LOGICAL DATABASE DESIGN AND THE RELATIONAL MODEL

Chapter 4

COMPONENTS OF RELATIONAL MODEL

- Data structure
  - Tables (relations), rows, columns
- Data manipulation
  - Powerful SQL operations for retrieving and modifying data
- Data integrity
  - Mechanisms for implementing business rules that maintain integrity of manipulated data

RELATION

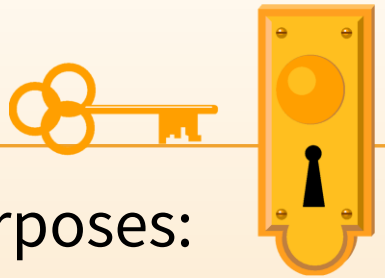
- A relation is a named, two-dimensional table of data.
- A table consists of rows (records) and columns (attributes or fields).
- Requirements for a table to qualify as a relation:
  - It must have a unique name.
  - Every attribute value must be atomic (not multivalued, not composite).
  - Every row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

CORRESPONDENCE WITH E-R MODEL

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

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

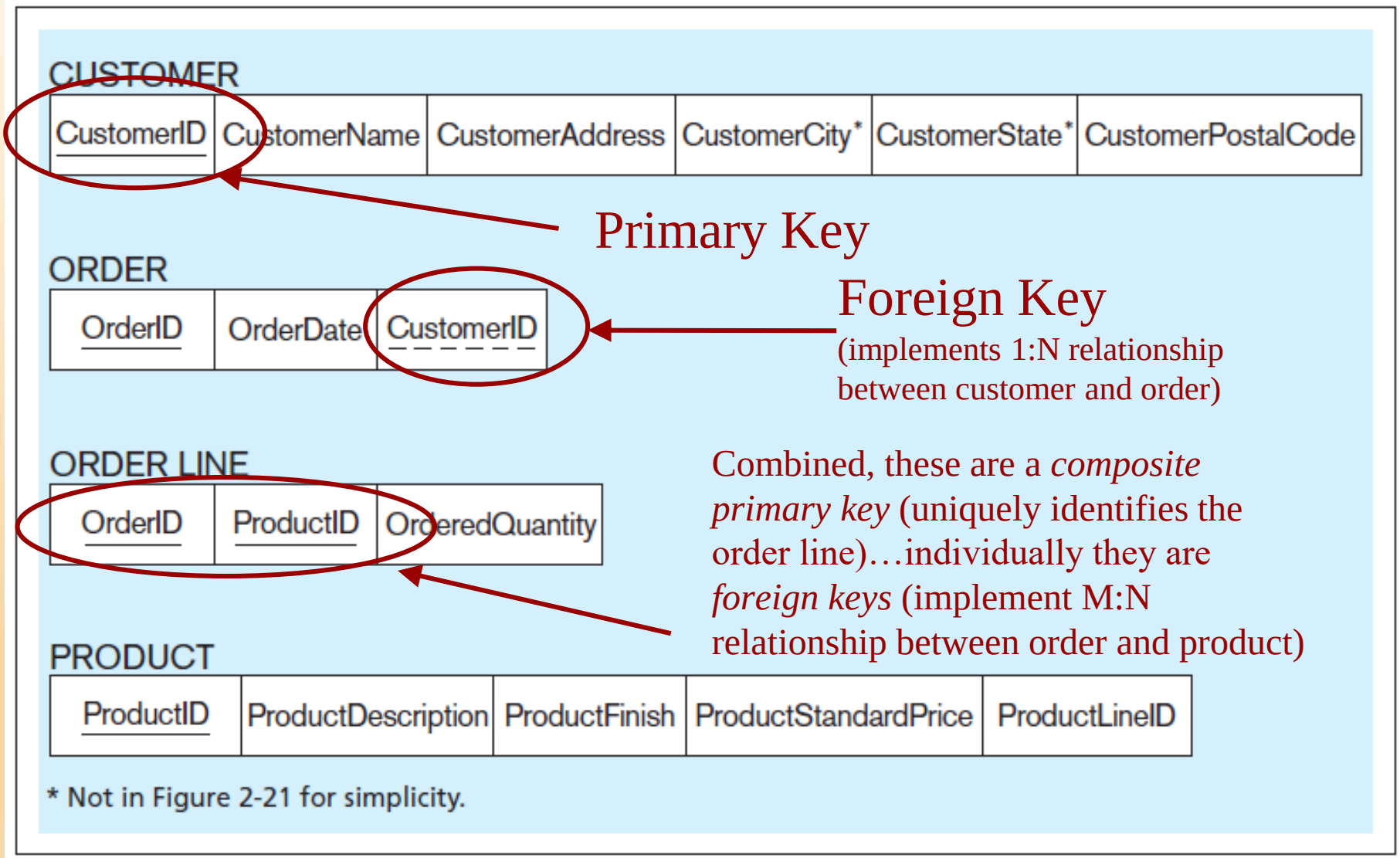
KEY FIELDS



- Keys are special fields that serve two main purposes:
  - ***Primary keys.*** Unique identifiers of the relation. Examples include employee numbers, social security numbers, etc. *This guarantees that all rows are unique.*
  - ***Foreign keys*** .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 4-3 Schema for four relations (Pine Valley Furniture Company)



INTEGRITY CONSTRAINTS

- Domain Constraints
  - Allowable values for an attribute.
  - Example – ZIP = 5 characters
  - Size = Small, Medium, Large

- Entity Integrity
  - No primary key attribute may be null. All primary key fields **MUST** have data

TABLE 4-1 Domain Definitions for INVOICE Attributes

Attribute	Domain Name	Description	Domain
CustomerID	Customer IDs	Set of all possible customer IDs	character: size 5
CustomerName	Customer Names	Set of all possible customer names	character: size 25
CustomerAddress	Customer Addresses	Set of all possible customer addresses	character: size 30
CustomerCity	Cities	Set of all possible cities	character: size 20
CustomerState	States	Set of all possible states	character: size 2
CustomerPostalCode	Postal Codes	Set of all possible postal zip codes	character: size 10
OrderID	Order IDs	Set of all possible order IDs	character: size 5
OrderDate	Order Dates	Set of all possible order dates	date: format mm/dd/yy
ProductID	Product IDs	Set of all possible product IDs	character: size 5
ProductDescription	Product Descriptions	Set of all possible product descriptions	character: size 25
ProductFinish	Product Finishes	Set of all possible product finishes	character: size 15
ProductStandardPrice	Unit Prices	Set of all possible unit prices	monetary: 6 digits
ProductLineID	Product Line IDs	Set of all possible product line IDs	integer: 3 digits
OrderedQuantity	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)
- See next slide.

