Entity-Relationship Modelling

- Entities
- Attributes
- Relationships
- Mapping Cardinality
- Keys
- Reduction of an E-R Diagram to Tables

Entity Sets

- A database can be modeled as a collection of:
  - entities, and
  - relationships among those entities.

- An *entity* is an object that is distinguishable from other objects.
  - A specific person, company, automobile, etc.

- Entities have *attributes:*
  - People have *names* and *addresses*
  - An entity and its' attributes are represented by a tuple

    (342-97-4873, Smith, Main, Orlando)

- An *entity set* is a set of entities of the same type, i.e., that share the same properties and attributes.
  - Set of all students, set of all companies, set of all automobiles

Entity Sets customer *and* loan

- Entity sets:
  - The set of all customers of the Bank
  - The set of all loans at the bank
- Entities:
  - Customers of the Bank – Bob Jones, Sue Smith, Mark Hayes, etc.
  - Loans at the Bank – L17, L15, L23, etc.
- Attributes*:*
  - Bob Jones has an ID# (321-12-3231), a street address (475 Main Street), a city of residence (Orlando), and a last name (Jones).
  - Loan L17 has an amount ($4537), a date when the loan was taken out (12/15/2009), and a loan number (L17).

Attributes

- The set of permitted values for an attribute is call the *domain* of that attribute.
- Attributes can be one of several types:
  - Simple (i.e., atomic) – height in inches, weight in ounces, last-name
  - Composite – name, address
  - Single-valued – date of birth, name
  - Multi-valued – phone-numbers, dependents, hobbies
  - Derived – “age” is derived, or rather, computed from “date-of-birth”

Attributes, Cont.

- Keep in mind that modeling is NOT design!
  - during modeling we are focused on what the relevant data is, and not whether or how it will be stored in the database.
  - age vs. date-of-birth
- This approach is:
  - consistent with most text-books
  - somewhat *inconsistent* with industry

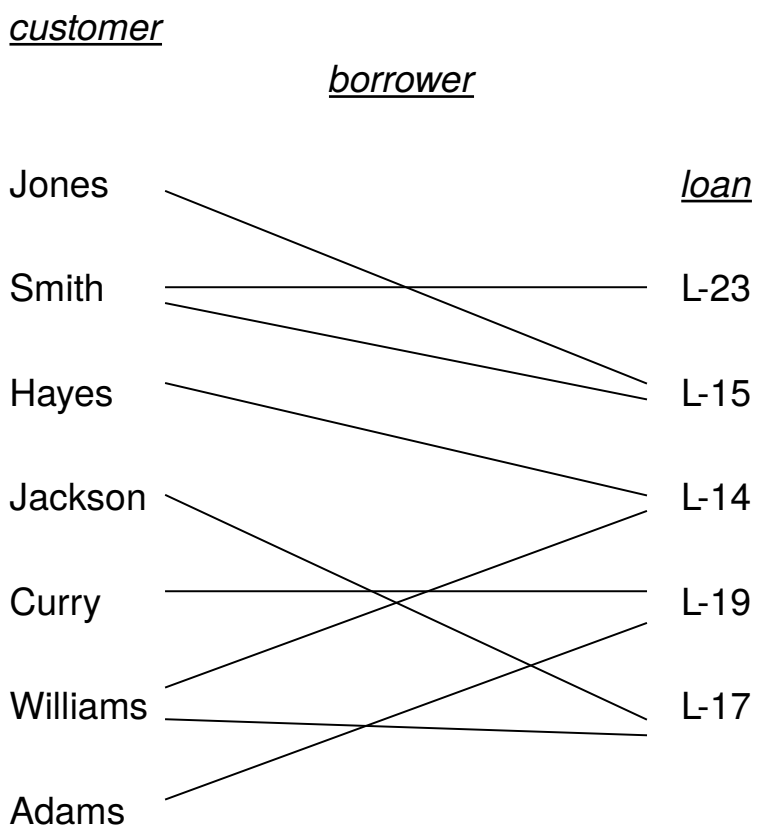
Relationship Sets

- A *relationship* is an association among two (or more) entities
  - *Hayes* is a *depositor* for account *A-102*
  - The relationship is denoted by a tuple (Hayes, A-102)

- A *relationship set* is a set of relationships, all of the same type.

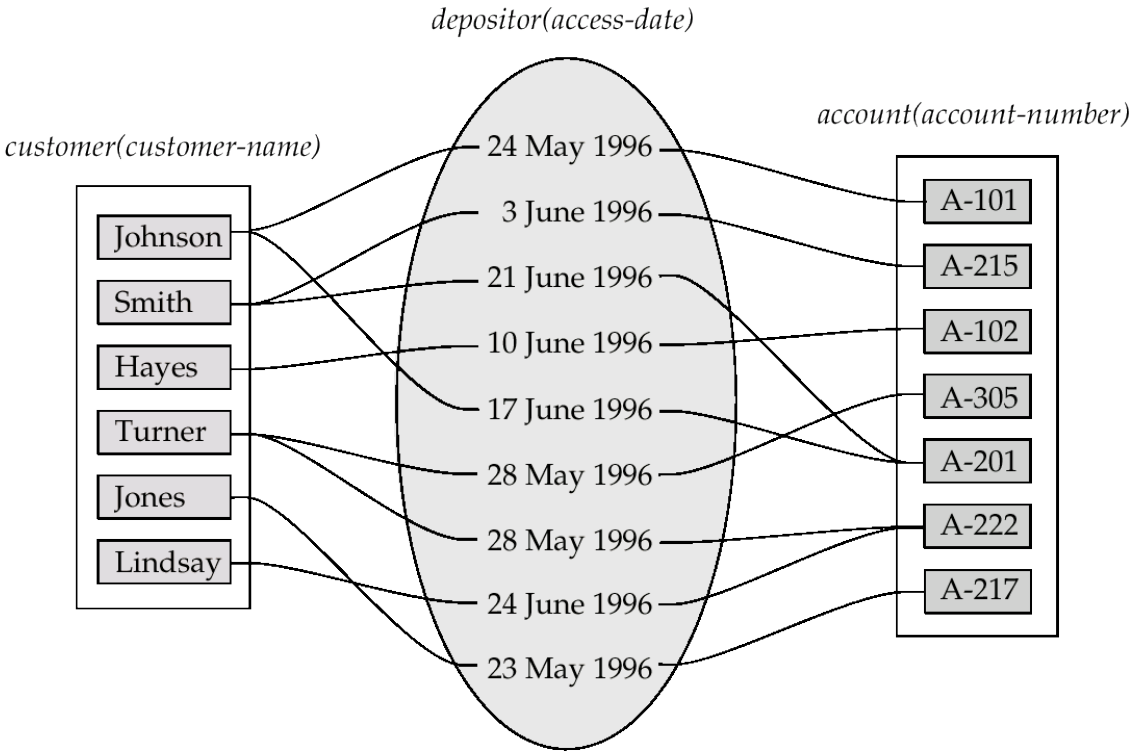
Attributes, Cont.

- Relationships can be visualized graphically:



Relationship Sets (Cont.)

- An attribute can also be property of a relationship set.



Relationship Sets with Attributes, Cont.

- Another example of a relationship set having attributes:
  - Entities: *Student* and *Course*
  - Relationship: *Has-Taken*

- Where does the attribute *grade* go?

