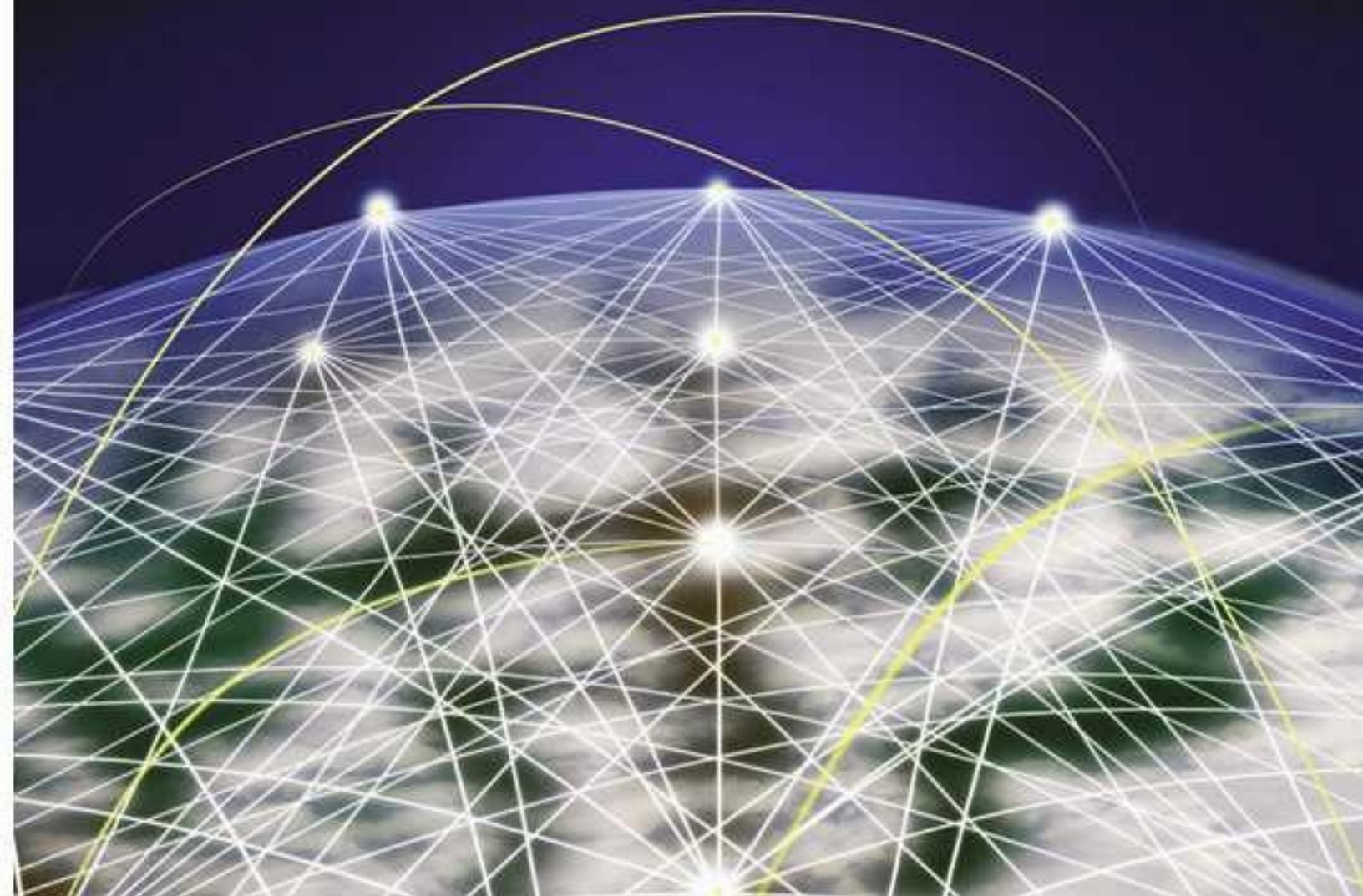


Coronel / Morris / Rob

Database Systems

Design, Implementation,
and Management 10e



DATABASE SYSTEMS

DESIGN, IMPLEMENTATION, AND MANAGEMENT



CARLOS CORONEL • STEVEN MORRIS • PETER ROB



Australia • Brazil • Japan • Korea • Mexico • Singapore • Spain • United Kingdom • United States



Database Systems: Design, Implementation, and Management, Tenth Edition

Carlos Coronel, Steven Morris, and Peter Rob

Publisher: Joe Sabatino

Senior Acquisitions Editor: Charles McCormick, Jr.

Senior Product Manager: Kate Mason

Development Editor: Dan Seiter

Editorial Assistant: Courtney Bavaro

Marketing Director: Keri Witman

Marketing Manager: Adam Marsh

Senior Marketing Communications Manager: Libby Shipp Marketing Coordinator: Suellen Ruttkay

Content Project Manager: Jennifer Feltri-George Media Editor: Chris Valentine

Senior Art Director: Stacy Jenkins Shirley Cover Designer: LouAnn Thesing

Cover Credit: iStockPhoto

Manufacturing Coordinator: Julio Esperas

Compositor: GEX Publishing Services

©2013 Course Technology, Cengage Learning

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced, transmitted, stored or used in any form or by any means—graphic, electronic, or mechanical, including but not limited to photocopying, recording, scanning, digitizing, taping, Web distribution, information networks, or information storage and retrieval systems, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act—with the prior written permission of the publisher.

For product information and technology assistance, contact us at **Cengage Learning Customer & Sales Support, 1-800-354-9706.**

For permission to use material from this text or product, submit all requests online at www.cengage.com/permissions. Further permissions questions can be e-mailed to permissionrequest@cengage.com.

Some of the product names and company names used in this book have been used for identification purposes only and may be trademarks or registered trademarks of their respective manufacturers and sellers.

Library of Congress Control Number: 2011938493

ISBN-13: 978-1-111-96960-8

ISBN-10: 1-111-96960-4

Instructor Edition:

ISBN-13: 978-1-133-52679-7

ISBN-10: 1-133-52679-9

Cengage Learning

20 Channel Center Street

Boston, MA 02210

USA

Screenshots for this book were created using Microsoft Access® and Visio®, and were used with permission from Microsoft.

Microsoft and the Office logo are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries. Course Technology, a part of Cengage Learning, is an independent entity from the Microsoft Corporation, and not affiliated with Microsoft in any manner.

Oracle is a registered trademark, and Oracle11g and MySQL are trademarks of Oracle Corporation.

iPhone, iPad, and iPod are registered trademarks of Apple Inc.

Course Technology, a part of Cengage Learning, reserves the right to revise this publication and make changes from time to time in its content without notice.

Cengage Learning is a leading provider of customized learning solutions with office locations around the globe, including Singapore, the United Kingdom, Australia, Mexico, Brazil, and Japan. Locate your local office at: international.cengage.com/region

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

To learn more about Course Technology, visit www.cengage.com/coursetechnology.

Purchase any of our products at your local college store or at our preferred online store:

www.cengagebrain.com

Printed in the United States of America

1 2 3 4 5 6 7 17 16 15 14 13 12 11

Kindle textbooks are functionally equivalent to the print textbook. In some cases, individual items such as ancillary images or multimedia have been removed for digital delivery due to rights restrictions.

Dedication

To the treasures in my life: To Victoria, for 21 wonderful years. Thank you for your unending support, for being my angel, my sweetie, and most importantly, my best friend. To Carlos Anthony for the many good times you have given us; you show us the way. Thank you for your words of wisdom, contagious happiness, and for bringing us shining days. You are still young; your best times are still to come. To Gabriela Victoria, who is the image of brilliance, beauty, and faithfulness. Thank you for being the sunshine in my cloudy days. To Christian Javier, whose endless energy and delightful smiles keep us going every day. Thank you for being the youthful reminder of life's simple beauties. To my parents, Sarah and Carlos, thank you for your sacrifice and example. To all of you, you are all my inspiration. "TQTATA."

Carlos Coronel

To Pamela, from high school sweetheart through 22 years of marriage, the beautiful love of my life who has supported, encouraged, and inspired me. More than anyone else, you are responsible for whatever successes I have achieved. To my son, Alexander Logan, whose depth of character is without measure. You are my pride and joy. To my daughter, Lauren Elizabeth, whose beauty and intensity take my breath away. You are my heart and soul. Thank you all for the sacrifices you have made that enabled me to pursue this dream. I love you so much more than I can express. To my mother, Florence Maryann, and to the memory of my father, Alton Lamar, who together instilled in me the desire to learn and the passion to achieve. To my mother-in-law, Connie Duke, and to the memory of my father-in-law, Wayne Duke, who taught me to find joy in all things. To all of you, with all my love, I dedicate this book.

Steven Morris

To Anne, who remains my best friend after 50 years of marriage. To our son, Peter William, who turned out to be the man we hoped he would be and who proved his wisdom by making Sheena our treasured daughter-in-law. To Sheena, who stole our hearts so many years ago. To our grandsons, Adam Lee and Alan Henri, who are growing up to be the fine human beings their parents are. To the memory of my mother-in-law, Nini Fontein, and to the memory of my father-in-law, Henri Fontein—their life experiences in Europe and Southeast Asia would fill a history book, and they enriched my life by entrusting me with their

daughter's future. To the memory of my parents, Hendrik and Hermine Rob, who rebuilt their lives after World War II's horrors, who did it again after a failed insurgency in Indonesia, and who finally found their promised land in these United States. To the memory of Heinz, who taught me daily lessons about loyalty, uncritical acceptance, and boundless understanding. And to the memory of Sissy Mae, who defined the meaning of perfection. I dedicate this book to you, with love.

Peter Rob

BRIEF CONTENTS

PART I: DATABASE CONCEPTS

[Chapter 1: Database Systems](#)
[Chapter 2: Data Models](#)

PART II: DESIGN CONCEPTS

[Chapter 3: The Relational Database Model](#)
[Chapter 4: Entity Relationship \(ER\) Modeling](#)
[Chapter 5: Advanced Data Modeling](#)
[Chapter 6: Normalization of Database Tables](#)

PART III: ADVANCED DESIGN AND IMPLEMENTATION

[Chapter 7: Introduction to Structured Query Language \(SQL\)](#)
[Chapter 8: Advanced SQL](#)
[Chapter 9: Database Design](#)

PART IV: ADVANCED DATABASE CONCEPTS

[Chapter 10: Transaction Management and Concurrency Control](#)
[Chapter 11: Database Performance Tuning and Query Optimization](#)
[Chapter 12: Distributed Database Management Systems](#)
[Chapter 13: Business Intelligence and Data Warehouses](#)

PART V: DATABASES AND THE INTERNET

[Chapter 14: Database Connectivity and Web Technologies](#)

PART VI: DATABASE ADMINISTRATION

[Chapter 15: Database Administration and Security](#)

GLOSSARY

INDEX

The following appendixes are included on the Essentials Site or at the CourseMate site for this text, www.cengagebrain.com.

APPENDIX A: DESIGNING DATABASES WITH VISIO PROFESSIONAL: A TUTORIAL

APPENDIX B: THE UNIVERSITY LAB: CONCEPTUAL DESIGN

APPENDIX C: THE UNIVERSITY LAB: CONCEPTUAL DESIGN VERIFICATION,
LOGICAL DESIGN, AND IMPLEMENTATION

APPENDIX D: CONVERTING AN ER MODEL INTO A DATABASE STRUCTURE

APPENDIX E: COMPARISON OF ER MODEL NOTATIONS

APPENDIX F: CLIENT/SERVER SYSTEMS

APPENDIX G: OBJECT-ORIENTED DATABASES

APPENDIX H: UNIFIED MODELING LANGUAGE (UML)

APPENDIX I: DATABASES IN ELECTRONIC COMMERCE

APPENDIX J: WEB DATABASE DEVELOPMENT WITH COLDFUSION

APPENDIX K: THE HIERARCHICAL DATABASE MODEL

APPENDIX L: THE NETWORK DATABASE MODEL

APPENDIX M: MICROSOFT® ACCESS® TUTORIAL

APPENDIX N: CREATING A NEW DATABASE USING ORACLE 11G

APPENDIX O: DATA WAREHOUSE IMPLEMENTATION FACTORS

The Essentials Site and CourseMate Site for this text are available at www.cengagebrain.com. Locate your access cards in the front of each new book purchase, and click Create My Account to begin the registration process. If you purchased a used book, search for *Database Systems, Tenth Edition* at www.cengagebrain.com, where you can purchase instant access.

TABLE OF CONTENTS

PART I DATABASE CONCEPTS

Business Vignette

CHAPTER 1 DATABASE SYSTEMS

1.1 Why Databases?

1.2 Data vs. Information

1.3 Introducing the Database

1.3.1 Role and Advantages of the DBMS

1.3.2 Types of Databases

1.4 Why Database Design is Important

1.5 Evolution of File System Data Processing

1.5.1 Manual File Systems

1.5.2 Computerized File Systems

1.5.3 File System Redux: Modern End-User Productivity Tools

1.6 Problems with File System Data Processing

1.6.1 Structural and Data Dependence

1.6.2 Data Redundancy

1.6.3 Lack of Design and Data-Modeling Skills

1.7 Database Systems

1.7.1 The Database System Environment

1.7.2 DBMS Functions

1.7.3 Managing the Database System: A Shift in Focus

1.8 Preparing for Your Database Professional Career

Summary

Key Terms

Review Questions

Problems

CHAPTER 2 DATA MODELS

2.1 Data Modeling and Data Models

2.2 The Importance of Data Models

2.3 Data Model Basic Building Blocks

2.4 Business Rules

2.4.1 Discovering Business Rules

2.4.2 Translating Business Rules into Data Model Components

2.4.3 Naming Conventions

2.5 The Evolution of Data Models

2.5.1 Hierarchical and Network Models

2.5.2 The Relational Model

2.5.3 The Entity Relationship Model

2.5.4 The Object-Oriented (OO) Model

2.5.5 Object/Relational and XML

2.5.6 Emerging Data Models: Big Data and NoSQL

2.5.7 Data Models: A Summary

2.6 Degrees of Data Abstraction

2.6.1 The External Model

2.6.2 The Conceptual Model

2.6.3 The Internal Model

Summary

Key Terms

Review Questions

Problems

PART II DESIGN CONCEPTS

Business Vignette

CHAPTER 3 THE RELATIONAL DATABASE MODEL

3.1 A Logical View of Data

3.1.1 Tables and Their Characteristics

3.2 Keys

3.2.1 Dependencies

3.2.2 Types of Keys

3.3 Integrity Rules

3.4 Relational Set Operators

3.5 The Data Dictionary and the System Catalog

3.6 Relationships within the Relational Database

3.6.1 The 1:M Relationship

3.6.2 The 1:1 Relationship

3.6.3 The M:N Relationship

3.7 Data Redundancy Revisited

3.8 Indexes

3.9 Codd's Relational Database Rules

Summary

Key Terms

Review Questions

Problems

CHAPTER 4 ENTITY RELATIONSHIP (ER) MODELING

4.1 The Entity Relationship Model (ERM)

4.1.1 Entities

4.1.2 Attributes

4.1.3 Relationships

4.1.4 Connectivity and Cardinality

4.1.5 Existence Dependence

4.1.6 Relationship Strength

4.1.7 Weak Entities

4.1.8 Relationship Participation

4.1.9 Relationship Degree

4.1.10 Recursive Relationships

4.1.11 Associative (Composite) Entities

4.2 Developing an ER Diagram

4.3 Database Design Challenges: Conflicting Goals

Summary

Key Terms

Review Questions

Problems

Cases

CHAPTER 5 ADVANCED DATA MODELING

5.1 The Extended Entity Relationship Model

- 5.1.1 Entity Supertypes and Subtypes**
- 5.1.2 Specialization Hierarchy**
- 5.1.3 Inheritance**
- 5.1.4 Subtype Discriminator**
- 5.1.5 Disjoint and Overlapping Constraints**
- 5.1.6 Completeness Constraint**
- 5.1.7 Specialization and Generalization**

5.2 Entity Clustering

5.3 Entity Integrity: Selecting Primary Keys

- 5.3.1 Natural Keys and Primary Keys**
- 5.3.2 Primary Key Guidelines**
- 5.3.3 When to Use Composite Primary Keys**
- 5.3.4 When to Use Surrogate Primary Keys**

5.4 Design Cases: Learning Flexible Database Design

- 5.4.1 Design Case 1: Implementing 1:1 Relationships**
- 5.4.2 Design Case 2: Maintaining History of Time-Variant Data**
- 5.4.3 Design Case 3: Fan Traps**
- 5.4.4 Design Case 4: Redundant Relationships**

Summary

Key Terms

Review Questions

Problems

Cases

CHAPTER 6 NORMALIZATION OF DATABASE TABLES

6.1 Database Tables and Normalization

6.2 The Need for Normalization

6.3 The Normalization Process

- 6.3.1 Conversion to First Normal Form**
- 6.3.2 Conversion to Second Normal Form**
- 6.3.3 Conversion to Third Normal Form**

6.4 Improving the Design

6.5 Surrogate Key Considerations

6.6 Higher-Level Normal Forms

[6.6.1 The Boyce-Codd Normal Form](#)

[6.6.2 Fourth Normal Form \(4NF\)](#)

6.7 Normalization and Database Design

6.8 Denormalization

6.9 Data-Modeling Checklist

Summary

Key Terms

Review Questions

Problems

PART III ADVANCED DESIGN AND IMPLEMENTATION

Business Vignette

CHAPTER 7 INTRODUCTION TO STRUCTURED QUERY LANGUAGE (SQL)

7.1 Introduction to SQL

7.2 Data Definition Commands

[7.2.1 The Database Model](#)

[7.2.2 Creating the Database](#)

[7.2.3 The Database Schema](#)

[7.2.4 Data Types](#)

[7.2.5 Creating Table Structures](#)

[7.2.6 SQL Constraints](#)

[7.2.7 SQL Indexes](#)

7.3 Data Manipulation Commands

[7.3.1 Adding Table Rows](#)

[7.3.2 Saving Table Changes](#)

[7.3.3 Listing Table Rows](#)

[7.3.4 Updating Table Rows](#)

[7.3.5 Restoring Table Contents](#)

[7.3.6 Deleting Table Rows](#)

[7.3.7 Inserting Table Rows with a Select Subquery](#)

7.4 Select Queries

- [7.4.1 Selecting Rows with Conditional Restrictions](#)
- [7.4.2 Arithmetic Operators: The Rule of Precedence](#)
- [7.4.3 Logical Operators: AND, OR, and NOT](#)
- [7.4.4 Special Operators](#)

7.5 Additional Data Definition Commands

- [7.5.1 Changing a Column's Data Type](#)
- [7.5.2 Changing a Column's Data Characteristics](#)
- [7.5.3 Adding a Column](#)
- [7.5.4 Dropping a Column](#)
- [7.5.5 Advanced Data Updates](#)
- [7.5.6 Copying Parts of Tables](#)
- [7.5.7 Adding Primary and Foreign Key Designations](#)
- [7.5.8 Deleting a Table from the Database](#)

7.6 Additional Select Query Keywords

- [7.6.1 Ordering a Listing](#)
- [7.6.2 Listing Unique Values](#)
- [7.6.3 Aggregate Functions](#)
- [7.6.4 Grouping Data](#)

7.7 Joining Database Tables

- [7.7.1 Joining Tables with an Alias](#)
- [7.7.2 Recursive Joins](#)

[Summary](#)

[Key Terms](#)

[Review Questions](#)

[Problems](#)

[Cases](#)

CHAPTER 8 ADVANCED SQL

8.1 SQL Join Operators

- [8.1.1 Cross Join](#)
- [8.1.2 Natural Join](#)
- [8.1.3 Join USING Clause](#)
- [8.1.4 JOIN ON Clause](#)
- [8.1.5 Outer Joins](#)

8.2 Subqueries and Correlated Queries

- [8.2.1 WHERE Subqueries](#)
- [8.2.2 IN Subqueries](#)
- [8.2.3 HAVING Subqueries](#)
- [8.2.4 Multirow Subquery Operators: ANY and ALL](#)
- [8.2.5 FROM Subqueries](#)
- [8.2.6 Attribute List Subqueries](#)
- [8.2.7 Correlated Subqueries](#)

8.3 SQL Functions

- [8.3.1 Date and Time Functions](#)
- [8.3.2 Numeric Functions](#)
- [8.3.3 String Functions](#)
- [8.3.4 Conversion Functions](#)

8.4 Relational Set Operators

- [8.4.1 UNION](#)
- [8.4.2 UNION ALL](#)
- [8.4.3 INTERSECT](#)
- [8.4.4 MINUS](#)
- [8.4.5 Syntax Alternatives](#)

8.5 Virtual Tables: Creating a View

- [8.5.1 Updatable Views](#)

8.6 Oracle Sequences

8.7 Procedural SQL

- [8.7.1 Triggers](#)
- [8.7.2 Stored Procedures](#)
- [8.7.3 PL/SQL Processing with Cursors](#)
- [8.7.4 PL/SQL Stored Functions](#)

8.8 Embedded SQL

[Summary](#)

[Key Terms](#)

[Review Questions](#)

[Problems](#)

[Cases](#)

[CHAPTER 9 DATABASE DESIGN](#)

9.1 The Information System

9.2 The Systems Development Life Cycle

- 9.2.1 Planning**
- 9.2.2 Analysis**
- 9.2.3 Detailed Systems Design**
- 9.2.4 Implementation**
- 9.2.5 Maintenance**

9.3 The Database Life Cycle

- 9.3.1 The Database Initial Study**
- 9.3.2 Database Design**
- 9.3.3 Implementation and Loading**
- 9.3.4 Testing and Evaluation**
- 9.3.5 Operation**
- 9.3.6 Maintenance and Evolution**

9.4 Conceptual Design

- 9.4.1 Data Analysis and Requirements**
- 9.4.2 Entity Relationship Modeling and Normalization**
- 9.4.3 Data Model Verification**
- 9.4.4 Distributed Database Design**

9.5 DBMS Software Selection

9.6 Logical Design

- 9.6.1 Map the Conceptual Model to the Logical Model**
- 9.6.2 Validate the Logical Model Using Normalization**
- 9.6.3 Validate Logical Model Integrity Constraints**
- 9.6.4 Validate the Logical Model Against User Requirements**

9.7 Physical Design

- 9.7.1 Define Data Storage Organization**
- 9.7.2 Define Integrity and Security Measures**
- 9.7.3 Determine Performance Measures**

9.8 Database Design Strategies

9.9 Centralized vs. Decentralized Design

Summary

Key Terms

Review Questions

Problems

PART IV ADVANCED DATABASE CONCEPTS

Business Vignette

CHAPTER 10 TRANSACTION MANAGEMENT AND CONCURRENCY CONTROL

10.1 What is a Transaction?

- 10.1.1 Evaluating Transaction Results
- 10.1.2 Transaction Properties
- 10.1.3 Transaction Management with SQL
- 10.1.4 The Transaction Log

10.2 Concurrency Control

- 10.2.1 Lost Updates
- 10.2.2 Uncommitted Data
- 10.2.3 Inconsistent Retrievals
- 10.2.4 The Scheduler

10.3 Concurrency Control with Locking Methods

- 10.3.1 Lock Granularity
- 10.3.2 Lock Types
- 10.3.3 Two-Phase Locking to Ensure Serializability
- 10.3.4 Deadlocks

10.4 Concurrency Control with Timestamping Methods

- 10.4.1 Wait/Die and Wound/Wait Schemes

10.5 Concurrency Control with Optimistic Methods

10.6 Database Recovery Management

- 10.6.1 Transaction Recovery

Summary

Key Terms

Review Questions

Problems

CHAPTER 11 DATABASE PERFORMANCE TUNING AND QUERY OPTIMIZATION

11.1 Database Performance-Tuning Concepts

- 11.1.1 Performance Tuning: Client and Server
- 11.1.2 DBMS Architecture

[11.1.3 Database Query Optimization Modes](#)

[11.1.4 Database Statistics](#)

[11.2 Query Processing](#)

[11.2.1 SQL Parsing Phase](#)

[11.2.2 SQL Execution Phase](#)

[11.2.3 SQL Fetching Phase](#)

[11.2.4 Query Processing Bottlenecks](#)

[11.3 Indexes and Query Optimization](#)

[11.4 Optimizer Choices](#)

[11.4.1 Using Hints to Affect Optimizer Choices](#)

[11.5 SQL Performance Tuning](#)

[11.5.1 Index Selectivity](#)

[11.5.2 Conditional Expressions](#)

[11.6 Query Formulation](#)

[11.7 DBMS Performance Tuning](#)

[11.8 Query Optimization Example](#)

[Summary](#)

[Key Terms](#)

[Review Questions](#)

[Problems](#)

[CHAPTER 12 DISTRIBUTED DATABASE MANAGEMENT SYSTEMS](#)

[12.1 The Evolution of Distributed Database Management Systems](#)

[12.2 DDBMS Advantages and Disadvantages](#)

[12.3 Distributed Processing and Distributed Databases](#)

[12.4 Characteristics of Distributed Database Management Systems](#)

[12.5 DDBMS Components](#)

[12.6 Levels of Data and Process Distribution](#)

[12.6.1 Single-Site Processing, Single-Site Data](#)

[12.6.2 Multiple-Site Processing, Single-Site Data](#)

[12.6.3 Multiple-Site Processing, Multiple-Site Data](#)

[12.7 Distributed Database Transparency Features](#)

[12.8 Distribution Transparency](#)

[12.9 Transaction Transparency](#)

[12.9.1 Distributed Requests and Distributed Transactions](#)

[12.9.2 Distributed Concurrency Control](#)

[12.9.3 Two-Phase Commit Protocol](#)

[12.10 Performance and Failure Transparency](#)

[12.11 Distributed Database Design](#)

[12.11.1 Data Fragmentation](#)

[12.11.2 Data Replication](#)

[12.11.3 Data Allocation](#)

[12.12 The CAP Theorem](#)

[12.13 C. J. Date's 12 Commandments for Distributed Databases](#)

[Summary](#)

[Key Terms](#)

[Review Questions](#)

[Problems](#)

[CHAPTER 13 BUSINESS INTELLIGENCE AND DATA WAREHOUSES](#)

[13.1 The Need for Data Analysis](#)

[13.2 Business Intelligence](#)

[13.2.1 Business Intelligence Architecture](#)

[13.2.2 Business Intelligence Benefits](#)

[13.2.3 Business Intelligence Evolution](#)

[13.2.4 Business Intelligence Technology Trends](#)

[13.3 Decision Support Data](#)

[13.3.1 Operational Data vs. Decision Support Data](#)

[13.3.2 Decision Support Database Requirements](#)

[13.4 The Data Warehouse](#)

[13.4.1 Data Marts](#)

[13.4.2 Twelve Rules That Define a Data Warehouse](#)

[13.5 Star Schemas](#)

[13.5.1 Facts](#)

[13.5.2 Dimensions](#)

[13.5.3 Attributes](#)

[13.5.4 Attribute Hierarchies](#)

[13.5.5 Star Schema Representation](#)

[13.5.6 Performance-Improving Techniques for the Star Schema](#)

13.6 Data Analytics

[13.6.1 Data Mining](#)

[13.6.2 Predictive Analytics](#)

13.7 Online Analytical Processing

[13.7.1 Multidimensional Data Analysis Techniques](#)

[13.7.2 Advanced Database Support](#)

[13.7.3 Easy-to-Use End-User Interfaces](#)

[13.7.4 OLAP Architecture](#)

[13.7.5 Relational OLAP](#)

[13.7.6 Multidimensional OLAP](#)

[13.7.7 Relational vs. Multidimensional OLAP](#)

13.8 SQL Extensions for OLAP

[13.8.1 The ROLLUP Extension](#)

[13.8.2 The CUBE Extension](#)

[13.8.3 Materialized Views](#)

[Summary](#)

[Key Terms](#)

[Review Questions](#)

[Problems](#)

PART V DATABASES AND THE INTERNET

[**Business Vignette**](#)

CHAPTER 14 DATABASE CONNECTIVITY AND WEB TECHNOLOGIES

14.1 Database Connectivity

[14.1.1 Native SQL Connectivity](#)

[14.1.2 ODBC, DAO, and RDO](#)

[14.1.3 OLE-DB](#)

[14.1.4 ADO.NET](#)

[14.1.5 Java Database Connectivity \(JDBC\)](#)

14.2 Database Internet Connectivity

[14.2.1 Web-to-Database Middleware: Server-Side Extensions](#)

[14.2.2 Web Server Interfaces](#)

- [14.2.3 The Web Browser](#)
- [14.2.4 Client-Side Extensions](#)
- [14.2.5 Web Application Servers](#)
- [14.2.6 Web Database Development](#)

14.3 Extensible Markup Language (XML)

- [14.3.1 Document Type Definitions \(DTD\) and XML Schemas](#)
- [14.3.2 XML Presentation](#)
- [14.3.3 XML Applications](#)

14.4 Cloud Computing Services

- [14.4.1 Cloud Implementation Types](#)
- [14.4.2 Characteristics of Cloud Services](#)
- [14.4.3 Types of Cloud Services](#)
- [14.4.4 Cloud Services: Advantages and Disadvantages](#)
- [14.4.5 SQL Data Services](#)

Summary

Key Terms

Review Questions

Problems

PART VI DATABASE ADMINISTRATION

Business Vignette

CHAPTER 15 DATABASE ADMINISTRATION AND SECURITY

15.1 Data as a Corporate Asset

15.2 The Need for a Database and Its Role in an Organization

15.3 Introduction of a Database: Special Considerations

15.4 The Evolution of Database Administration

15.5 The Database Environment's Human Component

- [15.5.1 The DBA's Managerial Role](#)
- [15.5.2 The DBA's Technical Role](#)
- [15.5.3 The DBA's Role in the Cloud](#)

15.6 Security

- [15.6.1 Security Policies](#)

[15.6.2 Security Vulnerabilities](#)

[15.6.3 Database Security](#)

[15.7 Database Administration Tools](#)

[15.7.1 The Data Dictionary](#)

[15.7.2 CASE Tools](#)

[15.8 Developing a Data Administration Strategy](#)

[15.9 The DBA at Work: Using Oracle for Database Administration](#)

[15.9.1 Oracle Database Administration Tools](#)

[15.9.2 The Default Login](#)

[15.9.3 Ensuring that the RDBMS Starts Automatically](#)

[15.9.4 Creating Tablespaces and Datafiles](#)

[15.9.5 Managing the Database Objects: Tables, Views, Triggers, and Procedures](#)

[15.9.6 Managing Users and Establishing Security](#)

[15.9.7 Customizing the Database Initialization Parameters](#)

[Summary](#)

[Key Terms](#)

[Review Questions](#)

[GLOSSARY](#)

[INDEX](#)

The following appendixes are included on the Essentials Site or at the CourseMate site for this text, www.cengagebrain.com.

APPENDIX A: DESIGNING DATABASES WITH VISIO PROFESSIONAL: A TUTORIAL

APPENDIX B: THE UNIVERSITY LAB: CONCEPTUAL DESIGN

APPENDIX C: THE UNIVERSITY LAB: CONCEPTUAL DESIGN VERIFICATION, LOGICAL DESIGN, AND IMPLEMENTATION

APPENDIX D: CONVERTING AN ER MODEL INTO A DATABASE STRUCTURE

APPENDIX E: COMPARISON OF ER MODEL NOTATIONS

APPENDIX F: CLIENT/SERVER SYSTEMS

APPENDIX G: OBJECT-ORIENTED DATABASES

APPENDIX H: UNIFIED MODELING LANGUAGE (UML)

APPENDIX I: DATABASES IN ELECTRONIC COMMERCE

APPENDIX J: WEB DATABASE DEVELOPMENT WITH COLDFUSION

APPENDIX K: THE HIERARCHICAL DATABASE MODEL

APPENDIX L: THE NETWORK DATABASE MODEL

APPENDIX M: MICROSOFT® ACCESS® TUTORIAL

APPENDIX N: CREATING A NEW DATABASE WITH ORACLE 11G

APPENDIX O: DATA WAREHOUSE IMPLEMENTATION FACTORS

The Essentials Site and CourseMate Site for this text are available at www.cengagebrain.com. Locate your access cards in the front of each new book purchase, and click Create My Account to begin the registration process. If you purchased a used book, search for *Database Systems, Tenth Edition* at www.cengagebrain.com, where you can purchase instant access.

PREFACE

A tenth edition is a milestone that few textbooks achieve. We wrote the first edition of this book because we wanted to explain the complexity of database systems in a language that was easy for students to understand. Over the years, we have maintained this emphasis on reaching out to students to explain complex concepts in a practical, approachable manner. This book has been successful through nine editions because the authors, editors, and the publisher paid attention to the impact of technology and to adopter questions and suggestions. We believe that this tenth edition successfully reflects the same attention to such factors.

In many respects, rewriting a book is more difficult than writing it the first time. If the book is successful, as this one is, a major concern is that the updates, inserts, and deletions will adversely affect writing style and continuity of coverage. The combination of superb reviewers and editors, plus a wealth of feedback from adopters and students of the previous editions, helped make this new edition the best yet.

CHANGES TO THE TENTH EDITION

In this tenth edition, we have added some new features and reorganized some coverage to provide a better flow of material. Aside from enhancing the already strong coverage of database design, we have made other improvements in the topical coverage. Here are a few of the highlights:

- Updated Business Vignettes showing the impact of database technologies in the real world
- Expanded coverage of cloud data services such as Platform as a Service, Software as a Service, and Infrastructure as a Service
- Added coverage of the emergence of Big Data and related NoSQL data models
- Enhanced and streamlined coverage of business intelligence and data analytics
- Streamlined coverage of SQL and PL/SQL

- Enhanced coverage of data models by shifting the focus from a historical perspective to emerging data technologies
- Expanded end-of-chapter review questions and problems
- Improved readability and overall visual appeal of the book

This tenth edition continues to provide a solid and practical foundation for the design, implementation, and management of database systems. This foundation is built on the notion that, while databases are very practical, their successful creation depends on understanding the important concepts that define them. It's not easy to come up with the proper mix of theory and practice, but the previously mentioned feedback suggests that we largely succeeded in our quest to maintain the proper balance.

THE APPROACH: A CONTINUED EMPHASIS ON DESIGN

As the title suggests, ***Database Systems: Design, Implementation, and Management*** covers three broad aspects of database systems. However, for several important reasons, special attention is given to database design.

- The availability of excellent database software enables people with little experience to create databases and database applications. Unfortunately, the “create without design” approach usually paves the road to any number of database disasters. In our experience, many database system failures are traceable to poor design and cannot be solved with the help of even the best programmers and managers. Nor is better DBMS software likely to overcome problems created or magnified by poor design. Even the best bricklayers and carpenters can't create a good building from a bad blueprint.
- Most vexing problems of database system management seem to be triggered by poorly designed databases. It hardly seems worthwhile to use scarce resources to develop excellent database management skills merely to use them on crises induced by poorly designed databases.
- Design provides an excellent means of communication. Clients are more likely to get what they need when database system design is approached carefully and thoughtfully. In fact, clients may discover how their organizations really

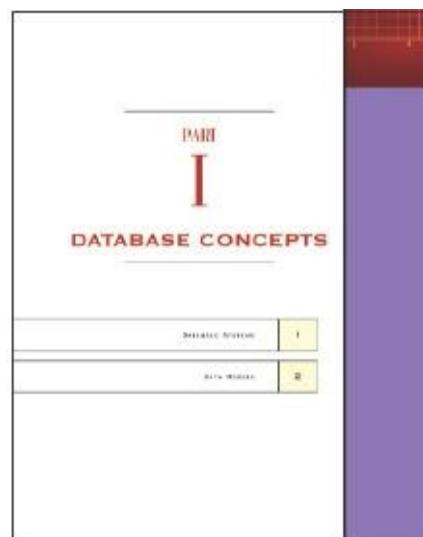
function once a good database design is completed.

- Familiarity with database design techniques promotes understanding of current database technologies. For example, because data warehouses derive much of their data from operational databases, data warehouse concepts, structures, and procedures make more sense when the operational database's structure and implementation are understood.

Because the practical aspects of database design are stressed, we have covered design concepts and procedures in detail, making sure that the numerous end-of-chapter problems and cases are sufficiently challenging so students can develop real and useful design skills. We also make sure that students understand the potential and actual conflicts between database design elegance, information requirements, and transaction processing speed. For example, it makes little sense to design databases that meet design elegance standards while they fail to meet end-user information requirements. Therefore, we explore the use of carefully defined trade-offs to ensure that the databases meet end-user requirements while conforming to high design standards.

TOPICAL COVERAGE

The Systems View



The book's title begins with ***Database Systems***. Therefore, we examine the database and design concepts covered in [Chapters 1–6](#) as part of a larger whole by placing them within the systems analysis framework of [Chapter 9](#). Database designers who fail to understand that the database is part of a larger system are likely to overlook important design requirements. In fact, [Chapter 9](#), Database Design, provides the map for the advanced database design developed in Appendixes B and C. Within the larger systems framework, we can also explore issues such as transaction management and concurrency control ([Chapter 10](#)), distributed database management systems ([Chapter 12](#)), business intelligence and data warehouses ([Chapter 13](#)), database connectivity and Web technologies ([Chapter 14](#)), and database administration and security ([Chapter 15](#)).

Database Design



The first item in the book's subtitle is ***Design***, and our examination of database design is comprehensive. For example, [Chapters 1](#) and [2](#) examine the development and future of databases and data models, and illustrate the need for design. [Chapter 3](#) examines the details of the relational database model; [Chapter 4](#) provides extensive, in-depth, and practical database design coverage; and [Chapter 5](#) explores advanced database design topics. [Chapter 6](#) is devoted to critical normalization issues that affect database efficiency and effectiveness. [Chapter 9](#) examines database design within the systems framework and maps the activities required to successfully design and implement the complex, real-world database developed in Appendixes B and C. Appendix A, Designing Databases with Visio Professional: A Tutorial, provides a good introductory tutorial for the use of a database design tool.

Because database design is affected by real-world transactions, the way data are distributed, and ever-increasing information requirements, we examine major database features that must be supported in current-generation databases and models. For example, [Chapter 10](#), Transaction Management and Concurrency Control, focuses on the characteristics of database transactions and how they affect database integrity and consistency. [Chapter 11](#), Database Performance Tuning and Query Optimization, illustrates the need for query efficiency in a world that routinely generates and uses terabyte-sized databases and tables with millions of records. [Chapter 12](#), Distributed Database Management Systems, focuses on data distribution, replication, and allocation. In [Chapter 13](#), Business Intelligence and Data Warehouses, we explore the characteristics of databases that are used in decision support and online analytical processing. [Chapter 14](#), Database Connectivity and Web Technologies, covers the basic database connectivity issues in a Web-based data world, development of Web-based database front ends, and emerging cloud-based services.

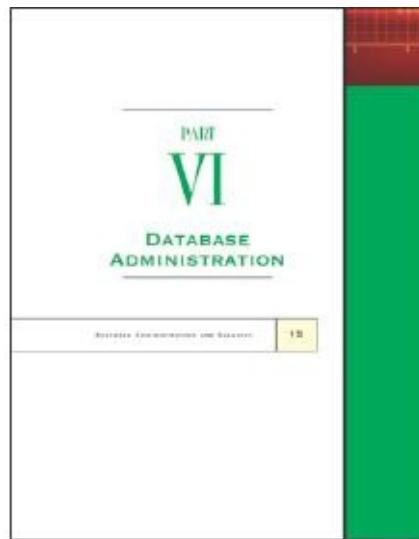
Implementation



The second portion of the subtitle is **Implementation**. We use Structured Query Language (SQL) in [Chapters 7](#) and [8](#) to show how databases are implemented and managed. Appendix M, Microsoft Access Tutorial, provides a quick but comprehensive guide to implementing an MS Access database. Appendixes B and C demonstrate the design of a database that was fully implemented; these appendixes illustrate a wide range of implementation issues. We had to deal with conflicting design goals: design elegance, information requirements, and operational speed. Therefore, we carefully audited the initial design in Appendix

B to check its ability to meet end-user needs and establish appropriate implementation protocols. The result of this audit yielded the final design developed in Appendix C. The special issues encountered in an Internet database environment are addressed in [Chapter 14](#), Database Connectivity and Web Technologies, and in Appendix J, Web Database Development with ColdFusion.

Management



The final portion of the subtitle is **Management**. We deal with database management issues in [Chapter 10](#), Transaction Management and Concurrency Control; [Chapter 12](#), Distributed Database Management Systems; and [Chapter 15](#), Database Administration and Security. [Chapter 11](#), Database Performance Tuning and Query Optimization, is a valuable resource that illustrates how a DBMS manages data retrieval. In addition, Appendix N, Creating a New Database Using Oracle 11g, walks you through the process of setting up a new database.

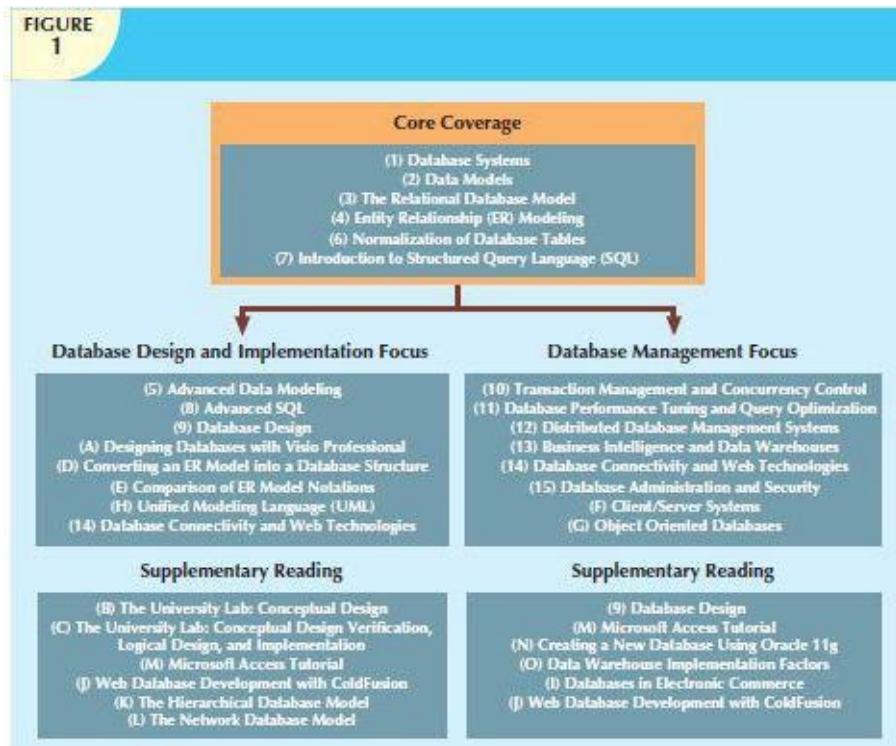
TEACHING DATABASE: A MATTER OF FOCUS

Given the wealth of detailed coverage, instructors can “mix and match” chapters to produce the desired coverage. Depending on where database courses fit into the curriculum, instructors may choose to emphasize database design or database management. (See [Figure 1](#).)

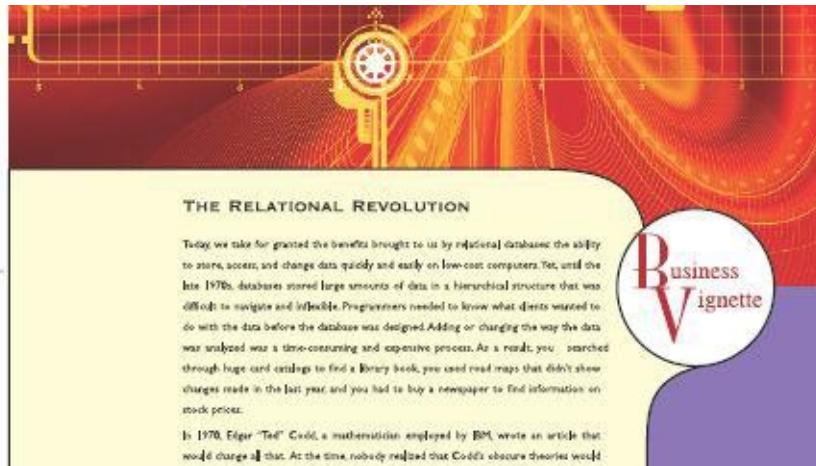
The hands-on nature of database design lends itself particularly well to class

projects for which students use instructor-selected software to prototype a system they design for the end user. Several end-of-chapter problems are sufficiently complex to serve as projects, or an instructor may work with local businesses to give students hands-on experience. Note that some elements of the database design track are also found in the database management track, because it is difficult to manage database technologies that are not well understood.

The options shown in [Figure 1](#) serve only as a starting point. Naturally, instructors will tailor their coverage based on their specific course requirements. For example, an instructor may decide to make Appendix I an outside reading assignment and Appendix A a self-taught tutorial, and then use that time to cover client/server systems or object-oriented databases. The latter choice would serve as a gateway to UML coverage.



TEXT FEATURES



Business Vignettes highlight topics in a real-life setting.



Online Content Boxes draw attention to material at www.cengagebrain.com for this text and provide ideas for incorporating this content into the course.

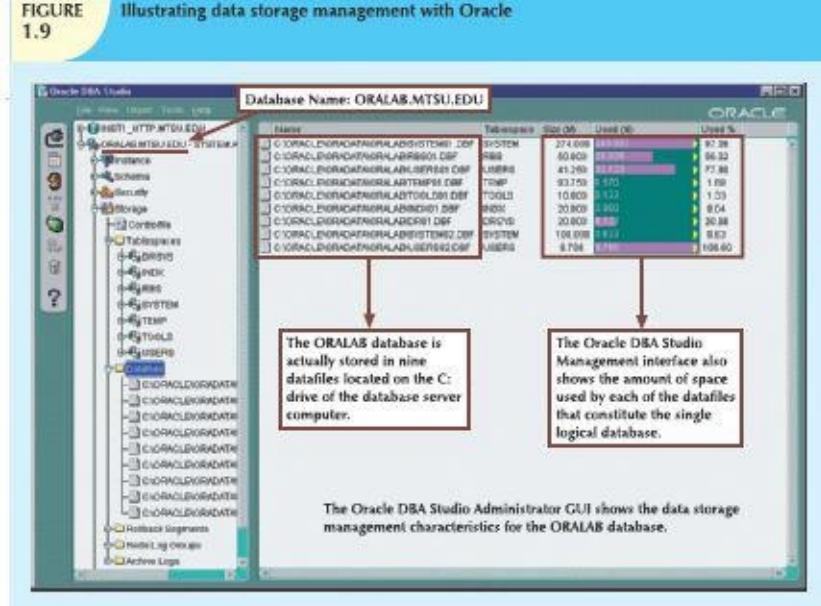
NOTE

Data that display data inconsistency are also referred to as data that lack data integrity. **Data integrity** is defined as the condition in which all of the data in the database are consistent with the real-world events and conditions. In other words, data integrity means that:

- Data are accurate—there are no data inconsistencies.
- Data are verifiable—the data will always yield consistent results.

Notes highlight important facts about the concepts introduced in the chapter.

FIGURE 1.9 Illustrating data storage management with Oracle



A variety of **four-color figures**, including ER models and implementations, tables, and illustrations, clearly illustrate difficult concepts.

SUMMARY

- The ERM uses ERDs to represent the conceptual database as viewed by the end user. The ERM's main components are entities, relationships, and attributes. The ERD also includes connectivity and cardinality notations. An ERD can also show relationship strength, relationship participation (optional or mandatory), and degree of relationship (unary, binary, ternary, etc.).
- Connectivity describes the relationship classification (1:1, 1:M, or M:N). Cardinality expresses the specific number of entity occurrences associated with an occurrence of a related entity. Connectivities and cardinalities are usually based on business rules.
- In the ERM, an M:N relationship is valid at the conceptual level. However, when implementing the ERM in a relational database, the M:N relationship must be mapped to a set of 1:M relationships through a composite entity.

A robust **Summary** at the end of each chapter ties together the major concepts and serves as a quick review for students.

KEY TERMS

algorithms	data mart	explanatory analytics
attribute hierarchy	data mining	extraction, transformation, and loading (ETL)
business intelligence (BI)	data warehouse	fact table
cube cache	decision support system (DSS)	facts
dashboard	dimension tables	governance
data analytics	dimensions	key performance indicators (KPIs)
data cube	drill down	

An alphabetic list of **Key Terms** summarizes important terms.

REVIEW QUESTIONS

1. What two conditions must be met before an entity can be classified as a weak entity? Give an example of a weak entity.
2. What is a strong (or identifying) relationship, and how is it depicted in a Crow's Foot ERD?
3. Given the business rule "an employee may have many degrees," discuss its effect on attributes, entities, and relationships. (Hint: Remember what a multivalued attribute is and how it might be implemented.)
4. What is a composite entity, and when is it used?
5. Suppose you are working within the framework of the conceptual model in Figure Q4.5.

Review Questions challenge students to apply the skills learned in each chapter.

PROBLEMS

1. Given the following business rules, create the appropriate Crow's Foot ERD.
 - a. A company operates many departments.
 - b. Each department employs one or more employees.
 - c. Each of the employees may or may not have one or more dependents.
 - d. Each employee may or may not have an employment history.
2. The Hudson Engineering Group (HEG) has contacted you to create a conceptual model whose application will meet the expected database requirements for the company's training program. The HEG administrator gives you

Problems become progressively more complex as students draw on the lessons learned from the completion of preceding problems.

COURSEMATE

Cengage Learning's *Database Systems* CourseMate brings course concepts to life with interactive learning, study, and exam preparation tools that support the printed textbook. Watch student comprehension soar as your class works with the printed textbook and the textbook-specific Website. CourseMate goes beyond the book to deliver what you need! Learn more at www.cengage.com/coursemate.

Engagement Tracker

How do you assess your students' engagement in your course? How do you know students have read the material or viewed the resources you've assigned? How can you tell if your students are struggling with a concept? With CourseMate, you can use the included Engagement Tracker to assess student preparation and engagement. Use the tracking tools to see progress for the class as a whole or for individual students. Identify students at risk early in the course. Uncover which concepts are most difficult for your class. Monitor time on task. Keep your students engaged.

Interactive Teaching and Learning Tools

CourseMate includes interactive teaching and learning tools:

- Quizzes
- Crossword puzzles
- Flashcards
- Videos
- PowerPoint presentations
- and more

These assets enable students to review for tests, prepare for class, and address

the needs of their varied learning styles.

Interactive eBook

In addition to interactive teaching and learning tools, CourseMate includes an interactive eBook. Students can take notes, highlight, search for, and interact with embedded media specific to their book. Use the eBook as a supplement to the printed text, or as a substitute—the choice is your students' with CourseMate.

Single Sign On (SSO) provides a central location from which you can access Cengage Learning's online learning solutions with convenience and flexibility. You can:

- Gain access to online resources, including the Essentials Site and CourseMate that accompany this book.
- Simplify your coursework by reducing human error and the need to keep track of multiple passwords.

See the insert card at the front of this book for instructions on accessing this text's SSO site.

This Web resource, which is referenced throughout the book in the Online Content boxes, includes the following features:

Appendices

Fifteen appendixes provide additional material on a variety of important areas, such as using Microsoft® Visio® and Microsoft® Access®, ER model notations, UML, object-oriented databases, databases and electronic commerce, and Adobe® ColdFusion®.

Database, SQL Script, and ColdFusion Files

The online materials for this book include all of the database structures and table contents used in the text. For students using Oracle® and Microsoft SQL Server™, SQL scripts are included to help students create and load all tables used in the SQL chapters ([7](#) and [8](#)). In addition, all ColdFusion scripts used to develop the Web interfaces in Appendix J are included.

Database Systems: Design, Implementation, and Management, Tenth Edition, includes teaching tools to support instructors in the classroom. The ancillary material that accompanies the textbook is listed below. Most of the teaching tools available with this book are provided to the instructor on a single CD-ROM; they are also available on the Web at www.cengage.com.

Instructor's Manual

The authors have created this manual to help instructors make their classes informative and interesting. Because the authors tackle so many problems in depth, instructors will find the ***Instructor's Manual*** especially useful. The details of the design solution process are shown in the ***Instructor's Manual***, as well as notes about alternative approaches that may be used to solve a particular problem.

SQL Script Files for Instructors

The authors have provided teacher's SQL script files to create and delete users. They have also provided SQL scripts to let instructors cut and paste the SQL code into the SQL windows. (Scripts are provided for Oracle as well as for MS SQL Server.) The SQL scripts, which have all been tested by Course Technology, are a major convenience for instructors. You won't have to type in the SQL commands, and the use of the scripts eliminates typographical errors that are sometimes difficult to trace.

ColdFusion Files for Instructors

The ColdFusion Web development solutions are provided. Instructors have access to a menu-driven system that lets teachers show the code as well as its execution.

Databases

For many chapters, Microsoft® Access® instructor databases are available that include features not found in the student databases. For example, the databases that accompany [Chapters 7](#) and [8](#) include many of the queries that produce the problem solutions. Other Access databases, such as the ones that accompany [Chapters 3, 4, 5](#), and [6](#), include implementations of the design problem solutions to let instructors illustrate the effect of design decisions. All the MS Access files are in Access 2000 format so that students can use them regardless of the version installed on their computers. In addition, instructors have access to all the script

files for both Oracle and MS SQL Server so that all the databases and their tables can be converted easily and precisely.

ExamView®

This objective-based test generator lets the instructor create paper, LAN, or Web-based tests from test banks designed specifically for this book. Instructors can use the QuickTest Wizard to create tests in fewer than five minutes by taking advantage of Course Technology's question banks, or instructors can create customized exams.

PowerPoint® Presentations

Microsoft PowerPoint slides are included for each chapter. Instructors can use the slides in a variety of ways—for example, as teaching aids during classroom presentations or as printed handouts for classroom distribution. Instructors can modify these slides or include slides of their own for additional topics introduced to the class.

Figure Files

Figure files for solutions are presented in the Instructor's Manual to allow instructors to create their own presentations. Instructors can also manipulate these files to meet their particular needs.

ACKNOWLEDGMENTS

Regardless of how many editions of this book are published, they will always rest on the solid foundation created by the first edition. We remain convinced that our work has become successful because that first edition was guided by Frank Ruggirello, a former Wadsworth senior editor and publisher. Aside from guiding the book's development, Frank also managed to solicit the great Peter Keen's evaluation (thankfully favorable) and subsequently convinced PK to write the foreword for the first edition. Although we sometimes found Frank to be an especially demanding taskmaster, we also found him to be a superb professional and a fine friend. We suspect Frank will still see his fingerprints all over our current work. Many thanks.

A difficult task in rewriting a book is deciding what new approaches, topical coverage, and changes to depth of coverage are appropriate for a product that has successfully weathered the test of the marketplace. The comments and suggestions made by the book's adopters, students, and reviewers play a major role in deciding what coverage is desirable and how that coverage is to be treated.

Some adopters became extraordinary reviewers, providing incredibly detailed and well-reasoned critiques even as they praised the book's coverage and style. Dr. David Hatherly, a superb database professional who is a senior lecturer in the School of Information Technology, Charles Sturt University–Mitchell, Bathurst, Australia, made sure that we knew precisely what issues led to his critiques. Even better for us, he provided the suggestions that made it much easier for us to improve the topical coverage in earlier editions. Dr. Hatherly's recommendations continue to be reflected in this tenth edition. All of his help was given freely and without prompting on our part. His efforts are much appreciated, and our thanks are heartfelt.

We also owe a debt of gratitude to Professor Emil T. Cipolla, who teaches at St. Mary College. Professor Cipolla's wealth of IBM experience turned out to be a valuable resource when we tackled the embedded SQL coverage in [Chapter 8](#).

Every technical book receives careful scrutiny by several groups of reviewers selected by the publisher. We were fortunate to face the scrutiny of reviewers who were superbly qualified to offer their critiques, comments, and suggestions —many of which strengthened this edition. While holding them blameless for

any remaining shortcomings, we owe these reviewers many thanks for their contributions:

Misti Clark, Ouachita Baptist University	James Reneau, Shawnee State University
Gary Garrison, Belmont University	Robert Schudy, Boston University
Connie Hecker, Missouri Western State College	Ronghua Shan, Dakota State University
Laurene Hutchinson, Louisiana State University	Ganesan Shankaranarayanan, Babson University
Margaret Porciello, Farmingdale State University	William Viereck, Penn State-Great Valley of New York
	Padmal Vitharana, Syracuse University
Frances Rampey, Wilson Community College	Anita Whitehill, Foothill College

Because this tenth edition is built solidly on the foundation of the previous editions, we would also like to thank the following reviewers for their efforts in helping to make the previous editions successful: Larry Molloy, Oakland Community College; Bruce Myers, Austin Peay State University; Steven Robinett, Allegany College of Maryland; Ioulia Rytikova, George Mason University; Samuel Sambasivam, Azusa Pacific University; Kevin Scheibe, Iowa State University; Ganesan Shankaranarayanan, Boston University; Xingzhong (Frank) Shi, New Jersey Institute of Technology; Yingbing Yu, Austin Peay State University; Dr. Reza Barkhi, Pamplin College of Business, Virginia Polytechnic Institute and State University; Amita G. Chin, Virginia Commonwealth University; Samuel Conn, Regis University; Dr. Vance Cooney, Xavier University; Harpal S. Dillion, Southwestern Oklahoma State University; Janusz Szczypula, Carnegie Mellon University; Dr. Ahmad Abuhejleh, University of Wisconsin, River Falls; Dr. Terence M. Baron, University of Toledo; Dr. Juan Estava, Eastern Michigan University; Dr. Kevin Gorman, University of North Carolina, Charlotte; Dr. Jeff Hedrington, University of Wisconsin, Eau Claire; Lionel M. Holguin, Jr., Athens State University; Dr. Herman P. Hoplin, Syracuse University; Dr. Sophie Lee, University of Massachusetts, Boston; Dr. Michael Mannino, University of Washington; Dr. Carol Chrisman, Illinois State University; Dr. Timothy Heintz, Marquette University; Bill Hochstettler, Franklin University; Dr. Herman Hoplin, Syracuse University; Dr. Dean James, Embry-Riddle University; Dr. Constance Knapp, Pace University; Dr. Mary Ann

Robbert, Bentley College; Dr. Francis J. Van Wetering, University of Nebraska; Dr. Joseph Walls, University of Southern California; Dr. Stephen C. Solosky, Nassau Community College; Dr. Robert Chiang, Syracuse University; Dr. Crist Costa, Rhode Island College; Dr. Sudesh M. Duggal, Northern Kentucky University; Dr. Chang Koh, University of North Carolina, Greensboro; Paul A. Seibert, North Greenville College; Neil Dunlop, Vista Community College; Ylber Ramadani, George Brown College; Samuel Sambasivam, Azusa Pacific University; Arjan Sadhwani, San Jose State University; Genard Catalano, Columbia College; Craig Shaw, Central Community College; Lei-da Chen, Creighton University; Linda K. Lau, Longwood University; Anita Lee-Post, University of Kentucky; Lenore Horowitz, Schenectady County Community College; Dr. Scott L. Schneberger, Georgia State University; Tony Pollard, University of Western Sydney; Lejla Vrazalic, University of Wollongong; and David Witzany, Parkland College.

In some respects, writing books resembles building construction: When 90 percent of the work seems done, 90 percent of the work remains to be done. Fortunately for us, we had a great team on our side.

- We are deeply indebted to Dan Seiter for his help and guidance. The development editor is so crucial to the writing process that working with a different editor for the first time invokes a certain amount of trepidation. Dan has been everything we could have hoped for in a development editor and more. He brought fresh eyes and a new perspective that meshed wonderfully with our vision for the new edition.
- After writing so many books and nine editions of **this** book, we know just how difficult it can be to transform the authors' work into an attractive product. The production team, both at Course Technology (Jennifer Feltri-George) and GEX Publishing Services (Marisa Taylor), have done an excellent job.
- We also owe Kate Mason, our product manager, special thanks for her ability to guide this book to a successful conclusion. Kate's work touched on all of the publication bases, and her managerial skills protected us from publishing gremlins that might have become a major nuisance. Also, her skills in dealing with occasionally cranky authors far exceed those of any diplomat we can think of. And did we mention that Kate is, quite simply, a delightful person?

- Many thanks to Mark Goodin, our copyeditor. We can only imagine the level of mental discipline required to perform his job, and we salute him.

We also thank our students for their comments and suggestions. They are the reason for writing this book in the first place. One comment stands out in particular: “I majored in systems for four years, and I finally discovered why when I took your course.” And one of our favorite comments by a former student was triggered by a question about the challenges created by a real-world information systems job: “Doc, it’s just like class, only easier. You really prepared me well. Thanks!”

Last, and certainly not least, we thank our families for their solid support at home. They graciously accepted the fact that during more than a year’s worth of rewriting, there would be no free weekends, rare free nights, and even rarer free days. We owe you much, and the dedications we wrote are but a small reflection of the important space you occupy in our hearts.

Carlos Coronel, Steven Morris, and Peter Rob

PART
I
DATABASE CONCEPTS

[DATABASE SYSTEMS](#) **1**

[DATA MODELS](#) **2**

Business Vignette

In 1979, Oracle CEO Larry Ellison, who was closely following the work of researchers at IBM and the University of California at Berkeley, released the first commercial database management system (DBMS) based on the relational model. Relational databases (RDBMSs) burst on the scene in the 1980s and quickly dominated the database market.

For more than 40 years, the RDBMS industry has expanded rapidly, with Oracle maintaining its leading position. In 2010, Gartner, the leading information technology research company, reported that Oracle held a greater share of RDBMS revenue than its five closest competitors combined. In 2010, Oracle's revenue grew 10.9 percent, ahead of the 9.9 percent industry average.¹

In 2008, a group of leading database researchers met in Berkeley and issued a report declaring that the industry had reached an exciting turning point and was on the verge of another database revolution.² Over time, analysts, journalists, and business leaders have seen that new developments, such as the explosion of unstructured data in cyberspace, the growing importance of business intelligence, and the emergence of cloud technologies, may require the development of new database models.

Although relational databases meet rigorous standards for data integrity and consistency, they do not scale unstructured data as well as new database models such as NoSQL.³ As a result, social networking sites such as Twitter and Facebook, which do not require high levels of data consistency and integrity, have adopted NoSQL databases. These types of sites are home to semistructured data such as Web logs and instant messages, giving the NoSQL model an edge in these domains. In addition, as the number of data transactions has skyrocketed in recent years, many “Big Data” companies have turned to these new data models to process their data. When Visa needed to process two years of credit transactions, the company turned to new technologies such as Hadoop to handle the 70 billion transactions; processing time was reduced from one month to 13 minutes.⁴

Another technology that is fast gaining ground is in-memory databases, which store data in main memory rather than secondary storage. In-memory databases take advantage of parallel computing and multicore processors to deliver faster

business intelligence.⁵ Additionally, cloud computing provides on-demand access to clusters of computers on the Web at a reasonable cost. Cloud computing does not require that companies invest heavily in massive server infrastructure.⁶ All these technology advances are revolutionizing the database market. For example, in 2009, SAP co-founder Hasso Plattner announced that his company was taking a lead in developing in-memory databases. He said SAP was close to developing an in-memory system that could accommodate a database large enough for Walmart's needs.

However, the relational model is not standing idly by. Today, most large relational database vendors provide in-memory database capabilities. For example, in 2005, Oracle acquired in-memory database technology with the purchase of TimesTen. Cloud computing is also enabling the widespread adoption of relational databases in organizations that could not previously afford a high-availability infrastructure. The relational model has a history of overcoming challenges from other emerging database technologies, which is why the overwhelming majority of existing systems still rely on relational databases. It remains to be seen if the relational model will evolve one more time and adapt to these new challenges. The race is on.

¹ “Oracle Is #1 in the RDBMS Sector for 2010,” Oracle Website, www.oracle.com/us/products/database/number-one-database-069037.html.

² Rakesh Agrawal et al., “The Claremont Report on Database Research,” <http://db.cs.berkeley.edu/claremont/claremontreport08.pdf>.

³ Guy Harrison, “10 Things You Should Know About NoSQL Databases,” *TechRepublic*, August 26, 2010, www.techrepublic.com/blog/10things/10things-you-should-know-about-nosql-databases/1772.

⁴ David Strom, “NoSQL: Breaking Free of Structured Data,” *IT World*, June 9, 2011, www.itworld.com/data-centerservers/172477/nosql-breaking-free-structured-data.

⁵ Mike Simons, “SAP Cofounder Hasso Plattner Promises in-Memory Database Revolution,” *CIO*, May 14, 2009, www.cio.com/article/492832/SAP_Cofounder_Hasso_Plattner_Promises_in_Memory_Database_Rev

⁶ Joshua Greenbaum, “A Revolution Threatens the Relational Database,” *IT Management*, May 13, 2008, <http://itmanagement.earthweb.com/columns/entad/article.php/3746191>.

1 DATABASE SYSTEMS

In this chapter, you will learn:

- The difference between data and information
 - What a database is, the various types of databases, and why they are valuable assets for decision making
 - The importance of database design
 - How modern databases evolved from file systems
 - About flaws in file system data management
 - The main components of the database system
 - The main functions of a database management system (DBMS)
-

Preview

Good decisions require good information that is derived from raw facts. These raw facts are known as data. Data are likely to be managed most efficiently when they are stored in a database. In this chapter, you will learn what a database is, what it does, and why it yields better results than other data management methods. You will also learn about various types of databases and why database design is so important.

Databases evolved from computer file systems. Although file system data management is now largely outmoded, understanding the characteristics of file systems is important because file systems are the source of serious data management limitations. In this chapter, you will also learn how the database system approach helps eliminate most of the shortcomings of file system data management.

1.1 WHY DATABASES?

Imagine trying to operate a business without knowing who your customers are,

what products you are selling, who is working for you, who owes you money, and to whom you owe money. All businesses have to keep this type of data and much more; just as importantly, they must have those data available to decision makers when necessary. It can be argued that the ultimate purpose of all business information systems is to help businesses use information as an organizational resource. At the heart of all of these systems are the collection, storage, aggregation, manipulation, dissemination, and management of data.

Depending on the type of information system and the characteristics of the business, these data could vary from a few megabytes on just one or two topics to terabytes covering hundreds of topics within the business's internal and external environment. Telecommunications companies such as Sprint and AT&T are known to have systems that keep data on trillions of phone calls, with new data being added to the system at speeds up to 70,000 calls per second!¹ Not only do these companies have to store and manage immense collections of data, they have to be able to find any given fact in that data quickly. Consider the case of Internet search staple Google. While Google is reluctant to disclose many details about its data storage specifications, it is estimated that the company responds to over 91 million searches per day across a collection of data that is several terabytes in size. Impressively, the results of these searches are available almost instantly.

How can these businesses process this much data? How can they store it all, and then quickly retrieve just the facts that decision makers want to know, just when they want to know it? The answer is that they use databases. Databases, as explained in detail throughout this book, are specialized structures that allow computer-based systems to store, manage, and retrieve data very quickly. Virtually all modern business systems rely on databases; therefore, a good understanding of how these structures are created and their proper use is vital for any information systems professional. Even if your career does not take you down the amazing path of database design and development, databases will be a key component underpinning the systems that you use. In any case, you will probably make decisions in your career based on information generated from data. Thus, it is important that you know the difference between data and information.

1.2 DATA VS. INFORMATION

To understand what drives database design, you must understand the difference between data and information. **Data** are raw facts. The word raw indicates that the facts have not yet been processed to reveal their meaning. For example, suppose that a university tracks data on faculty members for reporting to accrediting bodies. To get the data for each faculty member into the database, you would provide a screen to allow for convenient data entry, complete with drop-down lists, combo boxes, option buttons, and other data-entry validation controls. [Figure 1.1](#), Panel A, shows a simple data-entry form from a software package named Sedona. When the data are entered into the form and saved, they are placed in the underlying database as raw data, as shown in [Figure 1.1](#), Panel B. Although you now have the facts in hand, they are not particularly useful in this format. Reading through hundreds of rows of data for faculty members does not provide much insight into the overall makeup of the faculty. Therefore, you transform the raw data into a data summary like the one shown in [Figure 1.1](#), Panel C. Now you can get quick answers to questions such as “What percentage of the faculty in the Information Systems (INFS) department are adjuncts?” In this case, you can quickly determine that 20% of the INFS faculty members are adjunct faculty. Because graphics can enhance your ability to quickly extract meaning from data, you show the data summary pie chart in [Figure 1.1](#), Panel D.

FIGURE 1.1 Transforming raw data into information

a) Data entry screen

The screenshot shows a web-based application for managing faculty members at Middle Tennessee State University. The main page has a header with the university's name and a navigation menu. Below the header, there's a sub-header for 'Faculty' and a link to 'Add Faculty Form'. The form itself has several sections: one for basic information like first name, last name, and department; another for title and rank (e.g., Professor, Associate Professor); and a third for tenure status (Participating or Supporting). There are also checkboxes for 'Chair/Head', 'Instructor', and 'Considered to be a long-term member'. At the bottom, there are dropdown menus for 'High Degree' and 'Year Awarded', and a 'Rank' dropdown.

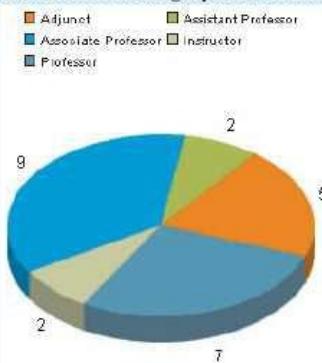
b) Raw data

First Name	Last Name	Title	Rank	Hire Year	Program
3	Whitlington	George	MOAT	1918	Business
2	Astres	Lester	RN	1912	Padron@mtsu.edu
1	Jefferson	L.	COURT	1912	schmieden@mtsu.edu
4	Merkonik	C.	James	1918	jmerkonik@mtsu.edu
5	Mossone	K.	James	1917	jmosson@mtsu.edu
6	Moore	C.	James	1917	jmoore@mtsu.edu
7	Jacobs	C.	Andrea	1990	ajacobs@mtsu.edu
8	Van Seren	T.	Markie	1996	mvanseren@mtsu.edu
9	Harrison	P.	Matthew	1915	wharrison@mtsu.edu
10	Tyler	N.	Matthew	1915	tylern@mtsu.edu
11	Wright	J.	Matthew	1915	jwright@mtsu.edu
12	Taylor	G.	Matthew	1915	gtaylor@mtsu.edu
13	Filimon	S.	Millard	1915	mfilimon@mtsu.edu
14	Pearce	A.	Merle	1953	gpearce@mtsu.edu
15	Bachman	T.	James	1917	tbachman@mtsu.edu
16	Wright	W.	James	1917	wwright@mtsu.edu
17	Johnson	A.	Archibald	1930	ajohnson@mtsu.edu
18	Johnson	S.	Albert	1915	ajohnson@mtsu.edu
19	Griffith	T.	Albert	1915	tgriffith@mtsu.edu
20	Overholt	G.	Albert	1915	goverholt@mtsu.edu
21	Overholt	G.	Albert	1915	goverholt@mtsu.edu
22	Harmon	X.	Albert	1915	pharmon@mtsu.edu
23	McClintock	B.	Philippa	1932	bmclintock@mtsu.edu
24	Douglas	P.	Philippe	1932	pdouglas@mtsu.edu
25	Miller	E.	Philippe	1932	emiller@mtsu.edu
26	Miller	E.	Philippe	1932	emiller@mtsu.edu
27	Miller	E.	Philippe	1932	emiller@mtsu.edu
28	Miller	E.	Philippe	1932	emiller@mtsu.edu
29	Wright	V.	Philippe	1932	vwright@mtsu.edu
30	Conditte	C.	Robert	1915	cconditte@mtsu.edu
31	Hoyer	U.	Robert	1915	uhoyer@mtsu.edu
32	Johnson	U.	Robert	1915	ujohnson@mtsu.edu

c) Information in summary format

Rank	COUNT	%/INFS	TOT/COL	%/COL.TOT.	%/COL. FAC.
Adjunct	5	20.00%	23	21.74%	3.27%
Assistant Professor	2	8.00%	28	7.14%	1.31%
Associate Professor	9	36.00%	37	24.32%	5.68%
Instructor	2	8.00%	18	11.11%	1.31%
Professor	7	28.00%	47	14.89%	4.58%

d) Information in graphical format



SOURCE: Course Technology/Cengage Learning Data entry screen courtesy of Sedona Systems, 2011. Information screens courtesy of JCBDashboard, 2011.

Information is the result of processing raw data to reveal its meaning. Data processing can be as simple as organizing data to reveal patterns or as complex as making forecasts or drawing inferences using statistical modeling. To reveal meaning, information requires *context*. For example, an average temperature reading of 105 degrees does not mean much unless you also know its context: Is this reading in degrees Fahrenheit or Celsius? Is this a machine temperature, a body temperature, or an outside air temperature? Information can be used as the foundation for decision making. For example, the data summary for the faculty can provide accrediting bodies with insights that are useful in determining whether to renew accreditation for the university.

Keep in mind that raw data must be properly *formatted* for storage, processing, and presentation. For example, dates might be stored in Julian calendar formats within the database, but displayed in a variety of formats, such as day-month-year or month/day/year, for different purposes. Respondents' yes/no responses might need to be converted to a Y/N, or 0/1, format for data storage. More complex formatting is required when working with complex data types, such as

sounds, videos, or images.

In this “information age,” production of accurate, relevant, and timely information is the key to good decision making. In turn, good decision making is the key to business survival in a global market. We are now said to be entering the “knowledge age.”² Data are the foundation of information, which is the bedrock of **knowledge**—that is, the body of information and facts about a specific subject. Knowledge implies familiarity, awareness, and understanding of information as it applies to an environment. A key characteristic of knowledge is that “new” knowledge can be derived from “old” knowledge.

Let’s summarize some key points:

- Data constitute the building blocks of information.
- Information is produced by processing data.
- Information is used to reveal the meaning of data.
- Accurate, relevant, and timely information is the key to good decision making.
- Good decision making is the key to organizational survival in a global environment.

Timely and useful information requires accurate data. Such data must be properly generated and stored in a format that is easy to access and process. And, like any basic resource, the data environment must be managed carefully. **Data management** is a discipline that focuses on the proper generation, storage, and retrieval of data. Given the crucial role that data play, it should not surprise you that data management is a core activity for any business, government agency, service organization, or charity.

1.3 INTRODUCING THE DATABASE

Efficient data management typically requires the use of a computer database. A **database** is a shared, integrated computer structure that stores a collection of:

- End-user data—that is, raw facts of interest to the end user.
- **Metadata**, or data about data, through which the end-user data are integrated and managed.

The metadata describe the data characteristics and the set of relationships that links the data found within the database. For example, the metadata component stores information such as the name of each data element, the type of values (numeric, dates, or text) stored on each data element, and whether the data element can be left empty. The metadata provide information that complements and expands the value and use of the data. In short, metadata present a more complete picture of the data in the database. Given the characteristics of metadata, you might hear a database described as a “collection of *self-describing* data.”

A **database management system (DBMS)** is a collection of programs that manages the database structure and controls access to the data stored in the database. In a sense, a database resembles a very well-organized electronic filing cabinet in which powerful software (the DBMS) helps manage the cabinet’s contents.

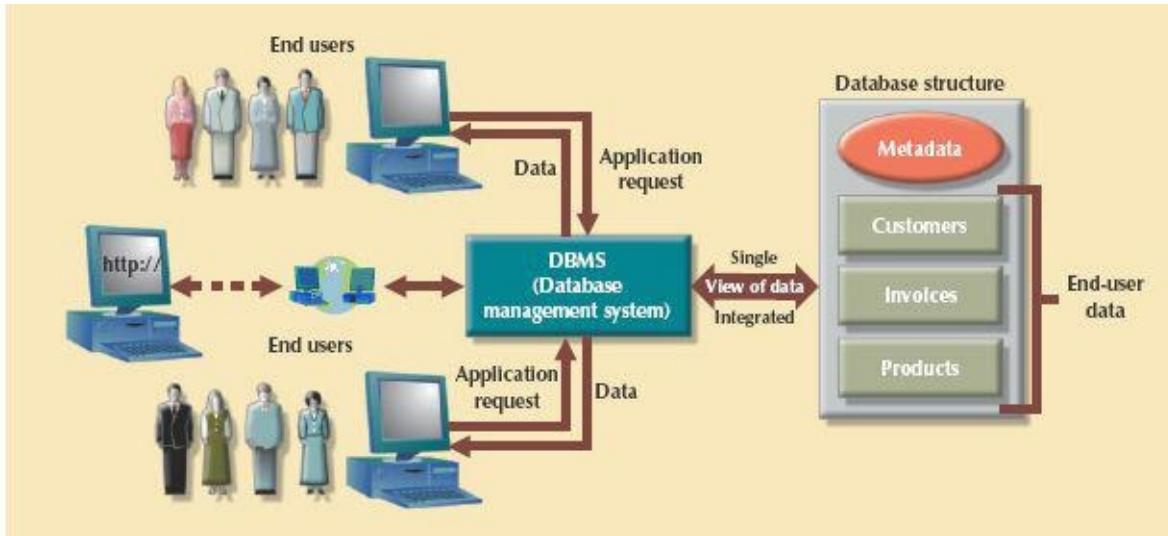
1.3.1 ROLE AND ADVANTAGES OF THE DBMS

The DBMS serves as the intermediary between the user and the database. The database structure itself is stored as a collection of files, and the only way to access the data in those files is through the DBMS. [Figure 1.2](#) emphasizes the point that the DBMS presents the end user (or application program) with a single, integrated view of the data in the database. The DBMS receives all application requests and translates them into the complex operations required to fulfill those requests. The DBMS hides much of the database’s internal complexity from the application programs and users. The application program might be written by a programmer using a programming language such as Visual Basic.NET, Java, or C#, or it might be created through a DBMS utility program.

Having a DBMS between the end user’s applications and the database offers some important advantages. First, the DBMS enables the data in the database *to be shared* among multiple applications or users. Second, the DBMS *integrates* the many different users’ views of the data into a single all-encompassing data

repository.

FIGURE 1.2 The DBMS manages the interaction between the end user and the database



SOURCE: Course Technology/Cengage Learning

Because data are the crucial raw material from which information is derived, you must have a good method to manage such data. As you will discover in this book, the DBMS helps make data management more efficient and effective. In particular, a DBMS provides advantages such as:

- *Improved data sharing.* The DBMS helps create an environment in which end users have better access to more and better-managed data. Such access makes it possible for end users to respond quickly to changes in their environment.
- *Improved data security.* The more users access the data, the greater the risks of data security breaches. Corporations invest considerable amounts of time, effort, and money to ensure that corporate data are used properly. A DBMS provides a framework for better enforcement of data privacy and security policies.
- *Better data integration.* Wider access to well-managed data promotes an

integrated view of the organization's operations and a clearer view of the big picture. It becomes much easier to see how actions in one segment of the company affect other segments.

- *Minimized data inconsistency.* **Data inconsistency** exists when different versions of the same data appear in different places. For example, data inconsistency exists when a company's sales department stores a sales representative's name as Bill Brown and the company's personnel department stores that same person's name as *William G. Brown*, or when the company's regional sales office shows the price of a product as \$45.95 and its national sales office shows the same product's price as \$43.95. The probability of data inconsistency is greatly reduced in a properly designed database.
- *Improved data access.* The DBMS makes it possible to produce quick answers to ad hoc queries. From a database perspective, a **query** is a specific request issued to the DBMS for data manipulation—for example, to read or update the data. Simply put, a query is a question, and an **ad hoc query** is a spur-of-the-moment question. The DBMS sends back an answer (called the **query result set**) to the application. For example, when dealing with large amounts of sales data, end users might want quick answers to questions (ad hoc queries). Some examples include:
 - What was the dollar volume of sales by product during the past six months?
 - What is the sales bonus figure for each of our salespeople during the past three months?
 - How many of our customers have credit balances of \$3,000 or more?
- *Improved decision making.* Better-managed data and improved data access make it possible to generate better-quality information, on which better decisions are based. The quality of the information generated depends on the quality of the underlying data. **Data quality** is a comprehensive approach to promoting the accuracy, validity, and timeliness of the data. While the DBMS does not guarantee data quality, it provides a framework to facilitate data quality initiatives. Data quality concepts will be covered in more detail in [Chapter 15](#), Database Administration and Security.

- *Increased end-user productivity.* The availability of data, combined with the tools that transform data into usable information, empowers end users to make quick, informed decisions that can make the difference between success and failure in the global economy.

The advantages of using a DBMS are not limited to the few just listed. In fact, you will discover many more advantages as you learn more about the technical details of databases and their proper design.

1.3.2 TYPES OF DATABASES

A DBMS can be used to build many different types of databases. Each database stores a particular collection of data and is used for a specific purpose. Over the years, as technology and innovative uses of databases have evolved, different methods have been used to classify databases. For example, databases can be classified by the number of users supported, where the data are located, the type of data stored, the intended data usage, and the degree to which the data are structured.

The number of users determines whether the database is classified as single-user or multiuser. A **single-user database** supports only one user at a time. In other words, if user A is using the database, users B and C must wait until user A is done. A single-user database that runs on a personal computer is called a **desktop database**. In contrast, a **multiuser database** supports multiple users at the same time. When the multiuser database supports a relatively small number of users (usually fewer than 50) or a specific department within an organization, it is called a **workgroup database**. When the database is used by the entire organization and supports many users (more than 50, usually hundreds) across many departments, the database is known as an **enterprise database**.

Location might also be used to classify the database. For example, a database that supports data located at a single site is called a **centralized database**. A database that supports data distributed across several different sites is called a **distributed database**. The extent to which a database can be distributed and the way in which such distribution is managed are addressed in detail in [Chapter 12](#), Distributed Database Management Systems.

In some contexts, such as research environments, a popular way of classifying databases is according to the type of data stored in them. Using this criterion,

databases are grouped into two categories: general-purpose and discipline-specific databases. **[General-purpose databases](#)** contain a wide variety of data used in multiple disciplines—for example, a census database that contains general demographic data, and the LexisNexis and ProQuest databases that contain newspaper, magazine, and journal articles for a variety of topics. **[Discipline-specific databases](#)** contain data focused on specific subject areas. The data in this type of database are used mainly for academic or research purposes within a small set of disciplines. Examples of discipline-specific databases include financial data stored in databases such as CompuStat or CRSP, geographic information system (GIS) databases that store geospatial and other related data, and medical databases that store confidential medical history data.

The most popular way of classifying databases today, however, is based on how they will be used and on the time sensitivity of the information gathered from them. For example, transactions such as product or service sales, payments, and supply purchases reflect critical day-to-day operations. Such transactions must be recorded accurately and immediately. A database that is designed primarily to support a company's day-to-day operations is classified as an **[operational database](#)**, also known as an **[online transaction processing \(OLTP\)](#)**, **[transactional](#)**, or **[production database](#)**. In contrast, **[analytical databases](#)** focus primarily on storing historical data and business metrics used exclusively for tactical or strategic decision making. Such analysis typically requires extensive “data massaging” (data manipulation) to produce information on which to base pricing decisions, sales forecasts, market strategies, and so on. Analytical databases allow the end user to perform advanced data analysis of business data using sophisticated tools.

Typically, analytical databases comprise two main components: a data warehouse and an online analytical processing (OLAP) front end. The **[data warehouse](#)** is a specialized database that stores data in a format optimized for decision support. The data warehouse contains historical data obtained from the operational databases as well as data from other external sources. **[Online analytical processing \(OLAP\)](#)** is a set of tools that work together to provide an advanced data analysis environment for retrieving, processing, and modeling data from the data warehouse. In recent times, this area of database application has grown in importance and usage, to the point that it has evolved into its own discipline: business intelligence. The term **[business intelligence](#)** describes a comprehensive approach to capture and process business data with the purpose of generating information to support business decision making. [Chapter 13](#), Business Intelligence and Data Warehouses, covers this topic in detail.

Databases can also be classified to reflect the degree to which the data are structured. **Unstructured data** are data that exist in their original (raw) state—that is, in the format in which they were collected. Therefore, unstructured data exist in a format that does not lend itself to the processing that yields information. **Structured data** are the result of formatting unstructured data to facilitate storage, use, and the generation of information. You apply structure (format) based on the type of processing that you intend to perform on the data. Some data might not be ready (unstructured) for some types of processing, but they might be ready (structured) for other types of processing. For example, the data value 37890 might refer to a zip code, a sales value, or a product code. If this value represents a zip code or a product code and is stored as text, you cannot perform mathematical computations with it. On the other hand, if this value represents a sales transaction, it must be formatted as numeric.

To further illustrate the concept of structure, imagine a stack of printed paper invoices. If you want to merely store these invoices as images for future retrieval and display, you can scan them and save them in a graphic format. On the other hand, if you want to derive information such as monthly totals and average sales, such graphic storage would not be useful. Instead, you could store the invoice data in a (structured) spreadsheet format so that you can perform the requisite computations. Actually, most data you encounter are best classified as semistructured. **Semistructured data** have already been processed to some extent. For example, if you look at a typical Web page, the data are presented in a prearranged format to convey some information. The database types mentioned thus far focus on the storage and management of highly structured data. However, corporations are not limited to the use of structured data. They also use semistructured and unstructured data. Just think of the valuable information that can be found on company e-mails, memos, and documents such as procedures, rules, and Web pages. Unstructured and semistructured data storage and management needs are being addressed through a new generation of databases known as XML databases. **Extensible Markup Language (XML)** is a special language used to represent and manipulate data elements in a textual format. An **XML database** supports the storage and management of semistructured XML data.

Table 1.1 compares the features of several well-known database management systems.

Table 1.1 Types of Databases

PRODUCT	NUMBER OF USERS			DATA LOCATION		DATA USAGE		XML	
	SINGLE USER	MULTIUSER		CENTRALIZED	DISTRIBUTED	OPERATIONAL	ANALYTICAL		
		WORKGROUP	ENTERPRISE						
MS Access	X	X		X		X			
MS SQL Server	X ³	X	X	X	X	X	X	X	
IBM DB2	X ³	X	X	X	X	X	X	X	
MySQL	X	X	X	X	X	X	X	X	
Oracle RDBMS	X ³	X	X	X	X	X	X	X	

With the emergence of the World Wide Web and Internet-based technologies as the basis for the new “social media” generation, great amounts of data are being stored and analyzed. **Social media** refers to Web and mobile technologies that enable “anywhere, anytime, always on” human interactions. Websites such as Google, Facebook, MySpace, Twitter, and LinkedIn capture vast amounts of data about end users and consumers. These data grow exponentially and require the use of specialized database systems. Over the past few years, this new breed of specialized database has grown in sophistication and widespread usage. Currently, this new type of database is known as a NoSQL database. The term **NoSQL** (Not only SQL) is generally used to describe a new generation of database management systems that is not based on the traditional relational database model. You will learn more about this type of system in [Chapter 2](#), Data Models.

1.4 WHY DATABASE DESIGN IS IMPORTANT

Database design refers to the activities that focus on the design of the database structure that will be used to store and manage end-user data. A database that meets all user requirements does not just happen; its structure must be designed carefully. In fact, database design is such a crucial aspect of working with databases that most of this book is dedicated to the development of good database design techniques. Even a good DBMS will perform poorly with a badly designed database.

Data is one of an organization’s most valuable assets. Data on customers, employees, orders, and receipts are all vital to the existence of a company. Tracking key growth and performance indicators are also vital to strategic and

tactical plans to ensure future success; therefore, an organization's data must not be handled lightly or carelessly. Thorough planning to ensure that data are properly used and leveraged to give the company the most benefit is just as important as proper financial planning to ensure that the company gets the best use from its financial resources.

Because current-generation DBMSs are easy to use, an unfortunate side effect is that many computer-savvy business users gain a false sense of confidence in their ability to build a functional database. These users can effectively navigate the creation of database objects, but without the proper understanding of database design, they tend to produce flawed, overly simplified structures that prevent the system from correctly storing data that corresponds to business realities, which produces incomplete or erroneous results when the data are retrieved. Consider the data shown in [Figure 1.3](#), which illustrates the storage of data about employees and skills. Some employees have not passed a certification test in any skill, while others have been certified in several skills. Some certified skills are stored for several employees, while other skills have no employees that hold those certifications.

FIGURE 1.3 Employee skill certification in a poor design

ID	EmployeeNumber	EmployeeName	Skill1	Skill1Date	Skill2	Skill2Date	Skill3	Skill3Date
1	02345	Johnny Jones	Basic Database Management	2/14/1993	Advanced Database Management	2/14/1993	Basic Web Design	8/9/1999
2	08273	Marco Bienz	Basic Web Design	3/8/2005	Advanced Process Modeling	8/19/2008		
3	06234	Jasmine Patel	Basic Web Design	8/10/2003	Advanced C# programming	8/10/2003	Basic DB manipulation	1/29/2008
4	03373	Franklin Johnson, Jr.	Advanced Spreadsheets	6/20/2007				
5	13567	Almond, Robert	Basic Process Modeling	9/30/2010	Basic Database Design	5/23/2011		
6	10282	Richardson, Amanda						
7	09382	Jessica Johnson	Basic DB Design	8/2/2008	Basic Database Manipulation	8/2/2008	Advanced DB Manipulation	5/1/2009
8	14311	Duong, Lee	Basic Web Design	9/1/2012				
9			Master Database Programming					
10			Basic Spreadsheets					
11	09002	Ben Joiner	Advanced Spreadsheets	5/16/2009	Basic Web Design	5/16/2009		
12	13383	Raymond F. Matthews	Basic C# Programming	3/12/2010				
13	09283	Chavez, Juan						
14	04893	Patricia Richards	Advanced Database Management	6/11/2002	Advanced Database Manipulation	9/20/2008		
15	13932	Lee, Megan						

SOURCE: Course Technology/Cengage Learning

Based on this storage of the data, notice the following problems.

- It would be difficult, if not impossible, to produce an alphabetical listing of employees based on their last names.

- To determine how many employees are certified in Basic Database Manipulation, you would need a program that counts the number of those certifications recorded in Skill1 and places it in a variable. Then the count of those certifications in Skill2 could be calculated and added to the variable. Finally, the count of those certifications in Skill3 could be calculated and added to the variable to produce the total.
- If you redundantly store the name of a skill with each employee who is certified in that skill, you run the risk of spelling the name differently for different employees. For example, the skill *Basic Database Manipulation* is also entered as *Basic DB Manipulation* for at least one employee in [Figure 1.3](#), which makes it difficult to get an accurate count of employees who have the certification.
- The structure of the database will have to be changed by adding more columns to the table when an employee is certified in a fourth skill. It will have to be modified again if an employee is certified in a fifth skill.

Contrast this poor design with that shown in [Figure 1.4](#), where the design has been improved by decomposing the data into three related tables. These tables contain all of the same data that were represented in [Figure 1.3](#), but they are structured so that you can easily manipulate the data to view it in different ways and answer simple questions.

FIGURE 1.4 Employee skill certifications in a good design

Table name: EMPLOYEE

Employee_ID	Employee_FName	Employee_LName	Employee_HireDate	Employee_Title
02345	Johnny	Jones	2/14/1993	DBA
03373	Franklin	Johnson	3/15/2000	Purchasing Agent
04893	Patricia	Richards	6/11/2002	DBA
06234	Jasmine	Patel	8/10/2003	Programmer
08273	Marco	Bienz	7/28/2004	Analyst
09002	Ben	Joiner	5/20/2008	Clerk
09283	Juan	Chavez	7/4/2008	Clerk
09382	Jessica	Johnson	8/2/2008	Database Programmer
10262	Amanda	Richardson	4/11/2009	Clerk
13383	Raymond	Matthews	3/12/2010	Programmer
13567	Robert	Almond	9/30/2010	Analyst
13932	Megan	Lee	9/29/2011	Programmer
14311	Lee	Duong	9/1/2012	Programmer

Table name: CERTIFIED

Employee_ID	Skill_ID	Certified_Date
02345	100	2/14/1993
02345	110	8/9/1999
02345	180	2/14/1993
03373	120	6/20/2007
04893	180	6/11/2002
04893	220	9/20/2008
06234	110	8/10/2003
06234	200	8/10/2003
06234	210	1/29/2008
08273	110	3/8/2005
08273	190	8/19/2008
09002	110	5/16/2009
09002	120	5/16/2009
09382	140	8/2/2008
09382	210	8/2/2008
09382	220	5/1/2009
13383	170	3/12/2010
13567	130	9/30/2010
13567	140	5/23/2011
14311	110	9/1/2012

Table name: SKILL

Skill_ID	Skill_Name	Skill_Description
100	Basic Database Management	Create and manage database user accounts.
110	Basic Web Design	Create and maintain HTML and CSS documents.
120	Advanced Spreadsheets	Use of advanced functions, user-defined functions, and macroing.
130	Basic Process Modeling	Create core business process models using standard libraries.
140	Basic Database Design	Create simple data models.
150	Master Database Programming	Create integrated trigger and procedure packages for a distributed environment.
160	Basic Spreadsheets	Create single tab worksheets with basic formulas.
170	Basic C# Programming	Create single-tier data aware modules.
180	Advanced Database Management	Manage Database Server Clusters.
190	Advanced Process Modeling	Evaluate and Redesign cross-functional internal and external business processes.
200	Advanced C# Programming	Create multi-tier applications using multi-threading.
210	Basic Database Manipulation	Create simple data retrieval and manipulation statements in SQL.
220	Advanced Database Manipulation	Use of advanced data manipulation methods for multi-table inserts, set operations, and correlated subqueries.

SOURCE: Course Technology/Cengage Learning

With the improved structure in [Figure 1.4](#), you can use simple commands in a standard data manipulation language to:

- Produce an alphabetical listing of employees by last name: `SELECT * FROM EMPLOYEE ORDER BY EMPLOYEE_LNAME;`
- Determine how many employees are certified in Basic Database Manipulation: `SELECT Count(*) FROM SKILL JOIN CERTIFIED ON SKILL.SKILL_ID = CERTIFIED.SKILL_ID WHERE SKILL_NAME = 'Basic Database Manipulation';`

You will learn more about these commands in [Chapter 7](#), Introduction to Structured Query Language.

Note that because each skill name is stored only once, the names cannot be

spelled or abbreviated differently for different employees. Also, the additional certification of an employee with a fourth or fifth skill does not require changes to the structure of the tables.

Proper database design requires the designer to identify precisely the database's expected use. Designing a transactional database emphasizes accurate and consistent data and operational speed. Designing a data warehouse database emphasizes the use of historical and aggregated data. Designing a database to be used in a centralized, single-user environment requires a different approach from that used in the design of a distributed, multiuser database. This book emphasizes the design of transactional, centralized, single-user, and multiuser databases. [Chapters 12](#) and [13](#) also examine critical issues confronting the designer of distributed and data warehouse databases.

Designing appropriate data repositories of integrated information using the two-dimensional table structures found in most databases is a process of decomposition. The integrated data must be decomposed properly into its constituent parts, with each part stored in its own table. Further, the relationships between these tables must be carefully considered and implemented so the integrated view of the data can be re-created later as information for the end user. A well-designed database facilitates data management and generates accurate and valuable information. A poorly designed database is likely to become a breeding ground for difficult-to-trace errors that may lead to bad decision making—and bad decision making can lead to the failure of an organization. Database design is simply too important to be left to luck. That's why college students study database design, why organizations of all types and sizes send personnel to database design seminars, and why database design consultants often make an excellent living.

1.5 EVOLUTION OF FILE SYSTEM DATA PROCESSING

Understanding what a database is, what it does, and the proper way to use it can be clarified by considering what a database is not. A brief explanation of the evolution of file system data processing can be helpful in understanding the data access limitations that databases attempt to overcome. Understanding these limitations is relevant to database designers and developers because database technologies do not make these problems magically disappear—database technologies simply make it easier to create solutions that avoid these problems.

Creating database designs that avoid the pitfalls of earlier systems requires that the designer understand these problems and how to avoid them; otherwise, the database technologies are no better (and are potentially even worse!) than the technologies and techniques they have replaced.

1.5.1 MANUAL FILE SYSTEMS

To be successful, an organization must develop systems for handling core business tasks. Historically, such systems were often manual, paper-and-pencil systems. The papers within these systems were organized to facilitate the expected use of the data. Typically, this was accomplished through a system of file folders and filing cabinets. As long as a collection of data was relatively small and an organization's business users had few reporting requirements, the manual system served its role well as a data repository. However, as organizations grew and as reporting requirements became more complex, keeping track of data in a manual file system became more difficult. Therefore, companies looked to computer technology for help.

1.5.2 COMPUTERIZED FILE SYSTEMS

Generating reports from manual file systems was slow and cumbersome. In fact, some business managers faced government-imposed reporting requirements that led to weeks of intensive effort each quarter, even when a well-designed manual system was used. Therefore, a **data processing (DP) specialist** was hired to create a computer-based system that would track data and produce required reports.

Initially, the computer files within the file system were similar to the manual files. A simple example of a customer data file for a small insurance company is shown in [Figure 1.5](#). (You will discover later that the file structure shown in [Figure 1.5](#), although typically found in early file systems, is unsatisfactory for a database.)

The description of computer files requires a specialized vocabulary. Every discipline develops its own terminology to enable its practitioners to communicate clearly. The basic file vocabulary shown in [Table 1.2](#) will help you to understand subsequent discussions more easily.

FIGURE 1.5 Contents of the CUSTOMER file

C_NAME	C_PHONE	C_ADDRESS	C_ZIP	A_NAME	A_PHONE	TP	AMT	REN
Alfred A. Ramas	615-844-2573	218 Fork Rd., Babs, TN	36123	Leah F. Hahn	615-882-1244	T1	100.00	05-Apr-2012
Leona K. Dunne	713-894-1238	Box 12A, Fox, KY	25246	Alex B. Alby	713-228-1249	T1	250.00	16-Jun-2012
Kathy W. Smith	615-894-2285	125 Oak Ln., Babs, TN	36123	Leah F. Hahn	615-882-2144	S2	150.00	29-Jan-2013
Paul F. Ołowski	615-894-2180	217 Lee Ln., Babs, TN	36123	Leah F. Hahn	615-882-1244	S1	300.00	14-Oct-2012
Myron Orlando	615-222-1672	Box 111, New, TN	36155	Alex B. Alby	713-228-1249	T1	100.00	28-Dec-2012
Amy B. O'Brien	713-442-3381	387 Troll Dr., Fox, KY	25246	John T. Okon	615-123-5589	T2	850.00	22-Sep-2012
James G. Brown	615-297-1228	21 Tye Rd., Nash, TN	37118	Leah F. Hahn	615-882-1244	S1	120.00	25-Mar-2013
George Williams	615-290-2556	155 Maple, Nash, TN	37119	John T. Okon	615-123-5589	S1	250.00	17-Jul-2012
Anne G. Farriss	713-382-7185	2119 Elm, Crew, KY	25432	Alex B. Alby	713-228-1249	T2	100.00	03-Dec-2012
Olette K. Smith	615-297-3809	2782 Main, Nash, TN	37118	John T. Okon	615-123-5589	S2	500.00	14-Mar-2013

C_NAME = Customer name **A_NAME** = Agent name
C_PHONE = Customer phone **A_PHONE** = Agent phone
C_ADDRESS = Customer address **TP** = Insurance type
C_ZIP = Customer zip code **AMT** = Insurance policy amount, in thousands of \$
REN = Insurance renewal date

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The databases used in each chapter are available at www.cengagebrain.com. Throughout the book, Online Content boxes highlight material related to chapter content on the Website.

TABLE 1.2 Basic File Terminology

TERM DEFINITION

- Data** Raw facts, such as a telephone number, a birth date, a customer name, and a year-to-date (YTD) sales value. Data have little meaning unless they have been organized in some logical manner.
- Field** A character or group of characters (alphabetic or numeric) that has a specific meaning. A field is used to define and store data.

Record	A logically connected set of one or more fields that describes a person, place, or thing. For example, the fields that constitute a customer record might consist of the customer's name, address, phone number, date of birth, credit limit, and unpaid balance.
File	A collection of related records. For example, a file might contain data about the students currently enrolled at Gigantic University.

Using the proper file terminology in [Table 1.2](#), you can identify the file components shown in [Figure 1.5](#). The CUSTOMER file contains 10 records. Each record is composed of nine fields: C_NAME, C_PHONE, C_ADDRESS, C_ZIP, A_NAME, A_PHONE, TP, AMT, and REN. The 10 records are stored in a named file. Because the file in [Figure 1.5](#) contains customer data for the insurance company, its filename is CUSTOMER.

When business users wanted data from the computerized file, they sent requests for the data to the DP specialist. For each request, the DP specialist had to create programs to retrieve the data from the file, manipulate it in whatever manner the user had requested, and present it as a printed report. If a request was for a report that had been run previously, the DP specialist could rerun the existing program and provide the printed results to the user. As other business users saw the new and innovative ways in which customer data were being reported, they wanted to be able to view their data in similar fashions. This generated more requests for the DP specialist to create more computerized files of other business data, which in turn meant that more data management programs had to be created, and more requests for reports. For example, the sales department at the insurance company created a file named SALES, which helped track daily sales efforts. The sales department's success was so obvious that the personnel department manager demanded access to the DP specialist to automate payroll processing and other personnel functions. Consequently, the DP specialist was asked to create the AGENT file shown in [Figure 1.6](#). The data in the AGENT file were used to write checks, keep track of taxes paid, and summarize insurance coverage, among other tasks.

FIGURE 1.6 Contents of the AGENT file

A_NAME	A_PHONE	A_ADDRESS	ZIP	HIRED	YTD_PAY	YTD_FIT	YTD_FICA	YTD_SLS	DEP
Alex B. Alby	713-228-1249	123 Toll, Nash, TN	37119	01-Nov-2000	26566.24	6641.56	2125.30	132737.75	3
Leah F. Hahn	615-882-1244	334 Main, Fox, KY	25246	23-May-1986	32213.78	8053.44	2577.10	138967.35	0
John T. Okon	615-123-5589	452 Elm, New, TN	36155	15-Jun-2005	23198.29	5799.57	1855.86	127093.45	2

A_NAME = Agent name

YTD_PAY = Year-to-date pay

A_PHONE = Agent phone

YTD_FIT = Year-to-date federal income tax paid

A_ADDRESS = Agent address

YTD_FICA = Year-to-date Social Security taxes paid

ZIP = Agent zip code

YTD_SLS = Year-to-date sales

HIRED = Agent date of hire

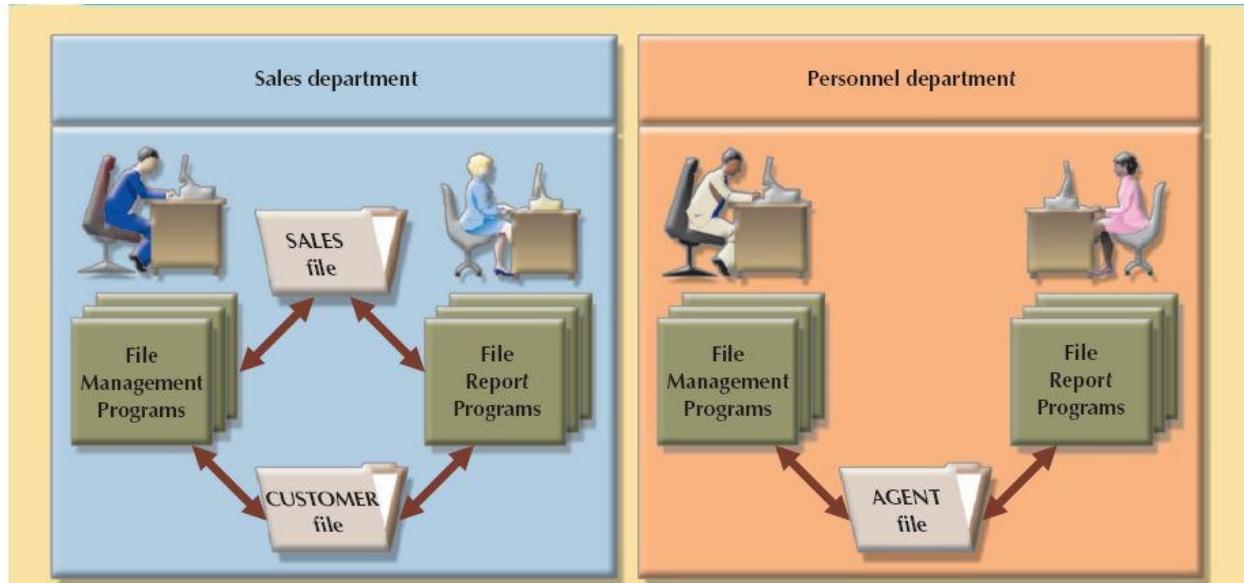
DEP = Number of dependents

SOURCE: Course Technology/Cengage Learning

As more and more computerized files were developed, the problems with this type of file system became apparent. While these problems are explored in detail in the next section, the problems basically centered on having many data files that contained related—often overlapping—data with no means of controlling or managing the data consistently across all of the files. As shown in [Figure 1.7](#), each file in the system used its own application program to store, retrieve, and modify data. Also, each file was owned by the individual or the department that commissioned its creation.

The advent of computer files to store company data was significant; it not only established a landmark in the use of computer technologies, it also represented a huge step forward in a business's ability to process data. Previously, users had direct, hands-on access to all of the business data. But they didn't have the tools to convert those data into the information they needed. The creation of computerized file systems gave them improved tools for manipulating the company data that allowed them to create new information. However, it had the additional effect of introducing a schism between the end users and their data. The desire to close the gap between the end users and the data influenced the development of many types of computer technologies, system designs, and uses (and misuses) of many technologies and techniques. However, such developments also created a split between the ways DP specialists and end users viewed the data.

FIGURE 1.7 A simple file system



SOURCE: Course Technology/Cengage Learning

- From the DP specialist's perspective, the computer files within the file system were created to be similar to the manual files. Data management programs were created to add to, update, and delete data from the file.
- From the end user's perspective, the systems separated the users from the data. As the users' competitive environment pushed them to make more and more decisions in less time, users became frustrated by the delay between conceiving of a new way to create information from the data and the point when the DP specialist actually created the programs to generate that information.

1.5.3 FILE SYSTEM REDUX: MODERN END-USER PRODUCTIVITY TOOLS

The users' desire for direct, hands-on access to data helped to fuel the adoption of personal computers for business use. Although not directly related to file system evolution, the ubiquitous use of personal productivity tools can introduce the same problems as the old file systems.

Personal computer spreadsheet programs such as Microsoft Excel are widely used by business users, and they allow the user to enter data in a series of rows and columns so the data can be manipulated using a wide range of functions. The popularity of spreadsheet applications has enabled users to conduct

sophisticated data analysis that has greatly enhanced their ability to understand the data and make better decisions. Unfortunately, as in the old adage “When the only tool you have is a hammer, every problem looks like a nail,” users have become so adept at working with spreadsheets, they tend to use them to complete tasks for which spreadsheets are not appropriate.

A common misuse of spreadsheets is as a substitute for a database. Interestingly, end users often take the limited data to which they have direct access and place it in a spreadsheet format similar to that of the traditional, manual data storage systems—which is precisely what the early DP specialists did when creating computerized data files. Due to the large number of users with spreadsheets, each making separate copies of the data, the resulting “file system” of spreadsheets suffers from the same problems as the file systems created by the early DP specialists, which are outlined in the next section.

1.6 PROBLEMS WITH FILE SYSTEM DATA PROCESSING

The file system method of organizing and managing data was a definite improvement over the manual system, and the file system served a useful purpose in data management for over two decades—a very long time in the computer era. Nonetheless, many problems and limitations became evident in this approach. A critique of the file system method serves two major purposes:

- Understanding the shortcomings of the file system enables you to understand the development of modern databases.
- Many of the problems are not unique to file systems. Failure to understand such problems is likely to lead to their duplication in a database environment, even though database technology makes it easy to avoid them.

The following problems associated with file systems, whether created by DP specialists or through a series of spreadsheets, severely challenge the types of information that can be created from the data as well as the accuracy of the information:

- *Lengthy development times.* The first and most glaring problem with the file system approach is that even the simplest data-retrieval task requires

extensive programming. With the older file systems, programmers had to specify what must be done and how to do it. As you will learn in upcoming chapters, modern databases use a nonprocedural data manipulation language that allows the user to specify what must be done without specifying how.

- *Difficulty of getting quick answers.* The need to write programs to produce even the simplest reports makes ad hoc queries impossible. Harried DP specialists who work with mature file systems often receive numerous requests for new reports. They are often forced to say that the report will be ready “next week” or even “next month.” If you need the information now, getting it next week or next month will not serve your information needs.
- *Complex system administration.* System administration becomes more difficult as the number of files in the system expands. Even a simple file system with a few files requires creating and maintaining several file management programs. Each file must have its own file management programs that allow the user to add, modify, and delete records; to list the file contents; and to generate reports. Because ad hoc queries are not possible, the file reporting programs can multiply quickly. The problem is compounded by the fact that each department in the organization “owns” its data by creating its own files.
- *Lack of security and limited data sharing.* Another fault of a file system data repository is a lack of security and limited data sharing. Data sharing and security are closely related. Sharing data among multiple geographically dispersed users introduces a lot of security risks. In terms of spreadsheet data, while many spreadsheet programs provide rudimentary security options, they are not always used, and even when they are, they are insufficient for robust data sharing among users. In terms of creating data management and reporting programs, security and data-sharing features are difficult to program and consequently are often omitted from a file system environment. Such features include effective password protection, the ability to lock out parts of files or parts of the system itself, and other measures designed to safeguard data

confidentiality. Even when an attempt is made to improve system and data security, the security devices tend to be limited in scope and effectiveness.

- *Extensive programming.* Making changes to an existing file structure can be difficult in a file system environment. For example, changing just one field in the original CUSTOMER file would require a program that:
 1. Reads a record from the original file.
 2. Transforms the original data to conform to the new structure's storage requirements.
 3. Writes the transformed data into the new file structure.
 4. Repeats the preceding steps for each record in the original file.

In fact, any change to a file structure, no matter how minor, forces modifications in all of the programs that use the data in that file. Modifications are likely to produce errors (bugs), and additional time is spent using a debugging process to find those errors. Those limitations, in turn, lead to problems of structural and data dependence.

1.6.1 STRUCTURAL AND DATA DEPENDENCE

A file system exhibits **structural dependence**, which means that access to a file is dependent on its structure. For example, adding a customer date-of-birth field to the CUSTOMER file shown in [Figure 1.5](#) would require the four steps described in the previous section. Given this change, none of the previous programs will work with the new CUSTOMER file structure. Therefore, all of the file system programs must be modified to conform to the new file structure. In short, because the file system application programs are affected by changes in the file structure, they exhibit structural dependence. Conversely, **structural independence** exists when you can change the file structure without affecting the application's ability to access the data.

Even changes in the characteristics of data, such as changing a field from integer to decimal, require changes in all the programs that access the file. Because all data access programs are subject to change when any of the file's data storage characteristics change (that is, changing the data type), the file system is said to exhibit **data dependence**. Conversely, **data independence** exists when you can change the data storage characteristics without affecting the program's ability to access the data.

The practical significance of data dependence is the difference between the **logical data format** (how the human being views the data) and the **physical data format** (how the computer must work with the data). Any program that accesses a file system's file must tell the computer not only what to do but how to do it. Consequently, each program must contain lines that specify the opening of a specific file type, its record specification, and its field definitions. Data dependence makes the file system extremely cumbersome from the point of view of a programmer and database manager.

1.6.2 DATA REDUNDANCY

The file system's structure makes it difficult to combine data from multiple sources, and its lack of security renders the file system vulnerable to security breaches. The organizational structure promotes the storage of the same basic data in different locations. (Database professionals use the term **islands of information** for such scattered data locations.) The dispersion of data is exacerbated by the use of spreadsheets to store data. In a file system, the entire sales department would share access to the SALES data file through the data management and reporting programs created by the DP specialist. With the use of spreadsheets, each member of the sales department can create his or her own copy of the sales data. Because data stored in different locations will probably not be updated consistently, the islands of information often contain different versions of the same data. For example, in [Figures 1.5](#) and [1.6](#), the agent names and phone numbers occur in both the CUSTOMER and the AGENT files. You only need one correct copy of the agent names and phone numbers. Having them occur in more than one place produces data redundancy. **Data redundancy** exists when the same data are stored unnecessarily at different places.

Uncontrolled data redundancy sets the stage for:

- *Poor data security.* Having multiple copies of data increases the chances for a copy of the data to be susceptible to unauthorized access. [Chapter 15](#), Database Administration and Security, explores the issues and techniques associated with securing data.
- *Data inconsistency.* Data inconsistency exists when different and conflicting versions of the same data appear in different places. For example, suppose you change an agent's phone number in the AGENT file. If you forget to make the corresponding change in the CUSTOMER

file, the files contain different data for the same agent. Reports will yield inconsistent results that depend on which version of the data is used.

NOTE

Data that display data inconsistency are also said to lack data integrity. **Data integrity** is defined as the condition in which all data in the database are consistent with real-world events and conditions. In other words, data integrity means that:

- Data are *accurate*—there are no data inconsistencies.
 - Data are *verifiable*—the data will always yield consistent results.
-

Data-entry errors are more likely to occur when complex entries (such as 10-digit phone numbers) are made in several different files or recur frequently in one or more files. In fact, the CUSTOMER file shown in [Figure 1.5](#) contains just such an entry error: the third record in the CUSTOMER file has a transposed digit in the agent's phone number (615-882-2144 rather than 615-882-1244).

It is possible to enter a nonexistent sales agent's name and phone number into the CUSTOMER file, but customers are not likely to be impressed if the insurance agency supplies the name and phone number of an agent who does not exist. Should the personnel manager allow a nonexistent agent to accrue bonuses and benefits? In fact, a data-entry error such as an incorrectly spelled name or an incorrect phone number yields the same kind of data integrity problems.

- *Data anomalies.* The dictionary defines *anomaly* as “an abnormality.” Ideally, a field value change should be made in only a single place. Data redundancy, however, fosters an abnormal condition by forcing field value changes in many different locations. Look at the CUSTOMER file in [Figure 1.5](#). If agent Leah F. Hahn decides to get married and move, the agent name, address, and phone number are likely to change. Instead of making these changes in a single file (AGENT), you must also make the change each time that agent's name and phone number occur in the CUSTOMER file. You could be faced with the prospect of making hundreds of corrections, one for each of the customers served by that agent! The same problem occurs when an agent decides to quit. Each

customer served by that agent must be assigned a new agent. Any change in any field value must be correctly made in many places to maintain data integrity. A **data anomaly** develops when not all of the required changes in the redundant data are made successfully. The data anomalies found in [Figure 1.5](#) are commonly defined as follows:

- *Update anomalies.* If agent Leah F. Hahn has a new phone number, it must be entered in each of the CUSTOMER file records in which Ms. Hahn's phone number is shown. In this case, only four changes must be made. In a large file system, such a change might occur in hundreds or even thousands of records. Clearly, the potential for data inconsistencies is great.
- *Insertion anomalies.* If only the CUSTOMER file existed and you needed to add a new agent, you would also add a dummy customer data entry to reflect the new agent's addition. Again, the potential for creating data inconsistencies would be great.
- *Deletion anomalies.* If you delete the customers Amy B. O'Brian, George Williams, and Olette K. Smith, you will also delete John T. Okon's agent data. Clearly, this is not desirable.

1.6.3 LACK OF DESIGN AND DATA-MODELING SKILLS

A new problem that has evolved with the use of personal productivity tools (such as spreadsheet and desktop databases) is that users typically lack proper design and data-modeling skills. People naturally have an integrated view of the data in their environment. For example, consider a student's class schedule. The schedule probably contains the student's identification number and name, class code, class description, class credit hours, class instructor name, the class meeting days and times, and the class room number. In the mind of the student, these various data items compose a single unit. If a student organization wanted to keep a record of the schedules of its members, an end user might make a spreadsheet to store the schedule information. Even if the student makes a foray into the realm of desktop databases, he or she is likely to create a structure composed of a single table that mimics the schedule structure. As you will learn in the coming chapters, forcing this type of integrated data into a single two-dimensional table structure is a poor data design that leads to a large degree of redundancy for several data items.

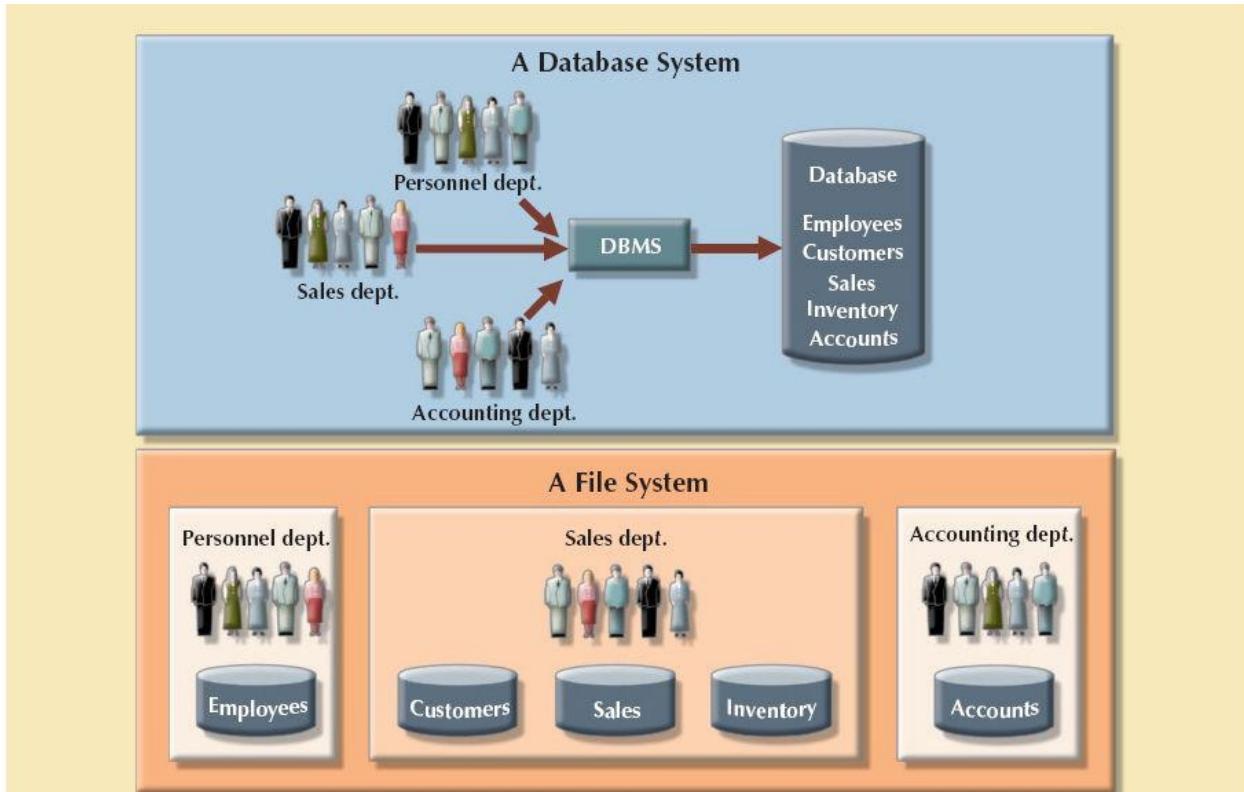
Data-modeling skills are also a vital part of the design process. It is important to

document the design properly. Design documentation is necessary to facilitate communication among the database designer, the end user, and the developer. Data modeling, as introduced later in this text, is the most common method of documenting database designs. Using a standardized data-modeling technique ensures that the data model fulfills its role in facilitating communication. The data model also provides an invaluable resource when maintaining or modifying a database as business requirements change. The data designs created by end users are rarely documented and never with an appropriate standardized data-modeling technique. On a positive note, however, this book will help you develop the skills needed to design and model a successful database that avoids the problems listed earlier in this section.

1.7 DATABASE SYSTEMS

The problems inherent in file systems make using a database system very desirable. Unlike the file system, with its many separate and unrelated files, the database system consists of logically related data stored in a single logical data repository. (The “logical” label reflects the fact that the data repository appears to be a single unit to the end user, even though data might be physically distributed among multiple storage facilities and locations.) Because the database’s data repository is a single logical unit, the database represents a major change in the way end-user data are stored, accessed, and managed. The database’s DBMS, shown in [Figure 1.8](#), provides numerous advantages over file system management, shown in [Figure 1.7](#), by making it possible to eliminate most of the file system’s data inconsistency, data anomaly, data dependence, and structural dependence problems. Better yet, the current generation of DBMS software stores not only the data structures, but also the relationships between those structures and the access paths to those structures—all in a central location. The current generation of DBMS software also takes care of defining, storing, and managing all required access paths to those components.

