E-R Diagram

Database Development

- We know how to query a database using SQL
  - A set of tables and their schemas are given
  - Data are properly loaded
- But, how can we develop appropriate tables and their schema for an application?
  - In real applications, data often does not present as tables naturally
  - What are the corresponding data units of tables?

What Is Data in Applications?

- A student information system
  - Objects: students (Ann, Bob, …), courses (354, 459, …), departments (CS, Engineering, …), …
- Objects are related
  - Students taking courses (Ann takes 354, Bob takes 459, …), courses offered by departments (354 and 459 are offered by CS), …
- Generally, an application contains a set of objects and their relationships

Entities

- An entity: an object that exists and is distinguishable from other objects
  - E.g., Ann, Bob, CS, Engineering, 354, 459, …
  - Entities have attributes, e.g., Ann has a phone number and an address
- An entity set: a set of entities of the same type that share the same properties
  - E.g., the set of students, the set of departments, the set of courses, …

Entity Sets in Relational Databases

customer_id	customer_name	customer_street	customer_city
321-12-3123	Jones	Main	Harrison
019-28-3746	Smith	North	Rye
677-89-9011	Hayes	Main	Harrison
555-55-5555	Jackson	Dupont	Woodside
244-66-8800	Curry	North	Rye
963-96-3963	Williams	Nassau	Princeton
335-57-7991	Adams	Spring	Pittsfield

customer

loan_number	amount
L-17	1000
L-23	2000
L-15	1500
L-14	1500
L-19	500
L-11	900
L-16	1300

loan

Attributes

- An entity is represented by a set of attributes – the descriptive properties possessed by all members of an entity set

  customer = (*customer_id, customer_name, customer_street, customer_city*)

  loan = (*loan_number, amount*)

