Chapter 5

Advanced Data Modeling

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Learning Objectives

- In this chapter, you will learn:
  - About the extended entity relationship (EER) model
  - How entity clusters are used to represent multiple entities and relationships
  - The characteristics of good primary keys and how to select them
  - How to use flexible solutions for special data-modeling cases

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Extended Entity Relationship Model (EERM)

- Result of adding more semantic constructs to the original entity relationship (ER) model
- **EER diagram (EERD)**: Uses the EER model

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Entity Supertypes and Subtypes

- **Entity supertype**: Generic entity type related to one or more entity subtypes
  - Contains common characteristics
- **Entity subtype**: Contains unique characteristics of each entity subtype
- Criteria to determine the usage
  - There must be different, identifiable kinds of the entity in the user's environment
  - The different kinds of instances should each have one or more attributes that are unique to that kind of instance

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Specialization Hierarchy

- Depicts arrangement of higher-level entity supertypes and lower-level entity subtypes
- Relationships are described in terms of "is-a" relationships
- Subtype exists within the context of a supertype
- Every subtype has one supertype to which it is directly related
- Supertype can have many subtypes

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Specialization Hierarchy

- Provides the means to:
  - Support attribute inheritance
  - Define a special supertype attribute known as the subtype discriminator
  - Define disjoint/overlapping constraints and complete/partial constraints

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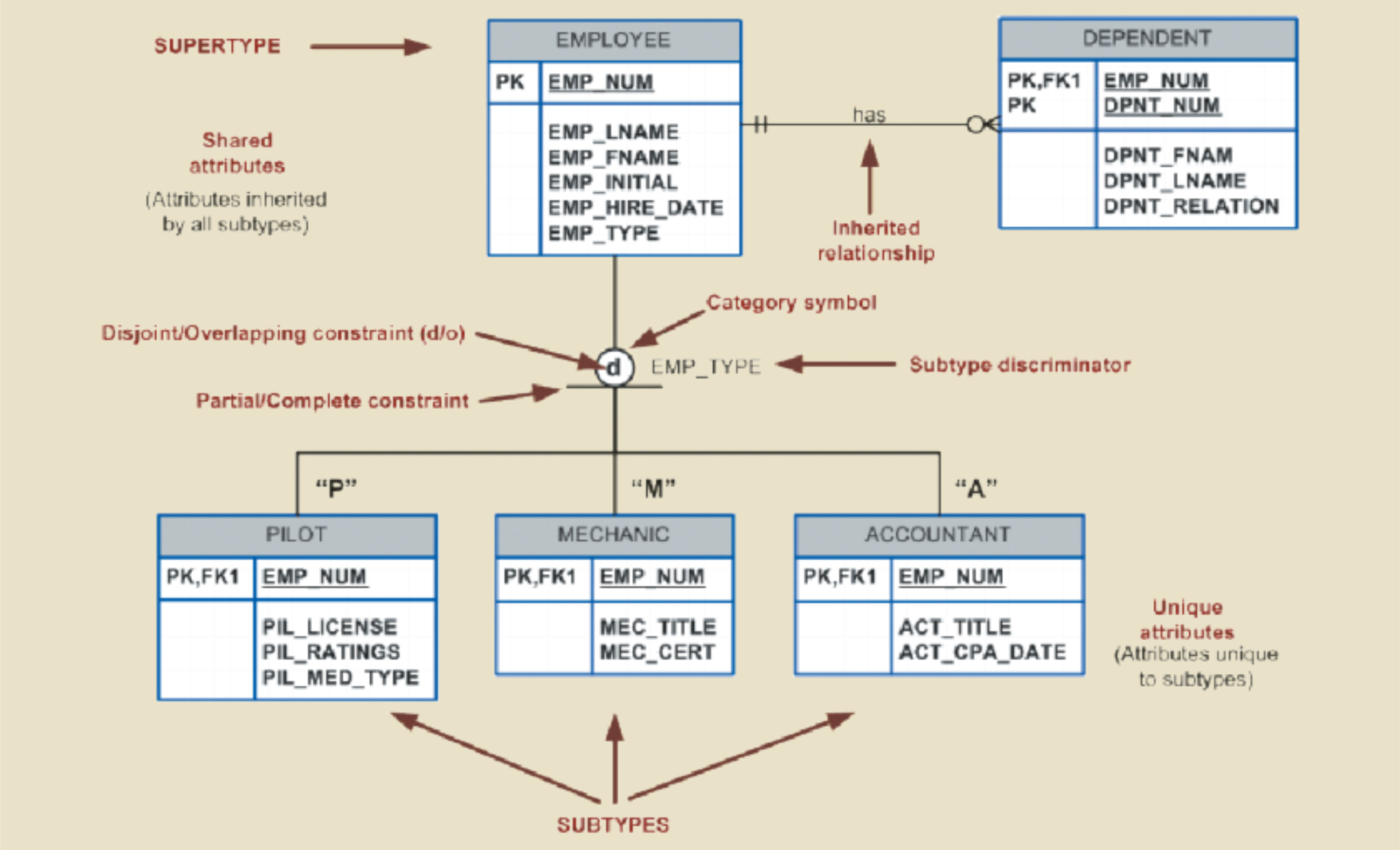
Figure 5.2 - Specialization Hierarchy

FIGURE 5.2 A SPECIALIZATION HIERARCHY



SUPERTYPE

Shared attributes

(Attributes inherited by all subtypes)

EMPLOYEE	
PK	EMP_NUM
	EMP_LNAME EMP_FNAME EMP_INITIAL EMP_HIRE_DATE EMP_TYPE

DEPENDENT	
PK,FK1 PK	EMP_NUM DPNT_NUM
	DPNT_FNAM DPNT_LNAME DPNT_RELATION

has

Inherited relationship

Category symbol

Disjoint/Overlapping constraint (d/o)

Subtype discriminator

Partial/Complete constraint

PILOT	
PK,FK1	EMP_NUM
	PIL_LICENSE PIL_RATINGS PIL_MED_TYPE

MECHANIC	
PK,FK1	EMP_NUM
	MEC_TITLE MEC_CERT

ACCOUNTANT	
PK,FK1	EMP_NUM
	ACT_TITLE ACT_CPA_DATE

Unique attributes

(Attributes unique to subtypes)

SUBTYPES

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Inheritance

- Enables an entity subtype to inherit attributes and relationships of the supertype
- All entity subtypes inherit their primary key attribute from their supertype
- At the implementation level, supertype and its subtype(s) maintain a 1:1 relationship
- Entity subtypes inherit all relationships in which supertype entity participates
- Lower-level subtypes inherit all attributes and relationships from its upper-level supertypes

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Subtype Discriminator

- Attribute in the supertype entity that determines to which entity subtype the supertype occurrence is related
- Default comparison condition is the equality comparison

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Disjoint and Overlapping Constraints

- **Disjoint subtypes**: Contain a unique subset of the supertype entity set
  - Known as **nonoverlapping subtypes**
  - Implementation is based on the value of the subtype discriminator attribute in the supertype
- **Overlapping subtypes**: Contain nonunique subsets of the supertype entity set
  - Implementation requires the use of one discriminator attribute for each subtype