FIGURE 1.8 Contrasting database and file systems



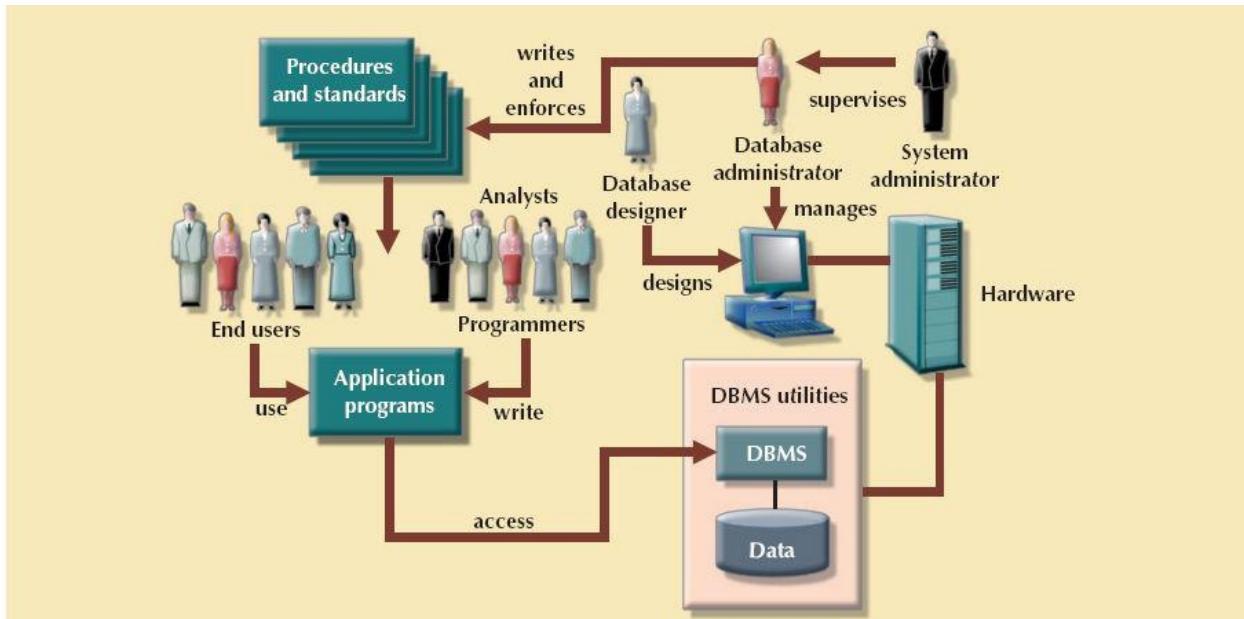
SOURCE: Course Technology/Cengage Learning

Remember that the DBMS is just one of several crucial components of a database system. The DBMS may even be referred to as the database system's heart. However, just as it takes more than a heart to make a human being function, it takes more than a DBMS to make a database system function. In the sections that follow, you'll learn what a database system is, what its components are, and how the DBMS fits into the picture.

1.7.1 THE DATABASE SYSTEM ENVIRONMENT

The term **database system** refers to an organization of components that define and regulate the collection, storage, management, and use of data within a database environment. From a general management point of view, the database system is composed of the five major parts shown in [Figure 1.9](#): hardware, software, people, procedures, and data.

FIGURE 1.9 The database system environment



SOURCE: Course Technology/Cengage Learning

Let's take a closer look at the five components shown in [Figure 1.9](#):

- **Hardware.** Hardware refers to all of the system's physical devices, including computers (PCs, workstations, servers, and supercomputers), storage devices, printers, network devices (hubs, switches, routers, fiber optics), and other devices (automated teller machines, ID readers, and so on).
- **Software.** Although the most readily identified software is the DBMS itself, three types of software are needed to make the database system function fully: operating system software, DBMS software, and application programs and utilities.
- **Operating system software** manages all hardware components and makes it possible for all other software to run on the computers. Examples of operating system software include Microsoft Windows, Linux, Mac OS, UNIX, and MVS.
- **DBMS software** manages the database within the database system. Some examples of DBMS software include Microsoft's SQL Server, Oracle Corporation's Oracle, Sun's MySQL, and IBM's DB2.
- **Application programs and utility software** are used to access and

manipulate data in the DBMS and to manage the computer environment in which data access and manipulation take place. Application programs are most commonly used to access data within the database to generate reports, tabulations, and other information to facilitate decision making. Utilities are the software tools used to help manage the database system's computer components. For example, all of the major DBMS vendors now provide graphical user interfaces (GUIs) to help create database structures, control database access, and monitor database operations.

- *People*. This component includes all users of the database system. On the basis of primary job functions, five types of users can be identified in a database system: system administrators, database administrators, database designers, system analysts and programmers, and end users. Each user type, described below, performs both unique and complementary functions.
 - *System administrators* oversee the database system's general operations.
 - *Database administrators*, also known as DBAs, manage the DBMS and ensure that the database is functioning properly. The DBA's role is sufficiently important to warrant a detailed exploration in [Chapter 15](#), Database Administration and Security .
 - *Database designers* design the database structure. They are, in effect, the database architects. If the database design is poor, even the best application programmers and the most dedicated DBAs cannot produce a useful database environment. Because organizations strive to optimize their data resources, the database designer's job description has expanded to cover new dimensions and growing responsibilities.
 - *System analysts and programmers* design and implement the application programs. They design and create the data-entry screens, reports, and procedures through which end users access and manipulate the database's data.
 - *End users* are the people who use the application programs to run the organization's daily operations. For example, sales clerks, supervisors, managers, and directors are all classified as end users. High-level end users employ the information obtained from the database to make tactical and strategic business decisions.
- *Procedures*. Procedures are the instructions and rules that govern the design and use of the database system. Procedures are a critical, although

occasionally forgotten, component of the system. Procedures play an important role in a company because they enforce the standards by which business is conducted within the organization and with customers. Procedures also help to ensure that companies have an organized way to monitor and audit the data that enter the database and the information generated from those data.

- *Data*. The word *data* covers the collection of facts stored in the database. Because data are the raw material from which information is generated, determining what data to enter into the database and how to organize those data is a vital part of the database designer's job.

A database system adds a new dimension to an organization's management structure. The complexity of this managerial structure depends on the organization's size, its functions, and its corporate culture. Therefore, database systems can be created and managed at different levels of complexity and with varying adherence to precise standards. For example, compare a local movie rental system with a national insurance claims system. The movie rental system may be managed by two people, the hardware used is probably a single PC, the procedures are probably simple, and the data volume tends to be low. The national insurance claims system is likely to have at least one systems administrator, several full-time DBAs, and many designers and programmers; the hardware probably includes several servers at multiple locations throughout the United States; the procedures are likely to be numerous, complex, and rigorous; and the data volume tends to be high.

In addition to the different levels of database system complexity, managers must also take another important fact into account: database solutions must be cost-effective as well as tactically and strategically effective. Producing a million-dollar solution to a thousand-dollar problem is hardly an example of good database system selection or of good database design and management. Finally, the database technology already in use is likely to affect the selection of a database system.

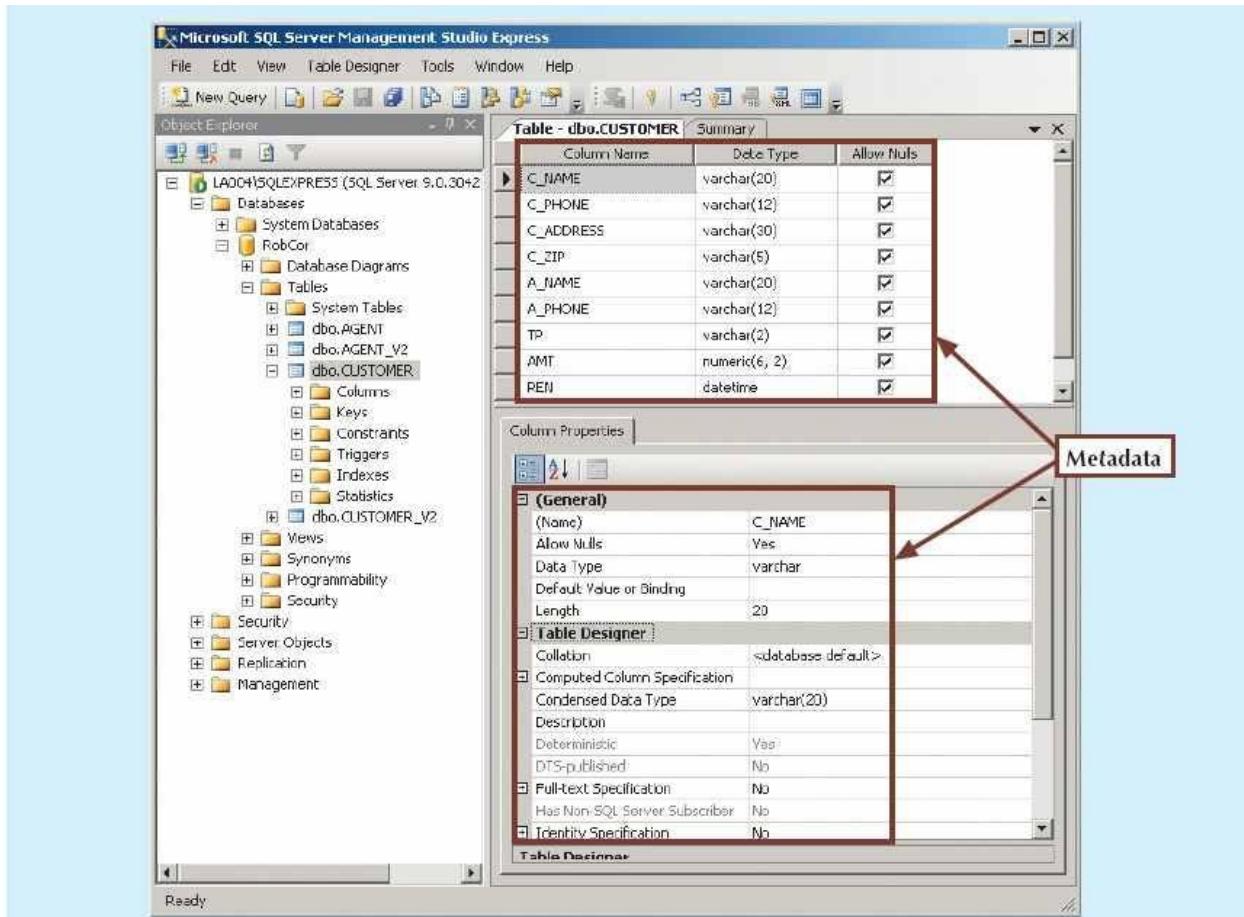
1.7.2 DBMS FUNCTIONS

A DBMS performs several important functions that guarantee the integrity and consistency of the data in the database. Most of those functions are transparent to

end users, and most can be achieved only through the use of a DBMS. They include data dictionary management, data storage management, data transformation and presentation, security management, multiuser access control, backup and recovery management, data integrity management, database access languages and application programming interfaces, and database communication interfaces. Each of these functions is explained below.

- *Data dictionary management.* The DBMS stores definitions of the data elements and their relationships (metadata) in a data dictionary. In turn, all programs that access the data in the database work through the DBMS. The DBMS uses the [**data dictionary**](#) to look up the required data component structures and relationships, thus relieving you from having to code such complex relationships in each program. Additionally, any changes made in a database structure are automatically recorded in the data dictionary, thereby freeing you from having to modify all of the programs that access the changed structure. In other words, the DBMS provides data abstraction, and it removes structural and data dependence from the system. For example, [Figure 1.10](#) shows how Microsoft SQL Server Express presents the data definition for the CUSTOMER table.

FIGURE 1.10 Illustrating metadata with Microsoft SQL Server Express

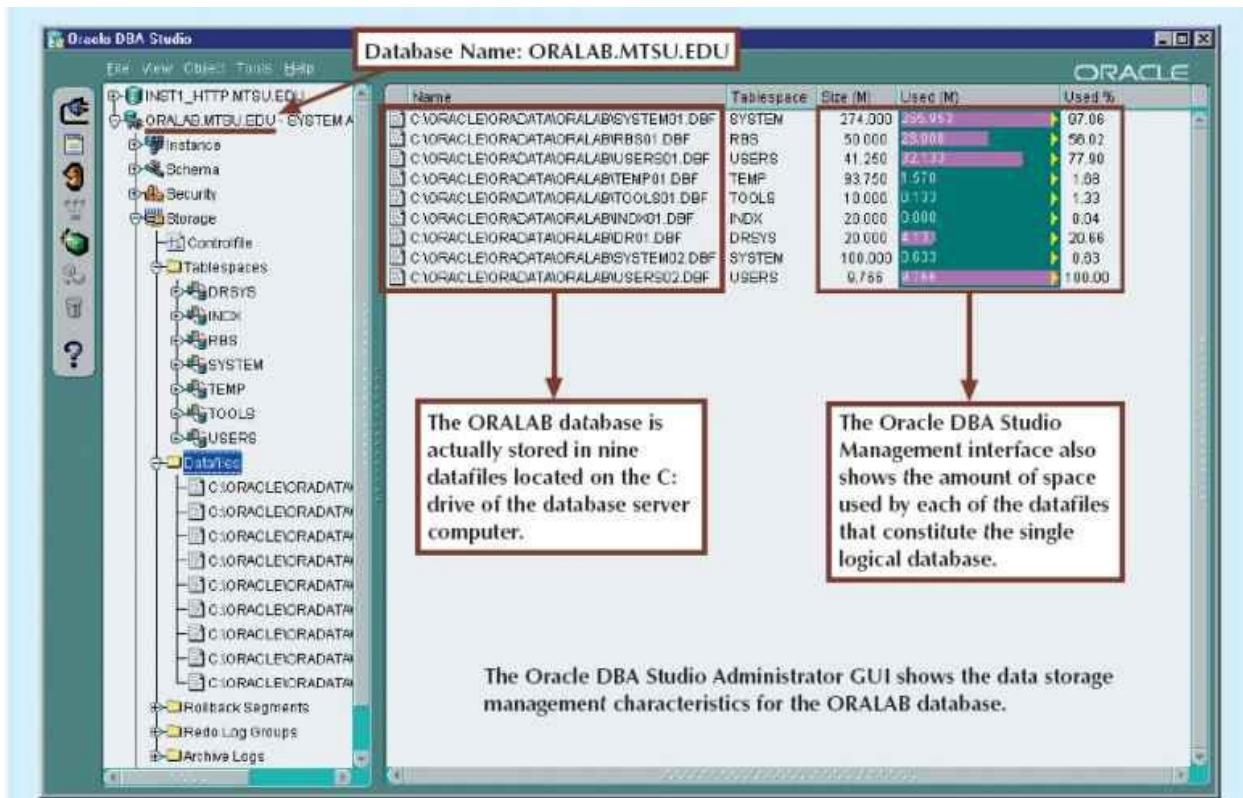


SOURCE: Course Technology/Cengage Learning

- *Data storage management.* The DBMS creates and manages the complex structures required for data storage, thus relieving you from the difficult task of defining and programming the physical data characteristics. A modern DBMS provides storage not only for the data but for related data-entry forms or screen definitions, report definitions, data validation rules, procedural code, structures to handle video and picture formats, and so on. Data storage management is also important for database performance tuning. **Performance tuning** relates to the activities that make the database perform more efficiently in terms of storage and access speed. Although the user sees the database as a single data storage unit, the DBMS actually stores the database in multiple physical data files. (See [Figure 1.11](#).) Such data files may even be stored on different storage media. Therefore, the DBMS doesn't have to wait for one disk request to finish before the next one starts. In other words, the DBMS can fulfill database requests concurrently. Data storage management and

performance tuning issues are addressed in [Chapter 11](#), Database Performance Tuning and Query Optimization.

FIGURE 1.11 Illustrating data storage management with Oracle



SOURCE: Course Technology/Cengage Learning

- *Data transformation and presentation.* The DBMS transforms entered data to conform to required data structures. The DBMS relieves you of the chore of distinguishing between the logical data format and the physical data format. That is, the DBMS formats the physically retrieved data to make it conform to the user's logical expectations. For example, imagine an enterprise database used by a multinational company. An end user in England would expect to enter the date July 11, 2013, as "11/07/2013." In contrast, the same date would be entered in the United States as "07/11/2013." Regardless of the data presentation format, the DBMS must manage the date in the proper format for each country.

- *Security management.* The DBMS creates a security system that enforces user security and data privacy. Security rules determine which users can access the database, which data items each user can access, and which data operations (read, add, delete, or modify) the user can perform. This is especially important in multiuser database systems. [Chapter 15](#), Database Administration and Security, examines data security and privacy issues in greater detail. All database users may be authenticated to the DBMS through a username and password or through biometric authentication such as a fingerprint scan. The DBMS uses this information to assign access privileges to various database components such as queries and reports.
- *Multiuser access control.* To provide data integrity and data consistency, the DBMS uses sophisticated algorithms to ensure that multiple users can access the database concurrently without compromising its integrity. [Chapter 10](#), Transaction Management and Concurrency Control, covers the details of multiuser access control.
- *Backup and recovery management.* The DBMS provides backup and data recovery to ensure data safety and integrity. Current DBMS systems provide special utilities that allow the DBA to perform routine and special backup and restore procedures. Recovery management deals with the recovery of the database after a failure, such as a bad sector in the disk or a power failure. Such capability is critical to preserving the database's integrity. [Chapter 15](#) covers backup and recovery issues.
- *Data integrity management.* The DBMS promotes and enforces integrity rules, thus minimizing data redundancy and maximizing data consistency. The data relationships stored in the data dictionary are used to enforce data integrity. Ensuring data integrity is especially important in transaction-oriented database systems. Data integrity and transaction management issues are addressed in [Chapter 7](#), Introduction to Structured Query Language (SQL), and [Chapter 10](#).
- *Database access languages and application programming interfaces.* The

DBMS provides data access through a query language. A [**query language**](#) is a nonprocedural language—one that lets the user specify what must be done without having to specify how. [**Structured Query Language \(SQL\)**](#) is the de facto query language and data access standard supported by the majority of DBMS vendors. [Chapter 7](#) and [Chapter 8](#), Advanced SQL, address the use of SQL. The DBMS also provides application programming interfaces to procedural languages such as COBOL, C, Java, Visual Basic.NET, and C#. In addition, the DBMS provides administrative utilities used by the DBA and the database designer to create, implement, monitor, and maintain the database.

- *Database communication interfaces.* A current-generation DBMS accepts end-user requests via multiple, different network environments. For example, the DBMS might provide access to the database via the Internet through the use of Web browsers such as Mozilla Firefox or Microsoft Internet Explorer. In this environment, communications can be accomplished in several ways:
 - End users can generate answers to queries by filling in screen forms through their preferred Web browser.
 - The DBMS can automatically publish predefined reports on a Website.
 - The DBMS can connect to third-party systems to distribute information via e-mail or other productivity applications.

Database communication interfaces are examined in greater detail in [Chapter 12](#), Distributed Database Management Systems; in [Chapter 14](#), Database Connectivity and Web Technologies; and in Appendix I, Databases in Electronic Commerce. (Appendices are available at www.cengagebrain.com.)

NOTE

Why a Spreadsheet Is Not a Database

While a spreadsheet allows for the creation of multiple tables, it does not support even the most basic database functionality such as support for self-documentation through metadata, enforcement of data types or domains to ensure consistency of data within a column, defined relationships among tables, or constraints to ensure consistency of data across related tables.

Most users lack the necessary training to recognize the limitations of spreadsheets for these types of tasks.

1.7.3 MANAGING THE DATABASE SYSTEM: A SHIFT IN FOCUS

The introduction of a database system over the file system provides a framework in which strict procedures and standards can be enforced. Consequently, the role of the human component changes from an emphasis on programming (in the file system) to a focus on the broader aspects of managing the organization's data resources and on the administration of the complex database software itself.

The database system makes it possible to tackle far more sophisticated uses of the data resources, as long as the database is designed to make use of that power. The kinds of data structures created within the database and the extent of the relationships among them play a powerful role in determining the effectiveness of the database system.

Although the database system yields considerable advantages over previous data management approaches, database systems do carry significant disadvantages. For example:

- *Increased costs.* Database systems require sophisticated hardware and software and highly skilled personnel. The cost of maintaining the hardware, software, and personnel required to operate and manage a database system can be substantial. Training, licensing, and regulation compliance costs are often overlooked when database systems are implemented.
- *Management complexity.* Database systems interface with many different technologies and have a significant impact on a company's resources and culture. The changes introduced by the adoption of a database system must be properly managed to ensure that they help advance the company's objectives. Because database systems hold crucial company data that are accessed from multiple sources, security issues must be assessed constantly.
- *Maintaining currency.* To maximize the efficiency of the database system, you must keep your system current. Therefore, you must perform frequent updates and apply the latest patches and security measures to all

components. Because database technology advances rapidly, personnel training costs tend to be significant.

- *Vendor dependence.* Given the heavy investment in technology and personnel training, companies might be reluctant to change database vendors. As a consequence, vendors are less likely to offer pricing point advantages to existing customers, and those customers might be limited in their choice of database system components.
- *Frequent upgrade/replacement cycles.* DBMS vendors frequently upgrade their products by adding new functionality. Such new features often come bundled in new upgrade versions of the software. Some of these versions require hardware upgrades. Not only do the upgrades themselves cost money, it also costs money to train database users and administrators to properly use and manage the new features.

Now that you know what a database and DBMS are, and why they are necessary, you are ready to begin developing your career as a database professional.

1.8 PREPARING FOR YOUR DATABASE PROFESSIONAL CAREER

In this chapter, you were introduced to the concepts of data, information, databases, and DBMSs. You also learned that, regardless of what type of database you use (OLTP or OLAP), or what type of database environment you are working in (for example, Oracle, Microsoft, or IBM), the success of a database system greatly depends on how well the database structure is designed.

Throughout this book, you will learn the building blocks that lay the foundation for your career as a database professional. Understanding these building blocks and developing the skills to use them effectively will prepare you to work with databases at many different levels within an organization. A small sample of such career opportunities is shown in [Table 1.3](#).

TABLE 1.3 Database Career Opportunities

JOB TITLE	DESCRIPTION	SAMPLE SKILLS REQUIRED
Database developer	Creates and maintains database-based applications	Programming, database fundamentals, SQL
Database designer	Designs and maintains databases	Systems design, database design, SQL
Database administrator	Manages and maintains DBMS and databases	Database fundamentals, SQL, vendor courses
Database analyst	Develops databases for decision support reporting	SQL, query optimization, data warehouses
Database architect	Designs and implements database environments (conceptual, logical, and physical)	DBMS fundamentals, data modeling, SQL, hardware knowledge
Database consultant	Helps companies leverage database technologies to improve business processes and achieve specific goals	Database fundamentals, data modeling, database design, SQL, DBMS, hardware, vendor-specific technologies
Database security officer	Implements security policies for data administration	DBMS fundamentals, database administration, SQL, data security technologies

As you also learned in this chapter, database technologies are constantly evolving to address new challenges such as large databases, semistructured and unstructured data, increasing processing speed, and lowering costs. While database technologies can change quickly, the fundamental concepts and skills do not. It is our goal that after you learn the database essentials in this book, you will be ready to apply your knowledge and skills to work with traditional OLTP and OLAP systems as well as cutting-edge, complex database technologies such as:

- *Very Large Databases (VLDB)*. Many vendors are addressing the need for databases that support large amounts of data, usually in the petabyte range. (A petabyte is more than 1,000 terabytes.) VLDB vendors include Oracle Exadata, IBM's Netezza, Greenplum, HP's Vertica, and Teradata.

VLDB are now being overtaken in market interest by Big Data databases.

- *Big Data databases*. Products such as Cassandra (Facebook) and BigTable (Google) are using “columnar-database” technologies to support the needs of database applications that manage large amounts of “nontabular” data. See more about this topic in [Chapter 2](#).
- *In-memory databases*. Most major database vendors also offer some type of in-memory database support to address the need for faster database processing. In-memory databases store most of their data in primary memory (RAM) rather than in slower secondary storage (hard disks). In-memory databases include IBM’s solidDB and Oracle’s TimesTen.
- *Cloud databases*. Companies can now use cloud database services to quickly add database systems to their environment while simultaneously lowering the total cost of ownership of a new DBMS. A cloud database offers all the advantages of a local DBMS, but instead of residing within your organization’s network infrastructure, it resides on the Internet. See more about this topic in [Chapter 14](#).

We address some of these topics in this book, but not all—no single book can cover the entire realm of database technologies. This book’s primary focus is to help you learn database fundamentals, develop your database design skills, and master your SQL skills so you will have a head start in becoming a successful database professional. However, you first must learn about the tools at your disposal. In the next chapter, you will learn different approaches to data management and how these approaches influence your designs.

SUMMARY

- Data are raw facts. Information is the result of processing data to reveal their meaning. Accurate, relevant, and timely information is the key to good decision making, and good decision making is the key to organizational survival in a global environment.

- Data are usually stored in a database. To implement a database and to manage its contents, you need a database management system (DBMS). The DBMS serves as the intermediary between the user and the database. The database contains the data you have collected and “data about data,” known as metadata.
 - Database design defines the database structure. A well-designed database facilitates data management and generates accurate and valuable information. A poorly designed database can lead to bad decision making, and bad decision making can lead to the failure of an organization.
-
- Databases can be classified according to the number of users supported, where the data are located, the type of data stored, the intended data usage, and the degree to which the data are structured.
 - Databases evolved from manual and then computerized file systems. In a file system, data are stored in independent files, each requiring its own data management programs. Although this method of data management is largely outmoded, understanding its characteristics makes database design easier to comprehend.
-
- Some limitations of file system data management are that it requires extensive programming, system administration can be complex and difficult, making changes to existing structures is difficult, and security features are likely to be inadequate. Also, independent files tend to contain redundant data, leading to problems of structural and data dependence.
 - Database management systems were developed to address the file system’s inherent weaknesses. Rather than depositing data in independent files, a DBMS presents the database to the end user as a single data repository. This arrangement promotes data sharing, thus eliminating the potential problem of islands of information. In addition, the DBMS enforces data integrity, eliminates redundancy, and promotes data security.

KEY TERMS

[ad hoc query](#)

[analytical database](#)
[business intelligence](#)
[centralized database](#)
[data](#)
[data anomaly](#)
[data dependence](#)
[data dictionary](#)
[data inconsistency](#)
[data independence](#)
[data integrity](#)
[data management](#)
[data processing \(DP\) specialist](#)
[data quality](#)
[data redundancy](#)
[data warehouse](#)
[database](#)
[database design](#)
[database management system \(DBMS\)](#)
[database system](#)
[desktop database](#)
[discipline-specific database](#)
[distributed database](#)
[enterprise database](#)
[Extensible Markup Language \(XML\)](#)
[field](#)
[file](#)
[general-purpose database](#)
[information](#)
[islands of information](#)
[knowledge](#)
[logical data format](#)
[metadata](#)
[multiuser database](#)
[NoSQL](#)
[online analytical processing \(OLAP\)](#)
[online transaction processing \(OLTP\)](#)

[operational database](#)
[performance tuning](#)
[physical data format](#)
[production database](#)
[query](#)
[query language](#)
[query result set](#)
[record](#)
[semistructured data](#)
[single-user database](#)
[social media](#)
[structural dependence](#)
[structural independence](#)
[structured data](#)
[Structured Query Language \(SQL\)](#)
[transactional database](#)
[unstructured data](#)
[workgroup database](#)
[XML database](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at
www.cengagebrain.com.

REVIEW QUESTIONS

1. Define each of the following terms:
 - a. data
 - b. field
 - c. record

- d. file
- 2. What is data redundancy, and which characteristics of the file system can lead to it?
- 3. What is data independence, and why is it lacking in file systems?
- 4. What is a DBMS, and what are its functions?
- 5. What is structural independence, and why is it important?
- 6. Explain the differences among data, information, and a database.
- 7. What is the role of a DBMS, and what are its advantages? What are its disadvantages?
- 8. List and describe the different types of databases.
- 9. What are the main components of a database system?
- 10. What are metadata?
- 11. Explain why database design is important.
- 12. What are the potential costs of implementing a database system?
- 13. Use examples to compare and contrast unstructured and structured data. Which type is more prevalent in a typical business environment?
- 14. What are some basic database functions that a spreadsheet cannot perform?
- 15. What common problems does a collection of spreadsheets created by end users share with the typical file system?
- 16. Explain the significance of the loss of direct, hands-on access to business

data that end users experienced with the advent of computerized data repositories.

PROBLEMS



ONLINE CONTENT

The file structures you see in this problem set are simulated in a Microsoft Access database named **Ch01_Problems**, which is available at www.cengagebrain.com.

FIGURE P1.1 The file structure for [Problems 1–4](#)

PROJECT_CODE	PROJECT_MANAGER	MANAGER_PHONE	MANAGER_ADDRESS	PROJECT_BID_PRICE
21-5Z	Holly B. Parker	904-338-3416	3334 Lee Rd., Gainesville, FL 37123	16833460.00
25-2D	Jane D. Grant	615-898-9909	218 Clark Blvd., Nashville, TN 36362	12500000.00
25-5A	George F. Dorts	615-227-1245	124 River Dr., Franklin, TN 29185	32512420.00
25-9T	Holly B. Parker	904-338-3416	3334 Lee Rd., Gainesville, FL 37123	21563234.00
27-4Q	George F. Dorts	615-227-1245	124 River Dr., Franklin, TN 29185	10314545.00
29-2D	Holly B. Parker	904-338-3416	3334 Lee Rd., Gainesville, FL 37123	25559999.00
31-7P	William K. Moor	904-445-2719	216 Morton Rd., Stetson, FL 30155	56850000.00

SOURCE: Course Technology/Cengage Learning

Given the file structure shown in [Figure P1.1](#), answer [Problems 1–4](#).

1. How many records does the file contain? How many fields are there per record?
2. What problem would you encounter if you wanted to produce a listing by city? How would you solve this problem by altering the file structure?
3. If you wanted to produce a listing of the file contents by last name, area code, city, state, or zip code, how would you alter the file structure?

4. What data redundancies do you detect? How could those redundancies lead to anomalies?
-

FIGURE P1.5 The file structure for [Problems 5–8](#)

PROJ_NUM	PROJ_NAME	EMP_NUM	EMP_NAME	JOB_CODE	JOB_CHG_HOUR	PROJ_HOURS	EMP_PHONE
1	Hurricane	101	John D. Newson	EE	85.00	13.3	653-234-3245
1	Hurricane	105	David F. Schwann	CT	60.00	16.2	653-234-1123
1	Hurricane	110	Anne R. Ramoras	CT	60.00	14.3	615-233-5568
2	Coast	101	John D. Newson	EE	85.00	19.8	653-234-3254
2	Coast	108	June H. Sattlemir	EE	85.00	17.5	905-554-7812
3	Satellite	110	Anne R. Ramoras	CT	62.00	11.6	615-233-5568
3	Satellite	105	David F. Schwann	CT	26.00	23.4	653-234-1123
3	Satellite	123	Mary D. Chen	EE	85.00	19.1	615-233-5432
3	Satellite	112	Allecia R. Smith	BE	85.00	20.7	615-678-6879

SOURCE: Course Technology/Cengage Learning

5. Identify and discuss the serious data redundancy problems exhibited by the file structure shown in [Figure P1.5](#).
6. Looking at the EMP_NAME and EMP_PHONE contents in [Figure P1.5](#), what change(s) would you recommend?
7. Identify the various data sources in the file you examined in [Problem 5](#).
8. Given your answer to [Problem 7](#), what new files should you create to help eliminate the data redundancies found in the file shown in [Figure P1.5](#)?
-

FIGURE P1.9 The file structure for [Problems 9–10](#)

BUILDING_CODE	ROOM_CODE	TEACHER_LNAME	TEACHER_FNAME	TEACHER_INITIAL	DAYS_TIME
KOM	204E	Williston	Horace	G	MWF 8:00-8:50
KOM	123	Cordoza	Maria	L	MWF 8:00-8:50
LDB	504	Patroski	Donald	J	TTh 1:00-2:15
KOM	34	Hawkins	Anne	W	MWF 10:00-10:50
JKP	225B	Risell	James		TTh 9:00-10:15
LDB	301	Robertson	Jeanette	P	TTh 9:00-10:15
KOM	204E	Cordoza	Maria	I	MWF 9:00-9:50
LDB	504	Williston	Horace	G	TTh 1:00-2:15
KOM	34	Cordoza	Maria	L	MWF 11:00-11:50
LDB	504	Patroski	Donald	J	MWF 2:00-2:50

SOURCE: Course Technology/Cengage Learning

-
9. Identify and discuss the serious data redundancy problems exhibited by the file structure shown in [Figure P1.9](#). (The file is meant to be used as a teacher class assignment schedule. One of the many problems with data redundancy is the likely occurrence of data inconsistencies—two different initials have been entered for the teacher named Maria Cordoza.)
 10. Given the file structure shown in [Figure P1.9](#), what problem(s) might you encounter if building KOM were deleted?
-

¹ “Top Ten Largest Databases in the World,” *Business Intelligence Lowdown*, February 15, 2007, http://www.businessintelligencelowdown.com/2007/02/top_10_largest_.html.

² Peter Drucker coined the phrase “knowledge worker” in 1959 in his book *Landmarks of Tomorrow*. In 1994, Esther Dyson, George Keyworth, and Dr. Alvin Toffler introduced the concept of the “knowledge age.”

³ Vendor offers single-user/personal DBMS version.

2 DATA MODELS

In this chapter, you will learn:

- About data modeling and why data models are important
 - About the basic data-modeling building blocks
 - What business rules are and how they influence database design
 - How the major data models evolved
 - About emerging alternative data models and the need they fulfill
 - How data models can be classified by their level of abstraction
-

Preview

This chapter examines data modeling. Data modeling is the first step in the database design journey, serving as a bridge between real-world objects and the computer database.

One of the most vexing problems of database design is that designers, programmers, and end users see data in different ways. Consequently, different views of the same data can lead to database designs that do not reflect an organization's actual operation, thus failing to meet end-user needs and data efficiency requirements. To avoid such failures, database designers must obtain a precise description of the data's nature and many uses within the organization. Communication among database designers, programmers, and end users should be frequent and clear. Data modeling clarifies such communication by reducing the complexities of database design to more easily understood abstractions that define entities and the relations among them.

First, you will learn some basic data-modeling concepts and how current data models developed from earlier models. Tracing the development of those database models will help you understand the database design and implementation issues that are addressed in the rest of this book. In chronological order, you will be introduced to the hierarchical and network models, the relational model, and the entity relationship (ER) model. You will

also learn about the use of the entity relationship diagram (ERD) as a data-modeling tool and the different notations used for ER diagrams. Next, you will be introduced to the object-oriented model and the object/relational model. Then, you will learn about the emerging NoSQL data model and how it is being used to fulfill the current need to manage very large social media data sets efficiently and effectively. Finally, you will learn how various degrees of data abstraction help reconcile varying views of the same data.

2.1 DATA MODELING AND DATA MODELS

Database design focuses on how the database structure will be used to store and manage end-user data. Data modeling, the first step in designing a database, refers to the process of creating a specific data model for a determined problem domain. (A *problem domain* is a clearly defined area within the real-world environment, with well-defined scope and boundaries, that will be systematically addressed.) A **data model** is a relatively simple representation, usually graphical, of more complex real-world data structures. In general terms, a *model* is an abstraction of a more complex real-world object or event. A model's main function is to help you understand the complexities of the real-world environment. Within the database environment, a data model represents data structures and their characteristics, relations, constraints, transformations, and other constructs with the purpose of supporting a specific problem domain.

NOTE

The terms *data model* and *database model* are often used interchangeably. In this book, the term *database model* is used to refer to the implementation of a *data model* in a specific database system.

Data modeling is an iterative, progressive process. You start with a simple understanding of the problem domain, and as your understanding increases, so does the level of detail of the data model. When done properly, the final data model effectively is a “blueprint” with all the instructions to build a database that will meet all end-user requirements. This blueprint is narrative and graphical in nature, meaning that it contains both text descriptions in plain, unambiguous

language and clear, useful diagrams depicting the main data elements.

NOTE

An implementation-ready data model should contain at least the following components:

- A description of the data structure that will store the end-user data.
 - A set of enforceable rules to guarantee the integrity of the data.
 - A data manipulation methodology to support the real-world data transformations.
-

Traditionally, database designers relied on good judgment to help them develop a good data model. Unfortunately, good judgment is often in the eye of the beholder, and it often develops after much trial and error. For example, if each student in this class has to create a data model for a video store, it is very likely that each will come up with a different model. Which one would be correct? The simple answer is “the one that meets all the end-user requirements,” and there may be more than one correct solution! Fortunately, database designers make use of existing data-modeling constructs and powerful database design tools that substantially diminish the potential for errors in database modeling. In the following sections, you will learn how existing data models are used to represent real-world data and how the different degrees of data abstraction facilitate data modeling.

2.2 THE IMPORTANCE OF DATA MODELS

Data models can facilitate interaction among the designer, the applications programmer, and the end user. A well-developed data model can even foster improved understanding of the organization for which the database design is developed. In short, data models are a communication tool. This important aspect of data modeling was summed up neatly by a client whose reaction was as follows: “I created this business, I worked with this business for years, and this is the first time I’ve really understood how all the pieces really fit together.”

The importance of data modeling cannot be overstated. Data constitute the most

basic information units employed by a system. Applications are created to manage data and to help transform data into information, but data are viewed in different ways by different people. For example, contrast the view of a company manager with that of a company clerk. Although both work for the same company, the manager is more likely to have an enterprise-wide view of company data than the clerk.

Even different managers view data differently. For example, a company president is likely to take a universal view of the data because he or she must be able to tie the company's divisions to a common (database) vision. A purchasing manager in the same company is likely to have a more restricted view of the data, as is the company's inventory manager. In effect, each department manager works with a subset of the company's data. The inventory manager is more concerned about inventory levels, while the purchasing manager is more concerned about the cost of items and about relationships with the suppliers of those items.

Applications programmers have yet another view of data, being more concerned with data location, formatting, and specific reporting requirements. Basically, applications programmers translate company policies and procedures from a variety of sources into appropriate interfaces, reports, and query screens.

The different users and producers of data and information often reflect the fable of the blind men and the elephant: the blind man who felt the elephant's trunk had quite a different view from the one who felt the elephant's leg or tail. A view of the whole elephant is needed. Similarly, a house is not a random collection of rooms; to build a house, a person should first have the overall view that is provided by blueprints. Likewise, a sound data environment requires an overall database blueprint based on an appropriate data model.

When a good database blueprint is available, it does not matter that an applications programmer's view of the data is different from that of the manager or the end user. Conversely, when a good database blueprint is not available, problems are likely to ensue. For instance, an inventory management program and an order entry system may use conflicting product-numbering schemes, thereby costing the company thousands or even millions of dollars.

Keep in mind that a house blueprint is an abstraction; you cannot live in the blueprint. Similarly, the data model is an abstraction; you cannot draw the required data out of the data model. Just as you are not likely to build a good house without a blueprint, you are equally unlikely to create a good database

without first creating an appropriate data model.

2.3 DATA MODEL BASIC BUILDING BLOCKS

The basic building blocks of all data models are entities, attributes, relationships, and constraints. An **entity** is a person, place, thing, or event about which data will be collected and stored. An entity represents a particular type of object in the real world, which means an entity is “distinguishable”—that is, each entity occurrence is unique and distinct. For example, a CUSTOMER entity would have many distinguishable customer occurrences, such as John Smith, Pedro Dinamita, and Tom Strickland. Entities may be physical objects, such as customers or products, but entities may also be abstractions, such as flight routes or musical concerts.

An **attribute** is a characteristic of an entity. For example, a CUSTOMER entity would be described by attributes such as customer last name, customer first name, customer phone number, customer address, and customer credit limit. Attributes are the equivalent of fields in file systems.

A **relationship** describes an association among entities. For example, a relationship exists between customers and agents that can be described as follows: an agent can serve many customers, and each customer may be served by one agent. Data models use three types of relationships: one-to-many, many-to-many, and one-to-one. Database designers usually use the shorthand notations 1:M or 1..*, M:N or *..*, and 1:1 or 1..1, respectively. (Although the M:N notation is a standard label for the many-to-many relationship, the label M:M may also be used.) The following examples illustrate the distinctions among the three relationships.

- **One-to-many (1:M or 1..*) relationship.** A painter creates many different paintings, but each is painted by only one painter. Thus, the painter (the “one”) is related to the paintings (the “many”). Therefore, database designers label the relationship “PAINTER paints PAINTING” as 1:M. Note that entity names are often capitalized as a convention, so they are easily identified. Similarly, a customer (the “one”) may generate many invoices, but each invoice (the “many”) is generated by only a single customer. The “CUSTOMER generates INVOICE” relationship would also be labeled 1:M.

- **Many-to-many (M:N or ..) relationship**. An employee may learn many job skills, and each job skill may be learned by many employees. Database designers label the relationship “EMPLOYEE learns SKILL” as M:N. Similarly, a student can take many classes and each class can be taken by many students, thus yielding the M:N label for the relationship expressed by “STUDENT takes CLASS.”
- **One-to-one (1:1 or 1..1) relationship**. A retail company’s management structure may require that each of its stores be managed by a single employee. In turn, each store manager, who is an employee, manages only a single store. Therefore, the relationship “EMPLOYEE manages STORE” is labeled 1:1.

The preceding discussion identified each relationship in both directions; that is, relationships are bidirectional:

- *One CUSTOMER* can generate *many INVOICES*.
- Each of the *many INVOICES* is generated by only *one CUSTOMER*.

A **constraint** is a restriction placed on the data. Constraints are important because they help to ensure data integrity. Constraints are normally expressed in the form of rules. For example:

- An employee’s salary must have values that are between 6,000 and 350,000.
- A student’s GPA must be between 0.00 and 4.00.
- Each class must have one and only one teacher.

How do you properly identify entities, attributes, relationships, and constraints? The first step is to clearly identify the business rules for the problem domain you are modeling.

2.4 BUSINESS RULES

When database designers go about selecting or determining the entities, attributes, and relationships that will be used to build a data model, they might start by gaining a thorough understanding of what types of data exist in an organization, how the data are used, and in what time frames they are used. But such data and information do not, by themselves, yield the required understanding of the total business. From a database point of view, the collection of data becomes meaningful only when it reflects properly defined *business rules*. A **business rule** is a brief, precise, and unambiguous description of a policy, procedure, or principle within a specific organization. In a sense, business rules are misnamed: they apply to *any* organization, large or small—a business, a government unit, a religious group, or a research laboratory—that stores and uses data to generate information.

Business rules derived from a detailed description of an organization's operations help to create and enforce actions within that organization's environment. Business rules must be rendered in writing and updated to reflect any change in the organization's operational environment.

Properly written business rules are used to define entities, attributes, relationships, and constraints. Any time you see relationship statements such as “an agent can serve many customers, and each customer can be served by only one agent,” business rules are at work. You will see the application of business rules throughout this book, especially in the chapters devoted to data modeling and database design.

To be effective, business rules must be easy to understand and widely disseminated to ensure that every person in the organization shares a common interpretation of the rules. Business rules describe, in simple language, the main and distinguishing characteristics of the data *as viewed by the company*. Examples of business rules are as follows:

- A customer may generate many invoices.
- An invoice is generated by only one customer.
- A training session cannot be scheduled for fewer than 10 employees or for more than 30 employees.

Note that those business rules establish entities, relationships, and constraints. For example, the first two business rules establish two entities (CUSTOMER

and INVOICE) and a 1:M relationship between those two entities. The third business rule establishes a constraint (no fewer than 10 people and no more than 30 people), two entities (EMPLOYEE and TRAINING), and a relationship between EMPLOYEE and TRAINING.

2.4.1 DISCOVERING BUSINESS RULES

The main sources of business rules are company managers, policy makers, department managers, and written documentation such as a company's procedures, standards, and operations manuals. A faster and more direct source of business rules is direct interviews with end users. Unfortunately, because perceptions differ, end users are sometimes a less reliable source when it comes to specifying business rules. For example, a maintenance department mechanic might believe that any mechanic can initiate a maintenance procedure, when actually only mechanics with inspection authorization can perform such a task. Such a distinction might seem trivial, but it can have major legal consequences. Although end users are crucial contributors to the development of business rules, *it pays to verify end-user perceptions*. Too often, interviews with several people who perform the same job yield very different perceptions of what the job components are. While such a discovery may point to "management problems," that general diagnosis does not help the database designer. The database designer's job is to reconcile such differences and verify the results of the reconciliation to ensure that the business rules are appropriate and accurate.

The process of identifying and documenting business rules is essential to database design for several reasons:

- They help to standardize the company's view of data.
- They can be a communications tool between users and designers.
- They allow the designer to understand the nature, role, and scope of the data.
- They allow the designer to understand business processes.
- They allow the designer to develop appropriate relationship participation rules and constraints and to create an accurate data model.

Of course, not all business rules can be modeled. For example, a business rule that specifies “no pilot can fly more than 10 hours within any 24-hour period” cannot be modeled. However, such a business rule can be enforced by application software.

2.4.2 TRANSLATING BUSINESS RULES INTO DATA MODEL COMPONENTS

Business rules set the stage for the proper identification of entities, attributes, relationships, and constraints. In the real world, names are used to identify objects. If the business environment wants to keep track of the objects, there will be specific business rules for the objects. As a general rule, a noun in a business rule will translate into an entity in the model, and a verb (active or passive) that associates the nouns will translate into a relationship among the entities. For example, the business rule “a customer may generate many invoices” contains two nouns (*customer* and *invoices*) and a verb (*generate*) that associates the nouns. From this business rule, you could deduce that:

- Customer and invoice are objects of interest for the environment and should be represented by their respective entities.
- There is a “generate” relationship between customer and invoice.

To properly identify the type of relationship, you should consider that relationships are bidirectional; that is, they go both ways. For example, the business rule “a customer may generate many invoices” is complemented by the business rule “an invoice is generated by only one customer.” In that case, the relationship is one-to-many (1:M). Customer is the “1” side, and invoice is the “many” side.

As a general rule, to properly identify the relationship type, you should ask two questions:

- How many instances of B are related to one instance of A?
- How many instances of A are related to one instance of B?

For example, you can assess the relationship between student and class by asking two questions:

- In how many classes can one student enroll? Answer: many classes.
- How many students can enroll in one class? Answer: many students.

Therefore, the relationship between student and class is many-to-many (M:N). You will have many opportunities to determine the relationships between entities as you proceed through this book, and soon the process will become second nature.

2.4.3 NAMING CONVENTIONS

During the translation of business rules to data model components, you identify entities, attributes, relationships, and constraints. This identification process includes naming the object in a way that makes it unique and distinguishable from other objects in the problem domain. Therefore, it is important to pay special attention to how you name the objects you are discovering.

Entity names should be descriptive of the objects in the business environment and use terminology that is familiar to the users. An attribute name should also be descriptive of the data represented by that attribute. It is also a good practice to prefix the name of an attribute with the name or abbreviation of the entity in which it occurs. For example, in the CUSTOMER entity, the customer's credit limit may be called CUS_CREDIT_LIMIT. The CUS indicates that the attribute is descriptive of the CUSTOMER entity, while CREDIT_LIMIT makes it easy to recognize the data that will be contained in the attribute. This will become increasingly important in later chapters when you learn about the need to use common attributes to specify relationships between entities. The use of a proper naming convention will improve the data model's ability to facilitate communication among the designer, application programmer, and the end user. In fact, a proper naming convention can go a long way toward making your model self-documenting.

2.5 THE EVOLUTION OF DATA MODELS

The quest for better data management has led to several models that attempt to resolve the previous model's critical shortcomings and to provide solutions to ever-evolving data management needs. These models represent schools of

thought as to what a database is, what it should do, the types of structures that it should employ, and the technology that would be used to implement these structures. Perhaps confusingly, these models are called data models, as are the graphical data models discussed earlier in this chapter. This section gives an overview of the major data models in roughly chronological order. You will discover that many of the “new” database concepts and structures bear a remarkable resemblance to some of the “old” data model concepts and structures. [Table 2.1](#) traces the evolution of the major data models.

TABLE 2.1 Evolution of Major Data Models

GENERATION	TIME	DATA MODEL	EXAMPLES	COMMENTS
First	1960s–1970s	File system	VMS/VSAM	Used mainly on IBM mainframe systems Managed records, not relationships
Second	1970s	Hierarchical and network	IMS, ADABAS, IDS-II	Early database systems Navigational access
Third	Mid-1970s	Relational	DB2 Oracle MS SQL Server MySQL	Conceptual simplicity Entity relationship (ER) modeling and support for relational data modeling
Fourth	Mid-1980s	Object-oriented Object/relational (O/R)	Versant Objectivity/DB DB2 UDB Oracle 11g	Object/relational supports object data types Star Schema support for data warehousing Web databases become common
Fifth	Mid-1990s	XML Hybrid DBMS	dbXML Tamino DB2 UDB Oracle 11g MS SQL Server	Unstructured data support O/R model supports XML documents Hybrid DBMS adds object front end to relational databases Support large databases (terabyte size)
Emerging Models: NoSQL	Late 2000s to present	Key-value store Column store	SimpleDB (Amazon) BigTable (Google) Cassandra (Apache)	Distributed, highly scalable High performance, fault tolerant Very large storage (petabytes) Suited for sparse data Proprietary API



ONLINE CONTENT

The hierarchical and network models are largely of historical interest, yet they do contain some elements and features that interest current database professionals. The technical details of those two models are discussed in **Appendices K** and **L**, respectively, which are available at www.cengagebrain.com. **Appendix G** is devoted to the object-oriented (OO) model. However, given the dominant market presence of the relational model, most of the book focuses on that model.

2.5.1 HIERARCHICAL AND NETWORK MODELS

The **hierarchical model** was developed in the 1960s to manage large amounts of data for complex manufacturing projects, such as the Apollo rocket that landed on the moon in 1969. The model's basic logical structure is represented by an upside-down tree. The hierarchical structure contains levels, or segments. A **segment** is the equivalent of a file system's record type. Within the hierarchy, a higher layer is perceived as the parent of the segment directly beneath it, which is called the child. The hierarchical model depicts a set of one-to-many (1:M) relationships between a parent and its children segments. (Each parent can have many children, but each child has only one parent.)

The **network model** was created to represent complex data relationships more effectively than the hierarchical model, to improve database performance, and to impose a database standard. In the network model, the user perceives the network database as a collection of records in 1:M relationships. However, unlike the hierarchical model, the network model allows a record to have more than one parent. While the network database model is generally not used today, the definitions of standard database *concepts* that emerged with the network model are still used by modern data models:

- The **schema** is the conceptual organization of the entire database as viewed by the database administrator.
- The **subschema** defines the portion of the database “seen” by the application programs that actually produce the desired information from the data within the database.
- A **data manipulation language (DML)** defines the environment in which data can be managed and is used to work with the data in the database.

- A schema [**data definition language \(DDL\)**](#) enables the database administrator to define the schema components.

As information needs grew and more sophisticated databases and applications were required, the network model became too cumbersome. The lack of ad hoc query capability put heavy pressure on programmers to generate the code required to produce even the simplest reports. Although the existing databases provided limited data independence, any structural change in the database could still produce havoc in all application programs that drew data from the database. Because of the disadvantages of the hierarchical and network models, they were largely replaced by the relational data model in the 1980s.

2.5.2 THE RELATIONAL MODEL

The [**relational model**](#) was introduced in 1970 by E. F. Codd of IBM in his landmark paper “A Relational Model of Data for Large Shared Databanks” (*Communications of the ACM*, June 1970). The relational model represented a major breakthrough for both users and designers. To use an analogy, the relational model produced an “automatic transmission” database to replace the “standard transmission” databases that preceded it. Its conceptual simplicity set the stage for a genuine database revolution.

NOTE

The relational database model presented in this chapter is an introduction and an overview. A more detailed discussion is in [**Chapter 3, The Relational Database Model**](#). In fact, the relational model is so important that it will serve as the basis for discussions in most of the remaining chapters.

The relational model’s foundation is a mathematical concept known as a relation. To avoid the complexity of abstract mathematical theory, you can think of a [**relation**](#) (sometimes called a [**table**](#)) as a matrix composed of intersecting rows and columns. Each row in a relation is called a [**tuple**](#). Each column represents an attribute. The relational model also describes a precise set of data manipulation constructs based on advanced mathematical concepts.

In 1970, Codd's work was considered ingenious but impractical. The relational model's conceptual simplicity was bought at the expense of computer overhead; computers at that time lacked the power to implement the relational model. Fortunately, computer power grew exponentially, as did operating system efficiency. Better yet, the cost of computers diminished rapidly as their power grew. Today, even PCs, which cost a fraction of what their mainframe ancestors cost, can run sophisticated relational database software such as Oracle, DB2, Microsoft SQL Server, MySQL, and other mainframe relational software.

The relational data model is implemented through a very sophisticated **relational database management system (RDBMS)**. The RDBMS performs the same basic functions provided by the hierarchical and network DBMS systems, in addition to a host of other functions that make the relational data model easier to understand and implement.

Arguably the most important advantage of the RDBMS is its ability to hide the complexities of the relational model from the user. The RDBMS manages all of the physical details, while the user sees the relational database as a collection of tables in which data are stored. The user can manipulate and query the data in a way that seems intuitive and logical.

Tables are related to each other through the sharing of a common attribute (a value in a column). For example, the CUSTOMER table in [Figure 2.1](#) might contain a sales agent's number that is also contained in the AGENT table.

FIGURE 2.1 Linking relational tables

Table name: AGENT (first six attributes)

AGENT_CODE	AGENT_LNAME	AGENT_FNAME	AGENT_INITIAL	AGENT_AREACODE	AGENT_PHONE
501	Alby	Alex	B	713	228-1249
502	Hahn	Leah	F	615	882-1244
503	Okon	John	T	615	123-5589

Database name: Ch02_InsureCo

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_INSURE_TYPE	CUS_INSURE_AMT	CUS_RENEW_DATE	AGENT_CODE
10010	Ramas	Alfred	A	615	844-2673	T1	100.00	05-Apr-2012	502
10011	Dunne	Leona	K	713	894-1230	T1	250.00	16-Jun-2012	501
10012	Smith	Kathy	W	615	894-2285	S2	150.00	29-Jan-2013	502
10013	Olowski	Paul	F	615	894-2180	S1	300.00	14-Oct-2012	502
10014	Orlando	Myron		615	222-1672	T1	100.00	20-Dec-2013	501
10015	O'Brian	Amy	B	713	442-3381	T2	850.00	22-Sep-2012	503
10016	Brown	James	G	615	297-1228	S1	120.00	25-Mar-2013	502
10017	Williams	George		615	290-2556	S1	250.00	17-Jul-2012	503
10018	Farris	Anne	G	713	382-7185	T2	100.00	03-Dec-2012	501
10019	Smith	Olett	K	615	297-3800	S2	500.00	14-Mar-2013	503

Link through AGENT_CODE

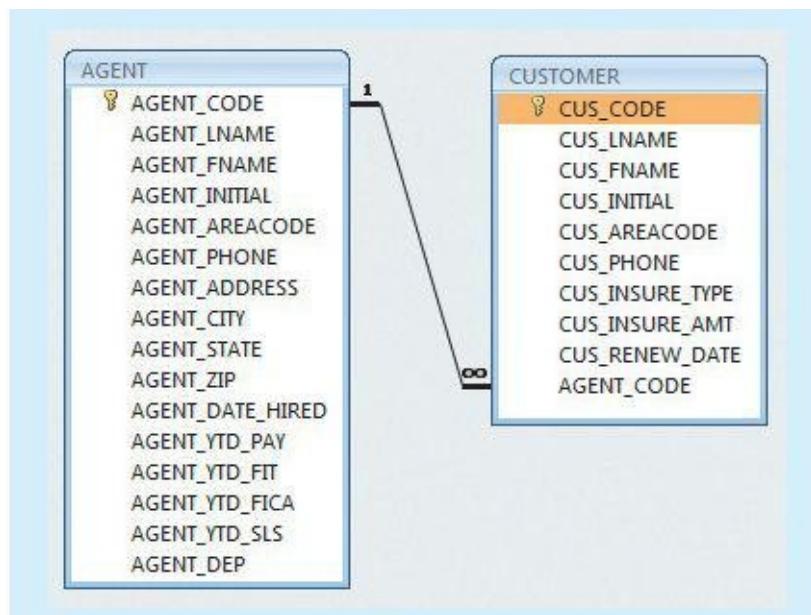


ONLINE CONTENT

This chapter's databases are available at www.cengagebrain.com. For example, the contents of the AGENT and CUSTOMER tables shown in [Figure 2.1](#) are in the database named **Ch02_InsureCo**.

The common link between the CUSTOMER and AGENT tables enables you to match the customer to his or her sales agent, even though the customer data are stored in one table and the sales representative data are stored in another table. For example, you can easily determine that customer Dunne's agent is Alex Alby because for customer Dunne, the CUSTOMER table's AGENT_CODE is 501, which matches the AGENT table's AGENT_CODE for Alex Alby. Although the tables are independent of one another, you can easily associate the data between tables. The relational model provides a minimum level of controlled redundancy to eliminate most of the redundancies commonly found in file systems.

FIGURE 2.2 A relational diagram



SOURCE: Course Technology/Cengage Learning

The relationship type (1:1, 1:M, or M:N) is often shown in a relational schema, an example of which is shown in [Figure 2.2](#). A **relational diagram** is a representation of the relational database's entities, the attributes within those entities, and the relationships between those entities.

In [Figure 2.2](#), the relational diagram shows the connecting fields (in this case, AGENT_CODE) and the relationship type, 1:M. Microsoft Access, the database software application used to generate [Figure 2.2](#), employs the infinity symbol (∞) to indicate the “many” side. In this example, the CUSTOMER represents the “many” side because an AGENT can have many CUSTOMERS. The AGENT represents the “1” side because each CUSTOMER has only one AGENT.

A relational table stores a collection of related entities. In this respect, the relational database table resembles a file, but there is a crucial difference between a table and a file: A table yields complete data and structural independence because it is a purely logical structure. How the data are physically stored in the database is of no concern to the user or the designer; the perception is what counts. This property of the relational data model, which is explored in depth in the next chapter, became the source of a real database revolution.

Another reason for the relational data model’s rise to dominance is its powerful and flexible query language. Most relational database software uses Structured

Query Language (SQL), which allows the user to specify what must be done without specifying how. The RDBMS uses SQL to translate user queries into instructions for retrieving the requested data. SQL makes it possible to retrieve data with far less effort than any other database or file environment.

From an end-user perspective, any SQL-based relational database application involves three parts: a user interface, a set of tables stored in the database, and the SQL “engine.” Each of these parts is explained below.

- *The end-user interface.* Basically, the interface allows the end user to interact with the data (by automatically generating SQL code). Each interface is a product of the software vendor’s idea of meaningful interaction with the data. You can also design your own customized interface with the help of application generators that are now standard fare in the database software arena.
- *A collection of tables stored in the database.* In a relational database, all data are perceived to be stored in tables. The tables simply “present” the data to the end user in a way that is easy to understand. Each table is independent. Rows in different tables are related by common values in common attributes.
- *SQL engine.* Largely hidden from the end user, the SQL engine executes all queries, or data requests. Keep in mind that the SQL engine is part of the DBMS software. The end user uses SQL to create table structures and to perform data access and table maintenance. The SQL engine processes all user requests—largely behind the scenes and without the end user’s knowledge. Hence, SQL is said to be a declarative language that tells what must be done but not how. (You will learn more about the SQL engine in [Chapter 11](#), Database Performance Tuning and Query Optimization.)

Because the RDBMS performs some tasks behind the scenes, it is not necessary to focus on the physical aspects of the database. Instead, the following chapters concentrate on the logical portion of the relational database and its design. Furthermore, SQL is covered in detail in [Chapter 7](#), Introduction to Structured Query Language (SQL), and in [Chapter 8](#), Advanced SQL.

2.5.3 THE ENTITY RELATIONSHIP MODEL

The conceptual simplicity of relational database technology triggered the demand for RDBMSs. In turn, the rapidly increasing requirements for transaction and information created the need for more complex database implementation structures, thus creating the need for more effective database design tools. (Building a skyscraper requires more detailed design activities than building a doghouse, for example.)

Complex design activities require conceptual simplicity to yield successful results. Although the relational model was a vast improvement over the hierarchical and network models, it still lacked the features that would make it an effective database *design* tool. Because it is easier to examine structures graphically than to describe them in text, database designers prefer to use a graphical tool in which entities and their relationships are pictured. Thus, the **entity relationship (ER) model**, or **ERM**, has become a widely accepted standard for data modeling.

Peter Chen first introduced the ER data model in 1976; the graphical representation of entities and their relationships in a database structure quickly became popular because it *complemented* the relational data model concepts. The relational data model and ERM combined to provide the foundation for tightly structured database design. ER models are normally represented in an **entity relationship diagram (ERD)**, which uses graphical representations to model database components.

NOTE

Because this chapter's objective is to introduce data-modeling concepts, a simplified ERD is discussed in this section. You will learn how to use ERDs to design databases in [**Chapter 4, Entity Relationship \(ER\) Modeling**](#).

The ER model is based on the following components:

- *Entity*. Earlier in this chapter, an entity was defined as anything about which data will be collected and stored. An entity is represented in the ERD by a rectangle, also known as an entity box. The name of the entity, a noun, is written in the center of the rectangle. The entity name is generally written in capital letters and in singular form: PAINTER rather than PAINTERS, and EMPLOYEE rather than EMPLOYEES. Usually, when applying the ERD to the relational model, an entity is mapped to a

relational table. Each row in the relational table is known as an [entity instance](#) or [entity occurrence](#) in the ER model.

NOTE

A collection of like entities is known as an [entity set](#). For example, you can think of the AGENT file in [Figure 2.1](#) as a collection of three agents (*entities*) in the AGENT *entity set*. Technically speaking, the ERD depicts entity sets. Unfortunately, ERD designers use the word *entity* as a substitute for *entity set*, and this book will conform to that established practice when discussing any ERD and its components.

Each entity consists of a set of *attributes* that describes particular characteristics of the entity. For example, the entity EMPLOYEE will have attributes such as a Social Security number, a last name, and a first name. ([Chapter 4](#) explains how attributes are included in the ERD.)

- *Relationships.* Relationships describe associations among data. Most relationships describe associations between two entities. When the basic data model components were introduced, three types of data relationships were illustrated: one-to-many (1:M), many-to-many (M:N), and one-to-one (1:1). The ER model uses the term [connectivity](#) to label the relationship types. The name of the relationship is usually an active or passive verb. For example, a PAINTER *paints* many PAINTINGS, an EMPLOYEE *learns* many SKILLS, and an EMPLOYEE *manages* a STORE.

[Figure 2.3](#) shows the different types of relationships using three ER notations: the original [Chen notation](#), the [Crow's Foot notation](#), and the newer [class diagram notation](#), which is part of the Unified Modeling Language (UML).

The left side of the ER diagram shows the Chen notation, based on Peter Chen's landmark paper. In this notation, the connectivities are written next to each entity box. Relationships are represented by a diamond connected to the related entities through a relationship line. The relationship name is written inside the diamond.

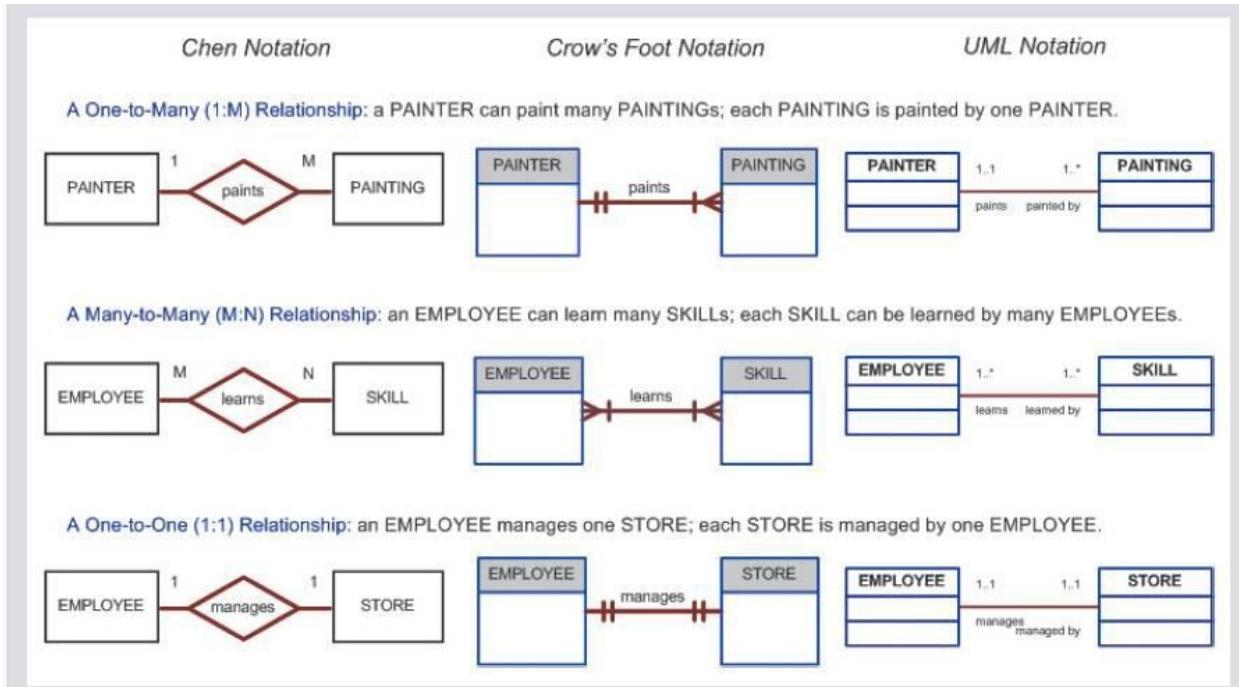
The middle of [Figure 2.3](#) illustrates the Crow's Foot notation. The name *Crow's*

Foot is derived from the three-pronged symbol used to represent the “many” side of the relationship. As you examine the basic Crow’s Foot ERD in [Figure 2.3](#), note that the connectivities are represented by symbols. For example, the “1” is represented by a short line segment, and the “M” is represented by the three-pronged “crow’s foot.” In this example, the relationship name is written above the relationship line.

The right side of [Figure 2.3](#) shows the UML notation (also known as the UML class notation). Note that the connectivities are represented by lines with symbols (1..1, 1..*). Also, the UML notation uses names in both sides of the relationship. For example, to read the relationship between PAINTER and PAINTING, note that:

- A PAINTER “paints” one to many PAINTINGS, as indicated by the 1..* symbol.
- A PAINTING is “painted by” one and only one PAINTER, as indicated by the 1..1 symbol.

FIGURE 2.3 The ER model notations



SOURCE: Course Technology/Cengage Learning

NOTE

Many-to-many (M:N) relationships exist at a conceptual level, and you should know how to recognize them. However, you will learn in [Chapter 3](#) that M:N relationships are not appropriate in a relational model. For that reason, Microsoft Visio does not support the M:N relationship directly. Therefore, to illustrate the existence of an M:N relationship using Visio, you have to change the line style of the connector (see **Appendix A, Designing Databases with Visio Professional: A Tutorial**, at www.cengagebrain.com).

In [Figure 2.3](#), entities and relationships are shown in a horizontal format, but they may also be oriented vertically. The entity location and the order in which the entities are presented are immaterial; just remember to read a 1:M relationship from the “1” side to the “M” side.

The Crow’s Foot notation is used as the design standard in this book. However, the Chen notation is used to illustrate some of the ER modeling concepts whenever necessary. Most data modeling tools let you select the Crow’s Foot or

UML's class diagram notation. Microsoft Visio Professional software was used to generate the Crow's Foot designs you will see in subsequent chapters.



ONLINE CONTENT

Aside from the Chen, Crow's Foot, and UML notations, there are other ER model notations. For a summary of the symbols used by several additional ER model notations, see **Appendix E, Comparison of ER Model Notations**, at www.cengagebrain.com.

The ER model's exceptional visual simplicity makes it the dominant database modeling and design tool. Nevertheless, the search for better data-modeling tools continues as the data environment continues to evolve.

2.5.4 THE OBJECT-ORIENTED (OO) MODEL

Increasingly complex real-world problems demonstrated a need for a data model that more closely represented the real world. In the **object-oriented data model (OODM)**, both data *and their relationships* are contained in a single structure known as an **object**. In turn, the OODM is the basis for the **object-oriented database management system (OODBMS)**.



ONLINE CONTENT

This chapter introduces only basic OO concepts. You can examine object-orientation concepts and principles in detail in **Appendix G, Object-Oriented Databases**, at www.cengagebrain.com.

An OODM reflects a very different way to define and use entities. Like the relational model's entity, an object is described by its factual content. But, quite *unlike* an entity, an object includes information about relationships between the facts within the object, as well as information about its relationships with other

objects. Therefore, the facts within the object are given greater *meaning*. The OODM is said to be a **semantic data model because** *semantic* indicates meaning.

Subsequent OODM development has allowed an object also to contain all *operations* that can be performed on it, such as changing its data values, finding a specific data value, and printing data values. Because objects include data, various types of relationships, and operational procedures, the object becomes self-contained, thus making it—at least potentially—a basic building block for autonomous structures.

The OO data model is based on the following components:

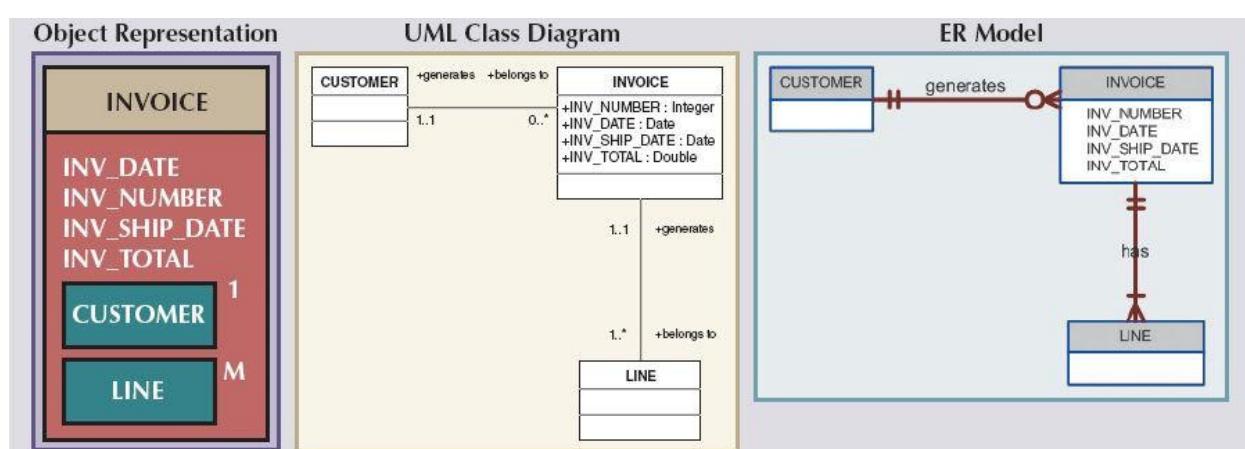
- An object is an abstraction of a real-world entity. In general terms, an object may be considered equivalent to an ER model's entity. More precisely, an object represents only one occurrence of an entity. (The object's semantic content is defined through several of the items in this list.)
- Attributes describe the properties of an object. For example, a PERSON object includes the attributes Name, Social Security Number, and Date of Birth.
- Objects that share similar characteristics are grouped in classes. A **class** is a collection of similar objects with shared structure (attributes) and behavior (methods). In a general sense, a class resembles the ER model's *entity set*. However, a class is different from an entity set in that it contains a set of procedures known as *methods*. A class's **method** represents a real-world action such as *finding* a selected PERSON's name, *changing* a PERSON's name, or *printing* a PERSON's address. In other words, methods are the equivalent of *procedures* in traditional programming languages. In OO terms, methods define an object's *behavior*.
- Classes are organized in a *class hierarchy*. The **class hierarchy** resembles an upside-down tree in which each class has only one parent. For example, the CUSTOMER class and the EMPLOYEE class share a parent PERSON class. (Note the similarity to the hierarchical data model in this respect.)
- **Inheritance** is the ability of an object within the class hierarchy to inherit

the attributes and methods of the classes above it. For example, two classes, CUSTOMER and EMPLOYEE, can be created as subclasses from the class PERSON. In this case, CUSTOMER and EMPLOYEE will inherit all attributes and methods from PERSON.

Object-oriented data models are typically depicted using [Unified Modeling Language \(UML\)](#) class diagrams. UML is a language based on OO concepts that describes a set of diagrams and symbols you can use to graphically model a system. UML [class diagrams](#) are used to represent data and their relationships within the larger UML object-oriented system's modeling language. For a more complete description of UML, see Appendix H, Unified Modeling Language (UML).

To illustrate the main concepts of the object-oriented data model, consider a simple invoicing problem. In this case, invoices are generated by customers, each invoice references one or more lines, and each line represents an item purchased by a customer. [Figure 2.4](#) illustrates the object representation for this simple invoicing problem, as well as the equivalent UML class diagram and ER model. The object representation is a simple way to visualize a single object occurrence.

FIGURE 2.4 A comparison of OO, UML, and ER models



SOURCE: Course Technology/Cengage Learning

As you examine [Figure 2.4](#), note that:

- The object representation of the INVOICE includes all related objects within the *same* object box. Note that the connectivities (1 and M) indicate the relationship of the related objects to the INVOICE. For example, the “1” next to the CUSTOMER object indicates that each INVOICE is related to only one CUSTOMER. The “M” next to the LINE object indicates that each INVOICE contains many LINES.
- The UML class diagram uses three separate object classes (CUSTOMER, INVOICE, and LINE) and two relationships to represent this simple invoicing problem. Note that the relationship connectivities are represented by the 1..1, 0..*, and 1..* symbols, and that the relationships are named in both ends to represent the different “roles” that the objects play in the relationship.
- The ER model also uses three separate entities and two relationships to represent this simple invoice problem.

The OODM advances influenced many areas, from system modeling to programming. (Most contemporary programming languages have adopted OO concepts, including Java, Ruby, Perl, C#, and Visual Studio .NET.) The added semantics of the OODM allowed for a richer representation of complex objects. This in turn enabled applications to support increasingly complex objects in innovative ways. As you will see in the next section, such evolutionary advances also affected the relational model.

2.5.5 OBJECT/RELATIONAL AND XML

Facing the demand to support more complex data representations, the relational model’s main vendors evolved the model further and created the [extended relational data model \(ERDM\)](#). The ERDM adds many of the OO model’s features within the inherently simpler relational database structure. The ERDM gave birth to a new generation of relational databases that support OO features such as objects (encapsulated data and methods), extensible data types based on classes, and inheritance. That’s why a DBMS based on the ERDM is often described as an [object/relational database management system \(O/R DBMS\)](#).

Today, most relational database products can be classified as object/relational, and they represent the dominant market share of OLTP and OLAP database

applications. The success of the O/R DBMS can be attributed to the model's conceptual simplicity, data integrity, easy-to-use query language, high transaction performance, high availability, security, scalability, and expandability. In contrast, the OO DBMS is popular in niche markets such as computer-aided drawing/computer-aided manufacturing (CAD/CAM), geographic information systems (GIS), telecommunications, and multimedia, which require support for more complex objects.

From the start, the OO and relational data models were developed in response to different problems. The OO data model was created to address very specific engineering needs, not the wide-ranging needs of general data management tasks. The relational model was created with a focus on better data management based on a sound mathematical foundation. Given its focus on a smaller set of problem areas, it is not surprising that the OO market has not grown as rapidly as the relational data model market.

The use of complex objects received a boost with the Internet revolution. When organizations integrated their business models with the Internet, they realized its potential to access, distribute, and exchange critical business information. This resulted in the widespread adoption of the Internet as a business communication tool. Within this environment, [**Extensible Markup Language \(XML\)**](#) emerged as the de facto standard for the efficient and effective exchange of structured, semistructured, and unstructured data. Organizations that use XML data soon realized that they needed to manage large amounts of unstructured data such as word-processing documents, Web pages, e-mails, and diagrams. To address this need, XML databases emerged to manage unstructured data within a native XML format. (See [Chapter 14](#), Database Connectivity and Web Technologies, for more information about XML.) At the same time, O/R DBMSs added support for XML-based documents within their relational data structure. Due to its robust foundation in broadly applicable principles, the relational model is easily extended to include new classes of capabilities, such as objects and XML.

Although relational and object/relational databases address most current data processing needs, a new generation of databases has emerged to address some very specific challenges found in some Internet-era organizations.

2.5.6 EMERGING DATA MODELS: BIG DATA AND NOSQL

Deriving usable business information from the mountains of Web data that organizations have accumulated over the years has become an imperative need.

Web data in the form of browsing patterns, purchasing histories, customer preferences, behavior patterns, and social media data from sources such as Facebook, Twitter, and LinkedIn have inundated organizations with combinations of structured and unstructured data. According to many studies, the rapid pace of data growth is the top challenge for organizations,¹ with system performance and scalability as the next biggest challenges. Today's information technology (IT) managers are constantly balancing the need to manage this rapidly growing data with shrinking budgets. The need to manage and leverage all these converging trends (rapid data growth, performance, scalability, and lower costs) has triggered a phenomenon called "Big Data." **Big Data** refers to a movement to find new and better ways to manage large amounts of Web-generated data and derive business insight from it, while simultaneously providing high performance and scalability at a reasonable cost.

The problem is that the relational approach does not always match the needs of organizations with Big Data challenges.

- It is not always possible to fit unstructured, social media data into the conventional relational structure of rows and columns.
- Adding millions of rows of multiformat (structured and nonstructured) data on a daily basis will inevitably lead to the need for more storage, processing power, and sophisticated data analysis tools that may not be available in the relational environment.
- Generally speaking, the type of high-volume implementations required in the RDBMS environment for the Big Data problem comes with a hefty price tag for expanding hardware, storage, and software licenses.
- Data analysis based on OLAP tools has proven to be very successful in relational environments with highly structured data. However, mining for usable data in the vast amounts of unstructured data collected from Web sources requires a different approach.

There is no "one-size-fits-all" cure to data management needs (although many established database vendors will probably try to sell you on the idea). For some organizations, creating a highly scalable, fault-tolerant infrastructure for Big Data analysis could prove to be a matter of business survival. The business

world has many examples of companies that leverage technology to gain a competitive advantage, and others that miss it. Just ask yourself how the business landscape would be different if:

- MySpace had responded to Facebook's challenge in time.
- Blockbuster had reacted to the Netflix business model sooner.
- Barnes & Noble had developed a viable Internet strategy before Amazon.

Therefore, it is not surprising that some organizations are turning to NoSQL databases to mine the wealth of information hidden in mountains of Web data and gain a competitive advantage.

NOTE

Does this mean that relational databases don't have a place in organizations with Big Data challenges? No, relational databases remain the preferred and dominant databases to support most day-to-day transactions and structured data analytics needs. Each DBMS technology has its areas of application, and the best approach is to use the best tool for the job. In perspective, object/relational databases serve 98% of market needs. For the remaining 2%, NoSQL databases are an option.

NoSQL Databases

Every time you search for a product on Amazon, send messages to friends in Facebook, watch a video in YouTube, or search for directions in Google Maps, you are using a NoSQL database. As with any new technology, the term *NoSQL* can be loosely applied to many different types of technologies. However, this chapter uses **NoSQL** to refer to a new generation of databases that address the specific challenges of the Big Data era and have the following general characteristics:

- Not based on the relational model, hence the name NoSQL.
- Supports distributed database architectures.

- Provides high scalability, high availability, and fault tolerance.
- Supports very large amounts of sparse data.
- Geared toward performance rather than transaction consistency.

Let's examine these characteristics in more detail.

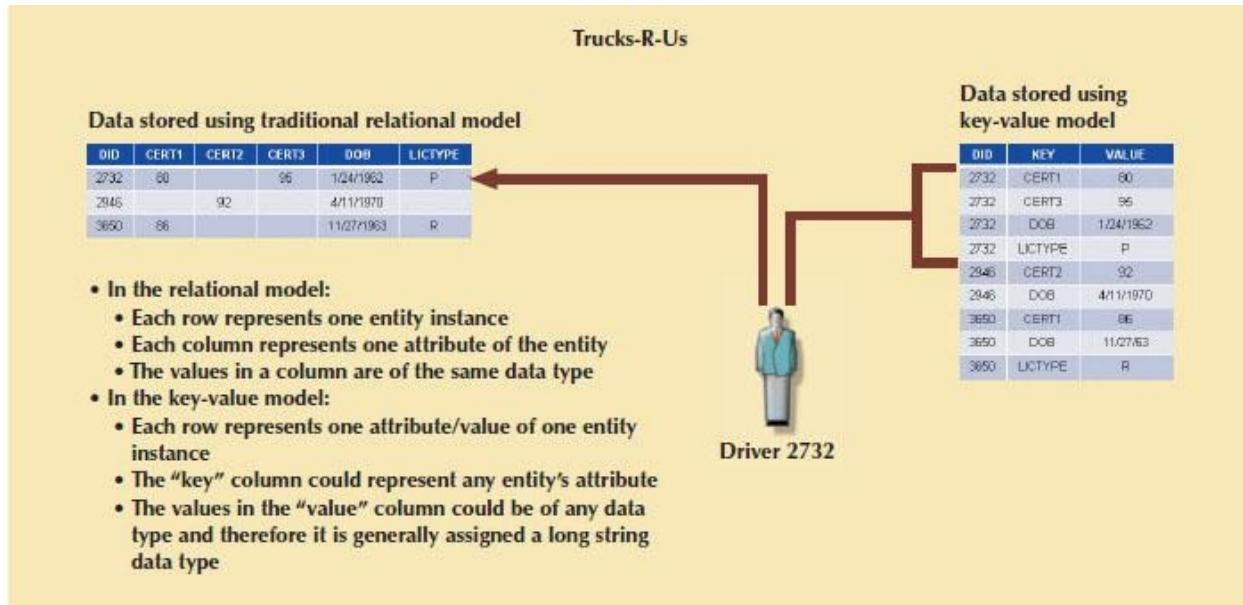
NoSQL databases are not based on the relational model. In fact, there is no standard NoSQL data model. To the contrary, many different data models are grouped under the NoSQL umbrella, from document databases to graph stores, column stores, and key-value stores. It is still too early to know which, if any, of these data models will survive and grow to become a dominant force in the database arena. However, the early success of products such as Amazon's SimpleDB, Google's BigTable, and Apache's Cassandra points to the *key-value stores* and *column stores* as the early leaders. The word *stores* indicates that these data models permanently store data in secondary storage, just like any other database. This added emphasis comes from the fact that these data models originated from programming languages (such as LISP), in which in-memory arrays of values are used to hold data.

The **key-value** data model is based on a structure composed of two data elements: a key and a value, in which every key has a corresponding value or set of values. The key-value data model is also referred to as the attribute-value or associative data model. To better understand the key-value model, look at the simple example in [Figure 2.5](#).

[Figure 2.5](#) shows the example of a small truck-driving company called Trucks-R-Us. Each of the three drivers has one or more certifications and other general information. Using this example, we can draw the following important points:

- In the relational model, every row represents a single entity occurrence and every column represents an attribute of the entity occurrence. Each column has a defined data type.

FIGURE 2.5 A simple key-value representation



SOURCE: Course Technology/Cengage Learning

- In the key-value data model, each row represents one attribute of one entity instance. The “key” column points to an attribute and the “value” column contains the actual value for the attribute.
- The data type of the “value” column is generally a long string to accommodate the variety of actual data types of the values placed in the column.
- To add a new entity attribute in the relational model, you need to modify the table definition. To add a new attribute in the key-value store, you add a row to the key-value store, which is why it is said to be “schema-less.”
- NoSQL databases do not store or enforce relationships among entities. The programmer is required to manage the relationships in the program code. Furthermore, all data and integrity validations must be done in the program code (although some implementations have been expanded to support metadata).
- NoSQL databases use their own native application programming interface (API) with simple data access commands, such as *put*, *read*, and *delete*. Because there is no declarative SQL-like syntax to retrieve data, the

program code must take care of retrieving related data in the correct way.

- Indexing and searches can be difficult. Because the “value” column in the key-value data model could contain many different data types, it is often difficult to create indexes on the data. At the same time, searches can become very complex.

As a matter of fact, you could use the key-value structure as a general data modeling technique when attributes are numerous but actual data values are scarce. The key-value data model is not exclusive of NoSQL databases; actually, key-value data structures could reside inside a relational database. However, because of the problems with maintaining relationships and integrity within the data, and the increased complexity of even simple queries, key-value structures would be a poor design for most structured business data.

Several NoSQL database implementations, such as Google’s BigTable and Apache’s Cassandra, have extended the key-value data model to group multiple key-value sets into column families or column stores. In addition, such implementations support features such as versioning using a date/time stamp. For example, BigTable stores data in the syntax of [row, column, time, value], where row, column, and value are string data types and time is a date/time data type. The key used to access the data is composed of (row, column, time), where time can be left blank to indicate the most recent stored value.

NoSQL supports distributed database architecture. One of the big advantages of NoSQL databases is that they generally use a distributed architecture. In fact, several of them (Cassandra, BigTable) are designed to use low-cost commodity servers to form a complex network of distributed database nodes. Remember that several NoSQL databases originated in the research labs of some of the most successful Web companies, and most started on very small budgets!

NoSQL supports very large amounts of sparse data. NoSQL databases can handle very high volumes of data. In particular, they are suited for **sparse data** —that is, for cases in which the number of attributes is very large but the number of actual data instances is low. Using the preceding example, drivers can take any certification exam, but they are not required to take all. In this case, if there are three drivers and three possible certificates for each driver, there will be nine possible data points. In practice, however, there are only four data instances. Now extrapolate this example for the case of a clinic with 15,000 patients and

more than 500 possible tests, remembering that each patient can take a few tests but is not required to take all.

NoSQL provides high scalability, high availability, and fault tolerance. True to its Web origins, NoSQL databases are designed to support Web operations, such as the ability to add capacity in the form of nodes to the distributed database when the demand is high, and to do it transparently and without downtime. Fault tolerance means that if one of the nodes in the distributed database fails, it will keep operating as normal.

Most NoSQL databases are geared toward performance rather than transaction consistency. One of the biggest problems of very large distributed databases is enforcing data consistency. Distributed databases automatically make copies of data elements at multiple nodes to ensure high availability and fault tolerance. If the node with the requested data goes down, the request can be served from any other node with a copy of the data. However, what happens if the network goes down during a data update? In a relational database, transaction updates are guaranteed to be consistent or the transaction is rolled back. NoSQL databases sacrifice consistency to attain high levels of performance. (See [Chapter 12](#), Distributed Database Management Systems, to learn more about this topic.) Some NoSQL databases provide a feature called **eventual consistency**, which means that updates to the database will propagate through the system and eventually all data copies will be consistent. With eventual consistency, data are not guaranteed to be consistent across all copies of the data immediately after an update.

NoSQL is one of the hottest items in database technologies today. But, as you learned in [Chapter 1](#), it is only one of many emerging trends in data management. Whatever database technology you use, you need to be able to select the best tool for the job by understanding the pros and cons of each technology. The following section briefly summarizes the evolution of data models and provides some advantages and disadvantages of each.

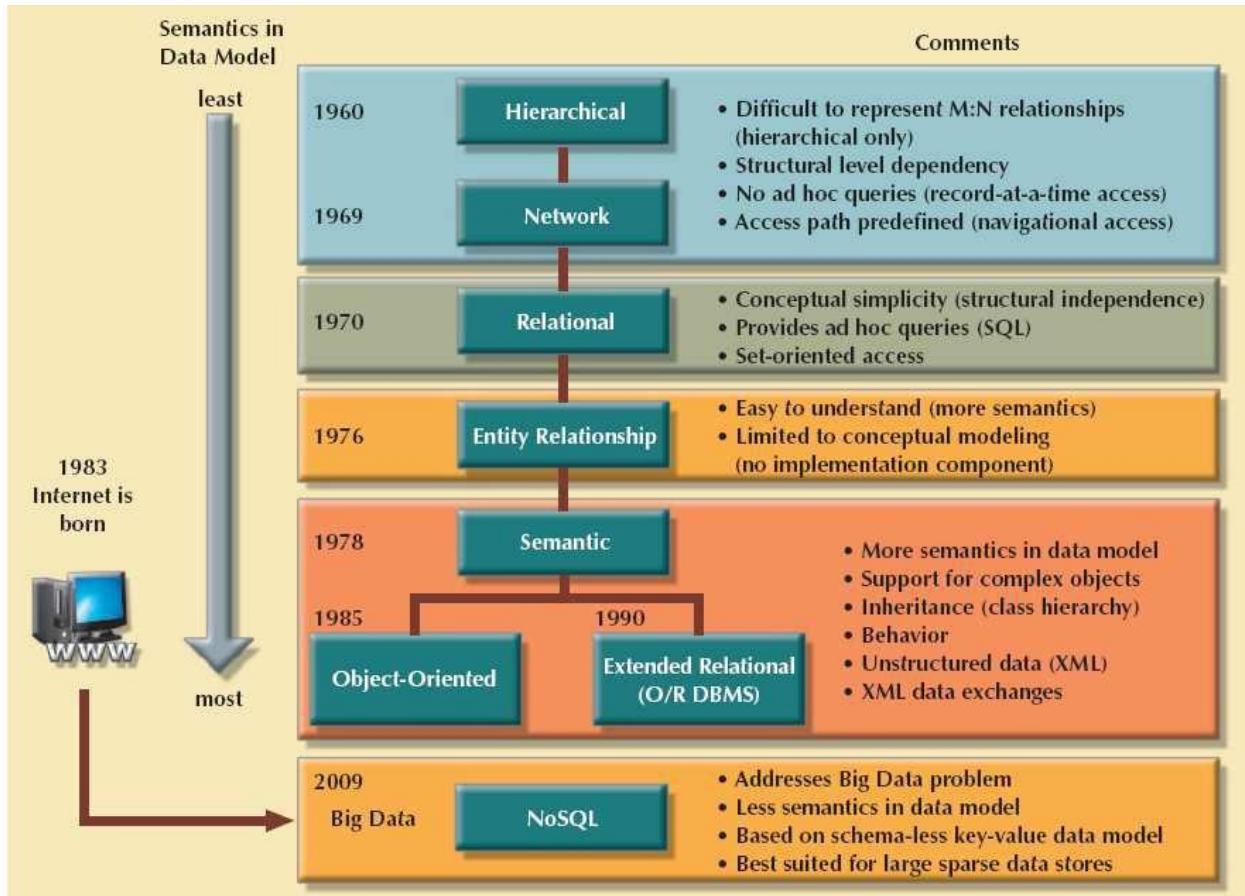
2.5.7 DATA MODELS: A SUMMARY

The evolution of DBMSs has always been driven by the search for new ways of modeling and managing increasingly complex real-world data. A summary of the most commonly recognized data models is shown in [Figure 2.6](#).

In the evolution of data models, some common characteristics have made them widely accepted:

- A data model must show some degree of conceptual simplicity without compromising the semantic completeness of the database. *It does not make sense to have a data model that is more difficult to conceptualize than the real world.* At the same time, the model should show clarity and relevance; that is, the data model should be unambiguous and applicable to the problem domain.
 - A data model must represent the real world as closely as possible. This goal is more easily realized by adding more semantics to the model's data representation. (Semantics concern dynamic data behavior, while data representation constitutes the static aspect of the real-world scenario.) In other words, the model should be accurate and complete—all the needed data are included and properly described.
 - Representation of the real-world transformations (behavior) must be in compliance with the consistency and integrity characteristics required by the intended use of the data model.
-

FIGURE 2.6 The evolution of data models



SOURCE: Course Technology/Cengage Learning

Each new data model addresses the shortcomings of previous models. The network model replaced the hierarchical model because the former made it much easier to represent complex (many-to-many) relationships. In turn, the relational model offers several advantages over the hierarchical and network models through its simpler data representation, superior data independence, and easy-to-use query language; these features made it the preferred data model for business applications. The OO data model introduced support for complex data within a rich semantic framework. The ERDM added many OO features to the relational model and allowed it to maintain strong market share within the business environment. In recent years, the Big Data phenomenon also has stimulated the development of alternative ways to model, store, and manage data that represents a break with traditional data management.

It is important to note that not all data models are created equal; some data models are better suited than others for some tasks. For example, *conceptual* models are better suited for high-level data modeling, while *implementation*

models are better for managing stored data for implementation purposes. The entity relationship model is an example of a conceptual model, while the hierarchical and network models are examples of implementation models. At the same time, some models, such as the relational model and the OODM, could be used as both conceptual and implementation models. [Table 2.2](#) summarizes the advantages and disadvantages of the various database models.

NOTE

All databases assume the use of a common data pool within the database. Therefore, *all* database models promote data sharing, thus reducing the potential problem of islands of information.

TABLE 2.2 Advantages and Disadvantages of Various Database Models

DATA MODEL	DATA INDEPENDENCE	STRUCTURAL INDEPENDENCE	ADVANTAGES	DISADVANTAGES
Hierarchical	Yes	No	<ul style="list-style-type: none"> 1. It promotes data sharing. 2. Parent/child relationship promotes conceptual simplicity. 3. Database security is provided and enforced by DBMS. 4. Parent/child relationship promotes data integrity. 5. It is efficient with 1:M relationships. 	<ul style="list-style-type: none"> 1. Complex implementation requires knowledge of physical data storage characteristics. 2. Navigational system yields complex application development, management, and use; requires knowledge of hierarchical path. 3. Changes in structure require changes in all application programs. 4. There are implementation limitations (no multiparent or M:N relationships). 5. There is no data definition or data manipulation language in the DBMS. 6. There is a lack of standards.
Network	Yes	No	<ul style="list-style-type: none"> 1. Conceptual simplicity is at least equal to that of the hierarchical model. 2. It handles more relationship types, such as M:N and multiparent. 3. Data access is more flexible than in hierarchical and file system models. 4. Data owner/member relationship promotes data integrity. 5. There is conformance to standards. 6. It includes data definition language (DDL) and data manipulation language (DML) in DBMS. 	<ul style="list-style-type: none"> 1. System complexity limits efficiency—still a navigational system. 2. Navigational system yields complex implementation, application development, and management. 3. Structural changes require changes in all application programs.
Relational	Yes	Yes	<ul style="list-style-type: none"> 1. Structural independence is promoted by the use of independent tables. Changes in a table's structure do not affect data access or application programs. 2. Tabular view substantially improves conceptual simplicity, thereby promoting easier database design, implementation, management, and use. 3. Ad hoc query capability is based on SQL. 4. Powerful RDBMS isolates the end user from physical-level details and improves implementation and management simplicity. 	<ul style="list-style-type: none"> 1. The RDBMS requires substantial hardware and system software overhead. 2. Conceptual simplicity gives relatively untrained people the tools to use a good system poorly, and if unchecked, it may produce the same data anomalies found in file systems. 3. It may promote islands of information problems as individuals and departments can easily develop their own applications.

Entity relationship	Yes	Yes	<ul style="list-style-type: none"> 1. Visual modeling yields exceptional conceptual simplicity. 2. Visual representation makes it an effective communication tool. 3. It is integrated with the dominant relational model. 	<ul style="list-style-type: none"> 1. There is limited constraint representation. 2. There is limited relationship representation. 3. There is no data manipulation language. 4. Loss of information content occurs when attributes are removed from entities to avoid crowded displays. (This limitation has been addressed in subsequent graphical versions.)
Object-oriented	Yes	Yes	<ul style="list-style-type: none"> 1. Semantic content is added. 2. Visual representation includes semantic content. 3. Inheritance promotes data integrity. 	<ul style="list-style-type: none"> 1. Slow development of standards caused vendors to supply their own enhancements, thus eliminating a widely accepted standard. 2. It is a complex navigational system. 3. There is a steep learning curve. 4. High system overhead slows transactions.
NoSQL	Yes	Yes	<ul style="list-style-type: none"> 1. High scalability, availability, and fault tolerance are provided. 2. It uses low-cost commodity hardware. 3. It supports Big Data. 4. Key-value model improves storage efficiency. 	<ul style="list-style-type: none"> 1. Complex programming is required. 2. There is no relationship support—only by application code. 3. There is no transaction integrity support. 4. In terms of data consistency, it provides an eventually consistent model.

Thus far, you have been introduced to the basic constructs of the more prominent data models. Each model uses such constructs to capture the meaning of the real-world data environment. [Table 2.3](#) shows the basic terminology used by the various data models.

TABLE 2.3 Data Model Basic Terminology Comparison

REAL WORLD	EXAMPLE	FILE PROCESSING	HIERARCHICAL MODEL	NETWORK MODEL	RELATIONAL MODEL	ER MODEL	OO MODEL
A group of vendors	Vendor file cabinet	File	Segment type	Record type	Table	Entity set	Class
A single vendor	Global supplies	Record	Segment occurrence	Current record	Row (tuple)	Entity occurrence	Object instance
The contact name	Johnny Ventura	Field	Segment field	Record field	Table attribute	Entity attribute	Object attribute
The vendor identifier	G12987	Index	Sequence field	Record key	Key	Entity identifier	Object identifier

Note: For additional information about the terms used in this table, consult the corresponding chapters and online appendixes that accompany this book. For example, if you want to know more about the OO model, refer to [Appendix G, Object-Oriented Databases](#).

2.6 DEGREES OF DATA ABSTRACTION

If you ask 10 database designers what a data model is, you will end up with 10 different answers—depending on the degree of data abstraction. To illustrate the meaning of data abstraction, consider the example of automotive design. A car designer begins by drawing the *concept* of the car to be produced. Next, engineers design the details that help transfer the basic concept into a structure that can be produced. Finally, the engineering drawings are translated into production specifications to be used on the factory floor. As you can see, the process of producing the car begins at a high level of abstraction and proceeds to an ever-increasing level of detail. The factory floor process cannot proceed unless the engineering details are properly specified, and the engineering details cannot exist without the basic conceptual framework created by the designer. Designing a usable database follows the same basic process. That is, a database designer starts with an abstract view of the overall data environment and adds details as the design comes closer to implementation. Using levels of abstraction

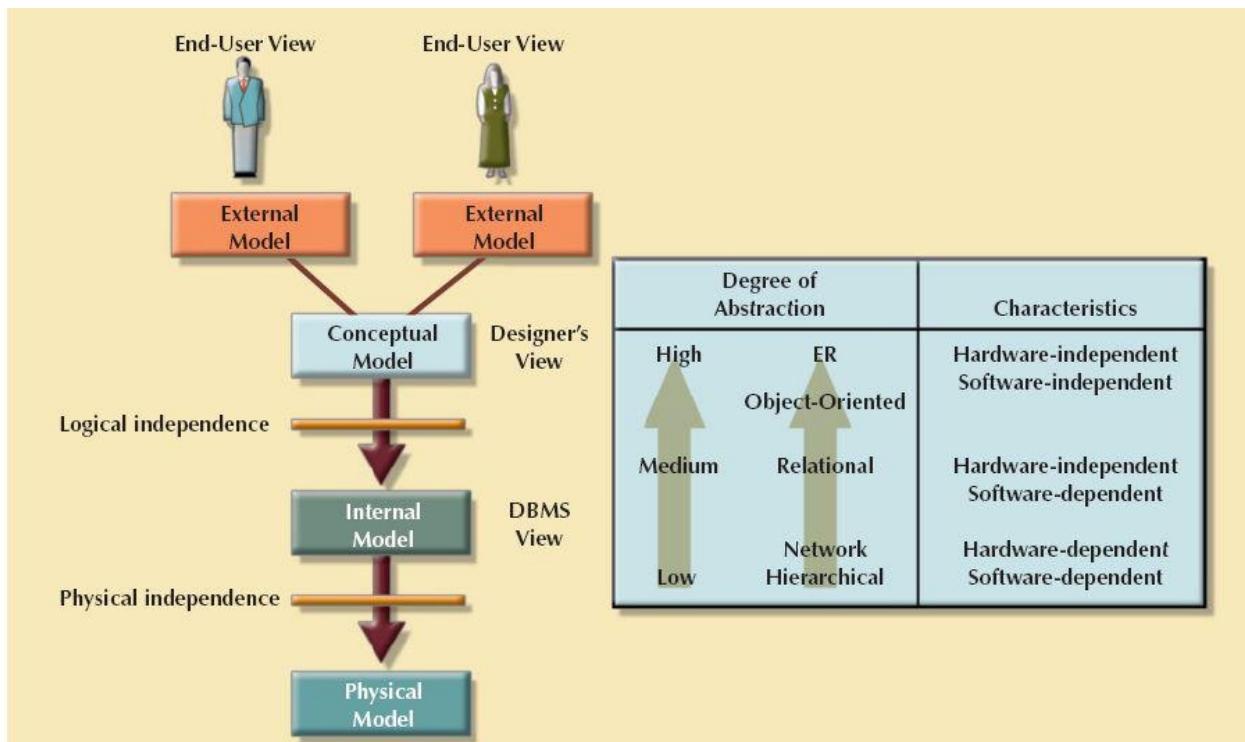
can also be very helpful in integrating multiple (and sometimes conflicting) views of data at different levels of an organization.

In the early 1970s, the [**American National Standards Institute \(ANSI\)**](#) Standards Planning and Requirements Committee (SPARC) defined a framework for data modeling based on degrees of data abstraction. The resulting ANSI/SPARC architecture defines three levels of data abstraction: external, conceptual, and internal. You can use this framework to better understand database models, as shown in [Figure 2.7](#). In the figure, the ANSI/SPARC framework has been expanded with the addition of a *physical* model to explicitly address physical-level implementation details of the internal model.

2.6.1 THE EXTERNAL MODEL

The [**external model**](#) is the end users' view of the data environment. The term *end users* refers to people who use the application programs to manipulate the data and generate information. End users usually operate in an environment in which an application has a specific business unit focus. Companies are generally divided into several business units, such as sales, finance, and marketing. Each business unit is subject to specific constraints and requirements, and each one uses a subset of the overall data in the organization. Therefore, end users within those business units view their data subsets as separate from or external to other units within the organization.

FIGURE 2.7 Data abstraction levels



SOURCE: Course Technology/Cengage Learning

Because data are being modeled, ER diagrams will be used to represent the external views. A specific representation of an external view is known as an **external schema**. To illustrate the external model's view, examine the data environment of Tiny College.

[Figure 2.8](#) presents the external schemas for two Tiny College business units: student registration and class scheduling. Each external schema includes the appropriate entities, relationships, processes, and constraints imposed by the business unit. Also note that *although the application views are isolated from each other, each view shares a common entity with the other view*. For example, the registration and scheduling external schemas share the entities CLASS and COURSE.

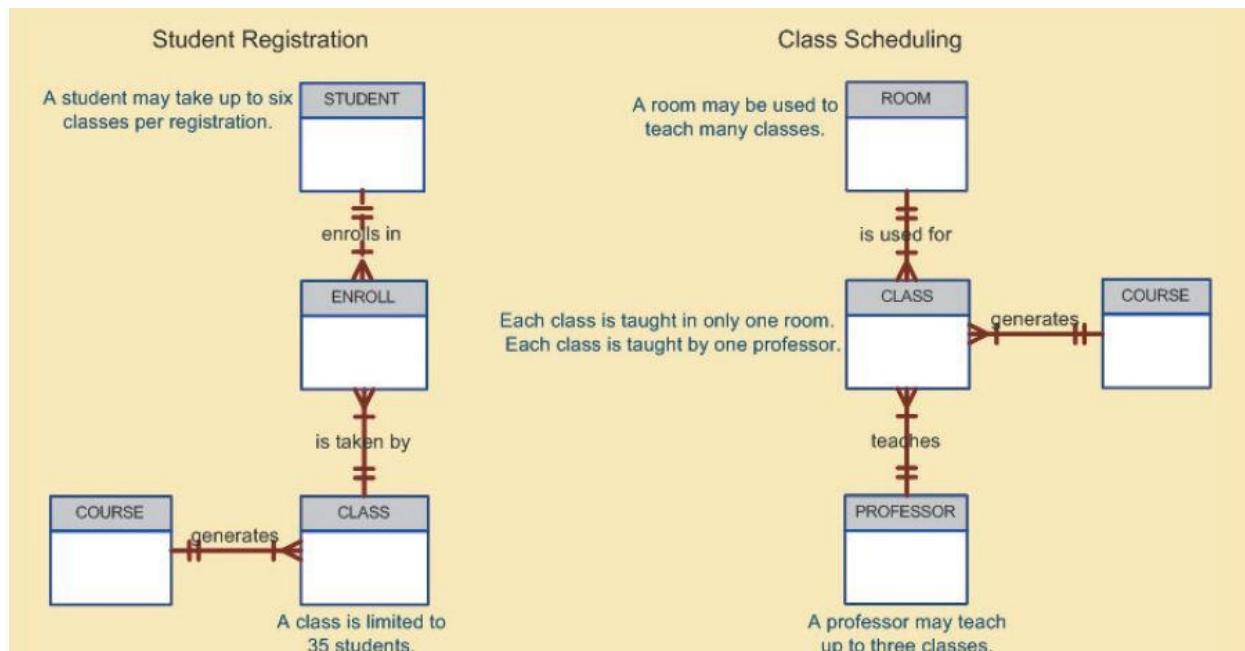
Note the entity relationships represented in [Figure 2.8](#). For example:

- A PROFESSOR may teach many CLASSES, and each CLASS is taught by only one PROFESSOR; there is a 1:M relationship between PROFESSOR and CLASS.
- A CLASS may ENROLL many students, and each STUDENT may ENROLL in many CLASSES, thus creating an M:N relationship between

STUDENT and CLASS. (You will learn about the precise nature of the ENROLL entity in [Chapter 4](#).)

- Each COURSE may generate many CLASSES, but each CLASS references a single COURSE. For example, there may be several classes (sections) of a database course that have a course code of CIS-420. One of those classes might be offered on MWF from 8:00 a.m. to 8:50 a.m., another might be offered on MWF from 1:00 p.m. to 1:50 p.m., while a third might be offered on Thursdays from 6:00 p.m. to 8:40 p.m. Yet, all three classes have the course code CIS-420.
- Finally, a CLASS requires one ROOM, but a ROOM may be scheduled for many CLASSES. That is, each classroom may be used for several classes: one at 9:00 a.m., one at 11:00 a.m., and one at 1:00 p.m., for example. In other words, there is a 1:M relationship between ROOM and CLASS.

FIGURE 2.8 External models for Tiny College



SOURCE: Course Technology/Cengage Learning

The use of external views that represent subsets of the database has some important advantages:

- It is easy to identify specific data required to support each business unit's operations.
- It makes the designer's job easy by providing feedback about the model's adequacy. Specifically, the model can be checked to ensure that it supports all processes as defined by their external models, as well as all operational requirements and constraints.
- It helps to ensure *security* constraints in the database design. Damaging an entire database is more difficult when each business unit works with only a subset of data.
- It makes application program development much simpler.

2.6.2 THE CONCEPTUAL MODEL

The **conceptual model** represents a global view of the entire database by the entire organization. That is, the conceptual model integrates all external views (entities, relationships, constraints, and processes) into a single global view of the data in the enterprise, as shown in [Figure 2.9](#). Also known as a **conceptual schema**, it is the basis for the identification and high-level description of the main data objects (avoiding any database model-specific details).

The most widely used conceptual model is the ER model. Remember that the ER model is illustrated with the help of the ERD, which is effectively the basic database blueprint. The ERD is used to graphically *represent* the conceptual schema.

The conceptual model yields some important advantages. First, it provides a bird's-eye (macro level) view of the data environment that is relatively easy to understand. For example, you can get a summary of Tiny College's data environment by examining the conceptual model in [Figure 2.9](#).

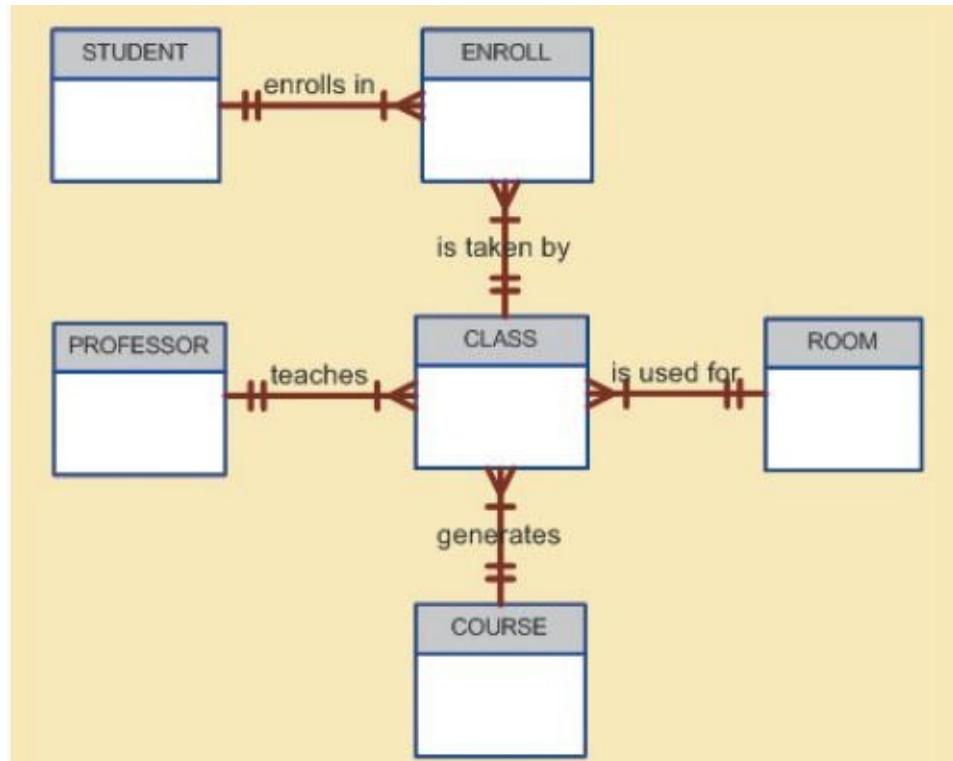
Second, the conceptual model is independent of both software and hardware. **Software independence** means that the model does not depend on the DBMS

software used to implement the model. **Hardware independence** means that the model does not depend on the hardware used in the implementation of the model. Therefore, changes in either the hardware or the DBMS software will have no effect on the database design at the conceptual level. Generally, the term **logical design** refers to the task of creating a conceptual data model that could be implemented in any DBMS.

2.6.3 THE INTERNAL MODEL

Once a specific DBMS has been selected, the internal model maps the conceptual model to the DBMS. The **internal model** is the representation of the database as “seen” by the DBMS. In other words, the internal model requires the designer to match the conceptual model’s characteristics and constraints to those of the selected implementation model. An **internal schema** depicts a specific representation of an internal model, using the database constructs supported by the chosen database.

FIGURE 2.9 Conceptual model for Tiny College



Because this book focuses on the relational model, a relational database was chosen to implement the internal model. Therefore, the internal schema should map the conceptual model to the relational model constructs. In particular, the entities in the conceptual model are mapped to tables in the relational model. Likewise, because a relational database has been selected, the internal schema is expressed using SQL, the standard language for relational databases. In the case of the conceptual model for Tiny College depicted in [Figure 2.9](#), the internal model was implemented by creating the tables PROFESSOR, COURSE, CLASS, STUDENT, ENROLL, and ROOM. A simplified version of the internal model for Tiny College is shown in [Figure 2.10](#).

The development of a detailed internal model is especially important to database designers who work with hierarchical or network models because those models require precise specification of data storage location and data access paths. In contrast, the relational model requires less detail in its internal model because most RDBMSs handle data access path definition *transparently*; that is, the designer need not be aware of the data access path details. Nevertheless, even relational database software usually requires specifications of data storage locations, especially in a mainframe environment. For example, DB2 requires that you specify the data storage group, the location of the database within the storage group, and the location of the tables within the database.

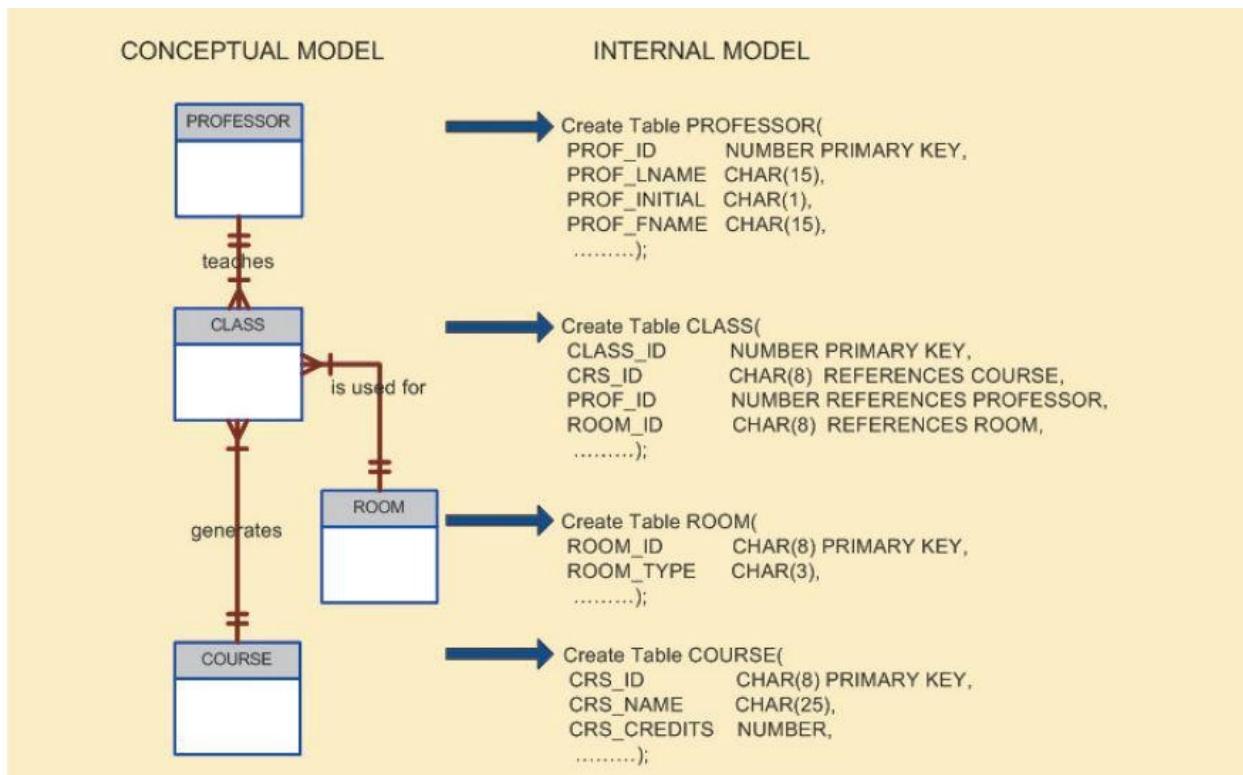
Because the internal model depends on specific database software, it is said to be software dependent. Therefore, a change in the DBMS software requires that the internal model be changed to fit the characteristics and requirements of the implementation database model. When you can change the internal model without affecting the conceptual model, you have [**logical independence**](#). However, the internal model is still hardware independent because it is unaffected by the type of computer on which the software is installed. Therefore, a change in storage devices or even a change in operating systems will not affect the internal model.

2.6.4 THE PHYSICAL MODEL

The [**physical model**](#) operates at the lowest level of abstraction, describing the way data are saved on storage media such as disks or tapes. The physical model requires the definition of both the physical storage devices and the (physical)

access methods required to reach the data within those storage devices, making it both software and hardware dependent. The storage structures used are dependent on the software (the DBMS and the operating system) and on the type of storage devices the computer can handle. The precision required in the physical model's definition demands that database designers have a detailed knowledge of the hardware and software used to implement the database design.

FIGURE 2.10 Internal model for Tiny College



SOURCE: Course Technology/Cengage Learning

Early data models forced the database designer to take the details of the physical model's data storage requirements into account. However, the now dominant relational model is aimed largely at the logical level rather than the physical level; therefore, it does not require the physical-level details common to its predecessors.

Although the relational model does not require the designer to be concerned about the data's physical storage characteristics, the *implementation* of a

relational model may require physical-level fine-tuning for increased performance. Fine-tuning is especially important when very large databases are installed in a mainframe environment, yet even such performance fine-tuning at the physical level does not require knowledge of physical data storage characteristics.

As noted earlier, the physical model is dependent on the DBMS, methods of accessing files, and types of hardware storage devices supported by the operating system. When you can change the physical model without affecting the internal model, you have **physical independence**. Therefore, a change in storage devices or methods and even a change in operating system will not affect the internal model.

The levels of data abstraction are summarized in [Table 2.4](#).

TABLE 2.4 Levels of Data Abstraction

MODEL	DEGREE OF ABSTRACTION	FOCUS	INDEPENDENT OF
External	High ↓ Low	End-user views	Hardware and software
Conceptual		Global view of data (database model independent)	Hardware and software
Internal		Specific database model	Hardware
Physical		Storage and access methods	Neither hardware nor software

SUMMARY

- A data model is an abstraction of a complex real-world data environment. Database designers use data models to communicate with programmers and end users. The basic data-modeling components are entities, attributes, relationships, and constraints. Business rules are used to identify and define the basic modeling components within a specific real-world environment.

- The hierarchical and network data models were early models that are no longer used, but some of the concepts are found in current data models.
- The relational model is the current database implementation standard. In the

relational model, the end user perceives the data as being stored in tables. Tables are related to each other by means of common values in common attributes. The entity relationship (ER) model is a popular graphical tool for data modeling that complements the relational model. The ER model allows database designers to visually present different views of the data—as seen by database designers, programmers, and end users—and to integrate the data into a common framework.

- The object-oriented data model (OODM) uses objects as the basic modeling structure. Like the relational model's entity, an object is described by its factual content. Unlike an entity, however, the object also includes information about relationships between the facts, as well as relationships with other objects, thus giving its data more meaning.
- The relational model has adopted many object-oriented (OO) extensions to become the extended relational data model (ERDM). Object/relational database management systems (O/R DBMS) were developed to implement the ERDM. At this point, the OODM is largely used in specialized engineering and scientific applications, while the ERDM is primarily geared to business applications.
- NoSQL databases are a new generation of databases that do not use the relational model and are geared to support the very specific needs of Big Data organizations. NoSQL databases offer distributed data stores that provide high scalability, availability, and fault tolerance by sacrificing data consistency and shifting the burden of maintaining relationships and data integrity to the program code.
- Data-modeling requirements are a function of different data views (global vs. local) and the level of data abstraction. The American National Standards Institute Standards Planning and Requirements Committee (ANSI/SPARC) describes three levels of data abstraction: external, conceptual, and internal. The fourth and lowest level of data abstraction, called the physical level, is concerned exclusively with physical storage methods.

KEY TERMS

[American National Standards Institute \(ANSI\)](#)
[attribute](#)
[Big Data](#)
[business rule](#)
[Chen notation](#)
[class](#)
[class diagram](#)
[class diagram notation](#)
[class hierarchy](#)
[conceptual model](#)
[conceptual schema](#)
[connectivity](#)
[constraint](#)
[Crow's Foot notation](#)
[data definition language \(DDL\)](#)
[data manipulation language \(DML\)](#)
[data model](#)
[entity](#)
[entity instance](#)
[entity occurrence](#)
[entity relationship diagram \(ERD\)](#)
[entity relationship \(ER\) model \(ERM\)](#)
[entity set](#)
[eventual consistency](#)
[extended relational data model \(ERDM\)](#)
[Extensible Markup Language \(XML\)](#)
[external model](#)
[external schema](#)
[hardware independence](#)
[hierarchical model](#)
[inheritance](#)
[internal model](#)
[internal schema](#)
[key-value](#)
[logical design](#)
[logical independence](#)

[many-to-many \(M:N or ..\) relationship](#)
[method](#)
[network model](#)
[NoSQL](#)
[object](#)
[object-oriented data model \(OODM\)](#)
[object-oriented database management system \(OODBMS\)](#)
[object/relational database management system \(O/R DBMS\)](#)
[one-to-many \(1:M or 1..*\) relationship](#)
[one-to-one \(1:1 or 1..1\) relationship](#)
[physical independence](#)
[physical model](#)
[relation](#)
[relational database management system \(RDBMS\)](#)
[relational diagram](#)
[relational model](#)
[relationship](#)
[schema](#)
[segment](#)
[semantic data model](#)
[software independence](#)
[sparse data](#)
[subschema](#)
[table](#)
[tuple](#)
[Unified Modeling Language \(UML\)](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at
www.cengagebrain.com.