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 4-5
Referential integrity constraints (Pine Valley Furniture)

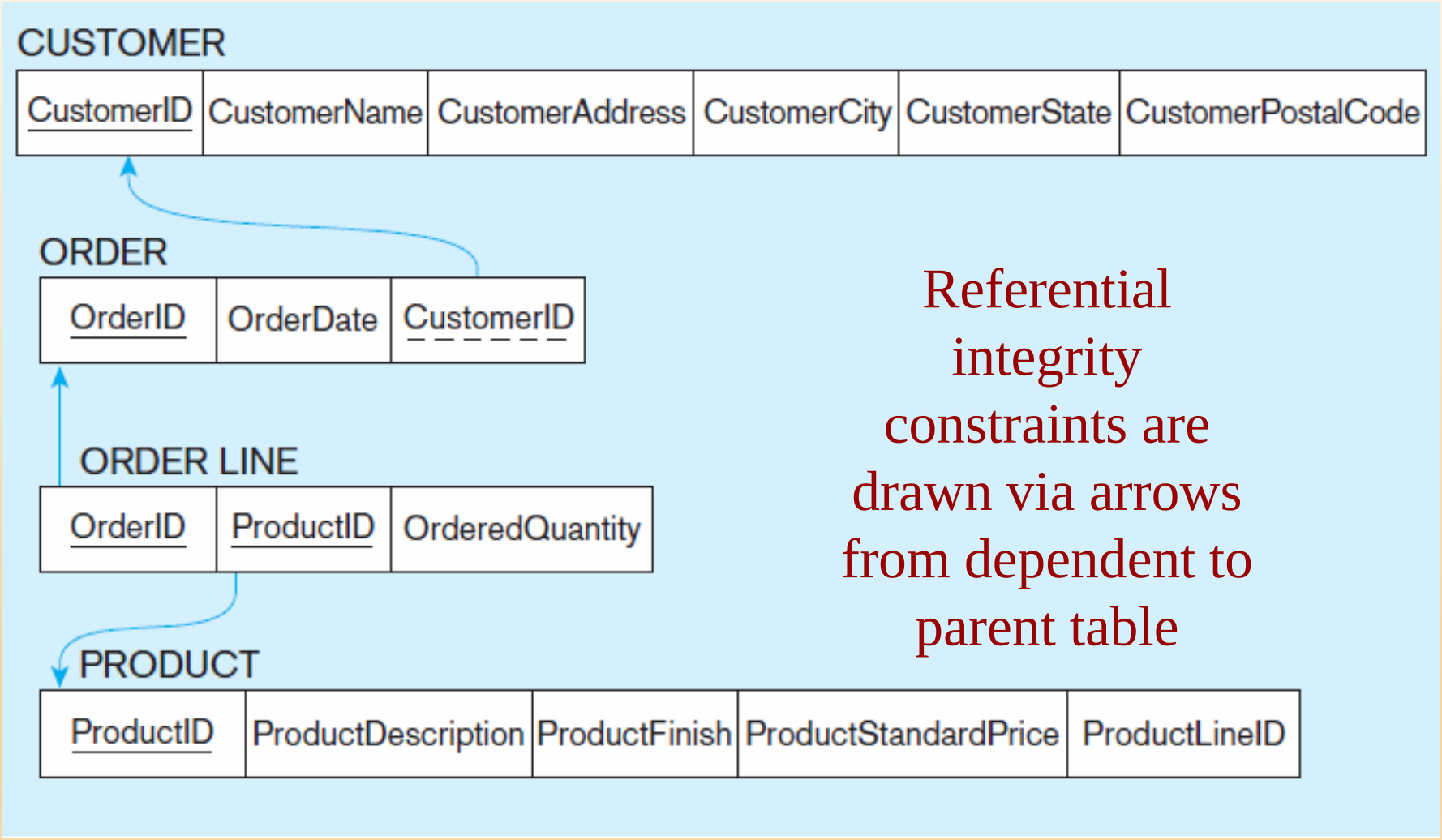


Figure 4-6 SQL table definitions

```
CREATE TABLE Customer_T
        (CustomerID                     NUMBER(11,0)      NOT NULL,
        CustomerName                    VARCHAR2(25)      NOT NULL,
        CustomerAddress                 VARCHAR2(30),
        CustomerCity                    VARCHAR2(20),
        CustomerState                   CHAR(2),
        CustomerPostalCode              VARCHAR2(9),
CONSTRAINT Customer_PK PRIMARY KEY (CustomerID));

CREATE TABLE Order_T
        (OrderID                        NUMBER(11,0)      NOT NULL,
        OrderDate                       DATE DEFAULT SYSDATE,
        CustomerID                      NUMBER(11,0),
CONSTRAINT Order_PK PRIMARY KEY (OrderID),
CONSTRAINT Order_FK FOREIGN KEY (CustomerID) REFERENCES Customer_T (CustomerID));

CREATE TABLE Product_T
        (ProductID                      NUMBER(11,0)      NOT NULL,
        ProductDescription              VARCHAR2(50),
        ProductFinish                   VARCHAR2(20),
        ProductStandardPrice            DECIMAL(6,2),
        ProductLineID                   NUMBER(11,0),
CONSTRAINT Product_PK PRIMARY KEY (ProductID));

CREATE TABLE OrderLine_T
        (OrderID                        NUMBER(11,0)      NOT NULL,
        ProductID                       NUMBER(11,0)      NOT NULL,
        OrderedQuantity                 NUMBER(11,0),
CONSTRAINT OrderLine_PK PRIMARY KEY (OrderID, ProductID),
CONSTRAINT OrderLine_FK1 FOREIGN KEY (OrderID) REFERENCES Order_T (OrderID),
CONSTRAINT OrderLine_FK2 FOREIGN KEY (ProductID) REFERENCES Product_T (ProductID));
```

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

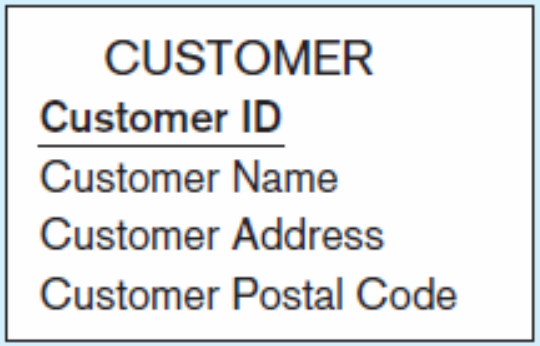
TRANSFORMING EER DIAGRAMS INTO RELATIONS

Mapping Regular Entities to Relations

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

Figure 4-8 Mapping a regular entity

(a) CUSTOMER entity type with simple attributes



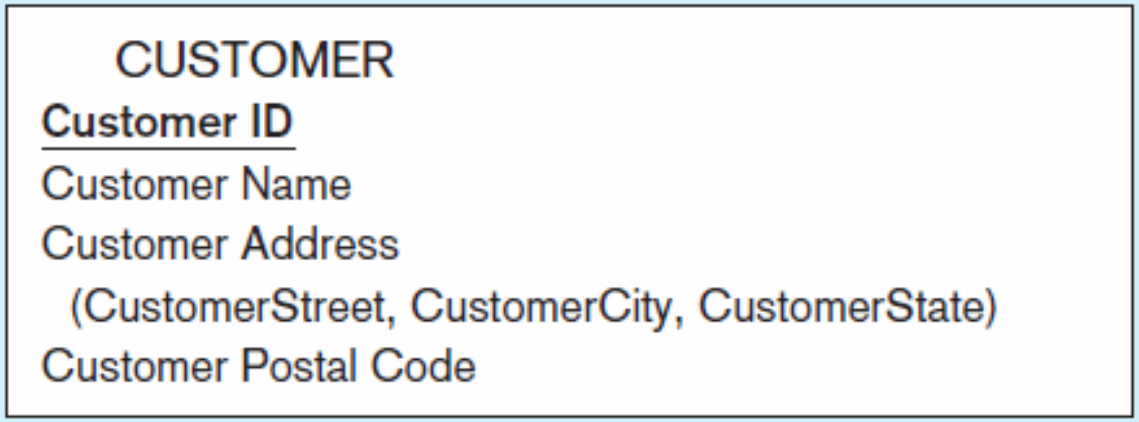
(b) CUSTOMER relation

CUSTOMER

CustomerID	CustomerName	CustomerAddress	CustomerPostalCode

Figure 4-9 Mapping a composite attribute

(a) CUSTOMER entity type with composite attribute



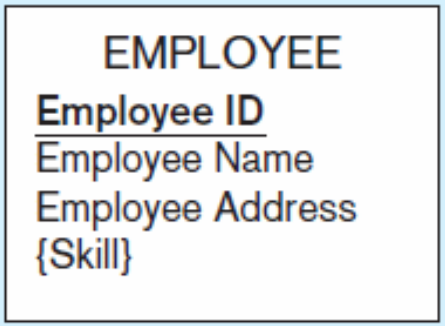
(b) CUSTOMER relation with address detail

