Database Management Systems

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Overview

- Conceptual Data Modeling/Schema in Organization
  - Entity Description
  - Modeling Business Rules
  - E-R Model Constructs
    - Modeling ENTITIES
    - Modeling ATTRIBUTES
    - Modeling RELATIONSHIPS
    - Modeling CARDINALITIES
  - Examples
  - Case Study: Pine Valley Furniture Company

E-R Model Overview

- The E-R model is a data model that describes relationships (1:1, 1:M, M:M) among entities at the conceptual level with the help of E-R diagrams

- E-R diagram is a diagram that shows the E-R model's entities, attributes, relations, connectivities and cardinalities
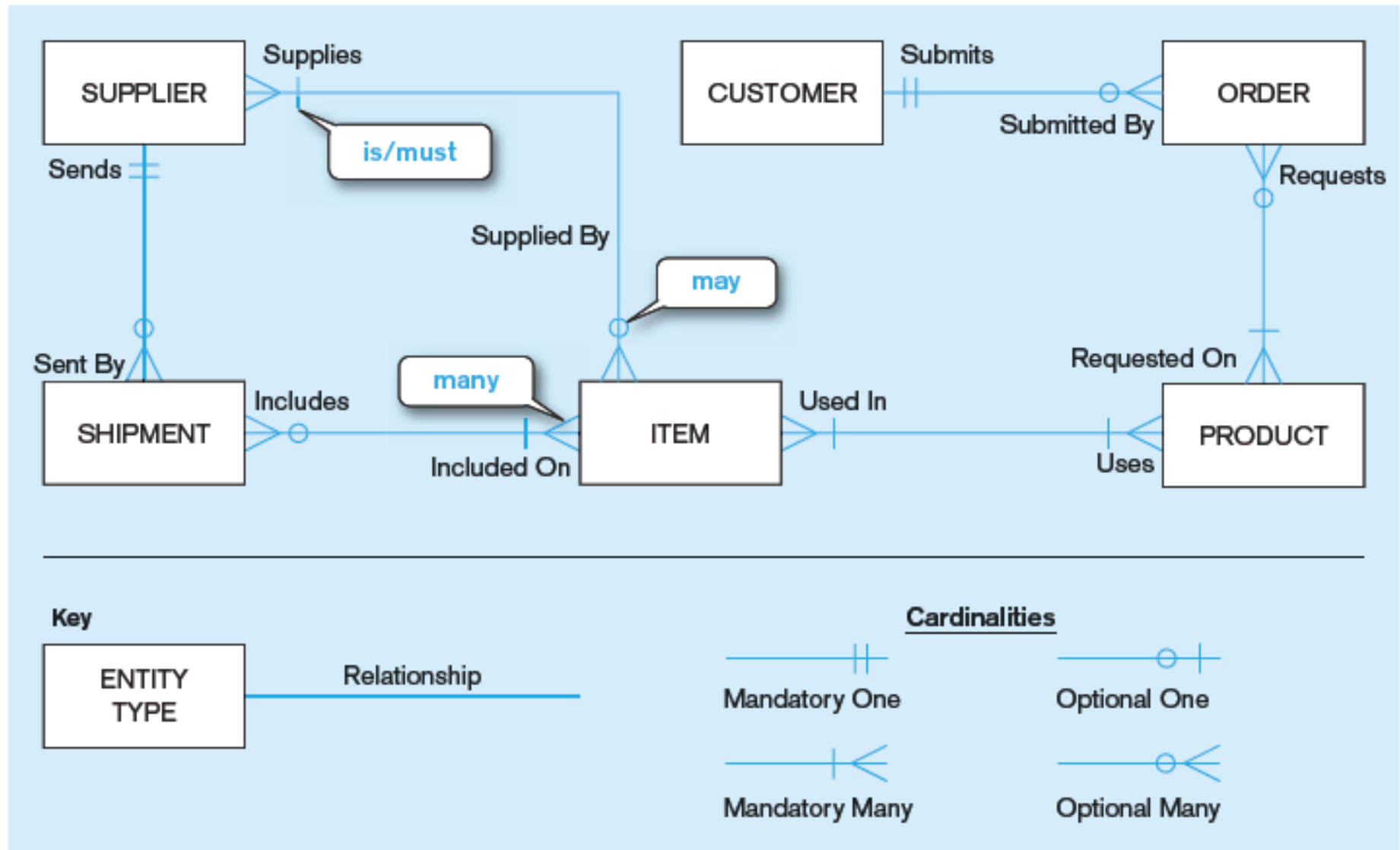
Example E-R Diagram
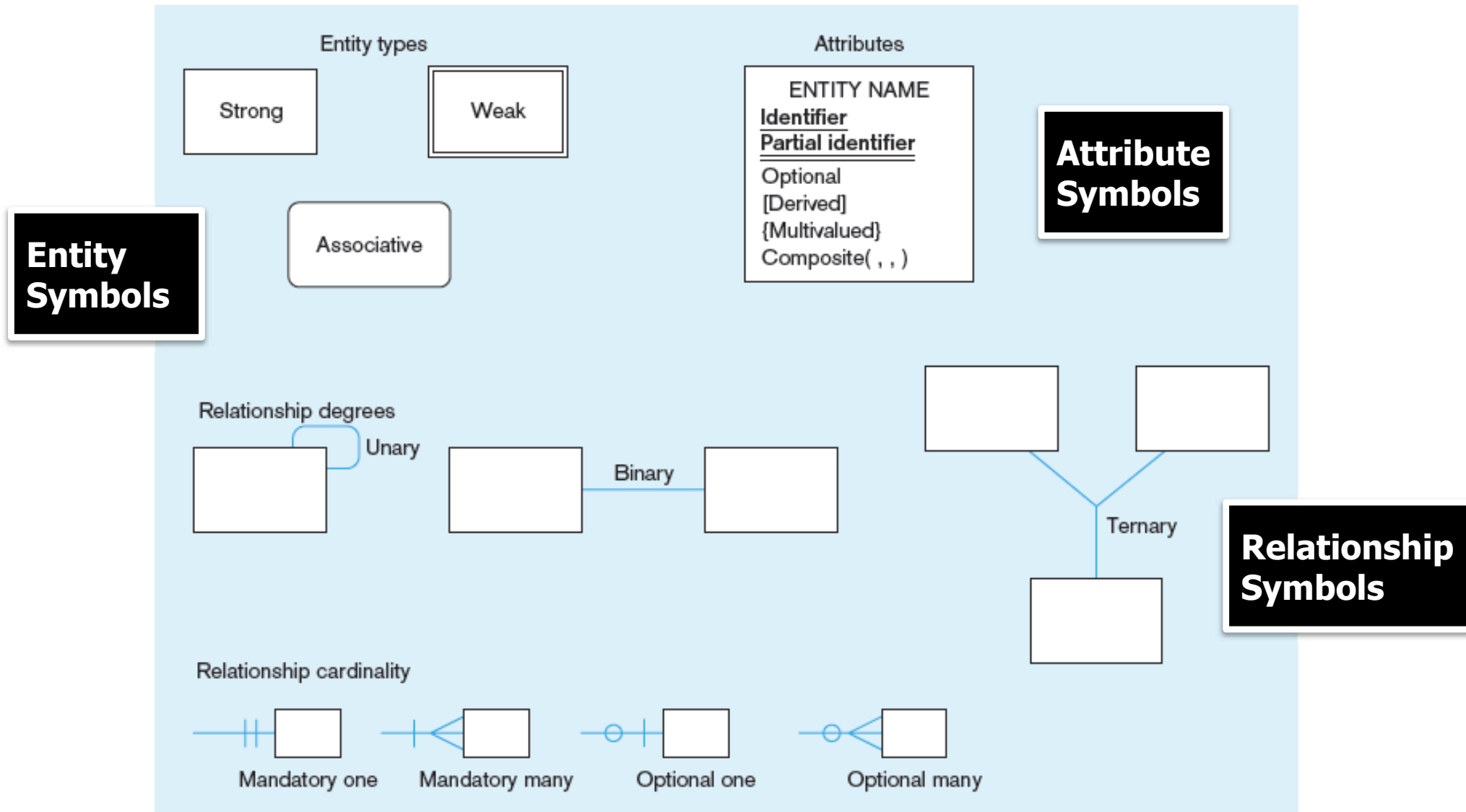

Figure 2-1: Sample E-R Diagram

Basic E-R Notation

Figure 2-2: Basic E-R Notation

Example ERD Entity Description

CUSTOMER	A person or an organization that has ordered or might order products. *Example*: L. L. Fish Furniture.
PRODUCT	A type of furniture made by Pine Valley Furniture that may be ordered by customers. Note that a product is not a specific bookcase, because individual bookcases do not need to be tracked. *Example*: A 6-foot, 5-shelf, oak bookcase called O600.
ORDER	The transaction associated with the sale of one or more products to a customer and identified by a transaction number from sales or accounting. *Example*: The event of L. L. Fish buying one product O600 and four products O623 on September 10, 2010.
ITEM	A type of component that goes into making one or more products and can be supplied by one or more suppliers. *Example*: A 4-inch ball-bearing caster called I-27–4375.
SUPPLIER	Another company that may provide items to Pine Valley Furniture. *Example*: Sure Fasteners, Inc.
SHIPMENT	The transaction associated with items received in the same package by Pine Valley Furniture from a supplier. All items in a shipment appear on one bill-of-lading document. *Example*: The receipt of 300 I-27-4375 and 200 I-27-4380 items from Sure Fasteners, Inc., on September 9, 2010.

Example ERD Business Rules

1. A SUPPLIER <u>may</u> supply <u>many</u> ITEMs (by "may supply," we mean the supplier may not supply any items). Each ITEM <u>is</u> supplied by any number of SUPPLIERs (by "is supplied," we mean that the item <u>must</u> be supplied by at least one supplier). See annotations in Figure 2-1 that correspond to underlined words.

2. Each ITEM must be used in the assembly of at least one PRODUCT and may be used in many products. Conversely, each PRODUCT must use one or more ITEMs.

3. A SUPPLIER may send many SHIPMENTs. However, each shipment must be sent by exactly one SUPPLIER. Notice that sends and supplies are separate concepts. A SUPPLIER may be able to supply an item, but may not yet have sent any shipments of that item.

4. A SHIPMENT must include one (or more) ITEMs. An ITEM may be included on several SHIPMENTs.

5. A CUSTOMER may submit any number of ORDERs. However, each ORDER must be submitted by exactly one CUSTOMER. Given that a CUSTOMER may not have submitted any ORDERs, some CUSTOMERs must be potential, inactive, or some other customer possibly without any related ORDERs.

6. An ORDER must request one (or more) PRODUCTs. A given PRODUCT may not be requested on any ORDER, or may be requested on one or more orders.

Business Rule Grammar & Example

- Business rules roughly follows certain grammar, that is:

<entity> <minimum cardinality> <relationship> <maximum cardinality> <entity>

- Example:

<CUSTOMER> <may> <Submit> <any number> <ORDER>

Modeling Organizational Rules

- Identify and understand those rules that govern data
- Represent those rules so that they can be unambiguously understood by information systems developers and users
- Implement those rules in database technology

Business Rule

- A statement that defines or constrains some aspect of the business. It is intended to assert business structure or to control or influence the behavior of the business.

  1) A student may register for a section of a course only if he or she has successfully completed the prerequisites for that course

  2) A preferred customer qualifies for a 10 percent discount, unless he has an overdue account balance

- In the database world, it has been more common to use the related term *integrity constraint* when referring to such rules.

  - referring to maintaining valid data values and relationships in the database.-

Scope of Business Rule

- Friday is business casual dress day
  - policy
  - no impact on database.

- A student may register for a section of a course only if he or she has successfully completed the prerequisites for that course.
  - constrains the transactions processed against the database
  - causes any transaction to be rejected that attempts to register a student who does not have the necessary prerequisites

Characteristics of Good Business Rules

TABLE 2-1 Characteristics of a Good Business Rule

Characteristic	Explanation
Declarative	A business rule is a statement of policy, not how policy is enforced or conducted; the rule does not describe a process or implementation, but rather describes what a process validates.
Precise	With the related organization, the rule must have only one interpretation among all interested people, and its meaning must be clear.
Atomic	A business rule marks one statement, not several; no part of the rule can stand on its own as a rule (that is, the rule is indivisible, yet sufficient).
Consistent	A business rule must be internally consistent (that is, not contain conflicting statements) and must be consistent with (and not contradict) other rules.
Expressible	A business rule must be able to be stated in natural language, but it will be stated in a structured natural language so that there is no misinterpretation.
Distinct	Business rules are not redundant, but a business rule may refer to other rules (especially to definitions).
Business-oriented	A business rule is stated in terms businesspeople can understand, and because it is a statement of business policy, only businesspeople can modify or invalidate a rule; thus, a business rule is owned by the business.

Source: Based on Gottesdiener (1999) and Plotkin (1999).

Gathering Business Rules (1)

- Appear in descriptions of business functions, events, policies, units, stakeholders, and other objects.

- Descriptions can be found in interview notes from individual and group information systems requirements collection sessions, organizational documents (e.g., personnel manuals, policies, contracts, marketing brochures, and technical instructions)

- Identified by asking questions about the who, what, when, where, why, and how of the organization

Gathering Business Rules (2)

- Be persistent in clarifying initial statements of rules because initial statements may be vague or imprecise.

- Precise rules are formulated from an iterative inquiry process.

- Asking proper questions:
  - "Is this always true?"
  - "Are there special circumstances when an alternative occurs?"
  - "Are there distinct kinds of that person?"
  - "Is there only one of those or are there many?" and
  - "Is there a need to keep a history of those, or is the current data all that is useful?"

Data Names and Definition

- Give entities, relationships, and attributes clear and distinct names and definitions.

- Data Name:
  - Related to business, not technical (hardware or software), characteristics: e.g. Customer while File10, Bit7, etc. not good
  - Be meaningful: avoid using generic words such as has, is, or it
  - Be unique: Home Address vs. Campus Address
  - Be readable: GPA vs. Average Grade Relative To A
  - Be composed of words taken from an approved list: Cust for Customer
  - Be repeatable: Employee Birth Date and Student Birth Date
  - Follow a standard syntax.

Data Definition

- Term
  - A word or phrase that has a specific meaning for the business
  - Example: course, section, flight, reservation, passenger, rental car, etc.
  - Key words
  - Must be defined carefully & concisely
- Fact
  - An association between two or more terms
  - Example 1: A course is module of instruction in a particular subject area.
  - Example 2: A customer may request a model of car from a rental branch on a particular date.

Guidelines for Good Data Definition

- On Page: 66-67, some mentioned here
- Gathered from the same sources as all requirements for information systems
- Accompanied by diagrams (e.g. ERD)
- Stated in the singular and explain what the data is
  - Use commonly understood terms and abbreviations
  - Where, when, and how the data are created or calculated in the organization
  - Whether the data are static or changes over time
  - Whether the data are singular or plural in its atomic form
  - Who determines the value for the data
  - Who owns the data
  - Whether the data are optional or whether empty/null values are allowed
  - Whether the data can be broken down into more atomic parts or are often combined with other data into some more composite or aggregate form

Entity

- Entity – A person, place, object, event, or concept in the user environment about which the organization wishes to maintain data.

