SE212 Database and Database design

Logical design

Midterm Exam

- 11th August 2020, Online, Tuesday 8:00am-11am.

Agenda

- Review of Relation, Keys and constraints (In action)
- Mapping ER to Relation
- Database Normalization

Review Relation

- Definition: A relation is a named, two-dimensional table of data
- Table consists of rows (records) and columns (attribute or field)
- Requirements for a table to qualify as a relation:
  - It must have a unique name
  - Every attribute value must be atomic (not multivalued, not composite)
  - Every row must be unique (can't have two rows with the same values for all their fields)
  - Attributes (columns) in tables must have unique names
  - The order of the columns must be irrelevant (not related/connected)
  - The order of the rows must be irrelevant

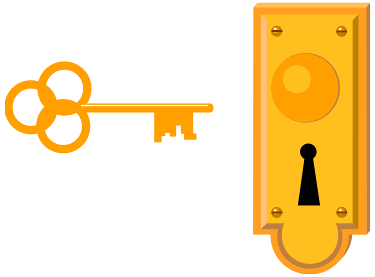
NOTE: all *relations* are in ***1st Normal form***

Correspondence with E-R Model

- Relations (tables) correspond with entity types and with many-to-many relationship types
- Rows correspond with entity instances and with many-to-many relationship instances
- Columns correspond with attributes

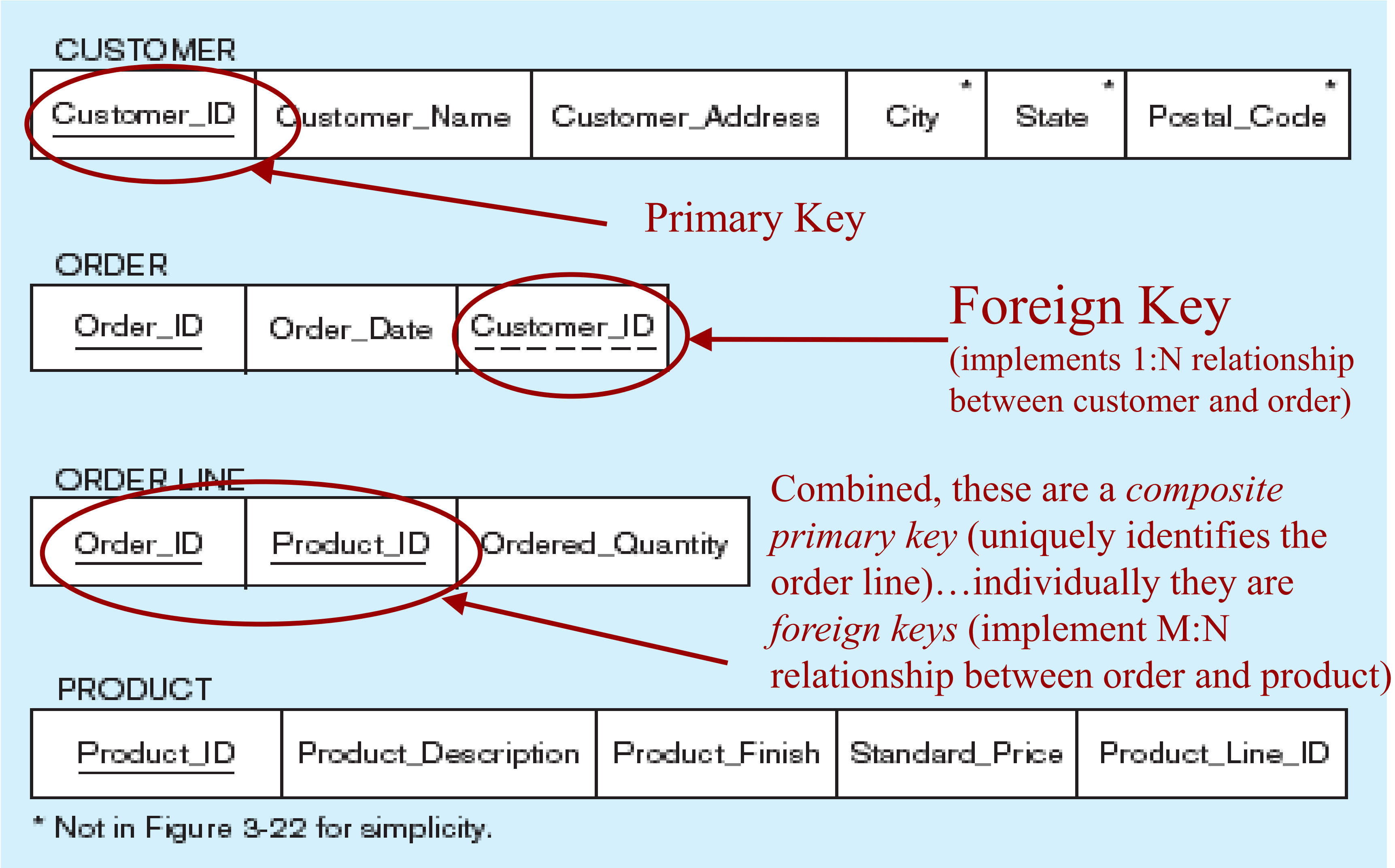
- NOTE: The word ***relation*** (in relational database) is NOT the same as the word ***relationship*** (in E-R model)

Key Fields



- Keys are special fields that serve two main purposes:
  - ***Primary keys*** are unique identifiers of the relation in question. Examples include employee numbers, social security numbers, etc. *This is how we can guarantee that all rows are unique*
  - ***Foreign keys*** are identifiers that enable a dependent relation (on the many side of a relationship) to refer to its parent relation (on the one side of the relationship)
- Keys can be ***simple*** (a single field) or ***composite*** (more than one field)
- Keys usually are used as indexes to speed up the response to user queries

Figure 5-3 Schema for four relations (Pine Valley Furniture Company)



Integrity Constraints (Recall)

- Domain Constraints
  - Allowable values for an attribute.
- Entity Integrity
  - No primary key attribute can be null. All primary key fields **MUST** have data
- Action Assertions
  - Business rules. Recall from previous lectures

Table 5-1 Domain Definitions for INVOICE Attributes

Attribute	*Domain Name*	*Description*	*Domain*
Customer_ID	Customer_IDs	Set of all possible customer IDs	character: size 5
Customer_Name	Customer_Names	Set of all possible customer names	character: size 25
Customer_Address	Customer_Addresses	Set of all possible customer addresses	character: size 30
City	Cities	Set of all possible cities	character: size 20
State	States	Set of all possible states	character: size 2
Postal_Code	Postal_Codes	Set of all possible postal zip codes	character: size 10
Order_ID	Order_IDs	Set of all possible order IDs	character: size 5
Order_Date	Order_Dates	Set of all possible order dates	date format mm/dd/yy
Product_ID	Product_IDs	Set of all possible product IDs	character: size 5
Product_Description	Product_Descriptions	Set of all possible product descriptions	character size 25
Product_Finish	Product_Finishes	Set of all possible product finishes	character: size 15
Standard_Price	Unit_Prices	Set of all possible unit prices	monetary: 6 digits
Product_Line_ID	Product_Line_IDs	Set of all possible product line IDs	integer: 3 digits
Ordered_Quantity	Quantities	Set of all possible ordered quantities	integer: 3 digits

Domain definitions enforce domain integrity constraints

Integrity Constraints

- Referential Integrity–rule states that any foreign key value (on the relation of the many side) MUST match a primary key value in the relation of the one side. (Or the foreign key can be null)
  - For example: Delete Rules
    - Restrict–don’t allow delete of “parent” side if related rows exist in “dependent” side
    - Cascade–automatically delete “dependent” side rows that correspond with the “parent” side row to be deleted
    - Set-to-Null–set the foreign key in the dependent side to null if deleting from the parent side → not allowed for weak entities

Figure 5-5
Referential integrity constraints (Pine Valley Furniture)

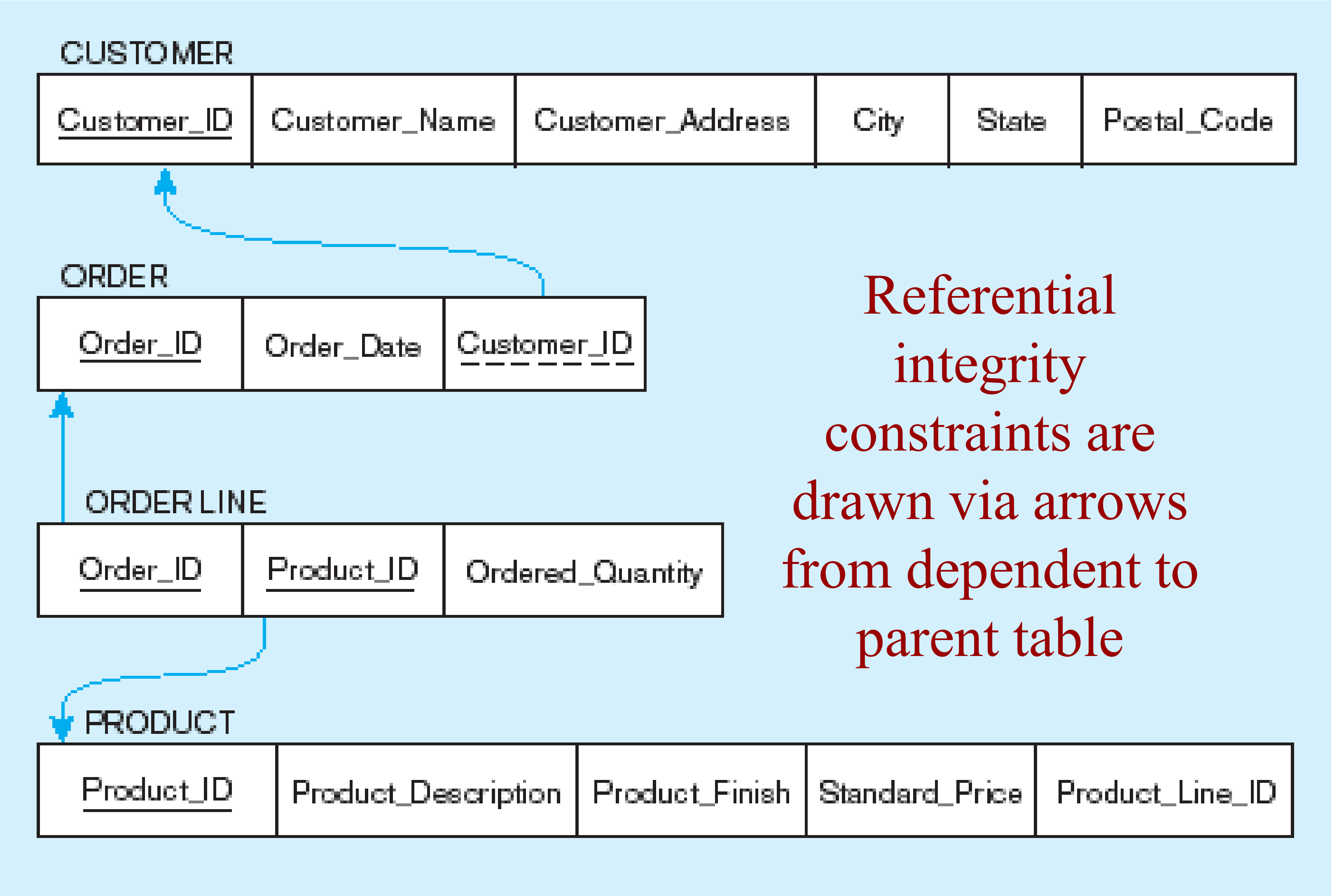


Figure 5-6 SQL table definitions

```
CREATE TABLE CUSTOMER
        (CUSTOMER_ID              VARCHAR(5)      NOT NULL,
        CUSTOMER_NAME             VARCHAR(25)     NOT NULL,
        CUSTOMER ADDRESS          VARCHAR(30)     NOT NULL,
        CITY                      VARCHAR(20)     NOT NULL,
        STATE                     CHAR(2)         NOT NULL,
        POSTAL_CODE               CHAR(10)        NOT NULL,
PRIMARY KEY (CUSTOMER_ID);

CREATE TABLE ORDER
        (ORDER_ID                 CHAR(5)         NOT NULL,
        ORDER DATE                DATE            NOT NULL,
        CUSTOMER_ID               VARCHAR(5)      NOT NULL,
PRIMARY KEY (ORDER_ID),
FOREIGN KEY (CUSTOMER_ID) REFERENCES CUSTOMER (CUSTOMER_ID);

CREATE TABLE ORDER_LINE
        (ORDER_ID                 CHAR(5)         NOT NULL,
        PRODUCT_ID                CHAR(5)         NOT NULL,
        ORDERED_QUANTITY          INT             NOT NULL,
PRIMARY KEY (ORDER_ID, PRODUCT_ID),
FOREIGN KEY (ORDER_ID) REFERENCES ORDER (ORDER_ID),
FOREIGN KEY (PRODUCT_ID) REFERENCES PRODUCT (PRODUCT_ID);

CREATE TABLE PRODUCT
        (PRODUCT_ID               CHAR(5)         NOT NULL,
        PRODUCT_DESCRIPTION       VARCHAR(25),
        PRODUCT_FINISH            VARCHAR(12),
        STANDARD_PRICE            DECIMAL(8,2)    NOT NULL,
        PRODUCT_LINE_ID           INT             NOT NULL,
PRIMARY KEY (PRODUCT_ID);
```

