Chapter 5: Logical Database Design and the Relational Model

Modern Database Management

6th Edition

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Relation

Definition: A relation is a named, two-dimensional table of data
- Table is made up of rows (records), and columns (attribute or field)

Not all tables qualify as relations

Requirements:
- Every relation has a unique name.
- Every attribute value is atomic (not multivalued, not composite)
- Every row is unique (can’t have two rows with exactly the same values for all their fields)
- Attributes (columns) in tables have unique names
- The order of the columns is irrelevant
- The order of the rows is irrelevant

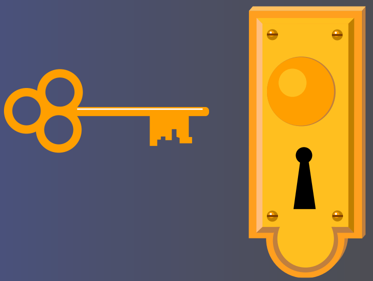
NOTE: all relations are in ***1st Normal form***

Correspondence with ER 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 same the word ***relationship*** (in ER 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 (More on this in Ch. 6)

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

CUSTOMER

Customer_ID	Customer_Name	Address	City*	State*	Zip*

Primary Key

ORDER

Order_ID	Order_Date	Customer_ID

Foreign Key
(implements 1:N relationship between customer and order)

ORDER LINE

Order_ID	Product_ID	Quantity

Combined, these are a *composite primary key* (uniquely identifies the order line)…individually they are *foreign keys* (implement M:N relationship between order and product)

PRODUCT

Product_ID	Product_Description	Product_Finish	Standard_Price	On_Hand*

* Not in Figure 3-22 for simplicity.

Integrity Constraints

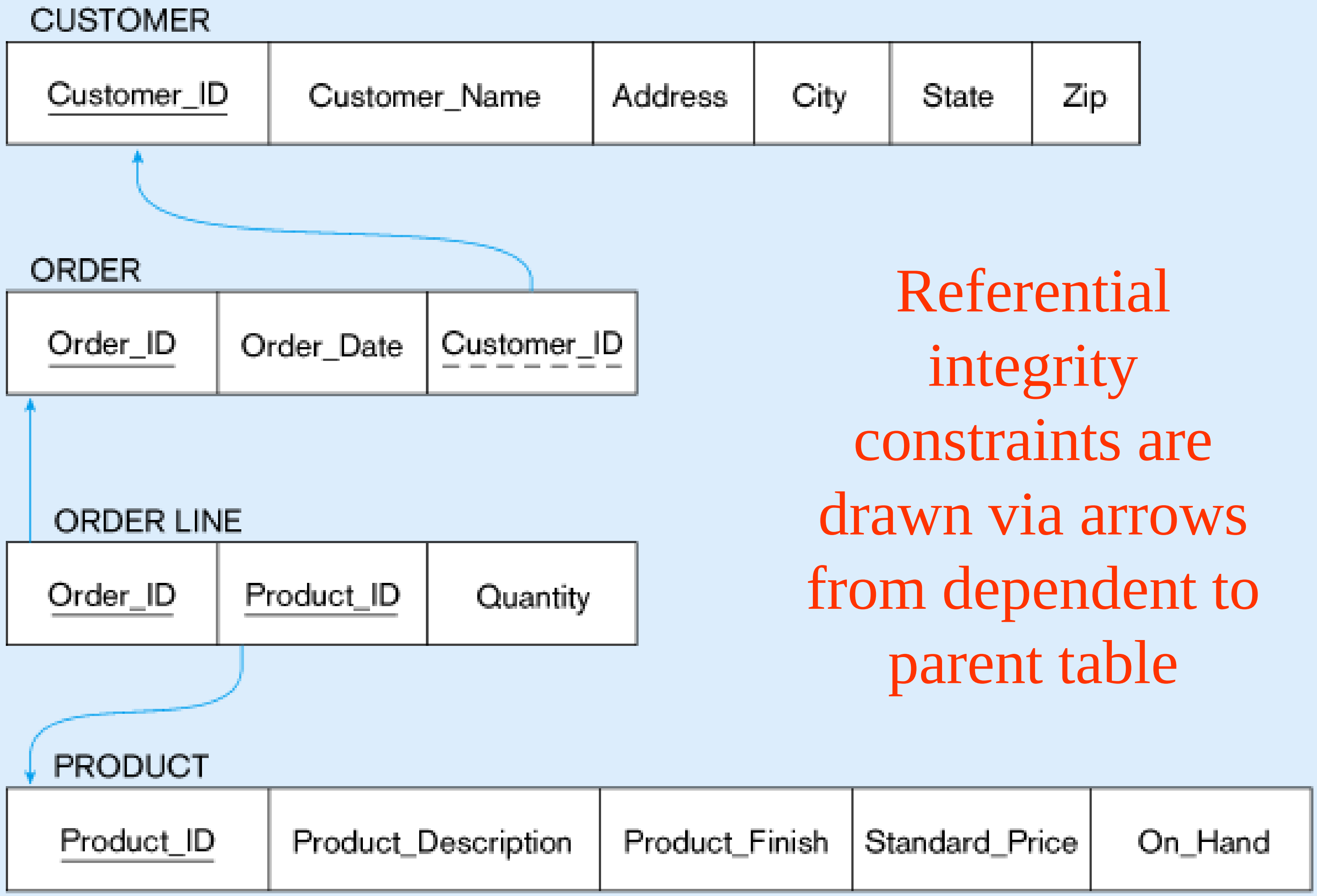
- Domain Constraints
  - Allowable values for an attribute. See Table 5-1
- Entity Integrity
  - No primary key attribute may be null. All primary key fields **MUST** have data
- Action Assertions
  - Business rules. Recall from Ch. 4

Integrity Constraints

Referential Integrity – rule that 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)



Referential integrity constraints are drawn via arrows from dependent to parent table

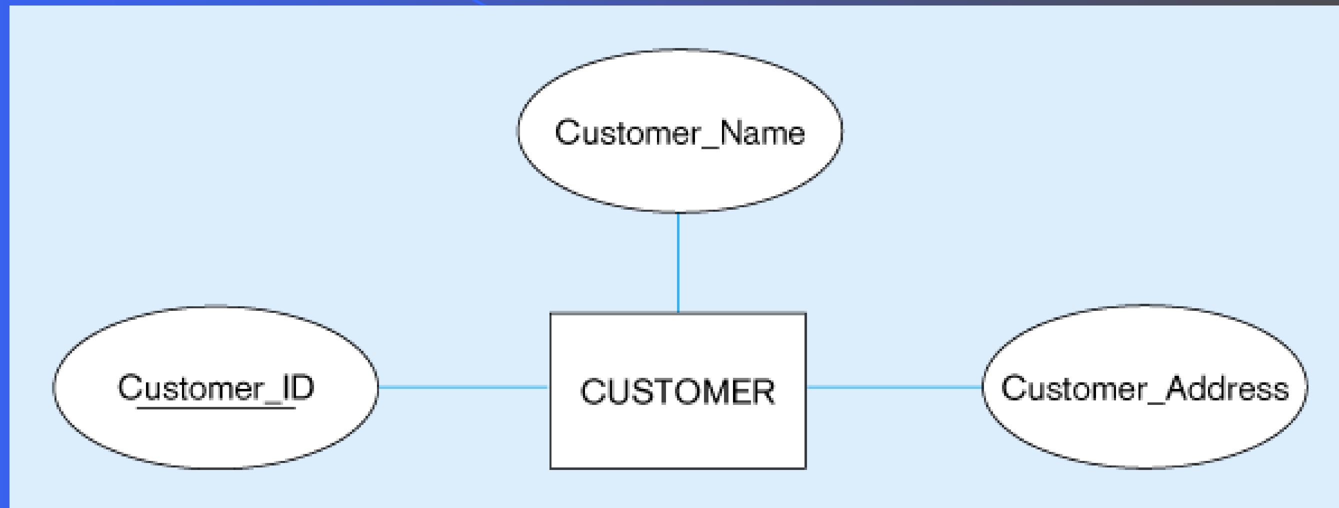
Transforming EER Diagrams into Relations

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. Multi-valued 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