Person:	EMPLOYEE, STUDENT, PATIENT
Place:	STORE, WAREHOUSE, STATE
Object:	MACHINE, BUILDING, AUTOMOBILE
Event:	SALE, REGISTRATION, RENEWAL
Concept:	ACCOUNT, COURSE, WORK CENTER

- Entity Type – A collection of entities that share common properties or characteristics

- Entity Instance – A single occurrence of entity type

Entity Type Vs. Entity Instance

Entity type: EMPLOYEE			
Attributes	**Attribute Data Type**	**Example Instance**	**Example Instance**
Employee Number	CHAR (10)	642-17-8360	534-10-1971
Name	CHAR (25)	Michelle Brady	David Johnson
Address	CHAR (30)	100 Pacific Avenue	450 Redwood Drive
City	CHAR (20)	San Francisco	Redwood City
State	CHAR (2)	CA	CA
Zip Code	CHAR (9)	98173	97142
Date Hired	DATE	03-21-1992	08-16-1994
Birth Date	DATE	06-19-1968	09-04-1975

Figure 2-3: Entity Type EMPLOYEE with two instances

What should an Entity Be?

- SHOULD BE
  - An object that will have many instances in the database
  - An object that will be composed of multiple attributes
  - An object that we are trying to model

- SHOULD NOT BE
  - A user of the database system
  - An output of the database system (e.g. a report)

Example
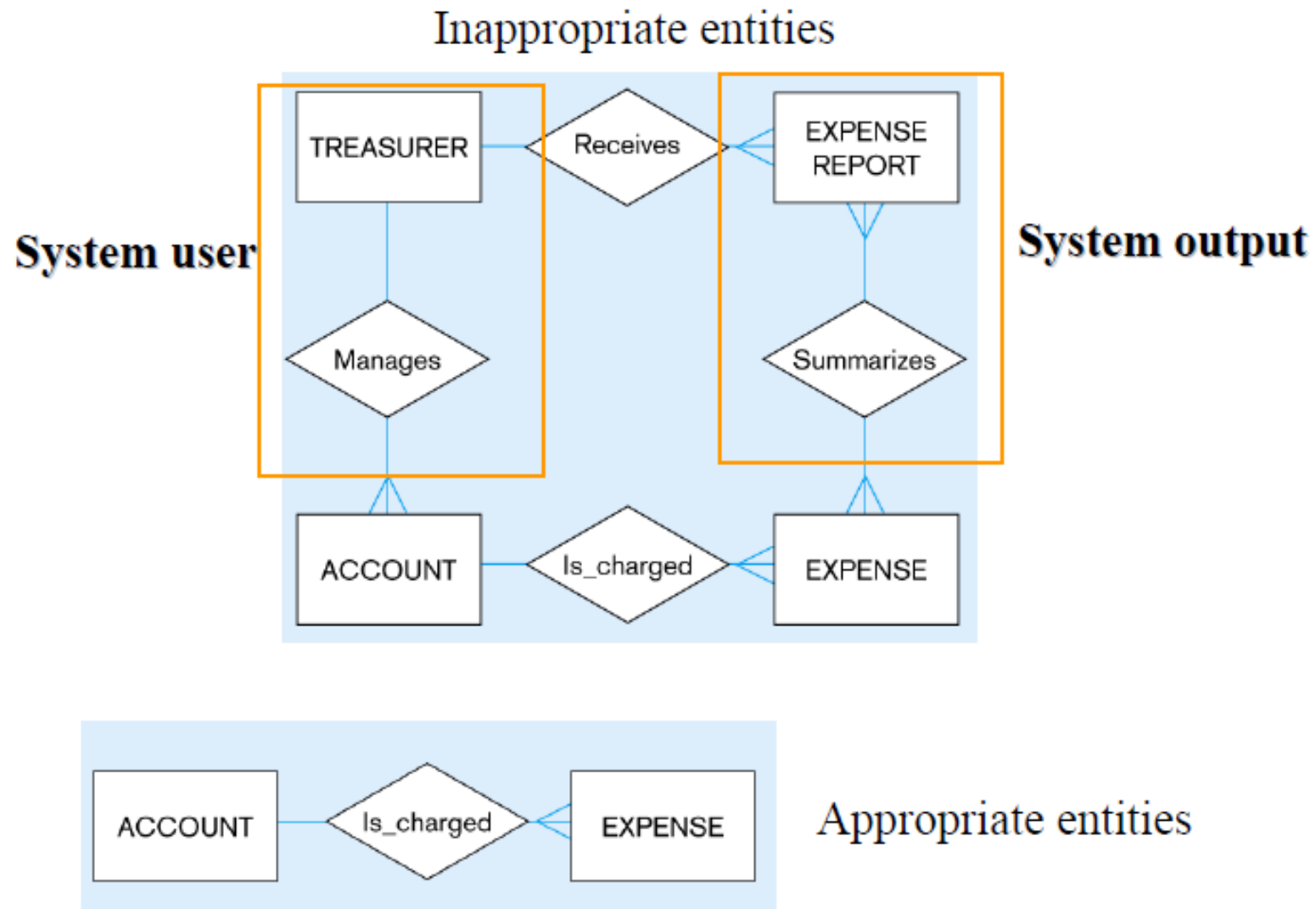
Figure 2-4: Example of Inappropriate Entities

Strong vs. Weak Entities & Identifying Relationships

- Strong Entity
  - Exists independently of other types of entities
  - Has its own unique identifier
  - Represented with single–line rectangle

- Weak Entity
  - Dependent on a strong entity… can't exist on its own
  - Does not have a unique identifier
  - Represented with double–line rectangle

- Identifying Relationship
  - Link strong entities to weak entities
  - Represented with double line diamond

Strong & Weak Entities
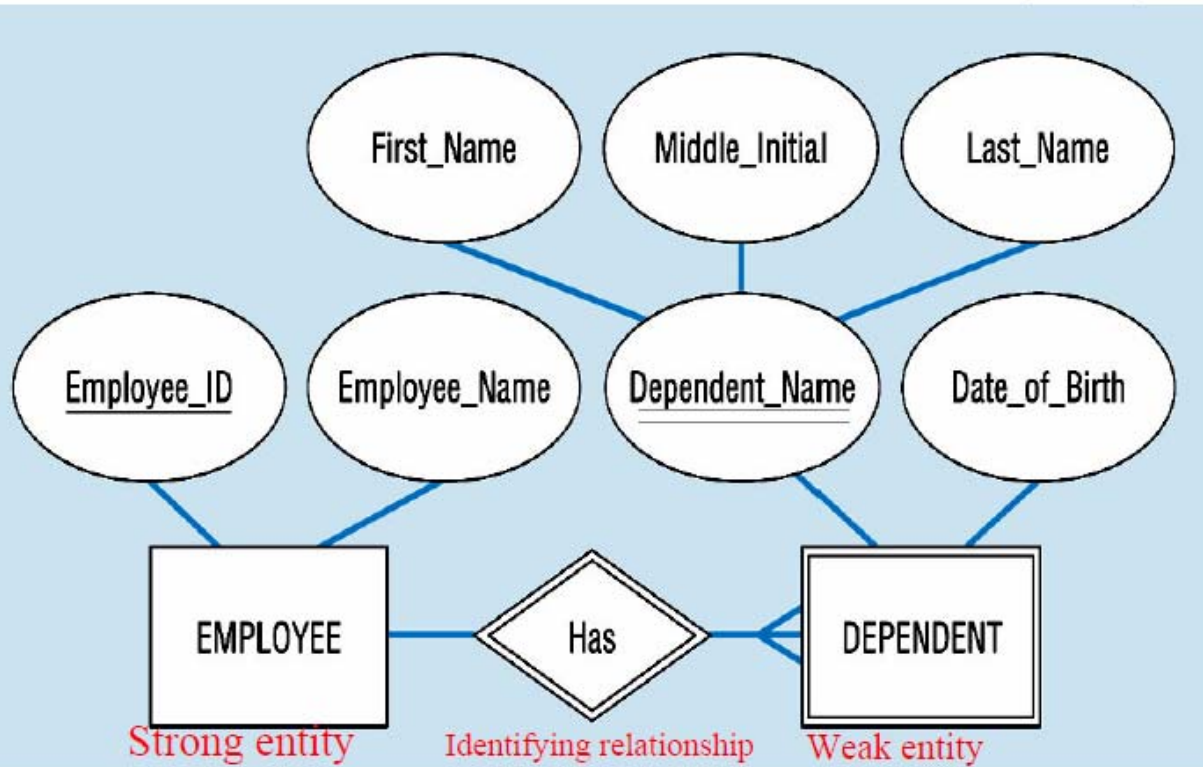
Figure 2-5: Example of Weak Entity
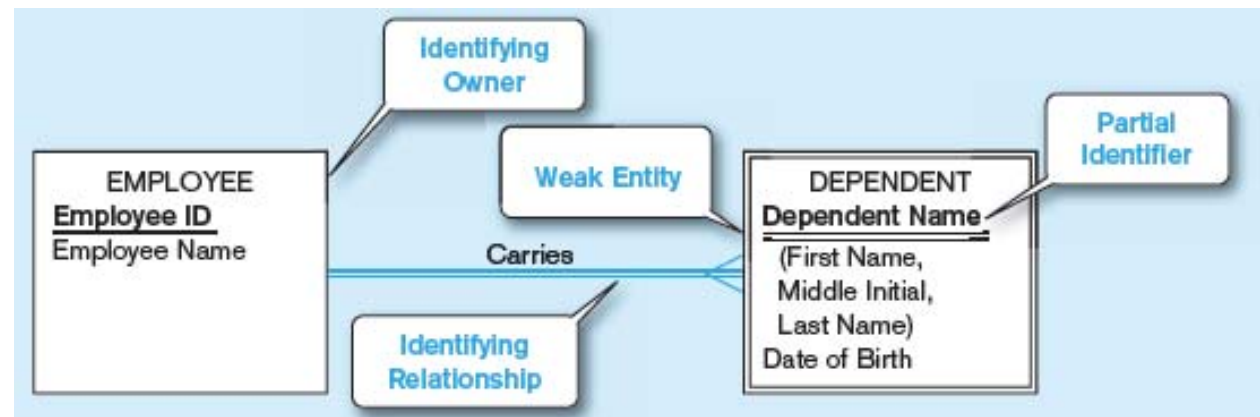
Attributes

- Attribute – A property or characteristic of an entity or relationship type that is of interest to the organization

STUDENT	Student ID, Student Name, Home Address, Phone Number, Major
AUTOMOBILE	Vehicle ID, Color, Weight, Horsepower
EMPLOYEE	Employee ID, Employee Name, Payroll Address, Skill

- Required Attribute – An attribute that must have a value for every entity (or relationship) instance with which it is associated

- Optional Attribute – An attribute that may not have a value for every entity (or relationship) instance with which it is associated

When we represent entities in a database, we actually store only the attributes.

Required & Optional Attributes

Entity type: STUDENT

Attributes	Attribute Data Type	Required or Optional	Example Instance	Example Instance
Student ID	CHAR (10)	Required	876-24-8217	822-24-4456
Student Name	CHAR (40)	Required	Michael Grant	Melissa Kraft
Home Address	CHAR (30)	Required	314 Baker St.	1422 Heft Ave
Home City	CHAR (20)	Required	Centerville	Miami
Home State	CHAR (2)	Required	OH	FL
Home Zip Code	CHAR (9)	Required	45459	33321
Major	CHAR (3)	Optional	MIS	

Figure 2-6: Entity Type STUDENT with required and optional attributes

Classification of Attributes

- Classification of attributes
    - <u>Simple</u> (e.g. age, sex, marital status) versus <u>Composite</u> (e.g. address, phone number) Attribute
    - <u>Single-Valued</u> (e.g. NIC number, serial number of a manufactured part SE-08-02-189935) versus <u>Multi- valued</u> (e.g. a house having several phones, a person having several degrees) Attribute
    - <u>Stored</u> versus <u>Derived</u> (whose values are calculated from other attributes e.g. age is current date minus DOB. In Access: INT((Date() EMP_DOB)/365)) Attributes
    - Identifier Attributes

Composite Attribute

An Attribute broken into component parts →

Address

Street_Address   City   State   Postal_Code
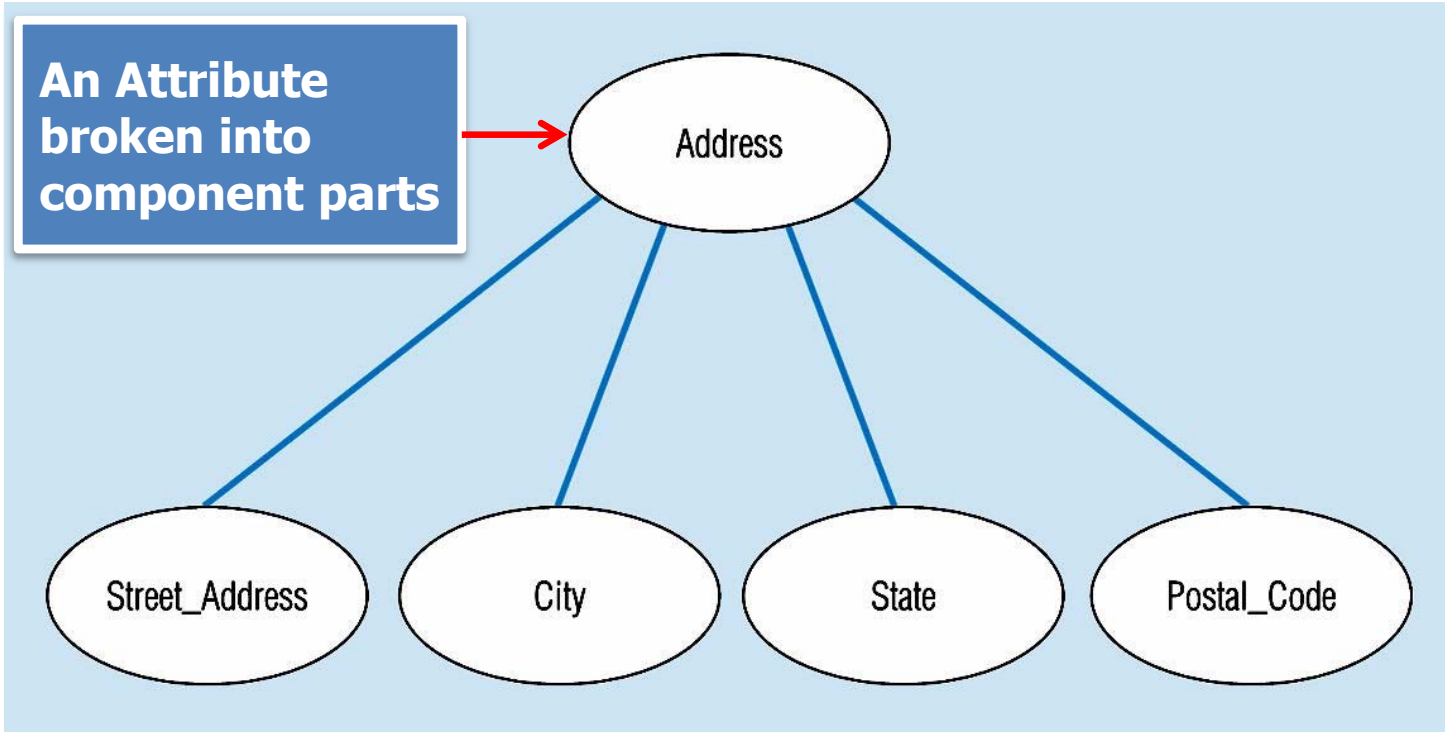
Figure 2-7: Example of Composite Attribute

EMPLOYEE
. . .
Employee Address
(Street Address, City,
State, Postal Code)
. . .

