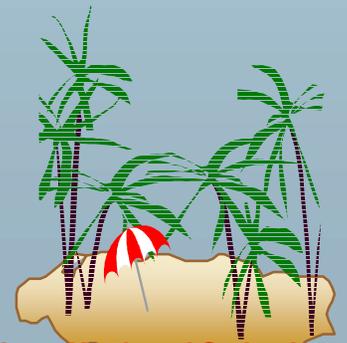




# Chapter 2: Entity-Relationship Model

- Entity Sets
- Relationship Sets
- Design Issues
- Mapping Constraints
- Keys
- E-R Diagram
- Extended E-R Features
- Design of an E-R Database Schema
- Reduction of an E-R Schema to Tables





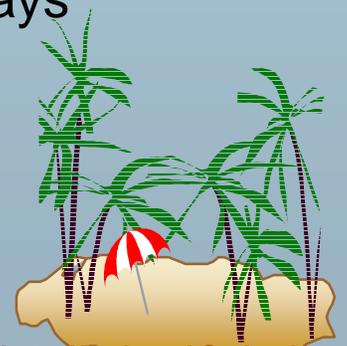
# Entity Sets

- A *database* can be modeled as:
  - a collection of entities,
  - relationship among entities.
- An *entity* is an object that exists and is distinguishable from other objects.

Example: specific person, company, event, plant

- Entities have *attributes*  
Example: people have *names* and *addresses*
- An *entity set* is a set of entities of the same type that share the same properties.

Example: set of all persons, companies, trees, holidays







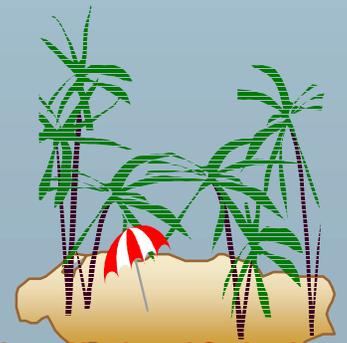
# Attributes

- An entity is represented by a set of attributes, that is descriptive properties possessed by all members of an entity set.

Example:

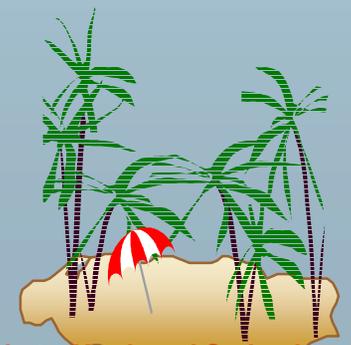
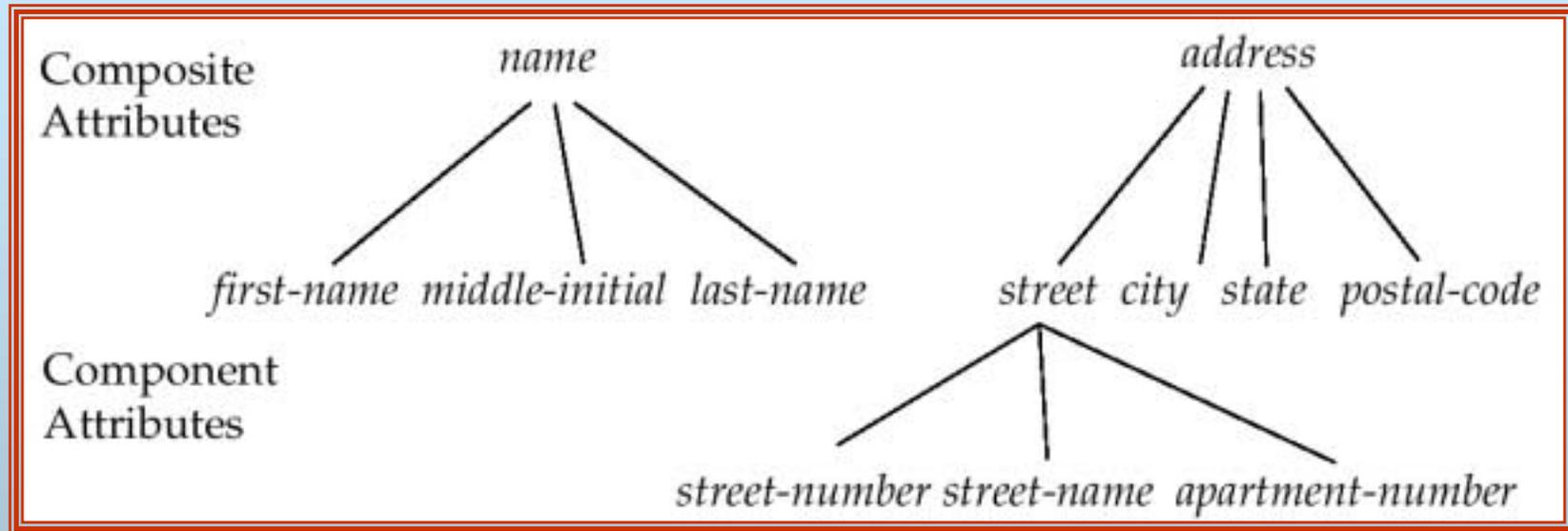
*customer = (customer-id, customer-name,  
customer-street, customer-city)*  
*loan = (loan-number, amount)*

- **Domain** – the set of permitted values for each attribute
- Attribute types:
  - *Simple and composite* attributes.
  - *Single-valued and multi-valued* attributes
    - E.g. multivalued attribute: *phone-numbers*
  - *Derived* attributes
    - Can be computed from other attributes
    - E.g. *age*, given date of birth





# Composite Attributes





# Relationship Sets

- A **relationship** is an association among several entities

Example:

Hayes                      depositor                      A-102  
*customer* entity      relationship set      *account* entity

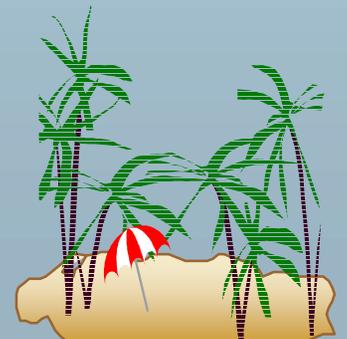
- A **relationship set** is a mathematical relation among  $n \geq 2$  entities, each taken from entity sets

$$\{(e_1, e_2, \dots, e_n) \mid e_1 \in E_1, e_2 \in E_2, \dots, e_n \in E_n\}$$

where  $(e_1, e_2, \dots, e_n)$  is a relationship

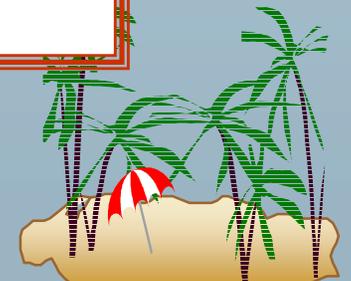
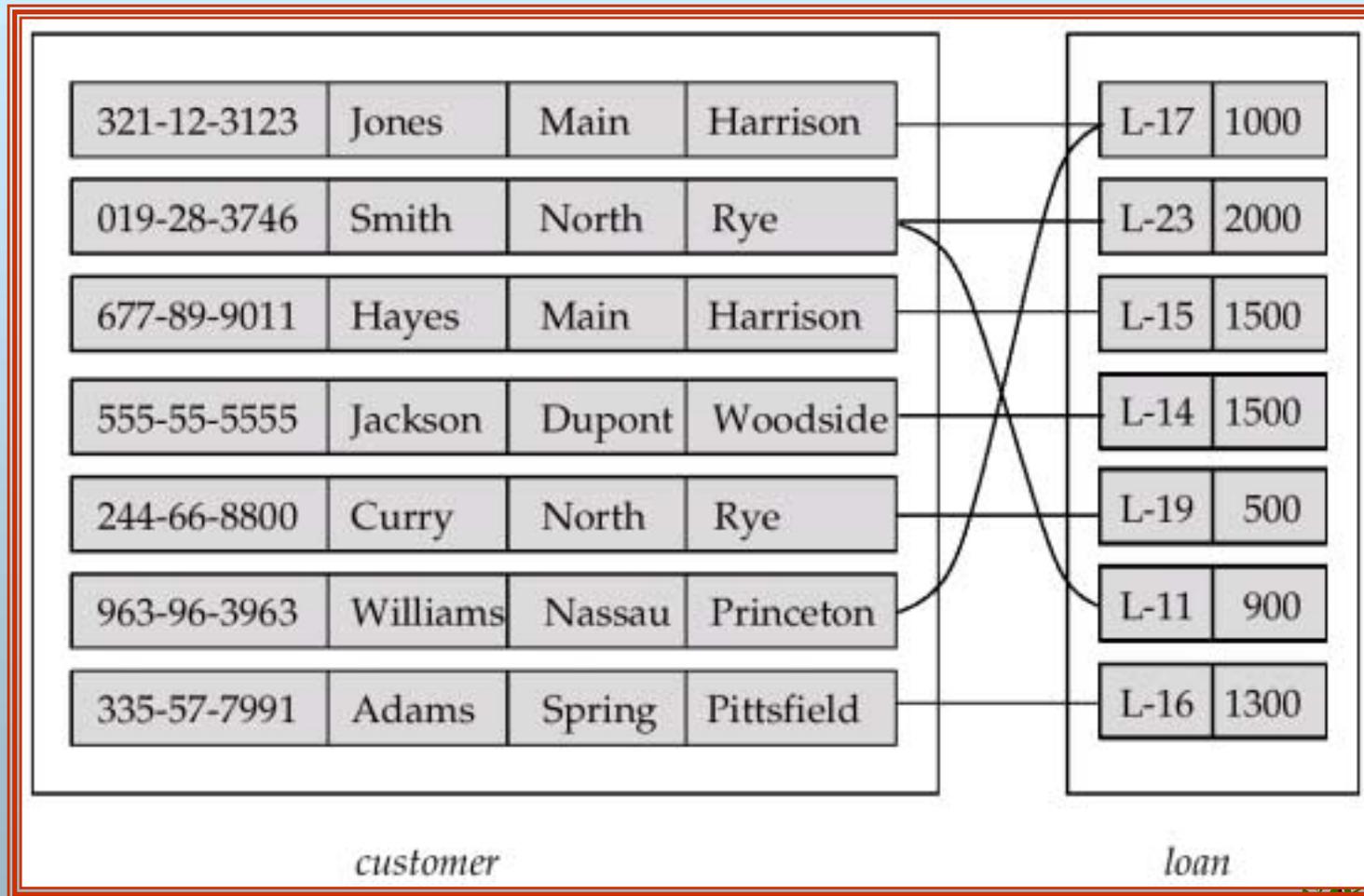
- Example:

$$(Hayes, A-102) \in depositor$$





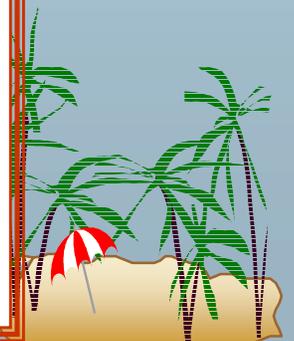
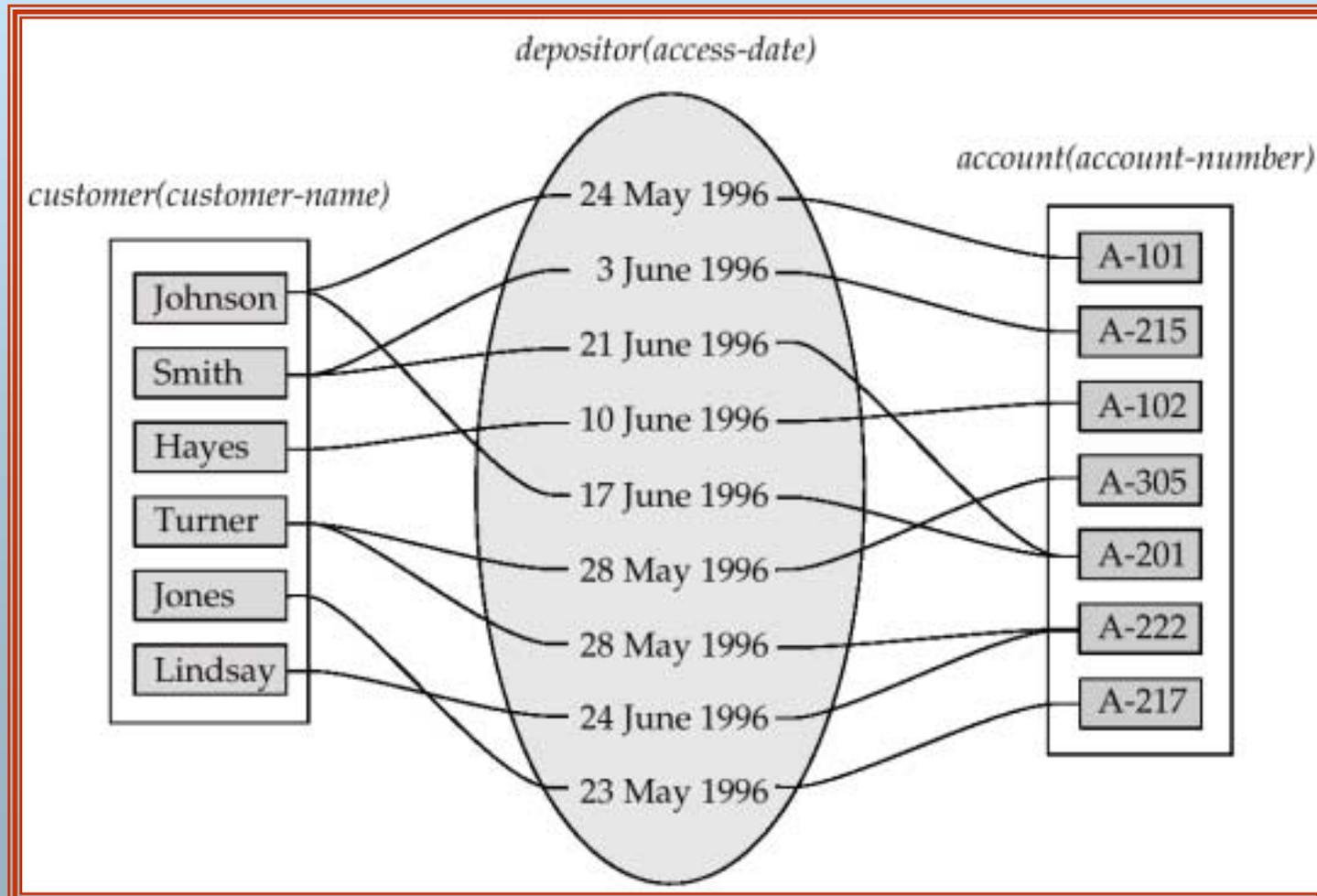
# Relationship Set *borrower*





## Relationship Sets (Cont.)

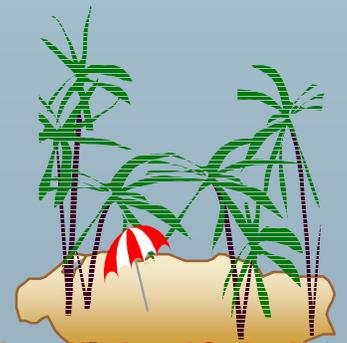
- An *attribute* can also be property of a relationship set.
- For instance, the *depositor* relationship set between entity sets *customer* and *account* may have the attribute *access-date*





# Degree of a Relationship Set

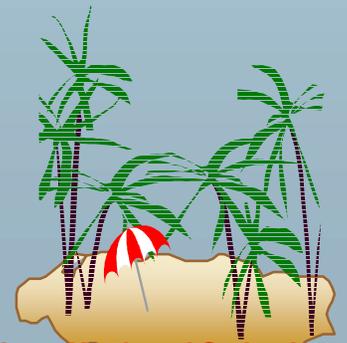
- Refers to number of entity sets that participate in a relationship set.
- Relationship sets that involve two entity sets are *binary* (or degree two). Generally, most relationship sets in a database system are binary.
- Relationship sets may involve more than two entity sets.
  - E.g. Suppose employees of a bank may have jobs (responsibilities) at multiple branches, with different jobs at different branches. Then there is a ternary relationship set between entity sets *employee*, *job* and *branch*
- Relationships between more than two entity sets are rare. Most relationships are binary. (More on this later.)





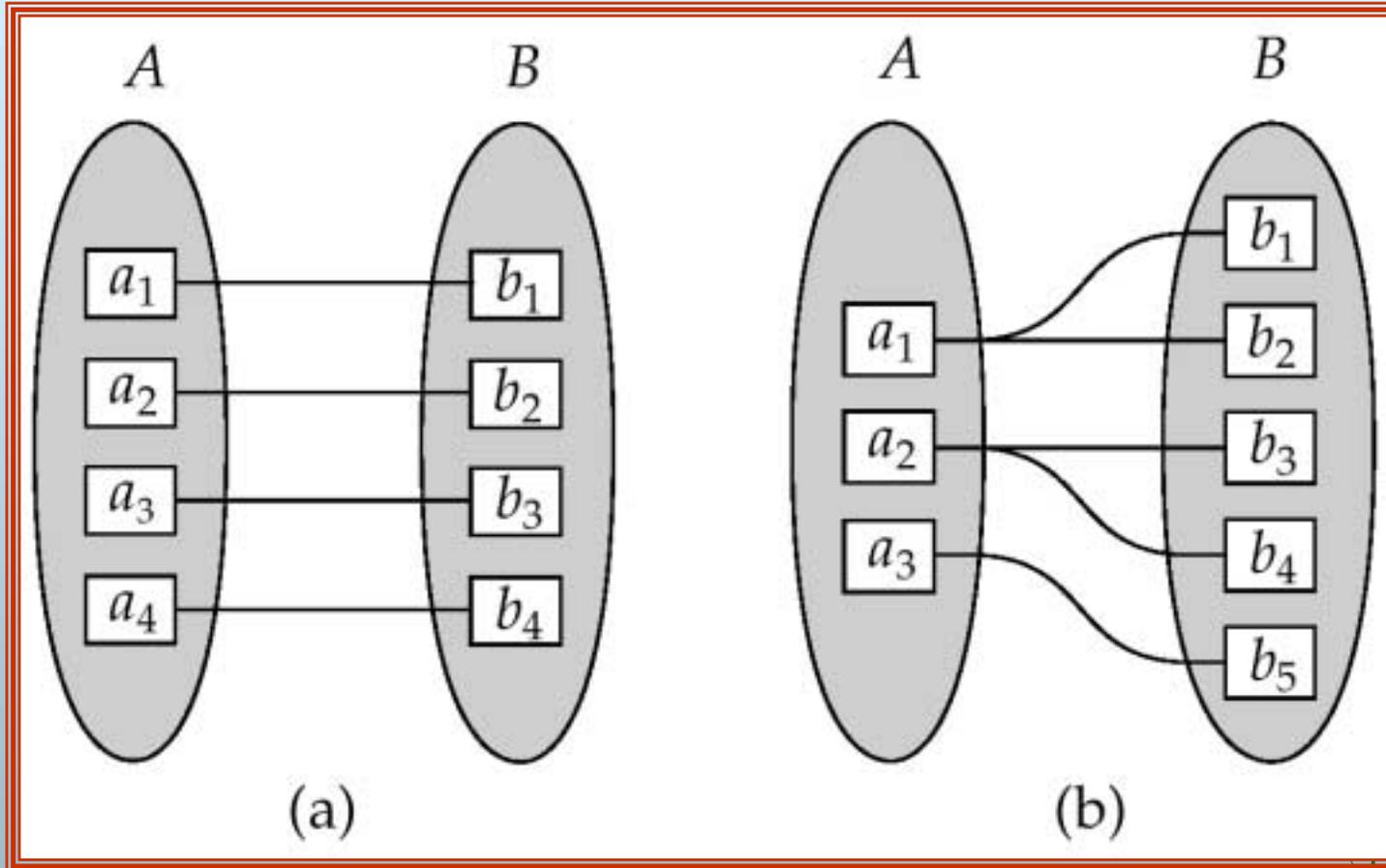
# Mapping Cardinalities

- Express the number of entities to which another entity can be associated via a relationship set.
- Most useful in describing binary relationship sets.
- For a binary relationship set the mapping cardinality must be one of the following types:
  - One to one
  - One to many
  - Many to one
  - Many to many





