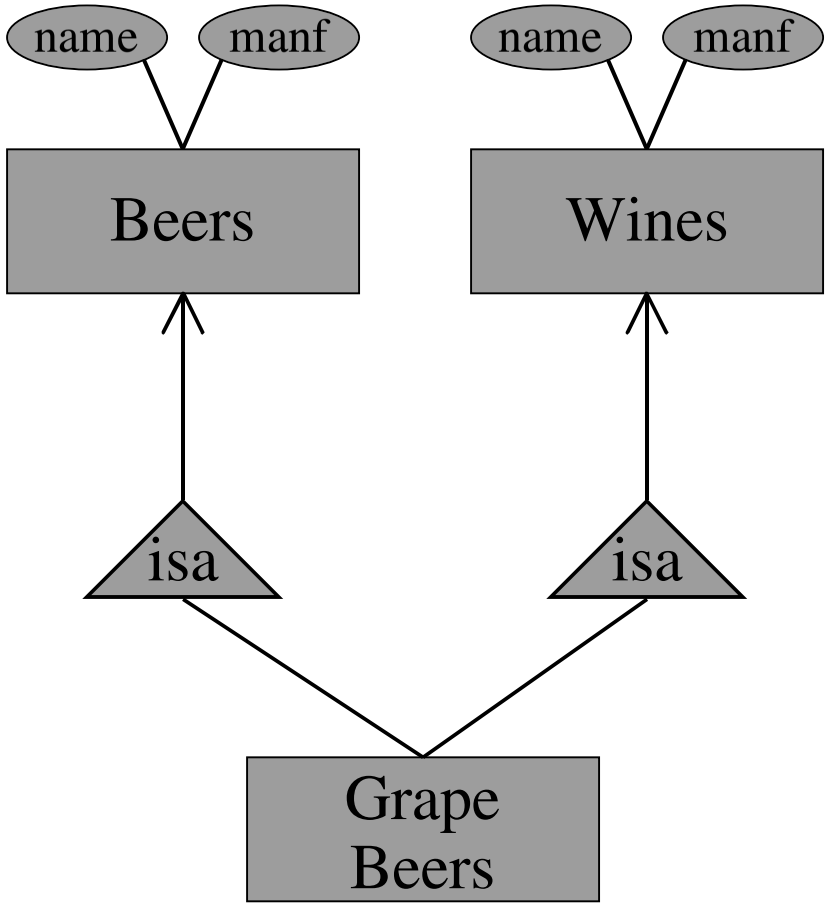
Different Subclass Viewpoints

1. *E/R viewpoint*: An entity has a *component* in each entity set to which it logically belongs.
   - Its properties are the union of the properties of these E.S.
2. Contrasts with *object-oriented viewpoint*: An object (entity) belongs to exactly one class.
   - It *inherits* properties of its superclasses.



Multiple Inheritance

Theoretically, an E.S. could be a subclass of several other entity sets.



Problems

How should conflicts be resolved?

- Example: `manf` means vintner for wines, bottler for beers. What does `manf` mean for "grape beers"?
- Need ad-hoc notation to resolve meanings.
- In practice, we shall assume a tree of entity sets connected by *isa*, with all "isas" pointing from child to parent.

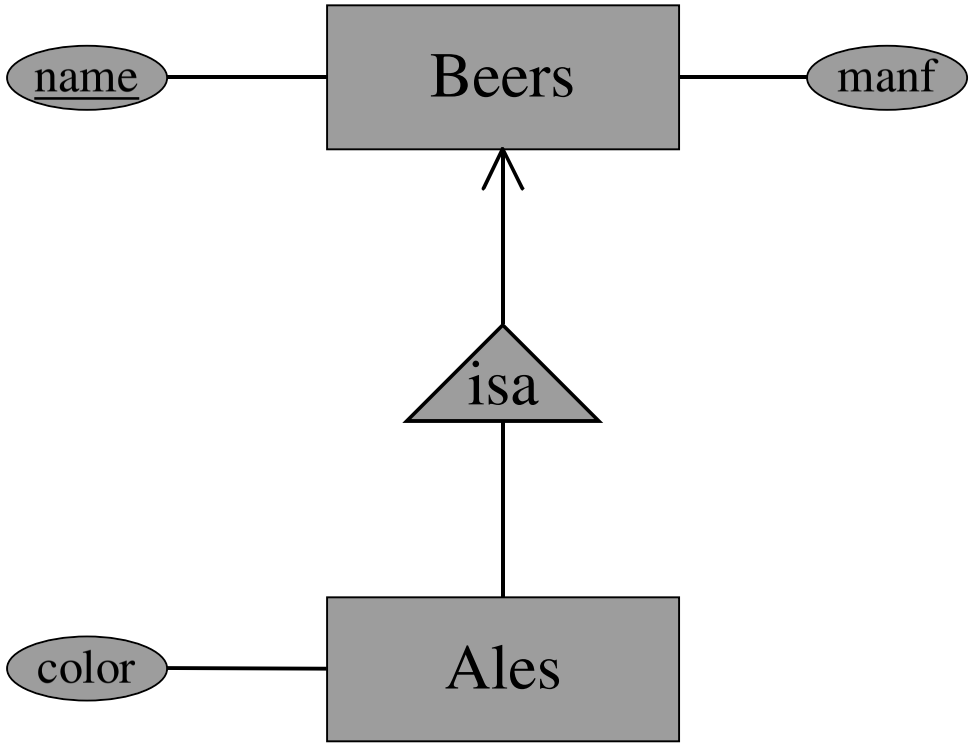
Keys

A *key* is a set of attributes whose values can belong to at most one entity.

- In E/R model, every E.S. must have a key.
  - It could have more than one key, but one set of attributes is the "designated" key.
- In E/R diagrams, you should underline all attributes of the designated key.

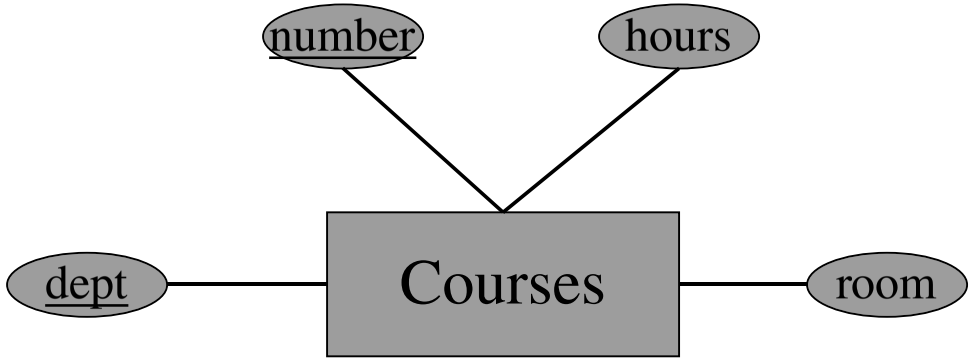
Example

- Suppose `name` is key for *Beers*.



- Beer name is also key for ales.
  - In general, key at root is key for all.

Example: A Multiattribute Key



- Possibly, the combination of hours + room also forms a key, but we have not designated it as such.