Composite Attribute

Component Attributes
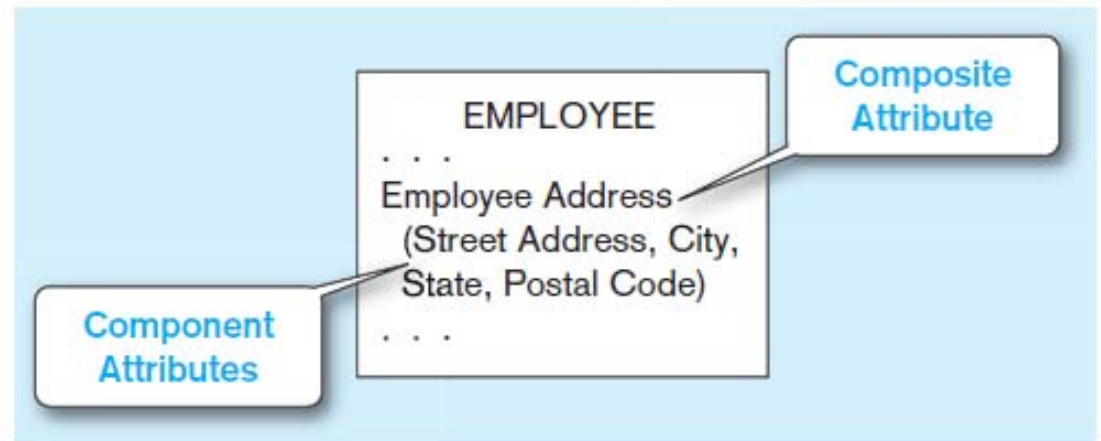
Entity with Multi-Valued & Derived Attributes

Multi-valued:
An employee can have more than one skill

Derived:
From date employed & current date

Figure 2-8: Example of Multivalued & Derived Attribute
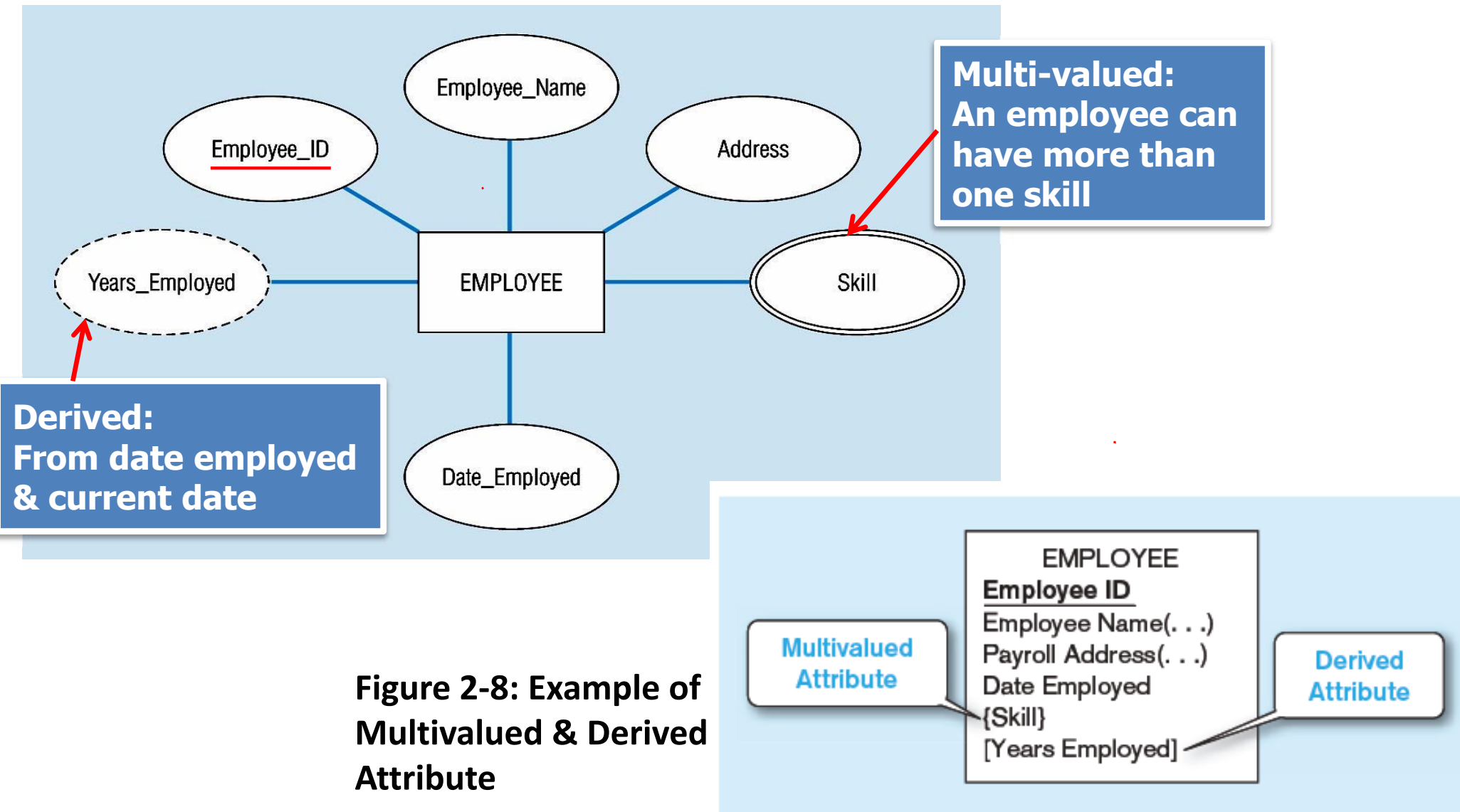
Identifiers (Keys)

- Identifier (Key) – An attribute (or combination of attributes) that uniquely identifies individual instances of an entity type

- Simple Key versus Composite Key

- Candidate Key – an attribute that could be a key... satisfies the requirements for being key

Key Attribute

Key is underlined
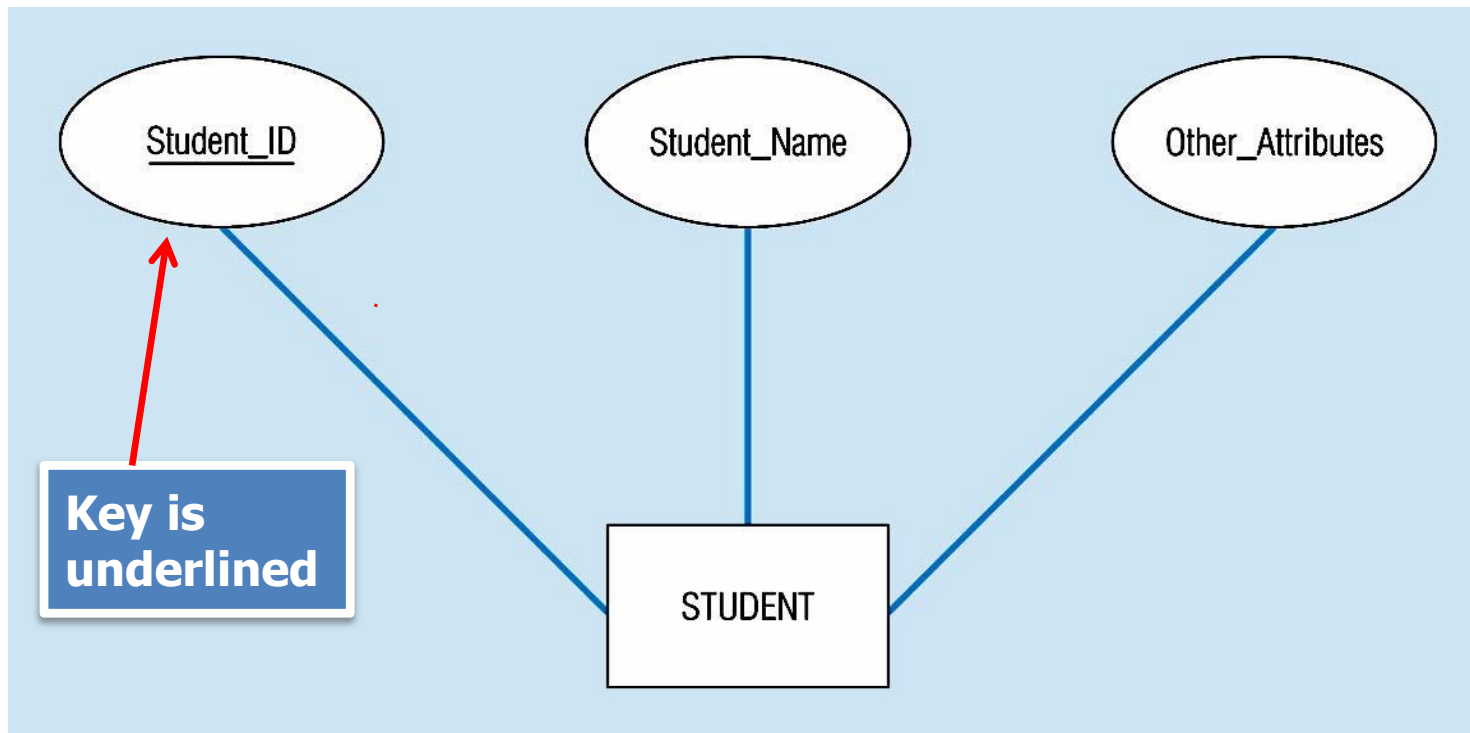
Figure 2-9a: Simple Identifier Attribute
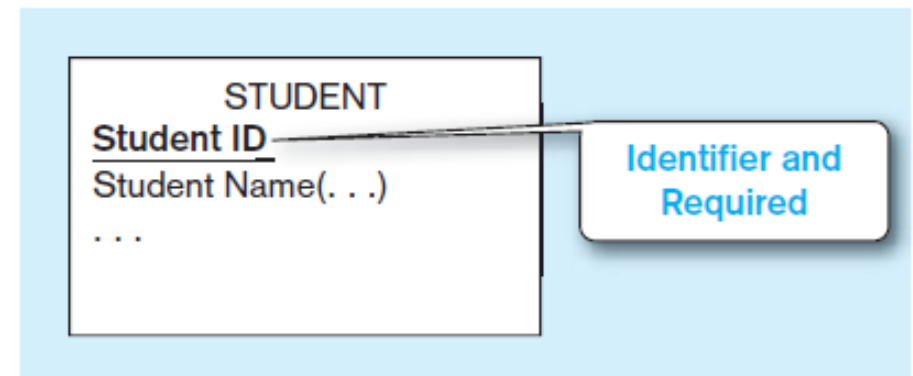
Composite Key Attribute

Key is composed of two sub-parts
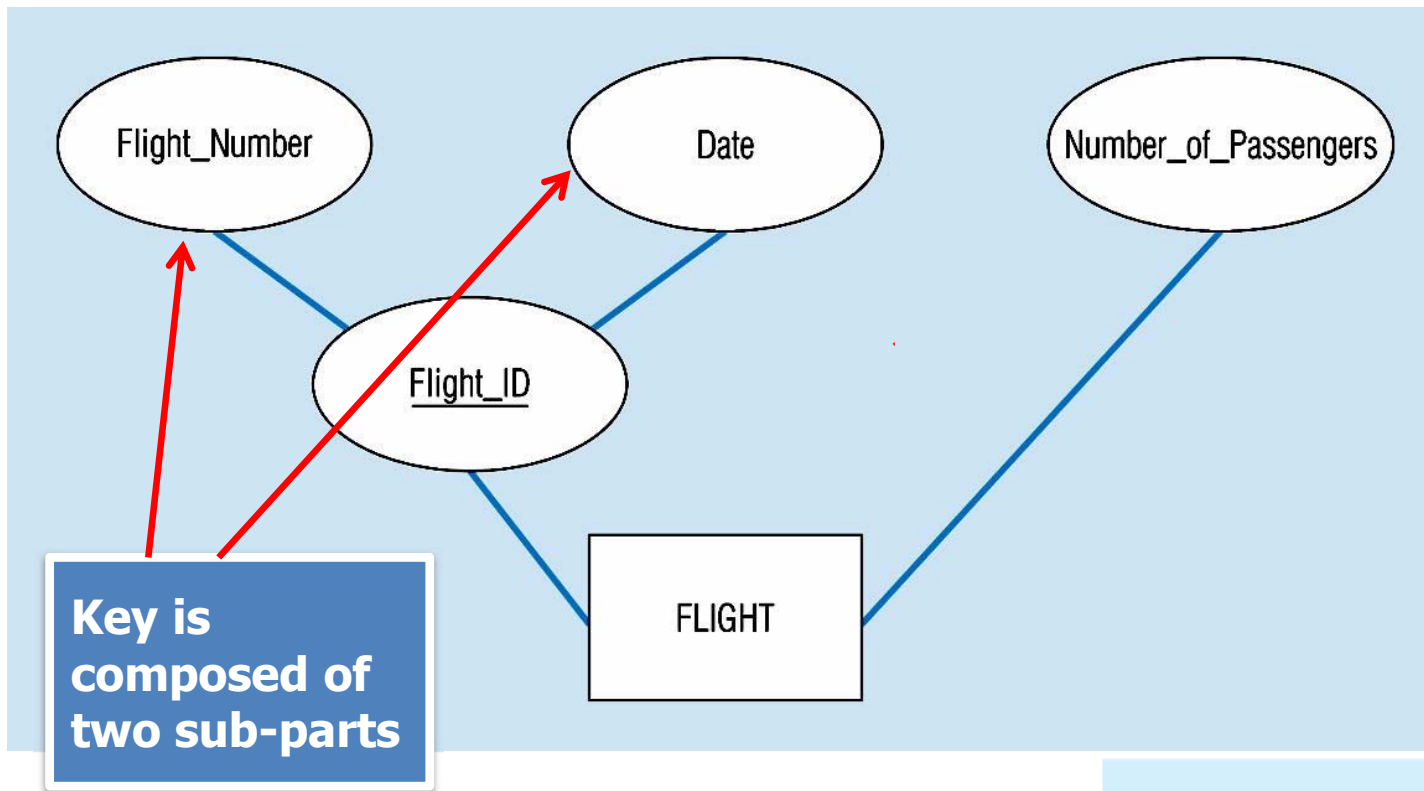
Figure 2-9b: Composite Identifier Attribute
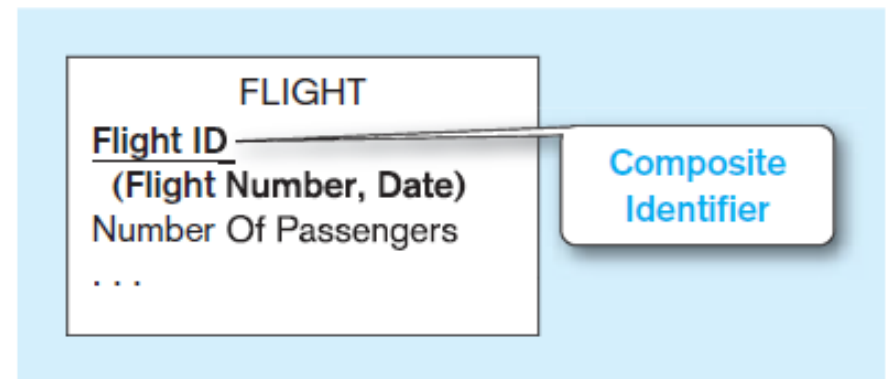
Characteristics of Identifiers