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Figure 5.4 - Specialization Hierarchy with Overlapping Subtypes

FIGURE 5.4 SPECIALIZATION HIERARCHY WITH OVERLAPPING SUBTYPES

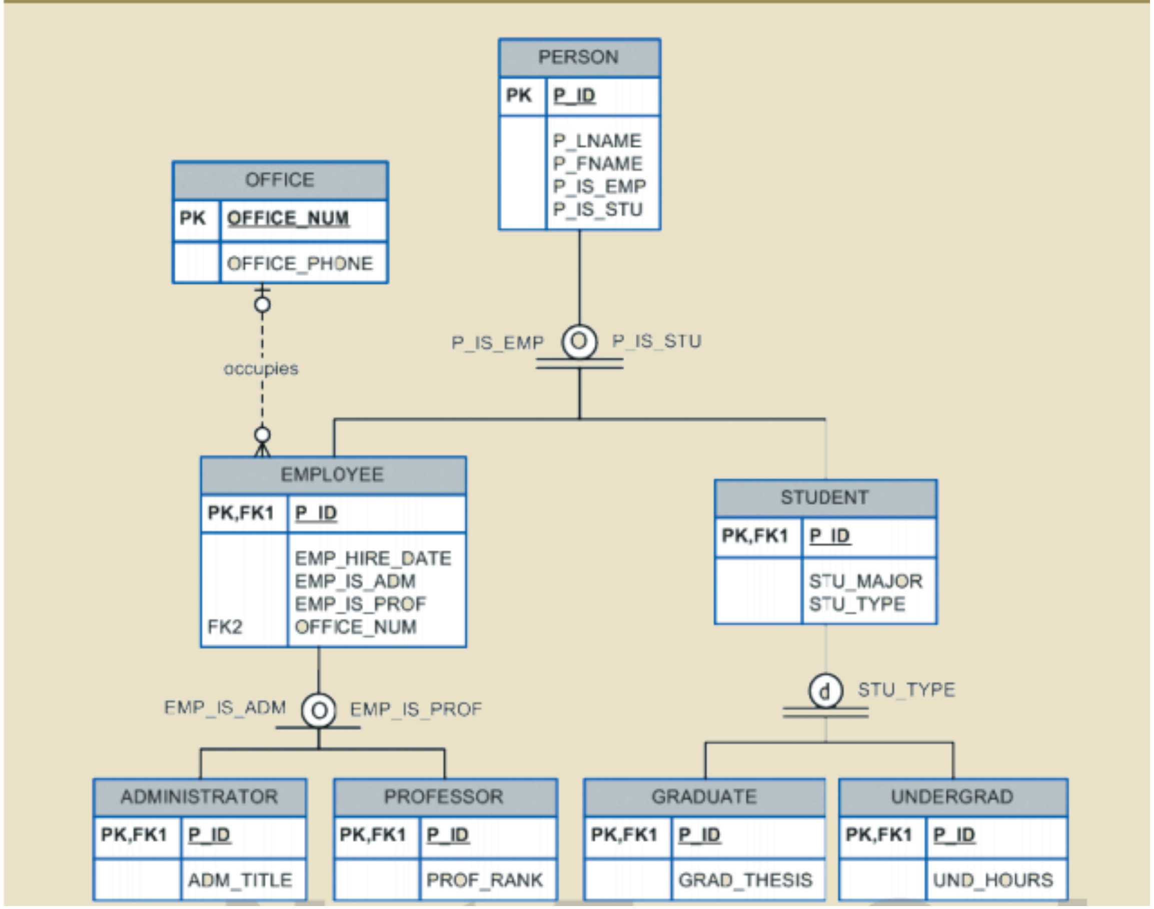

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Table 5.1 - Discriminator Attributes with Overlapping Subtypes

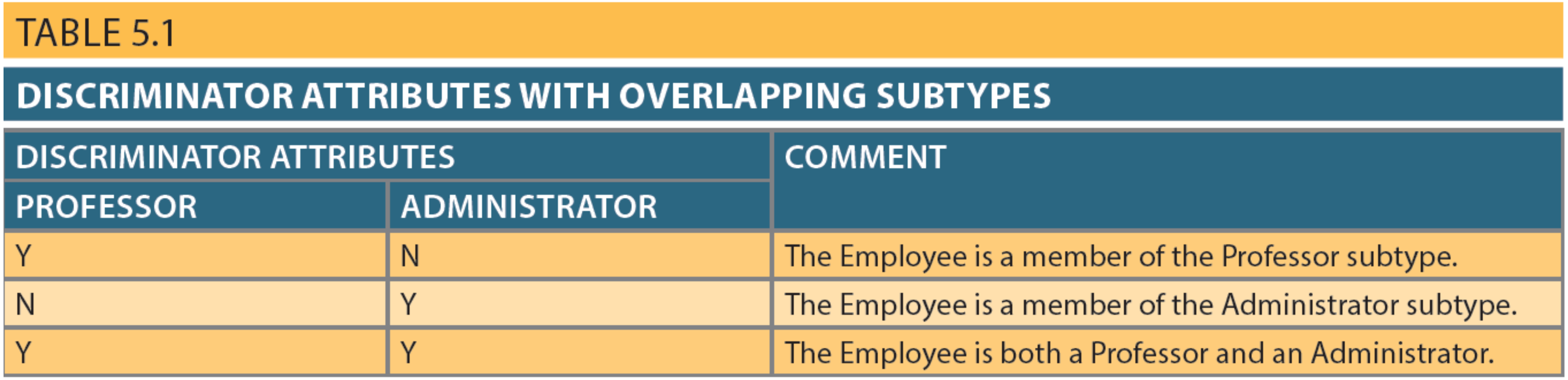

TABLE 5.1

DISCRIMINATOR ATTRIBUTES WITH OVERLAPPING SUBTYPES

DISCRIMINATOR ATTRIBUTES		COMMENT
PROFESSOR	ADMINISTRATOR	
Y	N	The Employee is a member of the Professor subtype.
N	Y	The Employee is a member of the Administrator subtype.
Y	Y	The Employee is both a Professor and an Administrator.

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Completeness Constraint

- Specifies whether each supertype occurrence must also be a member of at least one subtype
- Types
  - **Partial completeness**: Not every supertype occurrence is a member of a subtype
  - **Total completeness**: Every supertype occurrence must be a member of any

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Table 5.2 - Specialization Hierarchy Constraint Scenarios