Referential integrity constraints are implemented with foreign key to primary key references

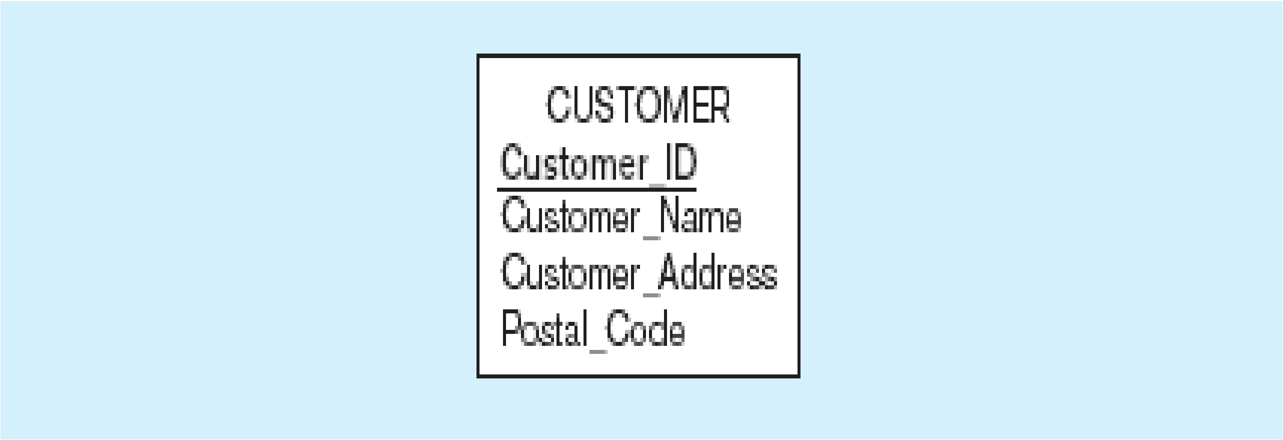
Transforming EER Diagrams into Relations

Mapping Regular Entities to Relations

1. Simple attributes: E-R attributes map directly onto the relation
2. Composite attributes: Use only their simple, component attributes
3. Multivalued Attribute–Becomes a separate relation with a foreign key taken from the superior entity

Figure 5-8 Mapping a regular entity

(a) CUSTOMER entity type with simple attributes



(b) CUSTOMER relation

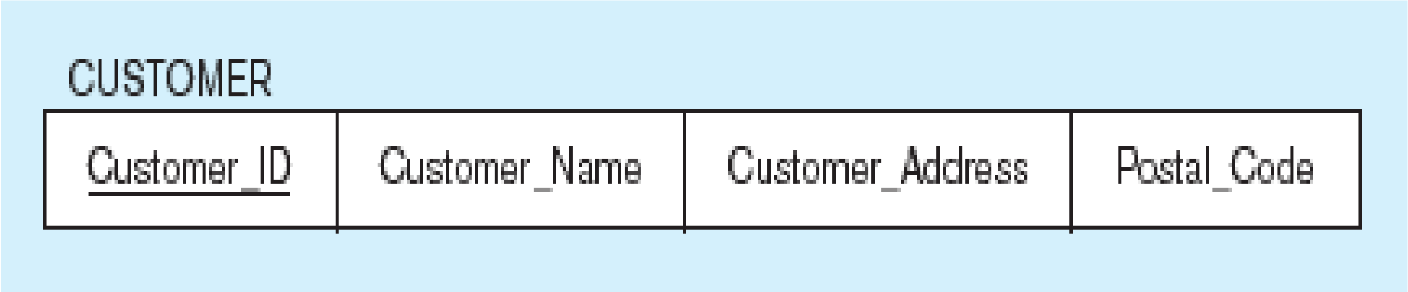


Figure 5-9 Mapping a composite attribute

(a) CUSTOMER entity type with composite attribute

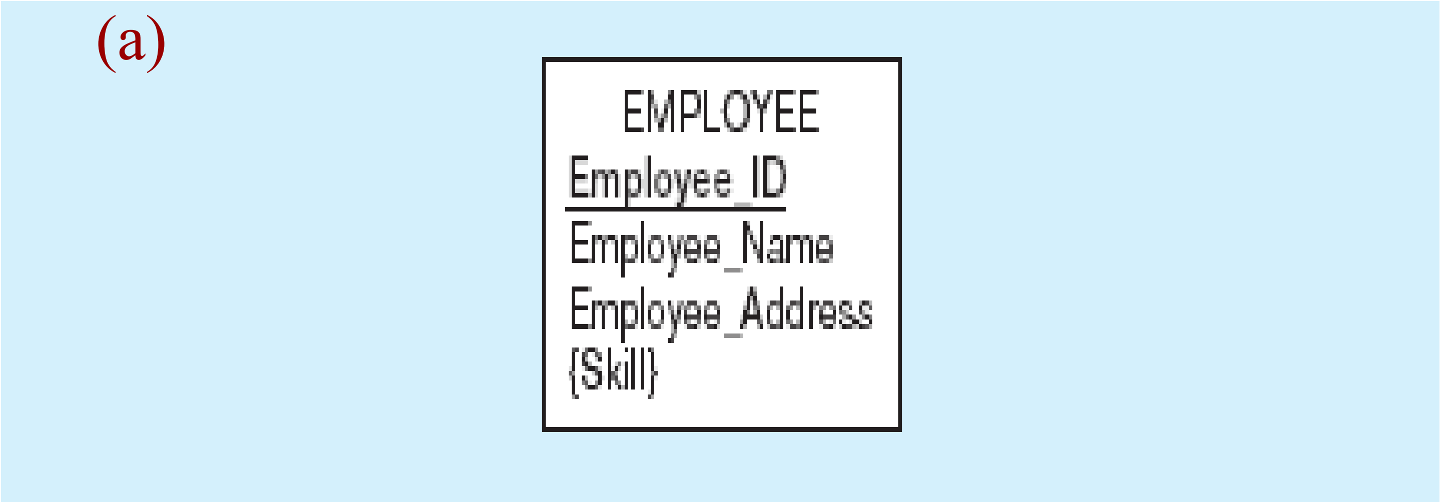
CUSTOMER
Customer_ID
Customer_Name
Customer_Address
(Street, City, State)
Postal_Code

(b) CUSTOMER relation with address detail

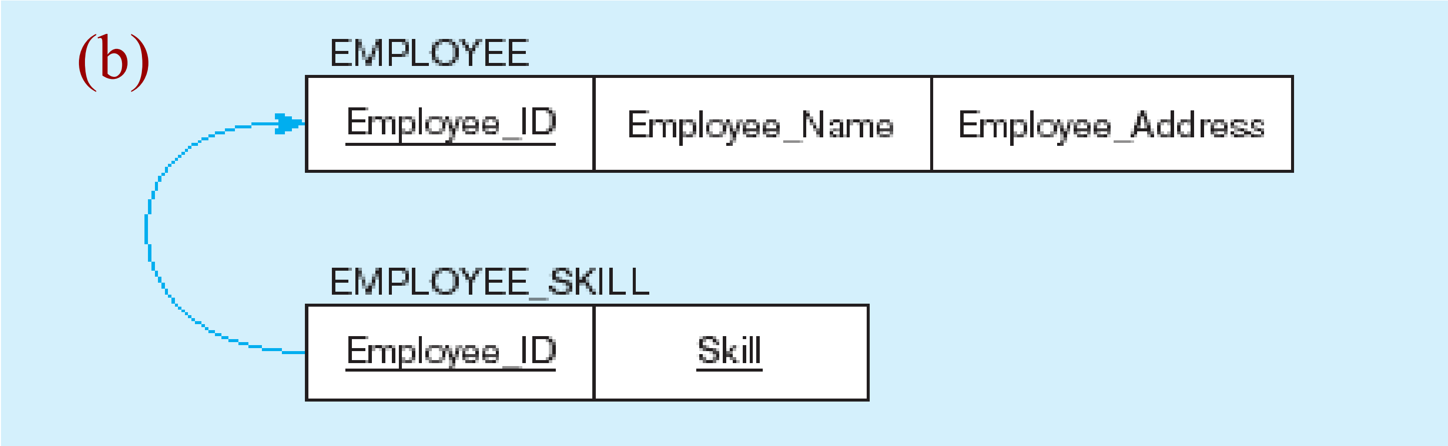
CUSTOMER

Customer_ID	Customer_Name	Street	City	State	Postal_Code

Figure 5-10 Mapping an entity with a multivalued attribute



Multivalued attribute becomes a separate relation with foreign key



One–to–many relationship between original entity and new relation

Transforming EER Diagrams into Relations (cont.)

Mapping Weak Entities

- Becomes a separate relation with a foreign key taken from the superior entity
- Primary key composed of:
  - Partial identifier of weak entity
  - Primary key of identifying relation (strong entity)