CUSTOMER

CustomerID	CustomerName	CustomerStreet	CustomerCity	CustomerState	CustomerPostalCode

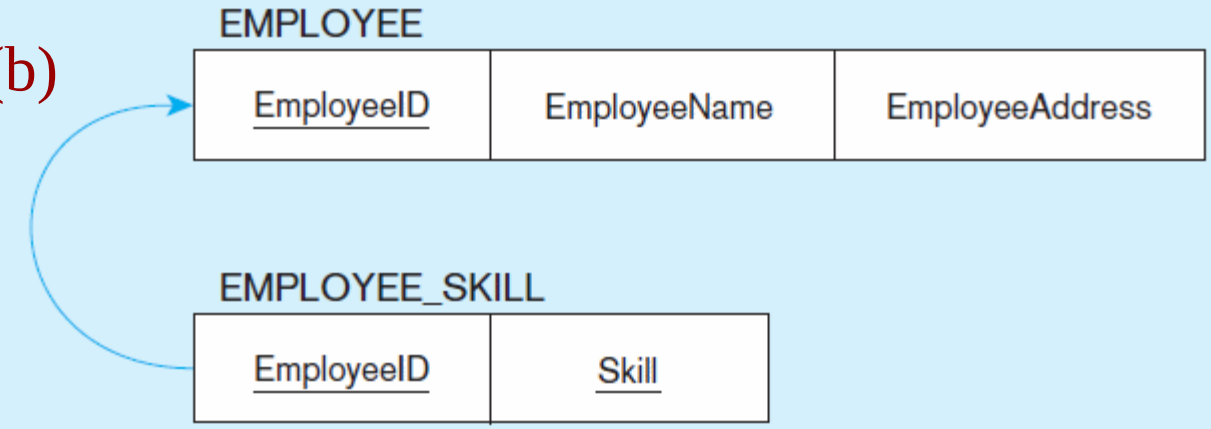
Figure 4-10 Mapping an entity with a multivalued attribute

(a)



Multivalued attribute becomes a separate relation with foreign key

(b)



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 4-11 Example of mapping a weak entity

a) Weak entity DEPENDENT

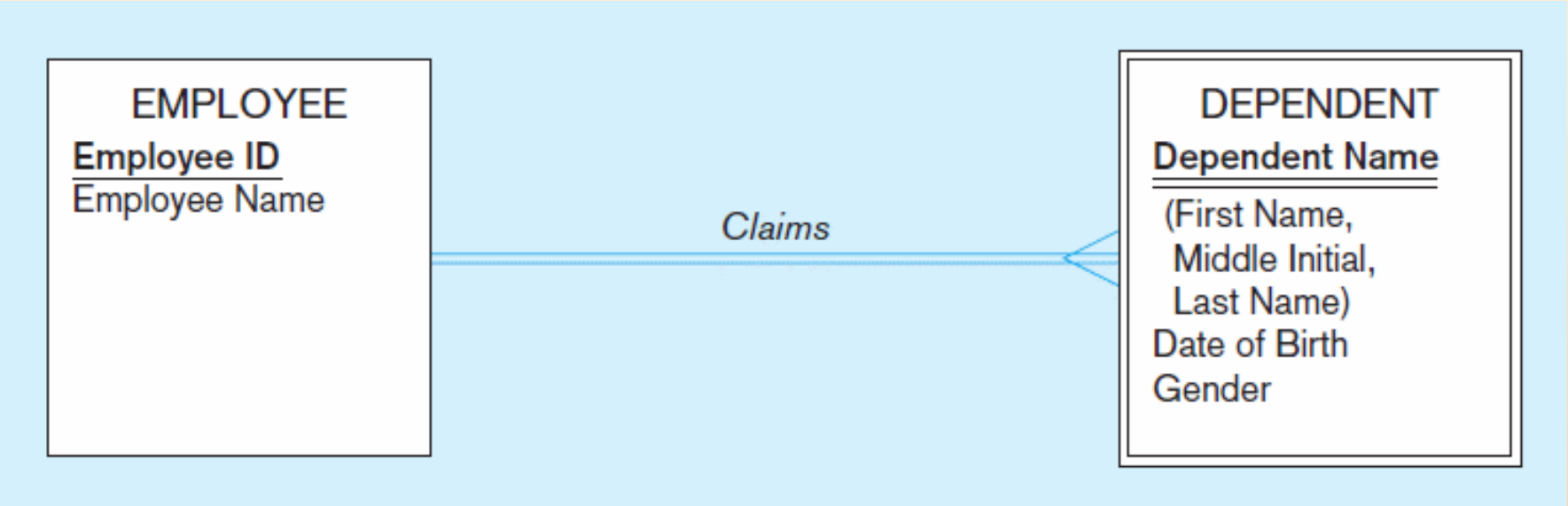
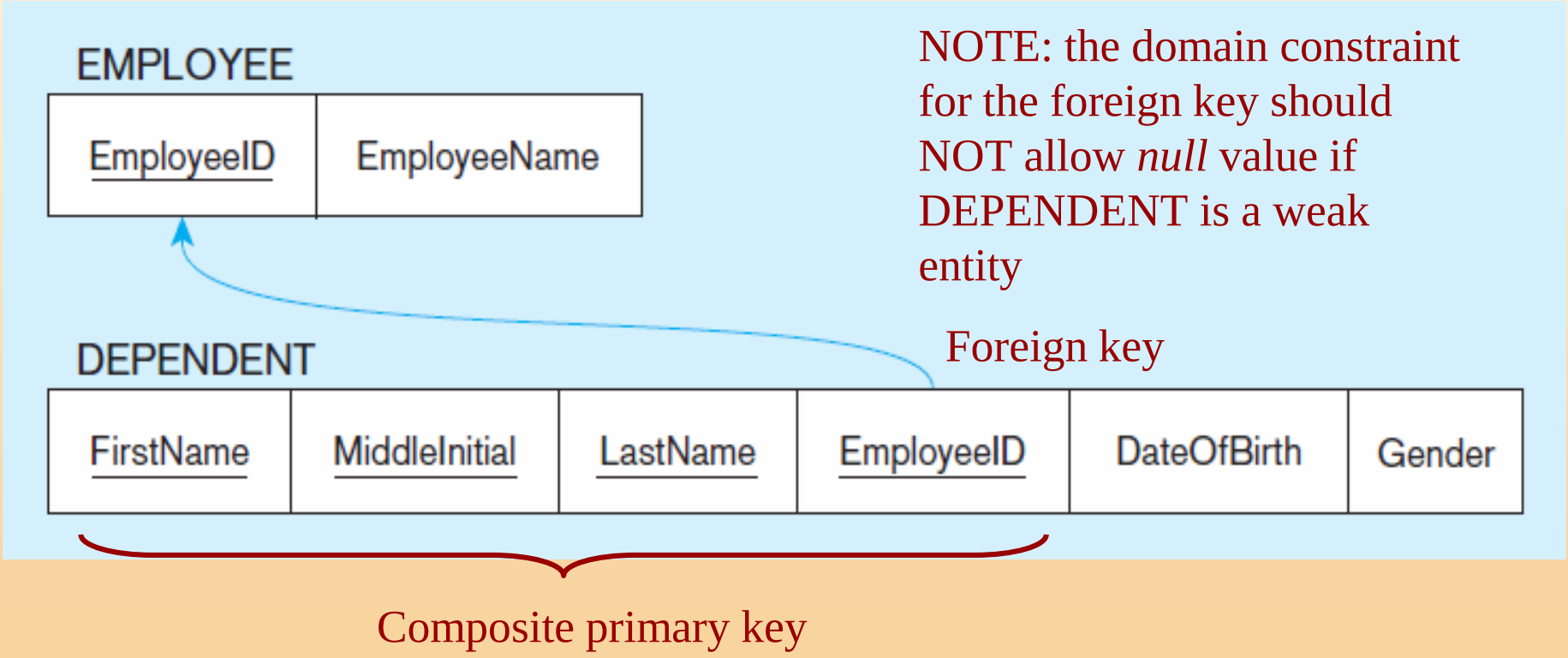


