Relational Database Design using E/R

Introduction to Databases

CompSci 316 Fall 2020

DUKE
COMPUTER SCIENCE

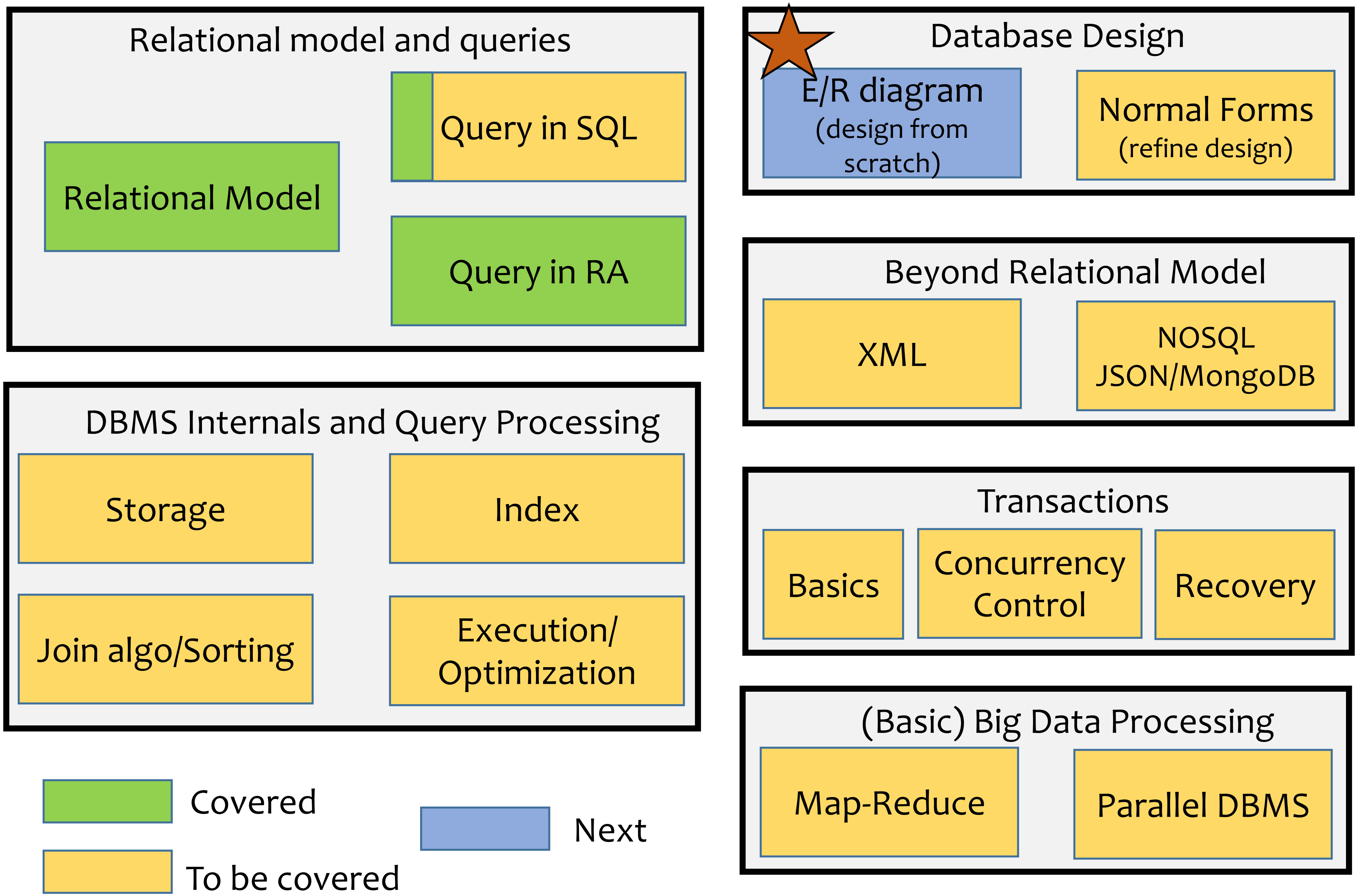
Announcements (Thu. Aug. 27)

- Reminder: HW1 due Tuesday, 9/1, 11:59 pm

- Project team formation: by Tuesday 9/8
  - Read the pdf on project details and choose fixed/open
  - See the email sent on sakai and piazza for shared google spreadsheet
  - If you have formed a group – add it to the spreadsheet
  - If you are looking for members – add your project to the spreadsheet
  - Each project team should have 5 members
  - By default, all group members from the same discussions
  - Need help? Reach out to Yesenia and Sudeepa

- Anonymous feedback form posted on Piazza
  - If you would like us to repeat a concept next week in discussions/lectures, please write it there and submit
  - Any comments/feedback/difficulties: let us know!

Where are we now?