Figure 5-11 Example of mapping a weak entity

a) Weak entity DEPENDENT

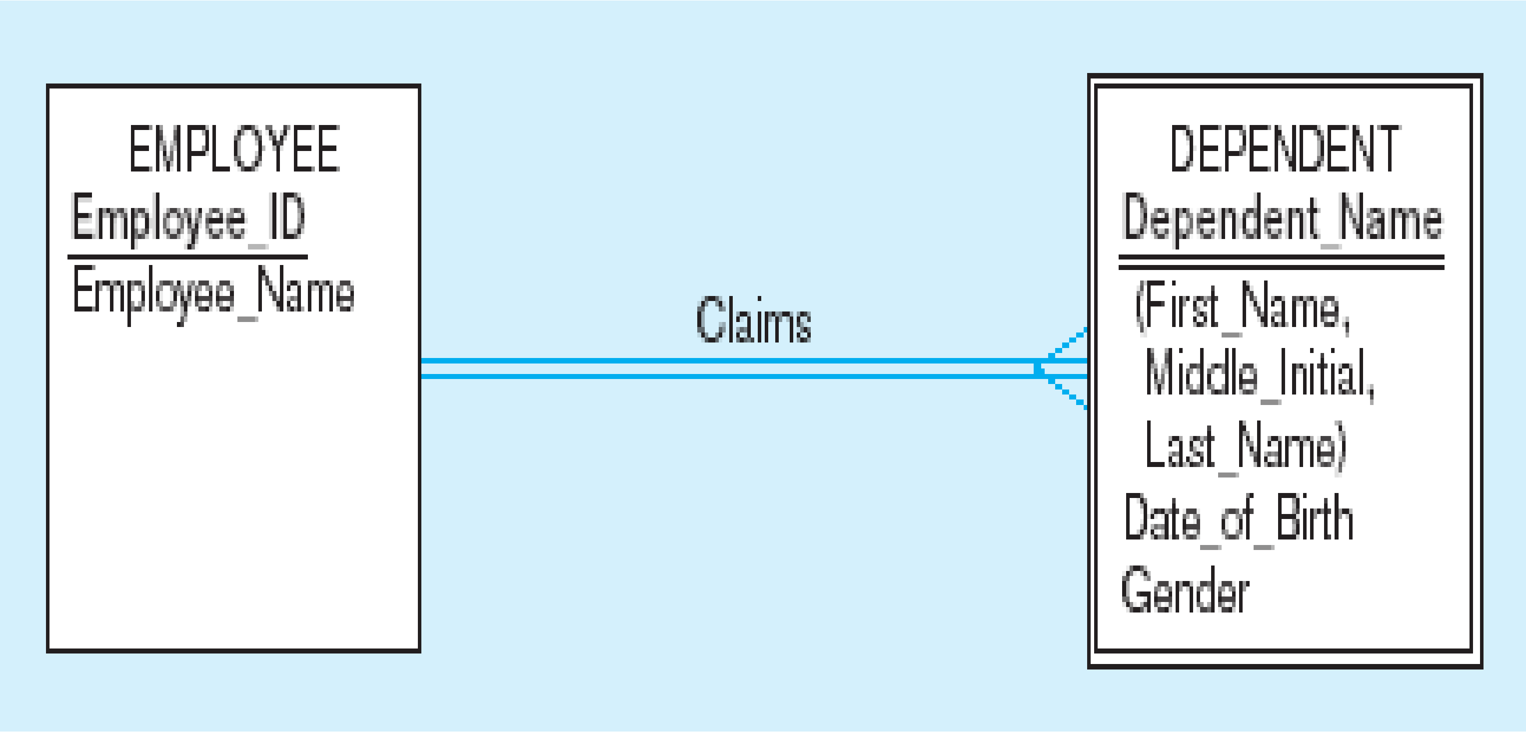
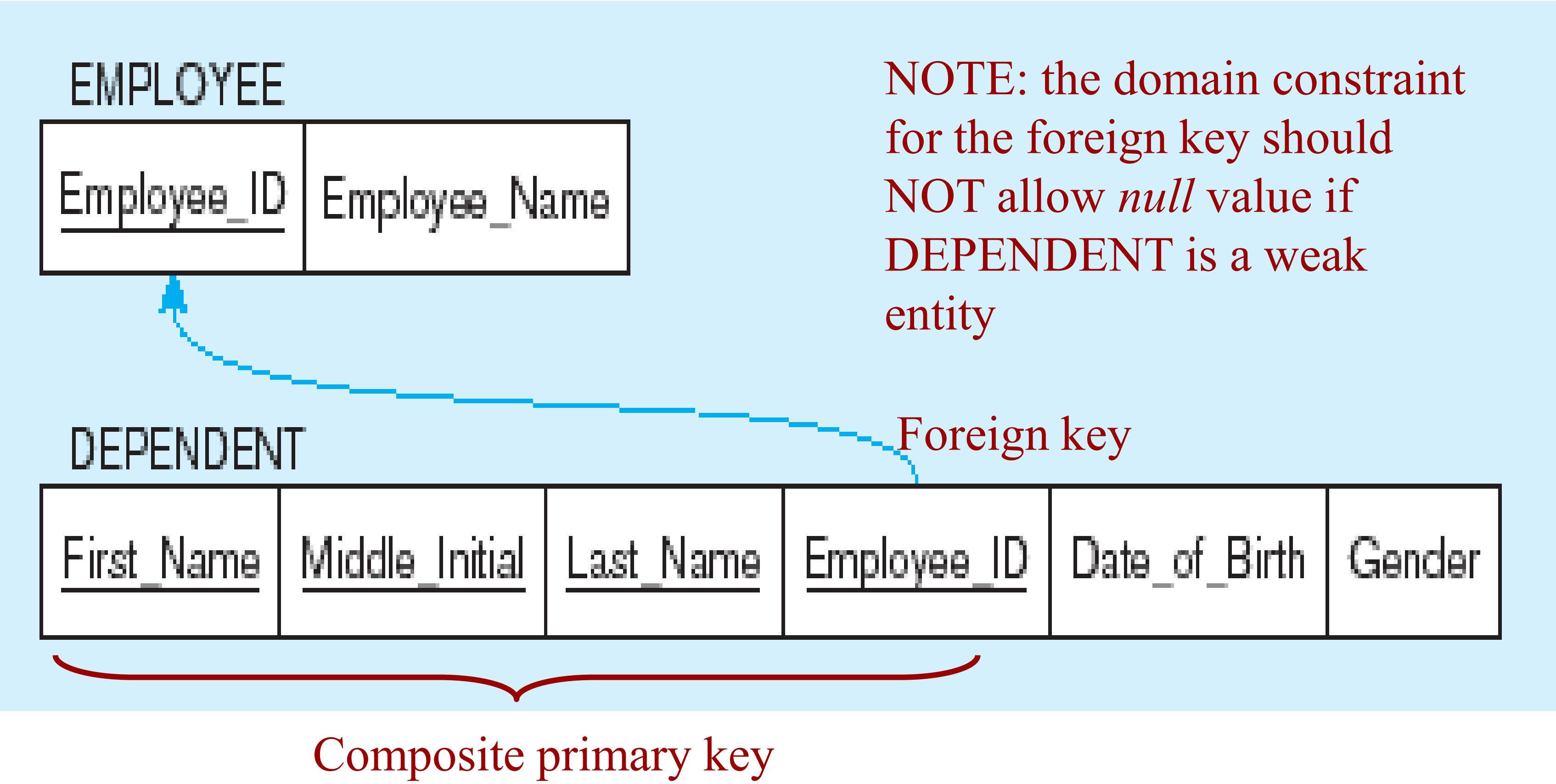


Figure 5-11 Example of mapping a weak entity (cont.)

b) Relations resulting from weak entity



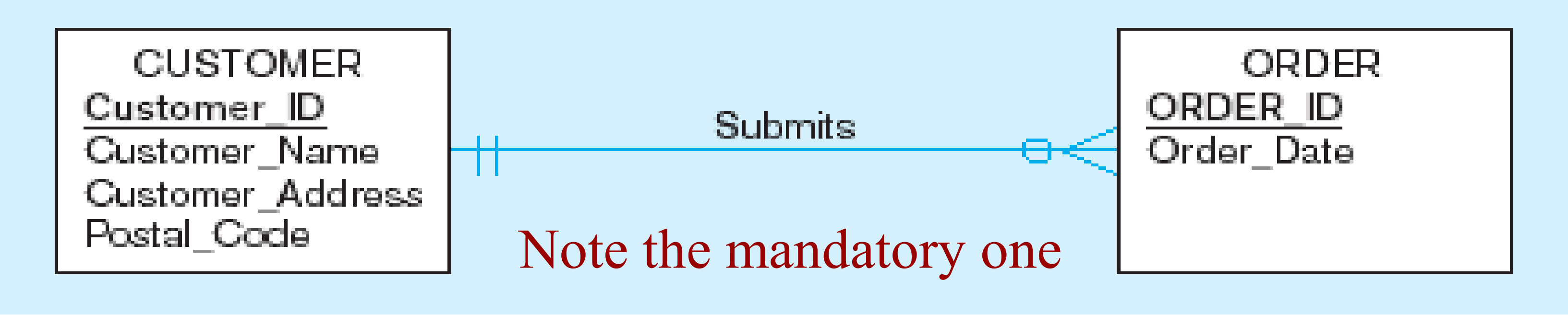
Transforming EER Diagrams into Relations (cont.)

Mapping Binary Relationships

- One-to-Many–Primary key on the one side becomes a foreign key on the many side
- Many-to-Many–Create a ***new relation*** with the primary keys of the two entities as its primary key
- One-to-One–Primary key on the mandatory side becomes a foreign key on the optional side

Figure 5-12 Example of mapping a 1:M relationship

a) Relationship between customers and orders



b) Mapping the relationship

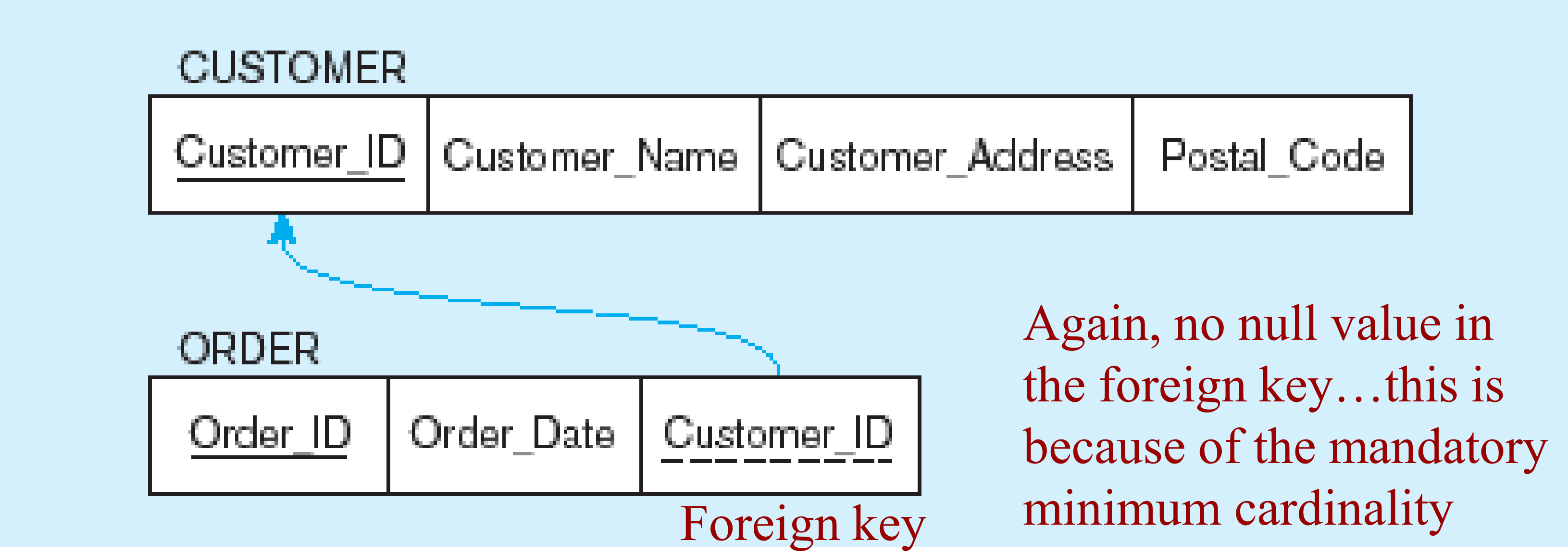
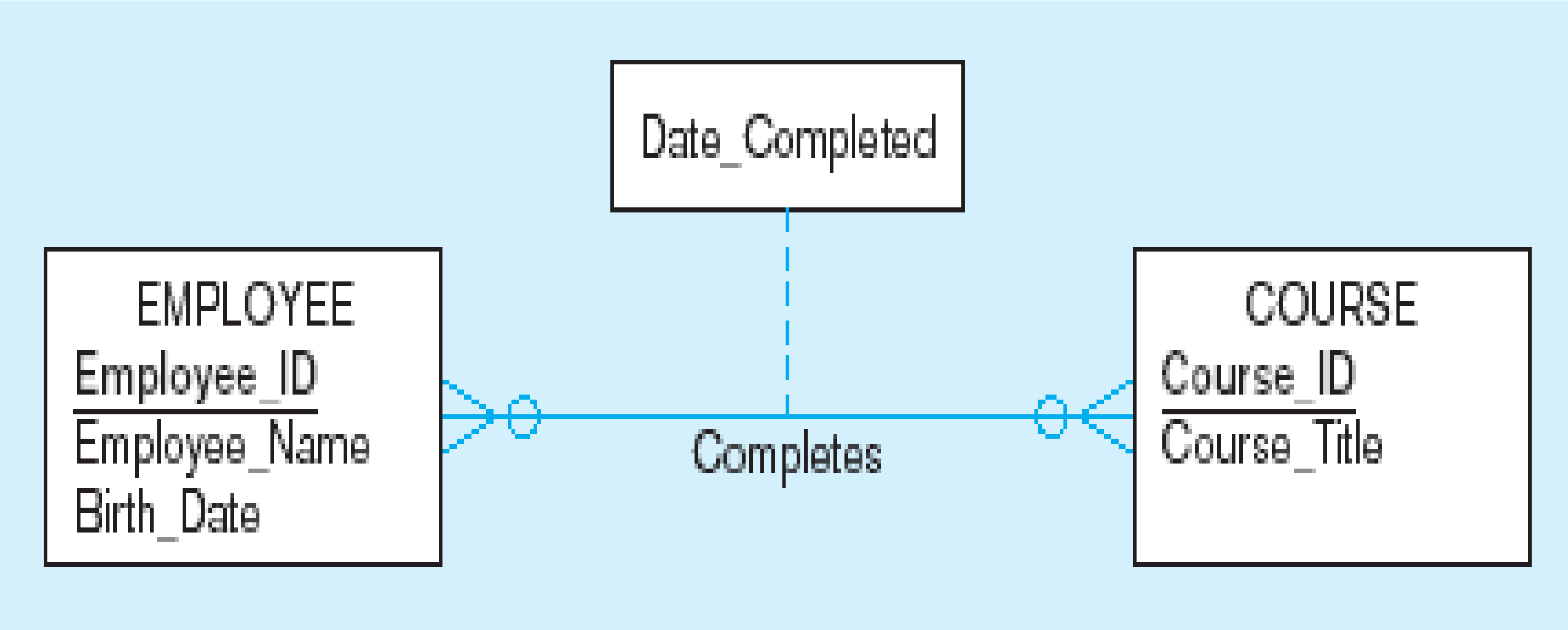