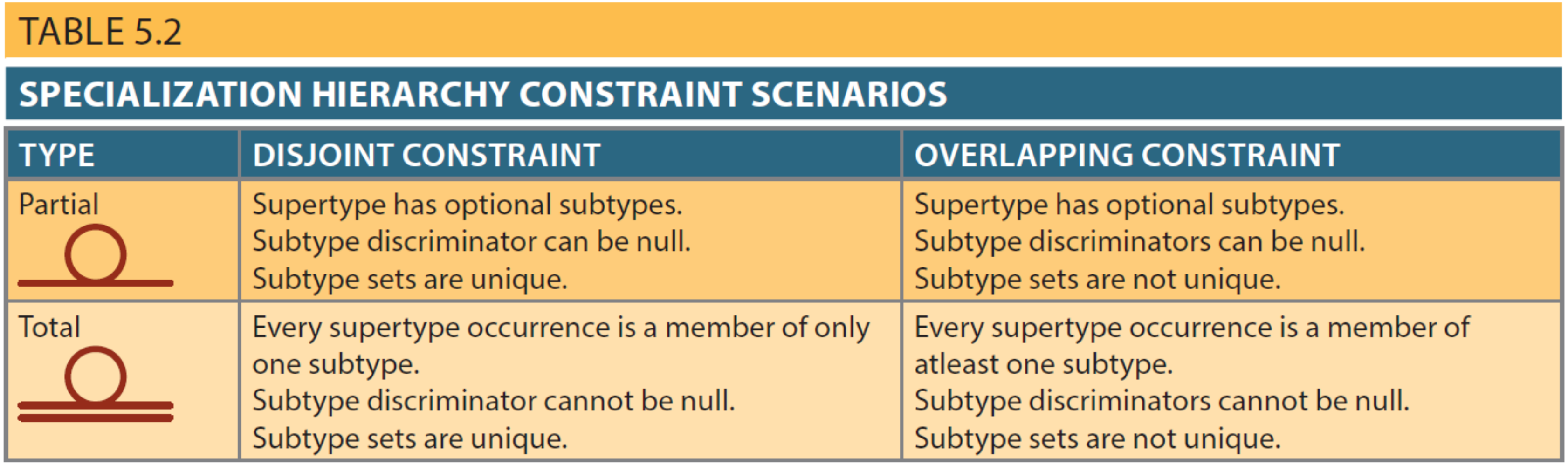

TABLE 5.2

SPECIALIZATION HIERARCHY CONSTRAINT SCENARIOS

TYPE	DISJOINT CONSTRAINT	OVERLAPPING CONSTRAINT
Partial	Supertype has optional subtypes. Subtype discriminator can be null. Subtype sets are unique.	Supertype has optional subtypes. Subtype discriminators can be null. Subtype sets are not unique.
Total	Every supertype occurrence is a member of only one subtype. Subtype discriminator cannot be null. Subtype sets are unique.	Every supertype occurrence is a member of atleast one subtype. Subtype discriminators cannot be null. Subtype sets are not unique.

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Specialization and Generalization

Specialization

- •Top-down process
- •Identifies lower-level, more specific entity subtypes from a higher-level entity supertype
- •Based on grouping unique characteristics and relationships of the subtypes

Generalization

- •Bottom-up process
- •Identifies a higher-level, more generic entity supertype from lower-level entity subtypes
- •Based on grouping common characteristics and relationships of the subtypes

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Entity Cluster

- Virtual entity type used to represent multiple entities and relationships in ERD
- Avoid the display of attributes to eliminate complications that result when the inheritance rules change

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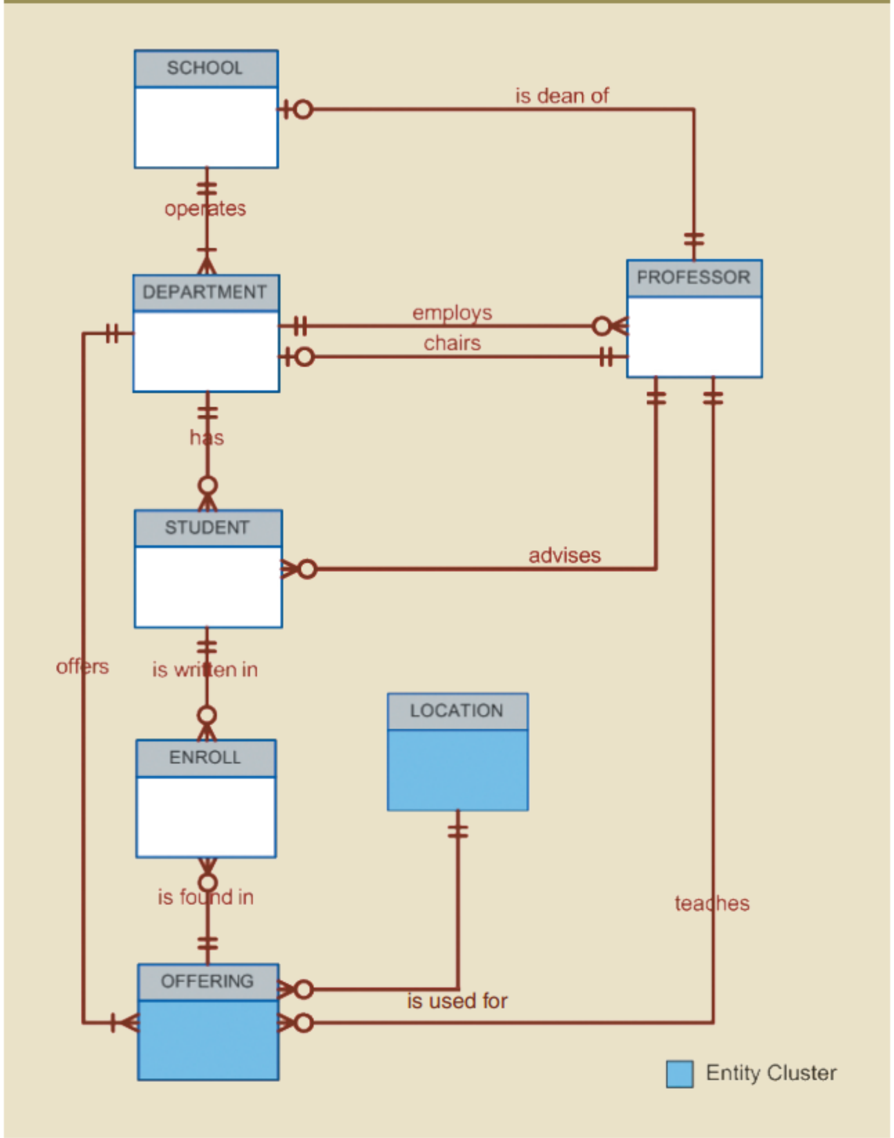
Figure 5.5 - Tiny College ERD Using Entity Clusters

FIGURE 5.5 TINY COLLEGE ERD USING ENTITY CLUSTERS



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Primary Keys

- Single attribute or a combination of attributes, which uniquely identifies each entity instance
  - Guarantees entity integrity
  - Works with foreign keys to implement relationships

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Natural Keys or Natural Identifier

- Real-world identifier used to uniquely identify real-world objects
  - Familiar to end users and forms part of their day-to-day business vocabulary
  - Also known as natural identifier
  - Used as the primary key of the entity being modeled

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Desirable Primary Key Characteristics

- Non intelligent
- No change over time
- Preferably single-attribute
- Preferably numeric
- Security-compliant

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Use of Composite Primary Keys

- Identifiers of composite entities
  - Each primary key combination is allowed once in M:N relationship
- Identifiers of weak entities
  - Weak entity has a strong identifying relationship with the parent entity

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Use of Composite Primary Keys

- When used as identifiers of weak entities, represent a real-world object that is:
  - Existence-dependent on another real-world object
  - Represented in the data model as two separate entities in a strong identifying relationship

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Figure 5.6 - The M:N Relationship between STUDENT and CLASS