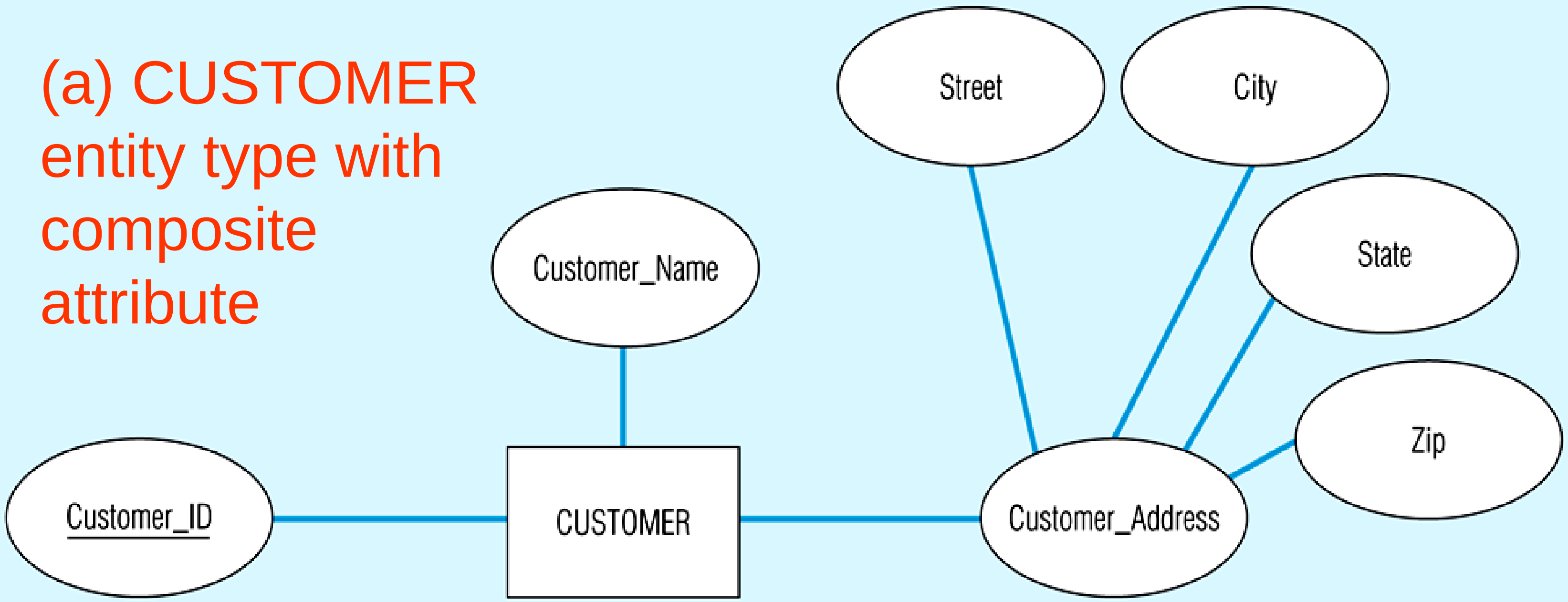
(b) CUSTOMER relation

CUSTOMER

Customer_ID	Customer_Name	Customer_Address

Figure 5-9: Mapping a composite attribute

(a) CUSTOMER entity type with composite attribute

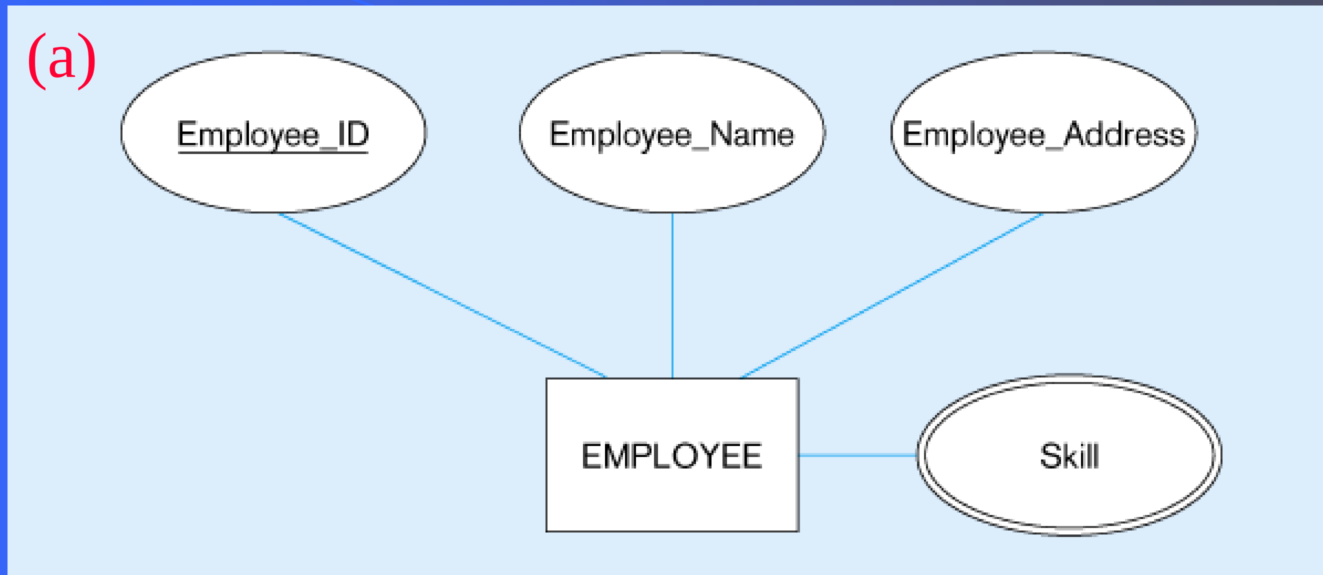


(b) CUSTOMER relation with address detail

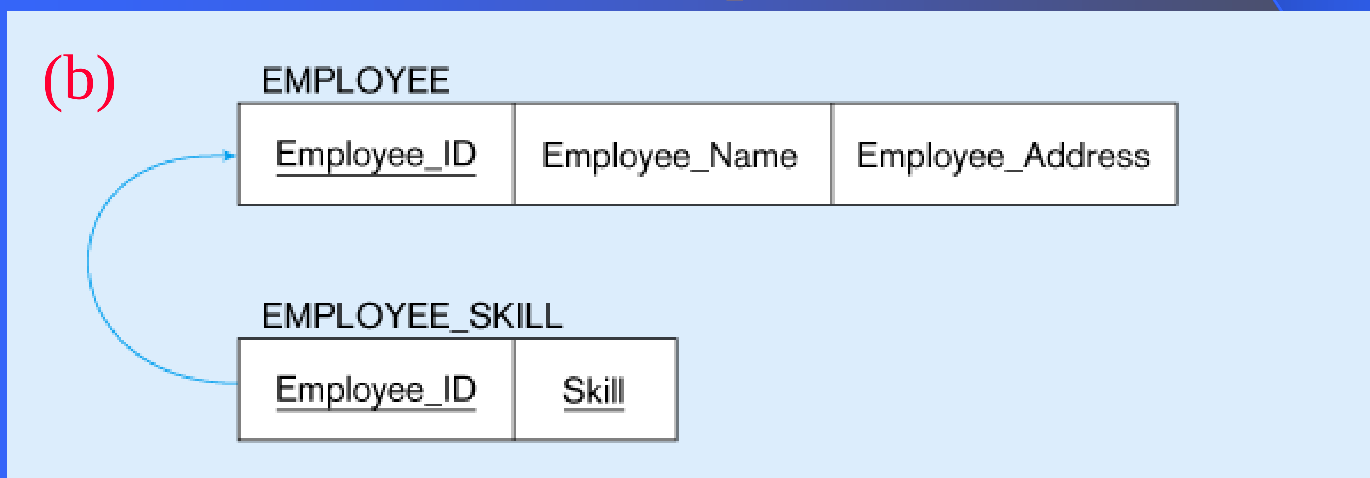
CUSTOMER

Customer_ID	Customer_Name	Street	City	State	Zip

Figure 5-10: Mapping a multivalued attribute



Multivalued attribute becomes a separate relation with foreign key



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

Transforming EER Diagrams into Relations

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

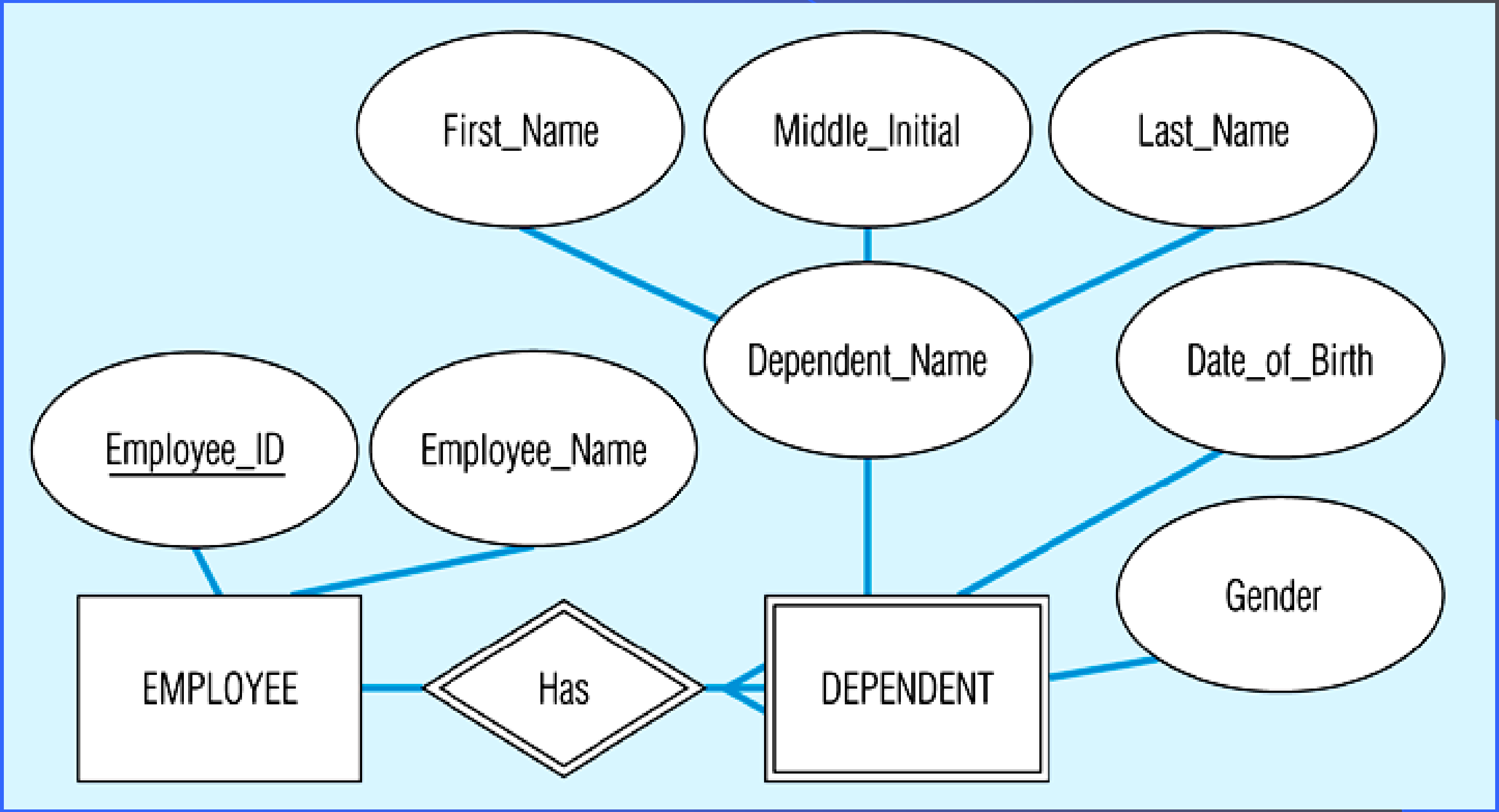
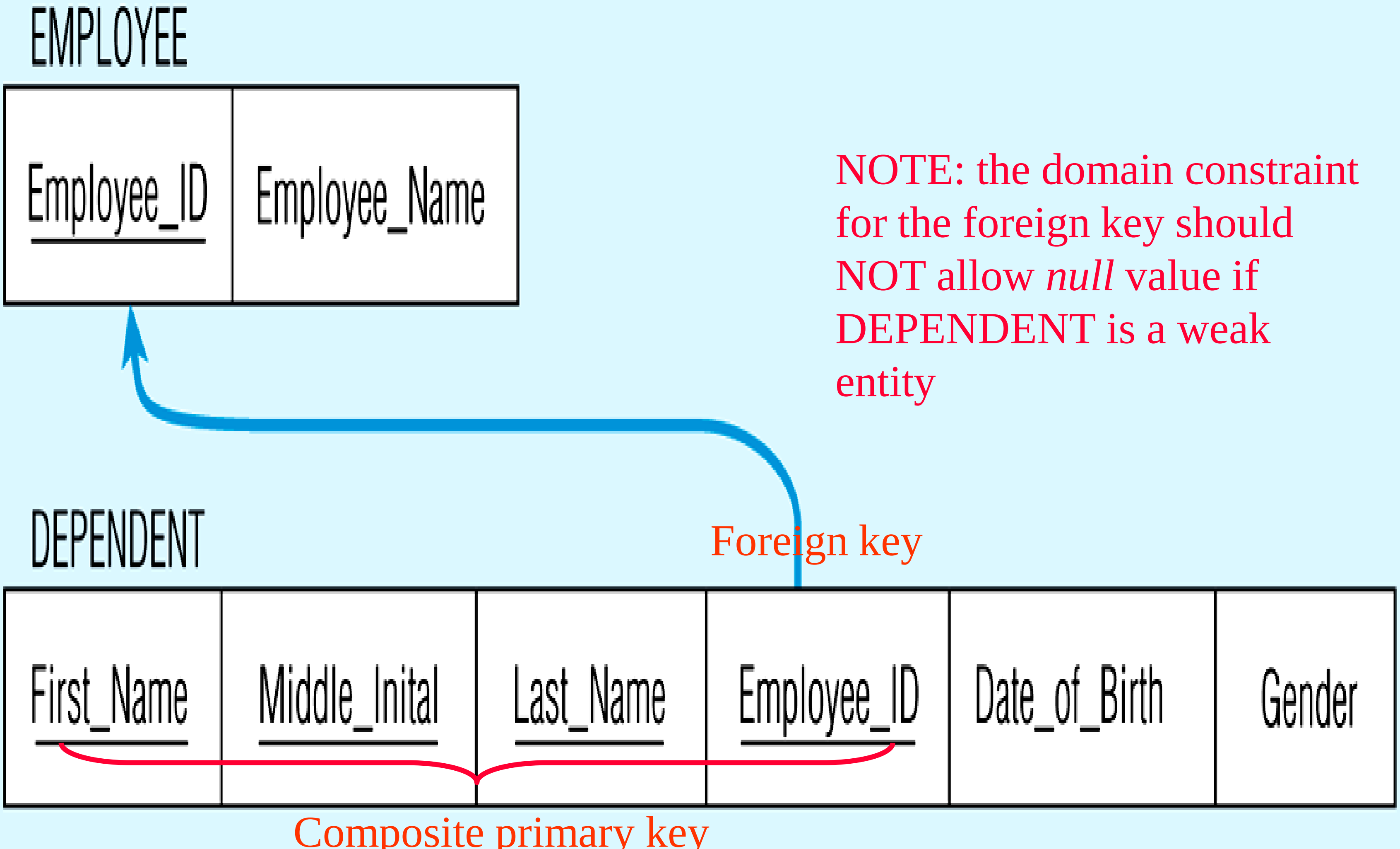