Figure 5-13 Example of mapping an M:N relationship

a) Completes relationship (M:N)



The *Completes* relationship will need to become a separate relation

Figure 5-13 Example of mapping an M:N relationship (cont.)

b) Three resulting relations

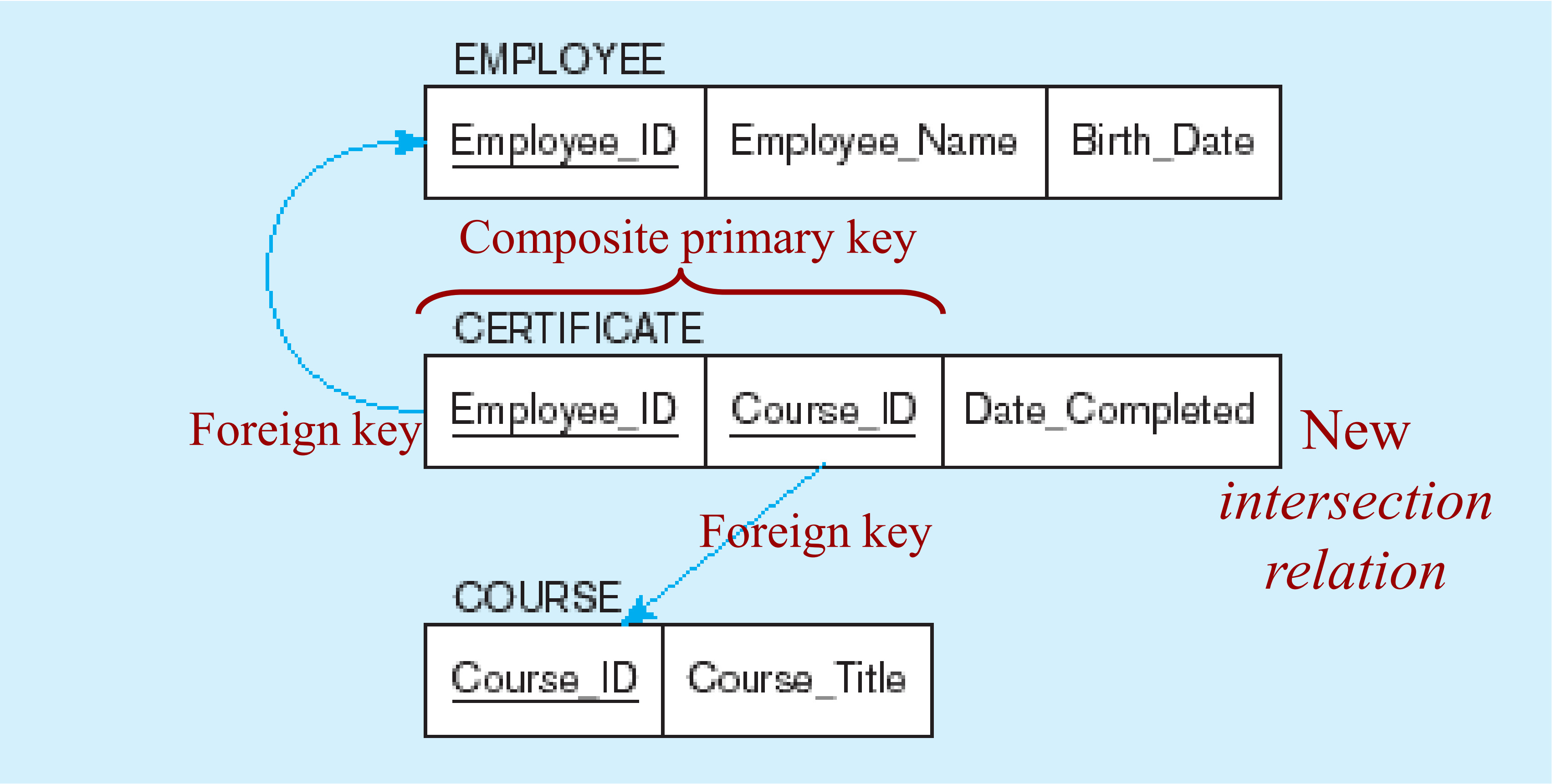
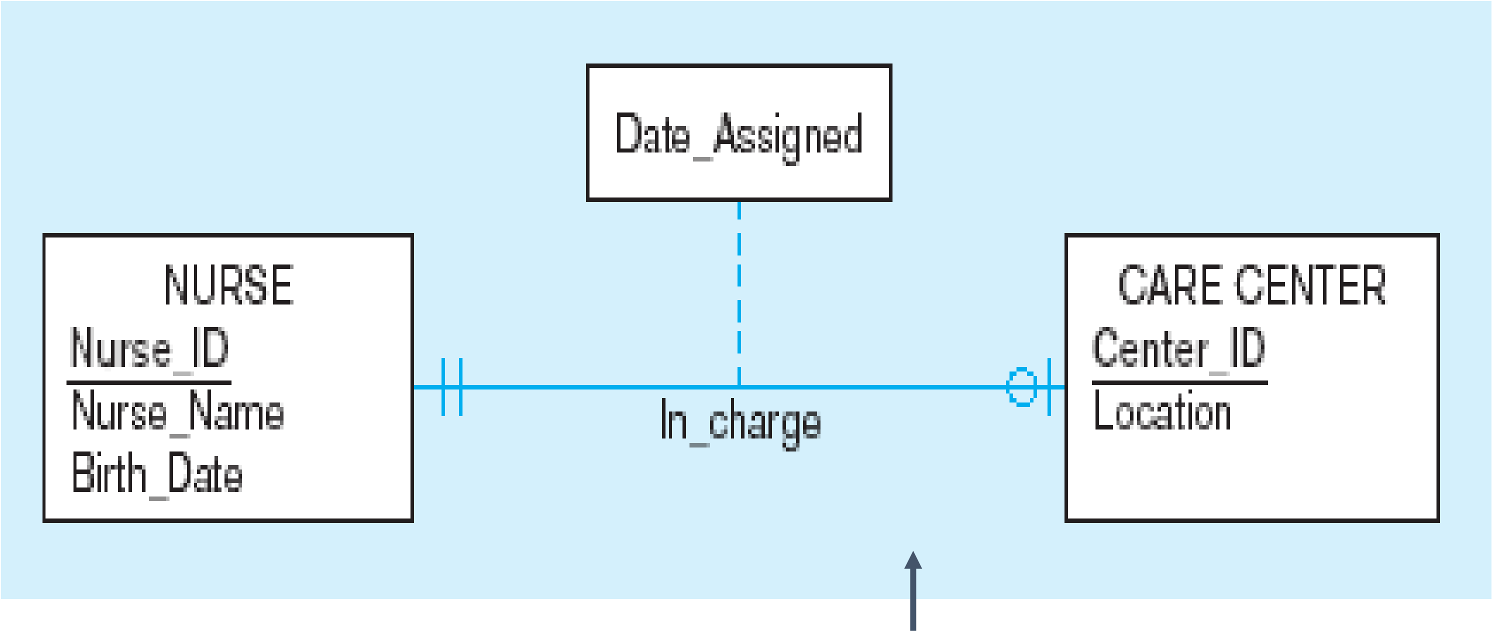


Figure 5-14 Example of mapping a binary 1:1 relationship

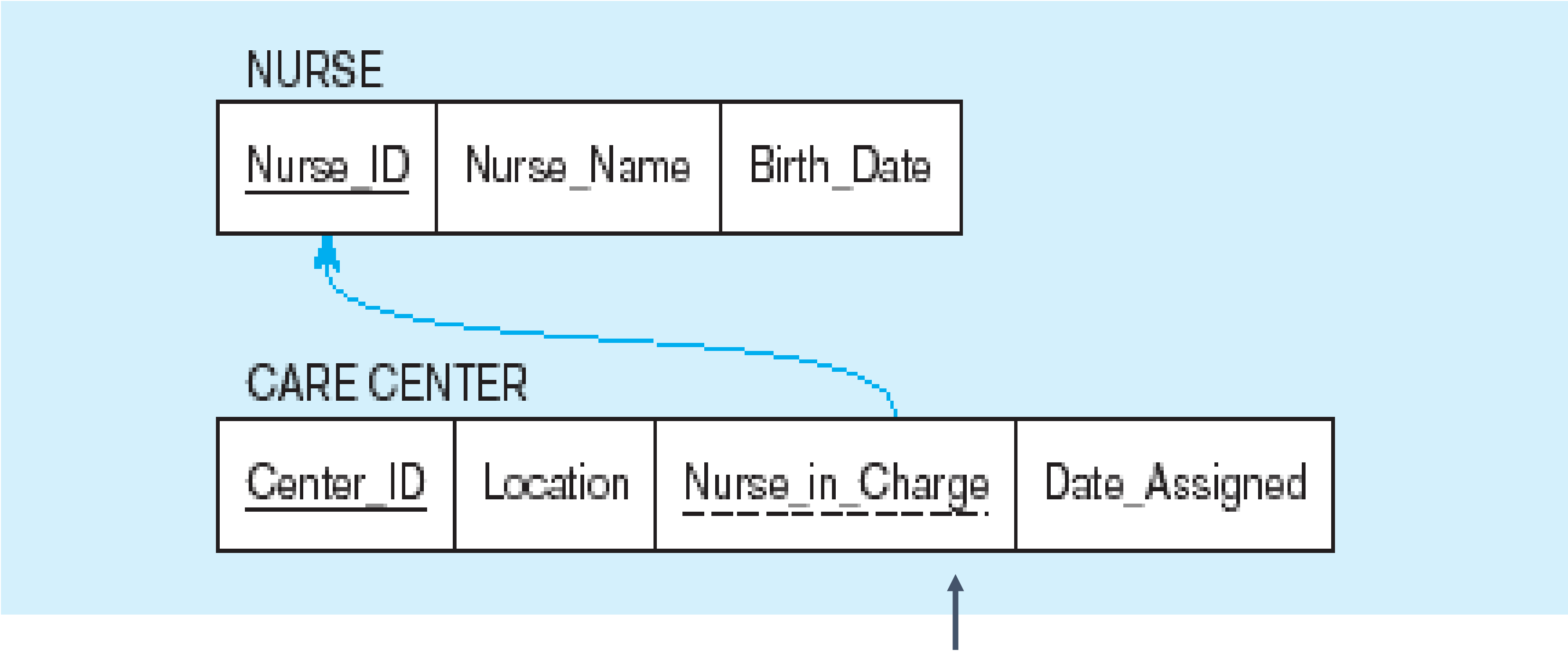
a) In_charge relationship (1:1)



Often in 1:1 relationships, one direction is optional.

Figure 5-14 Example of mapping a binary 1:1 relationship (cont.)

b) Resulting relations



Foreign key goes in the relation on the optional side,
Matching the primary key on the mandatory side

Transforming EER Diagrams into Relations (cont.)

