Chapter 4

Entity Relationship (ER) Modeling

Database Systems:
Design, Implementation, and Management,
Sixth Edition, Rob and Coronel

In this chapter, you will learn:

- How relationships between entities are defined and refined, and how such relationships are incorporated into the database design process
- How ERD components affect database design and implementation
- How to interpret the modeling symbols for the four most popular ER modeling tools
- That real-world database design often requires that you reconcile conflicting goals

The Entity Relationship (ER) Model

- ER model forms the basis of an ER diagram
- ERD represents the conceptual database as viewed by end user
- ERDs depict the ER model's three main components:
  - Entities
  - Attributes
  - Relationships

Entities

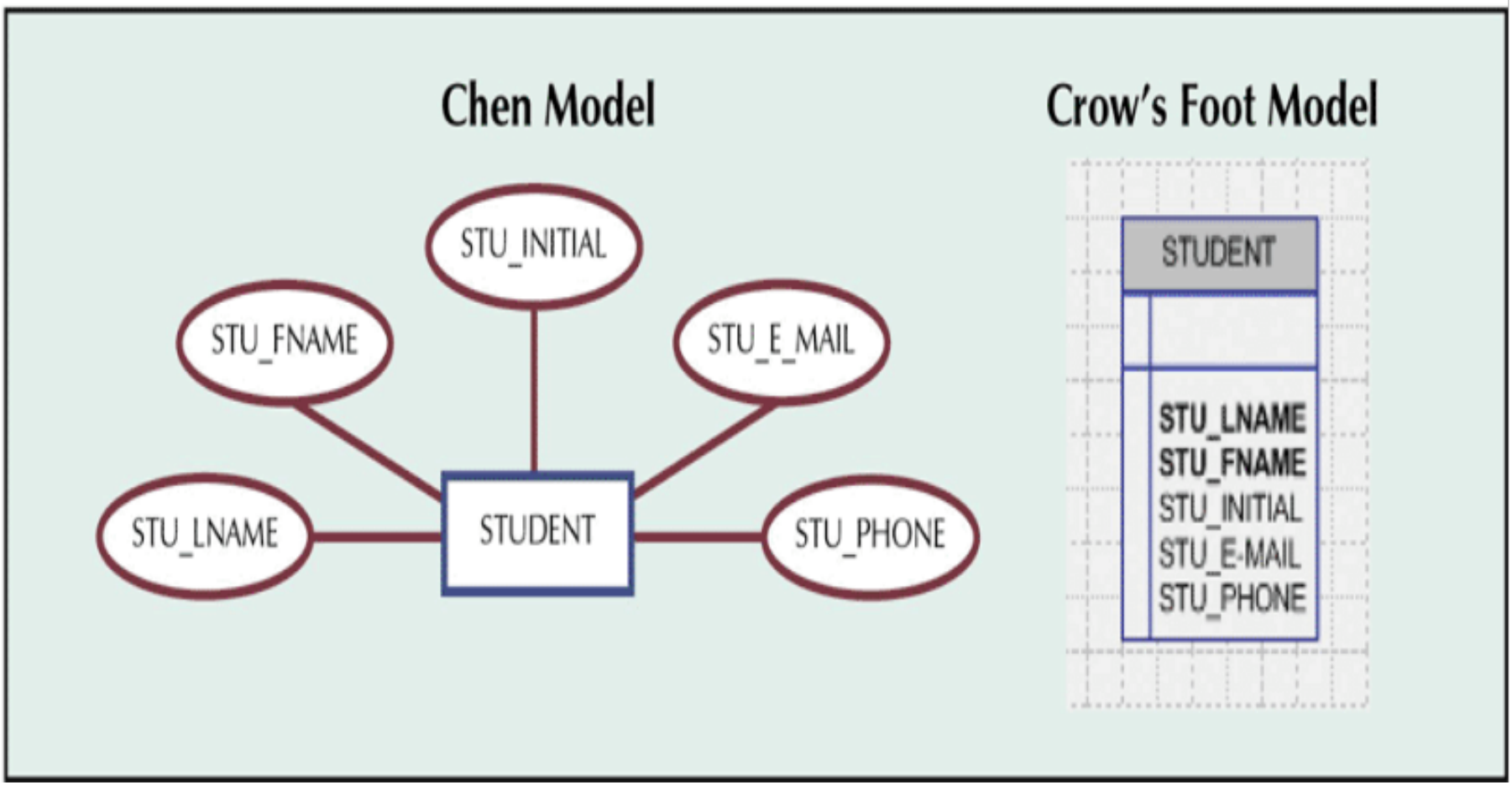
- Refers to the *entity set* and not to a single entity occurrence
- Corresponds to a table and not to a row in the relational environment
- In both the Chen and Crow's Foot models, an entity is represented by a rectangle containing the entity's name
- Entity name, a noun, is usually written in capital letters

Attributes

- Characteristics of entities
- In Chen model, attributes are represented by ovals and are connected to the entity rectangle with a line
- Each oval contains the name of the attribute it represents
- In the Crow's Foot model, the attributes are simply written in the attribute box below the entity rectangle

The Attributes of the STUDENT Entity

FIGURE 4.1 THE ATTRIBUTES OF THE STUDENT ENTITY



Domains

- Attributes have a *domain*:
  - The attribute's set of possible values
- Attributes may share a domain

Primary Keys

- Underlined in the ER diagram
- Key attributes are also underlined in frequently used table structure shorthand
- Ideally composed of only a single attribute
- Possible to use a *composite key*:
  - Primary key composed of more than one attribute

The CLASS Table (Entity) Components and Contents

FIGURE 4.2 THE CLASS TABLE (ENTITY) COMPONENTS AND CONTENTS

Table name: CLASS Database name: Ch04_TinyCollege

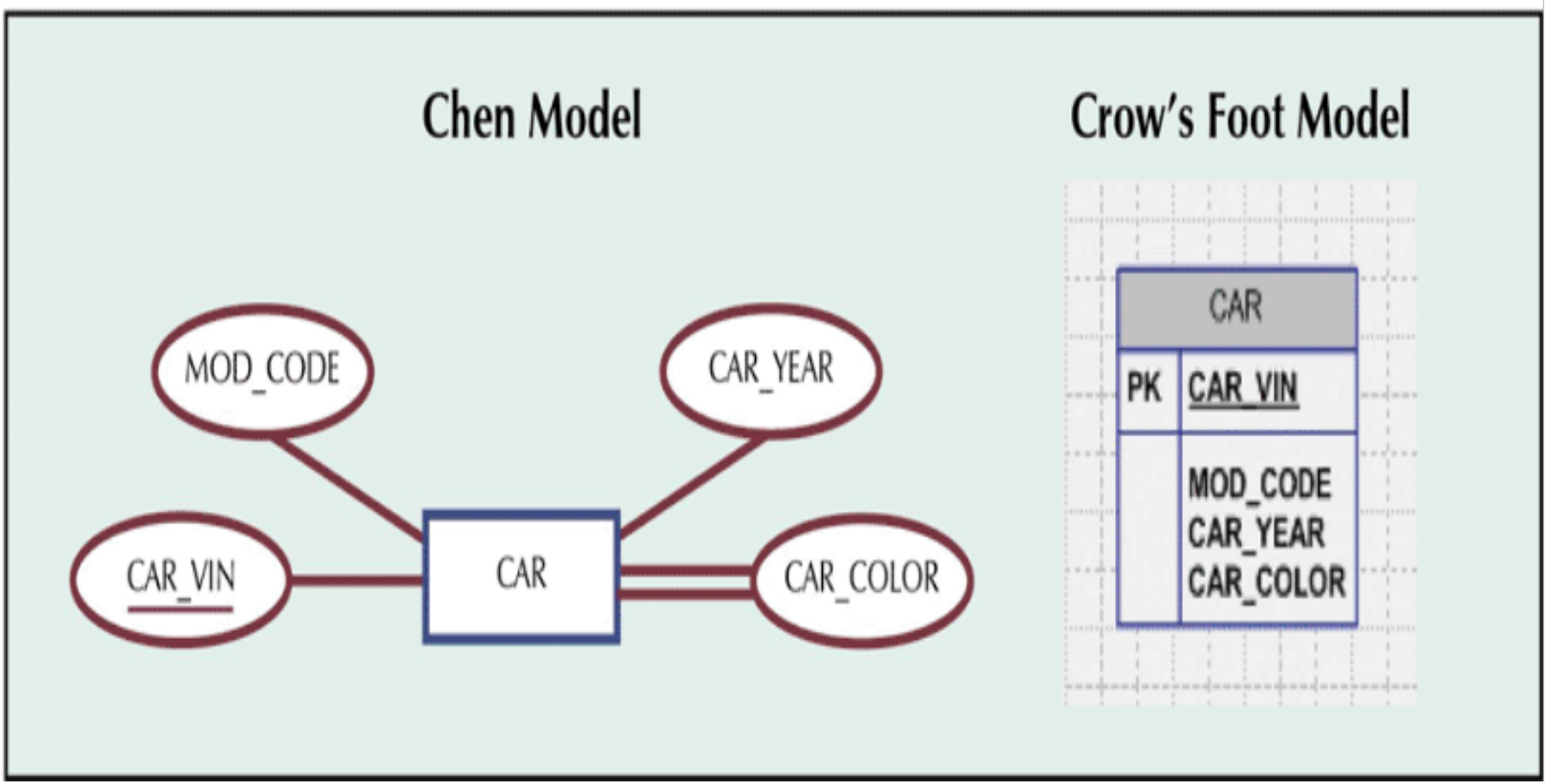
CLASS_CODE	CRS_CODE	CLASS_SECTION	CLASS_TIME	CLASS_ROOM	PROF_NUM
10012	ACCT-211	1	MWF 8:00-8:50 a.m.	BUS311	105
10013	ACCT-211	2	MWF 9:00-9:50 a.m.	BUS200	105
10014	ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
10015	ACCT-212	1	MWF 10:00-10:50 a.m.	BUS311	301
10016	ACCT-212	2	Th 6:00-8:40 p.m.	BUS252	301
10017	CIS-220	1	MWF 9:00-9:50 a.m.	KLR209	228
10018	CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
10019	CIS-220	3	MWF 10:00-10:50 a.m.	KLR209	228
10020	CIS-420	1	W 6:00-8:40 p.m.	KLR209	162
10021	QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114
10022	QM-261	2	TTh 1:00-2:15 p.m.	KLR200	114
10023	QM-362	1	MWF 11:00-11:50 a.m.	KLR200	162
10024	QM-362	2	TTh 2:30-3:45 p.m.	KLR200	162

Attributes

- Composite attribute
- Simple attribute
- Single-value attribute
- Multivalued attributes

A Multivalued Attribute in an Entity

FIGURE 4.3 A MULTIVALUED ATTRIBUTE IN AN ENTITY

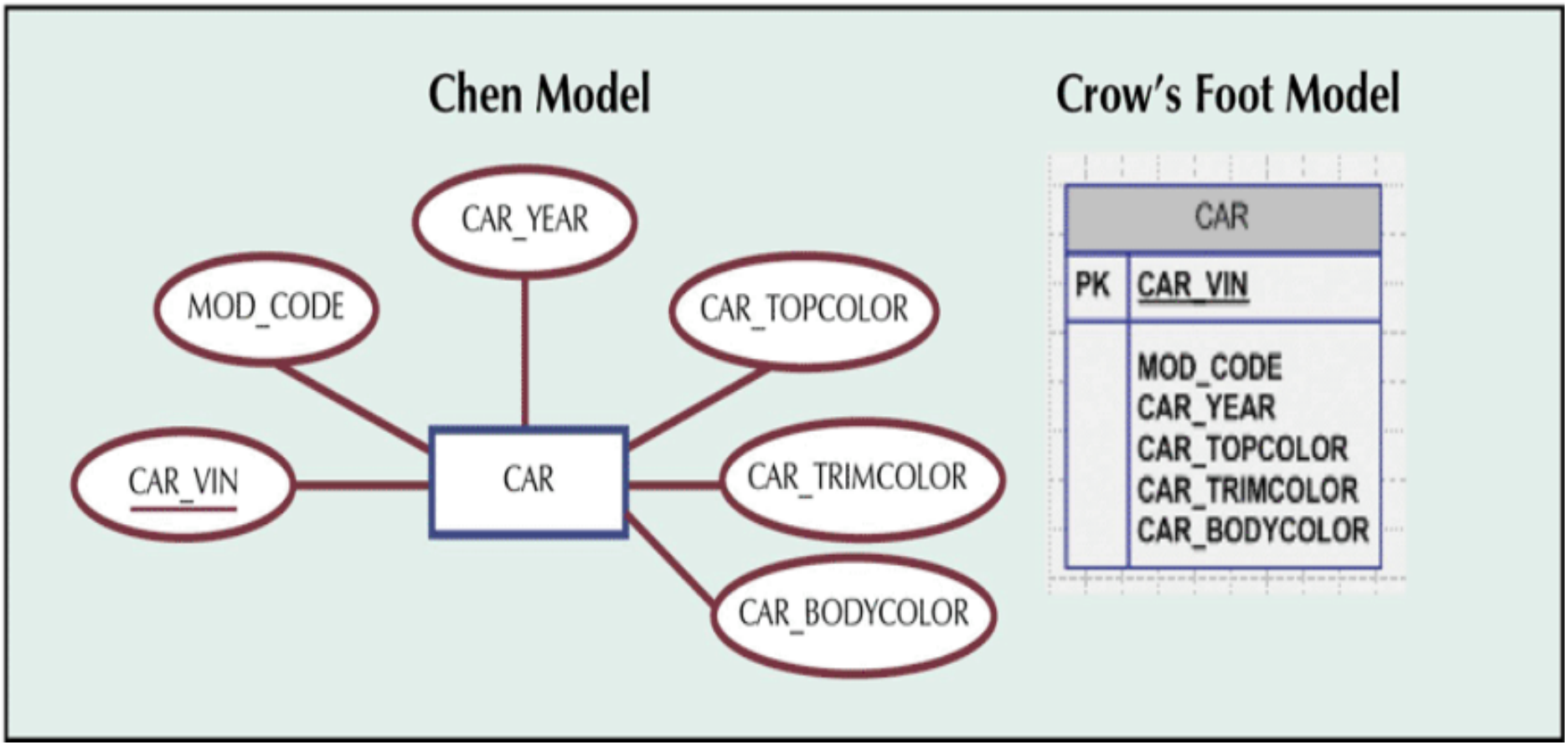


Resolving Multivalued Attribute Problems

- Although the conceptual model can handle multivalued attributes, *you should not implement them in the relational DBMS*
  - Within original entity, create several new attributes, one for each of the original multivalued attribute's components
    - Can lead to major structural problems in the table
  - Create a new entity composed of original multivalued attribute's components