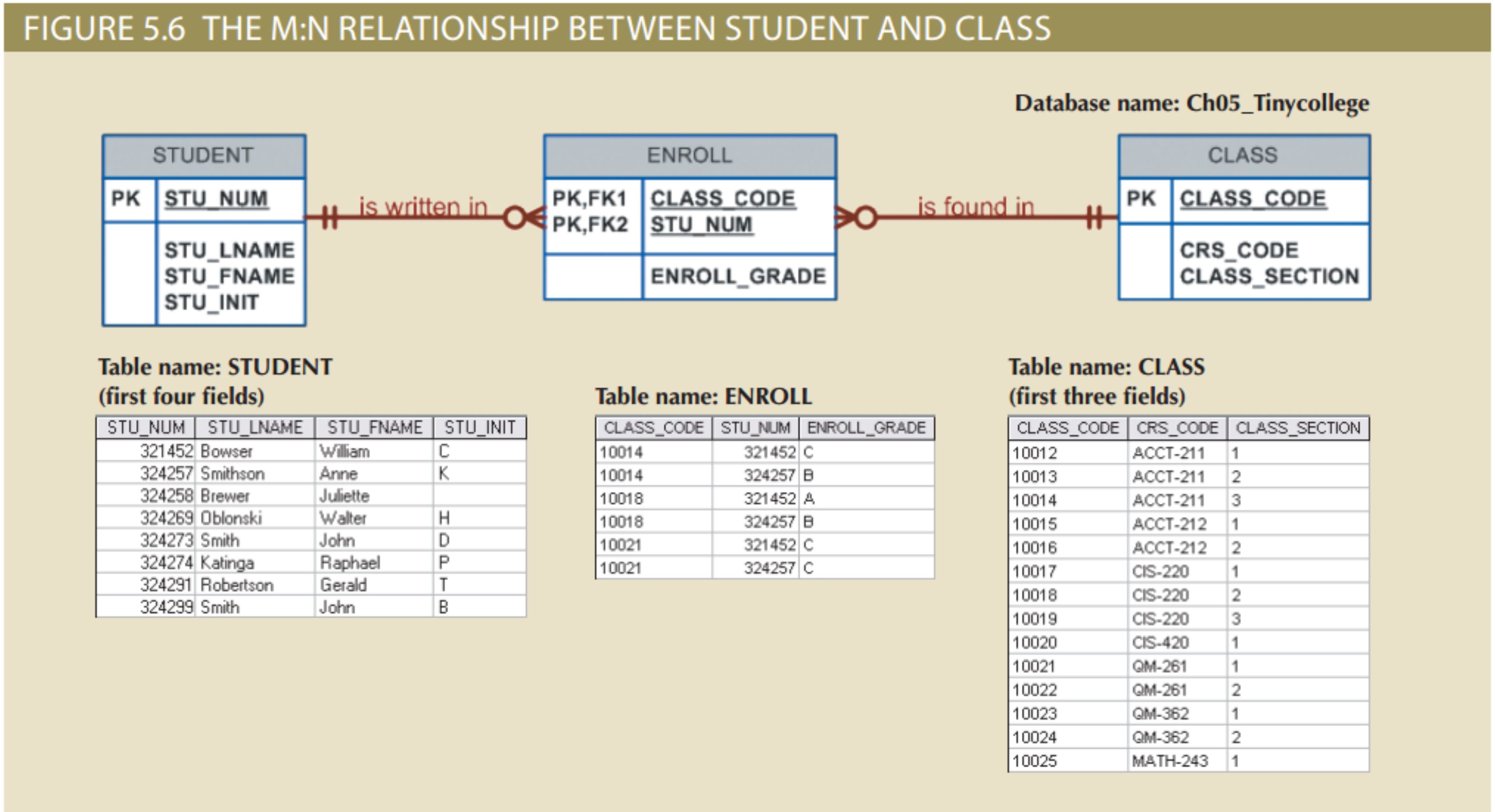

FIGURE 5.6 THE M:N RELATIONSHIP BETWEEN STUDENT AND CLASS

Database name: Ch05_Tinycollege

STUDENT
PK STU_NUM
STU_LNAME
STU_FNAME
STU_INIT

is written in

ENROLL
PK,FK1 CLASS_CODE
PK,FK2 STU_NUM
ENROLL_GRADE

is found in

CLASS
PK CLASS_CODE
CRS_CODE
CLASS_SECTION

Table name: STUDENT
(first four fields)

STU_NUM	STU_LNAME	STU_FNAME	STU_INIT
321452	Bowser	William	C
324257	Smithson	Anne	K
324258	Brewer	Juliette	
324269	Oblonski	Walter	H
324273	Smith	John	D
324274	Katinga	Raphael	P
324291	Robertson	Gerald	T
324299	Smith	John	B

Table name: ENROLL

CLASS_CODE	STU_NUM	ENROLL_GRADE
10014	321452	C
10014	324257	B
10018	321452	A
10018	324257	B
10021	321452	C
10021	324257	C

Table name: CLASS
(first three fields)

CLASS_CODE	CRS_CODE	CLASS_SECTION
10012	ACCT-211	1
10013	ACCT-211	2
10014	ACCT-211	3
10015	ACCT-212	1
10016	ACCT-212	2
10017	CIS-220	1
10018	CIS-220	2
10019	CIS-220	3
10020	CIS-420	1
10021	QM-261	1
10022	QM-261	2
10023	QM-362	1
10024	QM-362	2
10025	MATH-243	1

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Surrogate Primary Keys

- Primary key used to simplify the identification of entity instances are useful when:
  - There is no natural key
  - Selected candidate key has embedded semantic contents or is too long
- Require ensuring that the candidate key of entity in question performs properly
  - Use unique index and not null constraints

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Table 5.4 - Data Used to Keep Track of Events