Mapping Associative Entities

- Identifier Not Assigned
  - Default primary key for the association relation is composed of the primary keys of the two entities (as in M:N relationship)
- Identifier Assigned
  - It is natural and familiar to end-users
  - Default identifier may not be unique

Figure 5-15 Example of mapping an associative entity

a) An associative entity

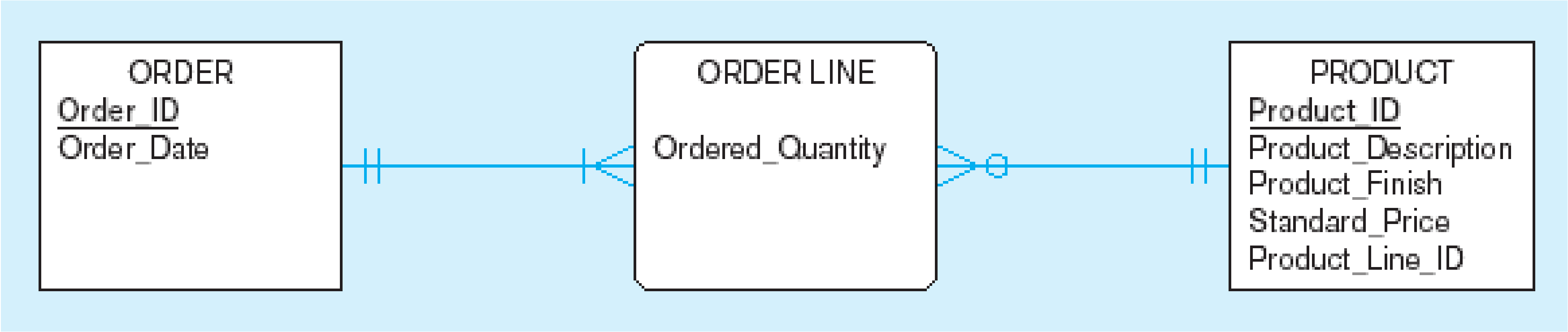
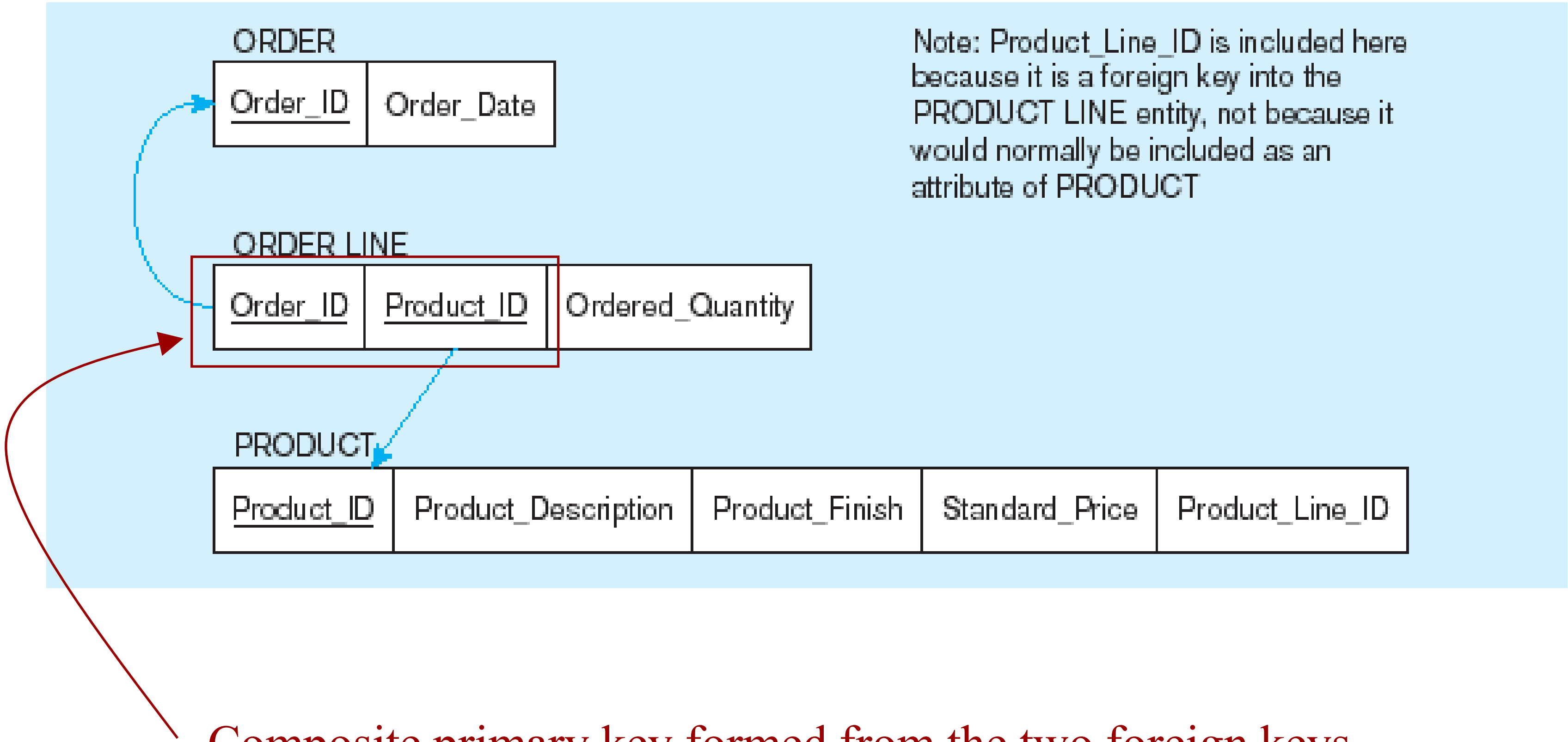


Figure 5-15 Example of mapping an associative entity (cont.)

b) Three resulting relations



Composite primary key formed from the two foreign keys

Figure 5-16 Example of mapping an associative entity with an identifier

a) SHIPMENT associative entity

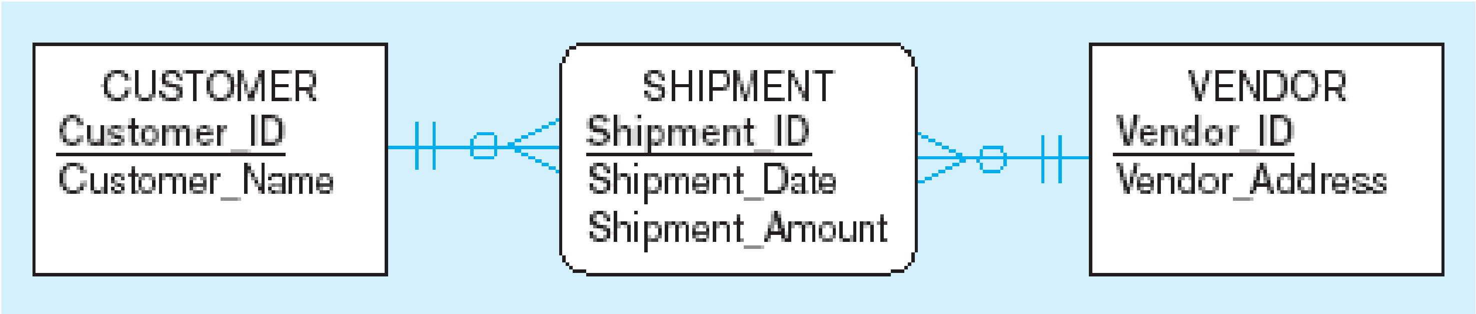
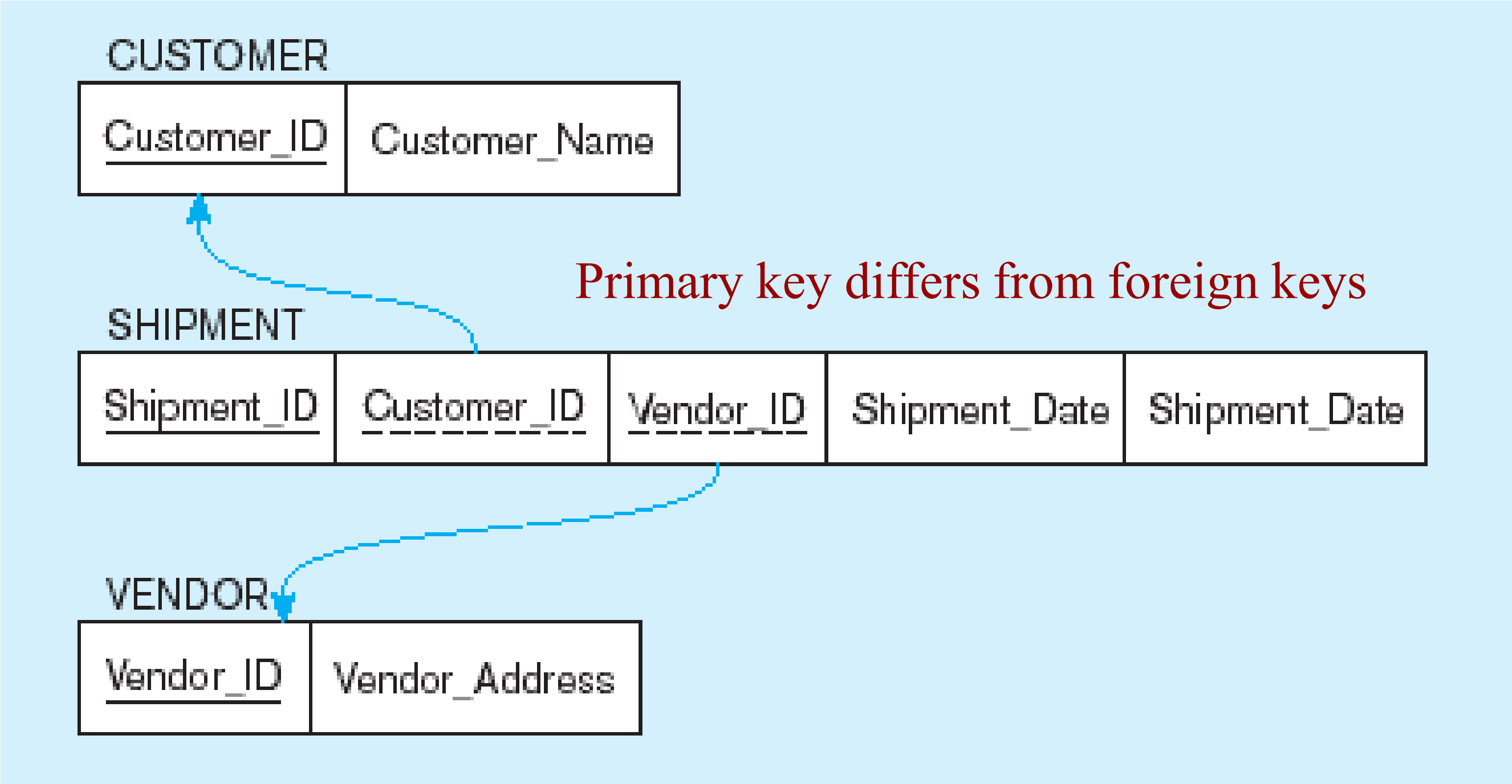


Figure 5-16 Example of mapping an associative entity with an identifier (cont.)

b) Three resulting relations

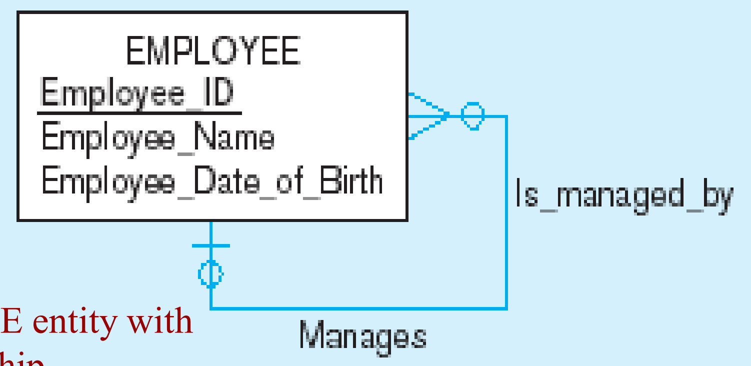


Transforming EER Diagrams into Relations (cont.)