Splitting the Multivalued Attribute into New Attributes

FIGURE 4.4 SPLITTING THE MULTIVALUED ATTRIBUTE INTO NEW ATTRIBUTES



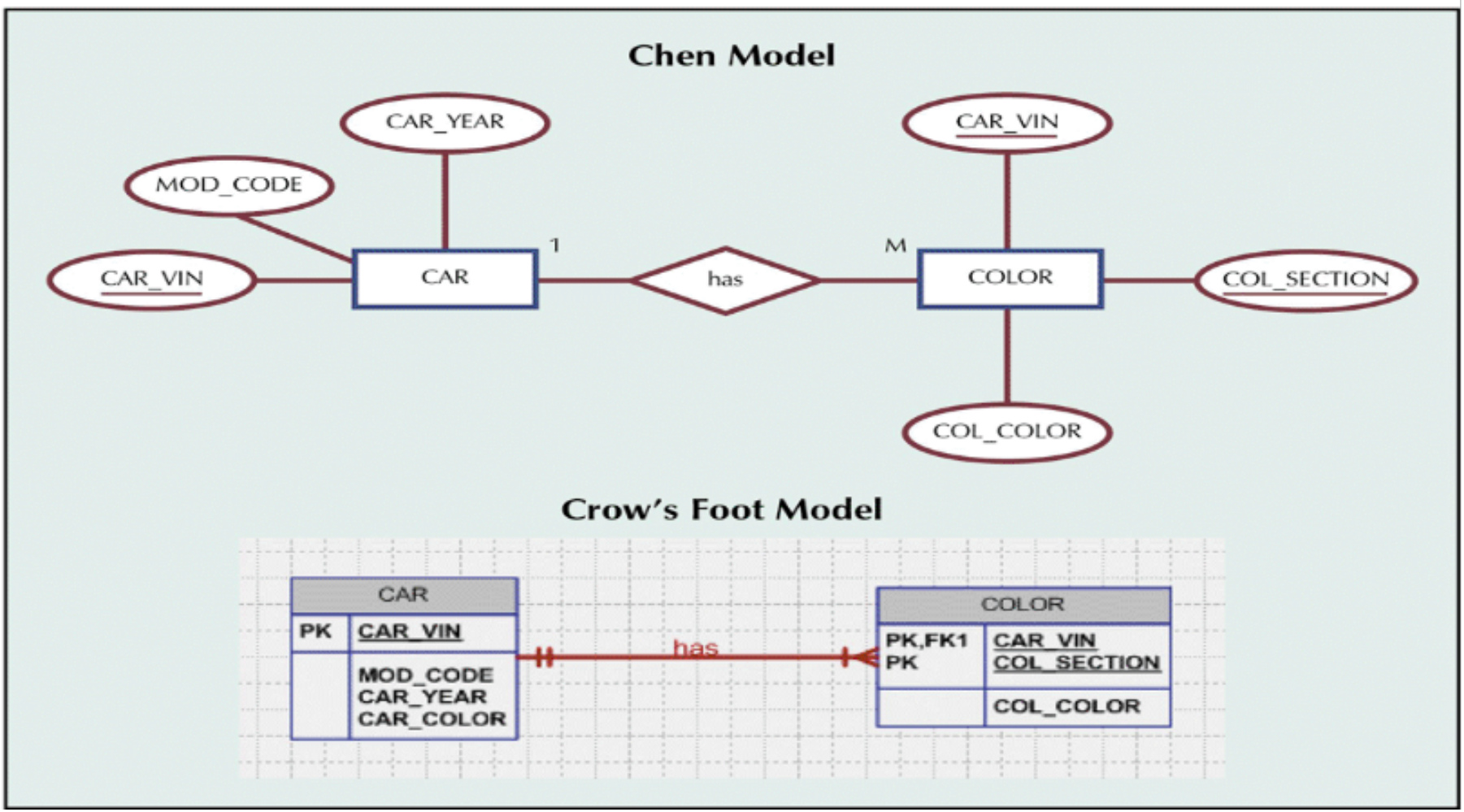
Components of the Multivalued Attribute

TABLE 4.1 COMPONENTS OF THE MULTIVALUED ATTRIBUTE

SECTION	COLOR
Top	White
Body	Blue
Trim	Gold
Interior	Blue

A New Entity Set Composed of a Multivalued Attribute's Components

FIGURE 4.5 A NEW ENTITY SET COMPOSED OF A MULTIVALUED ATTRIBUTE'S COMPONENTS

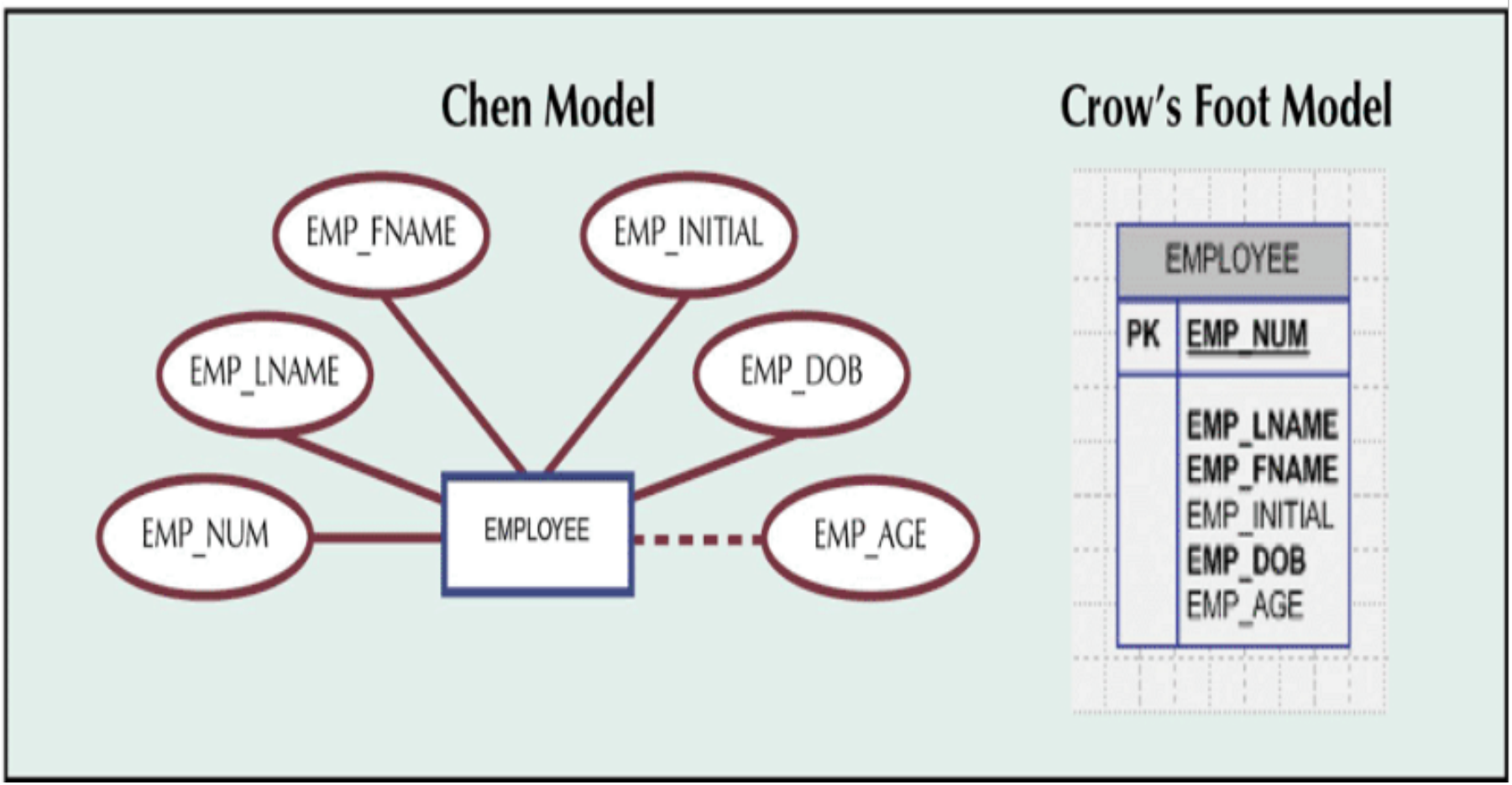


Derived Attributes

- Attribute whose value may be calculated (derived) from other attributes
- Need not be physically stored within the database
- Can be derived by using an algorithm

Depiction of a Derived Attribute

FIGURE 4.6 DEPICTION OF A DERIVED ATTRIBUTE



Relationships

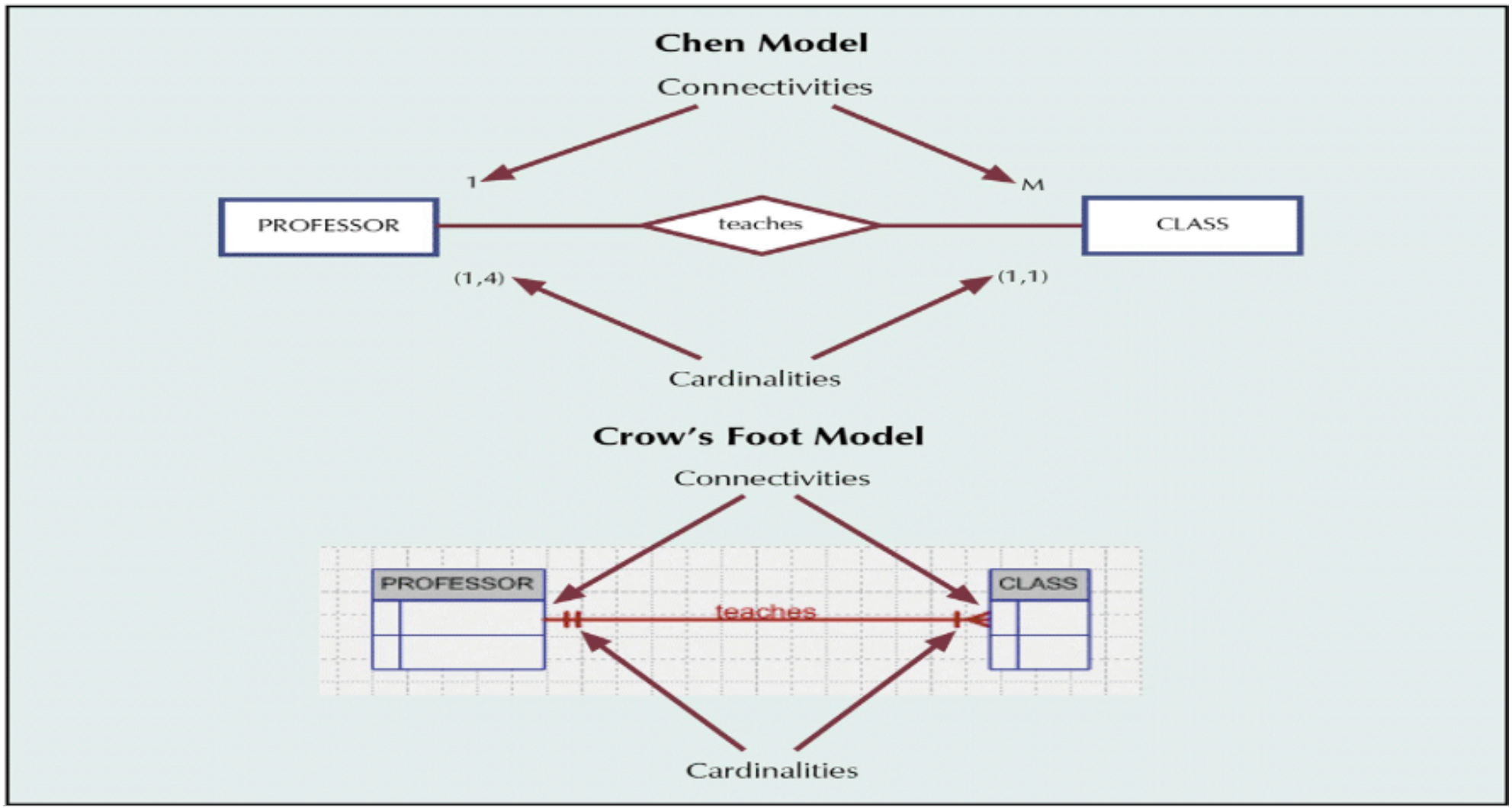
- Association between entities
- Participants:
  - Entities that participate in a relationship
- Relationships between entities always operate in both directions
- Relationship can be classified as 1:M
- Relationship classification is difficult to establish if you only know one side

Connectivity and Cardinality

- Connectivity
  - Used to describe the relationship classification
- Cardinality
  - Expresses the specific number of entity occurrences associated with one occurrence of the related entity
- Established by very concise statements known as *business rules*