- Will not change in value

- Will not be null

- No intelligent identifier (for instance containing locations or people that might change)

- Substitute new, simple keys for long, composite keys

Relationships

- Relationship Types vs. Relationship Instances
  - The relationship type is modeled as the diamond and lines between entity types... the instance between specific entity instances

- Relationships can have attributes
  - These describes features pertaining to the association between the entities in the relationship

- Two entities can have more than one type of relationship between them (multiple relationships)

- Associative Entity – combination of relationship and entity
  - More on this later

Relationship Type
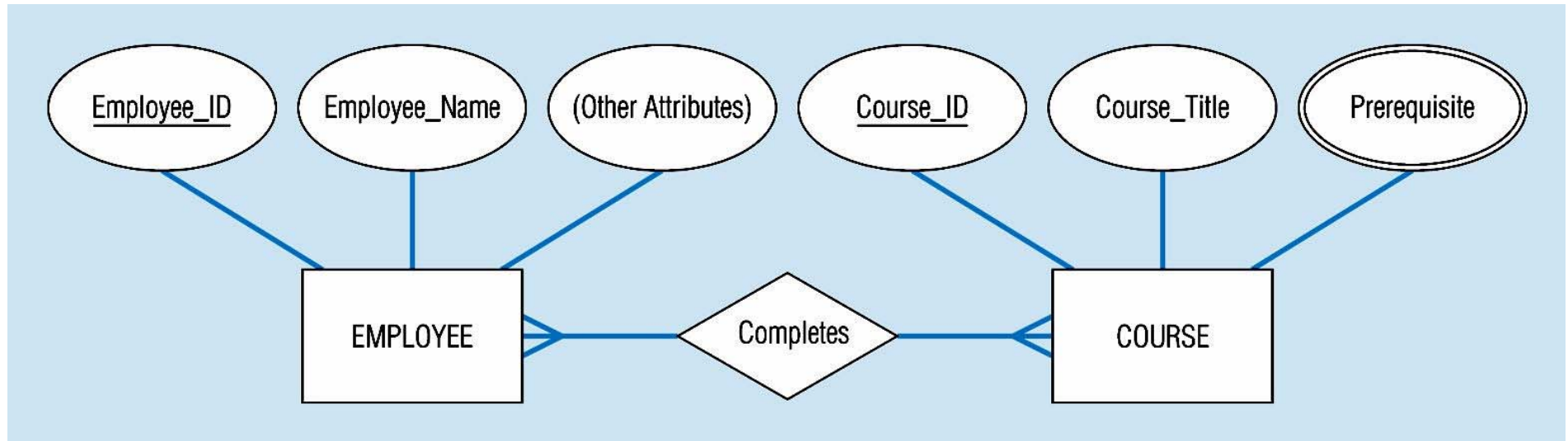
Figure 2-10a: Relationship Type

Relationship Instances
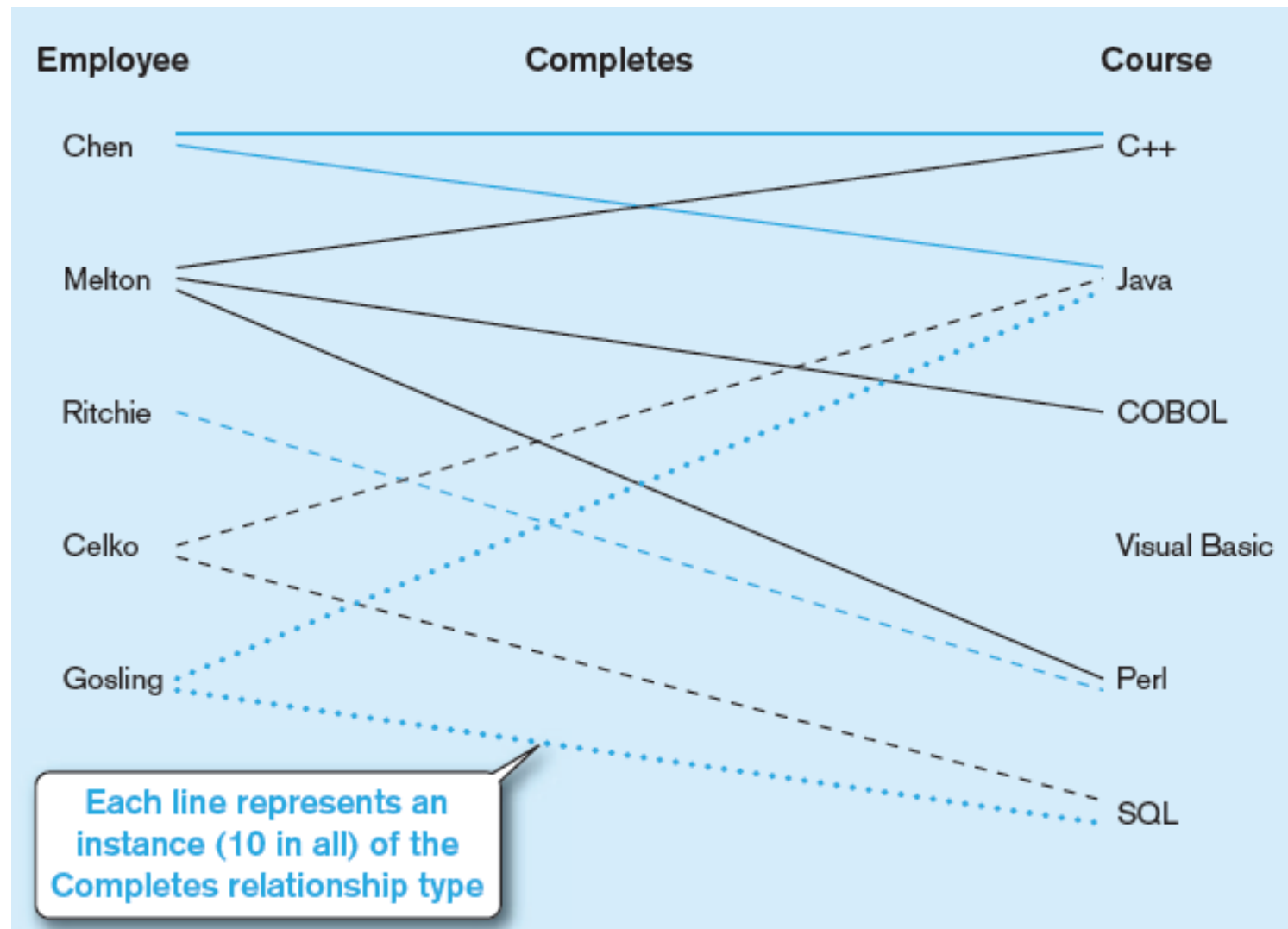
Figure 2-10b: Relationship Instances

Table 2-2

TABLE 2-2   Instances Showing Date Completed

Employee Name	Course Title	Date Completed
Chen	C++	06/2009
Chen	Java	09/2009
Melton	C++	06/2009
Melton	COBOL	02/2010
Melton	SQL	03/2009
Ritchie	Perl	11/2009
Celko	Java	03/2009
Celko	SQL	03/2010
Gosling	Java	09/2009
Gosling	Perl	06/2009

Binary Relationship with an Attribute
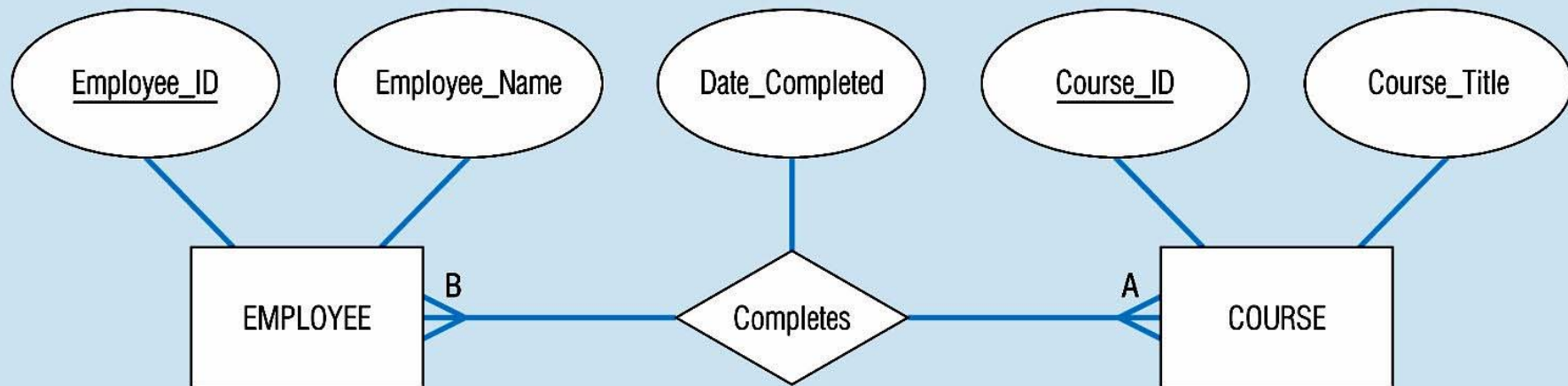
Figure 2-11a: Attribute on a Relationship
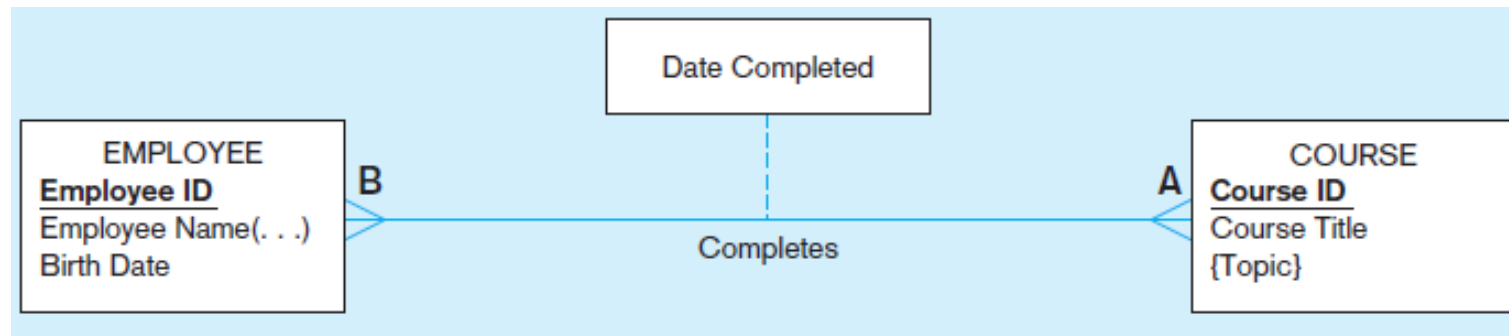
Here date_completed attribute pertains specifically to the employee's completion of a course... it is an attribute of the *relationship*

Associative Entities

- It's an entity – it has attributes

- And it's a relationship – it links entities together

- When should a relationship with attributes instead be an associative entity?
  - All relationships for the associative entity should be many
  - The associative entity could have meaning independent of the other entities
  - The associative entity preferably has a unique identifier, and should also have other attributes
  - The associative may be participating in other relationships other than the entities of the associated relationship
  - Ternary relationships should be converted to associative entities

An Associative Entity (Certificate)
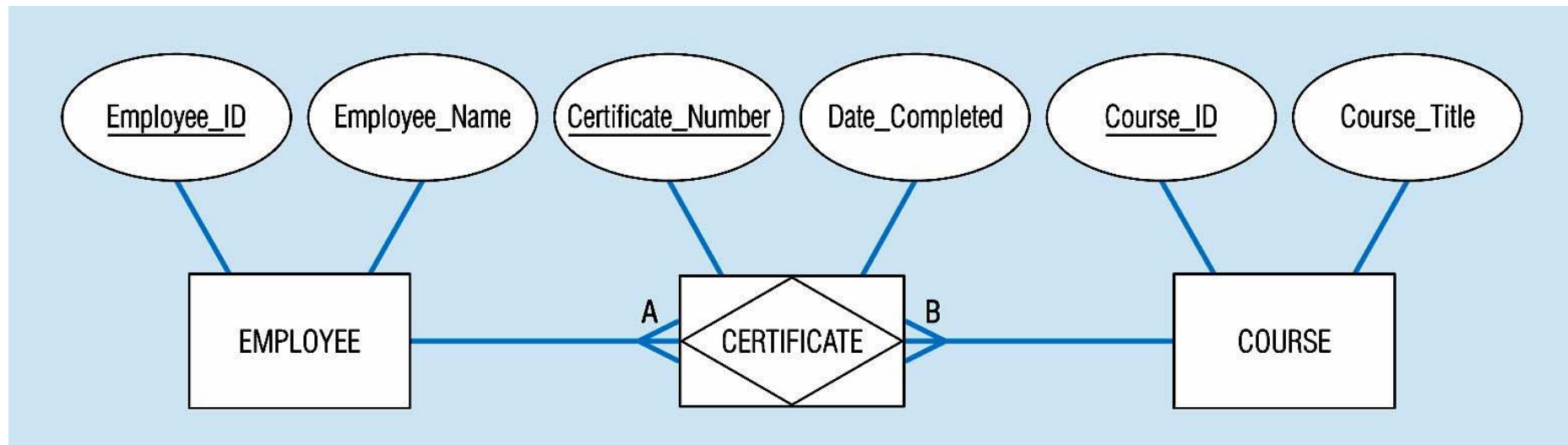
Figure 2-11b: Associative Entity

Associative entity involves a rectangle with a diamond inside. Note that the many-to-many cardinality symbols face toward the associative entity and not toward the other entities.

Degree of Relationships

- Degree of Relationship – The number of entity types that participate in a relationship
  - Unary Relationship
  - Binary Relationship
  - Ternary Relationship

Degree of Relationships

Relationship degree

Unary

Binary

Ternary

One entity related to another of the same entity type.

Entity of two different types related to each other.