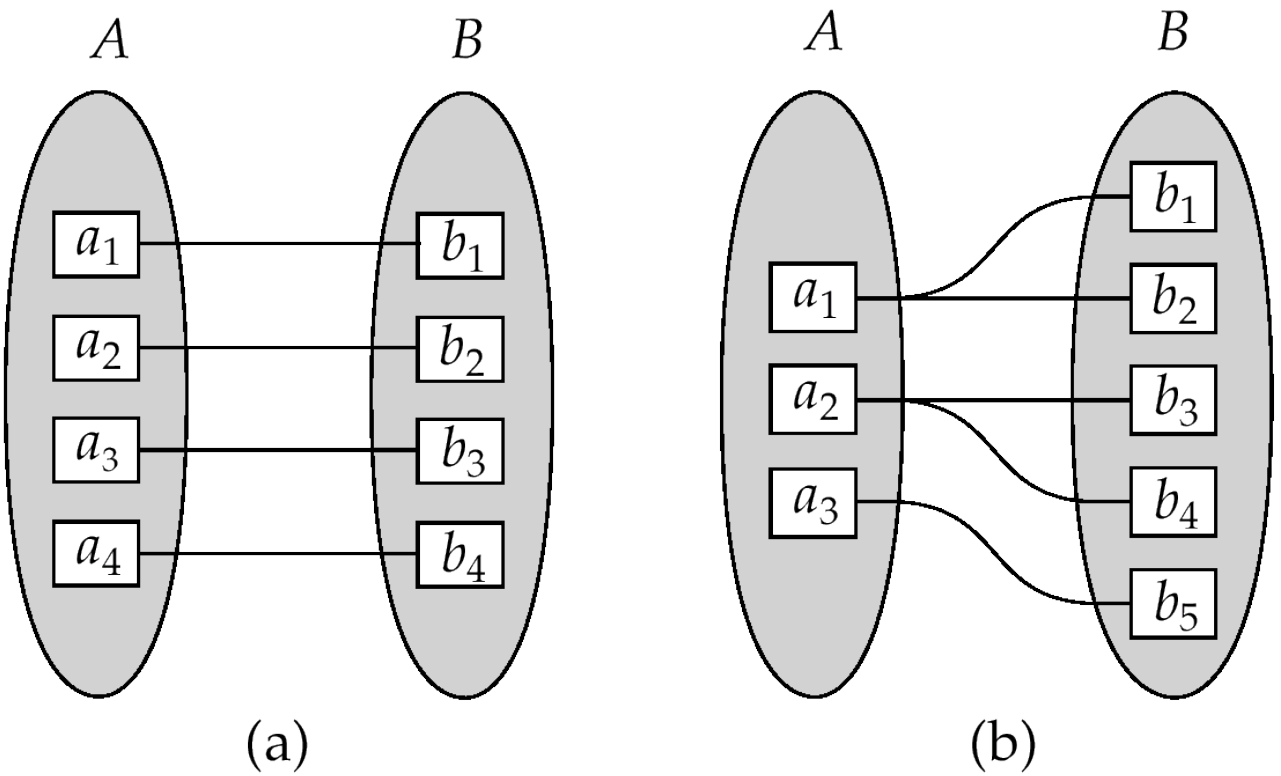
Degree of a Relationship Set

- The number of entity sets that participate in a relationship set is referred to as the *degree* of that relationship set.
- Relationship sets that involve two entity sets are called *binary*.
  - Most relationship sets are binary.
  - We will focus only on binary relationships.
- Example of a ternary relationship set:
  - Employees of a bank could have different jobs at different branches.
  - This gives a ternary relationship set between *employee, job* and *branch*.

Mapping Cardinalities

- The *mapping cardinality* of a relationship set expresses the number of entities to which one entity can be associated via the relationship set.
- Most useful in describing binary relationship sets.
- For a binary relationship there are four types:
  - One to one – US residents & social security #'s
  - One to many – academic advisors (assuming at most one major)
  - Many to one – same as one-to-many
  - Many to many – depositors

Mapping Cardinalities

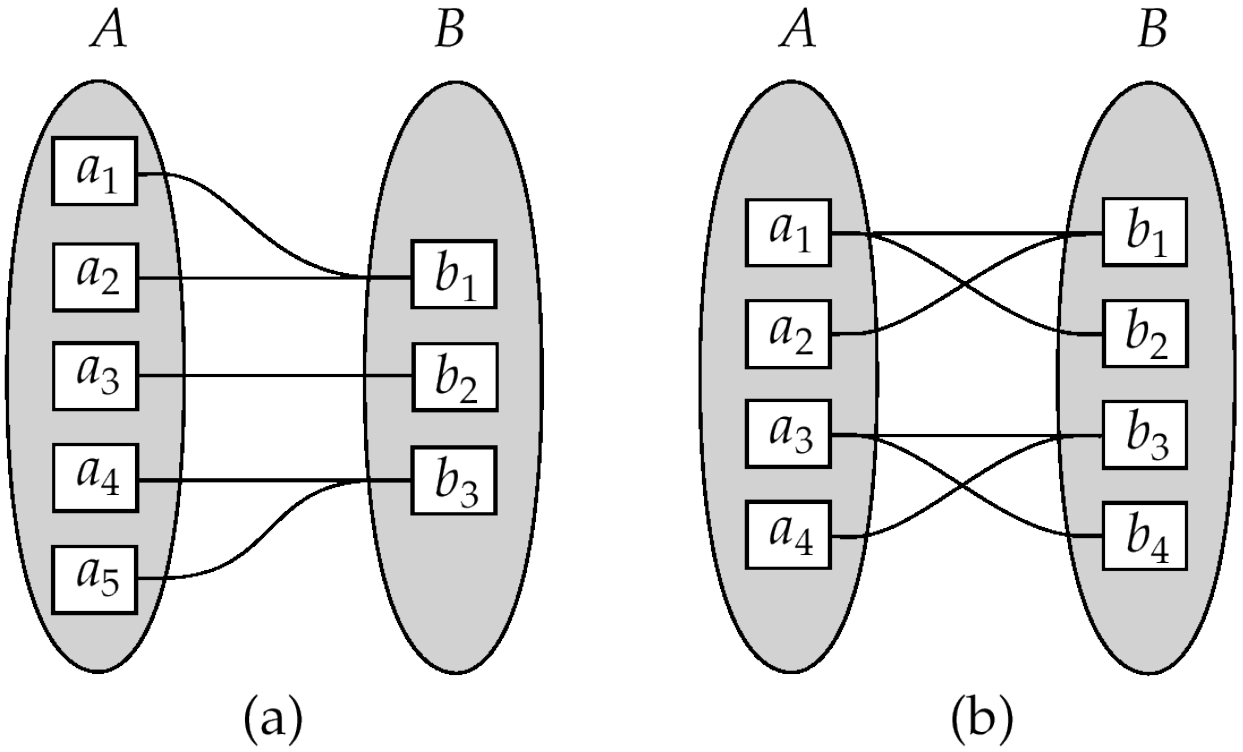


One to one

One to many

Note: Some elements in A and B may not be mapped to any elements in the other set

Mapping Cardinalities



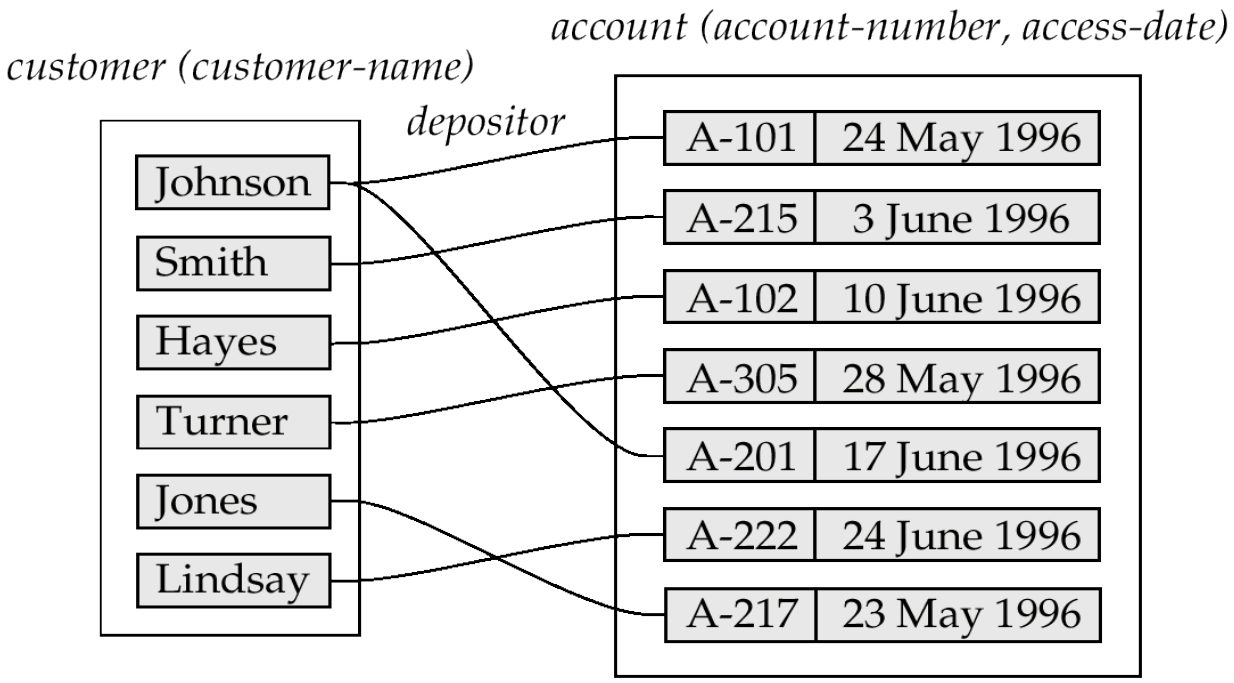
Many to one

Many to many

Note: Some elements in A and B may not be mapped to any elements in the other set

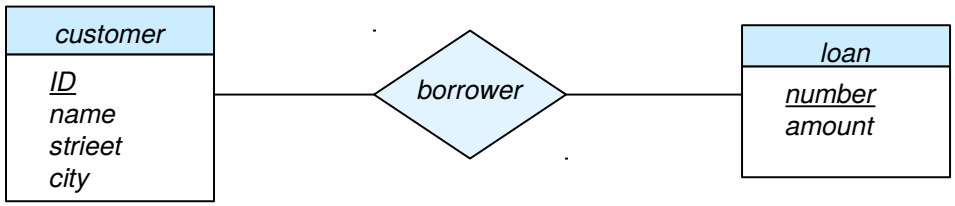
Mapping Cardinalities affect Attribute Placement

- In the banking enterprise, *access-date* could be an attribute of account instead of a relationship attribute if each account can have only one customer, i.e., if the relationship is one-to-many.