Figure 4-11 Example of mapping a weak entity (cont.)

b) Relations resulting from weak entity



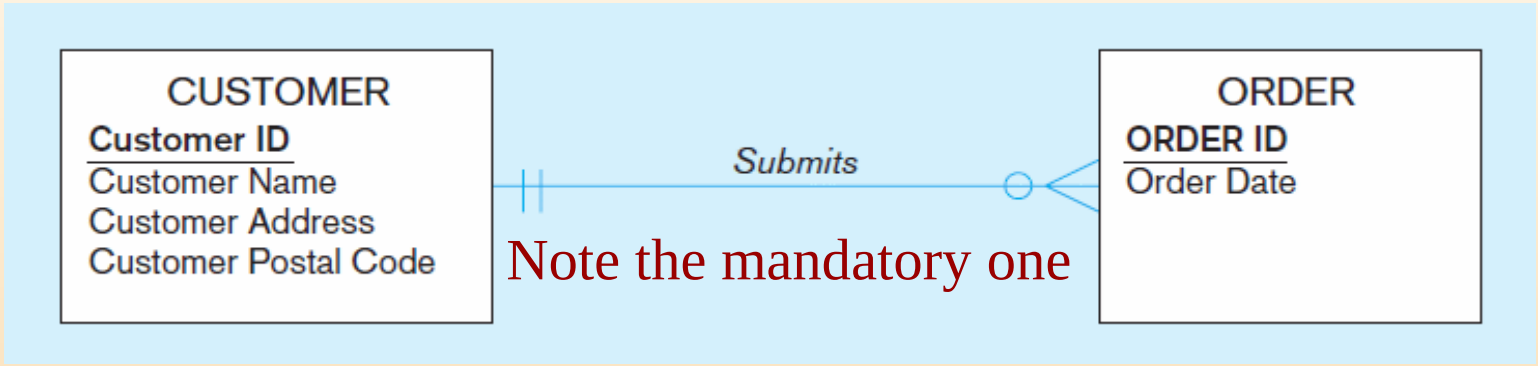
TRANSFORMING EER DIAGRAMS INTO RELATIONS (CONT.)

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 mandatory side becomes a foreign key on optional side

Figure 4-12 Example of mapping a 1:M relationship

a) Relationship between customers and orders



b) Mapping the relationship

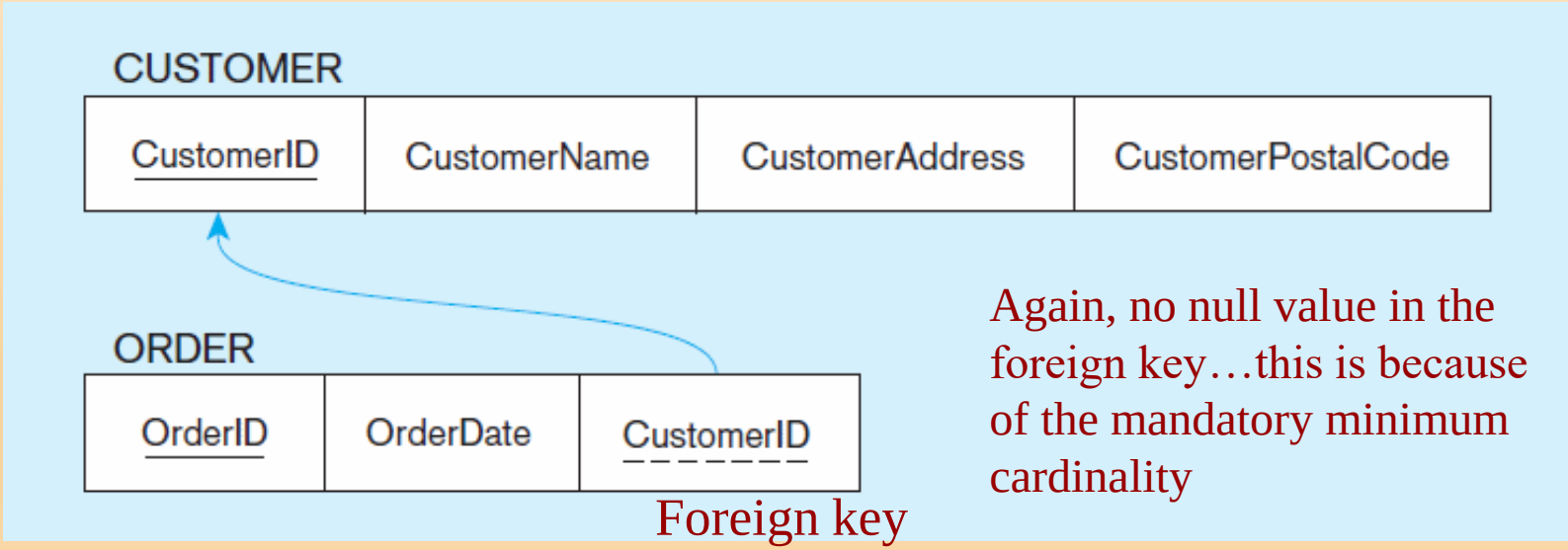
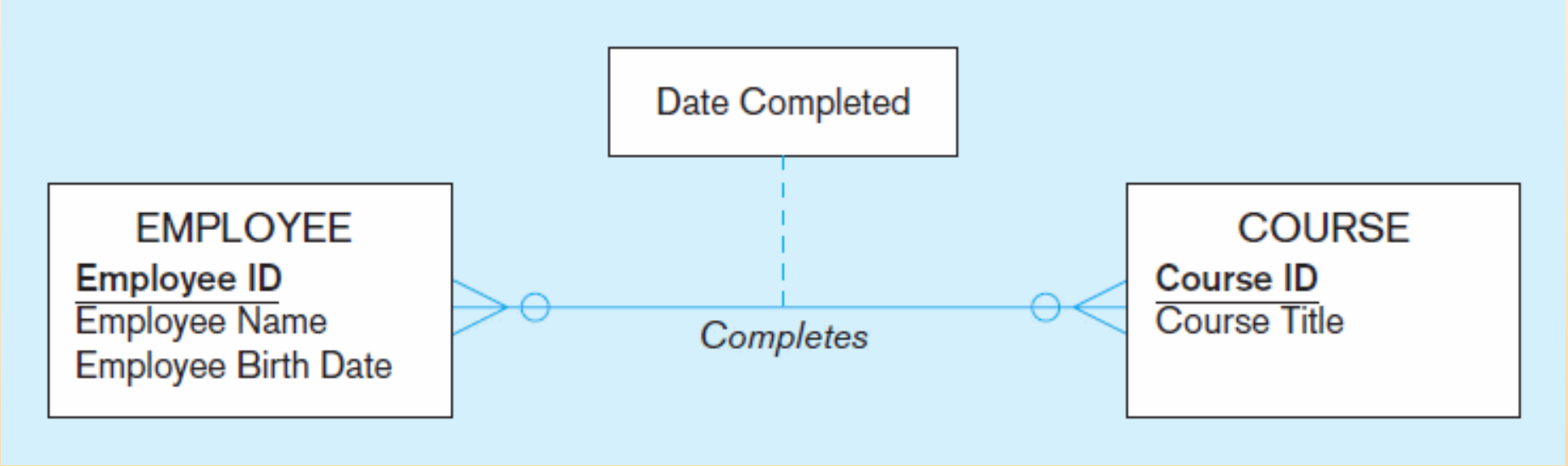