- Domain – the set of permitted values for an attribute

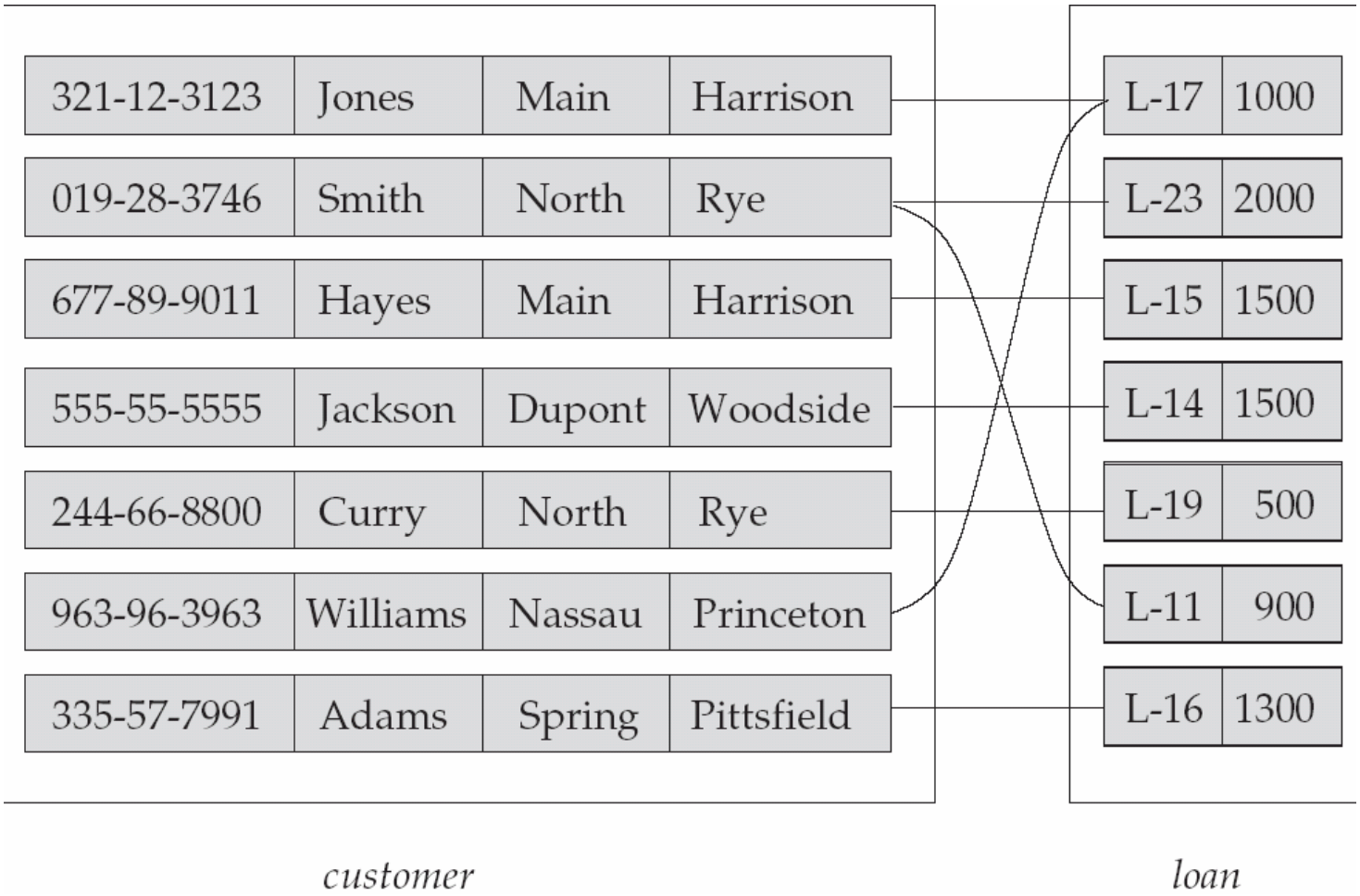
Attribute types

- Simple and composite attributes
  - Simple: cannot be divided into subparts
  - Composite: Name = first_name + last_name
- Single-valued and multi-valued attributes
  - Single-valued: each entity has only one value
  - Multi-valued: an entity may have zero, one, or more values, e.g., telephone numbers
- Derived attributes
  - Can be computed from other attributes
  - Example: age, given date_of_birth

Relationships

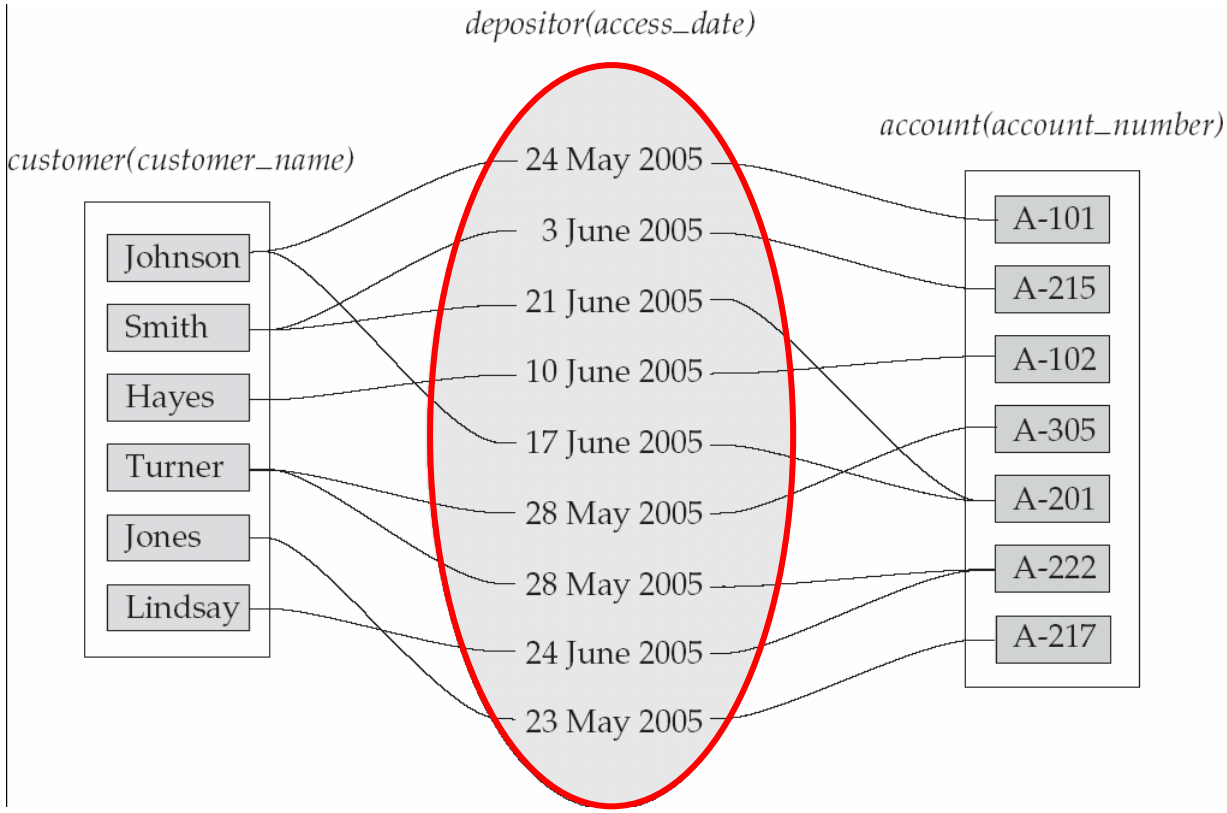
- A relationship: an association among several entities
  - Ann takes 354, Bob takes 459
  - A set of relationships may share common features: student-taking-courses
- A relationship set: a mathematical relation among $n \geq 2$ entities, each taken from an entity set
  - $\{(e_1, e_2, \ldots, e_n) \mid e_1 \in E_1, e_2 \in E_2, \ldots, e_n \in E_n\}$, where $(e_1, e_2, \ldots, e_n)$ is a relationship
  - Example: (Ann, 354) $\in$ std-take-crs, (Bob, 459) $\in$ std-take-crs