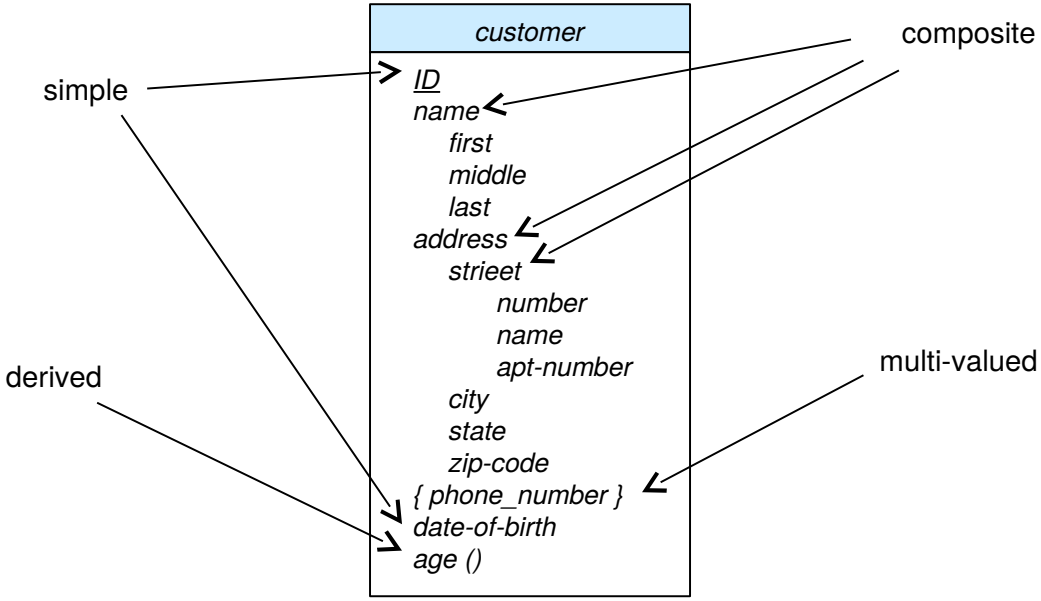


E-R Diagrams

- Rectangles - entity sets
- Diamonds - relationship sets
- Lines - connect attributes to entity sets, and entity sets to relationship sets.
- Underlined Attributes – primary key attributes

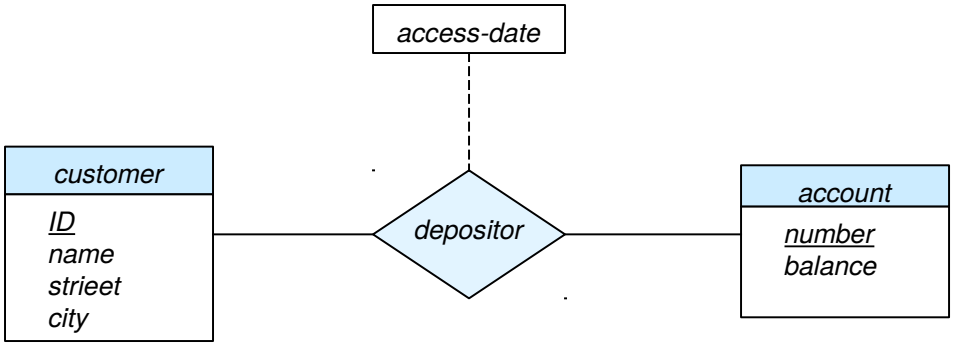


E-R Diagram with Composite, Multi-valued, and Derived Attributes



- Notes:
  - In many applications the terms are much more ambiguous (e.g., function designators)
  - An ER diagram is typically accompanied by a document that defines all the terms
  - Much harder to do than it appears (e.g., what is an “orbit” for a satellite?)

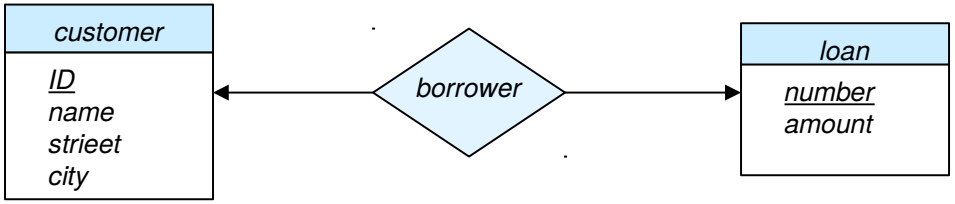
Relationship Sets with Attributes



Cardinality Constraints

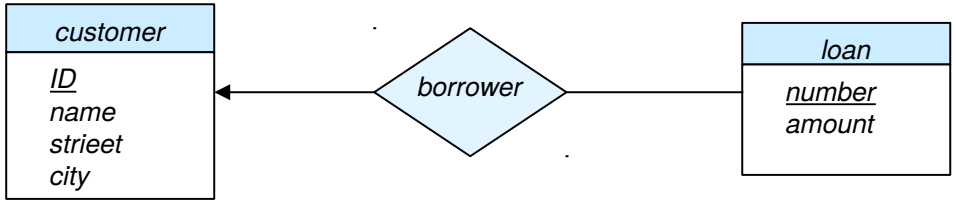
- Cardinality constraints are indicated by drawing a directed line (→), signifying “one,” or an undirected line (—), signifying “many,” between the relationship and the entity.

- If *borrower* were a one-to-one relationship:
  - A customer would be associated with <u>at most one</u> loan
  - n loan would be associated with <u>at most one</u> customer



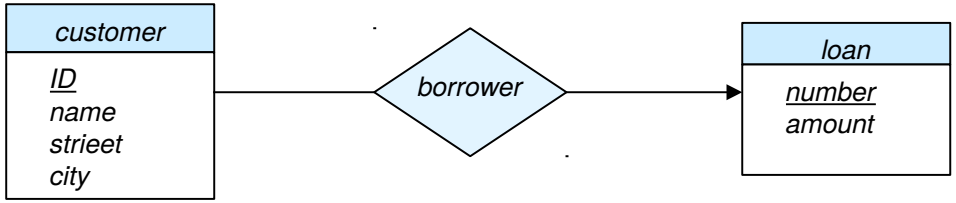
One-To-Many Relationship

- If *borrower* were a one-to-many relationship from customer to loan, then a customer would be associated with zero or more one loans, and a loan would be associated with at most one customer.



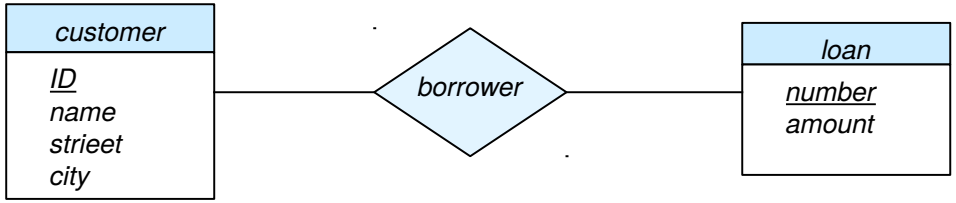
Many-To-One Relationships

- If *borrower* were a many-to-one relationship from customer to loan, then a loan would be associated with zero or more customers, and a customer would be associated with at most one loan.



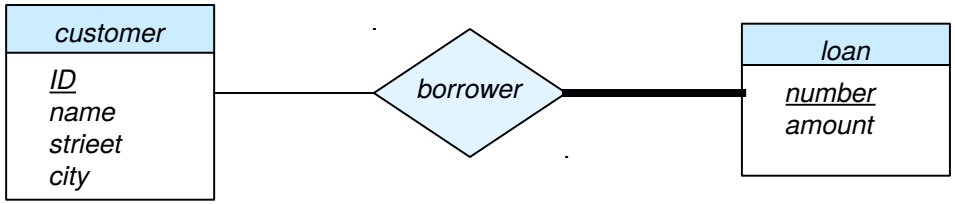
Many-To-Many Relationship

- If *borrower* were a many-to-many relationship then a customer would be associated with zero or more loans, and a loan would be associated with zero of more customers.



Participation of an Entity Set in a Relationship Set

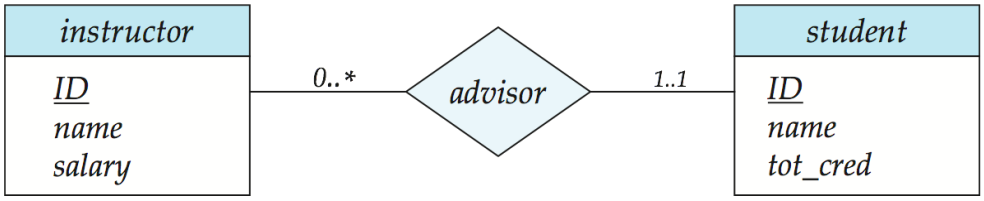
- If every entity in an entity set must participate in a relationship set, then that entity set is said to have *total participation* in the relationship; indicated by a double-line and a double-diamond.



- If participation in a relationship is optional for some entities then that entity set is said to have *partial participation* in the relationship.

Alternative Notation for Cardinality Limits

- Specific cardinality limits can also express participation constraints



Keys

- A *super key* of an entity set is a set of one or more attributes that uniquely identify each entity in the entity set.
- A *candidate key* of an entity set is a *minimal* super key
  - *customer-id* is candidate key of *customer*
  - *account-number* is candidate key of *account*
- Although several candidate keys may exist, one of the candidate keys is selected to be the *primary key*.
  - All others are referred to as *secondary keys*
  - Book says selection of the primary key is arbitrary, but this is not true.
- Later we will also discuss *foreign keys* and *search keys*.