Entity of three different types related to each other.
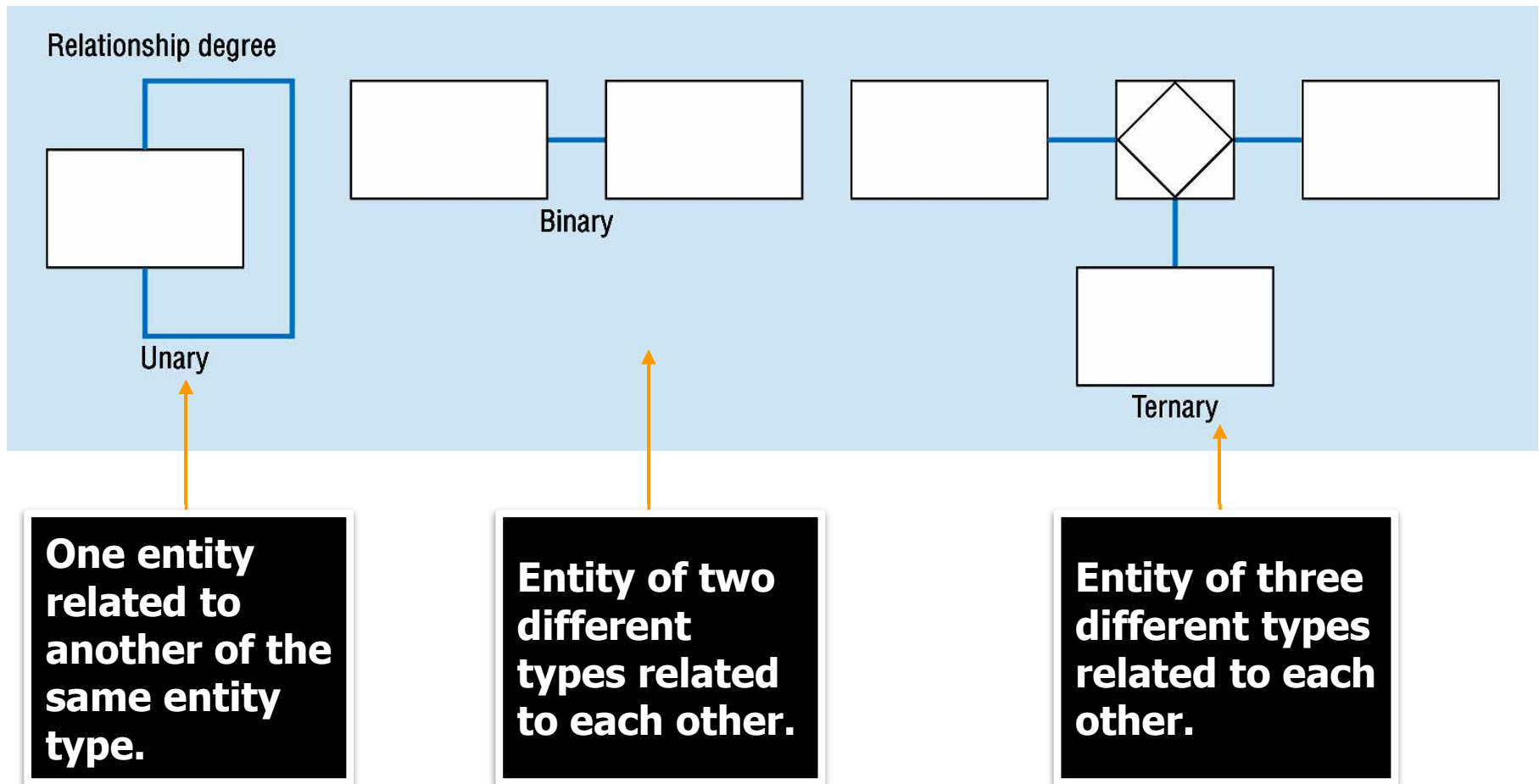
Unary Relationships

Figure 2-12a: Unary Relationships
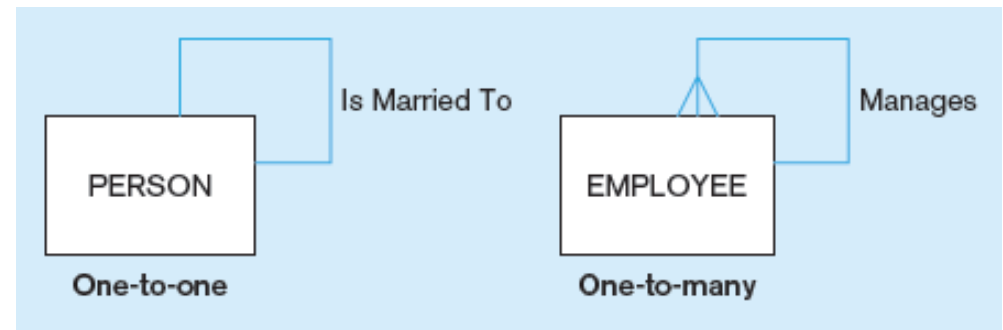
Unary Relationship with an Attribute

Unary relationship with an attribute (many-to-many relationship)

Representing a bill– of –material structure
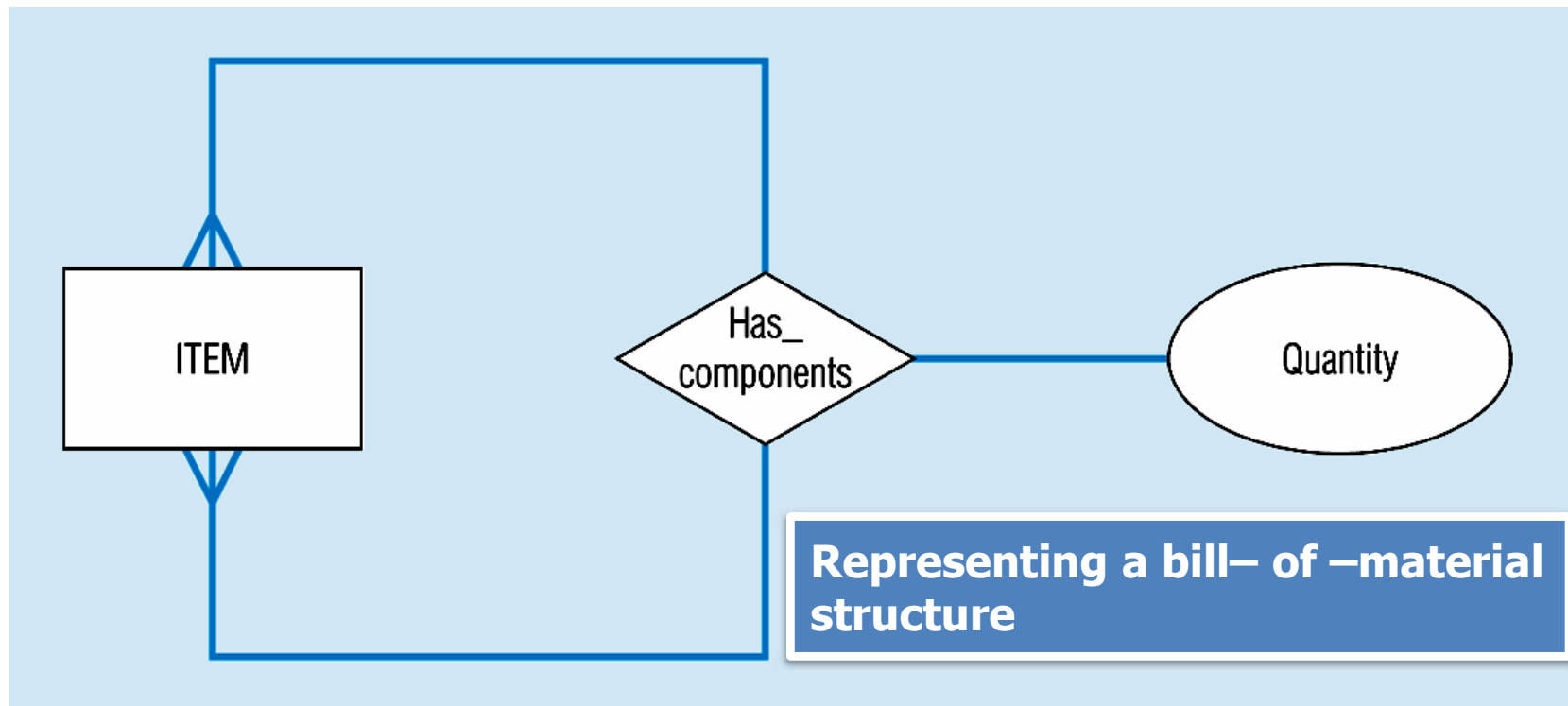
Figure 2-13a: Unary M:M Relationship

Example
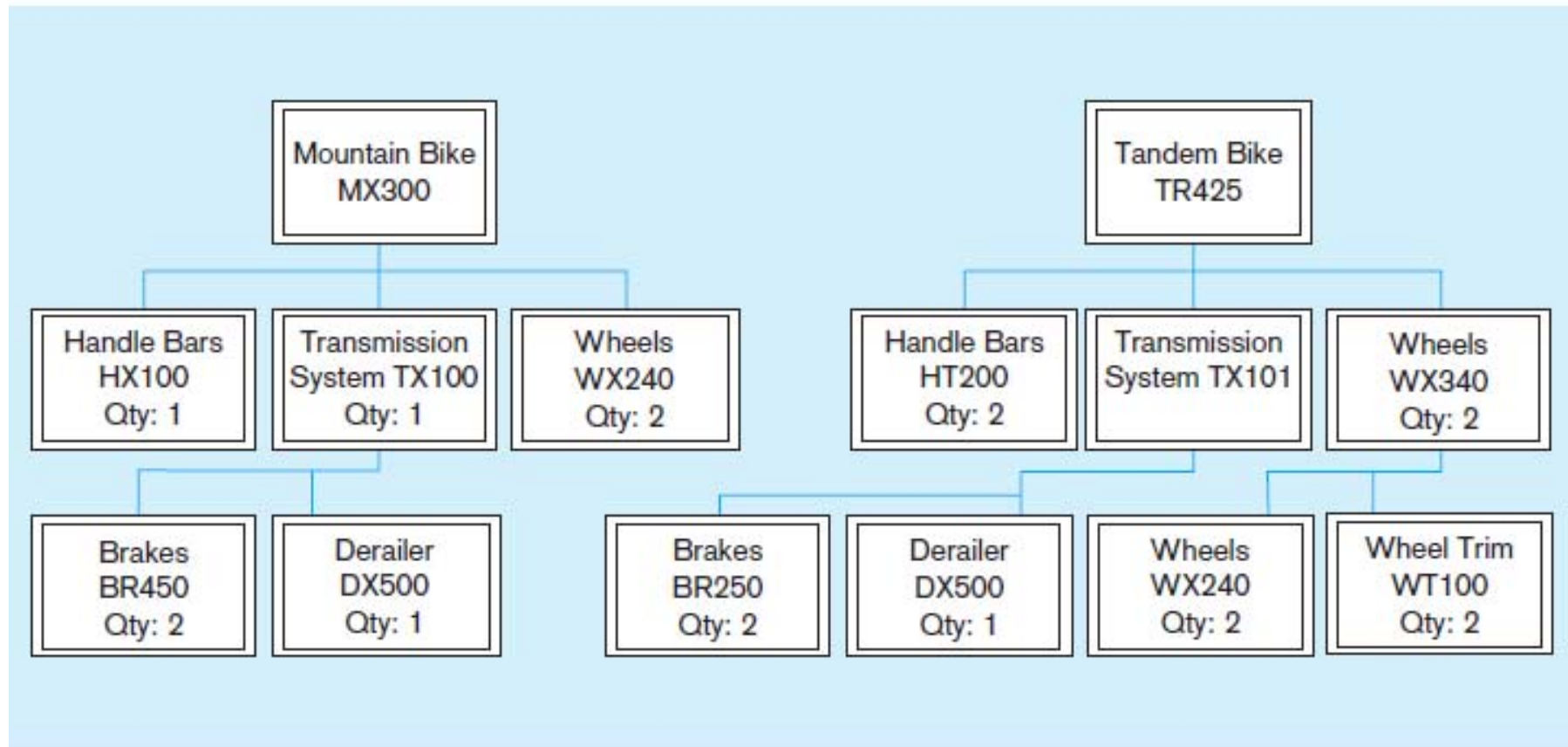
Figure 2-13b: Two ITEM bill-of-materials structure instances

An Associative Entity (Bill of Material Structure)
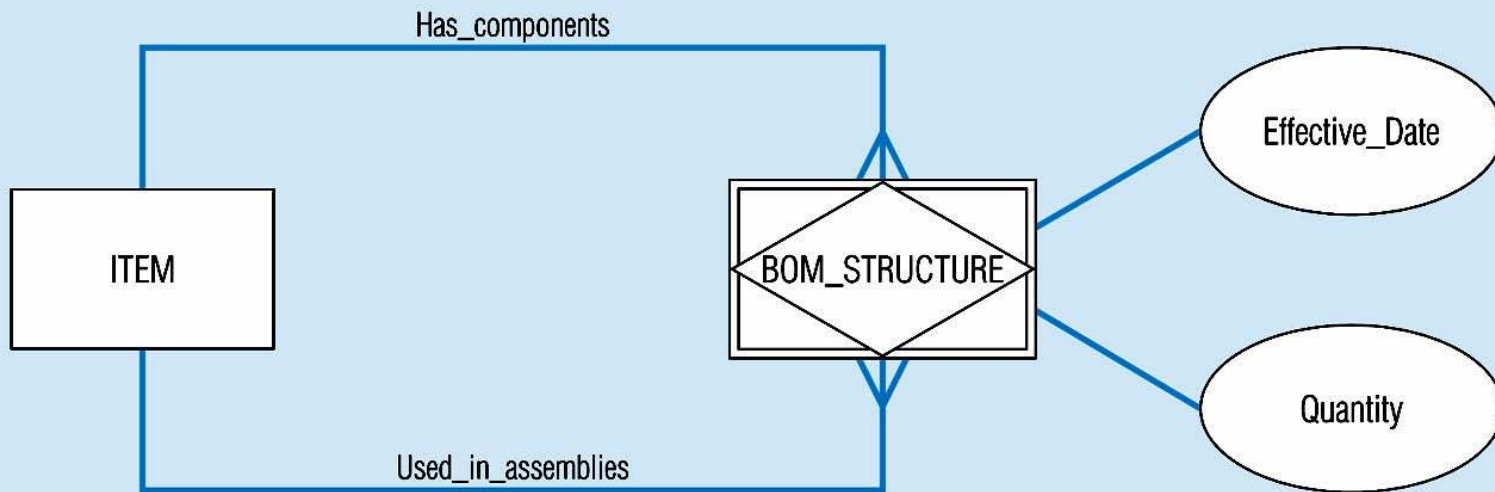
Figure 2-13c: An Associative Entity
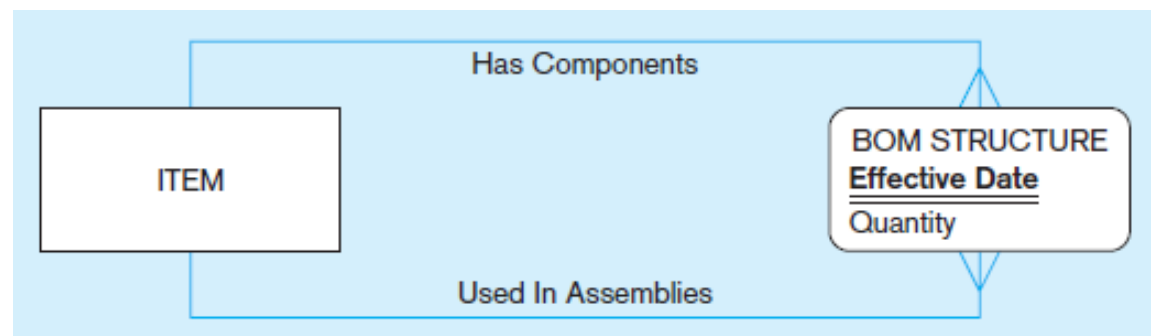
This could just be a relationship with attributes... it's a judgment call