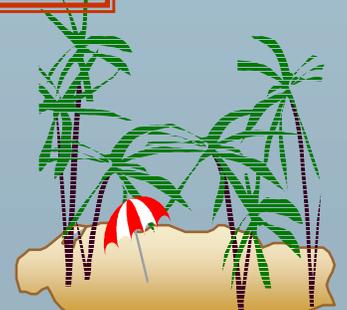
# Mapping Cardinalities



One to one

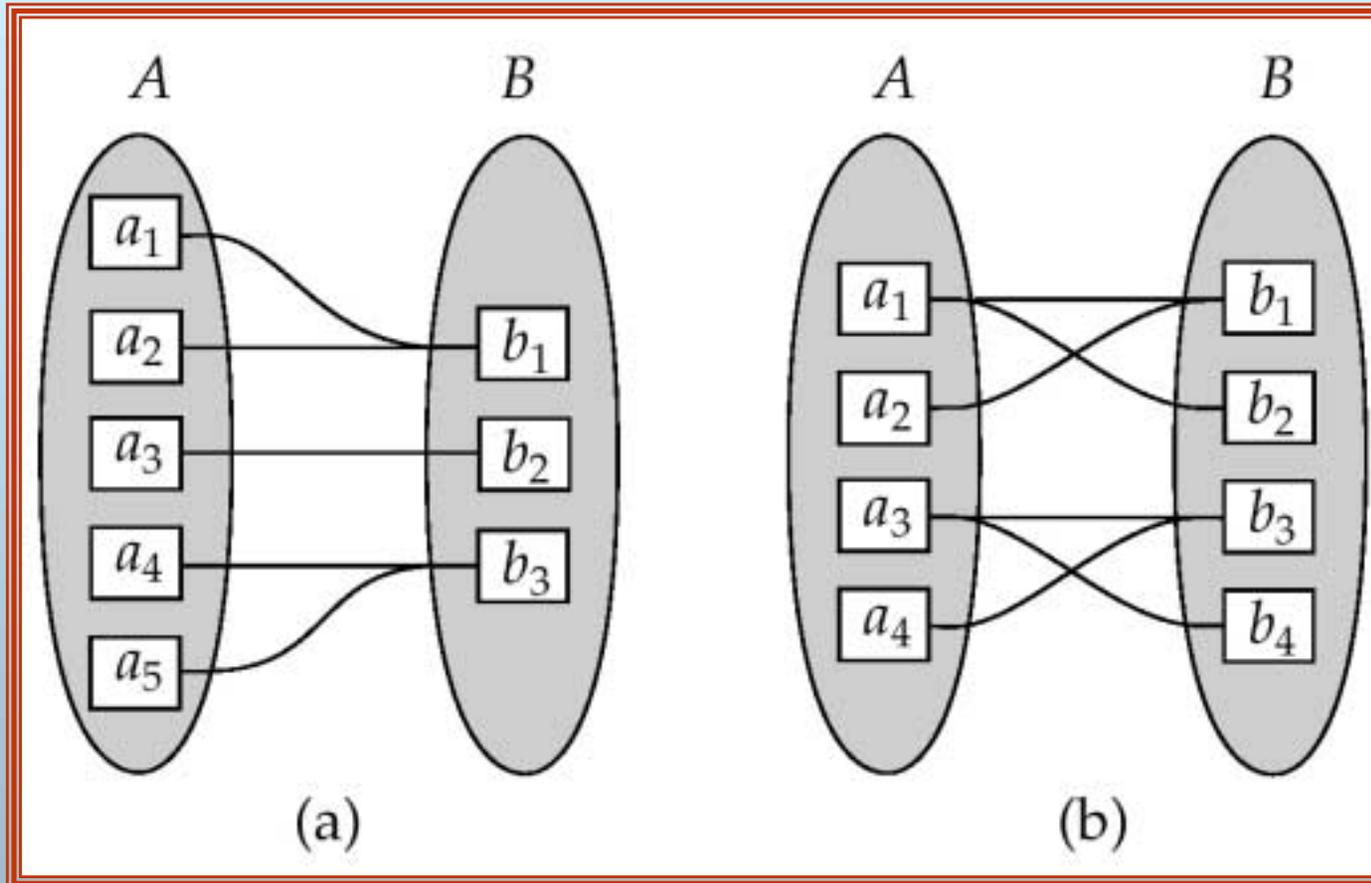
One to many

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





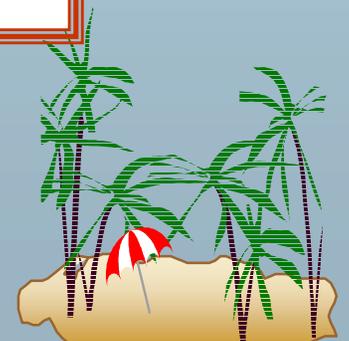
# Mapping Cardinalities



Many to one

Many to many

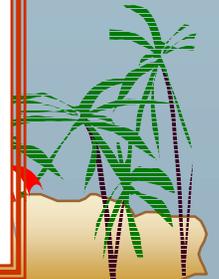
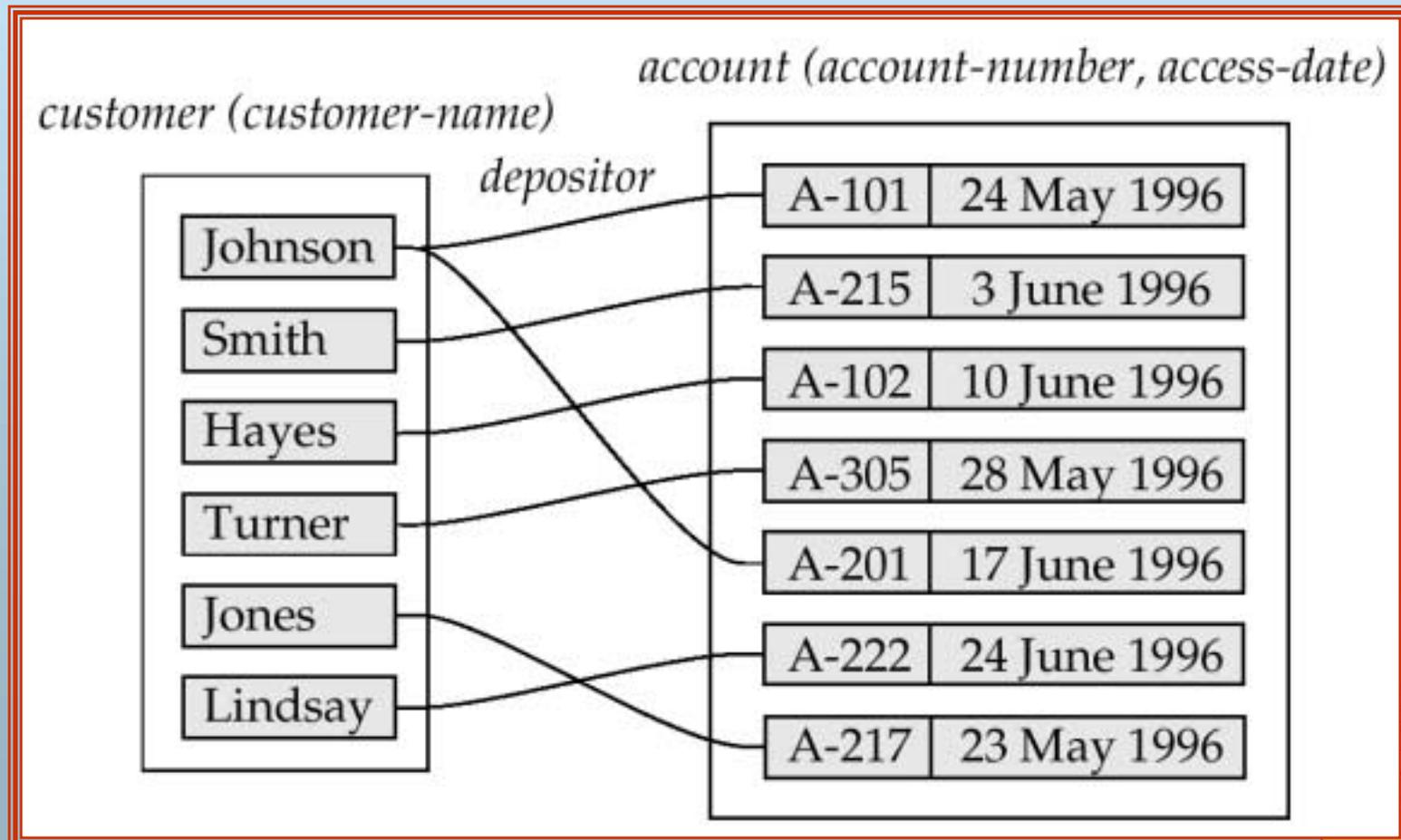
Note: Some elements in A and B may not be mapped to any elements in the other set





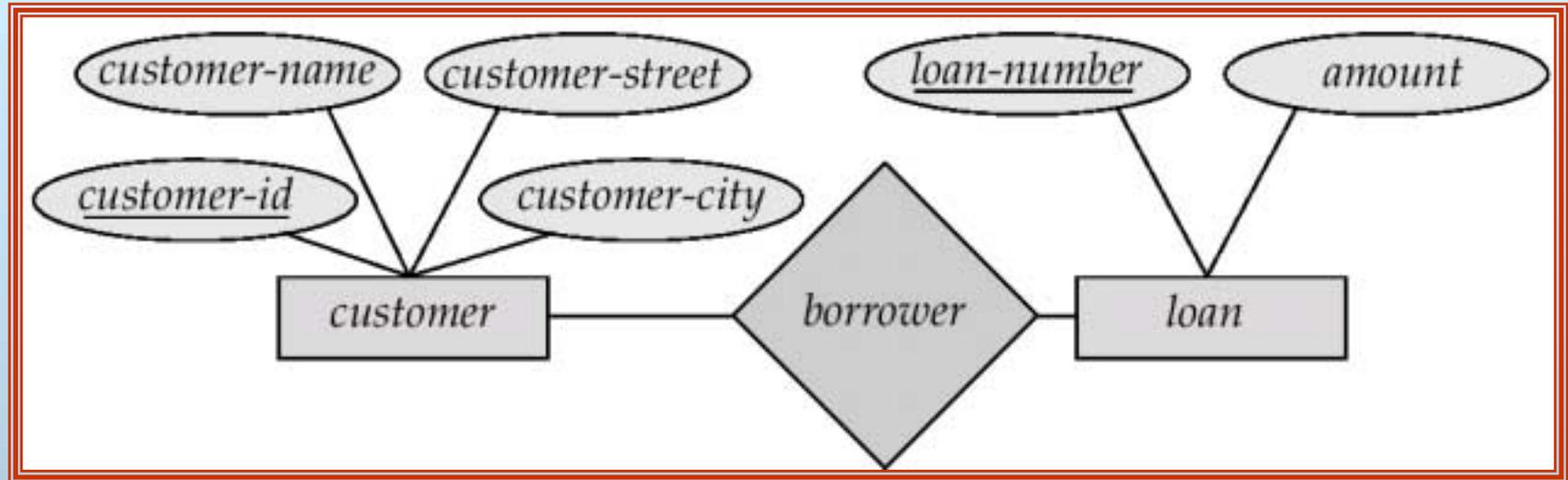
## Mapping Cardinalities affect ER Design

- Can make *access-date* an attribute of account, instead of a relationship attribute, if each account can have only one customer
  - I.e., the relationship from account to customer is many to one, or equivalently, customer to account is one to many

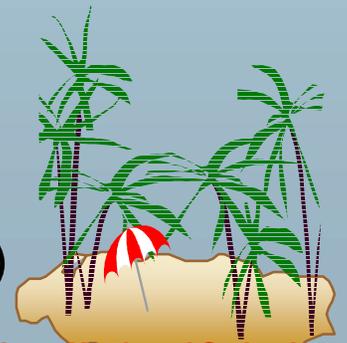




# E-R Diagrams

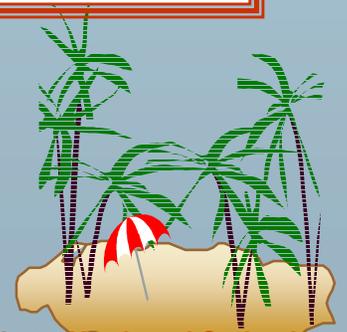
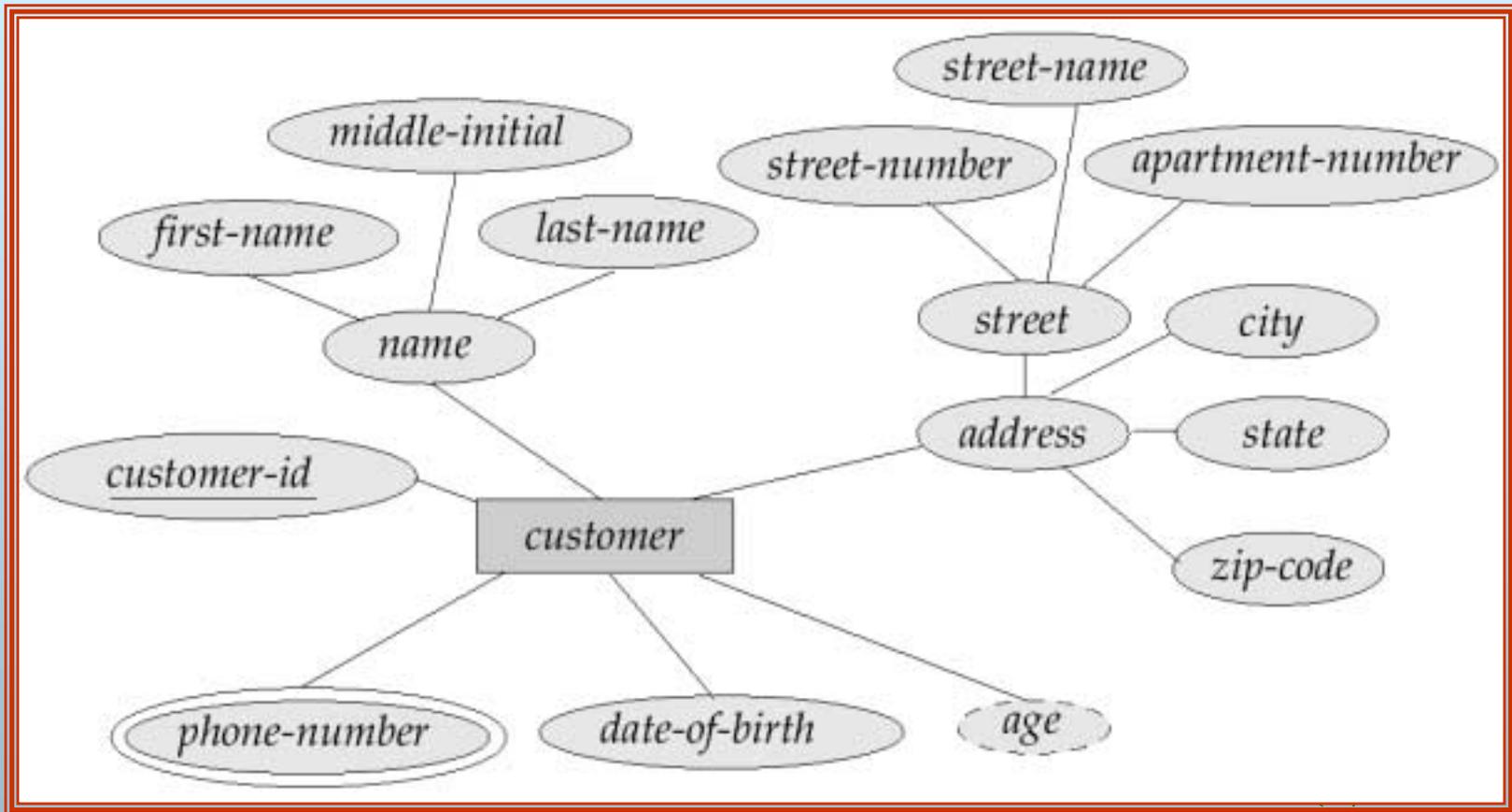


- **Rectangles** represent entity sets.
- **Diamonds** represent relationship sets.
- **Lines** link attributes to entity sets and entity sets to relationship sets.
- **Ellipses** represent attributes
  - **Double ellipses** represent multivalued attributes.
  - **Dashed ellipses** denote derived attributes.
- **Underline** indicates primary key attributes (will study later)



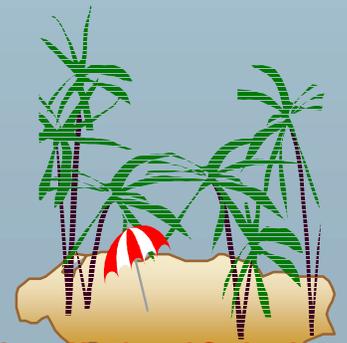
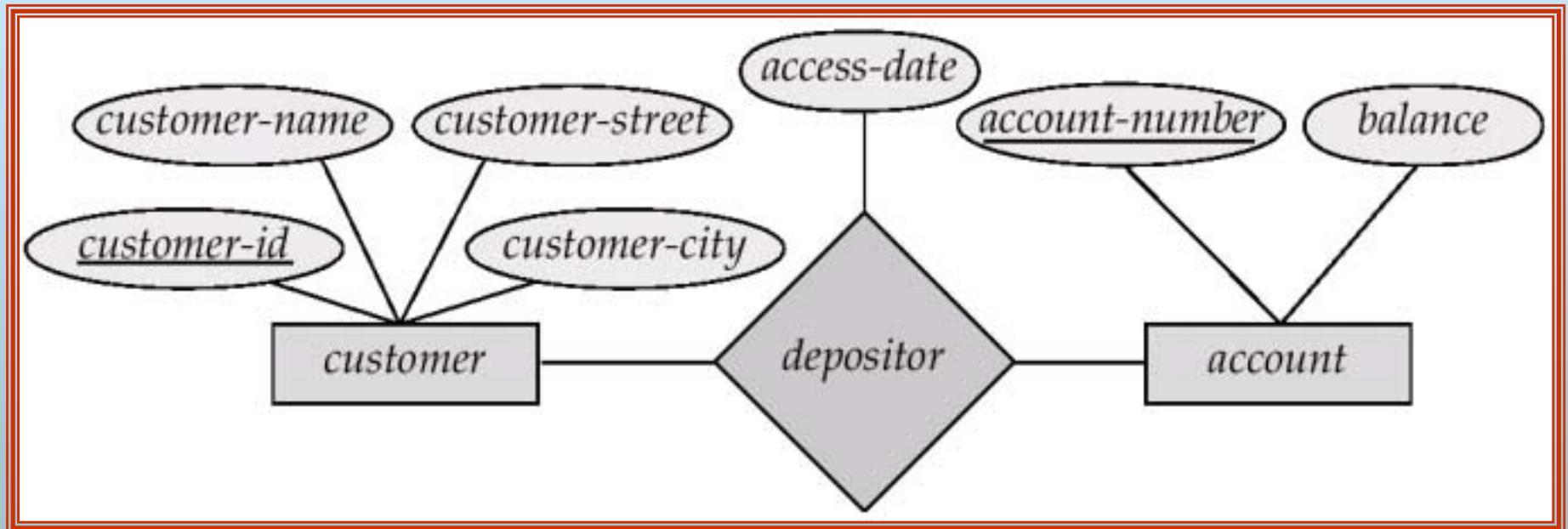