Other Examples of Keys

- Student = (SS#, Name, Date-of-Birth, Status)

SS#	- Super key and candidate key
SS#, Name, DOB	- Super key, but not candidate key
SS#, Status	- Super key, but not candidate key
Name	- Neither

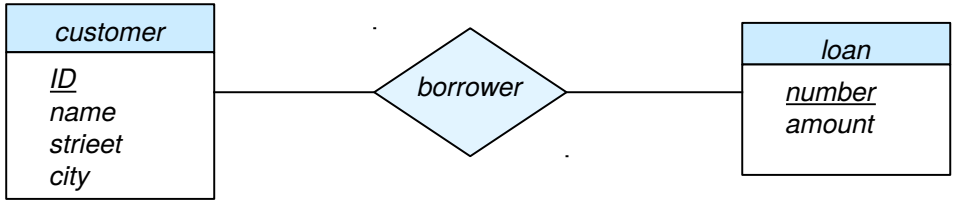
- Payment = (Payment#, Loan#, Date-Made, ID#)

ID#	- Super key, and candidate key
Payment#, Loan#	- Super key, and candidate key
ID#, Date-Made	- Super key, but not candidate key
Date-Made	- Neither

- ID# is frequently referred to ask a *pseudo-key*.

Keys in an ER Diagram

- A primary key of an entity set is specified in an ER diagram by underlining the key attributes.



Keys for Relationship Sets

- Much like an entity set, a relationship set can also have a super key.
- The combination of primary keys of the participating entity sets forms a super key of a relationship set.
  - (*customer-id, account-number*) is the super key of *depositor*
  - Question: why *primary* and *super* in the above?
- The mapping cardinality of a relationship set will determine, in part, what the candidate keys of the relationship set are.
- If the relationship is one-to-one, then using just one of the primary keys of the participating entity sets is, in fact, minimal, and hence forms a candidate key for the relationship set.

Design Options

- Frequently there are many ways to model a given situation.
- Use of an entity vs. an attribute:
  - Is *Telephone-Number* an attribute or an entity?
  - Choice mainly depends on the structure of the enterprise being modeled, and on the semantics/meaning associated with the attribute in question.
- Use of an entity vs. a relationship:
  - Is *Loan* an entity or a relationship?
  - Possible guideline - use a relationship to describe an action between entities
- Binary versus *n*-ary relationships:
  - e.g., Family, as opposed to mother, father, brother, sister
- Placement of relationship attributes

Lets Try an Example!

Construct an ER diagram for a car insurance company whose customers own one or more cars each. Each car has associated with it zero to any number of recorded accidents.

Lets Try an Example!

From the 6th edition…

Construct an ER diagram for a car insurance company whose customers own one or more cars each. Each car has associated with it zero to any number of recorded accidents. Each insurance policy covers one or more cars, and has one or more premium payments associated with it. Each payment is for a particular period of time, and has an associated due date, and the date when the payment was received.

Examples and Exercises

- Look for other ER diagramming exercises in the book, at the end of the chapter, or online.
- Google image search “ER diagram example”
- One example:
  - http://commons.wikimedia.org/wiki/File:ER_Diagram_MMORPG.png

Weak Entity Sets

- For most entity sets, a primary key is specified in terms of its immediate attributes.
- Such an entity set is referred to as a *strong entity set*.
- For some entities, however, it is helpful to specify its' primary key, at least in part, in terms of some other entities' attributes.
- Such an entity set is referred to as a *weak entity set*.
- A weak entity set is typically associated with an *identifying entity set* (which is usually strong) via a total, one-to-many relationship.

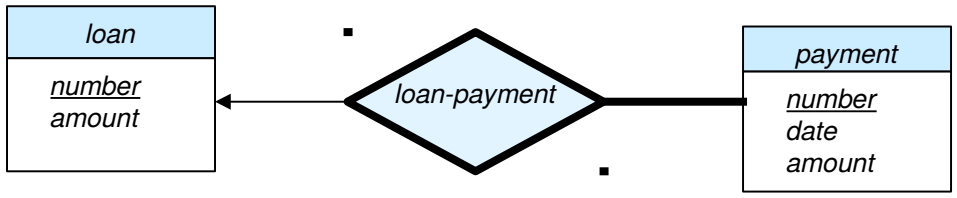
Weak Entity Sets, Cont.

- In such a case, the (weak) entity typically has a subset of attributes, called a *discriminator (or partial key)*, that distinguishes among all entities of the weak entity set associated with one identifying entity.

- In such a case, a primary key for the weak entity set can be constructed with two parts:
  - The primary key of the associated identifying entity set
  - The weak entity set's discriminator

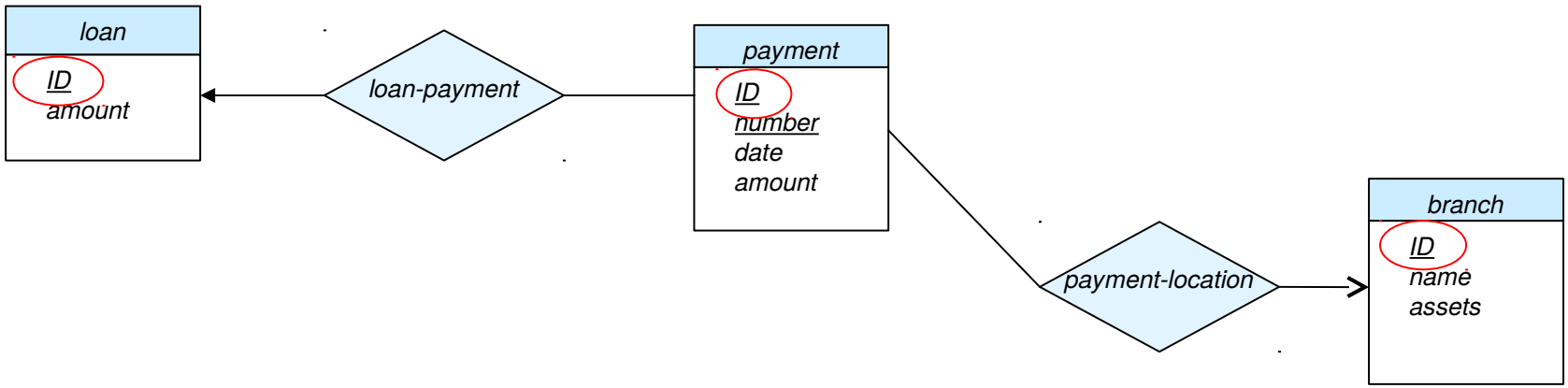
Weak Entity Sets (Cont.)

- A weak entity set is represented by double rectangles.
- The discriminator is underlined with a dashed line.
- Primary key for *payment* is (*loan-number, payment-number*)



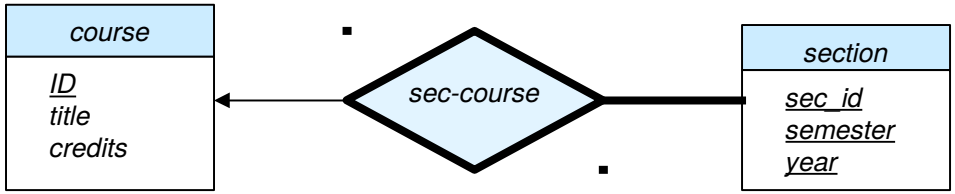
Weak Entity Sets (Cont.)

- The primary key of the strong entity set is not explicitly specified in the weak entity set, since it is implicit in the identifying relationship.
- If *loan-number* were explicitly specified:
  - *Payment* would be a strong entity set
  - The relationship between *payment* and *loan* might not be as clear



More Weak Entity Set Examples

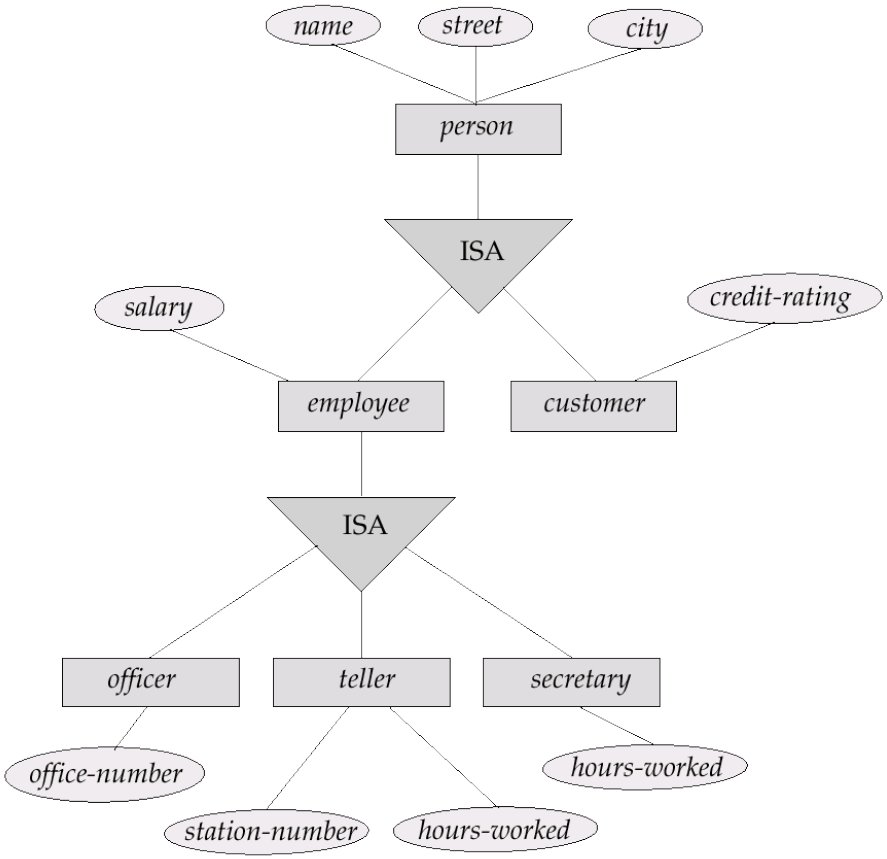
- In a university, a *course* is a strong entity and a *section* can be modeled as a weak entity.