Relational model and queries

🟩 Relational Model

🟩🟨 Query in SQL

🟩 Query in RA

DBMS Internals and Query Processing

🟨 Storage

🟨 Index

🟨 Join algo/Sorting

🟨 Execution/ Optimization

★ Database Design

🟦 E/R diagram (design from scratch)

🟨 Normal Forms (refine design)

Beyond Relational Model

🟨 XML

🟨 NOSQL JSON/MongoDB

Transactions

🟨 Basics

🟨 Concurrency Control

🟨 Recovery

(Basic) Big Data Processing

🟨 Map-Reduce

🟨 Parallel DBMS

🟩 Covered

🟨 To be covered

🟦 Next

Relational model: review

- A database is a collection of relations (or tables)
- Each relation has a set of attributes (or columns)
- Each attribute has a name and a domain (or type)
- Each relation contains a set of tuples (or rows)

How do we know which relations and attributes to have?

Example: Users, Groups, Members

Users

Each has uid (unique id), name, age, pop (popularity)

Groups

Each has gid (unique id), name

Member

Records fromDate
(when a user joined a group)

Keys

- A set of attributes K is a key for a relation R if
  - In no instance of R will two different tuples agree on all attributes of K
    - That is, K can serve as a "tuple identifier"
  - No proper subset of K satisfies the above condition
    - That is, K is minimal

- Example: *User (uid, name, age, pop)*
  - *uid* is a key of *User*
  - *age* is not a key (not an identifier)
  - {*uid*, *name*} is not a key (not minimal)

Schema vs. instance

uid	*name*	*age*	*pop*
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3

- Is *name* a key of *User*?
- Key declarations are part of the schema

More examples of keys

- *Member (uid, gid)*

- *Address (street_address, city, state, zip)*

Use of keys

- More constraints on data, fewer mistakes
- Look up a row by its key value
  - Many selection conditions are “key = value”
- “Pointers” to other rows (often across tables)
  - Example: *Member* (*uid*, *gid*)
    - *uid* is a key of *User*
    - *gid* is a key of *Group*
    - A *Member* row “links” a *User* row with a *Group* row
  - Many join conditions are “key = key value stored in another table”

Database design

- Understand the real-world domain being modeled
- Specify it using a database design model
  - More intuitive and convenient for schema design
  - But not necessarily implemented by DBMS
  - We will cover
    - Entity/Relationship (E/R) model
- Then
  1. Translate specification to the data model of DBMS
     - Relational, XML, object-oriented, etc.
  2. Create DBMS schema

Entity-relationship (E/R) model

- Historically and still very popular
- Designs represented by E/R diagrams
  - We use the style of E/R diagram covered by the GMUW book; there are other styles/extensions

Example: Users, Groups, Members

Users

Each has uid (unique id), name, age, pop (popularity)

Groups

Each has gid (unique id), name

Member

Records fromDate
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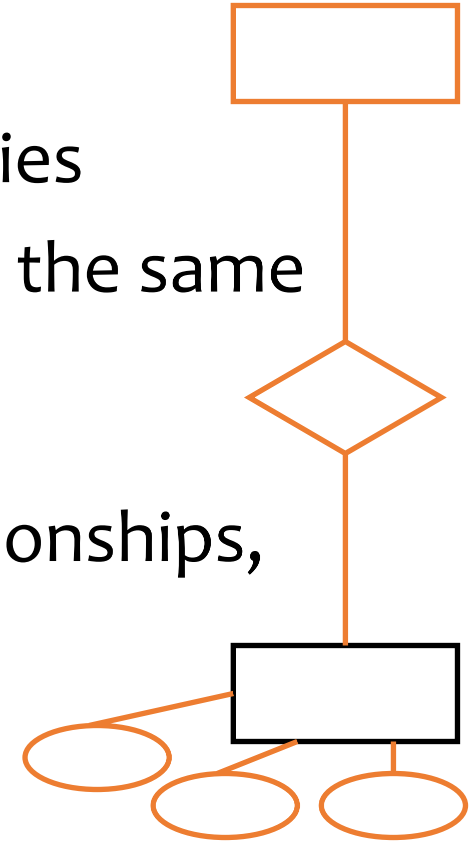
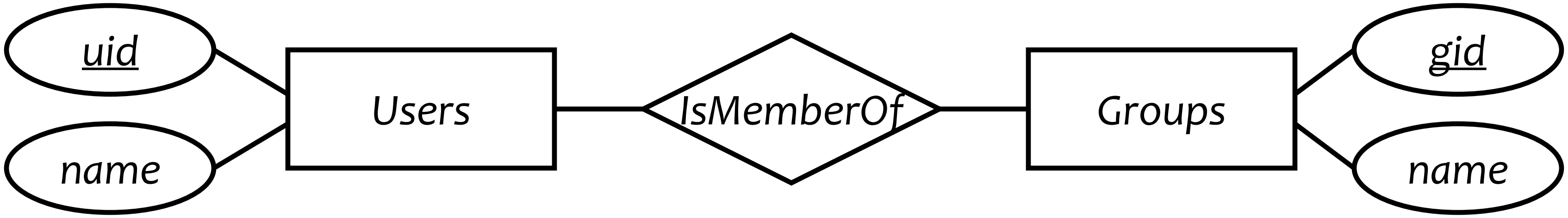
E/R basics