# E-R Diagram With Composite, Multivalued, and Derived Attributes





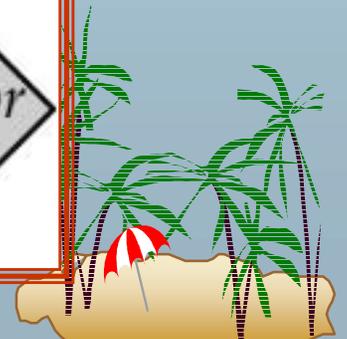
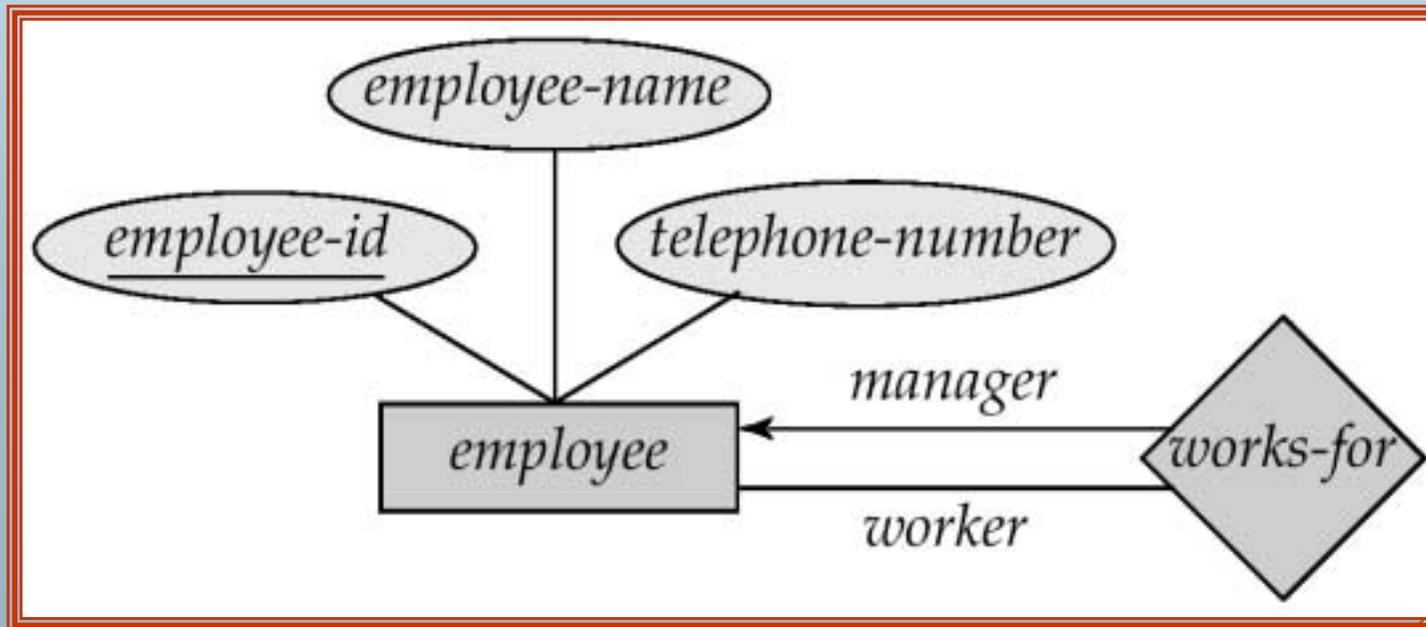
# Relationship Sets with Attributes





# Roles

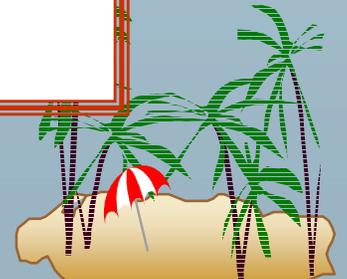
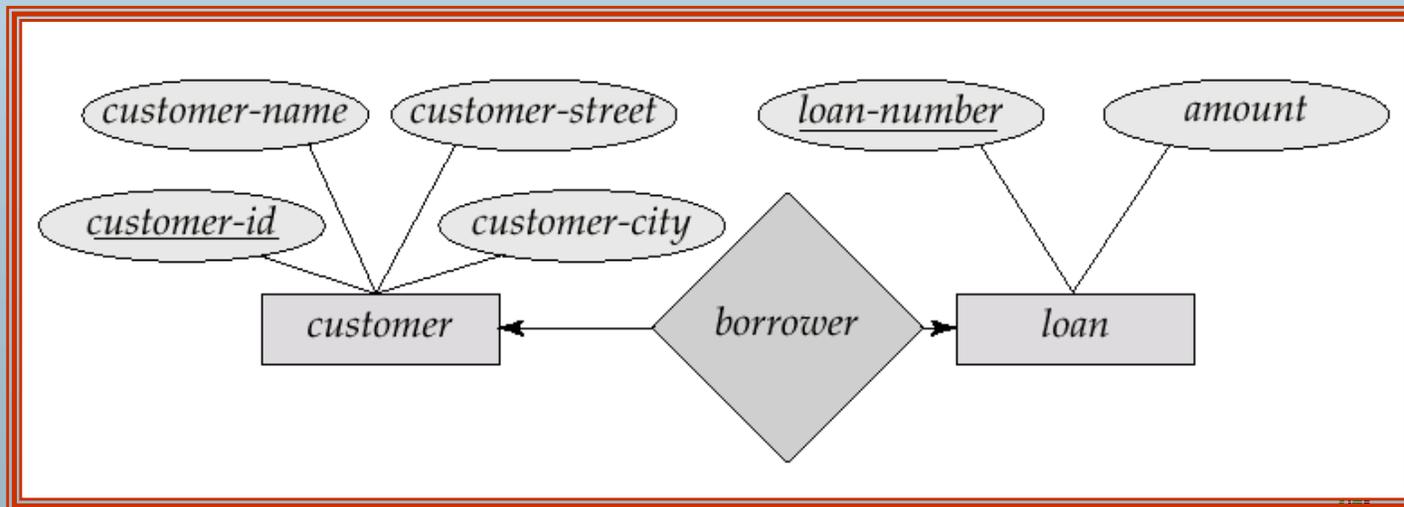
- Entity sets of a relationship need not be distinct
- The labels “manager” and “worker” are called **roles**; they specify how employee entities interact via the works-for relationship set.
- Roles are indicated in E-R diagrams by labeling the lines that connect diamonds to rectangles.
- Role labels are optional, and are used to clarify semantics of the relationship





# Cardinality Constraints

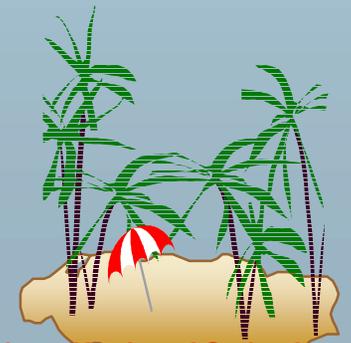
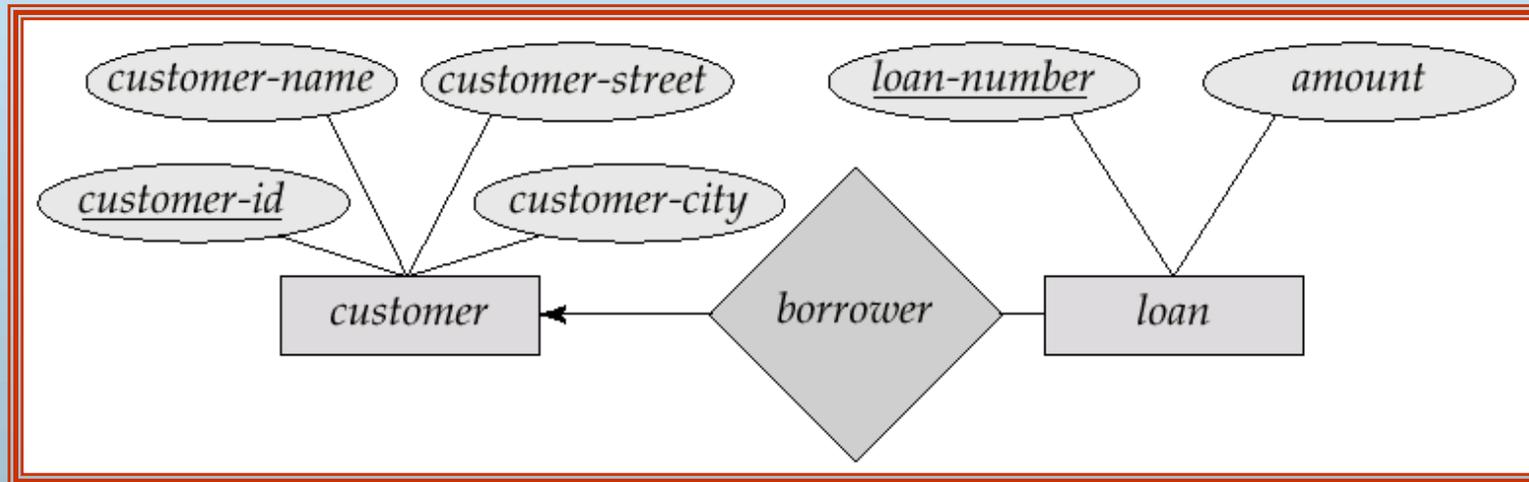
- We express cardinality constraints by drawing either a directed line ( $\rightarrow$ ), signifying “one,” or an undirected line ( $\text{—}$ ), signifying “many,” between the relationship set and the entity set.
- E.g.: One-to-one relationship:
  - A customer is associated with at most one loan via the relationship *borrower*
  - A loan is associated with at most one customer via *borrower*





# One-To-Many Relationship

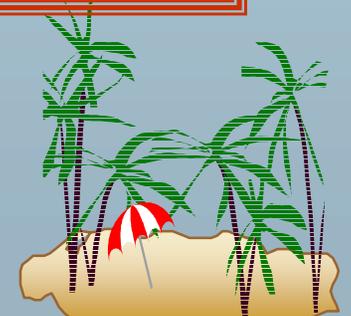
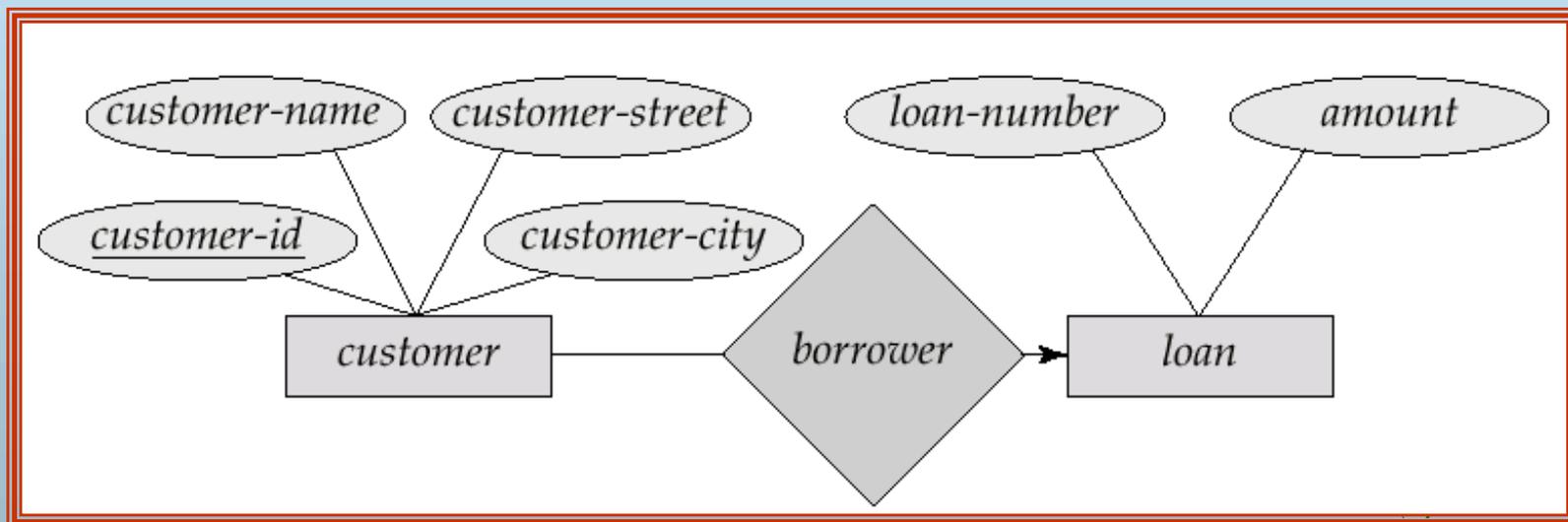
- In the one-to-many relationship a loan is associated with at most one customer via *borrower*, a customer is associated with several (including 0) loans via *borrower*





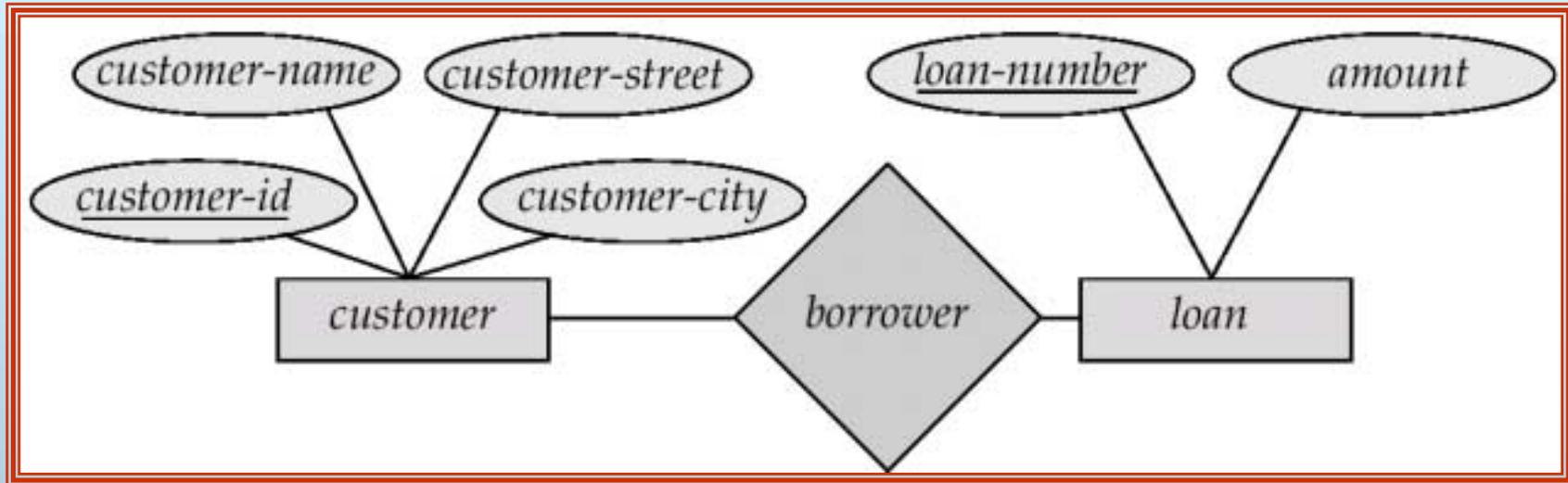
# Many-To-One Relationships

- In a many-to-one relationship a loan is associated with several (including 0) customers via *borrower*, a customer is associated with at most one loan via *borrower*

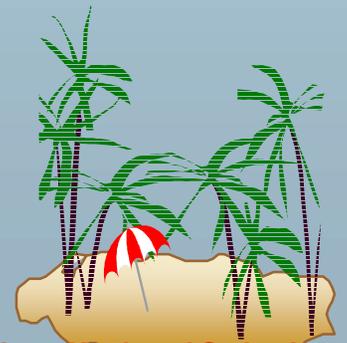




# Many-To-Many Relationship



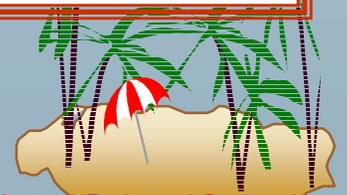
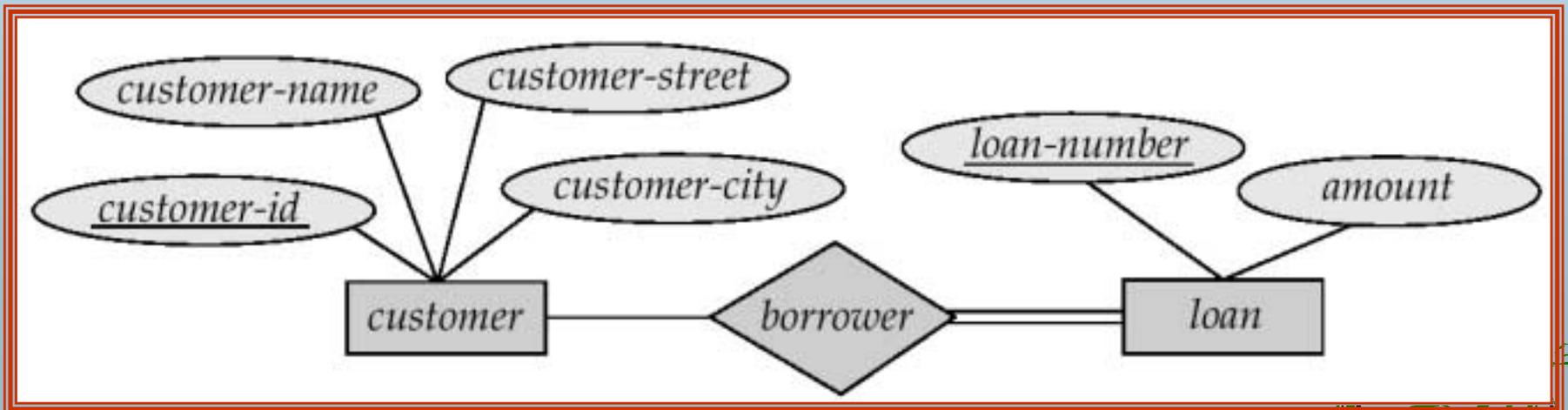
- A customer is associated with several (possibly 0) loans via borrower
- A loan is associated with several (possibly 0) customers via borrower