REVIEW QUESTIONS

1. Discuss the importance of data models.
2. What is a business rule, and what is its purpose in data modeling?
3. How do you translate business rules into data model components?
4. What languages emerged to standardize the basic network data model, and why was such standardization important to users and designers?
5. Describe the basic features of the relational data model and discuss their importance to the end user and the designer.
6. Explain how the entity relationship (ER) model helped produce a more structured relational database design environment.
7. Consider the scenario described by the statement “A customer can make many payments, but each payment is made by only one customer.” Use this scenario as the basis for an entity relationship diagram (ERD) representation.
8. Why is an object said to have greater semantic content than an entity?
9. What is the difference between an object and a class in the object-oriented data model (OODM)?
10. How would you model Question 7 with an OODM? (Use [Figure 2.4](#) as your guide.)
11. What is an ERDM, and what role does it play in the modern (production) database environment?
12. In terms of data and structural independence, compare file system data management with the five data models discussed in this chapter.
13. What is a relationship, and what three types of relationships exist?

14. Give an example of each of the three types of relationships.
15. What is a table, and what role does it play in the relational model?

16. What is a relational diagram? Give an example.
17. What is connectivity? (Use a Crow's Foot ERD to illustrate connectivity.)
18. Describe the Big Data phenomenon.
19. What is sparse data? Give an example.

20. Define and describe the basic characteristics of a NoSQL database.
21. Using the example of a medical clinic with patients and tests, provide a simple representation of how to model this example using the relational model and how it would be represented using the key-value data modeling technique.

22. What is logical independence?
23. What is physical independence?

PROBLEMS

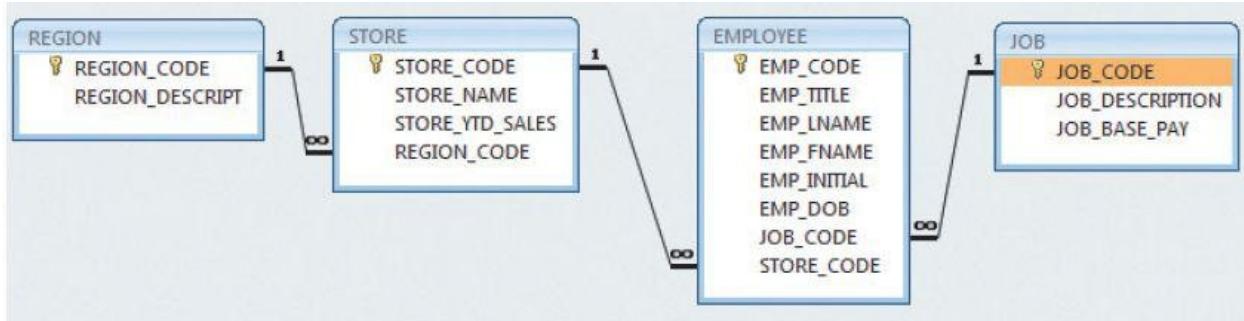
Use the contents of [Figure 2.1](#) to work [Problems 1–3](#).

1. Write the business rule(s) that govern the relationship between AGENT and CUSTOMER.

2. Given the business rule(s) you wrote in [Problem 1](#), create the basic Crow's Foot ERD.
3. Using the ERD you drew in [Problem 2](#), create the equivalent object representation and UML class diagram. (Use [Figure 2.4](#) as your guide.)

Using [Figure P2.4](#) as your guide, work [Problems 4–5](#). The DealCo relational diagram shows the initial entities and attributes for the DealCo stores, which are located in two regions of the country.

FIGURE P2.4 The DealCo relational diagram



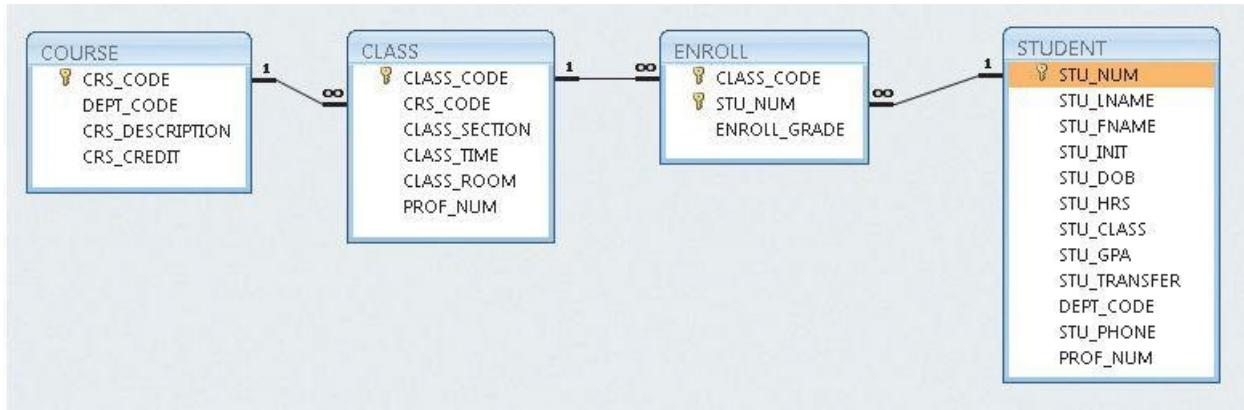
SOURCE: Course Technology/Cengage Learning

4. Identify each relationship type and write all of the business rules.

5. Create the basic Crow's Foot ERD for DealCo.

Using [Figure P2.6](#) as your guide, work [Problems 6–8](#). The Tiny College relational diagram shows the initial entities and attributes for the college.

FIGURE P2.6 The Tiny College relational diagram



SOURCE: Course Technology/Cengage Learning

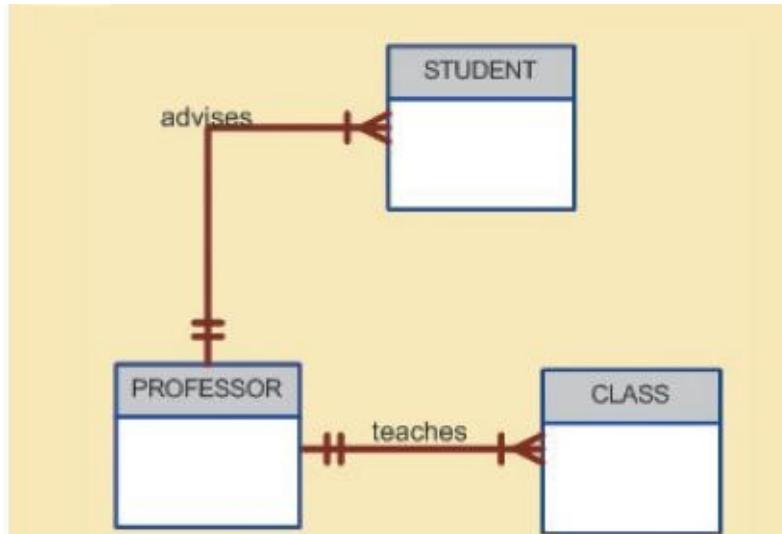
6. Identify each relationship type and write all of the business rules.

7. Create the basic Crow's Foot ERD for Tiny College.
8. Create the UML class diagram that reflects the entities and relationships you identified in the relational diagram.

9. Typically, a hospital patient receives medications that have been ordered by a particular doctor. Because the patient often receives several medications per day, there is a 1:M relationship between PATIENT and ORDER. Similarly, each order can include several medications, creating a 1:M relationship between ORDER and MEDICATION.
 - a. Identify the business rules for PATIENT, ORDER, and MEDICATION.
 - b. Create a Crow's Foot ERD that depicts a relational database model to capture these business rules.
10. United Broke Artists (UBA) is a broker for not-so-famous artists. UBA maintains a small database to track painters, paintings, and galleries. A painting is created by a particular artist and then exhibited in a particular gallery. A gallery can exhibit many paintings, but each painting can be exhibited in only one gallery. Similarly, a painting is created by a single painter, but each painter can create many paintings. Using PAINTER, PAINTING, and GALLERY, in terms of a relational database:
 - a. What tables would you create, and what would the table components be?

- b. How might the (independent) tables be related to one another?
11. Using the ERD from [Problem 10](#), create the relational schema. (Create an appropriate collection of attributes for each of the entities. Make sure you use the appropriate naming conventions to name the attributes.)
12. Convert the ERD from [Problem 10](#) into a corresponding UML class diagram.
13. Describe the relationships (identify the business rules) depicted in the Crow's Foot ERD shown in [Figure P2.13](#).

FIGURE P2.13 The Crow's Foot ERD for [Problem 13](#)

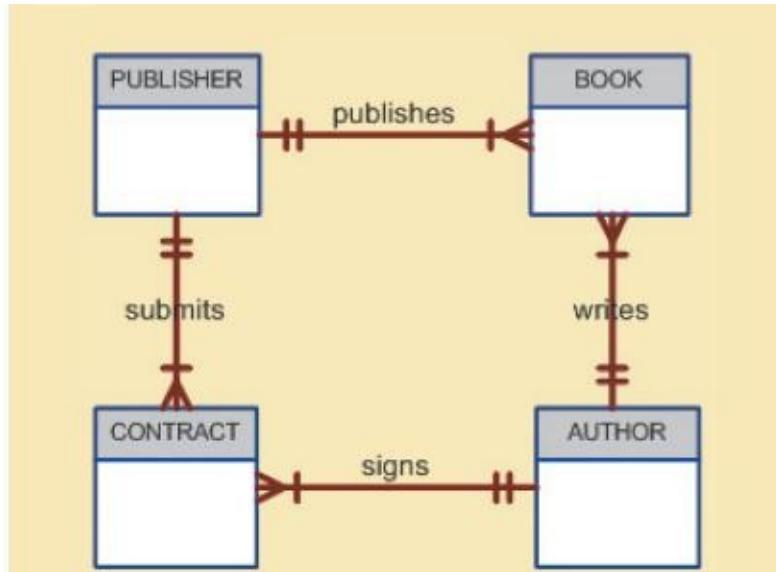


SOURCE: Course Technology/Cengage Learning

-
14. Create a Crow's Foot ERD to include the following business rules for the ProdCo company:
- Each sales representative writes many invoices.
 - Each invoice is written by one sales representative.
 - Each sales representative is assigned to one department.
 - Each department has many sales representatives.
 - Each customer can generate many invoices.
 - Each invoice is generated by one customer.

15. Write the business rules that are reflected in the ERD shown in [Figure P2.15](#). (Note that the ERD reflects some simplifying assumptions. For example, each book is written by only one author. Also, remember that the ERD is always read from the “1” to the “M” side, regardless of the orientation of the ERD components.)
-

FIGURE P2.15 The Crow’s Foot ERD for [Problem 15](#)



SOURCE: Course Technology/Cengage Learning

16. Create a Crow’s Foot ERD for each of the following descriptions. (Note that the word *many* merely means *more than one* in the database modeling environment.)
- Each of the MegaCo Corporation’s divisions is composed of many departments. Each department has many employees assigned to it, but each employee works for only one department. Each department is managed by one employee, and each of those managers can manage only one department at a time.
 - During some period of time, a customer can rent many videotapes from the BigVid store. Each of BigVid’s videotapes can be rented to many customers during that period of time.
 - An airliner can be assigned to fly many flights, but each flight is flown

by only one airliner.

- d. The KwikTite Corporation operates many factories. Each factory is located in a region, and each region can be “home” to many of KwikTite’s factories. Each factory has many employees, but each employee is employed by only one factory.
 - e. An employee may have earned many degrees, and each degree may have been earned by many employees.
-

¹ See www.gartner.com/it/page.jsp?id=1460213, “Gartner Survey Shows Data Growth as the Largest Data Center Infrastructure Challenge,” Nov. 2011.

PART
II
DESIGN CONCEPTS

[THE RELATIONAL DATABASE MODEL](#) **3**

[ENTITY RELATIONSHIP \(ER\) MODELING](#) **4**

[ADVANCED DATA MODELING](#) **5**

[NORMALIZATION OF DATABASE TABLES](#) **6**

Business Vignette

In 1857, the Spanish Board of Trade sponsored the establishment of Banco de Bilbao, a discount and currency-issuing bank.¹ Today, the bank, now called BBVA, is one of the most successful financial institutions in the world. It is the leading financial services provider in both the Spanish and Mexican markets and the 15th largest commercial bank in the United States. BBVA is prominent throughout South America and has large international operations in Turkey and China. The company has continued to grow and now serves more than 47 million customers with a staff of over 104,000 employees in over 30 countries.²

Not surprisingly, the company has a wide array of information systems with a tremendous amount of data and metadata used by approximately 1,000 developers and analysts. The developers require access to corporate data when building new applications; the analysts need to perform impact analyses after introducing modifications to systems. Until recently, BBVA did not have a common repository for data information models. This made it difficult to streamline report queries, guarantee information accuracy, and provide information to business leaders in a timely fashion.³

To increase the productivity of developers and analysts, BBVA decided to use Sybase Technology's PowerDesigner to create a single repository for data model information that supports the company's many systems.

"We had a complex environment of existing documentation with different tools and a set of already established changes to our databases," said BBVA director of architecture Manel Crepo Rodriquez. "We needed a new data modeling tool that could integrate with our existing tools and systems without affecting their performance and roles."

The BBVA data architects used PowerDesigner to centralize governance over all corporate data models. This centralization allowed BBVA to manage and integrate system data models consistently across its information systems and across the globe. The company's team of architects can guarantee correct integration and review design quality. It can compare databases with models, which helps support efficient documentation and new application development.

The results have allowed BBVA to better meet its business needs. Senior managers are making strategic decisions using reports that are based on more reliable data and that can be generated faster. The entire organization has

centralized access to corporate data models. As a result, porting to PowerDesigner has saved time and money in report generation and allowed the company to better serve its customers.

1 “A modern group with a distinguished past,” Grupo BBVA Website,
www.bbva.com/TLBB/tlbb/jsp/ing/conozca/historia/index.jsp.

2 “BBVA, we’re working for a better future for people,” Grupo BBVA Website,
www.bbva.com/TLBB/tlbb/jsp/ing/conozca/index.jsp.

3 BBVA, Customer Case Study, Sybase Success Stories,
www.sybase.com/files/Success_Stories/BBVA_DataArch_CS.pdf.

3 THE RELATIONAL DATABASE MODEL

In this chapter, you will learn:

- That the relational database model offers a logical view of data
- About the relational model's basic component: relations
 - That relations are logical constructs composed of rows (tuples) and columns (attributes)
- That relations are implemented as tables in a relational DBMS
- About relational database operators, the data dictionary, and the system catalog
- How data redundancy is handled in the relational database model
- Why indexing is important

Preview

In [Chapter 2](#), Data Models, you learned that the relational data model's structural and data independence allow you to examine the model's logical structure without considering the physical aspects of data storage and retrieval. You also learned that entity relationship diagrams (ERDs) may be used to depict entities and their relationships graphically. In this chapter, you will learn some important details about the relational model's logical structure and more about how the ERD can be used to design a relational database.

You will also learn how the relational database's basic data components fit into a logical construct known as a table. You will discover that one important reason for the relational database model's simplicity is that its tables can be treated as logical units rather than physical units. You will also learn how the independent tables within the database can be related to one another.

After learning about tables, their components, and their relationships, you will be introduced to the basic concepts that shape the design of tables. Because the table is such an integral part of relational database design, you will also learn the characteristics of well-designed and poorly designed tables.

Finally, you will be introduced to some basic concepts that will become your gateway to the next few chapters. For example, you will examine different kinds of relationships and the way they might be handled in the relational database environment.

NOTE

The relational model, introduced by E. F. Codd in 1970, is based on predicate logic and set theory. [Predicate logic](#), used extensively in mathematics, provides a framework in which an assertion (statement of fact) can be verified as either true or false. For example, suppose that a student with a student ID of 12345678 is named Melissa Sanduski. This assertion can easily be demonstrated to be true or false. [Set theory](#) is a mathematical science that deals with sets, or groups of things, and is used as the basis for data manipulation in the relational model. For example, assume that set A contains three numbers: 16, 24, and 77. This set is represented as $A(16, 24, 77)$. Furthermore, set B contains four numbers: 44, 77, 90, and 11, and so is represented as $B(44, 77, 90, 11)$. Given this information, you can conclude that the intersection of A and B yields a result set with a single number, 77. This result can be expressed as $A \cap B = 77$. In other words, A and B share a common value, 77.

Based on these concepts, the relational model has three well-defined components:

1. A logical data structure represented by relations (see [Sections 3.1, 3.2](#), and [3.5](#)).
2. A set of integrity rules to enforce that the data are and remain consistent over time (see [Sections 3.3, 3.6, 3.7](#), and [3.8](#)).
3. A set of operations that defines how data are manipulated (see [Section 3.4](#)).

3.1 A LOGICAL VIEW OF DATA

In [Chapter 1](#), Database Systems, you learned that a database stores and manages

both data and metadata. You also learned that the DBMS manages and controls access to the data and the database structure. Such an arrangement—placing the DBMS between the application and the database—eliminates most of the file system's inherent limitations. The result of such flexibility, however, is a far more complex physical structure. In fact, the database structures required by both the hierarchical and network database models often become complicated enough to diminish efficient database design. The relational data model changed all of that by allowing the designer to focus on the logical representation of the data and its relationships, rather than on the physical storage details. To use an automotive analogy, the relational database uses an automatic transmission to relieve you of the need to manipulate clutch pedals and gearshifts. In short, the relational model enables you to view data *logically* rather than *physically*.

The practical significance of taking the logical view is that it serves as a reminder of the simple file concept of data storage. Although the use of a table, quite unlike that of a file, has the advantages of structural and data independence, a table does resemble a file from a conceptual point of view. Because you can think of related records as being stored in independent tables, the relational database model is much easier to understand than the hierarchical and network models. Logical simplicity tends to yield simple and effective database design methodologies.

Because the table plays such a prominent role in the relational model, it deserves a closer look. Therefore, our discussion begins by exploring the details of table structure and contents.

3.1.1 TABLES AND THEIR CHARACTERISTICS

The logical view of the relational database is facilitated by the creation of data relationships based on a logical construct known as a relation. Because a relation is a mathematical construct, end users find it much easier to think of a relation as a table. A table is perceived as a two-dimensional structure composed of rows and columns. A table is also called a relation because the relational model's creator, E. F. Codd, used the two terms as synonyms. You can think of a table as a *persistent* representation of a logical relation—that is, a relation whose contents can be permanently saved for future use. As far as the table's user is concerned, a table contains a *group of related entity occurrences*—that is, an entity set. For example, a STUDENT table contains a collection of entity occurrences, each representing a student. For that reason, the terms *entity set* and *table* are often used interchangeably.

NOTE

The word *relation*, also known as a *dataset* in Microsoft Access, is based on the mathematical set theory from which Codd derived his model. Because the relational model uses attribute values to establish relationships among tables, many database users incorrectly assume that the term *relation* refers to such relationships. Many then incorrectly conclude that only the relational model permits the use of relationships.

You will discover that the table view of data makes it easy to spot and define entity relationships, thereby greatly simplifying the task of database design. The characteristics of a relational table are summarized in [Table 3.1](#).

TABLE 3.1 Characteristics of a Relational Table

- 1 A table is perceived as a two-dimensional structure composed of rows and columns.
 - 2 Each table row ([tuple](#)) represents a single entity occurrence within the entity set.
 - 3 Each table column represents an attribute, and each column has a distinct name.
 - 4 Each intersection of a row and column represents a single data value.
 - 5 All values in a column must conform to the same data format.
 - 6 Each column has a specific range of values known as the [attribute domain](#).
 - 7 The order of the rows and columns is immaterial to the DBMS.
 - 8 Each table must have an attribute or combination of attributes that uniquely identifies each row.
-

The table shown in [Figure 3.1](#) illustrates the characteristics listed in [Table 3.1](#).

FIGURE 3.1 STUDENT table attribute values

Table name: STUDENT								Database name: Ch03_TinyCollege			
STU_NUM	STU_LNAME	STU_FNAME	STU_INIT	STU_DOB	STU_HRS	STU_CLASS	STU_GPA	STU_TRANSFER	DEPT_CODE	STU_PHONE	PROF_NUM
321452	Bowser	William	C	12-Feb-1975	42	So	2.84	No	BIOL	2134	205
324257	Smithson	Anne	K	15-Nov-1981	81	Jr	3.27	Yes	CIS	2256	222
324258	Brewer	Juliette		23-Aug-1969	36	So	2.26	Yes	ACCT	2256	228
324269	Oblonski	Walter	H	16-Sep-1976	66	Jr	3.09	No	CIS	2114	222
324273	Smith	John	D	30-Dec-1958	102	Sr	2.11	Yes	ENGL	2231	199
324274	Katinga	Raphael	P	21-Oct-1979	114	Sr	3.15	No	ACCT	2267	228
324291	Robertson	Gerald	T	08-Apr-1973	120	Sr	3.87	No	EDU	2267	311
324299	Smith	John	B	30-Nov-1986	15	Fr	2.92	No	ACCT	2315	230

STU_NUM = Student number
STU_LNAME = Student last name
STU_FNAME = Student first name
STU_INIT = Student middle initial
STU_DOB = Student date of birth
STU_HRS = Credit hours earned
STU_CLASS = Student classification
STU_GPA = Grade point average
STU_TRANSFER = Student transferred from another institution
DEPT_CODE = Department code
STU_PHONE = 4-digit campus phone extension
PROF_NUM = Number of the professor who is the student's advisor

SOURCE: Course Technology/Cengage Learning

NOTE

Relational database terminology is very precise. Unfortunately, file system terminology sometimes creeps into the database environment. Thus, rows are sometimes referred to as *records* and columns are sometimes labeled as *fields*. Occasionally, tables are labeled *files*. Technically speaking, this substitution of terms is not always appropriate; the database table is a logical concept rather than a physical concept, and the terms *file*, *record*, and *field* describe physical concepts. Nevertheless, as long as you recognize that the table is actually a logical concept rather than a physical construct, you may think of table rows as records and of table columns as fields. In fact, many database software vendors still use this familiar file system terminology.



ONLINE CONTENT

All of the databases used to illustrate the material in this chapter are available at www.cengagebrain.com. The database names used in the folder match the database names used in the figures. For example, the source of the tables shown in [Figure 3.1](#) is the **Ch03_TinyCollege** database.

Using the STUDENT table shown in [Figure 3.1](#), you can draw the following conclusions corresponding to the points in [Table 3.1](#):

1. The STUDENT table is perceived to be a two-dimensional structure composed of eight rows (tuples) and 12 columns (attributes).

2. Each row in the STUDENT table describes a single entity occurrence within the entity set. (The entity set is represented by the STUDENT table.) For example, row 4 in [Figure 3.1](#) describes a student named Walter H. Oblonski. Given the table contents, the STUDENT entity set includes eight distinct entities (rows), or students.

3. Each column represents an attribute, and each column has a distinct name.

4. All of the values in a column match the attribute's characteristics. For example, the grade point average (STU_GPA) column contains only STU_GPA entries for each of the table rows. Data must be classified according to their format and function. Although various DBMSs can support different data types, most support at least the following:
 - a. *Numeric*. You can use numeric data to perform meaningful arithmetic procedures. For example, in [Figure 3.1](#), STU_HRS and STU_GPA are numeric attributes.

 - b. *Character*. Character data, also known as text data or string data, can contain any character or symbol not intended for mathematical manipulation. In [Figure 3.1](#), STU_CLASS and STU_PHONE are examples of character attributes.

 - c. *Date*. Date attributes contain calendar dates stored in a special format known as the Julian date format. In [Figure 3.1](#), STU_DOB is a date

attribute.

- d. *Logical*. Logical data can only have true or false (yes or no) values. In [Figure 3.1](#), the STU_TRANSFER attribute uses a logical data format.
- 5. The column's range of permissible values is known as its **domain**. Because the STU_GPA values are limited to the range 0–4, inclusive, the domain is [0,4].
- 6. The order of rows and columns is immaterial to the user.
- 7. Each table must have a primary key. In general terms, the **primary key (PK)** is an attribute or combination of attributes that uniquely identifies any given row. In this case, STU_NUM (the student number) is the primary key. Using the data in [Figure 3.1](#), observe that a student's last name (STU_LNAME) would not be a good primary key because several students have the last name of Smith. Even the combination of the last name and first name (STU_FNAME) would not be an appropriate primary key because more than one student is named John Smith.

3.2 KEYS

In the relational model, keys are important because they are used to ensure that each row in a table is uniquely identifiable. They are also used to establish relationships among tables and to ensure the integrity of the data. A **key** consists of one or more attributes that determine other attributes. For example, an invoice number identifies all of the invoice attributes, such as the invoice date and the customer name.

One type of key, the primary key, has already been introduced. Given the structure of the STUDENT table shown in [Figure 3.1](#), defining and describing the primary key seem simple enough. However, because the primary key plays such an important role in the relational environment, you will examine the primary key's properties more carefully. In this section, you also will become acquainted with superkeys, candidate keys, and secondary keys.

3.2.1 DEPENDENCIES

The role of a key is based on the concept of determination. **Determination** is the state in which knowing the value of one attribute makes it possible to determine the value of another. The idea of determination is not unique to the database environment. You are familiar with the formula $\text{revenue} - \text{cost} = \text{profit}$. This is a form of determination, because if you are given the *revenue* and the *cost*, you can determine the *profit*. Given *profit* and *revenue*, you can determine the *cost*. Given any two values, you can determine the third. Determination in a database environment, however, is not normally based on a formula but on the relationships among the attributes.

If you consider what the attributes of the STUDENT table in [Figure 3.1](#) actually represent, you will see a relationship among the attributes. If you are given a value for STU_NUM, then you can determine the value for STU_LNAME because one and only one value of STU_LNAME is associated with any given value of STU_NUM. A specific terminology and notation is used to describe relationships based on determination. The relationship is called **functional dependence**, which means that the value of one or more attributes determines the value of one or more other attributes. The standard notation for representing the relationship between STU_NUM and STU_LNAME is:

STU_NUM → STU_LNAME

In this functional dependency, the attribute whose value determines another is called the **determinant** or the key. The attribute whose value is determined by the other attribute is called the **dependent**. Using this terminology, it would be correct to say that STU_NUM is the determinant and STU_LNAME is the dependent. STU_NUM functionally determines STU_LNAME, and STU_LNAME is functionally dependent on STU_NUM. As stated earlier, functional dependence can involve a determinant that comprises more than one attribute and multiple dependent attributes. Refer to the STUDENT table for the following example:

STU_NUM → (STU_LNAME, STU_FNAME, STU_GPA)

and

$(STU_FNAME, STU_LNAME, STU_INIT, STU_PHONE) \rightarrow (STU_DOB, STU_HRS, STU_GPA)$

Determinants made of more than one attribute require special consideration. It is possible to have a functional dependency in which the determinant contains attributes that are not necessary for the relationship. Consider the following two functional dependencies:

$STU_NUM \rightarrow STU_GPA$

$(STU_NUM, STU_LNAME) \rightarrow STU_GPA$

In the second functional dependency, the determinant includes STU_LNAME , but this attribute is not necessary for the relationship. The functional dependency is valid because given a pair of values for STU_NUM and STU_LNAME , only one value would occur for STU_GPA . A more specific term, **full functional dependence**, is used to refer to functional dependencies in which the entire collection of attributes in the determinant is necessary for the relationship. Therefore, the dependency shown in the preceding example is a functional dependency, but not a full functional dependency.

3.2.2 TYPES OF KEYS

Recall that a key is an attribute or group of attributes that can determine the values of other attributes. Therefore, keys are determinants in functional dependencies. Several different types of keys are used in the relational model, and you need to be familiar with them.

A **composite key** is a key that is composed of more than one attribute. An attribute that is a part of a key is called a **key attribute**. For example:

$STU_NUM \rightarrow STU_GPA$

$(STU_LNAME, STU_FNAME, STU_INIT, STU_PHONE) \rightarrow STU_HRS$

In the first functional dependency, STU_NUM is an example of a key composed of only one key attribute. In the second functional dependency, $(STU_LNAME, STU_FNAME, STU_INIT, STU_PHONE)$ is a composite key composed of four key attributes.

A **superkey** is a key that can uniquely identify any row in the table. In other

words, a superkey functionally determines every attribute in the row. In the STUDENT table, STU_NUM is a superkey, as are the composite keys (STU_NUM, STU_LNAME), (STU_NUM, STU_LNAME, STU_INIT), and (STU_LNAME, STU_FNAME, STU_INIT, STU_PHONE). In fact, because STU_NUM alone is a superkey, any composite key that has STU_NUM as a key attribute will also be a superkey. Be careful, however, because not all keys are superkeys. For example, Gigantic State University determines its student classification based on hours completed, as shown in [Table 3.2](#).

TABLE 3.2 Student Classification

HOURS COMPLETED

CLASSIFICATION

Less than 30

Fr

30–59

So
60–89

Jr

90 or more

Sr

Therefore, you can write $\text{STU_HRS} \rightarrow \text{STU_CLASS}$.

However, the specific number of hours is not dependent on the classification. It is quite possible to find a junior with 62 completed hours or one with 84 completed hours. In other words, the classification (STU_CLASS) does not determine one and only one value for completed hours (STU_HRS).

One specific type of superkey is called a candidate key. A **candidate key** is a minimal superkey—that is, a superkey without any unnecessary attributes. A candidate key is based on a full functional dependency. For example, STU_NUM would be a candidate key, as would $(\text{STU_LNAME}, \text{STU_FNAME}, \text{STU_INIT}, \text{STU_PHONE})$. On the other hand, $(\text{STU_NUM}, \text{STU_LNAME})$ is a superkey, but it is not a candidate key because STU_LNAME could be removed and the key would still be a superkey. A table can have many different candidate keys. If the STUDENT table also included the students' Social Security numbers as STU_SSN , then it would appear to be a candidate key. Candidate keys are called *candidates* because they are the eligible options from which the designer will choose when selecting the primary key. The primary key is the candidate key chosen to be the primary means by which the rows of the table are uniquely identified.

Entity integrity is the condition in which each row (entity instance) in the table has its own unique identity. To ensure entity integrity, the primary key has two requirements: (1) all of the values in the primary key must be unique, and (2) no key attribute in the primary key can contain a null.

NOTE

A null is no value at all. It does *not* mean a zero or a space. A null is created when you press the Enter key or the Tab key to move to the next entry without making an entry of any kind. Pressing the Spacebar creates a blank (or a space).

Null values are problematic in the relational model. A **null** is the absence of any data value, and it is never allowed in any part of the primary key. From a theoretical perspective, it can be argued that a table that contains a null is not

properly a relational table at all. From a practical perspective, however, some nulls cannot be reasonably avoided. For example, not all students have a middle initial. As a general rule, nulls should be avoided as much as reasonably possible. In fact, an abundance of nulls is often a sign of a poor design. Also, nulls should be avoided in the database because their meaning is not always identifiable. For example, a null could represent:

- An unknown attribute value.
- A known, but missing, attribute value.
- A “not applicable” condition.

Depending on the sophistication of the application development software, nulls can create problems when functions such as COUNT, AVERAGE, and SUM are used. In addition, nulls can create logical problems when relational tables are linked.

In addition to its role in providing a unique identity to each row in the table, the primary key may play an additional role in the controlled redundancy that allows the relational model to work. Recall from [Chapter 2](#) that a hallmark of the relational model is that relationships between tables are implemented through common attributes as a form of controlled redundancy. For example, [Figure 3.2](#) shows PRODUCT and VENDOR tables that are linked through a common attribute, VEND_CODE. VEND_CODE is referred to as a foreign key in the PRODUCT table. A [foreign key](#) is the primary key of one table that has been placed into another table to create a common attribute. In [Figure 3.2](#), the primary key of VENDOR, VEND_CODE, was placed in the PRODUCT table; therefore, VEND_CODE is a foreign key in PRODUCT. One advantage of using a proper naming convention for table attributes is that you can identify foreign keys more easily. For example, because the STUDENT table in [Figure 3.1](#) used a proper naming convention, you can identify two foreign keys in the table (DEPT_CODE and PROF_NUM) that imply the existence of two other tables in the database (DEPARTMENT and PROFESSOR) related to STUDENT.

FIGURE 3.2 An example of a simple relational database

Table name: PRODUCT
Primary key: PROD_CODE
Foreign key: VEND_CODE

Database name: Ch03_SaleCo

PROD_CODE	PROD_DESCRPT	PROD_PRICE	PROD_ON_HAND	VEND_CODE
001278-AB	Claw hammer	12.95	23	232
123-21UY	Houselite chain saw, 16-in. bar	189.99	4	235
QER-34256	Sledge hammer, 16-lb. head	18.63	6	231
SRE-657UG	Rat-tail file	2.99	15	232
ZZX/3245Q	Steel tape, 12-ft. length	6.79	8	235

link

Table name: VENDOR
Primary key: VEND_CODE
Foreign key: none

VEND_CODE	VEND_CONTACT	VEND_AREACODE	VEND_PHONE
230	Shelly K. Smithson	608	555-1234
231	James Johnson	615	123-4536
232	Annelise Crystall	608	224-2134
233	Candice Wallace	904	342-6567
234	Arthur Jones	615	123-3324
235	Henry Ortozo	615	899-3425

SOURCE: Course Technology/Cengage Learning

Just as the primary key has a role in ensuring the integrity of the database, so does the foreign key. Foreign keys are used to ensure **referential integrity**, the condition in which every reference to an entity instance by another entity instance is valid. In other words, every foreign key entry must either be null or a valid value in the primary key of the related table. Note that the PRODUCT table has referential integrity because every entry in VEND_CODE in the PRODUCT table is either null or a valid value in VEND_CODE in the VENDOR table. Every vendor referred to by a row in the PRODUCT table is a valid vendor.

Finally, a **secondary key** is defined as a key that is used strictly for data retrieval purposes. Suppose that customer data are stored in a CUSTOMER table in which the customer number is the primary key. Do you think that most customers will remember their numbers? Data retrieval for a customer is easier when the customer's last name and phone number are used. In that case, the primary key is the customer number; the secondary key is the combination of the customer's last name and phone number. Keep in mind that a secondary key does not necessarily yield a unique outcome. For example, a customer's last name and home telephone number could easily yield several matches in which one family lives together and shares a phone line. A less efficient secondary key would be the combination of the last name and zip code; this could yield dozens of matches, which could then be combed for a specific match.

A secondary key's effectiveness in narrowing down a search depends on how restrictive the key is. For instance, although the secondary key CUS_CITY is legitimate from a database point of view, the attribute values *New York* or *Sydney* are not likely to produce a usable return unless you want to examine millions of possible matches. (Of course, CUS_CITY is a better secondary key than CUS_COUNTRY.)

[Table 3.3](#) summarizes the various relational database table keys.

TABLE 3.3 Relational Database Keys

KEY TYPE

DEFINITION

Superkey An attribute or combination of attributes that uniquely identifies each row in a table

Candidate A minimal (irreducible) superkey; a superkey that does not contain a key subset of attributes that is itself a superkey

Primary key	A candidate key selected to uniquely identify all other attribute values in any given row; cannot contain null entries
Foreign key	An attribute or combination of attributes in one table whose values must either match the primary key in another table or be null
Secondary key	An attribute or combination of attributes used strictly for data retrieval purposes

3.3 INTEGRITY RULES

Relational database integrity rules are very important to good database design. RDBMSs enforce integrity rules automatically, but it is much safer to make sure your application design conforms to the entity and referential integrity rules mentioned in this chapter. Those rules are summarized in [Table 3.4](#).

TABLE 3.4 Integrity Rules

ENTITY INTEGRITY

DESCRIPTION

Requirement All primary key entries are unique, and no part of a primary key may be null.

Purpose Each row will have a unique identity, and foreign key values can properly reference primary key values.

Example No invoice can have a duplicate number, nor can it be null. In short, all invoices are uniquely identified by their invoice number.

REFERENTIAL INTEGRITY

DESCRIPTION

Requirement A foreign key may have either a null entry, as long as it is not a part of its table's primary key, or an entry that matches the primary key value in a table to which it is related. (Every non-null foreign key value *must* reference an *existing* primary key value.)

It is possible for an attribute *not* to have a corresponding value, but it will be impossible to have an invalid entry. The enforcement of the Purpose referential integrity rule makes it impossible to delete a row in one table whose primary key has mandatory matching foreign key values in another table.

A customer might not yet have an assigned sales representative Example (number), but it will be impossible to have an invalid sales representative (number).

The integrity rules summarized in [Table 3.4](#) are illustrated in [Figure 3.3](#).

FIGURE 3.3 An illustration of integrity rules

Table name: CUSTOMER

Primary key: CUS_CODE

Foreign key: AGENT_CODE

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_RENEW_DATE	AGENT_CODE
10010	Ramas	Alfred	A	05-Apr-2012	502
10011	Dunne	Leona	K	16-Jun-2012	501
10012	Smith	Kathy	W	29-Jan-2013	502
10013	Ołowski	Paul	F	14-Oct-2012	
10014	Orlando	Myron		28-Dec-2012	501
10015	O'Brian	Amy	B	22-Sep-2012	503
10016	Brown	James	G	25-Mar-2013	502
10017	Williams	George		17-Jul-2012	503
10018	Farriss	Anne	G	03-Dec-2012	501
10019	Smith	Olette	K	14-Mar-2013	503

Database name: Ch03_InsureCo

Table name: AGENT (only five selected fields are shown)

Primary key: AGENT_CODE

Foreign key: none

AGENT_CODE	AGENT_AREACODE	AGENT_PHONE	AGENT_LNAME	AGENT_YTD_SLS
501	713	228-1249	Alby	132735.75
502	615	882-1244	Hahn	138967.35
503	615	123-5589	Okon	127093.45

SOURCE: Course Technology/Cengage Learning

Note the following features of [Figure 3.3](#).

- *Entity integrity.* The CUSTOMER table's primary key is CUS_CODE. The CUSTOMER primary key column has no null entries, and all entries are unique. Similarly, the AGENT table's primary key is AGENT_CODE, and this primary key column is also free of null entries.
- *Referential integrity.* The CUSTOMER table contains a foreign key, AGENT_CODE, that links entries in the CUSTOMER table to the

AGENT table. The CUS_CODE row identified by the (primary key) number 10013 contains a null entry in its AGENT_CODE foreign key because Paul F. Ołowski does not yet have a sales representative assigned to him. The remaining AGENT_CODE entries in the CUSTOMER table all match the AGENT_CODE entries in the AGENT table.

To avoid nulls, some designers use special codes, known as [flags](#), to indicate the absence of some value. Using [Figure 3.3](#) as an example, the code -99 could be used as the AGENT_CODE entry in the fourth row of the CUSTOMER table to indicate that customer Paul Ołowski does not yet have an agent assigned to him. If such a flag is used, the AGENT table must contain a dummy row with an AGENT_CODE value of -99. Thus, the AGENT table's first record might contain the values shown in [Table 3.5](#).

TABLE 3.5 A Dummy Variable Value Used as a Flag

AGENT_CODE	AGENT_AREACODE	AGENT_PHONE	AGENT_LNAME	AGENT_YTD_SLS
-99	000	000-0000	None	\$0.00

[Chapter 4](#), Entity Relationship (ER) Modeling, discusses several ways to handle nulls.

Other integrity rules that can be enforced in the relational model are the NOT NULL and UNIQUE constraints. The NOT NULL constraint can be placed on a column to ensure that every row in the table has a value for that column. The UNIQUE constraint is a restriction placed on a column to ensure that no duplicate values exist for that column.

3.4 RELATIONAL SET OPERATORS

The data in relational tables are of limited value unless the data can be manipulated to generate useful information. This section describes the basic data manipulation capabilities of the relational model. [Relational algebra](#) defines the theoretical way of manipulating table contents using the eight relational operators: SELECT, PROJECT, JOIN, INTERSECT, UNION, DIFFERENCE,

PRODUCT, and DIVIDE. In [Chapter 7](#), Introduction to Structured Query Language (SQL), and [Chapter 8](#), Advanced SQL, you will learn how SQL commands can be used to accomplish relational algebra operations.

NOTE

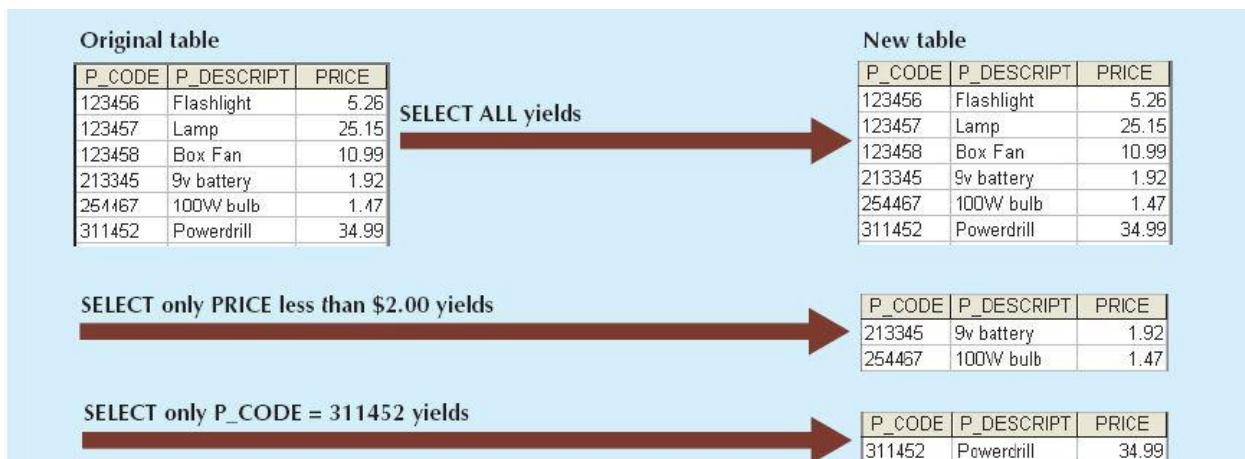
The degree of relational completeness can be defined by the extent to which relational algebra is supported. To be considered minimally relational, the DBMS must support the key relational operators SELECT, PROJECT, and JOIN. Very few DBMSs can support all eight relational operators.

The relational operators have the property of [**closure**](#); that is, the use of relational algebra operators on existing relations (tables) produces new relations. There is no need to examine the mathematical definitions, properties, and characteristics of relational algebra operators. However, their *use* can easily be illustrated as follows:

1. SELECT, also known as RESTRICT, yields values for all rows found in a table that satisfy a given condition. SELECT can be used to list all of the row values, or it can yield only row values that match a specified criterion. In other words, SELECT yields a horizontal subset of a table. The effect of a SELECT operation is shown in [Figure 3.4](#).

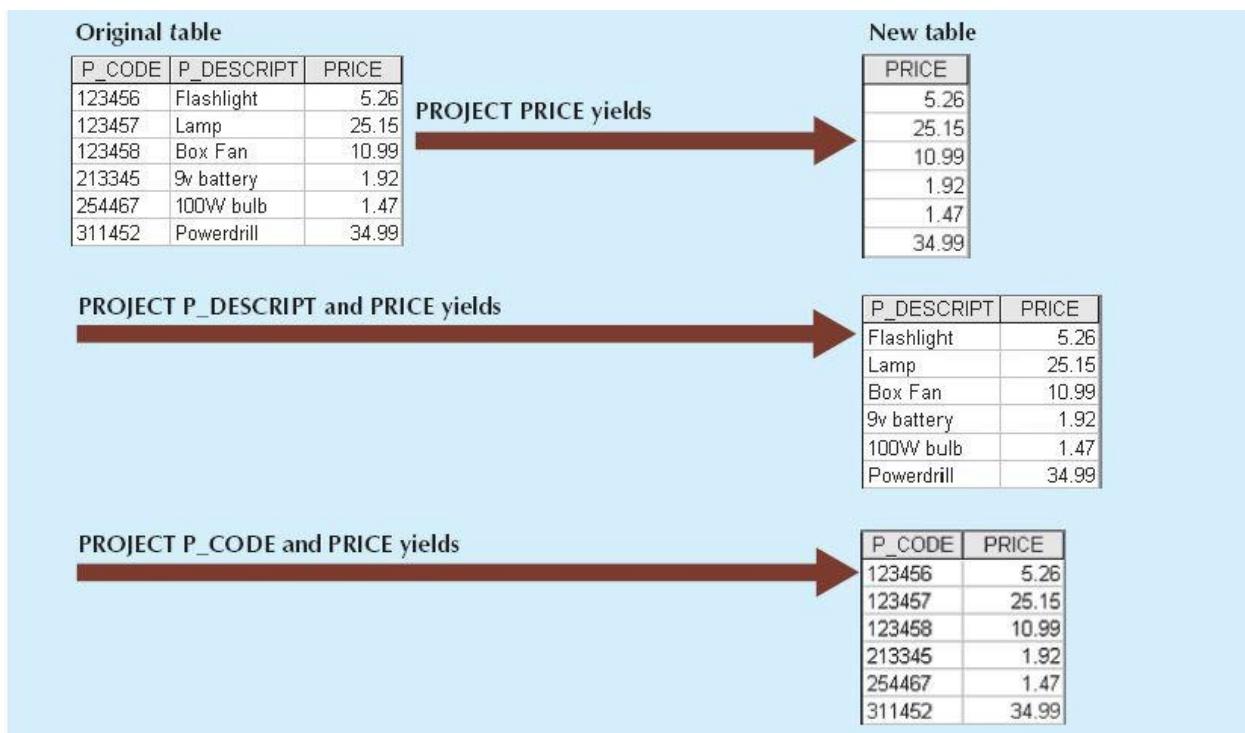
 2. PROJECT yields all values for selected attributes. In other words, PROJECT yields a vertical subset of a table. The effect of a PROJECT operation is shown in [Figure 3.5](#).
-

FIGURE 3.4 SELECT



SOURCE: Course Technology/Cengage Learning

FIGURE 3.5 PROJECT



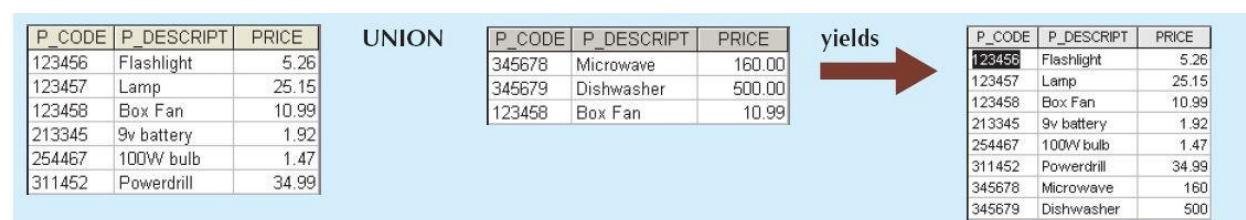
SOURCE: Course Technology/Cengage Learning

3. UNION combines all rows from two tables, excluding duplicate rows. To be used in the UNION, the tables must have the same attribute characteristics;

in other words, the columns and domains must be compatible. When two or more tables share the same number of columns, and when their corresponding columns share the same or compatible domains, they are said to be **union-compatible**. The effect of a UNION operation is shown in [Figure 3.6](#).

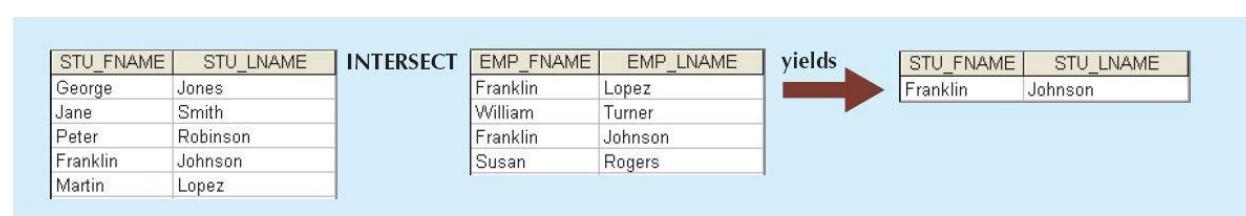
4. INTERSECT yields only the rows that appear in both tables. As with UNION, the tables must be union-compatible to yield valid results. For example, you cannot use INTERSECT if one of the attributes is numeric and one is character-based. The effect of an INTERSECT operation is shown in [Figure 3.7](#).

FIGURE 3.6 UNION



SOURCE: Course Technology/Cengage Learning

FIGURE 3.7 INTERSECT



SOURCE: Course Technology/Cengage Learning

5. DIFFERENCE yields all rows in one table that are not found in the other table; that is, it subtracts one table from the other. As with UNION, the

tables must be union-compatible to yield valid results. The effect of a DIFFERENCE operation is shown in [Figure 3.8](#). However, note that subtracting the first table from the second table is not the same as subtracting the second table from the first table.

FIGURE 3.8 DIFFERENCE

The diagram illustrates the DIFFERENCE operation. On the left, there are two tables: 'STU_FNAME' and 'STU_LNAME' (containing rows for George, Jones; Jane, Smith; Peter, Robinson; Franklin, Johnson; Martin, Lopez), and 'EMP_FNAME' and 'EMP_LNAME' (containing rows for Franklin, Lopez; William, Turner; Franklin, Johnson; Susan, Rogers). A large red arrow labeled 'DIFFERENCE' points from the first table to the second. To the right of the arrow is the text 'yields', followed by a third table containing all rows from the first table except for the ones found in the second table: George, Jones; Jane, Smith; Peter, Robinson; and Martin, Lopez.

STU_FNAME	STU_LNAME
George	Jones
Jane	Smith
Peter	Robinson
Franklin	Johnson
Martin	Lopez

DIFFERENCE

EMP_FNAME	EMP_LNAME
Franklin	Lopez
William	Turner
Franklin	Johnson
Susan	Rogers

yields

STU_FNAME	STU_LNAME
George	Jones
Jane	Smith
Peter	Robinson
Martin	Lopez

SOURCE: Course Technology/Cengage Learning

6. PRODUCT yields all possible pairs of rows from two tables—also known as the Cartesian product. Therefore, if one table has six rows and the other table has three rows, the PRODUCT yields a list composed of $6 \times 3 = 18$ rows. The effect of a PRODUCT operation is shown in [Figure 3.9](#).

7. JOIN allows information to be combined from two or more tables. JOIN is the real power behind the relational database, allowing the use of independent tables linked by common attributes. The CUSTOMER and AGENT tables shown in [Figure 3.10](#) will be used to illustrate several types of joins.

FIGURE 3.9 PRODUCT

The diagram illustrates a natural join operation. On the left, there are two tables: 'PRODUCT' and a derived table. The 'PRODUCT' table has columns P_CODE, P_DESCRPT, and PRICE, with data rows: (123456, Flashlight, 5.26), (123457, Lamp, 25.15), (123458, Box Fan, 10.99), (213345, 9v battery, 1.92), (254467, 100W bulb, 1.47), and (311452, Powerdrill, 34.99). The derived table has columns STORE, AISLE, and SHELF, with data rows: (23, W, 5), (24, K, 9), and (25, Z, 6). A red arrow labeled 'yields' points from the 'PRODUCT' table to the right, indicating the result of the join. The resulting table contains all columns from both tables: P_CODE, P_DESCRPT, PRICE, STORE, AISLE, and SHELF. It includes all rows from the 'PRODUCT' table and adds three new rows where the common attribute (P_CODE) matches the corresponding row in the derived table.

P_CODE	P_DESCRPT	PRICE	STORE	AISLE	SHELF
123456	Flashlight	5.26	23	W	5
123457	Lamp	25.15	24	K	9
123458	Box Fan	10.99	25	Z	6
213345	9v battery	1.92			
254467	100W bulb	1.47			
311452	Powerdrill	34.99			

P_CODE	P_DESCRPT	PRICE	STORE	AISLE	SHELF
123456	Flashlight	5.26	23	W	5
123456	Flashlight	5.26	24	K	9
123456	Flashlight	5.26	25	Z	6
123457	Lamp	25.15	23	W	5
123457	Lamp	25.15	24	K	9
123457	Lamp	25.15	25	Z	6
123458	Box Fan	10.99	23	W	5
123458	Box Fan	10.99	24	K	9
123458	Box Fan	10.99	25	Z	6
213345	9v battery	1.92	23	W	5
213345	9v battery	1.92	24	K	9
213345	9v battery	1.92	25	Z	6
311452	Powerdrill	34.99	23	W	5
311452	Powerdrill	34.99	24	K	9
311452	Powerdrill	34.99	25	Z	6
254467	100W bulb	1.47	23	W	5
254467	100W bulb	1.47	24	K	9
254467	100W bulb	1.47	25	Z	6

SOURCE: Course Technology/Cengage Learning

FIGURE 3.10 Two tables that will be used in join illustrations

Table name: CUSTOMER

CUS_CODE	CUS_LNAME	CUS_ZIP	AGENT_CODE
1132445	Walker	32145	231
1217782	Adares	32145	125
1312243	Rakowski	34129	167
1321242	Rodriguez	37134	125
1542311	Smithson	37134	421
1657399	Vanloo	32145	231

Table name: AGENT

AGENT_CODE	AGENT_PHONE
125	6152439887
167	6153426778
231	6152431124
333	9041234445

SOURCE: Course Technology/Cengage Learning

A **natural join** links tables by selecting only the rows with common values in their common attribute(s). A natural join is the result of a three-stage process:

- First, a PRODUCT of the tables is created, yielding the results shown in [Figure 3.11](#).
- Second, a SELECT is performed on the output of Step a to yield only the rows for which the AGENT_CODE values are equal. The common columns are referred to as the **join columns**. Step b yields the results shown in [Figure 3.12](#).
- A PROJECT is performed on the results of Step b to yield a single copy of each attribute, thereby eliminating duplicate columns. Step c yields the output shown in [Figure 3.13](#).

The final outcome of a natural join yields a table that does not include unmatched pairs and provides only the copies of the matches.

Note a few crucial features of the natural join operation:

- If no match is made between the table rows, the new table does not include the unmatched row. In that case, neither AGENT_CODE 421 nor the customer whose last name is Smithson is included. Smithson's AGENT_CODE 421 does not match any entry in the AGENT table.
- The column on which the join was made—that is, AGENT_CODE—occurs only once in the new table.
- If the same AGENT_CODE were to occur several times in the AGENT table, a customer would be listed for each match. For example, if the AGENT_CODE 167 occurred three times in the AGENT table, the customer named Rakowski would also occur three times in the resulting table because Rakowski is associated with AGENT_CODE 167. (Of course, a good AGENT table cannot yield such a result because it would contain unique primary key values.)

FIGURE 3.11 Natural join, Step 1: PRODUCT

CUS_CODE	CUS_LNAME	CUS_ZIP	CUSTOMER.AGENT_CODE	AGENT.AGENT_CODE	AGENT_PHONE
1132445	Walker	32145	231	125	6152439887
1132445	Walker	32145	231	167	6153426778
1132445	Walker	32145	231	231	6152431124
1132445	Walker	32145	231	333	9041234445
1217782	Adares	32145	125	125	6152439887
1217782	Adares	32145	125	167	6153426778
1217782	Adares	32145	125	231	6152431124
1217782	Adares	32145	125	333	9041234445
1312243	Rakowski	34129	167	125	6152439887
1312243	Rakowski	34129	167	167	6153426778
1312243	Rakowski	34129	167	231	6152431124
1312243	Rakowski	34129	167	333	9041234445
1321242	Rodriguez	37134	125	125	6152439887
1321242	Rodriguez	37134	125	167	6153426778
1321242	Rodriguez	37134	125	231	6152431124
1321242	Rodriguez	37134	125	333	9041234445
1542311	Smithson	37134	421	125	6152439887
1542311	Smithson	37134	421	167	6153426778
1542311	Smithson	37134	421	231	6152431124
1542311	Smithson	37134	421	333	9041234445
1657399	Vanloo	32145	231	125	6152439887
1657399	Vanloo	32145	231	167	6153426778
1657399	Vanloo	32145	231	231	6152431124
1657399	Vanloo	32145	231	333	9041234445

SOURCE: Course Technology/Cengage Learning

FIGURE 3.12 Natural join, Step 2: SELECT

CUS_CODE	CUS_LNAME	CUS_ZIP	CUSTOMER.AGENT_CODE	AGENT.AGENT_CODE	AGENT_PHONE
1217782	Adares	32145	125	125	6152439887
1321242	Rodriguez	37134	125	125	6152439887
1312243	Rakowski	34129	167	167	6153426778
1132445	Walker	32145	231	231	6152431124
1657399	Vanloo	32145	231	231	6152431124

SOURCE: Course Technology/Cengage Learning

FIGURE 3.13 Natural join, Step 3: PROJECT

CUS_CODE	CUS_LNAME	CUS_ZIP	AGENT_CODE	AGENT_PHONE
1217782	Adares	32145	125	6152439887
1321242	Rodriguez	37134	125	6152439887
1312243	Rakowski	34129	167	6153426778
1132445	Walker	32145	231	6152431124
1657399	Vanloo	32145	231	6152431124

SOURCE: Course Technology/Cengage Learning

Another form of join, known as an [equijoin](#), links tables on the basis of an equality condition that compares specified columns of each table. The outcome of the equijoin does not eliminate duplicate columns, and the condition or criterion used to join the tables must be explicitly defined. In fact, the result of an equijoin looks just like the outcome shown in [Figure 3.12](#) for step 2 of a natural join. The equijoin takes its name from the equality comparison operator (=) used in the condition. If any other comparison operator is used, the join is called a [theta join](#).

Each of the preceding joins is often classified as an inner join. An [inner join](#) only returns matched records from the tables that are being joined. In an [outer join](#), the matched pairs would be retained, and any unmatched values in the other table would be left null. It is an easy mistake to think that an outer join is the opposite of an inner join. However, it is more accurate to think of an outer join as an “inner join plus.” The outer join still returns all of the matched records that the inner join returns, plus it returns the unmatched records from one of the tables. More specifically, if an outer join is produced for tables CUSTOMER and AGENT, two scenarios are possible:

A [left outer join](#) yields all of the rows in the CUSTOMER table, including those that do not have a matching value in the AGENT table. An example of such a join is shown in [Figure 3.14](#).

FIGURE 3.14 Left outer join

CUS_CODE	CUS_LNAME	CUS_ZIP	CUSTOMER.AGENT_CODE	AGENT.AGENT_CODE	AGENT_PHONE
1217782	Adares	32145	125	125	6152439887
1321242	Rodriguez	37134	125	125	6152439887
1312243	Rakowski	34129	167	167	6153426778
1132445	Walker	32145	231	231	6152431124
1657399	Vanloo	32145	231	231	6152431124
1542311	Smithson	37134	421		

SOURCE: Course Technology/Cengage Learning

A **right outer join** yields all of the rows in the AGENT table, including those that do not have matching values in the CUSTOMER table. An example of such a join is shown in [Figure 3.15](#).

FIGURE 3.15 Right outer join

CUS_CODE	CUS_LNAME	CUS_ZIP	CUSTOMER.AGENT_CODE	AGENT.AGENT_CODE	AGENT_PHONE
1217782	Adares	32145	125	125	6152439887
1321242	Rodriguez	37134	125	125	6152439887
1312243	Rakowski	34129	167	167	6153426778
1132445	Walker	32145	231	231	6152431124
1657399	Vanloo	32145	231	231	6152431124
				333	9041234445

SOURCE: Course Technology/Cengage Learning

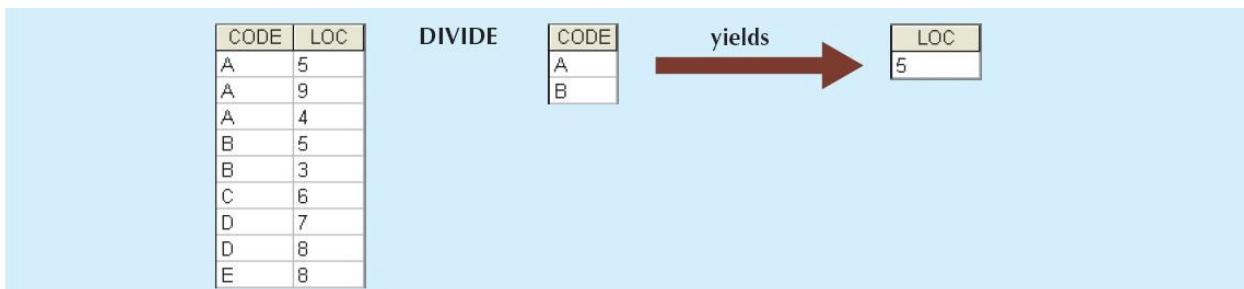
Outer joins are especially useful when you are trying to determine what values in related tables cause referential integrity problems. Such problems are created when foreign key values do not match the primary key values in the related table(s). In fact, if you are asked to convert large spreadsheets or other “nondatabase” data into relational database tables, you will discover that the outer joins save you vast amounts of time and uncounted headaches when you encounter referential integrity errors after the conversions.

You may wonder why the outer joins are labeled “left” and “right.” The labels refer to the order in which the tables are listed in the SQL command. [Chapter 8](#) explores such joins in more detail.

8. The DIVIDE operation uses one 2-column table (Table 1) as the dividend and one single-column table (Table 2) as the divisor. In [Figure 3.16](#), the dividend contains the CODE and LOC columns. The divisor contains the

CODE column. The tables must have a common column—in this case, the CODE column. The output of the DIVIDE operation is a single column that contains all values from the second column of the dividend (LOC) that are associated with every row in the divisor. [Figure 3.16](#) shows a DIVIDE.

FIGURE 3.16 DIVIDE



SOURCE: Course Technology/Cengage Learning

Using the example shown in [Figure 3.16](#), note that:

- Table 1 is “divided” by Table 2 to produce Table 3. Tables 1 and 2 both contain the CODE column but do not share the LOC column.
- To be included in the resulting Table 3, a value in the unshared column (LOC) must be associated with every value in Table 2.
- The only value associated with both A and B is 5.

3.5 THE DATA DICTIONARY AND THE SYSTEM CATALOG

The [data dictionary](#) provides a detailed description of all tables in the database created by the user and designer. Thus, the data dictionary contains at least all of the attribute names and characteristics for each table in the system. In short, the data dictionary contains metadata—data about data. Using the small database presented in [Figure 3.3](#), you might picture its data dictionary as shown in [Table 3.6](#).

NOTE

The data dictionary in [Table 3.6](#) is an example of the *human* view of the entities, attributes, and relationships. The purpose of this data dictionary is to ensure that all members of database design and implementation teams use the same table and attribute names and characteristics. The DBMS's internally stored data dictionary contains additional information about relationship types, entity and referential integrity checks and enforcement, and index types and components. This additional information is generated during the database implementation stage.

The data dictionary is sometimes described as “the database designer’s database” because it records the design decisions about tables and their structures.

TABLE 3.6 A Sample Data Dictionary

TABLE NAME	ATTRIBUTE NAME	CONTENTS	TYPE	FORMAT	RANGE	REQUIRED	PK or FK	FK REFERENCED TABLE
CUSTOMER	CUS_CODE CUS_LNAME CUS_FNAME CUS_INITIAL CUS_RENEW_DATE AGENT_CODE	Customer account code Customer last name Customer first name Customer initial Customer insurance renewal date Agent code	CHAR(5) VARCHAR(20) VARCHAR(20) CHAR(1) DATE CHAR(3)	99999 XXXXXXXX XXXXXXXX X dd-mmm-yyyy 999	10000–99999	Y Y Y	PK FK	AGENT_CODE
AGENT	AGENT_CODE AGENT_AREACODE AGENT_PHONE AGENT_LNAME AGENT_YTD_SLS	Agent code Agent area code Agent telephone number Agent last name Agent year-to-date sales	CHAR(3) CHAR(3) CHAR(8) VARCHAR(20) NUMBER(9,2)	999 999 999-9999 XXXXXXXX 9,999,999.99		Y Y Y Y	PK	

FK =Foreign key

PK =Primary key

CHAR =Fixed character length data (1–255 characters)

VARCHAR =Variable character length data (1–2,000 characters)

=Numeric data (NUMBER(9,2)) are used to specify numbers with NUMBER two decimal places and up to nine digits, including the decimal places. Some

=RDBMSs permit the use of a MONEY or CURRENCY data type.

Note: Telephone area codes are always composed of digits 0–9, but because area codes are not used arithmetically, they are most efficiently stored as character data. Also, the area codes are always composed of three digits. Therefore, the area code data type is defined as CHAR(3). On the other hand, names do not conform to a standard length. Therefore, the customer first names are defined as VARCHAR(20), indicating that up to 20 characters may be used to store the names. Character data are shown as left-aligned.

Like the data dictionary, the [**system catalog**](#) contains metadata. The system catalog can be described as a detailed system data dictionary that describes all objects within the database, including data about table names, the table's creator and creation date, the number of columns in each table, the data type corresponding to each column, index filenames, index creators, authorized users, and access privileges. Because the system catalog contains all required data dictionary information, the terms *system catalog* and *data dictionary* are often used interchangeably. In fact, current relational database software generally provides only a system catalog, from which the designer's data dictionary information may be derived. The system catalog is actually a system-created database whose tables store the user/ designer-created database characteristics and contents. Therefore, the system catalog tables can be queried just like any user/designer-created table.

In effect, the system catalog automatically produces database documentation. As new tables are added to the database, that documentation also allows the RDBMS to check for and eliminate homonyms and synonyms. In general terms, [**homonyms**](#) are similar-sounding words with different meanings, such as *boar* and *bore*, or a word with different meanings, such as *fair* (which means “just” in some contexts and “festival” in others). In a database context, the word *homonym* indicates the use of the same name to label different attributes. For example, you might use C_NAME to label a customer name attribute in a CUSTOMER table and use C_NAME to label a consultant name attribute in a

CONSULTANT table. To lessen confusion, you should avoid database homonyms; the data dictionary is very useful in this regard.

In a database context, a **synonym** is the opposite of a homonym, and indicates the use of different names to describe the same attribute. For example, *car* and *auto* refer to the same object. Synonyms must be avoided; you will discover why when you work through [Problem 27](#) at the end of this chapter.

3.6 RELATIONSHIPS WITHIN THE RELATIONAL DATABASE

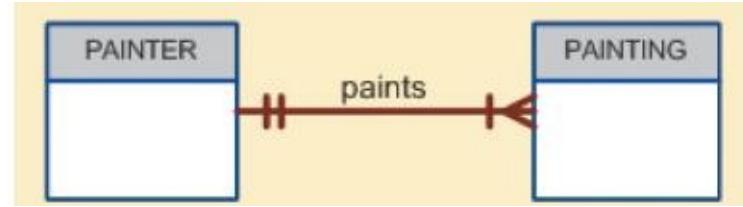
You already know that relationships are classified as one-to-one (1:1), one-to-many (1:M), and many-to-many (M:N or M:M). This section explores those relationships further to help you apply them properly when you start developing database designs. This section focuses on the following points:

- The 1:M relationship is the relational modeling ideal. Therefore, this relationship type should be the norm in any relational database design.
- The 1:1 relationship should be rare in any relational database design.
- M:N relationships cannot be implemented as such in the relational model. Later in this section, you will see how any M:N relationship can be changed into two 1:M relationships.

3.6.1 THE 1:M RELATIONSHIP

The 1:M relationship is the norm for relational databases. To see how such a relationship is modeled and implemented, consider the PAINTER and PAINTING example shown in [Figure 3.17](#).

FIGURE 3.17 The 1:M relationship between PAINTER and PAINTING



SOURCE: Course Technology/Cengage Learning

Compare the data model in [Figure 3.17](#) with its implementation in [Figure 3.18](#).

As you examine the PAINTER and PAINTING table contents in [Figure 3.18](#), note the following features:

- Each painting was created by one and only one painter, but each painter could have created many paintings. Note that painter 123 (Georgette P. Ross) has three works stored in the PAINTING table.
-

FIGURE 3.18 The implemented 1:M relationship between PAINTER and PAINTING

Table name: PAINTER				Database name: Ch03_Museum	
Primary key: PAINTER_NUM					
Foreign key: none					
PAINTER_NUM	PAINTER_LNAME	PAINTER_FNAME	PAINTER_INITIAL		
123	Ross	Georgette	P		
126	Itero	Julio	G		

Table name: PAINTING		
Primary key: PAINTING_NUM		
Foreign key: PAINTER_NUM		
PAINTING_NUM	PAINTING_TITLE	PAINTER_NUM
1338	Dawn Thunder	123
1339	Vanilla Roses To Nowhere	123
1340	Tired Flounders	126
1341	Hasty Exit	123
1342	Plastic Paradise	126

SOURCE: Course Technology/Cengage Learning

- There is only one row in the PAINTER table for any given row in the PAINTING table, but there may be many rows in the PAINTING table for any given row in the PAINTER table.

NOTE

The one-to-many (1:M) relationship is easily implemented in the relational model by putting the *primary key of the “1” side in the table of the “many” side as a foreign key*.

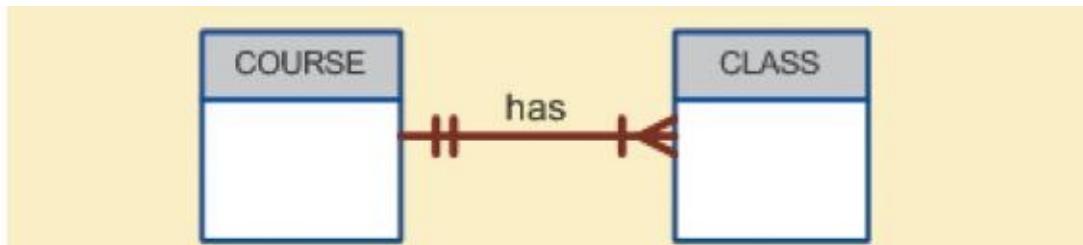
The 1:M relationship is found in any database environment. Students in a typical college or university will discover that each COURSE can generate many CLASSES but that each CLASS refers to only one COURSE. For example, an Accounting II course might yield two classes: one offered on Monday, Wednesday, and Friday (MWF) from 10:00 a.m. to 10:50 a.m., and one offered on Thursday (Th) from 6:00 p.m. to 8:40 p.m. Therefore, the 1:M relationship between COURSE and CLASS might be described this way:

- Each COURSE can have many CLASSES, but each CLASS references only one COURSE.
- There will be only one row in the COURSE table for any given row in the CLASS table, but there can be many rows in the CLASS table for any given row in the COURSE table.

[Figure 3.19](#) maps the ERM (entity relationship model) for the 1:M relationship between COURSE and CLASS.

The 1:M relationship between COURSE and CLASS is further illustrated in [Figure 3.20](#).

FIGURE 3.19 The 1:M relationship between COURSE and CLASS



SOURCE: Course Technology/Cengage Learning

FIGURE 3.20 The implemented 1:M relationship between COURSE and CLASS

Table name: COURSE				Database name: Ch03_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		
QM-261	CIS	Intro. to Statistics	3		
QM-362	CIS	Statistical Applications	4		

Table name: CLASS					
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

SOURCE: Course Technology/Cengage Learning

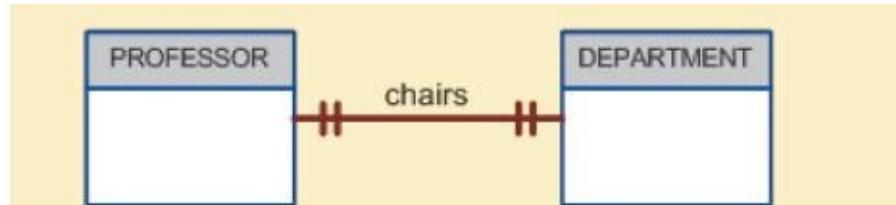
Using [Figure 3.20](#), take a minute to review some important terminology. Note that CLASS_CODE in the CLASS table uniquely identifies each row. Therefore, CLASS_CODE has been chosen to be the primary key. However, the combination CRS_CODE and CLASS_SECTION will also uniquely identify each row in the class table. In other words, the *composite key* composed of CRS_CODE and CLASS_SECTION is a candidate key. Any *candidate key* must have the not-null and unique constraints enforced. (You will see how this is done when you learn SQL in [Chapter 7](#).)

For example, note in [Figure 3.18](#) that the PAINTER table's primary key, PAINTER_NUM, is included in the PAINTING table as a foreign key. Similarly, in [Figure 3.20](#), the COURSE table's primary key, CRS_CODE, is included in the CLASS table as a foreign key.

3.6.2 THE 1:1 RELATIONSHIP

As the 1:1 label implies, one entity in a 1:1 relationship can be related to only one other entity, and vice versa. For example, one department chair—a professor—can chair only one department, and one department can have only one department chair. The entities PROFESSOR and DEPARTMENT thus exhibit a 1:1 relationship. (You might argue that not all professors chair a department and professors cannot be *required* to chair a department. That is, the relationship between the two entities is optional. However, at this stage of the discussion, you should focus your attention on the basic 1:1 relationship. Optional relationships will be addressed in [Chapter 4](#).) The basic 1:1 relationship is modeled in [Figure 3.21](#), and its implementation is shown in [Figure 3.22](#).

FIGURE 3.21 The 1:1 relationship between PROFESSOR and DEPARTMENT



SOURCE: Course Technology/Cengage Learning

As you examine the tables in [Figure 3.22](#), note several important features:

- Each professor is a Tiny College employee. Therefore, the professor identification is through the EMP_NUM. (However, note that not all employees are professors—there's another optional relationship.)
- The 1:1 “PROFESSOR chairs DEPARTMENT” relationship is implemented by having the EMP_NUM foreign key in the DEPARTMENT table. Note that the 1:1 relationship is treated as a special case of the 1:M relationship in which the “many” side is restricted

to a single occurrence. In this case, DEPARTMENT contains the EMP_NUM as a foreign key to indicate that it is the *department* that has a chair.

- Also note that the PROFESSOR table contains the DEPT_CODE foreign key to implement the 1:M “DEPARTMENT employs PROFESSOR” relationship. This is a good example of how two entities can participate in two (or even more) relationships simultaneously.



ONLINE CONTENT

If you open the **Ch03_TinyCollege** database at www.cengagebrain.com, you will see that the STUDENT and CLASS entities still use PROF_NUM as their foreign key. PROF_NUM and EMP_NUM are labels for the same attribute, which is an example of the use of synonyms—that is, different names for the same attribute. These synonyms will be eliminated in future chapters as the Tiny College database continues to be improved.

The preceding “PROFESSOR chairs DEPARTMENT” example illustrates a proper 1:1 relationship. *In fact, the use of a 1:1 relationship ensures that two entity sets are not placed in the same table when they should not be.* However, the existence of a 1:1 relationship sometimes means that the entity components were not defined properly. It could indicate that the two entities actually belong in the same table!

Although 1:1 relationships should be rare, certain conditions absolutely require their use. In [Chapter 5](#), Advanced Data Modeling, you will explore a concept called a generalization hierarchy, which is a powerful tool for improving database designs under specific conditions to avoid a proliferation of nulls. One characteristic of generalization hierarchies is that they are implemented as 1:1 relationships.



ONLINE CONTENT

If you look at the **Ch03_AviaCo** database at www.cengagebrain.com, you will see the implementation of the 1:1 PILOT to EMPLOYEE relationship. This relationship is based on a generalization hierarchy, which you will learn about in [Chapter 5](#).

FIGURE 3.22 The implemented 1:1 relationship between PROFESSOR and DEPARTMENT

Table name: PROFESSOR
 Primary key: EMP_NUM
 Foreign key: DEPT_CODE

Database name: Ch03_TinyCollege

EMP_NUM	DEPT_CODE	PROF_OFFICE	PROF_EXTENSION	PROF_HIGH_DEGREE
103	HIST	DRE 156	6783	Ph.D.
104	ENG	DRE 102	5561	MA
105	ACCT	KLR 229D	8665	Ph.D.
106	MKT/MGT	KLR 126	3899	Ph.D.
110	BIOL	AAK 160	3412	Ph.D.
114	ACCT	KLR 211	4438	Ph.D.
155	MATH	AAK 201	4440	Ph.D.
160	ENG	DRE 102	2248	Ph.D.
162	CIS	KLR 203E	2359	Ph.D.
191	MKT/MGT	KLR 409B	4016	DBA
195	PSYCH	AAK 297	3550	Ph.D.
209	CIS	KLR 333	3421	Ph.D.
228	CIS	KLR 300	3000	Ph.D.
297	MATH	AAK 194	1145	Ph.D.
299	ECON/FIN	KLR 284	2851	Ph.D.
301	ACCT	KLR 244	4683	Ph.D.
335	ENG	DRE 208	2000	Ph.D.
342	SOC	BIG 208	5514	Ph.D.
387	BIOL	AAK 230	8665	Ph.D.
401	HIST	DRE 156	6783	MA
425	ECON/FIN	KLR 284	2851	MBA
435	ART	BIG 185	2278	Ph.D.

The 1:M DEPARTMENT employs PROFESSOR relationship is implemented through the placement of the DEPT_CODE foreign key in the PROFESSOR table.

Table name: DEPARTMENT
 Primary key: DEPT_CODE
 Foreign key: EMP_NUM

The 1:1 PROFESSOR chairs DEPARTMENT relationship is implemented through the placement of the EMP_NUM foreign key in the DEPARTMENT table.

DEPT_CODE	DEPT_NAME	SCHOOL_CODE	EMP_NUM	DEPT_ADDRESS	DEPT_EXTENSION
ACCT	Accounting	BUS	114	KLR 211, Box 52	3119
ART	Fine Arts	A&SCI	435	BIG 185, Box 128	2278
BIOL	Biology	A&SCI	387	AAK 230, Box 415	4117
CIS	Computer Info. Systems	BUS	209	KLR 333, Box 56	3245
ECON/FIN	Economics/Finance	BUS	299	KLR 284, Box 63	3126
ENG	English	A&SCI	160	DRE 102, Box 223	1004
HIST	History	A&SCI	103	DRE 156, Box 284	1867
MATH	Mathematics	A&SCI	297	AAK 194, Box 422	4234
MKT/MGT	Marketing/Management	BUS	106	KLR 126, Box 55	3342
PSYCH	Psychology	A&SCI	195	AAK 297, Box 438	4110
SOC	Sociology	A&SCI	342	BIG 208, Box 132	2008

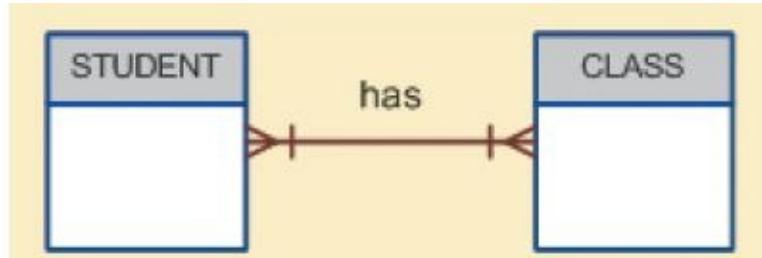
SOURCE: Course Technology/Cengage Learning

3.6.3 THE M:N RELATIONSHIP

A many-to-many (M:N) relationship is not supported directly in the relational environment. However, M:N relationships can be implemented by creating a

new entity in 1:M relationships with the original entities.

FIGURE 3.23 The ERM's M:N relationship between STUDENT and CLASS



SOURCE: Course Technology/Cengage Learning

To explore the many-to-many relationship, consider a typical college environment. The ER model in [Figure 3.23](#) shows this M:N relationship.

Note the features of the ERM in [Figure 3.23](#).

- Each CLASS can have many STUDENTS, and each STUDENT can take many CLASSES.
- There can be many rows in the CLASS table for any given row in the STUDENT table, and there can be many rows in the STUDENT table for any given row in the CLASS table.

To examine the M:N relationship more closely, imagine a small college with two students, each of whom takes three classes. [Table 3.7](#) shows the enrollment data for the two students.

TABLE 3.7 Sample Student Enrollment Data

STUDENT'S LAST NAME

SELECTED CLASSES

Bowser Accounting 1, ACCT-211, code 10014

Intro to Microcomputing, CIS-220, code 10018

Intro to Statistics, QM-261, code 10021

Smithson Accounting 1, ACCT-211, code 10014

Intro to Microcomputing, CIS-220, code 10018

Intro to Statistics, QM-261, code 10021

Given such a data relationship and the sample data in [Table 3.7](#), you could wrongly assume that you could implement this M:N relationship simply by adding a foreign key in the “many” side of the relationship that points to the primary key of the related table, as shown in [Figure 3.24](#).

FIGURE 3.24 The wrong implementation of the M:N relationship between STUDENT and CLASS

Table name: STUDENT			Database name: Ch03_CollegeTry			
STU_NUM	STU_LNAME	CLASS_CODE	CLASS_CODE	STU_NUM	CRS_CODE	CLASS_SECTION
321452	Bowser	10014	10014	321452	ACCT-211	3
321452	Bowser	10018	10018	321452	ACCT-211	3
321452	Bowser	10021	10021	321452	CIS-220	2
324257	Smithson	10014	10014	324257	CIS-220	2
324257	Smithson	10018	10018	324257	QM-261	1
324257	Smithson	10021	10021	324257	QM-261	1

Table name: CLASS						
CLASS_CODE	STU_NUM	CRS_CODE	CLASS_SECTION	CLASS_TIME	CLASS_ROOM	PROF_NUM
10014	321452	ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
10014	324257	ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
10018	321452	CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
10018	324257	CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
10021	321452	QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114
10021	324257	QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114

SOURCE: Course Technology/Cengage Learning

However, the M:N relationship should *not* be implemented as shown in [Figure 3.24](#) for two good reasons:

- The tables create many redundancies. For example, note that the STU_NUM values occur many times in the STUDENT table. In a real-world situation, additional student attributes such as address, classification, major, and home phone would also be contained in the STUDENT table, and each of those attribute values would be repeated in

each of the records shown here. Similarly, the CLASS table contains many duplications: each student taking the class generates a CLASS record. The problem would be even worse if the CLASS table included such attributes as credit hours and course description. Those redundancies lead to the anomalies discussed in [Chapter 1](#).

- Given the structure and contents of the two tables, the relational operations become very complex and are likely to lead to system efficiency errors and output errors.

Fortunately, the problems inherent in the many-to-many relationship can easily be avoided by creating a [composite entity](#) (also referred to as a [bridge entity](#) or an [associative entity](#)). Because such a table is used to link the tables that were originally related in an M:N relationship, the composite entity structure includes—as foreign keys—at least the primary keys of the tables that are to be linked. The database designer has two main options when defining a composite table’s primary key: use the combination of those foreign keys or create a new primary key.

Remember that each entity in the ERM is represented by a table. Therefore, you can create the composite ENROLL table shown in [Figure 3.25](#) to link the tables CLASS and STUDENT. In this example, the ENROLL table’s primary key is the combination of its foreign keys CLASS_CODE and STU_NUM. However, the designer could have decided to create a single-attribute new primary key such as ENROLL_LINE, using a different line value to identify each ENROLL table row uniquely. (Microsoft Access users might use the Autonumber data type to generate such line values automatically.)

FIGURE 3.25 Converting the M:N relationship into two 1:M relationships

Table name: STUDENT
Primary key: STU_NUM
Foreign key: none

Database name: Ch03_CollegeTry2

STU_NUM	STU_LNAME
321452	Bowser
324257	Smithson

Table name: ENROLL
Primary key: CLASS_CODE + STU_NUM
Foreign key: CLASS_CODE, STU_NUM

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
Primary key: CLASS_CODE
Foreign key: CRS_CODE

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

SOURCE: Course Technology/Cengage Learning

Because the ENROLL table in [Figure 3.25](#) links two tables, STUDENT and CLASS, it is also called a [linking table](#). In other words, a linking table is the implementation of a composite entity.

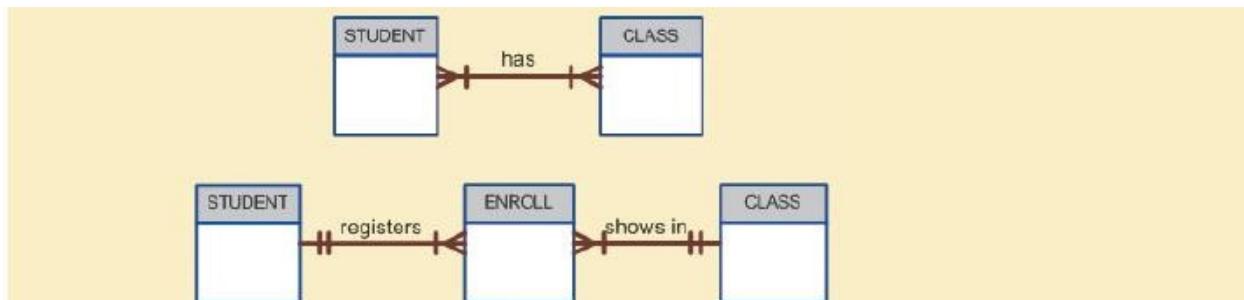
NOTE

In addition to the linking attributes, the composite ENROLL table can also contain such relevant attributes as the grade earned in the course. In fact, a composite table can contain any number of attributes that the designer wants to track. Keep in mind that the composite entity, *although implemented as an actual table*, is *conceptually* a logical entity that was created as a means to an end: to eliminate the potential for multiple redundancies in the original M:N relationship.

The ENROLL table shown in [Figure 3.25](#) yields the required M:N to 1:M conversion. Observe that the composite entity represented by the ENROLL table must contain at least the primary keys of the CLASS and STUDENT tables

(CLASS_CODE and STU_NUM, respectively) for which it serves as a connector. Also note that the STUDENT and CLASS tables now contain only one row per entity. The ENROLL table contains multiple occurrences of the foreign key values, but those controlled redundancies are incapable of producing anomalies as long as referential integrity is enforced. Additional attributes may be assigned as needed. In this case, ENROLL_GRADE is selected to satisfy a reporting requirement. Also note that the ENROLL table's primary key consists of the two attributes CLASS_CODE and STU_NUM because both the class code and the student number are needed to define a particular student's grade. Naturally, the conversion is reflected in the ERM, too. The revised relationship is shown in [Figure 3.26](#).

FIGURE 3.26 Changing the M:N relationship to two 1:M relationships



SOURCE: Course Technology/Cengage Learning

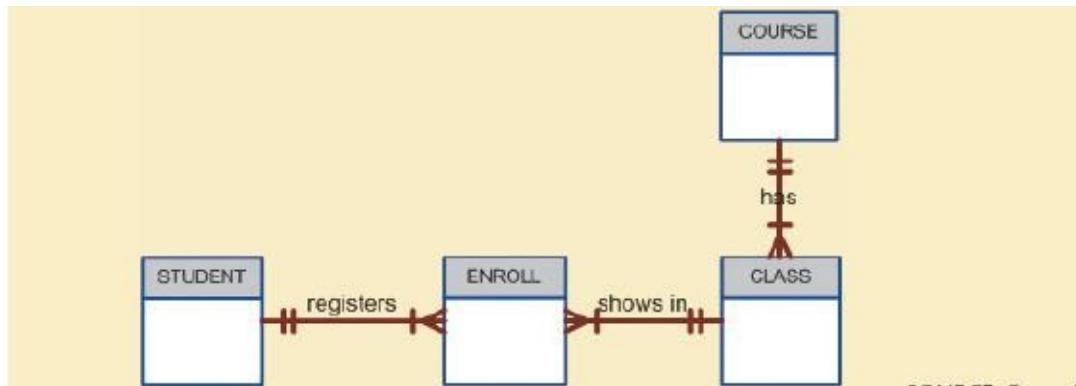
As you examine [Figure 3.26](#), note that the composite entity named ENROLL represents the linking table between STUDENT and CLASS.

The 1:M relationship between COURSE and CLASS was first illustrated in [Figure 3.19](#) and [Figure 3.20](#). You can increase the amount of available information even as you control the database's redundancies. Thus, [Figure 3.27](#) shows the expanded ERM, including the 1:M relationship between COURSE and CLASS shown in [Figure 3.19](#). Note that the model can handle multiple sections of a CLASS while controlling redundancies by making sure that all of the COURSE data common to each CLASS are kept in the COURSE table.

The relational diagram that corresponds to the ERM in [Figure 3.27](#) is shown in [Figure 3.28](#).

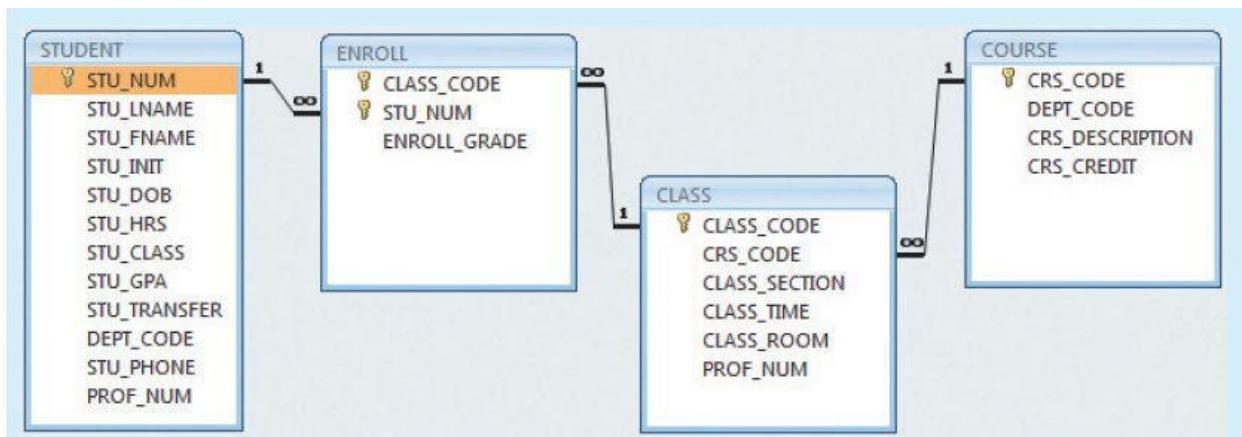
The ERM will be examined in greater detail in [Chapter 4](#) to show you how it is used to design more complex databases. The ERM will also be used as the basis for developing and implementing a realistic database design of a university computer lab in Appendixes B and C. These appendixes are available at www.cengagebrain.com.

FIGURE 3.27 The expanded entity relationship model



SOURCE: Course Technology/Cengage Learning

FIGURE 3.28 The relational diagram for the Ch03_TinyCollege database



SOURCE: Course Technology/Cengage Learning

3.7 DATA REDUNDANCY REVISITED

In [Chapter 1](#) you learned that data redundancy leads to data anomalies, which can destroy the effectiveness of the database. You also learned that the relational database makes it possible to control data redundancies by using common attributes that are shared by tables, called foreign keys.

The proper use of foreign keys is crucial to controlling data redundancy, although they do not totally eliminate the problem because the foreign key values can be repeated many times. However, the proper use of foreign keys *minimizes* data redundancies and the chances that destructive data anomalies will develop.

NOTE

The real test of redundancy is *not* how many copies of a given attribute are stored, *but whether the elimination of an attribute will eliminate information*. Therefore, if you delete an attribute and the original information can still be generated through relational algebra, the inclusion of that attribute would be redundant. Given that view of redundancy, proper foreign keys are clearly not redundant in spite of their multiple occurrences in a table. However, even when you use this less restrictive view of redundancy, keep in mind that *controlled* redundancies are often designed as part of the system to ensure transaction speed and/or information requirements. Exclusive reliance on relational algebra to produce required information may lead to elegant designs that fail the test of practicality.

You will learn in [Chapter 4](#) that database designers must reconcile three often contradictory requirements: design elegance, processing speed, and information requirements. Also, you will learn in [Chapter 13](#), Business Intelligence and Data Warehouses, that proper data warehousing design requires carefully defined and controlled data redundancies to function properly. Regardless of how you describe data redundancies, the potential for damage is limited by proper implementation and careful control.

As important as it is to control data redundancy, sometimes the level of data

redundancy must actually be increased to make the database serve crucial information purposes. You will learn about such redundancies in [Chapter 13](#). Also, data redundancies sometimes *seem* to exist to preserve the historical accuracy of the data. For example, consider a small invoicing system. The system includes the CUSTOMER, who may buy one or more PRODUCTS, thus generating an INVOICE. Because a customer may buy more than one product at a time, an invoice may contain several invoice LINES, each providing details about the purchased product. The PRODUCT table should contain the product price to provide a consistent pricing input for each product that appears on the invoice. The tables that are part of such a system are shown in [Figure 3.29](#). The system's relational diagram is shown in [Figure 3.30](#).

FIGURE 3.29 A small invoicing system

Table name: CUSTOMER
Primary key: CUS_CODE
Foreign key: none

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE
10010	Ramas	Alfred	A	615	844-2573
10011	Dunne	Leona	K	713	894-1208
10012	Smith	Kathy	W	615	894-2285
10013	Oleowski	Paul	F	615	894-2100
10014	Orlando	Myron		615	222-1672
10015	O'Brian	Amy	B	713	442-3301
10016	Brown	James	G	615	297-1228
10017	Williams	George		615	290-2550
10018	Farris	Anne	G	713	382-7185
10019	Smith	Oletta	K	615	297-3809

Table name: INVOICE
Primary key: INV_NUMBER
Foreign key: CUS_CODE

INV_NUMBER	CUS_CODE	INV_DATE
1001	10014	08-Mar-12
1002	10011	08-Mar-12
1003	10012	08-Mar-12
1004	10011	09-Mar-12

Table name: PRODUCT
Primary key: PROD_CODE
Foreign key: none

PROD_CODE	PROD_DESCRPT	PROD_PRICE	PROD_ON_HAND	VEND_CODE
001278-AB	Claw hammer	12.95	23	232
123-21ULY	Houselite chain saw, 16-in bar	199.99	4	235
GER-34256	Sledge hammer, 16-lb. head	18.63	6	231
SRE-657UG	Rattail file	2.99	15	232
ZZX3245Q	Steel tape, 12-ft. length	6.79	8	235

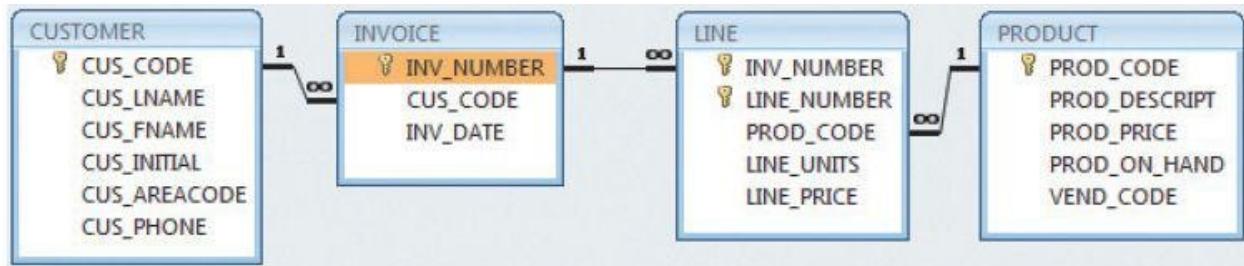
Database name: Ch03_SaleCo

Table name: LINE
Primary key: INV_NUMBER + LINE_NUMBER
Foreign key: INV_NUMBER, PROD_CODE

INV_NUMBER	LINE_NUMBER	PROD_CODE	LINE_UNITS	LINE_PRICE
1001	1	123-21ULY	1	189.99
1001	2	SRE-657UG	3	2.99
1002	1	GER-34256	2	18.63
1003	1	ZZX3245Q	1	6.79
1003	2	SRE-657UG	1	2.99
1003	3	001278-AB	1	12.95
1004	1	001278-AB	1	12.95
1004	2	SRE-657UG	2	2.99

SOURCE: Course Technology/Cengage Learning

FIGURE 3.30 The relational diagram for the invoicing system



SOURCE: Course Technology/Cengage Learning

As you examine the tables and relationships in the two figures, note that you can keep track of typical sales information. For example, by tracing the relationships among the four tables, you discover that customer 10014 (Myron Orlando) bought two items on March 8, 2012, that were written to invoice number 1001: one Houselite chain saw with a 16-inch bar and three rat-tail files. In other words, trace the CUS_CODE number 10014 in the CUSTOMER table to the matching CUS_CODE value in the INVOICE table. Next, trace the INV_NUMBER 1001 to the first two rows in the LINE table. Finally, match the two PROD_CODE values in LINE with the PROD_CODE values in PRODUCT. Application software will be used to write the correct bill by multiplying each invoice line item's LINE_UNITS by its LINE_PRICE, adding the results, and applying appropriate taxes. Later, other application software might use the same technique to write sales reports that track and compare sales by week, month, or year.

As you examine the sales transactions in [Figure 3.29](#), you might reasonably suppose that the product price billed to the customer is derived from the PRODUCT table because the product data are stored there. *But why does that same product price occur again in the LINE table? Is that not a data redundancy?* It certainly appears to be, but this time, the apparent redundancy is crucial to the system's success. Copying the product price from the PRODUCT table to the LINE table maintains the *historical accuracy of the transactions*. Suppose, for instance, that you fail to write the LINE_PRICE in the LINE table and that you use the PROD_PRICE from the PRODUCT table to calculate the sales revenue. Now suppose that the PRODUCT table's PROD_PRICE changes, as prices frequently do. This price change will be properly reflected in all subsequent sales revenue calculations. However, the calculations of past sales revenues will also reflect the new product price, which was not in effect when

the transaction took place! As a result, the revenue calculations for all past transactions will be incorrect, thus eliminating the possibility of making proper sales comparisons over time. On the other hand, if the price data are copied from the PRODUCT table and stored with the transaction in the LINE table, that price will always accurately reflect the transaction that took place *at that time*. You will discover that such planned “redundancies” are common in good database design.

Finally, you might wonder why the LINE_NUMBER attribute was used in the LINE table in [Figure 3.29](#). Wouldn’t the combination of INV_NUMBER and PROD_CODE be a sufficient composite primary key—and, therefore, isn’t the LINE_NUMBER redundant? Yes, it is, but this redundancy is common practice on invoicing software that typically generates such line numbers automatically. In this case, the redundancy is not necessary, but given its automatic generation, the redundancy is not a source of anomalies. The inclusion of LINE_NUMBER also adds another benefit: the order of the retrieved invoicing data will always match the order in which the data were entered. If product codes are used as part of the primary key, indexing will arrange those product codes as soon as the invoice is completed and the data are stored. You can imagine the potential confusion when a customer calls and says, “The second item on my invoice has an incorrect price,” and you are looking at an invoice whose lines show a different order from those on the customer’s copy!

3.8 INDEXES

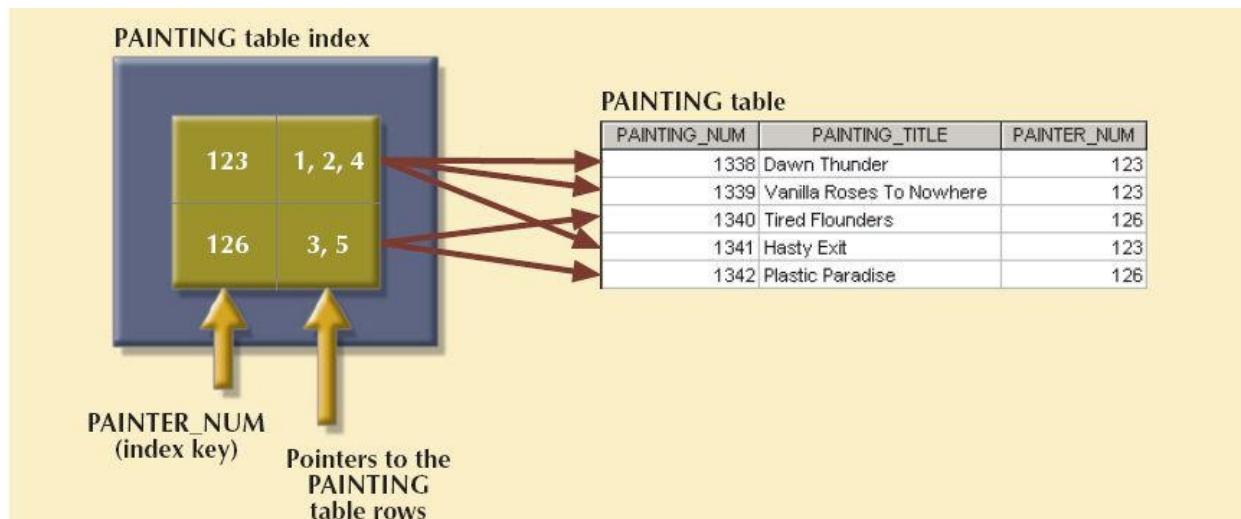
Suppose you want to locate a book in a library. Does it make sense to look through every book until you find the one you want? Of course not; you use the library’s catalog, which is indexed by title, topic, and author. The index (in either a manual or computer system) points you to the book’s location, making retrieval a quick and simple matter. An **index** is an orderly arrangement used to logically access rows in a table.

Or, suppose you want to find a topic in this book, such as *ER model*. Does it make sense to read through every page until you stumble across the topic? Of course not; it is much simpler to go to the book’s index, look up the phrase *ER model*, and read the references that point you to the appropriate page(s). In each case, an index is used to locate a needed item quickly.

Indexes in the relational database environment work like the indexes described in the preceding paragraphs. From a conceptual point of view, an index is composed of an index key and a set of pointers. The **index key** is, in effect, the index's reference point. More formally, an index is an ordered arrangement of keys and pointers. Each key points to the location of the data identified by the key.

For example, suppose you want to look up all of the paintings created by a given painter in the Ch03_Museum database in [Figure 3.18](#). Without an index, you must read each row in the PAINTING table and see if the PAINTER_NUM matches the requested painter. However, if you index the PAINTER table and use the index key PAINTER_NUM, you merely need to look up the appropriate PAINTER_NUM in the index and find the matching pointers. Conceptually speaking, the index would resemble the presentation in [Figure 3.31](#).

FIGURE 3.31 Components of an index



SOURCE: Course Technology/Cengage Learning

As you examine [Figure 3.31](#), note that the first PAINTER_NUM index key value (123) is found in records 1, 2, and 4 of the PAINTING table. The second PAINTER_NUM index key value (126) is found in records 3 and 5 of the PAINTING table.

DBMSs use indexes for many different purposes. You just learned that an index

can be used to retrieve data more efficiently, but indexes can also be used by a DBMS to retrieve data ordered by a specific attribute or attributes. For example, creating an index on a customer's last name will allow you to retrieve the customer data alphabetically by the customer's last name. Also, an index key can be composed of one or more attributes. For example, in [Figure 3.29](#), you can create an index on VEND_CODE and PROD_CODE to retrieve all rows in the PRODUCT table ordered by vendor, and within vendor, ordered by product.

Indexes play an important role in DBMSs for the implementation of primary keys. When you define a table's primary key, the DBMS automatically creates a unique index on the primary key column(s) you declared. For example, in [Figure 3.29](#), when you declare CUS_CODE to be the primary key of the CUSTOMER table, the DBMS automatically creates a unique index on that attribute. In a [unique index](#), as its name implies, the index key can have only one pointer value (row) associated with it. (The index in [Figure 3.31](#) is not a unique index because the PAINTER_NUM has multiple pointer values associated with it. For example, painter number 123 points to three rows—1, 2, and 4—in the PAINTING table.)

A table can have many indexes, but each index is associated with only one table. The index key can have multiple attributes (a composite index). Creating an index is easy. You will learn in [Chapter 7](#) that a simple SQL command produces any required index.

3.9 CODD'S RELATIONAL DATABASE RULES

In 1985, Dr. E. F. Codd published a list of 12 rules to define a relational database system.¹ He published the list out of concern that many vendors were marketing products as “relational” even though those products did not meet minimum relational standards. Dr. Codd’s list, shown in [Table 3.8](#), is a frame of reference for what a truly relational database should be. Bear in mind that even the dominant database vendors do not fully support all 12 rules.

TABLE 3.8 Dr. Codd's 12 Relational Database Rules

RULE

RULE NAME

DESCRIPTION

1

Information All information in a relational database must be logically represented as column values in rows within tables.

2

Guaranteed Every value in a table is guaranteed to be accessible through a
access combination of table name, primary key value, and column name.

3

	Nulls must be represented and treated in a systematic way, independent of data type.
4	Dynamic online catalog based on the relational model
5	The metadata must be stored and managed as ordinary data—that is, in tables within the database. Such data must be available to authorized users using the standard database relational language.

Comprehensive
data
sublanguage

The relational database may support many languages; however, it must support one well-defined, declarative language as well as data definition, view definition, data manipulation (interactive and by program), integrity constraints, authorization, and transaction management (begin, commit, and rollback).

	<p>View updating</p> <p>Any view that is theoretically updatable must be updatable through the system.</p>	
7	High-level insert, update, and delete	The database must support set-level inserts, updates, and deletes.
8		

Physical data independence Application programs and ad hoc facilities are logically unaffected when physical access methods or storage structures are changed.

Application programs and ad hoc facilities are logically unaffected when changes are made to the table structures that preserve the original table values (changing order of columns or inserting columns).

10

Integrity independence All relational integrity constraints must be definable in the relational language and stored in the system catalog, not at the application level.

Distribution The end users and application programs are unaware of and independence unaffected by the data location (distributed vs. local databases).

12

Nonsubversion If the system supports low-level access to the data, users must not be allowed to bypass the integrity rules of the database.

Rule All preceding rules are based on the notion that to be considered relational, zero a database must use its relational facilities exclusively for management.

SUMMARY

- Tables are the basic building blocks of a relational database. A grouping of related entities, known as an entity set, is stored in a table. Conceptually speaking, the relational table is composed of intersecting rows (tuples) and columns. Each row represents a single entity, and each column represents the characteristics (attributes) of the entities.
- Keys are central to the use of relational tables. Keys define functional dependencies; that is, other attributes are dependent on the key and can therefore be found if the key value is known. A key can be classified as a superkey, a candidate key, a primary key, a secondary key, or a foreign key.
- Each table row must have a primary key. The primary key is an attribute or combination of attributes that uniquely identifies all remaining attributes found in any given row. Because a primary key must be unique, no null values are allowed if entity integrity is to be maintained.
- Although tables are independent, they can be linked by common attributes. Thus, the primary key of one table can appear as the foreign key in another table to which it is linked. Referential integrity dictates that the foreign key must contain values that match the primary key in the related table, or must contain nulls.
- The relational model supports relational algebra functions: SELECT, PROJECT, JOIN, INTERSECT, UNION, DIFFERENCE, PRODUCT, and DIVIDE. A relational database performs much of the data manipulation work behind the scenes. For example, when you create a database, the RDBMS automatically produces a structure to house a data dictionary for your database. Each time you create a new table within the database, the RDBMS updates the data dictionary, thereby providing the database documentation.
- Once you know the basics of relational databases, you can concentrate on

design. Good design begins by identifying appropriate entities and their attributes and then the relationships among the entities. Those relationships (1:1, 1:M, and M:N) can be represented using ERDs. The use of ERDs allows you to create and evaluate simple logical design. The 1:M relationship is most easily incorporated in a good design; just make sure that the primary key of the “1” is included in the table of the “many.”

KEY TERMS

[associative entity](#)
[attribute domain](#)
[bridge entity](#)
[candidate key](#)
[closure](#)
[composite entity](#)
[composite key](#)
[data dictionary](#)
[dependent](#)
[determinant](#)
[determination](#)
[domain](#)
[entity integrity](#)
[equijoin](#)
[flags](#)
[foreign key \(FK\)](#)
[full functional dependence](#)
[functional dependence](#)
[homonym](#)
[index](#)
[index key](#)
[inner join](#)
[join column\(s\)](#)
[key](#)
[key attribute](#)
[left outer join](#)

[linking table](#)
[natural join](#)
[null](#)
[outer join](#)
[predicate logic](#)
[primary key \(PK\)](#)
[referential integrity](#)
[relational algebra](#)
[right outer join](#)
[secondary key](#)
[set theory](#)
[superkey](#)
[synonym](#)
[system catalog](#)
[theta join](#)
[tuple](#)
[union-compatible](#)
[unique index](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at
www.cengagebrain.com.

REVIEW QUESTIONS

1. What is the difference between a database and a table?

2. What does it mean to say that a database displays both entity integrity and referential integrity?

3. Why are entity integrity and referential integrity important in a database?
4. What are the requirements that two relations must satisfy to be considered union-compatible?
5. Which relational algebra operators can be applied to a pair of tables that are not union-compatible?
6. Explain why the data dictionary is sometimes called “the database designer’s database.”
7. A database user manually notes that “The file contains two hundred records, each record containing nine fields.” Use appropriate relational database terminology to “translate” that statement.



ONLINE CONTENT

All of the databases used in the questions and problems are available at www.cengagebrain.com. The database names used in the folder match the database names used in the figures. For example, the source of the tables shown in [Figure Q3.8](#) is the **Ch03_CollegeQue** database.

FIGURE Q3.8 The Ch03_CollegeQue database tables

Table name: BOOTH		Table name: MACHINE	
BOOTH_PRODUCT	BOOTH_PRICE	MACHINE_PRODUCT	MACHINE_PRICE
Chips	1.5	Chips	1.25
Cola	1.25	Chocolate Bar	1
Energy Drink	2	Energy Drink	2

SOURCE: Course Technology/Cengage Learning

Use [Figure Q3.8](#) to answer Questions 8–10.

8. Using the STUDENT and PROFESSOR tables, illustrate the difference between a natural join, an equijoin, and an outer join.
9. Create the basic ERD for the database shown in [Figure Q3.8](#).
10. Create the relational diagram for the database shown in [Figure Q3.8](#).

Use [Figure Q3.11](#) to answer Questions 11–13.

FIGURE Q3.11 The Ch03_VendingCo database tables

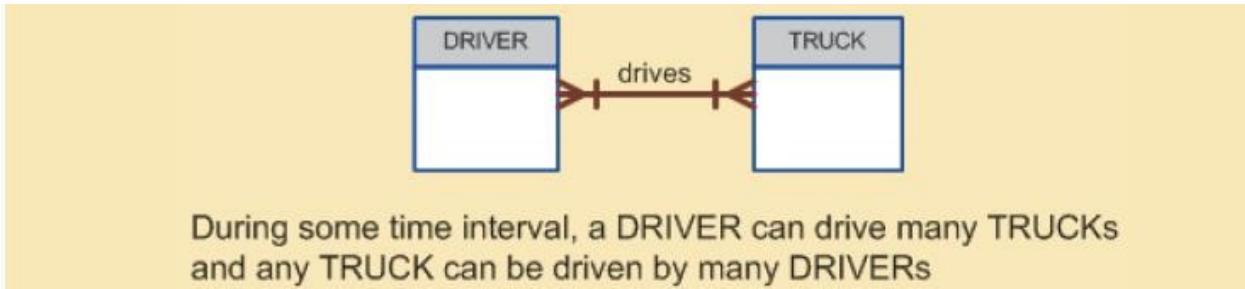
Database name: Ch03_VendingCo	
Table name: BOOTH	Table name: MACHINE
BOOTH_PRODUCT	BOOTH_PRICE
Chips	1.5
Cola	1.25
Energy Drink	2
MACHINE_PRODUCT	MACHINE_PRICE
Chips	1.25
Chocolate Bar	1
Energy Drink	2

SOURCE: Course Technology/Cengage Learning

11. Create the table that results from applying a UNION relational operator to the tables shown in [Figure Q3.11](#).
12. Create the table that results from applying an INTERSECT relational operator to the tables shown in [Figure Q3.11](#).
13. Using the tables in [Figure Q3.11](#), create the table that results from MACHINE DIFFERENCE BOOTH.

Use [Figure Q3.14](#) to answer Question 14.

FIGURE Q3.14 The Crow's Foot ERM for Question 14



SOURCE: Course Technology/Cengage Learning

14. Suppose you have the ERM shown in [Figure Q3.14](#). How would you convert this model into an ERM that displays only 1:M relationships? (Make sure you create the revised ERM.)
15. What are homonyms and synonyms, and why should they be avoided in database design?
16. How would you implement a 1:M relationship in a database composed of two tables? Give an example.

Use [Figure Q3.17](#) to answer Question 17.

FIGURE Q3.17 The Ch03_NoComp database EMPLOYEE table

Table name: EMPLOYEE**Database name: Ch03_NoComp**

EMP_NUM	EMP_LNAME	EMP_INITIAL	EMP_FNAME	DEPT_CODE	JOB_CODE
11234	Friedman	K	Robert	MKTG	12
11238	Olanski	D	Delbert	MKTG	12
11241	Fontein		Juliette	INFS	5
11242	Cruazona	J	Maria	ENG	9
11245	Smithson	B	Bernard	INFS	6
11248	Washington	G	Oleta	ENGR	8
11256	McBride		Randall	ENGR	8
11257	Kachinn	D	Melanie	MKTG	14
11258	Smith	W	William	MKTG	14
11260	Ratula	A	Katrina	INFS	5

SOURCE: Course Technology/Cengage Learning

-
17. Identify and describe the components of the table shown in [Figure Q3.17](#), using correct terminology. Use your knowledge of naming conventions to identify the table's probable foreign key(s).

Use the database shown in [Figure Q3.18](#) to answer Questions 18–23.

FIGURE Q3.18 The Ch03_Theater database tables**Database name: Ch03_Theater****Table name: DIRECTOR**

DIR_NUM	DIR_LNAME	DIR_DOB
100	Broadway	12-Jan-65
101	Hollywoody	18-Nov-53
102	Goofy	21-Jun-62

Table name: PLAY

PLAY_CODE	PLAY_NAME	DIR_NUM
1001	Cat On a Cold, Bare Roof	102
1002	Hold the Mayo, Pass the Bread	101
1003	I Never Promised You Coffee	102
1004	Silly Putty Goes To Washington	100
1005	See No Sound, Hear No Sight	101
1006	Starstruck in Biloxi	102
1007	Stranger In Parrot Ice	101

SOURCE: Course Technology/Cengage Learning

18. Identify the primary keys.
19. Identify the foreign keys.

20. Create the ERM.
21. Create the relational diagram to show the relationship between DIRECTOR and PLAY.

22. Suppose you wanted quick lookup capability to get a listing of all plays directed by a given director. Which table would be the basis for the INDEX table, and what would be the index key?
23. What would be the conceptual view of the INDEX table described in Question 22? Depict the contents of the conceptual INDEX table.

PROBLEMS

Use the database shown in [Figure P3.1](#) to answer [Problems 1–9](#).

1. For each table, identify the primary key and the foreign key(s). If a table does not have a foreign key, write *None* in the space provided.

TABLE	PRIMARY KEY	FOREIGN KEY(S)
EMPLOYEE		
STORE		
REGION		

2. Do the tables exhibit entity integrity? Answer yes or no, and then explain your answer.

3. Do the tables exhibit referential integrity? Answer yes or no, and then explain your answer. Write NA (Not Applicable) if the table does not have a foreign key.

TABLE	REFERENTIAL INTEGRITY	EXPLANATION
EMPLOYEE		
STORE		
REGION		

FIGURE P3.1 The Ch03_StoreCo database tables

Table name: EMPLOYEE							Database name: Ch03_StoreCo	
EMP_CODE	EMP_TITLE	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_DOB	STORE_CODE		
1	Mr.	Williamson	John	W	21-May-64	3		
2	Ms.	Ratula	Nancy		09-Feb-69	2		
3	Ms.	Greenboro	Lottie	R	02-Oct-61	4		
4	Mrs.	Rumpersfro	Jennie	S	01-Jun-71	5		
5	Mr.	Smith	Robert	L	23-Nov-59	3		
6	Mr.	Renselaer	Cary	A	25-Dec-65	1		
7	Mr.	Ogallo	Roberto	S	31-Jul-62	3		
8	Ms.	Johnsson	Elizabeth	I	10-Sep-68	1		
9	Mr.	Eindsmar	Jack	W	19-Apr-55	2		
10	Mrs.	Jones	Rose	R	06-Mar-66	4		
11	Mr.	Broderick	Tom		21-Oct-72	3		
12	Mr.	Washington	Alan	Y	08-Sep-74	2		
13	Mr.	Smith	Peter	N	25-Aug-64	3		
14	Ms.	Smith	Sherry	H	25-May-66	4		
15	Mr.	Olenko	Howard	U	24-May-64	5		
16	Mr.	Archialo	Barry	V	03-Sep-60	5		
17	Ms.	Grimaldo	Jeanine	K	12-Nov-70	4		
18	Mr.	Rosenberg	Andrew	D	24-Jan-71	4		
19	Mr.	Rosten	Peter	F	03-Oct-68	4		
20	Mr.	McKee	Robert	S	06-Mar-70	1		
21	Ms.	Baumann	Jennifer	A	11-Dec-74	3		

Table name: STORE				
STORE_CODE	STORE_NAME	STORE_YTD_SALES	REGION_CODE	EMP_CODE
1	Access Junction	1003455.76	2	8
2	Database Corner	1421987.39	2	12
3	Tuple Charge	986783.22	1	7
4	Attribute Alley	944568.56	2	3
5	Primary Key Point	2930098.45	1	15

Table name: REGION	
REGION_CODE	REGION_DESCRPT
1	East
2	West

SOURCE: Course Technology/Cengage Learning

4. Describe the type(s) of relationship(s) between STORE and REGION.

5. Create the ERD to show the relationship between STORE and REGION.

6. Create the relational diagram to show the relationship between STORE and

REGION.

7. Describe the type(s) of relationship(s) between EMPLOYEE and STORE.
(Hint: Each store employs many employees, one of whom manages the store.)
8. Create the ERD to show the relationships among EMPLOYEE, STORE, and REGION.

9. Create the relational diagram to show the relationships among EMPLOYEE, STORE, and REGION.

Use the database shown in [Figure P3.10](#) to work [Problems 10–16](#). Note that the database is composed of four tables that reflect these relationships:

- An EMPLOYEE has only one JOB_CODE, but a JOB_CODE can be held by many EMPLOYEES.
- An EMPLOYEE can participate in many PLANS, and any PLAN can be assigned to many EMPLOYEES.

Note also that the M:N relationship has been broken down into two 1:M relationships for which the BENEFIT table serves as the composite or bridge entity.

FIGURE P3.10 The Ch03_BeneCo database tables

Database name: Ch03_BeneCo

Table name: EMPLOYEE

EMP_CODE	EMP_LNAME	JOB_CODE
14	Rudell	2
15	McDade	1
16	Ruellardo	1
17	Smith	3
20	Smith	2

Table name: BENEFIT

EMP_CODE	PLAN_CODE
15	2
15	3
16	1
17	1
17	3
17	4
20	3

Table name: JOB

JOB_CODE	JOB_DESCRIPTION
1	Clerical
2	Technical
3	Managerial

Table name: PLAN

PLAN_CODE	PLAN_DESCRIPTION
1	Term life
2	Stock purchase
3	Long-term disability
4	Dental

SOURCE: Course Technology/Cengage Learning

10. For each table in the database, identify the primary key and the foreign key(s). If a table does not have a foreign key, write *None* in the space provided.

TABLE	PRIMARY KEY	FOREIGN KEY(S)
EMPLOYEE		
BENEFIT		
JOB		
PLAN		

11. Create the ERD to show the relationship between EMPLOYEE and JOB.
 12. Create the relational diagram to show the relationship between EMPLOYEE and JOB.
 13. Do the tables exhibit entity integrity? Answer yes or no, and then explain your answer.

TABLE	ENTITY INTEGRITY	EXPLANATION
EMPLOYEE		
BENEFIT		
JOB		
PLAN		

14. Do the tables exhibit referential integrity? Answer yes or no, and then explain your answer. Write NA (Not Applicable) if the table does not have a

foreign key.

TABLE	REFERENTIAL INTEGRITY	EXPLANATION
EMPLOYEE		
BENEFIT		
JOB		
PLAN		

15. Create the ERD to show the relationships among EMPLOYEE, BENEFIT, JOB, and PLAN.
16. Create the relational diagram to show the relationships among EMPLOYEE, BENEFIT, JOB, and PLAN.

Use the database shown in [Figure P3.17](#) to answer [Problems 17–23](#).