- The discriminator of *section* would be *sec-id, semester* and *year.*

- If *section* were modeled as a strong entity then it would have *id* as an attribute; the relationship with *course* would be implicit in the *id* attribute.

Specialization and Generalization Example



Specialization

- Top-down design process; we designate sub-groupings within an entity set that are distinctive from other entities in the set.
- The lower-level entity sets may:
  - Have attributes that do not apply to the higher-level entity set.
  - Participate in relationships that do not apply to the higher-level entity set, e.g., airline employees, pilots, crew, agents, etc., but only pilots are certified certified to fly certain aircraft types.
- A lower-level entity set is said to *inherit* all the attributes and relationships from the higher-level entity set to which it is linked.
- Depicted by a triangle component labeled ISA, e.g. *customer* “is a” *person*.

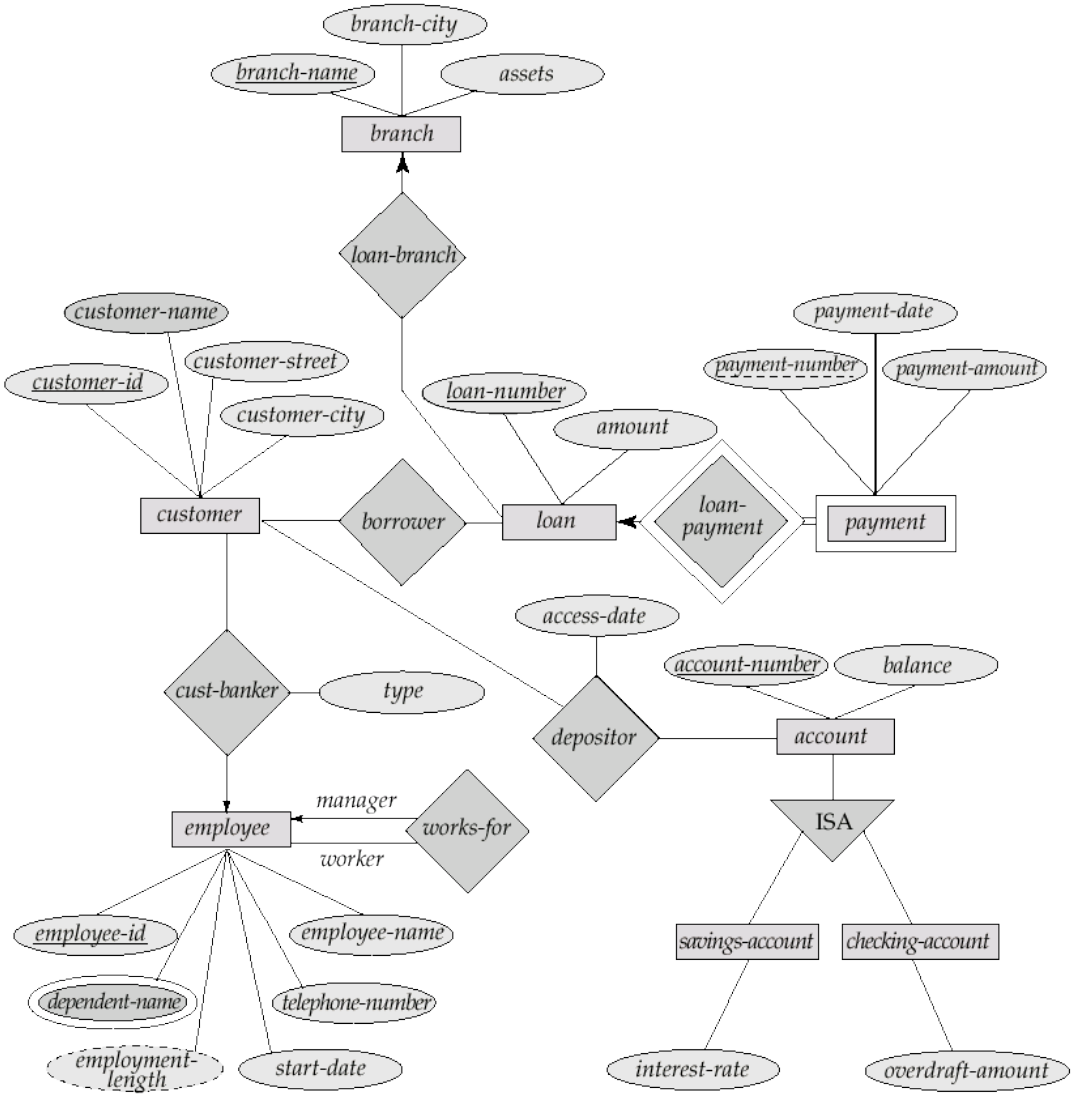
Generalization

- Bottom-up design process: combine a number of entity sets that share the same features into a higher-level entity set.
- The terms specialization and generalization are used interchangeably, for the obvious reasons.
- The ISA relationship also referred to as a *superclass-subclass* relationship.

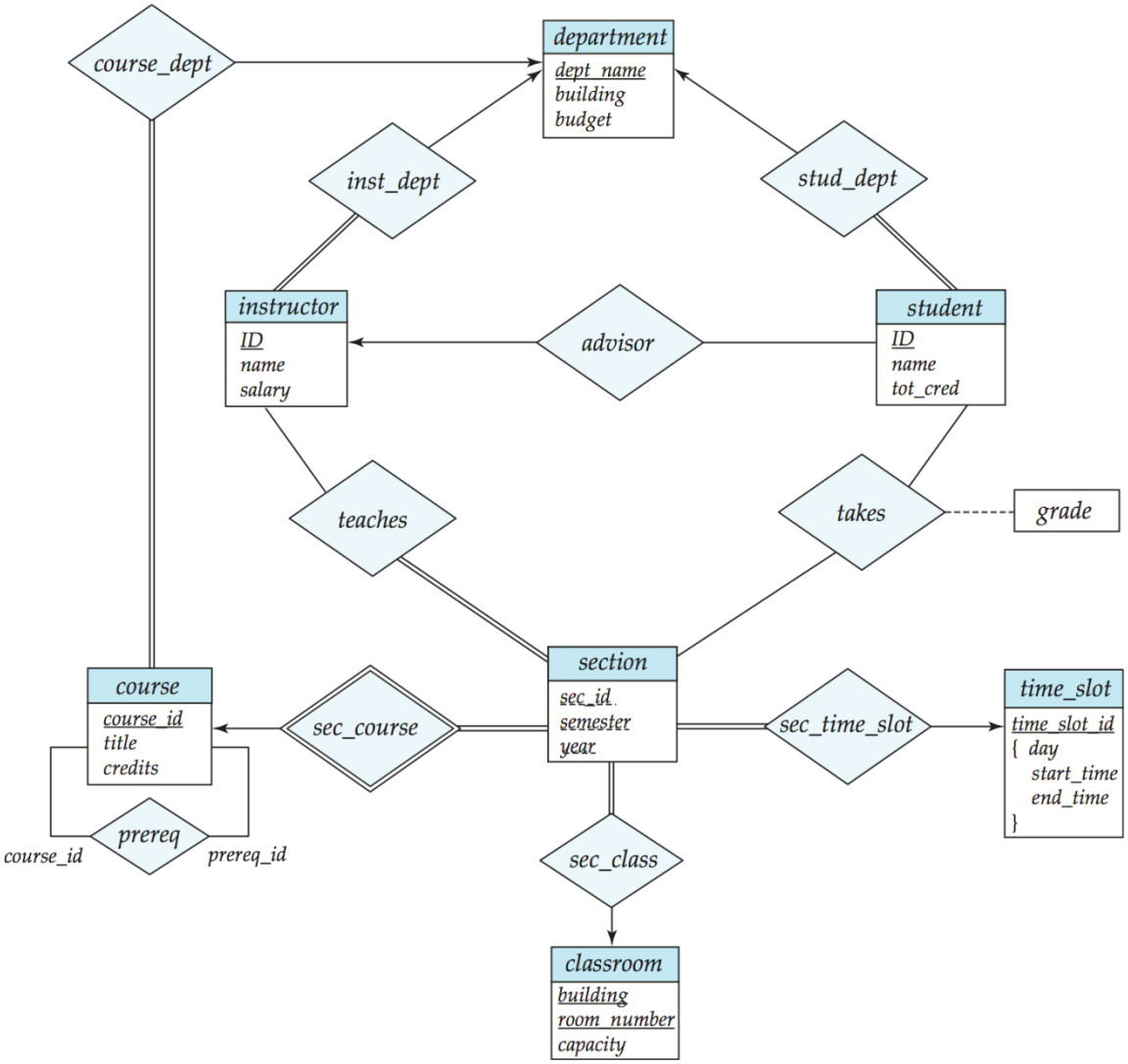
Specialization and Generalization, Cont.