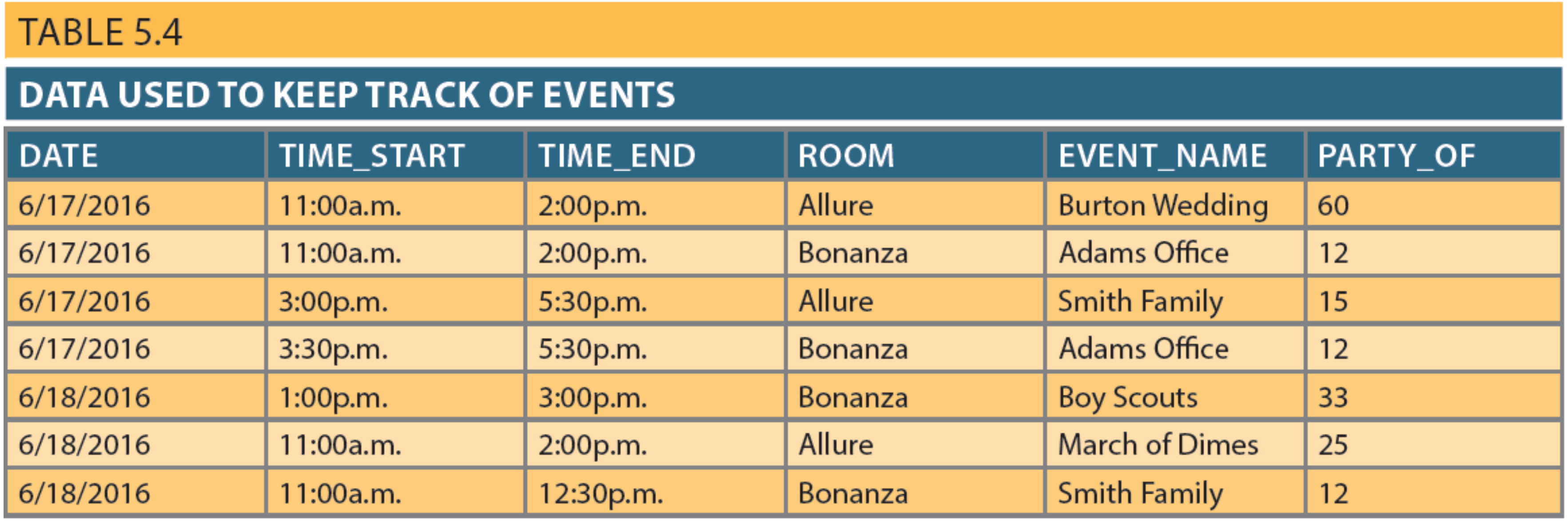

TABLE 5.4

DATA USED TO KEEP TRACK OF EVENTS

DATE	TIME_START	TIME_END	ROOM	EVENT_NAME	PARTY_OF
6/17/2016	11:00a.m.	2:00p.m.	Allure	Burton Wedding	60
6/17/2016	11:00a.m.	2:00p.m.	Bonanza	Adams Office	12
6/17/2016	3:00p.m.	5:30p.m.	Allure	Smith Family	15
6/17/2016	3:30p.m.	5:30p.m.	Bonanza	Adams Office	12
6/18/2016	1:00p.m.	3:00p.m.	Bonanza	Boy Scouts	33
6/18/2016	11:00a.m.	2:00p.m.	Allure	March of Dimes	25
6/18/2016	11:00a.m.	12:30p.m.	Bonanza	Smith Family	12

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Design Case 1: Implementing 1:1 Relationships

- Foreign keys work with primary keys to properly implement relationships in relational model
- Rule
  - Put primary key of the parent entity on the dependent entity as foreign key
- Options for selecting and placing the foreign key:
  - Place a foreign key in both entities
  - Place a foreign key in one of the entities

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Table 5.5 - Selection of Foreign Key in a 1:1 Relationship

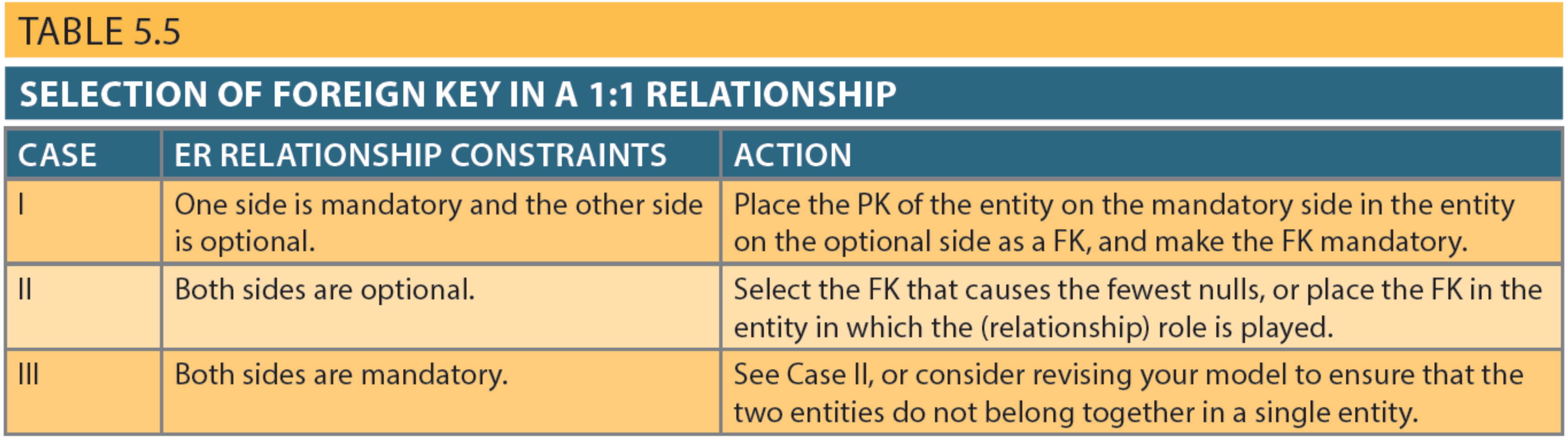

TABLE 5.5

SELECTION OF FOREIGN KEY IN A 1:1 RELATIONSHIP

CASE	ER RELATIONSHIP CONSTRAINTS	ACTION
I	One side is mandatory and the other side is optional.	Place the PK of the entity on the mandatory side in the entity on the optional side as a FK, and make the FK mandatory.
II	Both sides are optional.	Select the FK that causes the fewest nulls, or place the FK in the entity in which the (relationship) role is played.
III	Both sides are mandatory.	See Case II, or consider revising your model to ensure that the two entities do not belong together in a single entity.

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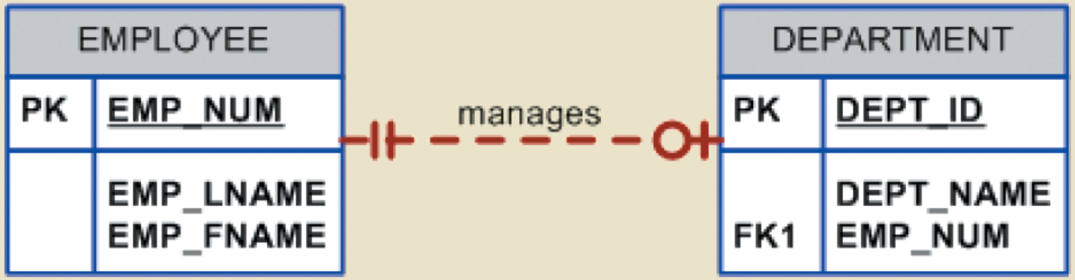
Figure 5.7 - The 1:1 Relationship between Department and Employee

FIGURE 5.7 THE 1:1 RELATIONSHIP BETWEEN DEPARTMENT AND EMPLOYEE

A One-to-One (1:1) Relationship:

An EMPLOYEE manages zero or one DEPARTMENT;
each DEPARTMENT is managed by one EMPLOYEE.