Relationship Set borrower



Properties of Relationship Sets

- A relationship set can also have properties



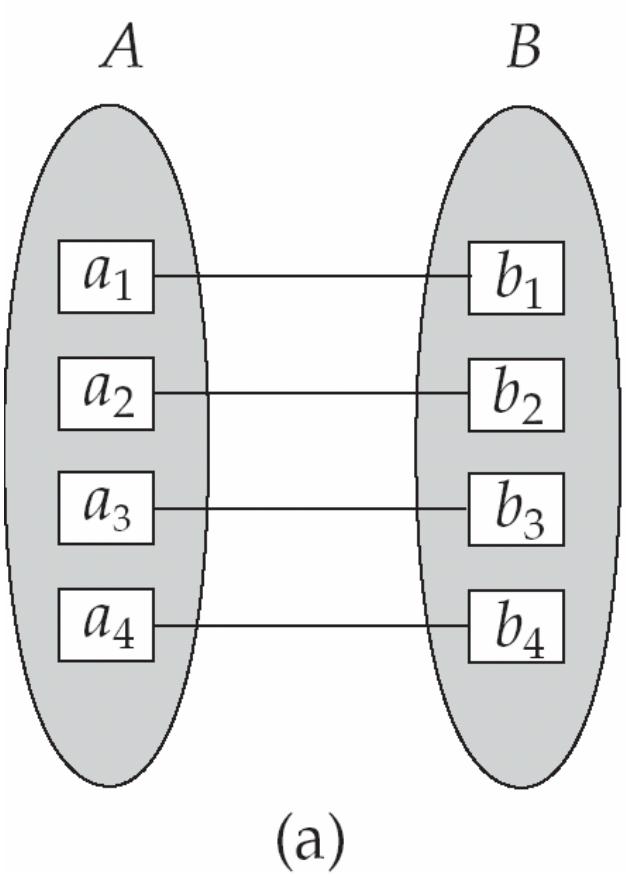
Degree of a Relationship Set

- The number of entity sets that participate in a relationship set
  - Relationship sets that involve two entity sets are binary (or of degree two)
  - Most relationship sets in a database system are binary
- Relationship sets may involve more than two entity sets
  - Example: a ternary relationship set between entity sets *student, course,* and *instructor*