Mapping Unary Relationships

- One-to-Many–Recursive foreign key in the same relation
- Many-to-Many–Two relations:
  - One for the entity type
  - One for an associative relation in which the primary key has two attributes, both taken from the primary key of the entity

Figure 5-17 Mapping a unary 1:N relationship



(a) EMPLOYEE entity with unary relationship

(b) EMPLOYEE relation with recursive foreign key

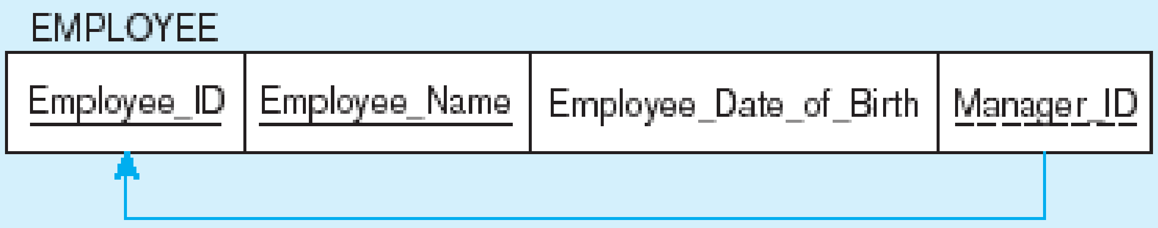
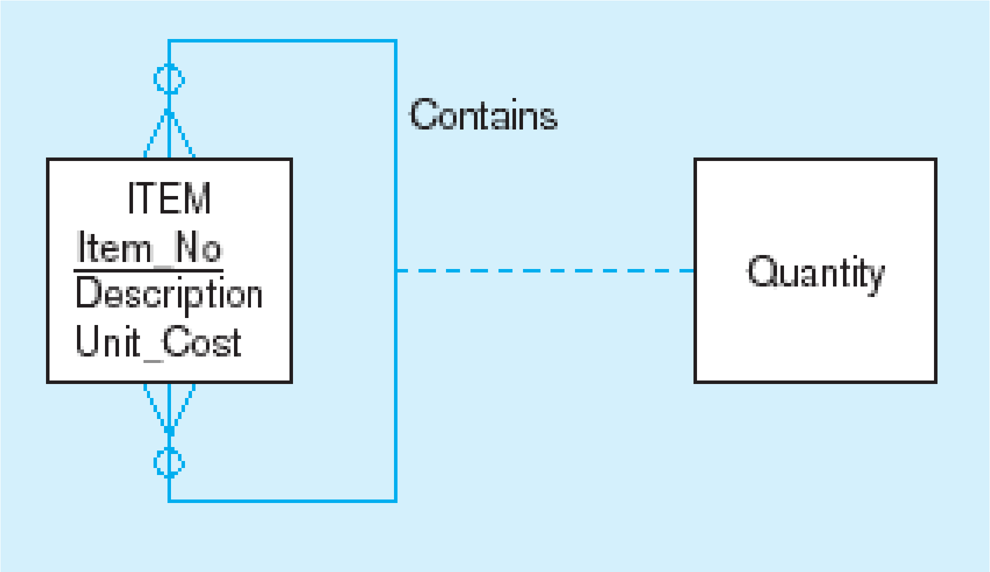
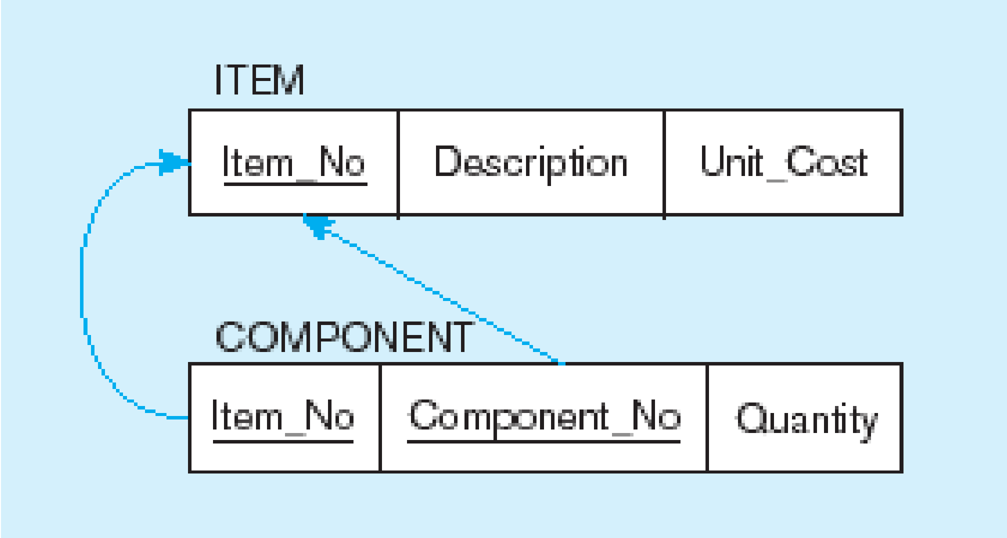


Figure 5-18 Mapping a unary M:N relationship



(a) Bill-of-materials relationships (M:N)

(b) ITEM and COMPONENT relations



Transforming EER Diagrams into Relations (cont.)

Mapping Ternary (and n-ary) Relationships

- One relation for each entity and one for the associative entity
- Associative entity has foreign keys to each entity in the relationship

Figure 5-19 Mapping a ternary relationship

a) PATIENT TREATMENT Ternary relationship with associative entity

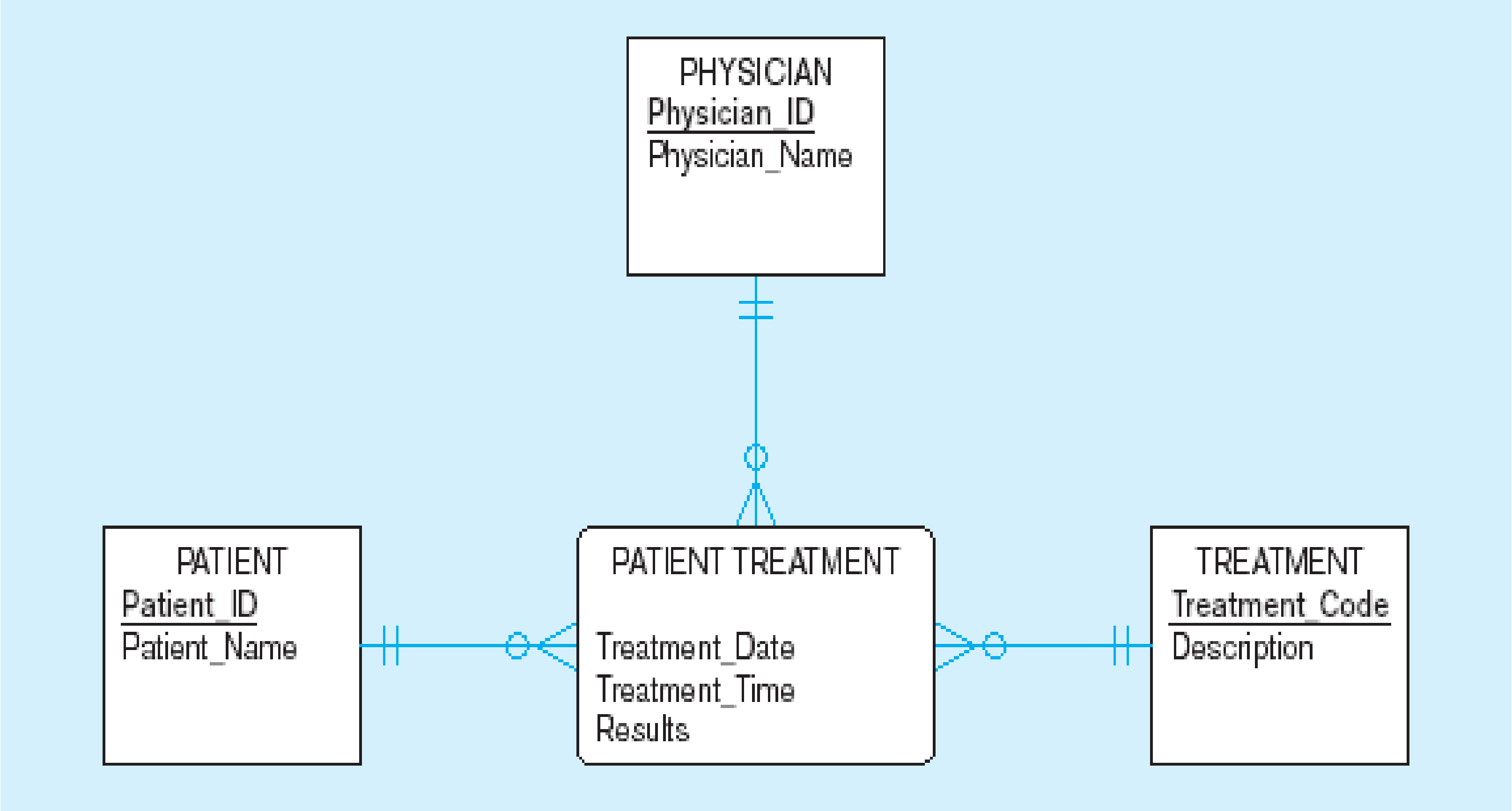
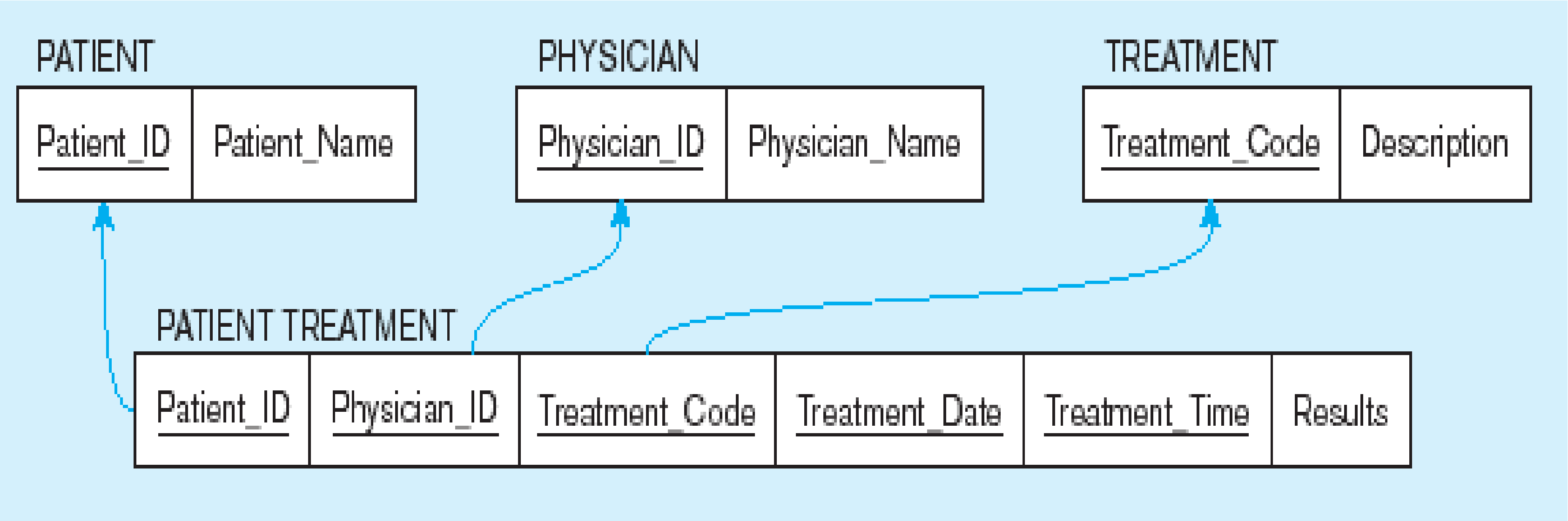


Figure 5-19 Mapping a ternary relationship (cont.)