EMPLOYEE	
PK	EMP_NUM
	EMP_LNAME EMP_FNAME

DEPARTMENT	
PK	DEPT_ID
FK1	DEPT_NAME EMP_NUM

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Design Case 2: Maintaining History of Time-Variant Data

- **Time-variant data**: Data whose values change over time and for which a history of the data changes must be retained
  - Requires creating a new entity in a 1:M relationship with the original entity
  - New entity contains the new value, date of the change, and other pertinent attribute

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Figure 5.8 - Maintaining Salary History

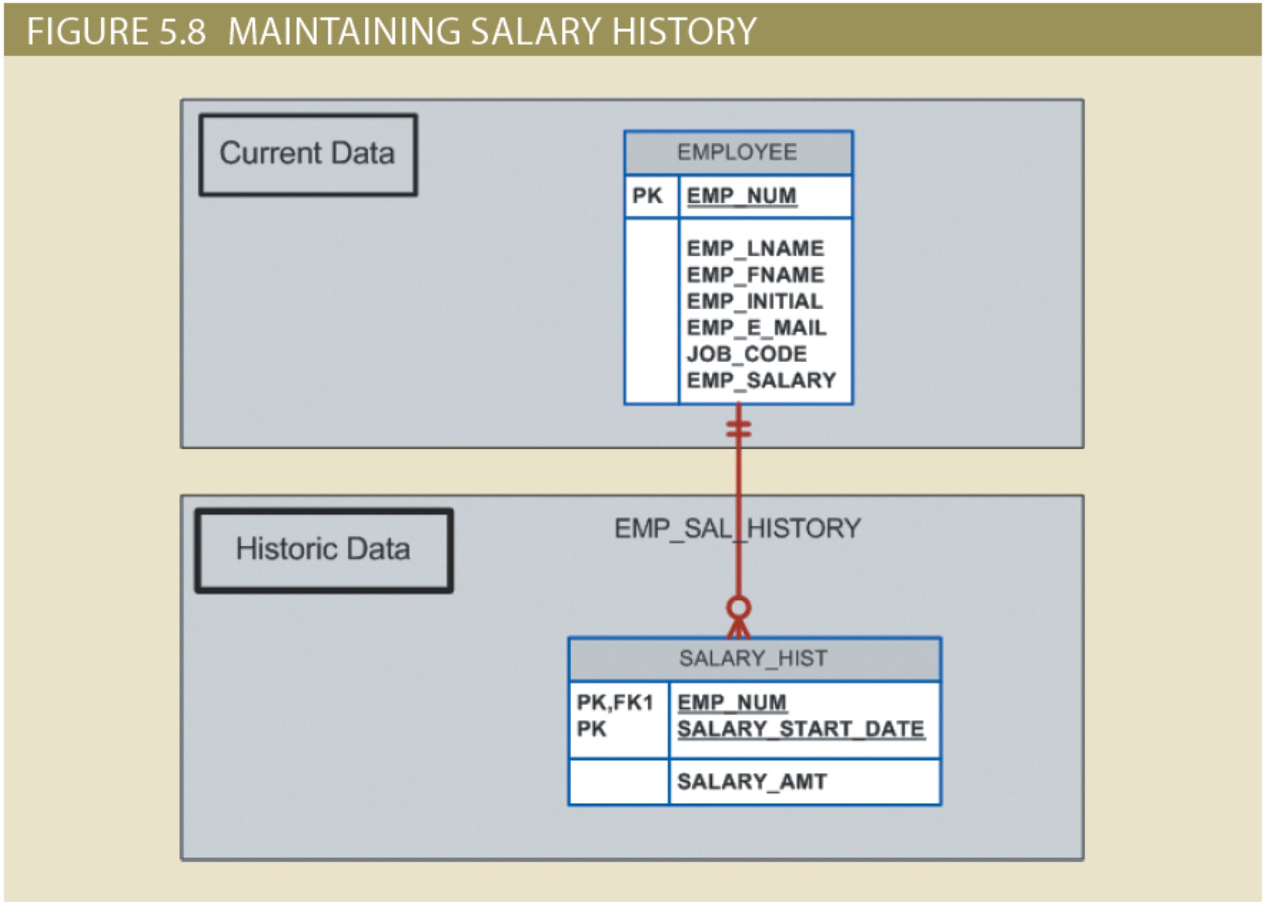

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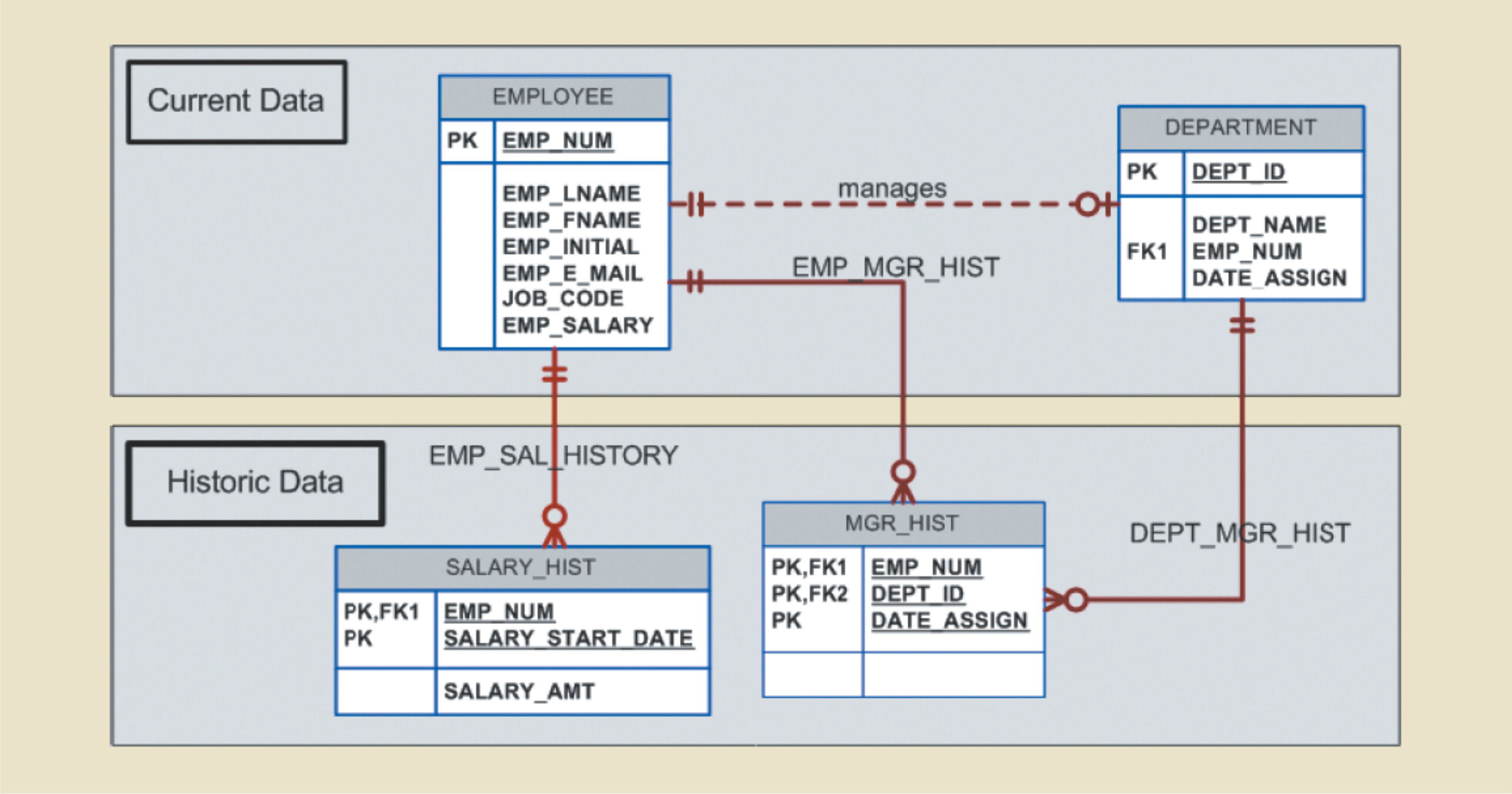
Figure 5.9 - Maintaining Manager History