- A specialization/generalization relationship can be:
  - disjoint vs. overlapping – notated in any number of ways.
  - total vs. partial – notated as before.
- Multiple specializations of an entity set are possible:
  - *permanent-employee* vs. *temporary-employee*
  - In addition to *officer* vs. *secretary* vs. *teller*
- Each particular employee would be a member of:
  - one of *permanent-employee* or *temporary-employee*, and
  - one of *officer*, *secretary*, or *teller*

E-R Diagram for a Banking Enterprise

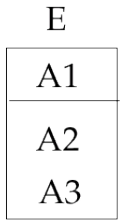


E-R Diagram for a University

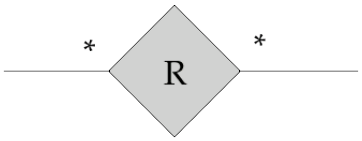


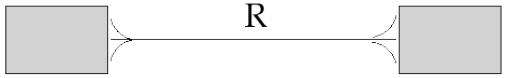
Alternative E-R Notations

Entity set E with attributes A1, A2, A3 and primary key A1

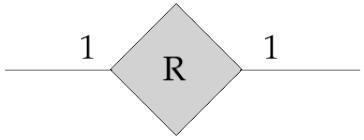


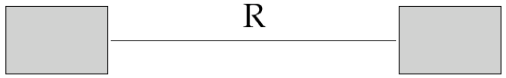
Many to Many Relationship



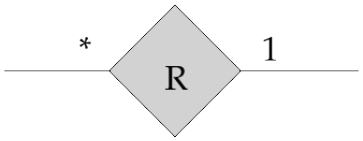


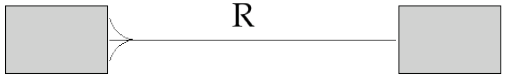
One to One Relationship





Many to One Relationship





UML

- UML: Unified Modeling Language
- UML has many components to graphically model different aspects of an entire software system
- UML Class Diagrams correspond to E-R Diagram, but several differences.
  - Focus is on software components (not data), e.g., UML includes methods

ER Diagramming Practice

- Practice developing ER diagrams:
  - see exercises at the end of the chapter on ER diagrams
  - use your imagination!

- Possible enterprises to model:
  - airline or airport
  - hospital
  - Insurance company
  - library
  - retailor – clothing, food, equipment
  - your favorite government agency

Reduction of an E-R Schema to Tables

- Converting an E-R diagram to a relational database:
  - Each entity set is converted to its' own table.
  - Each relationship *can be* (but may not be) converted to its' own table.
- Each table has a number of columns, which generally corresponding to the attributes in the corresponding entity or relationship set.
- The resulting tables can be modified in a variety of ways to support performance, space, or other requirements.

Representing Entity Sets as Tables

- A strong entity set reduces to a table with the same attributes.

customer-id	*customer-name*	*customer-street*	*customer-city*
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park	Pittsfield
677-89-9011	Hayes	Main	Harrison
963-96-3963	Williams	Nassau	Princeton

Composite and Multi-valued Attributes

- Composite attributes are broken up:
  - Example: attribute *name* with components *first-name* and *last-name* becomes two attributes in the corresponding table - *name.first-name* and *name.last-name*.

- A multi-valued attribute *M* of entity *E* is represented by a new table with the following attributes:
  - The primary key of *E*
  - An attribute corresponding to multi-valued attribute *M*

- Example:

  Entity Set:

  employee with attributes *id#, name, phone#, dependents*

  Tables:

  employee (id#, name, phone#)

  dependent (id#, dname)

Representing Weak Entity Sets

- A weak entity set becomes a table that includes a column for the primary key of the identifying strong entity set.

loan-number	*payment-number*	*payment-date*	*payment-amount*
L-11	53	7 June 2001	125
L-14	69	28 May 2001	500
L-15	22	23 May 2001	300
L-16	58	18 June 2001	135
L-17	5	10 May 2001	50
L-17	6	7 June 2001	50
L-17	7	17 June 2001	100
L-23	11	17 May 2001	75
L-93	103	3 June 2001	900
L-93	104	13 June 2001	200

Representing Relationship Sets as Tables

- A many-to-many relationship set is represented as a table with columns for the primary keys of the two participating entity sets, and any descriptive attributes of the relationship set.

- Example: the *borrower* relationship set:

customer-id	*loan-number*
019-28-3746	L-11
019-28-3746	L-23
244-66-8800	L-93
321-12-3123	L-17
335-57-7991	L-16
555-55-5555	L-14
677-89-9011	L-15
963-96-3963	L-17

Representing Relationship Sets as Tables, cont.

- A many-to-one relationship set can be represented just like a many-to-many relationship.
- Technically this is not necessary, and in some cases it does not result in a good design.
- Example:

  Entity Sets:

  account with attributes *account-number, balance*

  branch with attributes *branch-name, branch-city, assets*

  Relationship Set (total, many-to-one from account to branch):

Representing Relationship Sets as Tables, cont.

- The preceding could be converted to 3 tables directly, or as follows:

  account (<u>account-number</u>, balance, branch-name)

  branch (<u>branch-name</u>, branch-city, assets)

- Since the above relationship is total, a distinct table for the relationship set is probably not necessary.
  - by the way, eliminating an unnecessary table is frequently considered…cool…

- On the other hand, suppose:
  - the relationship is partial
  - lots of accounts
  - most accounts don't have branches

- Consider a query that looks up account #'s for a given branch-name.
  - In this case, 3 tables are probably better (why?).

Representing Relationship Sets as Tables, cont.

- For one-to-one relationship sets, the extra attribute can be added to either of the tables corresponding to the two entity sets.
- Other relationship attributes would be treated similarly.
- Note that either of the above could introduce null values if the relationship is not total.

Representing Specialization as Tables

- Note: This discussion assumes a 2-level inheritance hierarchy.
  - Exercise: Generalize it to an arbitrarily deep hierarchy.

- Method 1:
  - Form a table for the higher level entity set.
  - Form a table for each lower level entity set, including the primary key of the higher level entity set and local attributes.

table	attributes
person	*name, street, city*
customer	*name, credit-rating*
employee	*name, salary*

  - One Drawback: getting information about specific entities requires accessing two tables

Representing Specialization as Tables cont.

- Method 2:
  - Form a table for each entity set with all local and inherited attributes

table	table attributes
person	*name, street, city*
customer	*name, street, city, credit-rating*
employee	*name, street, city, salary*

- This method has obvious redundancies.
  - Particularly bad for persons who are both customers and employees.

- If specialization is total, the table for the generalized entity is redundant.
  - Temptation is to delete the *person* table; still might be needed for foreign key constraints.

Representing Specialization as Tables

- Method 3: (not presented in the book)
  - Form one table for the higher level entity set
  - This table has one column for every attribute in every subclass.

table	attributes
person	*name, street, city, credit-rating, salary*

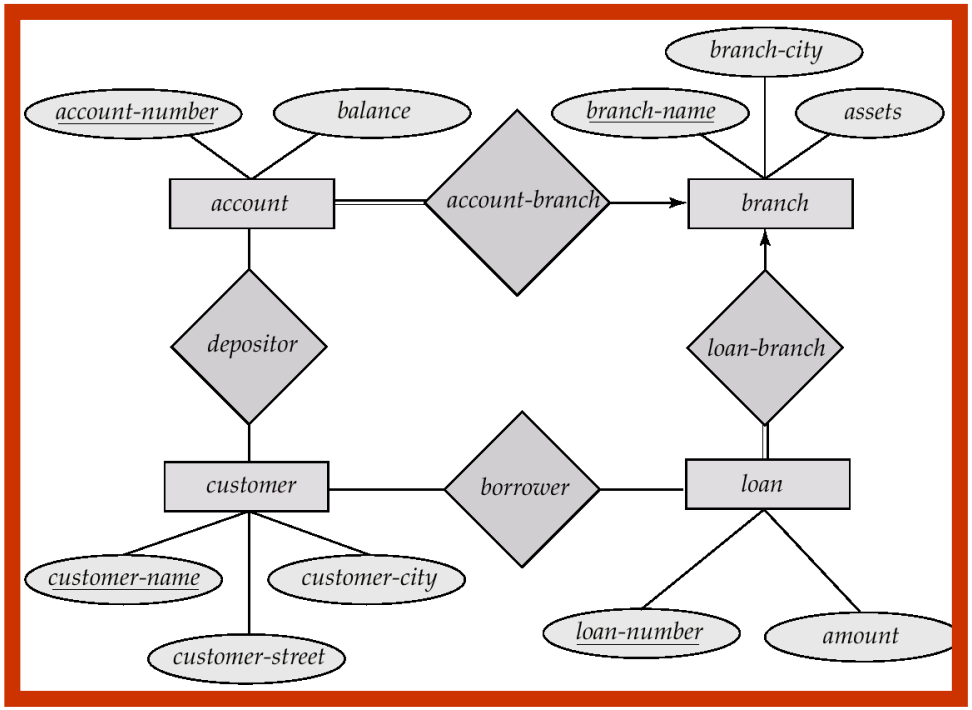
  - Optionally, include a *type* attribute that indicates which subclass the stored entity belongs to.

- Obvious drawback - contains multiple nullable attributes.