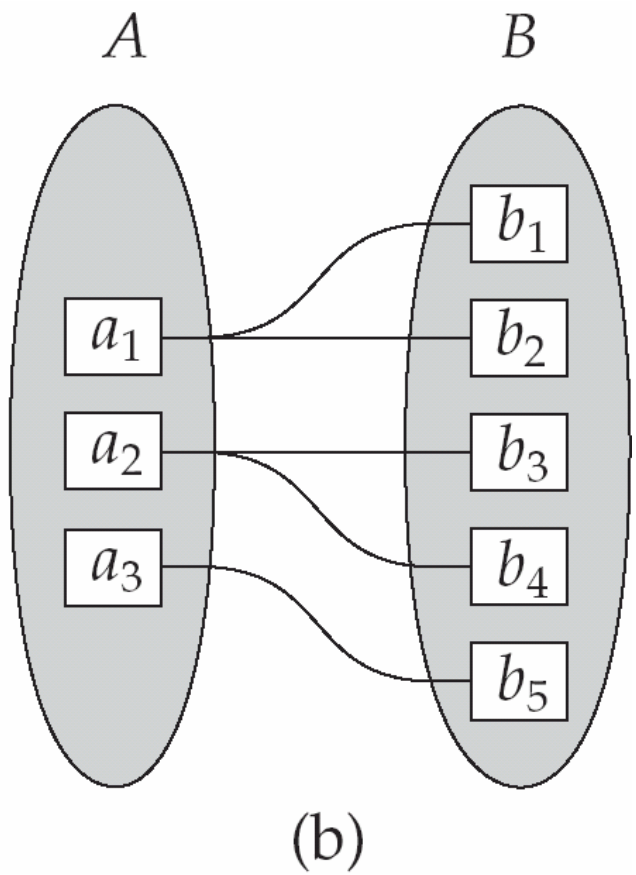
Mapping Cardinality Constraints

- 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, e.g., president – university
  - One to many, e.g.,. instructor – course
  - Many to one, e.g., course – instructor
  - Many to many, e.g., student – course