FIGURE 5.9 MAINTAINING MANAGER HISTORY



EMPLOYEE	
PK	EMP_NUM
	EMP_LNAME EMP_FNAME EMP_INITIAL EMP_E_MAIL JOB_CODE EMP_SALARY

DEPARTMENT	
PK	DEPT_ID
FK1	DEPT_NAME EMP_NUM DATE_ASSIGN

SALARY_HIST	
PK,FK1 PK	EMP_NUM SALARY_START_DATE
	SALARY_AMT

MGR_HIST	
PK,FK1 PK,FK2 PK	EMP_NUM DEPT_ID DATE_ASSIGN

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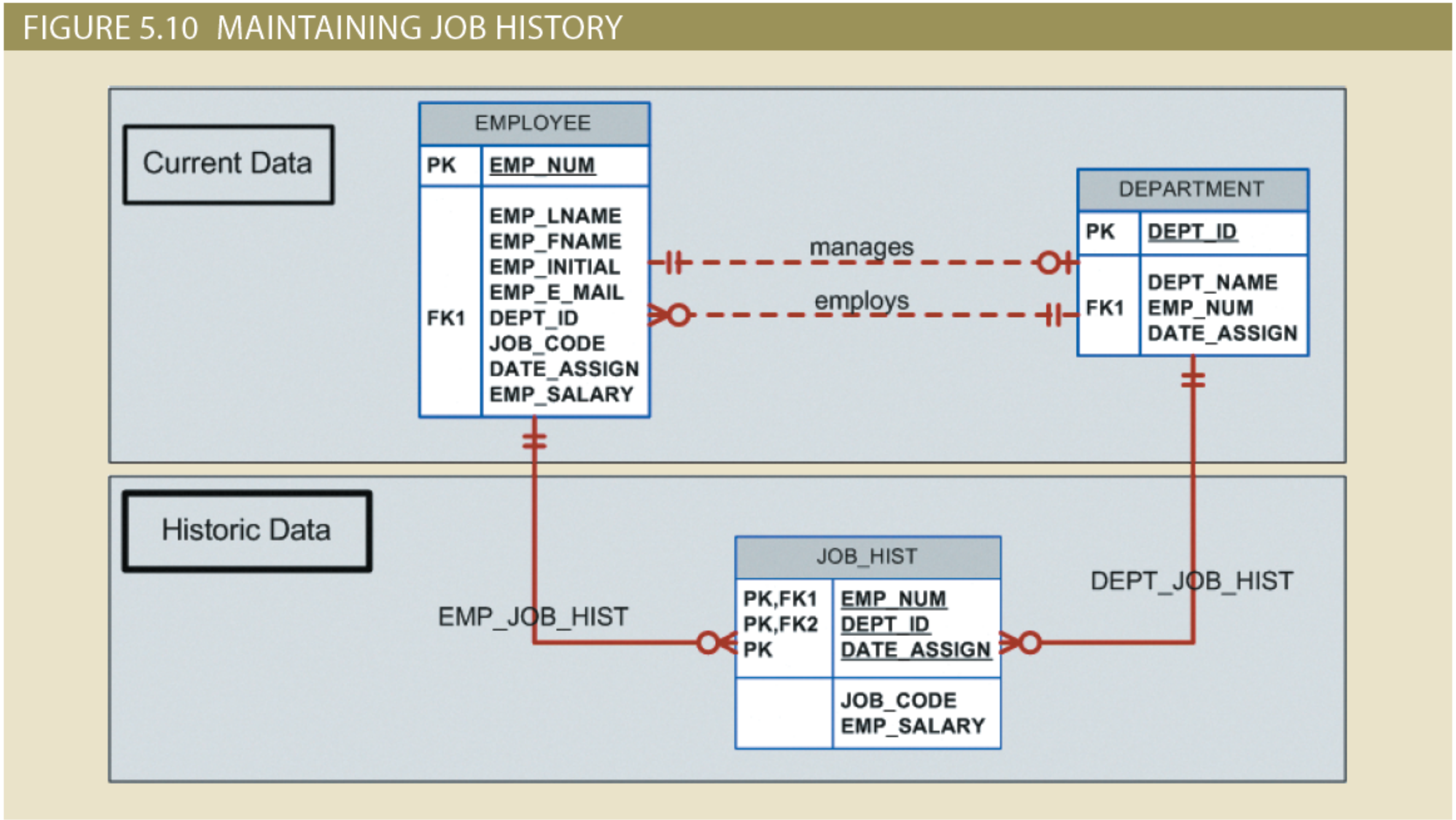
Figure 5.10 - Maintaining Job History

FIGURE 5.10 MAINTAINING JOB HISTORY



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Design Case 3: Fan Traps

- **Design trap**: Occurs when a relationship is improperly or incompletely identified
  - Represented in a way not consistent with the real world
- **Fan trap**: Occurs when one entity is in two 1:M relationships to other entities
  - Produces an association among other entities not expressed in the model

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Figure 5.11 - Incorrect ERD with Fan Trap Problem