Figure 5-11(b) Relations resulting from weak entity



NOTE: the domain constraint for the foreign key should NOT allow *null* value if DEPENDENT is a weak entity

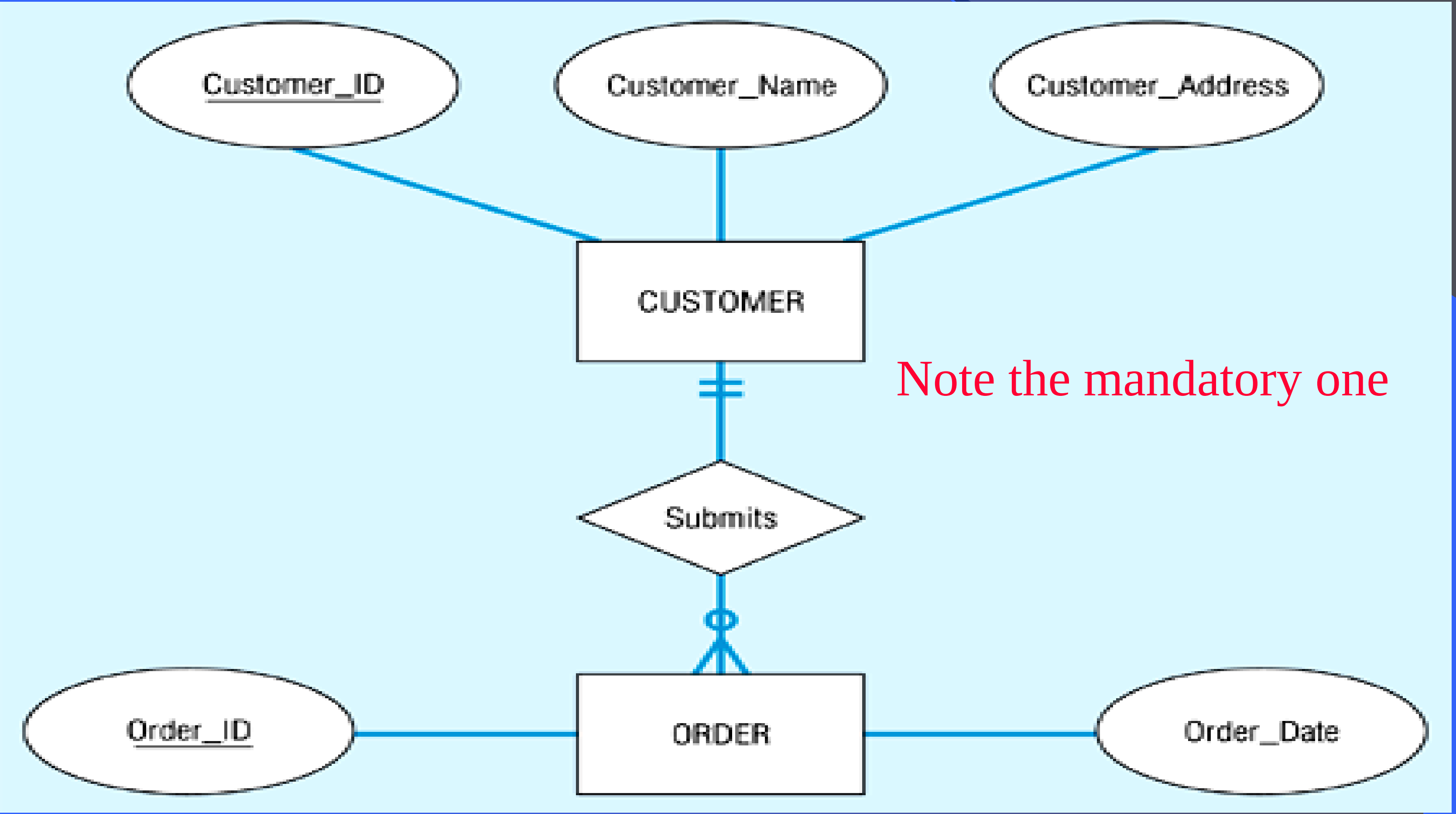
Transforming EER Diagrams into Relations

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



Note the mandatory one

CUSTOMER

Customer_ID	Customer_Name	Customer_Address

ORDER

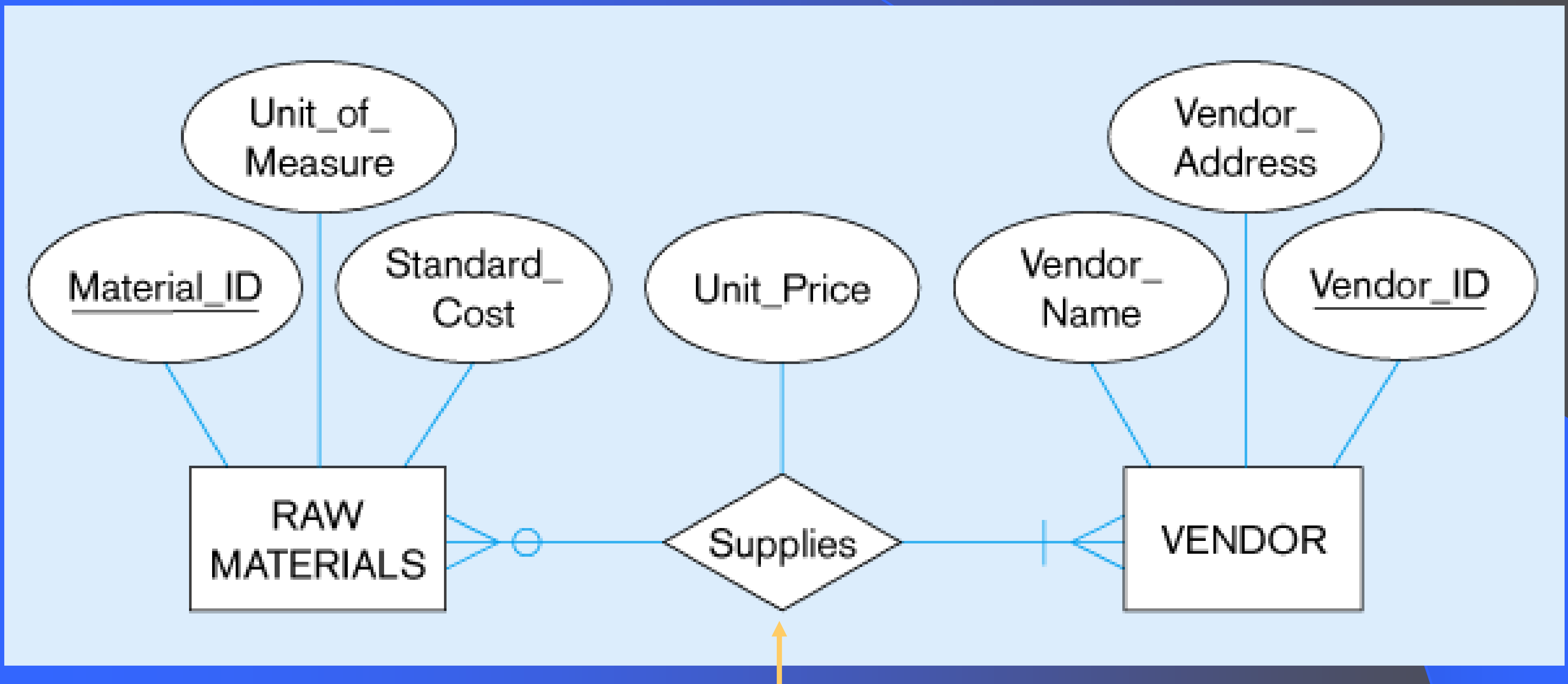
Order_ID	Order_Date	Customer_ID

Again, no null value in the foreign key…this is because of the mandatory minimum cardinality

Foreign key

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

(a) ER diagram (M:N)