Figure 4-13 Example of mapping an M:N relationship

a) Completes relationship (M:N)



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

Figure 4-13 Example of mapping an M:N relationship (cont.)

b) Three resulting relations

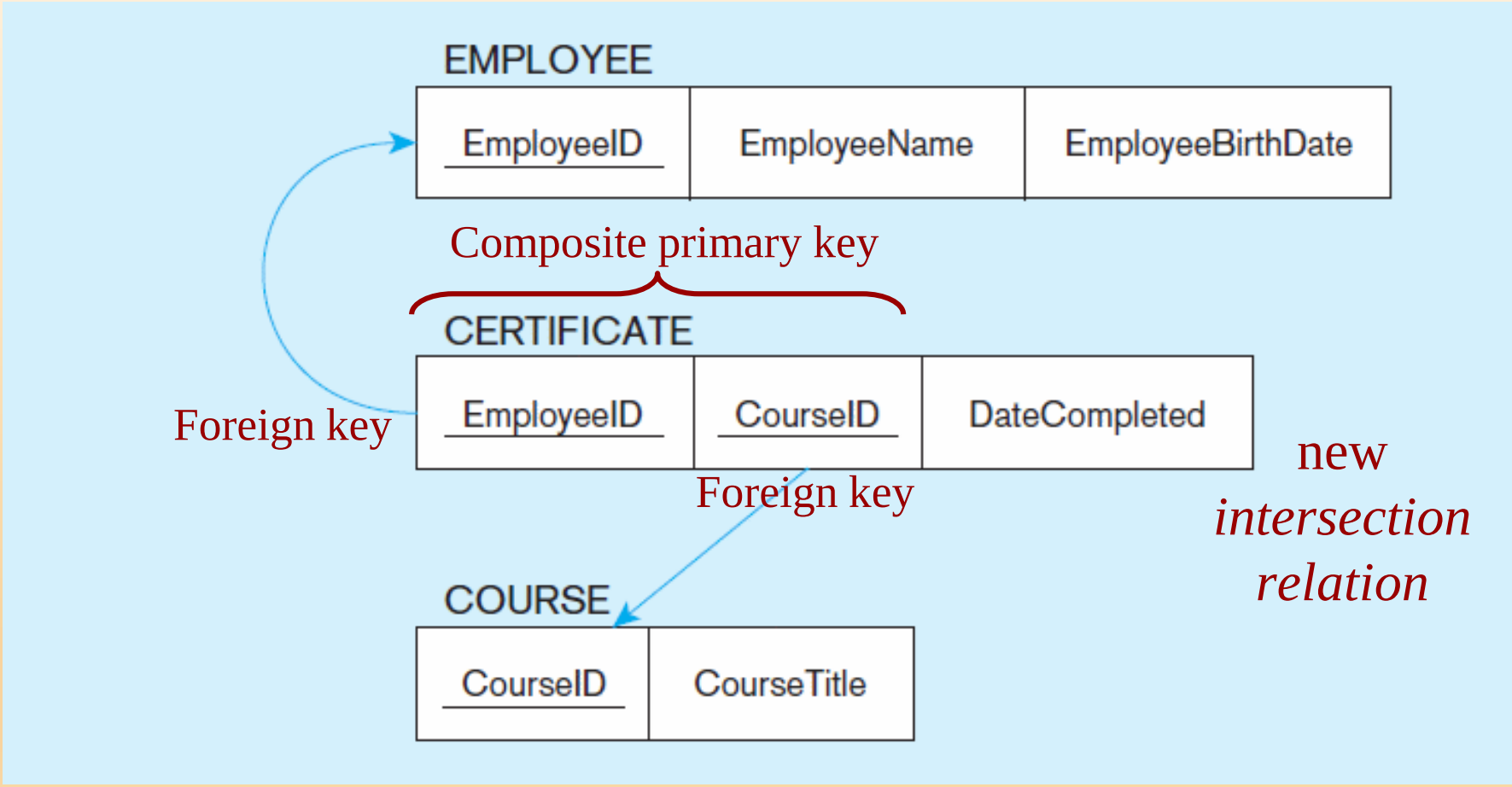


Figure 4-19 Mapping a ternary relationship