FIGURE P3.17 The Ch03_TransCo database tables

Table name: TRUCK						Database name: Ch03_TransCo
Primary key: TRUCK_NUM						
Foreign key: BASE_CODE, TYPE_CODE						
TRUCK_NUM	BASE_CODE	TYPE_CODE	TRUCK_MILES	TRUCK_BUY_DATE	TRUCK_SERIAL_NUM	
1001	501	1	32123.5	23-Sep-07	AA-322-12212-W11	
1002	502	1	76984.3	05-Feb-06	AC-342-22134-Q23	
1003	501	2	12346.6	11-Nov-06	AC-445-78656-Z99	
1004		1	2894.3	06-Jan-07	WQ-112-23144-T34	
1005	503	2	45673.1	01-Mar-08	FR-998-32245-W12	
1006	501	2	193245.7	15-Jul-03	AD-456-00845-R45	
1007	502	3	32012.3	17-Oct-04	AA-341-96573-Z84	
1008	502	3	44213.6	07-Aug-05	DR-559-22189-D33	
1009	503	2	10932.9	12-Feb-08	DE-887-98456-E94	

Table name: BASE					
Primary key: BASE_CODE					
Foreign key: none					
BASE_CODE	BASE_CITY	BASE_STATE	BASE_AREA_CODE	BASE_PHONE	BASE_MANAGER
501	Murfreesboro	TN	615	123-4567	Andrea D. Gallagher
502	Lexington	KY	568	234-5678	George H. Delarosa
503	Cape Girardeau	MO	456	345-6789	Maria J. Talindo
504	Dalton	GA	901	456-7890	Peter F. McAtee

Table name: TYPE	
Primary key: TYPE_CODE	
Foreign key: none	
TYPE_CODE	TYPE_DESCRIPTION
1	Single box, double-axle
2	Single box, single-axle
3	Tandem trailer, single-axle

SOURCE: Course Technology/Cengage Learning

17. For each table, identify the primary key and the foreign key(s). If a table does not have a foreign key, write *None* in the space provided.

TABLE	PRIMARY KEY	FOREIGN KEY(S)
TRUCK		
BASE		
TYPE		

18. Do the tables exhibit entity integrity? Answer yes or no, and then explain your answer.

TABLE	ENTITY INTEGRITY	EXPLANATION
TRUCK		
BASE		
TYPE		

19. Do the tables exhibit referential integrity? Answer yes or no, and then explain your answer. Write *NA* (Not Applicable) if the table does not have a foreign key.

TABLE	REFERENTIAL INTEGRITY	EXPLANATION
TRUCK		
BASE		
TYPE		

20. Identify the TRUCK table's candidate key(s).

21. For each table, identify a superkey and a secondary key.

TABLE	SUPERKEY	SECONDARY KEY
TRUCK		
BASE		
TYPE		

22. Create the ERD for this database.

23. Create the relational diagram for this database.

Use the database shown in [Figure P3.24](#) to answer [Problems 24–31](#). AviaCo is an aircraft charter company that supplies on-demand charter flight services using

a fleet of four aircraft. Aircraft are identified by a unique registration number. Therefore, the aircraft registration number is an appropriate primary key for the AIRCRAFT table.

FIGURE P3.24 The Ch03_AviaCo database tables

Table name: CHARTER										Database name: Ch03_AviaCo			
CHARTER_ID	CHART_DATE	CHART_FLOT	CHART_CUSTID	AC_NUMBER	CHART_DESTINATION	CHART_DISTANCE	CHART_HOURS_FLIGHT	CHART_HOURS_WAIT	CHART_FUEL_GALLONS	CHART_OIL_STL	SUB_CODE		
10001	05-Feb-12	104	239R	ATL		300.0	6.1	2.2	364.1	1	10011		
10002	05-Feb-12	101	2778V	OMV		320.0	6.8	0.0	372.0	0	10011		
10003	05-Feb-12	105	105-2778Y	TYS		374.0	7.8	0.0	439.6	2	10014		
10004	06-Feb-12	106	1484P	STL		472.0	3.9	1.9	572.2	1	10015		
10005	06-Feb-12	101	239R	ATL		322.0	5.7	3.5	397.7	2	10011		
10006	06-Feb-12	109	4278Y	STL		472.0	2.6	5.2	517.1	0	10017		
10007	06-Feb-12	104	105-2778V	OMV		374.0	2.9	9.0	469.4	2	10012		
10008	07-Feb-12	108	1484P	TYS		344.0	4.1	0.6	440.6	1	10014		
10009	07-Feb-12	105	239R	OMV		374.0	6.6	39.4	493.0	0	10017		
10010	07-Feb-12	109	4278Y	ATL		388.0	8.2	3.2	479.7	0	10016		
10011	07-Feb-12	101	104-1804P	BNA		352.0	1.9	6.3	466.4	1	10012		
10012	08-Feb-12	101	2778V	MOR		384.0	4.8	4.2	495.1	0	10010		
10013	08-Feb-12	105	4278Y	TYS		344.0	3.9	4.6	474.3	1	10011		
10014	09-Feb-12	106	4278Y	ATL		360.0	6.1	2.1	507.6	0	10017		
10015	09-Feb-12	104	101-239R	OMV		345.0	6.7	0.0	459.5	2	10016		
10016	09-Feb-12	106	105-2778V	MOR		312.0	1.5	0.0	472.3	0	10011		
10017	10-Feb-12	101	1484P	STL		388.0	3.1	0.0	488.2	0	10014		
10018	10-Feb-12	105	104-2778Y	TYS		544.0	3.8	1.5	617.4	0	10017		

The destinations are indicated by standard three-letter airport codes. For example,
 STL = St. Louis, MO ATL = Atlanta, GA BNA = Nashville, TN

Table name: AIRCRAFT				
AC_NUMBER	MOD_CODE	AC_TTAF	AC_TTEL	AC_TTER
1484P	PA23-260	1833.1	1833.1	101.8
2289L	C-90A	4243.8	768.9	1123.4
2778V	PA31-350	7992.9	1513.1	789.5
4278Y	PA31-350	2147.3	622.1	243.2

AC_TTAF = Aircraft total time, airframe (hours)
 AC_TTEL = Total time, left engine (hours)
 AC_TTER = Total time, right engine (hours)

In a fully developed system, such attribute values would be updated by application software when the CHARTER table entries were posted.

MOD_CODE	MOD_MANUFACTURER	MOD_NAME	MOD_SEATS	MOD_CHG_MILE
C-90A	Beechcraft	KingAir	8	2.67
PA23-260	Piper	Aztec	6	1.93
PA31-350	Piper	Navajo Chieftain	10	2.35

Customers are charged per round-trip mile, using the MOD_CHG_MILE rate. The MOD_SEATS column lists the total number of seats in the airplane, including the pilot and copilot seats. Therefore, a PA31-350 trip that is flown by a pilot and a copilot has eight passenger seats available.

Table name: PILOT

Database name: Ch03_AviaCo

EMP_NUM	PIL LICENSE	PIL RATINGS	PIL_MED_TYPE	PL_MED_DATE	PIL_PT135_DATE
101 ATP	ATP/SEL/MEL/Instr/CFII	1		20-Jan-12	11-Jan-12
104 ATP	ATP/SEL/MEL/Instr	1		18-Dec-11	17-Jan-12
105 COM	COMM/SEL/MEL/Instr/CFI	2		05-Jan-12	02-Jan-12
106 COM	COMM/SEL/MEL/Instr	2		10-Dec-11	02-Feb-12
109 COM	ATP/SEL/MEL/SES/Inst/CFII	1		22-Jan-12	15-Jan-12

The pilot licenses shown in the PILOT table include ATP = Airline Transport Pilot and COMM = Commercial Pilot. Businesses that operate on-demand air services are governed by Part 135 of the Federal Air Regulations (FARs), which are enforced by the Federal Aviation Administration (FAA). Such businesses are known as "Part 135 operators." Part 135 operations require that pilots successfully complete flight proficiency checks every six months. The "Part 135" flight proficiency check date is recorded in PIL_PT135_DATE. To fly commercially, pilots must have at least a commercial license and a second-class medical certificate (PIL_MED_TYPE = 2).

The PIL_RATINGS include:

SEL = Single Engine, Land
 SES = Single Engine, Sea
 CFI = Certified Flight Instructor

MEL = Multiengine, Land
 Instr. = Instrument
 CFII = Certified Flight Instructor, Instrument

Table name: EMPLOYEE

EMP_NUM	EMP_TITLE	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_DOB	EMP_HIRE_DATE
100 Mr.	Kolmycz	George		B	15-Jun-42	15-Mar-88
101 Ms.	Lewis	Rhunda		G	19-Mar-65	25-Apr-86
102 Mr.	Vandam	Rhett			14-Nov-58	18-May-93
103 Ms.	Jones	Anne		M	11-May-74	26-Jul-99
104 Mr.	Linge	John		P	12-Jul-71	20-Aug-90
105 Mr.	Williams	Robert		D	14-Mar-75	19-Jun-03
106 Mrs.	Duzak	Jeanine		K	12-Feb-68	13-Mar-89
107 Mr.	Dante	Jorge		D	01-May-75	02-Jul-97
108 Mr.	Wiesenthal	Paul		R	14-Feb-66	03-Jun-93
109 Ms.	Trots	Elizabeth		K	18-Jun-61	14-Feb-06
110 Mrs.	Genkazi	Leighla		W	19-May-70	29-Jun-90

Table name: CUSTOMER

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_BALANCE
10010 Rames	Alfred		A	615	844-2573	0.00
10011 Dunne	Leona		K	713	894-1238	0.00
10012 Smith	Kathy		W	615	894-2285	896.54
10013 Ołowski	Paul		F	615	894-2180	1285.19
10014 Orlando	Myron			615	222-1672	673.21
10015 O'Brian	Amy		B	713	442-3381	1014.56
10016 Brown	James		G	615	297-1226	0.00
10017 Williams	George			615	290-2556	0.00
10018 Farris	Anne		G	713	362-7185	0.00
10019 Smith	Olette		K	615	297-3809	453.98

SOURCE: Course Technology/Cengage Learning

The nulls in the CHARTER table's CHAR_COPILOT column indicate that a copilot is not required for some charter trips or for some aircraft. Federal Aviation Administration (FAA) rules require a copilot on jet aircraft and on aircraft that have a gross take-off weight over 12,500 pounds. None of the aircraft in the AIRCRAFT table are governed by this requirement; however, some customers may require the presence of a copilot for insurance reasons. All charter trips are recorded in the CHARTER table.

NOTE

Earlier in the chapter, you were instructed to avoid homonyms and synonyms. In this problem, both the pilot and the copilot are listed in the PILOT table, but EMP_NUM cannot be used for both in the CHARTER table. Therefore, the synonyms CHAR_PILOT and CHAR_COPILOT were used in the CHARTER table.

Although the solution works in this case, it is very restrictive and it generates nulls when a copilot is not required. Worse, such nulls proliferate as crew requirements change. For example, if the AviaCo charter company grows and starts using larger aircraft, crew requirements may increase to include flight engineers and load masters. The CHARTER table would then have to be modified to include the additional crew assignments; such attributes as CHAR_FLT_ENGINEER and CHAR_LOADMASTER would have to be added to the CHARTER table. Given this change, each time a smaller aircraft flew a charter trip without the number of crew members required in larger aircraft, the missing crew members would yield additional nulls in the CHARTER table.

You will have a chance to correct those design shortcomings in [Problem 27](#). The problem illustrates two important points:

1. Don't use synonyms. If your design requires the use of synonyms, revise the design!
 2. To the greatest possible extent, design the database to accommodate growth without requiring structural changes in the database tables. Plan ahead and try to anticipate the effects of change on the database.
-

24. For each table, identify each of the following when possible:
 - a. The primary key
 - b. A superkey
 - c. A candidate key
 - d. The foreign key(s)
 - e. A secondary key
25. Create the ERD. (*Hint:* Look at the table contents. You will discover that an AIRCRAFT can fly many CHARTER trips but that each CHARTER trip is

flown by one AIRCRAFT, that a MODEL references many AIRCRAFT but that each AIRCRAFT references a single MODEL, and so on.)

26. Create the relational diagram.
27. Modify the ERD you created in [Problem 25](#) to eliminate the problems created by the use of synonyms. (*Hint:* Modify the CHARTER table structure by eliminating the CHAR_PILOT and CHAR_COPILOT attributes; then create a composite table named CREW to link the CHARTER and EMPLOYEE tables. Some crew members, such as flight attendants, may not be pilots. That's why the EMPLOYEE table enters into this relationship.)
28. Create the relational diagram for the design you revised in [Problem 27](#). (After you have had a chance to revise the design, your instructor will show you the results of the design change, using a copy of the revised database named Ch03_AviaCo_2.)

You want to see data on charters flown by either Robert Williams (employee number 105) or Elizabeth Travis (employee number 109) as pilot or copilot, but not charters flown by both of them. Complete [Problems 29–31](#) to find these data.

29. Create the table that would result from applying the SELECT and PROJECT relational operators to the CHARTER table to return only the CHAR_TRIP, CHAR_PILOT, and CHAR_COPILOT attributes for charters flown by either employee 105 or employee 109.
30. Create the table that would result from applying the SELECT and PROJECT relational operators to the CHARTER table to return only the CHAR_TRIP, CHAR_PILOT, and CHAR_COPILOT attributes for charters flown by both employee 105 and employee 109.
31. Create the table that would result from applying a DIFFERENCE relational operator of your result from [Problem 29](#) to your result from [Problem 30](#).

¹ Codd, E., “Is Your DBMS Really Relational?” and “Does Your DBMS Run by the Rules?” *Computerworld*, October 14 and October 21, 1985.

4 ENTITY RELATIONSHIP (ER) MODELING

In this chapter, you will learn:

- The main characteristics of entity relationship components
- How relationships between entities are defined, refined, and incorporated into the database design process
- How ERD components affect database design and implementation
 - That real-world database design often requires the reconciliation of conflicting goals

Preview

This chapter expands coverage of the data-modeling aspect of database design. Data modeling is the first step in the database design journey, serving as a bridge between real-world objects and the database model that is implemented in the computer. Therefore, the importance of data-modeling details, expressed graphically through entity relationship diagrams (ERDs), cannot be overstated.

Most of the basic concepts and definitions used in the entity relationship model (ERM) were introduced in [Chapter 2](#), Data Models. For example, the basic components of entities and relationships and their representation should now be familiar to you. This chapter goes much deeper, analyzing the graphic depiction of relationships among the entities and showing how those depictions help you summarize the wealth of data required to implement a successful design.

Finally, the chapter illustrates how conflicting goals can be a challenge in database design and might require design compromises.

NOTE

Because this book generally focuses on the relational model, you might be tempted to conclude that the ERM is exclusively a relational tool. Actually, conceptual models such as the ERM can be used to understand and design

the data requirements of an organization. Therefore, the ERM is independent of the database type. Conceptual models are used in the conceptual design of databases, while relational models are used in the logical design of databases. However, because you are familiar with the relational model from the previous chapter, the relational model is used extensively in this chapter to explain ER constructs and the way they are used to develop database designs.

4.1 THE ENTITY RELATIONSHIP MODEL (ERM)

You should remember from [Chapter 2](#), Data Models, and [Chapter 3](#), The Relational Database Model, that the ERM forms the basis of an ERD. The ERD represents the conceptual database as viewed by the end user. ERDs depict the database's main components: entities, attributes, and relationships. Because an entity represents a real-world object, the words *entity* and *object* are often used interchangeably. Thus, the entities (objects) of the Tiny College database design developed in this chapter include students, classes, teachers, and classrooms. The order in which the ERD components are covered in the chapter is dictated by the way the modeling tools are used to develop ERDs that can form the basis for successful database design and implementation.

In [Chapter 2](#), you also learned about the various notations used with ERDs—the original Chen notation and the newer Crow's Foot and UML notations. The first two notations are used at the beginning of this chapter to introduce some basic ER modeling concepts. Some conceptual database modeling concepts can be expressed only using the Chen notation. However, because the emphasis is on *design and implementation* of databases, the Crow's Foot and UML class diagram notations are used for the final Tiny College ER diagram example. Because of its emphasis on implementation, the Crow's Foot notation can represent only what could be implemented. In other words:

- The Chen notation favors conceptual modeling.
- The Crow's Foot notation favors a more implementation-oriented approach.

- The UML notation can be used for both conceptual and implementation modeling.
-



ONLINE CONTENT

To learn how to create ER diagrams with the help of Microsoft Visio, go to www.cengagebrain.com:

- **Appendix A, Designing Databases with Visio Professional: A Tutorial** shows you how to create Crow's Foot ERDs.
 - **Appendix H, Unified Modeling Language (UML)**, shows you how to create UML class diagrams.
-

4.1.1 ENTITIES

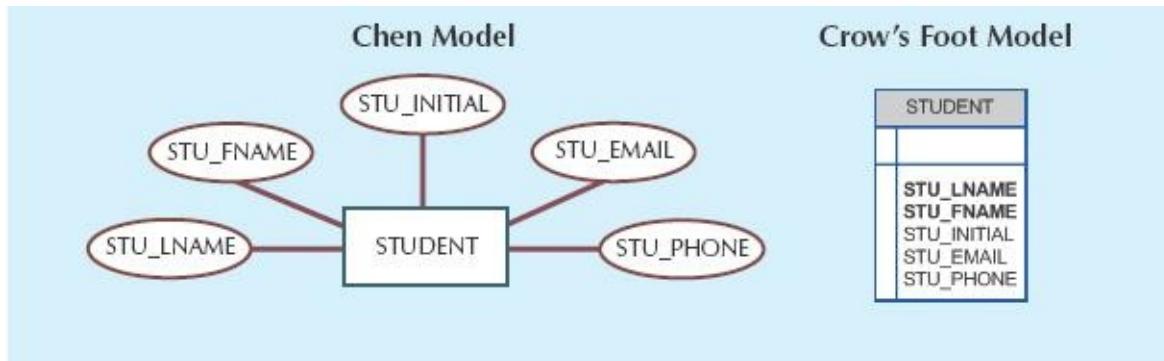
Recall that an entity is an object of interest to the end user. In [Chapter 2](#), you learned that at the ER modeling level, an entity actually refers to the *entity set* and not to a single entity occurrence. In other words, an *entity* in the ERM corresponds to a table—not to a row—in the relational environment. The ERM refers to a table row as an *entity instance* or *entity occurrence*. In the Chen, Crow's Foot, and UML notations, an entity is represented by a rectangle that contains the entity's name. The entity name, a noun, is usually written in all capital letters.

4.1.2 ATTRIBUTES

Attributes are characteristics of entities. For example, the STUDENT entity includes the attributes STU_LNAME, STU_FNAME, and STU_INITIAL, among many others. In the original Chen notation, 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 notation, the attributes are written in the attribute box below the entity rectangle. (See [Figure 4.1](#).) Because the Chen representation consumes more space, software vendors have

adopted the Crow's Foot attribute display.

FIGURE 4.1 The attributes of the STUDENT entity: Chen and Crow's Foot



SOURCE: Course Technology/Cengage Learning

Required and Optional Attributes

A **required attribute** is an attribute that must have a value; in other words, it cannot be left empty. As shown in [Figure 4.1](#), the two boldfaced attributes in the Crow's Foot notation indicate that data entry will be required. STU_LNAME and STU_FNAME require data entries because all students are assumed to have a last name and a first name. However, students might not have a middle name, and perhaps they do not yet have a phone number and an e-mail address. Therefore, those attributes are not presented in boldface in the entity box. An **optional attribute** is an attribute that does not require a value; therefore, it can be left empty.

Domains

Attributes have a domain. As you learned in [Chapter 3](#), a *domain* is the set of possible values for a given attribute. For example, the domain for a grade point average (GPA) attribute is written (0,4) because the lowest possible GPA value is 0 and the highest possible value is 4. The domain for a gender attribute consists of only two possibilities: M or F (or some other equivalent code). The domain for a company's date of hire attribute consists of all dates that fit in a range (for example, company startup date to current date).

Attributes may share a domain. For instance, a student address and a professor address share the same domain of all possible addresses. In fact, the data

dictionary may let a newly declared attribute inherit the characteristics of an existing attribute if the same attribute name is used. For example, the PROFESSOR and STUDENT entities may each have an attribute named ADDRESS and could therefore share a domain.

Identifiers (Primary Keys)

The ERM uses **identifiers**—one or more attributes that uniquely identify each entity instance. In the relational model, entities are mapped to tables, and the entity identifier is mapped as the table’s primary key (PK). Identifiers are underlined in the ERD. Key attributes are also underlined in a frequently used shorthand notation for the table structure, called a **relational schema**, that uses the following format:

TABLE NAME (KEY_ATTRIBUTE 1, ATTRIBUTE 2, ATTRIBUTE 3, ...
ATTRIBUTE K)

For example, a CAR entity may be represented by:

CAR (CAR_VIN, MOD_CODE, CAR_YEAR, CAR_COLOR)

Each car is identified by a unique vehicle identification number, or CAR_VIN.

Composite Identifiers

Ideally, an entity identifier is composed of only a single attribute. For example, the table in [Figure 4.2](#) uses a single-attribute primary key named CLASS_CODE. However, it is possible to use a **composite identifier**, a primary key composed of more than one attribute. For instance, the Tiny College database administrator may decide to identify each CLASS entity instance (occurrence) by using a composite primary key of CRS_CODE and CLASS_SECTION instead of using CLASS_CODE. Either approach uniquely identifies each entity instance. Given the structure of the CLASS table shown in [Figure 4.2](#), CLASS_CODE is the primary key, and the combination of CRS_CODE and CLASS_SECTION is a proper candidate key. If the CLASS_CODE attribute is deleted from the CLASS entity, the candidate key (CRS_CODE and CLASS_SECTION) becomes an acceptable composite primary key.

FIGURE 4.2 The CLASS table (entity) components and contents

Database name: Ch04_TinyCollege

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

SOURCE: Course Technology/Cengage Learning

NOTE

Remember that [Chapter 3](#) made a commonly accepted distinction between COURSE and CLASS. A CLASS constitutes a specific time and place of a COURSE offering. A class is defined by the course description and its time and place, or section. Consider a professor who teaches Database I, Section 2; Database I, Section 5; Database I, Section 8; and Spreadsheet II, Section 6. The professor teaches two courses (Database I and Spreadsheet II), but four classes. Typically, the COURSE offerings are printed in a course catalog, while the CLASS offerings are printed in a class schedule for each semester, trimester, or quarter.

If the CLASS_CODE in [Figure 4.2](#) is used as the primary key, the CLASS entity may be represented in shorthand form by:

CLASS (**CLASS_CODE**, CRS_CODE, CLASS_SECTION, CLASS_TIME, ROOM_CODE, PROF_NUM)

On the other hand, if CLASS_CODE is deleted, and the composite primary key is the combination of CRS_CODE and CLASS_SECTION, the CLASS entity may be represented by:

CLASS (**CRS_CODE**, **CLASS SECTION**, CLASS_TIME, ROOM_CODE, PROF_NUM)

Note that *both* key attributes are underlined in the entity notation.

Composite and Simple Attributes

Attributes are classified as simple or composite. A **composite attribute**, not to be confused with a composite key, is an attribute that can be further subdivided to yield additional attributes. For example, the attribute ADDRESS can be subdivided into street, city, state, and zip code. Similarly, the attribute PHONE_NUMBER can be subdivided into area code and exchange number. A **simple attribute** is an attribute that cannot be subdivided. For example, age, sex, and marital status would be classified as simple attributes. To facilitate detailed queries, it is wise to change composite attributes into a series of simple attributes.

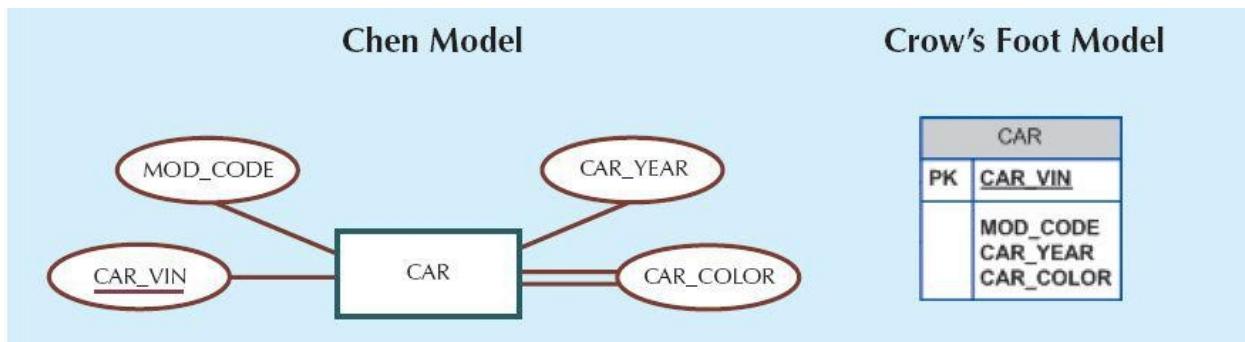
Single-Valued Attributes

A **single-valued attribute** is an attribute that can have only a single value. For example, a person can have only one Social Security number, and a manufactured part can have only one serial number. *Keep in mind that a single-valued attribute is not necessarily a simple attribute.* For instance, a part's serial number, such as SE-08-02-189935, is single-valued, but it is a composite attribute because it can be subdivided into the region in which the part was produced (SE), the plant within that region (08), the shift within the plant (02), and the part number (189935).

Multivalued Attributes

Multivalued attributes are attributes that can have many values. For instance, a person may have several college degrees, and a household may have several different phones, each with its own number. Similarly, a car's color may be subdivided into many colors for the roof, body, and trim. In the Chen ERM, multivalued attributes are shown by a double line connecting the attribute to the entity. The Crow's Foot notation does not identify multivalued attributes. The ERD in [Figure 4.3](#) contains all of the components introduced thus far; note that CAR_VIN is the primary key, and CAR_COLOR is a multivalued attribute of the CAR entity.

FIGURE 4.3 A multivalued attribute in an entity



SOURCE: Course Technology/Cengage Learning

NOTE

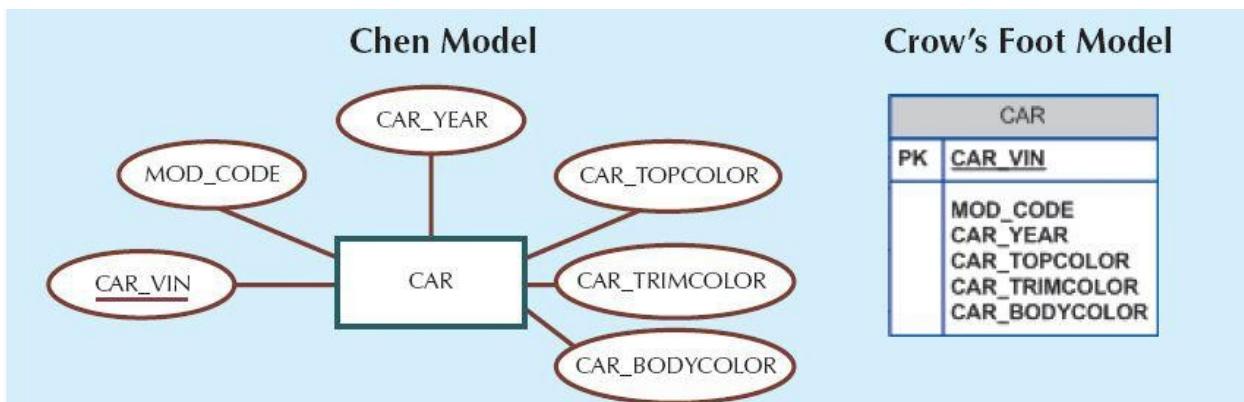
In the ERD models in [Figure 4.3](#), the CAR entity's foreign key (FK) has been typed as MOD_CODE. This attribute was manually added to the entity. Actually, proper use of database modeling software will automatically produce the FK when the relationship is defined. In addition, the software will label the FK appropriately and write the FK's implementation details in a data dictionary. Therefore, when you use database modeling software like Visio Professional, *never type the FK attribute yourself*; let the software handle that task when the relationship between the entities is defined. (You can see how in **Appendix A, Designing Databases with Visio Professional: A Tutorial**, at www.cengagebrain.com.)

Implementing Multivalued Attributes

Although the conceptual model can handle M:N relationships and multivalued attributes, *you should not implement them in the RDBMS*. Remember from [Chapter 3](#) that in the relational table, each column and row intersection represents a single data value. So, if multivalued attributes exist, the designer must decide on one of two possible courses of action:

1. Within the original entity, create several new attributes, one for each component of the original multivalued attribute. For example, the CAR entity's attribute CAR_COLOR can be split to create the new attributes CAR_TOPCOLOR, CAR_BODYCOLOR, and CAR_TRIMCOLOR, which are then assigned to the CAR entity. (See [Figure 4.4](#).)

FIGURE 4.4 Splitting the multivalued attribute into new attributes



SOURCE: Course Technology/Cengage Learning

Although this solution seems to work, its adoption can lead to major structural problems in the table. For example, if additional color components—such as a logo color—are added for some cars, the table structure must be modified to accommodate the new color section. In that case, cars that do not have such color sections generate nulls for the nonexistent components, or their color entries for those sections are entered as N/A to indicate “not applicable.” (The solution in [Figure 4.4](#) is to split a multivalued attribute into new attributes, but imagine the problems this type of solution would cause if it were applied to an employee entity that contains employee degrees and certifications. If some employees have 10 degrees and certifications while most have fewer or none, the number of degree/certification attributes would be 10, and most of those attribute values would be null for most employees.) In short, although you have seen solution 1 applied, it is not always acceptable.

2. Create a new entity composed of the original multivalued attribute’s components. This new entity allows the designer to define color for different sections of the car. (See [Table 4.1](#).) Then, this new CAR_COLOR entity is related to the original CAR entity in a 1:M relationship.

TABLE 4.1 Components of the Multivalued Attribute

SECTION COLOR

Top	White
Body	Blue
Trim	Gold
Interior	Blue

Using the approach illustrated in [Table 4.1](#), you even get a fringe benefit: you can now assign as many colors as necessary without having to change the table structure. The ERM shown in [Figure 4.5](#) reflects the components listed in [Table 4.1](#). This is the preferred way to deal with multivalued attributes. Creating a new entity in a 1:M relationship with the original entity yields several benefits: it is a more flexible, expandable solution, and it is compatible with the relational model!

FIGURE 4.5 A new entity set composed of a multivalued attribute's components



SOURCE: Course Technology/Cengage Learning

NOTE

If you are used to looking at relational diagrams such as the ones produced by Microsoft Access, you expect to see the relationship line *in the relational diagram* drawn from the PK to the FK. However, the relational diagram convention is not necessarily reflected in the ERD. In an ERD, the focus is on the entities and the relationships between them, rather than how

those relationships are anchored graphically. In a complex ERD that includes both horizontally and vertically placed entities, the placement of the relationship lines is largely dictated by the designer's decision to improve the readability of the design. (Remember that the ERD is used for communication between designers and end users.)

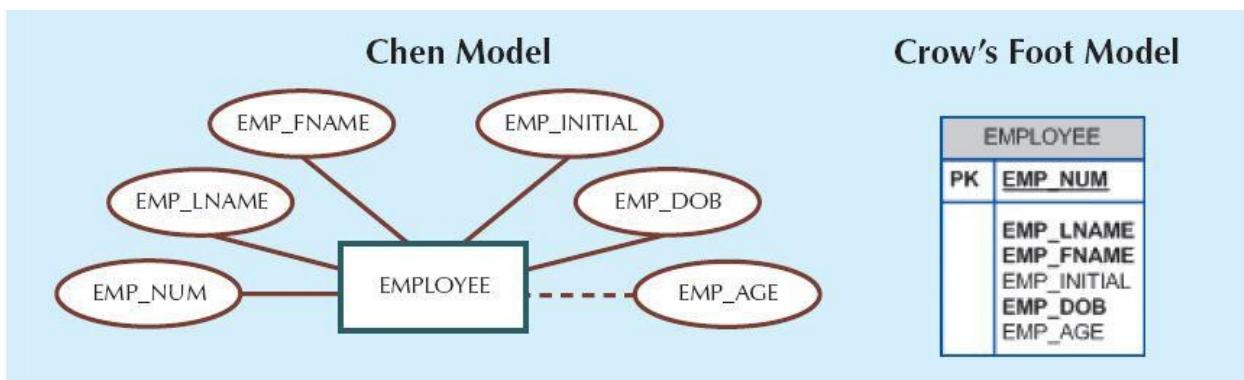
Derived Attributes

Finally, a **derived attribute** is an attribute whose value is calculated (derived) from other attributes. The derived attribute need not be physically stored within the database; instead, it can be derived by using an algorithm. For example, an employee's age, EMP_AGE, may be found by computing the integer value of the difference between the current date and the EMP_DOB. If you use Microsoft Access, you would use the formula `INT((DATE() – EMP_DOB)/365)`. In Microsoft SQL Server, you would use `SELECT DATEDIFF("YEAR", EMP_DOB, GETDATE())`, where `DATEDIFF` is a function that computes the difference between dates. The first parameter indicates the measurement (in this case, years). If you use Oracle, you would use `SYSDATE` instead of `DATE()`. (You are assuming, of course, that the `EMP_DOB` was stored in the Julian date format.)

Similarly, the total cost of an order can be derived by multiplying the quantity ordered by the unit price. Or, the estimated average speed can be derived by dividing trip distance by the time spent en route. A derived attribute is indicated in the Chen notation by a dashed line that connects the attribute and the entity. (See [Figure 4.6](#).) The Crow's Foot notation does not have a method for distinguishing the derived attribute from other attributes.

Derived attributes are sometimes referred to as *computed attributes*. Computing a derived attribute can be as simple as adding two attribute values located on the same row, or it can be the result of aggregating the sum of values located on many table rows (from the same table or from a different table). The decision to store derived attributes in database tables depends on the processing requirements and the constraints placed on a particular application. The designer should be able to balance the design in accordance with such constraints. [Table 4.2](#) shows the advantages and disadvantages of storing (or not storing) derived attributes in the database.

FIGURE 4.6 Depiction of a derived attribute



SOURCE: Course Technology/Cengage Learning

TABLE 4.2 Advantages and Disadvantages of Storing Derived Attributes

DERIVED ATTRIBUTE

	STORED	NOT STORED
Advantage	<ul style="list-style-type: none"> Saves CPU processing cycles Saves data access time Data value is readily available Can be used to keep track of historical data	<ul style="list-style-type: none"> Saves storage space Computation always yields current value
Disadvantage	<ul style="list-style-type: none"> Requires constant maintenance to ensure derived value is current, especially if any values used in the calculation change 	<ul style="list-style-type: none"> Uses CPU processing cycles Increases data access time Adds coding complexity to queries

4.1.3 RELATIONSHIPS

Recall from [Chapter 2](#) that a relationship is an association between entities. The entities that participate in a relationship are also known as **participants**, and each relationship is identified by a name that describes the relationship. The relationship name is an active or passive verb; for example, a STUDENT *takes* a CLASS, a PROFESSOR *teaches* a CLASS, a DEPARTMENT *employs* a PROFESSOR, a DIVISION *is managed* by an EMPLOYEE, and an AIRCRAFT *is flown* by a CREW.

Relationships between entities always operate in both directions. To define the relationship between the entities named CUSTOMER and INVOICE, you would specify that:

- A CUSTOMER may generate many INVOICES.
- Each INVOICE is generated by one CUSTOMER.

Because you know both directions of the relationship between CUSTOMER and INVOICE, it is easy to see that this relationship can be classified as 1:M.

The relationship classification is difficult to establish if you know only one side of the relationship. For example, if you specify that:

A DIVISION is managed by one EMPLOYEE.

You don't know if the relationship is 1:1 or 1:M. Therefore, you should ask the question "Can an employee manage more than one division?" If the answer is yes, the relationship is 1:M, and the second part of the relationship is then written as:

An EMPLOYEE may manage many DIVISIONS.

If an employee cannot manage more than one division, the relationship is 1:1, and the second part of the relationship is then written as:

An EMPLOYEE may manage only one DIVISION.

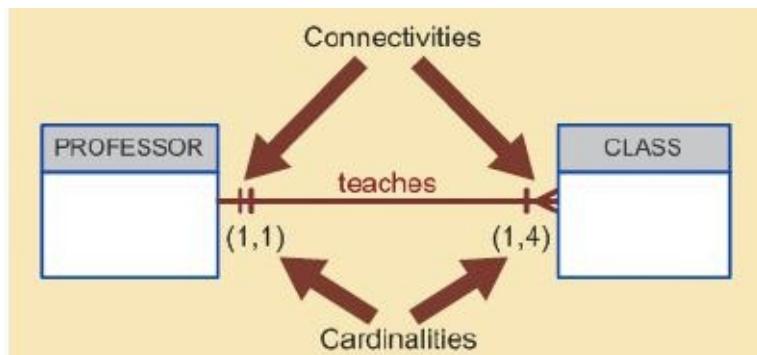
4.1.4 CONNECTIVITY AND CARDINALITY

You learned in [Chapter 2](#) that entity relationships may be classified as one-to-one, one-to-many, or many-to-many. You also learned how such relationships were depicted in the Chen and Crow's Foot notations. The term **connectivity** is

used to describe the relationship classification.

Cardinality expresses the minimum and maximum number of entity occurrences associated with one occurrence of the related entity. In the ERD, cardinality is indicated by placing the appropriate numbers beside the entities, using the format (x,y). The first value represents the minimum number of associated entities, while the second value represents the maximum number of associated entities. Many database designers who use Crow's Foot modeling notation do not depict the specific cardinalities on the ER diagram itself because the specific limits described by the cardinalities cannot be implemented directly through the database design. Correspondingly, some Crow's Foot ER modeling tools do not print the numeric cardinality range in the diagram; instead, you can add it as text if you want to have it shown. When the specific cardinalities are not included on the diagram in Crow's Foot notation, cardinality is implied by the use of the symbols shown in [Figure 4.7](#), which describe the connectivity and participation (discussed below). The numeric cardinality range has been added using the Visio text drawing tool.

FIGURE 4.7 Connectivity and cardinality in an ERD



SOURCE: Course Technology/Cengage Learning

Knowing the minimum and maximum number of entity occurrences is very useful at the application software level. For example, Tiny College might want to ensure that a class is not taught unless it has at least 10 students enrolled. Similarly, if the classroom can hold only 30 students, the application software should use that cardinality to limit enrollment in the class. However, keep in mind that the DBMS cannot handle the implementation of the cardinalities at the

table level—that capability is provided by the application software or by triggers. You will learn how to create and execute triggers in [Chapter 8](#), Advanced SQL.

As you examine the Crow’s Foot diagram in [Figure 4.7](#), keep in mind that the cardinalities represent the number of occurrences in the *related* entity. For example, the cardinality (1,4) next to the CLASS entity in the “PROFESSOR teaches CLASS” relationship indicates that each professor teaches up to four classes, which means that the PROFESSOR table’s primary key value occurs at least once and no more than four times as foreign key values in the CLASS table. If the cardinality had been written as (1,N), there would be no upper limit to the number of classes a professor might teach. Similarly, the cardinality (1,1) next to the PROFESSOR entity indicates that each class is taught by one and only one professor. That is, each CLASS entity occurrence is associated with one and only one entity occurrence in PROFESSOR.

Connectivities and cardinalities are established by concise statements known as business rules, which were introduced in [Chapter 2](#). Such rules, derived from a precise and detailed description of an organization’s data environment, also establish the ERM’s entities, attributes, relationships, connectivities, cardinalities, and constraints. Because business rules define the ERM’s components, making sure that all appropriate business rules are identified is an important part of a database designer’s job.

NOTE

The placement of the cardinalities in the ER diagram is a matter of convention. The Chen notation places the cardinalities on the side of the related entity. The Crow’s Foot and UML diagrams place the cardinalities next to the entity to which they apply.



ONLINE CONTENT

Because the careful definition of complete and accurate business rules is crucial

to good database design, their derivation is examined in detail in **Appendix B, The University Lab: Conceptual Design**. The modeling skills you are learning in this chapter are applied in the development of a real database design in Appendix B. The initial design shown in Appendix B is then modified in **Appendix C, The University Lab: Conceptual Design Verification, Logical Design, and Implementation**. (Both appendixes are available at www.cengagebrain.com.)

4.1.5 EXISTENCE DEPENDENCE

An entity is said to be **existence-dependent** if it can exist in the database only when it is associated with another related entity occurrence. In implementation terms, an entity is existence-dependent if it has a mandatory foreign key—that is, a foreign key attribute that cannot be null. For example, if an employee wants to claim one or more dependents for tax-withholding purposes, the relationship “EMPLOYEE claims DEPENDENT” would be appropriate. In that case, the DEPENDENT entity is clearly existence-dependent on the EMPLOYEE entity because it is impossible for the dependent to exist apart from the EMPLOYEE in the database.

If an entity can exist apart from all of its related entities, then it is **existence-independent**, and it is referred to as a **strong entity** or **regular entity**. For example, suppose that the XYZ Corporation uses parts to produce its products. Furthermore, suppose that some of those parts are produced in-house and other parts are bought from vendors. In that scenario, it is quite possible for a PART to exist independently from a VENDOR in the relationship “PART is supplied by VENDOR,” because at least some of the parts are not supplied by a vendor. Therefore, PART is existence-independent from VENDOR.

NOTE

The concept of relationship strength is not part of the original ERM. Instead, this concept applies directly to Crow’s Foot diagrams. Because Crow’s Foot diagrams are used extensively to design relational databases, it is important to understand relationship strength as it affects database implementation. The Chen ERD notation is oriented toward conceptual modeling and therefore does not distinguish between weak and strong

relationships.

4.1.6 RELATIONSHIP STRENGTH

The concept of relationship strength is based on how the primary key of a related entity is defined. To implement a relationship, the primary key of one entity (the parent entity, normally on the “one” side of the one-to-many relationship) appears as a foreign key in the related entity (the child entity, mostly the entity on the “many” side of the one-to-many relationship). Sometimes the foreign key also is a primary key component in the related entity. For example, in [Figure 4.5](#), the CAR entity primary key (CAR_VIN) appears as both a primary key component and a foreign key in the CAR_COLOR entity. In this section, you will learn how various relationship strength decisions affect primary key arrangement in database design.

Weak (Non-Identifying) Relationships

A [weak relationship](#), also known as a [non-identifying relationship](#), exists if the primary key of the related entity does not contain a primary key component of the parent entity. By default, relationships are established by having the primary key of the parent entity appear as a foreign key (FK) on the related entity (also known as the child entity). For example, suppose the 1:M relationship between COURSE and CLASS is defined as:

COURSE (CRS_CODE, DEPT_CODE, CRS_DESCRIPTION, CRS_CREDIT)

CLASS (CLASS_CODE, CRS_CODE, CLASS_SECTION, CLASS_TIME, ROOM_CODE, PROF_NUM)

In this case, a weak relationship exists between COURSE and CLASS because CRS_CODE (the primary key of the parent entity) is only a foreign key in the CLASS entity. In this example, the CLASS primary key did not inherit a primary key component from the COURSE entity.

[Figure 4.8](#) shows how the Crow’s Foot notation depicts a weak relationship by placing a dashed relationship line between the entities. The tables shown below the ERD illustrate how such a relationship is implemented.

FIGURE 4.8 A weak (non-identifying) relationship between COURSE and CLASS

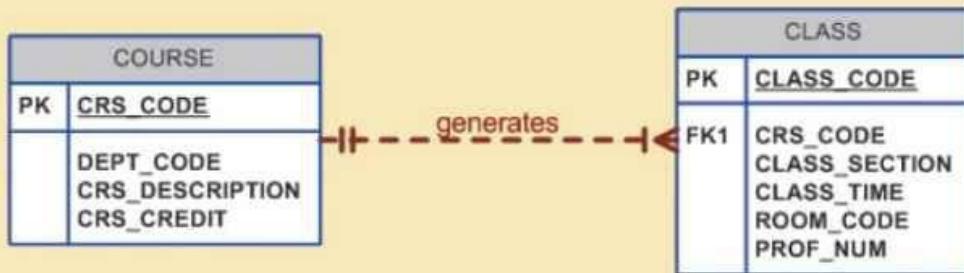


Table name: COURSE

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

Database name: Ch04_TinyCollege

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

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

All of the databases used to illustrate the material in this chapter are available at www.cengagebrain.com.

Strong (Identifying) Relationships

A **strong relationship**, also known as an **identifying relationship**, exists when the primary key of the related entity contains a primary key component of the parent entity. For example, suppose the 1:M relationship between COURSE and CLASS is defined as:

COURSE (CRS_CODE, DEPT_CODE, CRS_DESCRIPTION, CRS_CREDIT)

CLASS (CRS_CODE, CLASS_SECTION, CLASS_TIME, ROOM_CODE, PROF_NUM)

In this case, the CLASS entity primary key is composed of CRS_CODE and CLASS_SECTION. Therefore, a strong relationship exists between COURSE and CLASS because CRS_CODE (the primary key of the parent entity) is a primary key component in the CLASS entity. In other words, the CLASS primary key did inherit a primary key component from the COURSE entity. (Note that the CRS_CODE in CLASS is *also* the FK to the COURSE entity.)

The Crow's Foot notation depicts the strong (identifying) relationship with a solid line between the entities, as shown in [Figure 4.9](#).

NOTE

Keep in mind that the *order in which the tables are created and loaded is very important*. For example, in the “COURSE generates CLASS” relationship, the COURSE table must be created before the CLASS table. After all, it would not be acceptable to have the CLASS table’s foreign key refer to a COURSE table that did not yet exist. In fact, *you must load the data of the “1” side first in a 1:M relationship to avoid the possibility of referential integrity errors*, regardless of whether the relationships are weak or strong.

As you examine [Figure 4.9](#), you might wonder what the O symbol next to the CLASS entity signifies. You will discover the meaning of this cardinality in [Section 4.1.8](#), Relationship Participation.

In summary, whether the relationship between COURSE and CLASS is strong or weak depends on how the CLASS entity’s primary key is defined. Remember that the nature of the relationship is often determined by the database designer, who must use professional judgment to determine which relationship type and

strength best suit the database transaction, efficiency, and information requirements. That point will often be emphasized in detail!

4.1.7 WEAK ENTITIES

In contrast to the strong or regular entity mentioned in [Section 4.1.5](#), a **weak entity** is one that meets two conditions:

1. The entity is existence-dependent; it cannot exist without the entity with which it has a relationship.
 2. The entity has a primary key that is partially or totally derived from the parent entity in the relationship.
-

FIGURE 4.9 A strong (identifying) relationship between COURSE and CLASS

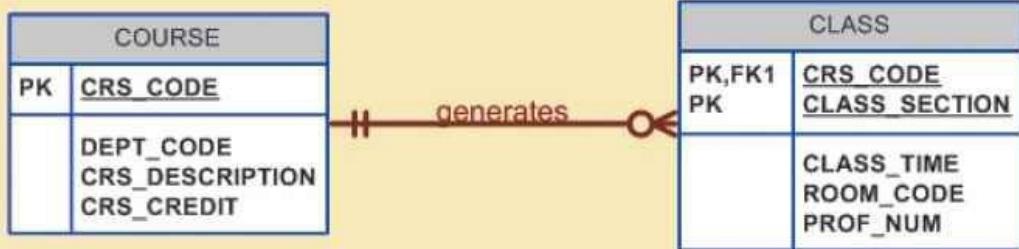


Table name: COURSE

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

Database name: Ch04_TinyCollege_Alt

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

SOURCE: Course Technology/Cengage Learning

For example, a company insurance policy insures an employee and any dependents. For the purpose of describing an insurance policy, an EMPLOYEE might or might not have a DEPENDENT, but the DEPENDENT must be associated with an EMPLOYEE. Moreover, the DEPENDENT cannot exist without the EMPLOYEE; that is, a person cannot get insurance coverage as a dependent unless the person is a dependent of an employee. DEPENDENT is the weak entity in the relationship “EMPLOYEE has DEPENDENT.” This relationship is shown in [Figure 4.10](#).

Note that the Chen notation in [Figure 4.10](#) identifies the weak entity by using a double-walled entity rectangle. The Crow’s Foot notation generated by Visio Professional uses the relationship line and the PK/FK designation to indicate

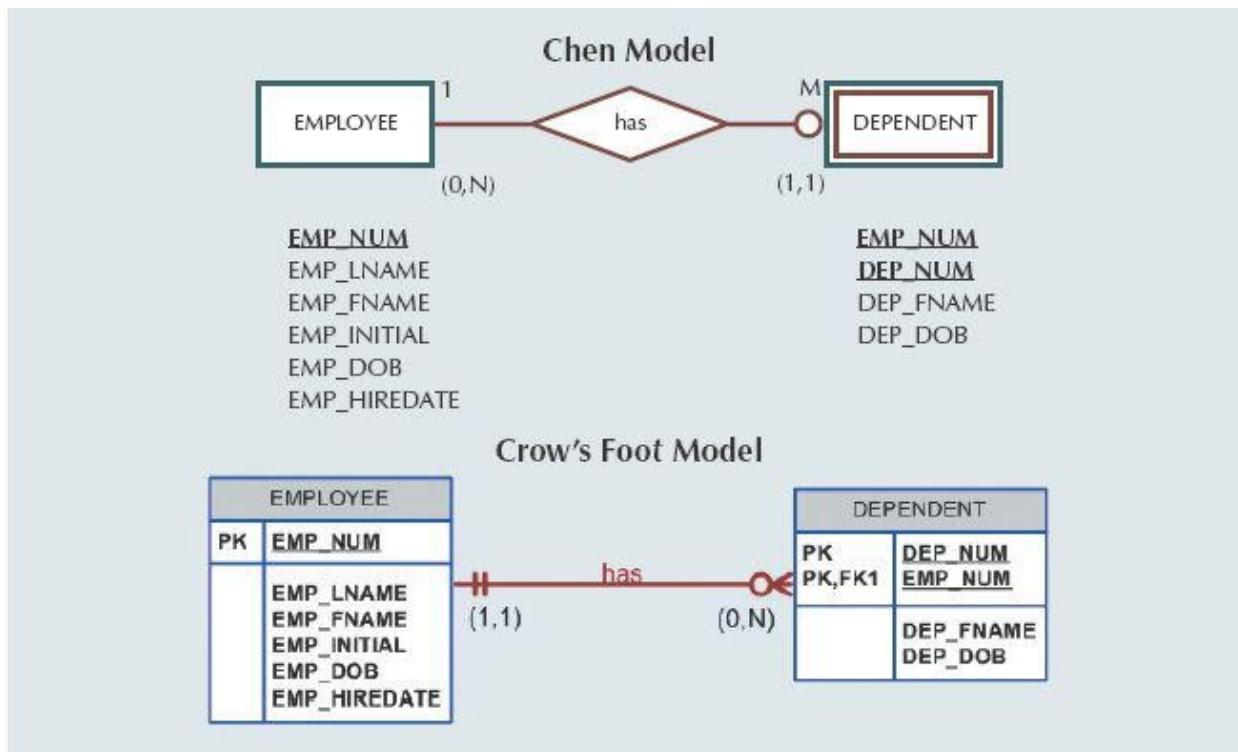
whether the related entity is weak. A strong (identifying) relationship indicates that the related entity is weak. Such a relationship means that both conditions have been met for the weak entity definition—the related entity is existence-dependent, and the PK of the related entity contains a PK component of the parent entity.

Remember that the weak entity inherits part of its primary key from its strong counterpart. For example, at least part of the DEPENDENT entity's key shown in [Figure 4.10](#) was inherited from the EMPLOYEE entity:

EMPLOYEE (EMP_NUM, EMP_LNAME, EMP_FNAME, EMP_INITIAL, EMP_DOB, EMP_HIREDATE)

DEPENDENT (EMP_NUM, DEP_NUM, DEP_FNAME, DEP_DOB)

FIGURE 4.10 A weak entity in an ERD



SOURCE: Course Technology/Cengage Learning

[Figure 4.11](#) illustrates the implementation of the relationship between the weak

entity (DEPENDENT) and its parent or strong counterpart (EMPLOYEE). Note that DEPENDENT's primary key is composed of two attributes, EMP_NUM and DEP_NUM, and that EMP_NUM was inherited from EMPLOYEE.

FIGURE 4.11 A weak entity in a strong relationship

Database name: Ch04_ShortCo					
Table name: EMPLOYEE					
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	Brzinski	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

SOURCE: Course Technology/Cengage Learning

Given this scenario, and with the help of this relationship, you can determine that:

Jeanine J. Callifante claims two dependents, Annelise and Jorge.

Keep in mind that the database designer usually determines whether an entity can be described as weak based on the business rules. An examination of [Figure 4.8](#) might cause you to conclude that CLASS is a weak entity to COURSE. After all, it seems clear that a CLASS cannot exist without a COURSE, so there is existence dependence. For example, a student cannot enroll in the Accounting I class ACCT-211, Section 3 (CLASS_CODE 10014), unless there is an ACCT-211 course. However, note that the CLASS table's primary key is CLASS_CODE, which is not derived from the COURSE parent entity. That is, CLASS may be represented by:

CLASS (CLASS_CODE, CRS_CODE, CLASS_SECTION, CLASS_TIME, ROOM_CODE, PROF_NUM)

The second weak entity requirement has not been met; therefore, by definition, the CLASS entity in [Figure 4.8](#) may not be classified as weak. On the other hand, if the CLASS entity's primary key had been defined as a composite key composed of the combination CRS_CODE and CLASS_SECTION, CLASS could be represented by:

CLASS (CRS_CODE, CLASS_SECTION, CLASS_TIME, ROOM_CODE, PROF_NUM)

In that case, as illustrated in [Figure 4.9](#), the CLASS primary key is partially derived from COURSE because CRS_CODE is the COURSE table's primary key. Given this decision, CLASS is a weak entity by definition. (In Visio Professional Crow's Foot terms, the relationship between COURSE and CLASS is classified as strong, or identifying.) In any case, CLASS is always existence-dependent on COURSE, *whether or not it is defined as weak*.

4.1.8 RELATIONSHIP PARTICIPATION

Participation in an entity relationship is either optional or mandatory. Recall that relationships are bidirectional; that is, they operate in both directions. If COURSE is related to CLASS, then by definition, CLASS is related to COURSE. Because of the bidirectional nature of relationships, it is necessary to determine the connectivity of the relationship from COURSE to CLASS and the connectivity of the relationship from CLASS to COURSE. Similarly, the specific maximum and minimum cardinalities must be determined in each direction for the relationship. Once again, you must consider the bidirectional nature of the relationship when determining participation.

Optional participation means that one entity occurrence does not *require* a corresponding entity occurrence in a particular relationship. For example, in the “COURSE generates CLASS” relationship, you noted that at least some courses do not generate a class. In other words, an entity occurrence (row) in the COURSE table does not necessarily require the existence of a corresponding entity occurrence in the CLASS table. (Remember that each entity is implemented as a table.) Therefore, the CLASS entity is considered to be *optional* to the COURSE entity. In Crow's Foot notation, an optional relationship between entities is shown by drawing a small circle (O) on the side of the optional entity, as illustrated in [Figure 4.9](#). The existence of an *optional*

entity indicates that its minimum cardinality is 0. (The term *optionality* is used to label any condition in which one or more optional relationships exist.)

NOTE

Remember that the burden of establishing the relationship is always placed on the entity that contains the foreign key. In most cases, that entity is on the “many” side of the relationship.

Mandatory participation means that one entity occurrence *requires* a corresponding entity occurrence in a particular relationship. If no optionality symbol is depicted with the entity, the entity is assumed to exist in a mandatory relationship with the related entity. If the mandatory participation is depicted graphically, it is typically shown as a small hash mark across the relationship line, similar to the Crow’s Foot depiction of a connectivity of 1. The existence of a mandatory relationship indicates that the minimum cardinality is at least 1 for the mandatory entity.

NOTE

You might be tempted to conclude that relationships are weak when they occur between entities in an optional relationship and that relationships are strong when they occur between entities in a mandatory relationship. However, this conclusion is not warranted. Keep in mind that relationship participation and relationship strength do not describe the same thing. You are likely to encounter a strong relationship when one entity is optional to another. For example, the relationship between EMPLOYEE and DEPENDENT is clearly a strong one, but DEPENDENT is clearly optional to EMPLOYEE. After all, you cannot require employees to have dependents. Also, it is just as possible for a weak relationship to be established when one entity is mandatory to another. The relationship strength depends on how the PK of the related entity is formulated, while the relationship participation depends on how the business rule is written. For example, the business rules “Each part must be supplied by a vendor” and “A part may or may not be supplied by a vendor” create different optionalities for the same entities! Failure to understand this distinction may

lead to poor design decisions that cause major problems when table rows are inserted or deleted.

When you create a relationship in MS Visio, the default relationship will be mandatory on the “1” side and optional on the “many” side. [Table 4.3](#) shows the various connectivity and participation combinations that are supported by the Crow’s Foot notation. Recall that these combinations are often referred to as cardinality in Crow’s Foot notation when specific cardinalities are not used.

TABLE 4.3 Crow’s Foot Symbols

CROW’S FOOT SYMBOLS	CARDINALITY	COMMENT
	(0,N)	Zero or many; the “many” side is optional.
	(1,N)	One or many; the “many” side is mandatory.
	(1,1)	One and only one; the “1” side is mandatory.
	(0,1)	Zero or one; the “1” side is optional.

Because relationship participation is an important component of database design, you should examine a few more scenarios. Suppose that Tiny College employs some professors who conduct research without teaching classes. If you examine the “PROFESSOR teaches CLASS” relationship, it is quite possible for a PROFESSOR not to teach a CLASS. Therefore, CLASS is *optional* to PROFESSOR. On the other hand, a CLASS must be taught by a PROFESSOR. Therefore, PROFESSOR is *mandatory* to CLASS. Note that the ERD model in [Figure 4.12](#) shows the cardinality next to CLASS to be (0,3), indicating that a professor may teach no classes or as many as three classes. Also, each CLASS table row references one and only one PROFESSOR row—assuming each class is taught by one and only one professor—represented by the (1,1) cardinality next to the PROFESSOR table.

FIGURE 4.12 An optional CLASS entity in the relationship “PROFESSOR teaches CLASS”



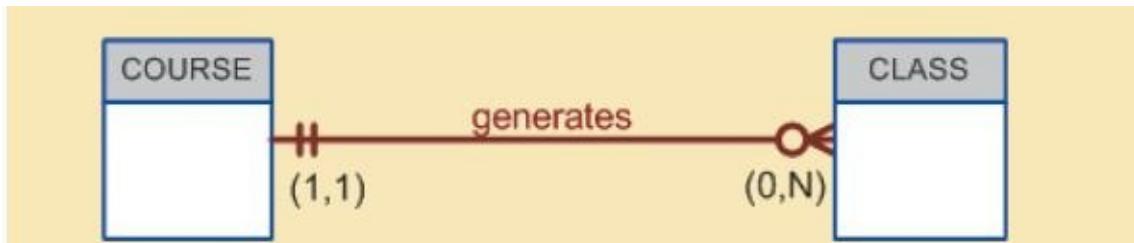
SOURCE: Course Technology/Cengage Learning

It is important that you clearly understand the distinction between mandatory and optional participation in relationships. Otherwise, you might develop designs in which awkward and unnecessary temporary rows (entity instances) must be created just to accommodate the creation of required entities.

It is also important to understand that the semantics of a problem might determine the type of participation in a relationship. For example, suppose that Tiny College offers several courses; each course has several classes. Note again the distinction between *class* and *course* in this discussion: a CLASS constitutes a specific offering (or section) of a COURSE. Typically, courses are listed in the university's course catalog, while classes are listed in the class schedules that students use to register for their classes.

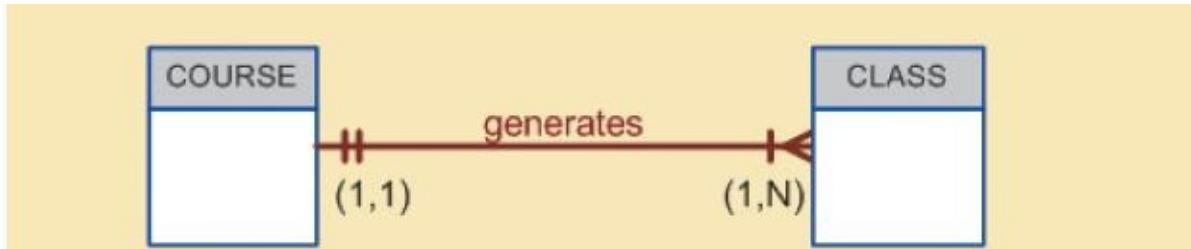
By analyzing the CLASS entity's contribution to the "COURSE generates CLASS" relationship, it is easy to see that a CLASS cannot exist without a COURSE. Therefore, you can conclude that the COURSE entity is *mandatory* in the relationship. However, two scenarios for the CLASS entity may be written, as shown in [Figures 4.13](#) and [4.14](#).

FIGURE 4.13 CLASS is optional to COURSE



SOURCE: Course Technology/Cengage Learning

FIGURE 4.14 COURSE and CLASS in a mandatory relationship



SOURCE: Course Technology/Cengage Learning

The different scenarios are a function of the problem's semantics; that is, they depend on how the relationship is defined.

1. *CLASS is optional.* It is possible for the department to create the COURSE entity first and then create the CLASS entity after making the teaching assignments. In the real world, such a scenario is very likely; there may be courses for which sections (classes) have not yet been defined. In fact, some courses are taught only once a year and do not generate classes each semester.

2. *CLASS is mandatory.* This condition is created by the constraint imposed by the semantics of the statement "Each COURSE generates one or more CLASSES." In ER terms, each COURSE in the "generates" relationship must have at least one CLASS. Therefore, a CLASS must be created as the COURSE is created to comply with the semantics of the problem.

Keep in mind the practical aspects of the scenario presented in [Figure 4.14](#). Given the semantics of this relationship, the system should not accept a course that is not associated with at least one class section. Is such a rigid environment desirable from an operational point of view? For example, when a new COURSE is created, the database first updates the COURSE table, thereby inserting a COURSE entity that does not yet have a CLASS associated with it. Naturally, the apparent problem seems to be solved when CLASS entities are inserted into the corresponding CLASS table. However, because of the mandatory relationship, the system will temporarily violate the business rule

constraint. For practical purposes, it would be desirable to classify the CLASS as optional to produce a more flexible design.

Finally, as you examine the scenarios in [Figures 4.13](#) and [4.14](#), keep in mind the role of the DBMS. To maintain data integrity, the DBMS must ensure that the “many” side (CLASS) is associated with a COURSE through the foreign key rules.

4.1.9 RELATIONSHIP DEGREE

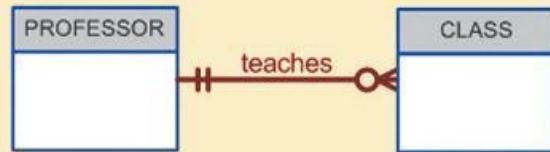
A **relationship degree** indicates the number of entities or participants associated with a relationship. A **unary relationship** exists when an association is maintained within a single entity. A **binary relationship** exists when two entities are associated. A **ternary relationship** exists when three entities are associated. Although higher degrees exist, they are rare and are not specifically named. (For example, an association of four entities is described simply as a *four-degree relationship*.) [Figure 4.15](#) shows these types of relationship degrees.

FIGURE 4.15 Three types of relationship degree

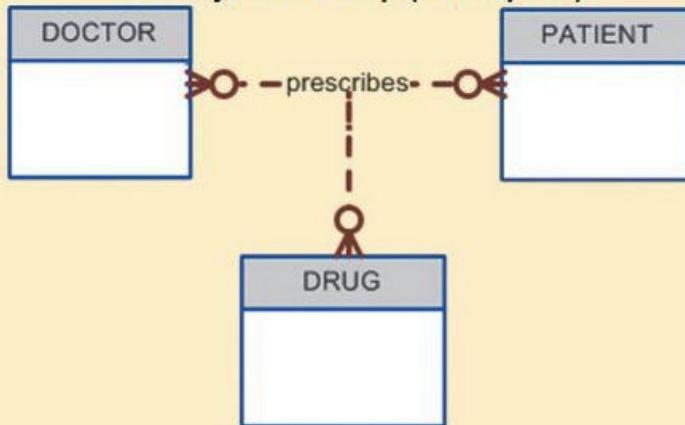
Unary relationship



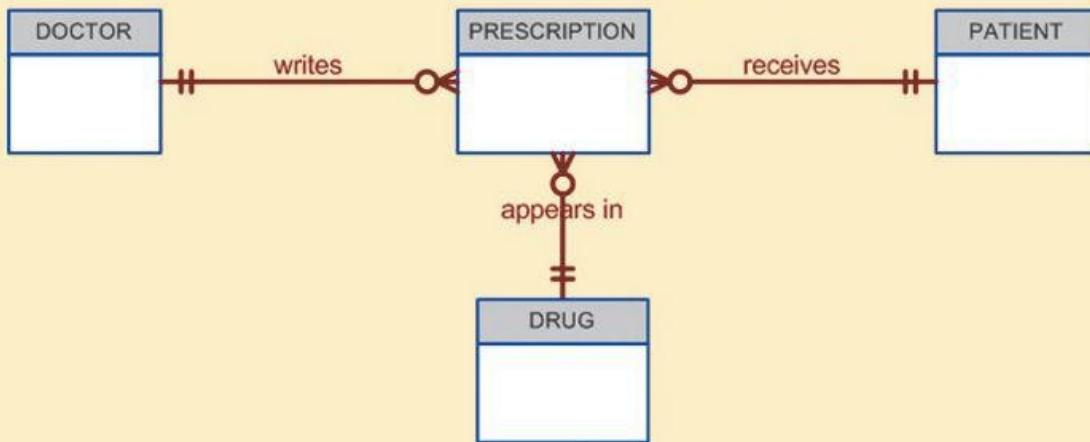
Binary relationship



Ternary relationship (Conceptual)



Ternary relationship (Logical)



SOURCE: Course Technology/Cengage Learning

Unary Relationships

In the case of the unary relationship shown in [Figure 4.15](#), an employee within the EMPLOYEE entity is the manager for one or more employees within that entity. In this case, the existence of the “manages” relationship means that EMPLOYEE requires another EMPLOYEE to be the manager—that is,

EMPLOYEE has a relationship with itself. Such a relationship is known as a recursive relationship. The various cases of [**recursive relationships**](#) are explained in [Section 4.1.10](#).

Binary Relationships

A binary relationship exists when two entities are associated in a relationship. Binary relationships are the most common type of relationship. In fact, to simplify the conceptual design, most higher-order (ternary and higher) relationships are decomposed into appropriate equivalent binary relationships whenever possible. In [Figure 4.15](#), “a PROFESSOR teaches one or more CLASSES” represents a binary relationship.

Ternary and Higher-Order Relationships

Although most relationships are binary, the use of ternary and higher-order relationships does allow the designer some latitude regarding the semantics of a problem. A ternary relationship implies an association among three different entities. For example, in [Figure 4.16](#), note the relationships and their consequences, which are represented by the following business rules:

- A DOCTOR writes one or more PRESCRIPTIONS.
- A PATIENT may receive one or more PRESCRIPTIONS.
- A DRUG may appear in one or more PRESCRIPTIONS. (To simplify this example, assume that the business rule states that each prescription contains only one drug. In short, if a doctor prescribes more than one drug, a separate prescription must be written for each drug.)

As you examine the table contents in [Figure 4.16](#), note that it is possible to track all transactions. For instance, you can tell that the first prescription was written by doctor 32445 for patient 102, using the drug DRZ.

4.1.10 RECURSIVE RELATIONSHIPS

As you just learned, a *recursive relationship* is one in which a relationship can exist between occurrences of the same entity set. (Naturally, such a condition is found within a unary relationship.) For example, a 1:M unary relationship can be expressed by “an EMPLOYEE may manage many EMPLOYEES, and each EMPLOYEE is managed by one EMPLOYEE.” Also, as long as polygamy is

not legal, a 1:1 unary relationship may be expressed by “an EMPLOYEE may be married to one and only one other EMPLOYEE.” Finally, the M:N unary relationship may be expressed by “a COURSE may be a prerequisite to many other COURSES, and each COURSE may have many other COURSES as prerequisites.” Those relationships are shown in [Figure 4.17](#).

The 1:1 relationship shown in [Figure 4.17](#) can be implemented in the single table shown in [Figure 4.18](#). Note that you can determine that James Ramirez is married to Louise Ramirez, who is married to James Ramirez. Also, Anne Jones is married to Anton Shapiro, who is married to Anne Jones.

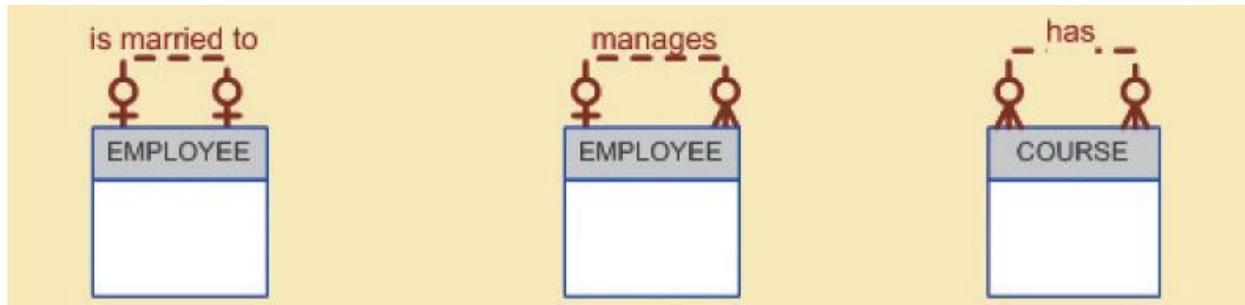
FIGURE 4.16 The implementation of a ternary relationship

Database name: Ch04_Clinic								
Table name: DRUG			Table name: PATIENT					
DOC_ID	DOC_LNAME	DOC_FNAME	DOC_INITIAL	DOC_SPECIALTY	PAT_NUM	PAT_TITLE	PAT_LNAME	PAT_FNAME
29827	Sanchez	Julio	J	Dermatology	100	Mr.	Kolmycz	George
32445	Jorgensen	Annelise	G	Neurology	101	Ms.	Lewis	Rhonda
33456	Korenski	Anatoly	A	Urology	102	Mr.	Vandam	Rhett
33989	LeGrande	George		Pediatrics	103	Ms.	Jones	Anne
34409	Washington	Dennis	F	Orthopaedics	104	Mr.	Lange	John
36221	McPherson	Katye	H	Dermatology	105	Mr.	Williams	Robert
36712	Dreifag	Herman	G	Psychiatry	106	Mrs.	Smith	Jeanine
38995	Minh	Tran		Neurology	107	Mr.	Dante	Jorge
40004	Chin	Ming	D	Orthopaedics	108	Mr.	Wiesenbach	Paul
40028	Feinstein	Denise	L	Gynecology	109	Mrs.	Smith	George
					110	Mrs.	Genkazi	Leighla
					111	Mr.	vWashington	Rupert
					112	Mr.	Johnson	Edward
					113	Ms.	Smythe	Melanie
					114	Ms.	Brandon	Marie
					115	Mrs.	Saranda	Hermine
					116	Mr.	Smith	George

Table name: DOCTOR					Table name: PRESCRIPTION				
DOC_ID	DOC_LNAME	DOC_FNAME	DOC_INITIAL	DOC_SPECIALTY	DOC_ID	PAT_NUM	DRUG_CODE	PRES_DOSAGE	PRES_DATE
29827	Sanchez	Julio	J	Dermatology	32445	102	DRZ	2 tablets every four hours -- 50 tablets total	12-Nov-12
32445	Jorgensen	Annelise	G	Neurology	32445	113	OLE	1 teaspoon with each meal -- 250 ml total	14-Nov-12
33456	Korenski	Anatoly	A	Urology	34409	101	KO15	1 tablet every six hours -- 30 tablets total	14-Nov-12
33989	LeGrande	George		Pediatrics	36221	109	DRO	2 tablets with every meal -- 60 tablets total	14-Nov-12
34409	Washington	Dennis	F	Orthopaedics	38995	107	KO15	1 tablet every six hours -- 30 tablets total	14-Nov-12
36221	McPherson	Katye	H	Dermatology					
36712	Dreifag	Herman	G	Psychiatry					
38995	Minh	Tran		Neurology					
40004	Chin	Ming	D	Orthopaedics					
40028	Feinstein	Denise	L	Gynecology					

SOURCE: Course Technology/Cengage Learning

FIGURE 4.17 An ER representation of recursive relationships



SOURCE: Course Technology/Cengage Learning

FIGURE 4.18 The 1:1 recursive relationship “EMPLOYEE is married to EMPLOYEE”

Database name: CH04_PartCo			
Table name: EMPLOYEE_V1			
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

SOURCE: Course Technology/Cengage Learning

Unary relationships are common in manufacturing industries. For example, [Figure 4.19](#) illustrates that a rotor assembly (C-130) is composed of many parts, but each part is used to create only one rotor assembly. [Figure 4.19](#) indicates that a rotor assembly is composed of four 2.5-cm washers, two cotter pins, one 2.5-cm steel shank, four 10.25-cm rotor blades, and two 2.5-cm hex nuts. The relationship implemented in [Figure 4.19](#) thus enables you to track each part within each rotor assembly.

If a part can be used to assemble several different kinds of other parts and is itself composed of many parts, two tables are required to implement the “PART contains PART” relationship. [Figure 4.20](#) illustrates such an environment. Parts tracking is increasingly important as managers become more aware of the legal ramifications of producing more complex output. In many industries, especially those involving aviation, full parts tracking is required by law.

FIGURE 4.19 Another unary relationship: “PART contains PART”

Table name: PART_V1					Database name: CH04_PartCo
PART_CODE	PART_DESCRIPTION	PART_IN_STOCK	PART_UNITS_NEEDED	PART_OF_PART	
AA21-6	2.5 cm. washer, 1.0 mm. rim	432	4	C-130	
AB-121	Cotter pin, copper	1034	2	C-130	
C-130	Rotor assembly	36			
E129	2.5 cm. steel shank	128	1	C-130	
X10	10.25 cm. rotor blade	345	4	C-130	
X34AW	2.5 cm. hex nut	879	2	C-130	

SOURCE: Course Technology/Cengage Learning

FIGURE 4.20 Implementation of the M:N recursive relationship “PART contains PART”

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	1034
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

SOURCE: Course Technology/Cengage Learning

The M:N recursive relationship might be more familiar in a school environment. For instance, note how the M:N “COURSE requires COURSE” relationship illustrated in [Figure 4.17](#) is implemented in [Figure 4.21](#). In this example, MATH-243 is a prerequisite to QM-261 and QM-362, while both MATH-243 and QM-

261 are prerequisites to QM-362.

Finally, the 1:M recursive relationship “EMPLOYEE manages EMPLOYEE,” shown in [Figure 4.17](#), is implemented in [Figure 4.22](#).

One common pitfall when working with unary relationships is to confuse participation with referential integrity. In theory, participation and referential integrity are very different concepts and are normally easy to distinguish in binary relationships. In practical terms, conversely, participation and referential integrity are very similar because they are both implemented through constraints on the same set of attributes. This similarity often leads to confusion when the concepts are applied within the limited structure of a unary relationship. Consider the unary 1:1 spousal relationship between employees, which is described in [Figure 4.18](#). Participation, as described above, is bidirectional, meaning that it must be addressed in both directions along the relationship. Participation in [Figure 4.18](#) addresses the following questions:

FIGURE 4.21 Implementation of the M:N recursive relationship “COURSE requires COURSE”

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: PREREQ	
CRS_CODE	PRE_TAKE
CIS-420	CIS-220
QM-261	MATH-243
QM-362	MATH-243
QM-362	QM-261

SOURCE: Course Technology/Cengage Learning

FIGURE 4.22 Implementation of the 1:M recursive relationship “EMPLOYEE manages EMPLOYEE”

Database name: Ch04_PartCo

Table name: EMPLOYEE_V2

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

SOURCE: Course Technology/Cengage Learning

- Must every employee have a spouse who is an employee?
- Must every employee be a spouse to another employee?

For the data shown in [Figure 4.18](#), the correct answer to both questions is “No.” It is possible to be an employee and not have another employee as a spouse. Also, it is possible to be an employee and not be the spouse of another employee.

Referential integrity deals with the correspondence of values in the foreign key with values in the related primary key. Referential integrity is not bidirectional, and therefore answers only one question:

- Must every employee spouse be a valid employee?

For the data shown in [Figure 4.18](#), the correct answer is “Yes.” Another way to frame this question is to consider whether every value provided for the EMP_SPOUSE attribute must match some value in the EMP_NUM attribute.

In practical terms, both participation and referential integrity involve the values used as primary keys and foreign keys to implement the relationship. Referential integrity requires that the values in the foreign key correspond to values in the primary key. In one direction, participation considers whether the foreign key can contain a null. In [Figure 4.18](#), for example, employee Robert Delaney is not required to have a value in EMP_SPOUSE. In the other direction, participation

considers whether every value in the primary key must appear as a value in the foreign key. In [Figure 4.18](#), for example, employee Robert Delaney's value for EMP_NUM (348) is not required to appear as a value in EMP_SPOUSE for any other employee.

4.1.11 ASSOCIATIVE (COMPOSITE) ENTITIES

M:N relationships are a valid construct at the conceptual level, and therefore are found frequently during the ER modeling process. However, implementing the M:N relationship, particularly in the relational model, requires the use of an additional entity, as you learned in [Chapter 3](#). The ER model uses the associative entity to represent an M:N relationship between two or more entities. This associative entity, also called a *composite* or *bridge entity*, is in a 1:M relationship with the parent entities and is composed of the primary key attributes of each parent entity. Furthermore, the associative entity can have additional attributes of its own, as shown by the ENROLL associative entity in [Figure 4.23](#). When using the Crow's Foot notation, the associative entity is identified as a strong (identifying) relationship, as indicated by the solid relationship lines between the parents and the associative entity.

FIGURE 4.23 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
10014	ACCT-211	3	TTh 2:30-3:45 p.m.
10018	CIS-220	2	MWF 9:00-9:50 a.m.
10021	QM-261	1	MWF 8:00-8:50 a.m.
			ROOM_CODE PROF_NUM
			BUS252 342
			KLR211 114
			KLR200 114

SOURCE: Course Technology/Cengage Learning

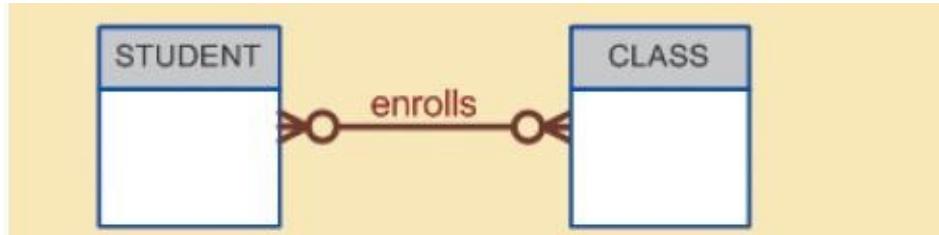
Note that the composite ENROLL entity in [Figure 4.23](#) is existence-dependent on the other two entities; the composition of the ENROLL entity is based on the primary keys of the entities that are connected by the composite entity. The composite entity may also contain additional attributes that play no role in the connective process. For example, although the entity must be composed of at least the STUDENT and CLASS primary keys, it may also include such additional attributes as grades, absences, and other data uniquely identified by the student's performance in a specific class.

Finally, keep in mind that the ENROLL table's key (CLASS_CODE and STU_NUM) is composed entirely of the primary keys of the CLASS and STUDENT tables. Therefore, no null entries are possible in the ENROLL table's key attributes.

Implementing the small database shown in [Figure 4.23](#) requires that you define the relationships clearly. Specifically, you must know the "1" and the "M" sides of each relationship, and you must know whether the relationships are mandatory or optional. For example, note the following points:

- A class may exist (at least at the start of registration) even though it contains no students. Therefore, in [Figure 4.24](#), an optional symbol should appear on the STUDENT side of the M:N relationship between STUDENT and CLASS.

FIGURE 4.24 The M:N relationship between STUDENT and CLASS



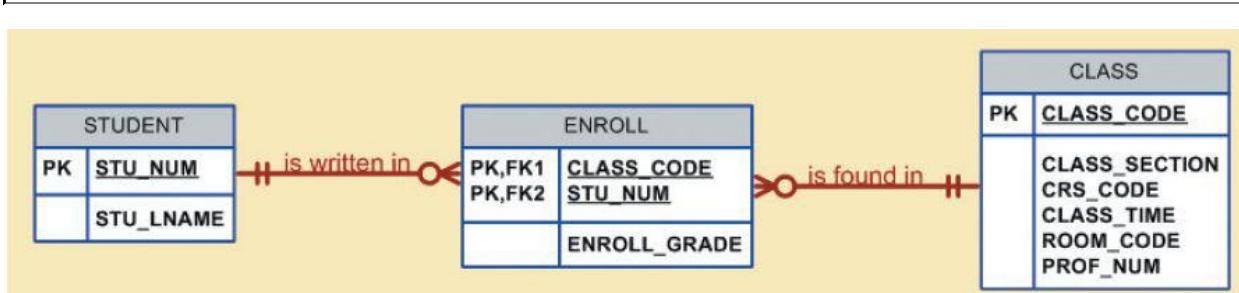
SOURCE: Course Technology/Cengage Learning

You might argue that to be classified as a STUDENT, a person must be enrolled in at least one CLASS. Therefore, CLASS is mandatory to STUDENT from a

purely conceptual point of view. However, when a student is admitted to college, that student has not yet signed up for any classes. Therefore, *at least initially*, CLASS is optional to STUDENT. Note that the practical considerations in the data environment help dictate the use of optionalities. If CLASS is *not* optional to STUDENT from a database point of view, a class assignment must be made when the student is admitted. However, that's *not* how the process actually works, and the database design must reflect this. In short, the optionality reflects practice.

Because the M:N relationship between STUDENT and CLASS is decomposed into two 1:M relationships through ENROLL, the optionalities must be transferred to ENROLL. (See [Figure 4.25](#).) In other words, it now becomes possible for a class not to occur in ENROLL if no student has signed up for that class. Because a class need not occur in ENROLL, the ENROLL entity becomes optional to CLASS. Also, because the ENROLL entity is created before any students have signed up for a class, the ENROLL entity is also optional to STUDENT, at least initially.

FIGURE 4.25 A composite entity in an ERD



SOURCE: Course Technology/Cengage Learning

- As students begin to sign up for their classes, they will be entered into the ENROLL entity. Naturally, if a student takes more than one class, that student will occur more than once in ENROLL. For example, note that in the ENROLL table in [Figure 4.23](#), STU_NUM = 321452 occurs three times. On the other hand, each student occurs only once in the STUDENT entity. (Note that the STUDENT table in [Figure 4.23](#) has only one STU_NUM = 321452 entry.) Therefore, in [Figure 4.25](#), the relationship between STUDENT and ENROLL is shown to be 1:M, with

the “M” on the ENROLL side.

- As you can see in [Figure 4.23](#), a class can occur more than once in the ENROLL table. For example, CLASS_CODE = 10014 occurs twice. However, CLASS_CODE = 10014 occurs only once in the CLASS table to reflect that the relationship between CLASS and ENROLL is 1:M. Note that in [Figure 4.25](#), the “M” is located on the ENROLL side, while the “1” is located on the CLASS side.

4.2 DEVELOPING AN ER DIAGRAM

The process of database design is iterative rather than a linear or sequential process. The verb *iterate* means “to do again or repeatedly.” Thus, an [**iterative process**](#) is based on repetition of processes and procedures. Building an ERD usually involves the following activities:

- Create a detailed narrative of the organization’s description of operations.
- Identify the business rules based on the description of operations.
- Identify the main entities and relationships from the business rules.
- Develop the initial ERD.
- Identify the attributes and primary keys that adequately describe the entities.
- Revise and review the ERD.

During the review process, additional objects, attributes, and relationships probably will be uncovered. Therefore, the basic ERM will be modified to incorporate the newly discovered ER components. Subsequently, another round

of reviews might yield additional components or clarification of the existing diagram. The process is repeated until the end users and designers agree that the ERD is a fair representation of the organization's activities and functions.

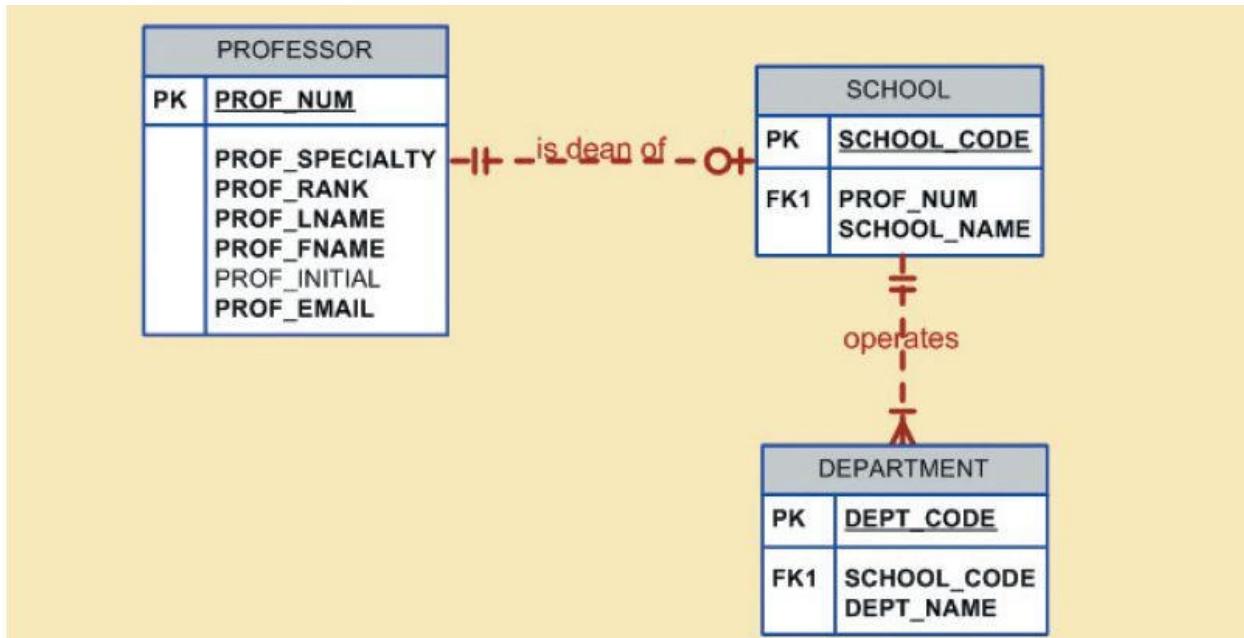
During the design process, the database designer does not depend simply on interviews to help define entities, attributes, and relationships. A surprising amount of information can be gathered by examining the business forms and reports that an organization uses in its daily operations.

To illustrate the use of the iterative process that ultimately yields a workable ERD, start with an initial interview with the Tiny College administrators. The interview process yields the following business rules:

1. Tiny College (TC) is divided into several schools: business, arts and sciences, education, and applied sciences. Each school is administered by a dean who is a professor. Each professor can be the dean of only one school, and a professor is not required to be the dean of any school. Therefore, a 1:1 relationship exists between PROFESSOR and SCHOOL. Note that the cardinality can be expressed by writing (1,1) next to the entity PROFESSOR and (0,1) next to the entity SCHOOL.

2. Each school comprises several departments. For example, the school of business has an accounting department, a management/marketing department, an economics/finance department, and a computer information systems department. Note again the cardinality rules: The smallest number of departments operated by a school is one, and the largest number of departments is indeterminate (N). On the other hand, each department belongs to only a single school; thus, the cardinality is expressed by (1,1). That is, the minimum number of schools to which a department belongs is one, as is the maximum number. [Figure 4.26](#) illustrates these first two business rules.

FIGURE 4.26 The first Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

NOTE

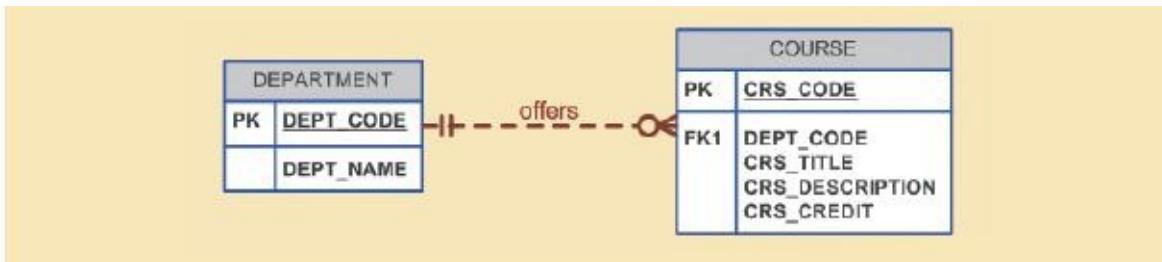
It is again appropriate to evaluate the reason for maintaining the 1:1 relationship between PROFESSOR and SCHOOL in the “PROFESSOR is dean of SCHOOL” relationship. It is worth repeating that the existence of 1:1 relationships often indicates a misidentification of attributes as entities. In this case, the 1:1 relationship could easily be eliminated by storing the dean’s attributes in the SCHOOL entity. This solution would also make it easier to answer the queries “Who is the dean?” and “What are the dean’s credentials?” The downside of this solution is that it requires the duplication of data that are already stored in the PROFESSOR table, thus setting the stage for anomalies. However, because each school is run by a single dean, the problem of data duplication is rather minor. The selection of one approach over another often depends on information requirements, transaction speed, and the database designer’s professional judgment. In short, do not use 1:1 relationships lightly, and make sure that each 1:1 relationship within the database design is defensible.

3. Each department may offer courses. For example, the

management/marketing department offers courses such as Introduction to Management, Principles of Marketing, and Production Management. The ERD segment for this condition is shown in [Figure 4.27](#). Note that this relationship is based on the way Tiny College operates. For example, if Tiny College had some departments that were classified as “research only,” they would not offer courses; therefore, the COURSE entity would be optional to the DEPARTMENT entity.

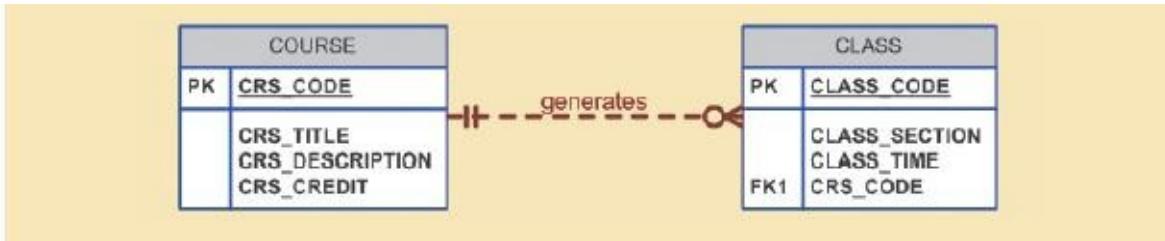
4. The relationship between COURSE and CLASS was illustrated in [Figure 4.9](#). Nevertheless, it is worth repeating that a CLASS is a section of a COURSE. That is, a department may offer several sections (classes) of the same database course. Each of those classes is taught by a professor at a given time in a given place. In short, a 1:M relationship exists between COURSE and CLASS. However, because a course may exist in Tiny College’s course catalog even when it is not offered as a class in a current class schedule, CLASS is optional to COURSE. Therefore, the relationship between COURSE and CLASS looks like [Figure 4.28](#).

FIGURE 4.27 The second Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

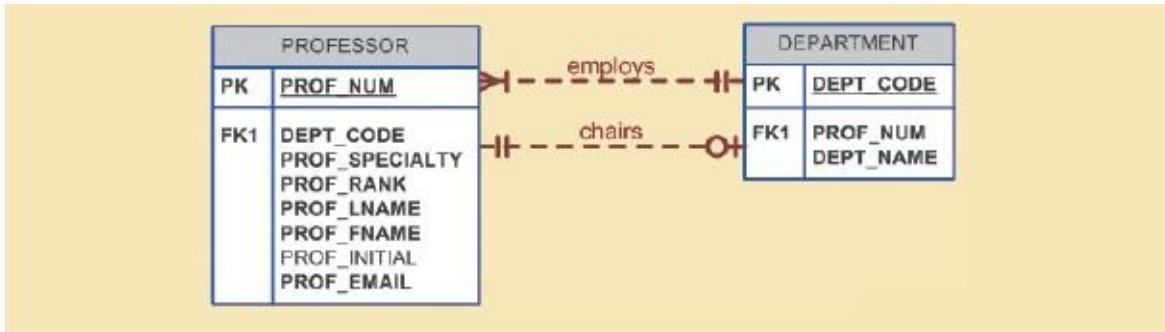
FIGURE 4.28 The third Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

-
5. Each department should have one or more professors assigned to it. One and only one of those professors chairs the department, and no professor is required to accept the chair position. Therefore, DEPARTMENT is optional to PROFESSOR in the “chairs” relationship. Those relationships are summarized in the ER segment shown in [Figure 4.29](#).
-

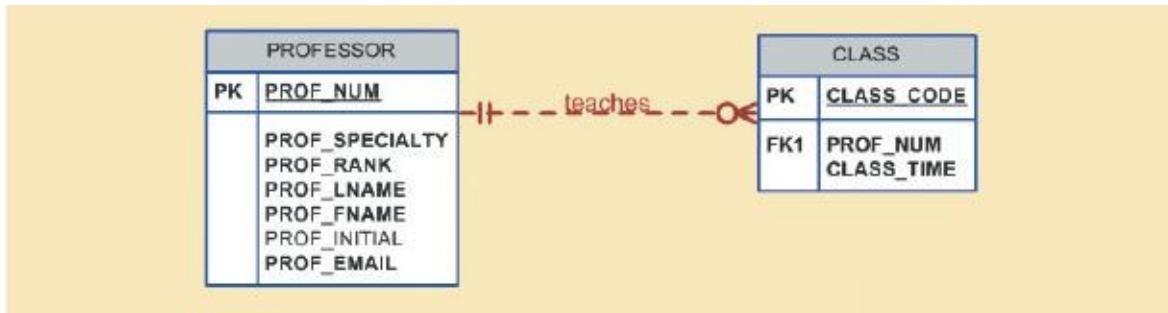
FIGURE 4.29 The fourth Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

-
6. Each professor may teach up to four classes; each class is a section of a course. A professor may also be on a research contract and teach no classes at all. The ER segment in [Figure 4.30](#) depicts those conditions.
-

FIGURE 4.30 The fifth Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

-
7. A student may enroll in several classes but take each class only once during any given enrollment period. For example, during the current enrollment period, a student may decide to take five classes—Statistics, Accounting, English, Database, and History—but that student would not be enrolled in the same Statistics class five times during the enrollment period! Each student may enroll in up to six classes, and each class may have up to 35 students, thus creating an M:N relationship between STUDENT and CLASS. Because a CLASS can initially exist at the start of the enrollment period even though no students have enrolled in it, STUDENT is optional to CLASS in the M:N relationship. This M:N relationship must be divided into two 1:M relationships through the use of the ENROLL entity, shown in the ERD segment in [Figure 4.31](#). However, note that the optional symbol is shown next to ENROLL. If a class exists but has no students enrolled in it, that class does not occur in the ENROLL table. Note also that the ENROLL entity is weak: it is existence-dependent, and its (composite) PK is composed of the PKs of the STUDENT and CLASS entities. You can add the cardinalities (0,6) and (0,35) next to the ENROLL entity to reflect the business rule constraints, as shown in [Figure 4.31](#). (Visio Professional does not automatically generate such cardinalities, but you can use a text box to accomplish that task.)
-

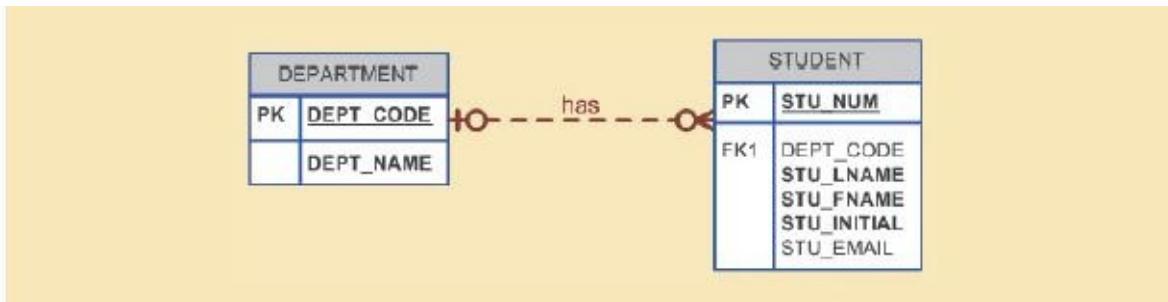
FIGURE 4.31 The sixth Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

-
8. Each department has several (or many) students whose major is offered by that department. However, each student has only a single major and is therefore associated with a single department. (See [Figure 4.32](#).) However, in the Tiny College environment, it is possible—at least for a while—for a student not to declare a major field of study. Such a student would not be associated with a department; therefore, DEPARTMENT is optional to STUDENT. It is worth repeating that the relationships between entities and the entities themselves reflect the organization's operating environment. That is, the business rules define the ERD components.
-

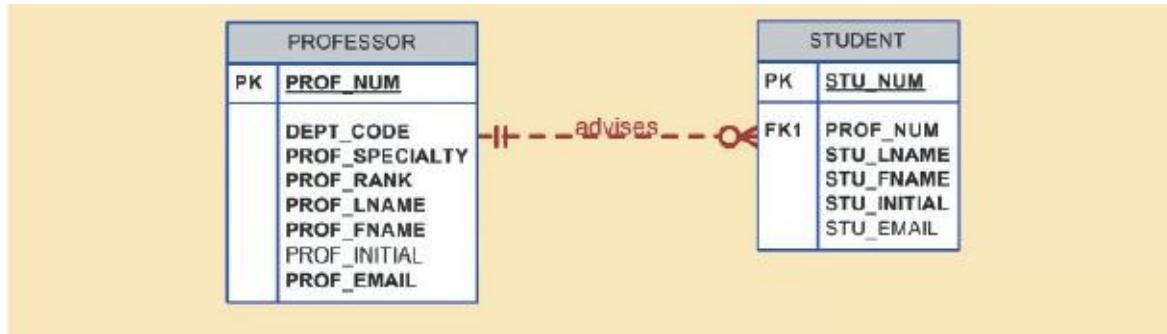
FIGURE 4.32 The seventh Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

-
9. Each student has an advisor in his or her department; each advisor counsels several students. An advisor is also a professor, but not all professors advise students. Therefore, STUDENT is optional to PROFESSOR in the “PROFESSOR advises STUDENT” relationship. (See [Figure 4.33](#).)
-

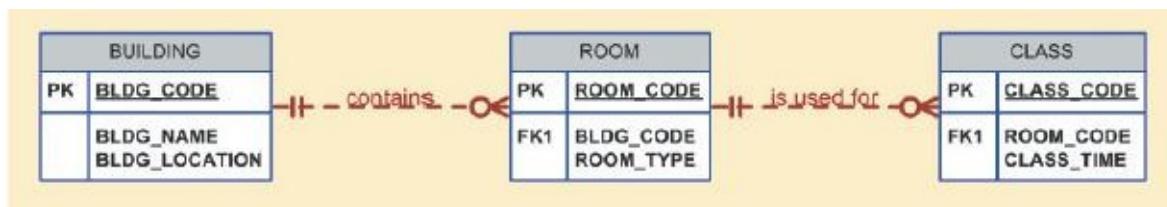
FIGURE 4.33 The eighth Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

10. As you can see in [Figure 4.34](#), the CLASS entity contains a ROOM_CODE attribute. Given the naming conventions, it is clear that ROOM_CODE is an FK to another entity. Clearly, because a class is taught in a room, it is reasonable to assume that the ROOM_CODE in CLASS is the FK to an entity named ROOM. In turn, each room is located in a building. So, the last Tiny College ERD is created by observing that a BUILDING can contain many ROOMS, but each ROOM is found in a single BUILDING. In this ERD segment, it is clear that some buildings do not contain (class) rooms. For example, a storage building might not contain any named rooms at all.

FIGURE 4.34 The ninth Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

Using the preceding summary, you can identify the following entities:

COURSE

SCHOOL

DEPARTMENT CLASS

PROFESSOR STUDENT

BUILDING ROOM

ENROLL (the associative entity between STUDENT and CLASS)

Once you have discovered the relevant entities, you can define the initial set of relationships among them. Next, you describe the entity attributes. Identifying the attributes of the entities helps you to better understand the relationships among entities. [Table 4.4](#) summarizes the ERM's components, and names the entities and their relations.

TABLE 4.4 Components of the ERM

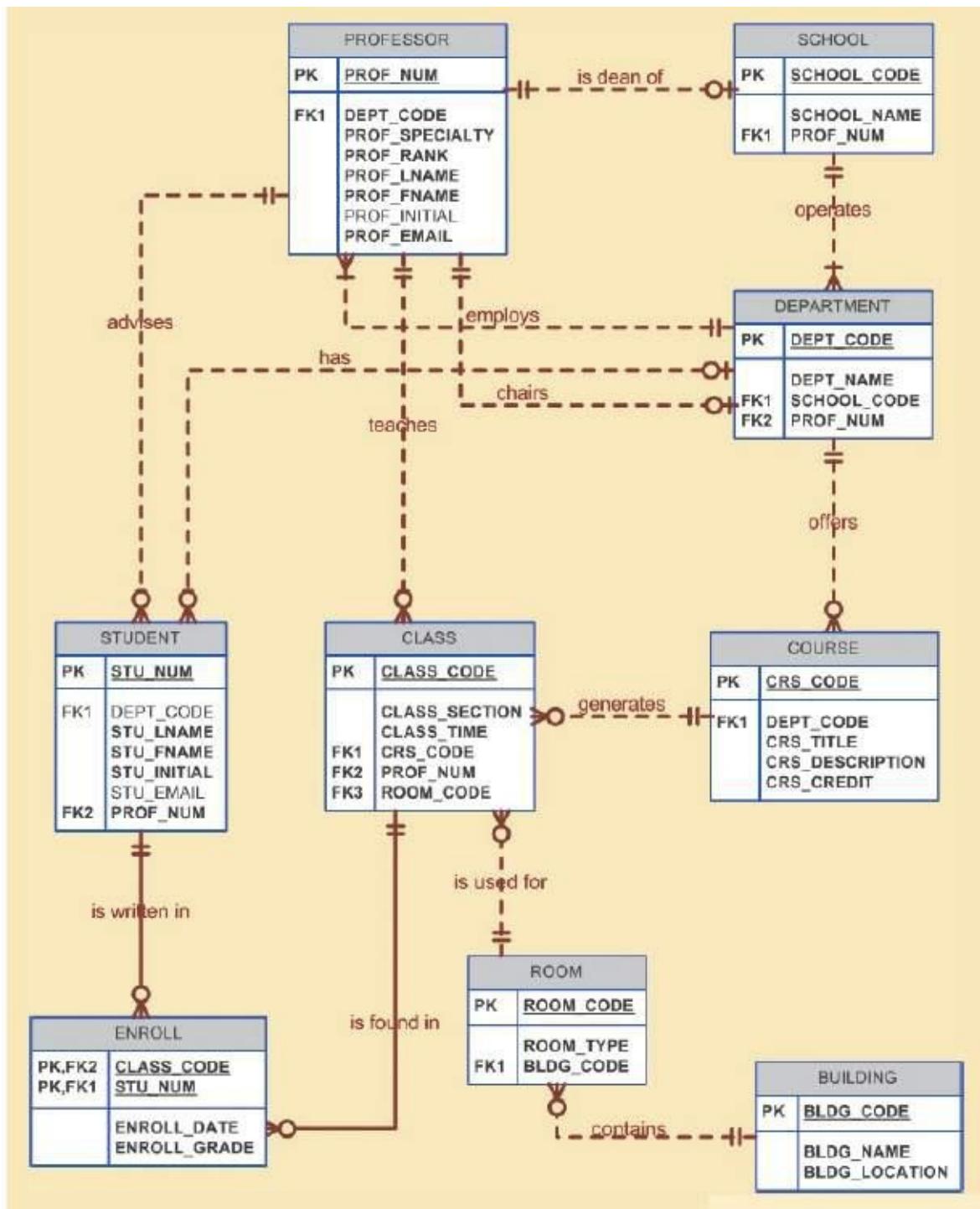
ENTITY	RELATIONSHIP	CONNECTIVITY	ENTITY
SCHOOL	operates	1:M	DEPARTMENT
DEPARTMENT	has	1:M	STUDENT
DEPARTMENT	employs	1:M	PROFESSOR
DEPARTMENT	offers	1:M	COURSE
COURSE	generates	1:M	CLASS
PROFESSOR	is dean of	1:1	SCHOOL
PROFESSOR	chairs	1:1	DEPARTMENT
PROFESSOR	teaches	1:M	CLASS
PROFESSOR	advises	1:M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

Note: ENROLL is the composite entity that implements the M:N relationship “STUDENT enrolls in CLASS.”

You must also define the connectivity and cardinality for the just-discovered relations based on the business rules. However, to avoid crowding the diagram, the cardinalities are not shown. [Figure 4.35](#) shows the Crow's Foot ERD for Tiny College. Note that this is an implementation-ready model, so it shows the ENROLL composite entity.

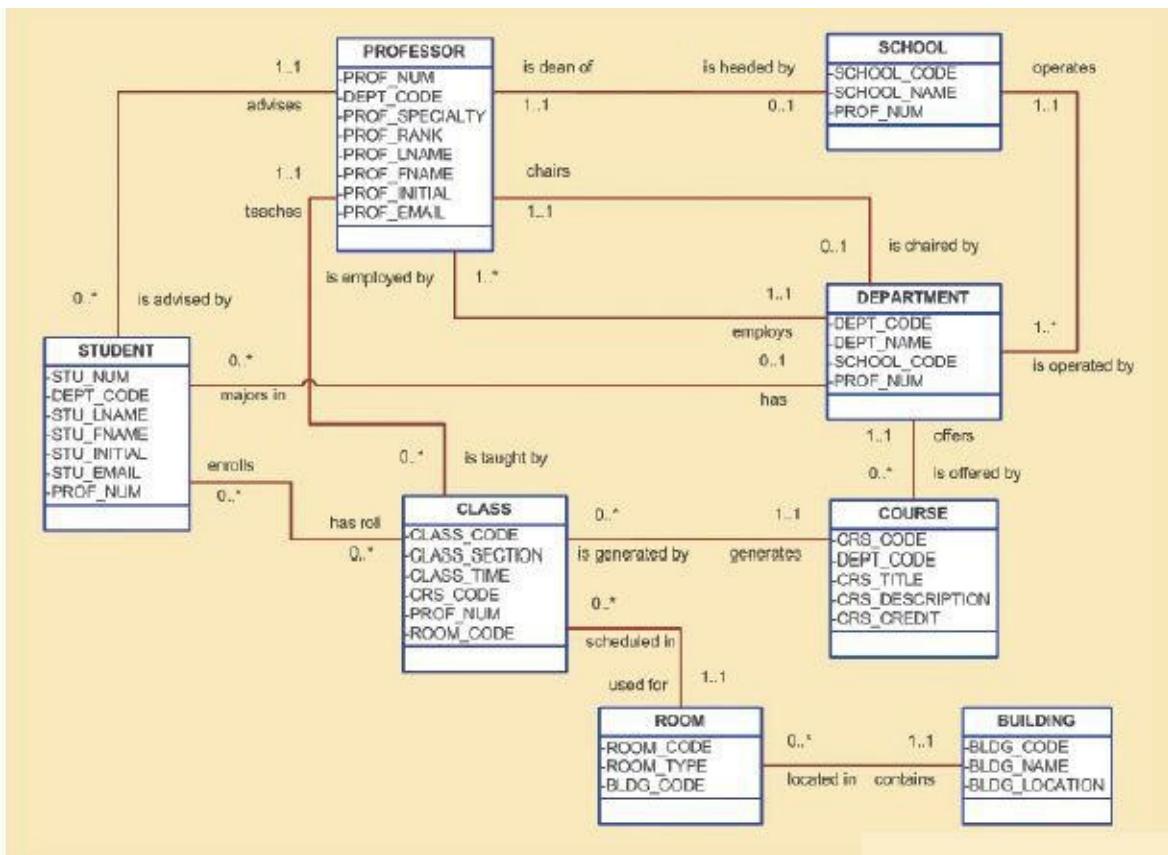
[Figure 4.36](#) shows the conceptual UML class diagram for Tiny College. Note that this class diagram depicts the M:N relationship between STUDENT and CLASS. [Figure 4.37](#) shows the implementation-ready UML class diagram for Tiny College (note that the ENROLL composite entity is shown in this class diagram). If you are a good observer, you will also notice that the UML class diagrams in [Figures 4.36](#) and [4.37](#) show the entity and attribute names but do not identify the primary key attributes. The reason goes back to UML's roots. UML class diagrams are an object-oriented modeling language, and therefore do not support the notion of "primary or foreign keys" found mainly in the relational world. Rather, in the object-oriented world, objects inherit a unique object identifier at creation time. For more information, see Appendix G, Object-Oriented Databases.

FIGURE 4.35 The completed Tiny College ERD



SOURCE: Course Technology/Cengage Learning

FIGURE 4.36 The conceptual UML class diagram for Tiny College



SOURCE: Course Technology/Cengage Learning

4.3 DATABASE DESIGN CHALLENGES: CONFLICTING GOALS

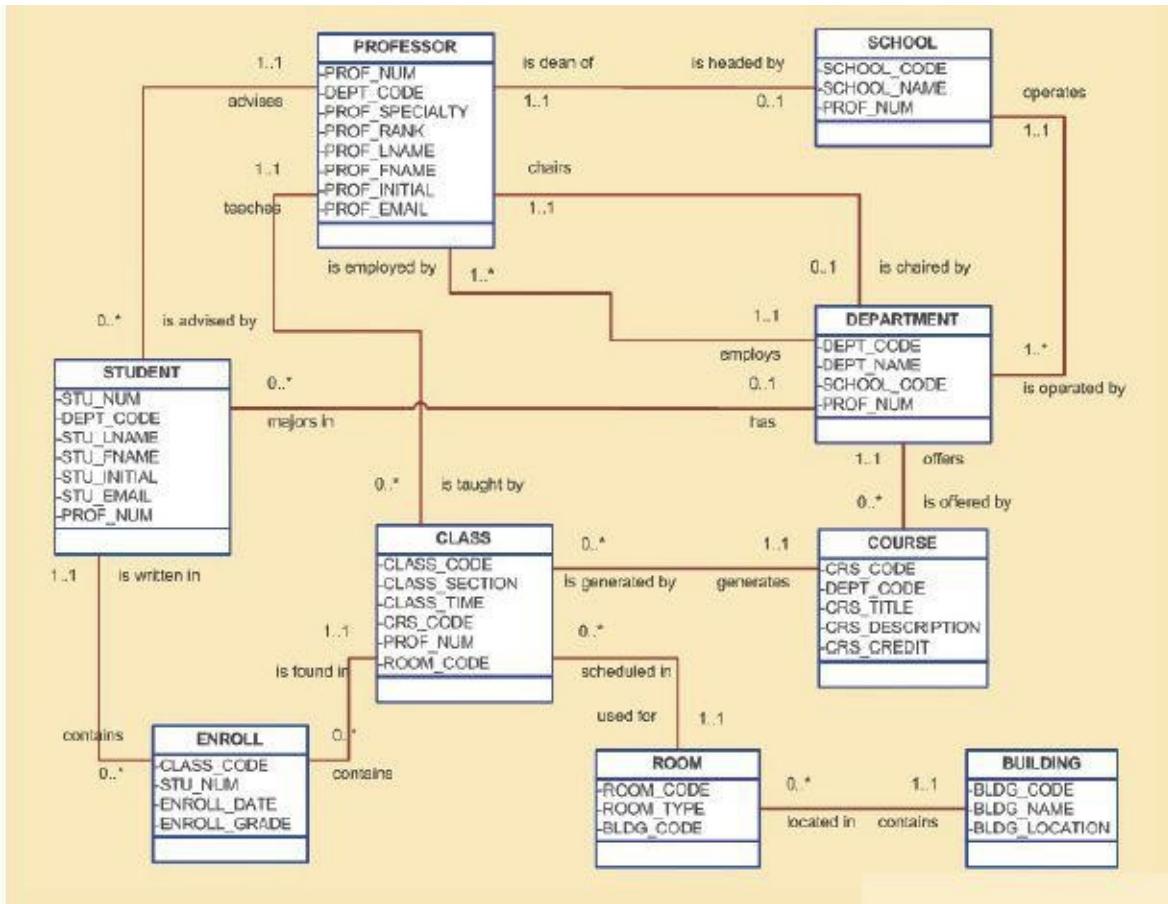
Database designers must often make design compromises that are triggered by conflicting goals, such as adherence to design standards (design elegance), processing speed, and information requirements.

- *Design standards.* The database design must conform to design standards. Such standards guide you in developing logical structures that minimize data redundancies, thereby minimizing the likelihood that destructive data anomalies will occur. You have also learned how standards prescribe avoiding nulls to the greatest extent possible. In fact, you have learned that design standards govern the presentation of all components within the database design. In short, design standards allow you to work with

well-defined components and to evaluate the interaction of those components with some precision. Without design standards, it is nearly impossible to formulate a proper design process, to evaluate an existing design, or to trace the likely logical impact of changes in design.

- *Processing speed.* In many organizations, particularly those that generate large numbers of transactions, high processing speeds are often a top priority in database design. High processing speed means minimal access time, which may be achieved by minimizing the number and complexity of logically desirable relationships. For example, a “perfect” design might use a 1:1 relationship to avoid nulls, while a design that emphasizes higher transaction speed might combine the two tables to avoid the use of an additional relationship, using dummy entries to avoid the nulls. If the focus is on data-retrieval speed, you might also be forced to include derived attributes in the design.

FIGURE 4.37 The implementation-ready UML class diagram for Tiny College



SOURCE: Course Technology/Cengage Learning

-
- *Information requirements.* The quest for timely information might be the focus of database design. Complex information requirements may dictate data transformations, and they may expand the number of entities and attributes within the design. Therefore, the database may have to sacrifice some of its “clean” design structures and high transaction speed to ensure maximum information generation. For example, suppose that a detailed sales report must be generated periodically. The sales report includes all invoice subtotals, taxes, and totals; even the invoice lines include subtotals. If the sales report includes hundreds of thousands (or even millions) of invoices, computing the totals, taxes, and subtotals is likely to take some time. If those computations had been made and the results had been stored as derived attributes in the INVOICE and LINE tables at the time of the transaction, the real-time transaction speed might have declined. However, that loss of speed would only be noticeable if there were many simultaneous transactions. The cost of a slight loss of transaction speed at the front end and the addition of multiple derived

attributes is likely to pay off when the sales reports are generated (not to mention that it will be simpler to generate the queries).

A design that meets all logical requirements and design conventions is an important goal. However, if this perfect design fails to meet the customer's transaction speed and information requirements, the designer will not have done a proper job from the end user's point of view. Compromises are a fact of life in the real world of database design.

Even while focusing on the entities, attributes, relationships, and constraints, the designer should begin thinking about end-user requirements such as performance, security, shared access, and data integrity. The designer must consider processing requirements and verify that all update, retrieval, and deletion options are available. Finally, a design is of little value unless the end product can deliver all specified query and reporting requirements.

You will probably discover that even the best design process produces an ERD that requires further changes mandated by operational requirements. Such changes should not discourage you from using the process. ER modeling is essential in the development of a sound design that can meet the demands of adjustment and growth. Using ERDs yields perhaps the richest bonus of all: a thorough understanding of how an organization really functions.

Occasionally, design and implementation problems do not yield "clean" implementation solutions. To get a sense of the design and implementation choices a database designer faces, you will revisit the 1:1 recursive relationship "EMPLOYEE is married to EMPLOYEE," first examined in [Figure 4.18](#). [Figure 4.38](#) shows three different ways of implementing such a relationship.

FIGURE 4.38 Various implementations of the 1:1 recursive relationship

Table name: EMPLOYEE_V1

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

Database name: Ch04_PartCo

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 diagram for the third implementation



Third implementation

SOURCE: Course Technology/Cengage Learning

Note that the EMPLOYEE_V1 table in [Figure 4.38](#) is likely to yield data anomalies. For example, if Anne Jones divorces Anton Shapiro, two records must be updated—by setting the respective EMP_SPOUSE values to null—to properly reflect that change. If only one record is updated, inconsistent data occur. The problem becomes even worse if several of the divorced employees then marry each other. In addition, that implementation also produces undesirable nulls for employees who are *not* married to other employees in the company.

Another approach would be to create a new entity shown as MARRIED_V1 in a 1:M relationship with EMPLOYEE. (See [Figure 4.38](#).) This second implementation does eliminate the nulls for employees who are not married to other employees in the same company. (Such employees would not be entered in the MARRIED_V1 table.) However, this approach still yields possible duplicate

values. For example, the marriage between employees 345 and 347 may still appear twice, once as 345,347 and once as 347,345. (Because each of those permutations is unique the first time it appears, the creation of a unique index will not solve the problem.)

As you can see, the first two implementations yield several problems:

- Both solutions use synonyms. The EMPLOYEE_V1 table uses EMP_NUM and EMP_SPOUSE to refer to an employee. The MARRIED_V1 table uses the same synonyms.
- Both solutions are likely to produce redundant data. For example, it is possible to enter employee 345 as married to employee 347 and to enter employee 347 as married to employee 345.
- Both solutions are likely to produce inconsistent data. For example, it is possible to have data pairs such as 345,347 and 348,345 and 347,349, none of which will violate entity integrity requirements because they are all unique. However, this solution would allow any one employee to be married to multiple employees.

A third approach would be to have two new entities, MARRIAGE and MARPART, in a 1:M relationship. MARPART contains the EMP_NUM foreign key to EMPLOYEE. (See the relational diagram in [Figure 4.38](#).) However, even this approach has issues. It requires the collection of additional data regarding the employees' marriage—the marriage date. If the business users do not need this data, then requiring them to collect it would be inappropriate. To ensure that an employee occurs only once in any given marriage, you would have to create a unique index on the EMP_NUM attribute in the MARPART table. Another potential problem with this solution is that the database implementation would theoretically allow more than two employees to “participate” in the same marriage.

As you can see, a recursive 1:1 relationship yields many different solutions with varying degrees of effectiveness and adherence to basic design principles. Any of the above solutions would likely involve the creation of program code to help ensure the integrity and consistency of the data. In a later chapter, you will examine the creation of database triggers that can do exactly that. Your job as a

database designer is to use your professional judgment to yield a solution that meets the requirements imposed by business rules, processing requirements, and basic design principles.

Finally, document, document, and document! Put all design activities in writing, and then review what you have written. Documentation not only helps you stay on track during the design process, it also enables you and your coworkers to pick up the design thread when the time comes to modify the design. Although the need for documentation should be obvious, one of the most vexing problems in database and systems analysis work is that this need is often ignored in the design and implementation stages. The development of organizational documentation standards is an important aspect of ensuring data compatibility and coherence.

SUMMARY

- The ERM uses ERDs to represent the conceptual database as viewed by the end user. The ERM's main components are entities, relationships, and attributes. The ERD includes connectivity and cardinality notations, and can also show relationship strength, relationship participation (optional or mandatory), and degree of relationship (such as unary, binary, or ternary).
- Connectivity describes the relationship classification (1:1, 1:M, or M:N). Cardinality expresses the specific number of entity occurrences associated with an occurrence of a related entity. Connectivities and cardinalities are usually based on business rules.
- In the ERM, an M:N relationship is valid at the conceptual level. However, when implementing the ERM in a relational database, the M:N relationship must be mapped to a set of 1:M relationships through a composite entity.
- ERDs may be based on many different ERMs. However, regardless of which model is selected, the modeling logic remains the same. Because no ERM can accurately portray all real-world data and action constraints, application software must be used to augment the implementation of at least some of the business rules.

- Unified Modeling Language (UML) class diagrams are used to represent the static data structures in a data model. The symbols used in the UML class and ER diagrams are very similar. The UML class diagrams can be used to depict data models at the conceptual or implementation abstraction levels.
- Database designers, no matter how well they can produce designs that conform to all applicable modeling conventions, are often forced to make design compromises. Those compromises are required when end users have vital transaction-speed and information requirements that prevent the use of “perfect” modeling logic and adherence to all modeling conventions. Therefore, database designers must use their professional judgment to determine how and to what extent the modeling conventions are subject to modification. To ensure that their professional judgments are sound, database designers must have detailed and in-depth knowledge of data-modeling conventions. It is also important to document the design process from beginning to end, which helps keep the design process on track and allows for easy modifications in the future.