Connectivity and Cardinality in an ERD

FIGURE 4.7 CONNECTIVITY AND CARDINALITY IN AN ERD

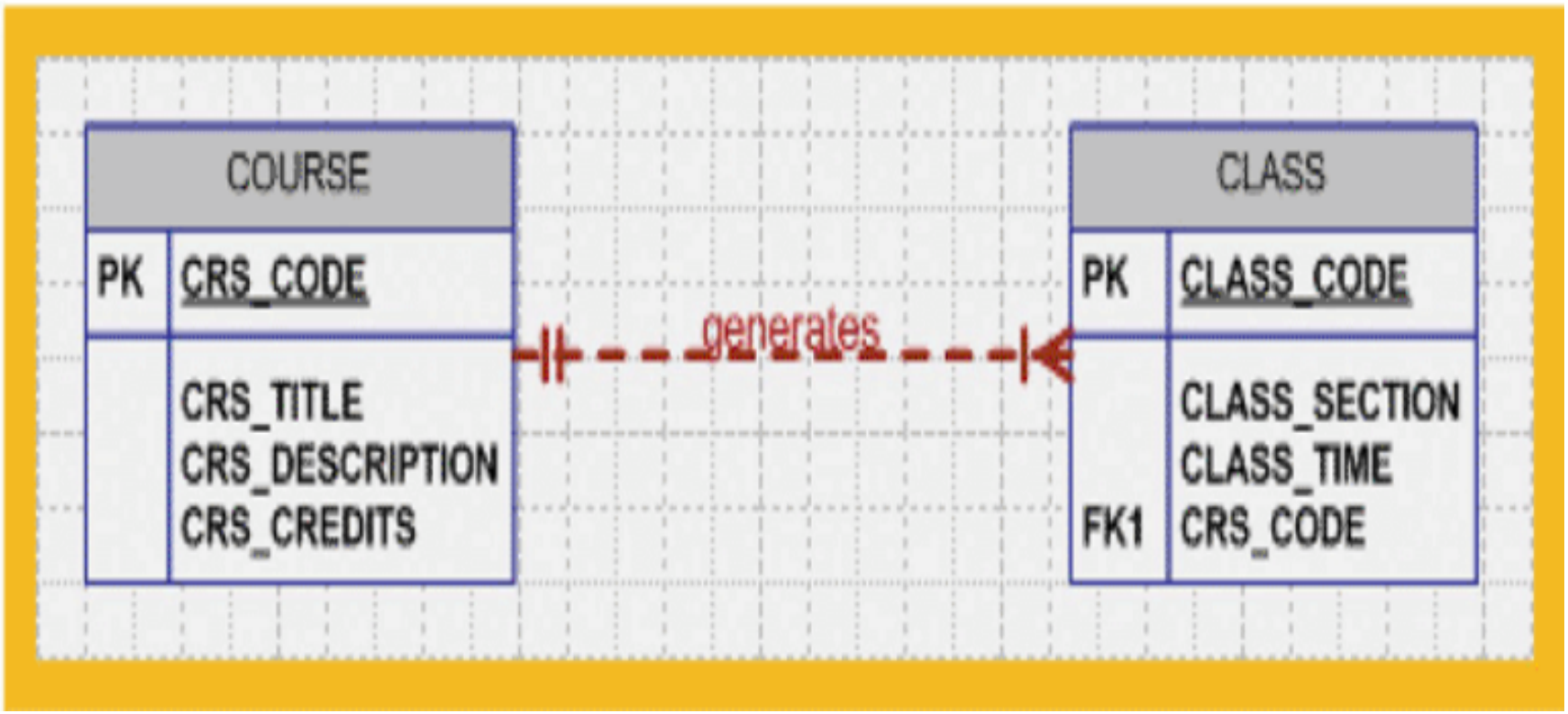


RELATIONSHIP Strength

- Existence dependence
  - Entity's existence depends on the existence of one or more other entities
- Existence independence
  - Entity can exist apart from one or more related entities
- Weak (non-identifying) relationships
  - One entity is not existence-independent on another entity
- Strong (Identifying) Relationships
  - Related entities are existence-dependent

A Weak (Non-Identifying) Relationship Between COURSE and CLASS

FIGURE 4.8 A WEAK (NON-IDENTIFYING) RELATIONSHIP BETWEEN COURSE AND CLASS



A Weak Relationship Between COURSE and CLASS

FIGURE 4.9 A WEAK RELATIONSHIP BETWEEN COURSE AND CLASS

Table name: COURSE **Database name: Ch04_TinyCollege**

CRS_CODE	DEPT_CODE	CRS_DESCRIPTION	CRS_CREDIT
ACCT-211	ACCT	Accounting I	3
ACCT-212	ACCT	Accounting II	3
CIS-220	CIS	Intro. to Microcomputing	3
CIS-420	CIS	Database Design and Implementation	4
MATH-243	MATH	Mathematics for Managers	3
QM-261	CIS	Intro. to Statistics	3
QM-362	CIS	Statistical Applications	4

Table name: CLASS

CLASS_CODE	CRS_CODE	CLASS_SECTION	CLASS_TIME	ROOM_CODE	PROF_NUM
10012	ACCT-211	1	MWF 8:00-8:50 a.m.	BUS311	105
10013	ACCT-211	2	MWF 9:00-9:50 a.m.	BUS200	105
10014	ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
10015	ACCT-212	1	MWF 10:00-10:50 a.m.	BUS311	301
10016	ACCT-212	2	Th 6:00-8:40 p.m.	BUS252	301
10017	CIS-220	1	MWF 9:00-9:50 a.m.	KLR209	228
10018	CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
10019	CIS-220	3	MWF 10:00-10:50 a.m.	KLR209	228
10020	CIS-420	1	W 6:00-8:40 p.m.	KLR209	162
10021	QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114
10022	QM-261	2	TTh 1:00-2:15 p.m.	KLR200	114
10023	QM-362	1	MWF 11:00-11:50 a.m.	KLR200	162
10024	QM-362	2	TTh 2:30-3:45 p.m.	KLR200	162
10025	MATH-243	1	Th 6:00-8:40 p.m.	DRE155	325

Relationship Participation

- Optional:
  - One entity occurrence does not *require* a corresponding entity occurrence in a particular relationship
- Mandatory:
  - One entity occurrence *requires* a corresponding entity occurrence in a particular relationship

A Strong (Identifying) Relationship Between COURSE and CLASS

FIGURE 4.10 A STRONG (IDENTIFYING) RELATIONSHIP BETWEEN COURSE AND CLASS

Table name: COURSE **Database name: Ch04_TinyCollege_Alt**

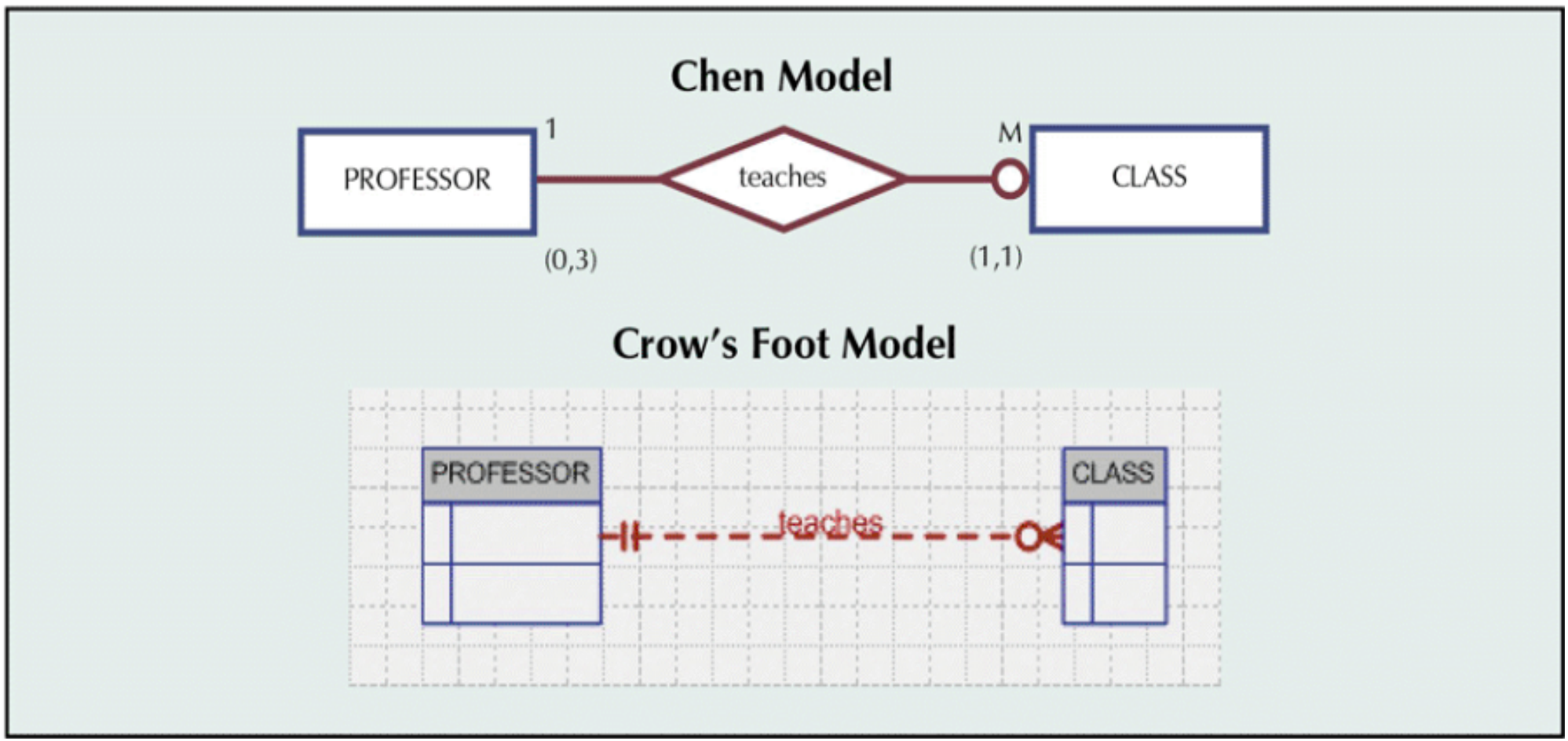
CRS_CODE	DEPT_CODE	CRS_DESCRIPTION	CRS_CREDIT
ACCT-211	ACCT	Accounting I	3
ACCT-212	ACCT	Accounting II	3
CIS-220	CIS	Intro. to Microcomputing	3
CIS-420	CIS	Database Design and Implementation	4
MATH-243	MATH	Mathematics for Managers	3
QM-261	CIS	Intro. to Statistics	3
QM-362	CIS	Statistical Applications	4

Table name: CLASS

CRS_CODE	CLASS_SECTION	CLASS_TIME	ROOM_CODE	PROF_NUM
ACCT-211	1	MWF 8:00-8:50 a.m.	BUS311	105
ACCT-211	2	MWF 9:00-9:50 a.m.	BUS200	105
ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
ACCT-212	1	MWF 10:00-10:50 a.m.	BUS311	301
ACCT-212	2	Th 6:00-8:40 p.m.	BUS252	301
CIS-220	1	MWF 9:00-9:50 a.m.	KLR209	228
CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
CIS-220	3	MWF 10:00-10:50 a.m.	KLR209	228
CIS-420	1	W 6:00-8:40 p.m.	KLR209	162
MATH-243	1	Th 6:00-8:40 p.m.	DRE155	325
QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114
QM-261	2	TTh 1:00-2:15 p.m.	KLR200	114
QM-362	1	MWF 11:00-11:50 a.m.	KLR200	162
QM-362	2	TTh 2:30-3:45 p.m.	KLR200	162

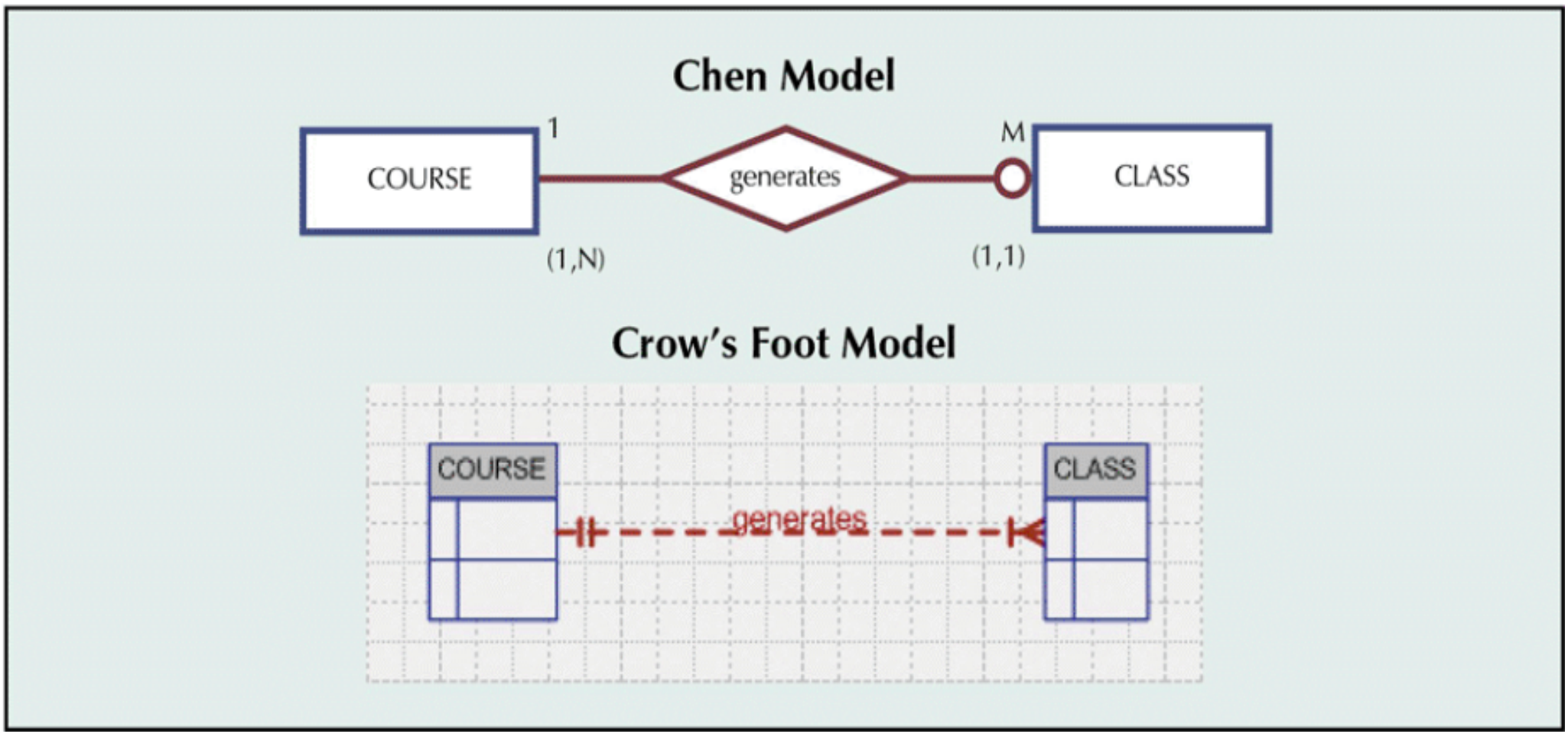
An Optional CLASS Entity in the Relationship PROFESSOR teaches CLASS