- Sometimes referred to as a “junk drawer”

E-R Diagram for the Banking Enterprise

- The (modified) E-R diagram from the banking enterprise:



Relational Schemes for the Banking Enterprise

- The following relational schemes result:

  branch (branch-name, branch-city, assets)

  customer (customer-name, customer-street, customer-city)

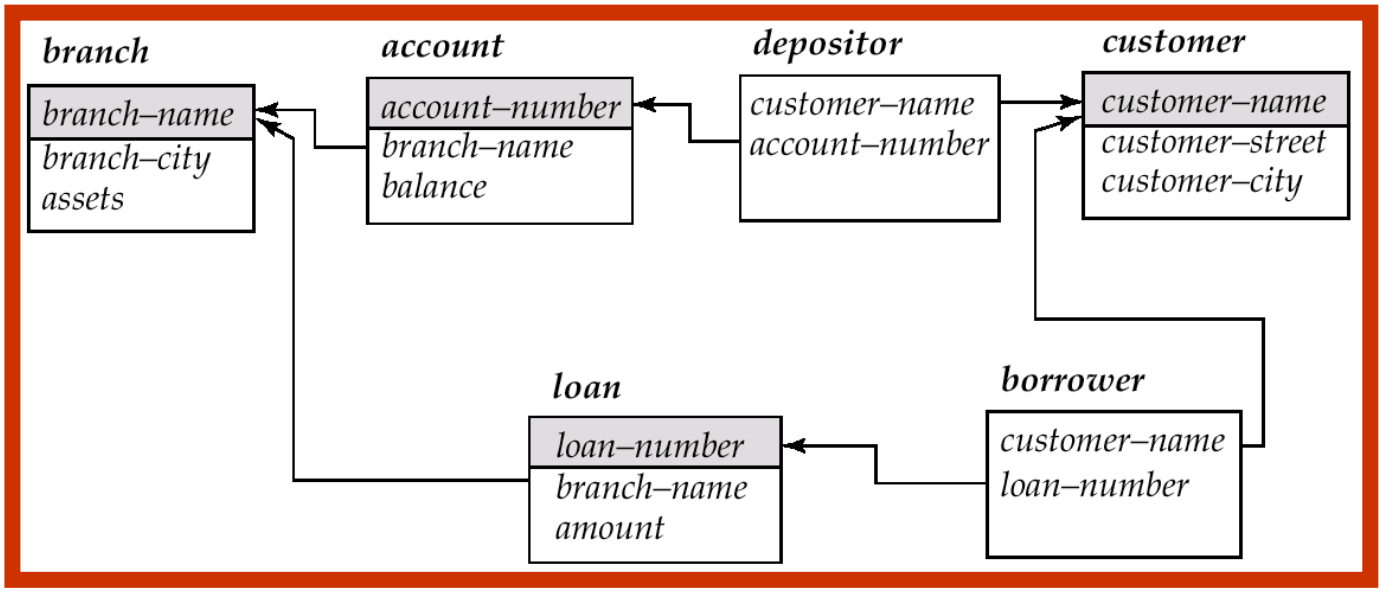
  account (account-number, branch-name, balance)

  loan (loan-number, branch-name, amount)

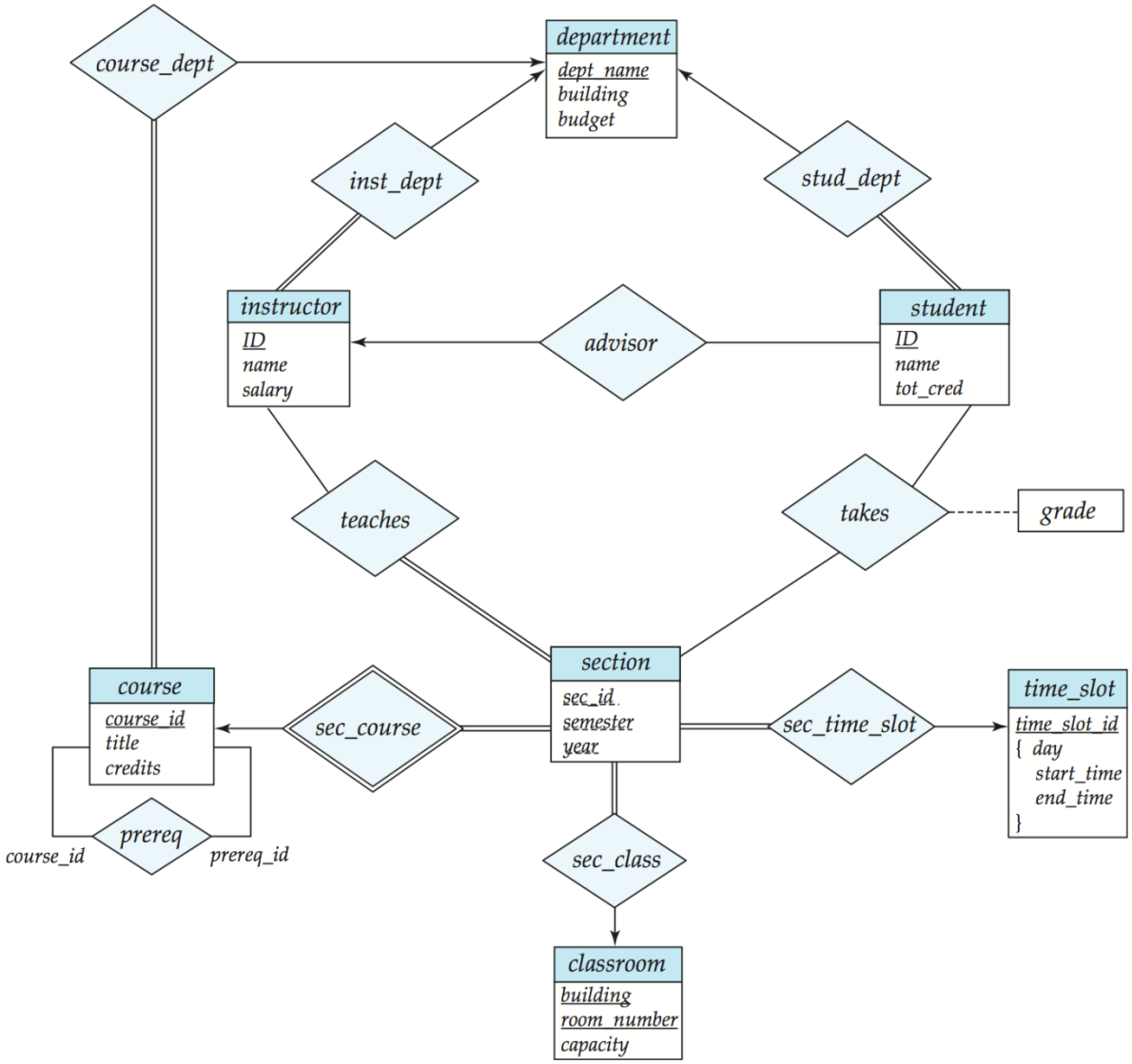
  depositor (customer-name, account-number)

  borrower (customer-name, loan-number)

Schema Diagram for the Banking Enterprise



E-R Diagram for a University



Relational Schemes for a University

Classroom (building, room-number, capacity)

Department (dept-name, building, budget)

Course (course-id, title, dept-name, credits)

Instructor (ID, name, depart-name, salary)

Section (course-id, sec-id, semester, year, building, room-number, time-slot-id)

Teaches (ID, course-id, sec-id, semester, year)

Student (ID, name, dept-name, tot-cred)

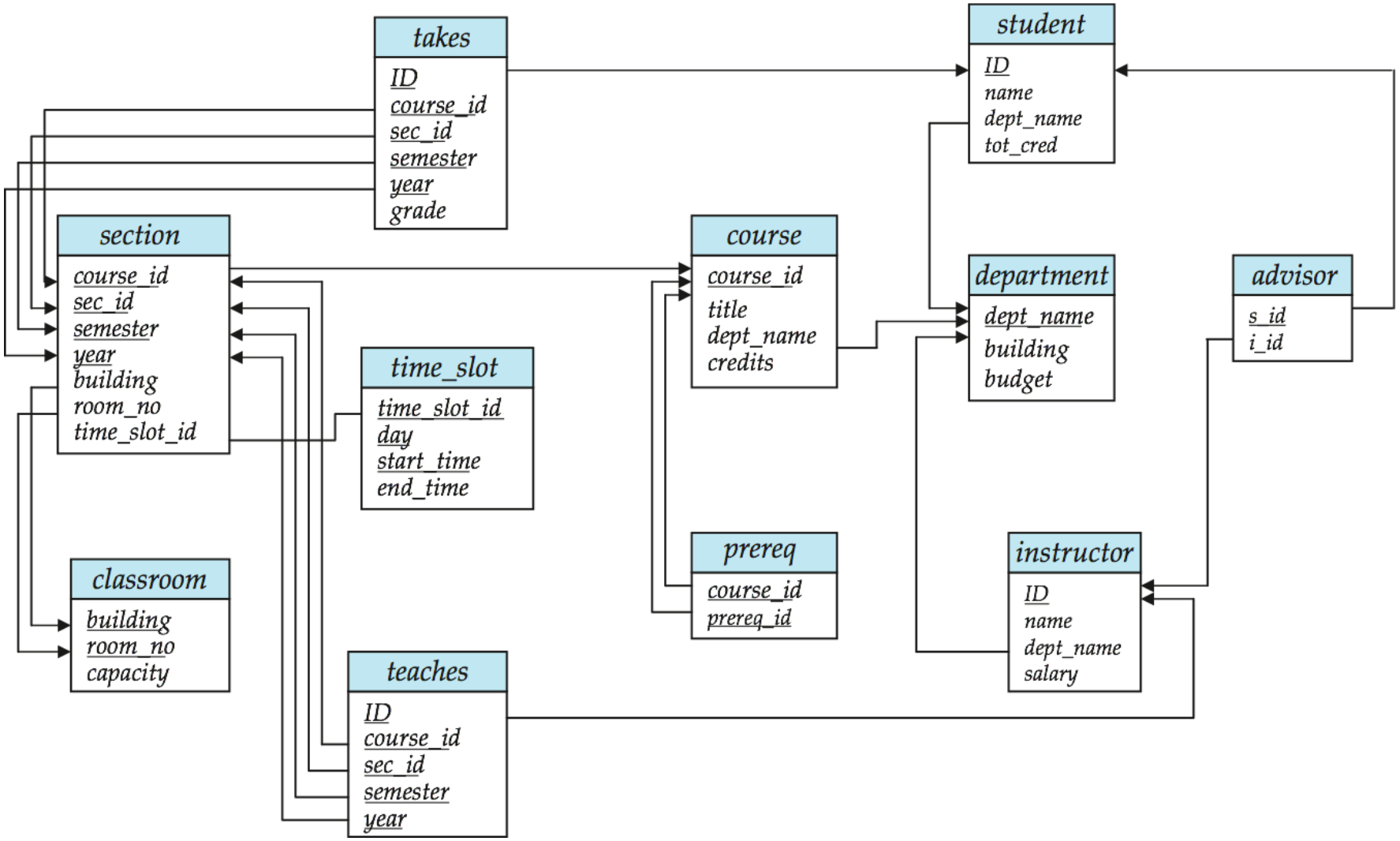
Takes (ID, course-id, sec-id, semester, year, grade)