KEY TERMS

[binary relationship](#)
[cardinality](#)
[composite attribute](#)
[composite identifier](#)
[connectivity](#)
[derived attribute](#)
[existence-dependent](#)
[existence-independent](#)
[identifiers](#)
[identifying relationship](#)
[iterative process](#)
[mandatory participation](#)
[multivalued attributes](#)
[non-identifying relationship](#)
[optional attribute](#)

[optional participation](#)
[participants](#)
[recursive relationship](#)
[regular entity](#)
[relational schema](#)
[relationship degree](#)
[required attribute](#)
[simple attribute](#)
[single-valued attribute](#)
[strong entity](#)
[strong relationship](#)
[ternary relationship](#)
[unary relationship](#)
[weak entity](#)
[weak relationship](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at www.cengagebrain.com.

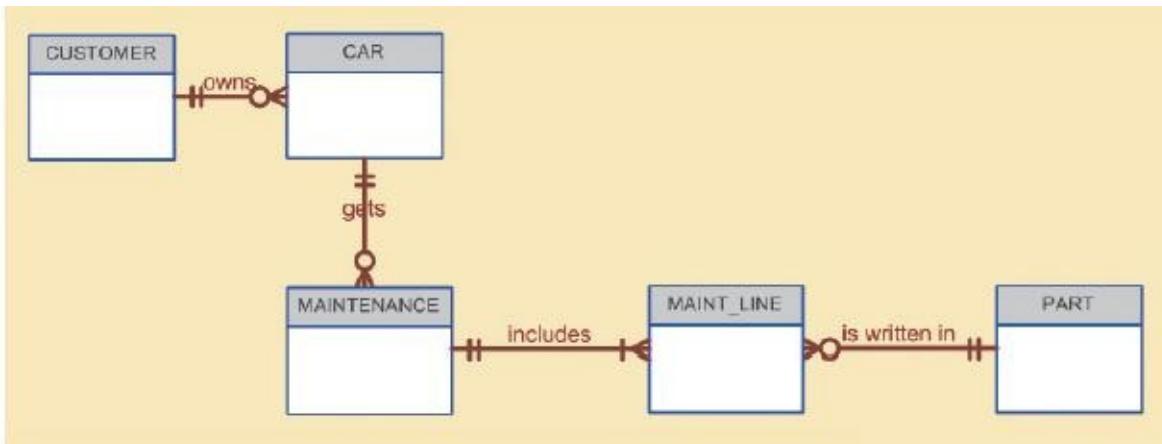
REVIEW QUESTIONS

1. What two conditions must be met before an entity can be classified as a weak entity? Give an example of a weak entity.
2. What is a strong (or identifying) relationship, and how is it depicted in a Crow's Foot ERD?
3. Given the business rule “an employee may have many degrees,” discuss its effect on attributes, entities, and relationships. (*Hint:* Remember what a

multivalued attribute is and how it might be implemented.)

4. What is a composite entity, and when is it used?
 5. Suppose you are working within the framework of the conceptual model in [Figure Q4.5](#).
-

FIGURE Q4.5 The conceptual model for Question 5



SOURCE: Course Technology/Cengage Learning

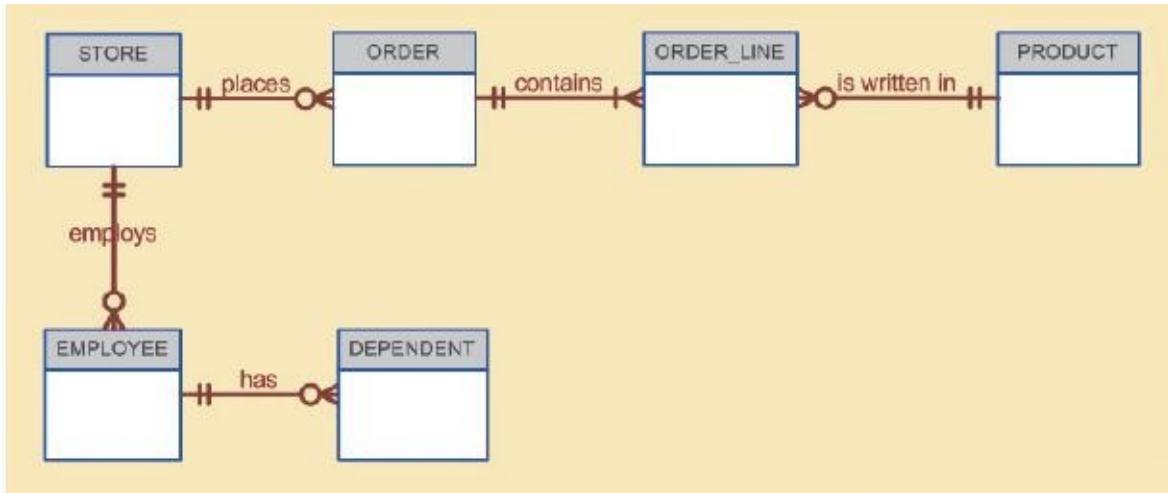
Given the conceptual model in [Figure Q4.5](#):

- a. Write the business rules that are reflected in it.
- b. Identify all of the cardinalities.
6. What is a recursive relationship? Give an example.
7. How would you (graphically) identify each of the following ERM components in a Crow's Foot notation?
 - a. an entity
 - b. the cardinality (0,N)
 - c. a weak relationship
 - d. a strong relationship
8. Discuss the difference between a composite key and a composite attribute. How would each be indicated in an ERD?

9. What two courses of action are available to a designer who encounters a multivalued attribute?
 10. What is a derived attribute? Give an example.
-
11. How is a relationship between entities indicated in an ERD? Give an example using the Crow's Foot notation.
 12. Discuss two ways in which the 1:M relationship between COURSE and CLASS can be implemented. (*Hint:* Think about relationship strength.)
 13. How is a composite entity represented in an ERD, and what is its function? Illustrate the Crow's Foot notation.
 14. What three (often conflicting) database requirements must be addressed in database design?
-
15. Briefly, but precisely, explain the difference between single-valued attributes and simple attributes. Give an example of each.
 16. What are multivalued attributes, and how can they be handled within the database design?

The next four questions are based on the ERD in [Figure Q4.17](#).

FIGURE Q4.17 The ERD for Questions 17–20



SOURCE: Course Technology/Cengage Learning

-
17. Write the 10 cardinalities that are appropriate for this ERD.
 18. Write the business rules reflected in this ERD.

 19. What two attributes must be contained in the composite entity between STORE and PRODUCT? Use proper terminology in your answer.
 20. Describe precisely the composition of the DEPENDENT weak entity's primary key. Use proper terminology in your answer.

 21. The local city youth league needs a database system to help track children who sign up to play soccer. Data need to be kept on each team, the children who will play on each team, and their parents. Also, data need to be kept on the coaches for each team.
Draw the data model described below.
Entities required: Team, Player, Coach, and Parent.
Attributes required:
Team: Team ID number, Team name, and Team colors.
Player: Player ID number, Player first name, Player last name, and Player age.
Coach: Coach ID number, Coach first name, Coach last name, and Coach

home phone number.

Parent: Parent ID number, Parent last name, Parent first name, Home phone number, and Home Address
(Street, City, State, and Zip Code).

The following relationships must be defined:

- Team is related to Player.
- Team is related to Coach.
- Player is related to Parent.

Connectivities and participations are defined as follows:

- A Team may or may not have a Player.
- A Player must have a Team.
- A Team may have many Players.
- A Player has only one Team.
- A Team may or may not have a Coach.
- A Coach must have a Team.
- A Team may have many Coaches.
- A Coach has only one Team.
- A Player must have a Parent.
- A Parent must have a Player.
- A Player may have many Parents.
- A Parent may have many Players.

PROBLEMS

1. Use the following business rules to create a Crow's Foot ERD. Write all appropriate connectivities and cardinalities in the ERD.
 - A department employs many employees, but each employee is employed by only one department.
 - Some employees, known as "rovers," are not assigned to any department.
 - A division operates many departments, but each department is operated

by only one division.

- An employee may be assigned many projects, and a project may have many employees assigned to it.
 - A project must have at least one employee assigned to it.
 - One of the employees manages each department, and each department is managed by only one employee.
 - One of the employees runs each division, and each division is run by only one employee.
2. Create a complete ERD in Crow's Foot notation that can be implemented in the relational model using the following description of operations. Hot Water (HW) is a small startup company that sells spas. HW does not carry any stock. A few spas are set up in a simple warehouse so customers can see some of the models available, but any products sold must be ordered at the time of the sale.
- HW can get spas from several different manufacturers.
 - Each manufacturer produces one or more different brands of spas.
 - Each and every brand is produced by only one manufacturer.
 - Every brand has one or more models.
 - Every model is produced as part of a brand. For example, Iguana Bay Spas is a manufacturer that produces Big Blue Iguana spas, a premium-level brand, and Lazy Lizard spas, an entry-level brand. The Big Blue Iguana brand offers several models, including the BBI-6, an 81-jet spa with two 6-hp motors, and the BBI-10, a 102-jet spa with three 6-hp motors.
 - Every manufacturer is identified by a manufacturer code. The company name, address, area code, phone number, and account number are kept in the system for every manufacturer.
 - For each brand, the brand name and brand level (premium, mid-level, or entry-level) are kept in the system.
 - For each model, the model number, number of jets, number of motors, number of horsepower per motor, suggested retail price, HW retail price, dry weight, water capacity, and seating capacity must be kept in the system.
3. The Jonesburgh County Basketball Conference (JCBC) is an amateur basketball association. Each city in the county has one team as its representative. Each team has a maximum of 12 players and a minimum of 9 players. Each team also has up to three coaches (offensive, defensive, and

physical training coaches). During the season, each team plays two games (home and visitor) against each of the other teams. Given those conditions, do the following:

- a. Identify the connectivity of each relationship.
 - b. Identify the type of dependency that exists between CITY and TEAM.
 - c. Identify the cardinality between teams and players and between teams and city.
 - d. Identify the dependency between COACH and TEAM and between TEAM and PLAYER.
 - e. Draw the Chen and Crow's Foot ERDs to represent the JCBC database.
 - f. Draw the UML class diagram to depict the JCBC database.
4. Create an ERD based on the Crow's Foot notation, using the following requirements:
 - An INVOICE is written by a SALESREP. Each sales representative can write many invoices, but each invoice is written by a single sales representative.
 - The INVOICE is written for a single CUSTOMER. However, each customer can have many invoices.
 - An INVOICE can include many detail lines (LINE), each of which describes one product bought by the customer.
 - The product information is stored in a PRODUCT entity.
 - The product's vendor information is found in a VENDOR entity.
 5. The Hudson Engineering Group (HEG) has contacted you to create a conceptual model whose application will meet the expected database requirements for the company's training program. The HEG administrator gives you the following description of the training group's operating environment. (*Hint:* Some of the following sentences identify the volume of data rather than cardinalities. Can you tell which ones?) The HEG has 12 instructors and can handle up to 30 trainees per class. HEG offers five Advanced Technology courses, each of which may generate several classes. If a class has fewer than 10 trainees, it will be canceled. Therefore, it is possible for a course not to generate any classes. Each class is taught by one instructor. Each instructor may teach up to two classes or may be assigned to do research only. Each trainee may take up to two classes per year.

Given that information, do the following:

- a. Define all of the entities and relationships. (Use [Table 4.4](#) as your guide.)
 - b. Describe the relationship between instructor and class in terms of connectivity, cardinality, and existence dependence.
6. Automata, Inc. produces specialty vehicles by contract. The company operates several departments, each of which builds a particular vehicle, such as a limousine, a truck, a van, or an RV.
- Before a new vehicle is built, the department places an order with the purchasing department to request specific components. Automata's purchasing department is interested in creating a database to keep track of orders and to accelerate the process of delivering materials.
 - The order received by the purchasing department may contain several different items. An inventory is maintained so the most frequently requested items are delivered almost immediately. When an order comes in, it is checked to determine whether the requested item is in inventory. If an item is not in inventory, it must be ordered from a supplier. Each item may have several suppliers.

Given that functional description of the processes at Automata's purchasing department, do the following:

- a. Identify all of the main entities.
 - b. Identify all of the relations and connectivities among entities.
 - c. Identify the type of existence dependence in all the relationships.
 - d. Give at least two examples of the types of reports that can be obtained from the database.
7. United Helpers is a nonprofit organization that provides aid to people after natural disasters. Based on the following brief description of operations, create the appropriate fully labeled Crow's Foot ERD.
- Volunteers carry out the tasks of the organization. The name, address, and telephone number are tracked for each volunteer. Each volunteer may be assigned to several tasks, and some tasks require many volunteers. A volunteer might be in the system without having been assigned a task yet. It is possible to have tasks that no one has been assigned. When a volunteer is assigned to a task, the system should track the start time and end time of that assignment.
 - Each task has a task code, task description, task type, and task status.

For example, there may be a task with task code “101,” a description of “answer the telephone,” a type of “recurring,” and a status of “ongoing.” Another task might have a code of “102,” a description of “prepare 5,000 packages of basic medical supplies,” a type of “packing,” and a status of “open.”

- For all tasks of type “packing,” there is a packing list that specifies the contents of the packages. There are many packing lists to produce different packages, such as basic medical packages, child-care packages, and food packages. Each packing list has an ID number, a packing list name, and a packing list description, which describes the items that should make up the package. Every packing task is associated with only one packing list. A packing list may not be associated with any tasks, or it may be associated with many tasks. Tasks that are not packing tasks are not associated with any packing list.
- Packing tasks result in the creation of packages. Each individual package of supplies produced by the organization is tracked, and each package is assigned an ID number. The date the package was created and its total weight are recorded. A given package is associated with only one task. Some tasks (such as “answer the phones”) will not produce any packages, while other tasks (such as “prepare 5,000 packages of basic medical supplies”) will be associated with many packages.
- The packing list describes the *ideal* contents of each package, but it is not always possible to include the ideal number of each item. Therefore, the actual items included in each package should be tracked. A package can contain many different items, and a given item can be used in many different packages.
- Each item that the organization provides has an item ID number, item description, item value, and item quantity on hand stored in the system. Along with tracking the actual items that are placed in each package, the quantity of each item placed in the package must be tracked as well. For example, a packing list may state that basic medical packages should include 100 bandages, 4 bottles of iodine, and 4 bottles of hydrogen peroxide. However, because of the limited supply of items, a given package may include only 10 bandages, 1 bottle of iodine, and no hydrogen peroxide. The fact that the package includes bandages and iodine needs to be recorded along with the quantity of each item included . It is possible for the organization to have items that have not been included in any package yet, but every package will contain at least one item.

8. Using the Crow's Foot notation, create an ERD that can be implemented for a medical clinic, using the following business rules:

- A patient can make many appointments with one or more doctors in the clinic, and a doctor can accept appointments with many patients. However, each appointment is made with only one doctor and one patient.
- Emergency cases do not require an appointment. However, for appointment management purposes, an emergency is entered in the appointment book as “unscheduled.”
- If kept, an appointment yields a visit with the doctor specified in the appointment. The visit yields a diagnosis and, when appropriate, treatment.
- With each visit, the patient’s records are updated to provide a medical history.
- Each patient visit creates a bill. Each patient visit is billed by one doctor, and each doctor can bill many patients.
- Each bill must be paid. However, a bill may be paid in many installments, and a payment may cover more than one bill.
- A patient may pay the bill directly, or the bill may be the basis for a claim submitted to an insurance company.
- If the bill is paid by an insurance company, the deductible is submitted to the patient for payment.

NOTE

You can use the following cases and additional problems from the Instructor Online Companion as the basis for class projects. These problems illustrate the challenge of translating a description of operations into a set of business rules that will define the components for an ERD you can implement successfully. These problems can also be used as the basis for discussions about the components and contents of a proper description of operations. If you want to create databases that can be successfully implemented, you must learn to separate the generic background material from the details that directly affect database design. You must also keep in mind that many constraints cannot be incorporated into the database design; instead, such constraints are handled by the application software.

CASES

9. The administrators of Tiny College are so pleased with your design and implementation of their student registration and tracking system that they want you to expand the design to include the database for their motor vehicle pool. A brief description of operations follows:
- Faculty members may use the vehicles owned by Tiny College for officially sanctioned travel. For example, the vehicles may be used by faculty members to travel to off-campus learning centers, to travel to locations at which research papers are presented, to transport students to officially sanctioned locations, and to travel for public service purposes. The vehicles used for such purposes are managed by Tiny College's Travel Far But Slowly (TFBS) Center.
 - Using reservation forms, each department can reserve vehicles for its faculty, who are responsible for filling out the appropriate trip completion form at the end of a trip. The reservation form includes the expected departure date, vehicle type required, destination, and name of the authorized faculty member. The faculty member who picks up a vehicle must sign a checkout form to log out the vehicle and pick up a trip completion form. (The TFBS employee who releases the vehicle for use also signs the checkout form.) The faculty member's trip completion form includes the faculty member's identification code, the vehicle's identification, the odometer readings at the start and end of the trip, maintenance complaints (if any), gallons of fuel purchased (if any), and the Tiny College credit card number used to pay for the fuel. If fuel is purchased, the credit card receipt must be stapled to the trip completion form. Upon receipt of the trip completion form, the faculty member's department is billed at a mileage rate based on the vehicle type used: sedan, station wagon, panel truck, minivan, or minibus. (*Hint: Do not use more entities than are necessary. Remember the difference between attributes and entities!*)
 - All vehicle maintenance is performed by TFBS. Each time a vehicle requires maintenance, a maintenance log entry is completed on a prenumbered maintenance log form. The maintenance log form includes the vehicle identification, a brief description of the type of maintenance required, the initial log entry date, the date the maintenance was completed, and the name of the mechanic who released the vehicle back into service. (Only mechanics who have an inspection authorization may release a

vehicle back into service.)

- As soon as the log form has been initiated, the log form's number is transferred to a maintenance detail form; the log form's number is also forwarded to the parts department manager, who fills out a parts usage form on which the maintenance log number is recorded. The maintenance detail form contains separate lines for each maintenance item performed, for the parts used, and for identification of the mechanic who performed the maintenance. When all maintenance items have been completed, the maintenance detail form is stapled to the maintenance log form, the maintenance log form's completion date is filled out, and the mechanic who releases the vehicle back into service signs the form. The stapled forms are then filed, to be used later as the source for various maintenance reports.
- TFBS maintains a parts inventory, including oil, oil filters, air filters, and belts of various types. The parts inventory is checked daily to monitor parts usage and to reorder parts that reach the "minimum quantity on hand" level. To track parts usage, the parts manager requires each mechanic to sign out the parts that are used to perform each vehicle's maintenance; the parts manager records the maintenance log number under which the part is used.
- Each month TFBS issues a set of reports. The reports include the mileage driven by vehicle, by department, and by faculty members within a department. In addition, various revenue reports are generated by vehicle and department. A detailed parts usage report is also filed each month. Finally, a vehicle maintenance summary is created each month.

Given that brief summary of operations, draw the appropriate (and fully labeled) ERD. Use the Chen methodology to indicate entities, relationships, connectivities, and cardinalities.

10. During peak periods, Temporary Employment Corporation (TEC) places temporary workers in companies. TEC's manager gives you the following description of the business:
 - TEC has a file of candidates who are willing to work.
 - Any candidate who has worked before has a specific job history. (Naturally, no job history exists if the candidate has never worked.) Each time the candidate works, one additional job history record is created.
 - Each candidate has earned several qualifications. Each qualification may be earned by more than one candidate. (For example, more than one candidate may have earned a Bachelor of Business Administration degree

or a Microsoft Network Certification, and clearly a candidate may have earned both a BBA and a Microsoft Network Certification.)

- TEC offers courses to help candidates improve their qualifications.
- Every course develops one specific qualification; however, TEC does not offer a course for every qualification. Some qualifications are developed through multiple courses.
- Some courses cover advanced topics that require specific qualifications as prerequisites. Some courses cover basic topics that do not require any prerequisite qualifications. A course can have several prerequisites. A qualification can be a prerequisite for more than one course.
- Courses are taught during training sessions. A training session is the presentation of a single course. Over time, TEC will offer many training sessions for each course; however, new courses may not have any training sessions scheduled right away.
- Candidates can pay a fee to attend a training session. A training session can accommodate several candidates, although new training sessions will not have any candidates registered at first.
- TEC also has a list of companies that request temporaries.
- Each time a company requests a temporary employee, TEC makes an entry in the Openings folder. That folder contains an opening number, a company name, required qualifications, a starting date, an anticipated ending date, and hourly pay.
- Each opening requires only one specific or main qualification.
- When a candidate matches the qualification, the job is assigned, and an entry is made in the Placement Record folder. The folder contains such information as an opening number, a candidate number, and the total hours worked. In addition, an entry is made in the job history for the candidate.
- An opening can be filled by many candidates, and a candidate can fill many openings.
- TEC uses special codes to describe a candidate's qualifications for an opening. The list of codes is shown in [Table P4.10](#).

TABLE P4.10

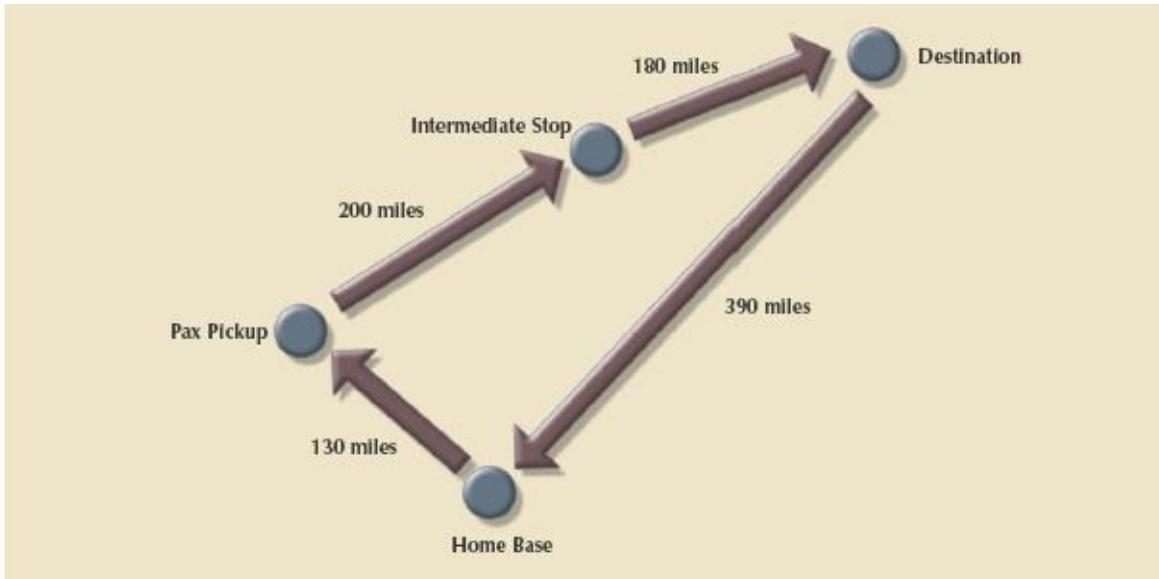
CODE	DESCRIPTION
SEC-45	Secretarial work; candidate must type at least 45 words per minute
SEC-60	Secretarial work; candidate must type at least 60 words per minute
CLERK	General clerking work
PRG-VB	Programmer, Visual Basic
PRG-C++	Programmer, C++
DBA-ORA	Database Administrator, Oracle
DBA-DB2	Database Administrator, IBM DB2
DBA-SQLSERV	Database Administrator, MS SQL Server
SYS-1	Systems Analyst, level 1
SYS-2	Systems Analyst, level 2
NW-NOV	Network Administrator, Novell experience
WD-CF	Web Developer, ColdFusion

TEC's management wants to keep track of the following entities:

COMPANY, OPENING, QUALIFICATION, CANDIDATE, JOB_HISTORY, PLACEMENT, COURSE, and SESSION. Given that information, do the following:

- a. Draw the Crow's Foot ERDs for this enterprise.
 - b. Identify all necessary relationships.
 - c. Identify the connectivity for each relationship.
 - d. Identify the mandatory and optional dependencies for the relationships.
 - e. Resolve all M:N relationships.
11. Use the following description of the operations of the RC_Charter2 Company to complete this exercise.
- The RC_Charter2 Company operates a fleet of aircraft under the Federal Air Regulations (FAR) Part 135 (air taxi or charter) certificate, enforced by the FAA. The aircraft are available for air taxi (charter) operations within the United States and Canada.
 - Charter companies provide so-called unscheduled operations—that is, charter flights take place only after a customer reserves the use of an aircraft at a designated date and time to fly to one or more designated destinations; the aircraft transports passengers, cargo, or some combination of passengers and cargo. Of course, a customer can reserve many different charter trips during any time frame. However, for billing purposes, each charter trip is reserved by one and only one customer. Some of RC_Charter2's customers do not use the company's charter operations; instead, they purchase fuel, use maintenance services, or use other RC_Charter2 services. However, this database design will focus on the charter operations only.
 - Each charter trip yields revenue for the RC_Charter2 Company. This revenue is generated by the charges a customer pays upon the completion of a flight. The charter flight charges are a function of aircraft model used, distance flown, waiting time, special customer requirements, and crew expenses. The distance flown charges are computed by multiplying the round-trip miles by the model's charge per mile. Round-trip miles are based on the actual navigational path flown. The sample route traced in [Figure P4.11](#) illustrates the procedure. Note that the number of round-trip miles is calculated to be $130 + 200 + 180 + 390 = 900$.
-

FIGURE P4.11 Round-trip mile determination



SOURCE: Course Technology/Cengage Learning

Depending on whether a customer has RC_Charter2 credit authorization, the customer may:

- Pay the entire charter bill upon the completion of the charter flight.
- Pay a part of the charter bill and charge the remainder to the account. The charge amount may not exceed the available credit.
- Charge the entire charter bill to the account. The charge amount may not exceed the available credit.
- Customers may pay all or part of the existing balance for previous charter trips. Such payments may be made at any time and are not necessarily tied to a specific charter trip. The charter mileage charge includes the expense of the pilot(s) and other crew required by FAR 135. However, if customers request *additional* crew not required by FAR 135, those customers are charged for the crew members on an hourly basis. The hourly crew-member charge is based on each crew member's qualifications.
- The database must be able to handle crew assignments. Each charter trip requires the use of an aircraft, and a crew flies each aircraft. The smaller, piston-engine charter aircraft require a crew consisting of only a single pilot. All jets and other aircraft that have a gross takeoff weight of at least 12,500 pounds require a pilot and a copilot, while some of the larger aircraft

used to transport passengers may require flight attendants as part of the crew. Some of the older aircraft require the assignment of a flight engineer, and larger cargo-carrying aircraft require the assignment of a loadmaster. In short, a crew can consist of more than one person, and not all crew members are pilots.

- The charter flight's aircraft waiting charges are computed by multiplying the hours waited by the model's hourly waiting charge. Crew expenses are limited to meals, lodging, and ground transportation.

The RC_Charter2 database must be designed to generate a monthly summary of all charter trips, expenses, and revenues derived from the charter records. Such records are based on the data that each pilot in command is required to record for each charter trip: trip date(s) and time(s), destination(s), aircraft number, pilot data and other crew data, distance flown, fuel usage, and other data pertinent to the charter flight. Such charter data are then used to generate monthly reports that detail revenue and operating cost information for customers, aircraft, and pilots. All pilots and other crew members are RC_Charter2 Company employees; that is, the company does not use contract pilots and crew.

FAR Part 135 operations are conducted under a strict set of requirements that govern the licensing and training of crew members. For example, pilots must have earned either a commercial license or an Airline Transport Pilot (ATP) license. Both licenses require appropriate ratings, which are specific competency requirements. For example:

- To operate a multiengine aircraft designed for takeoffs and landings on land only, the appropriate rating is MEL, or Multiengine Landplane. When a multiengine aircraft can take off and land on water, the appropriate rating is MES, or Multiengine Seaplane.
- The instrument rating is based on a demonstrated ability to conduct all flight operations with sole reference to cockpit instrumentation. The instrument rating is required to operate an aircraft under Instrument Meteorological Conditions (IMC), and all such operations are governed under FAR-specified Instrument Flight Rules (IFR). In contrast, operations conducted under "good weather" or *visual* flight conditions are based on the FAR Visual Flight Rules (VFR).
- The type rating is required for all aircraft with a takeoff weight of more than 12,500 pounds or for aircraft that are purely jet-powered. If an aircraft uses jet engines to drive propellers, that aircraft is said to be turboprop-

powered. A turboprop—that is, a turbo-propeller-powered aircraft—does not require a type rating unless it meets the 12,500-pound weight limitation.

- Although pilot licenses and ratings are not time limited, exercising the privilege of the license and ratings under Part 135 requires both *a current medical certificate and a current Part 135 checkride*. The following distinctions are important:
 - The medical certificate may be Class I or Class II. The Class I medical is more stringent than the Class II, and it must be renewed every six months. The Class II medical must be renewed yearly. If the Class I medical is not renewed during the six-month period, it automatically reverts to a Class II certificate. If the Class II medical is not renewed within the specified period, it automatically reverts to a Class III medical, which is not valid for commercial flight operations.
 - A Part 135 checkride is a practical flight examination that must be successfully completed every six months. The checkride includes all flight maneuvers and procedures specified in Part 135.

Nonpilot crew members must also have the proper certificates to meet specific job requirements. For example, loadmasters need an appropriate certificate, as do flight attendants. Crew members such as loadmasters and flight attendants may be required in operations that involve large aircraft with a takeoff weight of more than 12,500 pounds and more than 19 passengers; these crew members are also required to pass a written and practical exam periodically. The RC_Charter2 Company is required to keep a complete record of all test types, dates, and results for each crew member, as well as examination dates for pilot medical certificates.

In addition, all flight crew members are required to submit to periodic drug testing; the results must be tracked as well. Note that nonpilot crew members are not required to take pilot-specific tests such as Part 135 checkrides, nor are pilots required to take crew tests such as loadmaster and flight attendant practical exams. However, many crew members have licenses and certifications in several areas. For example, a pilot may have an ATP and a loadmaster certificate. If that pilot is assigned to be a loadmaster on a given charter flight, the loadmaster certificate is required. Similarly, a flight attendant may have earned a commercial pilot's license. Sample data formats are shown in [Table P4.11](#).

TABLE P4.11

PART A TESTS			
TEST CODE	TEST DESCRIPTION		TEST FREQUENCY
1	Part 135 Flight Check		6 months
2	Medical, Class I		6 months
3	Medical, Class II		12 months
4	Loadmaster Practical		12 months
5	Flight Attendant Practical		12 months
6	Drug test		Random
7	Operations, written exam		6 months
PART B RESULTS			
EMPLOYEE	TEST CODE	TEST DATE	TEST RESULT
101	1	12-Nov-11	Pass-1
103	6	23-Dec-11	Pass-1
112	4	23-Dec-11	Pass-2
103	7	11-Jan-12	Pass-1
112	7	16-Jan-12	Pass-1
101	7	16-Jan-12	Pass-1
101	6	11-Feb-12	Pass-2
125	2	15-Feb-12	Pass-1
PART C LICENSES AND CERTIFICATIONS			
LICENSE OR CERTIFICATE	LICENSE OR CERTIFICATE DESCRIPTION		
ATP	Airline Transport Pilot		
Comm	Commercial license		
Med-1	Medical certificate, Class I		
Med-2	Medical certificate, Class II		
Instr	Instrument rating		
MEL	Multiengine Land aircraft rating		
LM	Loadmaster		
FA	Flight Attendant		
EMPLOYEE	LICENSE OR CERTIFICATE	DATE EARNED	
101	Comm	12-Nov-93	
101	Instr	28-Jun-94	
101	MEL	9-Aug-94	
103	Comm	21-Dec-95	
112	FA	23-Jun-02	
103	Instr	18-Jan-96	
112	LM	27-Nov-05	

Pilots and other crew members must receive recurrency training appropriate to their work assignments. Recurrency training is based on an FAA-approved curriculum that is job-specific. For example, pilot recurrency training includes a review of all applicable Part 135 flight rules and regulations, weather data interpretation, company flight operations requirements, and specified flight procedures. The RC_Charter2 Company is required to keep a complete record of all recurrency training for each crew member subject to the training.

The RC_Charter2 Company is required to maintain a detailed record of all crew credentials and all training mandated by Part 135. The company must keep a

complete record of each requirement and of all compliance data.

To conduct a charter flight, the company must have a properly maintained aircraft available. A pilot who meets all of the FAA's licensing and currency requirements must fly the aircraft as Pilot in Command (PIC). For aircraft that are powered by piston engines or turboprops and have a gross takeoff weight under 12,500 pounds, single-pilot operations are permitted under Part 135 as long as a properly maintained autopilot is available. However, even if FAR Part 135 permits single-pilot operations, many customers require the presence of a copilot who is capable of conducting the flight operations under Part 135.

The RC_Charter2 operations manager anticipates the lease of turbojet-powered aircraft, which are required to have a crew consisting of a pilot and copilot. Both the pilot and copilot must meet the same Part 135 licensing, ratings, and training requirements.

The company also leases larger aircraft that exceed the 12,500-pound gross takeoff weight. Those aircraft might carry enough passengers to require the presence of one or more flight attendants. If those aircraft carry cargo that weighs more than 12,500 pounds, a loadmaster must be assigned as a crew member to supervise the loading and securing of the cargo. *The database must be designed to meet the anticipated capability for additional charter crew assignments.*

- a. Given this incomplete description of operations, write all applicable business rules to establish entities, relationships, optionalities, connectivities, and cardinalities. (*Hint:* Use the following five business rules as examples, and write the remaining business rules in the same format.)
 - A customer may request many charter trips.
 - Each charter trip is requested by only one customer.
 - Some customers have not yet requested a charter trip.
 - An employee may be assigned to serve as a crew member on many charter trips.
 - Each charter trip may have many employees assigned to serve as crew members.
- b. Draw the fully labeled and implementable Crow's Foot ERD based on the business rules you wrote in Part (a) of this problem. Include all entities, relationships, optionalities, connectivities, and cardinalities.

5 ADVANCED DATA MODELING

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
-

Preview

In the previous two chapters, you learned how to use entity relationship diagrams (ERDs) to properly create a data model. In this chapter, you will learn about the extended entity relationship (EER) model. The EER model builds on ER concepts and adds support for entity supertypes, subtypes, and entity clustering.

Most current database implementations are based on relational databases. Because the relational model uses keys to create associations among tables, it is essential to learn the characteristics of good primary keys and how to select them. Selecting a good primary key is too important to be left to chance, so this chapter covers the critical aspects of primary key identification and placement.

Focusing on practical database design, this chapter also illustrates some special design cases that highlight the importance of flexible designs, which can be adapted to meet the demands of changing data and information requirements. Data modeling is a vital step in the development of databases that in turn provides a good foundation for successful application development. Remember that good database applications cannot be based on bad database designs, and no amount of outstanding coding can overcome the limitations of poor database design.

5.1 THE EXTENDED ENTITY RELATIONSHIP MODEL

As the complexity of the data structures being modeled has increased and as application software requirements have become more stringent, the need to capture more information in the data model has increased. The [**extended entity relationship model \(EERM\)**](#), sometimes referred to as the enhanced entity relationship model, is the result of adding more semantic constructs to the original entity relationship (ER) model. As you might expect, a diagram that uses the EERM is called an [**EER diagram \(EERD\)**](#). In the following sections, you will learn about the main EER model constructs—entity supertypes, entity subtypes, and entity clustering—and see how they are represented in ERDs.

5.1.1 ENTITY SUPERTYPES AND SUBTYPES

Because most employees possess a wide range of skills and special qualifications, data modelers must find a variety of ways to group employees based on their characteristics. For instance, a retail company could group employees as salaried and hourly, while a university could group employees as faculty, staff, and administrators.

The grouping of employees into various *types* provides two important benefits:

- It avoids unnecessary nulls in attributes when some employees have characteristics that are not shared by other employees.
- It enables a particular employee type to participate in relationships that are unique to that employee type.

To illustrate those benefits, you will explore the case of an aviation business, which employs pilots, mechanics, secretaries, accountants, database managers, and many other types of employees. [**Figure 5.1**](#) illustrates how pilots share certain characteristics with other employees, such as a last name (EMP_LNAME) and hire date (EMP_HIRE_DATE). On the other hand, many pilot characteristics are not shared by other employees. For example, unlike other employees, pilots must meet special requirements such as flight hour restrictions, flight checks, and periodic training. Therefore, if all employee characteristics and special qualifications were stored in a single EMPLOYEE entity, you would have a lot of nulls or you would have to create a lot of needless dummy entries. In this case, special pilot characteristics such as

EMP_LICENSE, EMP_RATINGS, and EMP_MED_TYPE will generate nulls for employees who are not pilots. In addition, pilots participate in some relationships that are unique to their qualifications. For example, not all employees can fly airplanes; only employees who are pilots can participate in the “employee flies airplane” relationship.

FIGURE 5.1 Nulls created by unique attributes

Database name: Ch05_AirCo							
EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_LICENSE	EMP_RATINGS	EMP_MED_TYPE	EMP_HIRE_DATE
100	Kolmycz	Xavier	T				15-Mar-88
101	Lewis	Marcos		ATP	SEL/MEL/Instr/CFII	1	25-Apr-89
102	Vandam	Jean					20-Dec-93
103	Jones	Victoria	R				28-Aug-03
104	Lange	Edith		ATP	SEL/MEL/Instr	1	20-Oct-97
105	Williams	Gabriel	U	COM	SEL/MEL/Instr/CFI	2	08-Nov-97
106	Duzak	Mario		COM	SEL/MEL/Instr	2	05-Jan-04
107	Dianite	Venite	L				02-Jul-97
108	Wiesenbach	Joni					18-Nov-95
109	Travis	Brett	T	COM	SEL/MEL/SES/Instr/CFII	1	14-Apr-01
110	Genkazi	Stan					01-Dec-03

SOURCE: Course Technology/Cengage Learning

Based on the preceding discussion, you would correctly deduce that the PILOT entity stores only attributes that are unique to pilots, and that the EMPLOYEE entity stores attributes that are common to all employees. Based on that hierarchy, you can conclude that PILOT is a *subtype* of EMPLOYEE, and that EMPLOYEE is the *supertype* of PILOT. In modeling terms, an **entity supertype** is a generic entity type that is related to one or more **entity subtypes**. The entity supertype contains common characteristics, and the entity subtypes each contain their own unique characteristics.

Two criteria help the designer determine when to use subtypes and supertypes:

- There must be different, identifiable kinds or types of the entity in the user’s environment.
- The different kinds or types of instances should each have one or more attributes that are unique to that kind or type of instance.

In the preceding example, because pilots meet both criteria of being an identifiable kind of employee and having unique attributes that other employees do not possess, it is appropriate to create PILOT as a subtype of EMPLOYEE. Assume that mechanics and accountants also each have attributes that are unique to them, respectively, and that clerks do not. In that case, MECHANIC and ACCOUNTANT would also be legitimate subtypes of EMPLOYEE because they are identifiable kinds of employees and have unique attributes. CLERK would *not* be an acceptable subtype of EMPLOYEE because it only satisfies one of the criteria—it is an identifiable kind of employee—but none of the attributes are unique to just clerks. In the next section, you will learn how entity supertypes and subtypes are related in a specialization hierarchy.

5.1.2 SPECIALIZATION HIERARCHY

Entity supertypes and subtypes are organized in a **specialization hierarchy**, which depicts the arrangement of higherlevel entity supertypes (parent entities) and lower-level entity subtypes (child entities). [Figure 5.2](#) shows the specialization hierarchy formed by an EMPLOYEE supertype and three entity subtypes—PILOT, MECHANIC, and ACCOUNTANT. The specialization hierarchy reflects the 1:1 relationship between EMPLOYEE and its subtypes. For example, a PILOT subtype occurrence is related to one instance of the EMPLOYEE supertype, and a MECHANIC subtype occurrence is related to one instance of the EMPLOYEE supertype. The terminology and symbols in [Figure 5.2](#) are explained throughout this chapter.

The relationships depicted within the specialization hierarchy are sometimes described in terms of “is-a” relationships. For example, a pilot *is an* employee, a mechanic *is an* employee, and an accountant *is an* employee. It is important to understand that within a specialization hierarchy, a subtype can exist only within the context of a supertype, and every subtype can have only one supertype to which it is directly related. However, a specialization hierarchy can have many levels of supertype/subtype relationships—that is, you can have a specialization hierarchy in which a supertype has many subtypes. In turn, one of the subtypes is the supertype to other lower-level subtypes.



ONLINE CONTENT

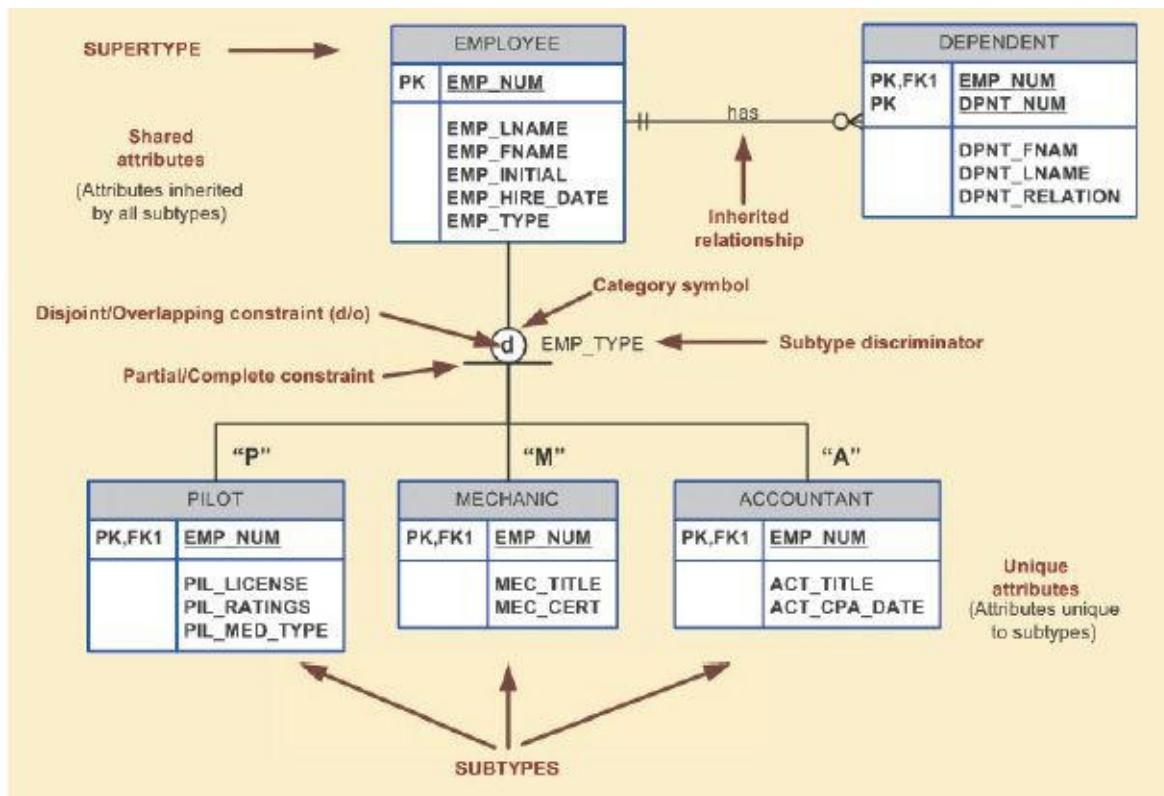
This chapter covers only specialization hierarchies. The EER model also supports specialization *lattices*, in which a subtype can have multiple parents (supertypes). However, those concepts are better covered under the object-oriented model in **Appendix G, Object-Oriented Databases**. The appendix is available at www.cengagebrain.com.

As you can see in [Figure 5.2](#), the arrangement of entity supertypes and subtypes in a specialization hierarchy is more than a cosmetic convenience. Specialization hierarchies enable the data model to capture additional semantic content (meaning) into the ERD. A 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.

The following sections cover such characteristics and constraints in more detail.

FIGURE 5.2 A specialization hierarchy



SOURCE: Course Technology/Cengage Learning

5.1.3 INHERITANCE

The property of **inheritance** enables an entity subtype to inherit the attributes and relationships of the supertype. As discussed earlier, a supertype contains attributes that are common to all of its subtypes. In contrast, subtypes contain only the attributes that are unique to the subtype. For example, [Figure 5.2](#) illustrates that pilots, mechanics, and accountants all inherit the employee number, last name, first name, middle initial, and hire date from the EMPLOYEE entity. However, [Figure 5.2](#) also illustrates that pilots have unique attributes; the same is true for mechanics and accountants. *One important inheritance characteristic is that all entity subtypes inherit their primary key attribute from their supertype.* Note in [Figure 5.2](#) that the EMP_NUM attribute is the primary key for each of the subtypes.

At the implementation level, the supertype and its subtype(s) depicted in the specialization hierarchy maintain a 1:1 relationship. For example, the specialization hierarchy lets you replace the undesirable EMPLOYEE table structure in [Figure 5.1](#) with two tables—one representing the supertype

EMPLOYEE and the other representing the subtype PILOT. (See [Figure 5.3](#).)

Entity subtypes inherit all relationships in which the supertype entity participates. For example, [Figure 5.2](#) shows the EMPLOYEE entity supertype participating in a 1:M relationship with a DEPENDENT entity. Through inheritance, all subtypes also participate in that relationship. In specialization hierarchies with multiple levels of supertype and subtypes, a lower-level subtype inherits all of the attributes and relationships from all of its upper-level supertypes.

FIGURE 5.3 The EMPLOYEE-PILOT supertype-subtype relationship

Table name: EMPLOYEE						Database name: Ch05_AirCo			
EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIRE_DATE	EMP_TYPE	EMP_NUM	PIL_LICENSE	PIL_RATINGS	PIL_MED_TYPE
100 Kolmycz	Xavier	T		15-Mar-88		101 ATP	SEL/MEL/Instr/CFII	1	
101 Lewis	Marcos			25-Apr-89 P		104 ATP	SEL/MEL/Instr	1	
102 Vandam	Jean			20-Dec-93 A		105 COM	SEL/MEL/Instr/CFI	2	
103 Jones	Victoria	R		28-Aug-03		106 COM	SEL/MEL/Instr	2	
104 Lange	Edith			20-Oct-97 P		109 COM	SEL/MEL/SES/Instr/CFII	1	
105 Williams	Gabriel	U		08-Nov-97 P					
106 Duzak	Mario			05-Jan-04 P					
107 Dianto	Venite	L		02-Jul-97 M					
108 Wiesenbach	Joni			18-Nov-95 M					
109 Travis	Brett	T		14-Apr-01 P					
110 Genkazi	Stan			01-Dec-03 A					

SOURCE: Course Technology/Cengage Learning

5.1.4 SUBTYPE DISCRIMINATOR

A **subtype discriminator** is the attribute in the supertype entity that determines to which subtype the supertype occurrence is related. In [Figure 5.2](#), the subtype discriminator is the employee type (EMP_TYPE).

It is common practice to show the subtype discriminator and its value for each subtype in the ER diagram, as shown in [Figure 5.2](#). However, not all ER modeling tools follow that practice. For example, MS Visio shows the subtype discriminator but not its value. In [Figure 5.2](#), the Visio text tool was used to manually add the discriminator value above the entity subtype, close to the connector line. Using [Figure 5.2](#) as your guide, note that the supertype is related to a PILOT subtype if the EMP_TYPE has a value of “P.” If the EMP_TYPE value is “M,” the supertype is related to a MECHANIC subtype. If the EMP_TYPE value is “A,” the supertype is related to the ACCOUNTANT

subtype.

Note that the default comparison condition for the subtype discriminator attribute is the equality comparison. However, in some situations the subtype discriminator is not necessarily based on an equality comparison. For example, based on business requirements, you might create two new pilot subtypes: pilot-in-command (PIC)-qualified and copilot-qualified only. A PIC-qualified pilot must have more than 1,500 PIC flight hours. In this case, the subtype discriminator would be “Flight_Hours,” and the criteria would be $> 1,500$ or $\leq 1,500$, respectively.

NOTE

In Visio, you select the subtype discriminator when creating a category by using the Category shape from the available shapes. The Category shape is a small circle with a horizontal line underneath that connects the supertype to its subtypes.



ONLINE CONTENT

For a tutorial on using MS Visio to create a specialization hierarchy, see **Appendix A, Designing Databases with Visio Professional: A Tutorial**, at www.cengagebrain.com.

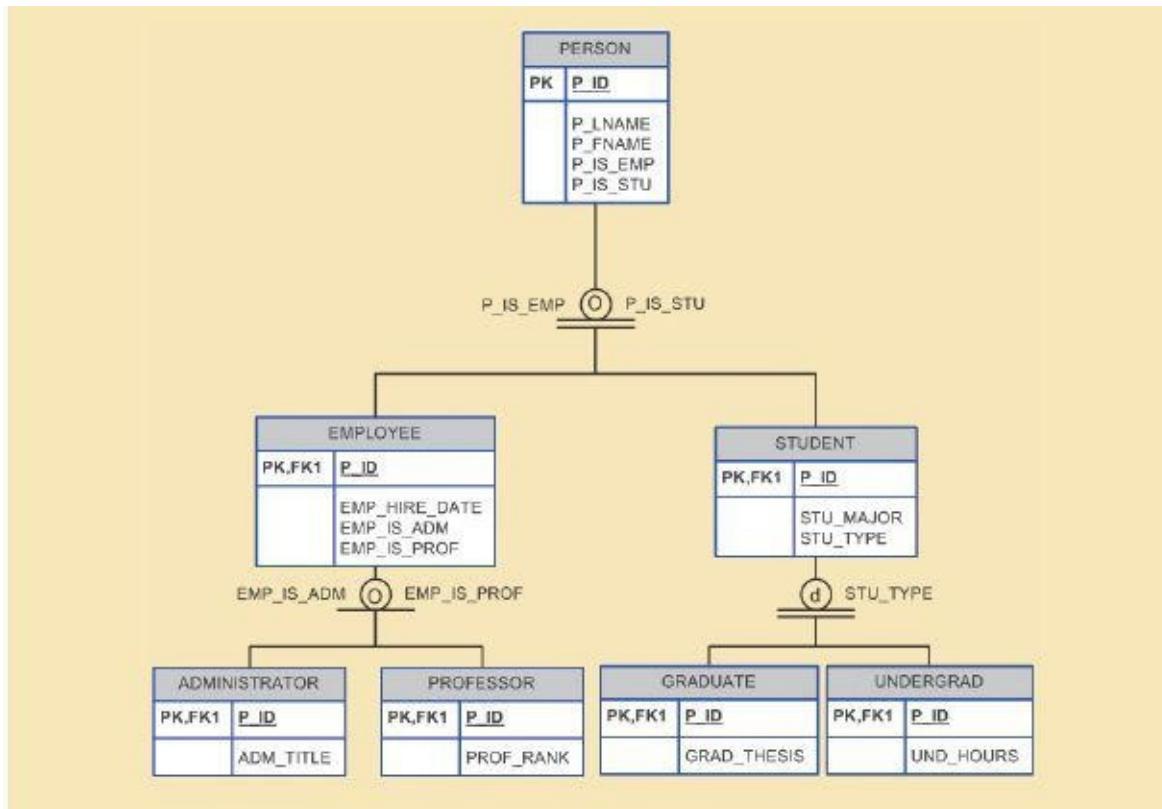
5.1.5 DISJOINT AND OVERLAPPING CONSTRAINTS

An entity supertype can have disjoint or overlapping entity subtypes. In the aviation example, an employee can be a pilot, a mechanic, or an accountant. Assume that one of the business rules dictates that an employee cannot belong to more than one subtype at a time; that is, an employee cannot be a pilot and a mechanic at the same time. **Disjoint subtypes**, also known as **nonoverlapping subtypes**, are subtypes that contain a *unique* subset of the supertype entity set; in other words, each entity instance of the supertype can appear in only one of the

subtypes. For example, in [Figure 5.2](#), an employee (supertype) who is a pilot (subtype) can appear only in the PILOT subtype, not in any of the other subtypes. In Visio, such disjoint subtypes are indicated by the letter *d* inside the category shape.

On the other hand, if the business rule specifies that employees can have multiple classifications, the EMPLOYEE supertype may contain *overlapping* job classification subtypes. [Overlapping subtypes](#) are subtypes that contain nonunique subsets of the supertype entity set; that is, each entity instance of the supertype may appear in more than one subtype. For example, in a university environment, a person may be an employee, a student, or both. In turn, an employee may be a professor as well as an administrator. Because an employee may also be a student, STUDENT and EMPLOYEE are overlapping subtypes of the supertype PERSON, just as PROFESSOR and ADMINISTRATOR are overlapping subtypes of the supertype EMPLOYEE. [Figure 5.4](#) illustrates overlapping subtypes with the letter *o* inside the category shape.

FIGURE 5.4 Specialization hierarchy with overlapping subtypes



It is common practice to show disjoint and overlapping symbols in the ERD. (See [Figures 5.2](#) and [5.4](#).) However, not all ER modeling tools follow that practice. For example, by default, Visio shows only the subtype discriminator (using the Category shape), but not the disjoint and overlapping symbols. The Visio text tool was used to manually add the *d* and *o* symbols in [Figures 5.2](#) and [5.4](#).

NOTE

Alternative notations exist for representing disjoint and overlapping subtypes. For example, Toby J. Teorey popularized the use of G and Gs to indicate disjoint and 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.

As you learned earlier in this section, the implementation of disjoint subtypes is based on the value of the subtype discriminator attribute in the supertype. However, *implementing* overlapping subtypes requires the use of one discriminator attribute for each subtype. For example, in the case of the Tiny College database design in [Chapter 4](#), Entity Relationship (ER) Modeling, a professor can also be an administrator. Therefore, the EMPLOYEE supertype would have the subtype discriminator attributes and values shown in [Table 5.1](#).

5.1.6 COMPLETENESS CONSTRAINT

The **completeness constraint** specifies whether each entity supertype occurrence must also be a member of at least one subtype. The completeness

constraint can be partial or total. **Partial completeness** means that not every supertype occurrence is a member of a subtype; some supertype occurrences may not be members of any subtype. **Total completeness** means that every supertype occurrence must be a member of at least one subtype.

The ERDs in [Figures 5.2](#) and [5.4](#) represent the completeness constraint based on the Visio Category shape. A single horizontal line under the circle represents a partial completeness constraint; a double horizontal line under the circle represents a total completeness constraint.

NOTE

Alternative notations exist to represent the completeness constraint. For example, some notations use a single line (partial) or double line (total) to connect the supertype to the Category shape.

Given the disjoint and overlapping subtypes and completeness constraints, it is possible to have the specialization hierarchy constraint scenarios shown in [Table 5.2](#).

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 at least one subtype. Subtype discriminators cannot be null. Subtype sets are not unique.

5.1.7 SPECIALIZATION AND GENERALIZATION

You can use various approaches to develop entity supertypes and subtypes. For example, you can first identify a regular entity, and then identify all entity subtypes based on their distinguishing characteristics. You can also start by identifying multiple entity types and then later extract the common

characteristics of those entities to create a higherlevel supertype entity.

Specialization is the top-down process of identifying lower-level, more specific entity subtypes from a higherlevel entity supertype. Specialization is based on grouping the unique characteristics and relationships of the subtypes. In the aviation example, you used specialization to identify multiple entity subtypes from the original employee supertype. **Generalization** is the bottom-up process of identifying a higherlevel, more generic entity supertype from lower-level entity subtypes. Generalization is based on grouping the common characteristics and relationships of the subtypes. For example, you might identify multiple types of musical instruments: piano, violin, and guitar. Using the generalization approach, you could identify a “string instrument” entity supertype to hold the common characteristics of the multiple subtypes.

5.2 ENTITY CLUSTERING

Developing an ER diagram entails the discovery of possibly hundreds of entity types and their respective relationships. Generally, the data modeler will develop an initial ERD that contains a few entities. As the design approaches completion, the ERD will contain hundreds of entities and relationships that crowd the diagram to the point of making it unreadable and inefficient as a communication tool. In those cases, you can use entity clusters to minimize the number of entities shown in the ERD.

An **entity cluster** is a “virtual” entity type used to represent multiple entities and relationships in the ERD. An entity cluster is formed by combining multiple interrelated entities into a single, abstract entity object. An entity cluster is considered “virtual” or “abstract” in the sense that it is not actually an entity in the final ERD. Instead, it is a temporary entity used to represent multiple entities and relationships, with the purpose of simplifying the ERD and thus enhancing its readability.

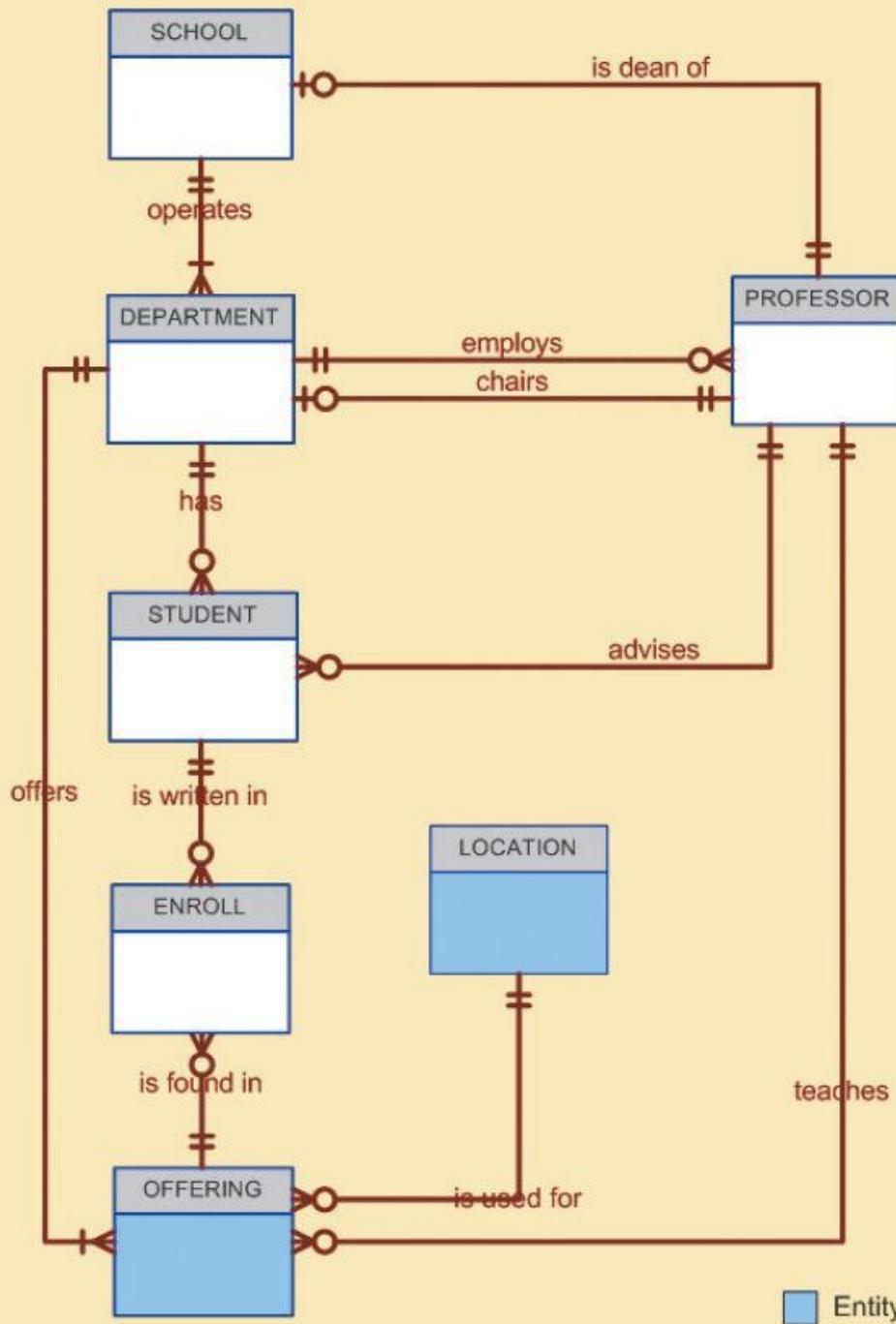
[Figure 5.5](#) illustrates the use of entity clusters based on the Tiny College example in [Chapter 4](#). Note that the ERD contains two entity clusters:

- OFFERING, which groups the COURSE and CLASS entities and relationships.

- LOCATION, which groups the ROOM and BUILDING entities and relationships.

Note also that the ERD in [Figure 5.5](#) does not show attributes for the entities. When using entity clusters, the key attributes of the combined entities are no longer available. Without the key attributes, primary key inheritance rules change. In turn, the change in the inheritance rules can have undesirable consequences, such as changes in relationships—from identifying to nonidentifying or vice versa—and the loss of foreign key attributes from some entities. To eliminate those problems, the general rule is to *avoid the display of attributes when entity clusters are used*.

FIGURE 5.5 Tiny College ERD using entity clusters



SOURCE: Course Technology/Cengage Learning

5.3 ENTITY INTEGRITY: SELECTING PRIMARY KEYS

Arguably, the most important characteristic of an entity is its primary key (a single attribute or some combination of attributes), which uniquely identifies each entity instance. The primary key's function is to guarantee entity integrity. Furthermore, primary keys and foreign keys work together to implement relationships in the relational model. Therefore, the importance of properly selecting the primary key has a direct bearing on the efficiency and effectiveness of database implementation.

5.3.1 NATURAL KEYS AND PRIMARY KEYS

The concept of a unique identifier is commonly encountered in the real world. For example, you use class or section numbers to register for classes, invoice numbers to identify specific invoices, and account numbers to identify credit cards. Those examples illustrate natural identifiers or keys. A **natural key** or **natural identifier** is a real-world, generally accepted identifier used to distinguish—that is, uniquely identify—real-world objects. As its name implies, a natural key is familiar to end users and forms part of their day-to-day business vocabulary.

Usually, if an entity *has* a natural identifier, a data modeler uses it as the primary key of the entity being modeled. Generally, most natural keys make acceptable primary key identifiers. The next section presents some basic guidelines for selecting primary keys.

5.3.2 PRIMARY KEY GUIDELINES

A primary key is the attribute or combination of attributes that uniquely identifies entity instances in an entity set. However, can the primary key be based on, say, 12 attributes? And just how long can a primary key be? In previous examples, why was EMP_NUM selected as a primary key of EMPLOYEE and not a combination of EMP_LNAME, EMP_FNAME, EMP_INITIAL, and EMP_DOB? Can a single, 256-byte text attribute be a good primary key? There is no single answer to those questions, but database experts have built a body of practice over the years. This section examines that body of documented practices.

First, you should understand the function of a primary key. Its main function is to uniquely identify an entity instance or row within a table. In particular, given a primary key value—that is, the determinant—the relational model can determine the value of all dependent attributes that “describe” the entity. Note that

identification and description are separate semantic constructs in the model. *The function of the primary key is to guarantee entity integrity, not to “describe” the entity.*

Second, primary keys and foreign keys are used to implement relationships among entities. However, the implementation of such relationships is done mostly behind the scenes, hidden from end users. In the real world, end users identify objects based on the characteristics they know about the objects. For example, when shopping at a grocery store, you select products by taking them from a display shelf and reading the labels, not by looking at the stock number. It is wise for database applications to mimic the human selection process as much as possible. Therefore, database applications should let the end user choose among multiple descriptive narratives of different objects, while using primary key values behind the scenes. Keeping those concepts in mind, look at [Table 5.3](#), which summarizes desirable primary key characteristics.

5.3.3 WHEN TO USE COMPOSITE PRIMARY KEYS

In the previous section, you learned about the desirable characteristics of primary keys. For example, you learned that the primary key should use the minimum number of attributes possible. However, that does *not* mean that composite primary keys are not permitted in a model. In fact, composite primary keys are particularly useful in two cases:

- As identifiers of composite entities, in which each primary key combination is allowed only once in the M:N relationship.
- As identifiers of weak entities, in which the weak entity has a strong identifying relationship with the parent entity.

To illustrate the first case, assume that you have a STUDENT entity set and a CLASS entity set. In addition, assume that those two sets are related in an M:N relationship via an ENROLL entity set, in which each student/class combination may appear only once in the composite entity. [Figure 5.6](#) shows the ERD to represent such a relationship.

As shown in [Figure 5.6](#), the composite primary key automatically provides the benefit of ensuring that there cannot be duplicate values—that is, it ensures that the same student cannot enroll more than once in the same class.

TABLE 5.3 Desirable Primary Key Characteristics

PK CHARACTERISTIC	RATIONALE
Unique values	The PK must uniquely identify each entity instance. A primary key must be able to guarantee unique values. It cannot contain nulls.
Nonintelligent	The PK should not have embedded semantic meaning other than to uniquely identify each entity instance. An attribute with embedded semantic meaning is probably better used as a descriptive characteristic of the entity than as an identifier. For example, a student ID of 650973 would be preferred over <i>Smith, Martha L.</i> as a primary key identifier.
No change over time	If an attribute has semantic meaning, it might be subject to updates, which is why names do not make good primary keys. If Vickie Smith is the primary key, what happens if she changes her name when she gets married? If a primary key is subject to change, the foreign key values must be updated, thus adding to the database work load. Furthermore, changing a primary key value means that you are basically changing the identity of an entity. In short, the PK should be permanent and unchangeable.
	A primary key should have the minimum number of attributes possible (irreducible). Single-attribute primary keys are desirable but not required. Single-attribute primary keys simplify the implementation of foreign keys.

Preferably single-attribute	Having multiple attribute primary keys can cause primary keys of related entities to grow through the possible addition of many attributes, thus adding to the database work load and making (application) coding more cumbersome.
Preferably numeric	Unique values can be better managed when they are numeric, because the database can use internal routines to implement a counter-style attribute that automatically increments values with the addition of each new row. In fact, most database systems include the ability to use special constructs, such as Autonumber in Microsoft Access, to support self-incrementing primary key attributes.
Security-compliant	The selected primary key must not be composed of any attribute(s) that might be considered a security risk or violation. For example, using a Social Security number as a PK in an EMPLOYEE table is not a good idea.

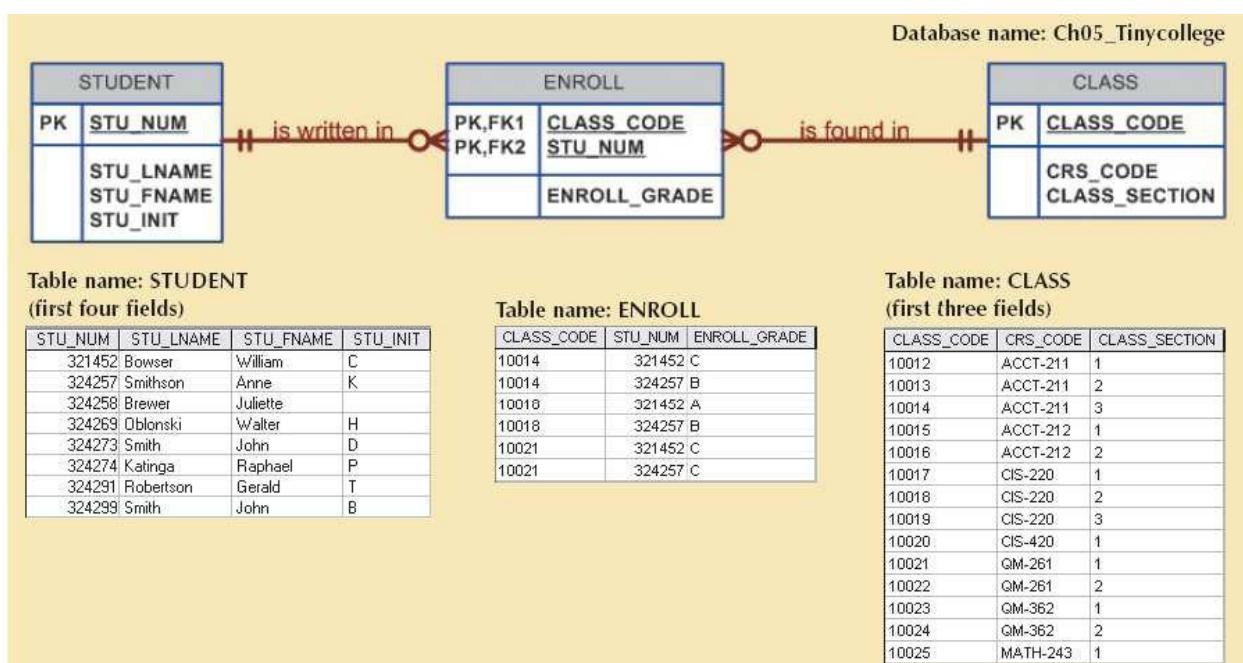
In the second case, a weak entity in a strong identifying relationship with a parent entity is normally used to represent one of two situations:

1. *A real-world object that is existence-dependent on another real-world object.* Such objects are distinguishable in the real world. A dependent and an employee are two separate people who exist independently of each other. However, such objects can exist in the model only when they relate to each other in a strong identifying relationship. For example, the relationship between EMPLOYEE and DEPENDENT is one of existence dependency, in which the primary key of the dependent entity is a composite key that contains the key of the parent entity.
2. *A real-world object that is represented in the data model as two separate entities in a strong identifying relationship.* For example, the real-world invoice object is represented by two entities in a data model: INVOICE and LINE. Clearly, the LINE entity does not exist in the real world as an

independent object, but as part of an INVOICE.

In both situations, having a strong identifying relationship ensures that the dependent entity can exist only when it is related to the parent entity. In summary, the selection of a composite primary key for composite and weak entity types provides benefits that enhance the integrity and consistency of the model.

FIGURE 5.6 The M:N relationship between STUDENT and CLASS



SOURCE: Course Technology/Cengage Learning

5.3.4 WHEN TO USE SURROGATE PRIMARY KEYS

In some instances a primary key doesn't exist in the real world or the existing natural key might not be a suitable primary key. In these cases, it is standard practice to create a surrogate key. A surrogate key is a primary key created by the database designer to simplify the identification of entity instances. The surrogate key has no meaning in the user's environment—it exists only to distinguish one entity instance from another. One practical advantage of a surrogate key is that because it has no intrinsic meaning, values for it can be

generated by the DBMS to ensure that unique values are always provided.

For example, consider the case of a park recreation facility that rents rooms for small parties. The manager of the facility keeps track of all events, using a folder with the format shown in [Table 5.4](#).

TABLE 5.4 Data Used to Keep Track of Events

DATE	TIME_START	TIME_END	ROOM	EVENT_NAME	PARTY_OF
6/17/2012	11:00AM	2:00PM	Allure	Burton Wedding	60
6/17/2012	11:00AM	2:00PM	Bonanza	Adams Office	12
6/17/2012	3:00PM	5:30PM	Allure	Smith Family	15
6/17/2012	3:30PM	5:30PM	Bonanza	Adams Office	12
6/18/2012	1:00PM	3:00PM	Bonanza	Boy Scouts	33
6/18/2012	11:00AM	2:00PM	Allure	March of Dimes	25
6/18/2012	11:00AM	12:30PM	Bonanza	Smith Family	12

Given the data shown in [Table 5.4](#), you would model the EVENT entity as:

EVENT (DATE, TIME_START, TIME_END, ROOM, EVENT_NAME, PARTY_OF)

What primary key would you suggest? In this case, there is no simple natural key that could be used as a primary key in the model. Based on the primary key concepts you learned in previous chapters, you might suggest one of these options:

(DATE, TIME_START, ROOM) or (DATE, TIME_END, ROOM)

Assume that you select the composite primary key **(DATE, TIME_START, ROOM)** for the EVENT entity. Next, you determine that one EVENT may use many RESOURCES (such as tables, projectors, PCs, and stands), and that the same RESOURCE may be used for many EVENTS. The RESOURCE entity would be represented by the following attributes:

RESOURCE (RSC_ID, RSC_DESCRIPTION, RSC_TYPE, RSC_QTY, RSC_PRICE)

Given the business rules, the M:N relationship between RESOURCE and EVENT would be represented via the EVNTRSC composite entity with a composite primary key as follows:

EVNTRSC (DATE, TIME_START, ROOM, RSC_ID, QTY_USED)

You now have a lengthy, four-attribute composite primary key. What would happen if the EVNTRSC entity's primary key were inherited by another existence-dependent entity? At this point, you can see that the composite primary key could make the database implementation and program coding unnecessarily complex.

As a data modeler, you probably noticed that the EVENT entity's selected primary key might not fare well, given the primary key guidelines in [Table 5.3](#). In this case, the EVENT entity's selected primary key contains embedded semantic information and is formed by a combination of date, time, and text data columns. In addition, the selected primary key would cause lengthy primary keys for existence-dependent entities. The preferred alternative is to use a numeric, single-attribute surrogate primary key.

Surrogate primary keys are accepted practice in today's complex data environments. They are especially helpful when there is no natural key, when the selected candidate key has embedded semantic contents, or when the selected candidate key is too long or cumbersome. However, there is a trade-off: if you use a surrogate key, you must ensure that the candidate key of the entity in question performs properly through the use of "unique index" and "not null" constraints.

5.4 DESIGN CASES: LEARNING FLEXIBLE DATABASE DESIGN

Data modeling and database design require skills that are acquired through experience. In turn, experience is acquired through practice—regular and frequent repetition, applying the concepts learned to specific and different design problems. This section presents four special design cases that highlight the importance of flexible designs, proper identification of primary keys, and placement of foreign keys.

NOTE

In describing the various modeling concepts throughout this book, the focus is on relational models. Also, given the focus on the practical nature of

database design, all design issues are addressed with the implementation goal in mind. Therefore, there is no sharp line of demarcation between design and implementation.

At the pure conceptual stage of the design, foreign keys are not part of an ER diagram. The ERD displays only entities and relationships. Entity instances are distinguished by identifiers that may become primary keys. During design, the modeler attempts to understand and define the entities and relationships. Foreign keys are the mechanism through which the relationship designed in an ERD is implemented in a relational model. If you use Visio Professional as your modeling tool, you will discover that this book's methodology is reflected in the Visio modeling practice.

5.4.1 DESIGN CASE 1: IMPLEMENTING 1:1 RELATIONSHIPS

Foreign keys work with primary keys to properly implement relationships in the relational model. The basic rule is very simple: put the primary key of the “one” side (the parent entity) on the “many” side (the dependent entity) as a foreign key. However, where do you place the foreign key when you are working with a 1:1 relationship? For example, take the case of a 1:1 relationship between EMPLOYEE and DEPARTMENT based on the business rule “one EMPLOYEE is the manager of one DEPARTMENT, and one DEPARTMENT is managed by one EMPLOYEE.” In that case, there are two options for selecting and placing the foreign key:

1. *Place a foreign key in both entities.* This option is derived from the basic rule you learned in [Chapter 4](#). Place EMP_NUM as a foreign key in DEPARTMENT, and place DEPT_ID as a foreign key in EMPLOYEE. However, this solution is not recommended because it duplicates work, and it could conflict with other existing relationships. (Remember that DEPARTMENT and EMPLOYEE also participate in a 1:M relationship—one department employs many employees.)
2. *Place a foreign key in one of the entities.* In that case, the primary key of one of the two entities appears as a foreign key in the other entity. That is the preferred solution, but a question remains: *which* primary key should be used as a foreign key? The answer is found in [Table 5.5](#), which shows the rationale for selecting the foreign key in a 1:1 relationship based on the relationship properties in the ERD.

TABLE 5.5 Selection of Foreign Key in a 1:1 Relationship

ER CASE RELATIONSHIP ACTION CONSTRAINTS

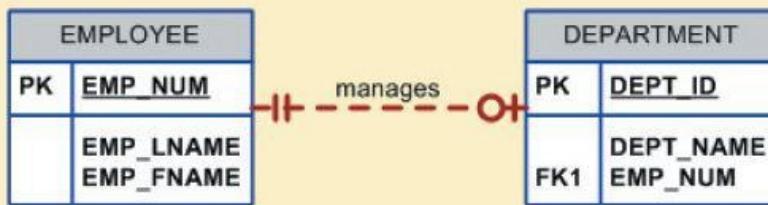
I	One side is mandatory and the other side is optional.	Place the PK of the entity on the mandatory side in the entity on the optional side as a FK, and make the FK mandatory.
II	Both sides are optional.	Select the FK that causes the fewest nulls, or place the FK in the entity in which the (relationship) 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.

[Figure 5.7](#) illustrates the “EMPLOYEE manages DEPARTMENT” relationship. Note that in this case, EMPLOYEE is mandatory to DEPARTMENT. Therefore, EMP_NUM is placed as the foreign key in DEPARTMENT. Alternatively, you might also argue that the “manager” role is played by the EMPLOYEE in the DEPARTMENT.

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.



As a designer, you must recognize that 1:1 relationships exist in the real world; therefore, they should be supported in the data model. In fact, a 1:1 relationship is used to ensure that two entity sets are not placed in the same table. In other words, EMPLOYEE and DEPARTMENT are clearly separate and unique entity types that do not belong together in a single entity. If you grouped them together in one entity, what would you name that entity?

5.4.2 DESIGN CASE 2: MAINTAINING HISTORY OF TIME-VARIANT DATA

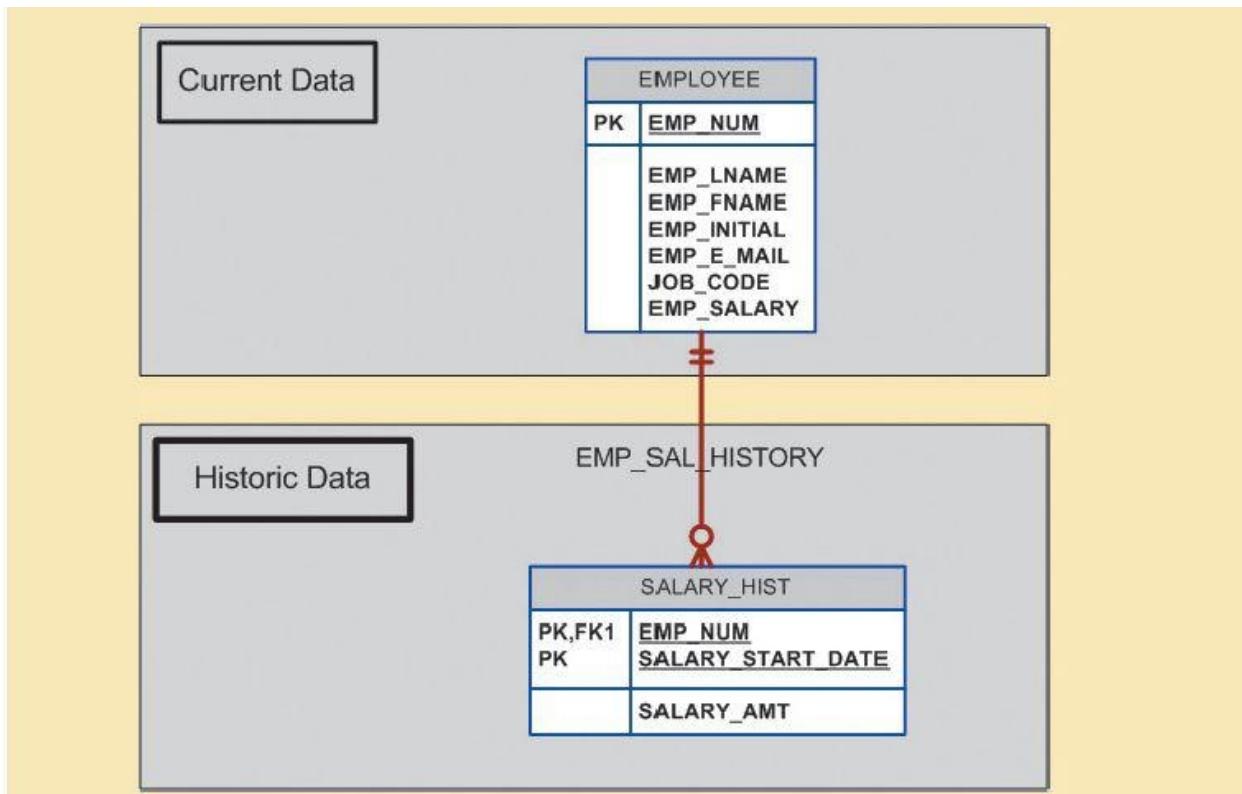
Company managers generally realize that good decision making is based on the information generated through the data stored in databases. Such data reflect both current and past events. Company managers use the data stored in databases to answer questions such as: “How do the current company profits compare to those of previous years?” and “What are XYZ product’s sales trends?” In other words, the data stored in databases reflect not only current data, but historic data.

Normally, data changes are managed by replacing the existing attribute value with the new value, without regard to the previous value. However, in some situations the history of values for a given attribute must be preserved. From a data-modeling point of view, **timevariant data** refer to data whose values change over time and for which you *must* keep a history of the data changes. You could argue that all data in a database are subject to change over time and are therefore time variant. However, some attribute values, such as your date of birth or your Social Security number, are not time variant. On the other hand, attributes such as your student GPA or your bank account balance are subject to change over time. Sometimes the data changes are externally originated and event driven, such as a product price change. On other occasions, changes are based on well-defined schedules, such as the daily stock quote “open” and “close” values.

The storage of timevariant data requires changes in the data model; the type of change depends on the nature of the data. Some timevariant data is equivalent to having a multivalued attribute in your entity. To model this type of timevariant data, you must create a new entity in a 1:M relationship with the original entity. This new entity will contain the new value, the date of the change, and any other attribute that is pertinent to the event being modeled. For example, if you want to track salary histories for each employee, then the EMP_SALARY attribute

becomes multivalued, as shown in [Figure 5.8](#). In this case, for each employee, there will be one or more records in the SALARY_HIST entity, which stores the salary amount and the date when the new salary goes into effect.

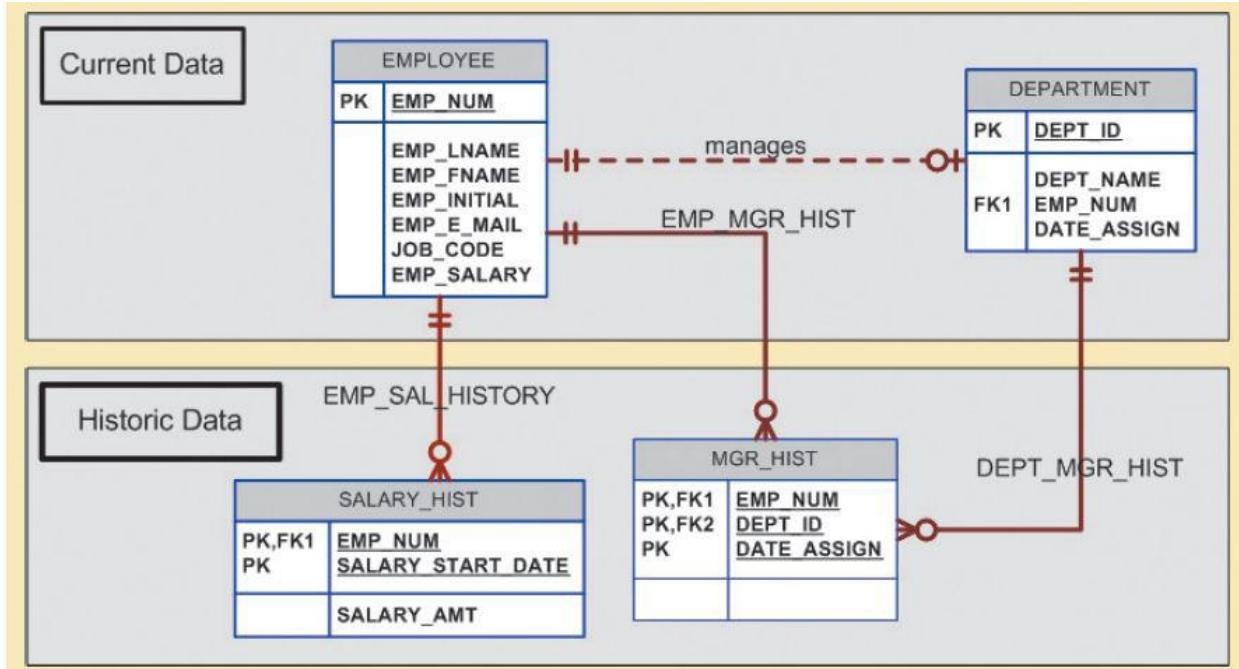
FIGURE 5.8 Maintaining salary history



SOURCE: Course Technology/Cengage Learning

Other timevariant data can turn a 1:M relationship into an M:N relationship. Assume that in addition to employee data, your data model includes data about the different departments in the organization and which employee manages each department. Assuming that each department is managed by only one employee and each employee can manage one department at most, then a 1:1 relationship would exist between **EMPLOYEE** and **DEPARTMENT**. This relationship would record the current manager of each department. However, if you want to keep track of the history of all department managers as well as the current manager, you can create the model shown in [Figure 5.9](#).

FIGURE 5.9 Maintaining manager history



SOURCE: Course Technology/Cengage Learning

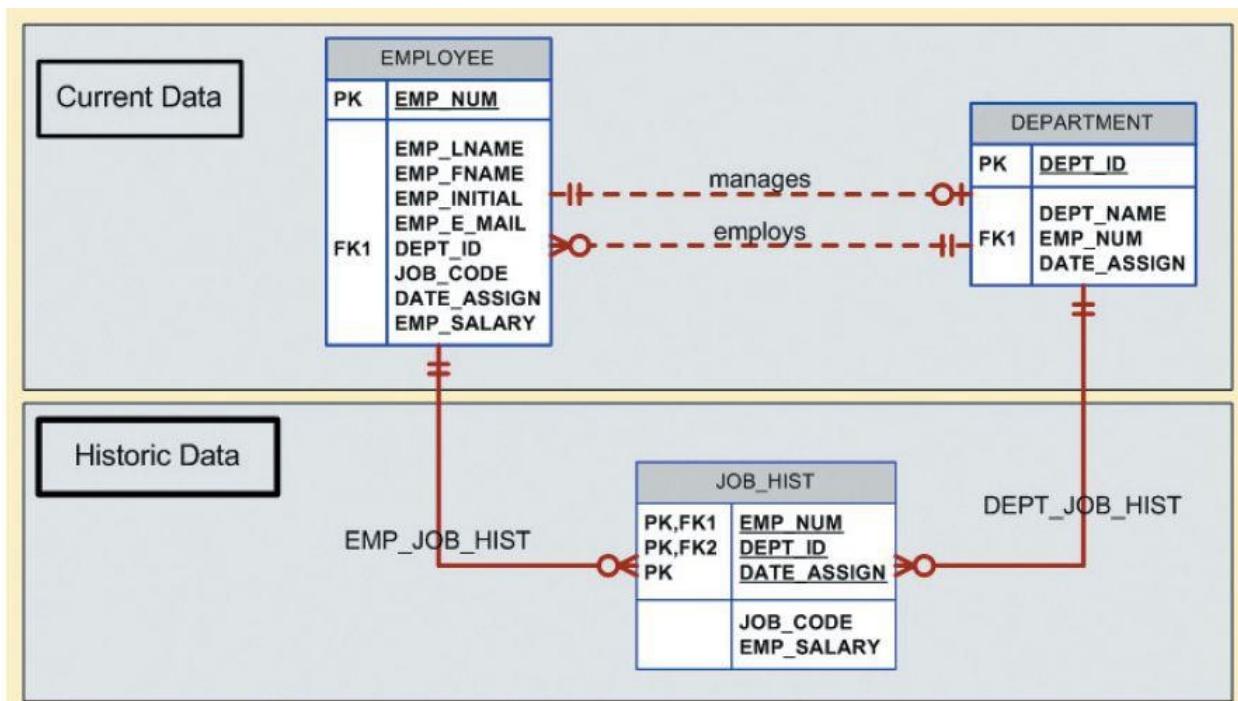
Note that in [Figure 5.9](#), the MGR_HIST entity has a 1:M relationship with EMPLOYEE and a 1:M relationship with DEPARTMENT to reflect the fact that an employee could be the manager of many different departments over time, and a department could have many different employee managers. Because you are recording timevariant data, you must store the DATE_ASSIGN attribute in the MGR_HIST entity to provide the date that the employee (EMP_NUM) became the department manager. The primary key of MGR_HIST permits the same employee to be the manager of the same department, but on different dates. If that scenario is not the case in your environment—if, for example, an employee is the manager of a department only once—you could make DATE_ASSIGN a nonprime attribute in the MGR_HIST entity.

Note in [Figure 5.9](#) that the “manages” relationship is optional in theory and redundant in practice. At any time, you could identify the manager of a department by retrieving the most recent DATE_ASSIGN date from MGR_HIST for a given department. On the other hand, the ERD in [Figure 5.9](#) differentiates

between current data and historic data. The *current* manager relationship is implemented by the “manages” relationship between EMPLOYEE and DEPARTMENT. Additionally, the historic data are managed through EMP_MGR_HIST and DEPT_MGR_HIST. The trade-off with that model is that each time a new manager is assigned to a department, there will be two data modifications: one update in the DEPARTMENT entity and one insert in the MGR_HIST entity.

The flexibility of the model proposed in [Figure 5.9](#) becomes more apparent when you add the 1:M “one department employs many employees” relationship. In that case, the PK of the “1” side (DEPT_ID) appears in the “many” side (EMPLOYEE) as a foreign key. Now suppose you would like to keep track of the job history for each of the company’s employees—you’d probably want to store the department, the job code, the date assigned, and the salary. To accomplish that task, you could modify the model in [Figure 5.9](#) by adding a JOB_HIST entity. [Figure 5.10](#) shows the use of the new JOB_HIST entity to maintain the employee’s history.

FIGURE 5.10 Maintaining job history



SOURCE: Course Technology/Cengage Learning

Again, it is worth emphasizing that the “manages” and “employs” relationships are theoretically optional and redundant in practice. You can always find out where each employee works by looking at the job history and selecting only the most current data row for each employee. However, as you will discover in [Chapter 7](#), Introduction to Structured Query Language (SQL), and in [Chapter 8](#), Advanced SQL, finding where each employee works is not a trivial task. Therefore, the model represented in [Figure 5.10](#) includes the admittedly redundant but unquestionably useful “manages” and “employs” relationships to separate current data from historic data.

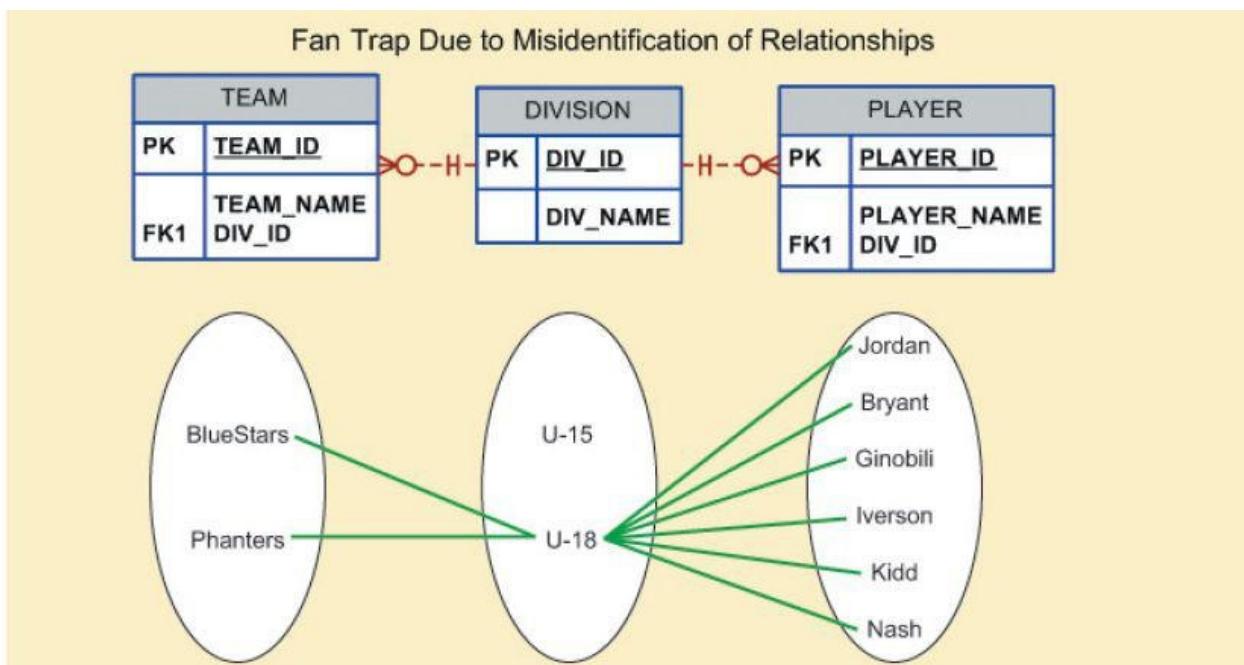
5.4.3 DESIGN CASE 3: FAN TRAPS

Creating a data model requires proper identification of the data relationships among entities. However, due to miscommunication or incomplete understanding of the business rules or processes, it is not uncommon to misidentify relationships among entities. Under those circumstances, the ERD may contain a design trap. A [design trap](#) occurs when a relationship is improperly or incompletely identified and is therefore represented in a way that is not consistent with the real world. The most common design trap is known as a *fan trap*.

A [fan trap](#) occurs when you have one entity in two 1:M relationships to other entities, thus producing an association among the other entities that is not expressed in the model. For example, assume that the JCB basketball league has many divisions. Each division has many players, and each division has many teams. Given those “incomplete” business rules, you might create an ERD that looks like the one in [Figure 5.11](#).

As you can see in [Figure 5.11](#), DIVISION is in a 1:M relationship with TEAM and in a 1:M relationship with PLAYER. Although that representation is semantically correct, the relationships are not properly identified. For example, there is no way to identify which players belong to which team. [Figure 5.11](#) also shows a sample instance relationship representation for the ERD. Note that the relationship lines for the DIVISION instances fan out to the TEAM and PLAYER entity instances—thus the “fan trap” label.

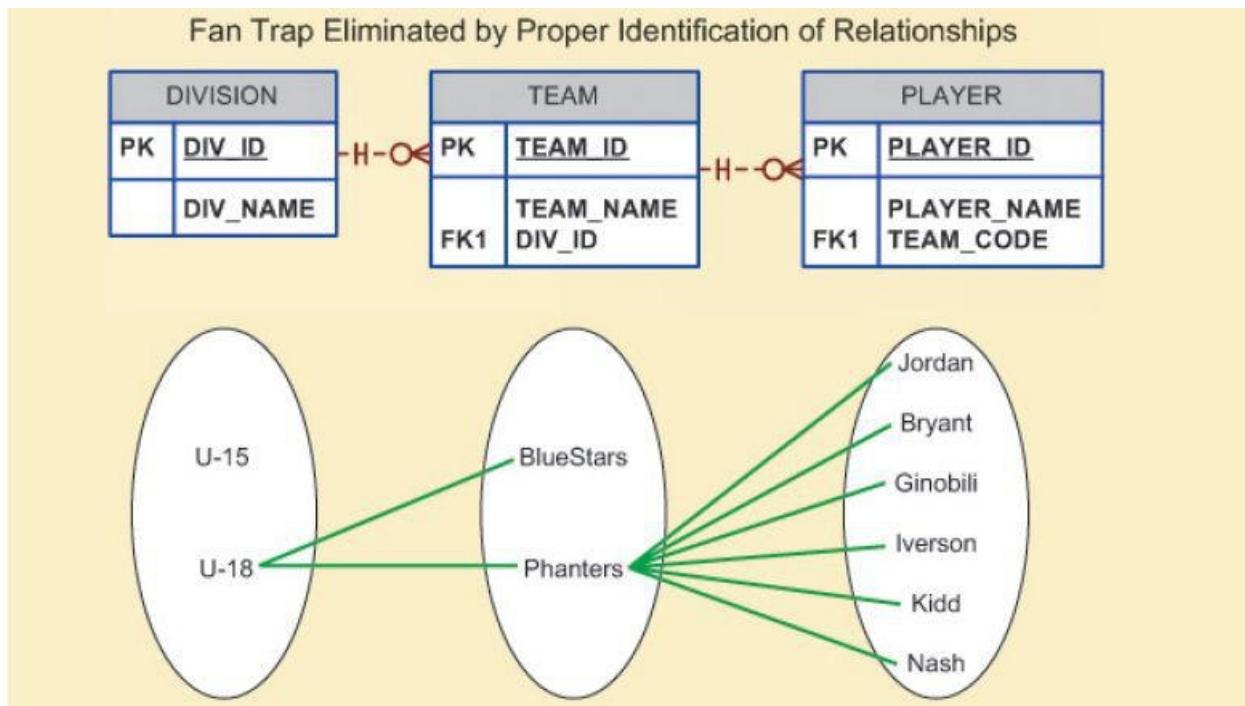
FIGURE 5.11 Incorrect ERD with fan trap problem



SOURCE: Course Technology/Cengage Learning

[Figure 5.12](#) shows the correct ERD after the fan trap has been eliminated. Note that, in this case, DIVISION is in a 1:M relationship with TEAM. In turn, TEAM is in a 1:M relationship with PLAYER. [Figure 5.12](#) also shows the instance relationship representation after eliminating the fan trap.

FIGURE 5.12 Corrected ERD after removal of the fan trap



SOURCE: Course Technology/Cengage Learning

Given the design in [Figure 5.12](#), note how easy it is to see which players play for which team. However, to find out which players play in which division, you first need to see what teams belong to each division; then you need to find out which players play on each team. In other words, there is a transitive relationship between DIVISION and PLAYER via the TEAM entity.

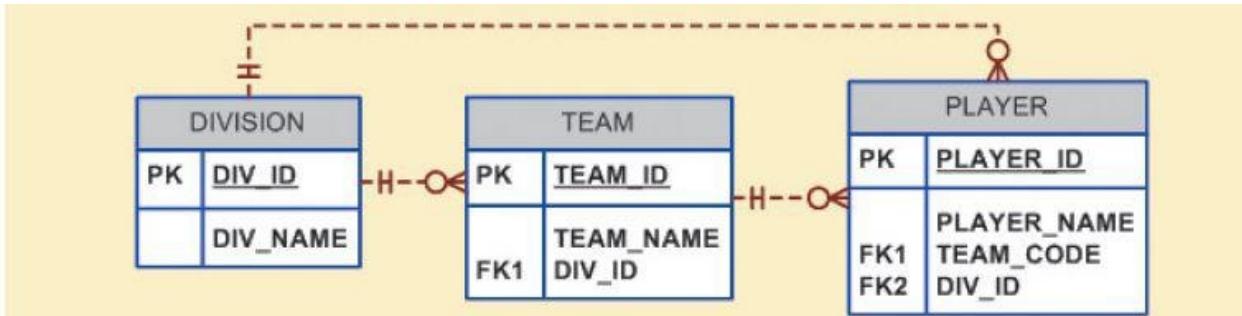
5.4.4 DESIGN CASE 4: REDUNDANT RELATIONSHIPS

Although redundancy is often good to have in computer environments (multiple backups in multiple places, for example), redundancy is seldom good in the database environment. (As you learned in [Chapter 3](#), The Relational Database Model, redundancies can cause data anomalies in a database.) Redundant relationships occur when there are multiple relationship paths between related entities. The main concern with redundant relationships is that they remain consistent across the model. However, it is important to note that some designs use redundant relationships as a way to simplify the design.

An example of redundant relationships was first introduced in [Figure 5.9](#) during the discussion of maintaining a history of timevariant data. However, the use of the redundant “manages” and “employs” relationships was justified by the fact that such relationships dealt with current data rather than historic data. Another

more specific example of a redundant relationship is represented in [Figure 5.13](#).

FIGURE 5.13 A redundant relationship



SOURCE: Course Technology/Cengage Learning

In [Figure 5.13](#), note the transitive 1:M relationship between DIVISION and PLAYER through the TEAM entity set. Therefore, the relationship that connects DIVISION and PLAYER is redundant, for all practical purposes. In that case, the relationship could be safely deleted without losing any information-generation capabilities in the model.

SUMMARY

- The extended entity relationship (EER) model adds semantics to the ER model via entity supertypes, subtypes, and clusters. An entity supertype is a generic entity type that is related to one or more entity subtypes.

- A specialization hierarchy depicts the arrangement and relationships between entity supertypes and entity subtypes. Inheritance means that an entity subtype inherits the attributes and relationships of the supertype. Subtypes can be disjoint or overlapping. A subtype discriminator is used to determine to which entity subtype the supertype occurrence is related. The subtypes can exhibit partial or total completeness. There are basically two approaches to developing a specialization hierarchy of entity supertypes and subtypes: specialization and generalization.

- An entity cluster is a “virtual” entity type used to represent multiple entities and relationships in the ERD. An entity cluster is formed by combining multiple interrelated entities and relationships into a single, abstract entity object.
- Natural keys are identifiers that exist in the real world. Natural keys sometimes make good primary keys, but not always. Primary keys must have unique values, they should be nonintelligent, they must not change over time, and they are preferably numeric and composed of a single attribute.
- Composite keys are useful to represent M:N relationships and weak (strong identifying) entities.
- Surrogate primary keys are useful when there is no natural key that makes a suitable primary key, when the primary key is a composite primary key with multiple data types, or when the primary key is too long to be usable.
- In a 1:1 relationship, place the PK of the mandatory entity as a foreign key in the optional entity, as an FK in the entity that causes the fewest nulls, or as an FK where the role is played.
- Timevariant data refer to data whose values change over time and require that you keep a history of data changes. To maintain the history of timevariant data, you must create an entity that contains the new value, the date of change, and any other time-relevant data. This entity maintains a 1:M relationship with the entity for which the history is to be maintained.
- A fan trap occurs when you have one entity in two 1:M relationships to other entities, and there is an association among the other entities that is not expressed in the model. Redundant relationships occur when there are multiple relationship paths between related entities. The main concern with redundant relationships is that they remain consistent across the model.

KEY TERMS

[completeness constraint](#)
[design trap](#)
[disjoint subtype \(nonoverlapping subtype\)](#)
[EER diagram \(EERD\)](#)
[entity cluster](#)
[entity subtype](#)
[entity supertype](#)
[extended entity relationship model\(EERM\)](#)
[fan trap](#)
[generalization](#)
[inheritance](#)
[natural key \(natural identifier\)](#)
[overlapping subtype](#)
[partial completeness](#)
[specialization](#)
[specialization hierarchy](#)
[subtype discriminator](#)
[surrogate key](#)
[timevariant data](#)
[total completeness](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at www.cengagebrain.com.

REVIEW QUESTIONS

1. What is an entity supertype, and why is it used?

2. What kinds of data would you store in an entity subtype?

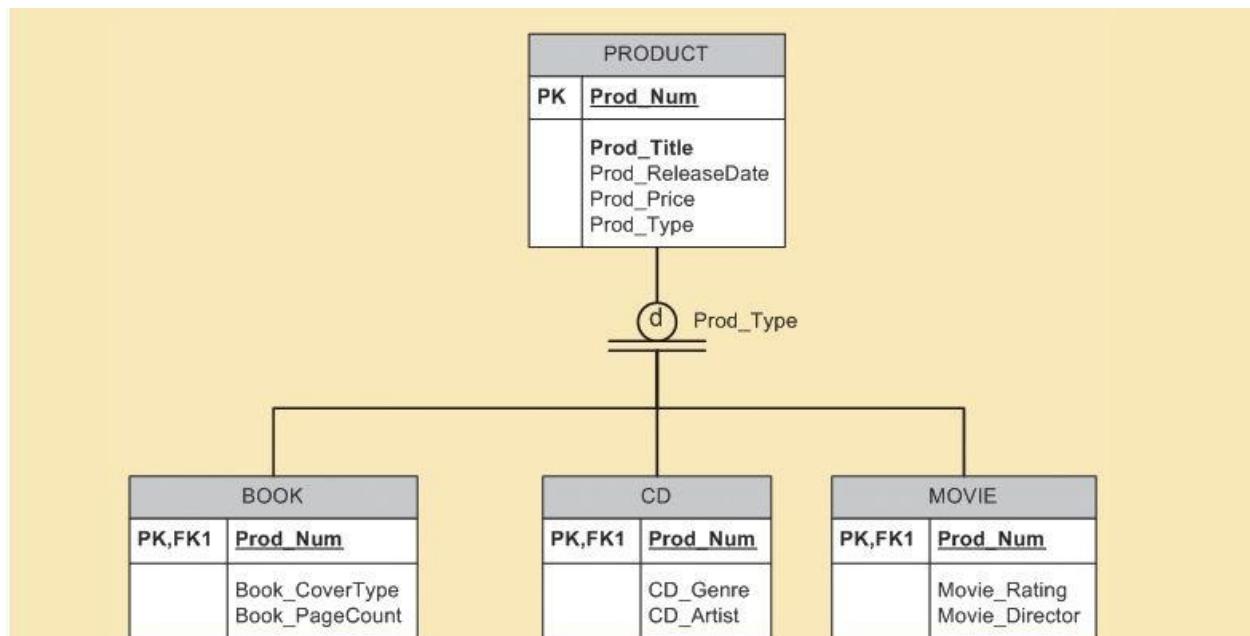
3. What is a specialization hierarchy?

4. What is a subtype discriminator? Give an example of its use.
5. What is an overlapping subtype? Give an example.

6. What is the difference between partial completeness and total completeness?

For Questions 7–9, refer to [Figure Q5.7](#).

FIGURE Q5.7 The PRODUCT data model



SOURCE: Course Technology/Cengage Learning

7. List all of the attributes of a movie.

8. According to the data model, is it required that every entity instance in the **PRODUCT** table be associated with an entity instance in the **CD** table? Why, or why not?

9. Is it possible for a book to appear in the BOOK table without appearing in the PRODUCT table? Why, or why not?
10. What is an entity cluster, and what advantages are derived from its use?
11. What primary key characteristics are considered desirable? Explain *why* each characteristic is considered desirable.
12. Under what circumstances are composite primary keys appropriate?
13. What is a surrogate primary key, and when would you use one?
14. When implementing a 1:1 relationship, where should you place the foreign key if one side is mandatory and one side is optional? Should the foreign key be mandatory or optional?
15. What are timevariant data, and how would you deal with such data from a database design point of view?
16. What is the most common design trap, and how does it occur?

PROBLEMS

1. Given the following business scenario, create a Crow's Foot ERD using a specialization hierarchy if appropriate. Two-Bit Drilling Company keeps information on employees and their insurance dependents. Each employee has an employee number, name, date of hire, and title. If an employee is an inspector, then the date of certification and certification renewal date should also be recorded in the system. For all employees, the Social Security number and dependent names should be kept. All dependents must be associated with one and only one employee. Some employees will not have dependents, while others will have many dependents.

2. Given the following business scenario, create a Crow's Foot ERD using a specialization hierarchy if appropriate. Tiny Hospital keeps information on patients and hospital rooms. The system assigns each patient a patient ID number. In addition, the patient's name and date of birth are recorded. Some patients are resident patients who spend at least one night in the hospital, and others are outpatients who are treated and released. Resident patients are assigned to a room. Each room is identified by a room number. The system also stores the room type (private or semiprivate) and room fee. Over time, each room will have many patients. Each resident patient will stay in only one room. Every room must have had a patient, and every resident patient must have a room.
3. Given the following business scenario, create a Crow's Foot ERD using a specialization hierarchy if appropriate. Granite Sales Company keeps information on employees and the departments in which they work. For each department, the department name, internal mail box number, and office phone extension are kept. A department can have many assigned employees, and each employee is assigned to only one department. Employees can be salaried, hourly, or work on contract. All employees are assigned an employee number, which is kept along with the employee's name and address. For hourly employees, hourly wages and target weekly work hours are stored; for example, the company may target 40 hours/week for some employees, 32 for others, and 20 for others. Some salaried employees are salespeople who can earn a commission in addition to their base salary. For all salaried employees, the yearly salary amount is recorded in the system. For salespeople, their commission percentage on sales and commission percentage on profit are stored in the system. For example, John is a salesperson with a base salary of \$50,000 per year plus 2 percent commission on the sales price for all sales he makes, plus another 5 percent of the profit on each of those sales. For contract employees, the beginning date and end date of their contracts are stored along with the billing rate for their hours.
4. In [Chapter 4](#), you saw the creation of the Tiny College database design, which reflected such business rules as “a professor may advise many students” and “a professor may chair one department.” Modify the design shown in [Figure 4.36](#) to include these business rules:
 - An employee could be staff, a professor, or an administrator.

- A professor may also be an administrator.
- Staff employees have a work-level classification, such as Level I or Level II.
- Only professors can chair a department. A department is chaired by only one professor.
- Only professors can serve as the dean of a college. Each of the university's colleges is served by one dean.
- A professor can teach many classes.
- Administrators have a position title.

Given that information, create the complete ERD that contains all primary keys, foreign keys, and main attributes.

5. Tiny College wants to keep track of the history of all its administrative appointments, including dates of appointment and dates of termination. (*Hint:* Timevariant data are at work.) The Tiny College chancellor may want to know how many deans worked in the College of Business between January 1, 1960, and January 1, 2012, or who the dean of the College of Education was in 1990. Given that information, create the complete ERD that contains all primary keys, foreign keys, and main attributes.
6. Some Tiny College staff employees are information technology (IT) personnel. Some IT personnel provide technology support for academic programs, some provide technology infrastructure support, and some provide support for both. IT personnel are not professors; they are required to take periodic training to retain their technical expertise. Tiny College tracks all IT personnel training by date, type, and results (completed vs. not completed). Given that information, create the complete ERD that contains all primary keys, foreign keys, and main attributes.
7. The FlyRight Aircraft Maintenance (FRAM) division of the FlyRight Company (FRC) performs all maintenance for FRC's aircraft. Produce a data model segment that reflects the following business rules:
 - All mechanics are FRC employees. Not all employees are mechanics.
 - Some mechanics are specialized in engine (EN) maintenance. Others are specialized in airframe (AF) maintenance or avionics (AV) maintenance. (Avionics are the electronic components of an aircraft that are used in

communication and navigation.) All mechanics take periodic refresher courses to stay current in their areas of expertise. FRC tracks all courses taken by each mechanic—date, course type, certification (Y/N), and performance.

- FRC keeps an employment history of all mechanics. The history includes the date hired, date promoted, and date terminated.

Given those requirements, create the Crow's Foot ERD segment.

CASES

8. “Martial Arts R Us” (MARU) needs a database. MARU is a martial arts school with hundreds of students. The database must keep track of all the classes that are offered, who is assigned to teach each class, and which students attend each class. Also, it is important to track the progress of each student as they advance. Create a complete Crow’s Foot ERD for these requirements:

- Students are given a student number when they join the school. The number is stored along with their name, date of birth, and the date they joined the school.
- All instructors are also students, but clearly not all students are instructors. In addition to the normal student information, for all instructors, the date that they start working as an instructor must be recorded along with their instructor status (compensated or volunteer).
- An instructor may be assigned to teach any number of classes, but each class has one and only one assigned instructor. Some instructors, especially volunteer instructors, may not be assigned to any class.
- A class is offered for a specific level at a specific time, day of the week, and location. For example, one class taught on Mondays at 5:00 p.m. in Room 1 is an intermediate-level class. Another class taught on Mondays at 6:00 p.m. in Room 1 is a beginner-level class. A third class taught on Tuesdays at 5:00 p.m. in Room 2 is an advanced-level class.
- Students may attend any class of the appropriate level during each week, so there is no expectation that any particular student will attend any particular class session. Therefore, the attendance of students at each individual class meeting must be tracked.
- A student will attend many different class meetings, and each class meeting is normally attended by many students. Some class meetings may

not be attended by any students. New students may not have attended any class meetings yet.

- At any given meeting of a class, instructors other than the assigned instructor may show up to help. Therefore, a given class meeting may have a head instructor and many assistant instructors, but it will always have at least the one instructor who is assigned to that class. For each class meeting, the date of the class and the instructors' roles (head instructor or assistant instructor) need to be recorded. For example, Mr. Jones is assigned to teach the Monday, 5:00 p.m., intermediate class in Room 1. During a particular meeting of that class, Mr. Jones was the head instructor and Ms. Chen served as an assistant instructor.
- Each student holds a rank in the martial arts. The rank name, belt color, and rank requirements are stored. Most ranks have numerous rank requirements, but each requirement is associated with only one particular rank. All ranks except white belt have at least one requirement.
- A given rank may be held by many students. While it is customary to think of a student as having a single rank, it is necessary to track each student's progress through the ranks. Therefore, every rank that a student attains is kept in the system. New students joining the school are automatically given the rank of white belt. The date that a student is awarded each rank should be kept in the system. All ranks have at least one student who has achieved that rank at some time.

9. The *Journal of E-commerce Research Knowledge* is a prestigious information systems research journal. It uses a peer-review process to select manuscripts for publication. Only about 10 percent of the manuscripts submitted to the journal are accepted for publication. A new issue of the journal is published each quarter. Create a complete ERD to support the business needs described below.

- Unsolicited manuscripts are submitted by authors. When a manuscript is received, the editor assigns it a number and records some basic information about it in the system, including the title of the manuscript, the date it was received, and a manuscript status of "received." Information about the author(s) is also recorded, including each author's name, mailing address, e-mail address, and affiliation (the author's school or company). Every manuscript must have an author. Only authors who have submitted manuscripts are kept in the system. It is typical for a manuscript to have several authors. A single author may have submitted many different

manuscripts to the journal. Additionally, when a manuscript has multiple authors, it is important to record the order in which the authors are listed in the manuscript credits.

- At her earliest convenience, the editor will briefly review the topic of the manuscript to ensure that its contents fall within the scope of the journal. If the content is not appropriate for the journal, the manuscript's status is changed to "rejected" and the author is notified via e-mail. If the content is within the scope of the journal, then the editor selects three or more reviewers to review the manuscript. Reviewers work for other companies or universities and read manuscripts to ensure their scientific validity. For each reviewer, the system records a reviewer number, name, e-mail address, affiliation, and areas of interest. Areas of interest are predefined areas of expertise that the reviewer has specified. An area of interest is identified by an IS code and includes a description (for example, IS2003 is the code for "database modeling"). A reviewer can have many areas of interest, and an area of interest can be associated with many reviewers. All reviewers must specify at least one area of interest. It is unusual, but possible, to have an area of interest for which the journal has no reviewers. The editor will change the status of the manuscript to "under review" and record which reviewers received the manuscript and the date it was sent to each reviewer. A reviewer will typically receive several manuscripts to review each year, although new reviewers may not have received any manuscripts yet.
- The reviewers will read the manuscript at their earliest convenience and provide feedback to the editor. The feedback from each reviewer includes rating the manuscript on a 10-point scale for appropriateness, clarity, methodology, and contribution to the field, as well as a recommendation for publication (accept or reject). The editor will record all of this information in the system for each review received, along with the date the feedback was received. Once all of the reviewers have provided their evaluations, the editor will decide whether to publish the manuscript and change its status to "accepted" or "rejected." If the manuscript will be published, the date of acceptance is recorded.
- Once a manuscript has been accepted for publication, it must be scheduled. For each issue of the journal, the publication period (fall, winter, spring, or summer), publication year, volume, and number are recorded. An issue will contain many manuscripts, although the issue may be created in the system before it is known which manuscripts will be published in that

issue. An accepted manuscript appears in only one issue of the journal. Each manuscript goes through a typesetting process that formats the content, including fonts, font size, line spacing, justification, and so on. Once the manuscript has been typeset, its number of pages is recorded in the system. The editor will then decide which issue each accepted manuscript will appear in and the order of manuscripts within each issue. The order and the beginning page number for each manuscript must be stored in the system. Once the manuscript has been scheduled for an issue, the status of the manuscript is changed to “scheduled.” Once an issue is published, the print date for the issue is recorded, and the status of each manuscript in that issue is changed to “published.”

10. Global Computer Solutions (GCS) is an information technology consulting company with many offices throughout the United States. The company’s success is based on its ability to maximize its resources—that is, its ability to match highly skilled employees with projects according to region. To better manage its projects, GCS has contacted you to design a database so GCS managers can keep track of their customers, employees, projects, project schedules, assignments, and invoices.

The GCS database must support all of GCS’s operations and information requirements. A basic description of the main entities follows:

- The *employees* of GCS must have an employee ID, a last name, a middle initial, a first name, a region, and a date of hire recorded in the system.
- Valid *regions* are as follows: Northwest (NW), Southwest (SW), Midwest North (MN), Midwest South (MS), Northeast (NE), and Southeast (SE).
- Each employee has many skills, and many employees have the same skill.
- Each *skill* has a skill ID, description, and rate of pay. Valid skills are as follows: Data Entry I, Data Entry II, Systems Analyst I, Systems Analyst II, Database Designer I, Database Designer II, Cobol I, Cobol II, C++ I, C++ II, VB I, VB II, ColdFusion I, ColdFusion II, ASP I, ASP II, Oracle DBA, MS SQL Server DBA, Network Engineer I, Network Engineer II, Web Administrator, Technical Writer, and Project Manager. [Table P5.10a](#) shows an example of the Skills Inventory.

TABLE P5.10a

SKILL	EMPLOYEE
Data Entry I	Seaton Amy; Williams Josh; Underwood Trish
Data Entry II	Williams Josh; Seaton Amy
Systems Analyst I	Craig Brett; Sewell Beth; Robbins Erin; Bush Emily; Zebras Steve
Systems Analyst II	Chandler Joseph; Burklow Shane; Robbins Erin
DB Designer I	Yarbrough Peter; Smith Mary
DB Designer II	Yarbrough Peter; Pascoe Jonathan
Cobol I	Kattan Chris; Ephonor Victor; Summers Anna; Ellis Maria
Cobol II	Kattan Chris; Ephonor Victor; Batts Melissa
C++ I	Smith Jose; Rogers Adam; Cope Leslie
C++ II	Rogers Adam; Bible Hanah
VB I	Zebras Steve; Ellis Maria
VB II	Zebras Steve; Newton Christopher
ColdFusion I	Duarte Miriam; Bush Emily
ColdFusion II	Bush Emily; Newton Christopher
ASP I	Duarte Miriam; Bush Emily
ASP II	Duarte Miriam; Newton Christopher
Oracle DBA	Smith Jose; Pascoe Jonathan

SQL Server DBA	Yarbrough Peter; Smith Jose
Network Engineer I	Bush Emily; Smith Mary
Network Engineer II	Bush Emily; Smith Mary
Web Administrator	Bush Emily; Smith Mary; Newton Christopher
Technical Writer	Kilby Surgena; Bender Larry
Project Manager	Paine Brad; Mudd Roger; Kenyon Tiffany; Connor Sean

- GCS has many *customers*. Each customer has a customer ID, name, phone number, and region.
- GCS works by *projects*. A project is based on a contract between the customer and GCS to design, develop, and implement a computerized solution. Each project has specific characteristics such as the project ID, the customer to which the project belongs, a brief description, a project date (the date the contract was signed), an estimated project start date and end date, an estimated project budget, an actual start date, an actual end date, an actual cost, and one employee assigned as the manager of the project.
- The actual cost of the project is updated each Friday by adding that week's cost to the actual cost. The week's cost is computed by multiplying the hours each employee worked by the rate of pay for that skill.
- The employee who is the manager of the project must complete a *project schedule*, which effectively is a design and development plan. In the project schedule (or plan), the manager must determine the tasks that will be performed to take the project from beginning to end. Each task has a task ID, a brief task description, starting and ending dates, the types of skills needed, and the number of employees (with the required skills) needed to complete the task. General tasks are the initial interview, database and system design, implementation, coding, testing, and final evaluation and sign-off. For example, GCS might have the project schedule shown in [Table P5.10b](#).