- Entity: a “thing,” like an object
- Entity set: a collection of things of the same type, like a relation of tuples or a class of objects
  - Represented as a rectangle
- Relationship: an association among entities
- Relationship set: a set of relationships of the same type (among same entity sets)
  - Represented as a diamond
- Attributes: properties of entities or relationships, like attributes of tuples or objects
  - Represented as ovals



An example E/R diagram

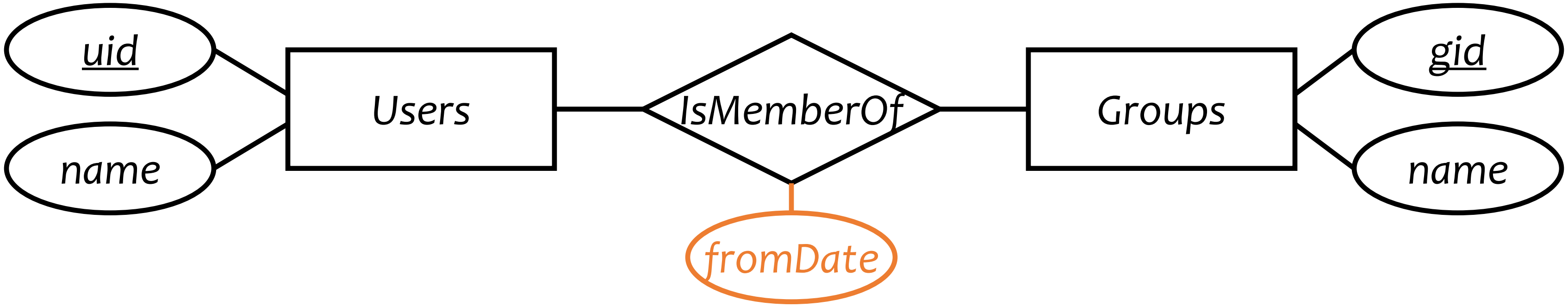
- Users are members of groups



- A key of an entity set is represented by underlining all attributes in the key
    - A key is a set of attributes whose values can belong to at most one entity in an entity set—like a key of a relation