FIGURE 4.11 AN OPTIONAL CLASS ENTITY IN THE RELATIONSHIP PROFESSOR TEACHES CLASS



COURSE and CLASS in a Mandatory Relationship

FIGURE 4.13 COURSE AND CLASS IN A MANDATORY RELATIONSHIP

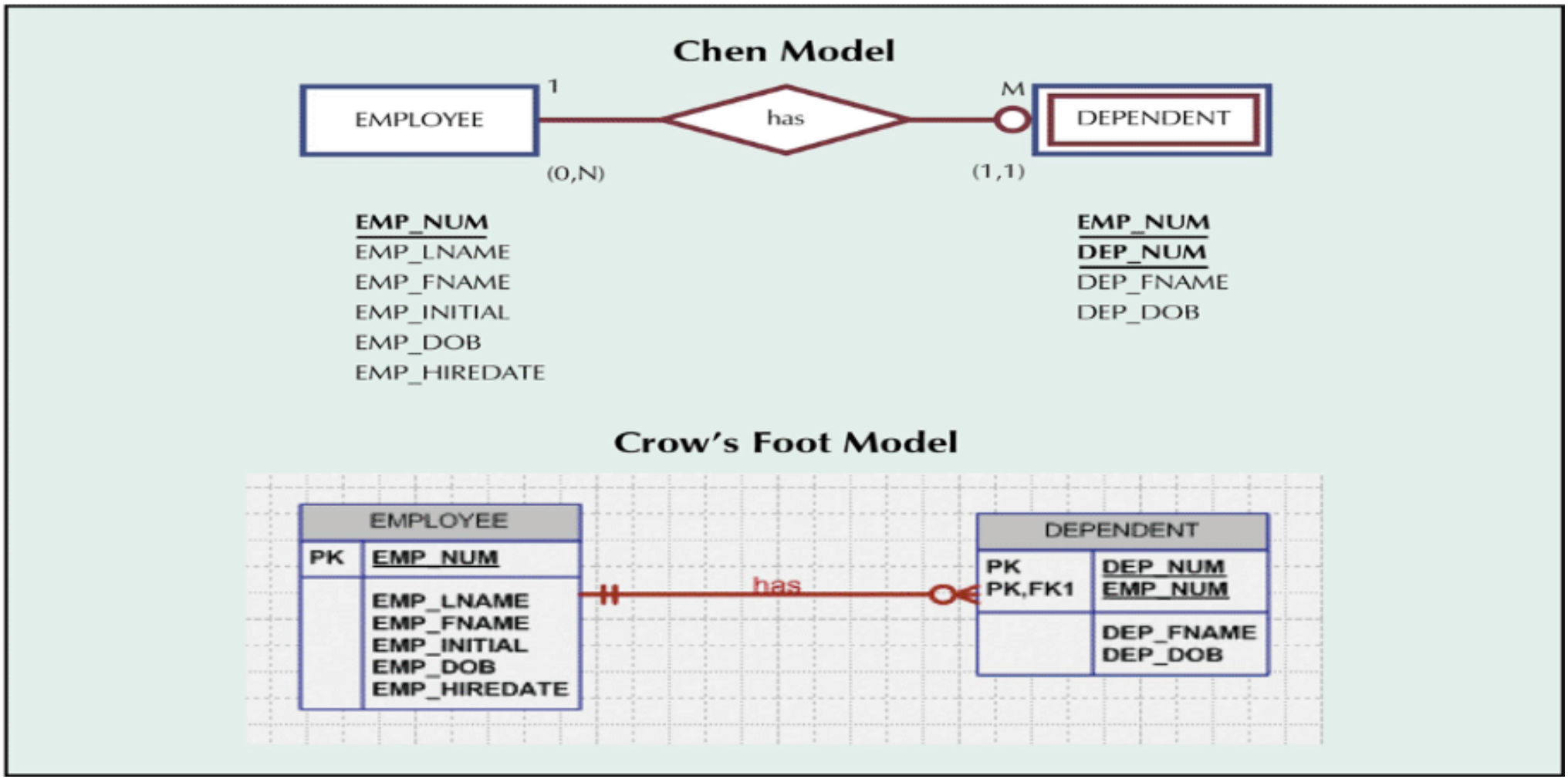


Relationship Strength and Weak Entities

- Weak entity meets two conditions
  - Existence-dependent:
    - Cannot exist without entity with which it has a relationship
  - Has primary key that is partially or totally derived from the parent entity in the relationship
- Database designer usually determines whether an entity can be described as weak based on the business rules

A Weak Entity in an ERD

FIGURE 4.14 A WEAK ENTITY IN AN ERD



A Weak Entity in a Strong Relationship

FIGURE 4.15 A WEAK ENTITY IN A STRONG RELATIONSHIP

Table name: EMPLOYEE **Database name: Ch04_ShortCo**

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_DOB	EMP_HIREDATE
1001	Callifante	Jeanine	J	12-Mar-64	25-May-97
1002	Smithson	William	K	23-Nov-70	28-May-97
1003	Washington	Herman	H	15-Aug-68	28-May-97
1004	Chen	Lydia	B	23-Mar-74	15-Oct-98
1005	Johnson	Melanie		28-Sep-66	20-Dec-98
1006	Ortega	Jorge	G	12-Jul-79	05-Jan-02
1007	O'Donnell	Peter	D	10-Jun-71	23-Jun-02
1008	Brzenski	Barbara	A	12-Feb-70	01-Nov-03

Table name: DEPENDENT

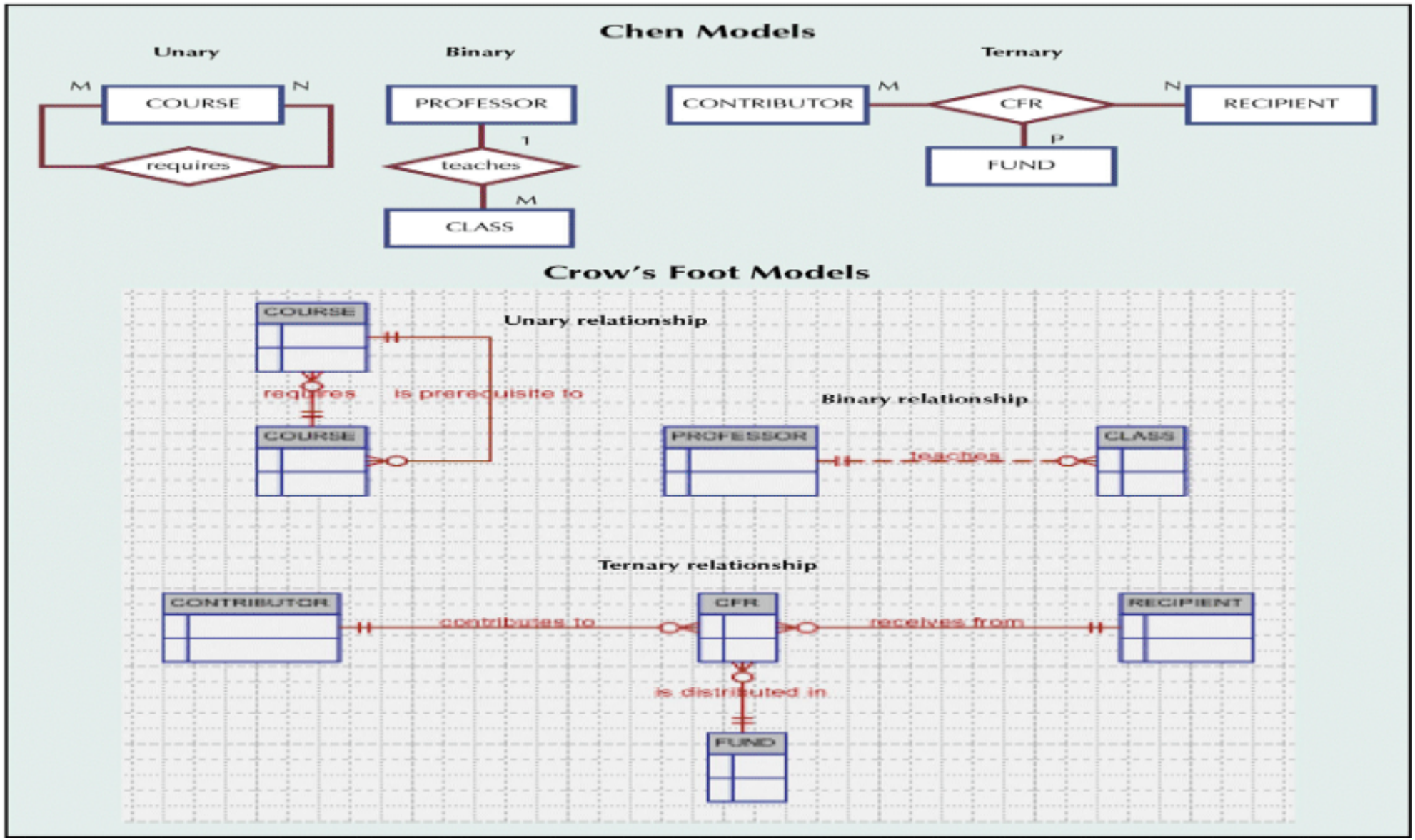
EMP_NUM	DEP_NUM	DEP_FNAME	DEP_DOB
1001	1	Annelise	05-Dec-97
1001	2	Jorge	30-Sep-02
1003	1	Suzanne	25-Jan-04
1006	1	Carlos	25-May-01
1008	1	Michael	19-Feb-95
1008	2	George	27-Jun-98
1008	3	Katherine	18-Aug-03

Relationship Degree

- Indicates number of associated entities or participants
- Unary relationship
  - Association is maintained within a single entity
- Binary relationship
  - Two entities are associated
- Ternary relationship
  - Three entities are associated

Three Types of Relationships

FIGURE 4.16 THREE TYPES OF RELATIONSHIPS



The Implementation of a Ternary Relationship

FIGURE 4.17 THE IMPLEMENTATION OF A TERNARY RELATIONSHIP

Database name: Ch04_MedCo

Table name: CONTRIBUTOR

CONTRIB_ID	CONTRIB_LNAME
C1	Brown
C2	Iglesas
C3	Smith

Table name: FUND

FUND_ID	FUND_NAME	CONTRIB_ID	FUND_AMOUNT
F1	Heart	C1	$50,000.00
F1	Heart	C2	$10,000.00
F2	Cancer	C1	$10,000.00
F2	Cancer	C2	$5,000.00
F2	Cancer	C3	$10,000.00

Table name: RECIPIENT

REC_ID	REC_TYPE
R1	Rogers
R2	Chen
R3	Oshanski

Table name: CFR

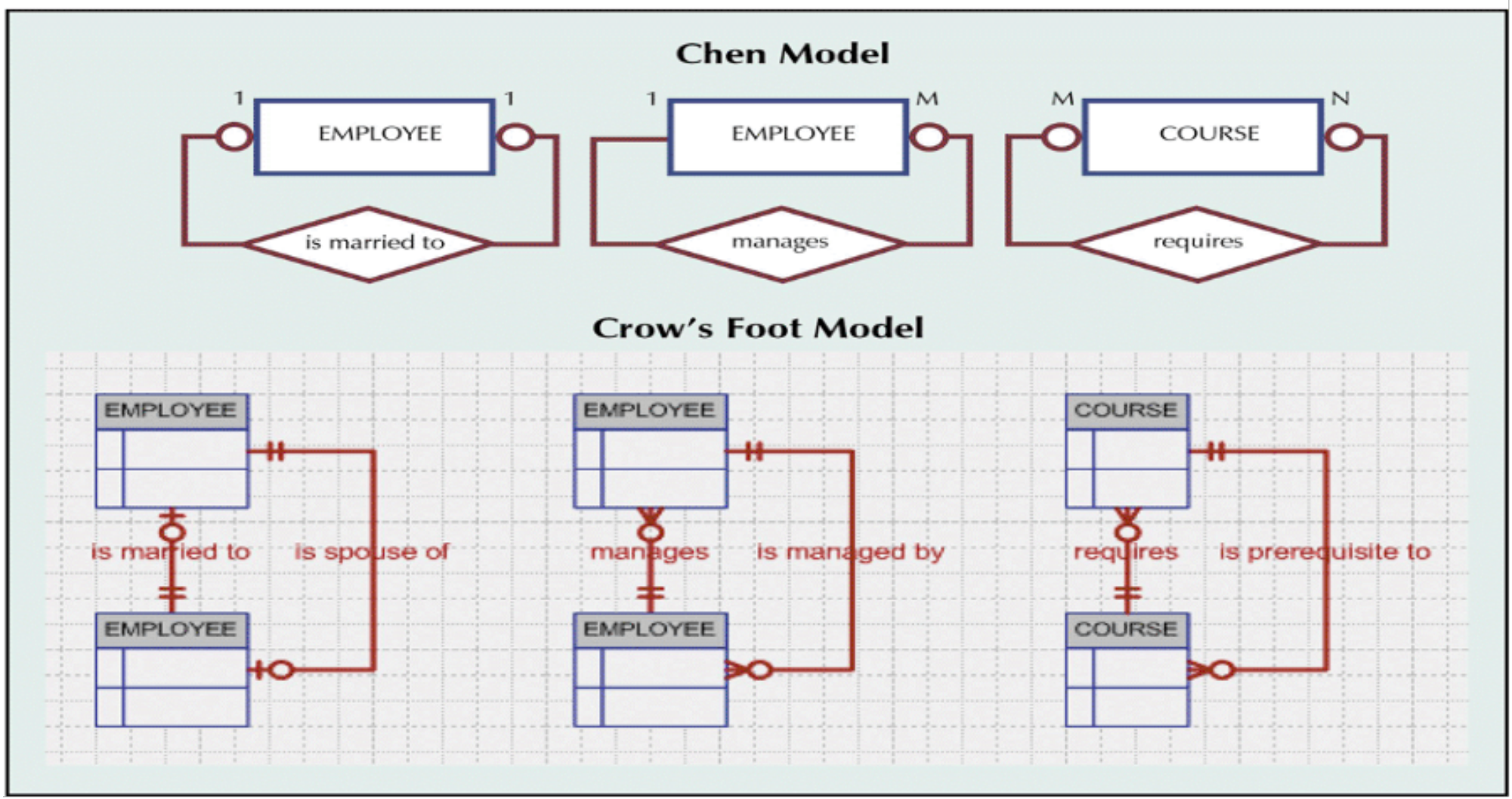
FUND_ID	CON_ID	REC_ID	CFR_AMOUNT
F1	C1	R2	$30,000.00
F1	C1	R3	$20,000.00
F1	C2	R2	$10,000.00
F2	C1	R1	$10,000.00
F2	C2	R1	$5,000.00