TABLE P5.10b

PROJECT ID: 1 COMPANY : SEE ROCKS START DATE: 3/1/2012		DESCRIPTION: SALES MANAGEMENT SYSTEM CONTRACT DATE: 2/12/2012 END DATE: 7/1/2012		REGION: NW BUDGET: \$15,500
START DATE	END DATE	TASK DESCRIPTION	SKILL(S) REQUIRED	QUANTITY REQUIRED
3/1/12	3/6/12	Initial interview	Project Manager Systems Analyst II DB Designer I	1 1 1
3/11/12	3/15/12	Database design	DB Designer I	1
3/11/12	4/12/12	System design	Systems Analyst II Systems Analyst I	1 2
3/18/12	3/22/12	Database implementation	Oracle DBA	1
3/25/12	5/20/12	System coding and testing	Cobol I Cobol II Oracle DBA	2 1 1
3/25/12	6/7/12	System documentation	Technical Writer	1
6/10/12	6/14/12	Final evaluation	Project Manager Systems Analyst II DB Designer I Cobol II	1 1 1 1
6/17/12	6/21/12	On-site system online and data loading	Project Manager Systems Analyst II DB Designer I Cobol II	1 1 1 1
7/1/12	7/1/12	Sign-off	Project Manager	1

- GCS pools all of its employees by region; from this pool, employees are assigned to a specific task scheduled by the project manager. For example, in the first project's schedule, you know that a Systems Analyst II, Database Designer I, and Project Manager are needed for the period from 3/1/12 to 3/6/12. The project manager is assigned when the project is created and remains for the duration of the project. Using that information, GCS searches the employees who are located in the same region as the customer, matches the skills required, and assigns the employees to the project task.
- Each project schedule task can have many employees assigned to it, and a given employee can work on multiple project tasks. However, an employee can work on only one project task at a time. For example, if an employee is already assigned to work on a project task from 2/20/12 to 3/3/12, the employee cannot work on another task until the current assignment is closed (ends). The date that an assignment is closed does not necessarily match the ending date of the project schedule task, because a task can be completed ahead of or behind schedule.
- Given all of the preceding information, you can see that the assignment associates an employee with a project task, using the project schedule. Therefore, to keep track of the *assignment*, you require at least the

following information: assignment ID, employee, project schedule task, assignment start date, and assignment end date. The end date could be any date, as some projects run ahead of or behind schedule. [Table P5.10c](#) shows a sample assignment form.

TABLE P5.10c

PROJECT ID: 1 COMPANY: SEE ROCKS		DESCRIPTION: SALES MANAGEMENT SYSTEM CONTRACT DATE: 2/12/2012			AS OF: 03/29/12		
PROJECT TASK	SCHEDULED			ACTUAL ASSIGNMENTS			
	START DATE	END DATE	SKILL	EMPLOYEE	START DATE	END DATE	
Initial interview	3/1/12	3/6/12	Project Mgr. Sys. Analyst II DB Designer I	101-Connor S. 102-Burklow S. 103-Smith M.	3/1/12 3/1/12 3/1/12	3/6/12 3/6/12 3/6/12	
Database design	3/11/12	3/15/12	DB Designer I	104-Smith M.	3/11/12	3/14/12	
System design	3/11/12	4/12/12	Sys. Analyst II Sys. Analyst I Sys. Analyst I	105-Burklow S. 106-Bush E. 107-Zebras S.	3/11/12 3/11/12 3/11/12		
Database implementation	3/18/12	3/22/12	Oracle DBA	108-Smith J.	3/15/12	3/19/12	
System coding and testing	3/25/12	5/20/12	Cobol I Cobol I Cobol II Oracle DBA	109-Summers A. 110-Ellis M. 111-Ephanor V. 112-Smith J.	3/21/12 3/21/12 3/21/12 3/21/12		
System documentation	3/25/12	6/7/12	Tech. Writer	113-Kilby S.	3/25/12		
Final evaluation	6/10/12	6/14/12	Project Mgr. Sys. Analyst II DB Designer I Cobol II				
On-site system online and data loading	6/17/12	6/21/12	Project Mgr. Sys. Analyst II DB Designer I Cobol II				
Sign-off	7/1/12	7/1/12	Project Mgr.				

- Employee work hours are kept in a *work log*, which contains a record of the actual hours worked by employees on a given assignment. The work log is a form that the employee fills out at the end of each week (Friday) or at the end of each month. The form contains the date, which is either the current Friday of the month or the last workday of the month if it does not fall on a Friday. The form also contains the assignment ID, the total hours worked either that week or up to the end of the month, and the bill number to which the work-log entry is charged. Obviously, each work-log entry can

be related to only one bill. A sample list of the current work-log entries for the first sample project is shown in [Table P5.10d](#).

TABLE P5.10d

EMPLOYEE NAME	WEEK ENDING	ASSIGNMENT NUMBER	HOURS WORKED	BILL NUMBER
Burklow S.	3/1/12	1-102	4	xxx
Connor S.	3/1/12	1-101	4	xxx
Smith M.	3/1/12	1-103	4	xxx
Burklow S.	3/8/12	1-102	24	xxx
Connor S.	3/8/12	1-101	24	xxx
Smith M.	3/8/12	1-103	24	xxx
Burklow S.	3/15/12	1-105	40	xxx
Bush E.	3/15/12	1-106	40	xxx
Smith J.	3/15/12	1-108	6	xxx
Smith M.	3/15/12	1-104	32	xxx
Zebras S.	3/15/12	1-107	35	xxx
Burklow S.	3/22/12	1-105	40	
Bush E.	3/22/12	1-106	40	
Ellis M.	3/22/12	1-110	12	
Ephanor V.	3/22/12	1-111	12	
Smith J.	3/22/12	1-108	12	
Smith J.	3/22/12	1-112	12	
Summers A.	3/22/12	1-109	12	
Zebras S.	3/22/12	1-107	35	
Burklow S.	3/29/12	1-105	40	
Bush E.	3/29/12	1-106	40	
Ellis M.	3/29/12	1-110	35	
Ephanor V.	3/29/12	1-111	35	
Kilby S.	3/29/12	1-113	40	
Smith J.	3/29/12	1-112	35	
Summers A.	3/29/12	1-109	35	
Zebras S.	3/29/12	1-107	35	

(Note: The assignment number is shown as a prefix of the employee name—for example, 101 or 102.) Assume that the assignments shown previously are the only ones as of the date of this design. The assignment number can be any number that matches your database design.

- Finally, every 15 days, a *bill* is written and sent to the customer for the total hours worked on the project during that period. When GCS generates a bill, it uses the bill number to update the work-log entries that are part of the bill. In summary, a bill can refer to many work-log entries, and each work-log entry can be related to only one bill. GCS sent one bill on 3/15/12

for the first project (SEE ROCKS), totaling the hours worked between 3/1/12 and 3/15/12. Therefore, you can safely assume that there is only one bill in this table and that the bill covers the work-log entries shown in the preceding form.

Your assignment is to create a database that fulfills the operations described in this problem. The minimum required entities are employee, skill, customer, region, project, project schedule, assignment, work log, and bill. (There are additional required entities that are not listed.)

- Create all of the required tables and required relationships.
- Create the required indexes to maintain entity integrity when using surrogate primary keys.
- Populate the tables as needed, as indicated in the sample data and forms.

6 NORMALIZATION OF DATABASE TABLES

In this chapter, you will learn:

- What normalization is and what role it plays in the database design process
 - About the normal forms 1NF, 2NF, 3NF, BCNF, and 4NF
 - How normal forms can be transformed from lower normal forms to higher normal forms
 - That normalization and ER modeling are used concurrently to produce a good database design
 - That some situations require denormalization to generate information efficiently
-

Preview

Good database design must be matched to good table structures. In this chapter, you will learn to evaluate and design good table structures to control data redundancies, thereby avoiding data anomalies. The process that yields such desirable results is known as normalization.

To recognize and appreciate the characteristics of a good table structure, it is useful to examine a poor one. Therefore, the chapter begins by examining the characteristics of a poor table structure and the problems it creates. You then learn how to correct the table structure. This methodology will yield important dividends: you will know how to design a good table structure and how to repair a poor one.

You will discover not only that data anomalies can be eliminated through normalization, but that a properly normalized set of table structures is actually less complicated to use than an unnormalized set. In addition, you will learn that the normalized set of table structures more faithfully reflects an organization's real operations.

6.1 DATABASE TABLES AND NORMALIZATION

Having good relational database software is not enough to avoid the data redundancy discussed in [Chapter 1](#), Database Systems. If the database tables are treated as though they are files in a file system, the relational database management system (RDBMS) never has a chance to demonstrate its superior data-handling capabilities.

The table is the basic building block of database design. Consequently, the table's structure is of great interest. Ideally, the database design process explored in [Chapter 4](#), Entity Relationship (ER) Modeling, yields good table structures. Yet, it is possible to create poor table structures even in a good database design. How do you recognize a poor table structure, and how do you produce a good table? The answer to both questions involves normalization. **Normalization** is a process for evaluating and correcting table structures to minimize data redundancies, thereby reducing the likelihood of data anomalies. The normalization process involves assigning attributes to tables based on the concept of determination you learned in [Chapter 3](#), The Relational Database Model.

Normalization works through a series of stages called normal forms. The first three stages are described as first normal form (1NF), second normal form (2NF), and third normal form (3NF). From a structural point of view, 2NF is better than 1NF, and 3NF is better than 2NF. For most purposes in business database design, 3NF is as high as you need to go in the normalization process. However, you will discover that properly designed 3NF structures also meet the requirements of fourth normal form (4NF).

Although normalization is a very important ingredient in database design, you should not assume that the highest level of normalization is always the most desirable. Generally, the higher the normal form, the more relational join operations you need to produce a specified output; also, more resources are required by the database system to respond to end-user queries. A successful design must also consider end-user demand for fast performance. Therefore, you will occasionally need to *denormalize* some portions of a database design to meet performance requirements. **Denormalization** produces a lower normal form; that is, a 3NF will be converted to a 2NF through denormalization. However, *the price you pay for increased performance through denormalization is greater data redundancy*.

NOTE

Although the word table is used throughout this chapter, formally, normalization is concerned with relations. In [Chapter 3](#) you learned that the terms table and relation are frequently used interchangeably. In fact, you can say that a table is the implementation view of a logical relation that meets some specific conditions. (See [Table 3.1](#).) However, being more rigorous, the mathematical relation does not allow duplicate tuples, whereas they could exist in tables (see [Section 6.5](#)). Also, in normalization terminology, any attribute that is at least part of a key is known as a **prime attribute** instead of the more common term key attribute, which was introduced earlier. Conversely, a **nonprime attribute**, or a nonkey attribute, is not part of any candidate key.

6.2 THE NEED FOR NORMALIZATION

Normalization is typically used in conjunction with the entity relationship modeling that you learned in the previous chapters. Database designers commonly use normalization in two situations. When designing a new database structure based on the business requirements of the end users, the database designer will construct a data model using a technique such as Crow's Foot notation ERDs. After the initial design is complete, the designer can use normalization to analyze the relationships among the attributes within each entity and determine if the structure can be improved through normalization. Alternatively, database designers are often asked to modify existing data structures that can be in the form of flat files, spreadsheets, or older database structures. Again, by analyzing relationships among the attributes or fields in the data structure, the database designer can use the normalization process to improve the existing data structure and create an appropriate database design. Whether you are designing a new database structure or modifying an existing one, the normalization process is the same.

To get a better idea of the normalization process, consider the simplified database activities of a construction company that manages several building projects. Each project has its own project number, name, assigned employees,

and so on. Each employee has an employee number, name, and job classification, such as engineer or computer technician.

The company charges its clients by billing the hours spent on each contract. The hourly billing rate is dependent on the employee's position. For example, one hour of computer technician time is billed at a different rate than one hour of engineer time. Periodically, a report is generated that contains the information displayed in [Table 6.1](#).

The total charge in [Table 6.1](#) is a derived attribute and is not stored in the table at this point.

The easiest short-term way to generate the required report might seem to be a table whose contents correspond to the reporting requirements. (See [Figure 6.1](#).)

FIGURE 6.1 Tabular representation of the report format

Table name: RPT_FORMAT				Database name: Ch06_ConstructCo		
PROJ_NUM	PROJ_NAME	EMP_NUM	EMP_NAME	JOB_CLASS	CHG_HOUR	HOURS
15	Evergreen	103	June E. Arbough	Elect. Engineer	84.50	23.8
		101	John G. News	Database Designer	105.00	19.4
		105	Alice K. Johnson *	Database Designer	105.00	35.7
		106	William Smithfield	Programmer	35.75	12.6
		102	David H. Senior	Systems Analyst	96.75	23.8
18	Amber Wave	114	Annelise Jones	Applications Designer	48.10	24.6
		118	James J. Frommer	General Support	18.36	45.3
		104	Anne K. Ramoras *	Systems Analyst	96.75	32.4
		112	Darlene M. Smithson	DSS Analyst	45.95	44.0
22	Rolling Tide	105	Alice K. Johnson	Database Designer	105.00	64.7
		104	Anne K. Ramoras	Systems Analyst	96.75	48.4
		113	Delbert K. Joenbrood *	Applications Designer	48.10	23.6
		111	Geoff B. Wabash	Clerical Support	26.87	22.0
		106	William Smithfield	Programmer	35.75	12.8
25	Starflight	107	Maria D. Alonzo	Programmer	35.75	24.6
		115	Travis B. Bawangi	Systems Analyst	96.75	45.8
		101	John G. News *	Database Designer	105.00	56.3
		114	Annelise Jones	Applications Designer	48.10	33.1
		108	Ralph B. Washington	Systems Analyst	96.75	23.6
		118	James J. Frommer	General Support	18.36	30.5
		112	Darlene M. Smithson	DSS Analyst	45.95	41.4

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The databases used to illustrate the material in this chapter are available at www.cengagebrain.com.

Note that the data in [Figure 6.1](#) reflect the assignment of employees to projects. Apparently, an employee can be assigned to more than one project. For example, Darlene Smithson (EMP_NUM = 112) has been assigned to two projects: Amber Wave and Starflight. Given the structure of the dataset, each project includes only a single occurrence of any one employee. Therefore, knowing the PROJ_NUM and EMP_NUM values will let you find the job classification and its hourly charge. In addition, you will know the total number of hours each employee worked on each project. (The total charge—a derived attribute whose value can be computed by multiplying the hours billed and the charge per hour—has not been included in [Figure 6.1](#). No structural harm is done if this derived attribute is included.)

TABLE 6.1 A Sample Report Layout

PROJECT NUMBER	PROJECT NAME	EMPLOYEE NUMBER	EMPLOYEE NAME	JOB CLASS	CHARGE/HOUR	HOURS BILLED	TOTAL CHARGE
15	Evergreen	103	June E. Arbough	Elec. Engineer	\$ 84.50	23.8	\$ 2,011.10
		101	John G. News	Database Designer	\$105.00	19.4	\$ 2,037.00
		105	Alice K. Johnson *	Database Designer	\$105.00	35.7	\$ 3,748.50
		106	William Smithfield	Programmer	\$ 35.75	12.6	\$ 450.45
		102	David H. Senior	Systems Analyst	\$ 96.75	23.8	\$ 2,302.65
				Subtotal			\$10,549.70
18	Amber Wave	114	Annelise Jones	Applications Designer	\$ 48.10	24.6	\$ 1,183.26
		118	James J. Frommer	General Support	\$ 18.36	45.3	\$ 831.71
		104	Anne K. Ramoras *	Systems Analyst	\$ 96.75	32.4	\$ 3,134.70
		112	Darlene M. Smithson	DSS Analyst	\$ 45.95	44.0	\$ 2,021.80
				Subtotal			\$ 7,171.47
22	Rolling Tide	105	Alice K. Johnson	Database Designer	\$105.00	64.7	\$ 6,793.50
		104	Anne K. Ramoras	Systems Analyst	\$ 96.75	48.4	\$ 4,682.70
		113	Delbert K. Joenbrood *	Applications Designer	\$ 48.10	23.6	\$ 1,135.16
		111	Geoff B. Wabash	Clerical Support	\$ 26.87	22.0	\$ 591.14
		106	William Smithfield	Programmer	\$ 35.75	12.8	\$ 457.60
				Subtotal			\$13,660.10
25	Starflight	107	Maria D. Alonso	Programmer	\$ 35.75	24.6	\$ 879.45
		115	Travis B. Bawangi	Systems Analyst	\$ 96.75	45.8	\$ 4,431.15
		101	John G. News *	Database Designer	\$105.00	56.3	\$ 5,911.50
		114	Annelise Jones	Applications Designer	\$ 48.10	33.1	\$ 1,592.11
		108	Ralph B. Washington	Systems Analyst	\$ 96.75	23.6	\$ 2,283.30
		118	James J. Frommer	General Support	\$ 18.36	30.5	\$ 559.98
		112	Darlene M. Smithson	DSS Analyst	\$ 45.95	41.4	\$ 1,902.33
				Subtotal			\$17,559.82
				Total			\$48,941.09

Unfortunately, the structure of the dataset in [Figure 6.1](#) does not conform to the requirements discussed in [Chapter 3](#), nor does it handle data very well. Consider the following deficiencies:

1. The project number (PROJ_NUM) is apparently intended to be a primary key (PK) or at least a part of a PK, but it contains nulls. Given the preceding discussion, you know that PROJ_NUM + EMP_NUM will define each row.
2. The table entries invite data inconsistencies. For example, the JOB_CLASS value “Elect. Engineer” might be entered as “Elect.Eng.” in some cases, “El. Eng.” in others, and “EE” in still others.
3. The table displays data redundancies that yield the following anomalies:
 - a. *Update anomalies.* Modifying the JOB_CLASS for employee number 105 requires many potential alterations, one for each EMP_NUM = 105.
 - b. *Insertion anomalies.* Just to complete a row definition, a new employee must be assigned to a project. If the employee is not yet assigned, a phantom project must be created to complete the employee data entry.
 - c. *Deletion anomalies.* Suppose that only one employee is associated with a given project. If that employee leaves the company and the employee data are deleted, the project information will also be deleted. To prevent the loss of the project information, a fictitious employee must be created.

In spite of those structural deficiencies, the table structure *appears* to work; the report is generated with ease. Unfortunately, the report might yield varying results depending on what data anomaly has occurred. For example, if you want to print a report to show the total “hours worked” value by the job classification “Database Designer,” that report will not include data for “DB Design” and “Database Design” data entries. Such reporting anomalies cause a multitude of problems for managers—and cannot be fixed through application programming.

Even if careful data-entry auditing can eliminate most of the reporting problems (at a high cost), it is easy to demonstrate that even a simple data entry becomes inefficient. Given the existence of update anomalies, suppose Darlene M. Smithson is assigned to work on the Evergreen project. The data-entry clerk

must update the PROJECT file with the following entry:

15	Evergreen	112	Darlene M. Smithson	DSS Analyst	\$45.95
		0.0			

to match the attributes PROJ_NUM, PROJ_NAME, EMP_NUM, EMP_NAME, JOB_CLASS, CHG_HOUR, and HOURS. (If Smithson has just been assigned to the project, the total number of hours worked is 0.0.)

NOTE

Remember that the naming convention makes it easy to see what each attribute stands for and its likely origin. For example, PROJ_NAME uses the prefix PROJ to indicate that the attribute is associated with the PROJECT table, while the NAME component is self-documenting as well. However, keep in mind that name length is also an issue, especially in the prefix designation. For that reason, the prefix CHG was used rather than CHARGE. (Given the database's context, it is not likely that the prefix will be misunderstood.)

Each time another employee is assigned to a project, some data entries (such as PROJ_NAME, EMP_NAME, and CHG_HOUR) are unnecessarily repeated. Imagine the data-entry chore when 200 or 300 table entries must be made! The entry of the employee number should be sufficient to identify Darlene M. Smithson, her job description, and her hourly charge. Because only one person is identified by the number 112, that person's characteristics (name, job classification, and so on) should not have to be entered each time the main file is updated. Unfortunately, the structure displayed in [Figure 6.1](#) does not make allowances for that possibility.

The data redundancy evident in [Figure 6.1](#) leads to wasted disk space. Even worse, data redundancy produces data anomalies. For example, suppose the data-entry clerk had entered the data as:

15	Evergeen	112	Darla Smithson	DCS Analyst	\$45.95	0.0
----	----------	-----	----------------	-------------	---------	-----

At first glance, the data entry appears to be correct. But is *Evergeen* the same project as *Evergreen*? And is *DCS Analyst* supposed to be *DSS Analyst*? Is Darla Smithson the same person as Darlene M. Smithson? Such confusion is a data

integrity problem because the data entry failed to conform to the rule that all copies of redundant data must be identical.

The possibility of introducing data integrity problems caused by data redundancy must be considered during database design. The relational database environment is especially well suited to help the designer overcome those problems.

6.3 THE NORMALIZATION PROCESS

In this section, you will learn how to use normalization to produce a set of normalized tables to store the data that will be used to generate the required information. The objective of normalization is to ensure that each table conforms to the concept of well-formed relations—in other words, tables that have the following characteristics:

- Each table represents a single subject. For example, a course table will contain only data that directly pertain to courses. Similarly, a student table will contain only student data.
- No data item will be *unnecessarily* stored in more than one table (in short, tables have minimum controlled redundancy). The reason for this requirement is to ensure that the data are updated in only one place.
- All nonprime attributes in a table are dependent on the primary key—the entire primary key and nothing but the primary key. The reason for this requirement is to ensure that the data are uniquely identifiable by a primary key value.
- Each table is void of insertion, update, or deletion anomalies, which ensures the integrity and consistency of the data.

To accomplish the objective, the normalization process takes you through the steps that lead to successively higher normal forms. The most common normal forms and their basic characteristic are listed in [Table 6.2](#). You will learn the details of these normal forms in the indicated sections.

TABLE 6.2 Normal Forms

NORMAL FORM	CHARACTERISTIC	SECTION
First normal form (1NF)	Table format, no repeating groups, and PK identified	6.3.1
Second normal form (2NF)	1NF and no partial dependencies	6.3.2
Third normal form (3NF)	2NF and no transitive dependencies	6.3.3
Boyce-Codd normal form (BCNF)	Every determinant is a candidate key (special case of 3NF)	6.6.1
Fourth normal form (4NF)	3NF and no independent multivalued dependencies	6.6.2

The concept of keys is central to the discussion of normalization. Recall from [Chapter 3](#) that a candidate key is a minimal (irreducible) superkey. The primary key is the candidate key selected to be the primary means used to identify the rows in the table. Although normalization is typically presented from the perspective of candidate keys, this initial discussion assumes for the sake of simplicity that each table has only one candidate key; therefore, that candidate key is the primary key.

From the data modeler's point of view, the objective of normalization is to ensure that all tables are at least in third normal form (3NF). Even higher-level normal forms exist. However, normal forms such as the fifth normal form (5NF) and domain-key normal form (DKNF) are not likely to be encountered in a business environment and are mainly of theoretical interest. Such higher normal forms usually increase joins, which slows performance without adding any value

in the elimination of data redundancy. Some very specialized applications, such as statistical research, might require normalization beyond the 4NF, but those applications fall outside the scope of most business operations. Because this book focuses on practical applications of database techniques, the higher-level normal forms are not covered.

Functional Dependence

Before outlining the normalization process, it is a good idea to review the concepts of determination and functional dependence that were covered in detail in [Chapter 3](#). [Table 6.3](#) summarizes the main concepts.

TABLE 6.3 Functional Dependence Concepts

CONCEPT	DEFINITION
Functional dependence	The attribute B is fully functionally dependent on the attribute A if each value of A determines one and only one value of B .
	Example: $\text{PROJ_NUM} \rightarrow \text{PROJ_NAME}$ (read as <i>PROJ_NUM functionally determines PROJ_NAME</i>)
	In this case, the attribute PROJ_NUM is known as the determinant attribute, and the attribute PROJ_NAME is known as the dependent attribute.
Functional dependence (generalized definition)	Attribute A determines attribute B (that is, B is functionally dependent on A) if all of the rows in the table that agree in value for attribute A also agree in value for attribute B .
Fully functional dependence (composite key)	If attribute B is functionally dependent on a composite key A but not on any subset of that composite key, the attribute B is fully functionally dependent on A .

It is crucial to understand these concepts because they are used to derive the set of functional dependencies for a given relation. The normalization process works one relation at a time, identifying the dependencies on that relation and normalizing the relation. As you will see in the following sections, normalization

starts by identifying the dependencies of a given relation and progressively breaking up the relation (table) into a set of new relations (tables) based on the identified dependencies.

Two types of functional dependencies that are of special interest in normalization are partial dependencies and transitive dependencies. A **partial dependency** exists when there is a functional dependence in which the determinant is only part of the primary key (remember the assumption that there is only one candidate key). For example, if $(A, B) \rightarrow (C, D)$, $B \rightarrow C$, and (A, B) is the primary key, then the functional dependence $B \rightarrow C$ is a partial dependency because only part of the primary key (B) is needed to determine the value of C . Partial dependencies tend to be straightforward and easy to identify.

A **transitive dependency** exists when there are functional dependencies such that $X \rightarrow Y$, $Y \rightarrow Z$, and X is the primary key. In that case, the dependency $X \rightarrow Z$ is a transitive dependency because X determines the value of Z via Y . Unlike partial dependencies, transitive dependencies are more difficult to identify among a set of data. Fortunately, there is an effective way to identify transitive dependencies: they occur only when a functional dependence exists among nonprime attributes. In the previous example, the actual transitive dependency is $X \rightarrow Z$. However, the dependency $Y \rightarrow Z$ signals that a transitive dependency exists. Hence, throughout the discussion of the normalization process, the existence of a functional dependence among nonprime attributes will be considered a sign of a transitive dependency. To address the problems related to transitive dependencies, changes to the table structure are made based on the functional dependence that signals the transitive dependency's existence. Therefore, to simplify the description of normalization, from this point forward the signaling dependency will be called the transitive dependency.

6.3.1 CONVERSION TO FIRST NORMAL FORM

Because the relational model views data as part of a table or a collection of tables in which all key values must be identified, the data depicted in [Figure 6.1](#) might not be stored as shown. Note that [Figure 6.1](#) contains what is known as repeating groups. A **repeating group** derives its name from the fact that a group of multiple entries of the same type can exist for any *single* key attribute occurrence. In [Figure 6.1](#), note that each single project number (PROJ_NUM) occurrence can reference a group of related data entries. For example, the Evergreen project (PROJ_NUM = 15) shows five entries at this point—and those entries are related because they each share the PROJ_NUM = 15 characteristic.

Each time a new record is entered for the Evergreen project, the number of entries in the group grows by one.

A relational table must not contain repeating groups. The existence of repeating groups provides evidence that the RPT_FORMAT table in [Figure 6.1](#) fails to meet even the lowest normal form requirements, thus reflecting data redundancies.

Normalizing the table structure will reduce the data redundancies. If repeating groups do exist, they must be eliminated by making sure that each row defines a single entity. In addition, the dependencies must be identified to diagnose the normal form. Identification of the normal form lets you know where you are in the normalization process. Normalization starts with a simple three-step procedure.

Step 1: Eliminate the Repeating Groups

Start by presenting the data in a tabular format, where each cell has a single value and there are no repeating groups. To eliminate the repeating groups, eliminate the nulls by making sure that each repeating group attribute contains an appropriate data value. That change converts the table in [Figure 6.1](#) to 1NF in [Figure 6.2](#).

FIGURE 6.2 A table in first normal form

Table name: DATA_ORG_1NF

Database name: Ch06_ConstructCo

PROJ_NUM	PROJ_NAME	EMP_NUM	EMP_NAME	JOB_CLASS	CHG_HOUR	HOURS
15	Evergreen	103	June E. Arbough	Elect. Engineer	84.50	23.8
15	Evergreen	101	John G. News	Database Designer	105.00	19.4
15	Evergreen	105	Alice K. Johnson *	Database Designer	105.00	35.7
15	Evergreen	106	William Smithfield	Programmer	35.75	12.6
15	Evergreen	102	David H. Senior	Systems Analyst	96.75	23.8
18	Amber Wave	114	Annelise Jones	Applications Designer	48.10	24.6
18	Amber Wave	118	James J. Frommer	General Support	18.36	45.3
18	Amber Wave	104	Anne K. Ramoras *	Systems Analyst	96.75	32.4
18	Amber Wave	112	Darlene M. Smithson	DSS Analyst	45.95	44.0
22	Rolling Tide	105	Alice K. Johnson	Database Designer	105.00	64.7
22	Rolling Tide	104	Anne K. Ramoras	Systems Analyst	96.75	48.4
22	Rolling Tide	113	Delbert K. Joenbrood *	Applications Designer	48.10	23.6
22	Rolling Tide	111	Geoff B. Wabash	Clerical Support	26.87	22.0
22	Rolling Tide	106	William Smithfield	Programmer	35.75	12.8
25	Starflight	107	Maria D. Alonzo	Programmer	35.75	24.6
25	Starflight	115	Travis B. Bawangi	Systems Analyst	96.75	45.8
25	Starflight	101	John G. News *	Database Designer	105.00	56.3
25	Starflight	114	Annelise Jones	Applications Designer	48.10	33.1
25	Starflight	108	Ralph B. Washington	Systems Analyst	96.75	23.6
25	Starflight	118	James J. Frommer	General Support	18.36	30.5
25	Starflight	112	Darlene M. Smithson	DSS Analyst	45.95	41.4

SOURCE: Course Technology/Cengage Learning

Step 2: Identify the Primary Key

The layout in [Figure 6.2](#) represents more than a mere cosmetic change. Even a casual observer will note that PROJ_NUM is not an adequate primary key because the project number does not uniquely identify all of the remaining entity (row) attributes. For example, the PROJ_NUM value 15 can identify any one of five employees. To maintain a proper primary key that will *uniquely* identify any attribute value, the new key must be composed of a *combination* of PROJ_NUM and EMP_NUM. For example, using the data shown in [Figure 6.2](#), if you know that PROJ_NUM = 15 and EMP_NUM = 103, the entries for the attributes PROJ_NAME, EMP_NAME, JOB_CLASS, CHG_HOUR, and HOURS must be Evergreen, June E. Arbough, Elect. Engineer, \$84.50, and 23.8, respectively.

Step 3: Identify All Dependencies

The identification of the PK in Step 2 means that you have already identified the following dependency:

PROJ_NUM, EMP_NUM → PROJ_NAME, EMP_NAME, JOB_CLASS, CHG_HOUR, HOURS

That is, the PROJ_NAME, EMP_NAME, JOB_CLASS, CHG_HOUR, and HOURS values are all dependent on—that is, they are determined by—the

combination of PROJ_NUM and EMP_NUM. There are additional dependencies. For example, the project number identifies (determines) the project name. In other words, the project name is dependent on the project number. You can write that dependency as:

PROJ_NUM → PROJ_NAME

Also, if you know an employee number, you also know that employee's name, job classification, and charge per hour. Therefore, you can identify the dependency shown next:

EMP_NUM → EMP_NAME, JOB_CLASS, CHG_HOUR

However, given the previous dependency components, you can see that knowing the job classification means knowing the charge per hour for that job classification. In other words, you can identify one last dependency:

JOB_CLASS → CHG_HOUR

This dependency exists between two nonprime attributes; therefore, it is a signal that a transitive dependency exists, and we will refer to it as a transitive dependency. The dependencies you have just examined can also be depicted with the help of the diagram shown in [Figure 6.3](#). Because such a diagram depicts all dependencies found within a given table structure, it is known as a **dependency diagram**. Dependency diagrams are very helpful in getting a bird's-eye view of all the relationships among a table's attributes, and their use makes it less likely that you will overlook an important dependency.

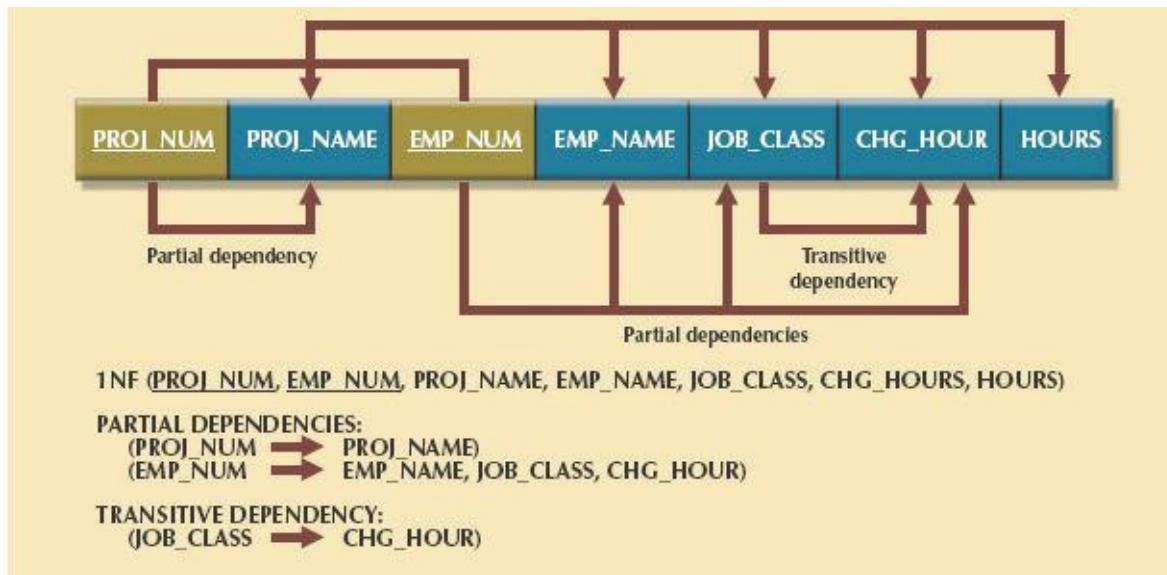
As you examine [Figure 6.3](#), note the following features of a dependency diagram:

1. The primary key attributes are bold, underlined, and shaded in a different color.
2. The arrows above the attributes indicate all desirable dependencies—that is, dependencies based on the primary key. In this case, note that the entity's attributes are dependent on the *combination* of PROJ_NUM and EMP_NUM.
3. The arrows below the dependency diagram indicate less desirable dependencies. Two types of such dependencies exist:

a. *Partial dependencies*. You need to know only the PROJ_NUM to determine the PROJ_NAME; that is, the PROJ_NAME is dependent on only part of the primary key. Also, you need to know only the EMP_NUM to find the EMP_NAME, the JOB_CLASS, and the CHG_HOUR. A dependency based on only a part of a composite primary key is a partial dependency.

b. *Transitive dependencies*. Note that CHG_HOUR is dependent on JOB_CLASS. Because neither CHG_HOUR nor JOB_CLASS is a prime attribute—that is, neither attribute is at least part of a key—the condition is a transitive dependency. In other words, a transitive dependency is a dependency of one nonprime attribute on another nonprime attribute. The problem with transitive dependencies is that they still yield data anomalies.

FIGURE 6.3 First normal form (1NF) dependency diagram



SOURCE: Course Technology/Cengage Learning

Figure 6.3 includes the relational schema for the table in 1NF and a textual notation for each identified dependency.

NOTE

The term **[first normal form \(1NF\)](#)** describes the tabular format in which:

- All of the **[key attributes](#)** are defined.
 - There are no repeating groups in the table. In other words, each row/column intersection contains one and only one value, not a set of values.
 - All attributes are dependent on the primary key.
-

All relational tables satisfy the 1NF requirements. The problem with the 1NF table structure shown in [Figure 6.3](#) is that it contains partial dependencies—that is, dependencies based on only a part of the primary key.

While partial dependencies are sometimes used for performance reasons, they should be used with caution. Such caution is warranted because a table that contains partial dependencies is still subject to data redundancies, and therefore to various anomalies. The data redundancies occur because every row entry requires duplication of data. For example, if Alice K. Johnson submits her work log, then the user would have to make multiple entries during the course of a day. For each entry, the EMP_NAME, JOB_CLASS, and CHG_HOUR must be entered each time, even though the attribute values are identical for each row entered. Such duplication of effort is very inefficient, and it helps create data anomalies; nothing prevents the user from typing slightly different versions of the employee name, the position, or the hourly pay. For instance, the employee name for EMP_NUM = 102 might be entered as *Dave Senior* or *D. Senior*. The project name might also be entered correctly as *Evergreen* or misspelled as *Evergeen*. Such data anomalies violate the relational database's integrity and consistency rules.

6.3.2 CONVERSION TO SECOND NORMAL FORM

Conversion to 2NF occurs only when the 1NF has a composite primary key. If the 1NF has a single-attribute primary key, then the table is automatically in 2NF. The 1NF-to-2NF conversion is simple. Starting with the 1NF format displayed in [Figure 6.3](#), you take the following steps:

Step 1: Make New Tables to Eliminate Partial Dependencies

For each component of the primary key that acts as a determinant in a partial

dependency, create a new table with a copy of that component as the primary key. While these components are placed in the new tables, it is important that they also remain in the original table as well. The determinants must remain in the original table because they will be the foreign keys for the relationships needed to relate these new tables to the original table. To construct the revised dependency diagram, write each key component on a separate line; then write the original (composite) key on the last line. For example:

PROJ_NUM

EMP_NUM

PROJ_NUM EMP_NUM

Each component will become the key in a new table. In other words, the original table is now divided into three tables (PROJECT, EMPLOYEE, and ASSIGNMENT).

Step 2: Reassign Corresponding Dependent Attributes

Use [Figure 6.3](#) to determine attributes that are dependent in the partial dependencies. The dependencies for the original key components are found by examining the arrows below the dependency diagram shown in [Figure 6.3](#). The attributes that are dependent in a partial dependency are removed from the original table and placed in the new table with the dependency's determinant. Any attributes that are not dependent in a partial dependency will remain in the original table. In other words, the three tables that result from the conversion to 2NF are given appropriate names (PROJECT, EMPLOYEE, and ASSIGNMENT) and are described by the following relational schemas:

PROJECT (PROJ_NUM, PROJ_NAME)

EMPLOYEE (EMP_NUM, EMP_NAME, JOB_CLASS, CHG_HOUR)

ASSIGNMENT (PROJ_NUM, EMP_NUM, ASSIGN_HOURS)

Because the number of hours spent on each project by each employee is dependent on both PROJ_NUM and EMP_NUM in the ASSIGNMENT table, you leave those hours in the ASSIGNMENT table as ASSIGN_HOURS. Notice that the ASSIGNMENT table contains a composite primary key composed of the attributes PROJ_NUM and EMP_NUM. Notice that by leaving the determinants in the original table as well as making them the primary keys of the new tables, primary key/foreign key relationships have been created. For example, in the

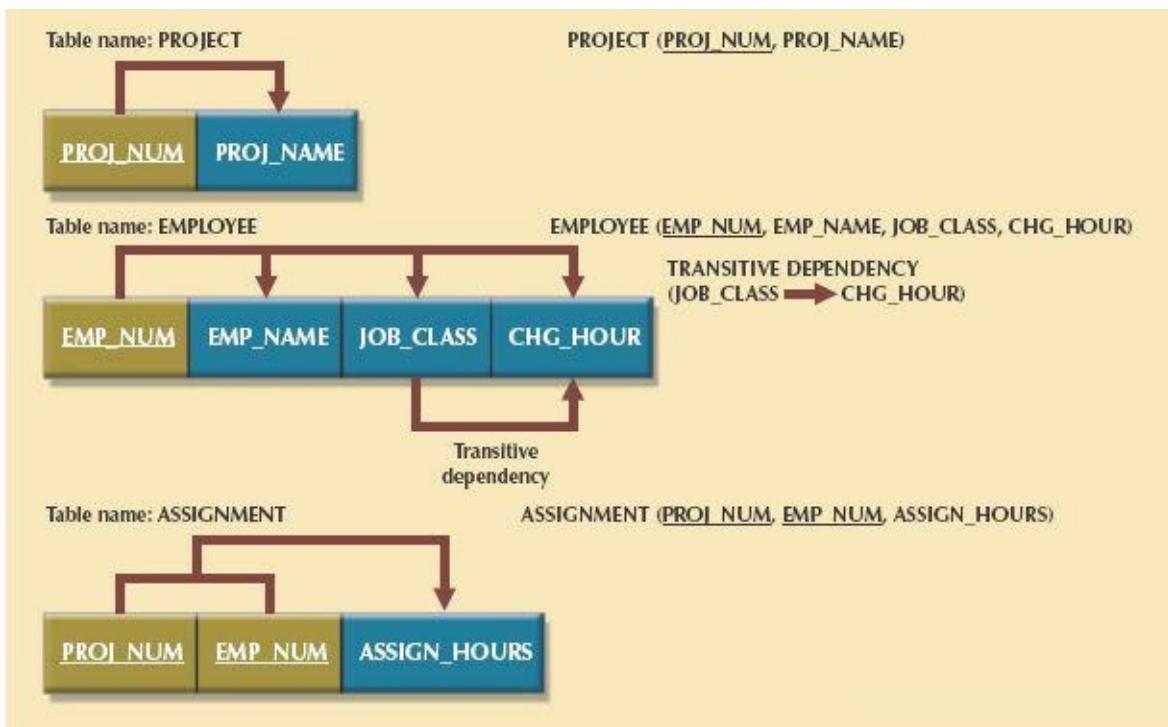
EMPLOYEE table, EMP_NUM is the primary key. In the ASSIGNMENT table, EMP_NUM is part of the composite primary key (PROJ_NUM, EMP_NUM) and is a foreign key relating the EMPLOYEE table to the ASSIGNMENT table.

The results of Steps 1 and 2 are displayed in [Figure 6.4](#). At this point, most of the anomalies discussed earlier have been eliminated. For example, if you now want to add, change, or delete a PROJECT record, you need to go only to the PROJECT table and make the change to only one row.

Because a partial dependency can exist only when a table's primary key is composed of several attributes, a table whose primary key consists of only a single attribute is automatically in 2NF once it is in 1NF.

[Figure 6.4](#) still shows a transitive dependency, which can generate anomalies. For example, if the charge per hour changes for a job classification held by many employees, that change must be made for *each* of those employees. If you forget to update some of the employee records that are affected by the charge per hour change, different employees with the same job description will generate different hourly charges.

FIGURE 6.4 Second normal form (2NF) conversion results



SOURCE: Course Technology/Cengage Learning

NOTE

A table is in **second normal form (2NF)** when:

- It is in 1NF.

and

- It includes no partial dependencies; that is, no attribute is dependent on only a portion of the primary key.

It is still possible for a table in 2NF to exhibit transitive dependency; that is, the primary key may rely on one or more nonprime attributes to functionally determine other nonprime attributes, as indicated by a functional dependence among the nonprime attributes.

6.3.3 CONVERSION TO THIRD NORMAL FORM

The data anomalies created by the database organization shown in [Figure 6.4](#) are easily eliminated by completing the following two steps:

Step 1: Make New Tables to Eliminate Transitive Dependencies

For every transitive dependency, write a copy of its [determinant](#) as a primary key for a new table. A determinant is any attribute whose value determines other values within a row. If you have three different transitive dependencies, you will have three different determinants. As with the conversion to 2NF, it is important for the determinant remain in the original table to serve as a foreign key. [Figure 6.4](#) shows only one table that contains a transitive dependency. Therefore, write the determinant for this transitive dependency as:

JOB_CLASS

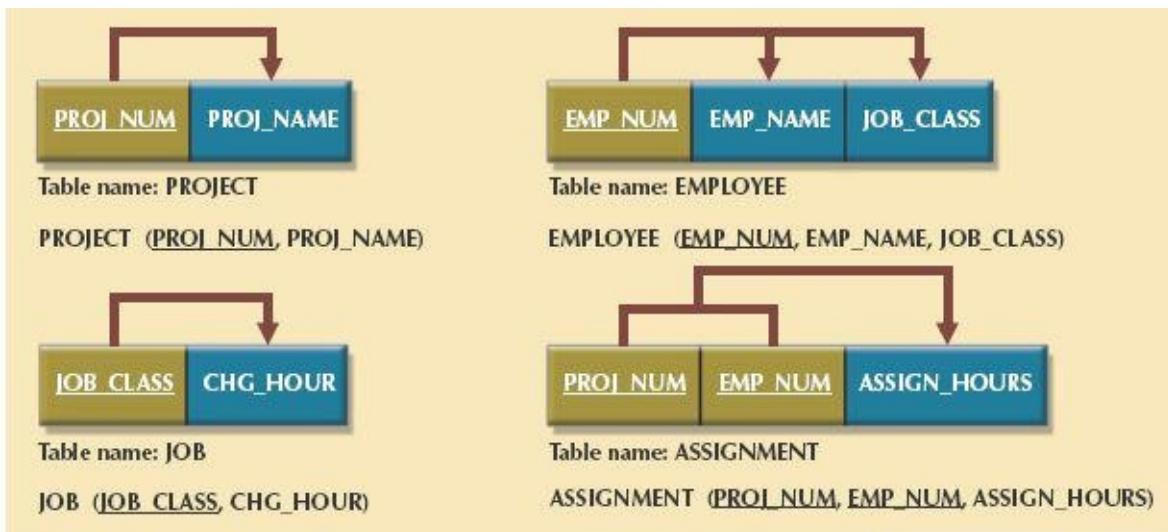
Step 2: Reassign Corresponding Dependent Attributes

Using [Figure 6.4](#), identify the attributes that are dependent on each determinant identified in Step 1. Place the dependent attributes in the new tables with their determinants and remove them from their original tables. In this example, eliminate CHG_HOUR from the EMPLOYEE table shown in [Figure 6.4](#) to leave the EMPLOYEE table dependency definition as:

EMP_NUM → EMP_NAME, JOB_CLASS

Draw a new dependency diagram to show all of the tables you have defined in Steps 1 and 2. Name the table to reflect its contents and function. In this case, JOB seems appropriate. Check all of the tables to make sure that each table has a determinant and that no table contains inappropriate dependencies. When you have completed these steps, you will see the results in [Figure 6.5](#).

FIGURE 6.5 Third normal form (3NF) conversion results



SOURCE: Course Technology/Cengage Learning

In other words, after the 3NF conversion has been completed, your database will contain four tables:

PROJECT (PROJ_NUM, PROJ_NAME)

EMPLOYEE (EMP_NUM, EMP_NAME, JOB_CLASS)

JOB (JOB_CLASS, CHG_HOUR)

ASSIGNMENT (PROJ_NUM, EMP_NUM, ASSIGN_HOURS)

Note that this conversion has eliminated the original EMPLOYEE table's transitive dependency; the tables are now said to be in third normal form (3NF).

NOTE

A table is in **third normal form (3NF)** when:

- It is in 2NF.

and

- It contains no transitive dependencies.
-

It is interesting to note the similarities between resolving 2NF and 3NF

problems. To convert a table from 1NF to 2NF, it is necessary to remove the partial dependencies. To convert a table from 2NF to 3NF, it is necessary to remove the transitive dependencies. No matter whether the “problem” dependency is a partial dependency or a transitive dependency, the solution is the same: create a new table for each problem dependency. The determinant of the problem dependency remains in the original table and is placed as the primary key of the new table. The dependents of the problem dependency are removed from the original table and placed as nonprime attributes in the new table.

Be aware, however, that while the technique is the same, it is imperative that 2NF be achieved before moving on to 3NF; be certain to resolve the partial dependencies before resolving the transitive dependencies. Also, recall the assumption that was made at the beginning of the normalization discussion—that each table has only one candidate key, which is the primary key. If a table has multiple candidate keys, then the overall process remains the same, but there are additional considerations.

For example, if a table has multiple candidate keys and one of them is a composite key, the table can have partial dependencies based on this composite candidate key, even when the primary key chosen is a single attribute. In those cases, following the process described above, those dependencies would be perceived as transitive dependencies and would not be resolved until 3NF. The simplified process described above will allow the designer to achieve the correct result, but through practice, you should recognize all candidate keys and their dependencies as such, and resolve them appropriately. The existence of multiple candidate keys can also influence the identification of transitive dependencies. Previously, a transitive dependency was defined to exist when one nonprime attribute determined another nonprime attribute. In the presence of multiple candidate keys, the definition of a nonprime attribute as an attribute that is not a part of any candidate key is critical. If the determinant of a functional dependence is not the primary key but is a part of another candidate key, then it is not a nonprime attribute and does not signal the presence of a transitive dependency.

6.4 IMPROVING THE DESIGN

Now that the table structures have been cleaned up to eliminate the troublesome partial and transitive dependencies, you can focus on improving the database’s

ability to provide information and on enhancing its operational characteristics. In the next few paragraphs, you will learn about the various types of issues you need to address to produce a good normalized set of tables. Note that for space issues, each section presents just one example—the designer must apply the principle to all remaining tables in the design. Remember that normalization cannot, by itself, be relied on to make good designs. Instead, normalization is valuable because its use helps eliminate data redundancies.

Evaluate PK Assignments

Each time a new employee is entered into the EMPLOYEE table, a JOB_CLASS value must be entered. Unfortunately, it is too easy to make data-entry errors that lead to referential integrity violations. For example, entering *DB Designer* instead of *Database Designer* for the JOB_CLASS attribute in the EMPLOYEE table will trigger such a violation. Therefore, it would be better to add a JOB_CODE attribute to create a unique identifier. The addition of a JOB_CODE attribute produces the following dependency:

JOB_CODE → JOB_CLASS, CHG_HOUR

If you assume that the JOB_CODE is a proper primary key, this new attribute does produce the following dependency:

JOB_CLASS → CHG_HOUR

However, this dependency is not a transitive dependency because the determinant is a candidate key. Further, the presence of JOB_CODE greatly decreases the likelihood of referential integrity violations. Note that the new JOB table now has two candidate keys—JOB_CODE and JOB_CLASS. In this case, JOB_CODE is the chosen primary key as well as a surrogate key. A surrogate key, as you should recall, is an artificial PK introduced by the designer with the purpose of simplifying the assignment of primary keys to tables. Surrogate keys are usually numeric, they are often generated automatically by the DBMS, they are free of semantic content (they have no special meaning), and they are usually hidden from the end users.

Evaluate Naming Conventions

It is best to adhere to the naming conventions outlined in [Chapter 2](#), Data Models. Therefore, CHG_HOUR will be changed to JOB_CHG_HOUR to indicate its association with the JOB table. In addition, the attribute name JOB_CLASS does not quite describe entries such as *Systems Analyst*, *Database Designer*, and so on; the label JOB_DESCRIPTION fits the entries better. Also,

you might have noticed that HOURS was changed to ASSIGN_HOURS in the conversion from 1NF to 2NF. That change lets you associate the hours worked with the ASSIGNMENT table.

Refine Attribute Atomicity

It is generally good practice to pay attention to the *atomicity* requirement. An **atomic attribute** is one that cannot be further subdivided. Such an attribute is said to display **atomicity**. Clearly, the use of the EMP_NAME in the EMPLOYEE table is not atomic because EMP_NAME can be decomposed into a last name, a first name, and an initial. By improving the degree of atomicity, you also gain querying flexibility. For example, if you use EMP_LNAME, EMP_FNAME, and EMP_INITIAL, you can easily generate phone lists by sorting last names, first names, and initials. Such a task would be very difficult if the name components were within a single attribute. In general, designers prefer to use simple, single-valued attributes, as indicated by the business rules and processing requirements.

Identify New Attributes

If the EMPLOYEE table were used in a real-world environment, several other attributes would have to be added. For example, year-to-date gross salary payments, Social Security payments, and Medicare payments would be desirable. An employee hire date attribute (EMP_HIREDATE) could be used to track an employee's job longevity, and could serve as a basis for awarding bonuses to long-term employees and for other morale-enhancing measures. The same principle must be applied to all other tables in your design.

Identify New Relationships

According to the original report, the users need to track which employee is acting as the manager of each project. This can be implemented as a relationship between EMPLOYEE and PROJECT. From the original report, it is clear that each project has only one manager. Therefore, the system's ability to supply detailed information about each project's manager is ensured by using the EMP_NUM as a foreign key in PROJECT. That action ensures that you can access the details of each PROJECT's manager data without producing unnecessary and undesirable data duplication. The designer must take care to place the right attributes in the right tables by using normalization principles.

Refine Primary Keys as Required for Data Granularity

Granularity refers to the level of detail represented by the values stored in a

table's row. Data stored at their lowest level of granularity are said to be *atomic data*, as explained earlier. In [Figure 6.5](#), the ASSIGNMENT table in 3NF uses the ASSIGN_HOURS attribute to represent the hours worked by a given employee on a given project. However, are those values recorded at their lowest level of granularity? In other words, does ASSIGN_HOURS represent the *hourly* total, *daily* total, *weekly* total, *monthly* total, or *yearly* total? Clearly, ASSIGN_HOURS requires more careful definition. In this case, the relevant question would be as follows: for what time frame—hour, day, week, month, and so on—do you want to record the ASSIGN_HOURS data?

For example, assume that the combination of EMP_NUM and PROJ_NUM is an acceptable (composite) primary key in the ASSIGNMENT table. That primary key is useful in representing only the total number of hours an employee worked on a project since its start. Using a surrogate primary key such as ASSIGN_NUM provides lower granularity and yields greater flexibility. For example, assume that the EMP_NUM and PROJ_NUM combination is used as the primary key, and then an employee makes two “hours worked” entries in the ASSIGNMENT table. That action violates the entity integrity requirement. Even if you add the ASSIGN_DATE as part of a composite PK, an entity integrity violation is still generated if any employee makes two or more entries for the same project on the same day. (The employee might have worked on the project for a few hours in the morning and then worked on it again later in the day.) The same data entry yields no problems when ASSIGN_NUM is used as the primary key.

NOTE

In an ideal database design, the level of desired granularity would be determined during the conceptual design or while the requirements were being gathered. However, as you have already seen in this chapter, many database designs involve the refinement of existing data requirements, thus triggering design modifications. In a real-world environment, changing granularity requirements might dictate changes in primary key selection, and those changes might ultimately require the use of surrogate keys.

Maintain Historical Accuracy

Writing the job charge per hour into the ASSIGNMENT table is crucial to

maintaining the historical accuracy of the table's data. It would be appropriate to name this attribute ASSIGN_CHG_HOUR. Although this attribute would appear to have the same value as JOB_CHG_HOUR, this is true *only* if the JOB_CHG_HOUR value remains the same forever. It is reasonable to assume that the job charge per hour will change over time. However, suppose that the charges to each project were calculated and billed by multiplying the hours worked from the ASSIGNMENT table by the charge per hour from the JOB table. Those charges would always show the current charge per hour stored in the JOB table rather than the charge per hour that was in effect at the time of the assignment.

Evaluate Using Derived Attributes

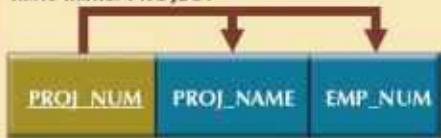
Finally, you can use a derived attribute in the ASSIGNMENT table to store the actual charge made to a project. That derived attribute, named ASSIGN_CHARGE, is the result of multiplying ASSIGN_HOURS by ASSIGN_CHG_HOUR. This creates a transitive dependency such that:

$$(ASSIGN_CHARGE + ASSIGN_HOURS) \rightarrow ASSIGN_CHG_HOUR.$$

From a system functionality point of view, such derived attribute values can be calculated when they are needed to write reports or invoices. However, storing the derived attribute in the table makes it easy to write the application software to produce the desired results. Also, if many transactions must be reported and/or summarized, the availability of the derived attribute will save reporting time. (If the calculation is done at the time of data entry, it will be completed when the end user presses the Enter key, thus speeding up the process.) Review [Chapter 4](#) for a discussion of the implications of storing derived attributes in a database table.

The enhancements described in the preceding sections are illustrated in the tables and dependency diagrams shown in [Figure 6.6](#).

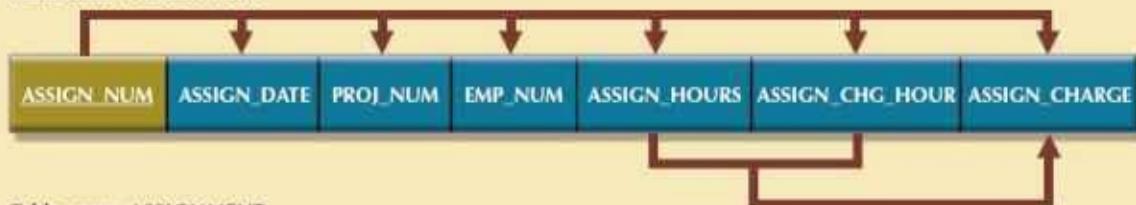
FIGURE 6.6 The completed database

Table name: PROJECT**Table name: PROJECT**

PROJ_NUM	PROJ_NAME	EMP_NUM
15	Evergreen	105
18	Amber Wave	104
22	Rolling Tide	113
25	Starflight	101

Table name: JOB**Table name: JOB**

JOB_CODE	JOB_DESCRIPTION	JOB_CHG_HOUR
500	Programmer	35.75
501	Systems Analyst	96.75
502	Database Designer	105.00
503	Electrical Engineer	84.50
504	Mechanical Engineer	67.90
505	Civil Engineer	55.78
506	Clerical Support	26.87
507	DSS Analyst	45.95
508	Applications Designer	48.10
509	Bio Technician	34.55
510	General Support	18.36

Table name: ASSIGNMENT**Table name: ASSIGNMENT**

ASSIGN_NUM	ASSIGN_DATE	PROJ_NUM	EMP_NUM	ASSIGN_HOURS	ASSIGN_CHG_HOUR	ASSIGN_CHARGE
1001	04-Mar-12 15	103		2.6	84.50	219.70
1002	04-Mar-12 18	118		1.4	18.36	25.70
1003	05-Mar-12 15	101		3.6	105.00	378.00
1004	05-Mar-12 22	113		2.5	48.10	120.25
1005	05-Mar-12 15	103		1.9	84.50	160.55
1006	05-Mar-12 25	115		4.2	96.75	406.35
1007	05-Mar-12 22	105		5.2	105.00	546.00
1008	05-Mar-12 25	101		1.7	105.00	178.50
1009	05-Mar-12 15	105		2.0	105.00	210.00
1010	06-Mar-12 15	102		3.6	96.75	357.65
1011	06-Mar-12 22	104		2.6	96.75	251.55
1012	06-Mar-12 15	101		2.3	105.00	241.50
1013	06-Mar-12 25	114		1.8	48.10	86.58
1014	06-Mar-12 22	111		4.0	26.87	107.48
1015	06-Mar-12 25	114		3.4	48.10	163.54
1016	06-Mar-12 18	112		1.2	45.95	55.14
1017	06-Mar-12 18	118		2.0	18.36	36.72
1018	06-Mar-12 18	104		2.6	96.75	251.55
1019	06-Mar-12 15	103		3.0	84.50	253.50
1020	07-Mar-12 22	105		2.7	105.00	283.50
1021	08-Mar-12 25	108		4.2	96.75	406.35
1022	07-Mar-12 25	114		5.8	48.10	278.98
1023	07-Mar-12 22	106		2.4	35.75	85.80

Table name: EMPLOYEE

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIREDATE	JOB_CODE
101	News	John	G	08-Nov-00	502
102	Senior	David	H	12-Jul-89	501
103	Arbough	June	E	01-Dec-97	503
104	Ramoras	Anne	K	15-Nov-88	501
105	Johnson	Alice	K	01-Feb-94	502
106	Smithfield	William		22-Jun-05	500
107	Alonzo	Maria	D	10-Oct-94	500
108	Washington	Ralph	B	22-Aug-89	501
109	Smith	Larry	W	18-Jul-99	501
110	Olenko	Gerald	A	11-Dec-96	505
111	Wabash	Geoff	B	04-Apr-89	506
112	Smithson	Darlene	M	23-Oct-95	507
113	Joenbrood	Delbert	K	15-Nov-94	508
114	Jones	Annelise		20-Aug-91	508
115	Bawangi	Travis	B	25-Jan-90	501
116	Pratt	Gerald	L	05-Mar-95	510
117	Williamson	Angie	H	19-Jun-94	509
118	Frommer	James	J	04-Jan-06	510

SOURCE: Course Technology/Cengage Learning

[Figure 6.6](#) is a vast improvement over the original database design. If the application software is designed properly, the most active table (ASSIGNMENT) requires the entry of only the PROJ_NUM, EMP_NUM, and ASSIGN_HOURS values. The values for the attributes ASSIGN_NUM and ASSIGN_DATE can be generated by the application. For example, the ASSIGN_NUM can be created by using a counter, and the ASSIGN_DATE can be the system date read by the application and automatically entered into the ASSIGNMENT table. In addition, the application software can automatically insert the correct ASSIGN_CHG_HOUR value by writing the appropriate JOB table's JOB_CHG_HOUR value into the ASSIGNMENT table. (The JOB and ASSIGNMENT tables are related through the JOB_CODE attribute.) If the JOB table's JOB_CHG_HOUR value changes, the next insertion of that value into the ASSIGNMENT table will reflect the change automatically. The table structure thus minimizes the need for human intervention. In fact, if the system requires the employees to enter their own work hours, they can scan their EMP_NUM into the ASSIGNMENT table by using a magnetic card reader that enters their

identity. Thus, the ASSIGNMENT table's structure can set the stage for maintaining some desired level of security.

6.5 SURROGATE KEY CONSIDERATIONS

Although this design meets the vital entity and referential integrity requirements, the designer must still address some concerns. For example, a composite primary key might become too cumbersome to use as the number of attributes grows. (It becomes difficult to create a suitable foreign key when the related table uses a composite primary key. In addition, a composite primary key makes it more difficult to write search routines.) Or, a primary key attribute might simply have too much descriptive content to be usable—which is why the JOB_CODE attribute was added to the JOB table to serve as its primary key. When the primary key is considered to be unsuitable for some reason, designers use surrogate keys, as discussed in the previous chapter.

At the implementation level, a surrogate key is a system-defined attribute generally created and managed via the DBMS. Usually, a system-defined surrogate key is numeric, and its value is automatically incremented for each new row. For example, Microsoft Access uses an AutoNumber data type, Microsoft SQL Server uses an identity column, and Oracle uses a sequence object.

Recall from [Section 6.4](#) that the JOB_CODE attribute was designated to be the JOB table's primary key. However, remember that the JOB_CODE attribute does not prevent duplicate entries, as shown in the JOB table in [Table 6.4](#).

TABLE 6.4 Duplicate Entries in the JOB Table

JOB_CODE JOB_DESCRIPTION JOB_CHG_HOUR

511 Programmer \$35.75

512 Programmer \$35.75

Clearly, the data entries in [Table 6.4](#) are inappropriate because they duplicate existing records—yet there has been no violation of either entity integrity or referential integrity. This problem of multiple duplicate records was created when the JOB_CODE attribute was added as the PK. (When the JOB_DESCRIPTION was initially designated to be the PK, the DBMS would ensure unique values for all job description entries when it was asked to enforce entity integrity. However, that option created the problems that caused the use of the JOB_CODE attribute in the first place!) In any case, if JOB_CODE is to be the surrogate PK, you still must ensure the existence of unique values in the JOB_DESCRIPTION *through the use of a unique index*.

Note that all of the remaining tables (PROJECT, ASSIGNMENT, and EMPLOYEE) are subject to the same limitations. For example, if you use the EMP_NUM attribute in the EMPLOYEE table as the PK, you can make multiple entries for the same employee. To avoid that problem, you might create a unique index for EMP_LNAME, EMP_FNAME, and EMP_INITIAL, but how would you then deal with two employees named Joe B. Smith? In that case, you might use another (preferably externally defined) attribute to serve as the basis for a unique index.

It is worth repeating that database design often involves trade-offs and the exercise of professional judgment. In a real-world environment, you must strike a balance between design integrity and flexibility. For example, you might design the ASSIGNMENT table to use a unique index on PROJ_NUM, EMP_NUM, and ASSIGN_DATE if you want to limit an employee to only one ASSIGN_HOURS entry per date. That limitation would ensure that employees could not enter the same hours multiple times for any given date. Unfortunately, that limitation is likely to be undesirable from a managerial point of view. After all, if an employee works several different times on a project during any given day, it must be possible to make multiple entries for that same employee and the same project during that day. In that case, the best solution might be to add a new externally defined attribute—such as a stub, voucher, or ticket number—to ensure uniqueness. In any case, frequent data audits would be appropriate.

6.6 HIGHER-LEVEL NORMAL FORMS

Tables in 3NF will perform suitably in business transactional databases. However, higher normal forms are sometimes useful. In this section, you will learn about a special case of 3NF, known as Boyce-Codd normal form, and about fourth normal form (4NF).

6.6.1 THE BOYCE-CODD NORMAL FORM

A table is in Boyce-Codd normal form (BCNF) when every determinant in the table is a candidate key. (Recall from [Chapter 3](#) that a candidate key has the same characteristics as a primary key, but for some reason, it was not chosen to be the primary key.) Clearly, when a table contains only one candidate key, the 3NF and the BCNF are equivalent. In other words, BCNF can be violated only when the table contains more than one candidate key.

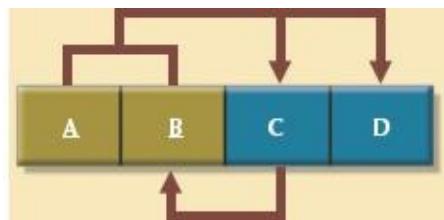
NOTE

A table is in **Boyce-Codd normal form (BCNF)** when every determinant in the table is a candidate key.

Most designers consider the BCNF to be a special case of the 3NF. In fact, if the techniques shown in this chapter are used, most tables conform to the BCNF requirements once the 3NF is reached. So, how can a table be in 3NF and not be in BCNF? To answer that question, you must keep in mind that a transitive dependency exists when one nonprime attribute is dependent on another nonprime attribute.

In other words, a table is in 3NF when it is in 2NF and there are no transitive dependencies, but what about a case in which a **nonkey attribute** is the determinant of a key attribute? That condition does not violate 3NF, yet it fails to meet the BCNF requirements (see [Figure 6.7](#)) because BCNF requires that every determinant in the table be a candidate key.

FIGURE 6.7 A table that is in 3NF but not in BCNF



SOURCE: Course Technology/Cengage Learning

Note these functional dependencies in [Figure 6.7](#):

$$A + B \rightarrow C, D$$

$$A + C \rightarrow B, D$$

$$C \rightarrow B$$

Notice that this structure has two candidate keys: $(A + B)$ and $(A + C)$. The table structure shown in [Figure 6.7](#) has no partial dependencies, nor does it contain transitive dependencies. (The condition $C \rightarrow B$ indicates that *a nonkey attribute determines part of the primary key*—and that dependency is *not* transitive or partial because the dependent is a prime attribute!) Thus, the table structure in [Figure 6.7](#) meets the 3NF requirements, although the condition $C \rightarrow B$ causes the table to fail to meet the BCNF requirements.

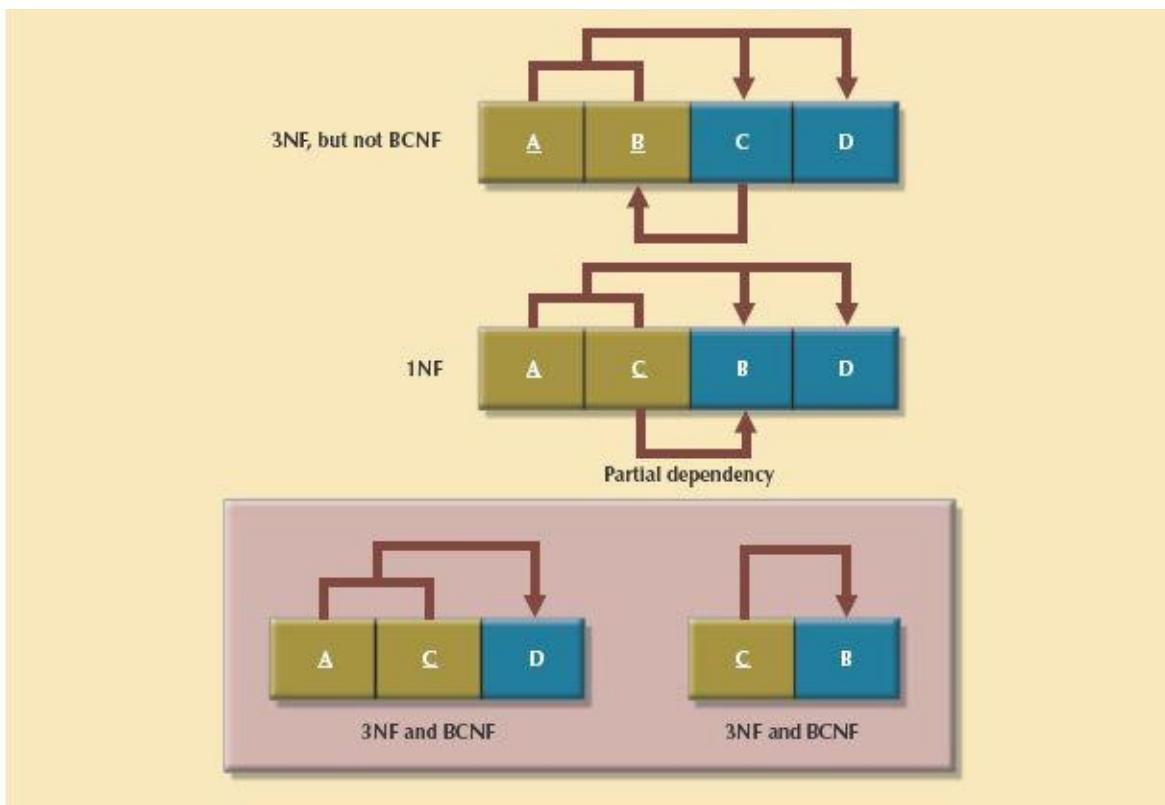
To convert the table structure in [Figure 6.7](#) into table structures that are in 3NF and in BCNF, first change the primary key to $A + C$. This change is appropriate because the dependency $C \rightarrow B$ means that C is effectively a superset of B . At this point, the table is in 1NF because it contains a partial dependency, $C \rightarrow B$. Next, follow the standard decomposition procedures to produce the results shown in [Figure 6.8](#).

To see how this procedure can be applied to an actual problem, examine the sample data in [Table 6.5](#).

TABLE 6.5 Sample Data for a BCNF Conversion

STU_ID	STAFF_ID	CLASS_CODE	ENROLL_GRADE
125	25	21334	A
125	20	32456	C
135	20	28458	B
144	25	27563	C
144	20	32456	B

FIGURE 6.8 Decomposition to BCNF



SOURCE: Course Technology/Cengage Learning

Table 6.5 reflects the following conditions:

- Each CLASS_CODE identifies a class uniquely. This condition illustrates the case in which a course might generate many classes. For example, a course labeled INFS 420 might be taught in two classes (sections), each identified by a unique code to facilitate registration. Thus, the CLASS_CODE 32456 might identify INFS 420, class section 1, while the CLASS_CODE 32457 might identify INFS 420, class section 2. Or, the CLASS_CODE 28458 might identify QM 362, class section 5.
- A student can take many classes. Note, for example, that student 125 has taken both 21334 and 32456, earning the grades A and C, respectively.

- A staff member can teach many classes, but each class is taught by only one staff member. Note that staff member 20 teaches the classes identified as 32456 and 28458.

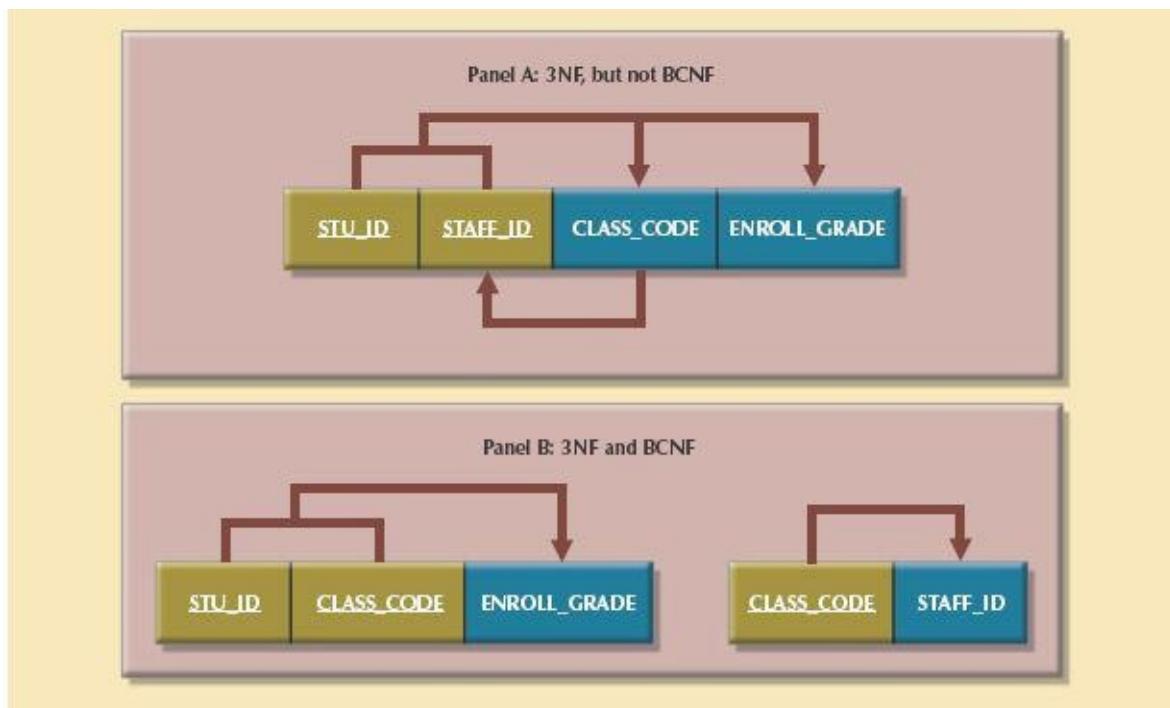
The structure shown in [Table 6.5](#) is reflected in Panel A of [Figure 6.9](#):

$\text{STU_ID} + \text{STAFF_ID} \rightarrow \text{CLASS_CODE}, \text{ENROLL_GRADE}$

$\text{CLASS_CODE} \rightarrow \text{STAFF_ID}$

Panel A of [Figure 6.9](#) shows a structure that is clearly in 3NF, but the table represented by this structure has a major problem because it is trying to describe two things: staff assignments to classes and student enrollment information. Such a dual-purpose table structure will cause anomalies. For example, if a different staff member is assigned to teach class 32456, two rows will require updates, thus producing an update anomaly. Also, if student 135 drops class 28458, information about who taught that class is lost, thus producing a deletion anomaly. The solution to the problem is to decompose the table structure, following the procedure outlined earlier. The decomposition of Panel B shown in [Figure 6.9](#) yields two table structures that conform to both 3NF and BCNF requirements.

FIGURE 6.9 Another BCNF decomposition



SOURCE: Course Technology/Cengage Learning

Remember that a table is in BCNF when every determinant in that table is a candidate key. Therefore, when a table contains only one candidate key, 3NF and BCNF are equivalent.

6.6.2 FOURTH NORMAL FORM (4NF)

You might encounter poorly designed databases, or you might be asked to convert spreadsheets into a database format in which multiple multivalued attributes exist. For example, consider the possibility that an employee can have multiple assignments and can also be involved in multiple service organizations. Suppose employee 10123 does volunteer work for the Red Cross and United Way. In addition, the same employee might be assigned to work on three projects: 1, 3, and 4. [Figure 6.10](#) illustrates how that set of facts can be recorded in very different ways.

FIGURE 6.10 Tables with multivalued dependencies

Table name: VOLUNTEER_V1

EMP_NUM	ORG_CODE	ASSIGN_NUM
10123	RC	1
10123	UW	3
10123		4

Table name: VOLUNTEER_V2

EMP_NUM	ORG_CODE	ASSIGN_NUM
10123	RC	
10123	UW	
10123		1
10123		3
10123		4

Table name: VOLUNTEER_V3

EMP_NUM	ORG_CODE	ASSIGN_NUM
10123	RC	1
10123	RC	3
10123	UW	4

SOURCE: Course Technology/Cengage Learning

There is a problem with the tables in [Figure 6.10](#). The attributes ORG_CODE and ASSIGN_NUM each may have many different values. In normalization terminology, this situation is referred to as a multivalued dependency, which occurs when one key determines multiple values of two other attributes and those attributes are independent of each other. (One employee can have many service entries and many assignment entries. Therefore, one EMP_NUM can determine multiple values of ORG_CODE and multiple values of ASSIGN_NUM; however, ORG_CODE and ASSIGN_NUM are independent of each other.) The presence of a multivalued dependency means that if table versions 1 and 2 are implemented, the tables are likely to contain quite a few null values; in fact, the tables do not even have a viable candidate key. (The EMP_NUM values are not unique, so they cannot be PKs. No combination of the attributes in table versions 1 and 2 can be used to create a PK because some of them contain nulls.) Such a condition is not desirable, especially when there are thousands of employees, many of whom may have multiple job assignments and many service activities. Version 3 at least has a PK, but it is composed of all the attributes in the table. In fact, version 3 meets 3NF requirements, yet it contains many redundancies that are clearly undesirable.

The solution is to eliminate the problems caused by the multivalued dependency. You do this by creating new tables for the components of the multivalued dependency. In this example, the multivalued dependency is resolved and eliminated by creating the ASSIGNMENT and SERVICE_V1 tables depicted in [Figure 6.11](#). Those tables are said to be in 4NF.

If you follow the proper design procedures illustrated in this book, you should not encounter the problem shown in [Figure 6.10](#). Specifically, the discussion of 4NF is largely academic if you make sure that your tables conform to the

following two rules:

1. All attributes must be dependent on the primary key, but they must be independent of each other.
2. No row may contain two or more multivalued facts about an entity.

NOTE

A table is in [**fourth normal form \(4NF\)**](#) when it is in 3NF and has no multivalued dependencies.

FIGURE 6.11 A set of tables in 4NF

Database name: CH06_Service

Table name: PROJECT

PROJ_CODE	PROJ_NAME	PROJ_BUDGET
1	BeThere	1023245.00
2	BlueMoon	20198608.00
3	GreenThumb	3234456.00
4	GoFast	5674000.00
5	GoSlow	1002500.00

Table name: EMPLOYEE

EMP_NUM	EMP_LNAME
10121	Rogers
10122	O'Leary
10123	Panera
10124	Johnson

Table name: ORGANIZATION

ORG_CODE	ORG_NAME
RC	Red Cross
UW	United Way
WF	Wildlife Fund

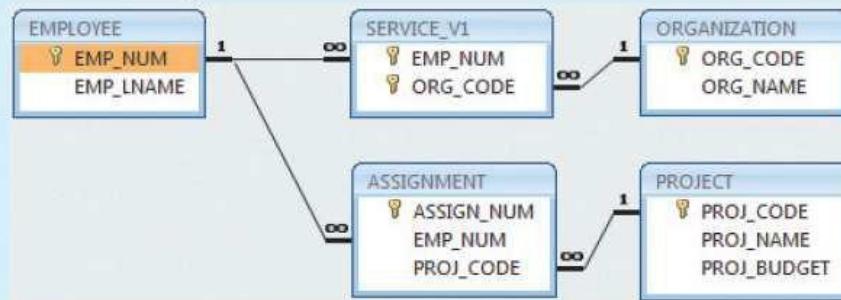
Table name: ASSIGNMENT

ASSIGN_NUM	EMP_NUM	PROJ_CODE
1	10123	1
2	10121	2
3	10123	3
4	10123	4
5	10121	1
6	10124	2
7	10124	3
8	10124	5

Table name: SERVICE_V1

EMP_NUM	ORG_CODE
10123	RC
10123	UW
10123	WF

The relational diagram



SOURCE: Course Technology/Cengage Learning

6.7 NORMALIZATION AND DATABASE DESIGN

The tables shown in [Figure 6.6](#) illustrate how normalization procedures can be used to produce good tables from poor ones. You will likely have ample opportunity to put this skill into practice when you begin to work with real-world databases. *Normalization should be part of the design process.* Therefore, make sure that proposed entities meet the required normal form *before* the table structures are created. Keep in mind that if you follow the design procedures discussed in [Chapters 3 and 4](#), the likelihood of data anomalies will be small. However, even the best database designers are known to make occasional mistakes that come to light during normalization checks. Also, many of the real-world databases you encounter will have been improperly designed or burdened

with anomalies if they were improperly modified over the course of time. That means you might be asked to redesign and modify existing databases that are, in effect, anomaly traps. Therefore, you should be aware of good design principles and procedures as well as normalization procedures.

First, an ERD is created through an iterative process. You begin by identifying relevant entities, their attributes, and their relationships. Then you use the results to identify additional entities and attributes. The ERD provides the big picture, or macro view, of an organization's data requirements and operations.

Second, normalization focuses on the characteristics of specific entities; that is, normalization represents a micro view of the entities within the ERD. Also, as you learned in the previous sections of this chapter, the normalization process might yield additional entities and attributes to be incorporated into the ERD. Therefore, it is difficult to separate normalization from ER modeling; the two techniques are used in an iterative and incremental process.

To understand the proper role of normalization in the design process, you should reexamine the operations of the contracting company whose tables were normalized in the preceding sections. Those operations can be summarized by using the following business rules:

- The company manages many projects.
- Each project requires the services of many employees.
- An employee may be assigned to several different projects.
- Some employees are not assigned to a project and perform duties not specifically related to a project. Some employees are part of a labor pool, to be shared by all project teams. For example, the company's executive secretary would not be assigned to any one particular project.
- Each employee has a single primary job classification, which determines the hourly billing rate.
- Many employees can have the same job classification. For example, the

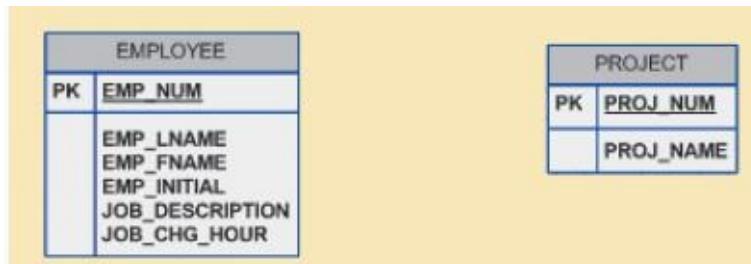
company employs more than one electrical engineer.

Given that simple description of the company's operations, two entities and their attributes are initially defined:

- PROJECT (**PROJ_NUM**, PROJ_NAME)
 - EMPLOYEE (**EMP_NUM**, EMP_LNAME, EMP_FNAME, EMP_INITIAL, JOB_DESCRIPTION, JOB_CHG_HOUR)

Those two entities constitute the initial ERD shown in [Figure 6.12](#).

FIGURE 6.12 Initial contracting company ERD



SOURCE: Course Technology/Cengage Learning

After creating the initial ERD shown in [Figure 6.12](#), the normal forms are defined:

- PROJECT is in 3NF and needs no modification at this point.
- EMPLOYEE requires additional scrutiny. The JOB_DESCRIPTION attribute defines job classifications such as Systems Analyst, Database Designer, and Programmer. In turn, those classifications determine the billing rate, JOB_CHG_HOUR. Therefore, EMPLOYEE contains a transitive dependency.

The removal of EMPLOYEE's transitive dependency yields three entities:

- PROJECT (**PROJ_NUM**, PROJ_NAME)
 - EMPLOYEE (**EMP_NUM**, EMP_LNAME, EMP_FNAME, EMP_INITIAL, JOB_CODE)

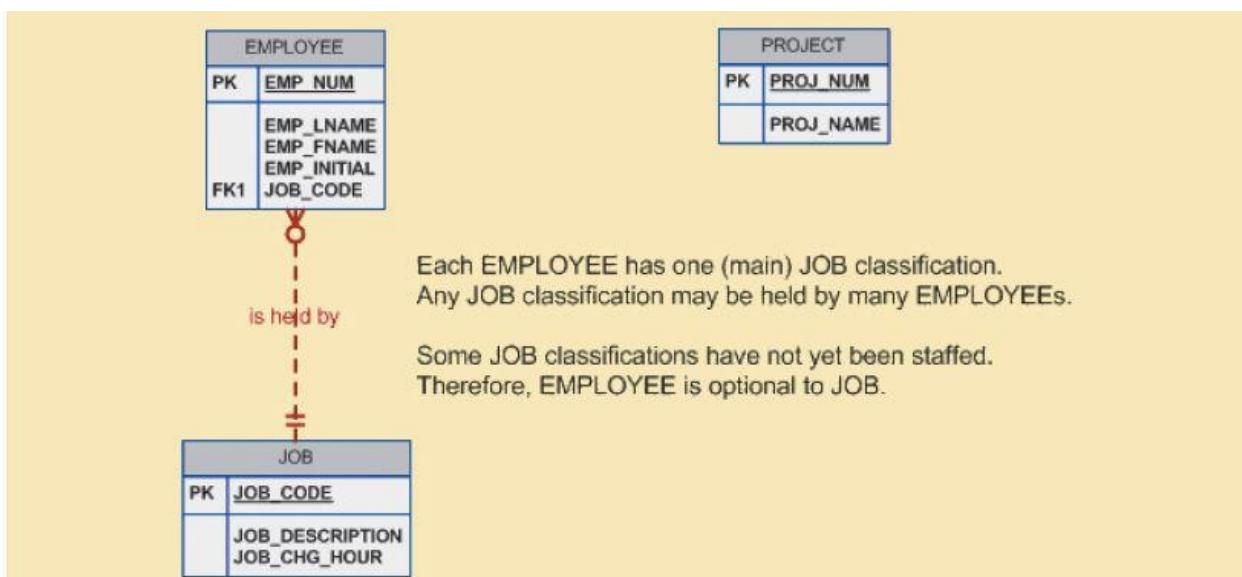
- JOB (JOB_CODE, JOB_DESCRIPTION, JOB_CHG_HOUR)

Because the normalization process yields an additional entity (JOB), the initial ERD is modified as shown in [Figure 6.13](#).

To represent the M:N relationship between EMPLOYEE and PROJECT, you might think that two 1:M relationships could be used—an employee can be assigned to many projects, and each project can have many employees assigned to it. (See [Figure 6.14](#).) Unfortunately, that representation yields a design that cannot be correctly implemented.

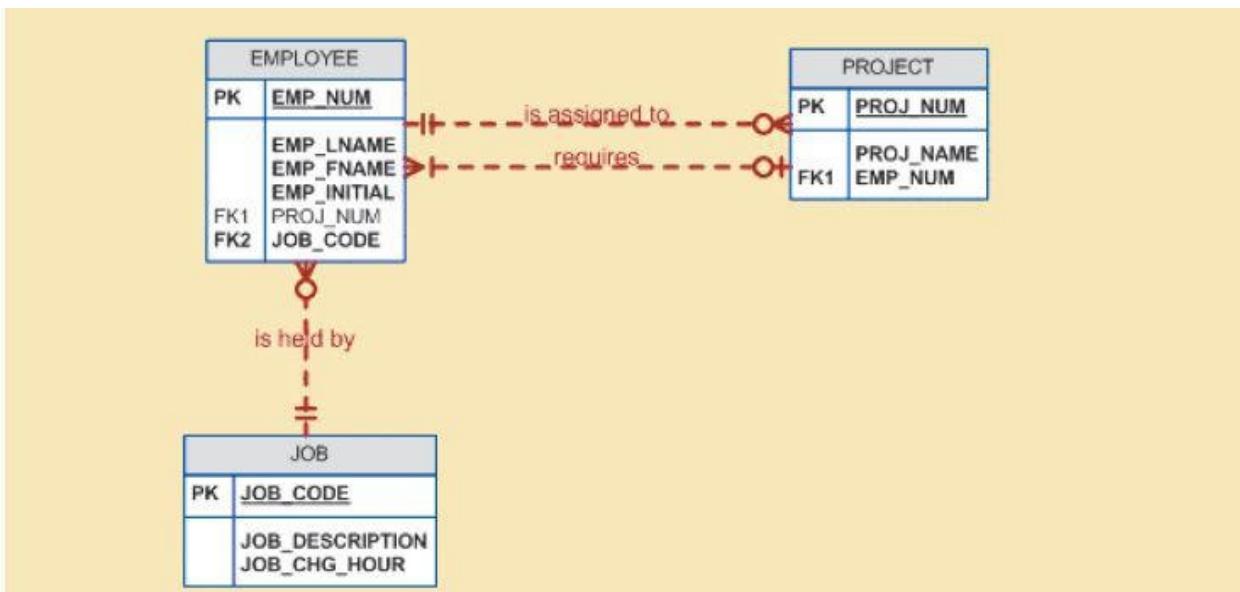
Because the M:N relationship between EMPLOYEE and PROJECT cannot be implemented, the ERD in [Figure 6.14](#) must be modified to include the ASSIGNMENT entity to track the assignment of employees to projects, thus yielding the ERD shown in [Figure 6.15](#). The ASSIGNMENT entity in [Figure 6.15](#) uses the primary keys from the entities PROJECT and EMPLOYEE to serve as its foreign keys. However, note that in this implementation, the ASSIGNMENT entity's surrogate primary key is ASSIGN_NUM, to avoid the use of a composite primary key. Therefore, the “enters” relationship between EMPLOYEE and ASSIGNMENT and the “requires” relationship between PROJECT and ASSIGNMENT are shown as weak or non-identifying.

FIGURE 6.13 Modified contracting company ERD



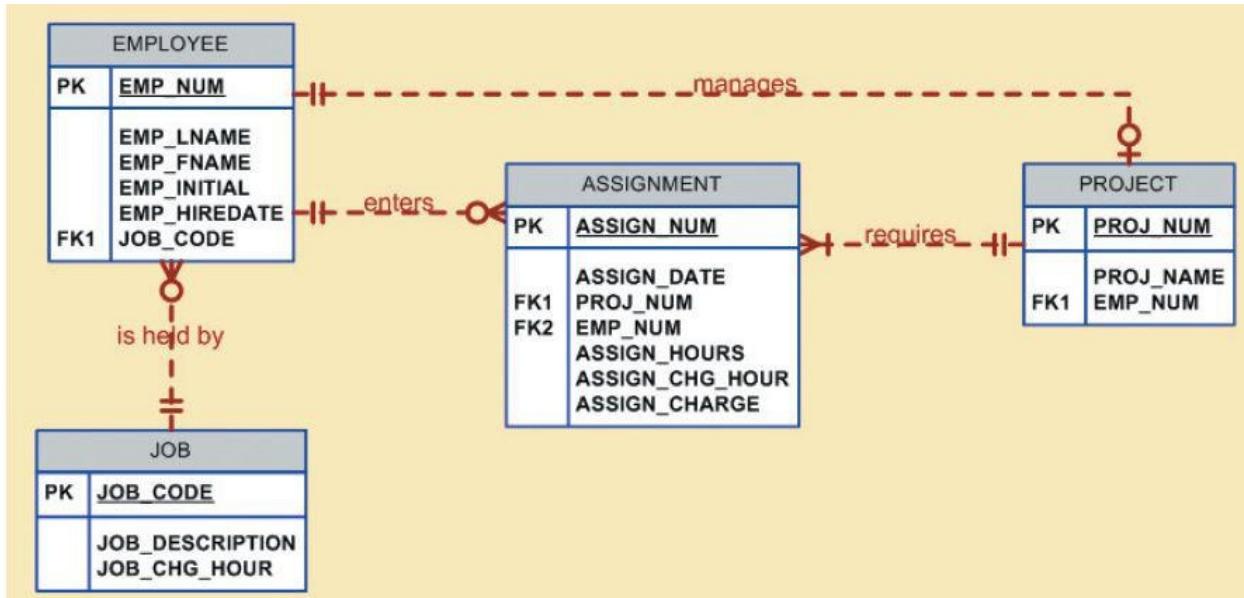
SOURCE: Course Technology/Cengage Learning

FIGURE 6.14 Incorrect M:N relationship representation



SOURCE: Course Technology/Cengage Learning

FIGURE 6.15 Final contracting company ERD



SOURCE: Course Technology/Cengage Learning

In [Figure 6.15](#), the ASSIGN_HOURS attribute is assigned to the composite entity named **ASSIGNMENT**. Because you will likely need detailed information about each project's manager, the creation of a “manages” relationship is useful. The “manages” relationship is implemented through the foreign key in **PROJECT**. Finally, some additional attributes may be created to improve the system's ability to generate additional information. For example, you may want to include the date the employee was hired (EMP_HIREDATE) to keep track of worker longevity. Based on this last modification, the model should include four entities and their attributes:

PROJECT (PROJ_NUM, PROJ_NAME, EMP_NUM)

EMPLOYEE (EMP_NUM, EMP_LNAME, EMP_FNAME, EMP_INITIAL, EMP_HIREDATE, JOB_CODE)

JOB (JOB_CODE, JOB_DESCRIPTION, JOB_CHG_HOUR)

ASSIGNMENT (ASSIGN_NUM, ASSIGN_DATE, PROJ_NUM, EMP_NUM, ASSIGN_HOURS, ASSIGN_CHG_HOUR, ASSIGN_CHARGE)

The design process is now on the right track. The ERD represents the operations accurately, and the entities now reflect their conformance to 3NF. The combination of normalization and ER modeling yields a useful ERD, whose entities may now be translated into appropriate table structures. In [Figure 6.15](#), note that **PROJECT** is optional to **EMPLOYEE** in the “manages” relationship.

This optionality exists because not all employees manage projects. The final database contents are shown in [Figure 6.16](#).

FIGURE 6.16 The implemented database

Table name: EMPLOYEE						Database name: Ch06_ConstructCo		
101	News	John	G	08-Nov-00	502	500	Programmer	35.75
102	Serier	David	H	12-Jul-89	501	501	Systems Analyst	96.75
103	Arbough	Jane	E	01-Dec-97	503	502	Database Designer	105.00
104	Ramorras	Annie	K	15-Nov-88	501	503	Electrical Engineer	84.50
105	Johnson	Alice	K	01-Feb-94	502	504	Mechanical Engineer	67.90
106	Smithfield	William		22-Jun-05	500	505	Civil Engineer	55.75
107	Alanzo	Maria	D	10-Oct-94	500	506	Clerical Support	26.87
108	Washington	Ralph	B	22-Aug-89	501	507	DSS Analyst	45.95
109	Smith	Larry	W	18-Jun-99	501	508	Applications Designer	48.10
110	Olonko	Gerard	A	11-Dec-96	506	509	Bio Technician	34.55
111	Wabash	Geoff	B	04-Apr-89	506	510	General Support	18.30
112	Smithson	Darlene	V	23-Oct-95	507			
113	Jonethood	Dether	K	15-Nov-94	508			
114	Jones	Annalisa		20-Aug-91	508			
115	Bawardi	Travis	B	25-Jan-90	501			
116	Prahl	Gerard	L	05-May-95	510			
117	Willmsman	Angie	H	19-Jun-94	509			
118	Frommer	James	J	04-Jan-06	510			

Table name: JOB		
JOB_CODE	JOB_DESCRIPTION	JOB_CHG_HOUR
500	Programmer	35.75
501	Systems Analyst	96.75
502	Database Designer	105.00
503	Electrical Engineer	84.50
504	Mechanical Engineer	67.90
505	Civil Engineer	55.75
506	Clerical Support	26.87
507	DSS Analyst	45.95
508	Applications Designer	48.10
509	Bio Technician	34.55
510	General Support	18.30

Table name: PROJECT		
PROJ_NUM	PROJ_NAME	EMP_NUM
15	Evergreen	105
10	Amber Wave	104
22	Rolling Tide	113
25	Starflight	101

Table name: ASSIGNMENT						
ASSIGN_NUM	ASSIGN_DATE	PROJ_NUM	EMP_NUM	ASSIGN_HOURS	ASSIGN_CHG_HOUR	ASSIGN_CHARGE
1001	04-Mar-12 15	103		2.5	64.50	219.70
1002	04-Mar-12 18	118		1.4	18.36	25.70
1003	05-Mar-12 15	101		3.5	105.00	378.00
1004	05-Mar-12 22	113		2.5	48.10	120.25
1005	05-Mar-12 15	103		1.9	64.50	160.55
1006	05-Mar-12 25	115		4.2	96.75	406.35
1007	05-Mar-12 22	105		5.2	105.00	546.00
1008	05-Mar-12 25	101		1.7	105.00	178.50
1009	05-Mar-12 15	105		2.0	105.00	210.00
1010	06-Mar-12 15	102		3.0	96.75	288.75
1011	06-Mar-12 22	104		2.6	96.75	251.55
1012	06-Mar-12 15	101		2.3	105.00	241.50
1013	06-Mar-12 25	114		1.8	48.10	86.58
1014	06-Mar-12 22	111		4.0	26.07	104.28
1015	06-Mar-12 25	114		3.4	48.10	163.54
1016	06-Mar-12 18	112		1.2	45.95	55.14
1017	06-Mar-12 18	118		2.0	18.36	36.72
1018	06-Mar-12 18	104		2.5	96.75	251.55
1019	06-Mar-12 15	103		3.0	64.50	253.50
1020	07-Mar-12 22	105		2.7	105.00	283.50
1021	06-Mar-12 25	108		4.2	96.75	406.35
1022	07-Mar-12 25	111		5.8	48.10	278.98
1023	07-Mar-12 22	106		2.4	35.75	86.30

SOURCE: Course Technology/Cengage Learning

6.8 DENORMALIZATION

It is important to remember that the optimal relational database implementation requires that all tables be at least in third normal form (3NF). A good relational DBMS excels at managing normalized relations—that is, relations void of any unnecessary redundancies that might cause data anomalies. Although the creation of normalized relations is an important database design goal, it is only one of many such goals. Good database design also considers processing (or reporting) requirements and processing speed. The problem with normalization is that as tables are decomposed to conform to normalization requirements, the number of database tables expands. Therefore, in order to generate information, data must be put together from various tables. Joining a large number of tables takes additional input/ output (I/O) operations and processing logic, thereby reducing system speed. Most relational database systems are able to handle joins very efficiently. However, rare and occasional circumstances may allow some degree of denormalization so processing speed can be increased.

Keep in mind that the advantage of higher processing speed must be carefully weighed against the disadvantage of data anomalies. On the other hand, some anomalies are of only theoretical interest. For example, should people in a real-world database environment worry that a ZIP_CODE determines CITY in a CUSTOMER table whose primary key is the customer number? Is it really practical to produce a separate table for

ZIP (ZIP_CODE, CITY)

to eliminate a transitive dependency from the CUSTOMER table? (Perhaps your answer to that question changes if you are in the business of producing mailing lists.) As explained earlier, the problem with denormalized relations and redundant data is that data integrity could be compromised due to the possibility of insert, update, and deletion anomalies. The advice is simple: use common sense during the normalization process.

Furthermore, the database design process could, in some cases, introduce some small degree of redundant data in the model, as seen in the previous example. This, in effect, creates “denormalized” relations. [Table 6.6](#) shows some common examples of data redundancy that are generally found in database implementations.

TABLE 6.6 Common Denormalization Examples

CASE	EXAMPLE	RATIONALE AND CONTROLS
Redundant data	Storing ZIP and CITY attributes in the AGENT table when ZIP determines CITY (see Figure 2.2)	<ul style="list-style-type: none">Avoid extra join operationsProgram can validate city (drop-down box) based on the zip code
Derived data	Storing STU_HRS and STU_CLASS (student classification) when STU_HRS determines STU_CLASS (see Figure 3.28)	<ul style="list-style-type: none">Avoid extra join operationsProgram can validate classification (lookup) based on the student hours
Preaggregated data (also derived data)	Storing the student grade point average (STU_GPA) aggregate value in the STUDENT table when this can be calculated from the ENROLL and COURSE tables (see Figure 3.28)	<ul style="list-style-type: none">Avoid extra join operationsProgram computes the GPA every time a grade is entered or updatedSTU_GPA can be updated only via administrative routine
Information requirements	Using a temporary denormalized table to hold report data; this is required when creating a tabular report in which the columns represent data that are stored in the table as rows (see Figures 6.17 and 6.18)	<ul style="list-style-type: none">Impossible to generate the data required by the report using plain SQLNo need to maintain tableTemporary table is deleted once report is doneProcessing speed is not an issue

A more comprehensive example of the need for denormalization due to reporting requirements is the case of a faculty evaluation report in which each row lists the scores obtained during the last four semesters taught. (See [Figure 6.17](#).)

FIGURE 6.17 The faculty evaluation report

Faculty Evaluation Report										
Instructor	Department	I		II		III		IV		Last Two Sem Avg.
		Semester	Mean	Semester	Mean	Semester	Mean	Semester	Mean	
Alton	INFS	200SS	2.91	2004F	2.84	2004S	2.55	2003F	2.51	2.875
Ames	INFS	200SS	3.24	2004F	3.26	2004S	3.31	2003F	3.19	3.250
Crandon	INFS	200SS	3.93	2004F	3.95	2004S	3.91	2003F	3.88	3.940
Dumas	MGMT	2004F	3.66	2004S	3.69	2003F	3.56	2003S	3.72	3.675
Landon	BMOM	200SS	3.57	2004F	3.64	2004S	3.39	2003F	3.57	3.605
Lohar	ECON	1999F	3.53	1998F	3.53					3.530
Rolman	INFS	1996S	3.50							3.500

SOURCE: Course Technology/Cengage Learning

Although this report seems simple enough, the problem is that the data are stored in a normalized table in which each row represents a different score for a given

faculty member in a given semester. (See [Figure 6.18](#).)

FIGURE 6.18 The EVALDATA and FACHIST tables

Table name: EVALDATA						Table name: FACHIST						Database name: Ch06_EVAL					
ID	INSTRUCTOR	DEPARTMENT	MEAN	SEMESTER		ID	INSTRUCTOR	DEPARTMENT	LAST1SEM	LAST1MEAN	LAST2SEM	LAST2MEAN	LAST3SEM	LAST3MEAN	LAST4SEM	LAST4MEAN	
3730	Altan	INFS	2.2	2000F		59602	Altan	INFS	2006S	2.91	2004F	2.84	2004S	2.56	2003F	2.51	
3764	Altan	INFS	2.69	2002S		59603	Ames	INFS	2005S	3.24	2004F	3.26	2004S	3.31	2003F	3.19	
3976	Altan	INFS	2.51	2003F		59605	Crandon	INFS	2005S	3.93	2004F	3.95	2004S	3.91	2003F	3.88	
4172	Altan	INFS	2.13	2003S		59607	Dumas	MGMT	2004F	3.66	2004S	3.66	2003F	3.56	2003S	3.72	
4450	Altan	INFS	2.84	2004F		59609	Landon	EMOM	2005S	3.57	2004F	3.64	2004S	3.39	2003F	3.57	
4333	Altan	INFS	2.65	2004S		59610	Loher	ECON	1998F	3.53	1998F	3.53					
4571	Altan	INFS	2.91	2005S		59611	Rolman	INFS	1996S	3.5							
2081	Ames	INFS	2.84	1996F													
2216	Ames	INFS	2.76	1996S													
2332	Ames	INFS	2.79	1997F													
2450	Ames	INFS	2.74	1997S													
2573	Ames	INFS	2.6	1998F													
2698	Ames	INFS	2.92	1998S													
2823	Ames	INFS	2.09	1999F													
2946	Ames	INFS	2.98	1999S													
3071	Ames	INFS	3.35	2000F													
3025	Ames	INFS	2.92	2000S													
3337	Ames	INFS	3.24	2001F													
3473	Ames	INFS	2.79	2001S													
3666	Ames	INFS	3.25	2002F													
3785	Ames	INFS	3.24	2002S													
3976	Ames	INFS	3.19	2003F													
4165	Ames	INFS	2.69	2003S													
4414	Ames	INFS	3.28	2004F													
4269	Ames	INFS	3.31	2004S													
4572	Ames	INFS	3.24	2006S													
3613	Crandon	INFS	3.79	2002F													
3977	Crandon	INFS	3.65	2003F													
4040	Crandon	INFS	3.79	2003S													
4248	Crandon	INFS	3.95	2004F													
4199	Crandon	INFS	3.91	2004S													
4573	Crandon	INFS	3.93	2006S													

SOURCE: Course Technology/Cengage Learning

The difficulty of transposing multirow data to multicolumn data is compounded by the fact that the last four semesters taught are not necessarily the same for all faculty members. Some might have taken sabbaticals, some might have had research appointments, some might be new faculty with only two semesters on the job, and so on. To generate this report, the two tables in [Figure 6.18](#) were used. The EVALDATA table is the master data table containing the evaluation scores for each faculty member for each semester taught; this table is normalized. The FACHIST table contains the last four data points—that is, evaluation score and semester—for each faculty member. The FACHIST table is a temporary denormalized table created from the EVALDATA table via a series of queries. (The FACHIST table is the basis for the report shown in [Figure 6.17](#).)

As shown in the faculty evaluation report, the conflicts between design efficiency, information requirements, and performance are often resolved through compromises that may include denormalization. In this case, and assuming there is enough storage space, the designer's choices could be narrowed down to:

- Store the data in a permanent denormalized table. This is not the recommended solution, because the denormalized table is subject to data anomalies (insert, update, and delete). This solution is viable only if performance is an issue.
- Create a temporary denormalized table from the permanent normalized table(s). The denormalized table exists only as long as it takes to generate the report; it disappears after the report is produced. Therefore, there are no data anomaly problems. This solution is practical only if performance is not an issue and there are no other viable processing options.

As shown, normalization purity is often difficult to sustain in the modern database environment. You will learn in [Chapter 13](#), Business Intelligence and Data Warehouses, that lower normalization forms occur (and are even required) in specialized databases known as data warehouses. Such specialized databases reflect the ever-growing demand for greater scope and depth in the data on which decision support systems increasingly rely. You will discover that the data warehouse routinely uses 2NF structures in its complex, multilevel, multisource data environment. In short, although normalization is very important, especially in the so-called production database environment, 2NF is no longer disregarded as it once was.

Although 2NF tables cannot always be avoided, the problem of working with tables that contain partial and/or transitive dependencies in a production database environment should not be minimized. Aside from the possibility of troublesome data anomalies being created, unnormalized tables in a production database tend to suffer from these defects:

- Data updates are less efficient because programs that read and update tables must deal with larger tables.
- Indexing is more cumbersome. It is simply not practical to build all of the indexes required for the many attributes that might be located in a single unnormalized table.
- Unnormalized tables yield no simple strategies for creating virtual tables known as *views*. You will learn how to create and use views in [Chapter 8](#), Advanced SQL.

Remember that good design cannot be created in the application programs that use a database. Also keep in mind that unnormalized database tables often lead to various data redundancy disasters in production databases, such as the problems examined thus far. In other words, use denormalization cautiously and make sure that you can explain why the unnormalized tables are a better choice in certain situations than their normalized counterparts.

6.9 DATA-MODELING CHECKLIST

In the chapters of Part II, you have learned how data modeling translates a specific real-world environment into a data model that represents the real-world data, users, processes, and interactions. The modeling techniques you have learned thus far give you the tools needed to produce successful database designs. However, just as any good pilot uses a checklist to ensure that all is in order for a successful flight, the data-modeling checklist shown in [Table 6.7](#) will help ensure that you perform data-modeling tasks successfully based on the concepts and tools you have learned in this text.

NOTE

You can also find this data-modeling checklist on the inside front cover of this book for easy reference.

TABLE 6.7 Data-Modeling Checklist

BUSINESS RULES

- Properly document and verify all business rules with the end users.
- Ensure that all business rules are written precisely, clearly, and simply. The business rules must help identify entities, attributes, relationships, and constraints.

- Identify the source of all business rules, and ensure that each business rule is justified, dated, and signed off by an approving authority.

DATA MODELING

Naming conventions: All names should be limited in length (database-dependent size).

- Entity names:
 - Should be nouns that are familiar to business and should be short and meaningful
 - Should document abbreviations, synonyms, and aliases for each entity
 - Should be unique within the model
 - For composite entities, may include a combination of abbreviated names of the entities linked through the composite entity
- Attribute names:
 - Should be unique within the entity
 - Should use the entity abbreviation as a prefix
 - Should be descriptive of the characteristic
 - Should use suffixes such as *ID*, *NUM*, or *_CODE* for the PK attribute
 - Should not be a reserved word
 - Should not contain spaces or special characters such as @, !, or &
- Relationship names:
 - Should be active or passive verbs that clearly indicate the nature of the relationship

Entities:

- Each entity should represent a single subject.
- Each entity should represent a set of distinguishable entity instances.
- All entities should be in 3NF or higher. Any entities below 3NF should be justified.

- The granularity of the entity instance should be clearly defined.
 - The PK should be clearly defined and support the selected data granularity.

Attributes:

- Should be simple and single-valued (atomic data)
- Should document default values, constraints, synonyms, and aliases
- Derived attributes should be clearly identified and include source(s)
- Should not be redundant unless this is required for transaction accuracy, performance, or maintaining a history
- Nonkey attributes must be fully dependent on the PK attribute

Relationships:

- Should clearly identify relationship participants
- Should clearly define participation, connectivity, and document cardinality

ER model:

- Should be validated against expected processes: inserts, updates, and deletes
 - Should evaluate where, when, and how to maintain a history
 - Should not contain redundant relationships except as required (see attributes)
 - Should minimize data redundancy to ensure single-place updates
 - Should conform to the minimal data rule: All that is needed is there, and all that is there is needed.
-

SUMMARY

- Normalization is a technique used to design tables in which data redundancies are minimized. The first three normal forms (1NF, 2NF, and 3NF) are the most common. From a structural point of view, higher normal forms are better than lower normal forms, because higher normal forms yield relatively fewer data redundancies in the database. Almost all business designs use 3NF as the ideal normal form. A special, more restricted 3NF known as Boyce-Codd normal form, or BCNF, is also used.
- A table is in 1NF when all key attributes are defined and all remaining attributes are dependent on the primary key. However, a table in 1NF can still contain both partial and transitive dependencies. A partial dependency is one in which an attribute is functionally dependent on only a part of a multiatribute primary key. A transitive dependency is one in which an attribute is functionally dependent on another nonkey attribute. A table with a single-attribute primary key cannot exhibit partial dependencies.
- A table is in 2NF when it is in 1NF and contains no partial dependencies. Therefore, a 1NF table is automatically in 2NF when its primary key is based on only a single attribute. A table in 2NF may still contain transitive dependencies.
- A table is in 3NF when it is in 2NF and contains no transitive dependencies. Given that definition, the Boyce-Codd normal form (BCNF) is merely a special 3NF case in which all determinant keys are candidate keys. When a table has only a single candidate key, a 3NF table is automatically in BCNF.
- A table that is not in 3NF may be split into new tables until all of the tables meet the 3NF requirements.
- Normalization is an important part—but only a part—of the design process. As entities and attributes are defined during the ER modeling process,

subject each entity (set) to normalization checks and form new entities (sets) as required. Incorporate the normalized entities into the ERD and continue the iterative ER process until all entities and their attributes are defined and all equivalent tables are in 3NF.

- A table in 3NF might contain multivalued dependencies that produce either numerous null values or redundant data. Therefore, it might be necessary to convert a 3NF table to the fourth normal form (4NF) by splitting the table to remove the multivalued dependencies. Thus, a table is in 4NF when it is in 3NF and contains no multivalued dependencies.

- The larger the number of tables, the more additional I/O operations and processing logic you need to join them. Therefore, tables are sometimes denormalized to yield less I/O in order to increase processing speed. Unfortunately, with larger tables, you pay for the increased processing speed by making the data updates less efficient, by making indexing more cumbersome, and by introducing data redundancies that are likely to yield data anomalies. In the design of production databases, use denormalization sparingly and cautiously.
- The data-modeling checklist provides a way for the designer to check that the ERD meets a set of minimum requirements.

KEY TERMS

[atomic attribute](#)

[atomicity](#)

[Boyce-Codd normal form \(BCNF\)](#)

[denormalization](#)

[dependency diagram](#)

[determinant](#)

[first normal form \(1NF\)](#)

[fourth normal form \(4NF\)](#)

[granularity](#)

[key attribute](#)

[nonkey attribute](#)

[nonprime attribute](#)

[normalization](#)
[partial dependency](#)
[prime attribute](#)
[repeating group](#)
[second normal form \(2NF\)](#)
[third normal form \(3NF\)](#)
[transitive dependency](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at www.cengagebrain.com.

REVIEW QUESTIONS

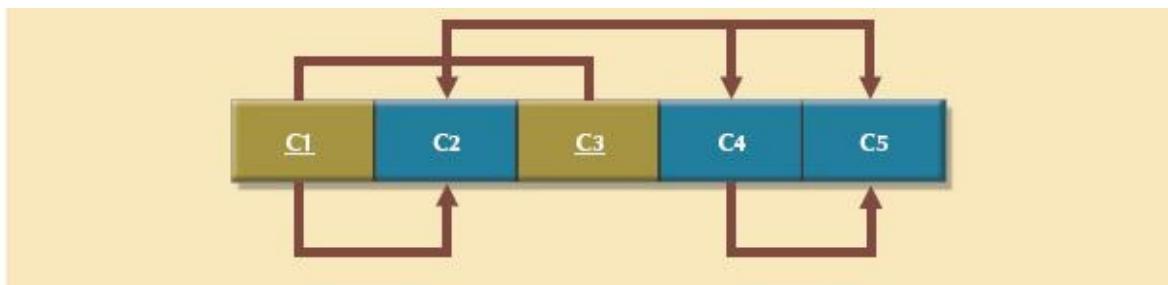
1. What is normalization?

 2. When is a table in 1NF?
 3. When is a table in 2NF?

 4. When is a table in 3NF?
 5. When is a table in BCNF?

 6. Given the dependency diagram shown in [Figure Q6.6](#), answer Items 6a-6c.
-

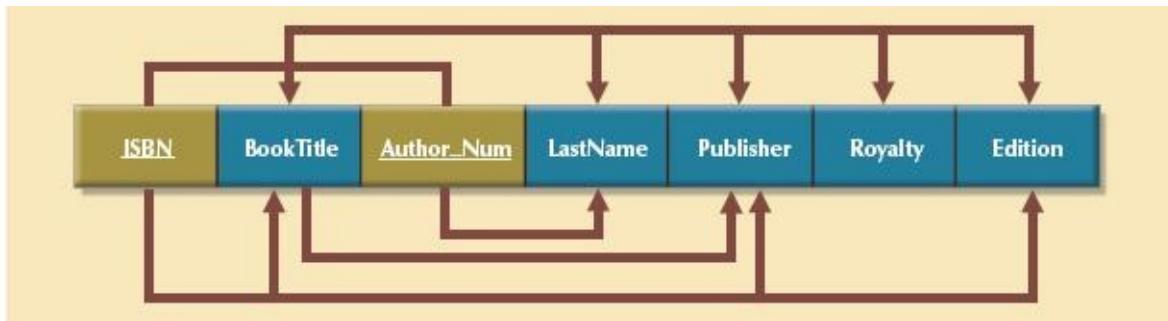
FIGURE Q6.6 Dependency diagram for Question 6



SOURCE: Course Technology/Cengage Learning

- a. Identify and discuss each of the indicated dependencies.
 - b. Create a database whose tables are at least in 2NF, showing the dependency diagrams for each table.
 - c. Create a database whose tables are at least in 3NF, showing the dependency diagrams for each table.
7. The dependency diagram in [Figure Q6.7](#) indicates that authors are paid royalties for each book they write for a publisher. The amount of the royalty can vary by author, by book, and by edition of the book.

FIGURE Q6.7 Book royalty dependency diagram

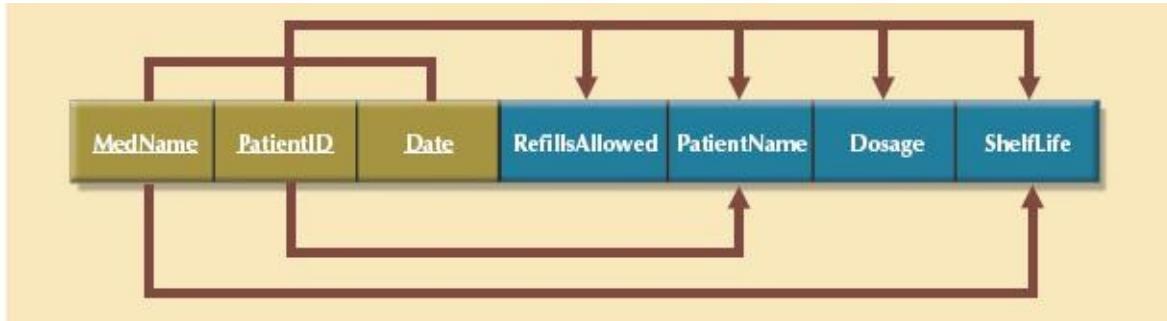


SOURCE: Course Technology/Cengage Learning

- a. Based on the dependency diagram, create a database whose tables are at least in 2NF, showing the dependency diagram for each table.
 - b. Create a database whose tables are at least in 3NF, showing the dependency diagram for each table.
8. The dependency diagram in [Figure Q6.8](#) indicates that a patient can receive

many prescriptions for one or more medicines over time. Based on the dependency diagram, create a database whose tables are in at least 2NF, showing the dependency diagram for each table.

FIGURE Q6.8 Prescription dependency diagram



SOURCE: Course Technology/Cengage Learning

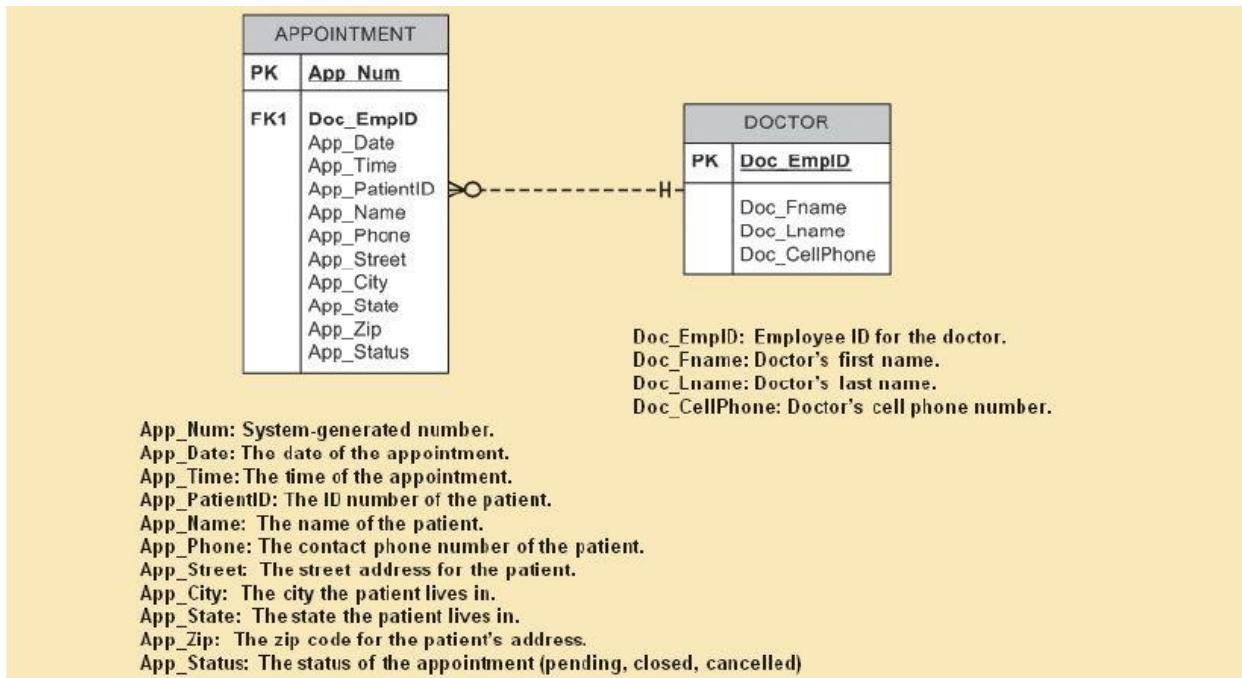
9. What is a partial dependency? With what normal form is it associated?
10. What three data anomalies are likely to be the result of data redundancy? How can such anomalies be eliminated?
11. Define and discuss the concept of transitive dependency.
12. What is a surrogate key, and when should you use one?
13. Why is a table whose primary key consists of a single attribute automatically in 2NF when it is in 1NF?
14. How would you describe a condition in which one attribute is dependent on another attribute when neither attribute is part of the primary key?
15. Suppose someone tells you that an attribute that is part of a composite primary key is also a candidate key. How would you respond to that statement?