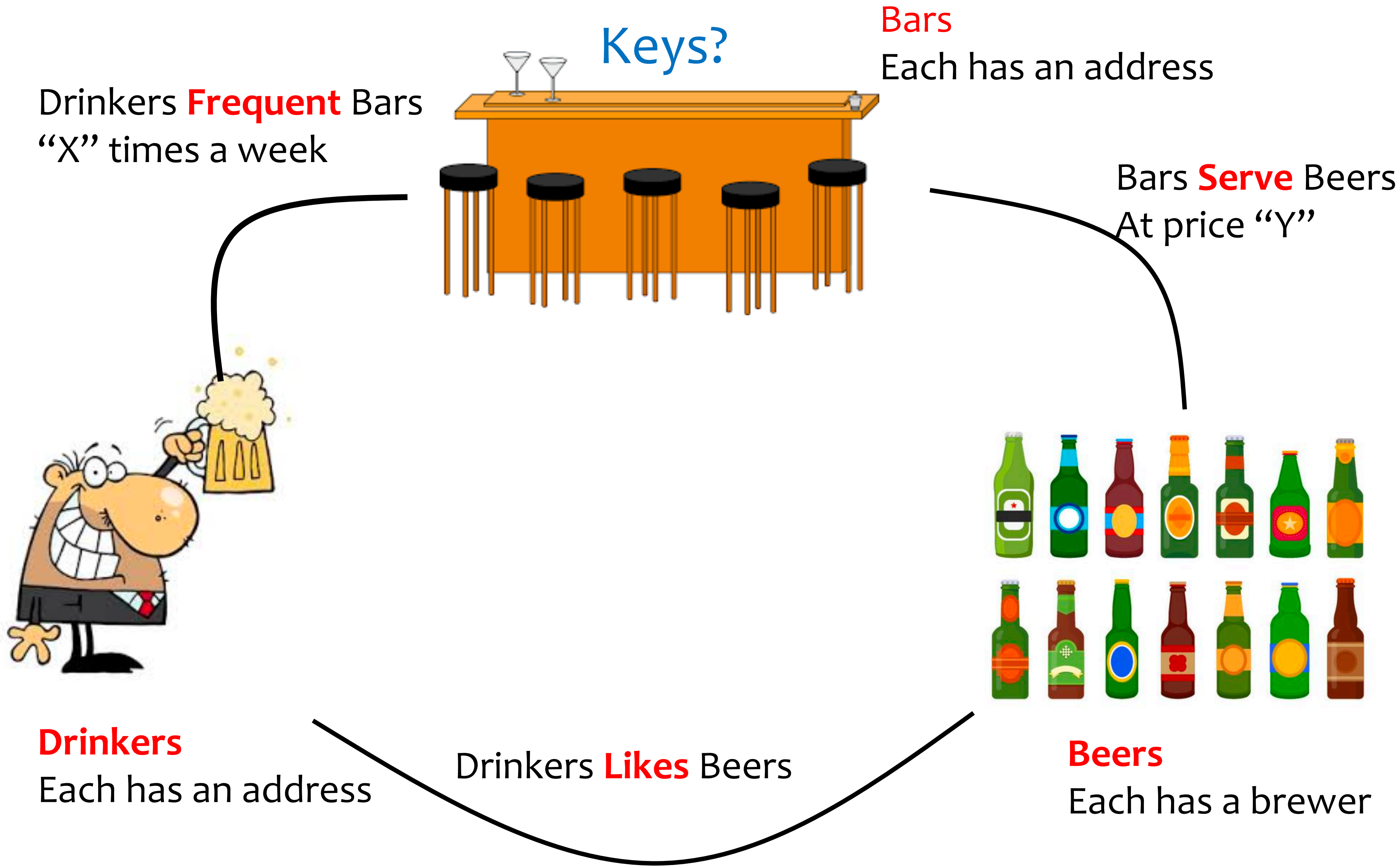
Attributes of relationships

- Example: a user belongs to a group since a particular date



- Where do the dates go?
  - With *Users*?
  - With *Groups*?

E/R diagram for Beers Database?



Keys?

Bars

Each has an address

Drinkers **Frequent** Bars

"X" times a week

Bars **Serve** Beers

At price "Y"

Drinkers

Each has an address

Drinkers **Likes** Beers

Beers

Each has a brewer

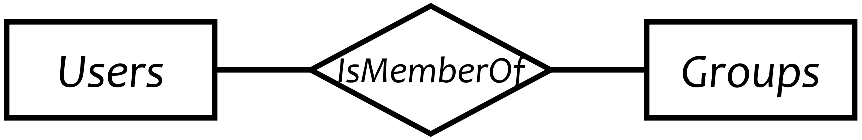
More on relationships

- There could be multiple relationship sets between the same entity sets
  - Example: *Users IsMemberOf Groups*; *Users Likes Groups*
- In a relationship set, each relationship is uniquely identified by the entities it connects
  - Example: Between Bart and “Dead Putting Society”, there can be at most one *IsMemberOf* relationship and at most one *Likes* relationship

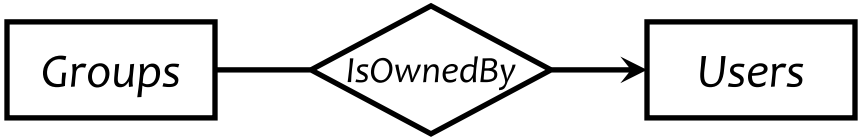
  ☞What if Bart joins DPS, leaves, and rejoins? How can we modify the design to capture historical membership information?

Multiplicity of relationships

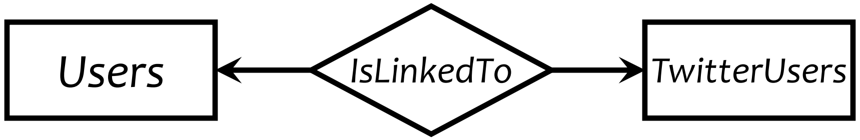
- E and F: entity sets
- Many-many: Each entity in E is related to 0 or more entities in F and vice versa
  - Example:

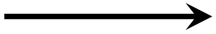
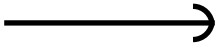


- Many-one: Each entity in E is related to 0 or 1 entity in F, but each entity in F is related to 0 or more in E
  - Example:



- One-one: Each entity in E is related to 0 or 1 entity in F and vice versa
  - Example:



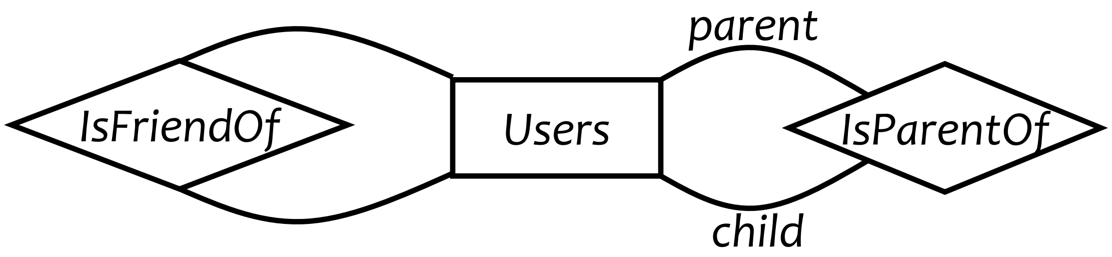
- "One" (0 or 1) is represented by an arrow 
- "Exactly one" is represented by a rounded arrow 

Roles in relationships

- How do we model "Friendship" among Users?
- An entity set may participate more than once in a relationship set