a) PATIENT TREATMENT Ternary relationship with associative entity

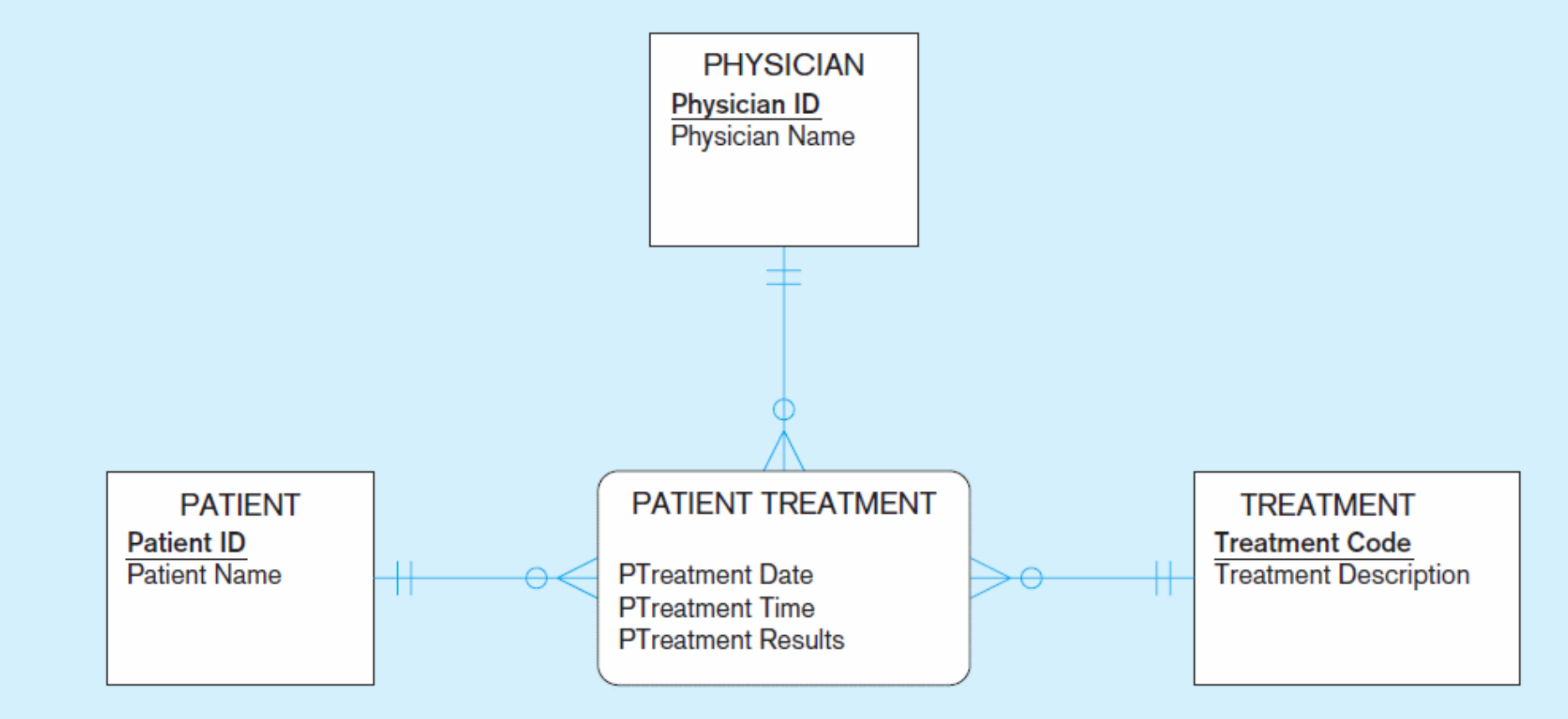
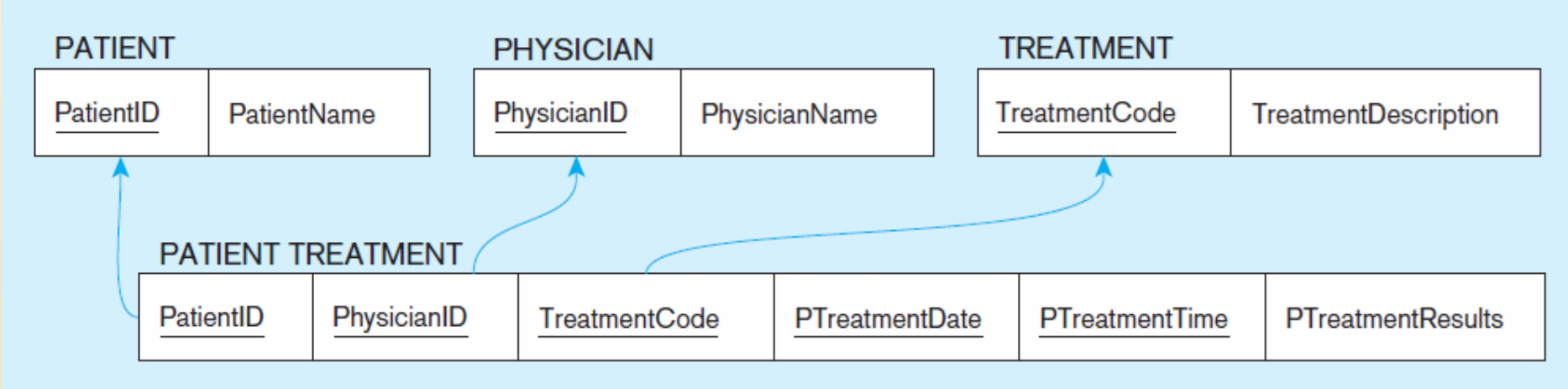


Figure 4-19 Mapping a ternary relationship (cont.)

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 4-20 Supertype/subtype relationships

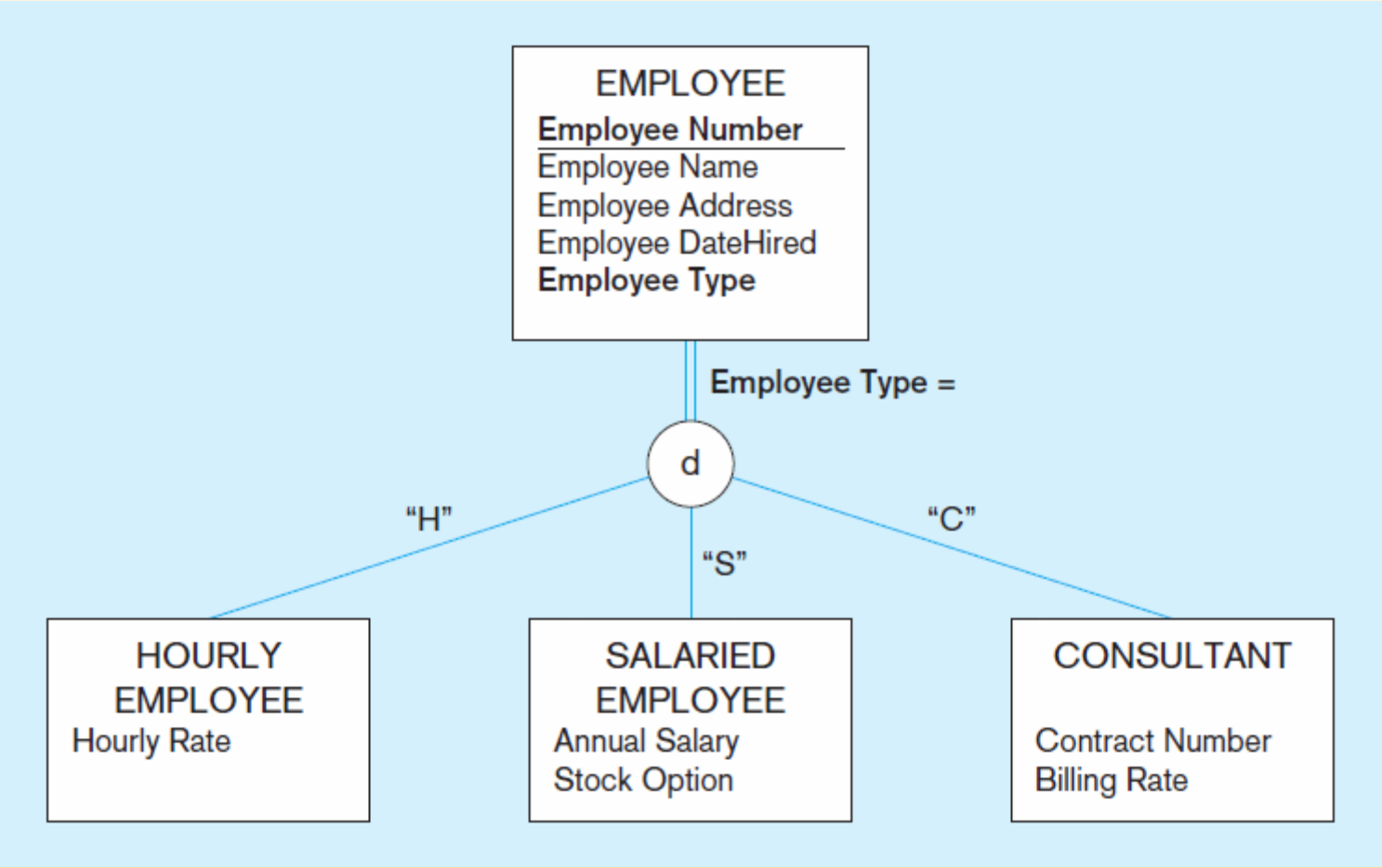
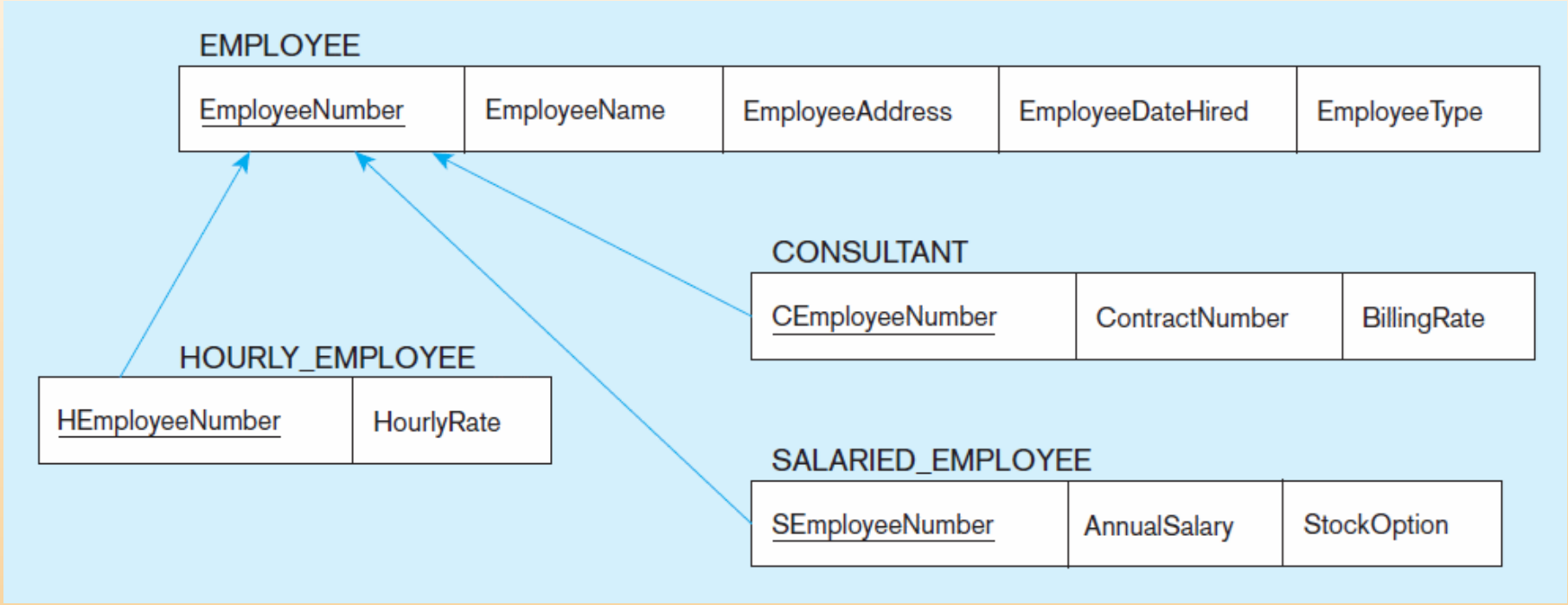