Mapping Cardinalities

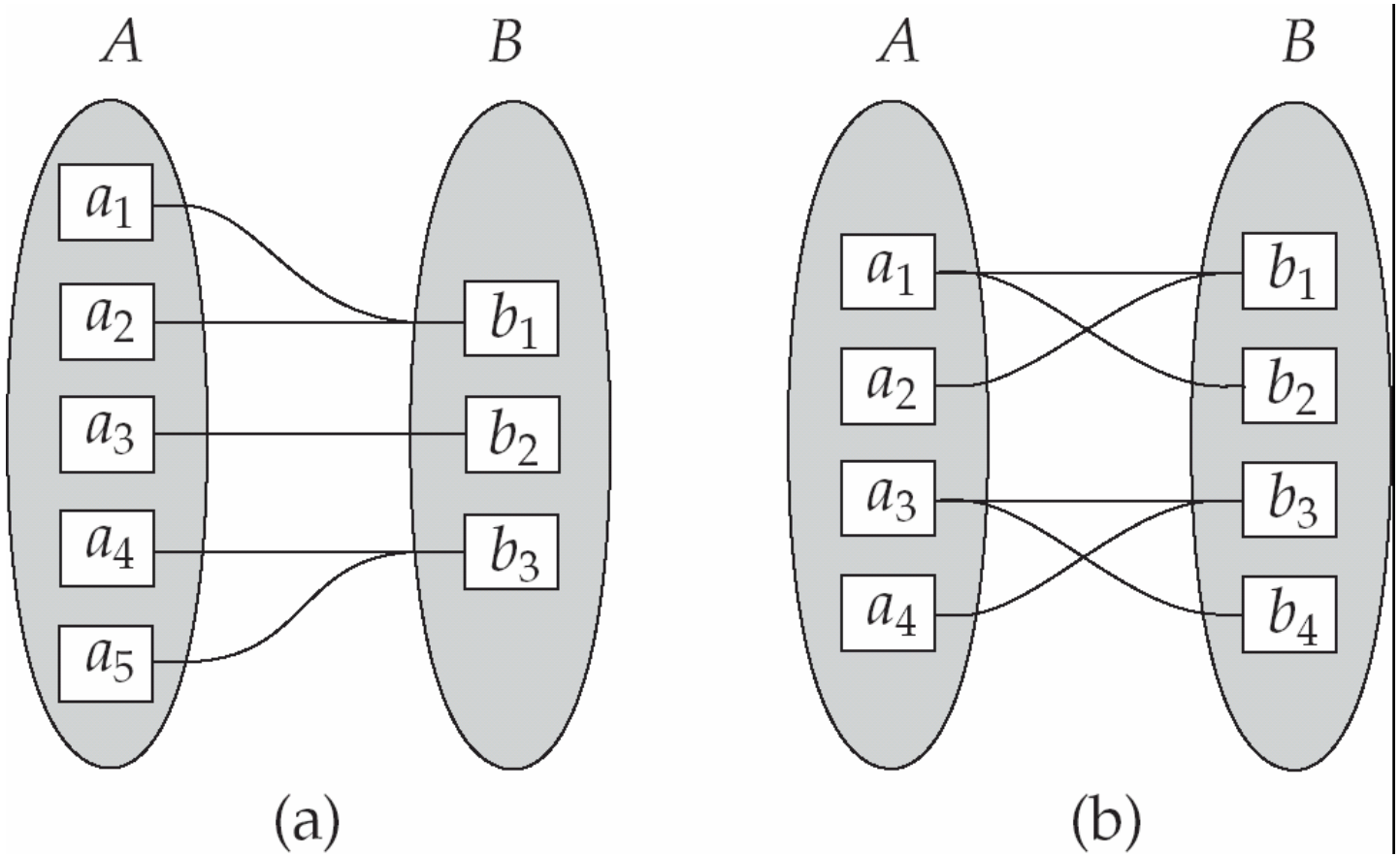


One to one



One to many

Mapping Cardinalities



Many to one

Many to many

Entity-Relationship (ER) Model

- Elements in a database: data entries
- Data entries represent
  - Entities: data objects, e.g., students, courses, and instructors
  - Relationships among entities: students take courses, instructors teach courses
- ER model: model data using entities and relationships

Object Identity and Keys

- In an application, we need to uniquely identify a natural object, and a natural relationship among multiple objects
  - Student: name, address, phone number
  - Course: name, instructor, time
  - Student-take-course: student-id, course-id
- The identities are modeled as keys

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 a candidate key of customer
  - account_number is a candidate key of account
- 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
- Need to consider the semantics of relationship set in selecting the primary key if more than one candidate key is feasible