16. A table is in _____ normal form when it is in _____ and there are no transitive dependencies.
-

PROBLEMS

1. Using the descriptions of the attributes given in the figure, convert the ERD shown in [Figure P6.1](#) into a dependency diagram that is in at least 3NF.
-

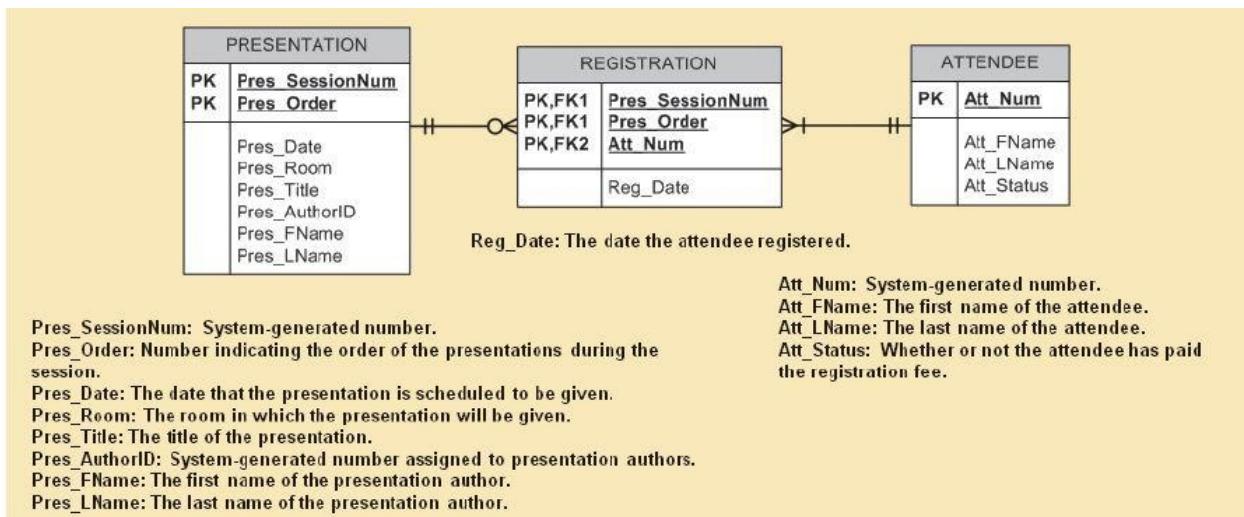
FIGURE P6.1 Appointment ERD for [Problem 1](#)



SOURCE: Course Technology/Cengage Learning

2. Using the descriptions of the attributes given in the figure, convert the ERD shown in [Figure P6.2](#) into a dependency diagram that is in at least 3NF.
-

FIGURE Presentation ERD for [Problem 2](#)



SOURCE: Course Technology/Cengage Learning

3. Using the INVOICE table structure shown in [Table P6.3](#), do the following:

TABLE P6.3

ATTRIBUTE NAME	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE
INV_NUM	211347	211347	211347	211348	211349
PROD_NUM	AA-E3422QW	QD-300932X	RU-995748G	AA-E3422QW	GH-778345P
SALE_DATE	15-Jan-2012	15-Jan-2012	15-Jan-2012	15-Jan-2012	16-Jan-2012
PROD_LABEL	Rotary sander	0.25-in. drill bit	Band saw	Rotary sander	Power drill
VEND_CODE	211	211	309	211	157
VEND_NAME	NeverFail, Inc.	NeverFail, Inc.	BeGood, Inc.	NeverFail, Inc.	ToughGo, Inc.
QUANT SOLD	1	8	1	2	1
PROD_PRICE	\$49.95	\$3.45	\$39.99	\$49.95	\$87.75

- a. Write the relational schema, draw its dependency diagram, and identify all dependencies, including all partial and transitive dependencies. You can assume that the table does not contain repeating groups and that an invoice number references more than one product. (*Hint:* This table uses a composite primary key.)
- b. Remove all partial dependencies, write the relational schema, and draw the new dependency diagrams. Identify the normal forms for each table structure you created.

NOTE

You can assume that any given product is supplied by a single vendor, but a vendor can supply many products. Therefore, it is proper to conclude that the following dependency exists:

PROD_NUM → PROD_LABEL, PROD_PRICE, VEND_CODE,
VEND_NAME

(*Hint:* Your actions should produce three dependency diagrams.)

- c. Remove all transitive dependencies, write the relational schema, and draw the new dependency diagrams. Also identify the normal forms for each table structure you created.
 - d. Draw the Crow's Foot ERD.
4. Using the STUDENT table structure shown in [Table P6.4](#), do the following:
 - a. Write the relational schema and draw its dependency diagram. Identify all dependencies, including all transitive dependencies.
 - b. Write the relational schema and draw the dependency diagram to meet the 3NF requirements to the greatest practical extent possible. If you believe that practical considerations dictate using a 2NF structure, explain why your decision to retain 2NF is appropriate. If necessary, add or modify attributes to create appropriate determinants and to adhere to the naming conventions.

TABLE P6.4

ATTRIBUTE NAME	SAMPLE VALUE				
STU_NUM	211343	200128	199876	199876	223456
STU_LNAME	Stephanos	Smith	Jones	Ortiz	McKulski
STU_MAJOR	Accounting	Accounting	Marketing	Marketing	Statistics
DEPT_CODE	ACCT	ACCT	MKTG	MKTG	MATH
DEPT_NAME	Accounting	Accounting	Marketing	Marketing	Mathematics
DEPT_PHONE	4356	4356	4378	4378	3420
COLLEGE_NAME	Business Admin	Business Admin	Business Admin	Business Admin	Arts & Sciences
ADVISOR_LNAME	Grastrand	Grastrand	Gentry	Tillery	Chen
ADVISOR_OFFICE	T201	T201	T228	T356	J331
ADVISOR_BLDG	Torre Building	Torre Building	Torre Building	Torre Building	Jones Building
ADVISOR_PHONE	2115	2115	2123	2159	3209
STU_GPA	3.87	2.78	2.31	3.45	3.58
STU_HOURS	75	45	117	113	87
STU_CLASS	Junior	Sophomore	Senior	Senior	Junior

c. Using the results of [Problem 4](#), draw the Crow's Foot ERD.

NOTE

Although the completed student hours (STU_HOURS) do determine the student classification (STU_CLASS), this dependency is not as obvious as you might initially assume it to be. For example, a student is considered a junior if the student has completed between 61 and 90 credit hours.

5. To keep track of office furniture, computers, printers, and other office equipment, the FOUNDIT Company uses the table structure shown in [Table P6.5](#).
-

TABLE P6.5

ATTRIBUTE NAME	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE
ITEM_ID	231134-678	342245-225	254668-449
ITEM_LABEL	HP DeskJet 895Cse	HP Toner	DT Scanner
ROOM_NUMBER	325	325	123
BLDG_CODE	NTC	NTC	CSF
BLDG_NAME	Nottooclear	Nottooclear	Canseefar
BLDG_MANAGER	I. B. Rightonit	I. B. Rightonit	May B. Next

- a. Given that information, write the relational schema and draw the dependency diagram. Make sure that you label the transitive and/or partial

dependencies.

- b. Write the relational schema and create a set of dependency diagrams that meet 3NF requirements. Rename attributes to meet the naming conventions, and create new entities and attributes as necessary.
- c. Draw the Crow's Foot ERD.
6. The table structure shown in [Table P6.6](#) contains many unsatisfactory components and characteristics. For example, there are several multivalued attributes, naming conventions are violated, and some attributes are not atomic.

TABLE P6.6

EMP_NUM	1003	1018	1019	1023
EMP_LNAME	Willaker	Smith	McGuire	McGuire
EMP_EDUCATION	BBA, MBA	BBA		BS, MS, Ph.D.
JOB_CLASS	SLS	SLS	JNT	DBA
EMP_DEPENDENTS	Gerald (spouse), Mary (daughter), John (son)		JoAnne (spouse)	George (spouse) Jill (daughter)
DEPT_CODE	MKTG	MKTG	SVC	INFS
DEPT_NAME	Marketing	Marketing	General Service	Info. Systems
DEPT_MANAGER	Jill H. Martin	Jill H. Martin	Hank B. Jones	Carlos G. Ortez
EMP_TITLE	Sales Agent	Sales Agent	Janitor	DB Admin
EMP_DOB	23-Dec-1968	28-Mar-1979	18-May-1982	20-Jul-1959
EMP_HIRE_DATE	14-Oct-1997	15-Jan-2006	21-Apr-2003	15-Jul-1999
EMP_TRAINING	L1, L2	L1	L1	L1, L3, L8, L15
EMP_BASE_SALARY	\$38,255.00	\$30,500.00	\$19,750.00	\$127,900.00
EMP_COMMISSION_RATE	0.015	0.010		

- a. Given the structure shown in [Table P6.6](#), write the relational schema and draw its dependency diagram. Label all transitive and/or partial dependencies.
- b. Draw the dependency diagrams that are in 3NF. (*Hint:* You might have to create a few new attributes. Also make sure that the new dependency diagrams contain attributes that meet proper design criteria; that is, make sure there are no multivalued attributes, that the naming conventions are met, and so on.)
- c. Draw the relational diagram.
- d. Draw the Crow's Foot ERD.

7. Suppose you are given the following business rules to form the basis for a database design. The database must enable the manager of a company dinner club to mail invitations to the club's members, to plan the meals, to keep track of who attends the dinners, and so on.

- Each dinner serves many members, and each member may attend many dinners.
- A member receives many invitations, and each invitation is mailed to many members.
- A dinner is based on a single entree, but an entree may be used as the basis for many dinners. For example, a dinner may be composed of a fish entree, rice, and corn, or the dinner may be composed of a fish entree, a baked potato, and string beans.

Because the manager is not a database expert, the first attempt at creating the database uses the structure shown in [Table P6.7](#).

TABLE P6.7

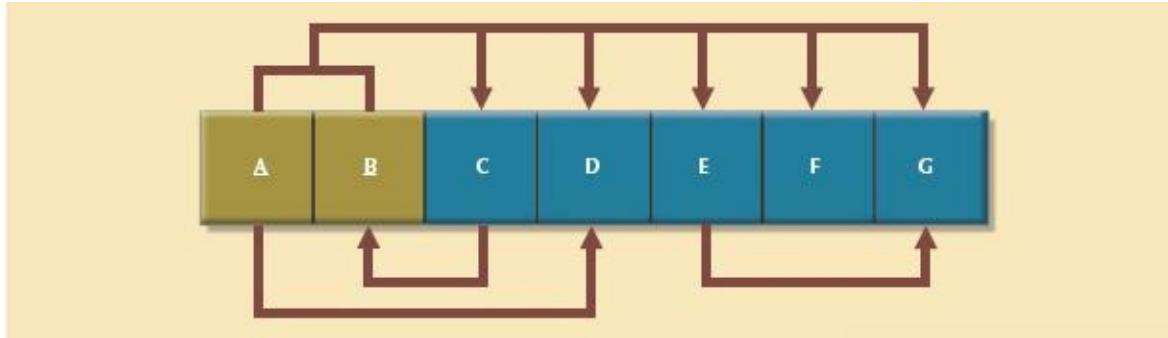
ATTRIBUTE NAME	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE
MEMBER_NUM	214	235	214
MEMBER_NAME	Alice B. VanderVoort	Gerald M. Gallega	Alice B. VanderVoort
MEMBER_ADDRESS	325 Meadow Park	123 Rose Court	325 Meadow Park
MEMBER_CITY	Murkywater	Highlight	Murkywater
MEMBER_ZIPCODE	12345	12349	12345
INVITE_NUM	8	9	10
INVITE_DATE	23-Feb-2012	12-Mar-2012	23-Feb-2012
ACCEPT_DATE	27-Feb-2012	15-Mar-2012	27-Feb-2012
DINNER_DATE	15-Mar-2012	17-Mar-2012	15-Mar-2012
DINNER_ATTENDED	Yes	Yes	No
DINNER_CODE	DI5	DI5	DI2
DINNER_DESCRIPTION	Glowing Sea Delight	Glowing Sea Delight	Ranch Superb
ENTREE_CODE	EN3	EN3	EN5
ENTREE_DESCRIPTION	Stuffed crab	Stuffed crab	Marinated steak
DESSERT_CODE	DE8	DE5	DE2
DESSERT_DESCRIPTION	Chocolate mousse with raspberry sauce	Cherries jubilee	Apple pie with honey crust

- Given the table structure illustrated in [Table P6.7](#), write the relational schema and draw its dependency diagram. Label all transitive and/or partial dependencies. (*Hint:* This structure uses a composite primary key.)
- Break up the dependency diagram you drew in [Problem 7a](#) to produce

dependency diagrams that are in 3NF, and write the relational schema. (*Hint:* You might have to create a few new attributes. Also, make sure that the new dependency diagrams contain attributes that meet proper design criteria; that is, make sure there are no multivalued attributes, that the naming conventions are met, and so on.)

- c. Using the results of [Problem 7b](#), draw the Crow's Foot ERD.
8. Use the dependency diagram shown in [Figure P6.8](#) to work the following problems.
- Break up the dependency diagram shown in [Figure P6.8](#) to create two new dependency diagrams: one in 3NF and one in 2NF.
 - Modify the dependency diagrams you created in [Problem 8a](#) to produce a set of dependency diagrams that are in 3NF. (*Hint:* One of your dependency diagrams will be in 3NF but not in BCNF.)
 - Modify the dependency diagrams you created in [Problem 8b](#) to produce a collection of dependency diagrams that are in 3NF and BCNF.

FIGURE P6.8 Initial dependency diagram for [Problem 8](#)



SOURCE: Course Technology/Cengage Learning

-
9. Suppose you have been given the table structure and data shown in [Table P6.9](#), which was imported from an Excel spreadsheet. The data reflect that a professor can have multiple advisees, can serve on multiple committees, and can edit more than one journal.

TABLE P6.9

ATTRIBUTE NAME	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE
EMP_NUM	123	104	118	
PROF_RANK	Professor	Asst. Professor	Assoc. Professor	Assoc. Professor
EMP_NAME	Ghee	Rankin	Ortega	Smith
DEPT_CODE	CIS	CHEM	CIS	ENG
DEPT_NAME	Computer Info. Systems	Chemistry	Computer Info. Systems	English
PROF_OFFICE	KDD-567	BLF-119	KDD-562	PRT-345
ADVISEE	1215, 2312, 3233, 2218, 2098	3102, 2782, 3311, 2008, 2876, 2222, 3745, 1783, 2378	2134, 2789, 3456, 2002, 2046, 2018, 2764	2873, 2765, 2238, 2901, 2308
COMMITTEE_CODE	PROMO, TRAF, APPL, DEV	DEV	SPR, TRAF	PROMO, SPR, DEV
JOURNAL_CODE	JMIS, QED, JMGT		JCIS, JMGT	

Given the information in [Table P6.9](#):

- Draw the dependency diagram.
 - Identify the multivalued dependencies.
 - Create the dependency diagrams to yield a set of table structures in 3NF.
 - Eliminate the multivalued dependencies by converting the affected table structures to 4NF.
 - Draw the Crow's Foot ERD to reflect the dependency diagrams you drew in [Problem 9c](#). (Note: You might have to create additional attributes to define the proper PKs and FKs. Make sure that all of your attributes conform to the naming conventions.)
10. The manager of a consulting firm has asked you to evaluate a database that contains the table structure shown in [Table P6.10](#).

[Table P6.10](#) was created to enable the manager to match clients with consultants. The objective is to match a client within a given region with a consultant in that region and to make sure that the client's need for specific consulting services is properly matched to the consultant's expertise. For example, if the client needs help with database design and is located in the Southeast, the objective is to make a match with a consultant who is located in the Southeast and whose expertise is in database design. (Although the consulting company manager tries to match consultant and client locations to minimize travel expense, it is not always possible to do so.) The following basic business rules are maintained:

- Each client is located in one region.

- A region can contain many clients.
- Each consultant can work on many contracts.
- Each contract might require the services of many consultants.
- A client can sign more than one contract, but each contract is signed by only one client.
- Each contract might cover multiple consulting classifications. (For example, a contract may list consulting services in database design and networking.)

TABLE P6.10

ATTRIBUTE NAME	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE
CLIENT_NUM	298	289	289
CLIENT_NAME	Marianne R. Brown	James D. Smith	James D. Smith
CLIENT_REGION	Midwest	Southeast	Southeast
CONTRACT_DATE	10-Feb-2012	15-Feb-2012	12-Mar-2012
CONTRACT_NUMBER	5841	5842	5843
CONTRACT_AMOUNT	\$2,985,000.00	\$670,300.00	\$1,250,000.00
CONSULT_CLASS_1	Database Administration	Internet Services	Database Design
CONSULT_CLASS_2	Web Applications		Database Administration
CONSULT_CLASS_3			Network Installation
CONSULT_CLASS_4			
CONSULTANT_NUM_1	29	34	25
CONSULTANT_NAME_1	Rachel G. Carson	Gerald K. Ricardo	Angela M. Jamison
CONSULTANT_REGION_1	Midwest	Southeast	Southeast
CONSULTANT_NUM_2	56	38	34
CONSULTANT_NAME_2	Karl M. Spenser	Anne T. Dimarco	Gerald K. Ricardo
CONSULTANT_REGION_2	Midwest	Southeast	Southeast
CONSULTANT_NUM_3	22	45	
CONSULTANT_NAME_3	Julian H. Donatello	Geraldo J. Rivera	
CONSULTANT_REGION_3	Midwest	Southeast	
CONSULTANT_NUM_4		18	
CONSULTANT_NAME_4		Donald Chen	
CONSULTANT_REGION_4		West	

- Each consultant is located in one region.
- A region can contain many consultants.
- Each consultant has one or more areas of expertise (class). For example, a consultant might be classified as an expert in both database design and networking.

- Each area of expertise (class) can have many consultants. For example, the consulting company might employ many consultants who are networking experts.

a. Given this brief description of the requirements and the business rules, write the relational schema and draw the dependency diagram for the preceding (and very poor) table structure. Label all transitive and/or partial dependencies.

b. Break up the dependency diagram you drew in [Problem 10a](#) to produce dependency diagrams that are in 3NF and write the relational schema. (*Hint:* You might have to create a few new attributes. Also make sure that the new dependency diagrams contain attributes that meet proper design criteria; that is, make sure there are no multivalued attributes, that the naming conventions are met, and so on.)

c. Using the results of [Problem 10b](#), draw the Crow's Foot ERD.

11. Given the sample records in the CHARTER table shown in [Table P6.11](#), do the following:

a. Write the relational schema and draw the dependency diagram for the table structure. Make sure that you label all dependencies. CHAR_PAX indicates the number of passengers carried. The CHAR_MILES entry is based on round-trip miles, including pickup points. (*Hint:* Look at the data values to determine the nature of the relationships. For example, note that employee Melton has flown two charter trips as pilot and one trip as copilot.)

b. Decompose the dependency diagram you drew to solve [Problem 11a](#) to create table structures that are in 3NF and write the relational schema.

c. Draw the Crow's Foot ERD to reflect the properly decomposed dependency diagrams you created in [Problem 11b](#). Make sure the ERD yields a database that can track all of the data shown in [Problem 11](#). Show all entities, relationships, connectivities, optionalities, and cardinalities.

TABLE P6.11

ATTRIBUTE NAME	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE	SAMPLE VALUE
CHAR_TRIP	10232	10233	10234	10235
CHAR_DATE	15-Jan-2012	15-Jan-2012	16-Jan-2012	17-Jan-2012
CHAR_CITY	STL	MIA	TYS	ATL
CHAR_MILES	580	1,290	524	768
CUST_NUM	784	231	544	784
CUST_LNAME	Brown	Hanson	Bryana	Brown
CHAR_PAX	5	12	2	5
CHAR_CARGO	235 lbs.	18,940 lbs.	348 lbs.	155 lbs.
PILOT	Melton	Chen	Henderson	Melton
COPILOT		Henderson	Melton	
FLT_ENGINEER		O'Shaski		
LOAD_MASTER		Benkasi		
AC_NUMBER	1234Q	3456Y	1234Q	2256W
MODEL_CODE	PA31-350	CV-580	PA31-350	PA31-350
MODEL_SEATS	10	38	10	10
MODEL_CHG_MILE	\$2.79	\$23.36	\$2.79	\$2.79

PART
III
ADVANCED DESIGN AND IMPLEMENTATION

[INTRODUCTION TO STRUCTURED QUERY LANGUAGE \(SQL\)](#) **7**

[ADVANCED SQL](#) **8**

[DATABASE DESIGN](#) **9**

Business Vignette

Mediterranean Shipping Company (MSC) is a leading global shipping line. The company serves 145 countries on six continents, calling at 335 ports and providing 200 weekly liner services. Established in 1970, MSC has grown internally rather than through merger or acquisition.¹ The company has experienced 30 percent annual growth in recent years, and its biggest challenge is to continue providing superior services to a rapidly growing customer base. Today, the company transports over 7 million containers each year.

A key to MSC's success is its MSCLink database, which keeps track of over 15 billion transactions per year. The 1.8-terabyte database, an internally developed application on Microsoft SQL Server, manages all aspects of the company's business. The application database consists of a client tier, an application tier, a data tier, a reporting tier, and an analysis tier. The client software is installed in over 70 local offices around the world.

The application tier consists of a set of Visual C++ modules that interact with stored procedures. The application tier handles contracts, bookings, e-commerce, import operations, billing, electronic data interchange (EDI), auditing, equipment control and trucking management, and reporting.² By accessing the tracking module through the client tier, customers can use their MSC bill-of-lading numbers to obtain a container's estimated time of arrival with great accuracy. Customers can also receive e-mail alerts to notify them of each movement of their containers.³ The application tier also handles millions of EDI transactions per day.

The data tier contains approximately 2,000 tables and 5,000 stored procedures. The stored procedures allow the application to encapsulate SQL statements that represent a business transaction and execute them as a single transaction, thus increasing performance and reducing network traffic. The MSCLink application includes approximately 700,000 lines of stored procedure code that allows the database to support 500 million database transactions per day. MSC then synchronizes the data among its three data centers in Singapore, Geneva, and the United States.

Additionally, MSCLink generates 300 recurring reports for 400 staff members. The company runs analytics on the data warehouse and pulls stored data from MSCLink and local accounting systems. The company manages 22 terabytes of data with MSCLink.

Faster performance and 24/7 reliability is critical to MSC. Just an hour's delay at a port can cost the company an enormous amount of money and leave customers dissatisfied. So, the tracking and EDI communication modules are mission critical. Since upgrading to the new system, the company has reported a 30 percent improvement in database performance and enjoyed uninterrupted access to its data. The company is counting on the system to accommodate its further growth.

¹ Mediterranean Shipping Company Website, www.msccgva.ch/about_us/about_us.html.

² Microsoft Case Studies, Mediterranean Shipping Company Managing 22 Terabytes of Data with SQL Server 2008, 1/14/2009, www.microsoft.com/casestudies/Microsoft-SQL-Server-2008/MediterraneanShipping-Company/MediterraneanShipping-Company-Managing-22-Terabytes-of-data-with-SQL-Server-2008/4000003470.

³ Tracking - FAQ, Mediterranean Shipping Company Website, www.msccgva.ch/tracking/tracking_faq_page.html.

7 INTRODUCTION TO STRUCTURED QUERY LANGUAGE (SQL)

In this chapter, you will learn:

- The basic commands and functions of SQL
 - How to use SQL for data administration (to create tables and indexes)
 - How to use SQL for data manipulation (to add, modify, delete, and retrieve data)
 - How to use SQL to query a database for useful information
-

Preview

In this chapter, you will learn the basics of Structured Query Language (SQL). SQL, which is pronounced *S-Q-L* or *sequel*, is composed of commands that enable users to create database and table structures, perform various types of data manipulation and data administration, and query the database to extract useful information. All relational DBMS software supports SQL, and many software vendors have developed extensions to the basic SQL command set.

Because SQL's vocabulary is simple, the language is relatively easy to learn. Its simplicity is enhanced by the fact that much of its work takes place behind the scenes. For example, a single command creates the complex table structures required to store and manipulate data successfully. Furthermore, SQL is a nonprocedural language; that is, the user specifies what must be done, but not how. To issue SQL commands, end users and programmers do not need to know the physical data storage format or the complex activities that take place when a SQL command is executed.

Although quite useful and powerful, SQL is not meant to stand alone in the applications arena. Data entry with SQL is possible but awkward, as are data corrections and additions. SQL itself does not create menus, special report forms, overlays, pop-ups, or any of the other utilities and screen devices that end users usually expect. Instead, those features are available as vendor-supplied enhancements. SQL focuses on data definition (creating tables and indexes) and data manipulation (adding, modifying, deleting, and retrieving data); this chapter

covers these basic functions. In spite of its limitations, SQL is a powerful tool for extracting information and managing data.

7.1 INTRODUCTION TO SQL

Ideally, a database language allows you to create database and table structures, perform basic data management chores (add, delete, and modify), and perform complex queries designed to transform the raw data into useful information. Moreover, a database language must perform such basic functions with minimal user effort, and its command structure and syntax must be easy to learn. Finally, it must be portable; that is, it must conform to some basic standard so a person does not have to relearn the basics when moving from one RDBMS to another. SQL meets those ideal database language requirements well.

SQL functions fit into two broad categories:

- It is a *data definition language (DDL)*. SQL includes commands to create database objects such as tables, indexes, and views, as well as commands to define access rights to those database objects. Some common data definition commands you will learn are listed in [Table 7.1](#).
-

TABLE 7.1 SQL Data Definition Commands

COMMAND OR OPTION	DESCRIPTION
CREATE SCHEMA AUTHORIZATION	Creates a database schema
CREATE TABLE	Creates a new table in the user's database schema

NOT NULL	Ensures that a column will not have null values
UNIQUE	Ensures that a column will not have duplicate values
PRIMARY KEY	Defines a primary key for a table
FOREIGN KEY	Defines a foreign key for a table
DEFAULT	Defines a default value for a column (when no value is given)
CHECK	Validates data in an attribute
CREATE INDEX	Creates an index for a table
CREATE VIEW	Creates a dynamic subset of rows and columns from one or more tables (see Chapter 8 , Advanced SQL)
ALTER TABLE	Modifies a table's definition (adds, modifies, or deletes attributes or constraints)
CREATE TABLE AS	Creates a new table based on a query in the user's database schema

DROP TABLE	Permanently deletes a table (and its data)
-------------------	--

DROP INDEX	Permanently deletes an index
-------------------	------------------------------

DROP VIEW	Permanently deletes a view
------------------	----------------------------

-
- It is a *data manipulation language (DML)*. SQL includes commands to insert, update, delete, and retrieve data within the database tables. The data manipulation commands you will learn in this chapter are listed in [Table 7.2](#).
-

TABLE 7.2 SQL Data Manipulation Commands

COMMAND OR OPTION	DESCRIPTION
INSERT	Inserts row(s) into a table
SELECT	Selects attributes from rows in one or more tables or views
WHERE	Restricts the selection of rows based on a conditional expression
GROUP BY	Groups the selected rows based on one or more attributes
HAVING	Restricts the selection of grouped rows based on a condition
	Orders the selected rows based on one or more

ORDER BY	attributes
UPDATE	Modifies an attribute's values in one or more table's rows
DELETE	Deletes one or more rows from a table
COMMIT	Permanently saves data changes
ROLLBACK	Restores data to their original values
Comparison operators	
=, <, >, <=, >=, <>	Used in conditional expressions
Logical operators	
AND/OR/NOT	Used in conditional expressions
Special operators	Used in conditional expressions
BETWEEN	Checks whether an attribute value is within a range
IS NULL	Checks whether an attribute value is null
LIKE	Checks whether an attribute value matches a given string pattern
IN	Checks whether an attribute value matches any value within a value list

EXISTS

Checks whether a subquery returns any rows

DISTINCT

Limits values to unique values

Aggregate functions

Used with SELECT to return mathematical summaries on columns

COUNT

Returns the number of rows with non-null values for a given column

MIN

Returns the minimum attribute value found in a given column

MAX

Returns the maximum attribute value found in a given column

SUM

Returns the sum of all values for a given column

AVG

Returns the average of all values for a given column

SQL is relatively easy to learn. Its basic command set has a vocabulary of fewer than 100 words. Better yet, SQL is a nonprocedural language: you merely command *what* is to be done; you do not have to worry about *how*. The American National Standards Institute (ANSI) prescribes a standard SQL—the current fully approved version is SQL-2003. The ANSI SQL standards are also accepted by the International Organization for Standardization (ISO), a consortium composed of national standards bodies of more than 150 countries. Although adherence to the ANSI/ISO SQL standard is usually required in commercial and government contract database specifications, many RDBMS

vendors add their own special enhancements. Consequently, it is seldom possible to move a SQL-based application from one RDBMS to another without making some changes.

However, even though there are several different SQL “dialects,” their differences are minor. Whether you use Oracle, Microsoft SQL Server, MySQL, IBM’s DB2, Microsoft Access, or any other well-established RDBMS, a software manual should be sufficient to get you up to speed if you know the material presented in this chapter.

At the heart of SQL is the query. In [Chapter 1](#), Database Systems, you learned that a query is a spur-of-the-moment question. Actually, in the SQL environment, the word *query* covers both questions and actions. Most SQL queries are used to answer questions such as these: “What products currently held in inventory are priced over \$100, and what is the quantity on hand for each of those products?” or “How many employees have been hired since January 1, 2008, by each of the company’s departments?” However, many SQL queries are used to perform actions such as adding or deleting table rows or changing attribute values within tables. Still other SQL queries create new tables or indexes. In short, for a DBMS, a query is simply a SQL statement that must be executed. However, before you can use SQL to query a database, you must define the database environment for SQL with its data definition commands.

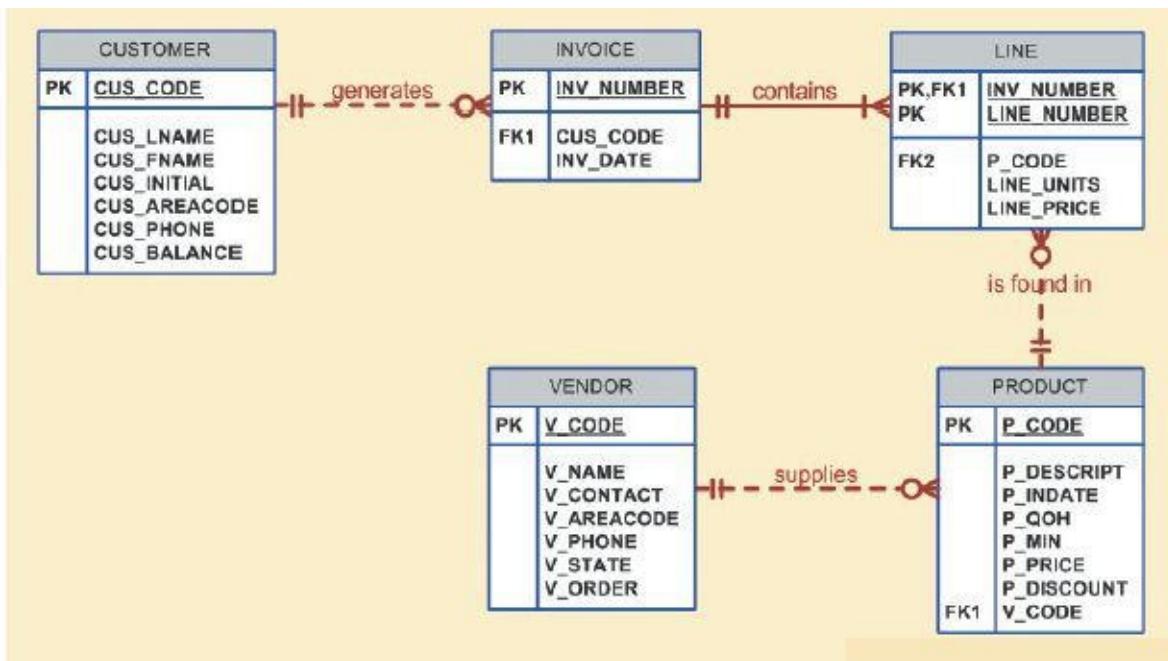
7.2 DATA DEFINITION COMMANDS

Before you examine the SQL syntax for creating and defining tables and other elements, first examine a simple database model and the database tables that form the basis for the many SQL examples you will explore in this chapter.

7.2.1 THE DATABASE MODEL

A simple database composed of the following tables is used to illustrate the SQL commands in this chapter: CUSTOMER, INVOICE, LINE, PRODUCT, and VENDOR. This database model is shown in [Figure 7.1](#).

FIGURE 7.1 The database model



SOURCE: Course Technology/Cengage Learning

The database model in [Figure 7.1](#) reflects the following business rules:

- A customer may generate many invoices. Each invoice is generated by one customer.
- An invoice contains one or more invoice lines. Each invoice line is associated with one invoice.
- Each invoice line references one product. A product may be found in many invoice lines. (You can sell more than one hammer to more than one customer.)
- A vendor *may* supply many products. Some vendors do not yet supply products. For example, a vendor list may include *potential* vendors.
- If a product is vendor supplied, it is supplied by only a single vendor.
- Some products are not supplied by a vendor. For example, some products

may be produced in-house or bought on the open market.

As you can see in [Figure 7.1](#), the database model contains many tables. However, to illustrate the initial set of data definition commands, the focus of attention will be the PRODUCT and VENDOR tables. You will have the opportunity to use the remaining tables later in this chapter and in the Problems section.



ONLINE CONTENT

The database model in [Figure 7.1](#) is implemented in the Microsoft Access **Ch07_SaleCo** database, which is available at www.cengagebrain.com. (This database contains a few additional tables that are not reflected in [Figure 7.1](#). These tables are used for discussion purposes only.) If you use MS Access, you can use the database supplied online. However, it is strongly suggested that you create your own database structures so you can practice the SQL commands illustrated in this chapter.

SQL script files for creating the tables and loading the data in Oracle and MS SQL Server are also available at www.cengagebrain.com. How you connect to your database depends on how the software was installed on your computer. Follow the instructions provided by your instructor or school.

To give you a point of reference for understanding the effect of the SQL queries, the contents of the PRODUCT and VENDOR tables are listed in [Figure 7.2](#).

FIGURE 7.2 The VENDOR and PRODUCT tables

Table name: VENDOR

Database name: Ch07_SaleCo

V_CODE	V_NAME	V_CONTACT	V_AREACODE	V_PHONE	V_STATE	V_ORDER
21225	Bryson, Inc.	Smithson	615	223-3234	TN	Y
21226	SuperLoo, Inc.	Flushing	904	215-8995	FL	N
21231	D&E Supply	Singh	615	228-3245	TN	Y
21344	Gomez Bros.	Ortega	615	889-2546	KY	N
22567	Dome Supply	Smith	901	678-1419	GA	N
23119	Randsets Ltd.	Anderson	901	678-3998	GA	Y
24004	Brackman Bros.	Browning	615	228-1410	TN	N
24288	ORDVA, Inc.	Hakford	615	898-1234	TN	Y
25443	B&K, Inc.	Smith	904	227-0093	FL	N
25501	Darmal Supplies	Smythe	615	890-3529	TN	N
25595	Rubicon Systems	Orton	904	456-0092	FL	Y

Table name: PRODUCT

P_CODE	P_DESCRPT	P_INDATE	P_QOH	P_MIN	P_PRICE	P_DISCOUNT	V_CODE
11QER/31	Power painter, 15 psi., 3-nozzle	03-Nov-11	8	5	109.99	0.00	25595
13-Q2/P2	7.25-in. pwr. saw blade	13-Dec-11	32	15	14.99	0.05	21344
14-Q1/L3	9.00-in. pwr. saw blade	13-Nov-11	18	12	17.49	0.00	21344
1546-QQ2	Hrd. cloth, 1/4-in., 2x50	15-Jan-12	15	8	39.95	0.00	23119
1558-QW1	Hrd. cloth, 1/2-in., 3x50	15-Jan-12	23	5	43.99	0.00	23119
2232/QTY	B&D jigsaw, 12-in. blade	30-Dec-11	8	5	109.92	0.05	24288
2232/QWE	B&D jigsaw, 8-in. blade	24-Dec-11	6	5	99.87	0.05	24288
2238/QPD	B&D cordless drill, 1/2-in.	20-Jan-12	12	5	38.95	0.05	25595
23109-HB	Claw hammer	20-Jan-12	23	10	9.95	0.10	21225
23114-AA	Sledge hammer, 12 lb.	02-Jan-12	8	5	14.40	0.05	
54778-2T	Rat-tail file, 1/8-in. fine	15-Dec-11	43	20	4.99	0.00	21344
89-WRE-Q	Hicut chain saw, 16 in.	07-Feb-12	11	5	256.99	0.05	24288
PVC23DRT	PVC pipe, 3.5-in., 8-ft	20-Feb-12	188	75	5.87	0.00	
SM-18277	1.25-in. metal screw, 25	01-Mar-12	172	75	6.99	0.00	21225
SW-23116	2.5-in. wd. screw, 50	24-Feb-12	237	100	8.45	0.00	21231
WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	17-Jan-12	18	5	119.95	0.10	25595

SOURCE: Course Technology/Cengage Learning

In the tables, note the following features, which correspond to the business rules reflected in the ERD shown in [Figure 7.1](#)

- The VENDOR table contains vendors who are not referenced in the PRODUCT table. Database designers note that possibility by saying that PRODUCT is optional to VENDOR; a vendor may exist without a reference to a product. You examined such optional relationships in detail in [Chapter 4](#), Entity Relationship (ER) Modeling.
- Existing V_CODE values in the PRODUCT table must (and do) have a match in the VENDOR table to ensure referential integrity.
- A few products are supplied factory-direct, a few are made in-house, and a few may have been bought in a warehouse sale. In other words, a product is not necessarily supplied by a vendor. Therefore, VENDOR is

optional to PRODUCT.

A few of the conditions just described were made for the sake of illustrating specific SQL features. For example, null V_CODE values were used in the PRODUCT table to illustrate later how you can track such nulls using SQL.

7.2.2 CREATING THE DATABASE

Before you can use a new RDBMS, you must complete two tasks: create the database structure, and create the tables that will hold the end-user data. To complete the first task, the RDBMS creates the physical files that will hold the database. When you create a new database, the RDBMS automatically creates the data dictionary tables in which to store the metadata and creates a default database administrator. Creating the physical files that will hold the database means interacting with the operating system and the file systems supported by the operating system. Therefore, creating the database structure is the one feature that tends to differ substantially from one RDBMS to another. However, it is relatively easy to create a database structure, regardless of which RDBMS you use.

If you use Microsoft Access, creating the database is simple: start Access, click the File tab, click New in the left pane, and then click Blank Database in the right pane. Specify the folder in which you want to store the database, and then name the database. However, if you work in a database environment typically used by larger organizations, you will probably use an enterprise RDBMS such as Oracle, MS SQL Server, MySQL, or DB2. Given their security requirements and greater complexity, creating a database with these products is a more elaborate process. (See Appendix N, *Creating a New Database Using Oracle 11g*, for specific instructions to create a database structure in Oracle.)

With the exception of creating the database, most RDBMS vendors use SQL that deviates little from the ANSI standard SQL. For example, most RDBMSs require each SQL command to end with a semicolon. However, some SQL implementations do not use a semicolon. Important syntax differences among implementations will be highlighted in the Note boxes in this chapter.

If you are using an enterprise RDBMS, you must be authenticated by the RDBMS before you can start creating tables. **Authentication** is the process the DBMS uses to verify that only registered users access the database. To be authenticated, you must log on to the RDBMS using a user ID and a password created by the database administrator. In an enterprise RDBMS, every user ID is

associated with a database schema.

7.2.3 THE DATABASE SCHEMA

In the SQL environment, a **schema** is a logical group of database objects—such as tables and indexes—that are related to each other. Usually, the schema belongs to a single user or application. A single database can hold multiple schemas that belong to different users or applications. Schemas are useful in that they group tables by owner (or function) and enforce a first level of security by allowing each user to see only the tables that belong to that user.

ANSI SQL standards define a command to create a database schema:

```
CREATE SCHEMA AUTHORIZATION {creator};
```

Therefore, if the creator is JONES, the following command is used:

```
CREATE SCHEMA AUTHORIZATION JONES;
```

Most enterprise RDBMSs support that command. However, the command is seldom used directly—that is, from the command line. (When a user is created, the DBMS automatically assigns a schema to that user.) When the DBMS *is* used, the CREATE SCHEMA AUTHORIZATION command must be issued by the user who owns the schema. That is, if you log on as JONES, you can only use CREATE SCHEMA AUTHORIZATION JONES.

For most RDBMSs, the CREATE SCHEMA AUTHORIZATION command is optional, which is why this chapter focuses on the ANSI SQL commands required to create and manipulate tables.

7.2.4 DATA TYPES

In the data dictionary in [Table 7.3](#), note the data types selected. Keep in mind that datatype selection is usually dictated by the nature of the data and the intended use. For example:

- P_PRICE clearly requires some kind of numeric data type; defining it as a character field is not acceptable.
- Just as clearly, a vendor name is an obvious candidate for a character data type. For example, VARCHAR(35) fits well because vendor names are

variable-length character strings, and in this case, such strings may be up to 35 characters long.

- At first glance, it might seem logical to select a numeric data type for V_AREACODE because it contains only digits. However, adding and subtracting area codes does not yield meaningful results. Therefore, selecting a character data type is more appropriate. This is true for many common attributes found in business data models. For example, even though zip codes contain all digits, they must be defined as character data because some zip codes begin with the digit zero (0), and a numeric data type would cause the leading zero to be dropped.
- U.S. state abbreviations are always two characters, so CHAR(2) is a logical choice.
- Selecting P_INDATE to be a (Julian) DATE field rather than a character field is desirable because Julian dates allow you to make simple date comparisons and perform date arithmetic. For instance, if you have used DATE fields, you can determine the number of days between dates.

If you use DATE fields, you can also determine a future date using a simple command. For example, you can determine the date that is 60 days from a given P_INDATE by using P_INDATE + 60. Or, you can use the RDBMS's system date—SYSDATE in Oracle, GETDATE() in MS SQL Server, and Date() in Access—to answer questions such as “What will be the date 60 days from today?” For example, you might use SYSDATE + 60 in Oracle, GETDATE() + 60 in MS SQL Server, or Date() + 60 in Access.

Date arithmetic capability is particularly useful in billing. Perhaps you want your system to start charging interest on a customer balance 60 days after the invoice is generated. Such simple date arithmetic would be impossible if you used a character data type.

Datatype selection sometimes requires professional judgment. For example, you must make a decision about the V_CODE's data type as follows:

- If you want the computer to generate new vendor codes by adding 1 to the largest recorded vendor code, you must classify V_CODE as a numeric attribute. (You cannot perform mathematical procedures on character data.) The designation INTEGER will ensure that only the counting

numbers (integers) can be used. Most SQL implementations also permit the use of SMALLINT for integer values up to six digits.

- If you do not want to perform mathematical procedures based on V_CODE, you should classify it as a character attribute, even though it is composed entirely of numbers. Character data are “quicker” to process in queries. Therefore, when there is no need to perform mathematical procedures on the attribute, store it as a character attribute.

The first option is used to demonstrate the SQL procedures in this chapter.

TABLE 7.3 Data Dictionary for the Ch07_SaleCo Database

TABLE NAME	ATTRIBUTE NAME	CONTENTS	TYPE	FORMAT	RANGE*	REQUIRED	PK OR FK	FK REFERENCED TABLE
PRODUCT	P_CODE	Product code	VARCHAR(10)	XXXXXXXXXX	NA	Y	PK	
	P_DESCRPT	Product description	VARCHAR(35)	Xxxxxxxxxxxxxx	NA	Y		
	P_INDATE	Stocking date	DATE	DD-MON-YYYY	NA	Y		
	P_QOH	Units available	SMALLINT	####	0-9999	Y		
	P_MIN	Minimum units	SMALLINT	###	0-9999	Y		
	P_PRICE	Product price	NUMBER(8,2)	####.##	0.00-9999.00	Y		
	P_DISCOUNT	Discount rate	NUMBER(5,2)	0.##	0.00-0.20	Y		
	V_CODE	Vendor code	INTEGER	##	100-999		FK	VENDOR
VENDOR	V_CODE	Vendor code	INTEGER	#####	1000-9999	Y	PK	
	V_NAME	Vendor name	VARCHAR(35)	Xxxxxxxxxxxxxxx	NA	Y		
	V_CONTACT	Contact person	VARCHAR(25)	Xxxxxxxxxxxxxxx	NA	Y		
	V_AREACODE	Area code	CHAR(3)	999	NA	Y		
	V_PHONE	Phone number	CHAR(8)	999-9999	NA	Y		
	V_STATE	State	CHAR(2)	XX	NA	Y		
	V_ORDER	Previous order	CHAR(1)	X	Y or N	Y		

FK

= Foreign key

PK

= Primary key

CHAR

= Fixed-length character data, 1 to 255 characters

= Variable-length character data, 1 to 2,000 characters. VARCHAR is automatically

VARCHAR

converted to VARCHAR2 in Oracle.

NUMBER

= Numeric data. NUMBER(9,2) is used to specify numbers that have two decimal places and are up to nine digits long, including the decimal places.

Some RDBMSs permit the use of a MONEY or a CURRENCY data type.

INT

= Integer values only. INT is automatically converted to NUMBER in Oracle.

SMALLINT

= Small integer values only. SMALLINT is automatically converted to NUMBER in Oracle.

DATE formats vary. Commonly accepted formats are DD-MON-YYYY, DD-MON-YY, MM/DD/YYYY, and MM/DD/YY.

* Not all the ranges shown here will be illustrated in this chapter. However, you can use these constraints to practice writing your own.

When you define the attribute's data type, you must pay close attention to the expected use of the attributes for sorting and data-retrieval purposes. For example, in a real estate application, an attribute that represents the numbers of bathrooms in a home (H_BATH_NUM) could be assigned the CHAR(3) data type because the application will probably not do any addition, multiplication, or division with the number of bathrooms. Based on the CHAR(3) datatype definition, valid H_BATH_NUM values would be '2', '1', '2.5', '10'. However, this datatype decision creates potential problems. For example, if an application sorts the homes by number of bathrooms, a query would "see" the value '10' as less than '2', which is clearly incorrect. So, you must consider the expected use of the data to properly define the attribute data type.

The data dictionary in [Table 7.3](#) contains only a few of the data types supported by SQL. For teaching purposes, the selection of data types is limited to ensure

that almost any RDBMS can be used to implement the examples. If your RDBMS is fully compliant with ANSI SQL, it will support many more data types than those shown in [Table 7.4](#). Also, many RDBMSs support data types beyond the ones specified in ANSI SQL.

TABLE 7.4 Some Common SQL Data Types

DATA TYPE	FORMAT	COMMENTS
Numeric	NUMBER(L,D)	The declaration NUMBER(7,2) indicates that numbers will be stored with two decimal places and may be up to seven digits long, including the sign and the decimal place (for example, 12.32 or -134.99).
INTEGER		May be abbreviated as INT. Integers are (whole) counting numbers, so they cannot be used if you want to store numbers that require decimal places.
SMALLINT		Like INTEGER but limited to integer values up to six digits. If your integer values are relatively small, use SMALLINT instead of INT.
	DECIMAL(L,D)	Like the NUMBER specification, but the storage length is a minimum specification. That is, greater lengths are acceptable, but smaller ones are not. DECIMAL(9,2), DECIMAL(9), and DECIMAL are all acceptable.
Character	CHAR(L)	Fixed-length character data for up to 255 characters. If you store strings that are not as long as the CHAR parameter value, the remaining spaces are left unused. Therefore, if you specify CHAR(25), strings such as Smith and Katzenjammer are each stored as 25 characters. However, a U.S. area code is always
	VARCHAR(L) or	

VARCHAR2(L)	three digits long, so CHAR(3) would be appropriate if you wanted to store such codes. Variable-length character data. The designation VARCHAR2(25) will let you
Date	Store characters up to 25 characters long. However, VARCHAR will not leave unused spaces. Oracle automatically converts VARCHAR to VARCHAR2.

In addition to the data types shown in [Table 7.4](#), SQL supports several other data types, including TIME, TIMESTAMP, REAL, DOUBLE, and FLOAT, and intervals such as INTERVAL DAY TO HOUR. Many RDBMSs have also expanded the list to include other types of data, such as LOGICAL, CURRENCY, AutoNumber (Access), and sequence (Oracle). However, because this chapter is designed to introduce the basics of SQL, the discussion is limited to the data types summarized in [Table 7.4](#).

7.2.5 CREATING TABLE STRUCTURES

Now you are ready to implement the PRODUCT and VENDOR table structures with the help of SQL, using the [**CREATE TABLE**](#) syntax shown next.

```
CREATE TABLE tablename (
    column1      data type  [constraint] [,,
    column2      data type  [constraint]] [,,
    PRIMARY KEY (column1 [, column2])] [,,
    FOREIGN KEY (column1 [, column2]) REFERENCES tablename] [,,
    CONSTRAINT constraint]);
```



ONLINE CONTENT

All the SQL commands used in this chapter are located in script files at www.cengagebrain.com. You can copy and paste the SQL commands into your SQL program. Script files are provided for Oracle and SQL Server users.

To make the SQL code more readable, most SQL programmers use one line per column (attribute) definition. In addition, spaces are used to line up the attribute characteristics and constraints. Finally, both table and attribute names are fully capitalized. Those conventions are used in the following examples that create VENDOR and PRODUCT tables and subsequent tables throughout the book.

NOTE

SQL Syntax

Syntax notation for SQL commands used in this book:

CAPITALS Required SQL command keywords

italics A parameter provided by the end user (generally required)

{a | b | ..} A mandatory parameter; use one option from the list separated by |

[.....] An optional parameter—anything inside square brackets is optional

Tablename The name of a table

Column The name of an attribute in a table

datatype A valid datatype definition

constraint A valid constraint definition

condition A valid conditional expression (evaluates to true or false)

columnlist One or more column names or expressions separated by commas

tablelist One or more table names separated by commas

conditionlist One or more conditional expressions separated by logical operators

expression A simple value (such as 76 or Married) or a formula (such as P_PRICE - 10)

CREATE TABLE VENDOR (

V_CODE INTEGER NOT NULL UNIQUE,

V_NAME VARCHAR(35) NOT NULL,

V_CONTACT VARCHAR(25) NOT NULL,

V_AREACODE CHAR(3) NOT NULL,

```
V_PHONE      CHAR(8)      NOT NULL,  
V_STATE      CHAR(2)      NOT NULL,  
PRIMARY KEY (V_CODE));
```

NOTE

- Because the PRODUCT table contains a foreign key that references the VENDOR table, create the VENDOR table first. (In fact, the “M” side of a relationship always references the “1” side. Therefore, in a 1:M relationship, you must *always* create the table for the “1” side first.)
 - If your RDBMS does not support the VARCHAR2 and FCHAR format, use CHAR.
 - Oracle accepts the VARCHAR data type and automatically converts it to VARCHAR2.
-
- If your RDBMS does not support SINT or SMALLINT, use INTEGER or INT. If INTEGER is not supported, use NUMBER.
 - If you use Access, you can use the NUMBER data type, but you cannot use the number delimiters at the SQL level. For example, using NUMBER(8,2) to indicate numbers with up to eight characters and two decimal places is fine in Oracle, but you cannot use it in Access—you must use NUMBER without the delimiters.
-
- If your RDBMS does not support primary and foreign key designations or the UNIQUE specification, delete them from the SQL code shown here.
 - If you use the PRIMARY KEY designation in Oracle, you do not need the NOT NULL and UNIQUE specifications.
-
- The ON UPDATE CASCADE clause is part of the ANSI standard, but it may not be supported by your RDBMS. In that case, delete the ON

UPDATE CASCADE clause.

```
CREATE TABLE PRODUCT (
    P_CODE          NOT NULL VARCHAR(10) UNIQUE,
    P_DESCRPT      NOT NULL VARCHAR(35),
    P_INDATE       NOT NULL DATE,
    P_QOH          NOT NULL SMALLINT,
    P_MIN          NOT NULL SMALLINT,
    P_PRICE         NOT NULL NUMBER(8,2),
    P_DISCOUNT     NOT NULL NUMBER(5,2),
    V_CODE          INTEGER,
    PRIMARY KEY (P_CODE),
    FOREIGN KEY (V_CODE) REFERENCES
    VENDOR ON UPDATE CASCADE);
```

As you examine the preceding SQL table-creating command sequences, note the following features:

- The NOT NULL specifications for the attributes ensure that a data entry will be made. When it is crucial to have the data available, the NOT NULL specification will not allow the end user to leave the attribute empty (with no data entry at all). Because this specification is made at the table level and stored in the data dictionary, application programs can use this information to create the data dictionary validation automatically.
- The UNIQUE specification creates a unique index in the respective attribute. Use it to avoid having duplicated values in a column.

- The primary key attributes contain both a NOT NULL and UNIQUE specification, which enforce the entity integrity requirements. If the NOT NULL and UNIQUE specifications are not supported, use PRIMARY KEY without the specifications. (For example, if you designate the PK in MS Access, the NOT NULL and UNIQUE specifications are automatically assumed and are not spelled out.)
 - The entire table definition is enclosed in parentheses. A comma is used to separate each table element definition (attributes, primary key, and foreign key).
-

NOTE

If you are working with a composite primary key, all of the primary key's attributes are contained within the parentheses and are separated with commas. For example, the LINE table in [Figure 7.1](#) has a primary key that consists of the two attributes INV_NUMBER and LINE_NUMBER. Therefore, you would define the primary key by typing the following:

PRIMARY KEY (INV_NUMBER, LINE_NUMBER),

The order of the primary key components is important because the indexing starts with the first mentioned attribute, then proceeds with the next attribute, and so on. In this example, the line numbers would be ordered within each of the invoice numbers:

INV_NUMBER	LINE_NUMBER
1001	1
1001	2
1002	1
1003	1
1003	2

- The ON UPDATE CASCADE specification ensures that if you make a change in any VENDOR's V_CODE, that change is automatically applied to all foreign key references throughout the system to ensure that referential integrity is maintained. (Although the ON UPDATE

CASCADE clause is part of the ANSI standard, some RDBMSs, such as Oracle, do not support it. If your RDBMS does not support the clause, delete it from the code shown here.)

- An RDBMS automatically enforces referential integrity for foreign keys. That is, you cannot have an invalid entry in the foreign key column; at the same time, you cannot delete a vendor row as long as a product row references that vendor.
- The command sequence ends with a semicolon. (Remember that your RDBMS may require you to omit the semicolon.)

NOTE

Note About Column Names

Do *not* use mathematical symbols such as +, -, and / in your column names; instead, use an underscore to separate words, if necessary. For example, PER-NUM might generate an error message, but PER_NUM is acceptable. Also, do *not* use reserved words. [Reserved words](#) are words used by SQL to perform specific functions. For example, in some RDBMSs, the column name INITIAL will generate the message “invalid column name.”

NOTE

Note to Oracle Users

When you press Enter after typing each line, a line number is automatically generated as long as you do not type a semicolon before pressing Enter. For example, Oracle’s execution of the CREATE TABLE command will look like this:

CREATE TABLE PRODUCT (

```

2      P_CODE          VARCHAR2(10)
3      CONSTRAINT      PRODUCT_P_CODE_PK PRIMARY KEY,
4      P_DESCRPT       VARCHAR2(35)           NOT NULL,
5      P_INDATE        DATE                 NOT NULL,
6      P_QOH           NUMBER               NOT NULL,
7      P_MIN           NUMBER               NOT NULL,
8      P_PRICE          NUMBER(8,2)          NOT NULL,
9      P_DISCOUNT      NUMBER(5,2)          NOT NULL,
10     V_CODE          NUMBER,
11     CONSTRAINT      PRODUCT_V_CODE_FK
12     FOREIGN KEY     V_CODE REFERENCES VENDOR)
13 ;

```

In the preceding SQL command sequence, note the following:

- The attribute definition for P_CODE starts in line 2 and ends with a comma at the end of line 3.
- The CONSTRAINT clause (line 3) allows you to define and name a constraint in Oracle. You can name the constraint to meet your own naming conventions. In this case, the constraint was named PRODUCT_P_CODE_PK.
- Examples of constraints are NOT NULL, UNIQUE, PRIMARY KEY, FOREIGN KEY, and CHECK. Additional details about constraints are explained below.
- To define a PRIMARY KEY constraint, you could also use the following syntax: P_CODE VARCHAR2(10) PRIMARY KEY.
In this case, Oracle would automatically name the constraint.
 - Lines 11 and 12 define a FOREIGN KEY constraint name PRODUCT_V_CODE_FK for the attribute V_CODE. The CONSTRAINT clause is generally used at the end of the CREATE TABLE command sequence.
 - If you do not name the constraints yourself, Oracle will automatically

assign a name. Unfortunately, the Oracle-assigned name makes sense only to Oracle, so you will have a difficult time deciphering it later. You should assign a name that makes sense to human beings!

7.2 .6 SQL CONSTRAINTS

In [Chapter 3](#), The Relational Database Model, you learned that adherence to rules for entity integrity and referential integrity is crucial in a relational database environment. Fortunately, most SQL implementations support both integrity rules. Entity integrity is enforced automatically when the primary key is specified in the CREATE TABLE command sequence. For example, you can create the VENDOR table structure and set the stage for the enforcement of entity integrity rules by using the following:

PRIMARY KEY (V_CODE)

In the PRODUCT table's CREATE TABLE sequence, note that referential integrity has been enforced by specifying the following in the PRODUCT table:

```
FOREIGN KEY (V_CODE) REFERENCES VENDOR ON UPDATE  
CASCADE
```

The foreign key constraint definition ensures that:

- You cannot delete a vendor from the VENDOR table if at least one product row references that vendor. This is the default behavior for the treatment of foreign keys.
- On the other hand, if a change is made in an existing VENDOR table's V_CODE, that change must be reflected automatically in any PRODUCT table V_CODE reference (ON UPDATE CASCADE). That restriction makes it impossible for a V_CODE value to exist in the PRODUCT table if it points to a nonexistent VENDOR table V_CODE value. In other words, the ON UPDATE CASCADE specification ensures the preservation of referential integrity. (Oracle does not support ON UPDATE CASCADE.)

In general, ANSI SQL permits the use of ON DELETE and ON UPDATE clauses to cover CASCADE, SET NULL, or SET DEFAULT.



ONLINE CONTENT

For a more detailed discussion of the options for using the ON DELETE and ON UPDATE clauses, see **Appendix D, Converting the ER Model into a Database Structure**, Section D.2, General Rules Governing Relationships Among Tables. Appendix D is available at www.cengagebrain.com.

NOTE

Note About Referential Constraint Actions

The support for the referential constraint's actions varies from product to product. For example:

- MS Access, SQL Server, and Oracle support ON DELETE CASCADE.
- MS Access and SQL Server support ON UPDATE CASCADE.
- Oracle does not support ON UPDATE CASCADE.
- Oracle supports SET NULL.
- MS Access and SQL Server do not support SET NULL.
- Refer to your product manuals for additional information on referential constraints.

While MS Access does not support ON DELETE CASCADE or ON UPDATE CASCADE at the SQL command-line level, it does support them through the relationship window interface. In fact, whenever you try to establish a relationship between two tables in Access, the relationship window interface will automatically pop up.

Besides the PRIMARY KEY and FOREIGN KEY constraints, the ANSI SQL standard also defines the following constraints:

- The NOT NULL constraint ensures that a column does not accept nulls.
- The UNIQUE constraint ensures that all values in a column are unique.
- The DEFAULT constraint assigns a value to an attribute when a new row is added to a table. The end user may, of course, enter a value other than the default value.
- The CHECK constraint is used to validate data when an attribute value is entered. The CHECK constraint does precisely what its name suggests: it checks to see that a specified condition exists. Examples of such constraints include the following:
 - The minimum order value must be at least 10.
 - The date must be after April 15, 2012.

If the CHECK constraint is met for the specified attribute (that is, the condition is true), the data are accepted for that attribute. If the condition is found to be false, an error message is generated and the data are not accepted.

Note that the CREATE TABLE command lets you define constraints in two different places:

- When you create the column definition (known as a column constraint).
- When you use the CONSTRAINT keyword (known as a table constraint).

A column constraint applies to just one column; a table constraint may apply to many columns. Those constraints are supported at varying levels of compliance by enterprise RDBMSs.

In this chapter, Oracle is used to illustrate SQL constraints. For example, note that the following SQL command sequence uses the DEFAULT and CHECK constraints to define the table named CUSTOMER.

```

CREATE TABLE CUSTOMER (
    CUS_CODE          NUMBER           PRIMARY KEY,
    CUS_LNAME         VARCHAR(15)      NOT NULL,
    CUS_FNAME         VARCHAR(15)      NOT NULL,
    CUS_INITIAL       CHAR(1),
    CUS_AREACODE     CHAR(3)          DEFAULT '615'    NOT NULL
                                      CHECK(CUS_AREACODE IN ('615','713','931')),
    CUS_PHONE         CHAR(8)          NOT NULL,
    CUS_BALANCE       NUMBER(9,2)      DEFAULT 0.00,
    CONSTRAINT CUS_UI1 UNIQUE (CUS_LNAME, CUS_FNAME));

```

In this case, the CUS_AREACODE attribute is assigned a default value of '615'. Therefore, if a new CUSTOMER table row is added and the end user makes no entry for the area code, the '615' value will be recorded. Also, the CHECK condition restricts the values for the customer's area code to 615, 713, and 931; any other values will be rejected.

It is important to note that the DEFAULT value applies only when new rows are added to a table, and then only when no value is entered for the customer's area code. (The default value is not used when the table is modified.) In contrast, the CHECK condition is validated whether a customer row is added or *modified*. However, while the CHECK condition may include any valid expression, it applies only to the attributes in the table being checked. If you want to check for conditions that include attributes in other tables, you must use triggers. (See [Chapter 8](#), Advanced SQL.) Finally, the last line of the CREATE TABLE command sequence creates a unique index constraint (named CUS_UI1) on the customer's last name and first name. The index will prevent the entry of two customers with the same last name and first name. (This index merely illustrates the process. Clearly, it should be possible to have more than one person named John Smith in the CUSTOMER table.)

NOTE

Note to MS Access Users

MS Access does not accept the DEFAULT or CHECK constraints. However, MS Access will accept the CONSTRAINT CUS_UI1 UNIQUE (CUS_LNAME, CUS_FNAME) line and create the unique index.

In the following SQL command to create the INVOICE table, the DEFAULT constraint assigns a default date to a new invoice, and the CHECK constraint validates that the invoice date is greater than January 1, 2012.

```
CREATE TABLE INVOICE (
    INV_NUMBER      NUMBER          PRIMARY KEY,
    CUS_CODE        NUMBER          NOT NULL REFERENCES CUSTOMER(CUS_CODE),
    INV_DATE        DATE           DEFAULT SYSDATE NOT NULL,
    CONSTRAINT INV_CK1 CHECK (INV_DATE > TO_DATE('01-JAN-2012','DD-MON-YYYY'));
```

In this case, notice the following:

- The CUS_CODE attribute definition contains REFERENCES CUSTOMER (CUS_CODE) to indicate that the CUS_CODE is a foreign key. This is another way to define a foreign key.
- The DEFAULT constraint uses the SYSDATE special function. This function always returns today's date.
- The invoice date (INV_DATE) attribute is automatically given today's date (returned by SYSDATE) when a new row is added and no value is given for the attribute.
- A CHECK constraint is used to validate that the invoice date is greater than 'January 1, 2012'. When comparing a date to a manually entered date in a CHECK clause, Oracle requires the use of the TO_DATE function. The TO_DATE function takes two parameters: the literal date and the date format used.

The final SQL command sequence creates the LINE table. The LINE table has a composite primary key (INV_NUMBER, LINE_NUMBER) and uses a UNIQUE constraint in INV_NUMBER and P_CODE to ensure that the same product is not ordered twice in the same invoice.

```

CREATE TABLE LINE (
    INV_NUMBER      NUMBER          NOT NULL,
    LINE_NUMBER     NUMBER(2,0)      NOT NULL,
    P_CODE          VARCHAR(10)     NOT NULL,
    LINE_UNITS      NUMBER(9,2)      DEFAULT 0.00      NOT NULL,
    LINE_PRICE      NUMBER(9,2)      DEFAULT 0.00      NOT NULL,
    PRIMARY KEY (INV_NUMBER, LINE_NUMBER),
    FOREIGN KEY (INV_NUMBER) REFERENCES INVOICE ON DELETE CASCADE,
    FOREIGN KEY (P_CODE) REFERENCES PRODUCT(P_CODE),
    CONSTRAINT LINE_UI1 UNIQUE(INV_NUMBER, P_CODE);

```

In the creation of the LINE table, note that a UNIQUE constraint is added to prevent the duplication of an invoice line. A UNIQUE constraint is enforced through the creation of a unique index. Also note that the ON DELETE CASCADE foreign key enforces referential integrity. The use of ON DELETE CASCADE is recommended for weak entities to ensure that the deletion of a row in the strong entity automatically triggers the deletion of the corresponding rows in the dependent weak entity. In that case, the deletion of an INVOICE row will automatically delete all of the LINE rows related to the invoice. In the following section, you will learn more about indexes and how to use SQL commands to create them.

7.2.7 SQL INDEXES

You learned in [Chapter 3](#) that indexes can be used to improve the efficiency of searches and to avoid duplicate column values. In the previous section, you saw how to declare unique indexes on selected attributes when the table is created. In fact, when you declare a primary key, the DBMS automatically creates a unique index. Even with this feature, you often need additional indexes. The ability to create indexes quickly and efficiently is important. Using the [**CREATE INDEX**](#) command, SQL indexes can be created on the basis of any selected attribute. The syntax is:

CREATE [UNIQUE] INDEX *indexname* ON *tablename*(*column1* [, *column2*])

For example, based on the attribute P_INDATE stored in the PRODUCT table, the following command creates an index named P_INDATEX:

CREATE INDEX P_INDATEX ON PRODUCT(P_INDATE);

SQL does not let you write over an existing index without warning you first, thus preserving the index structure within the data dictionary. Using the UNIQUE

index qualifier, you can even create an index that prevents you from using a value that has been used before. Such a feature is especially useful when the index attribute is a candidate key whose values must not be duplicated:

```
CREATE UNIQUE INDEX P_CODEX ON PRODUCT(P_CODE);
```

If you now try to enter a duplicate P_CODE value, SQL produces the error message “duplicate value in index.” Many RDBMSs, including Access, automatically create a unique index on the PK attribute(s) when you declare the PK.

A common practice is to create an index on any field that is used as a search key, in comparison operations in a conditional expression, or when you want to list rows in a specific order. For example, if you want to create a report of all products by vendor, it would be useful to create an index on the V_CODE attribute in the PRODUCT table. Remember that a vendor can supply many products. Therefore, you should not create a UNIQUE index in this case. Better yet, to make the search as efficient as possible, using a composite index is recommended.

Unique composite indexes are often used to prevent data duplication. For example, consider the case illustrated in [Table 7.5](#), in which required employee test scores are stored. (An employee can take a test only once on a given date.) Given the structure of [Table 7.5](#), the PK is EMP_NUM + TEST_NUM. The third test entry for employee 111 meets entity integrity requirements—the combination 111,3 is unique—yet the WEA test entry is clearly duplicated.

Table 7.5 A Duplicated Test Record

EMP_NUM	TEST_NUM	TEST_CODE	TEST_DATE	TEST_SCORE
110	1	WEA	15-Jan-2012	93
110	2	WEA	12-Jan-2012	87
111	1	HAZ	14-Dec-2011	91
111	2	WEA	18-Feb-2012	95
111	3	WEA	18-Feb-2012	95
112	1	CHEM	17-Aug-2011	91

Such duplication could have been avoided through the use of a unique composite index, using the attributes EMP_NUM, TEST_CODE, and TEST_DATE:

```
CREATE UNIQUE INDEX EMP_TESTDEX ON TEST(EMP_NUM,  
TEST_CODE, TEST_DATE);
```

By default, all indexes produce results that are listed in ascending order, but you can create an index that yields output in descending order. For example, if you routinely print a report that lists all products ordered by price from highest to lowest, you could create an index named PROD_PRICEX by typing:

```
CREATE INDEX PROD_PRICEX ON PRODUCT(P_PRICE DESC);
```

To delete an index, use the **DROP INDEX** command:

```
DROP INDEX indexname
```

For example, if you want to eliminate the PROD_PRICEX index, type:

```
DROP INDEX PROD_PRICEX;
```

After creating the tables and some indexes, you are ready to start entering data. The following sections use two tables (VENDOR and PRODUCT) to demonstrate most of the data manipulation commands.

7.3 DATA MANIPULATION COMMANDS

In this section, you will learn how to use the basic SQL data manipulation commands INSERT, SELECT, COMMIT, UPDATE, ROLLBACK, and DELETE.

7.3 .1 ADDING TABLE ROWS

SQL requires the use of the **INSERT** command to enter data into a table. The INSERT command's basic syntax looks like this:

```
INSERT INTO tablename VALUES (value1, value2, ..., valuen)
```

Because the PRODUCT table uses its V_CODE to reference the VENDOR table's V_CODE, an integrity violation will occur if the VENDOR table V_CODE values do not yet exist. Therefore, you need to enter the VENDOR rows before the PRODUCT rows. Given the VENDOR table structure defined earlier and the sample VENDOR data shown to in [Figure 7.2](#), you would enter the first two data rows as follows:

```
INSERT INTO VENDOR
```

```
VALUES (21225,'Bryson, Inc.', 'Smithson', '615', '223-3234', 'TN', 'Y');
```

```
INSERT INTO VENDOR
```

VALUES (21226,'Superloo, Inc.', 'Flushing', '904', '215-8995', 'FL', 'N');

and so on, until all of the VENDOR table records have been entered.

(To see the contents of the VENDOR table, use the SELECT * FROM VENDOR; command.)

The PRODUCT table rows would be entered in the same fashion, using the PRODUCT data shown in [Figure 7.2](#). For example, the first two data rows would be entered as follows, pressing Enter at the end of each line:

INSERT INTO PRODUCT

VALUES ('11QER/31', 'Power painter', 15, 'psi.', '3-nozzle', '03-Nov-11', 8, 5, 109.99, 0.00, 25595);

INSERT INTO PRODUCT

VALUES ('13-Q2/P2', '7.25-in. pwr. saw blade', '13-Dec-11', 32, 15, 14.99, 0.05, 21344);

(To see the contents of the PRODUCT table, use the SELECT * FROM PRODUCT; command.)

NOTE

Date entry is a function of the date format expected by the DBMS. For example, March 25, 2012, might be shown as 25-Mar-2012 in Access and Oracle, or it might be displayed in other presentation formats in another RDBMS. MS Access requires the use of # delimiters when performing any computations or comparisons based on date attributes, as in P_INDATE >= #25-Mar-12#.

In the preceding data-entry lines, observe that:

- The row contents are entered between parentheses. Note that the first character after VALUES is a parenthesis and that the last character in the command sequence is also a parenthesis.
- Character (string) and date values must be entered between apostrophes ('').

- Numerical entries are *not* enclosed in apostrophes.
- Attribute entries are separated by commas.
- A value is required for each column in the table.

This version of the INSERT command adds one table row at a time.

Inserting Rows with Null Attributes

Thus far, you have entered rows in which all of the attribute values are specified. But what do you do if a product does not have a vendor or if you do not yet know the vendor code? In those cases, you would want to leave the vendor code null. To enter a null, use the following syntax:

```
INSERT INTO PRODUCT
```

```
VALUES ('BRT-345','Titanium drill bit','18-Oct-11', 75, 10, 4.50, 0.06,
NULL);
```

Incidentally, note that the NULL entry is accepted only because the V_CODE attribute is optional—the NOT NULL declaration was not used in the CREATE TABLE statement for this attribute.

Inserting Rows with Optional Attributes

Sometimes, more than one attribute is optional. Rather than declaring each attribute as NULL in the INSERT command, you can indicate just the attributes that have required values. You do that by listing the attribute names inside parentheses after the table name. For the purpose of this example, assume that the only required attributes for the PRODUCT table are P_CODE and P_DESCRIPT:

```
INSERT INTO PRODUCT(P_CODE, P_DESCRIPT) VALUES ('BRT-345','Titanium drill bit');
```

7.3.2 SAVING TABLE CHANGES

Any changes made to the table contents are not saved on disk until you close the database, close the program you are using, or use the **COMMIT** command. If the database is open and a power outage or some other interruption occurs before you issue the COMMIT command, your changes will be lost and only the

original table contents will be retained. The syntax for the COMMIT command is:

COMMIT [WORK]

The COMMIT command permanently saves all changes—such as rows added, attributes modified, and rows deleted—made to any table in the database. Therefore, if you intend to make your changes to the PRODUCT table permanent, it is a good idea to save those changes by using the following command:

COMMIT;

NOTE

Note to MS Access Users

MS Access does not support the COMMIT command because it automatically saves changes after the execution of each SQL command.

However, the COMMIT command's purpose is not just to save changes. In fact, the ultimate purpose of the COMMIT and ROLLBACK commands (see [Section 7.3.5](#)) is to ensure database update integrity in transaction management. (You will see how such issues are addressed in [Chapter 10](#), Transaction Management and Concurrency Control.)

7.3.3 LISTING TABLE ROWS

The [**SELECT**](#) command is used to list the contents of a table. The syntax of the SELECT command is as follows:

SELECT *columnlist* **FROM** *tablename*

The *columnlist* represents one or more attributes, separated by commas. You could use the asterisk (*) as a wildcard character to list all attributes. A [**wildcard character**](#) is a symbol that can be used as a general substitute for other characters or commands. For example, to list all attributes and all rows of the PRODUCT table, use:

SELECT * **FROM** PRODUCT;

[Figure 7.3](#) shows the output generated by that command. ([Figure 7.3](#) shows all of the rows in the PRODUCT table that serve as the basis for subsequent discussions. If you entered only the PRODUCT table's first two records, as shown in the preceding section, the output of the preceding SELECT command would show only the rows you entered. Don't worry about the difference between your SELECT output and the output shown in [Figure 7.3](#). When you complete the work in this section, you will have created and populated your VENDOR and PRODUCT tables with the correct rows for use in future sections.)

FIGURE 7.3 The contents of the PRODUCT table

P_CODE	P_DESCRPT	P_INDATE	P_QOH	P_MIN	P_PRICE	P_DISCOUNT	V_CODE
11QER/31	Power painter, 15 psi., 3-nozzle	03-Nov-11	8	5	109.99	0.00	25595
13-Q2/P2	7.25-in. pwr. saw blade	13-Dec-11	32	15	14.99	0.05	21344
14-Q1/L3	9.00-in. pwr. saw blade	13-Nov-11	18	12	17.49	0.00	21344
1546-QQ2	Hrd. cloth, 1/4-in., 2x50	15-Jan-12	15	8	39.95	0.00	23119
1568-QW1	Hrd. cloth, 1/2-in., 3x50	15-Jan-12	23	5	43.99	0.00	23119
2232/QTY	B&D jigsaw, 12-in. blade	30-Dec-11	8	5	109.92	0.05	24288
2232/QWE	B&D jigsaw, 8-in. blade	24-Dec-11	6	5	99.87	0.05	24288
2238/QPD	B&D cordless drill, 1/2-in.	20-Jan-12	12	5	38.95	0.05	25595
23109-HB	Claw hammer	20-Jan-12	23	10	9.95	0.10	21225
23114-AA	Sledge hammer, 12 lb.	02-Jan-12	8	5	14.40	0.05	
54778-2T	Rat-tail file, 1/8-in. fine	15-Dec-11	43	20	4.99	0.00	21344
89-WRE-Q	Hicut chain saw, 16 in.	07-Feb-12	11	5	256.99	0.05	24288
PVC23DRT	PVC pipe, 3.5-in., 8-ft	20-Feb-12	188	75	5.87	0.00	
SM-18277	1.25-in. metal screw, 25	01-Mar-12	172	75	6.99	0.00	21225
SW-23116	2.5-in. wd. screw, 50	24-Feb-12	237	100	8.45	0.00	21231
WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	17-Jan-12	18	5	119.95	0.10	25595

SOURCE: Course Technology/Cengage Learning

NOTE

Your listing may not be in the order shown in [Figure 7.3](#). The listings shown in the figure are the result of system-controlled primary-key-based index operations. You will learn later how to control the output so that it conforms to the order you have specified.

NOTE

Note to Oracle Users

Some SQL implementations (such as Oracle's) cut the attribute labels to fit the width of the column. However, Oracle lets you set the width of the display column to show the complete attribute name. You can also change the display format, regardless of how the data are stored in the table. For example, if you want to display dollar symbols and commas in the P_PRICE output, you can declare:

```
COLUMN P_PRICE FORMAT $99,999.99
```

to change the output 12347.67 to \$12,347.67.

In the same manner, to display only the first 12 characters of the P_DESCRIPT attribute, use:

```
COLUMN P_DESCRIPT FORMAT A12 TRUNCATE
```

Although SQL commands can be grouped together on a single line, complex command sequences are best shown on separate lines, with space between the SQL command and the command's components. Using that formatting convention makes it much easier to see the components of the SQL statements, which in turn makes it easy to trace the SQL logic and make corrections if necessary. The number of spaces used in the indentation is up to you. For example, note the following format for a more complex statement:

```
SELECT P_CODE, P_DESCRIPT, P_INDATE, P_QOH, P_MIN, P_PRICE,  
      P_DISCOUNT, V_CODE  
FROM   PRODUCT;
```

When you run a SELECT command on a table, the RDBMS returns a set of one or more rows that have the same characteristics as a relational table. In addition, the SELECT command lists all rows from the table you specified in the FROM clause. This is a very important characteristic of SQL commands. By default, most SQL data manipulation commands operate over an entire table (or relation), which is why SQL commands are said to be *set-oriented* commands. A SQL set-oriented command works over a set of rows. The set may include one or more columns and zero or more rows from one or more tables.

7.3 . 4 UPDATING TABLE ROWS

Use the **UPDATE** command to modify data in a table. The syntax for this command is:

```
UPDATE tablename  
SET      columnname = expression [, columnname = expression]  
[WHERE conditionlist];
```

For example, if you want to change P_INDATE from December 13, 2011, to January 18, 2012, in the second row of the PRODUCT table (see [Figure 7.3](#)), use the primary key (13-Q2/P2) to locate the correct row. Therefore, type:

```
UPDATE PRODUCT  
SET      P_INDATE = '18-JAN-2012'  
WHERE  P_CODE = '13-Q2/P2';
```

If more than one attribute is to be updated in the row, separate the corrections with commas:

```
UPDATE PRODUCT  
SET      P_INDATE = '18-JAN-2012', P_PRICE = 17.99, P_MIN = 10  
WHERE  P_CODE = '13-Q2/P2';
```

What would have happened if the previous UPDATE command had not included the WHERE condition? The P_INDATE, P_PRICE, and P_MIN values would have been changed in *all* rows of the PRODUCT table. Remember, the UPDATE command is a set-oriented operator. Therefore, if you do not specify a WHERE condition, the UPDATE command will apply the changes to *all* rows in the specified table.

Confirm the correction(s) by using the following SELECT command to check the PRODUCT table's listing:

```
SELECT * FROM PRODUCT;
```

7.3.5 RESTORING TABLE CONTENTS

If you have not yet used the COMMIT command to store the changes permanently in the database, you can restore the database to its previous condition with the ROLLBACK command. **ROLLBACK** undoes any changes

since the last COMMIT command and brings the data back to the values that existed before the changes were made. To restore the data to their “prechange” condition, type:

ROLLBACK;

and then press Enter. Use the SELECT statement again to verify that the ROLLBACK restored the data to their original values.

COMMIT and ROLLBACK work only with data manipulation commands that add, modify, or delete table rows. For example, assume that you perform these actions:

1. CREATE a table called SALES.

2. INSERT 10 rows in the SALES table.
3. UPDATE two rows in the SALES table.

4. Execute the ROLLBACK command.

Will the SALES table be removed by the ROLLBACK command? No, the ROLLBACK command will undo *only* the results of the INSERT and UPDATE commands. All data definition commands (CREATE TABLE) are automatically committed to the data dictionary and cannot be rolled back. The COMMIT and ROLLBACK commands are examined in greater detail in [Chapter 10](#).

NOTE

Note to MS Access Users

MS Access does not support the ROLLBACK command.

Some RDBMSs, such as Oracle, automatically COMMIT data changes when issuing data definition commands. For example, if you had used the CREATE INDEX command after updating the two rows in the previous example, all previous changes would have been committed automatically; doing a ROLLBACK afterward would not have undone anything. *Check your RDBMS*

manual to understand these subtle differences.

7.3.6 DELETING TABLE ROWS

It is easy to delete a table row using the **DELETE** statement; the syntax is:

```
DELETE FROM tablename  
[WHERE      conditionlist];
```

For example, if you want to delete the product you added earlier whose code (P_CODE) is 'BRT-345', use the following command:

```
DELETE FROM PRODUCT  
WHERE      P_CODE = 'BRT-345';
```

In this example, the primary key value lets SQL find the exact record to be deleted from the PRODUCT table. However, deletions are not limited to a primary key match; any attribute may be used. For example, in your PRODUCT table, you will see several products for which the P_MIN attribute is equal to 5. Use the following command to delete all rows from the PRODUCT table for which the P_MIN is equal to 5:

```
DELETE FROM PRODUCT  
WHERE      P_MIN = 5;
```

Check the PRODUCT table's contents again to verify that all products with P_MIN equal to 5 have been deleted.

Finally, remember that DELETE is a set-oriented command, and that the WHERE condition is optional. Therefore, if you do not specify a WHERE condition, *all* rows from the specified table will be deleted!

7.3.7 INSERTING TABLE ROWS WITH A SELECT SUBQUERY

You learned in [Section 7.3.1](#) how to use the INSERT statement to add rows to a table. In that section, you added rows one at a time. In this section, you will learn how to add multiple rows to a table, using another table as the source of the data. The syntax for the INSERT statement is:

```
INSERT INTO tablename SELECT columnlist FROM tablename;
```

In this case, the INSERT statement uses a SELECT subquery. A **subquery**, also

known as a [nested query](#) or an [inner query](#), is a query that is embedded (or nested) inside another query. The inner query is always executed first by the RDBMS. Given the previous SQL statement, the INSERT portion represents the outer query, and the SELECT portion represents the subquery. You can nest queries (place queries inside queries) many levels deep; in every case, the output of the inner query is used as the input for the outer (higher-level) query. In [Chapter 8](#) you will learn more about the various types of subqueries.

The values returned by the SELECT subquery should match the attributes and data types of the table in the INSERT statement. If the table into which you are inserting rows has one date attribute, one number attribute, and one character attribute, the SELECT subquery should return one or more rows in which the first column has date values, the second column has number values, and the third column has character values.



ONLINE CONTENT

Before you execute the commands in the following sections, you *must* do the following:

If you are using Oracle or Microsoft SQL Server, run the respective **sqlintrodbinit.sql** script file at www.cengagebrain.com to create all tables and load the data in the database.

If you are using Access, copy the original **Ch07_SaleCo.mdb** file from www.cengagebrain.com.

7.4 SELECT QUERIES

In this section, you will learn how to fine-tune the SELECT command by adding restrictions to the search criteria. When coupled with appropriate search conditions, SELECT is an incredibly powerful tool that enables you to transform data into information. For example, in the following sections, you will learn how to create queries that can answer questions such as these: “What products were supplied by a particular vendor?”, “Which products are priced below \$10?”, and “How many products supplied by a given vendor were sold between January 5,

2012, and March 20, 2012?"

7.4.1 SELECTING ROWS WITH CONDITIONAL RESTRICTIONS

You can select partial table contents by placing restrictions on the rows to be included in the output. Use the WHERE clause to add conditional restrictions to the SELECT statement. The following syntax enables you to specify which rows to select:

```
SELECT columnlist
FROM   tablelist
[WHERE conditionlist];
```

The SELECT statement retrieves all rows that match the specified condition(s)—also known as the conditional criteria—you specified in the WHERE clause. The *conditionlist* in the WHERE clause of the SELECT statement is represented by one or more conditional expressions, separated by logical operators. The WHERE clause is optional. If no rows match the specified criteria in the WHERE clause, you see a blank screen or a message that tells you no rows were retrieved. For example, consider the following query:

```
SELECT P_DESCRIPTOR, P_INDATE, P_PRICE, V_CODE
FROM   PRODUCT
WHERE V_CODE = 21344;
```

This query returns the description, date, and price of products with a vendor code of 21344, as shown in [Figure 7.4](#).

FIGURE 7.4 Selected PRODUCT table attributes for VENDOR code 21344

P_DESCRIPTOR	P_INDATE	P_PRICE	V_CODE
7.25-in. pwr. saw blade	13-Dec-11	14.99	21344
9.00-in. pwr. saw blade	13-Nov-11	17.49	21344
Rat-tail file, 1/8-in. fine	15-Dec-11	4.99	21344

SOURCE: Course Technology/Cengage Learning

MS Access users can use the Access QBE (query by example) query generator. Although the Access QBE generates its own “native” version of SQL, you can also elect to type standard SQL in the Access SQL window, as shown at the bottom of [Figure 7.5](#). The figure shows the Access QBE screen, the SQL window’s QBE-generated SQL, and the listing of the modified SQL.

FIGURE 7.5 The Microsoft Access QBE and its SQL

The screenshot displays three windows related to Microsoft Access queries:

- Query view options:** A sidebar on the right showing various query views: Datasheet View, PivotTable View, PivotChart View, SQL View (which is selected), and Design View.
- Microsoft Access-generated SQL:** A window showing the generated SQL query:


```
SELECT PRODUCT.P_DESCRIPT, PRODUCT.P_INDATE, PRODUCT.P_PRICE, PRODUCT.V_CODE
FROM PRODUCT
WHERE ((PRODUCT.V_CODE)=21344);
```
- User-entered SQL:** A window showing the user-entered SQL query, which is identical to the generated one:


```
SELECT P_DESCRIPT, P_INDATE, P_PRICE, V_CODE
FROM PRODUCT
WHERE V_CODE=21344;
```

SOURCE: Course Technology/Cengage Learning

NOTE

Note to MS Access Users

The MS Access QBE interface automatically designates the data source by using the table name as a prefix. You will discover later that the table name prefix is used to avoid ambiguity when the same column name appears in multiple tables. For example, both the VENDOR and PRODUCT tables contain the V_CODE attribute. Therefore, if both tables are used (as they would be in a join), the source of the V_CODE attribute must be specified.

Numerous conditional restrictions can be placed on the selected table contents. For example, the comparison operators shown in [Table 7.6](#) can be used to restrict output.

TABLE 7.6 Comparison Operators

SYMBOL MEANING

=	Equal to
<	Less than
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
<> or !=	Not equal to

The following example uses the “not equal to” operator:

```
SELECT P_DESCRIP, P_INDATE, P_PRICE, V_CODE  
FROM   PRODUCT  
WHERE V_CODE <> 21344;
```

FIGURE 7.6 Selected PRODUCT table attributes for VENDOR codes other than 21344

P_DESCRIPTOR	P_INDATE	P_PRICE	V_CODE
Power painter, 15 psi., 3-nozzle	03-Nov-11	109.99	25595
Hrd. cloth, 1/4-in., 2x50	15-Jan-12	39.95	23119
Hrd. cloth, 1/2-in., 3x50	15-Jan-12	43.99	23119
B&D jigsaw, 12-in. blade	30-Dec-11	109.92	24288
B&D jigsaw, 8-in. blade	24-Dec-11	99.87	24288
B&D cordless drill, 1/2-in.	20-Jan-12	38.95	25595
Claw hammer	20-Jan-12	9.95	21225
Hicut chain saw, 16 in.	07-Feb-12	256.99	24288
1.25-in. metal screw, 25	01-Mar-12	6.99	21225
2.5-in. wd. screw, 50	24-Feb-12	8.45	21231
Steel matting, 4'x8'x1/6", .5" mesh	17-Jan-12	119.95	25595

SOURCE: Course Technology/Cengage Learning

The output, shown in [Figure 7.6](#), lists all of the rows for which the vendor code is *not* 21344.

Note that, in [Figure 7.6](#), rows with nulls in the V_CODE column (see [Figure 7.3](#)) are not included in the SELECT command's output.

The following command sequence:

```
SELECT P_DESCRIPTOR, P_QOH, P_MIN, P_PRICE
FROM PRODUCT
WHERE P_PRICE <= 10;
```

yields the output shown in [Figure 7.7](#).

FIGURE 7.7 Selected PRODUCT table attributes with a P_PRICE restriction

P_DESCRIPTOR	P_QOH	P_MIN	P_PRICE
Claw hammer	23	10	9.95
Rat-tail file, 1/8-in. fine	43	20	4.99
PVC pipe, 3.5-in., 8-ft	188	75	5.87
1.25-in. metal screw, 25	172	75	6.99
2.5-in. wd. screw, 50	237	100	8.45

```
SELECT P_CODE, P_DESCRIP, P_QOH, P_MIN,
       P_PRICE
  FROM PRODUCT
 WHERE P_CODE < '1558-QW1';
```

Using Comparison Operators on Character Attributes

Because computers identify all characters by their numeric American Standard Code for Information Interchange (ASCII) codes, comparison operators may even be used to place restrictions on character-based attributes. Therefore, the command: would be correct and would yield a list of all rows in which the P_CODE is alphabetically less than 1558-QW1. (Because the ASCII code value for the letter B is greater than the value of the letter A, it follows that A is less than B.) Therefore, the output will be generated as shown in [Figure 7.8](#).

FIGURE 7.8 Selected PRODUCT table attributes: the ASCII code effect

P_CODE	P_DESCRIP	P_QOH	P_MIN	P_PRICE
11QER/31	Power painter, 15 psi., 3-nozzle	8	5	109.99
13-Q2/P2	7.25-in. pwr. saw blade	32	15	14.99
14-Q1/L3	9.00-in. pwr. saw blade	18	12	17.49
1548-QQ2	Hrd. cloth, 1/4-in., 2x50	15	8	39.95

String (character) comparisons are made from left to right. This left-to-right comparison is especially useful when attributes such as names are to be compared. For example, the string “Ardmore” would be judged *greater than* the string “Aarenson” but *less than* the string “Brown”; such results may be used to generate alphabetical listings like those in a phone directory. If the characters 0-9 are stored as strings, the same left-to-right string comparisons can lead to apparent anomalies. For example, the ASCII code for the character “5” is *greater than* the ASCII code for the character “4,” as expected. Yet, the same “5” will

also be judged *greater than* the string “44” because the *first* character in the string “44” is less than the string “5.” For that reason, you may get some unexpected results from comparisons when dates or other numbers are stored in character format. For example, the left-to-right ASCII character comparison would force the conclusion that the date “01/01/2012” occurred *before* “12/31/2011.” Because the leftmost character “0” in “01/01/2012” is *less than* the leftmost character “1” in “12/31/2011,” “01/01/2012” is *less than* “12/31/2011.” Naturally, if date strings are stored in a yyyy/mm/dd format, the comparisons will yield appropriate results, but this is a nonstandard date presentation. Therefore, all current RDBMSs support date data types; you should use them. In addition, using date data types gives you the benefit of date arithmetic.

Using Comparison Operators on Dates

Date procedures are often more software-specific than other SQL procedures. For example, the query to list all of the rows in which the inventory stock dates occur on or after January 20, 2012, looks like this:

```
SELECT P_DESCRIPTOR, P_QOH, P_MIN, P_PRICE, P_INDATE  
FROM PRODUCT  
WHERE P_INDATE >= '20-Jan-2012';
```

Remember that MS Access users must use the # delimiters for dates. For example, you would use #20-Jan-12# in the preceding WHERE clause. The date-restricted output is shown in [Figure 7.9](#).

FIGURE 7.9 Selected PRODUCT table attributes: date restriction

P_DESCRIPTOR	P_QOH	P_MIN	P_PRICE	P_INDATE
B&D cordless drill, 1/2-in.	12	5	38.95	20-Jan-12
Claw hammer	23	10	9.95	20-Jan-12
Hicut chain saw, 16 in.	11	5	256.99	07-Feb-12
PVC pipe, 3.5-in., 8-ft	188	75	5.87	20-Feb-12
1.25-in. metal screw, 25	172	75	6.99	01-Mar-12
2.5-in. wd. screw, 50	237	100	8.45	24-Feb-12

SOURCE: Course Technology/Cengage Learning

Using Computed Columns and Column Aliases

Suppose that you want to determine the total value of each of the products currently held in inventory. Logically, that determination requires the multiplication of each product's quantity on hand by its current price. You can accomplish this task with the following command:

```
SELECT P_DESCRIPTOR, P_QOH, P_PRICE, P_QOH *  
      P_PRICE  
FROM PRODUCT
```

FIGURE 7.10 SELECT statement with a computed column

P_DESCRIPTOR	P_QOH	P_PRICE	Expr1
Power painter, 15 psi., 3-nozzle	8	109.99	879.92
7.25-in. pwr. saw blade	32	14.99	479.68
9.00-in. pwr. saw blade	18	17.49	314.82
Hrd. cloth, 1/4-in., 2x50	15	39.95	599.25
Hrd. cloth, 1/2-in., 3x50	23	43.99	1011.77
B&D jigsaw, 12-in. blade	8	109.92	879.36
B&D jigsaw, 8-in. blade	6	99.87	599.22
B&D cordless drill, 1/2-in.	12	38.95	467.40
Claw hammer	23	9.95	228.85
Sledge hammer, 12 lb.	8	14.40	115.20
Rat-tail file, 1/8-in. fine	43	4.99	214.57
Hicut chain saw, 16 in.	11	256.99	2826.89
PVC pipe, 3.5-in., 8-ft	188	5.87	1103.56
1.25-in. metal screw, 25	172	6.99	1202.28
2.5-in. wd. screw, 50	237	8.45	2002.65
Steel matting, 4'x8'x1/6", .5" mesh	18	119.95	2159.10

SOURCE: Course Technology/Cengage Learning

Entering the SQL command in Access generates the output shown in [Figure 7.10](#).

SQL accepts any valid expressions (or formulas) in the computed columns. Such

formulas can contain any valid mathematical operators and functions that are applied to attributes in any of the tables specified in the FROM clause of the SELECT statement. Note also that Access automatically adds an *Expr* label to all computed columns. (The first computed column would be labeled Expr1; the second, Expr2; and so on.) Oracle uses the actual formula text as the label for the computed column.

To make the output more readable, the SQL standard permits the use of **aliases** for any column in a SELECT statement. An alias is an alternate name given to a column or table in any SQL statement.

For example, you can rewrite the previous SQL statement as:

```
SELECT P_DESCRPT, P_QOH, P_PRICE, P_QOH * P_PRICE AS  
      TOTVALUE  
  FROM PRODUCT;
```

The output of the command is shown in [Figure 7.11](#).

FIGURE 7.11 SELECT statement with a computed column and an alias

P_DESCRPT	P_QOH	P_PRICE	TOTVALUE
Power painter, 15 psi., 3-nozzle	8	109.99	879.92
7.25-in. pwr. saw blade	32	14.99	479.68
9.00-in. pwr. saw blade	18	17.49	314.82
Hrd. cloth, 1/4-in., 2x50	15	39.95	599.25
Hrd. cloth, 1/2-in., 3x50	23	43.99	1011.77
B&D jigsaw, 12-in. blade	8	109.92	879.36
B&D jigsaw, 8-in. blade	6	99.87	599.22
B&D cordless drill, 1/2-in.	12	38.95	467.40
Claw hammer	23	9.95	228.85
Sledge hammer, 12 lb.	8	14.40	115.20
Rat-tail file, 1/8-in. fine	43	4.99	214.57
Hicut chain saw, 16 in.	11	256.99	2826.89
PVC pipe, 3.5-in., 8-ft	188	5.87	1103.56
1.25-in. metal screw, 25	172	6.99	1202.28
2.5-in. wd. screw, 50	237	8.45	2002.65
Steel matting, 4'x8'x1/6", .5" mesh	18	119.95	2159.10

You could also use a computed column, an alias, and date arithmetic in a single query. For example, assume that you want to get a list of out-of-warranty products that have been stored more than 90 days. In that case, the P_INDATE is at least 90 days less than the current (system) date. The MS Access version of this query is:

```
SELECT P_CODE, P_INDATE, DATE() - 90 AS CUTDATE  
FROM PRODUCT  
WHERE P_INDATE <= DATE() - 90;
```

The Oracle version of the same query is shown here:

```
SELECT P_CODE, P_INDATE, SYSDATE CUTDATE - 90 AS  
FROM PRODUCT  
WHERE P_INDATE <= SYSDATE - 90;
```

Note that DATE() and SYSDATE are special functions that return the current date in MS Access and Oracle, respectively. You can use the DATE() and SYSDATE functions anywhere a date literal is expected, such as in the value list of an INSERT statement, in an UPDATE statement when changing the value of a date attribute, or in a SELECT statement, as shown here. Of course, the previous query output would change based on the current date.

Suppose that a manager wants a list of all products, the dates they were received, and the warranty expiration date (90 days from receiving the product). To generate that list, type:

```
SELECT P_CODE, P_INDATE, P_INDATE + 90 AS EXPDATE  
FROM PRODUCT;
```

Note that you can use all arithmetic operators with date attributes as well as with numeric attributes.

7.4.2 ARITHMETIC OPERATORS: THE RULE OF PRECEDENCE

As you saw in the previous example, you can use arithmetic operators with table attributes in a column list or in a conditional expression. In fact, SQL commands are often used in conjunction with the arithmetic operators shown in [Table 7.7](#).

TABLE 7.7 The Arithmetic Operators

ARITHMETIC OPERATOR	DESCRIPTION
+	Add
-	Subtract
*	Multiply
/	Divide
$^$	Raise to the power of (some applications use ** instead of $^$)

Do not confuse the multiplication symbol (*) with the wildcard symbol used by some SQL implementations, such as MS Access; the latter is used only in string comparisons, while the former is used in conjunction with mathematical procedures.

As you perform mathematical operations on attributes, remember the **rules of precedence**. As the name suggests, the **rules of precedence** are the rules that establish the order in which computations are completed. For example, note the order of the following computational sequence:

1. Perform operations within parentheses.
2. Perform power operations.
3. Perform multiplications and divisions.
4. Perform additions and subtractions.

The application of the rules of precedence will tell you that $8 + 2 \cdot 5 = 8 + 10 = 18$, but $(8 + 2) \cdot 5 = 10 \cdot 5 = 50$. Similarly, $4 + 5^2 \cdot 3 = 4 + 25 \cdot 3 = 79$, but $(4 + 5)^2 \cdot 3 = 81 \cdot 3 = 243$, while the operation expressed by $(4 + 5^2) \cdot 3$ yields the answer $(4 + 25) \cdot 3 = 29 \cdot 3 = 87$.

7.4.3 LOGICAL OPERATORS: AND, OR, AND NOT

In the real world, a search of data normally involves multiple conditions. For example, when you are buying a new house, you look for a certain area, a certain number of bedrooms, bathrooms, stories, and so on. In the same way, SQL allows you to include multiple conditions in a query through the use of logical operators. The logical operators are **AND**, **OR**, and **NOT**. For example, if you want a list of the table contents for either the V_CODE = 21344 or the V_CODE = 24288, you can use the OR operator, as in the following command sequence:

```
SELECT P_DESCRIP, P_INDATE, P_PRICE, V_CODE  
FROM PRODUCT  
WHERE V_CODE = 21344 OR V_CODE = 24288;
```

FIGURE 7.12 Selected PRODUCT table attributes: the logical OR

P_DESCRIP	P_INDATE	P_PRICE	V_CODE
7.25-in. pwr. saw blade	13-Dec-11	14.99	21344
9.00-in. pwr. saw blade	13-Nov-11	17.49	21344
B&D jigsaw, 12-in. blade	30-Dec-11	109.92	24288
B&D jigsaw, 8-in. blade	24-Dec-11	99.87	24288
Rat-tail file, 1/8-in. fine	15-Dec-11	4.99	21344
Hicut chain saw, 16 in.	07-Feb-12	256.99	24288

SOURCE: Course Technology/Cengage Learning

This command generates the six rows shown in [Figure 7.12](#) that match the logical restriction.

The logical AND has the same SQL syntax requirement as OR. The following command generates a list of all rows for which P_PRICE is less than \$50 and for which P_INDATE is a date occurring after January 15, 2012:

```
SELECT P_DESCRIP, P_INDATE, P_PRICE, V_CODE  
FROM PRODUCT  
WHERE P_PRICE < 50  
AND P_INDATE > '15-Jan-2012';
```

This command produces the output shown in [Figure 7.13](#).

FIGURE 7.13 Selected PRODUCT table attributes: the logical AND

P_DESCRPT	P_INDATE	P_PRICE	V_CODE
B&D cordless drill, 1/2-in.	20-Jan-12	38.95	25595
Claw hammer	20-Jan-12	9.95	21225
PVC pipe, 3.5-in., 8-ft	20-Feb-12	5.87	
1.25-in. metal screw, 25	01-Mar-12	6.99	21225
2.5-in. wd. screw, 50	24-Feb-12	8.45	21231

SOURCE: Course Technology/Cengage Learning

You can combine the logical OR with the logical AND to place further restrictions on the output. For example, suppose that you want a table listing for the following conditions:

- The P_INDATE is after January 15, 2012, and the P_PRICE is less than \$50.
- Or the V_CODE is 24288.

The required listing can be produced by using the following:

```
SELECT P_DESCRPT, P_INDATE, P_PRICE, V_CODE  
FROM PRODUCT  
WHERE (P_PRICE < 50 AND P_INDATE > '15-Jan-2012')  
OR      V_CODE = 24288;
```

Note the use of parentheses to combine logical restrictions. Where you place the parentheses depends on how you want the logical restrictions to be executed. Conditions listed within parentheses are always executed first. The preceding query yields the output shown in [Figure 7.14](#).

FIGURE 7.14 Selected PRODUCT table attributes: the logical AND and OR

P_DESCRPT	P_INDATE	P_PRICE	V_CODE
B&D jigsaw, 12-in. blade	30-Dec-11	109.92	24288
B&D jigsaw, 8-in. blade	24-Dec-11	99.87	24288
B&D cordless drill, 1/2-in.	20-Jan-12	38.95	25595
Claw hammer	20-Jan-12	9.95	21225
Hicut chain saw, 16 in.	07-Feb-12	256.99	24288
PVC pipe, 3.5-in., 8-ft	20-Feb-12	5.87	
1.25-in. metal screw, 25	01-Mar-12	6.99	21225
2.5-in. wd. screw, 50	24-Feb-12	8.45	21231

SOURCE: Course Technology/Cengage Learning

Note that the three rows with the V_CODE = 24288 are included regardless of the P_INDATE and P_PRICE entries for those rows.

The use of the logical operators OR and AND can become quite complex when numerous restrictions are placed on the query. In fact, a specialty field in mathematics known as **Boolean algebra** is dedicated to the use of logical operators.

The logical operator NOT is used to negate the result of a conditional expression. That is, in SQL, all conditional expressions evaluate to true or false. If an expression is true, the row is selected; if an expression is false, the row is not selected.

The NOT logical operator is typically used to find the rows that *do not* match a certain condition. For example, if you want to see a listing of all rows for which the vendor code is not 21344, use the following command sequence:

```
SELECT *
FROM PRODUCT
WHERE NOT (V_CODE = 21344);
```

Note that the condition is enclosed in parentheses; that practice is optional, but it is highly recommended for clarity. The logical NOT can be combined with AND and OR.

NOTE

If your SQL version does not support the logical NOT, you can generate the required output by using the following condition:

`WHERE V_CODE <> 21344`

If your version of SQL does not support `<>`, use:

`WHERE V_CODE != 21344`

7.4.4 SPECIAL OPERATORS

ANSI-standard SQL allows the use of special operators in conjunction with the WHERE clause. These special operators include:

BETWEEN: Used to check whether an attribute value is within a range

IS NULL: Used to check whether an attribute value is null

LIKE: Used to check whether an attribute value matches a given string pattern

IN: Used to check whether an attribute value matches any value within a value list

EXISTS: Used to check whether a subquery returns any rows

The BETWEEN Special Operator

If you use software that implements a standard SQL, the operator BETWEEN may be used to check whether an attribute value is within a range of values. For example, if you want to see a listing for all products whose prices are between \$50 and \$100, use the following command sequence:

```
SELECT *
FROM  PRODUCT
WHERE P_PRICE BETWEEN 50.00 AND 100.00;
```

NOTE

Note to Oracle Users

When using the BETWEEN special operator, always specify the lower range value first. If you list the higher range value first, Oracle will return an empty result set.

If your DBMS does not support BETWEEN, you can use:

```
SELECT *
FROM  PRODUCT
WHERE P_PRICE > 50.00 AND P_PRICE < 100.00;
```

The IS NULL Special Operator

Standard SQL allows the use of IS NULL to check for a null attribute value. For example, suppose that you want to list all products that do not have a vendor assigned (V_CODE is null). Such a null entry could be found by using the following command sequence:

```
SELECT P_CODE, P_DESCRIP, V_CODE
FROM  PRODUCT
WHERE V_CODE IS NULL;
```

Similarly, if you want to check a null date entry, the command sequence is:

```
SELECT P_CODE, P_DESCRIP, P_INDATE
FROM  PRODUCT
WHERE P_INDATE IS NULL;
```

Note that SQL uses a special operator to test for nulls. Why? Couldn't you just enter a condition such as "V_CODE = NULL"? No. Technically, NULL is not a "value" the way the number 0 or the blank space is; instead, a NULL is a special property of an attribute that represents precisely the absence of any value.

The LIKE Special Operator

The LIKE special operator is used in conjunction with wildcards to find patterns within string attributes. Standard SQL allows you to use the percent sign (%) and underscore (_) wildcard characters to make matches when the entire string is not known:

- % means any and all *following* or *preceding* characters are eligible. For example:

'J%' includes Johnson, Jones, Jernigan, July, and J-231Q. 'Jo%' includes Johnson and Jones. '%n' includes Johnson and Jernigan.

- _ means any *one* character may be substituted for the underscore. For example:
_23-456-6789' includes 123-456-6789, 223-456-6789, and 323-456-6789.
23-56-678_ includes 123-156-6781, 123-256-6782, and 823-956-6788.
'oes' includes Jones, Cones, Cokes, totes, and roles.

NOTE

Some RDBMSs, such as Microsoft Access, use the wildcard characters * and ? instead of % and _.

For example, the following query would find all VENDOR rows for contacts whose last names begin with *Smith*.

```
SELECT V_NAME, V_CONTACT, V_AREACODE, V_PHONE  
FROM VENDOR  
WHERE V_CONTACT LIKE 'Smith%';
```

If you check the original VENDOR data in [Figure 7.2](#) again, you'll see that this SQL query yields three records: two Smiths and one Smithson.

Keep in mind that most SQL implementations yield case-sensitive searches. For example, Oracle will not yield a result that includes *Jones* if you use the wildcard search delimiter 'jo%' in a search for last names; *Jones* begins with a capital *J*, and your wildcard search starts with a lowercase *j*. On the other hand, MS Access searches are not case sensitive.

For example, suppose that you typed the following query in Oracle:

```
SELECT V_NAME, V_CONTACT, V_AREACODE, V_PHONE  
FROM VENDOR  
WHERE V_CONTACT LIKE 'SMITH%';
```

No rows will be returned because character-based queries may be case sensitive.

That is, an uppercase character has a different ASCII code than a lowercase character, causing *SMITH*, *Smith*, and *smith* to be evaluated as different (unequal) entries. Because the table contains no vendor whose last name begins with *SMITH* (in uppercase), the '*SMITH%*' used in the query cannot be matched. Matches can be made only when the query entry is written exactly like the table entry.

Some RDBMSs, such as Microsoft Access, automatically make the necessary conversions to eliminate case sensitivity. Others, such as Oracle, provide a special UPPER function to convert both table and query character entries to uppercase. (The conversion is done in the computer's memory only; the conversion has no effect on how the value is actually stored in the table.) So, if you want to avoid a no-match result based on case sensitivity, and if your RDBMS allows the use of the UPPER function, you can generate the same results by using the following query:

```
SELECT V_NAME, V_CONTACT, V_AREACODE, V_PHONE  
FROM VENDOR  
WHERE UPPER(V_CONTACT) LIKE 'SMITH%';
```

The preceding query produces a list that includes all rows containing a last name that begins with *Smith*, regardless of uppercase or lowercase letter combinations such as *Smith*, *smith*, and *SMITH*.

The logical operators may be used in conjunction with the special operators. For instance, the following query:

```
SELECT V_NAME, V_CONTACT, V_AREACODE, V_PHONE  
FROM VENDOR  
WHERE V_CONTACT NOT LIKE 'Smith%';
```

will yield an output of all vendors whose names do not start with *Smith*.

Suppose that you do not know whether a person's name is spelled *Johnson* or *Johnsen*. The wildcard character _ lets you find a match for either spelling. The proper search would be instituted by the following query:

```
SELECT *  
FROM VENDOR  
WHERE V_CONTACT LIKE 'Johns_n';
```

Thus, the wildcards allow you to make matches when only approximate spellings are known. Wildcard characters may be used in combinations. For example, the wildcard search based on the string '_l%' can yield the strings “Al”, “Alton”, “Elgin”, “Blakestom”, “blank”, “bloated”, and “eligible”.

The IN Special Operator

Many queries that would require the use of the logical OR can be more easily handled with the help of the special operator IN. For example, the following query:

```
SELECT *
FROM PRODUCT
WHERE V_CODE = 21344
OR      V_CODE = 24288;
```

can be handled more efficiently with:

```
SELECT *
FROM PRODUCT
WHERE V_CODE IN (21344, 24288);
```

Note that the IN operator uses a value list. All of the values in the list must be of the same data type. Each of the values in the value list is compared to the attribute—in this case, V_CODE. If the V_CODE value matches any of the values in the list, the row is selected. In this example, the rows selected will be only those in which the V_CODE is either 21344 or 24288.

If the attribute used is of a character data type, the list values must be enclosed in single quotation marks. For instance, if the V_CODE had been defined as CHAR(5) when the table was created, the preceding query would have read:

```
SELECT *
FROM PRODUCT
WHERE V_CODE IN ('21344', '24288');
```

The IN operator is especially valuable when it is used in conjunction with subqueries. For example, suppose that you want to list the V_CODE and V_NAME of only those vendors who provide products. In that case, you could use a subquery within the IN operator to automatically generate the value list. The query would be:

```
SELECT V_CODE, V_NAME  
FROM VENDOR  
WHERE V_CODE IN (SELECT V_CODE FROM PRODUCT);
```

The preceding query will be executed in two steps:

1. The inner query or subquery will generate a list of V_CODE values from the PRODUCT tables. Those V_CODE values represent the vendors who supply products.
2. The IN operator will compare the values generated by the subquery to the V_CODE values in the VENDOR table, and will select only the rows with matching values—that is, the vendors who provide products.

The IN special operator will receive additional attention in [Chapter 8](#), where you will learn more about subqueries.

The EXISTS Special Operator

The EXISTS special operator can be used whenever there is a requirement to execute a command based on the result of another query. That is, if a subquery returns any rows, run the main query; otherwise, do not. For example, the following query will list all vendors, but only if there are products to order:

```
FROM VENDOR  
WHERE EXISTS (SELECT * FROM PRODUCT WHERE P_QOH <=  
P_MIN);
```

The EXISTS special operator is used in the following example to list all vendors, but only if there are products with the quantity on hand, and less than double the minimum quantity:

```
SELECT *  
FROM VENDOR  
WHERE EXISTS (SELECT FROM PRODUCT WHERE P_QOH < P_MIN 2);
```

The EXISTS special operator will receive additional attention in [Chapter 8](#), where you will learn more about subqueries.

7.5 ADDITIONAL DATA DEFINITION COMMANDS

In this section, you will learn how to change table structures by changing attribute characteristics and by adding columns. Then you will learn how to make advanced data updates to the new columns. Finally, you will learn how to copy tables or parts of tables and how to delete tables.

All changes in the table structure are made by using the [**ALTER TABLE**](#) command, followed by a keyword that produces the specific change you want to make. Three options are available: ADD, MODIFY, and DROP. You use ADD to add a column, MODIFY to change column characteristics, and DROP to delete a column from a table. Most RDBMSs do not allow you to delete a column unless the column does not contain any values; otherwise, such an action might delete crucial data used by other tables. The basic syntax to add or modify columns is:

`ALTER TABLE tablename`

`{ADD | MODIFY} (columnname datatype [{ADD | MODIFY}`
`columnname datatype]);`

The ALTER TABLE command can also be used to add table constraints. In those cases, the syntax would be:

`ALTER TABLE tablename`

`ADD constraint [ADD constraint] ;`

where *constraint* refers to a constraint definition similar to those you learned in [Section 7.2.6](#).

You could also use the ALTER TABLE command to remove a column or table constraint. The syntax would be as follows:

`ALTER TABLE tablename`

`DROP{PRIMARY KEY | COLUMN columnname | CONSTRAINT`
`constraintname };`

Notice that when removing a constraint, you need to specify it by name, which is one reason you should always name constraints in your CREATE TABLE or ALTER TABLE statement.

7.5.1 CHANGING A COLUMN'S DATA TYPE

Using the ALTER syntax, the integer V_CODE in the PRODUCT table can be

changed to a character V_CODE by using the following command:

```
ALTER TABLE PRODUCT  
    MODIFY (V_CODE CHAR(5));
```

Some RDBMSs, such as Oracle, do not let you change data types unless the column to be changed is empty. For example, if you want to change the V_CODE field from the current number definition to a character definition, the preceding command will yield an error message because the V_CODE column already contains data. The error message is easily explained. Remember that the V_CODE in PRODUCT references the V_CODE in VENDOR. If you change the V_CODE data type, the data types do not match, and there is a referential integrity violation, which triggers the error message. If the V_CODE column does not contain data, the preceding command sequence will alter the table structure as expected (if the foreign key reference was not specified during the creation of the PRODUCT table).

7.5.2 CHANGING A COLUMN'S DATA CHARACTERISTICS

If the column to be changed already contains data, you can make changes in the column's characteristics if those changes do not alter the data type. For example, if you want to increase the width of the P_PRICE column to nine digits, use the following command:

```
ALTER TABLE PRODUCT  
    MODIFY (P_PRICE DECIMAL(9,2));
```

If you now list the table contents, you can see that the column width of P_PRICE has increased by one digit.

NOTE

Some DBMSs impose limitations on when it is possible to change attribute characteristics. For example, Oracle lets you increase (but not decrease) the size of a column because an attribute modification will affect the integrity of the data in the database. In fact, some attribute changes can be made only when there are no data in any rows for the affected attribute.

7.5.3 ADDING A COLUMN

You can alter an existing table by adding one or more columns. In the following example, you add the column named P_SALECODE to the PRODUCT table. (This column will be used later to determine whether goods that have been in inventory for a certain length of time should be placed on special sale.)

Suppose that you expect the P_SALECODE entries to be 1, 2, or 3. Because no arithmetic will be performed with the P_SALECODE, the P_SALECODE will be classified as a single-character attribute. Note the inclusion of all required information in the following ALTER command:

```
ALTER TABLE PRODUCT  
ADD (P_SALECODE CHAR(1));
```



ONLINE CONTENT

If you are using the MS Access databases provided at www.cengagebrain.com, you can track each of the updates in the following sections. For example, look at the copies of the PRODUCT table in the **Ch07_SaleCo** database, one named PRODUCT_2 and one named PRODUCT_3. Each of the two copies includes the new P_SALECODE column. If you want to see the *cumulative* effect of all UPDATE commands, you can continue using the PRODUCT table with the P_SALECODE modification and all of the changes you will make in the following sections. (You might even want to use both options, first to examine the individual effects of the update queries and then to examine the cumulative effects.)

When adding a column, be careful not to include the NOT NULL clause for the new column. Doing so will cause an error message; if you add a new column to a table that already has rows, the existing rows will default to a value of null for the new column. Therefore, it is not possible to add the NOT NULL clause for this new column. (Of course, you can add the NOT NULL clause to the table structure after all the data for the new column have been entered and the column no longer contains nulls.)

7.5.4 DROPPING A COLUMN

Occasionally, you might want to modify a table by deleting a column. Suppose that you want to delete the V_ORDER attribute from the VENDOR table. You would use the following command:

```
ALTER TABLE VENDOR  
    DROP COLUMN V_ORDER;
```

Again, some RDBMSs impose restrictions on attribute deletion. For example, you may not drop attributes that are involved in foreign key relationships, nor may you delete an attribute if it is the only one in a table.

7.5.5 ADVANCED DATA UPDATES

To make changes to data in the columns of existing rows, use the UPDATE command. Do not confuse the INSERT and UPDATE commands: INSERT creates new rows in the table, while UPDATE changes rows that already exist. For example, to enter the P_SALECODE value '2' in the fourth row, use the UPDATE command together with the primary key P_CODE '1546-QQ2'. Enter the value by using the following command sequence:

```
UPDATE PRODUCT  
SET      P_SALECODE = '2'  
WHERE   P_CODE = '1546-QQ2';
```

Subsequent data can be entered the same way, defining each entry location by its primary key (P_CODE) and its column location (P_SALECODE). For example, if you want to enter the P_SALECODE value '1' for the P_CODE values '2232/QWE' and '2232/QTY', you use:

```
UPDATE PRODUCT  
SET      P_SALECODE = '1'  
WHERE   P_CODE IN ('2232/QWE', '2232/QTY');
```

If your RDBMS does not support IN, use the following command:

```
UPDATE PRODUCT  
SET      P_SALECODE = '1'  
WHERE   P_CODE = '2232/QWE' OR P_CODE = '2232/QTY';
```

You can check the results of your efforts by using the following commands:

```
SELECT P_CODE, P_DESCRIP, P_INDATE, P_PRICE, P_SALECODE  
FROM PRODUCT;
```

Although the UPDATE sequences just shown allow you to enter values into specified table cells, the process is very cumbersome. Fortunately, if a relationship can be established between the entries and the existing columns, the relationship can be used to assign values to their appropriate slots. For example, suppose that you want to place sales codes into the table based on the P_INDATE using the following schedule:

P_INDATE	P_SALECODE
before December 25, 2011	2
between January 16, 2012, and February 10, 2012	1

Using the PRODUCT table, the following two command sequences make the appropriate assignments:

```
UPDATE PRODUCT  
SET P_SALECODE = '2'  
WHERE P_INDATE < '25-Dec-2011';
```

```
UPDATE PRODUCT  
SET P_SALECODE = '1'  
WHERE P_INDATE >= '16-Jan-2012' AND P_INDATE <='10-Feb-2012';
```

To check the results of those two command sequences, use:

```
SELECT P_CODE, P_DESCRIP, P_INDATE, P_PRICE, P_SALECODE  
FROM PRODUCT;
```

If you have made *all* of the updates shown in this section using Oracle, your PRODUCT table should look like [Figure 7.15](#). Make sure that you issue a COMMIT statement to save these changes.

FIGURE 7.15 The cumulative effect of the multiple updates in the PRODUCT table (Oracle)

The screenshot shows a Windows application window titled "SQL*PLUS". Inside, a SQL command is being run:

```
SQL> SELECT P_CODE, P_DESCRIP, P_INDATE, P_PRICE, P_SALECODE FROM PRODUCT;
```

The results are displayed in a tabular format:

P_CODE	P_DESCRIP	P_INDATE	P_PRICE	P_SALECODE
11QER/31	Power painter, 15 psi., 3-nozzle	03-NOV-11	109.99	2
13-Q2/P2	7.25-in. pwr. saw blade	13-DEC-11	14.99	2
14-Q1/L3	9.00-in. pwr. saw blade	13-NOV-11	17.49	2
1546-QQ2	Hrd. cloth, 1/4-in., 2x50	15-JAN-12	39.95	2
1558-QW1	Hrd. cloth, 1/2-in., 3x50	15-JAN-12	43.99	
2232-QTY	B\&D jigsaw, 12-in. blade	30-DEC-11	109.92	1
2232-QWE	B\&D jigsaw, 8-in. blade	24-DEC-11	99.87	2
2238-QPD	B\&D cordless drill, 1/2-in.	20-JAN-12	38.95	1
23109-HB	Claw hammer	20-JAN-12	9.95	1
23114-AA	Sledge hammer, 12 lb.	02-JAN-12	14.4	
54778-2T	Rat-tail file, 1/8-in. fine	15-DEC-11	4.99	2
89-WRE-Q	Hicut chain saw, 16 in.	07-FEB-12	256.99	1
PUC23DRT	PUC pipe, 3.5-in., 8-ft	20-FEB-12	5.87	
SM-18277	1.25-in. metal screw, 25	01-MAR-12	6.99	
SW-23116	2.5-in. wd. screw, 50	24-FEB-12	8.45	
WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	17-JAN-12	119.95	1

16 rows selected.