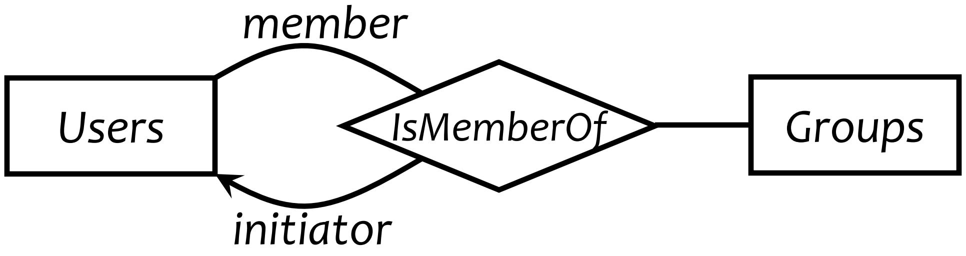
☞ May need to label edges to distinguish roles

- Examples
  - Users may be parents of others; label needed
  - Users may be friends of each other; label not needed



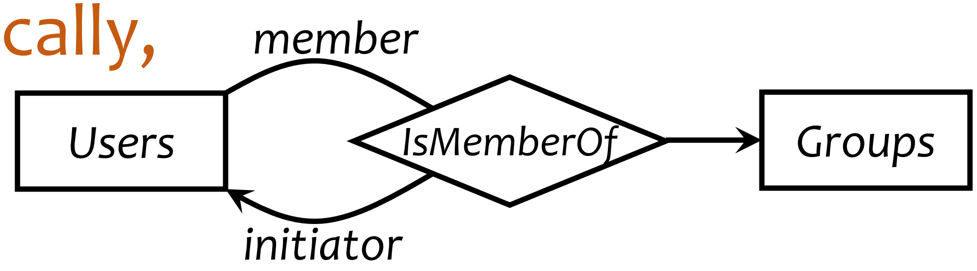
n-ary relationships

- Example: a user must have an initiator in order to join a group



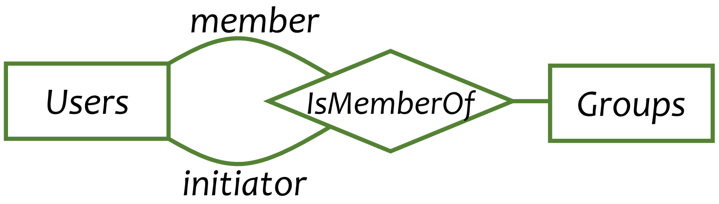
Rule for interpreting an arrow into entity set E in an n-ary relationship:

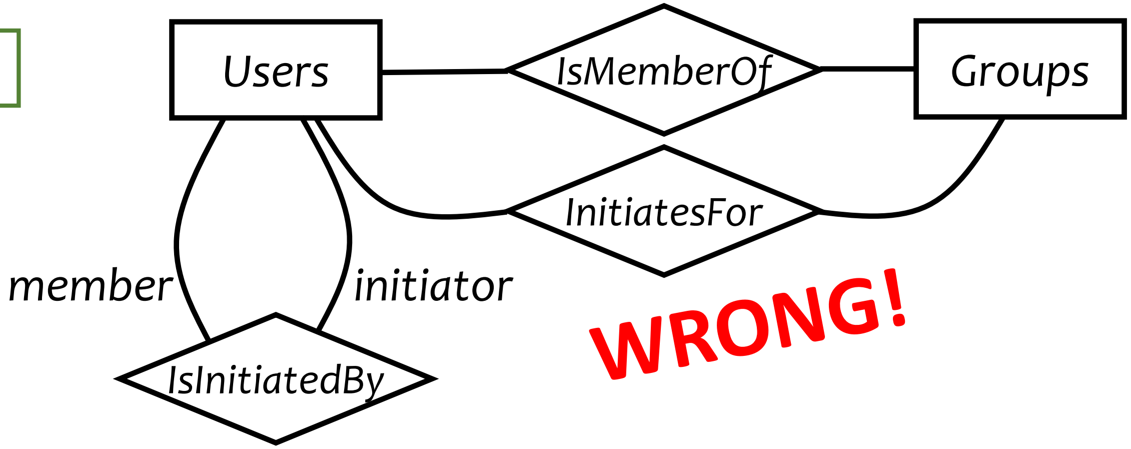
- Pick one entity from each of the other entity sets; together they can be related to at most one entity in E
- Exercise: hypothetically, what do these arrows imply?



n-ary versus binary relationships

- Can we model n-ary relationships using just binary relationships?