Advisor (s-ID, i-ID)

Time-slot (time-slot-id, day, start-time, end-time)

Prereq (course-id, prereq-id)

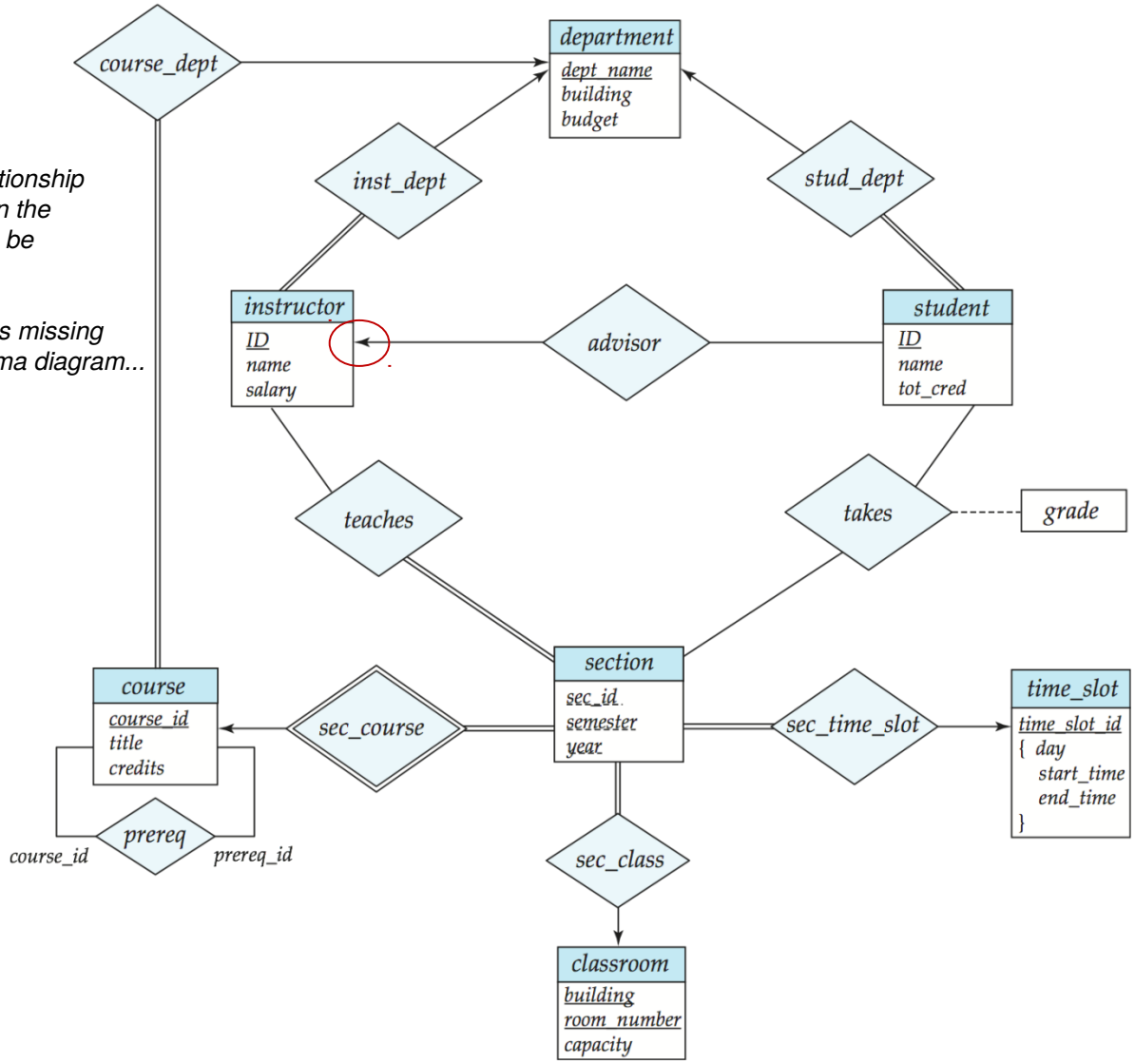
Schema Diagram for a University



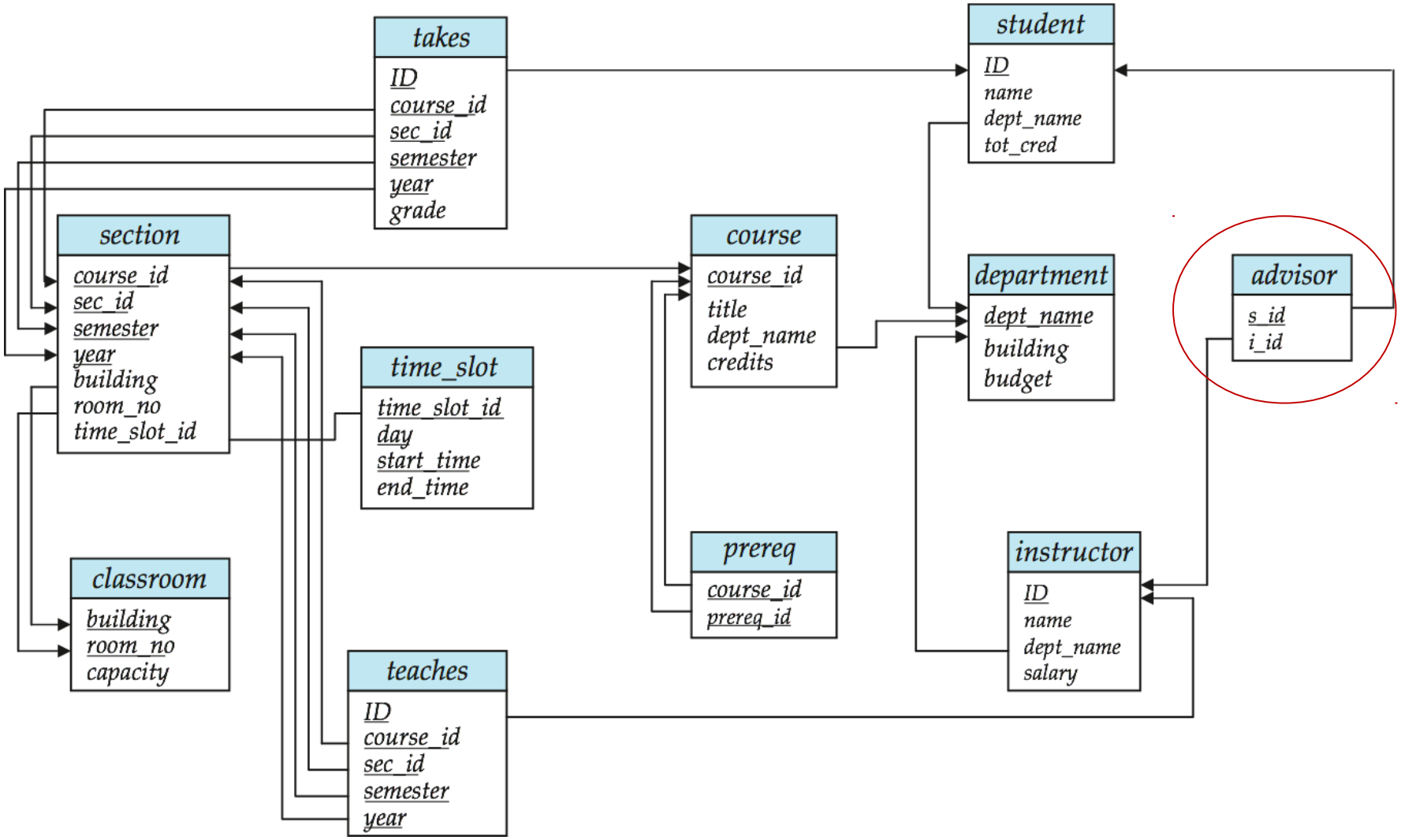
E-R Diagram for a University

Note the advisor relationship Is one-to-many, but in the schema it appears to be many-to-many.

Similarly, time—slot is missing an arrow in the schema diagram...



Schema Diagram for a University



End of Chapter 6