Figure 4-21
Mapping supertype/subtype relationships to relations



These are implemented as one-to-one relationships

DATA NORMALIZATION

- Primarily a tool to validate and improve a logical design so that it satisfies certain constraints that ***avoid unnecessary duplication of data***
- The process of decomposing relations with anomalies to produce smaller, ***well-structured*** relations

WELL-STRUCTURED RELATIONS

- A relation that contains minimal data redundancy and allows users to insert, delete, and update rows without causing data inconsistencies
- Goal is to avoid anomalies
  - **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

General rule of thumb: A table should not pertain to more than one entity type

EXAMPLE–FIGURE 4-2B

EMPLOYEE2

EmpID	Name	DeptName	Salary	CourseTitle	DateCompleted
100	Margaret Simpson	Marketing	48,000	SPSS	6/19/201X
100	Margaret Simpson	Marketing	48,000	Surveys	10/7/201X
140	Alan Beeton	Accounting	52,000	Tax Acc	12/8/201X
110	Chris Lucero	Info Systems	43,000	Visual Basic	1/12/201X
110	Chris Lucero	Info Systems	43,000	C++	4/22/201X
19 0	Lorenzo Davis	Finance	55,000		
15 0	Susan Martin	Marketing	42,000	SPSS	6/19/201X
15 0	Susan Martin	Marketing	42,000	Java	8/12/201X

Question–Is this a relation?

Answer–Yes: Unique rows and no multivalued attributes

Question–What's the primary key?

Answer–Composite: EmpID, CourseTitle

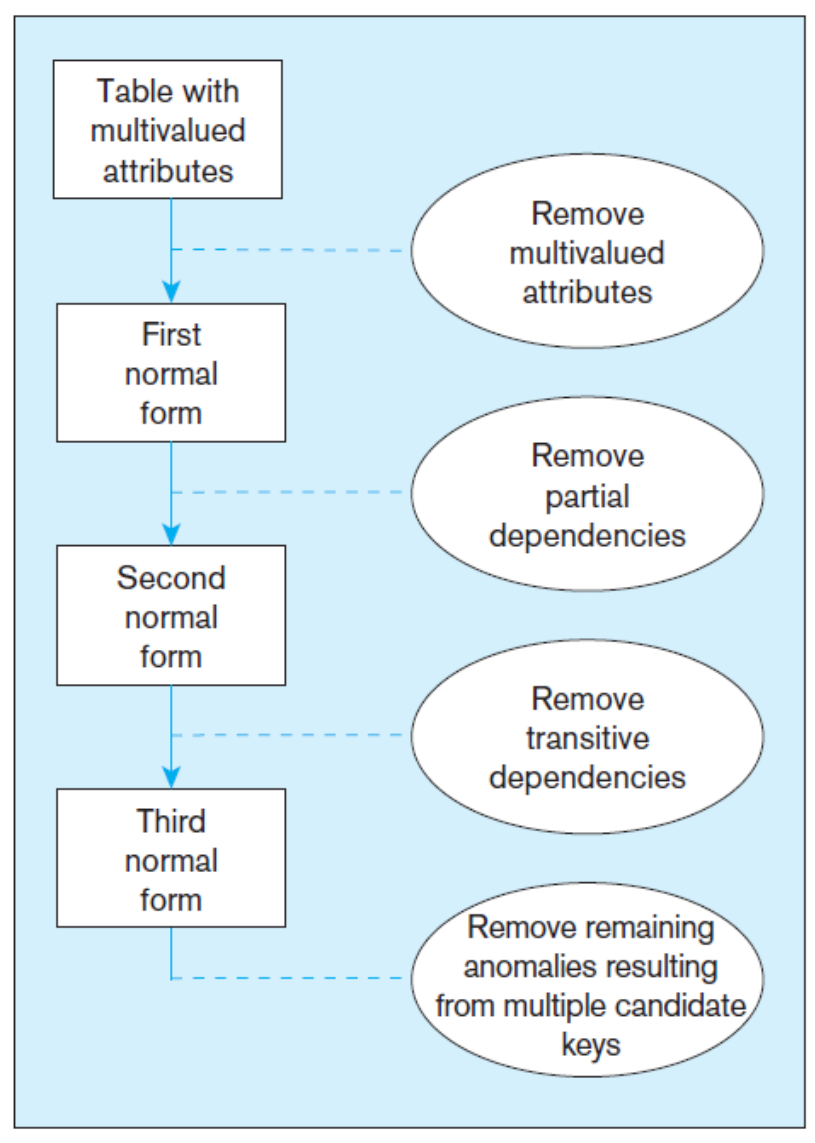
ANOMALIES IN THIS TABLE

- **Insertion**–can't enter a new employee without having the employee take a class (or at least empty fields of class information)
- **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.