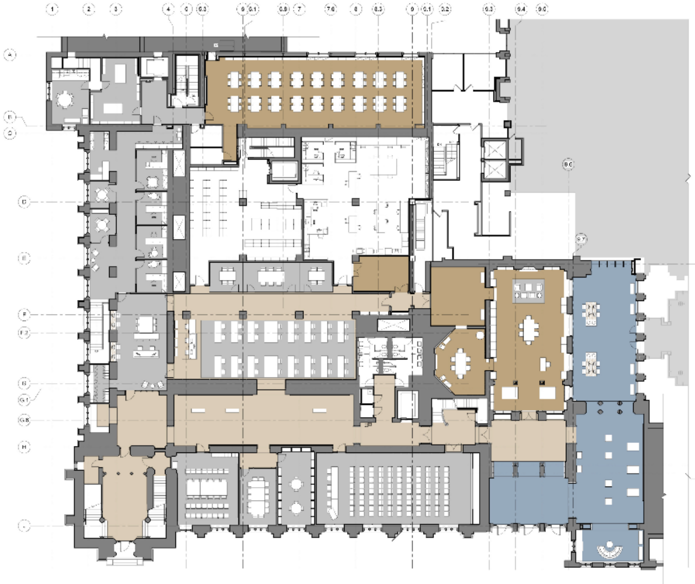




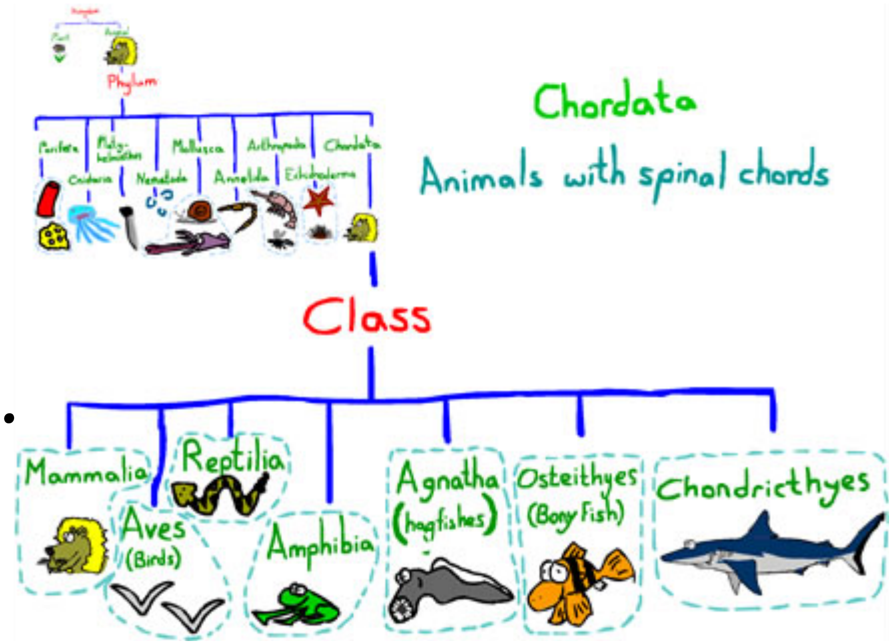
WRONG!

Are they equivalent?

Next: two special relationships



… is part of/belongs to …



… is a kind of …

http://blogs.library.duke.edu/renovation/files/2012/08/Rubenstein-Library-First-Floor-Floorplan.jpg
http://www.sharky-jones.com/Sharkyjones/Artwork/taxonomy%20artwork/Class1.jpg

Weak entity sets

Sometimes, an entity's identity depends on some others'

Can you come to my OH in 325?

Sorry 325 in..?

D wing

D-wing of… ?