Recursive Relationships

- Relationship can exist between occurrences of the same entity set
- Naturally found within a unary relationship

An ER Representation of Recursive Relationships

FIGURE 4.18 AN ER REPRESENTATION OF RECURSIVE RELATIONSHIPS



The 1:1 Recursive Relationship "EMPLOYEE is Married to EMPLOYEE"

FIGURE 4.19 THE 1:1 RECURSIVE RELATIONSHIP "EMPLOYEE IS MARRIED TO EMPLOYEE"

Table name: EMPLOYEE_V1 Database name: Ch04_PartCo

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_SPOUSE
345	Ramirez	James	347
346	Jones	Anne	349
347	Ramirez	Louise	345
348	Delaney	Robert	
349	Shapiro	Anton	346

Implementation of the M:N Recursive "PART Contains PART" Relationship

FIGURE 4.21 IMPLEMENTATION OF THE M:N RECURSIVE "PART CONTAINS PART" RELATIONSHIP

Table name: COMPONENT **Database name: Ch04_PartCo**

COMP_CODE	PART_CODE	COMP_PARTS_NEEDED
C-130	AA21-6	4
C-130	AB-121	2
C-130	E129	1
C-131A2	E129	1
C-130	X10	4
C-131A2	X10	1
C-130	X34AW	2
C-131A2	X34AW	2

Table name: PART

PART_CODE	PART_DESCRIPTION	PART_IN_STOCK
AA21-6	2.5 cm. washer, 1.0 mm. rim	432
AB-121	Cotter pin, copper	1,034
C-130	Rotor assembly	36
E129	2.5 cm. steel shank	128
X10	10.25 cm. rotor blade	345
X34AW	2.5 cm. hex nut	879

Implementation of the 1:M "EMPLOYEE Manages EMPLOYEE" Recursive Relationship

FIGURE 4.23 IMPLEMENTATION OF THE 1:M "EMPLOYEE MANAGES EMPLOYEE" RECURSIVE RELATIONSHIP

Table name: EMPLOYEE_V2 Database name: Ch04_PartCo

EMP_CODE	EMP_LNAME	EMP_MANAGER
101	Waddell	102
102	Orincona	
103	Jones	102
104	Reballoh	102
105	Robertson	102
106	Deltona	102

Composite Entities

- Also known as *bridge entities*
- Composed of the primary keys of each of the entities to be connected
- May also contain additional attributes that play no role in the connective process

Converting the M:N Relationship into Two 1:M Relationships

FIGURE 4.24 CONVERTING THE M:N RELATIONSHIP INTO TWO 1:M RELATIONSHIPS

Table name: STUDENT

Database name: Ch04_CollegeTry

STU_NUM	STU_LNAME
321452	Bowser
324257	Smithson

Table name: ENROLL

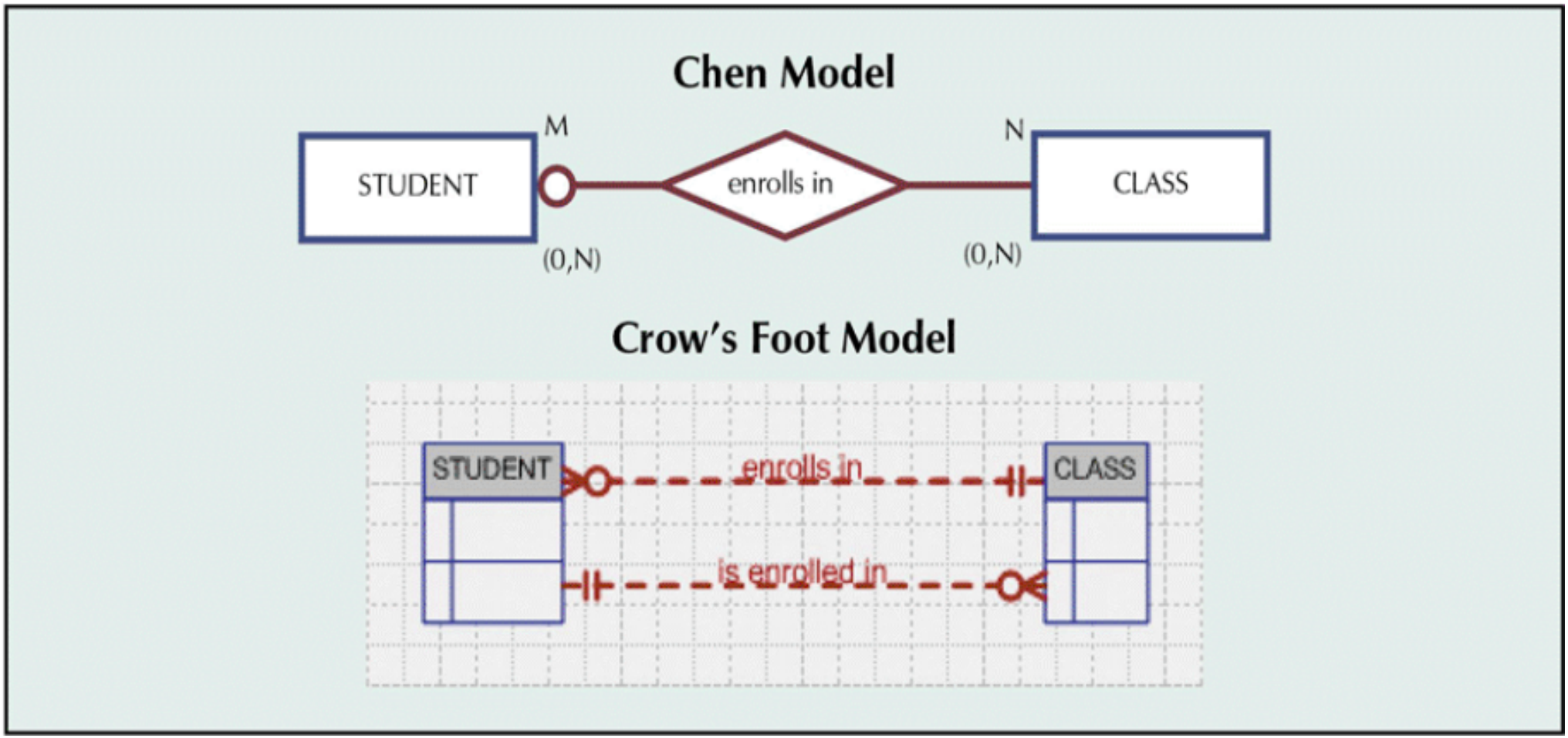
CLASS_CODE	STU_NUM	ENROLL_GRADE
10014	321452	C
10014	324257	B
10018	321452	A
10018	324257	B
10021	321452	C
10021	324257	C

Table name: CLASS

CLASS_CODE	CRS_CODE	CLASS_SECTION	CLASS_TIME	CLASS_ROOM	PROF_NUM
10014	ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
10018	CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
10021	QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114

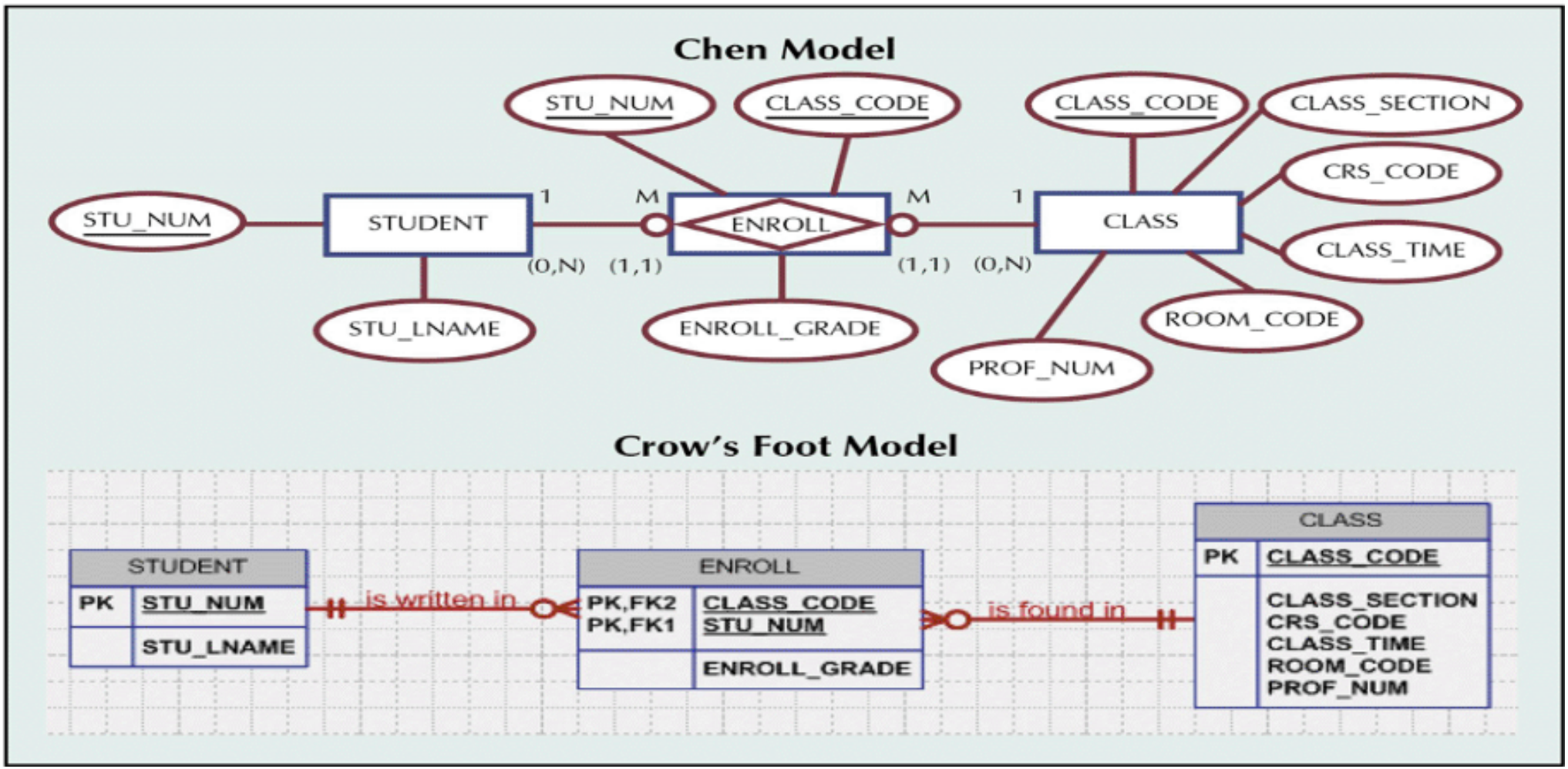
The M:N Relationship Between STUDENT and CLASS

FIGURE 4.25 THE M:N RELATIONSHIP BETWEEN STUDENT AND CLASS



A Composite Entity in an ERD

FIGURE 4.26 A COMPOSITE ENTITY IN AN ERD



Entity Supertypes and Subtypes

- Generalization hierarchy
  - Depicts a relationship between a higher-level supertype entity and a lower-level subtype entity
- Supertype entity
  - Contains shared attributes
- Subtype entity
  - Contains unique attributes