# Participation of an Entity Set in a Relationship Set

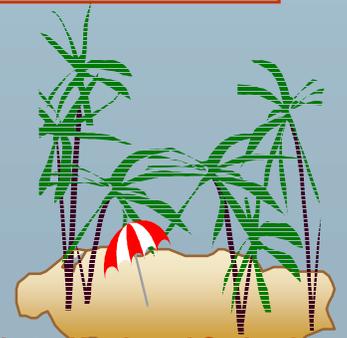
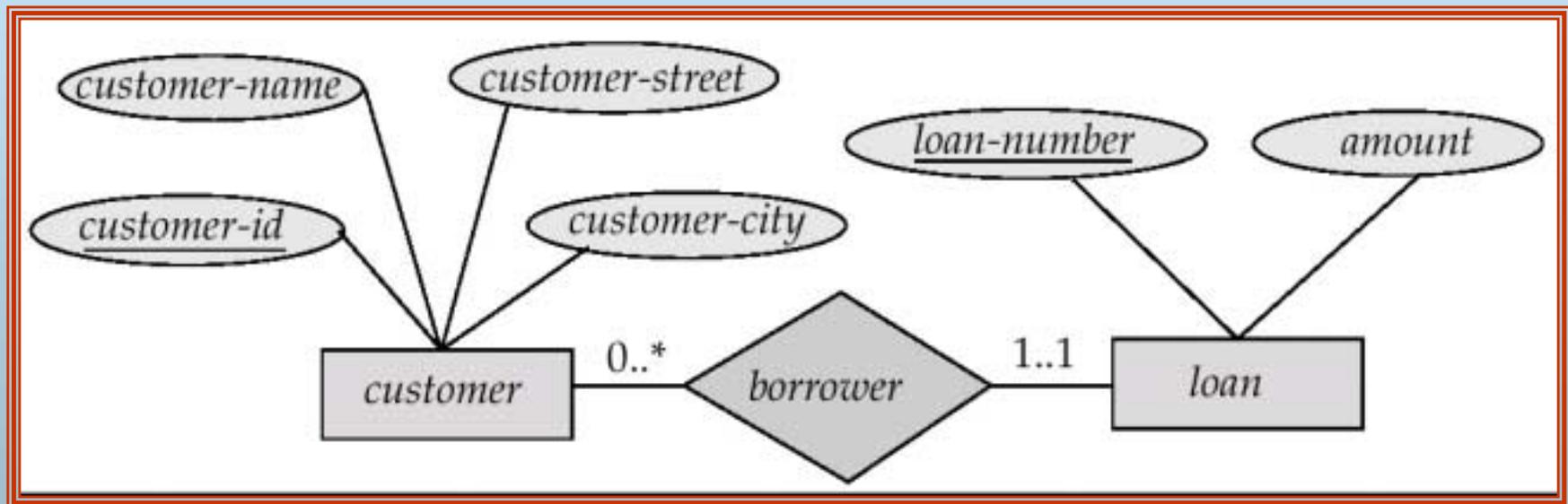
- **Total participation** (indicated by double line): every entity in the entity set participates in at least one relationship in the relationship set
  - E.g. participation of *loan* in *borrower* is total
    - every loan must have a customer associated to it via borrower
- **Partial participation**: some entities may not participate in any relationship in the relationship set
  - E.g. participation of *customer* in *borrower* is partial





# Alternative Notation for Cardinality Limits

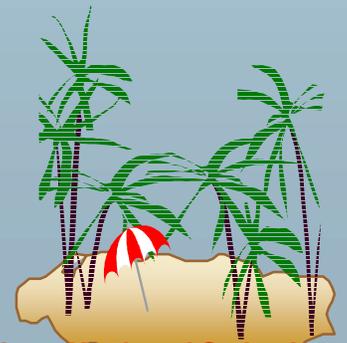
- Cardinality limits can also express participation constraints





# Keys

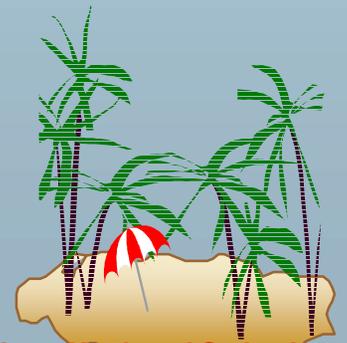
- A *super key* of an entity set is a set of one or more attributes whose values uniquely determine each entity.
- A *candidate key* of an entity set is a minimal super key
  - *Customer-id* is candidate key of *customer*
  - *account-number* is candidate key of *account*
- Although several candidate keys may exist, one of the candidate keys is selected to be the *primary key*.





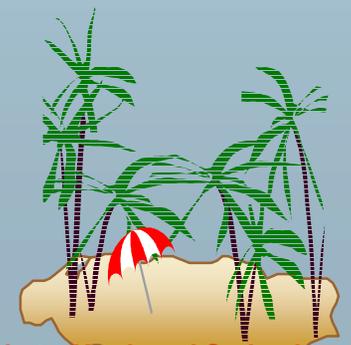
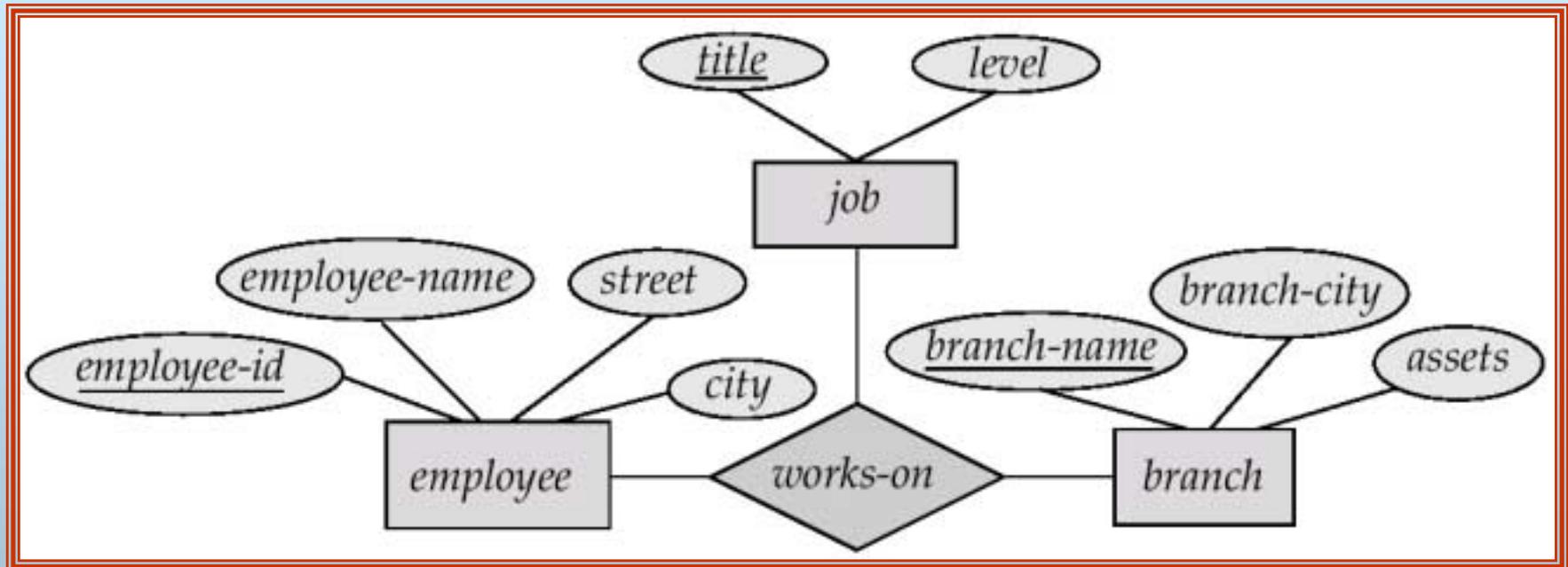
# Keys for Relationship Sets

- 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*
  - *NOTE: this means a pair of entity sets can have at most one relationship in a particular relationship set.*
    - E.g. if we wish to track all access-dates to each account by each customer, we cannot assume a relationship for each access. We can use a multivalued attribute though
- Must consider the mapping cardinality of the relationship set when deciding the what are the candidate keys
- Need to consider semantics of relationship set in selecting the *primary key* in case of more than one candidate key





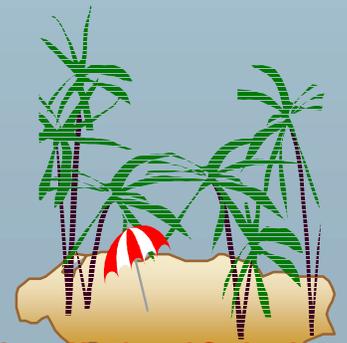
# E-R Diagram with a Ternary Relationship





# Cardinality Constraints on Ternary Relationship

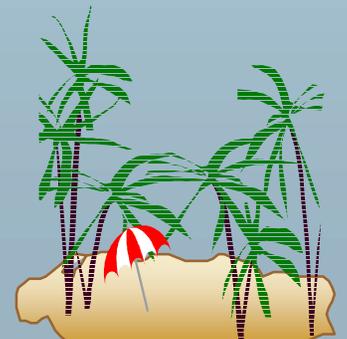
- We allow at most one arrow out of a ternary (or greater degree) relationship to indicate a cardinality constraint
- E.g. an arrow from *works-on* to *job* indicates each employee works on at most one job at any branch.
- If there is more than one arrow, there are two ways of defining the meaning.
  - E.g a ternary relationship  $R$  between  $A$ ,  $B$  and  $C$  with arrows to  $B$  and  $C$  could mean
    - 1. each  $A$  entity is associated with a unique entity from  $B$  and  $C$  or
    - 2. each pair of entities from  $(A, B)$  is associated with a unique  $C$  entity, and each pair  $(A, C)$  is associated with a unique  $B$
  - Each alternative has been used in different formalisms
  - To avoid confusion we outlaw more than one arrow





# Binary Vs. Non-Binary Relationships

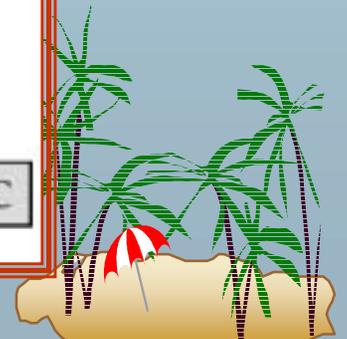
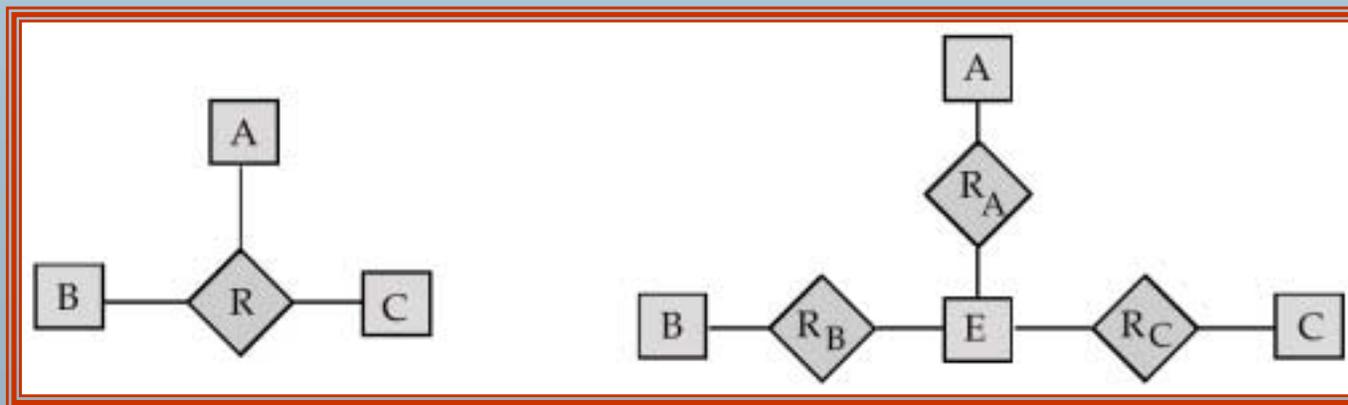
- Some relationships that appear to be non-binary may be better represented using binary relationships
  - E.g. A ternary relationship *parents*, relating a child to his/her father and mother, is best replaced by two binary relationships, *father* and *mother*
    - ➔ Using two binary relationships allows partial information (e.g. only mother being know)
  - But there are some relationships that are naturally non-binary
    - ➔ E.g. *works-on*





# Converting Non-Binary Relationships to Binary Form

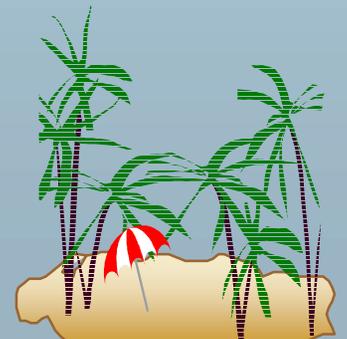
- In general, any non-binary relationship can be represented using binary relationships by creating an artificial entity set.
  - Replace  $R$  between entity sets  $A$ ,  $B$  and  $C$  by an entity set  $E$ , and three relationship sets:
    1.  $R_A$ , relating  $E$  and  $A$
    2.  $R_B$ , relating  $E$  and  $B$
    3.  $R_C$ , relating  $E$  and  $C$
  - Create a special identifying attribute for  $E$
  - Add any attributes of  $R$  to  $E$
  - For each relationship  $(a_i, b_i, c_i)$  in  $R$ , create
    1. a new entity  $e_i$  in the entity set  $E$
    2. add  $(e_i, a_i)$  to  $R_A$
    3. add  $(e_i, b_i)$  to  $R_B$
    4. add  $(e_i, c_i)$  to  $R_C$





# Converting Non-Binary Relationships (Cont.)

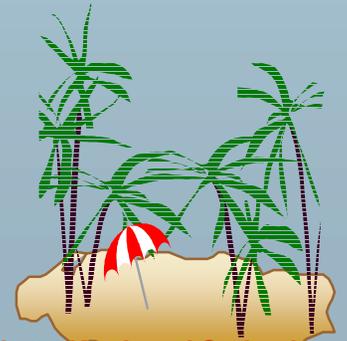
- Also need to translate constraints
  - Translating all constraints may not be possible
  - There may be instances in the translated schema that cannot correspond to any instance of  $R$ 
    - ➔ *Exercise: add constraints to the relationships  $R_A$ ,  $R_B$  and  $R_C$  to ensure that a newly created entity corresponds to exactly one entity in each of entity sets  $A$ ,  $B$  and  $C$*
  - We can avoid creating an identifying attribute by making  $E$  a weak entity set (described shortly) identified by the three relationship sets



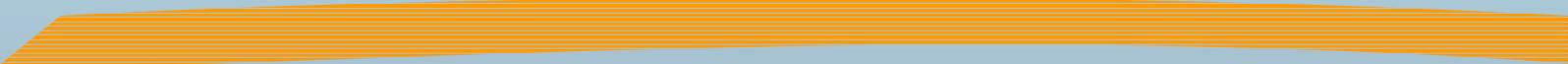


# Design Issues

- Use of entity sets vs. attributes  
Choice mainly depends on the structure of the enterprise being modeled, and on the semantics associated with the attribute in question.
- Use of entity sets vs. relationship sets  
Possible guideline is to designate a relationship set to describe an action that occurs between entities
- Binary versus  $n$ -ary relationship sets  
Although it is possible to replace any nonbinary ( $n$ -ary, for  $n > 2$ ) relationship set by a number of distinct binary relationship sets, a  $n$ -ary relationship set shows more clearly that several entities participate in a single relationship.
- Placement of relationship attributes



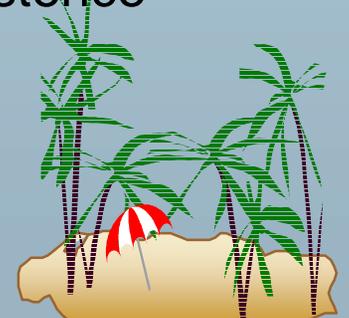
**How about doing an ER design  
interactively on the board?  
Suggest an application to be modeled.**





# Weak Entity Sets

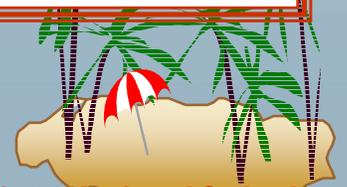
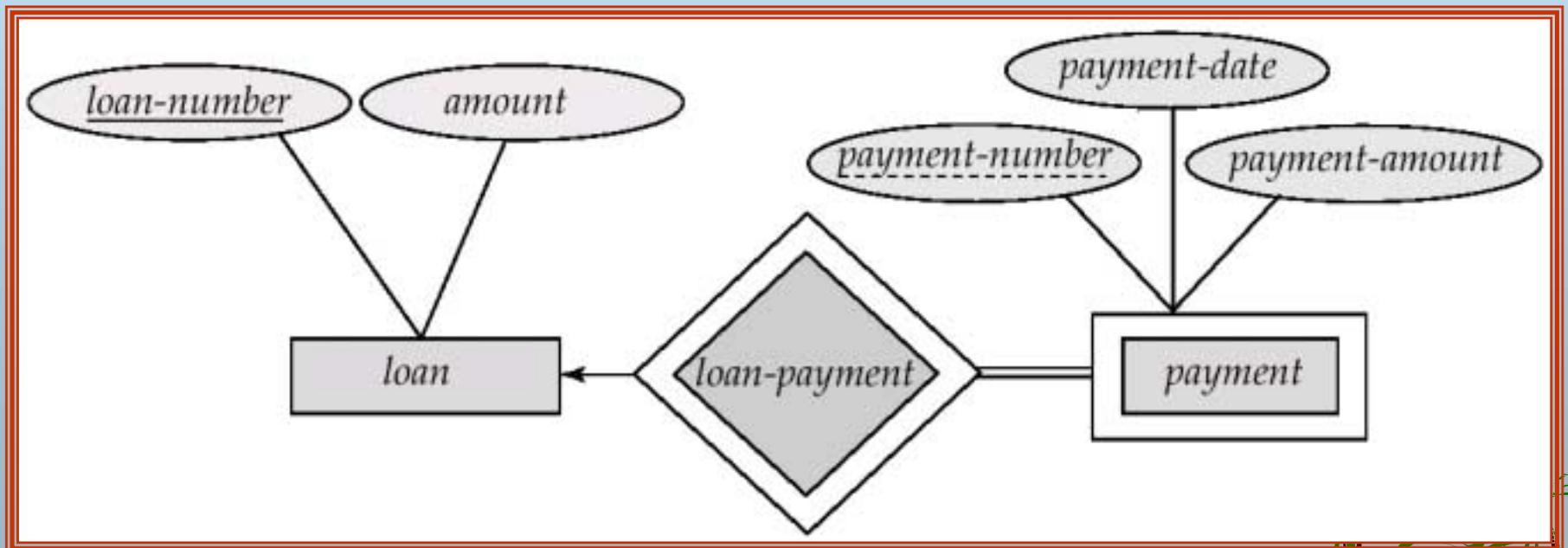
- An entity set that does not have a primary key is referred to as a *weak entity set*.
- The existence of a weak entity set depends on the existence of a *identifying entity set*
  - it must relate to the identifying entity set via a total, one-to-many relationship set from the identifying to the weak entity set
  - **Identifying relationship** depicted using a double diamond
- The *discriminator* (or *partial key*) of a weak entity set is the set of attributes that distinguishes among all the entities of a weak entity set.
- The primary key of a weak entity set is formed by the primary key of the strong entity set on which the weak entity set is existence dependent, plus the weak entity set's discriminator.





## Weak Entity Sets (Cont.)

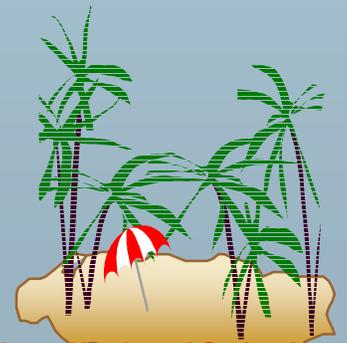
- We depict a weak entity set by double rectangles.
- We underline the discriminator of a weak entity set with a dashed line.
- *payment-number* – discriminator of the *payment* entity set
- Primary key for *payment* – (*loan-number*, *payment-number*)





## Weak Entity Sets (Cont.)

- Note: the primary key of the strong entity set is not explicitly stored with the weak entity set, since it is implicit in the identifying relationship.
- If *loan-number* were explicitly stored, *payment* could be made a strong entity, but then the relationship between *payment* and *loan* would be duplicated by an implicit relationship defined by the attribute *loan-number* common to *payment* and *loan*

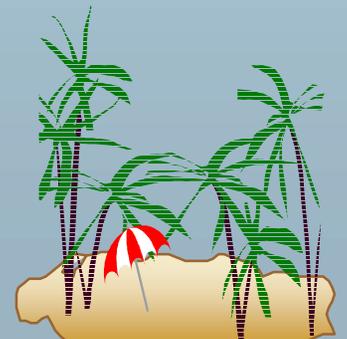




# More Weak Entity Set Examples

- In a university, a *course* is a strong entity and a *course-offering* can be modeled as a weak entity
- The discriminator of *course-offering* would be *semester* (including year) and *section-number* (if there is more than one section)
- If we model *course-offering* as a strong entity we would model *course-number* as an attribute.