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

Figure 5-13(b) Three resulting relations

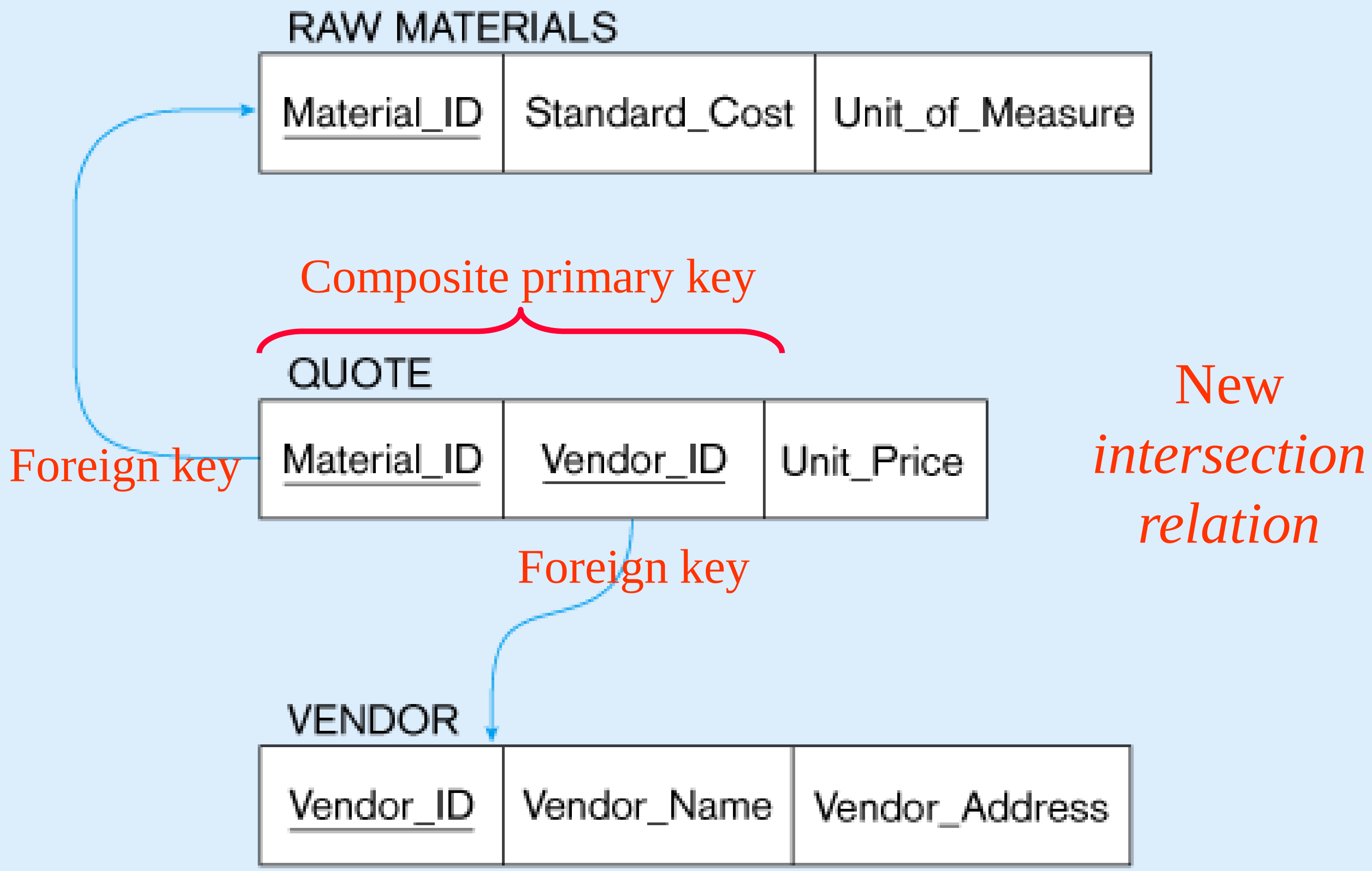


Figure 5-14: Mapping a binary 1:1 relationship

(a) Binary 1:1 relationship

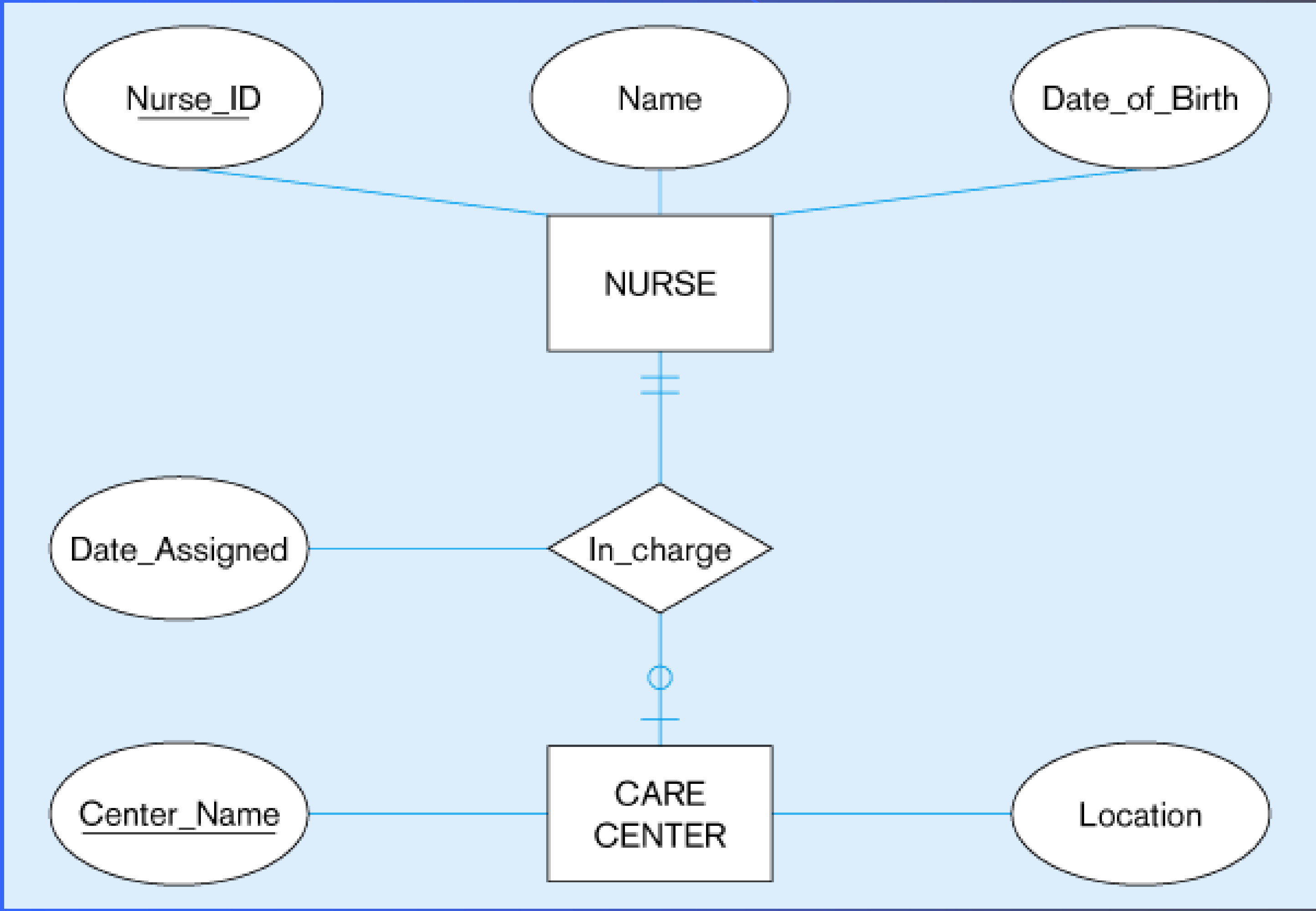
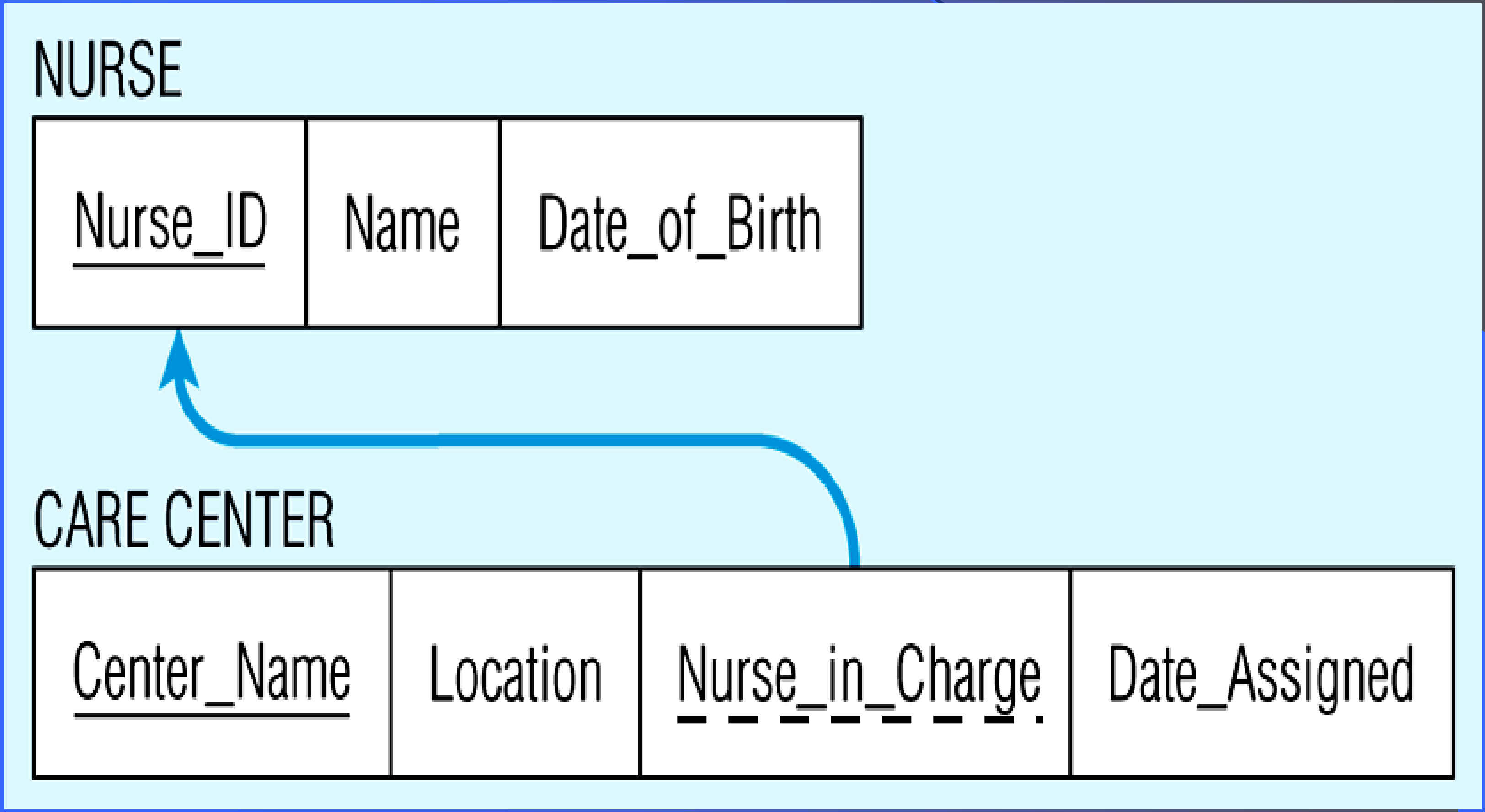


Figure 5-14(b) Resulting relations



Transforming EER Diagrams into Relations

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: Mapping an associative entity