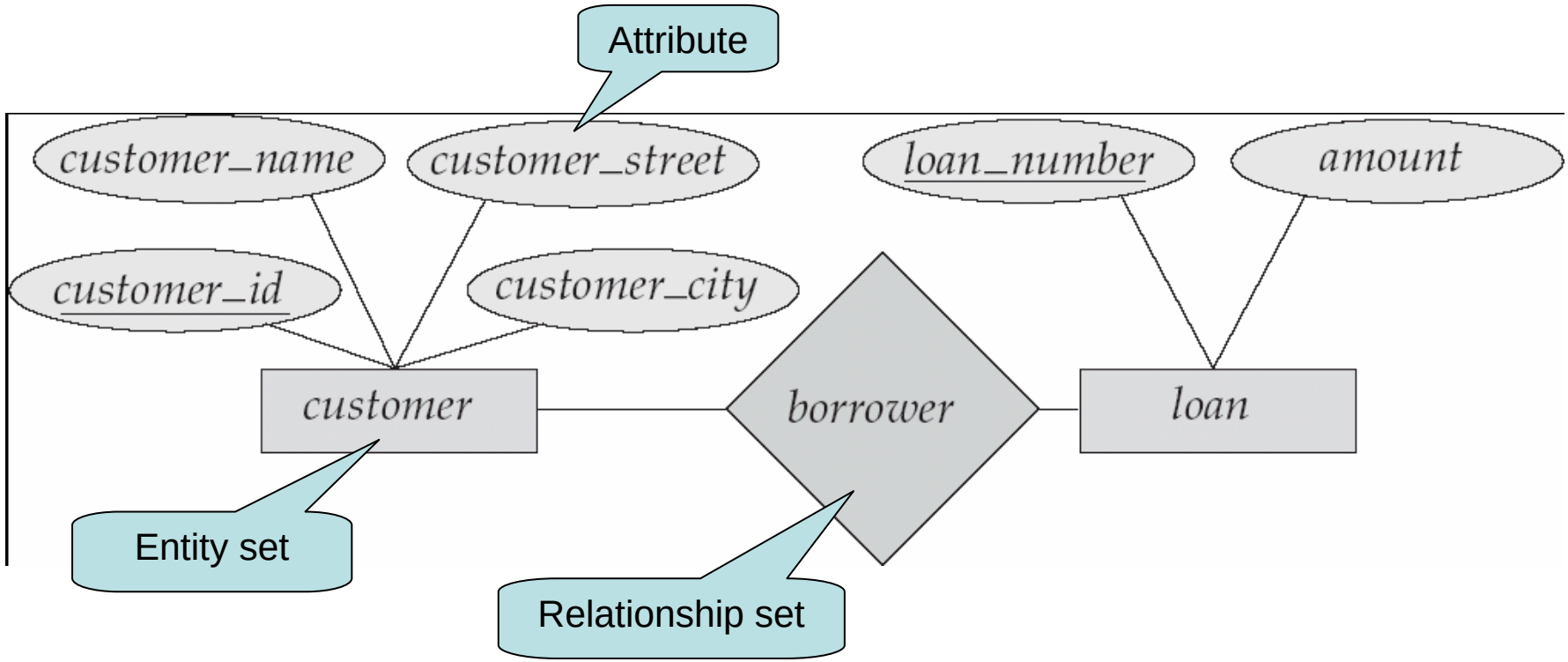
Keys and Mapping Cardinality

- One to one relationship set
  - Use a candidate key in either entity set
  - University-president (university, president)
- Many to one relationship set
  - Use a candidate key in the many side entity set
  - Teaching (instructor, courses)
- Many to many relationship set
  - Use a candidate key in each participating entity set
  - Take-course (student, course)