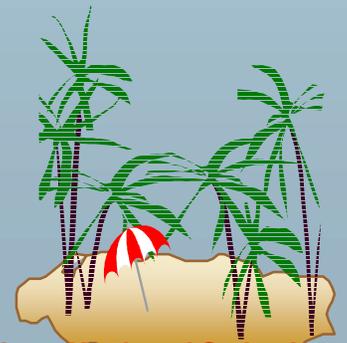
Then the relationship with *course* would be implicit in the *course-number* attribute





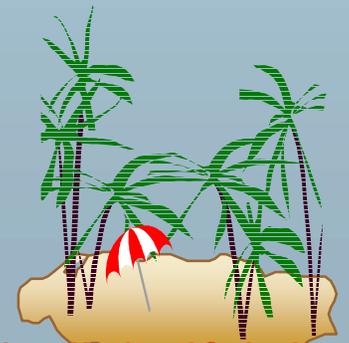
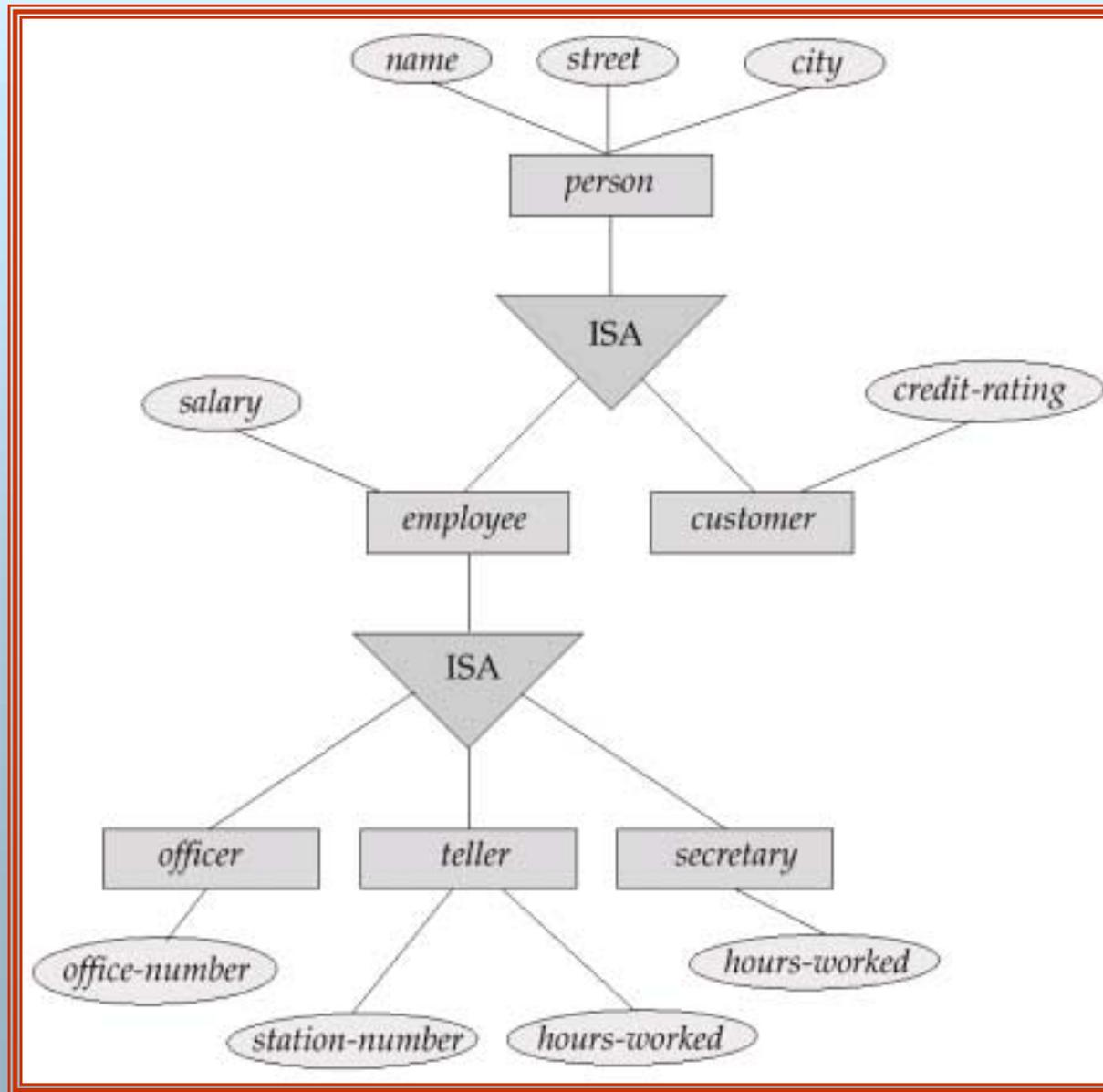
# Specialization

- Top-down design process; we designate subgroupings within an entity set that are distinctive from other entities in the set.
- These subgroupings become lower-level entity sets that have attributes or participate in relationships that do not apply to the higher-level entity set.
- Depicted by a *triangle* component labeled ISA (E.g. *customer* “is a” *person*).
- **Attribute inheritance** – a lower-level entity set inherits all the attributes and relationship participation of the higher-level entity set to which it is linked.





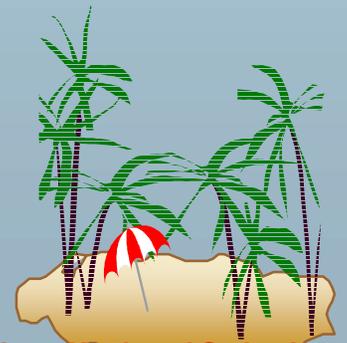
# Specialization Example





# Generalization

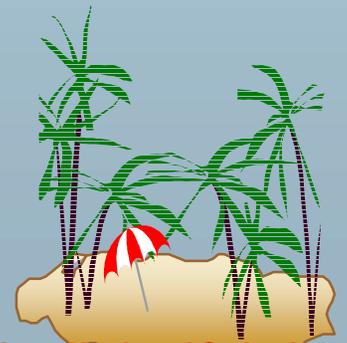
- A bottom-up design process – combine a number of entity sets that share the same features into a higher-level entity set.
- Specialization and generalization are simple inversions of each other; they are represented in an E-R diagram in the same way.
- The terms specialization and generalization are used interchangeably.





# Specialization and Generalization (Contd.)

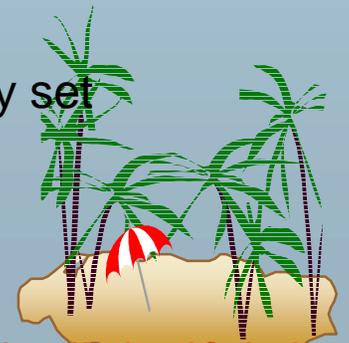
- Can have multiple specializations of an entity set based on different features.
- E.g. *permanent-employee* vs. *temporary-employee*, in addition to *officer* vs. *secretary* vs. *teller*
- Each particular employee would be
  - a member of one of *permanent-employee* or *temporary-employee*,
  - and also a member of one of *officer*, *secretary*, or *teller*
- The ISA relationship also referred to as **superclass - subclass** relationship





# Design Constraints on a Specialization/Generalization

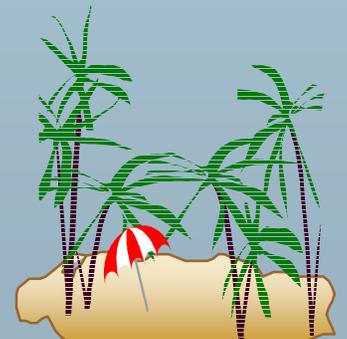
- Constraint on which entities can be members of a given lower-level entity set.
  - condition-defined
    - E.g. all customers over 65 years are members of *senior-citizen* entity set; *senior-citizen* ISA *person*.
  - user-defined
- Constraint on whether or not entities may belong to more than one lower-level entity set within a single generalization.
  - **Disjoint**
    - an entity can belong to only one lower-level entity set
    - Noted in E-R diagram by writing *disjoint* next to the ISA triangle
  - **Overlapping**
    - an entity can belong to more than one lower-level entity set





# Design Constraints on a Specialization/Generalization (Contd.)

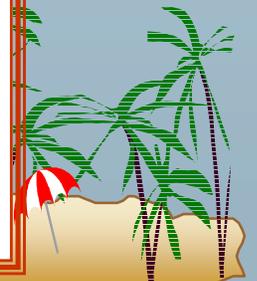
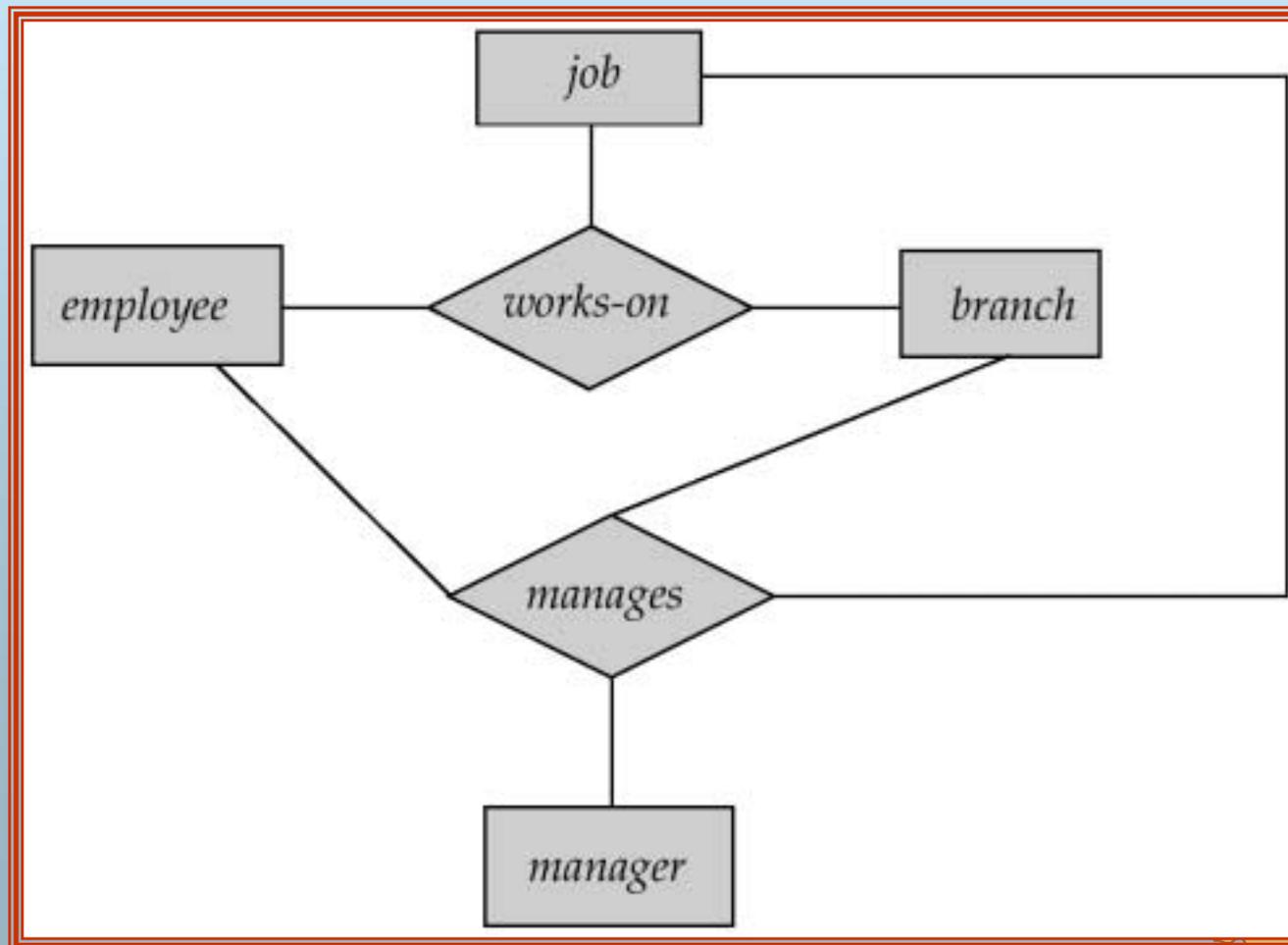
- **Completeness constraint** -- specifies whether or not an entity in the higher-level entity set must belong to at least one of the lower-level entity sets within a generalization.
  - **total** : an entity must belong to one of the lower-level entity sets
  - **partial**: an entity need not belong to one of the lower-level entity sets





# Aggregation

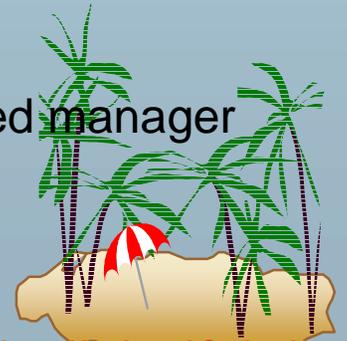
- Consider the ternary relationship *works-on*, which we saw earlier
- Suppose we want to record managers for tasks performed by an employee at a branch





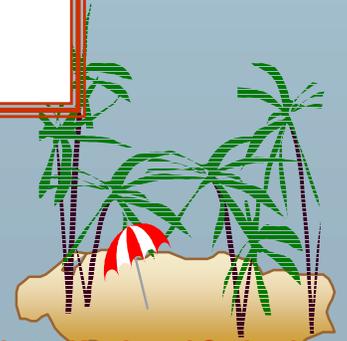
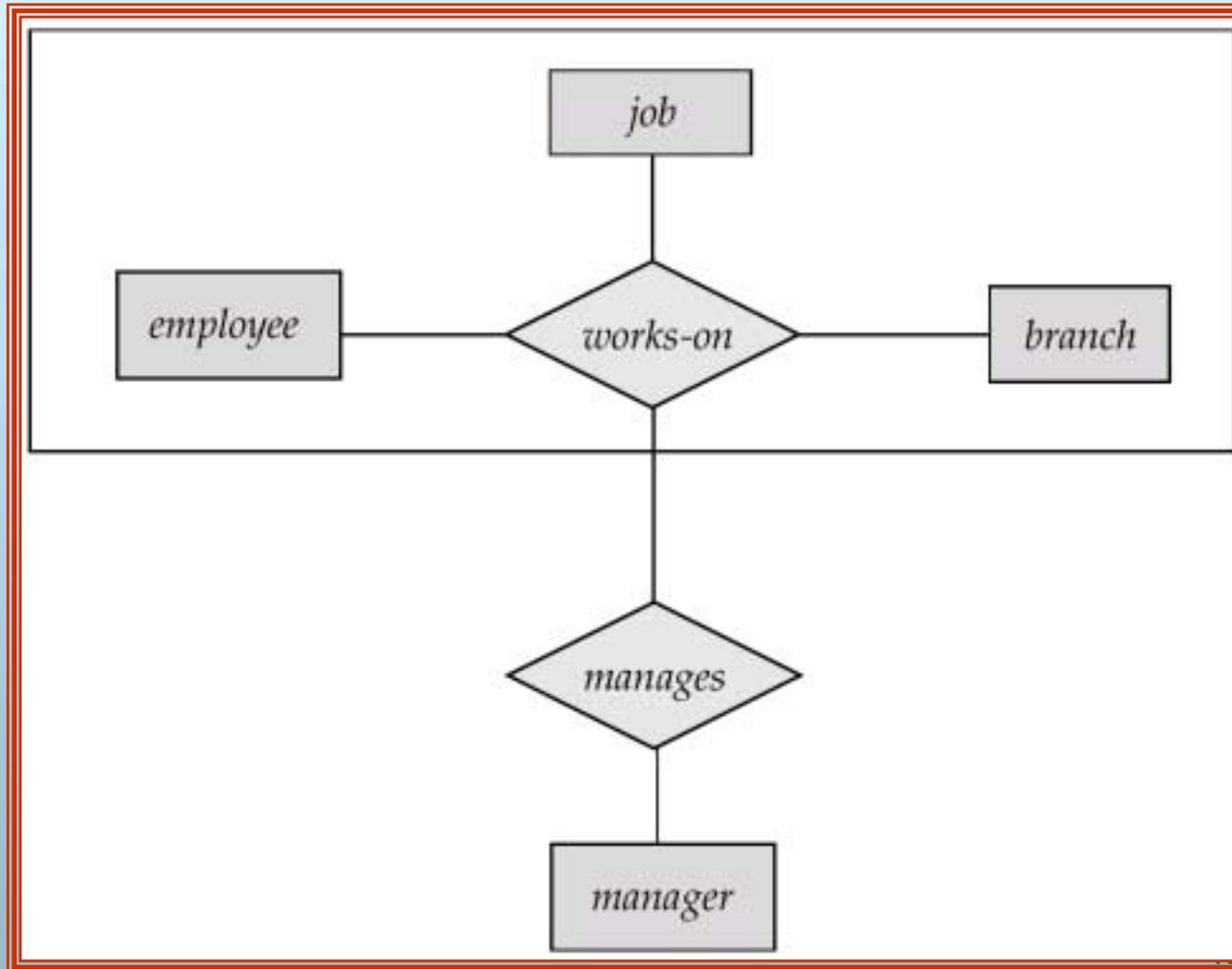
# Aggregation (Cont.)