Nulls Created by Unique Attributes

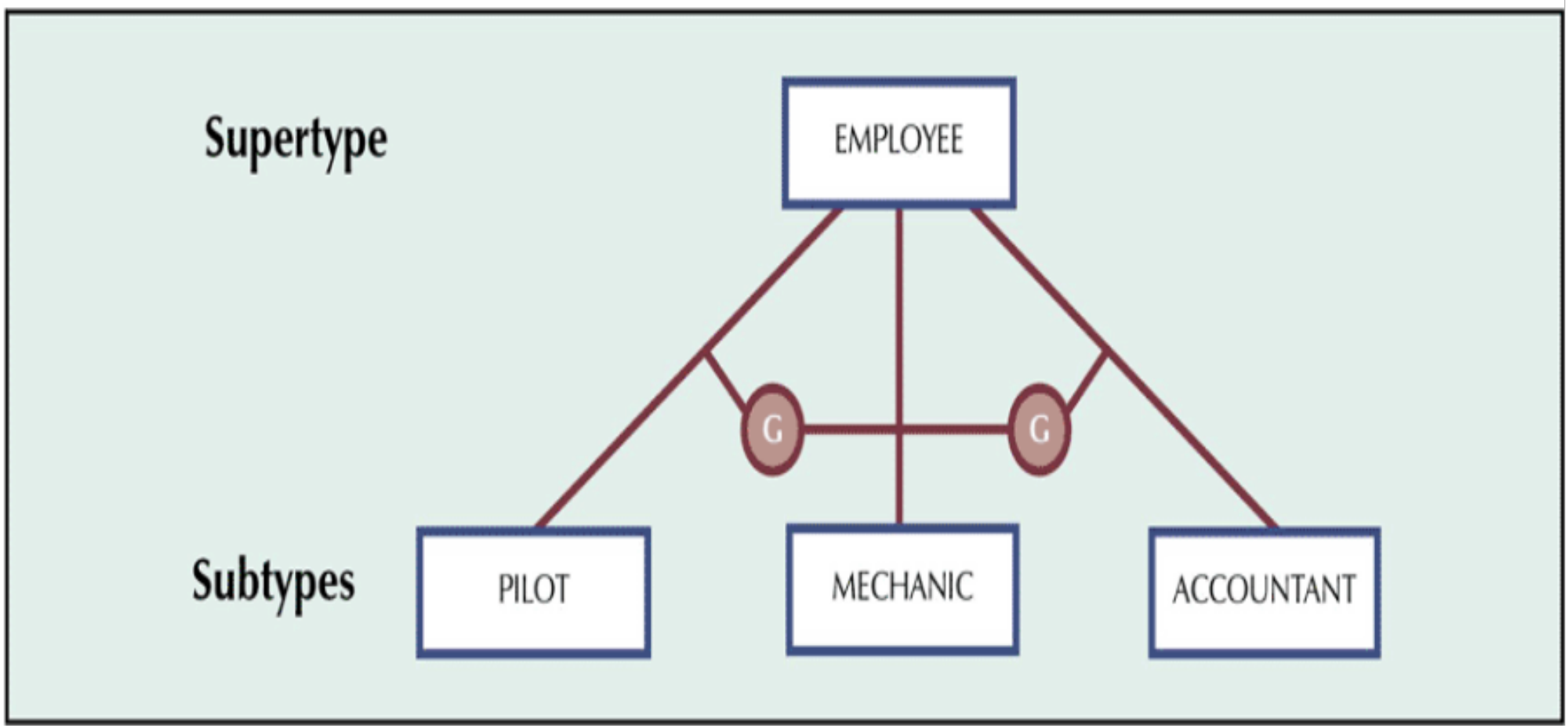
FIGURE 4.27 NULLS CREATED BY UNIQUE ATTRIBUTES

Table name: EMPLOYEE_V1 Database name: Ch04_AirCo

EMP_NUM	EMP_LNAME	EMP_LICENSE	EMP_RATINGS	EMP_MED_TYPE	EMP_HIRE_DATE
100	Kolmycz				15-Mar-88
101	Lewis	ATP	SEL/MEL/Instr/CFII	1	25-Apr-89
102	Vandam				20-Dec-93
103	Jones				28-Aug-03
104	Lange	ATP	SEL/MEL/Instr	1	20-Oct-97
105	Williams	COM	SEL/MEL/Instr/CFI	2	08-Nov-97
106	Duzak	COM	SEL/MEL/Instr	2	05-Jan-04
107	Diante				02-Jul-97
108	Wiesenbach				18-Nov-95
109	Travis	COM	SEL/MEL/SES/Instr/CFII	1	14-Apr-01
110	Genkazi				01-Dec-03

A Generalization Hierarchy

FIGURE 4.28 A GENERALIZATION HIERARCHY



Disjoint Subtypes

- Also known as non-overlapping subtypes
  - Subtypes that contain a subset of the supertype entity set
  - Each entity instance (row) of the supertype can appear in only one of the disjoint subtypes
- Supertype and its subtype(s) maintain a 1:1 relationship

The EMPLOYEE/PILOT Supertype/Subtype Relationship

FIGURE 4.29 THE EMPLOYEE/PILOT SUPERTYPE/SUBTYPE RELATIONSHIP

Table name: EMPLOYEE (the supertype) **Database name: Ch04_AirCo**

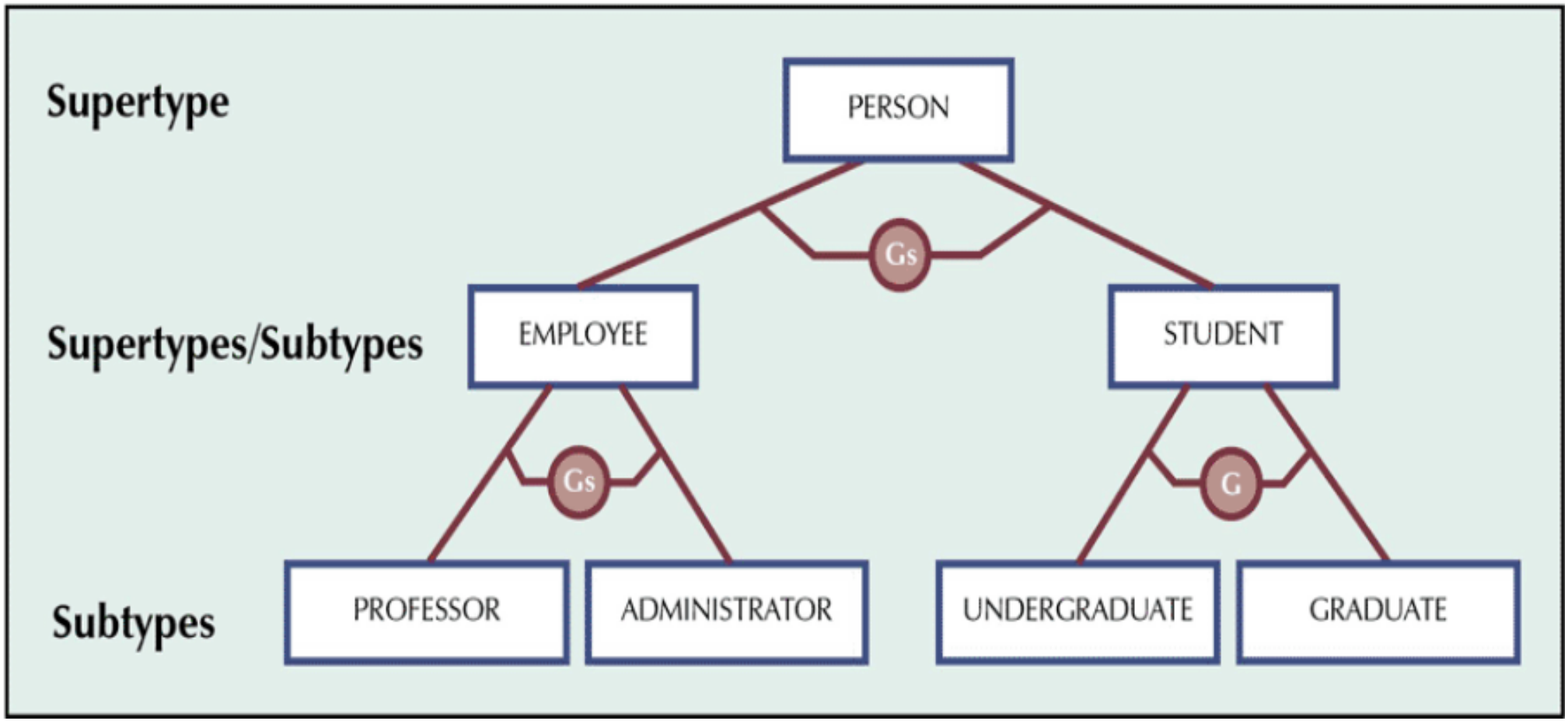
EMP_NUM	EMP_LNAME	EMP_HIRE_DATE
100	Kolmycz	15-Mar-88
101	Lewis	25-Apr-89
102	Vandam	20-Dec-93
103	Jones	28-Aug-03
104	Lange	20-Oct-97
105	Williams	08-Nov-97
106	Duzak	05-Jan-04
107	Diante	02-Jul-97
108	Wiesenbach	18-Nov-95
109	Travis	14-Apr-01
110	Genkazi	01-Dec-03

Table name: PILOT (the subtype)

EMP_NUM	PIL_LICENSE	PIL_RATINGS	PIL_MED_TYPE
101	ATP	SEL/MEL/Instr/CFII	1
104	ATP	SEL/MEL/Instr	1
105	COM	SEL/MEL/Instr/CFI	2
106	COM	SEL/MEL/Instr	2
109	COM	SEL/MEL/SES/Instr/CFII	1

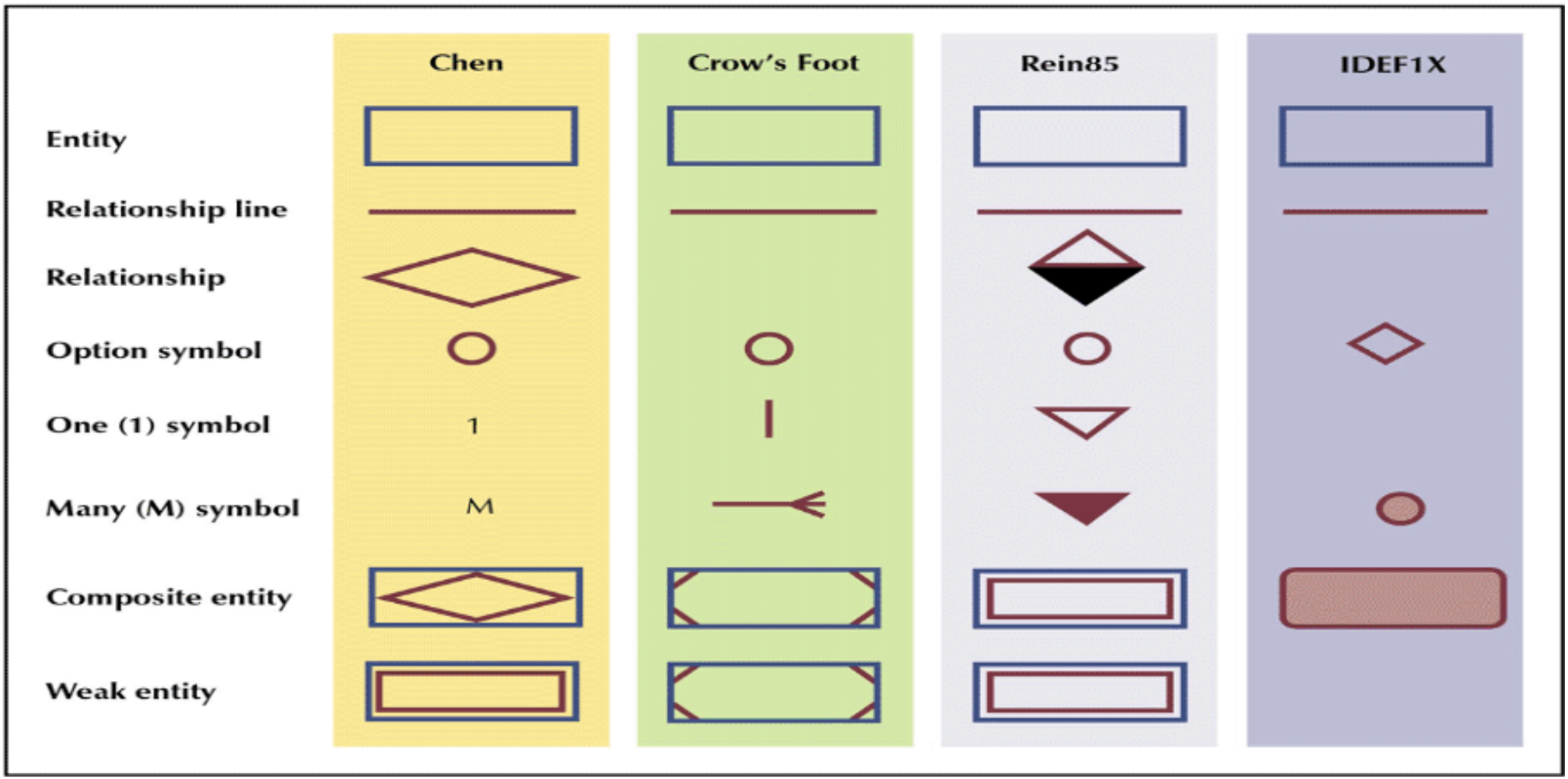
A Generalization Hierarchy with Overlapping Subtypes