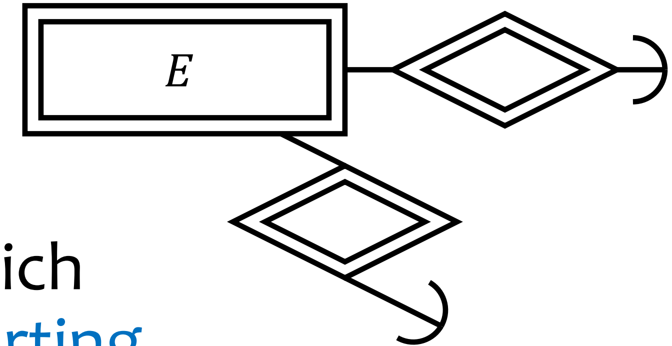
LSRC

Got it

Weak entity sets

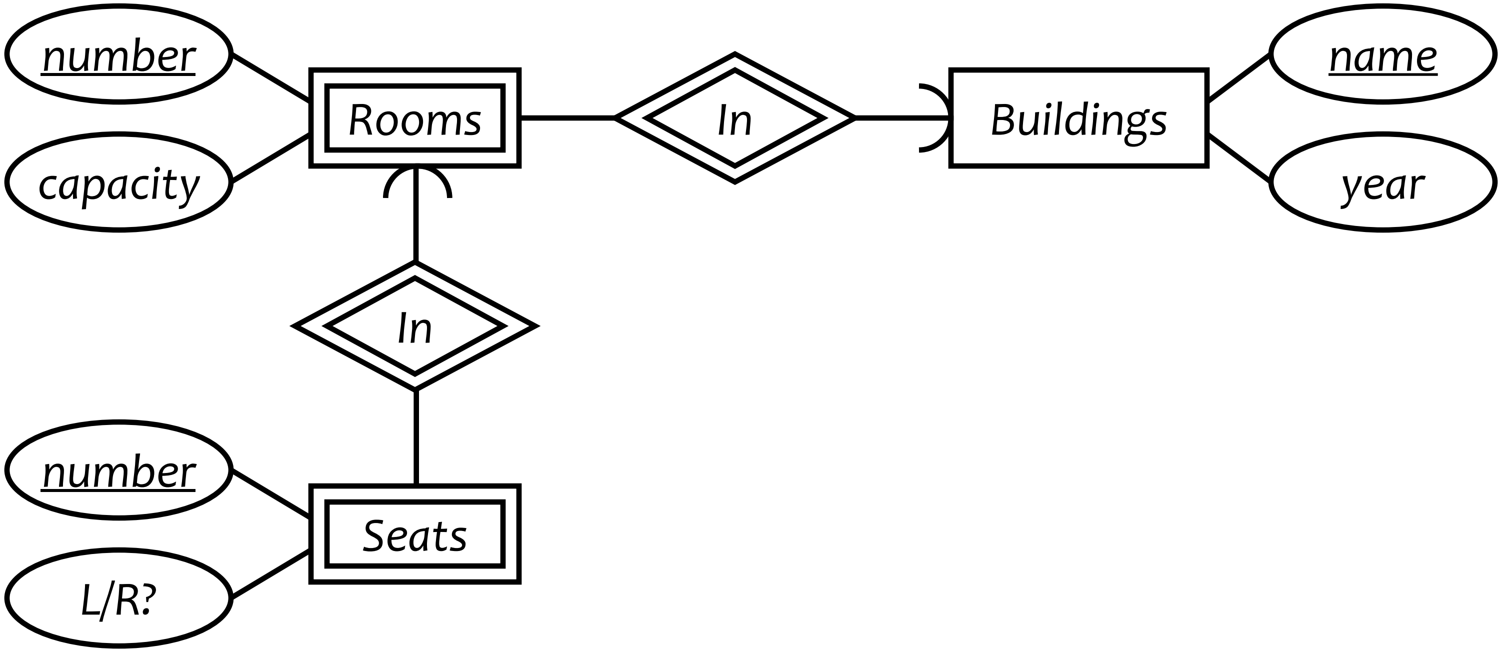
Sometimes, an entity’s identity depends on some others’

- The key of a weak entity set E comes not completely from its own attributes, but from the keys of one or more other entity sets
    - E must link to them via many-one or one-one relationship sets
- Example: *Rooms* inside *Buildings* are partly identified by *Buildings*’ name
- A weak entity set is drawn as a double rectangle
- The relationship sets through which it obtains its key are called supporting relationship sets, drawn as double diamonds