b) Mapping the ternary relationship PATIENT TREATMENT



Remember that the primary key MUST be unique

This is why treatment date and time are included in the composite primary key

But this makes a very cumbersome key…

It would be better to create a surrogate key like Treatment#

Figure 5-20 Supertype/subtype relationships

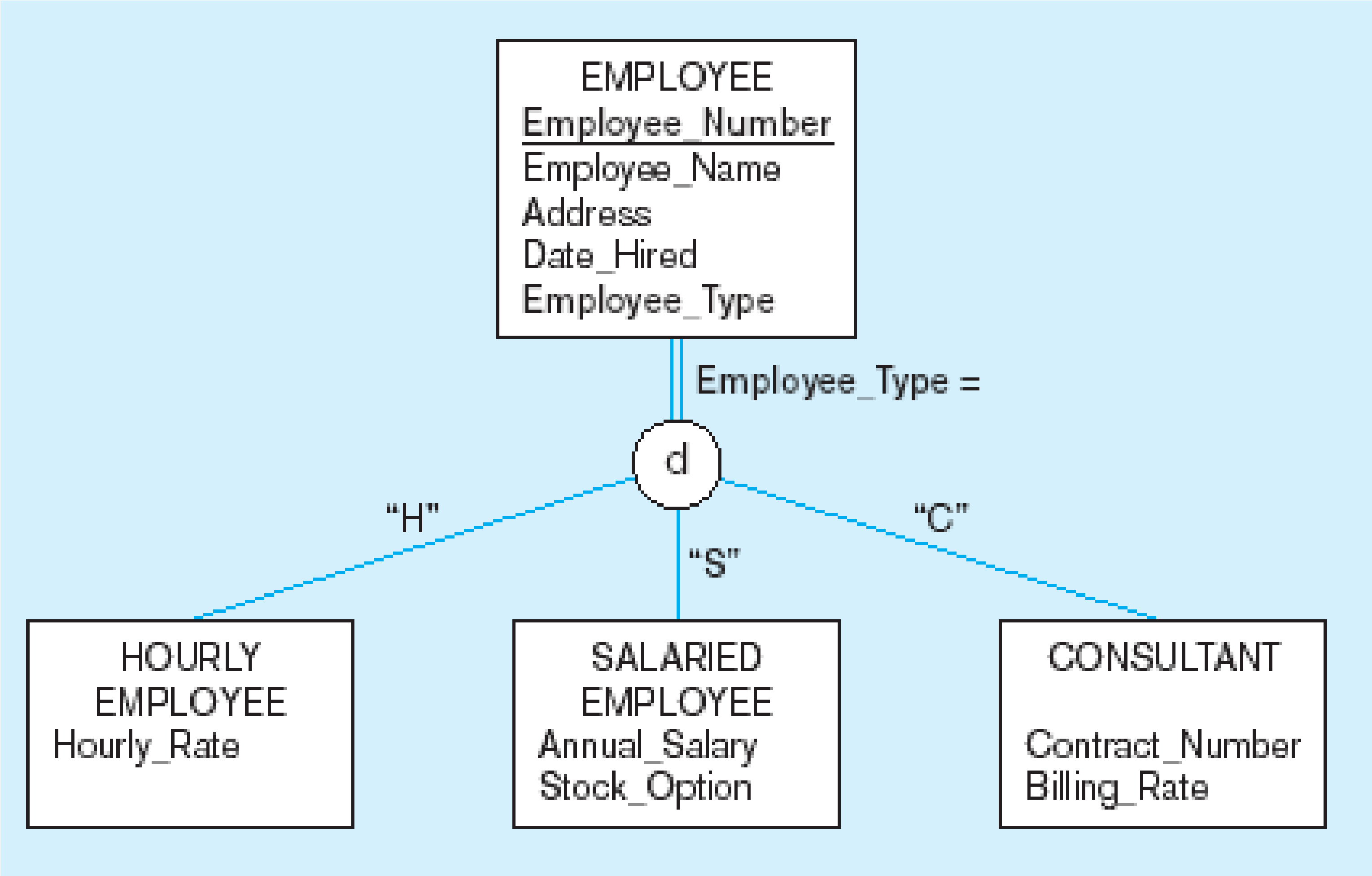
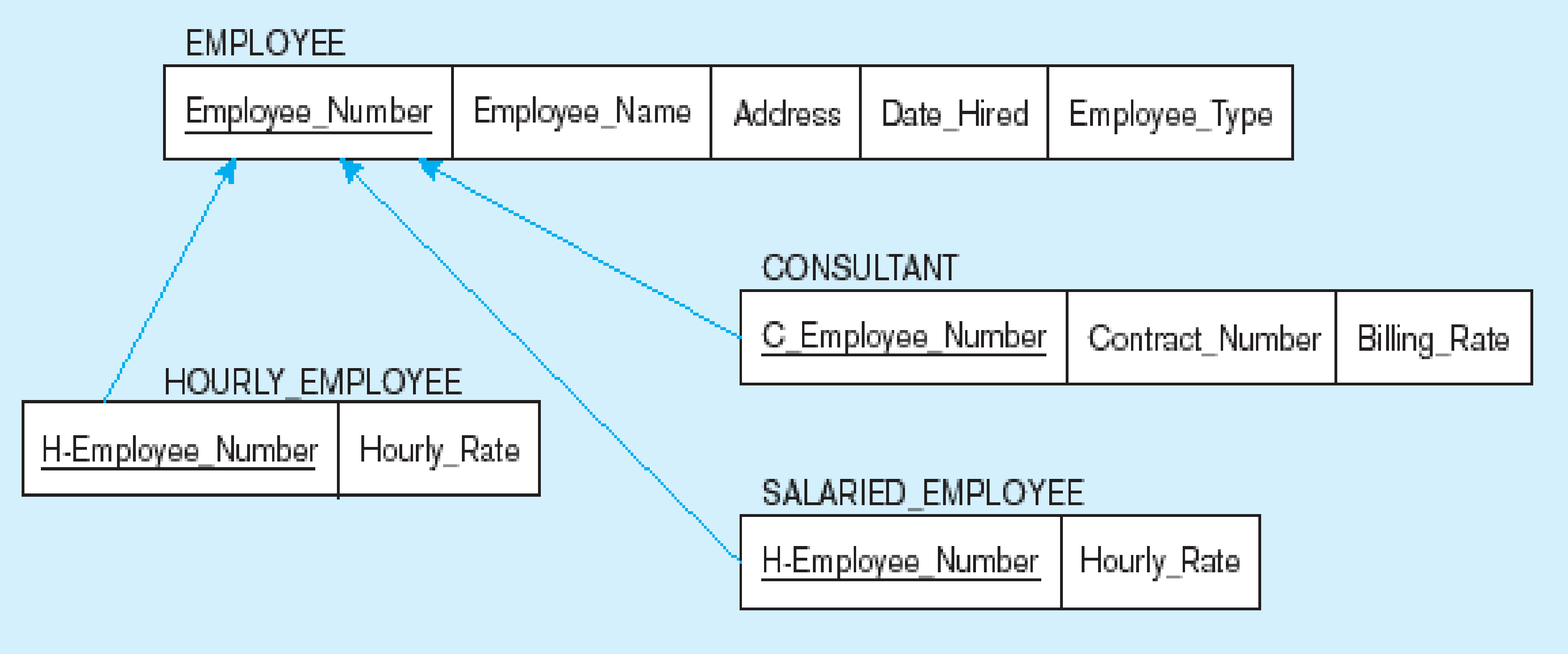


Figure 5-21
Mapping Supertype/subtype relationships to relations



These are implemented as one-to-one relationships

Example–Figure 5-2b

EMPLOYEE2

Emp_ID	Name	Dept_Name	Salary	Course_Title	Date_Completed
100	Margaret Simpson	Marketing	48,000	SPSS	6/19/200X
100	Margaret Simpson	Marketing	48,000	Surveys	10/7/200X
140	Alan Beeton	Accounting	52,000	Tax Acc	12/8/200X
110	Chris Lucero	Info Systems	43,000	Visual Basic	1/12/200X
110	Chris Lucero	Info Systems	43,000	C++	4/22/200X
190	Lorenzo Davis	Finance	55,000		
150	Susan Martin	Marketing	42,000	SPSS	6/19/200X
150	Susan Martin	Marketing	42,000	Java	8/12/200X

Question–Is this a relation?

Question–What's the primary key?

Answer–Composite: Emp_ID, Course_Title

Answer–Yes: Unique rows and no multivalued attributes

Anomalies in this Table

- **Insertion**–can't enter a new employee without having the employee take a class
- **Deletion**–if we remove employee 140, we lose information about the existence of a Tax Acc class
- **Modification**–giving a salary increase to employee 100 forces us to update multiple records

Why do these anomalies exist?

Because there are two themes (entity types) in this one relation. This results in data duplication and an unnecessary dependency between the entities

Functional Dependencies and Keys

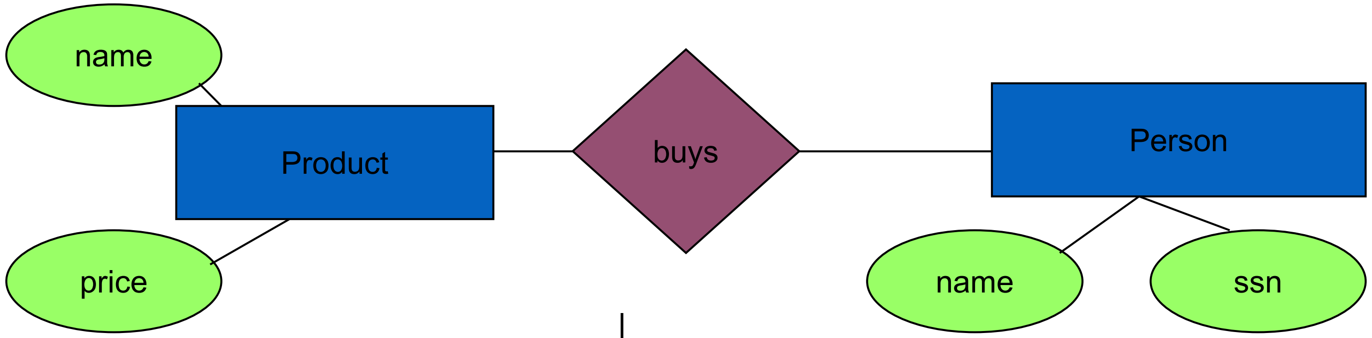
- Functional Dependency (FD): The value of one attribute (the ***determinant***) determines the value of another attribute
- Candidate Key:
  - A unique identifier. One of the candidate keys will become the primary key
    - E.g. perhaps there is both credit card number and SS# in a table…in this case both are candidate keys
  - Each non-key field is functionally dependent on every candidate key

The benefits of normalization

- Retrieval more efficient
- Insert, update, and delete operation more efficient
- Reduce data redundancy
- Simplifies maintenance and reduces storage

Relational Schema Design

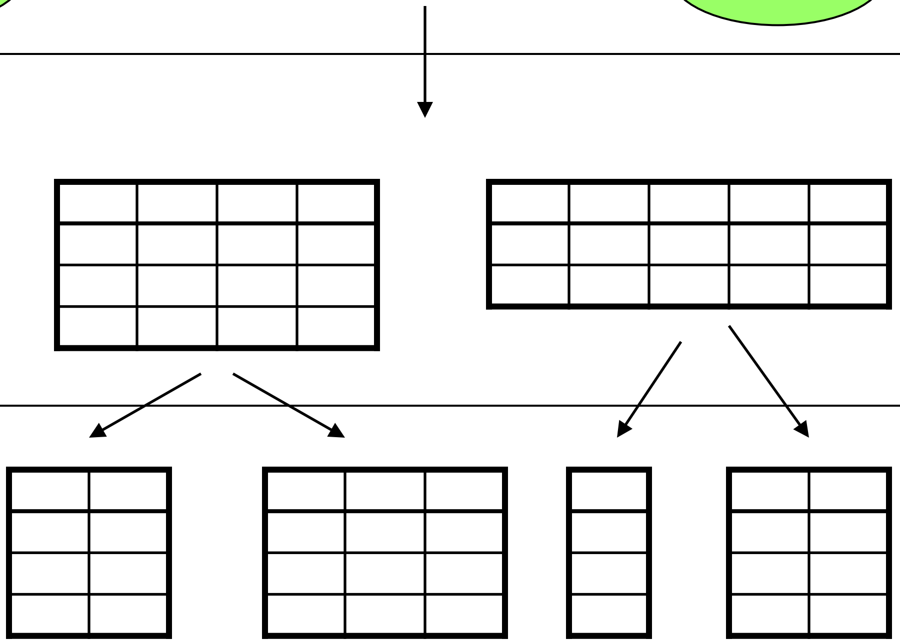
Conceptual Model:



Relational Model:

plus FD's

FD: Functional dependencies



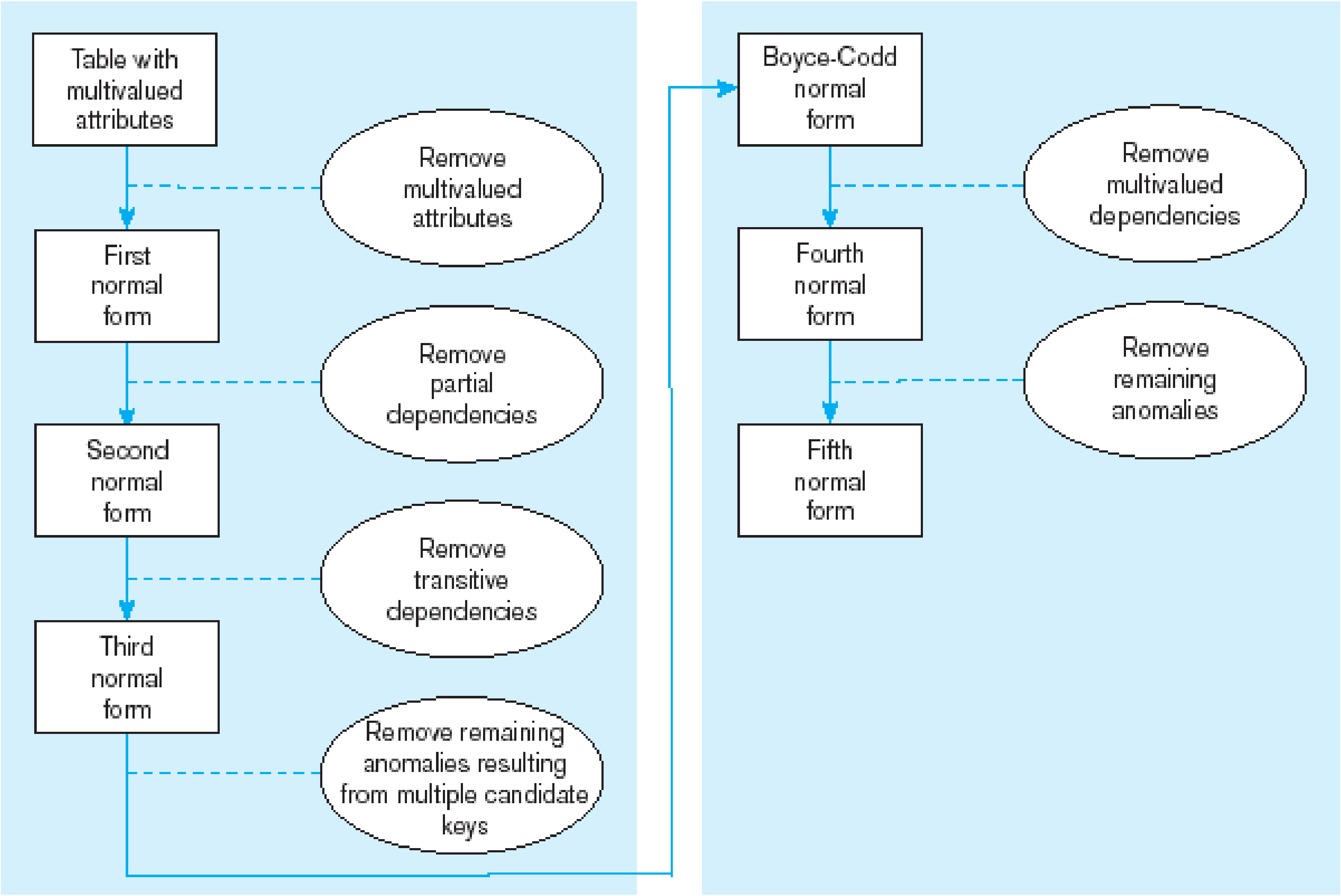
Normalization:

Eliminates ***anomalies***

Anomaly

- **Insertion Anomaly**–adding new rows forces user to create duplicate data
- **Deletion Anomaly**–deleting rows may cause a loss of data that would be needed for other future rows
- **Modification Anomaly**–changing data in a row forces changes to other rows because of duplication

Steps in normalization



First Normal Form

- No multivalued attributes
- Every attribute value is atomic
- ***All relations* are in 1st Normal Form**

Table with multivalued attributes, not in 1st normal form

Figure 5-25
INVOICE data (Pine Valley Furniture Company)

Order_ID	Order_ Date	Customer_ ID	Customer_ Name	Customer_ Address	Product_ID	Product_ Description	Product_ Finish	Unit_ Price	Ordered_ Quantity
1006	10/24/2006	2	Value Furniture	Plano, TX	7	Dining Table	Natural Ash	800.00	2
					5	Writer's Desk	Cherry	325.00	2
					4	Entertainment Center	Natural Maple	650.00	1
1007	10/25/2006	6	Furniture Gallery	Boulder, CO	11	4–Dr Dresser	Oak	500.00	4
					4	Entertainment Center	Natural Maple	650.00	3

Note: this is NOT a relation(Not in first normal form)

Table with no multivalued attributes and unique rows, in 1st normal form

Order_ID	Order_Date	Customer_ID	Customer_Name	Customer_Address	Product_ID	Product_Description	Product_Finish	Unit_Price	Ordered_Quantity
1006	10/24/2006	2	Value Furniture	Plano, TX	7	Dining Table	Natural Ash	800.00	2
1006	10/24/2006	2	Value Furniture	Plano, TX	5	Writer's Desk	Cherry	325.00	2
1006	10/24/2006	2	Value Furniture	Plano, TX	4	Entertainment Center	Natural Maple	650.00	1
1007	10/25/2006	6	Furniture Gallery	Boulder, CO	11	4–Dr Dresser	Oak	500.00	4
1007	10/25/2006	6	Furniture Gallery	Boulder, CO	4	Entertainment Center	Natural Maple	650.00	3

Figure 5-26
INVOICE relation (1NF) (Pine Valley Furniture Company)

Product_ID → Product_Description, Product_Finish, Unit_Price
Order_ID, Product_ID → Ordered_Quantity

Note: this is relation, but not a well-structured one (in 1st normal form)

Anomalies in this Table

- **Insertion**–if new product is ordered for order 1007 of existing customer, customer data must be re-entered, causing duplication
- **Deletion**–if we delete the Dining Table from Order 1006, we lose information concerning this item's finish and price
- **Update**–changing the price of product ID 4 requires update in several records

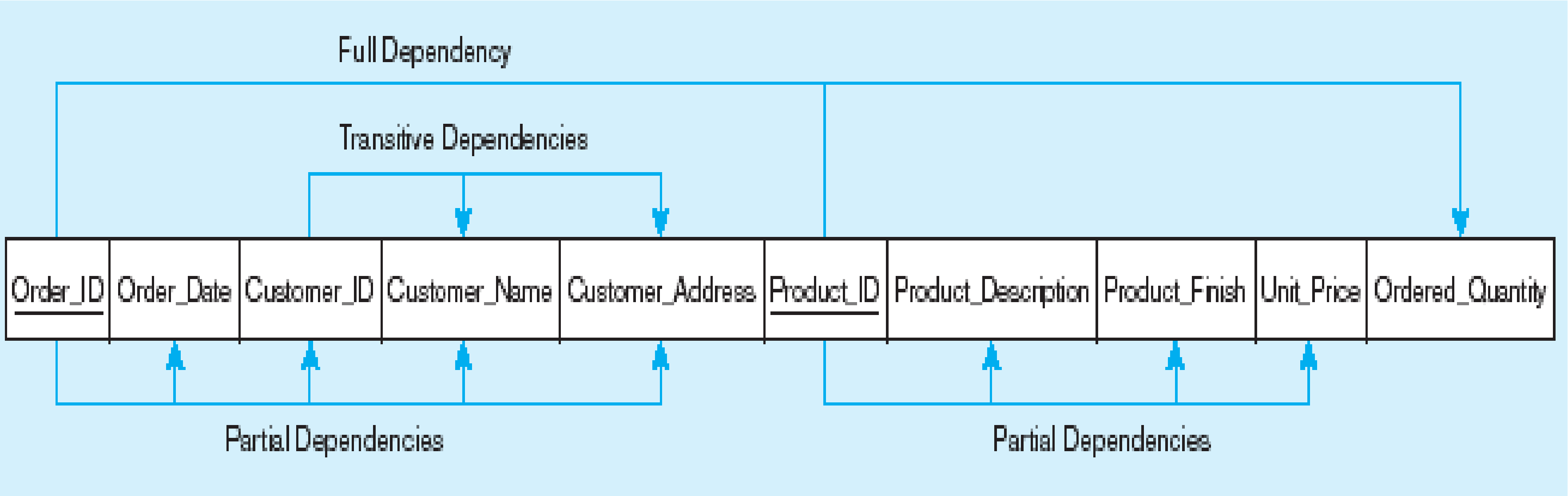
Why do these anomalies exist?

Because there are multiple themes (entity types) in one relation. This results in duplication and an unnecessary dependency between the entities

Second Normal Form

- 1NF PLUS ***every non-key attribute is fully functionally dependent on the ENTIRE primary key***
  - Every non-key attribute must be defined by the entire key, not by only part of the key
  - No partial functional dependencies

Functional dependency diagram for INVOICE



Order_ID ➔ Order_Date, Customer_ID, Customer_Name, Customer_Address

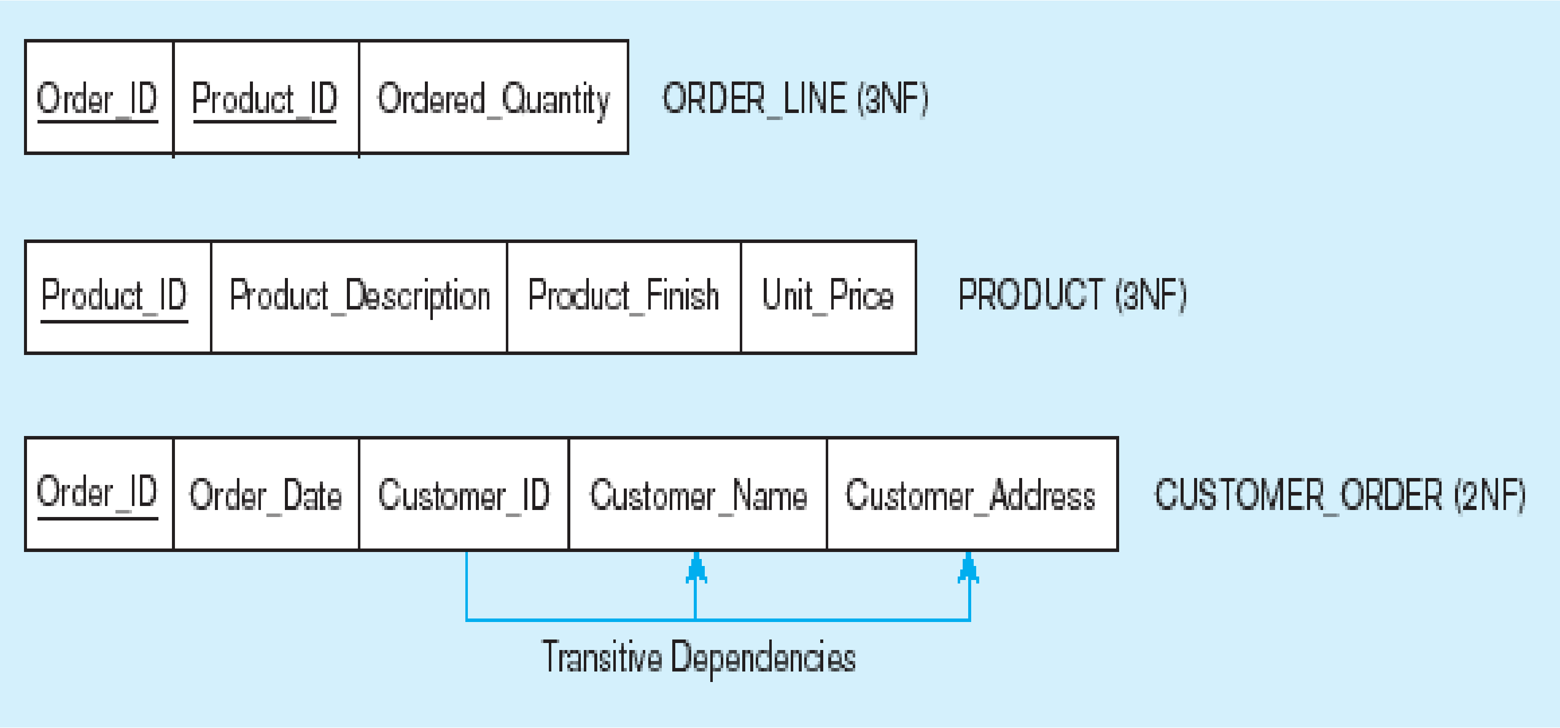
Customer_ID ➔ Customer_Name, Customer_Address

Product_ID ➔ Product_Description, Product_Finish, Unit_Price

Order_ID, Product_ID ➔ Order_Quantity

Therefore, NOT in 2nd Normal Form

Removing partial dependencies



Partial dependencies are removed, but there are still transitive dependencies

Getting it into Second Normal Form

Third Normal Form

- 2NF PLUS ***no transitive dependencies*** (functional dependencies on non-primary-key attributes)
- Note: This is called transitive, because the primary key is a determinant for another attribute, which in turn is a determinant for a third
- Solution: Non-key determinant with transitive dependencies go into a new table; non-key determinant becomes primary key in the new table and stays as foreign key in the old table

Figure 5-28 Removing partial dependencies

Order_ID	Order_Date	Customer_ID

ORDER (3NF)

Getting it into Third Normal Form

Customer_ID	Customer_Name	Customer_Address

CUSTOMER (3NF)

Transitive dependencies are removed