(a) Associative entity

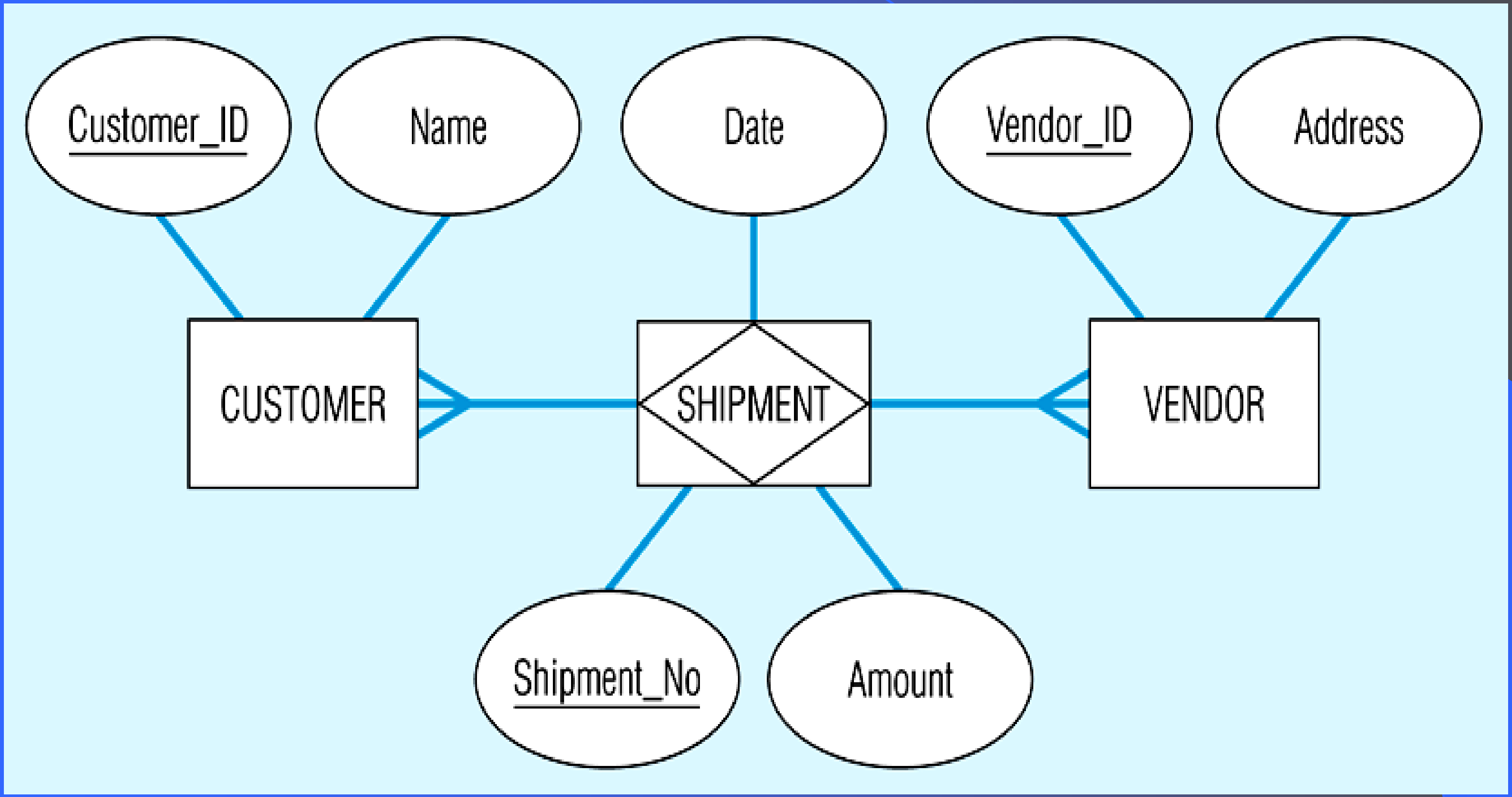
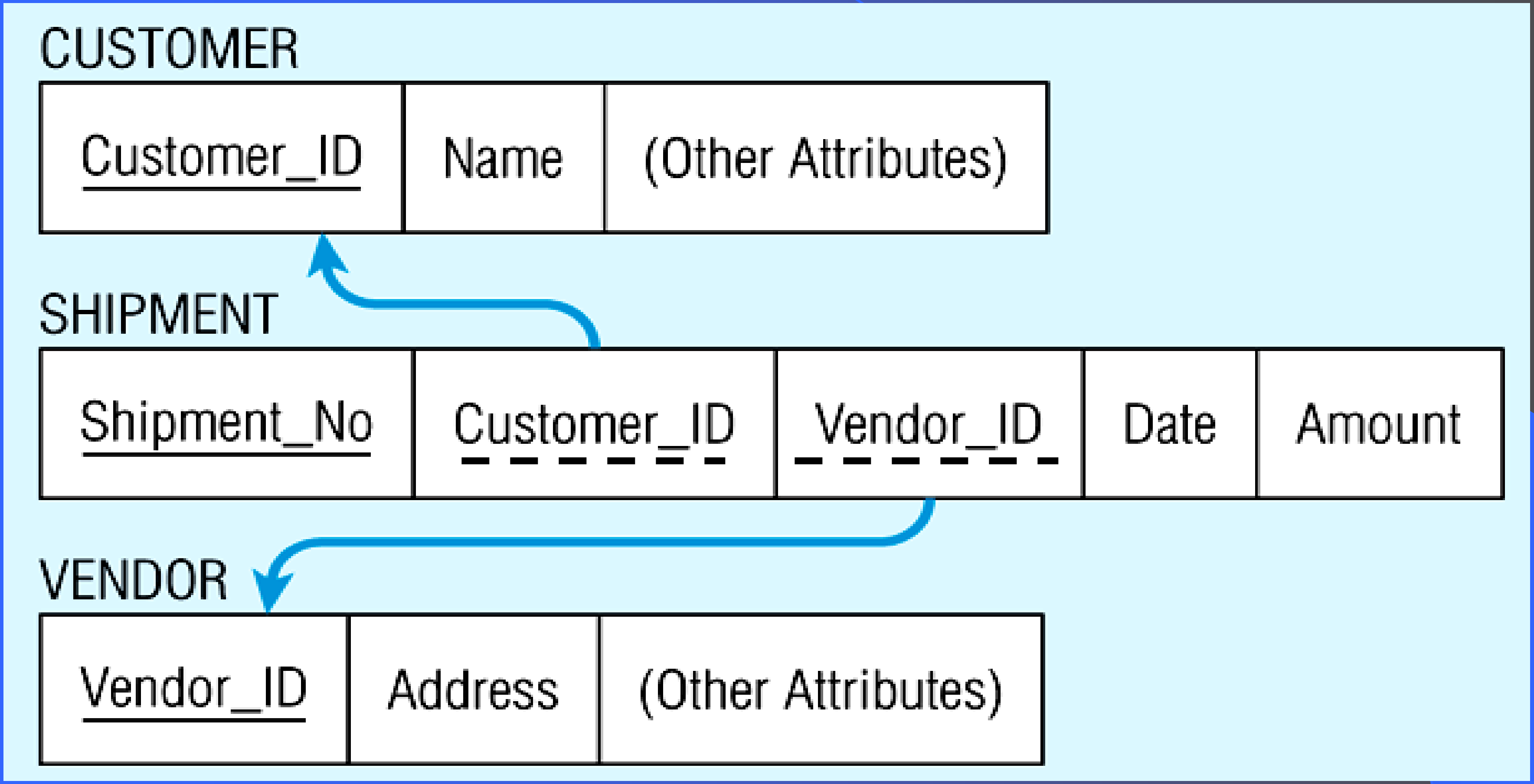


Figure 5-15(b) Three resulting relations

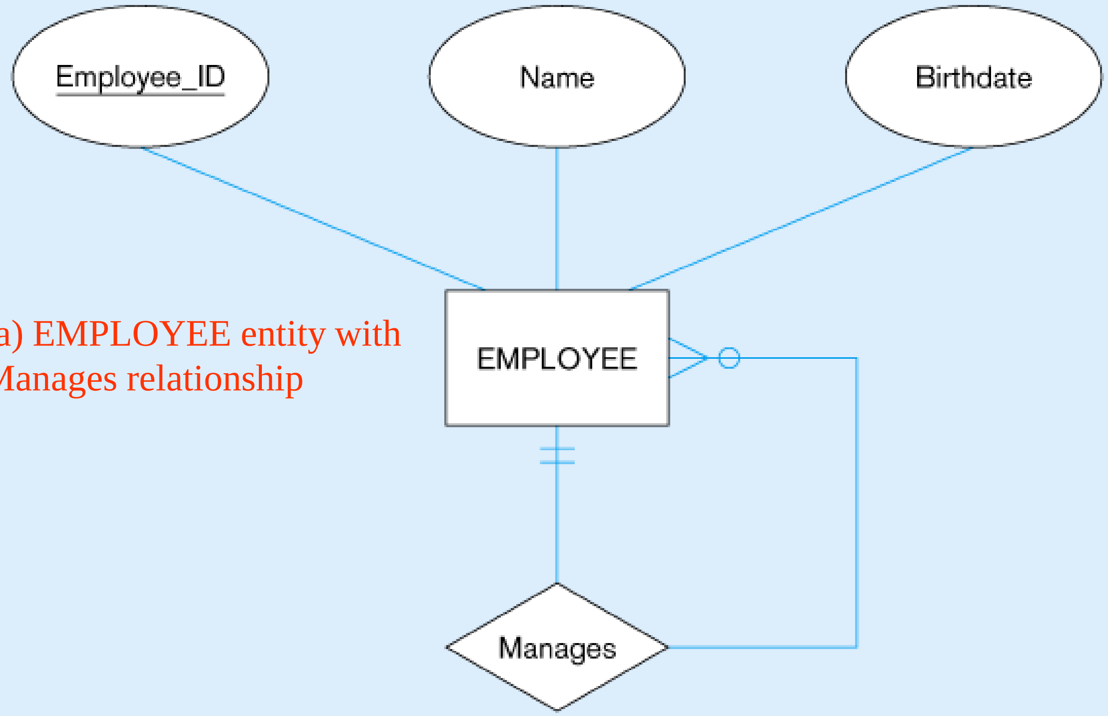


Transforming EER Diagrams into Relations

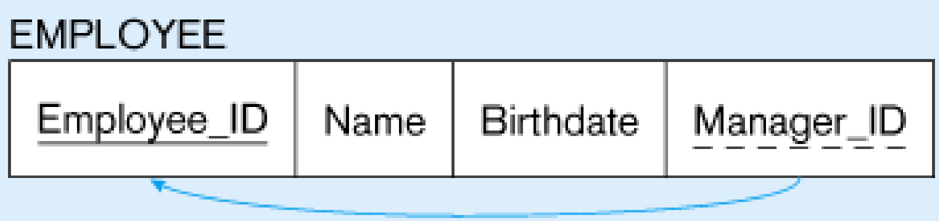
Mapping Unary Relationships

- 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

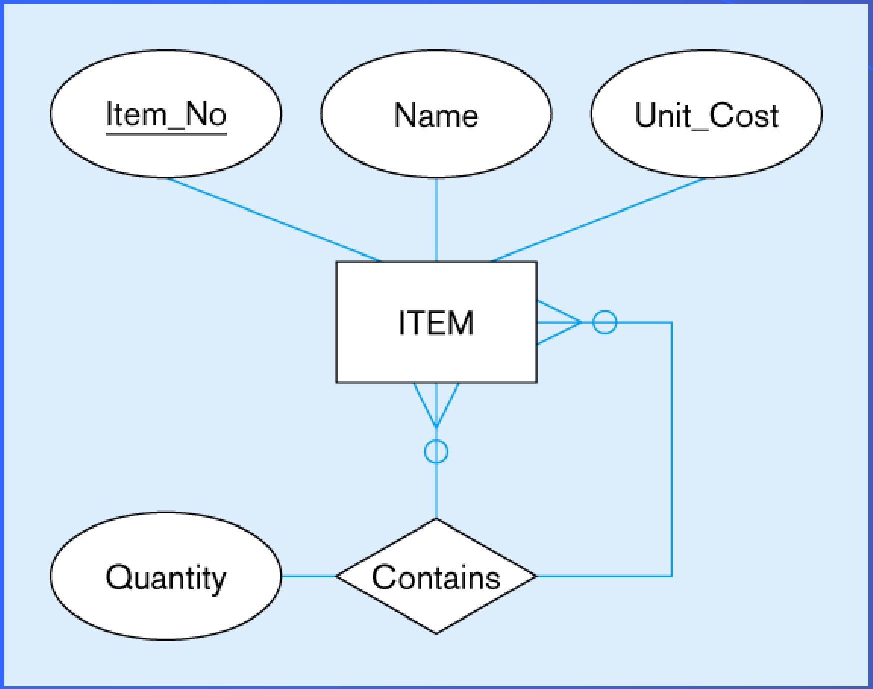


(a) EMPLOYEE entity with Manages relationship



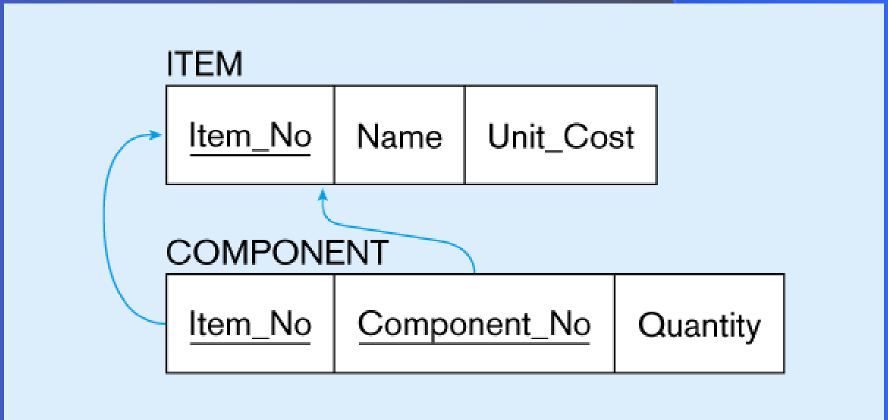
(b) EMPLOYEE relation with recursive foreign key