FIGURE 4.30 A GENERALIZATION HIERARCHY WITH OVERLAPPING SUBTYPES



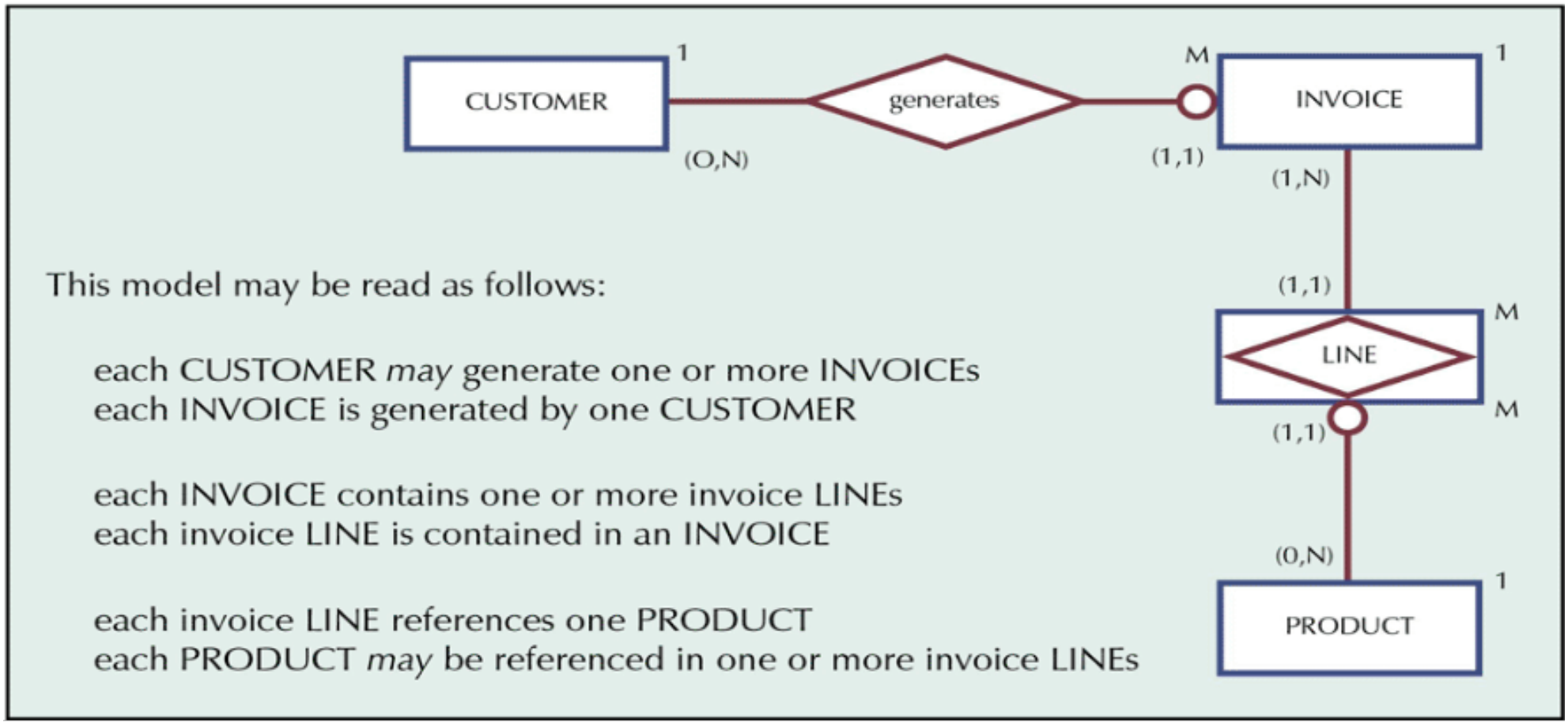
A Comparison of ER Modeling Symbols

FIGURE 4.31 A COMPARISON OF ER MODELING SYMBOLS



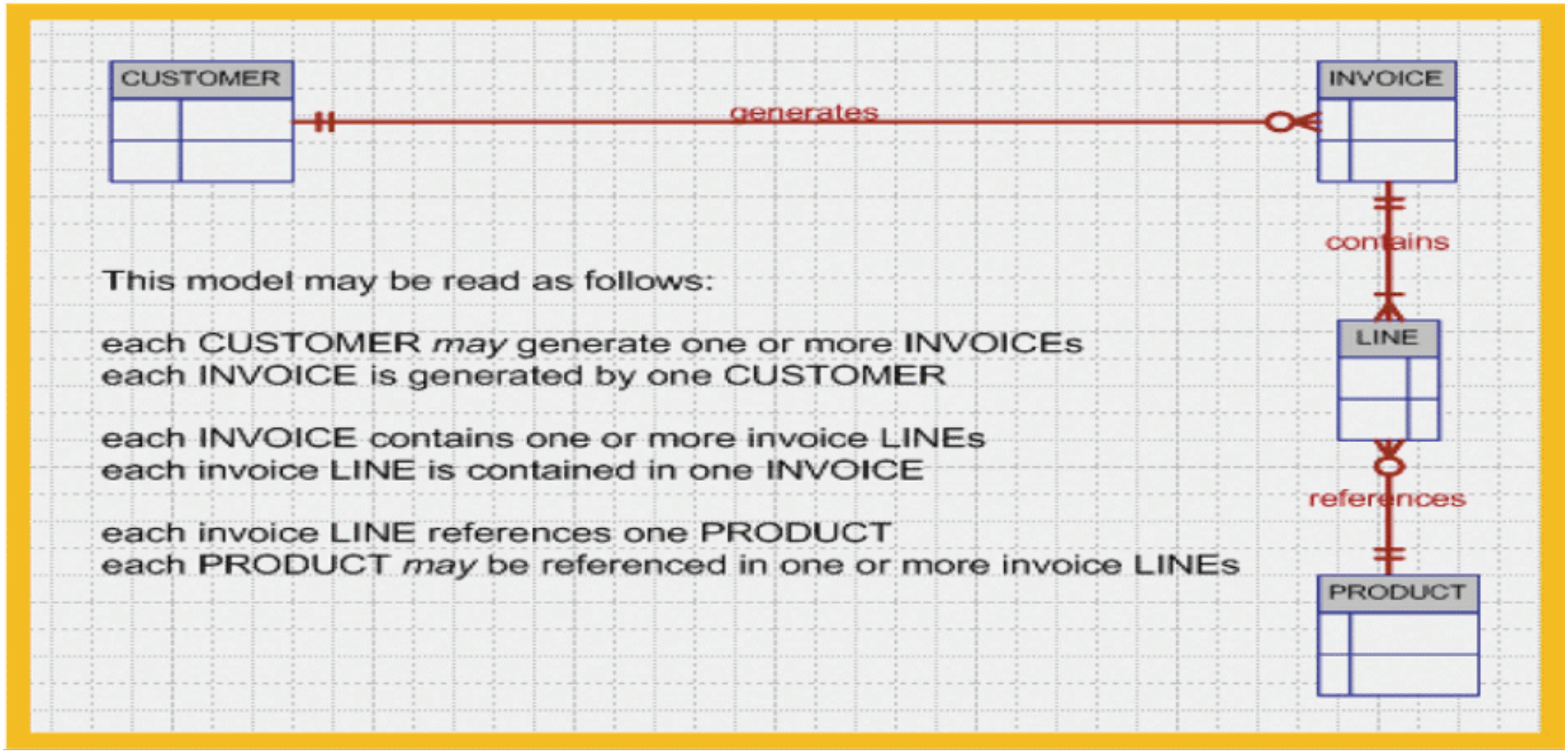
The Chen Representation of the Invoicing Problem

FIGURE 4.32 THE CHEN REPRESENTATION OF THE INVOICING PROBLEM



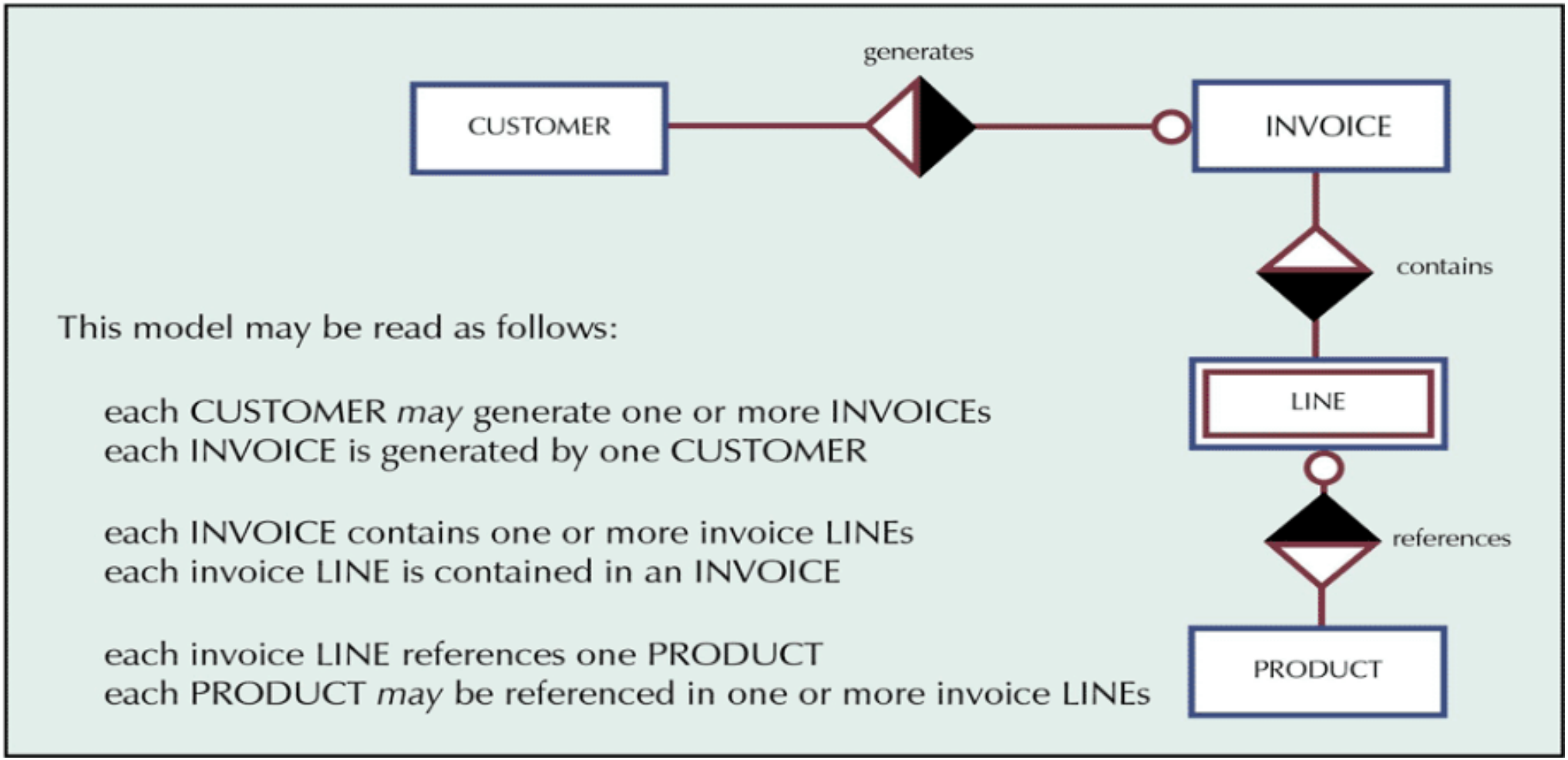
The Crow's Foot Representation of the Invoicing Problem

FIGURE 4.33 THE CROW'S FOOT REPRESENTATION OF THE INVOICING PROBLEM



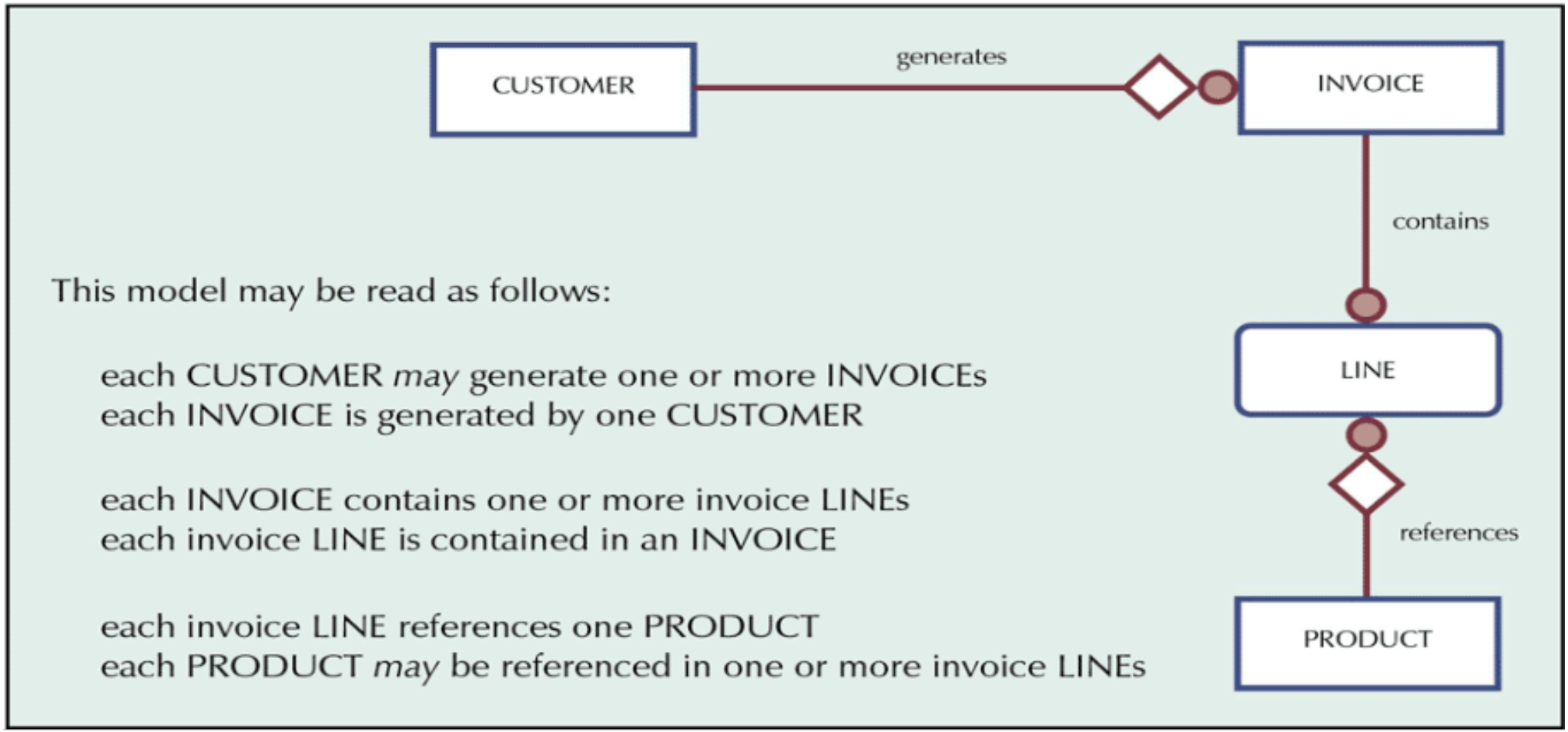
The Rein85 Representation of the Invoicing Problem