- Relationship sets *works-on* and *manages* represent overlapping information
  - Every *manages* relationship corresponds to a *works-on* relationship
  - However, some *works-on* relationships may not correspond to any *manages* relationships
    - ➔ So we can't discard the *works-on* relationship
- Eliminate this redundancy via *aggregation*
  - Treat relationship as an abstract entity
  - Allows relationships between relationships
  - Abstraction of relationship into new entity
- Without introducing redundancy, the following diagram represents:
  - An employee works on a particular job at a particular branch
  - An employee, branch, job combination may have an associated manager





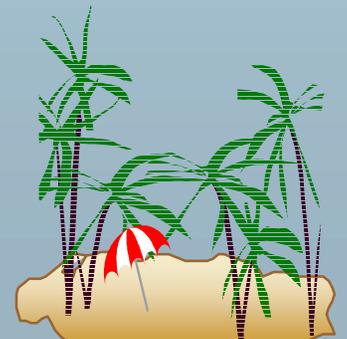
# E-R Diagram With Aggregation





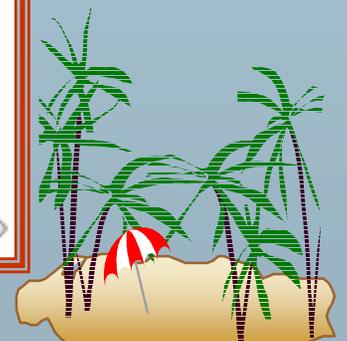
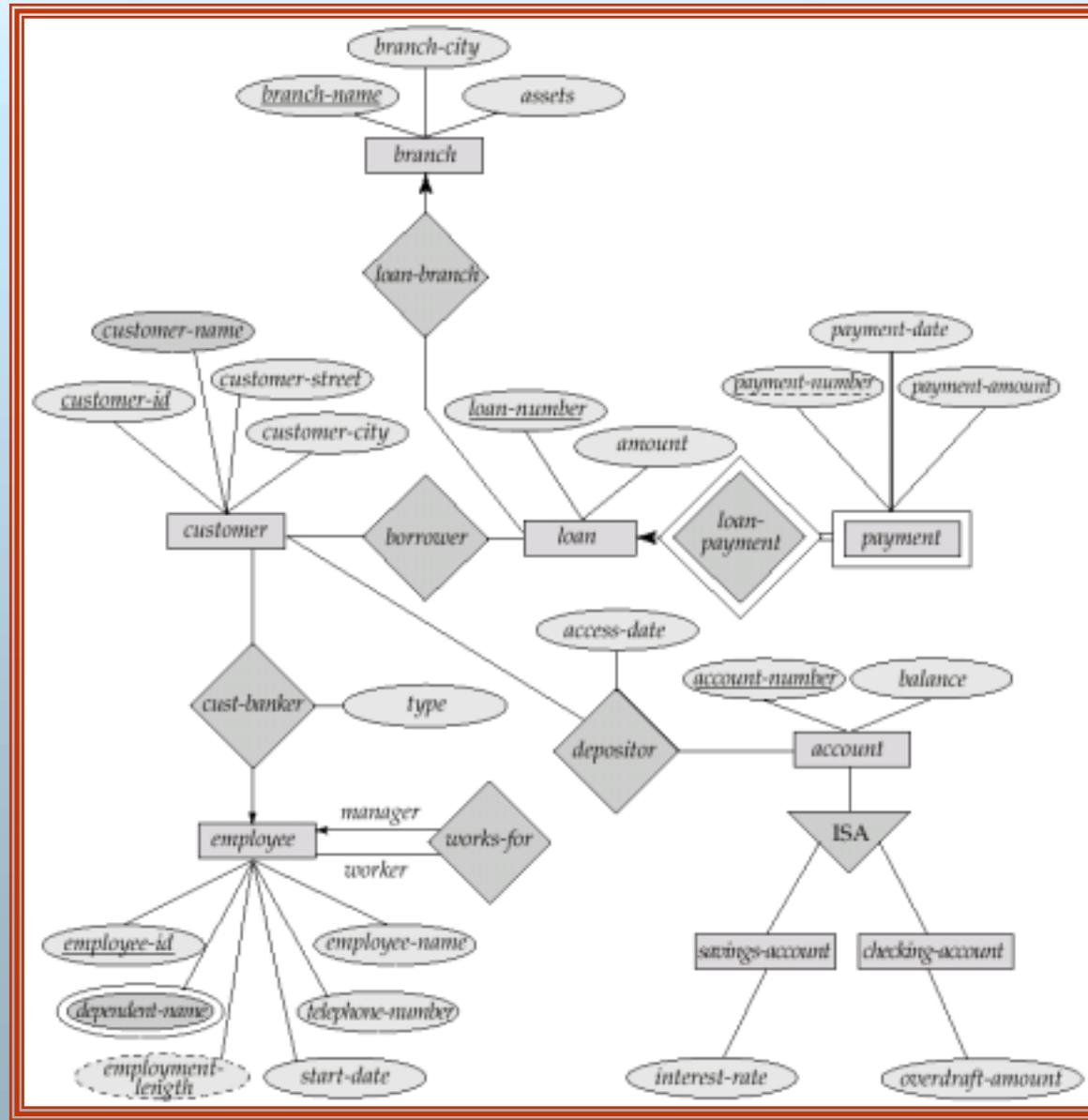
# E-R Design Decisions

- The use of an attribute or entity set to represent an object.
- Whether a real-world concept is best expressed by an entity set or a relationship set.
- The use of a ternary relationship versus a pair of binary relationships.
- The use of a strong or weak entity set.
- The use of specialization/generalization – contributes to modularity in the design.
- The use of aggregation – can treat the aggregate entity set as a single unit without concern for the details of its internal structure.

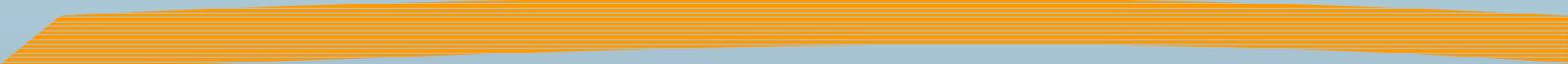




# E-R Diagram for a Banking Enterprise

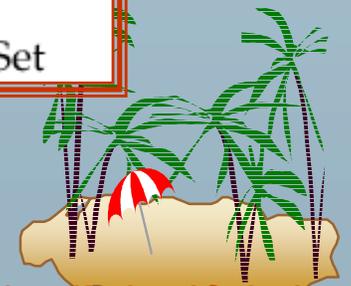
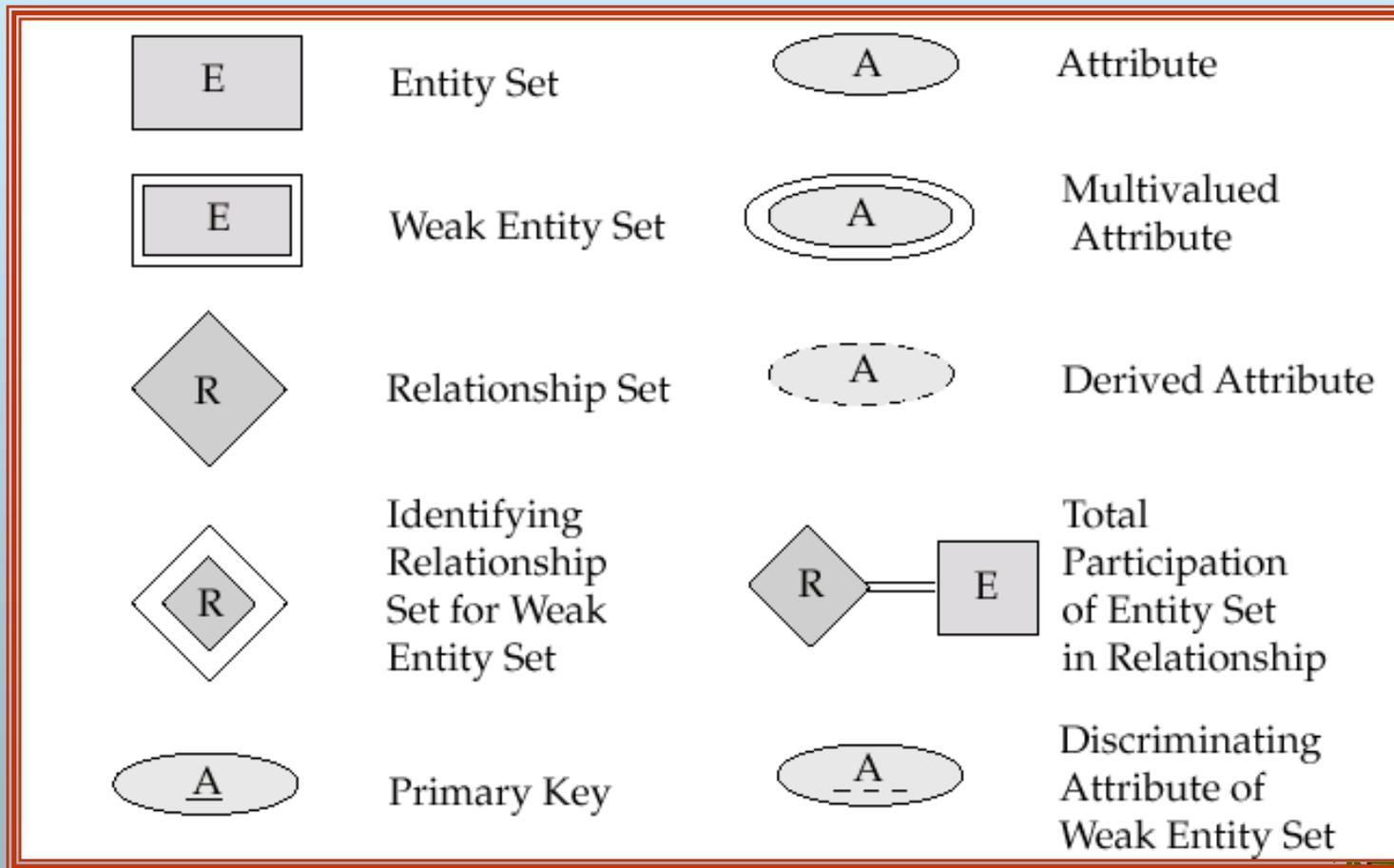


**How about doing another ER design  
interactively on the board?**



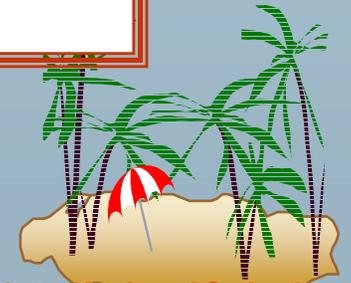
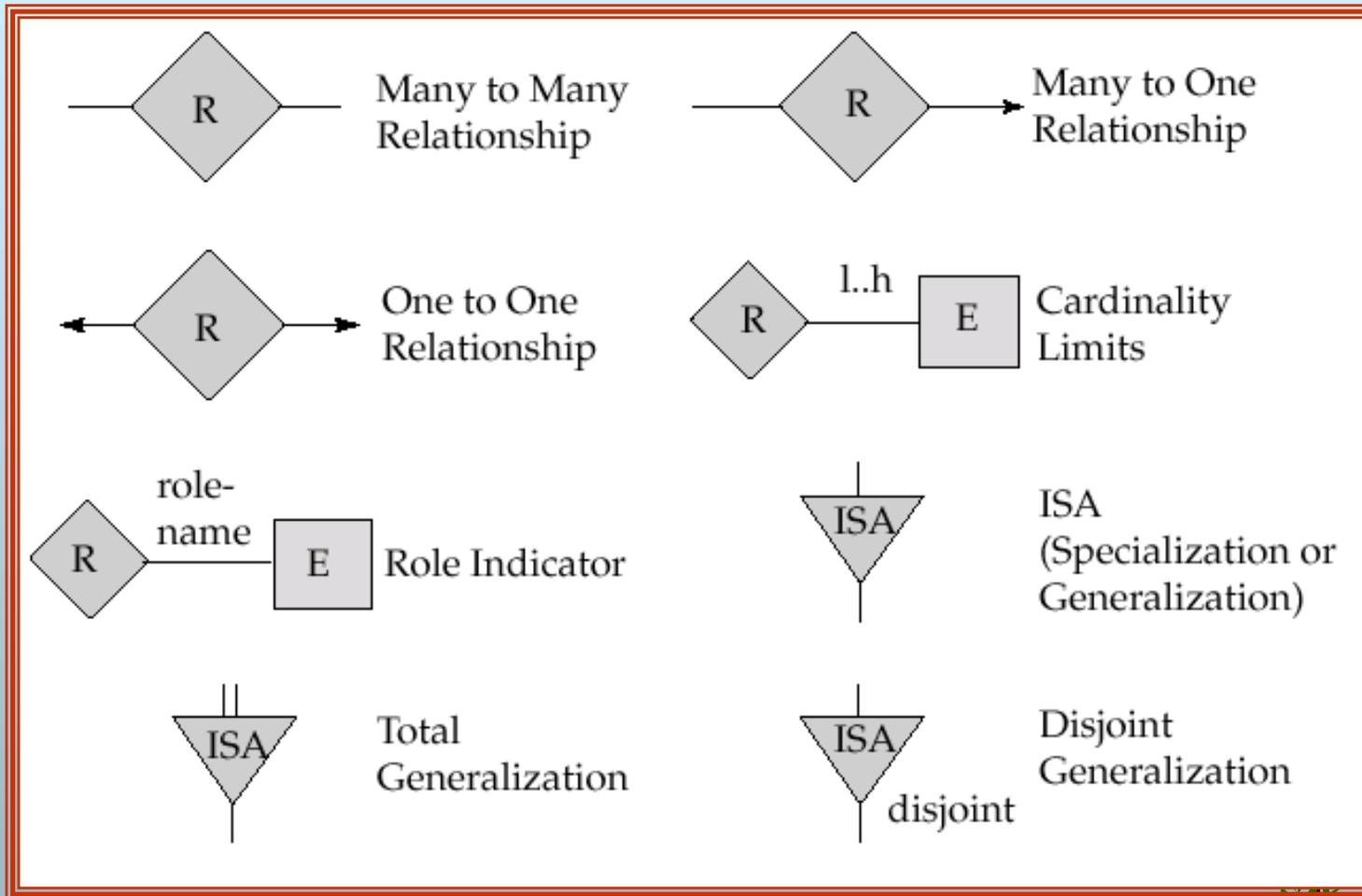


# Summary of Symbols Used in E-R Notation



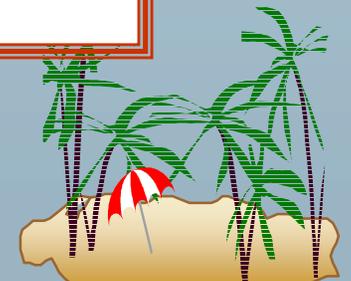
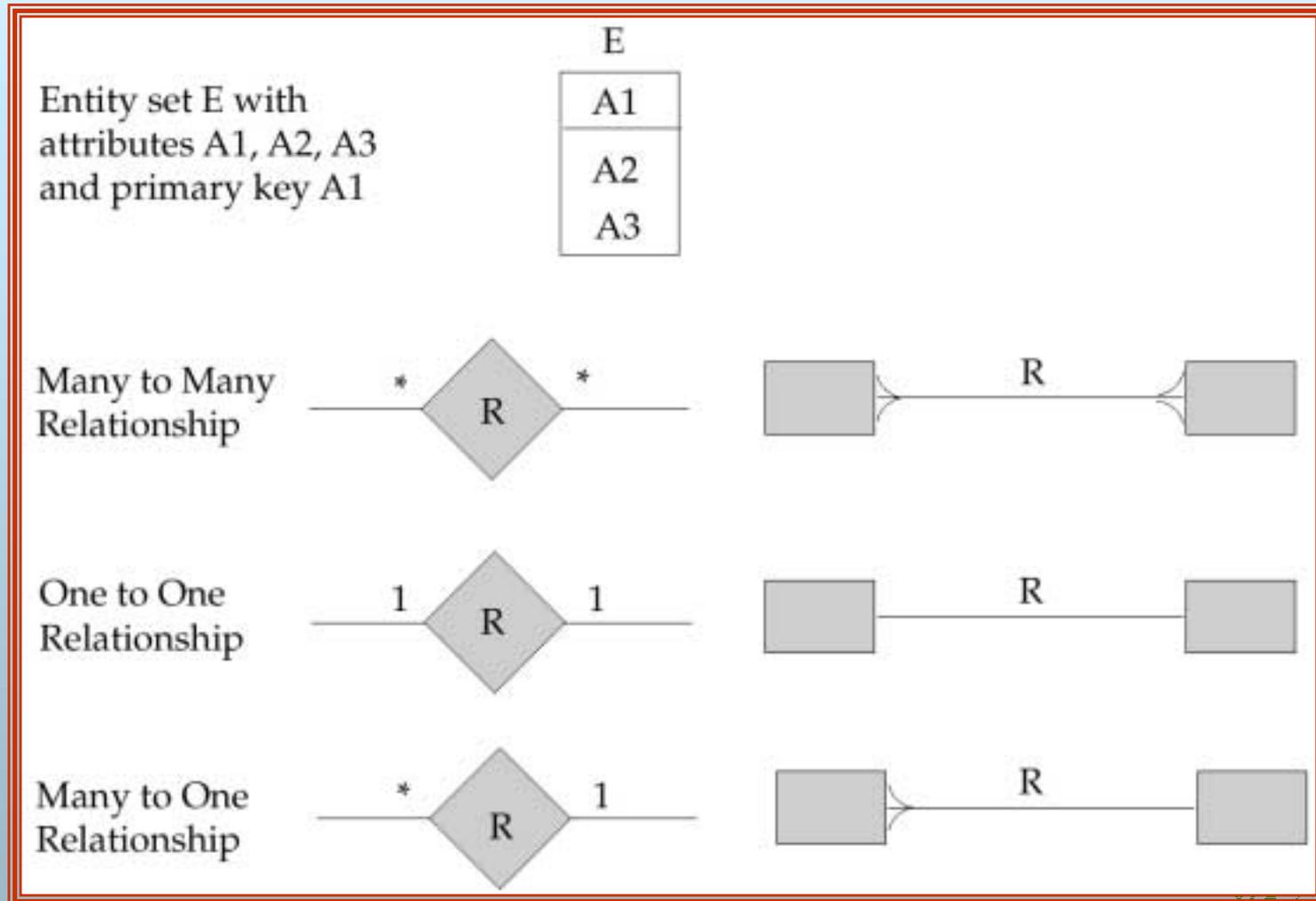


# Summary of Symbols (Cont.)





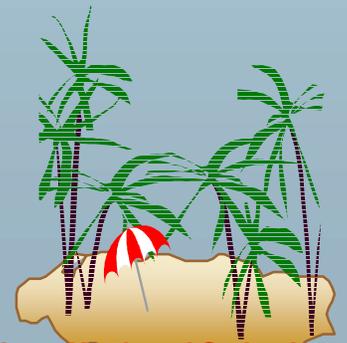
# Alternative E-R Notations





# UML

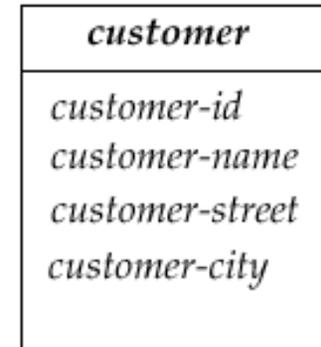
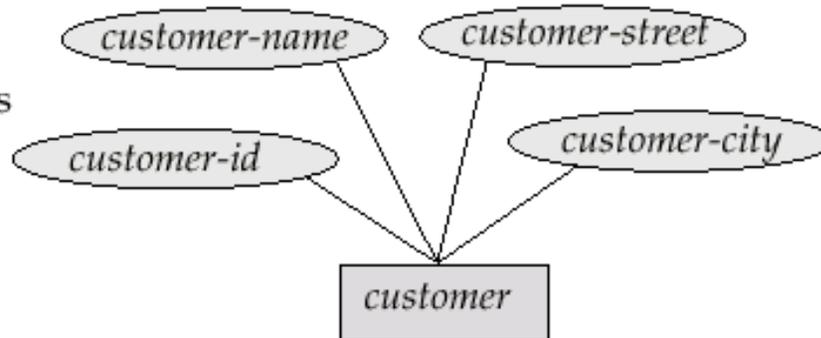
- UML: Unified Modeling Language
- UML has many components to graphically model different aspects of an entire software system
- UML Class Diagrams correspond to E-R Diagram, but several differences.