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

- 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) Ternary relationship with associative entity

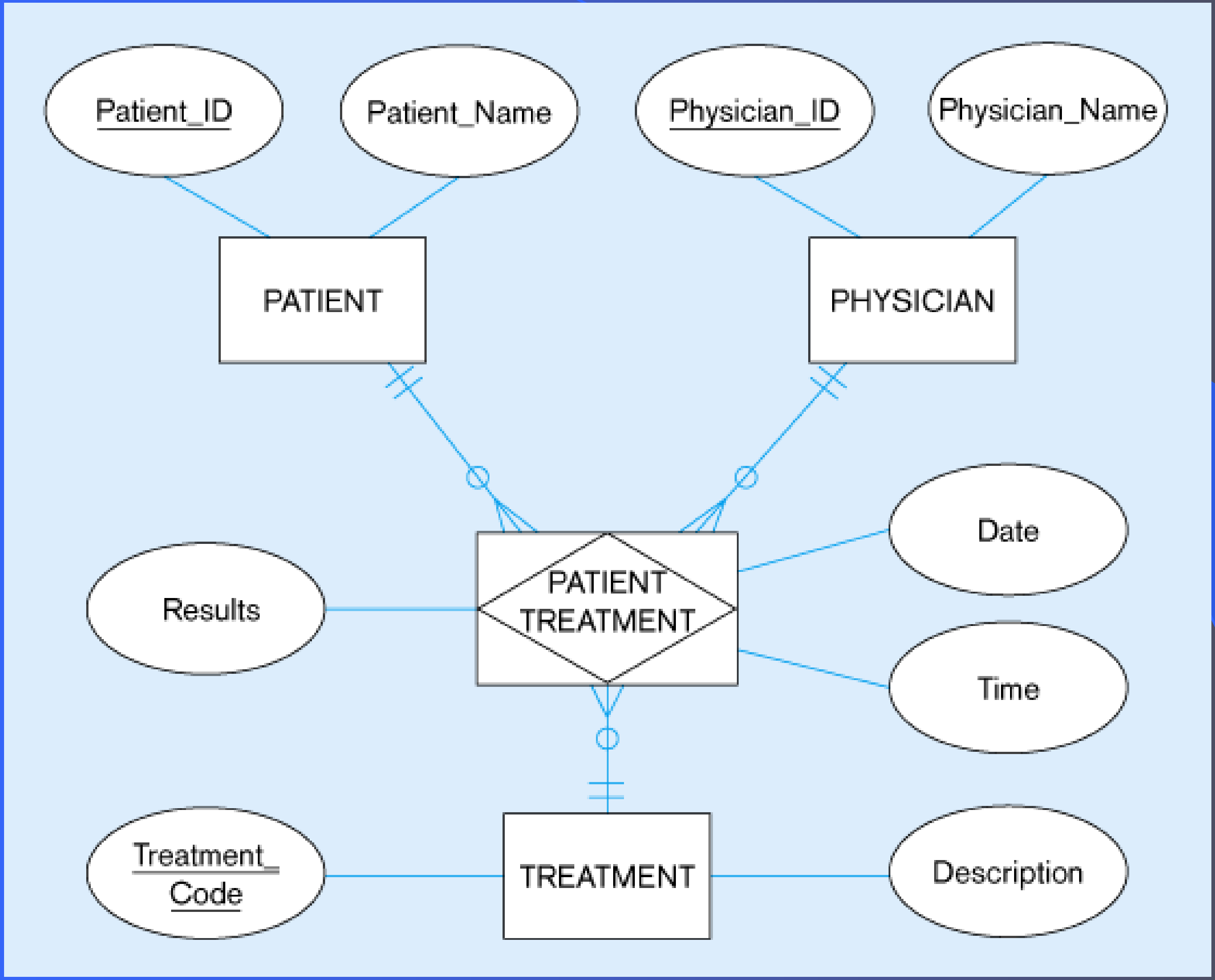
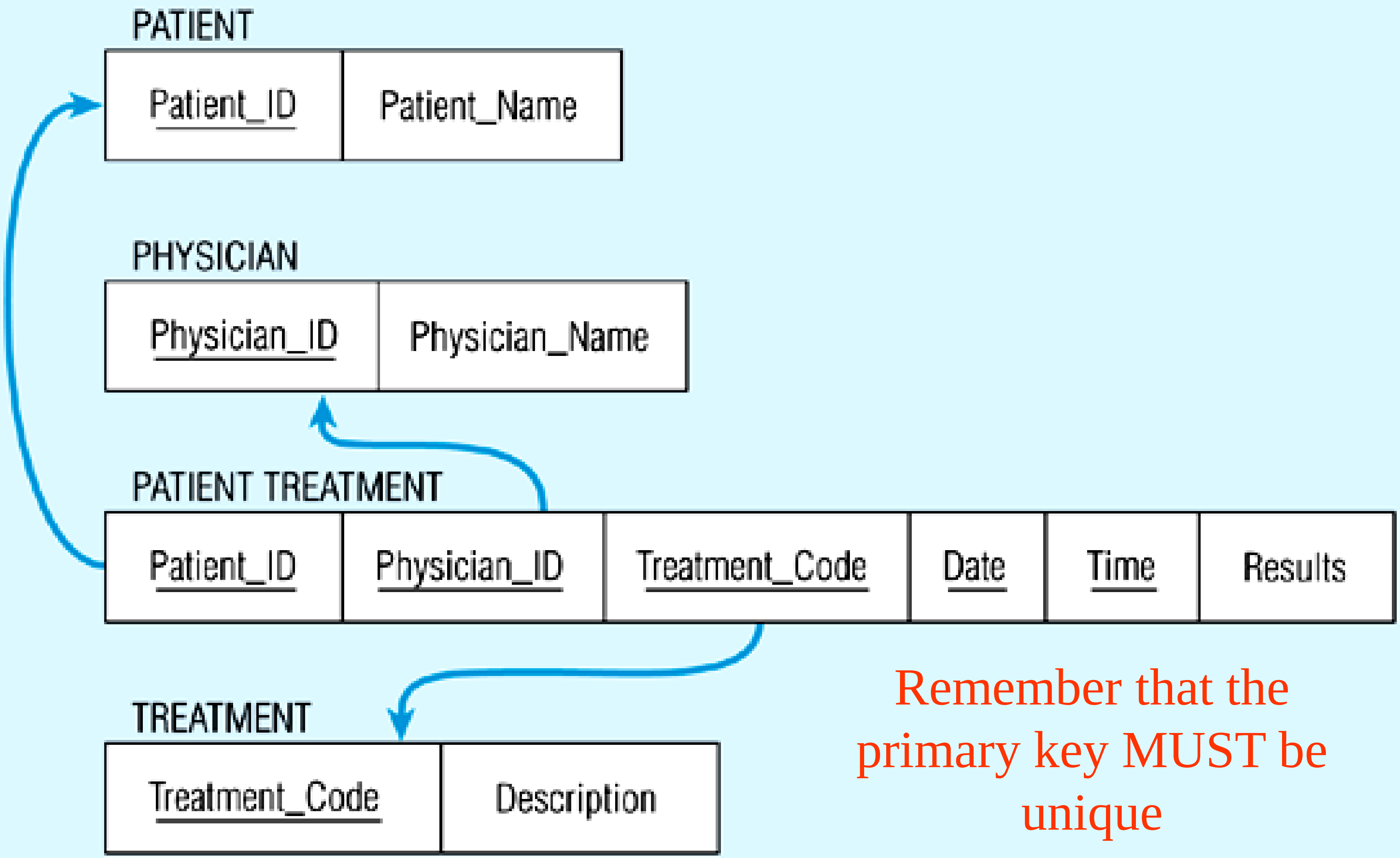


Figure 5-19(b) Mapping the ternary relationship



Remember that the primary key MUST be unique

Transforming EER Diagrams into Relations

Mapping Supertype/Subtype Relationships

- One relation for supertype and for each subtype
- Supertype attributes (including identifier and subtype discriminator) go into supertype relation
- Subtype attributes go into each subtype; primary key of supertype relation also becomes primary key of subtype relation
- 1:1 relationship established between supertype and each subtype, with supertype as primary table