Figure 4.22 Steps in normalization

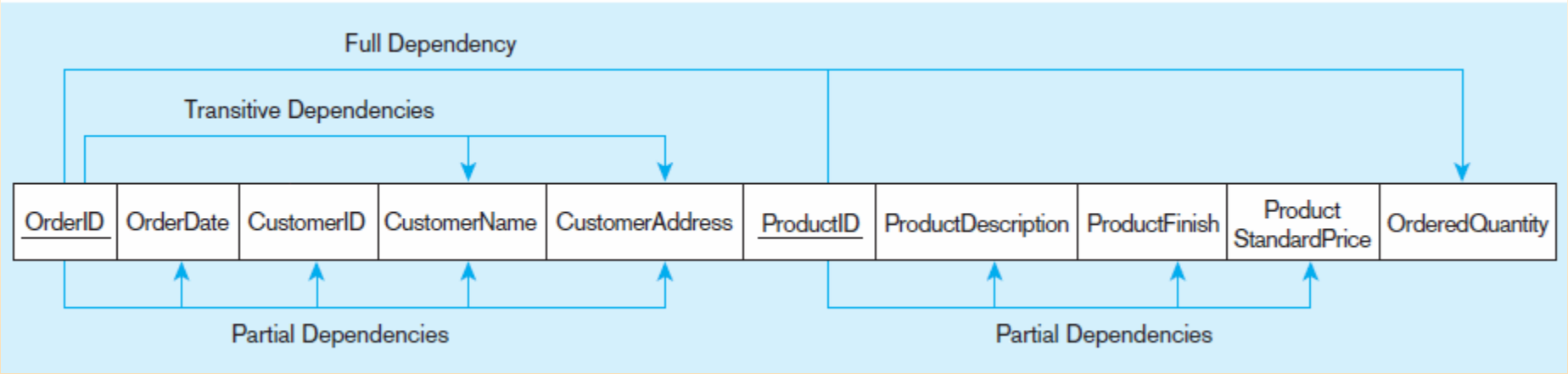


3rd normal form is generally considered to be sufficient, although higher degrees of normalization are possible.

FUNCTIONAL DEPENDENCIES AND KEYS

- Functional Dependency: 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

Figure 4-27 Functional dependency diagram for INVOICE



OrderID ➔ OrderDate, CustomerID, CustomerName, CustomerAddress

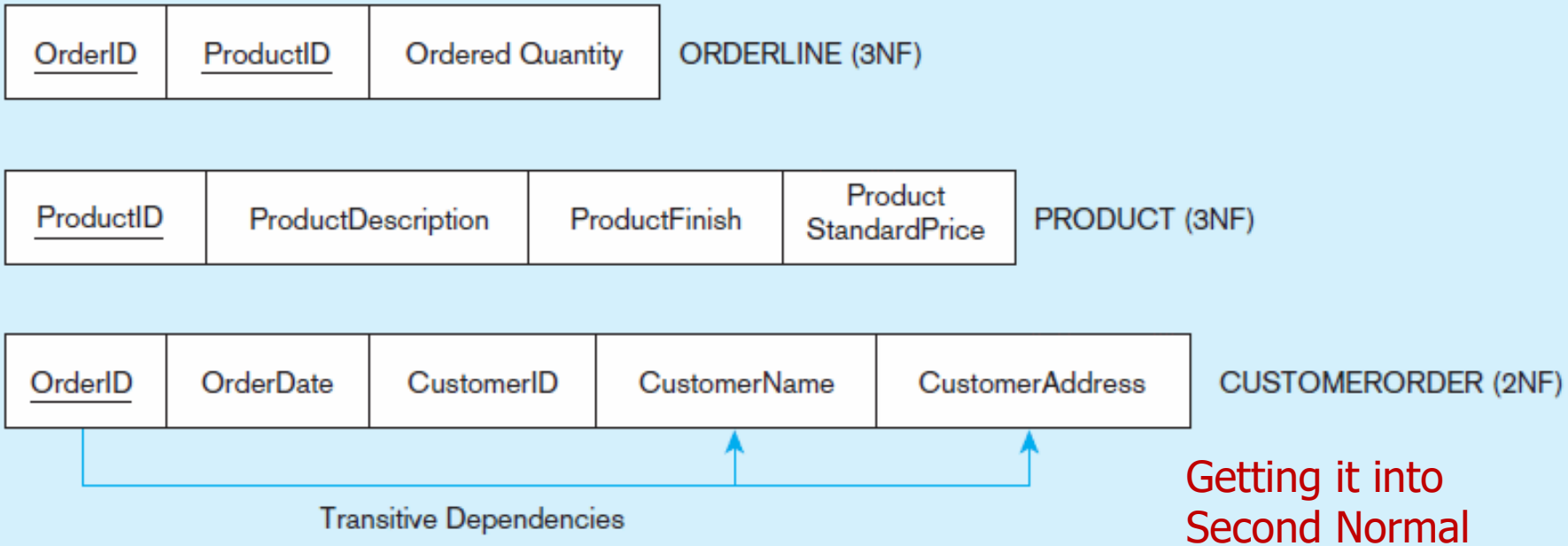
CustomerID ➔ CustomerName, CustomerAddress

ProductID ➔ ProductDescription, ProductFinish, ProductStandardPrice

OrderID, ProductID ➔ OrderQuantity

Therefore, NOT in 2nd Normal Form

Figure 4-28 Removing partial dependencies



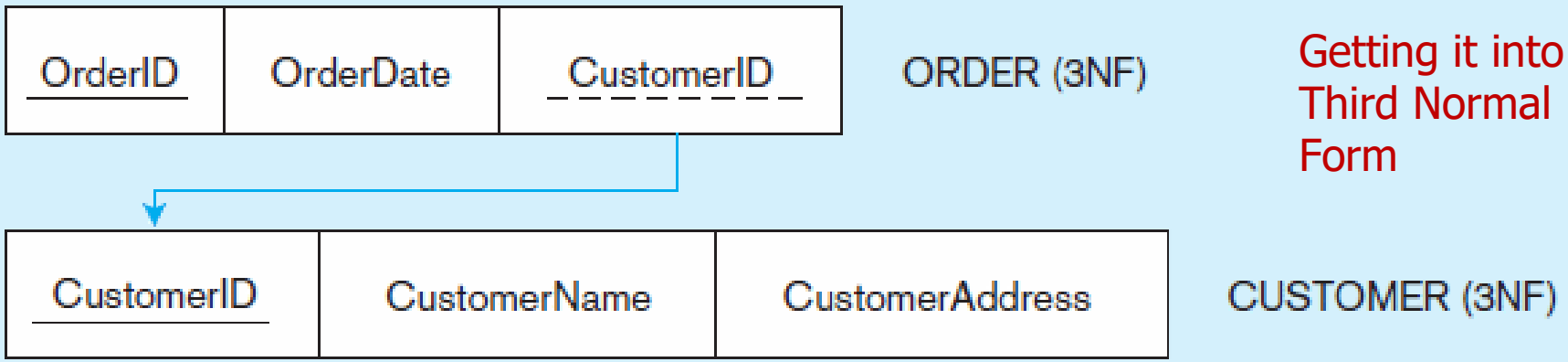
Getting it into Second Normal Form

Partial dependencies are removed, but there are still transitive dependencies

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 4-29 Removing partial dependencies



Getting it into Third Normal Form

Transitive dependencies are removed