FIGURE 4.34 THE REIN85 REPRESENTATION OF THE INVOICING PROBLEM



The IDEF1X Representation of the Invoicing Problem

FIGURE 4.35 THE IDEF1X REPRESENTATION OF THE INVOICING PROBLEM

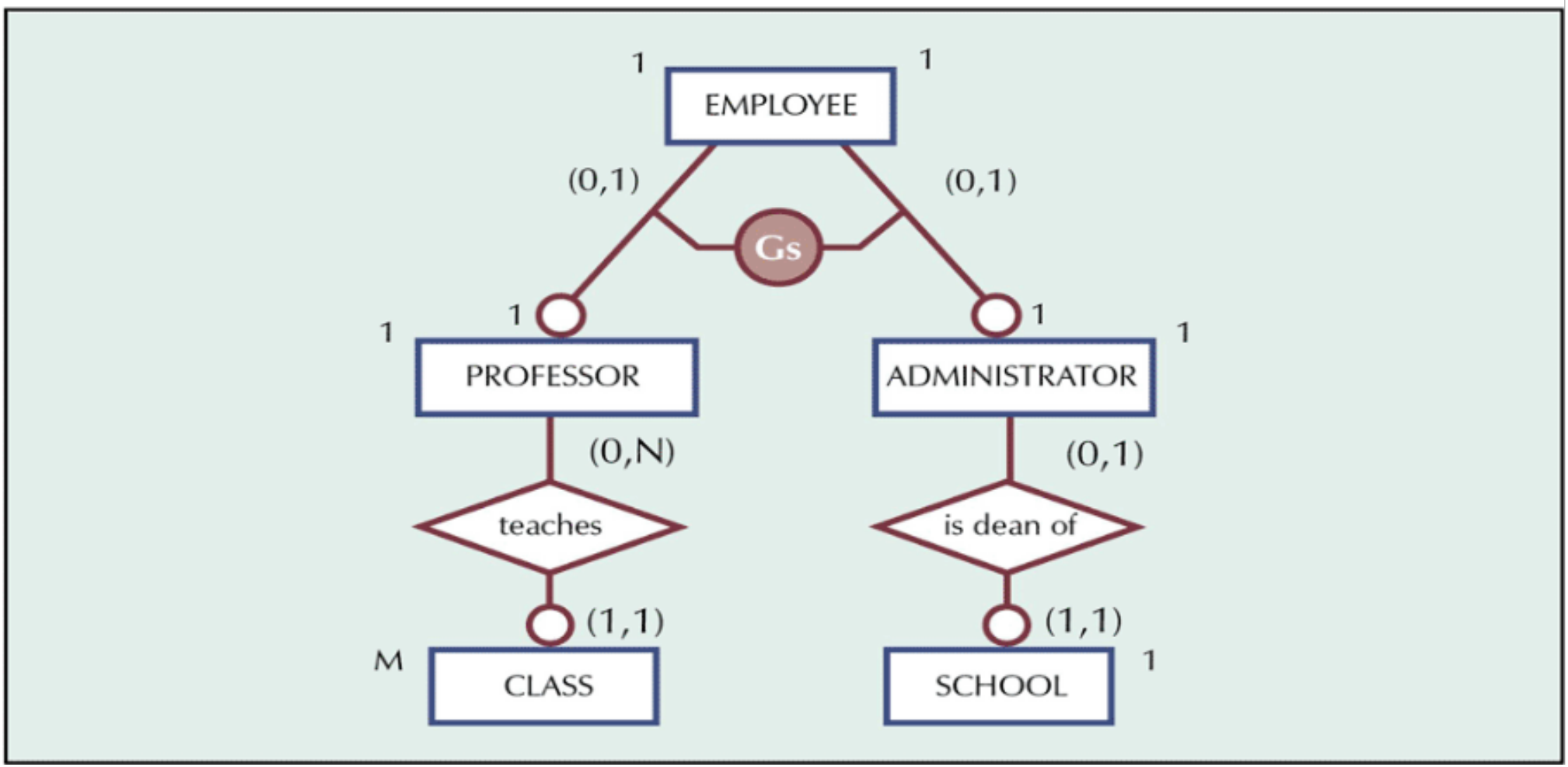


Developing an ER Diagram

- Database design is an iterative rather than a linear or sequential process
- Iterative process
  - Based on repetition of processes and procedures

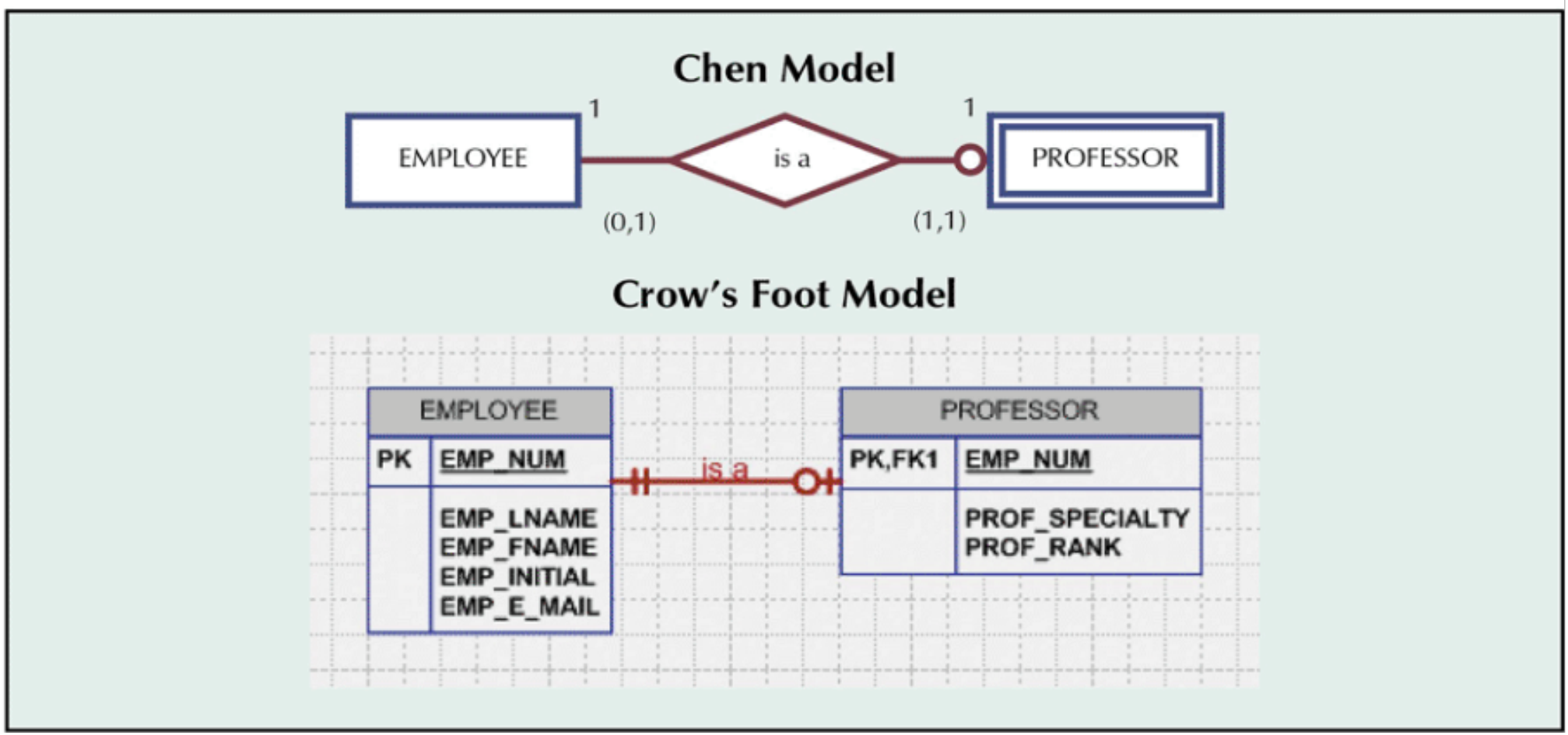
A Supertype/Subtype Relationship

FIGURE 4.36 A SUPERTYPE/SUBTYPE RELATIONSHIP



A Supertype/Subtype Relationship in an ERD

FIGURE 4.37 A SUPERTYPE/SUBTYPE RELATIONSHIP IN AN ERD



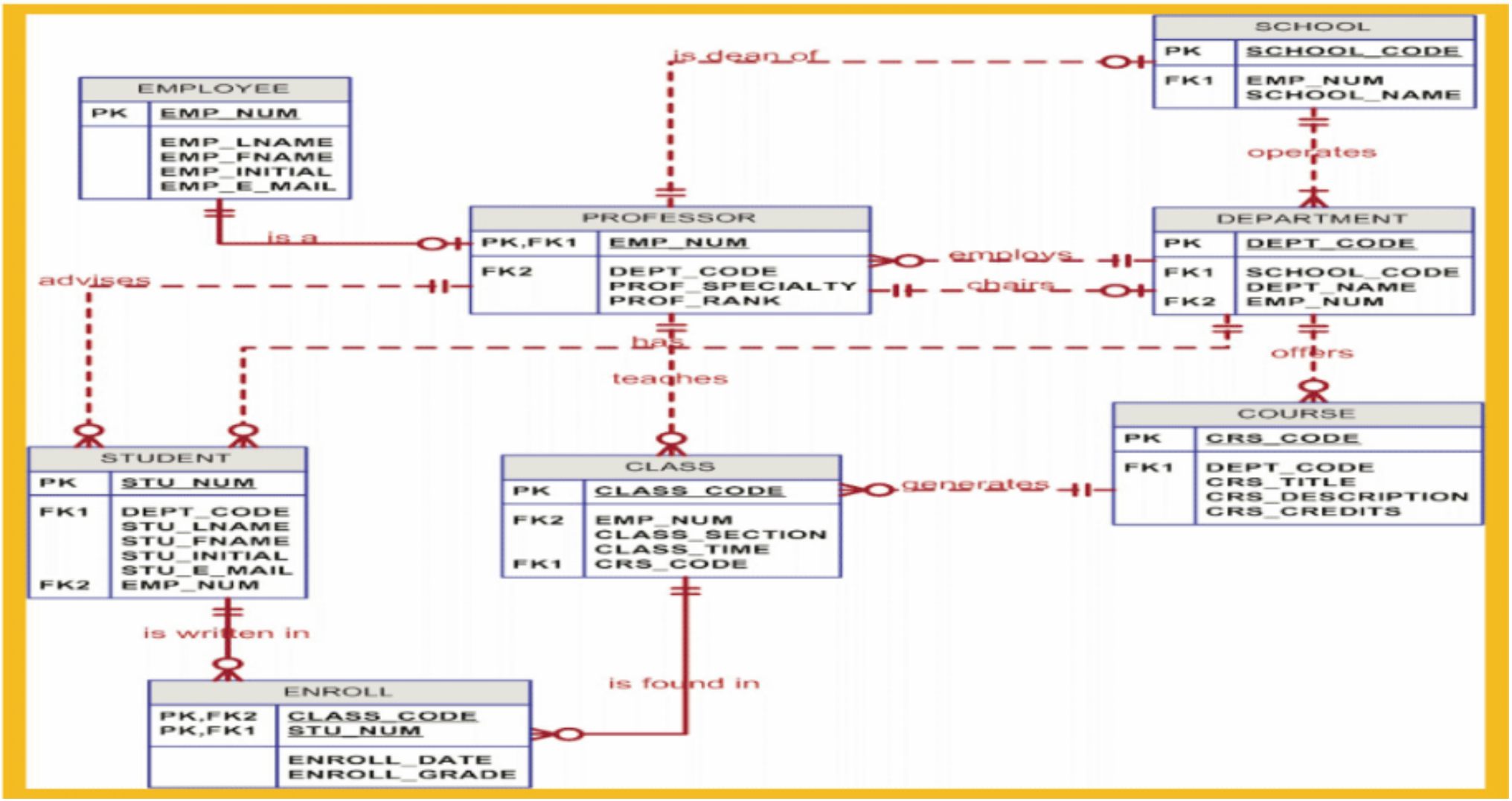
Components of the ER Model

TABLE 4.2 COMPONENTS OF THE ER MODEL

ENTITY	RELATIONSHIP	CONNECTIVITY	ENTITY
SCHOOL	operates	1:M	DEPARTMENT
DEPARTMENT	has	1:M	STUDENT
DEPARTMENT	employs	1:M	PROFESSOR
DEPARTMENT	offers	1:M	COURSE
COURSE	generates	1:M	CLASS
PROFESSOR	is an	1:1	EMPLOYEE
PROFESSOR	is dean of	1:1	SCHOOL
PROFESSOR	chairs	1:1	DEPARTMENT
PROFESSOR	teaches	1:M	CLASS
PROFESSOR	advises	1:M	STUDENT
STUDENT	enrolls in	1:M	CLASS
BUILDING	contains	1:M	ROOM
ROOM	is used for	1:M	CLASS

The Completed Tiny College ERD

FIGURE 4.47 THE COMPLETED TINY COLLEGE ERD



The Challenge of Database Design: Conflicting Goals

- Database design must conform to design standards
- High processing speeds are often a top priority in database design
- Quest for timely information might be the focus of database design

Various Implementations of a 1:1 Recursive Relationship

FIGURE 4.48 VARIOUS IMPLEMENTATIONS OF A 1:1 RECURSIVE RELATIONSHIP

Table name: EMPLOYEE_V1

Database name: Ch04_PartCo

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_SPOUSE
345	Ramirez	James	347
346	Jones	Anne	349
347	Ramirez	Louise	345
348	Delaney	Robert	
349	Shapiro	Anton	346

First implementation

Table name: EMPLOYEE

EMP_NUM	EMP_LNAME	EMP_FNAME
345	Ramirez	James
346	Jones	Anne
347	Ramirez	Louise
348	Delaney	Robert
349	Shapiro	Anton

Table name: MARRIED_V1

EMP_NUM	EMP_SPOUSE
345	347
346	349
347	345
349	346

Second implementation

Table name: MARRIAGE

MAR_NUM	MAR_DATE
1	04-Mar-03
2	02-Feb-99

Table name: MARPART

MAR_NUM	EMP_NUM
1	345
1	347
2	346
2	349

Table name: EMPLOYEE

EMP_NUM	EMP_LNAME	EMP_FNAME
345	Ramirez	James
346	Jones	Anne
347	Ramirez	Louise
348	Delaney	Robert
349	Shapiro	Anton

The Relational Schema for the Third Implementation

Third implementation

Summary

- Entity relationship (ER) model
  - Uses ER diagrams to represent conceptual database as viewed by the end user
  - Three main components
    - Entities
    - Relationships
    - Attributes
  - Includes connectivity and cardinality notations
- Connectivities and cardinalities are based on business rules

Summary (continued)

- ER symbols are used to graphically depict the ER model's components and relationships
- ERDs may be based on many different ER models
- Entities can also be classified as supertypes and subtypes within a generalization hierarchy
- Database designers are often forced to make design compromises