Figure 5-20: Supertype/subtype relationships

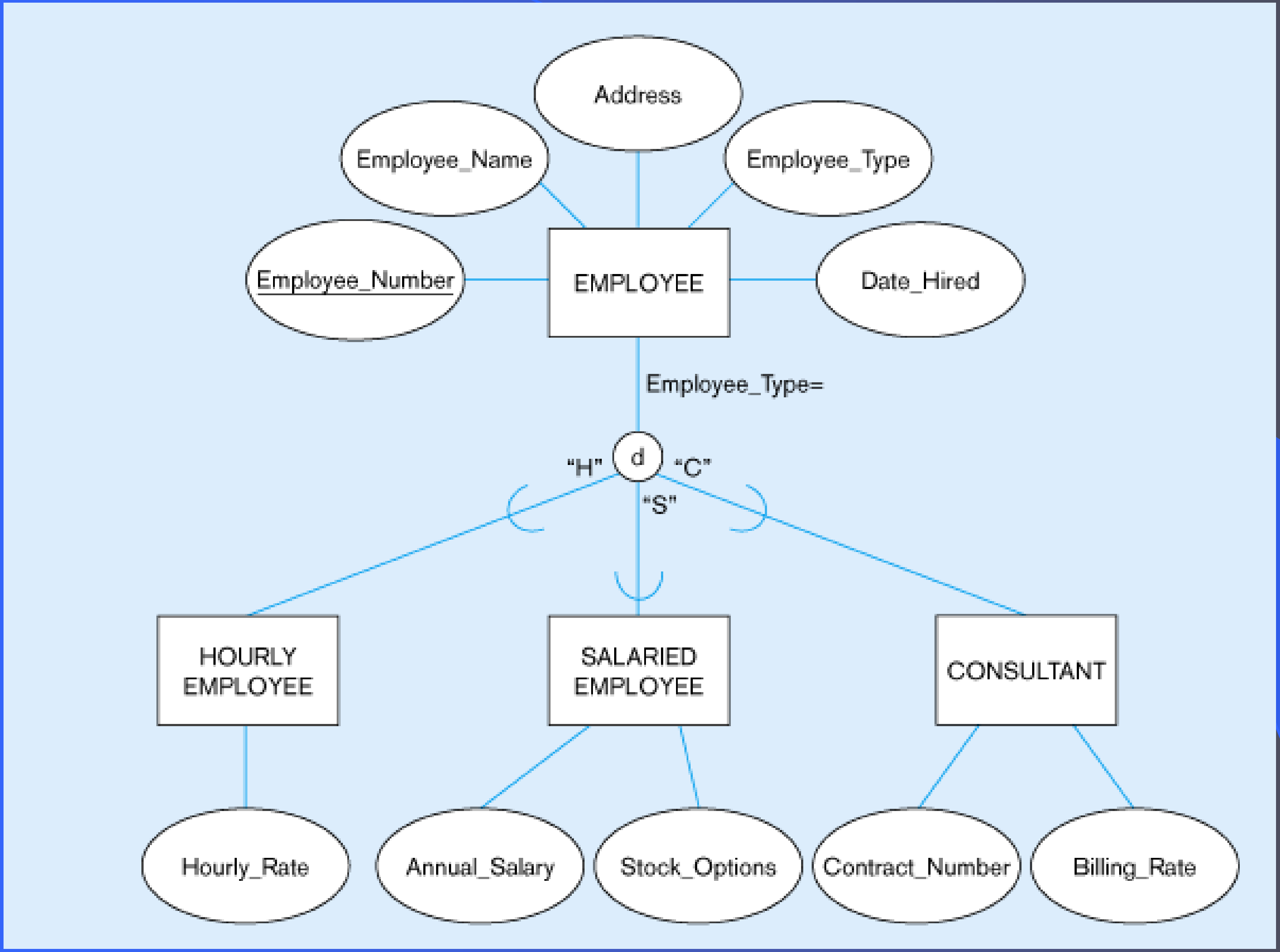
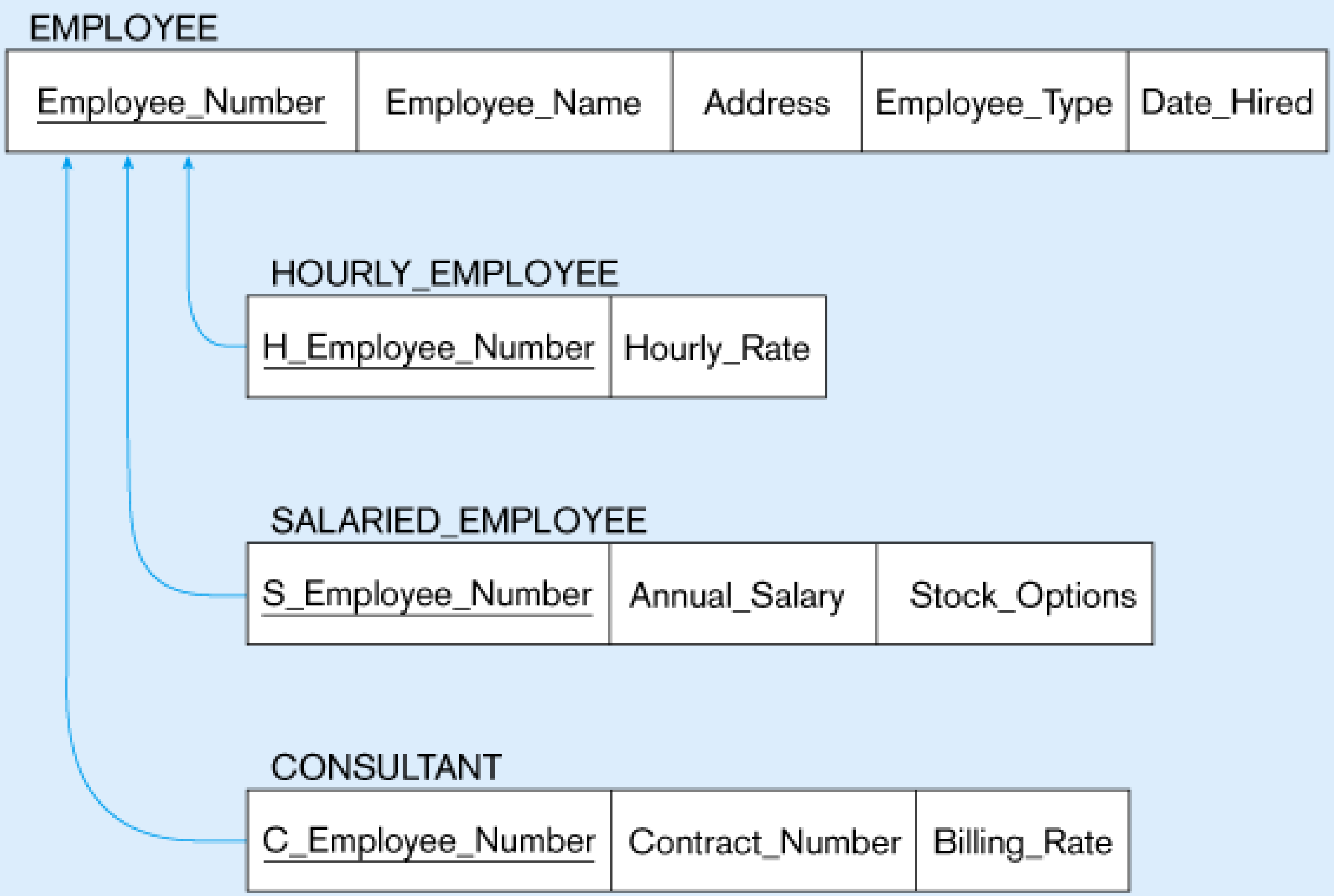


Figure 5-21:
Mapping Supertype/subtype relationships to relations



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 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	SPSS	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?

Answer – Yes: unique rows and no multivalued attributes

Question – What's the primary key?

Answer – Composite: Emp_ID, Course_Title

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 we’ve combined two themes (entity types) into one relation. This results in duplication, and an unnecessary dependency between the entities

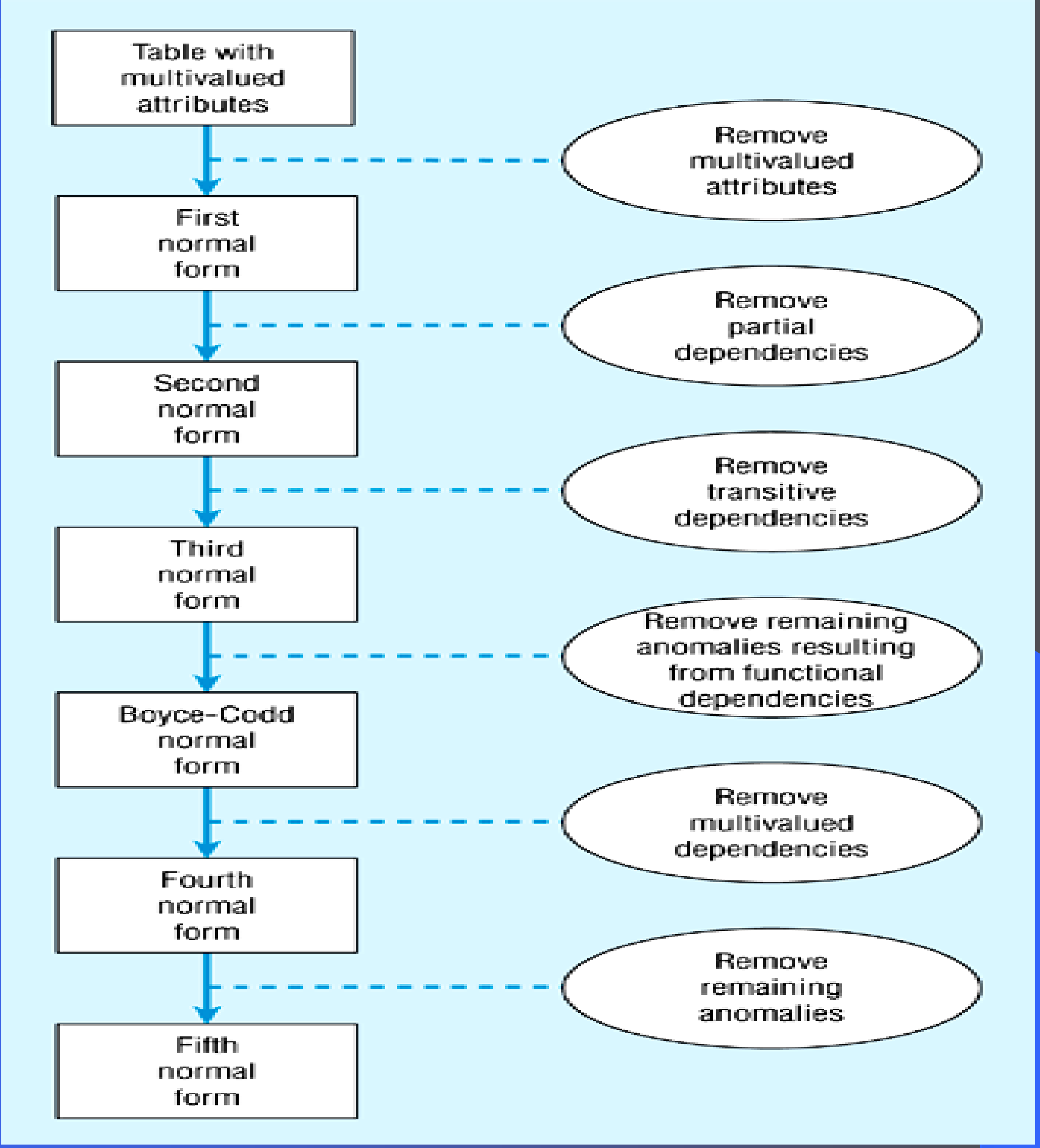
Functional Dependencies and Keys

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

5.22 -Steps in normalization



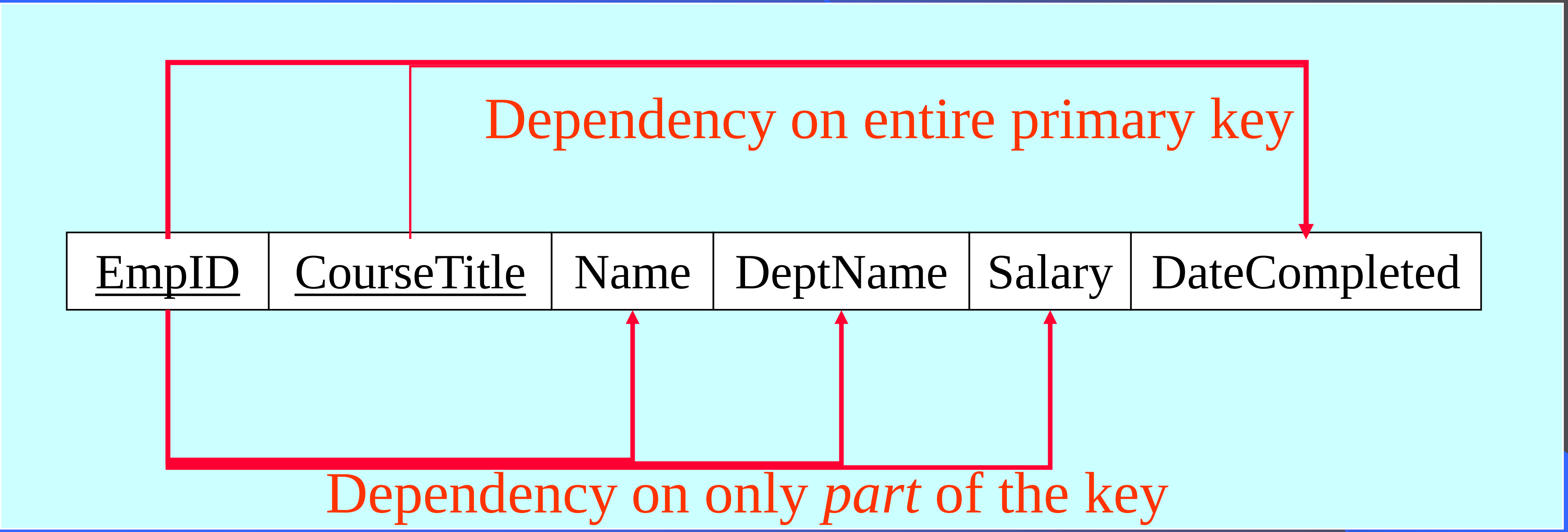
First Normal Form

- No multivalued attributes
- Every attribute value is atomic
- Fig. 5-2a *is not* in 1st Normal Form (multivalued attributes) ➔ it is not a relation
- Fig. 5-2b *is* in 1st Normal form
- ***All relations* are in 1st Normal Form**