Binary Relationships
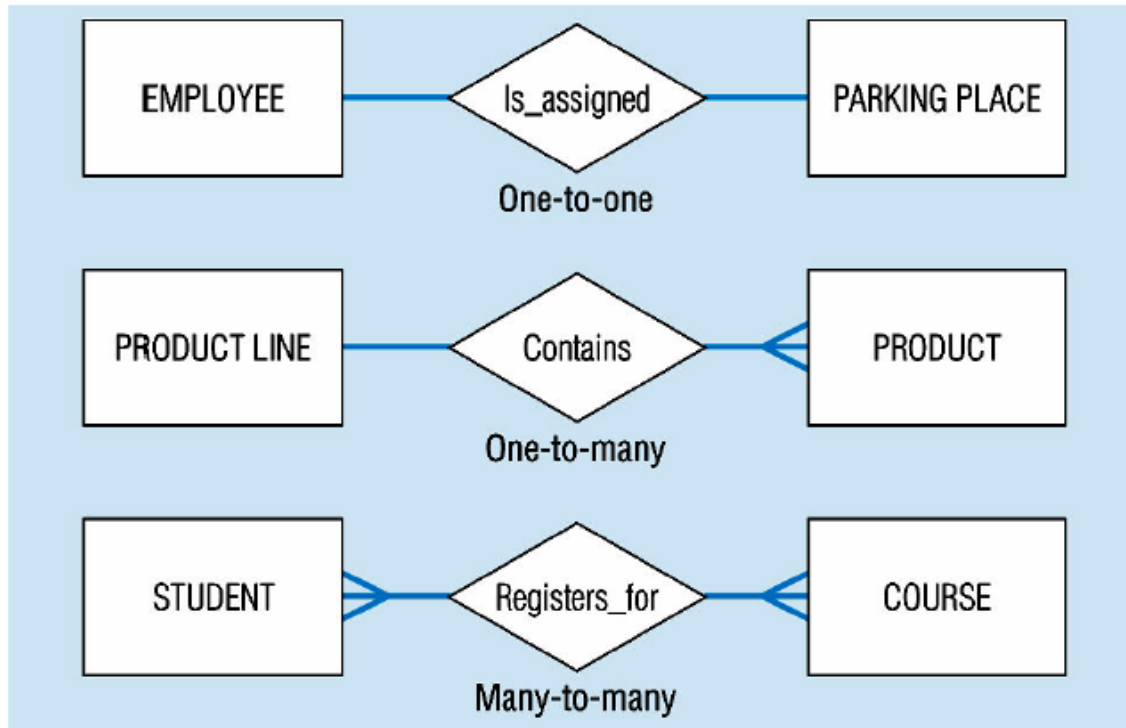
Figure 2-12b: Binary Relationships
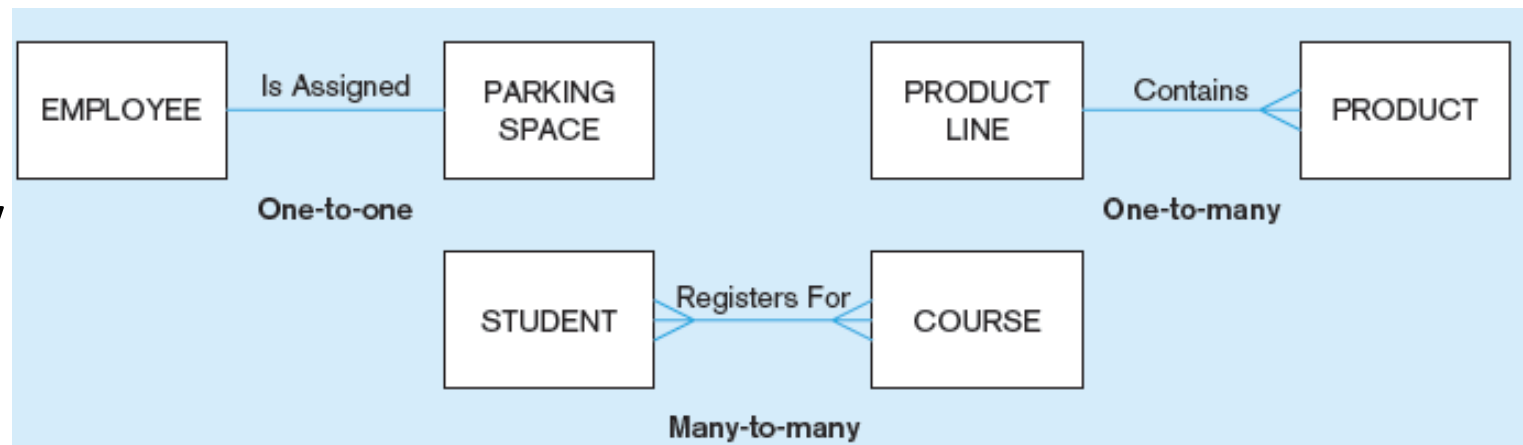
Ternary Relationships
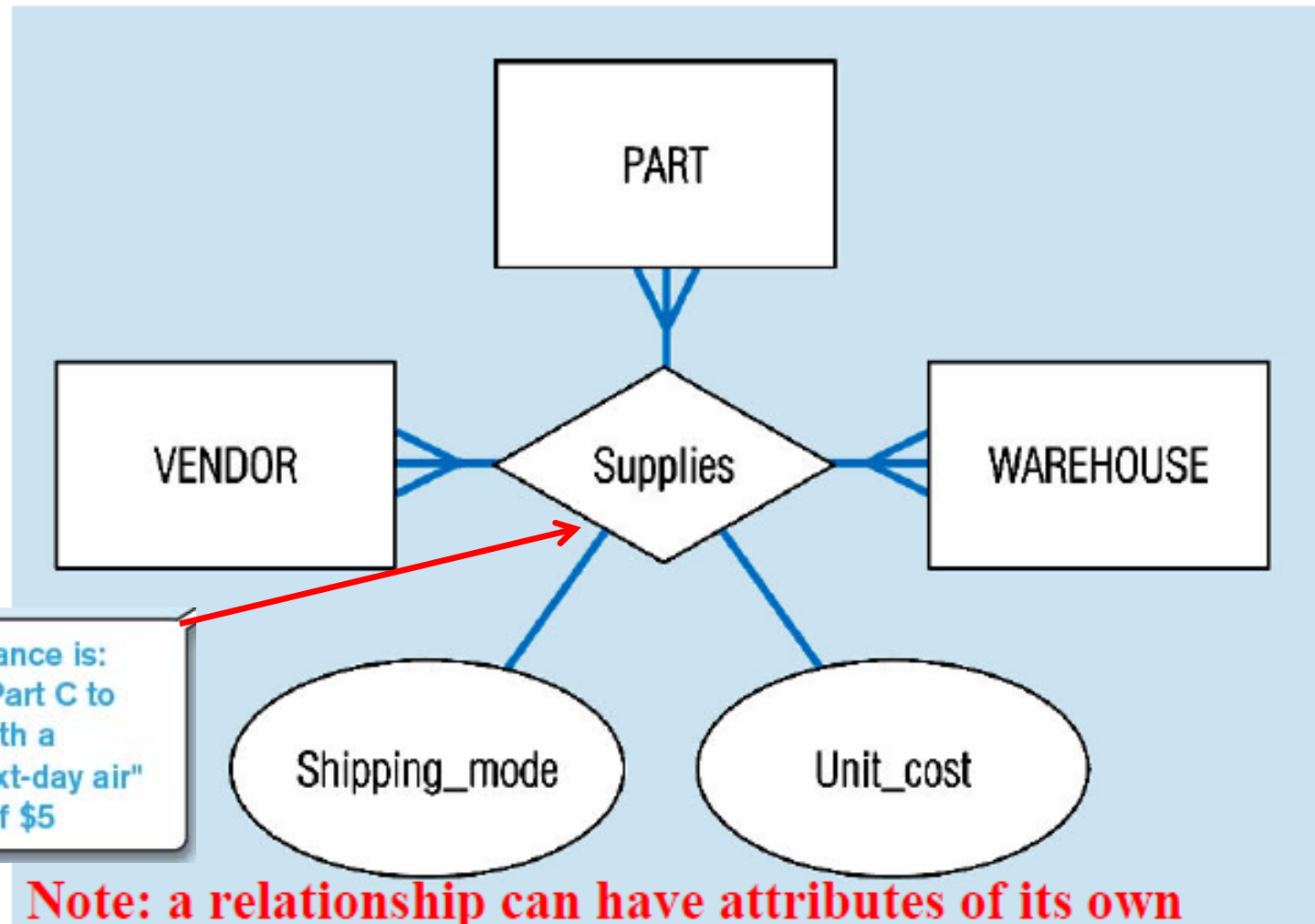
Figure 2-12c: Ternary Relationship

Cardinality of Relationships

- Cardinality Constraints - the number of instances of one entity that can or must be associated with each instance of another entity.

- Minimum Cardinality
  - If zero, then optional
  - If one or more, then mandatory

- Maximum Cardinality
  - The maximum number

Cardinality of Relationships

- ## One-to-One
  - Each entity in the relationship will have exactly one related entity

- ## One-to-Many
  - An entity on one side of the relationship can have many related entities, but an entity on other side will have a maximum of one related entity

- ## Many-to-Many
  - Entities on both sides of the relationship can have many related entities on the other side

Cardinality
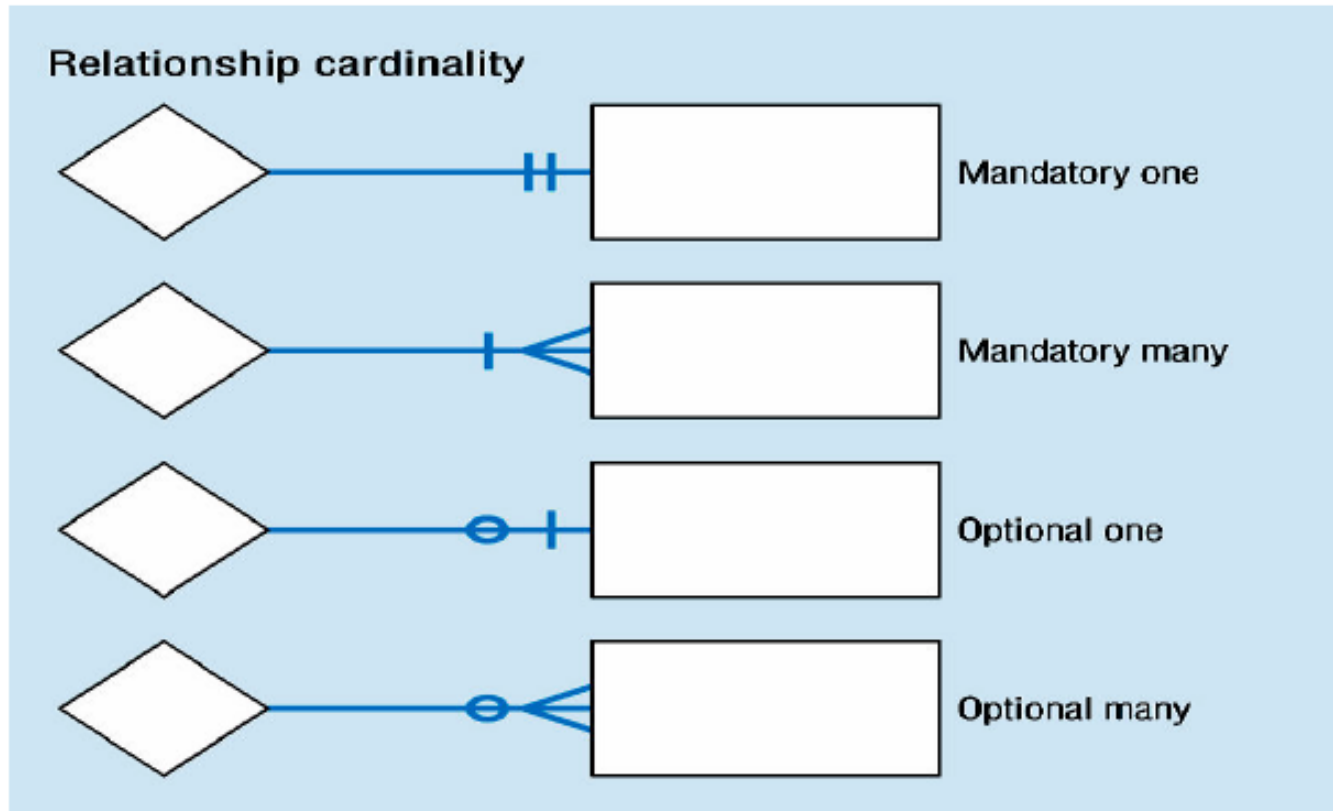
Minimum & Maximum Cardinalities Example

Basic relationship with only maximum cardinalities:
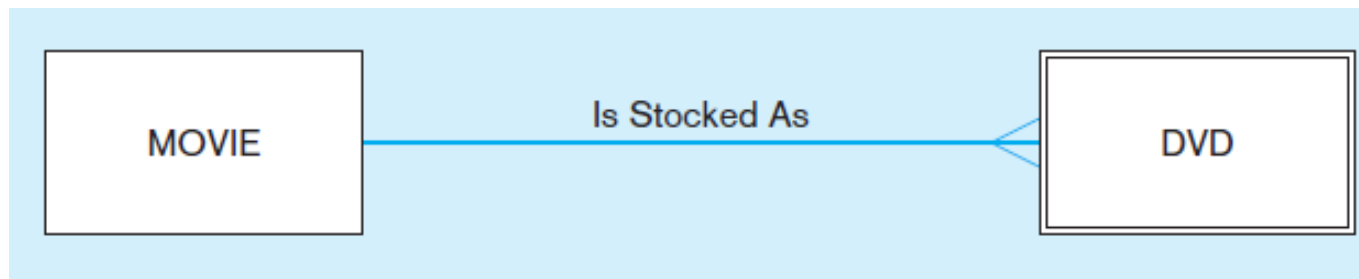
Relationship with cardinality constraints:

Figure 2-16: Cardinality Constraints

Example of Cardinality Constraints
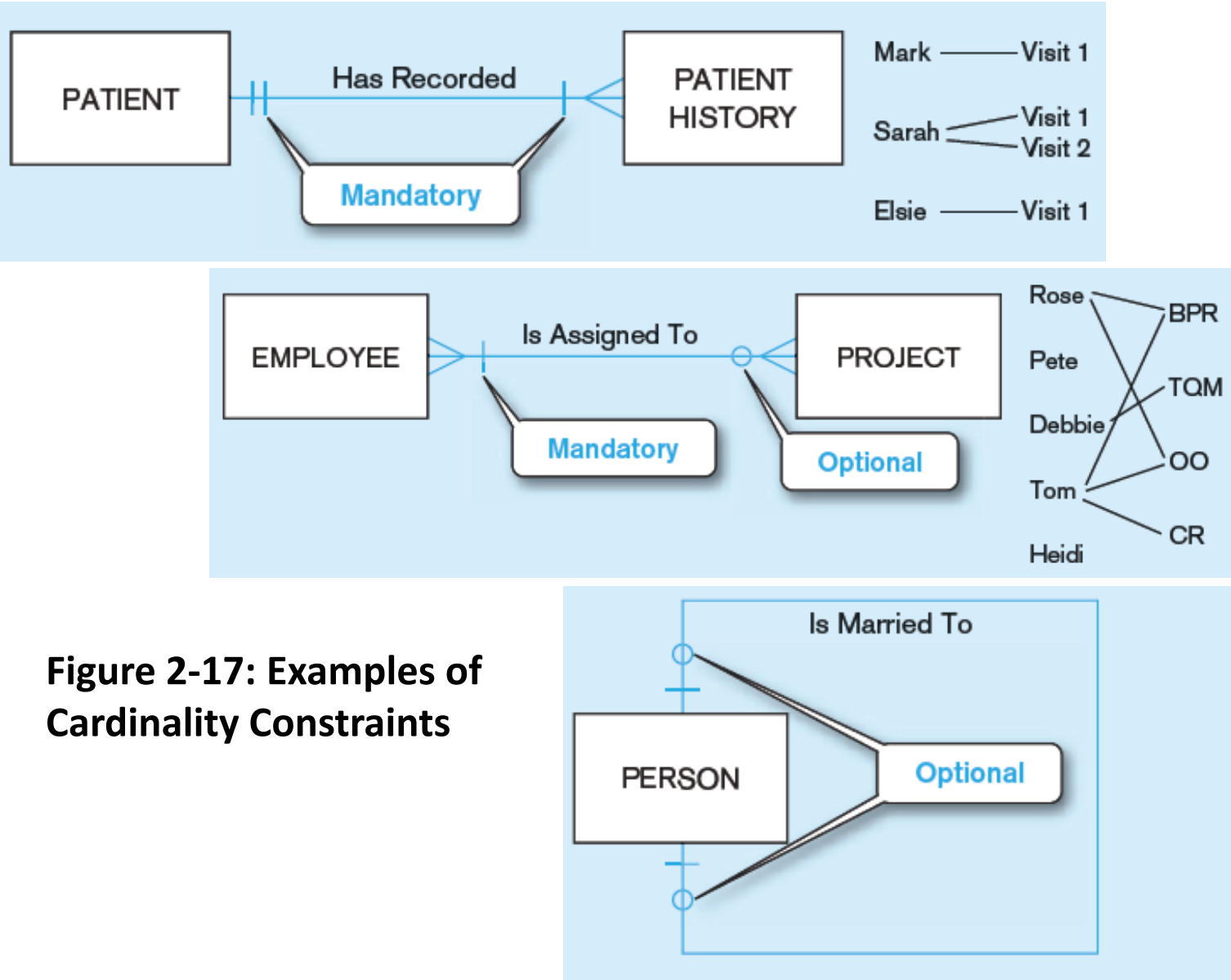
Figure 2-17: Examples of Cardinality Constraints

Ternary Relationship with Attributes
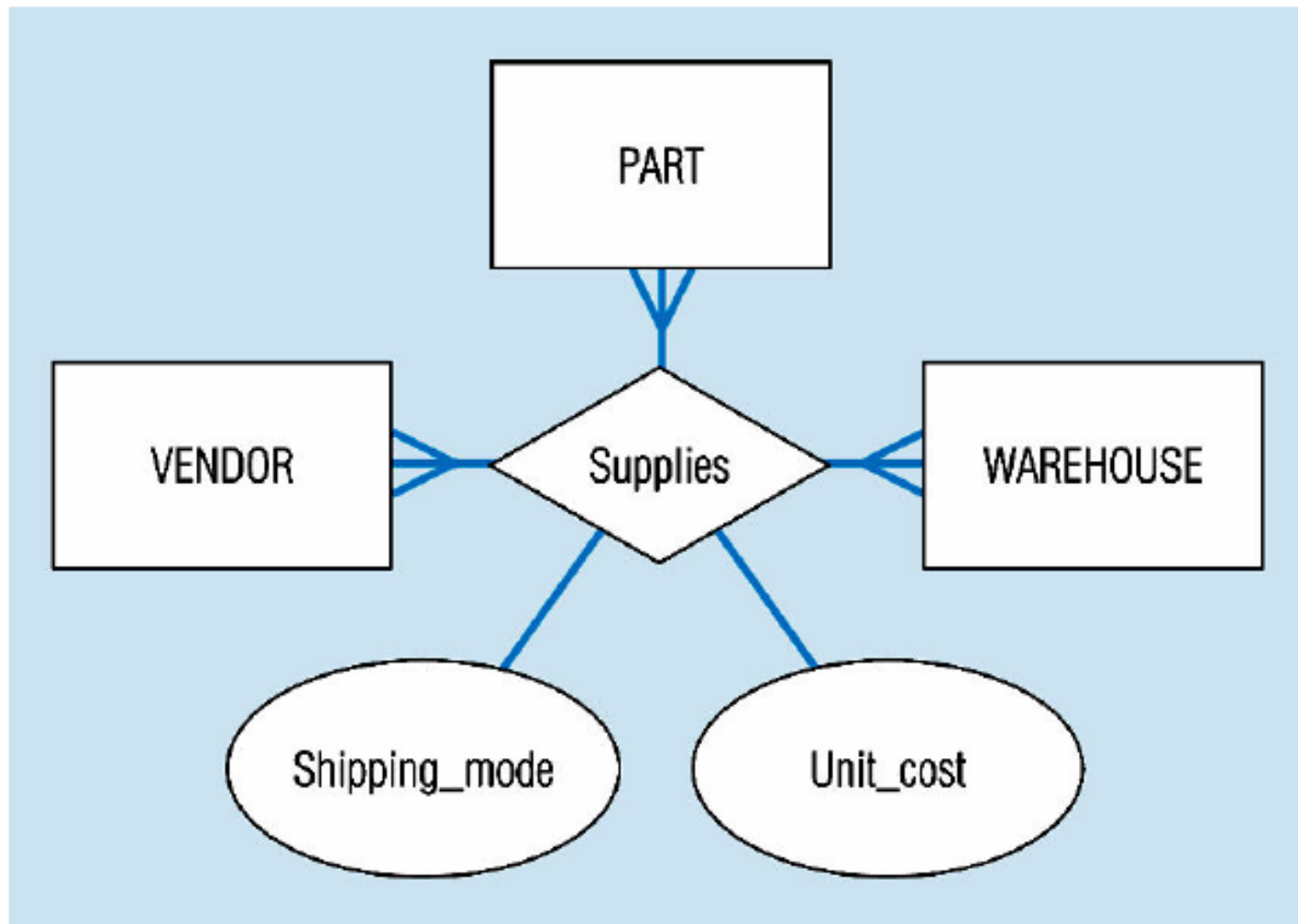
Ternary Relationship as an Associative Entity

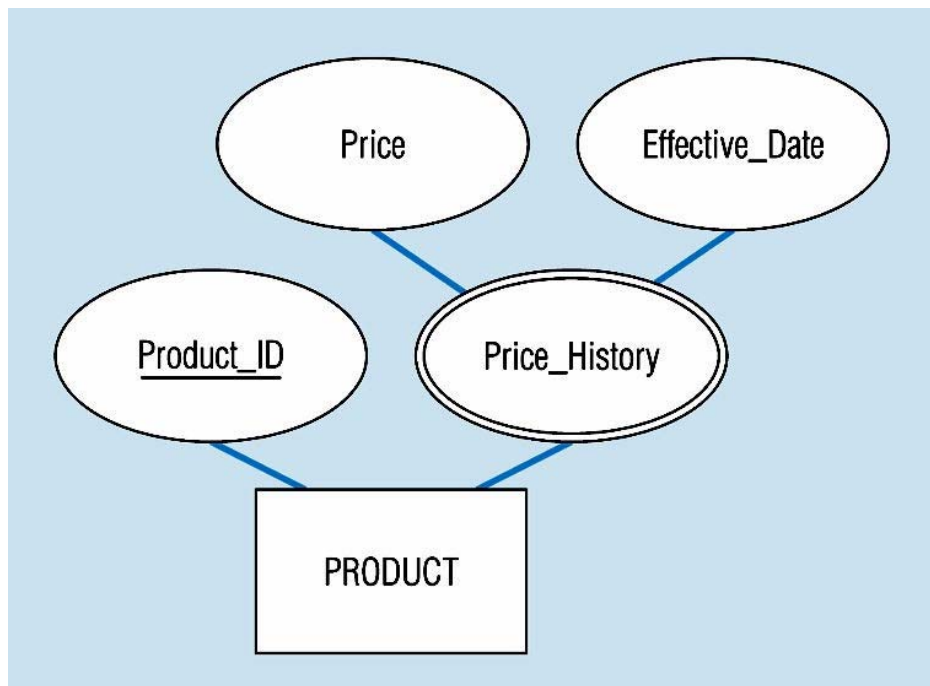**Business Rules**

① Each vendor can supply many parts to any number of warehouses, but need not supply any parts.

② Each part can be supplied by any number of vendors to more than one warehouse, but each part must be supplied by at least one vendor to a warehouse.

③ Each warehouse can be supplied with any number of parts from more than one vendor, but each warehouse must be supplied with at least one part.

Figure 2-18: Examples of Cardinality Constraints

Attribute – Both Multi-valued & Composite

This is an example of time-stamping

Figure 2-19: Simple Example of Time Stamping

PRODUCT
Product ID
{Price History
(Effective Date, Price)}

Time Stamp
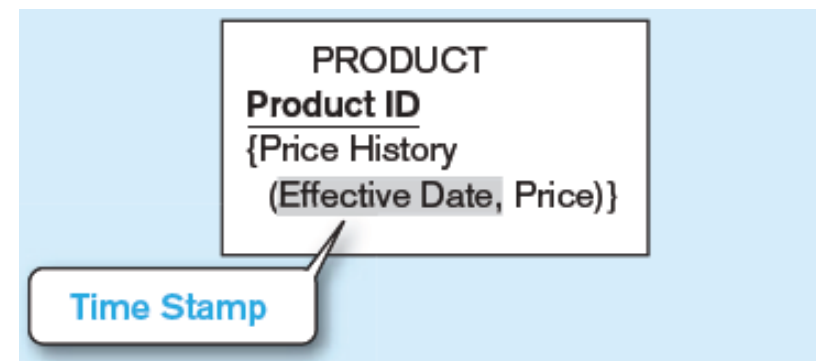
Example of Multiple Relationships

Entities can be related to one another in more than one way...
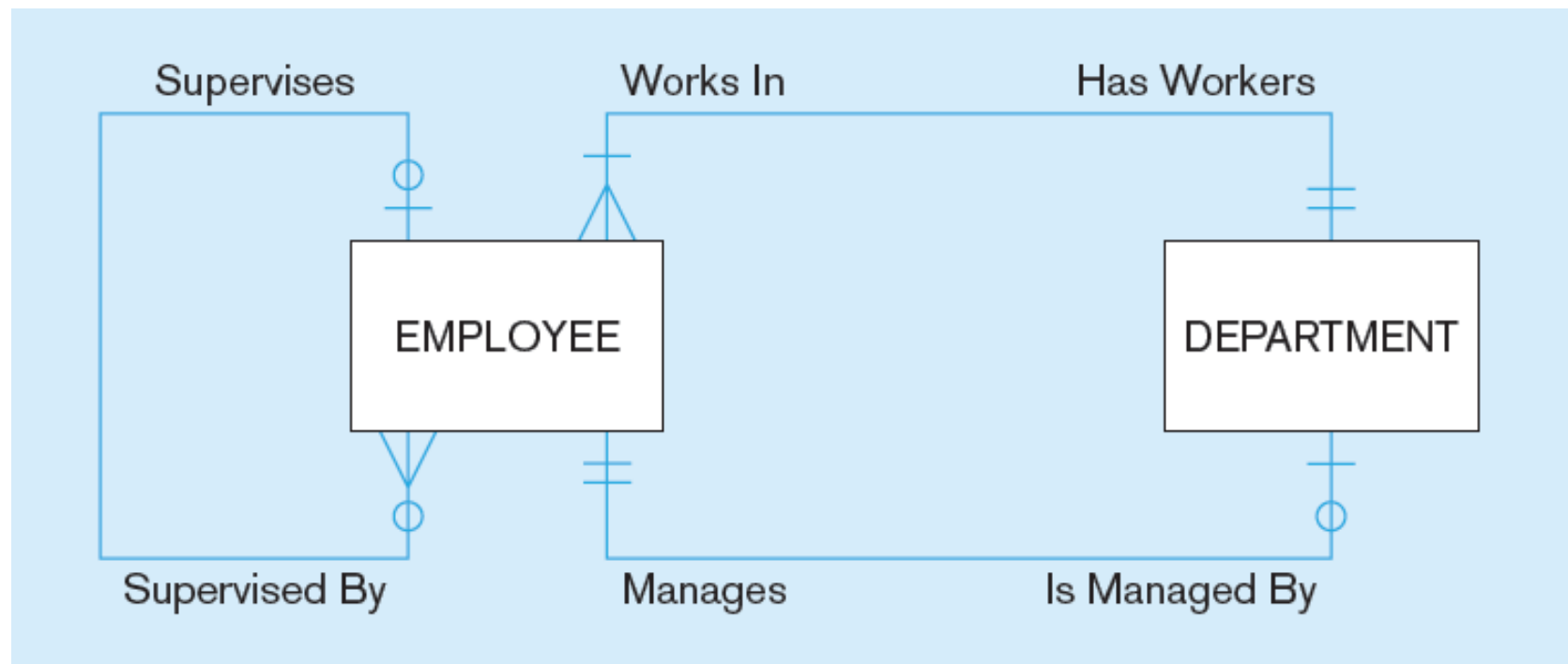
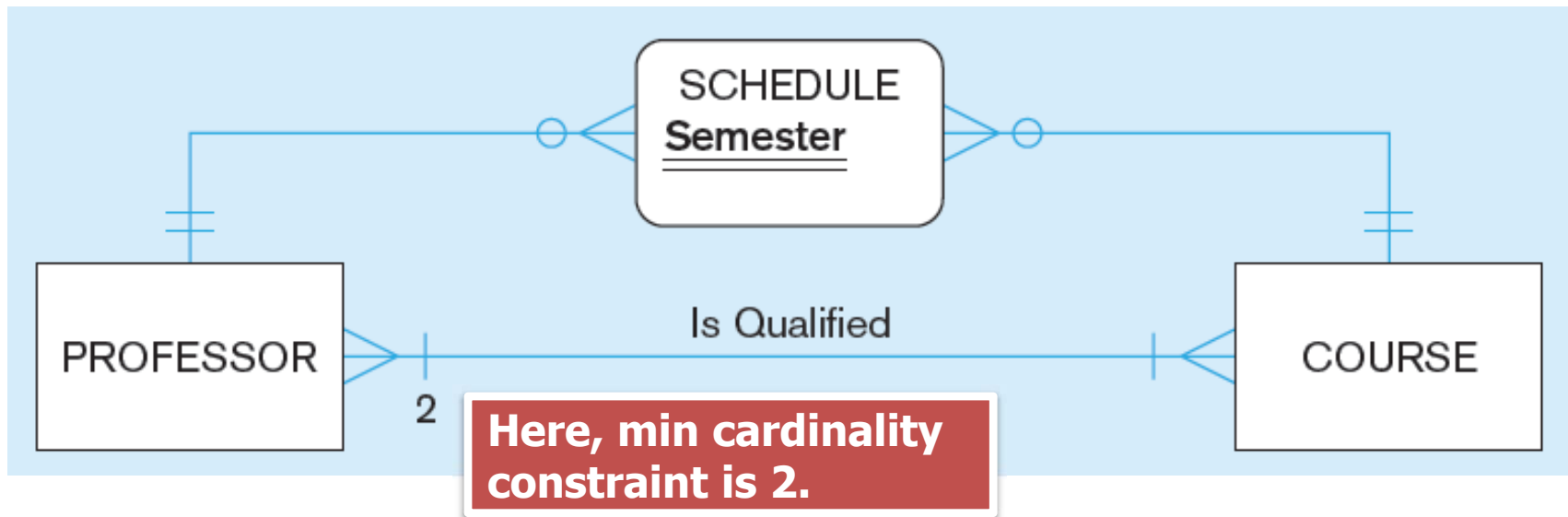**Figure 2-21a: Employees and Departments**

Professors & Courses

Is_qualified

PROFESSOR

COURSE

(4)

Is_scheduled

Semester

Here, max cardinality constraint is 4.