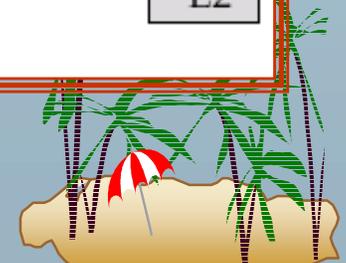
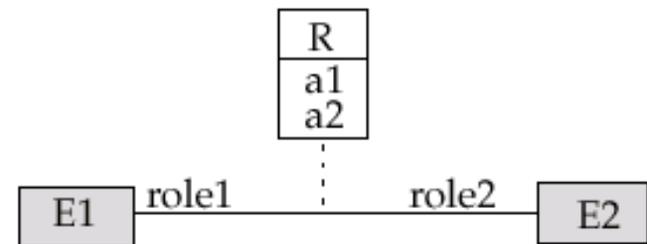
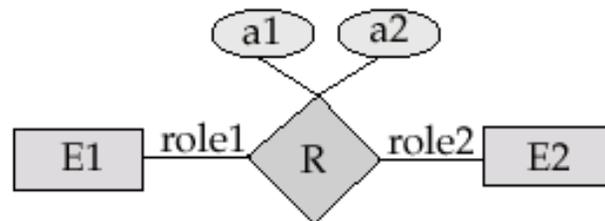
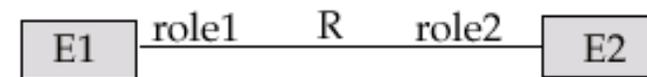
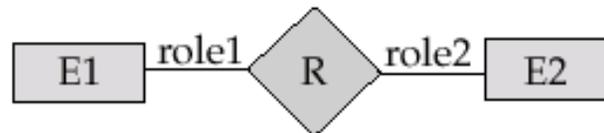


# Summary of UML Class Diagram Notation

## 1. Entity sets and attributes



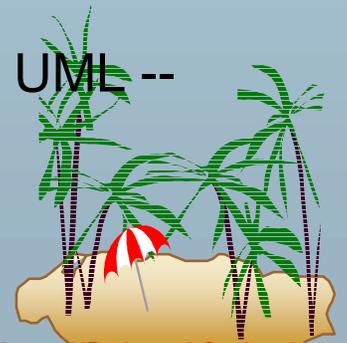
## 2. Relationships





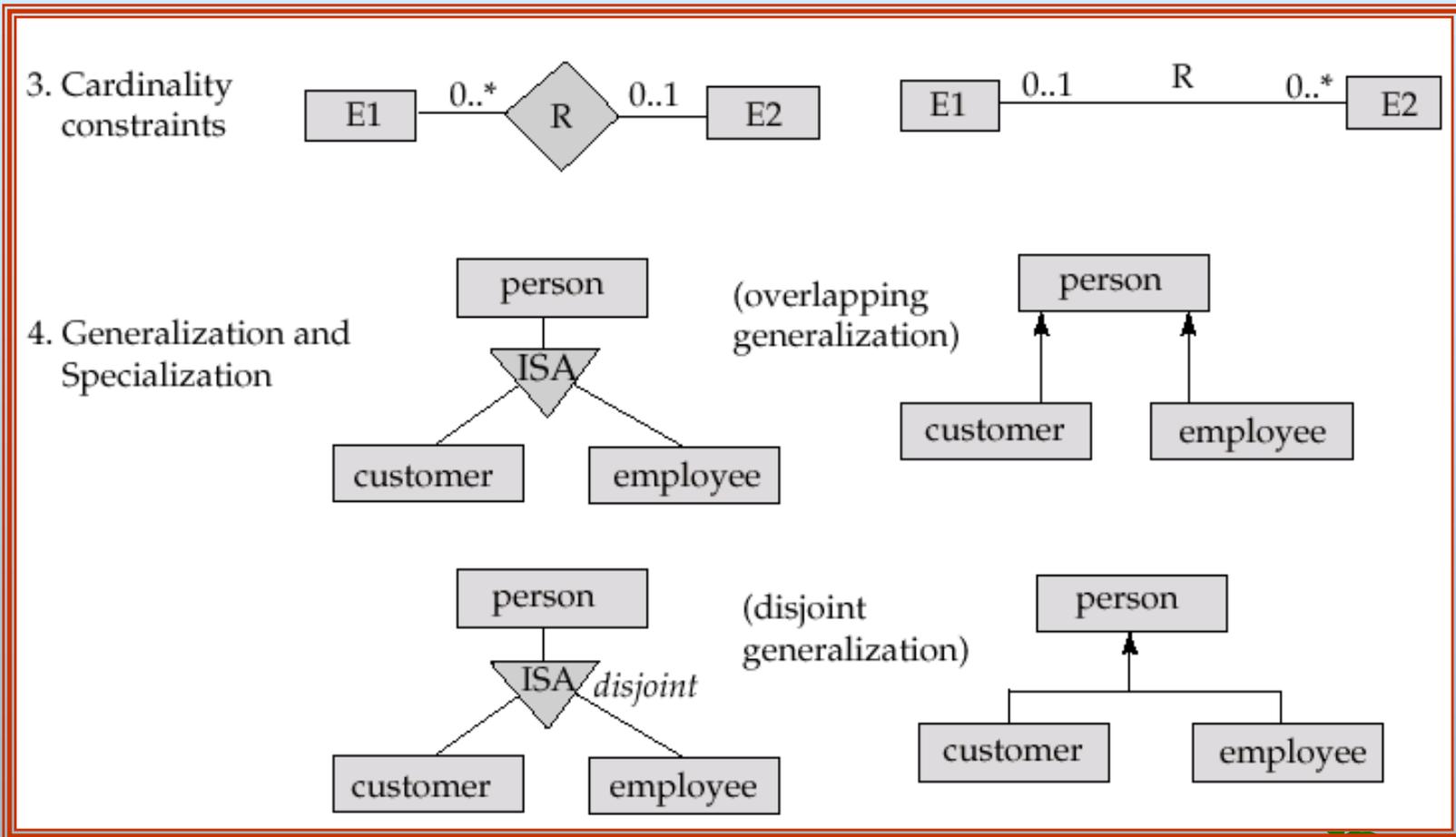
# UML Class Diagrams (Contd.)

- Entity sets are shown as boxes, and attributes are shown within the box, rather than as separate ellipses in E-R diagrams.
- Binary relationship sets are represented in UML by just drawing a line connecting the entity sets. The relationship set name is written adjacent to the line.
- The role played by an entity set in a relationship set may also be specified by writing the role name on the line, adjacent to the entity set.
- The relationship set name may alternatively be written in a box, along with attributes of the relationship set, and the box is connected, using a dotted line, to the line depicting the relationship set.
- Non-binary relationships cannot be directly represented in UML -- they have to be converted to binary relationships.

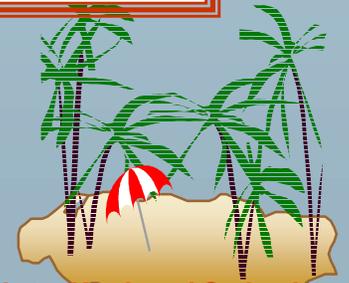




# UML Class Diagram Notation (Cont.)



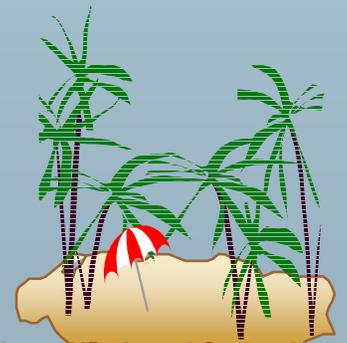
\*Note reversal of position in cardinality constraint depiction





# UML Class Diagrams (Contd.)

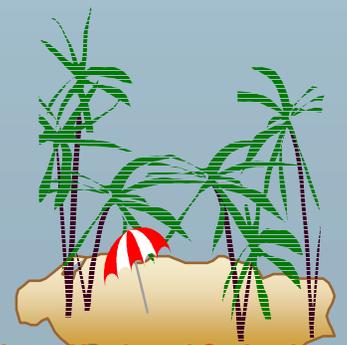
- Cardinality constraints are specified in the form  $l..h$ , where  $l$  denotes the minimum and  $h$  the maximum number of relationships an entity can participate in.
- Beware: the positioning of the constraints is exactly the reverse of the positioning of constraints in E-R diagrams.
- The constraint  $0..*$  on the  $E2$  side and  $0..1$  on the  $E1$  side means that each  $E2$  entity can participate in at most one relationship, whereas each  $E1$  entity can participate in many relationships; in other words, the relationship is many to one from  $E2$  to  $E1$ .
- Single values, such as 1 or \* may be written on edges; The single value 1 on an edge is treated as equivalent to  $1..1$ , while \* is equivalent to  $0..*$ .





# Reduction of an E-R Schema to Tables

- Primary keys allow entity sets and relationship sets to be expressed uniformly as *tables* which represent the contents of the database.
- A database which conforms to an E-R diagram can be represented by a collection of tables.
- For each entity set and relationship set there is a unique table which is assigned the name of the corresponding entity set or relationship set.
- Each table has a number of columns (generally corresponding to attributes), which have unique names.
- Converting an E-R diagram to a table format is the basis for deriving a relational database design from an E-R diagram.

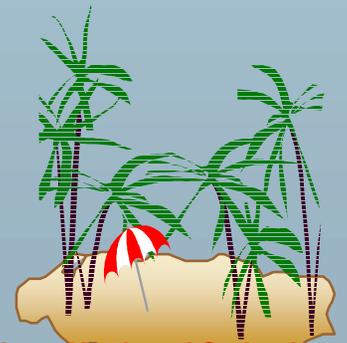




# Representing Entity Sets as Tables

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

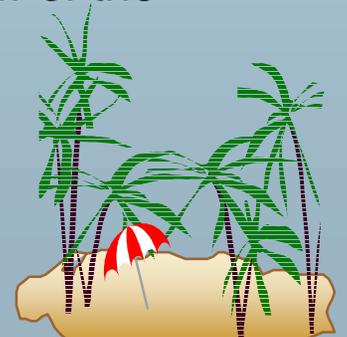
<i>customer-id</i>	<i>customer-name</i>	<i>customer-street</i>	<i>customer-city</i>
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park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





# Composite and Multivalued Attributes

- Composite attributes are flattened out by creating a separate attribute for each component attribute
  - E.g. given entity set *customer* with composite attribute *name* with component attributes *first-name* and *last-name* the table corresponding to the entity set has two attributes  
*name.first-name* and *name.last-name*
- A multivalued attribute M of an entity E is represented by a separate table EM
  - Table EM has attributes corresponding to the primary key of E and an attribute corresponding to multivalued attribute M
  - E.g. Multivalued attribute *dependent-names* of *employee* is represented by a table  
*employee-dependent-names( employee-id, dname)*
  - Each value of the multivalued attribute maps to a separate row of the table EM
    - ➔ E.g., an employee entity with primary key John and dependents Johnson and Johndotir maps to two rows:  
(John, Johnson) and (John, Johndotir)

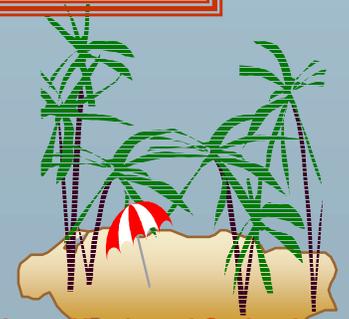




# Representing Weak Entity Sets

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

<i>loan-number</i>	<i>payment-number</i>	<i>payment-date</i>	<i>payment-amount</i>
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

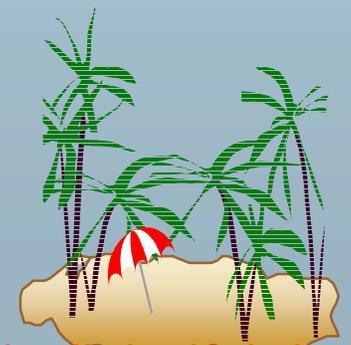




# Representing Relationship Sets as Tables

- 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.
- E.g.: table for relationship set *borrower*

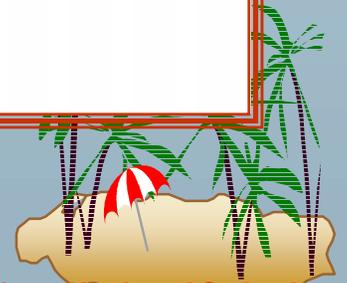
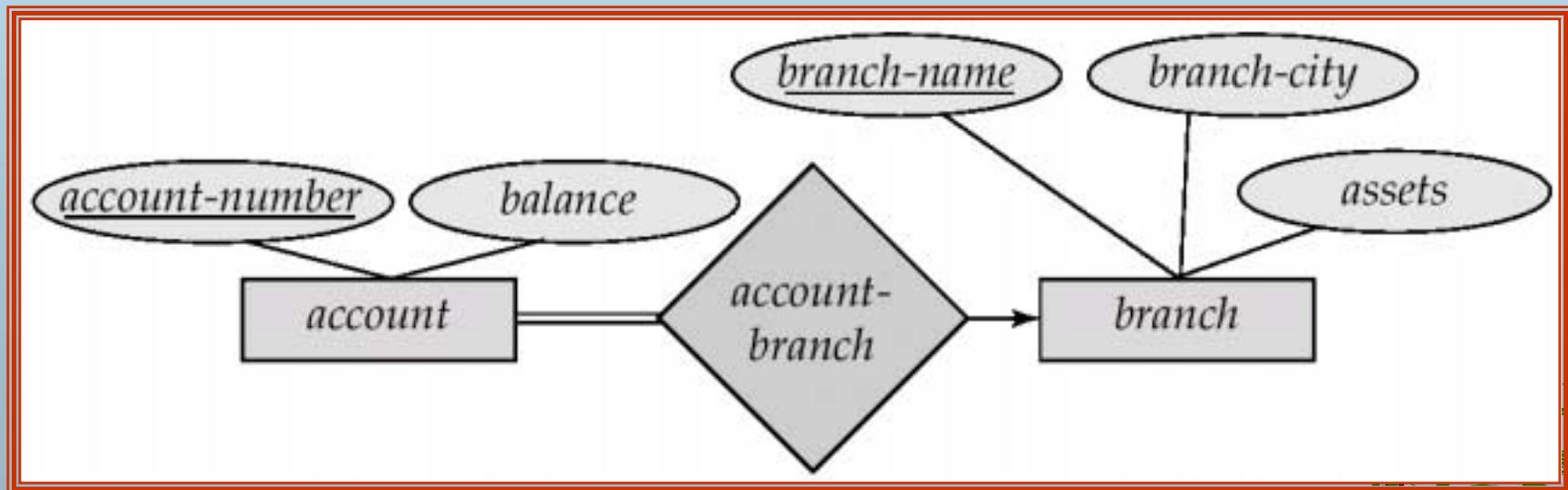
<i>customer-id</i>	<i>loan-number</i>
019-28-3746	L-11
019-28-3746	L-23
244-66-8800	L-93
321-12-3123	L-17
335-57-7991	L-16
555-55-5555	L-14
677-89-9011	L-15
963-96-3963	L-17





# Redundancy of Tables

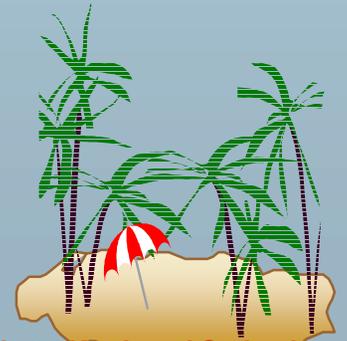
- Many-to-one and one-to-many relationship sets that are total on the many-side can be represented by adding an extra attribute to the many side, containing the primary key of the one side
- E.g.: Instead of creating a table for relationship *account-branch*, add an attribute *branch* to the entity set *account*





# Redundancy of Tables (Cont.)

- For one-to-one relationship sets, either side can be chosen to act as the “many” side
  - That is, extra attribute can be added to either of the tables corresponding to the two entity sets
- If participation is *partial* on the many side, replacing a table by an extra attribute in the relation corresponding to the “many” side could result in null values
- The table corresponding to a relationship set linking a weak entity set to its identifying strong entity set is redundant.
  - E.g. The *payment* table already contains the information that would appear in the *loan-payment* table (i.e., the columns *loan-number* and *payment-number*).





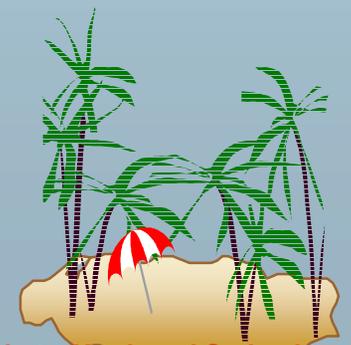
# Representing Specialization as Tables

## ■ Method 1:

- Form a table for the higher level entity
- Form a table for each lower level entity set, include primary key of higher level entity set and local attributes

table	table attributes
<i>person</i>	<i>name, street, city</i>
<i>customer</i>	<i>name, credit-rating</i>
<i>employee</i>	<i>name, salary</i>

- Drawback: getting information about, e.g., *employee* requires accessing two tables





# Representing Specialization as Tables (Cont.)

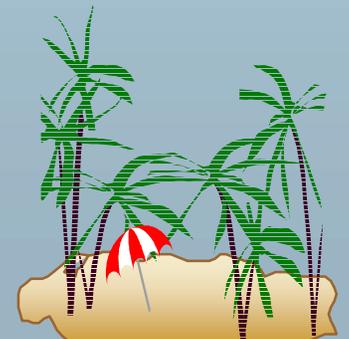
## ■ Method 2:

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

<b>table</b>	<b>table attributes</b>
<i>person</i>	<i>name, street, city</i>
<i>customer</i>	<i>name, street, city, credit-rating</i>
<i>employee</i>	<i>name, street, city, salary</i>

If specialization is total, no need to create table for generalized entity (*person*)

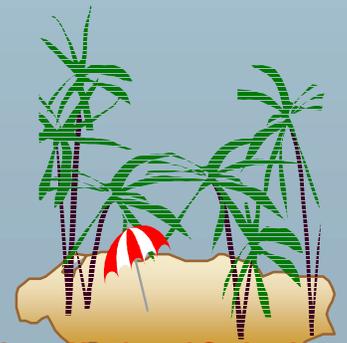
- Drawback: street and city may be stored redundantly for persons who are both customers and employees





# Relations Corresponding to Aggregation

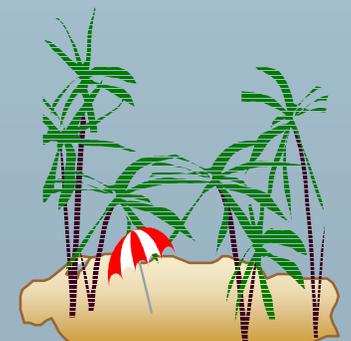
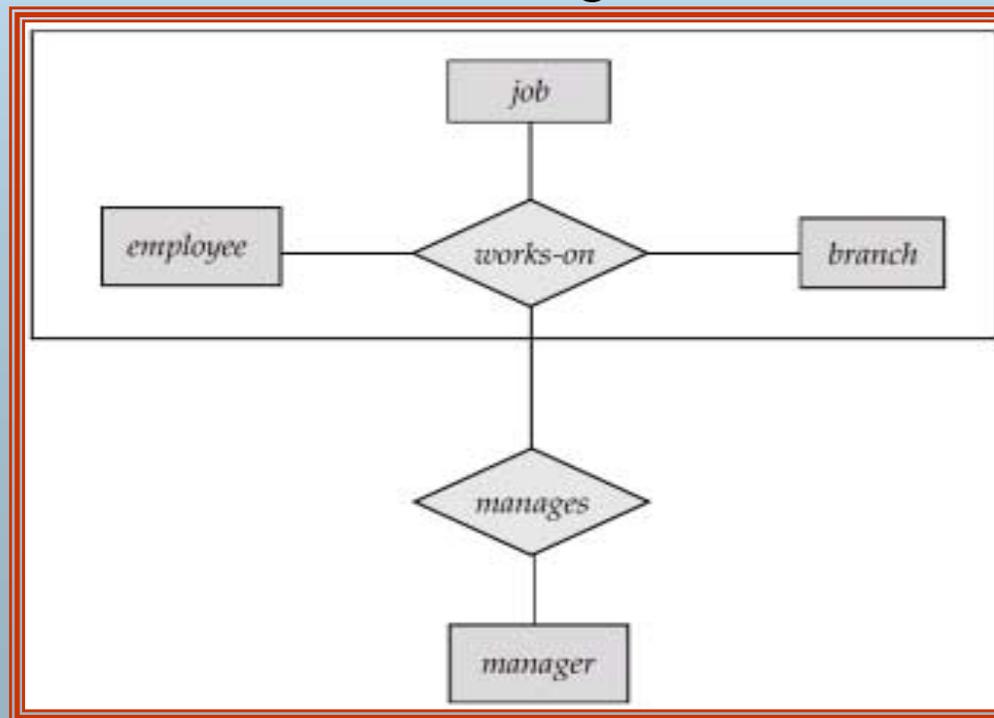
- To represent aggregation, create a table containing
  - primary key of the aggregated relationship,
  - the primary key of the associated entity set
  - Any descriptive attributes