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
- Fig. 5-2b is NOT in 2nd Normal Form (see fig 5-23b)

Fig 5.23(b) – Functional Dependencies in EMPLOYEE2



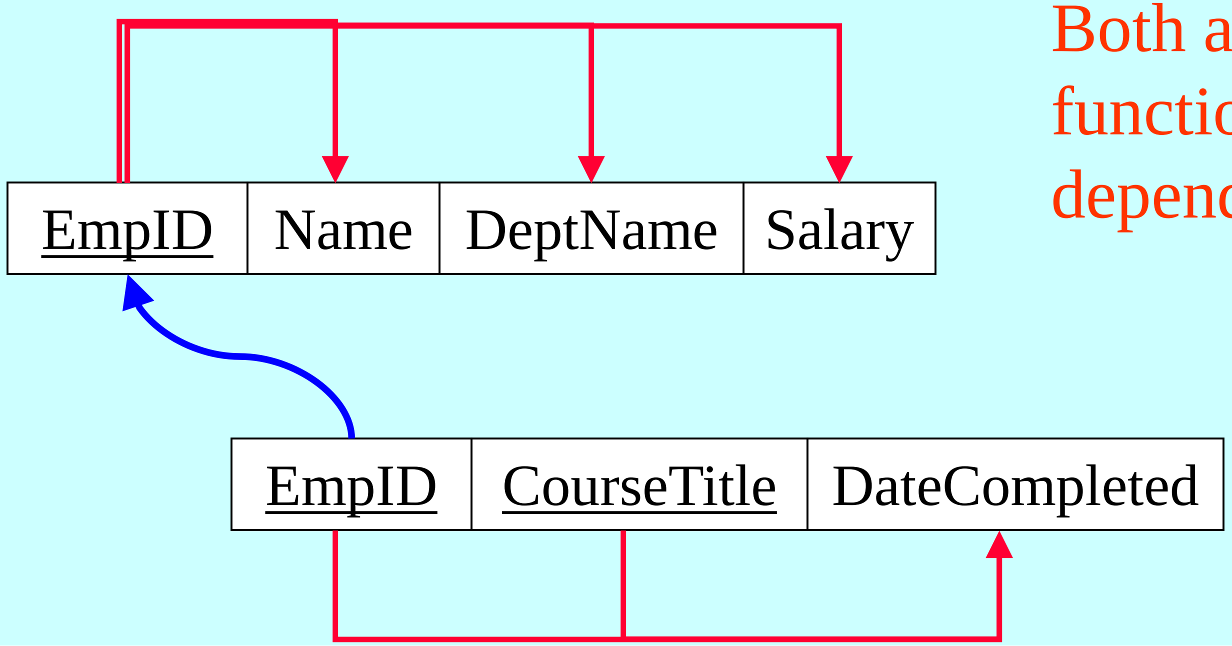
EmpID, CourseTitle → DateCompleted

EmpID → Name, DeptName, Salary

Therefore, NOT in 2^{nd} Normal Form!!

Getting it into 2nd Normal Form

See p193 – decomposed into two separate relations



Both are full functional dependencies

Third Normal Form

2NF PLUS ***no transitive dependencies*** (one attribute functionally determines a second, which functionally determines a third)

Fig. 5-24, 5-25

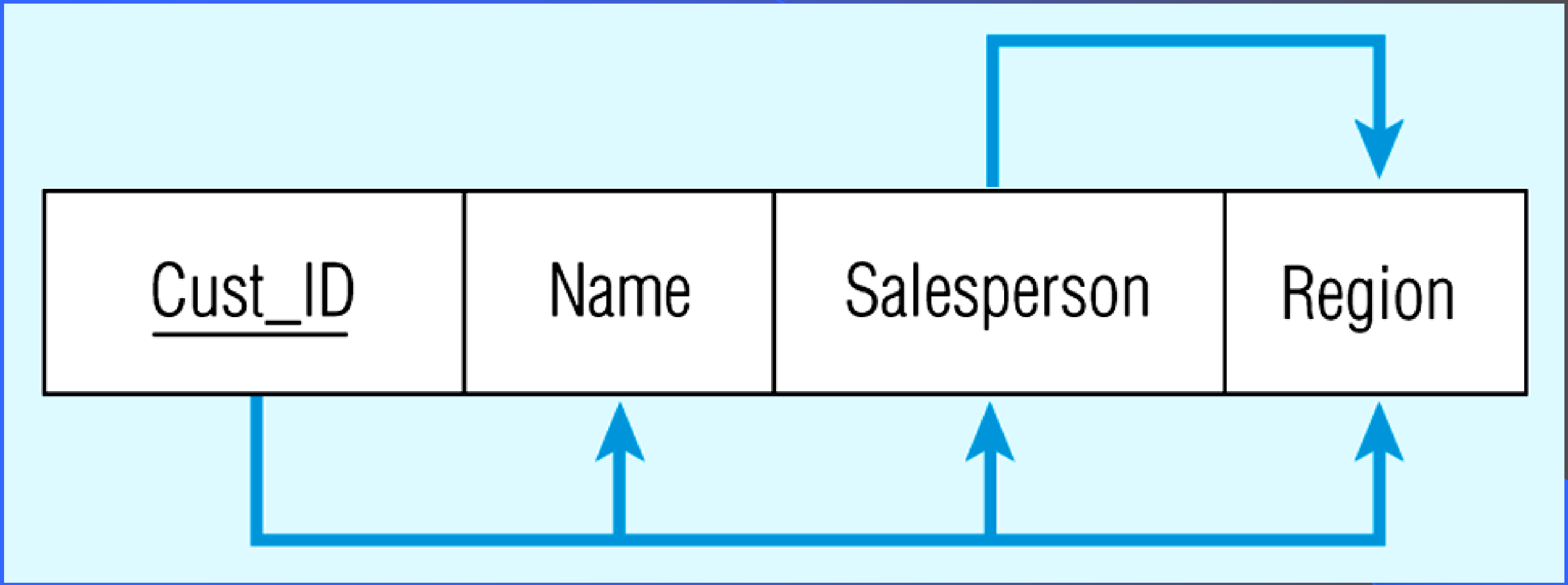
Figure 5-24 -- Relation with transitive dependency

(a) SALES relation with simple data

SALES

Cust_ID	Name	Salesperson	Region
8023	Anderson	Smith	South
9167	Bancroft	Hicks	West
7924	Hobbs	Smith	South
6837	Tucker	Hernandez	East
8596	Eckersley	Hicks	West
7018	Arnold	Faulb	North

Figure 5-24(b) Relation with transitive dependency



CustID → Name
CustID → Salesperson
CustID → Region

All this is OK
(2nd NF)

BUT

CustID → Salesperson → Region

Transitive dependency
(not 3rd NF)

Figure 5.25 -- Removing a transitive dependency
(a) Decomposing the SALES relation

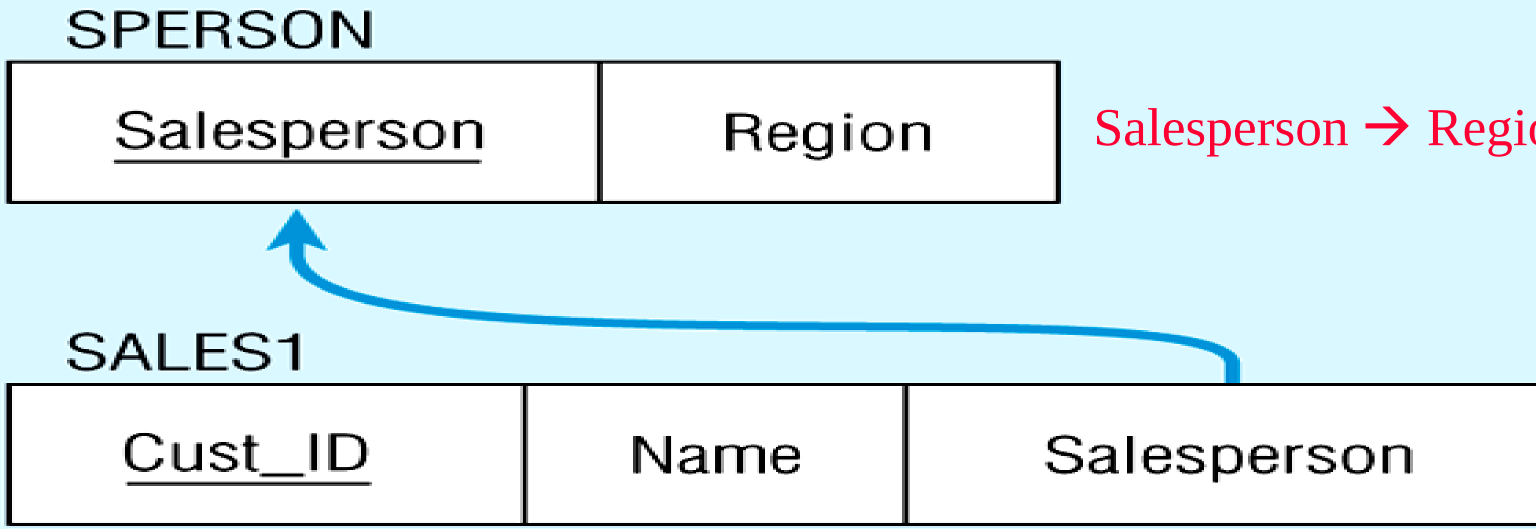
SALES1

Cust_ID	Name	Salesperson
8023	Anderson	Smith
9167	Bancroft	Hicks
7924	Hobbs	Smith
6837	Tucker	Hernandez
8596	Eckersley	Hicks
7018	Arnold	Faulb

SPERSON

Salesperson	Region
Smith	South
Hicks	West
Hernandez	East
Faulb	North

Figure 5.25(b) Relations in 3NF



Salesperson → Region

CustID → Name

CustID → Salesperson

Now, there are no transitive dependencies…
Both relations are in 3rd NF

Other Normal Forms (from Appendix B)

- Boyce-Codd NF
  - All determinants are candidate keys…there is no determinant that is not a unique identifier
- 4th NF
  - No multivalued dependencies
- 5th NF
  - No “lossless joins”
- Domain-key NF
  - The “ultimate” NF…perfect elimination of all possible anomalies