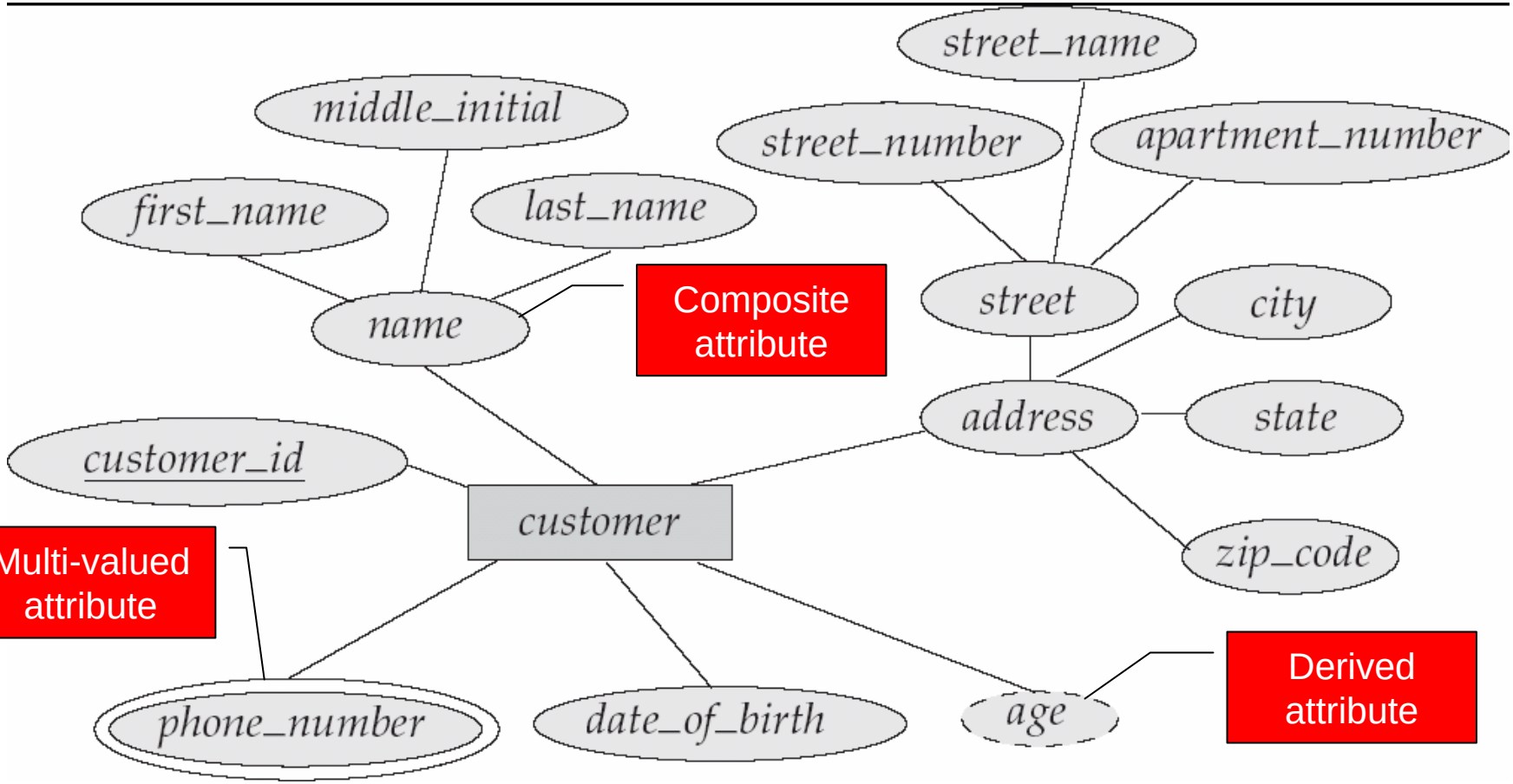
E-R Diagrams

- 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

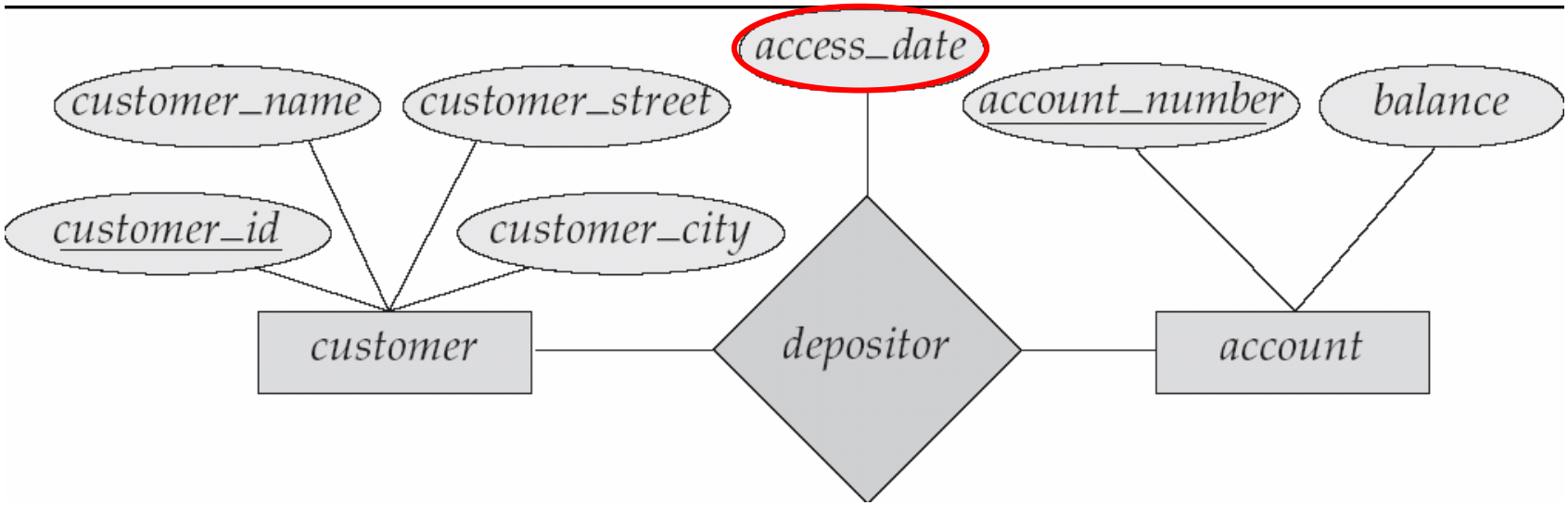
Example


Attribute
customer_name
customer_street
loan_number
amount
customer_id
customer_city
customer
borrower
loan
Entity set
Relationship set

A More Complicated Example



Relationship Sets with Attributes



Summary

- Model real world data using entities and relationships
- The ER model
- ER diagrams
  - Entities, relationships, attributes
  - Constraints, keys, cardinalities

To-Do-List

- Examine the tables in the TPC data set used in assignment 1. Can you guess for each table whether it models an entity set or a relationship set?