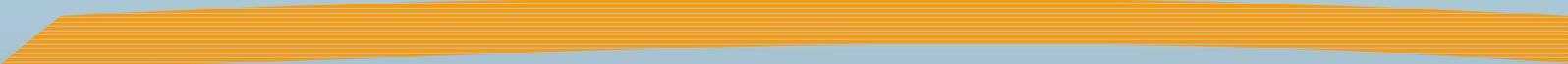


## Relations Corresponding to Aggregation (Cont.)

- E.g. to represent aggregation *manages* between relationship *works-on* and entity set *manager*, create a table *manages*(*employee-id*, *branch-name*, *title*, *manager-name*)
- Table *works-on* is redundant **provided** we are willing to store null values for attribute *manager-name* in table *manages*

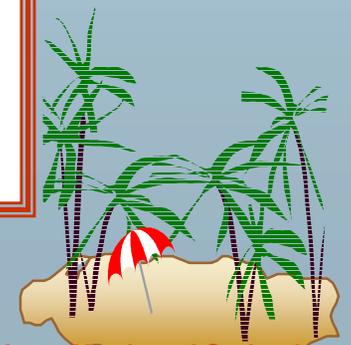
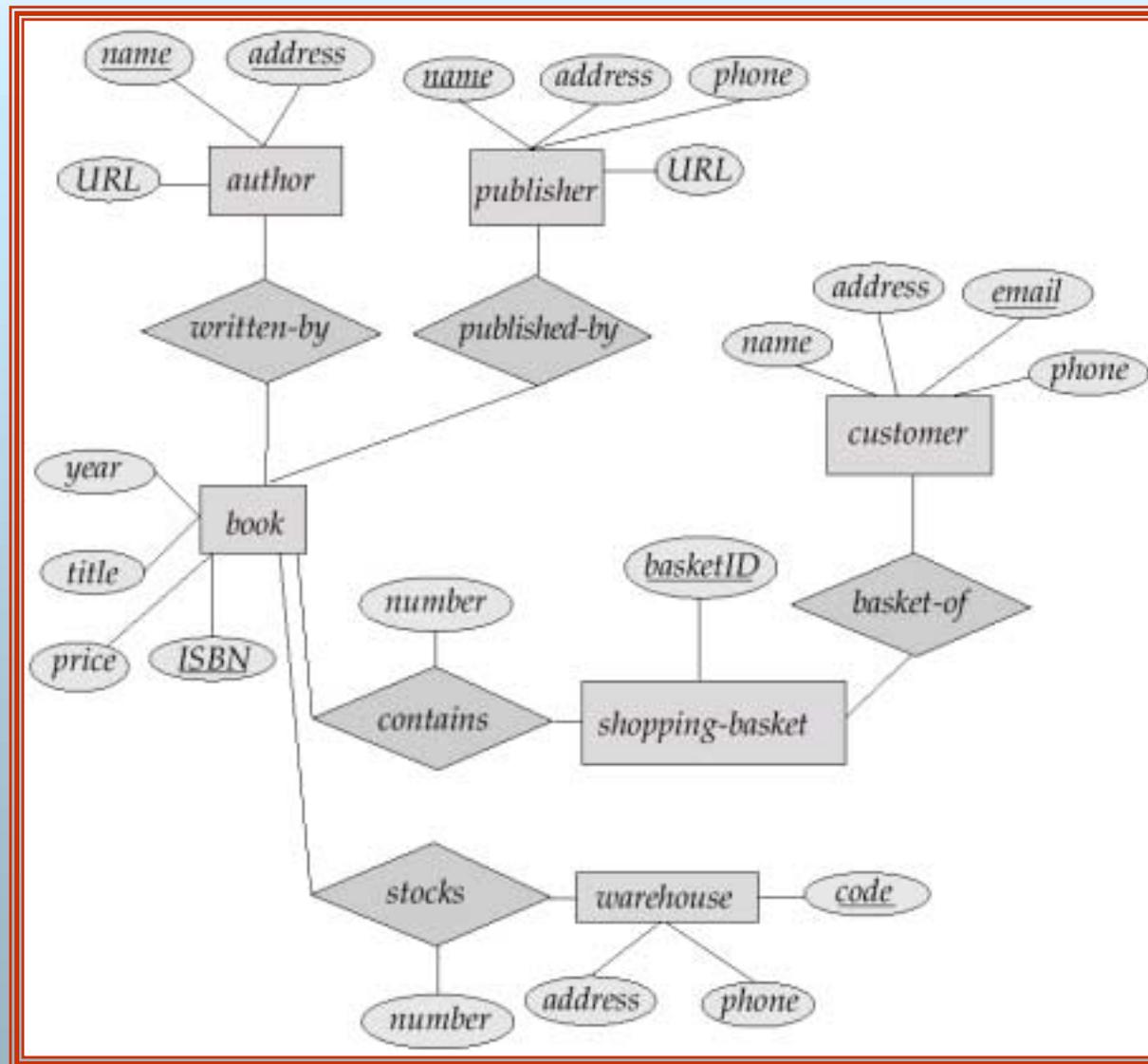


**End of Chapter 2**

A decorative orange brushstroke graphic consisting of many thin, parallel lines, positioned horizontally below the text.

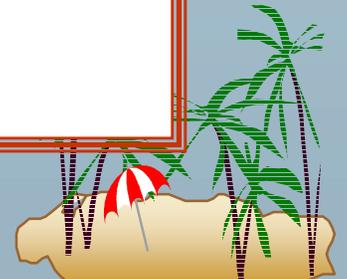
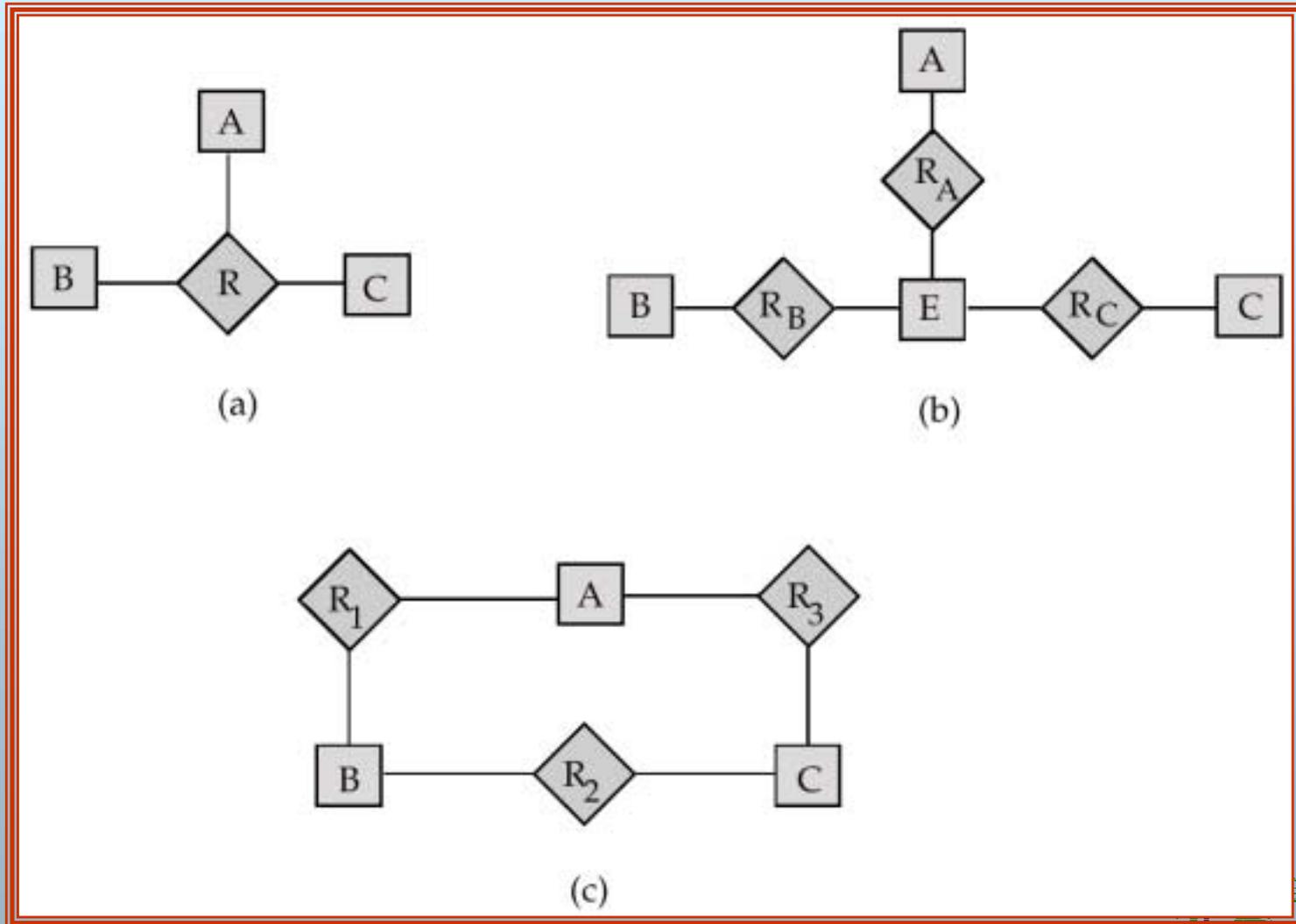


# E-R Diagram for Exercise 2.10



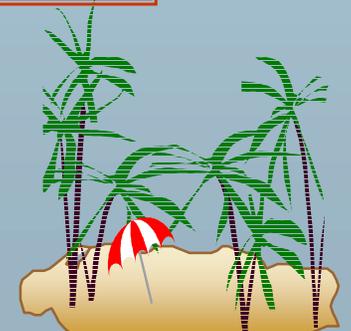
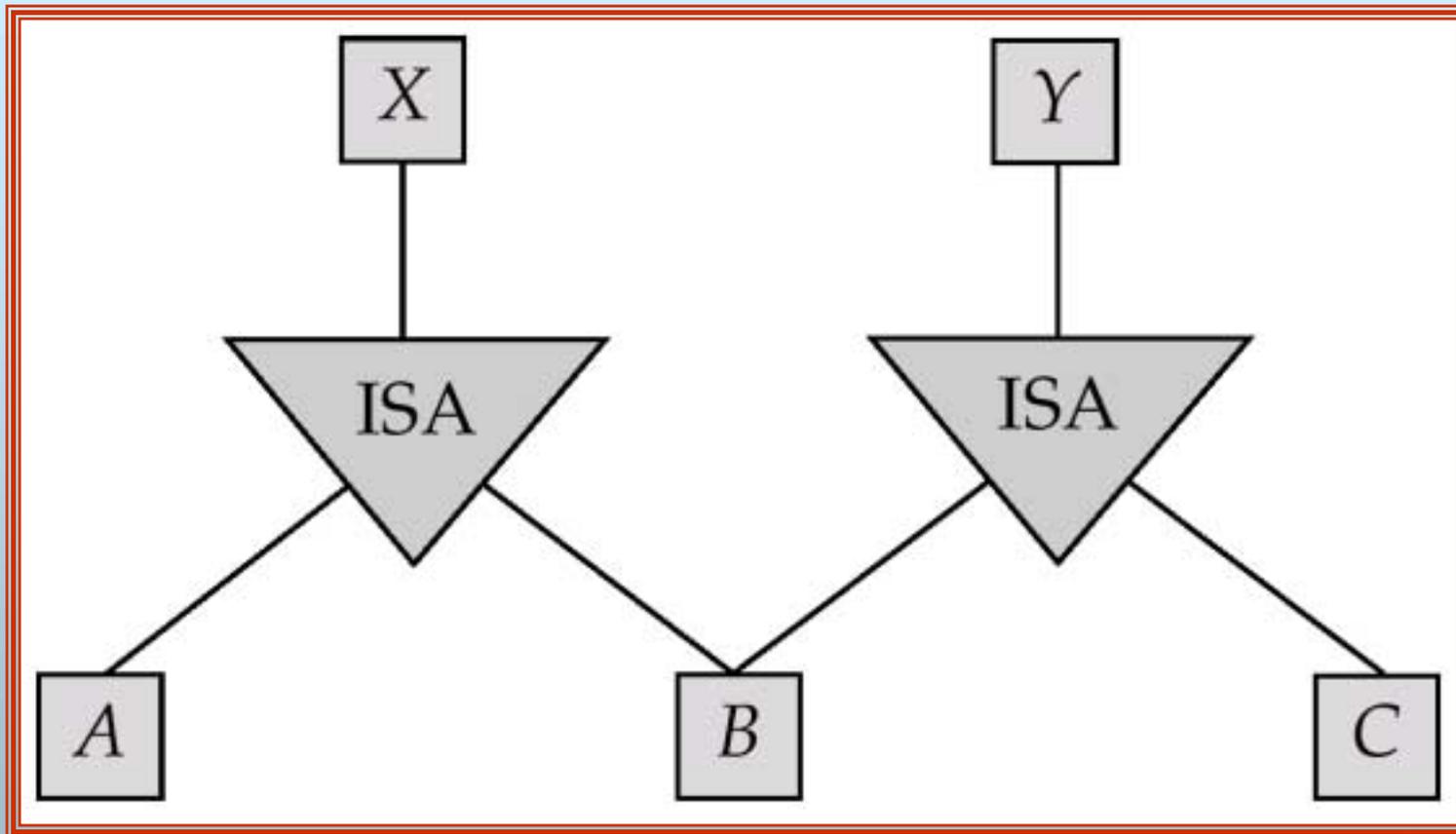


# E-R Diagram for Exercise 2.15



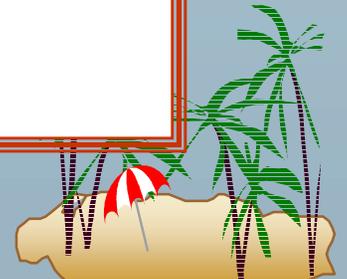
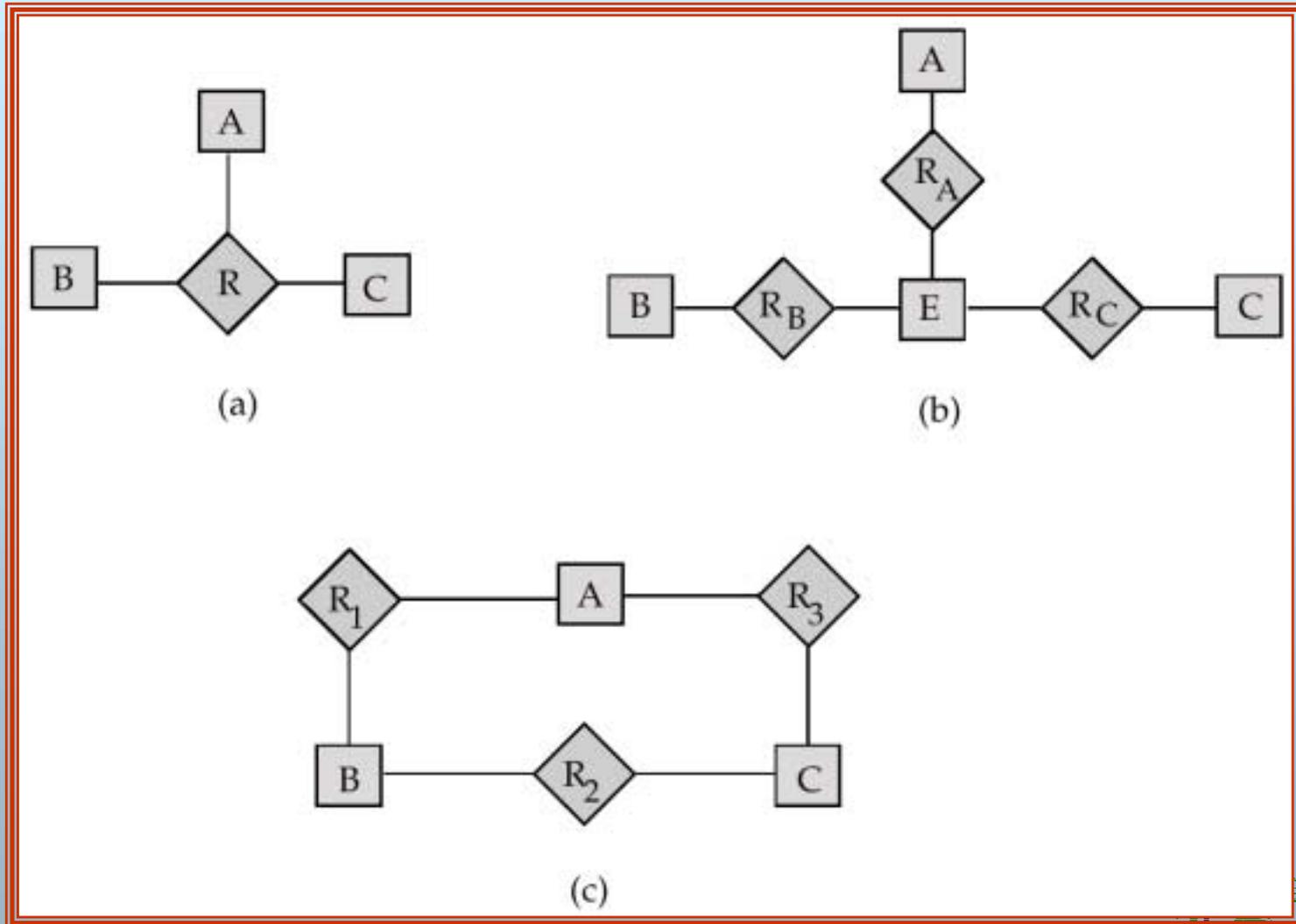


# E-R Diagram for Exercise 2.22





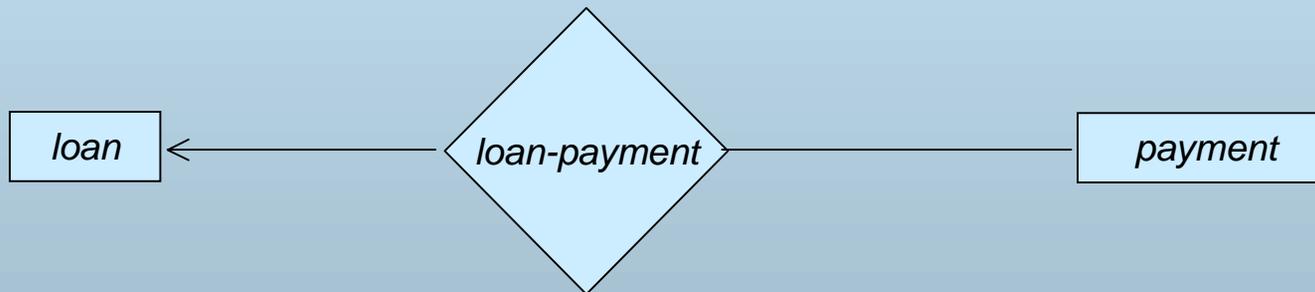
# E-R Diagram for Exercise 2.15





# Existence Dependencies

- If the existence of entity  $x$  depends on the existence of entity  $y$ , then  $x$  is said to be *existence dependent* on  $y$ .
  - $y$  is a *dominant entity* (in example below, *loan*)
  - $x$  is a *subordinate entity* (in example below, *payment*)



If a *loan* entity is deleted, then all its associated *payment* entities must be deleted also.