Weak entity set examples

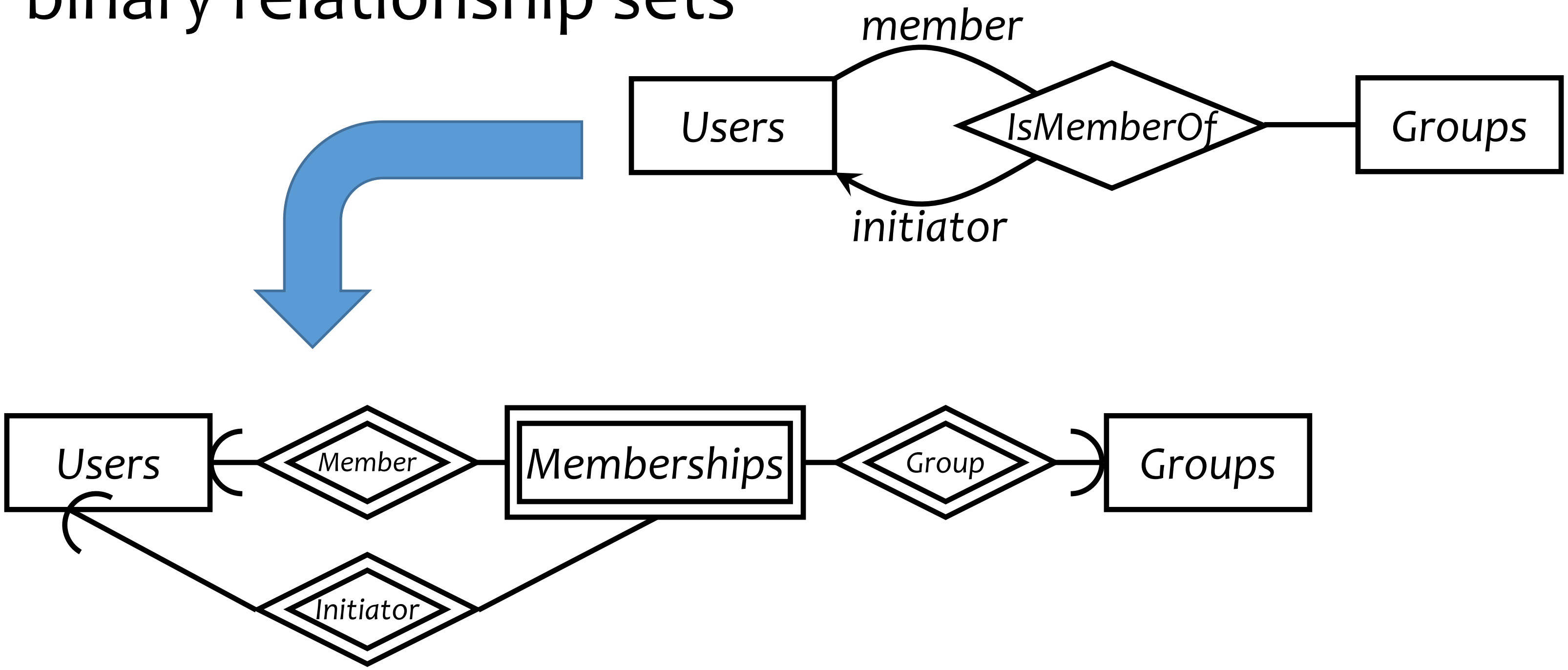
- Seats in rooms in building



- Why must double diamonds be many-one/one-one?

Remodeling n-ary relationships

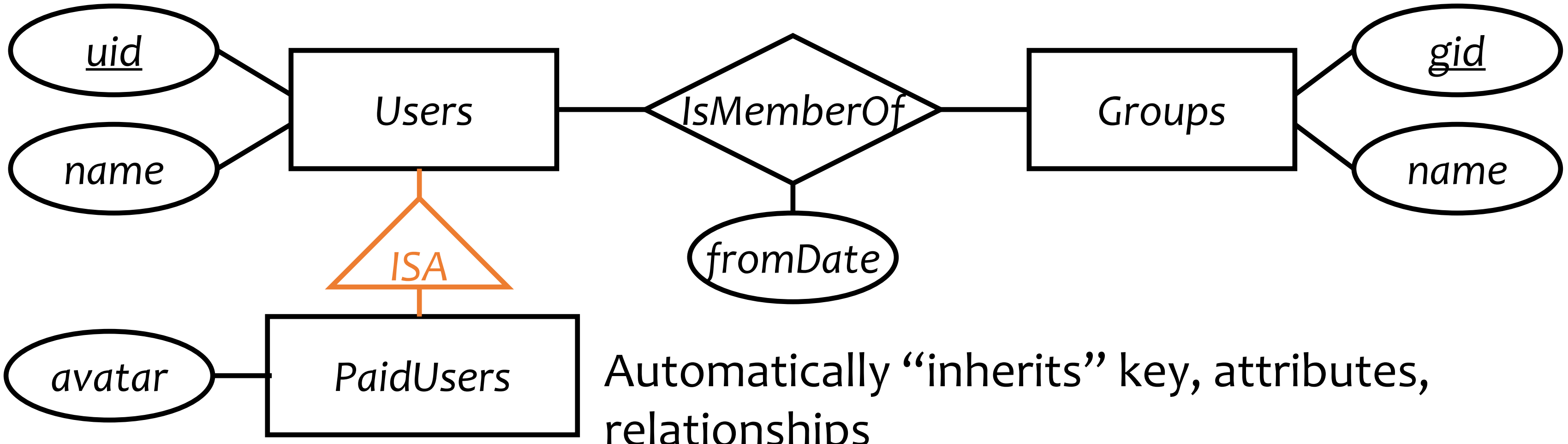
- An n-ary relationship set can be replaced by a weak entity set (called a connecting entity set) and n binary relationship sets



Are they equivalent now?

ISA relationships

- Similar to the idea of subclasses in object-oriented programming: subclass = special case, fewer entities, and possibly more properties
  - Represented as a triangle (direction is important)
- Example: paid users are users, but they also get avatars (yay!)



Automatically "inherits" key, attributes, relationships

Summary of E/R concepts

- Entity sets
  - Keys
  - Weak entity sets
- Relationship sets
  - Attributes of relationships
  - Multiplicity
  - Roles
  - Binary versus n-ary relationships
    - Modeling n-ary relationships with weak entity sets and binary relationships
  - ISA relationships

Case study 1

- Design a database representing cities, counties, and states
  - For states, record name and capital (city)
  - For counties, record name, area, and location (state)
  - For cities, record name, population, and location (county and state)
- Assume the following:
  - Names of states are unique
  - Names of counties are only unique within a state
  - Names of cities are only unique within a county
  - A city is always located in a single county
  - A county is always located in a single state

Case study 1: first design

Case study 1: second design

Case study 2

- Design a database consistent with the following:
  - A station has a unique name and an address, and is either an express station or a local station
  - A train has a unique number and an engineer, and is either an express train or a local train
  - A local train can stop at any station
  - An express train only stops at express stations
  - A train can stop at a station for any number of times during a day
  - Train schedules are the same everyday

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Case study 2: first design

Case study 2: second design