FIGURE 5.11 INCORRECT ERD WITH FAN TRAP PROBLEM

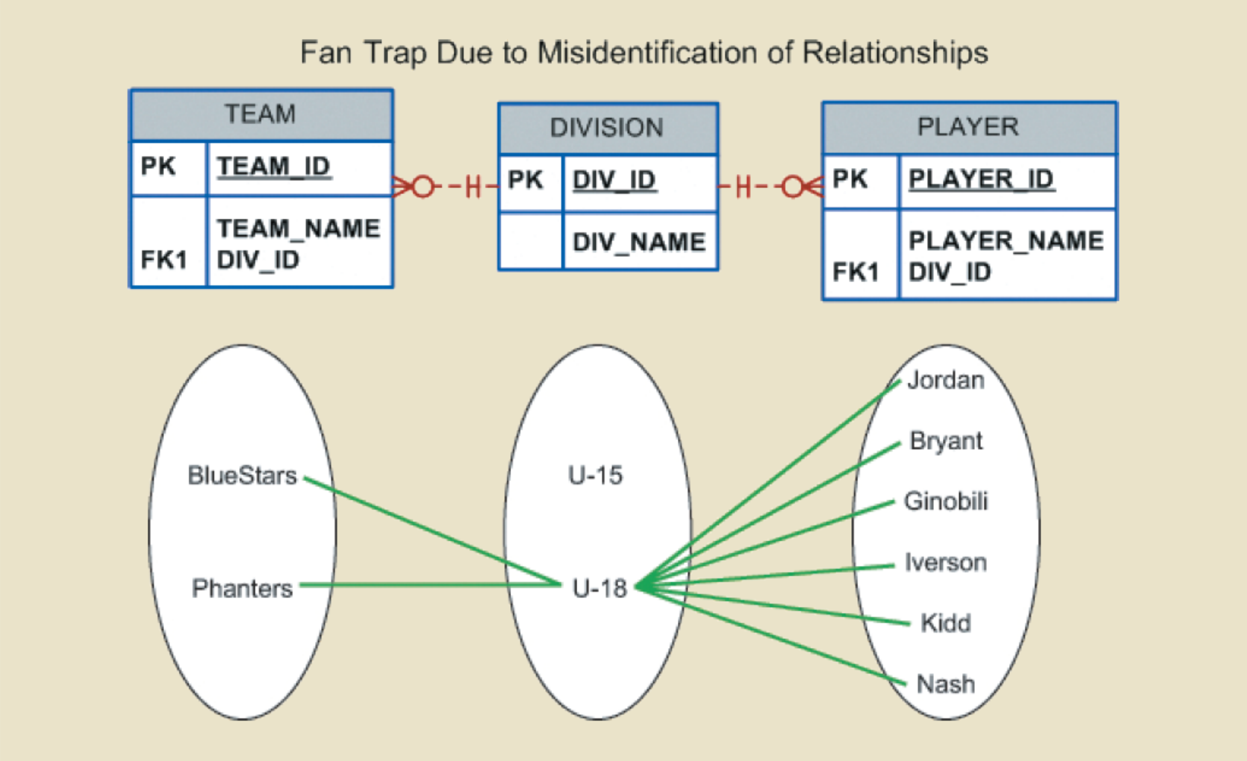

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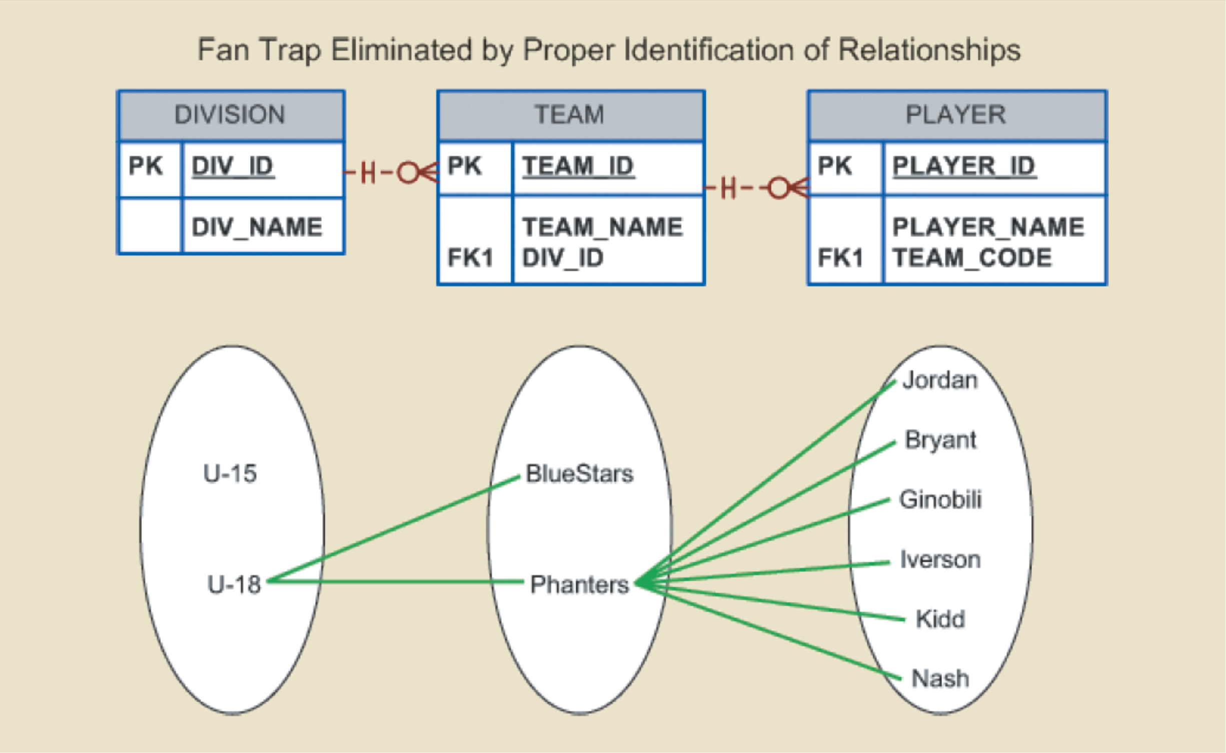
Figure 5.12 - Corrected ERD After Removal of the Fan Trap

FIGURE 5.12 CORRECTED ERD AFTER REMOVAL OF THE FAN TRAP



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Design Case 4: Redundant Relationships

- Occur when there are multiple relationship paths between related entities
- Need to remain consistent across the model
- Help simplify the design

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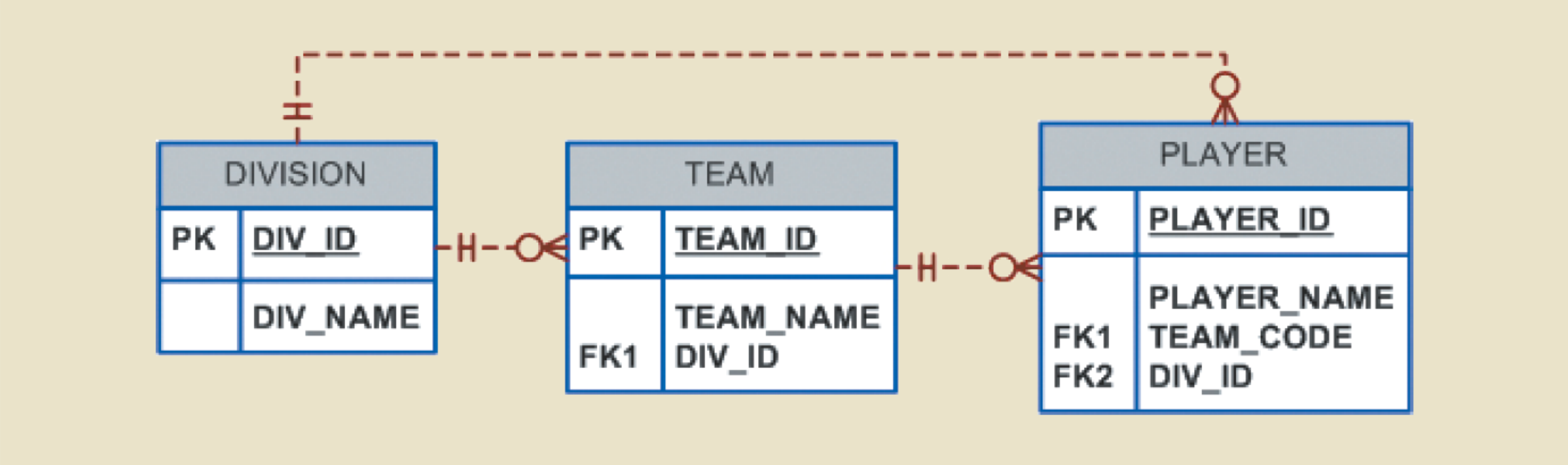
Figure 5.13 - A Redundant Relationship

FIGURE 5.13 A REDUNDANT RELATIONSHIP



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