Professors & Courses (Cont.)

SCHEDULE
Semester

PROFESSOR

Is Qualified

COURSE

2

Here, min cardinality constraint is 2.
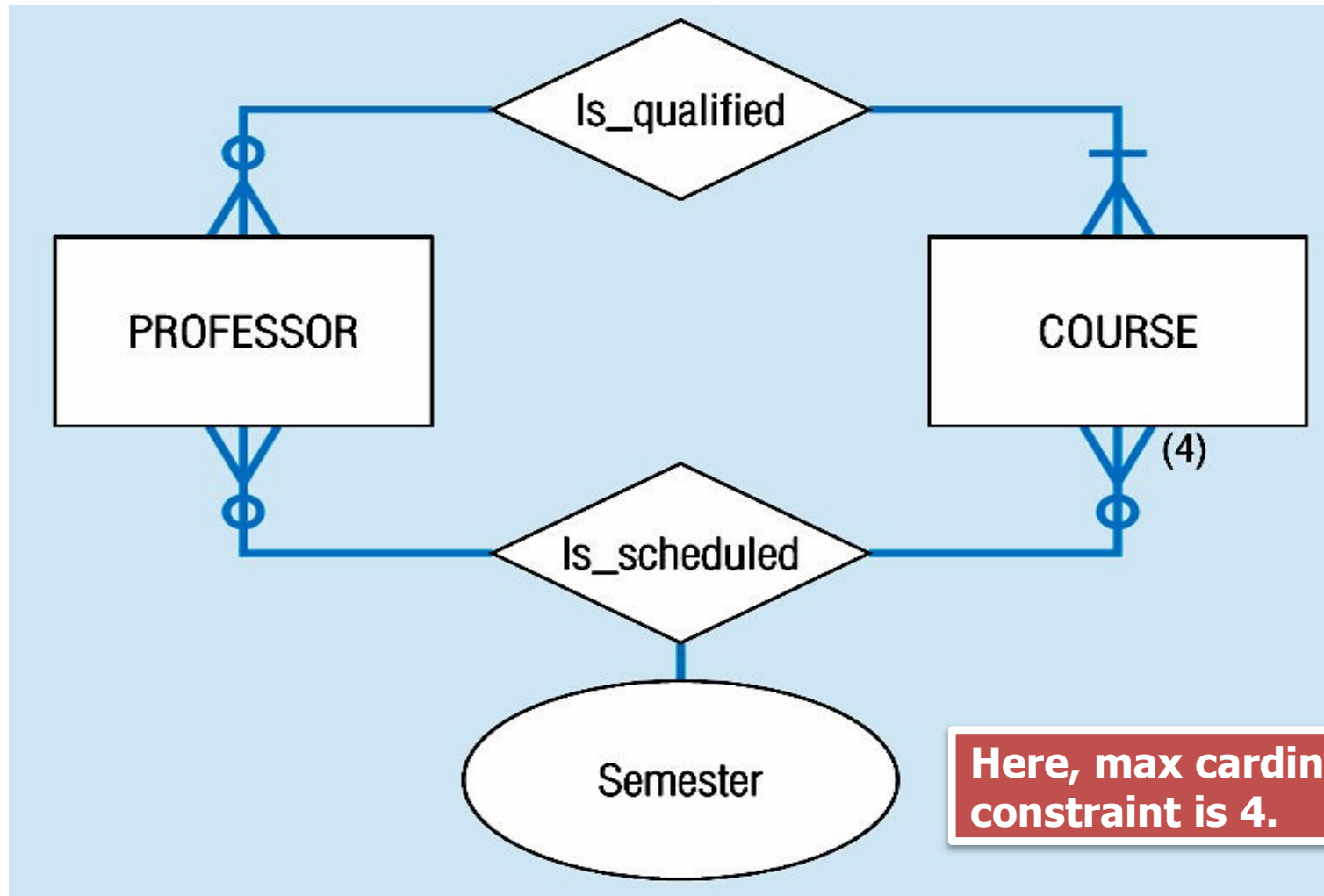
Figure 2-21a: Professors & Courses

Multi-valued Attribute vs. Relationship
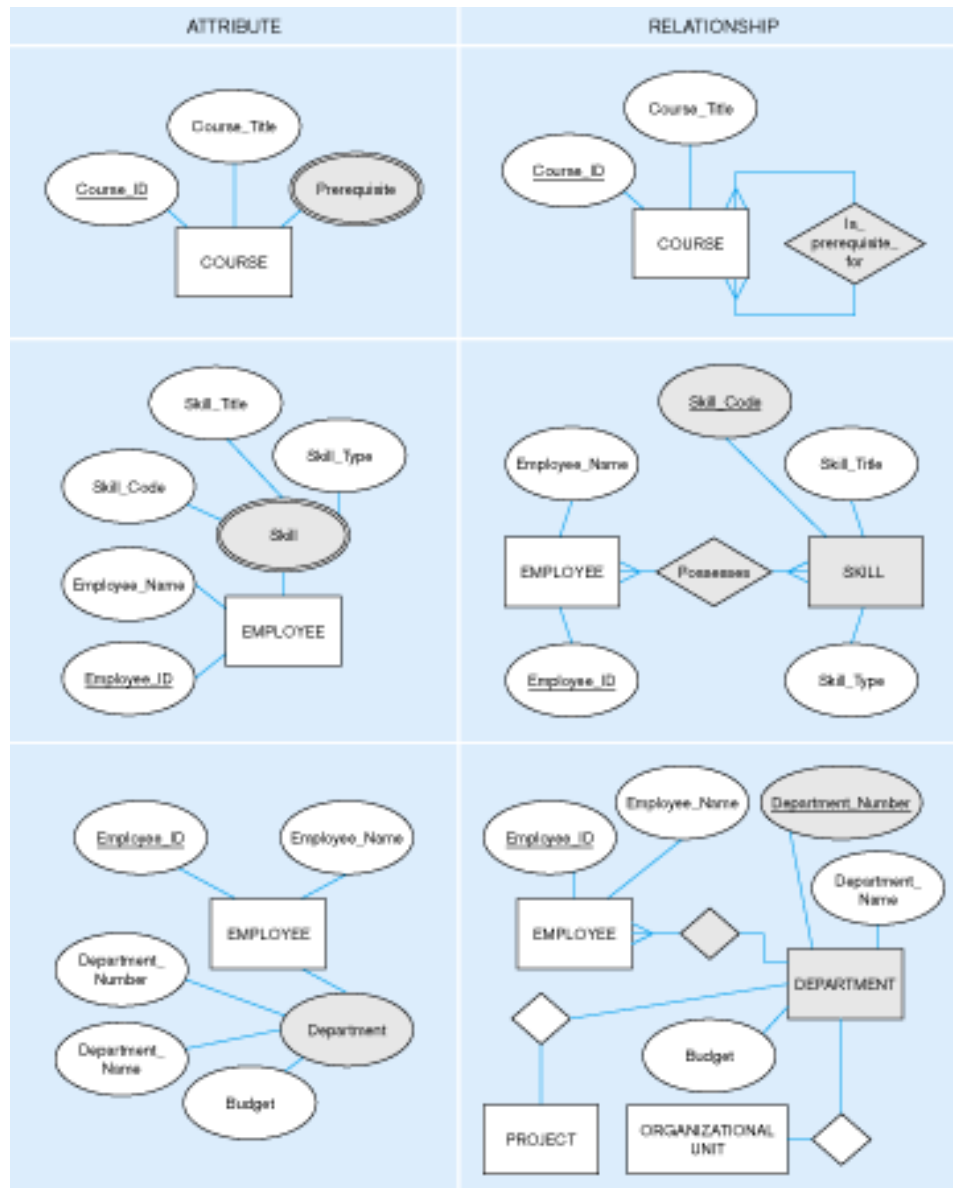
Alternative Approaches

Multi-valued Attribute vs. Relationship (1)

(a) Multivalued attribute versus relationships via bill-of-materials structure
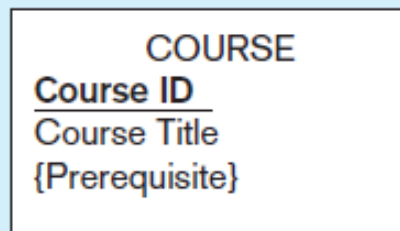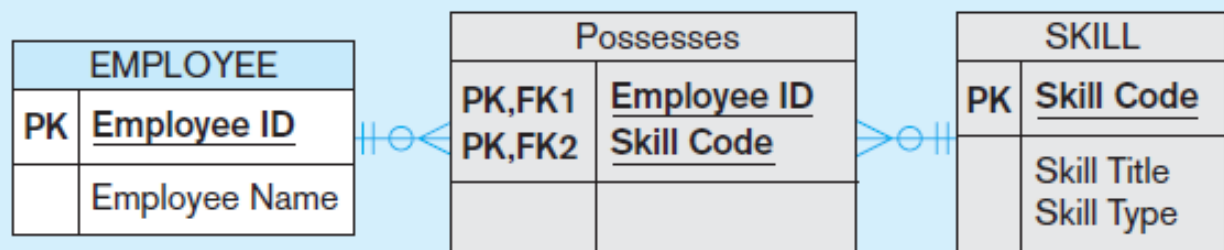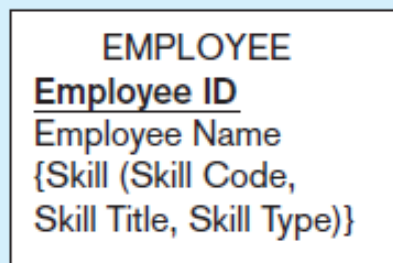
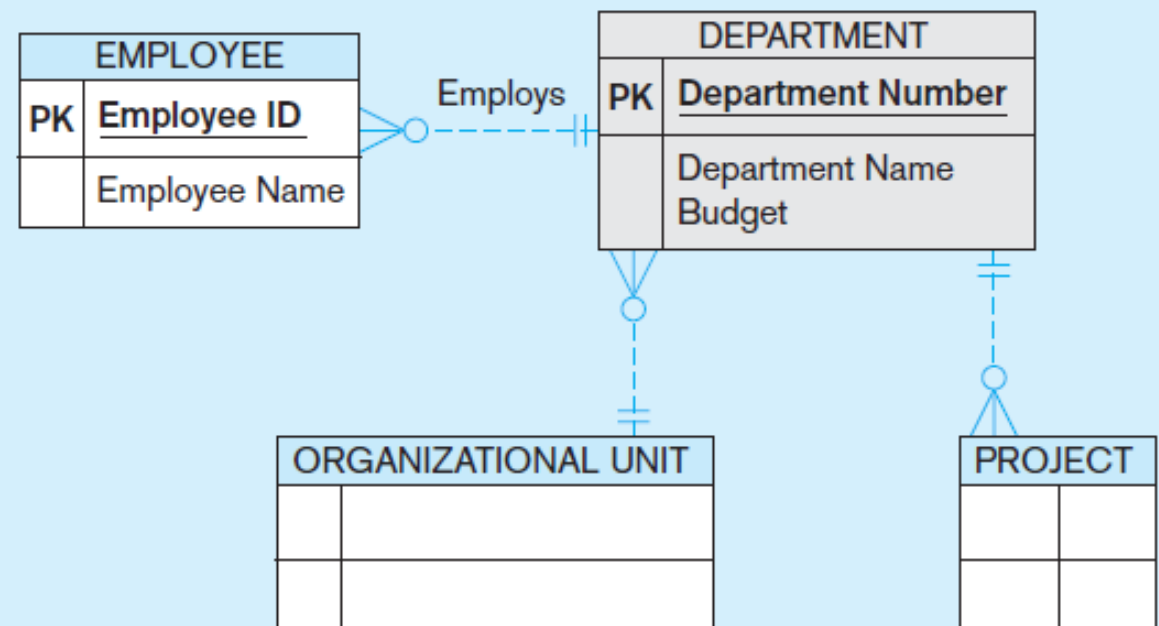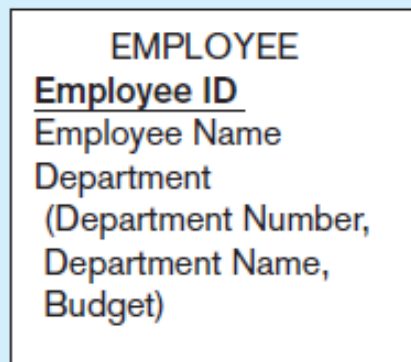| ATTRIBUTE	RELATIONSHIP & ENTITY
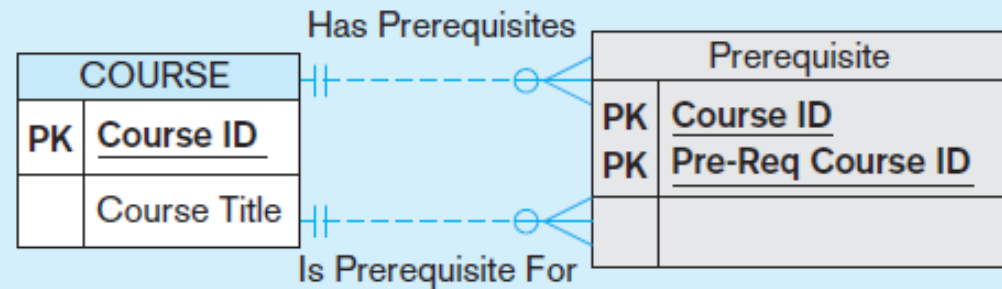
Multi-valued Attribute vs. Relationship (2)

(b) Composite, multivalued attribute versus relationship

Multi-valued Attribute vs. Relationship (3)

(c) Composite attribute of data shared with other entity types

Summary

- Covered Conceptual Data Modeling/Schema in detail
- Covered Business Rules
- Covered ERD and its constructs in detail using examples