SQL>

SOURCE: Course Technology/Cengage Learning

The arithmetic operators are particularly useful in data updates. For example, if the quantity on hand in your PRODUCT table has dropped below the minimum desirable value, you will order more of the product. Suppose, for example, that you have ordered 20 units of product 2232/QWE. When the 20 units arrive, you will want to add them to inventory using the following commands:

UPDATE PRODUCT

```
SET      P_QOH = P_QOH + 20
WHERE   P_CODE = '2232/QWE';
```

If you want to add 10 percent to the price for all products that have current prices below \$50, you can use:

UPDATE PRODUCT

```
SET      P_PRICE = P_PRICE * 1.10
WHERE   P_PRICE < 50.00;
```

If you are using Oracle, issue a ROLLBACK command to undo the changes made by the last two UPDATE statements.

NOTE

If you fail to roll back the changes of the preceding UPDATE queries, the output of the subsequent queries will not match the results shown in the figures. Therefore:

- If you are using Oracle, use the ROLLBACK command to restore the database to its previous state.
 - If you are using Access, copy the original **Ch07_SaleCo.mdb** file from www.cengagebrain.com.
-
-

7.5.6 COPYING PARTS OF TABLES

As you will discover in later chapters on database design, sometimes it is necessary to break up a table structure into several component parts (or smaller tables). Fortunately, SQL allows you to copy the contents of selected table columns so that the data need not be reentered manually into the newly created table(s). For example, if you want to copy P_CODE, P_DESCRIP, P_PRICE, and V_CODE from the PRODUCT table to a new table named PART, you create the PART table structure first, as follows:

```
CREATE TABLE PART(  
    PART_CODE      CHAR(8),  
    PART_DESCRIP  CHAR(35),  
    PART_PRICE     DECIMAL(8,2),  
    V_CODE         INTEGER,  
    PRIMARY KEY (PART_CODE));
```

Note that the PART column names need not be identical to those of the original table and that the new table need not have the same number of columns as the original table. In this case, the first column in the PART table is PART_CODE, rather than the original P_CODE in the PRODUCT table. Also, the PART table

contains only four columns rather than the eight columns in the PRODUCT table. However, column characteristics must match; you cannot copy a character-based attribute into a numeric structure, and vice versa.

Next, you need to add the rows to the PRODUCT table rows and the INSERT command you learned in [Section 7.3.7](#). The syntax is:

```
INSERT INTO target tablename[(target columnlist)]  
SELECT      source columnlist  
FROM        source tablename;
```

Note that the target column list is required if the source column list does not match all of the attribute names and characteristics of the target table (including the order of the columns). Otherwise, you do not need to specify the target column list. In this example, you must specify the target column list in the following INSERT command because the column names of the target table are different:

```
INSERT INTO      (PART_CODE, PART_DESCRIP, PART_PRICE,  
PART                V_CODE)  
SELECT      P_CODE, P_DESCRIP, P_PRICE, V_CODE FROM  
PRODUCT;
```

FIGURE 7.16 PART table attributes copied from the PRODUCT table

PART_CODE	PART_DESCRPT	PART_PRICE	V_CODE
11QER/31	Power painter, 15 psi., 3-nozzle	109.99	25595
13-Q2/P2	7.25-in. pwr. saw blade	14.99	21344
14-Q1/L3	9.00-in. pwr. saw blade	17.49	21344
1546-QQ2	Hrd. cloth, 1/4-in., 2x50	39.95	23119
1558-QW1	Hrd. cloth, 1/2-in., 3x50	43.99	23119
2232/QTY	B&D jigsaw, 12-in. blade	109.92	24288
2232/QWE	B&D jigsaw, 8-in. blade	99.87	24288
2238/QPD	B&D cordless drill, 1/2-in.	38.95	25595
23109-HB	Claw hammer	9.95	21225
23114-AA	Sledge hammer, 12 lb.	14.4	
54778-2T	Rat-tail file, 1/8-in. fine	4.99	21344
89-WRE-Q	Hicut chain saw, 16 in.	256.99	24288
PVC23DRT	PVC pipe, 3.5-in., 8-ft	5.87	
SM-18277	1.25-in. metal screw, 25	6.99	21225
SW-23116	2.5-in. wd. screw, 50	8.45	21231
WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	119.95	25595

SOURCE: Course Technology/Cengage Learning

The contents of the PART table can now be examined by using the following query to generate the new PART table's contents, shown in [Figure 7.16](#):

`SELECT * FROM PART;`

SQL provides another way to rapidly create a new table based on selected columns and rows of an existing table. In this case, the new table will copy the attribute names, data characteristics, and rows of the original table. The Oracle version of the command is:

CREATE TABLE PART AS

```
SELECT P_CODE AS PART_CODE, P_DESCRIP AS  
      PART_DESCRIP, P_PRICE AS PART_PRICE, V_CODE  
  FROM  PRODUCT;
```

If the PART table already exists, Oracle will not let you overwrite the existing table. To run this command, you must first delete the existing PART table. (See [Section 7.5.8.](#))

The MS Access version of this command is:

```
SELECT P_CODE AS PART_CODE, P_DESCRIP AS PART_DESCRIP,  
      P_PRICE AS PART_PRICE,  
      V_CODE INTO PART  
  FROM  PRODUCT;
```

If the PART table already exists, MS Access will ask if you want to delete the existing table and continue with the creation of the new PART table.

The SQL command just shown creates a new PART table with PART_CODE, PART_DESCRIP, PART_PRICE, and V_CODE columns. In addition, all of the data rows for the selected columns will be copied automatically. *However, note that no entity integrity (primary key) or referential integrity (foreign key) rules are automatically applied to the new table.* In the next section, you will learn how to define the PK to enforce entity integrity and the FK to enforce referential integrity.

7.5.7 ADDING PRIMARY AND FOREIGN KEY DESIGNATIONS

When you create a new table based on another table, the new table does not include integrity rules from the old table. In particular, there is no primary key. To define the primary key for the new PART table, use the following command:

```
ALTER TABLE PART  
ADD      PRIMARY KEY (PART_CODE);
```

Several other scenarios could leave you without entity and referential integrity.

For example, you might have forgotten to define the primary and foreign keys when you created the original tables. Or, if you imported tables from a different database, you might have discovered that the importing procedure did not transfer the integrity rules. In any case, you can reestablish the integrity rules by using the ALTER command. For example, if the PART table's foreign key has not yet been designated, it can be designated by:

```
ALTER TABLE PART  
ADD FOREIGN KEY (V_CODE) REFERENCES VENDOR;
```

Alternatively, if neither the PART table's primary key nor its foreign key has been designated, you can incorporate both changes at once:

```
ALTER TABLE PART  
ADD PRIMARY KEY (PART_CODE)  
ADD FOREIGN KEY (V_CODE) REFERENCES VENDOR;
```

Even composite primary keys and multiple foreign keys can be designated in a single SQL command. For example, if you want to enforce the integrity rules for the LINE table shown in [Figure 7.1](#), you can use:

```
ALTER TABLE LINE  
ADD PRIMARY KEY (INV_NUMBER, LINE_NUMBER)  
ADD FOREIGN KEY (INV_NUMBER) REFERENCES INVOICE  
ADD FOREIGN KEY (P_CODE) REFERENCES PRODUCT;
```

7.5.8 DELETING A TABLE FROM THE DATABASE

A table can be deleted from the database using the **DROP TABLE** command. For example, you can delete the PART table you just created with the following command:

```
DROP TABLE PART;
```

You can drop a table only if it is not the “one” side of any relationship. If you try to drop a table otherwise, the RDBMS will generate an error message indicating that a foreign key integrity violation has occurred.

7.6 ADDITIONAL SELECT QUERY KEYWORDS

One of the most important advantages of SQL is its ability to produce complex free-form queries. The logical operators that were introduced earlier to update table contents work just as well in the query environment. In addition, SQL provides useful functions that count, find minimum and maximum values, calculate averages, and so on. Better yet, SQL allows the user to limit queries to only those entries that have no duplicates or entries whose duplicates can be grouped.

7.6.1 ORDERING A LISTING

The **ORDER BY** clause is especially useful when the listing order is important to you. The syntax is:

```
SELECT      columnlist
FROM        tablelist
[WHERE      conditionlist ]
[ORDER BY columnlist [ASC | DESC] ] ;
```

Although you have the option of declaring the order type—ascending or descending—the default order is ascending. For example, if you want the contents of the PRODUCT table to be listed by P_PRICE in ascending order, use the following commands:

```
SELECT      P_CODE, P_DESCRIP, P_INDATE, P_PRICE
FROM        PRODUCT
ORDER BY P_PRICE;
```

The output is shown in [Figure 7.17](#). Note that ORDER BY yields an ascending price listing.

Comparing the listing in [Figure 7.17](#) to the actual table contents shown earlier in [Figure 7.2](#), you will see that the lowest-priced product is listed first in [Figure 7.17](#), followed by the next lowest-priced product, and so on. However, although ORDER BY produces a sorted output, the actual table contents are unaffected by the ORDER BY command.

FIGURE 7.17 Selected PRODUCT table attributes: ordered by ascending P_PRICE

P_CODE	P_DESCRIP	P_INDATE	P_PRICE
54778-2T	Rat-tail file, 1/8-in. fine	15-Dec-11	4.99
PVC23DRT	PVC pipe, 3.5-in., 8-ft	20-Feb-12	5.87
SM-18277	1.25-in. metal screw, 25	01-Mar-12	6.99
SW-23116	2.5-in. wd. screw, 50	24-Feb-12	8.45
23109-HB	Claw hammer	20-Jan-12	9.95
23114-AA	Sledge hammer, 12 lb.	02-Jan-12	14.40
13-Q2/P2	7.25-in. pwr. saw blade	13-Dec-11	14.99
14-Q1/L3	9.00-in. pwr. saw blade	13-Nov-11	17.49
2238/QPD	B&D cordless drill, 1/2-in.	20-Jan-12	38.95
1546-QQ2	Hrd. cloth, 1/4-in., 2x50	15-Jan-12	39.95
1558-QW1	Hrd. cloth, 1/2-in., 3x50	15-Jan-12	43.99
2232/QWE	B&D jigsaw, 8-in. blade	24-Dec-11	99.87
2232/QTY	B&D jigsaw, 12-in. blade	30-Dec-11	109.92
11QER/31	Power painter, 15 psi., 3-nozzle	03-Nov-11	109.99
WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	17-Jan-12	119.95
89-WRE-Q	Hicut chain saw, 16 in.	07-Feb-12	256.99

SOURCE: Course Technology/Cengage Learning

To produce the list in descending order, you would enter:

```
SELECT    P_CODE, P_DESCRIP, P_INDATE, P_PRICE
FROM      PRODUCT
ORDER BY P_PRICE DESC;
```

Ordered listings are used frequently. For example, suppose that you want to create a phone directory. It would be helpful if you could produce an ordered sequence (last name, first name, initial) in three stages:

1. ORDER BY last name.

2. Within the last names, ORDER BY first name.
3. Within the first and last names, ORDER BY middle initial.

Such a multilevel ordered sequence is known as a **cascading order sequence**, and it can be created easily by listing several attributes, separated by commas, after the ORDER BY clause.

The cascading order sequence is the basis for any telephone directory. To illustrate a cascading order sequence, use the following SQL command on the

EMPLOYEE table:

```
SELECT EMP_LNAME, EMP_FNAME, EMP_INITIAL,  
       EMP_AREACODE, EMP_PHONE  
  FROM EMPLOYEE  
 ORDER BY EMP_LNAME, EMP_FNAME, EMP_INITIAL;
```

This command yields the results shown in [Figure 7.18](#).

FIGURE 7.18 Telephone list query results

EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_AREACODE	EMP_PHONE
Brandon	Marie	G	901	882-0845
Dianete	Jorge	D	615	890-4567
Genkazi	Leighla	W	901	569-0093
Johnson	Edward	E	615	898-4387
Jones	Anne	M	615	898-3456
Kolmycz	George	D	615	324-5456
Lange	John	P	901	504-4430
Lewis	Rhonda	G	615	324-4472
Saranda	Hermine	R	615	324-5505
Smith	George	A	615	890-2984
Smith	George	K	901	504-3339
Smith	Jeanine	K	615	324-7883
Smythe	Melanie	P	615	324-9006
Vandam	Rhett		901	675-8993
Washington	Rupert	E	615	890-4925
Wiesenbach	Paul	R	615	897-4358
Williams	Robert	D	615	890-3220

SOURCE: Course Technology/Cengage Learning

The ORDER BY clause is useful in many applications, especially because the DESC qualifier can be invoked. For example, listing the most recent items first is a standard procedure. Typically, invoice due dates are listed in descending order. Or, if you want to examine budgets, it is probably useful to list the largest budget line items first.

FIGURE 7.19 A query based on multiple restrictions

P_DESCRIPTOR	V_CODE	P_INDATE	P_PRICE
Sledge hammer, 12 lb.		02-Jan-12	14.40
Claw hammer	21225	20-Jan-12	9.95
9.00-in. pwr. saw blade	21344	13-Nov-11	17.49
7.25-in. pwr. saw blade	21344	13-Dec-11	14.99
Rat-tail file, 1/8-in. fine	21344	15-Dec-11	4.99
Hrd. cloth, 1/2-in., 3x50	23119	15-Jan-12	43.99
Hrd. cloth, 1/4-in., 2x50	23119	15-Jan-12	39.95
B&D cordless drill, 1/2-in.	25595	20-Jan-12	38.95

SOURCE: Course Technology/Cengage Learning

You can use the ORDER BY clause in conjunction with other SQL commands, too. For example, note the use of restrictions on date and price in the following command sequence:

```
SELECT P_DESCRIPTOR, V_CODE, P_INDATE, P_PRICE  
FROM PRODUCT  
WHERE P_INDATE < '21-Jan-2012'  
AND P_PRICE <= 50.00  
ORDER BY V_CODE, P_PRICE DESC;
```

The output is shown in [Figure 7.19](#). Note that within each V_CODE, the P_PRICE values are in descending order.

7.6.2 LISTING UNIQUE VALUES

How many *different* vendors are currently represented in the PRODUCT table? A simple listing (SELECT) is not very useful if the table contains several thousand rows and you have to sift through the vendor codes manually. Fortunately, SQL's **DISTINCT** clause produces a list of only those values that are different from one another. For example, the command:

```
SELECT DISTINCT V_CODE
```

```
FROM PRODUCT;
```

yields only the different vendor codes (V_CODE) in the PRODUCT table, as shown in [Figure 7.20](#). Note that the first output row shows the null. The placement of nulls does not affect the list contents. In Oracle, you could use ORDER BY V_CODE NULLS FIRST to place nulls at the top of the list.

7.6.3 AGGREGATE FUNCTIONS

SQL can perform various mathematical summaries for you, such as counting the number of rows that contain a specified condition, finding the minimum or maximum values for a specified attribute, summing the values in a specified column, and averaging the values in a specified column. Those aggregate functions are shown in [Table 7.8](#).

FIGURE 7.20 A listing of distinct V_CODE values in the PRODUCT table

V_CODE
21225
21231
21344
23119
24288
25595

SOURCE: Course Technology/Cengage Learning

NOTE

If the ordering column has nulls, they are listed either first or last, depending on the RDBMS. The ORDER BY clause must always be listed last in the SELECT command sequence.

TABLE 7.8 Some Basic SQL Aggregate Functions

FUNCTION OUTPUT

COUNT The number of rows containing non-null values

MIN The minimum attribute value encountered in a given column

MAX The maximum attribute value encountered in a given column

SUM The sum of all values for a given column

AVG The arithmetic mean (average) for a specified column

To illustrate another standard SQL command format, most of the remaining input and output sequences are presented using the Oracle RDBMS.

COUNT

The **COUNT** function is used to tally the number of non-null values of an attribute. COUNT can be used in conjunction with the DISTINCT clause. For example, suppose that you want to find out how many different vendors are in the PRODUCT table. The answer, generated by the first SQL code set shown in [Figure 7.21](#), is 6. Note that the nulls are not counted as V_CODE values.

FIGURE 7.21 COUNT function output examples

The screenshot shows a window titled "SQL Plus" with three distinct SQL queries entered and their results displayed:

```
SQL> SELECT COUNT(DISTINCT V_CODE)
  2  FROM PRODUCT;
COUNT(DISTINCTV_CODE)
-----
6

SQL> SELECT COUNT(DISTINCT V_CODE)
  2  FROM PRODUCT
  3  WHERE P_PRICE <= 10.00;
COUNT(DISTINCTV_CODE)
-----
3

SQL> SELECT COUNT(*)
  2  FROM PRODUCT
  3  WHERE P_PRICE <= 10.00;
COUNT(*)
-----
5
```

SOURCE: Course Technology/Cengage Learning

The aggregate functions can be combined with the SQL commands explored earlier. For example, the second SQL command set in [Figure 7.21](#) supplies the answer to the question, “How many vendors referenced in the PRODUCT table have supplied products with prices that are less than or equal to \$10?” The answer is that three vendors’ products meet the price specification.

The COUNT aggregate function uses one parameter within parentheses, generally a column name such as COUNT(V_CODE) or COUNT(P_CODE). The parameter may also be an expression such as COUNT(DISTINCT V_CODE) or COUNT(P_PRICE+10). Using that syntax, COUNT always returns the number of non-null values in the given column. (Whether the column values are computed or show stored table row values is immaterial.) In contrast, the syntax COUNT(*) returns the number of total rows from the query, including the rows that contain nulls. In the example in [Figure 7.21](#), SELECT COUNT(P_CODE) FROM PRODUCT and SELECT COUNT(*) FROM PRODUCT will yield the same answer because there are no null values in the P_CODE primary key column.

Note that the third SQL command set in [Figure 7.21](#) uses the COUNT(*) command to answer the question, “How many rows in the PRODUCT table have a P_PRICE value less than or equal to \$10?” The answer indicates that five products have a listed price that meets the specification. The COUNT(*) aggregate function is used to count rows in a query result set. In contrast, the COUNT(*column*) aggregate function counts the number of non-null values in a given column. For example, in [Figure 7.20](#), the COUNT(*) function would return a value of 7 to indicate seven rows returned by the query. The COUNT(V_CODE) function would return a value of 6 to indicate the six non-null vendor code values.

NOTE

Note to MS Access Users

MS Access does not support the use of COUNT with the DISTINCT clause. If you want to use such queries in MS Access, you must create subqueries with DISTINCT and NOT NULL clauses. For example, the equivalent MS Access queries for the first two queries shown in [Figure 7.21](#) are:

```
SELECT COUNT(*)
FROM (SELECT DISTINCT V_CODE FROM PRODUCT WHERE V_CODE IS NOT NULL)
and
SELECT COUNT(*)
FROM (SELECT DISTINCT(V_CODE)
      FROM (SELECT V_CODE, P_PRICE FROM PRODUCT
            WHERE V_CODE IS NOT NULL AND P_PRICE<10))
```

The two queries are available at www.cengagebrain.com in the **Ch07_SaleCo** (Access) database. MS Access does add a trailer at the end of the query after you have executed it, but you can delete that trailer the next time you use the query.

MAX and MIN

The **MAX** and **MIN** functions help you find answers to problems such as the highest and lowest (maximum and minimum) prices in the PRODUCT table. The highest price, \$256.99, is supplied by the first SQL command set in [Figure 7.22](#). The second SQL command set shown in [Figure 7.22](#) yields the minimum

price of \$4.99.

The third SQL command set in [Figure 7.22](#) demonstrates that the numeric functions can be used in conjunction with more complex queries. However, you must remember that *the numeric functions yield only one value* based on all the values found in the table: a single maximum value, a single minimum value, a single count, or a single average value. *It is easy to overlook this warning.* For example, examine the question, “Which product has the highest price?”

Although that query seems simple enough, the SQL command sequence:

```
SELECT P_CODE, P_DESCRIP, P_PRICE  
FROM PRODUCT  
WHERE P_PRICE = MAX(P_PRICE);
```

does not yield the expected results because the use of MAX(P_PRICE) on the right side of a comparison operator is incorrect, thus producing an error message. The aggregate function MAX(*columnname*) can be used only in the column list of a SELECT statement. Also, in a comparison that uses an equality symbol, you can use only a single value to the right of the equals sign.

To answer the question, therefore, you must compute the maximum price first, then compare it to each price returned by the query. To do that, you need a nested query. In this case, the nested query is composed of two parts:

- The *inner query*, which is executed first.
- The *outer query*, which is executed last. (Remember that the outer query is always the first SQL command you encounter—in this case, SELECT.)

Using the following command sequence as an example, note that the inner query first finds the maximum price value, which is stored in memory. Because the outer query now has a value to which to compare each P_PRICE value, the query executes properly.

```
SELECT P_CODE, P_DESCRIP, P_PRICE  
FROM PRODUCT  
WHERE P_PRICE = (SELECT MAX(P_PRICE) FROM PRODUCT);
```

The execution of the nested query yields the correct answer, shown below the third (nested) SQL command set in [Figure 7.22](#).

FIGURE 7.22 MAX and MIN function output examples

```
SQL> SELECT MAX(P_PRICE)
  2  FROM PRODUCT;
MAX(P_PRICE)
-----
      256.99

SQL> SELECT MIN(P_PRICE)
  2  FROM PRODUCT;
MIN(P_PRICE)
-----
      4.99

SQL> SELECT P_CODE, P_DESCRIP, P_PRICE
  2  FROM PRODUCT
  3  WHERE P_PRICE = (SELECT MAX(P_PRICE) FROM PRODUCT);
P_CODE      P_DESCRIP          P_PRICE
-----      -----
89-WRE-Q    Hicut chain saw, 16 in.        256.99

SQL>
```

SOURCE: Course Technology/Cengage Learning

The MAX and MIN aggregate functions can also be used with date columns. For example, to find out which product has the oldest date, you would use MIN(P_INDATE). In the same manner, to find out the most recent product, you would use MAX(P_INDATE).

NOTE

You can use expressions anywhere a column name is expected. Suppose that you want to know what product has the highest inventory value. To find the answer, you can write the following query:

```
SELECT *
FROM PRODUCT
WHERE P_QOH*P_PRICE = (SELECT MAX(P_QOH*P_PRICE) FROM
PRODUCT);
```

SUM

The **SUM** function computes the total sum for any specified attribute, using any condition(s) you have imposed. For example, if you want to compute the total amount owed by your customers, you could use the following command:

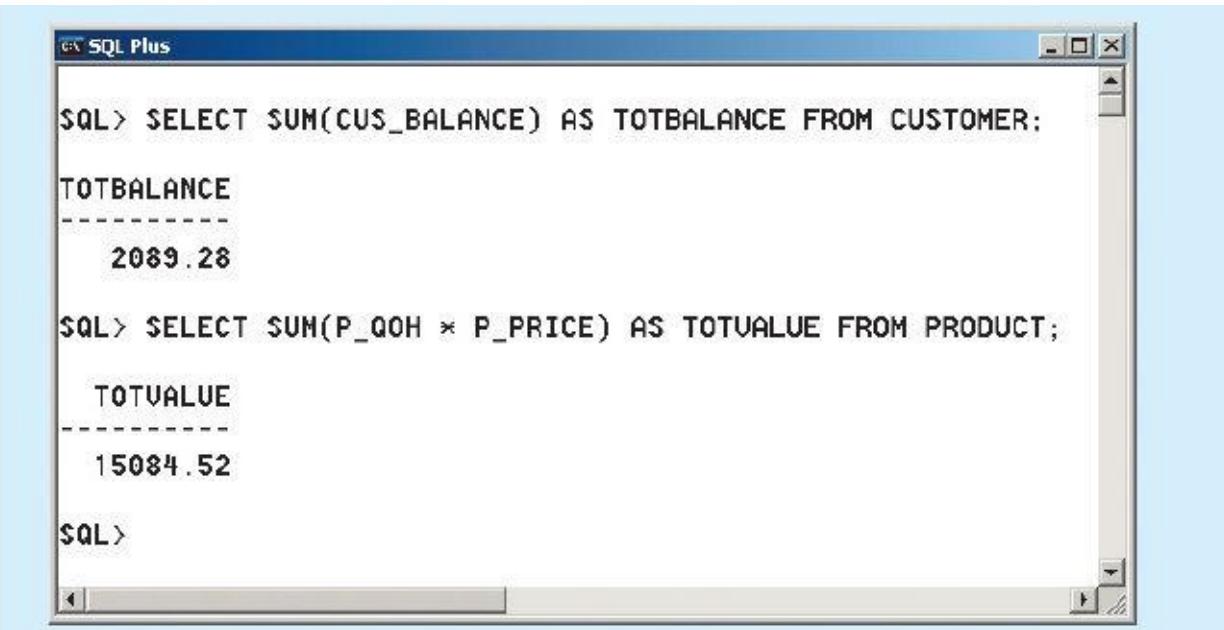
```
SELECT SUM(CUS_BALANCE) AS TOTBALANCE  
FROM CUSTOMER;
```

You could also compute the sum total of an expression. For example, if you want to find the total value of all items carried in inventory, you could use:

```
SELECT SUM(P_QOH * P_PRICE) AS TOTVALUE
```

The total value is the sum of the product of the quantity on hand and the price for all items. (See [Figure 7.23](#).)

FIGURE 7.23 The total value of all items in the PRODUCT table



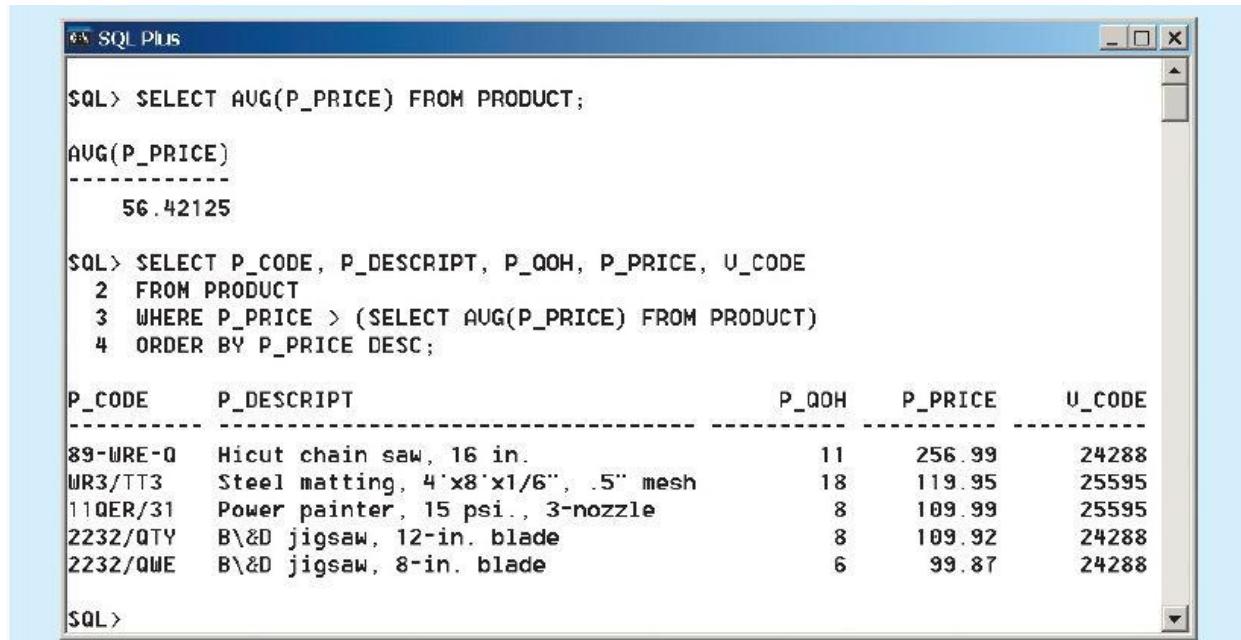
```
SQL> SELECT SUM(CUS_BALANCE) AS TOTBALANCE FROM CUSTOMER;  
TOTBALANCE  
-----  
2089.28  
  
SQL> SELECT SUM(P_QOH * P_PRICE) AS TOTVALUE FROM PRODUCT;  
TOTVALUE  
-----  
15084.52  
SQL>
```

SOURCE: Course Technology/Cengage Learning

AVG

The **AVG** function format is similar to those of MIN and MAX and is subject to the same operating restrictions. The first SQL command set in [Figure 7.24](#) shows how a simple average P_PRICE value can be generated to yield the computed average price of 56.42125. The second SQL command set in [Figure 7.24](#) produces five output lines that describe products whose prices exceed the average product price. Note that the second query uses nested SQL commands and the ORDER BY clause examined earlier.

FIGURE 7.24 AVG function output examples



```
SQL> SELECT AVG(P_PRICE) FROM PRODUCT;
          AVG(P_PRICE)
-----
      56.42125

SQL> SELECT P_CODE, P_DESCRIP, P_QOH, P_PRICE, U_CODE
  2  FROM PRODUCT
  3 WHERE P_PRICE > (SELECT AVG(P_PRICE) FROM PRODUCT)
  4 ORDER BY P_PRICE DESC;

P_CODE      P_DESCRIP          P_QOH    P_PRICE      U_CODE
-----  -----
89-WRE-Q    Hicut chain saw, 16 in.        11    256.99    24288
UR3/TT3     Steel matting, 4'x8'x1/6", .5" mesh   18    119.95    25595
11QER/31    Power painter, 15 psi., 3-nozzle       8    109.99    25595
2232/QTY    B&D jigsaw, 12-in. blade           8    109.92    24288
2232/QWE    B&D jigsaw, 8-in. blade            6     99.87    24288

SQL>
```

SOURCE: Course Technology/Cengage Learning

7.6.4 GROUPING DATA

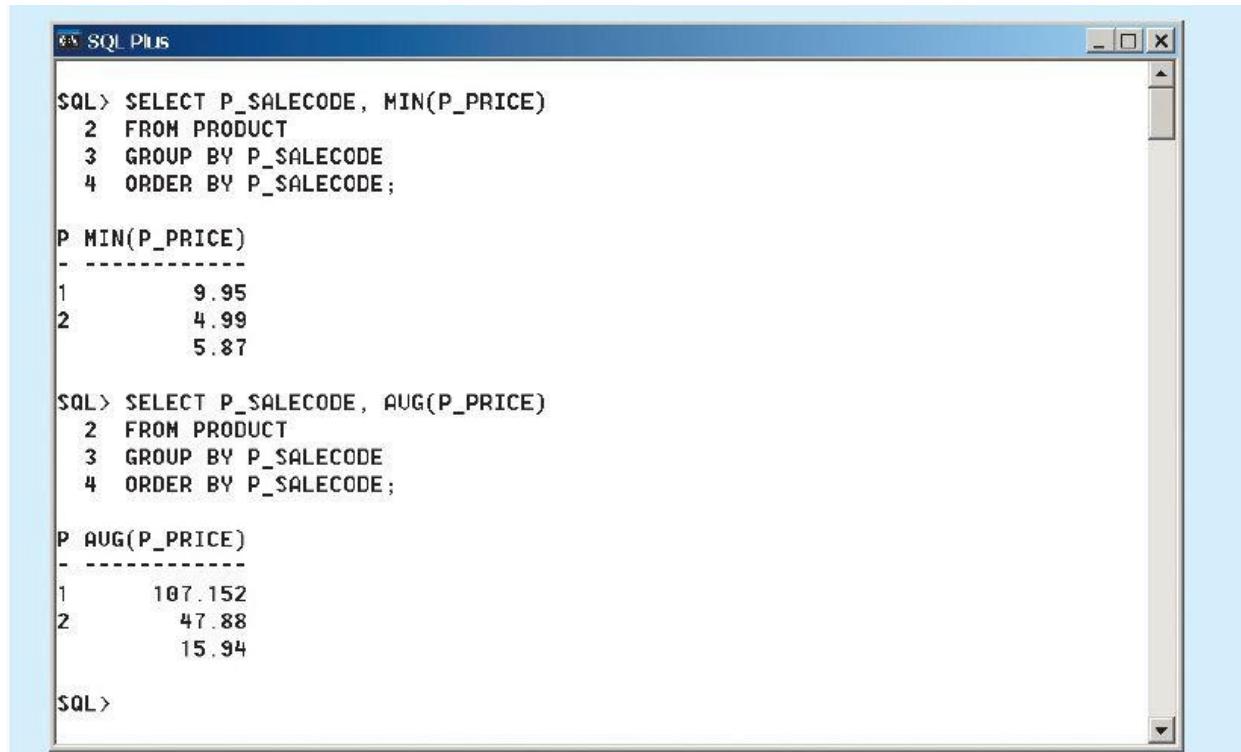
In the previous examples, the aggregate functions summarized data across all rows in the given tables. Sometimes, however, you do not want to treat the entire table as a single collection of data for summarizing. Rows can be grouped into smaller collections quickly and easily using the **GROUP BY** clause within the SELECT statement. The aggregate functions will then summarize the data within each smaller collection. The syntax is:

```
SELECT      columnlist
FROM        tablelist
[WHERE      conditionlist ]
[GROUP BY  columnlist ]
[HAVING    conditionlist ]
[ORDER BY  columnlist [ASC | DESC] ] ;
```

The GROUP BY clause is generally used when you have attribute columns combined with aggregate functions in the SELECT statement. For example, to determine the minimum price for each sales code, use the first SQL command set shown in [Figure 7.25](#).

The second SQL command set in [Figure 7.25](#) generates the average price within each sales code. Note that the P_SALECODE nulls are included within the grouping.

FIGURE 7.25 GROUP BY clause output examples



The screenshot shows an Oracle SQL Plus window with the title bar "SQL*Plus". Inside, two SQL queries are run against a "PRODUCT" table. The first query uses the MIN aggregate function to find the lowest price for each sales code. The second query uses the AVG aggregate function to find the average price for each sales code. Both queries include a GROUP BY clause on the P_SALECODE column and an ORDER BY clause on the same column.

```
SQL> SELECT P_SALECODE, MIN(P_PRICE)
  2  FROM PRODUCT
  3  GROUP BY P_SALECODE
  4  ORDER BY P_SALECODE;

P MIN(P_PRICE)
-----
1      9.95
2      4.99
      5.87

SQL> SELECT P_SALECODE, AVG(P_PRICE)
  2  FROM PRODUCT
  3  GROUP BY P_SALECODE
  4  ORDER BY P_SALECODE;

P AVG(P_PRICE)
-----
1     107.152
2      47.88
      15.94

SQL>
```

SOURCE: Course Technology/Cengage Learning

The GROUP BY clause is valid only when used in conjunction with one of the SQL aggregate functions, such as COUNT, MIN, MAX, AVG, and SUM. For example, as shown in the first command set in [Figure 7.26](#), if you try to group the output by using:

```
SELECT    V_CODE, P_CODE, P_DESCRIPT, P_PRICE  
FROM      PRODUCT  
GROUP BY V_CODE;
```

you generate a “not a GROUP BY expression” error. However, if you write the preceding SQL command sequence in conjunction with an aggregate function, the GROUP BY clause works properly. The second SQL command sequence in [Figure 7.26](#) properly answers the question, “How many products are supplied by each vendor?” because it uses a COUNT aggregate function.

Note that the last output line in [Figure 7.26](#) shows a null for the V_CODE, indicating that two products were not supplied by a vendor. Perhaps those products were produced in-house, or they might have been bought without the use of a vendor, or the person who entered the data might have merely forgotten to enter a vendor code. (Remember that nulls can be the result of many things.)

FIGURE 7.26 Incorrect and correct use of the GROUP BY clause

```
SQL> SELECT U_CODE, P_CODE, P_DESCRIPT, P_PRICE
  2  FROM PRODUCT
  3  GROUP BY U_CODE;
SELECT U_CODE, P_CODE, P_DESCRIPT, P_PRICE
*
ERROR at line 1:
ORA-00979: not a GROUP BY expression

SQL> SELECT U_CODE, COUNT(DISTINCT P_CODE)
  2  FROM PRODUCT
  3  GROUP BY U_CODE;

  U_CODE COUNT(DISTINCTP_CODE)
  -----
    21225                  2
    21231                  1
    21344                  3
    23119                  2
    24288                  3
    25595                  3
                           2

7 rows selected.

SQL>
```

SOURCE: Course Technology/Cengage Learning

NOTE

When using the GROUP BY clause with a SELECT statement:

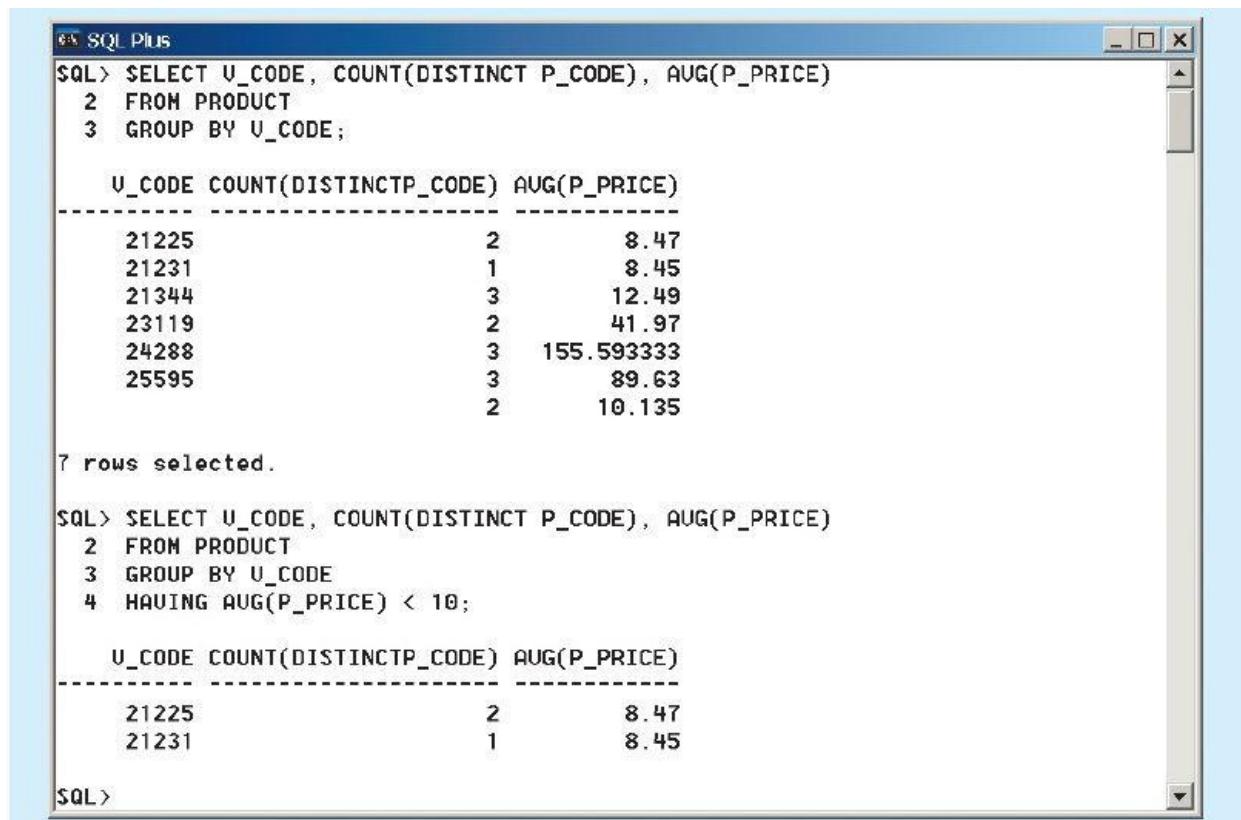
- The SELECT's *columnlist* must include a combination of column names and aggregate functions.
 - The GROUP BY clause's *columnlist* must include all nonaggregate function columns specified in the SELECT's *columnlist*. If required, you could also group by any aggregate function columns that appear in the SELECT's *columnlist*.
 - The GROUP BY clause *columnlist* can include any columns from the tables in the FROM clause of the SELECT statement, even if they do not appear in the SELECT's *columnlist*.
-

The GROUP BY Feature's HAVING Clause

A particularly useful extension of the GROUP BY feature is the **HAVING** clause. The HAVING clause operates very much like the WHERE clause in the SELECT statement. However, the WHERE clause applies to columns and expressions for individual rows, while the HAVING clause is applied to the output of a GROUP BY operation. For example, suppose that you want to generate a listing of the number of products in the inventory supplied by each vendor. However, this time you want to limit the listing to products whose prices average less than \$10. The first part of that requirement is satisfied with the help of the GROUP BY clause, as illustrated in the first SQL command set in [Figure 7.27](#). Note that the HAVING clause is used in conjunction with the GROUP BY clause in the second SQL command set in [Figure 7.27](#) to generate the desired result.

If you use the WHERE clause instead of the HAVING clause, the second SQL command set in [Figure 7.27](#) will produce an error message.

FIGURE 7.27 An application of the HAVING clause



```
SQL> SELECT U_CODE, COUNT(DISTINCT P_CODE), AVG(P_PRICE)
  2  FROM PRODUCT
  3  GROUP BY U_CODE;

U_CODE COUNT(DISTINCTP_CODE) AVG(P_PRICE)
-----
21225              2      8.47
21231              1      8.45
21344              3     12.49
23119              2     41.97
24288              3   155.593333
25595              3     89.63
                    2     10.135

7 rows selected.

SQL> SELECT U_CODE, COUNT(DISTINCT P_CODE), AVG(P_PRICE)
  2  FROM PRODUCT
  3  GROUP BY U_CODE
  4  HAVING AVG(P_PRICE) < 10;

U_CODE COUNT(DISTINCTP_CODE) AVG(P_PRICE)
-----
21225              2      8.47
21231              1      8.45

SQL>
```

You can also combine multiple clauses and aggregate functions. For example, consider the following SQL statement:

```
SELECT    V_CODE, SUM(P_QOH * P_PRICE) AS TOTCOST  
FROM      PRODUCT  
GROUP BY V_CODE  
HAVING   (SUM(P_QOH * P_PRICE) > 500)  
ORDER BY SUM(P_QOH * P_PRICE) DESC;
```

This statement will do the following:

- Aggregate the total cost of products grouped by V_CODE.
- Select only the rows with totals that exceed \$500.
- List the results in descending order by the total cost.

Note the syntax used in the HAVING and ORDER BY clauses; in both cases, you must specify the column expression (formula) used in the SELECT statement's column list, rather than the column alias (TOTCOST). Some RDBMSs allow you to replace the column expression with the column alias, while others do not.

7.7 JOINING DATABASE TABLES

The ability to combine, or join, tables on common attributes is perhaps the most important distinction between a relational database and other databases. A join is performed when data are retrieved from more than one table at a time. If necessary, review the join definitions and examples in [Chapter 3](#), The Relational Database Model.

To join tables, you simply list the tables in the FROM clause of the SELECT statement. The DBMS will create the Cartesian product of every table in the FROM clause. However, to get the correct result—that is, a natural join—you must select only the rows in which the common attribute values match. To do this, use the WHERE clause to indicate the common attributes used to link the tables; this WHERE clause is sometimes referred to as the join condition.

The join condition is generally composed of an equality comparison between the foreign key and the primary key of related tables. For example, suppose that you want to join the two tables VENDOR and PRODUCT. Because V_CODE is the foreign key in the PRODUCT table and the primary key in the VENDOR table, the link is established on V_CODE. (See [Table 7.9](#).)

TABLE 7.9 Creating Links Through Foreign Keys

TABLE	ATTRIBUTES TO BE SHOWN	LINKING ATTRIBUTE
PRODUCT	P_DESCRIPTOR, P_PRICE	V_CODE
VENDOR	V_NAME, V_CONTACT, V_AREACODE, V_PHONE	V_CODE

When the same attribute name appears in more than one of the joined tables, the source table of the attributes listed in the SELECT command sequence must be defined. To join the PRODUCT and VENDOR tables, you would use the following, which produces the output shown in [Figure 7.28](#):

```
SELECT P_DESCRIPTOR, P_PRICE, V_NAME, V_CONTACT,  
      V_AREACODE, V_PHONE  
FROM   PRODUCT, VENDOR  
WHERE  PRODUCT.V_CODE = VENDOR.V_CODE;
```

FIGURE 7.28 The results of a join

P_DESCRIPTOR	P_PRICE	V_NAME	V_CONTACT	V_AREACODE	V_PHONE
Claw hammer	9.95	Bryson, Inc.	Smithson	615	223-3234
1.25-in. metal screw, 25	6.99	Bryson, Inc.	Smithson	615	223-3234
2.5-in. wd. screw, 50	8.45	D&E Supply	Singh	615	228-3245
7.25-in. pwr. saw blade	14.99	Gomez Bros.	Ortega	615	889-2546
9.00-in. pwr. saw blade	17.49	Gomez Bros.	Ortega	615	889-2546
Rat-tail file, 1/8-in. fine	4.99	Gomez Bros.	Ortega	615	889-2546
Hrd. cloth, 1/4-in., 2x50	39.95	Randses Ltd.	Anderson	901	678-3998
Hrd. cloth, 1/2-in., 3x50	43.99	Randses Ltd.	Anderson	901	678-3998
B&D jigsaw, 12-in. blade	109.92	ORDVA, Inc.	Hakford	615	898-1234
B&D jigsaw, 8-in. blade	99.87	ORDVA, Inc.	Hakford	615	898-1234
Hicut chain saw, 16 in.	256.99	ORDVA, Inc.	Hakford	615	898-1234
Power painter, 15 psi., 3-nozzle	109.99	Rubicon Systems	Orton	904	456-0092
B&D cordless drill, 1/2-in.	38.95	Rubicon Systems	Orton	904	456-0092
Steel matting, 4'x8'x1/8", .5" mesh	119.95	Rubicon Systems	Orton	904	456-0092

SOURCE: Course Technology/Cengage Learning

Your output might be presented in a different order because the SQL command produces a listing in which the order of the rows is not relevant. In fact, you are likely to get a different order of the same listing the next time you execute the command. However, you can generate a more predictable list by using an ORDER BY clause:

```
SELECT PRODUCT.P_DESCRIPTOR, PRODUCT.P_PRICE,
       VENDOR.V_NAME, VENDOR.V_CONTACT,
       VENDOR.V_AREACODE, VENDOR.V_PHONE
  FROM PRODUCT, VENDOR
 WHERE PRODUCT.V_CODE = VENDOR.V_CODE
 ORDER BY PRODUCT.P_PRICE;
```

In this case, your listing will always be arranged from the lowest price to the highest price.

NOTE

Table names were used as prefixes in the preceding SQL command sequence. For example, PRODUCT.P_PRICE was used rather than P_PRICE. Most current-generation RDBMSs do not require table names to be used as prefixes unless the same attribute name occurs in several of the

tables being joined. In the previous case, V_CODE is used as a foreign key in PRODUCT and as a primary key in VENDOR; therefore, you must use the table names as prefixes in the WHERE clause. In other words, you can write the previous query as:

```
SELECT P_DESCRPT, P_PRICE, V_NAME, V_CONTACT,  
V_AREACODE, V_PHONE  
FROM PRODUCT, VENDOR WHERE PRODUCT.V_CODE =  
VENDOR.V_CODE ORDER BY P_PRICE;
```

Naturally, if an attribute name occurs in several places, its origin (table) must be specified. If you fail to provide such a specification, SQL will generate an error message to indicate that you have been ambiguous about the attribute's origin.

The preceding SQL command sequence joins a row in the PRODUCT table with a row in the VENDOR table, in which the V_CODE values of these rows are the same, as indicated in the WHERE clause's condition. Because any vendor can deliver any number of ordered products, the PRODUCT table might contain multiple V_CODE entries for each V_CODE entry in the VENDOR table. In other words, each V_CODE in VENDOR can be matched with many V_CODE rows in PRODUCT.

If you do not specify the WHERE clause, the result will be the Cartesian product of PRODUCT and VENDOR. Because the PRODUCT table contains 16 rows and the VENDOR table contains 11 rows, the Cartesian product will yield a listing of $(16 \times 11) = 176$ rows. (Each row in PRODUCT will be joined to each row in the VENDOR table.)

All of the SQL commands can be used on the joined tables. For example, the following command sequence is quite acceptable in SQL and produces the output shown in [Figure 7.29](#):

```
SELECT P_DESCRPT, P_PRICE, V_NAME, V_CONTACT,  
V_AREACODE, V_PHONE  
FROM PRODUCT, VENDOR  
WHERE PRODUCT.V_CODE = VENDOR.V_CODE  
AND P_INDATE > '15-Jan-2012';
```

FIGURE 7.29 An ordered and limited listing after a join

P_DESCRIPTOR	P_PRICE	V_NAME	V_CONTACT	V_AREACODE	V_PHONE
1.25-in. metal screw, 25	6.99	Bryson, Inc.	Smithson	615	223-3234
2.5-in. wd. screw, 50	8.45	D&E Supply	Singh	615	228-3245
Claw hammer	9.95	Bryson, Inc.	Smithson	615	223-3234
B&D cordless drill, 1/2-in.	38.95	Rubicon Systems	Orton	904	456-0092
Steel matting, 4'x8'x1/6", .5" mesh	119.95	Rubicon Systems	Orton	904	456-0092
Hicut chain saw, 16 in.	256.99	ORDVA, Inc.	Hakford	615	898-1234

SOURCE: Course Technology/Cengage Learning

When joining three or more tables, you need to specify a join condition for each pair of tables. The number of join conditions will always be $n-1$, where n represents the number of tables listed in the FROM clause. For example, if you have three tables, you must have two join conditions; if you have five tables, you must have four join conditions; and so on.

Remember, the join condition will match the foreign key of a table to the primary key of the related table. For example, using [Figure 7.1](#), if you want to list the customer last name, invoice number, invoice date, and product descriptions for all invoices for customer 10014, you must type the following:

```
SELECT CUS_LNAME, INVOICE.INV_NUMBER, INV_DATE,  
      P_DESCRIPTOR  
  FROM CUSTOMER, INVOICE, LINE, PRODUCT  
 WHERE CUSTOMER.CUS_CODE = INVOICE.CUS_CODE  
   AND INVOICE.INV_NUMBER = LINE.INV_NUMBER  
   AND LINE.P_CODE = PRODUCT.P_CODE  
   AND CUSTOMER.CUS_CODE = 10014  
 ORDER BY INV_NUMBER;
```

Finally, be careful not to create circular join conditions. For example, if Table A is related to Table B, Table B is related to Table C, and Table C is also related to Table A, create only two join conditions: join A with B and B with C. Do not join C with A!

7.7.1 JOINING TABLES WITH AN ALIAS

An alias may be used to identify the source table from which the data are taken. The aliases P and V are used to label the PRODUCT and VENDOR tables in the next command sequence. Any legal table name may be used as an alias. (Also notice that there are no table name prefixes because the attribute listing contains no duplicate names in the SELECT statement.)

```
SELECT P_DESCRIP, P_PRICE, V_NAME, V_CONTACT,  
      V_AREACODE, V_PHONE  
FROM   PRODUCT P, VENDOR V  
WHERE  P.V_CODE = V.V_CODE  
ORDER  BY P_PRICE;
```

7.7.2 RECURSIVE JOINS

An alias is especially useful when a table must be joined to itself in a [recursive query](#). For example, suppose that you are working with the EMP table shown in [Figure 7.30](#).

FIGURE 7.30 The contents of the EMP table

EMP_NUM	EMP_TITLE	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_DOB	EMP_HIRE_DATE	EMP_AREACODE	EMP_PHONE	EMP_MGR
100	Mr.	Kolmycz	George	D	15-Jun-42	15-Mar-85	615	324-5456	
101	Ms.	Lewis	Rhonda	G	19-Mar-65	25-Apr-86	615	324-4472	100
102	Mr.	Vandam	Rhett		14-Nov-58	20-Dec-90	901	675-8993	100
103	Ms.	Jones	Anne	M	16-Oct-74	28-Aug-94	615	898-3456	100
104	Mr.	Lange	John	P	08-Nov-71	20-Oct-94	901	504-4430	105
105	Mr.	Williams	Robert	D	14-Mar-75	08-Nov-98	615	890-3220	
106	Mrs.	Smith	Jeanine	K	12-Feb-68	05-Jan-89	615	324-7883	105
107	Mr.	Diantre	Jorge	D	21-Aug-74	02-Jul-94	615	890-4567	105
108	Mr.	Wiesenbach	Paul	R	14-Feb-66	18-Nov-92	615	897-4358	
109	Mr.	Smith	George	K	18-Jun-61	14-Apr-89	901	504-3339	108
110	Mrs.	Genkazi	Leighla	W	19-May-70	01-Dec-90	901	569-0093	108
111	Mr.	Washington	Rupert	E	03-Jan-66	21-Jun-93	615	890-4925	105
112	Mr.	Johnson	Edward	E	14-May-61	01-Dec-83	615	898-4387	100
113	Ms.	Smythe	Melanie	P	15-Sep-70	11-May-99	615	324-9006	105
114	Ms.	Brandon	Marie	G	02-Nov-56	15-Nov-79	901	882-0845	108
115	Mrs.	Saranda	Hermine	R	25-Jul-72	23-Apr-93	615	324-5505	105
116	Mr.	Smith	George	A	08-Nov-65	10-Dec-88	615	890-2984	108

SOURCE: Course Technology/Cengage Learning

Using the data in the EMP table, you can generate a list of all employees with

their managers' names by joining the EMP table to itself. In that case, you would also use aliases to differentiate the table from itself. The SQL command sequence would look like this:

```
SELECT      E.EMP_MGR, M.EMP_LNAME, E.EMP_NUM,  
           E.EMP_LNAME  
FROM        EMP E, EMP M  
WHERE       E.EMP_MGR=M.EMP_NUM  
ORDER       E.EMP_MGR;  
BY
```

The output of the preceding command sequence is shown in [Figure 7.31](#).

FIGURE 7.31 Using an alias to join a table to itself

EMP_NUM	E.EMP_LNAME	EMP_MGR	M.EMP_LNAME
112	Johnson	100	Kolmycz
103	Jones	100	Kolmycz
102	Vandam	100	Kolmycz
101	Lewis	100	Kolmycz
115	Saranda	105	Williams
113	Smythe	105	Williams
111	Washington	105	Williams
107	Dante	105	Williams
106	Smith	105	Williams
104	Lange	105	Williams
116	Smith	108	Wiesenbach
114	Brandon	108	Wiesenbach
110	Genkazi	108	Wiesenbach
109	Smith	108	Wiesenbach

SOURCE: Course Technology/Cengage Learning

NOTE

In MS Access, you would add AS to the previous SQL command sequence. For example:

```
SELECT      E.EMP_MGR,M.EMP_LNAME,E.EMP_NUM,E.EMP_LNAME  
FROM        EMP AS E, EMP AS M  
WHERE       E.EMP_MGR = M.EMP_NUM  
ORDER BY    E.EMP_MGR;
```



ONLINE CONTENT

For a complete walk-through example of converting an ER model into a database structure and using SQL commands to create tables, see Appendix D, Converting the ER Model into a Database Structure, at www.cengagebrain.com.

SUMMARY

- SQL commands can be divided into two overall categories: data definition language (DDL) commands and data manipulation language (DML) commands.

- The ANSI standard data types are supported by all RDBMS vendors in different ways. The basic data types are NUMBER, INTEGER, CHAR, VARCHAR, and DATE.
- The basic data definition commands allow you to create tables and indexes. Many SQL constraints can be used with columns. The commands are CREATE TABLE, CREATE INDEX, ALTER TABLE, DROP TABLE, and DROP INDEX.

- DML commands allow you to add, modify, and delete rows from tables. The basic DML commands are SELECT, INSERT, UPDATE, DELETE, COMMIT, and ROLLBACK.
- The INSERT command is used to add new rows to tables. The UPDATE command is used to modify data values in existing rows of a table. The DELETE command is used to delete rows from tables. The COMMIT and ROLLBACK commands are used to permanently save or roll back changes made to the rows. Once you COMMIT the changes, you cannot undo them with a ROLLBACK command.
- The SELECT statement is the main data retrieval command in SQL. A SELECT statement has the following syntax:

```
SELECT      columnlist
FROM        tablelist
[WHERE      conditionlist ]
[GROUP BY   columnlist ]
[HAVING     conditionlist ]
[ORDER BY   columnlist [ASC | DESC] ] ;
```

- The column list represents one or more column names separated by commas. The column list may also include computed columns, aliases, and aggregate functions. A computed column is represented by an expression or formula (for example, P_PRICE * P_QOH). The FROM clause contains a list of table names.
- The WHERE clause can be used with the SELECT, UPDATE, and DELETE statements to restrict the rows affected by the DDL command. The condition list represents one or more conditional expressions separated by logical operators (AND, OR, and NOT). The conditional expression can contain any comparison operators (=, >, <, >=, <=, and <>) as well as special operators (BETWEEN, IS NULL, LIKE, IN, and EXISTS).
- Aggregate functions (COUNT, MIN, MAX, and AVG) are special functions that perform arithmetic computations over a set of rows. The aggregate functions are usually used in conjunction with the GROUP BY clause to

group the output of aggregate computations by one or more attributes. The HAVING clause is used to restrict the output of the GROUP BY clause by selecting only the aggregate rows that match a given condition.

- The ORDER BY clause is used to sort the output of a SELECT statement. The ORDER BY clause can sort by one or more columns and can use either ascending or descending order.
- You can join the output of multiple tables with the SELECT statement. The join operation is performed every time you specify two or more tables in the FROM clause and use a join condition in the WHERE clause to match the foreign key of one table to the primary key of the related table. If you do not specify a join condition, the DBMS will automatically perform a Cartesian product of the tables you specify in the FROM clause.
- The natural join uses the join condition to match only rows with equal values in the specified columns.

KEY TERMS

[alias](#)
[ALTER TABLE](#)
[AND](#)
[authentication](#)
[AVG](#)
[BETWEEN](#)
[Boolean algebra](#)
[cascading order sequence](#)
[COMMIT](#)
[COUNT](#)
[CREATE INDEX](#)
[CREATE TABLE](#)
[DELETE](#)
[DISTINCT](#)
[DROP INDEX](#)
[DROP TABLE](#)

EXISTS
GROUP BY
HAVING
IN
inner query
INSERT
IS NULL
LIKE
MAX
MIN
nested query
NOT
OR
ORDER BY
recursive query
reserved words
ROLLBACK
rules of precedence
schema
SELECT
subquery
SUM
UPDATE
wildcard character



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at
www.cengagebrain.com.

REVIEW QUESTIONS

1. In a SELECT query, what is the difference between a WHERE clause and a HAVING clause?
2. Explain why the following command would create an error and what changes could be made to fix the error: SELECT V_CODE, SUM(P_QOH) FROM PRODUCT;
3. What type of integrity is enforced when a primary key is declared?
4. Explain why it might be more appropriate to declare an attribute that contains only digits as a character data type instead of a numeric data type.
5. What is the difference between a column constraint and a table constraint?
6. What are “referential constraint actions”?
7. Rewrite the following WHERE clause without the use of the IN special operator: WHERE V_STATE IN ('TN', 'FL', 'GA')
8. Explain the difference between an ORDER BY clause and a GROUP BY clause.
9. Explain why the following two commands produce different results: SELECT DISTINCT COUNT (V_CODE) FROM PRODUCT; SELECT COUNT (DISTINCT V_CODE) FROM PRODUCT;
10. What is the difference between the COUNT aggregate function and the SUM aggregate function?
11. Explain why it would be preferable to use a DATE data type to store date data instead of a character data type.
12. What is a recursive join?



ONLINE CONTENT

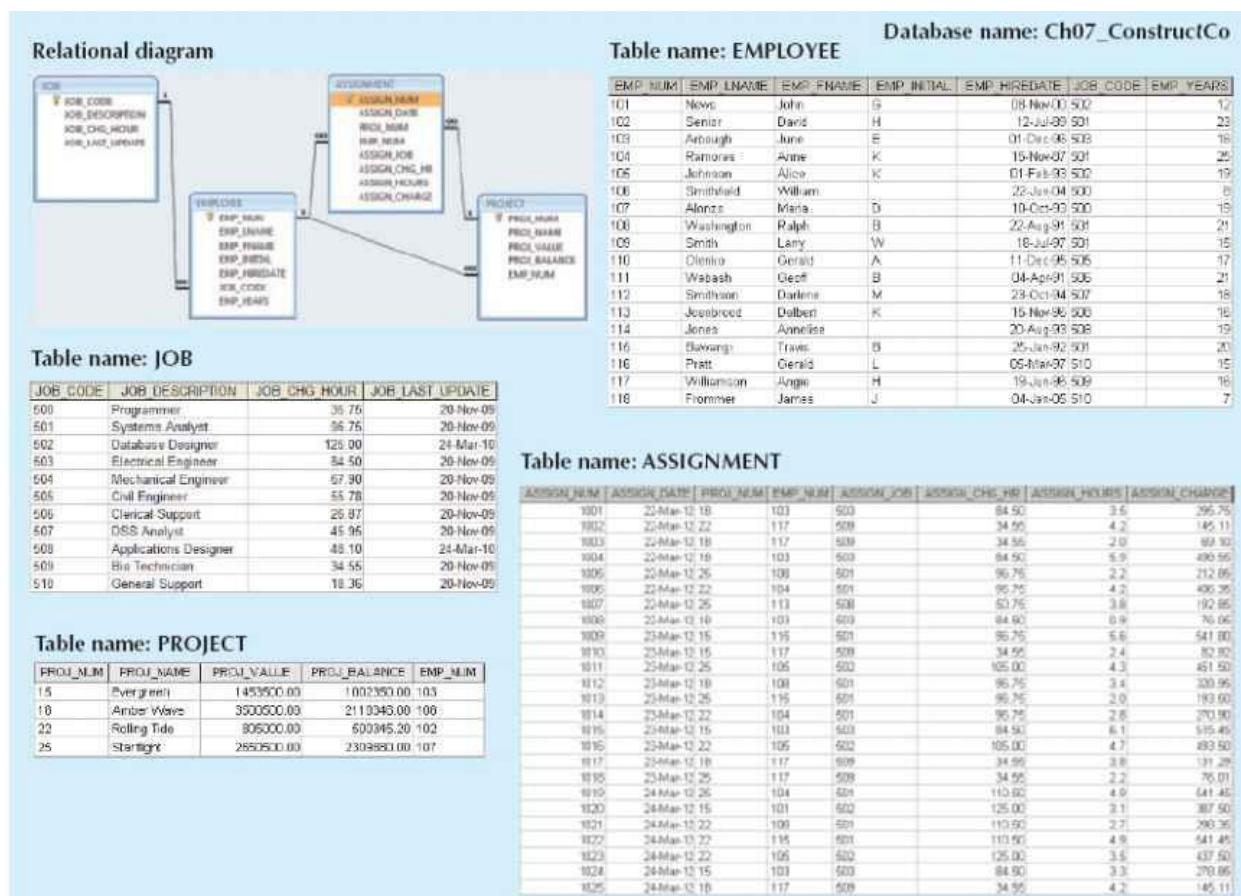
[Problems 1–25](#) are based on the **Ch07_ConstructCo** database at www.cengagebrain.com. This database is stored in Microsoft Access format. If

you use another DBMS such as Oracle, SQL Server, MySQL, or DB2, use its import utilities to import the Access database contents. Oracle and SQL script files are available at www.cengagebrain.com.

PROBLEMS

The Ch07_ConstructCo database stores data for a consulting company that tracks all charges to projects. The charges are based on the hours each employee works on each project. The structure and contents of the Ch07_ConstructCo database are shown in [Figure P7.1](#).

FIGURE P7.1 The Ch07_ConstructCo database



SOURCE: Course Technology/Cengage Learning

Note that the ASSIGNMENT table in [Figure P7.1](#) stores the JOB_CHG_HOUR values as an attribute (ASSIGN_CHG_HR) to maintain historical accuracy of the data. The JOB_CHG_HOUR values are likely to change over time. In fact, a JOB_CHG_HOUR change will be reflected in the ASSIGNMENT table. Naturally, the employee primary job assignment might also change, so the ASSIGN_JOB is also stored. Because those attributes are required to maintain the historical accuracy of the data, they are *not* redundant.

Given the structure and contents of the Ch07_ConstructCo database shown in [Figure P7.1](#), use SQL commands to answer [Problems 1–25](#).

1. Write the SQL code that will create the table structure for a table named EMP_1. This table is a subset of the EMPLOYEE table. The basic EMP_1 table structure is summarized in the following table. (Note that the JOB_CODE is the FK to JOB.)

ATTRIBUTE (FIELD) NAME DATA DECLARATION

EMP_NUM	CHAR(3)
EMP_LNAME	VARCHAR(15)
EMP_FNAME	VARCHAR(15)
EMP_INITIAL	CHAR(1)
EMP_HIREDATE	DATE
JOB_CODE	CHAR(3)

-
2. Having created the table structure in [Problem 1](#), write the SQL code to enter the first two rows for the table shown in [Figure P7.2](#).
-

FIGURE P7.2 The contents of the EMP_1 table

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIREDATE	JOB_CODE
101	News	John	G	08-Nov-00	502
102	Senior	David	H	12-Jul-89	501
103	Arbough	June	E	01-Dec-96	500
104	Ramoras	Anne	K	15-Nov-87	501
105	Johnson	Alice	K	01-Feb-93	502
106	Smithfield	William		22-Jun-04	500
107	Alonzo	Maria	D	10-Oct-93	500
108	Washington	Ralph	B	22-Aug-91	501
109	Smith	Larry	W	18-Jul-97	501

SOURCE: Course Technology/Cengage Learning

3. Assuming that the data shown in the EMP_1 table have been entered, write the SQL code that will list all attributes for a job code of 502.
 4. Write the SQL code that will save the changes made to the EMP_1 table.
 5. Write the SQL code to change the job code to 501 for the person whose employee number (EMP_NUM) is 107. After you have completed the task, examine the results and then reset the job code to its original value.
 6. Write the SQL code to delete the row for William Smithfield, who was hired on June 22, 2004, and whose job code is 500. (*Hint:* Use logical operators to include all of the information given in this problem.)
 7. Write the SQL code that will restore the data to its original status; that is, the table should contain the data that existed before you made the changes in [Problems 5](#) and [6](#).
 8. Write the SQL code to create a copy of EMP_1, naming the copy EMP_2. Then write the SQL code that will add the attributes EMP_PCT and PROJ_NUM to the structure. The EMP_PCT is the bonus percentage to be paid to each employee. The new attribute characteristics are:

EMP_PCT NUMBER(4,2)
PROJ_NUM CHAR(3)

(Note: If your SQL implementation allows it, you may use

DECIMAL(4,2) rather than NUMBER(4,2).)

9. Write the SQL code to change the EMP_PCT value to 3.85 for the person whose employee number (EMP_NUM) is 103. Next, write the SQL command sequences to change the EMP_PCT values, as shown in [Figure P7.9](#).

FIGURE P7.9 The EMP_2 table after the modifications

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIREDATE	JOB_CODE	EMP_PCT	PROJ_NUM
101	News	John	G	08-Nov-00	502	5.00	
102	Senior	David	H	12-Jul-89	501	8.00	
103	Arbough	June	E	01-Dec-96	500	3.85	
104	Ramoras	Anne	K	15-Nov-87	501	10.00	
105	Johnson	Alice	K	01-Feb-93	502	5.00	
106	Smithfield	William		22-Jun-04	500	6.20	
107	Alonzo	Maria	D	10-Oct-93	500	5.15	
108	Washington	Ralph	B	22-Aug-91	501	10.00	
109	Smith	Larry	W	18-Jul-97	501	2.00	

SOURCE: Course Technology/Cengage Learning

10. Using a single command sequence, write the SQL code that will change the project number (PROJ_NUM) to 18 for all employees whose job classification (JOB_CODE) is 500.
11. Using a single command sequence, write the SQL code that will change the project number (PROJ_NUM) to 25 for all employees whose job classification (JOB_CODE) is 502 or higher. When you finish [Problems 10](#) and [11](#), the EMP_2 table will contain the data shown in [Figure P7.11](#). (You may assume that the table has been saved again at this point.)

FIGURE P7.11 The EMP_2 table contents after the modifications

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIREDATE	JOB_CODE	EMP_PCT	PROJ_NUM
101	News	John	G	08-Nov-00	502	5.00	25
102	Senior	David	H	12-Jul-89	501	8.00	
103	Arbough	June	E	01-Dec-96	500	3.85	18
104	Ramoras	Anne	K	15-Nov-87	501	10.00	
105	Johnson	Alice	K	01-Feb-93	502	5.00	25
106	Smithfield	William		22-Jun-04	500	6.20	18
107	Alonzo	Maria	D	10-Oct-93	500	5.15	18
108	Washington	Ralph	B	22-Aug-91	501	10.00	
109	Smith	Larry	W	18-Jul-97	501	2.00	

SOURCE: Course Technology/Cengage Learning

12. Write the SQL code that will change the PROJ_NUM to 14 for employees who were hired before January 1, 1994, and whose job code is at least 501. (You may assume that the table will be restored to its condition preceding this question.)
 13. Write the two SQL command sequences required to:
 - a. Create a temporary table named TEMP_1 whose structure is composed of the EMP_2 attributes EMP_NUM and EMP_PCT.
 - b. Copy the matching EMP_2 values into the TEMP_1 table.
 14. Write the SQL command that will delete the newly created TEMP_1 table from the database.
 15. Write the SQL code required to list all employees whose last names start with *Smith*. In other words, the rows for both Smith and Smithfield should be included in the listing. Assume case sensitivity.
 16. Using the EMPLOYEE, JOB, and PROJECT tables in the Ch07_ConstructCo database (see [Figure P7.1](#)), write the SQL code that will produce the results shown in [Figure P7.16](#).

FIGURE P7.16 The query results for [Problem 16](#)

PROJ_NAME	PROJ_VALUE	PROJ_BALANCE	EMP_LNAME	EMP_FNAME	EMP_INITIAL	JOB_CODE	JOB_DESCRIPTION	JOB_CHG_HOUR
Rolling Tide	805000.00	500345.20	Senior	David	H	501	Systems Analyst	96.75
Evergreen	1453500.00	1002350.00	Arbough	June	E	500	Programmer	35.75
Starflight	2650500.00	2309880.00	Alonzo	Maria	D	500	Programmer	35.75
Amber Wave	3500500.00	2110346.00	vWashington	Ralph	B	501	Systems Analyst	96.75

17. Write the SQL code that will produce a virtual table named REP_1. The virtual table should contain the same information that was shown in [Problem 16](#).
 18. Write the SQL code to find the average bonus percentage in the EMP_2 table you created in [Problem 8](#).
 19. Write the SQL code that will produce a listing for the data in the EMP_2 table in ascending order by the bonus percentage.
 20. Write the SQL code that will list only the distinct project numbers in the EMP_2 table.
 21. Write the SQL code to calculate the ASSIGN_CHARGE values in the ASSIGNMENT table in the Ch07_ConstructCo database. (See [Figure P7.1](#).) Note that ASSIGN_CHARGE is a derived attribute that is calculated by multiplying ASSIGN_CHG_HR by ASSIGN_HOURS.
 22. Using the data in the ASSIGNMENT table, write the SQL code that will yield the total number of hours worked for each employee and the total charges stemming from those hours worked. The results of running that query are shown in [Figure P7.22](#).
-
-

FIGURE P7.22 Total hours and charges by employee

EMP_NUM	EMP_LNAME	SumOfASSIGN_HOURS	SumOfASSIGN_CHARGE
101	News	3.1	387.50
103	Arbough	19.7	1664.65
104	Ramoras	11.9	1218.70
105	Johnson	12.5	1382.50
108	Washington	8.3	840.15
113	Joenbrood	3.8	192.85
115	Bawangi	12.5	1276.75
117	Williamson	18.8	649.54

SOURCE: Course Technology/Cengage Learning

-
23. Write a query to produce the total number of hours and charges for each of the projects represented in the ASSIGNMENT table. The output is shown in [Figure P7.23](#).
-

FIGURE P7.23 Total hours and charges by project

PROJ_NUM	SumOfASSIGN_HOURS	SumOfASSIGN_CHARGE
15	20.5	1806.52
18	23.7	1544.80
22	27.0	2593.16
25	19.4	1668.16

SOURCE: Course Technology/Cengage Learning

-
24. Write the SQL code to generate the total hours worked and the total charges made by all employees. The results are shown in [Figure P7.24](#). (*Hint:* This is a nested query. If you use Microsoft Access, you can use the output shown in [Figure P7.22](#) as the basis for the query that will produce the output shown in [Figure P7.24](#).)
-

FIGURE P7.24 Total hours and charges, all employees

SumOfSumOfASSIGN_HOURS	SumOfSumOfASSIGN_CHARGE
90.6	7612.64

SOURCE: Course Technology/Cengage Learning

25. Write the SQL code to generate the total hours worked and the total charges made to all projects. The results should be the same as those shown in Figure P7.24. (*Hint:* This is a nested query. If you use Microsoft Access, you can use the output shown in Figure P7.23 as the basis for this query.)

The structure and contents of the Ch07_SaleCo database are shown in Figure P7.26. Use this database to answer the following problems. Save each query as QXX, where XX is the problem number.



ONLINE CONTENT

Problems 26–43 are based on the **Ch07_SaleCo** database, which is available at www.cengagebrain.com. This database is stored in Microsoft Access format. If you use another DBMS such as Oracle, SQL Server, MySQL, or DB2, use its import utilities to import the Access database contents. Oracle and SQL script files are available at www.cengagebrain.com.

26. Write a query to count the number of invoices.
27. Write a query to count the number of customers with a balance of more than \$500.
28. Generate a listing of all purchases made by the customers, using the output shown in Figure P7.28 as your guide. (*Hint:* Use the ORDER BY clause to order the resulting rows shown in Figure P7.28.)
-

FIGURE P7.26 The Ch07_SaleCo database

Relational diagram

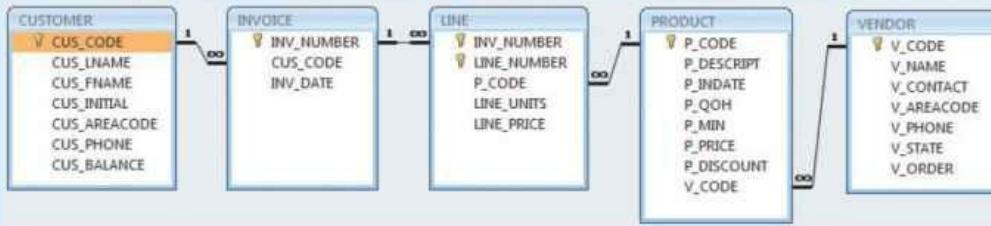


Table name: CUSTOMER

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_BALANCE
10010 Raines	Alfred	A		615	944-2573	0.00
10011 Donne	Leontine	K		713	894-1238	0.00
10012 Smith	Kathy	W		615	894-2265	345.66
10013 Kovacek	Paul	F		615	894-2180	536.75
10014 Orlando	Myron			615	222-1672	0.00
10015 O'Brian	Amy	B		713	442-3381	0.00
10016 Brown	James	G		615	297-1228	221.19
10017 Williams	George			615	297-2566	768.93
10018 Ferrini	Anne	G		713	382-7185	216.55
10019 Smith	Odetta	X		615	297-3069	0.00

Table name: INVOICE

INV_NUMBER	CUS_CODE	INV_DATE
1001	1001-8	16-Jan-12
1002	1001-1	16-Jan-12
1003	1001-2	16-Jan-12
1004	1001-3	17-Jan-12
1005	1001-6	17-Jan-12
1006	1001-14	17-Jan-12
1007	1001-15	17-Jan-12
1008	1001-11	17-Jan-12

Table name: LINE

INV_NUMBER	LINE_NUMBER	P_CODE	LINE_UNITS	LINE_PRICE
1001	1-13-02P2		1	14.99
	2-23109-HB		1	9.95
1002	1001-1		2	4.99
1003	1-54776-2T		2	4.99
1004	1-22394PD		1	38.95
1005	2-1548-002		1	39.95
1006	3-13-02P2		5	14.99
1007	1-54776-2T		3	4.99
1008	2-23109-HB		2	9.95
1009	1-PVC230R7		12	5.87
1006	1-SM-18277		3	6.99
1008	2-22380FY		1	109.92
1006	3-23109-HB		1	9.95
1006	4-EP-WIRE-Q		1	256.99
1007	1-13-02P2		2	14.99
1007	2-54776-2T		1	4.99
1009	1-PVC230R7		5	5.87
1008	2-WR3TT3		3	119.95
1009	3-23109-HB		1	9.95

Table name: VENDOR

V_CODE	V_NAME	V_CONTACT	V_AREACODE	V_PHONE	V_STATE	V_ORDER
21226 Bryson Inc.	Smithson	615	223-3234	TN	Y	
21228 SuperLoc, Inc.	Flushing	904	215-8805	FL	N	
21231 DSE Supply	Singh	615	226-3245	TN	Y	
21344 Gomez Bros.	Ortega	615	895-2548	KY	N	
22567 Dome Supply	Smith	901	678-1419	GA	N	
23119 Randalls Ltd.	Anderson	901	678-3998	GA	Y	
24004 Brackman Bros.	Browning	615	228-1410	TN	N	
24281 BK&L Inc.	Halkord	615	898-1234	TN	Y	
25491 Demel Supplies	Smith	904	227-0093	FL	N	
25501 Demel Supplies	Smythe	615	890-3529	TN	N	
35595 Rutledge Systems	Orton	904	458-0092	FL	Y	

FIGURE P7.28 List of customer purchases

SOURCE: Course Technology/Cengage Learning

CUS_CODE	INV_NUMBER	INV_DATE	P_DESCRPT	LINE_UNITS	LINE_PRICE
10011	1002	16-Jan-12	Rat-tail file, 1/8-in. fine	2	4.99
10011	1004	17-Jan-12	Claw hammer	2	9.95
10011	1004	17-Jan-12	Rat-tail file, 1/8-in. fine	3	4.99
10011	1008	17-Jan-12	Claw hammer	1	9.95
10011	1008	17-Jan-12	PVC pipe, 3.5-in., 8-ft	5	5.87
10011	1008	17-Jan-12	Steel matting, 4'x8'x1/6", .5" mesh	3	119.95
10012	1003	16-Jan-12	7.25-in. pwr. saw blade	5	14.99
10012	1003	16-Jan-12	B&D cordless drill, 1/2-in.	1	38.95
10012	1003	16-Jan-12	Hrd. cloth, 1/4-in., 2x50	1	39.95
10014	1001	16-Jan-12	7.25-in. pwr. saw blade	1	14.99
10014	1001	16-Jan-12	Claw hammer	1	9.95
10014	1006	17-Jan-12	1.25-in. metal screw, 25	3	6.99
10014	1006	17-Jan-12	B&D jigsaw, 12-in. blade	1	109.92
10014	1006	17-Jan-12	Claw hammer	1	9.95
10014	1006	17-Jan-12	Hicut chain saw, 16 in.	1	256.99
10015	1007	17-Jan-12	7.25-in. pwr. saw blade	2	14.99
10015	1007	17-Jan-12	Rat-tail file, 1/8-in. fine	1	4.99
10018	1005	17-Jan-12	PVC pipe, 3.5-in., 8-ft	12	5.87

SOURCE: Course Technology/Cengage Learning

-
29. Using the output shown in [Figure P7.29](#) as your guide, generate a list of customer purchases, including the subtotals for each of the invoice line numbers. (*Hint:* Modify the query format used to produce the list of customer purchases in [Problem 28](#), delete the INV_DATE column, and add the derived attribute LINE_UNITS * LINE_PRICE to calculate the subtotals.)
-

FIGURE P7.29 Summary of customer purchases with subtotals

CUS_CODE	INV_NUMBER	P_DESCRPT	Units Bought	Unit Price	Subtotal
10011	1002	Rat-tail file, 1/8-in. fine	2	4.99	9.98
10011	1004	Claw hammer	2	9.95	19.90
10011	1004	Rat-tail file, 1/8-in. fine	3	4.99	14.97
10011	1008	Claw hammer	1	9.95	9.95
10011	1008	PVC pipe, 3.5-in., 8-ft	5	5.87	29.35
10011	1008	Steel matting, 4'x8'x1/6", .5" mesh	3	119.95	359.85
10012	1003	7.25-in. pwr. saw blade	5	14.99	74.95
10012	1003	B&D cordless drill, 1/2-in.	1	38.95	38.95
10012	1003	Hrd. cloth, 1/4-in., 2x50	1	39.95	39.95
10014	1001	7.25-in. pwr. saw blade	1	14.99	14.99
10014	1001	Claw hammer	1	9.95	9.95
10014	1006	1.25-in. metal screw, 25	3	6.99	20.97
10014	1006	B&D jigsaw, 12-in. blade	1	109.92	109.92
10014	1006	Claw hammer	1	9.95	9.95
10014	1006	Hicut chain saw, 16 in.	1	256.99	256.99
10015	1007	7.25-in. pwr. saw blade	2	14.99	29.98
10015	1007	Rat-tail file, 1/8-in. fine	1	4.99	4.99
10018	1005	PVC pipe, 3.5-in., 8-ft	12	5.87	70.44

SOURCE: Course Technology/Cengage Learning

-
30. Modify the query used in [Problem 29](#) to produce the summary shown in [Figure P7.30](#).
31. Modify the query in [Problem 30](#) to include the number of individual product purchases made by each customer. (In other words, if the customer's invoice is based on three products, one per LINE_NUMBER, you count three product purchases. Note that in the original invoice data, customer 10011 generated three invoices, which contained a total of six lines, each representing a product purchase.) Your output values must match those shown in [Figure P7.31](#).
-

FIGURE P7.30 Customer purchase summary

CUS_CODE	CUS_BALANCE	Total Purchases
10011	0.00	444.00
10012	345.86	153.85
10014	0.00	422.77
10015	0.00	34.97
10018	216.55	70.44

SOURCE: Course Technology/Cengage Learning

FIGURE P7.31 Customer total purchase amounts and number of purchases

CUS_CODE	CUS_BALANCE	Total Purchases	Number of Purchases
10011	0.00	444.00	6
10012	345.86	153.85	3
10014	0.00	422.77	6
10015	0.00	34.97	2
10018	216.55	70.44	1

SOURCE: Course Technology/Cengage Learning

32. Use a query to compute the average purchase amount per product made by each customer. (*Hint:* Use the results of [Problem 31](#) as the basis for this query.) Your output values must match those shown in [Figure P7.32](#). Note that the average purchase amount is equal to the total purchases divided by the number of purchases per customer.
-

FIGURE P7.32 Average purchase amount by customer

CUS_CODE	CUS_BALANCE	Total Purchases	Number of Purchases	Average Purchase Amount
10011	0.00	444.00	6	74.00
10012	345.86	153.85	3	51.28
10014	0.00	422.77	6	70.46
10015	0.00	34.97	2	17.48
10018	216.55	70.44	1	70.44

SOURCE: Course Technology/Cengage Learning

33. Create a query to produce the total purchase per invoice, generating the results shown in [Figure P7.33](#). The invoice total is the sum of the product purchases in the LINE that corresponds to the INVOICE.
34. Use a query to show the invoices and invoice totals in [Figure P7.34](#). (*Hint:*

Group by the CUS_CODE.)

FIGURE P7.33 Invoice totals

INV_NUMBER	Invoice Total
1001	24.94
1002	9.98
1003	153.85
1004	34.87
1005	70.44
1006	397.83
1007	34.97
1008	399.15

SOURCE: Course Technology/Cengage Learning

FIGURE P7.34 Invoice totals by customer

CUS_CODE	INV_NUMBER	Invoice Total
10011	1002	9.98
10011	1004	34.87
10011	1008	399.15
10012	1003	153.85
10014	1001	24.94
10014	1006	397.83
10015	1007	34.97
10018	1005	70.44

SOURCE: Course Technology/Cengage Learning

35. Write a query to produce the number of invoices and the total purchase

amounts by customer, using the output shown in [Figure P7.35](#) as your guide. (Compare this summary to the results shown in [Problem 34](#).)

36. Using the query results in [Problem 35](#) as your basis, write a query to generate the total number of invoices, the invoice total for all of the invoices, the smallest invoice amount, the largest invoice amount, and the average of all the invoices. (*Hint:* Check the figure output in [Problem 35](#).) Your output must match [Figure P7.36](#).

FIGURE P7.35 Number of invoices and total purchase amounts by customer

CUS_CODE	Number of Invoices	Total Customer Purchases
10011	3	444.00
10012	1	153.85
10014	2	422.77
10015	1	34.97
10018	1	70.44

SOURCE: Course Technology/Cengage Learning

FIGURE P7.36 Number of invoices, invoice totals, minimum, maximum, and average sales

Total Invoices	Total Sales	Minimum Sale	Largest Sale	Average Sale
8	1126.83	34.97	444.00	225.21

SOURCE: Course Technology/Cengage Learning

37. List the balances of customers who have made purchases during the current invoice cycle—that is, for the customers who appear in the INVOICE table. The results of this query are shown in [Figure P7.37](#).
38. Using the results of the query created in [Problem 37](#), provide a summary of customer balance characteristics, as shown in [Figure P7.38](#).

FIGURE P7.37 Balances for customers who made purchases

CUS_CODE	CUS_BALANCE
10011	0.00
10012	345.86
10014	0.00
10015	0.00
10018	216.55

SOURCE: Course Technology/Cengage Learning

FIGURE P7.38 Balance summary of customers who made purchases

Minimum Balance	Maximum Balance	Average Balance
0	345.86	112.48

SOURCE: Course Technology/Cengage Learning

39. Create a query to find the balance characteristics for all customers, including the total of the outstanding balances. The results of this query are shown in [Figure P7.39](#).

 40. Find the listing of customers who did not make purchases during the invoicing period. Your output must match the output shown in [Figure P7.40](#).
-

FIGURE P7.39 Balance summary for all customers

Total Balances	Minimum Balance	Maximum Balance	Average Balance
2089.28	0.00	768.93	208.93

SOURCE: Course Technology/Cengage Learning

FIGURE P7.40 Balances of customers who did not make purchases

CUS_CODE	CUS_BALANCE
10010	0.00
10013	536.75
10016	221.19
10017	768.93
10019	0.00

SOURCE: Course Technology/Cengage Learning

41. Find the customer balance summary for all customers who have not made purchases during the current invoicing period. The results are shown in [Figure P7.41](#).

FIGURE P7.41 Summary of customer balances for customers who did not make purchases

Total Balance	Minimum Balance	Maximum Balance	Average Balance
1526.87	0.00	768.93	305.37

SOURCE: Course Technology/Cengage Learning

42. Create a query that summarizes the value of products currently in inventory. Note that the value of each product is a result of multiplying the units currently in inventory by the unit price. Use the ORDER BY clause to

match the order shown in [Figure P7.42](#).

FIGURE P7.42 Value of products currently in inventory

P_DESCRPT	P_QOH	P_PRICE	Subtotal
Power painter, 15 psi., 3-nozzle	8	109.99	879.92
7.25-in. pwr. saw blade	32	14.99	479.68
9.00-in. pwr. saw blade	18	17.49	314.82
Hrd. cloth, 1/4-in., 2x50	15	39.95	599.25
Hrd. cloth, 1/2-in., 3x50	23	43.99	1011.77
B&D jigsaw, 12-in. blade	8	109.92	879.36
B&D jigsaw, 8-in. blade	6	99.87	599.22
B&D cordless drill, 1/2-in.	12	38.95	467.40
Claw hammer	23	9.95	228.85
Sledge hammer, 12 lb.	8	14.40	115.20
Rat-tail file, 1/8-in. fine	43	4.99	214.57
Hicut chain saw, 16 in.	11	256.99	2826.89
PVC pipe, 3.5-in., 8-ft	188	5.87	1103.56
1.25-in. metal screw, 25	172	6.99	1202.28
2.5-in. wd. screw, 50	237	8.45	2002.65
Steel matting, 4'x8'x1/6", .5" mesh	18	119.95	2159.10

SOURCE: Course Technology/Cengage Learning

43. Using the results of the query created in [Problem 42](#), find the total value of the product inventory. The results are shown in [Figure P7.43](#).
-
-

FIGURE P7.43 Total value of all products in inventory

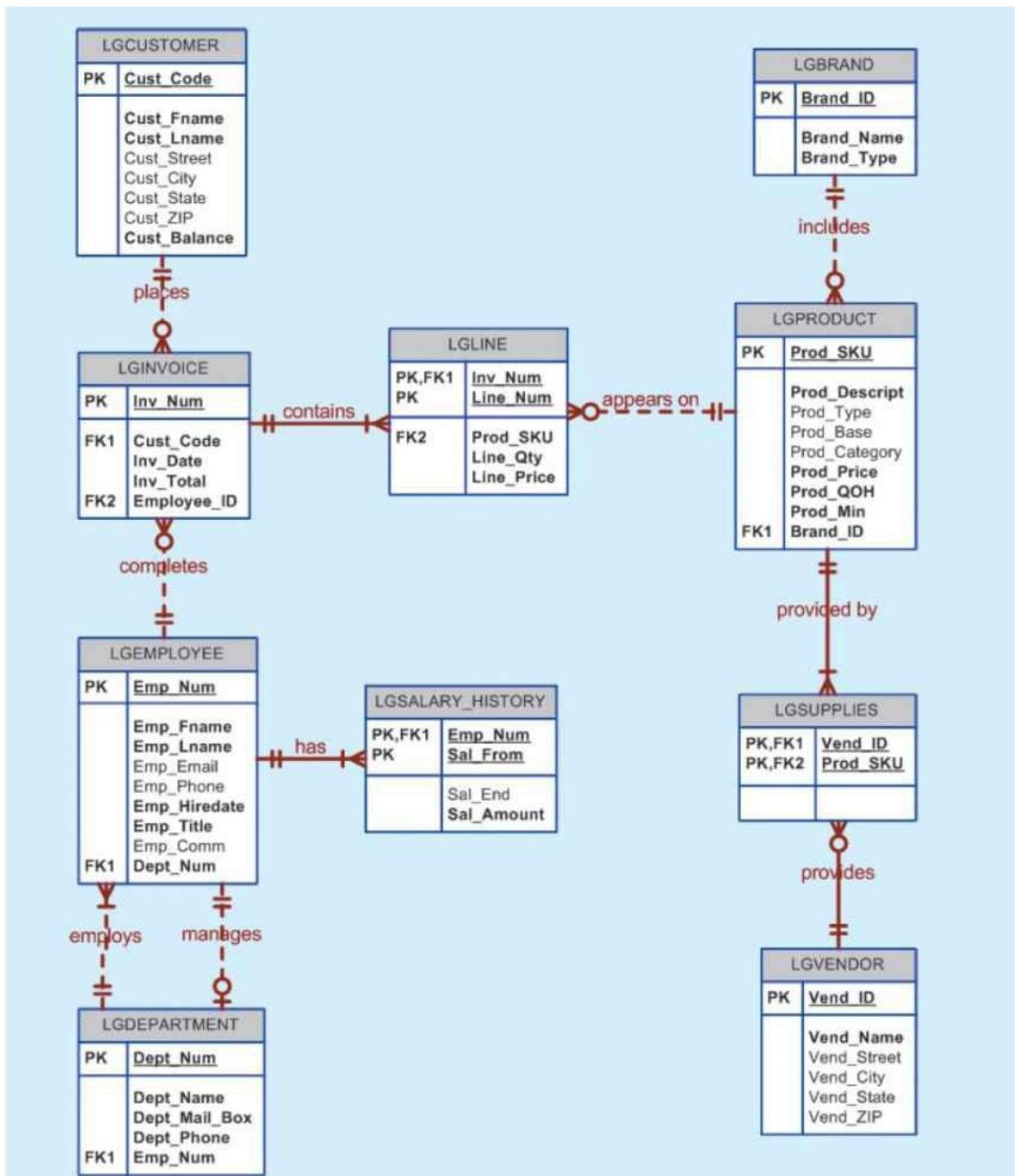
Total Value of Inventory
15084.52

SOURCE: Course Technology/Cengage Learning

The Ch07_LargeCo database stores data for a company that resells paints. The company tracks the sale of products to customers. The database keeps data on customers (LGCUSTOMER), sales (LGINVOICE), products (LGPRODUCT), which products are on which invoices (LGLINE),

employees (LGEMPLOYEE), the salary history of each employee (LGSALARY_HISTORY), departments (LGDEPARTMENT), product brands (LGBRAND), vendors (LGVENDOR), and which vendors supply each product (LGSUPPLIES), as shown in [Figure P7.44](#). Some of the tables contain only a few rows of data, while other tables are quite large; for example, there are only eight departments, but more than 3,300 invoices containing over 11,000 invoice lines. *For Problems 45–64*, if the output of the query is very large, only the first several rows of the output are shown.

FIGURE P7.44 The Ch07_LargeCo ERD



SOURCE: Course Technology/Cengage Learning

-
44. Write a query to display the eight departments in the LGDEPARTMENT table.

45. Write a query to display the SKU (stock keeping unit), description, type, base, category, and price for all products that have a PROD_BASE of water and a PROD_CATEGORY of sealer.
-

FIGURE P7.45 Water-based sealers

PROD_SKU	PROD_DESCRPT	PROD_TYPE	PROD_BASE	PROD_CATEGORY	PROD_PRICE
1403-TUY	Sealer, Water Based, for Concrete Floors	Interior	Water	Sealer	42.99

SOURCE: Course Technology/Cengage Learning

46. Write a query to display the first name, last name, and e-mail address of employees hired from January 1, 2001, to December 31, 2010. Sort the output by last name and then by first name.
-

FIGURE P7.46 Employees hired from 2001–2010

EMP_FNAME	EMP_LNAME	EMP_EMAIL
SAMANTHA	ALBRIGHT	S.ALBRIG8@LGCOMPANY.COM
TRISHA	ALVAREZ	T.ALVARE8@LGCOMPANY.COM
ROSALBA	BAKER	R.BAKER9@LGCOMPANY.COM
WILFORD	BURGOS	W.BURGOS6@LGCOMPANY.COM
IRENA	BURKETT	I.BURKET9@LGCOMPANY.COM
AARON	CARROLL	A.CARROL8@LGCOMPANY.COM
KASEY	CASH	K.CASH0@LGCOMPANY.COM
DOUG	CAUDILL	C.DOUGO@LGCOMPANY.COM
LUCIO	CAUDILL	L.CAUDIL4@LGCOMPANY.COM
HANNAH	COLEMAN	H.COLEMA7@LGCOMPANY.COM
PHILLIS	CONKLIN	P.CONKLI4@LGCOMPANY.COM
SADIE	COVINGTON	S.COVING6@LGCOMPANY.COM

SOURCE: Course Technology/Cengage Learning

47. Write a query to display the first name, last name, phone number, title, and department number of employees who work in department 300 or have the

title “CLERK I.” Sort the output by last name and then by first name.

FIGURE P7.47 Clerks and employees in department 300

EMP_FNAME	EMP_LNAME	EMP_PHONE	EMP_TITLE	DEPT_NUM
LAVINA	ACEVEDO	862-6787	ASSOCIATE	300
LAUREN	AVERY	550-2270	SENIOR ASSOCIATE	300
ROSALBA	BAKER	632-8197	ASSOCIATE	300
FERN	CARPENTER	735-4820	PURCHASING SPECIALIST	300
LEEANN	CLINTON	616-9615	CLERK I	600
TANIKA	CRANE	449-6336	PURCHASING SPECIALIST	300
SAMMY	DIGGS	525-2101	SENIOR ASSOCIATE	300
LANA	DOWDY	471-8795	SENIOR ASSOCIATE	300
STEPHAINA	DUNLAP	618-8203	BUYER - RAW MATERIALS	300
HAL	FISHER	676-3662	SENIOR ASSOCIATE	300
LINDSAY	GOOD	337-9570	CLERK I	600
LEEANN	HORN	828-4361	SENIOR ASSOCIATE	300

SOURCE: Course Technology/Cengage Learning

48. Write a query to display the employee number, last name, first name, salary “from” date, salary end date, and salary amount for employees 83731, 83745, and 84039. Sort the output by employee number and salary “from” date.
-

FIGURE P7.48 Salary history for selected employees

EMP_NUM	EMP_LNAME	EMP_FNAME	SAL_FROM	SAL_END	SAL_AMOUNT
83731	VARGAS	SHERON	7/15/2008	7/14/2009	43740
83731	VARGAS	SHERON	7/14/2009	7/13/2010	48110
83731	VARGAS	SHERON	7/14/2010	7/14/2011	49550
83731	VARGAS	SHERON	7/15/2011		51040
83745	SPICER	DWAIN	8/2/2005	8/1/2006	56020
83745	SPICER	DWAIN	8/2/2006	8/2/2007	57700
83745	SPICER	DWAIN	8/3/2007	8/1/2008	63470
83745	SPICER	DWAIN	8/2/2008	8/1/2009	68550
83745	SPICER	DWAIN	8/1/2009	7/31/2010	71980
83745	SPICER	DWAIN	8/1/2010	8/1/2011	74140
83745	SPICER	DWAIN	8/2/2011		76360
84039	COLEMAN	HANNAH	6/28/2008	6/27/2009	47380
84039	COLEMAN	HANNAH	6/27/2009	6/26/2010	51170
84039	COLEMAN	HANNAH	6/27/2010	6/27/2011	52700
84039	COLEMAN	HANNAH	6/28/2011		54280

SOURCE: Course Technology/Cengage Learning

-
49. Write a query to display the first name, last name, street, city, state, and zip code of any customer who purchased a Foresters Best brand top coat between July 15, 2011, and July 31, 2011. If a customer purchased more than one such product, display the customer's information only once in the output. Sort the output by state, last name, and then first name.
-

FIGURE P7.49 Customers who purchased Foresters Best top coat

CUST_FNAME	CUST_LNAME	CUST_STREET	CUST_CITY	CUST_STATE	CUST_ZIP
LUPE	SANTANA	1292 WEST 70TH PLACE	Phenix City	AL	36867
HOLLIS	STILES	1493 DOLLY MADISON CIRCLE	Snow Hill	AL	36778
LISETTE	WHITTAKER	339 NORTHPARK DRIVE	Montgomery	AL	36197
DEANDRE	JAMISON	1571 HANES STREET	Miami	FL	33169
CATHLEEN	WHITMAN	1712 NORTHFIELD DRIVE	Marshallville	GA	31057
SHERIE	STOVER	640 MOUNTAIN VIEW DRIVE	Parksville	KY	40464
BRYCE	HOGAN	1860 IMLACH DRIVE	Newbury	MA	01951
SHELBY	SALAS	486 SUSITNA VIEW COURT	North Tisbury	MA	02568
JERMAINE	HANCOCK	1627 SAUNDERS ROAD	Ellicott City	MD	21041
WHITNEY	WHITFIELD	1259 RHONE STREET	Phippsburg	ME	04567
MONROE	ALLISON	272 SCHODDE STREET	Kalamazoo	MI	49002
DARLEEN	PARRA	561 COLLIE HILL WAY	Madison	MS	39130
CLINTON	AGUIRRE	1651 VANGUARD DRIVE	Franklinville	NC	27248
TOMMIE	PALMER	933 ELCADORE CIRCLE	Arapahoe	NC	28510
JEFFEREY	MCBRIDE	1043 ROCKRIDGE DRIVE	Glenwood	NJ	07418
SIDNEY	GARZA	772 SHEPPARD DRIVE	Fair Harbor	NY	11706
TAMELA	GUIDRY	1873 BAXTER ROAD	Brooklyn	NY	11252
KAREN	LEVINE	1534 PALMER COURT	Cincinnati	OH	45218
STEPHENIE	MCKENZIE	1039 DELAWARE PLACE	Wilkes Barre	PA	18763
LAN	NICHOLS	367 LAKEVIEW DRIVE	Pittsburgh	PA	15262
KASEY	SOSA	975 WEST 96TH AVENUE	Kinzers	PA	17535
SHELBY	THAYER	1634 RUANE ROAD	Bordeaux	SC	29835
WILSON	BELL	1127 CUNNINGHAM STREET	Louisville	TN	37777
RENATE	LADD	652 LEWIS STREET	Crystal City	VA	22202
MELONIE	JIMENEZ	848 DOWNEY FINCH LANE	East Monkton	VT	05443

SOURCE: Course Technology/Cengage Learning

-
50. Write a query to display the employee number, last name, e-mail address, title, and department name of each employee whose job title ends in the word “ASSOCIATE.” Sort the output by department name and employee title.
-

FIGURE P7.50 Employees with the title of Associate

EMP_NUM	EMP_LNAME	EMP_EMAIL	EMP_TITLE	DEPT_NAME
84526	LASSITER	F.LASSIT8@LGCOMPANY.COM	ASSOCIATE	ACCOUNTING
83517	ALBRIGHT	S0.ALBRI96@LGCOMPANY.COM	ASSOCIATE	ACCOUNTING
84386	RIVERA	D.RIVERA76@LGCOMPANY.COM	ASSOCIATE	ACCOUNTING
83378	DUNHAM	F.DUNHAM5@LGCOMPANY.COM	ASSOCIATE	ACCOUNTING
83583	ROLLINS	M.ROLLIN99@LGCOMPANY.COM	ASSOCIATE	ACCOUNTING
83661	FINN	D.FINN87@LGCOMPANY.COM	ASSOCIATE	ACCOUNTING
84383	WASHINGTON	L.WASHIN98@LGCOMPANY.COM	ASSOCIATE	CUSTOMER SERVICE
84206	HEALY	N.HEALY82@LGCOMPANY.COM	ASSOCIATE	CUSTOMER SERVICE
83451	ELLIS	R.ELLIS81@LGCOMPANY.COM	ASSOCIATE	CUSTOMER SERVICE
84442	GREGORY	A.GREGOR95@LGCOMPANY.COM	ASSOCIATE	CUSTOMER SERVICE
84459	GILLIAM	E.GILLIA10@LGCOMPANY.COM	ASSOCIATE	CUSTOMER SERVICE
84300	SEAY	A.SEAY75@LGCOMPANY.COM	ASSOCIATE	CUSTOMER SERVICE

SOURCE: Course Technology/Cengage Learning

51. Write a query to display a brand name and the number of products of that brand that are in the database. Sort the output by the brand name.
-

FIGURE P7.51 Number of products of each brand

BRAND_NAME	NUMPRODUCTS
BINDER PRIME	27
BUSTERS	25
FORESTERS BEST	15
HOME COMFORT	36
LE MODE	36
LONG HAUL	41
OLDE TYME QUALITY	27
STUTTENFURST	27
VALU-MATTE	18

SOURCE: Course Technology/Cengage Learning

52. Write a query to display the number of products in each category that have a water base.
-

FIGURE P7.52 Number of water-based products in each category

PROD_CATEGORY	NUMPRODUCTS
Cleaner	2
Filler	2
Primer	16
Sealer	1
Top Coat	81

SOURCE: Course Technology/Cengage Learning

-
53. Write a query to display the number of products within each base and type combination.
-

FIGURE P7.53 Number of products of each base and type

PROD_BASE	PROD_TYPE	NUMPRODUCTS
Solvent	Exterior	67
Solvent	Interior	83
Water	Exterior	39
Water	Interior	63

SOURCE: Course Technology/Cengage Learning

-
54. Write a query to display the total inventory—that is, the sum of all products on hand for each brand ID. Sort the output by brand ID in descending order.
-

FIGURE P7.54 Total inventory of each brand of products

BRAND_ID	TOTALINVENTORY
35	2431
33	2158
31	1117
30	3012
29	1735
28	2200
27	2596
25	1829
23	1293

SOURCE: Course Technology/Cengage Learning

-
55. Write a query to display the brand ID, brand name, and average price of products of each brand. Sort the output by brand name. (Results are shown with the average price rounded to two decimal places.)
-

FIGURE P7.55 Average price of products of each brand

BRAND_ID	BRAND_NAME	AVGPRICE
33	BINDER PRIME	16.12
29	BUSTERS	22.59
23	FORESTERS BEST	20.94
27	HOME COMFORT	21.8
35	LE MODE	19.22
30	LONG HAUL	20.12
28	OLDE TYME QUALITY	18.33
25	STUTTENFURST	16.47
31	VALU-MATTE	16.84

SOURCE: Course Technology/Cengage Learning

-
56. Write a query to display the department number and most recent employee hire date for each department. Sort the output by department number.

FIGURE P7.56 Most recent hire in each department

DEPT_NUM	MOSTRECENT
200	6/8/2001
250	12/15/2011
280	4/16/2010
300	12/12/2010
400	1/26/2011
500	4/26/2011
550	10/22/2011
600	10/2/2011

SOURCE: Course Technology/Cengage Learning

57. Write a query to display the employee number, first name, last name, and largest salary amount for each employee in department 200. Sort the output by largest salary in descending order.
-

FIGURE P7.57 Largest salary amount for each employee in department 200

EMP_NUM	EMP_FNAME	EMP_LNAME	LARGESTSALARY
83509	FRANKLYN	STOVER	210000
83705	JOSE	BARR	147000
83537	CLEO	ENGLISH	136000
83565	LOURDES	ABERNATHY	133000
83593	ROSANNE	NASH	129000
83621	FONDA	GONZALEZ	126000
83649	DELMA	JACOB	123000
83677	HERB	MANNING	120000
83936	BRADFORD	BRAY	117000
83734	INEZ	ROCHA	112000
84049	LANE	BRANDON	110000
83763	JAIME	FELTON	107000

SOURCE: Course Technology/Cengage Learning

-
58. Write a query to display the customer code, first name, last name, and sum of all invoice totals for customers with cumulative invoice totals greater than \$1,500. Sort the output by the sum of invoice totals in descending order.
-

FIGURE P7.58 List of customers with cumulative purchases of more than \$1,500

CUST_CODE	CUST_FNAME	CUST_LNAME	TOTALINVOICES
215	CHARMAINE	BRYAN	3134.15
98	VALENTIN	MARINO	3052.46
152	LISETTE	WHITTAKER	3042.78
117	KARON	MATA	3009.63
97	ERWIN	ANDERSON	2895.49
112	LAN	NICHOLS	2867.14
118	JESSE	HICKS	2786.55
220	ABRAHAM	PLATT	2187.26
103	CORRINA	GIFFORD	2122.07
302	SHIRLENE	FITCH	2046.31
173	INGRID	HARDY	2040.31
132	JANIS	DUBOIS	2015.62

SOURCE: Course Technology/Cengage Learning

59. Write a query to display the department number, department name, department phone number, employee number, and last name of each department manager. Sort the output by department name.
-

FIGURE P7.59 Department managers

DEPT_NUM	DEPT_NAME	DEPT_PHONE	EMP_NUM	EMP_LNAME
600	ACCOUNTING	555-2333	84583	YAZZIE
250	CUSTOMER SERVICE	555-5555	84001	FARMER
500	DISTRIBUTION	555-3624	84052	FORD
280	MARKETING	555-8500	84042	PETTIT
300	PURCHASING	555-4873	83746	RANKIN
200	SALES	555-2824	83509	STOVER
550	TRUCKING	555-0057	83683	STONE
400	WAREHOUSE	555-1003	83759	CHARLES

SOURCE: Course Technology/Cengage Learning

-
60. Write a query to display the vendor ID, vendor name, brand name, and number of products of each brand supplied by each vendor. Sort the output by vendor name and then by brand name.
-

FIGURE P7.60 Number of products of each brand supplied by each vendor

VEND_ID	VEND_NAME	BRAND_NAME	NUMPRODUCTS
8	Baltimore Paints Consolidated	BINDER PRIME	27
8	Baltimore Paints Consolidated	FORESTERS BEST	1
8	Baltimore Paints Consolidated	HOME COMFORT	36
8	Baltimore Paints Consolidated	LE MODE	3
8	Baltimore Paints Consolidated	LONG HAUL	3
8	Baltimore Paints Consolidated	VALU-MATTE	1
13	Boykin Chemical Workshop	BUSTERS	1
13	Boykin Chemical Workshop	LE MODE	2
13	Boykin Chemical Workshop	LONG HAUL	2
13	Boykin Chemical Workshop	OLDE TYME QUALITY	2
13	Boykin Chemical Workshop	STUTTENFURST	1
13	Boykin Chemical Workshop	VALU-MATTE	1

SOURCE: Course Technology/Cengage Learning

-
61. Write a query to display the employee number, last name, first name, and sum of invoice totals for all employees who completed an invoice. Sort the output by employee last name and then by first name.
-

FIGURE P7.61 Total value of invoices completed by each employee

EMP_NUM	EMP_LNAME	EMP_FNAME	TOTALINVOICES
83565	ABERNATHY	LOURDES	19158.54
83792	ANDERSEN	WALLY	20627.47
83705	BARR	JOSE	22098.88
84049	BRANDON	LANE	20683.06
83936	BRAY	BRADFORD	21139.94
84248	CASTLE	DANICA	17700.42
84420	CAUDILL	DOUG	11308.21
83993	CORTES	SANG	17436.88
84021	DICKINSON	JAROD	20437.35
84163	EASLEY	GWEN	24813.26
83537	ENGLISH	CLEO	18883.13
84078	ERWIN	DIEGO	23839.85

SOURCE: Course Technology/Cengage Learning

62. Write a query to display the largest average product price of any brand.
-

FIGURE P7.62 Largest average brand price

LARGEST AVERAGE
22.59

SOURCE: Course Technology/Cengage Learning

63. Write a query to display the brand ID, brand name, brand type, and average price of products for the brand that has the largest average product price.
-

FIGURE P7.63 Brand with highest average price

BRAND_ID	BRAND_NAME	BRAND_TYPE	AVGPRICE
29	BUSTERS	VALUE	22.59

SOURCE: Course Technology/Cengage Learning

-
64. Write a query to display the manager name, department name, department phone number, employee name, customer name, invoice date, and invoice total for the department manager of the employee who made a sale to a customer whose last name is Hagan on May 18, 2011. For all person names, concatenate the first and last names into a single field.
-

FIGURE P7.64 Manager of employee making a sale to customer Hagan

MANAGER NAME	DEPT_NAME	DEPT_PHONE	EMPLOYEE NAME	CUSTOMER NAME	INV_DATE	INV_TOTAL
FRANKLYN STOVER	SALES	555-2824	THURMAN WILKINSON	DARELL HAGAN	5/18/2011	315.04

SOURCE: Course Technology/Cengage Learning

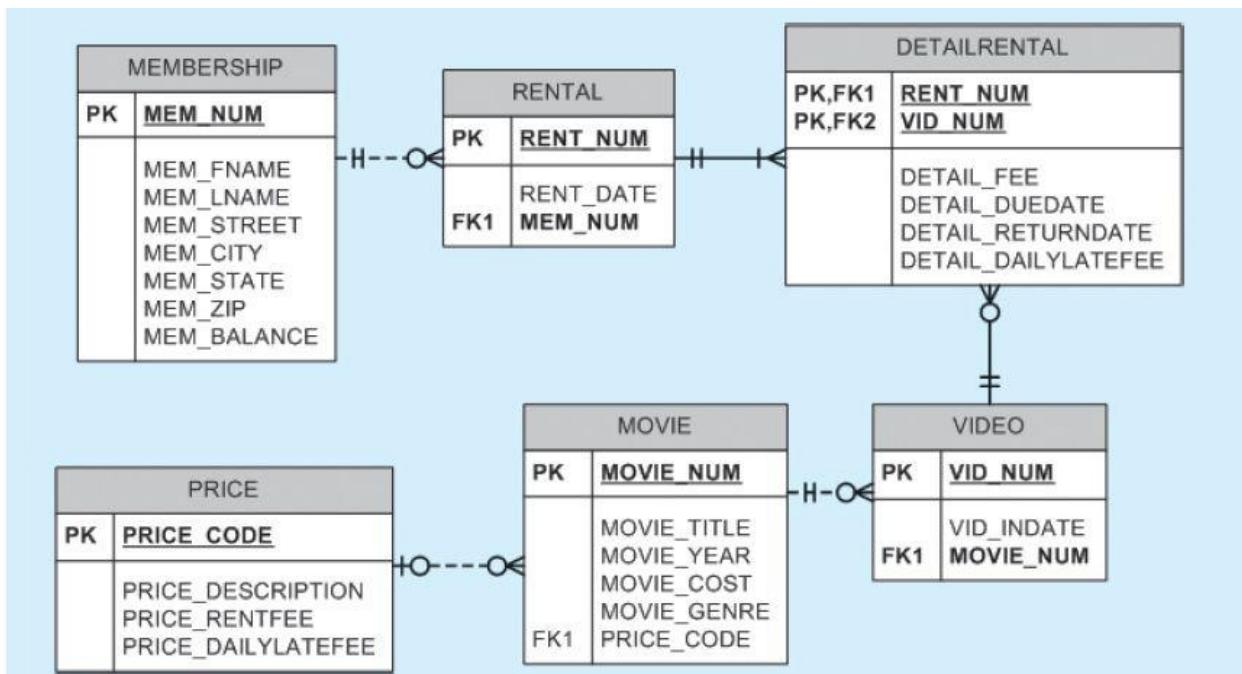
CASES

TinyVideo is a small movie rental company with a single store. It needs a database system to track the rental of movies to its members. TinyVideo can own several copies (VIDEO) of each movie (MOVIE). For example, the store may have 10 copies of the movie *Twist in the Wind*. In the database, *Twist in the Wind* would be one MOVIE, and each copy would be a VIDEO. A rental transaction (RENTAL) involves one or more videos being rented to a member (MEMBERSHIP). A video can be rented many times over its lifetime; therefore, there is an M:N relationship between RENTAL and VIDEO. DETAILRENTAL is the bridge table to resolve this relationship. The complete ERD is provided in [Figure P7.65](#).

65. Write the SQL code to create the table structures for the entities shown in [Figure P7.65](#). The structures should contain the attributes specified in the ERD. Use data types that are appropriate for the data that will need to be

stored in each attribute. Enforce primary key and foreign key constraints as indicated by the ERD.

FIGURE P7.65 The Ch07_MovieCo ERD



SOURCE: Course Technology/Cengage Learning

66. The following tables provide a very small portion of the data that will be kept in the database. These data need to be inserted into the database for testing purposes. Write the INSERT commands necessary to place the following data in the tables that were created in [Problem 65](#).

MEMBERSHIP							
MEM_NUM	MEM_FNAME	MEM_LNAME	MEM_STREET	MEM_CITY	MEM_STATE	MEM_ZIP	MEM_BALANCE
102	Tami	Dawson	2632 Takli Circle	Norene	TN	37136	11
103	Curt	Knight	4025 Cornell Court	Flatgap	KY	41219	6
104	Jamal	Melendez	788 East 145th Avenue	Quebeck	TN	38579	0
105	Iva	Mcclain	6045 Musket Ball Circle	Summit	KY	42783	15
106	Miranda	Parks	4469 Maxwell Place	Germantown	TN	38183	0
107	Rosario	Elliott	7578 Danner Avenue	Columbia	TN	38402	5
108	Mattie	Guy	4390 Evergreen Street	Lily	KY	40740	0
109	Clint	Ochoa	1711 Elm Street	Greeneville	TN	37745	10
110	Lewis	Rosales	4524 Southwind Circle	Counce	TN	38326	0
111	Stacy	Mann	2789 East Cook Avenue	Murfreesboro	TN	37132	8
112	Luis	Trujillo	7267 Melvin Avenue	Heiskell	TN	37754	3
113	Minnie	Gonzales	6430 Vasili Drive	Williston	TN	38076	0

RENTAL

RENT_NUM RENT_DATE MEM_NUM

1001 01-MAR-11 103

1002 01-MAR-11 105

1003 02-MAR-11 102

1004 02-MAR-11 110

1005 02-MAR-11 111

1006 02-MAR-11 107

1007 02-MAR-11 104

1008 03-MAR-11 105

1009 03-MAR-11 111

DETAILRENTAL					
RENT_NUM	VID_NUM	DETAIL_FEE	DETAIL_DUEDATE	DETAIL_RETURNDATE	DETAIL_DAILYLATEFEE
1001	34342	2	04-MAR-11	02-MAR-11	
1001	61353	2	04-MAR-11	03-MAR-11	1
1002	59237	3.5	04-MAR-11	04-MAR-11	3
1003	54325	3.5	04-MAR-11	09-MAR-11	3
1003	61369	2	06-MAR-11	09-MAR-11	1
1003	61388	0	06-MAR-11	09-MAR-11	1
1004	44392	3.5	05-MAR-11	07-MAR-11	3
1004	34367	3.5	05-MAR-11	07-MAR-11	3
1004	34341	2	07-MAR-11	07-MAR-11	1
1005	34342	2	07-MAR-11	05-MAR-11	1
1005	44397	3.5	05-MAR-11	05-MAR-11	3
1006	34366	3.5	05-MAR-11	04-MAR-11	3
1006	61367	2	07-MAR-11		1
1007	34368	3.5	05-MAR-11		3
1008	34369	3.5	05-MAR-11	05-MAR-11	3
1009	54324	3.5	05-MAR-11		3
1001	34366	3.5	04-MAR-11	02-MAR-11	3

VIDEO

VID_NUM VID_INDATE MOVIE_NUM

54321 18-JUN-10 1234

54324 **18-JUN-10** 1234

54325 **18-JUN-10** 1234

34341 **22-JAN-09** 1235

34342 **22-JAN-09** 1235

34366 **02-MAR-11** 1236

34367 **02-MAR-11** 1236

34368 **02-MAR-11** 1236

34369 **02-MAR-11** 1236

44392 **21-OCT-10** 1237

44397 **21-OCT-10** 1237

59237 **14-FEB-11** 1237

61388 25-JAN-09 1239

61353 28-JAN-08 1245

61354 28-JAN-08 1245

61367 30-JUL-10 1246

61369 30-JUL-10 1246

MOVIE					
MOVIE_NUM	MOVIE_TITLE	MOVIE_YEAR	MOVIE_COST	MOVIE_GENRE	PRICE_CODE
1234	The Cesar Family Christmas	2009	39.95	FAMILY	2
1235	Smokey Mountain Wildlife	2006	59.95	ACTION	1
1236	Richard Goodhope	2010	59.95	DRAMA	2
1237	Beatnik Fever	2009	29.95	COMEDY	2
1238	Constant Companion	2010	89.95	DRAMA	2
1239	Where Hope Dies	2000	25.49	DRAMA	3
1245	Time to Burn	2007	45.49	ACTION	1
1246	What He Doesn't Know	2008	58.29	COMEDY	1

PRICE			
PRICE_CODE	PRICE_DESCRIPTION	PRICE_RENTFEE	PRICE_DAILYRATEFEE
1	Standard	2	.1
2	New Release	3.5	.3
3	Discount	1.5	.1
4	Weekly Special	1	.5

For Questions 67–98, use the tables that were created in [Problem 65](#) and the data that were loaded into those tables in [Problem 66](#).

67. Write the SQL command to save the rows inserted in [Problem 66](#).
68. Write the SQL command to change the movie year for movie number 1245 to 2008.
69. Write the SQL command to change the price code for all action movies to price code 3.
70. Write a single SQL command to increase all price rental fee values by \$0.50.
71. Write the SQL command to save the changes made to the PRICE and MOVIE tables in [Problems 67–70](#).
72. Write a query to display the movie title, movie year, and movie genre for all movies. (The results are shown in [Figure P7.72](#).)

FIGURE P7.72 All movies

Movie_Title	Movie_Year	Movie_Genre
The Cesar Family Christmas	2009	FAMILY
Smokey Mountain Wildlife	2006	ACTION
Richard Goodhope	2010	DRAMA
Beatnik Fever	2009	COMEDY
Constant Companion	2010	DRAMA
Where Hope Dies	2000	DRAMA
Time to Burn	2008	ACTION
What He Doesn't Know	2008	COMEDY

SOURCE: Course Technology/Cengage Learning

73. Write a query to display the movie year, movie title, and movie cost sorted by movie year in descending order. (The results are shown in [Figure P7.73](#).)
-

FIGURE P7.73 Movies by year

Movie_Year	Movie_Title	Movie_Cost
2010	Constant Companion	89.95
2010	Richard Goodhope	59.95
2009	Beatnik Fever	29.95
2009	The Cesar Family Christmas	39.95
2008	What He Doesn't Know	58.29
2008	Time to Burn	45.49
2006	Smokey Mountain Wildlife	59.95
2000	Where Hope Dies	25.49

SOURCE: Course Technology/Cengage Learning

-
74. Write a query to display the movie title, movie year, and movie genre for all movies sorted by movie genre in ascending order, then sorted by movie year in descending order within genre. (The results are shown in [Figure P7.74](#).)
-

FIGURE P7.74 Movies with multicolumn sort

Movie_Title	Movie_Year	Movie_Genre
Time to Burn	2008	ACTION
Smokey Mountain Wildlife	2006	ACTION
Beatnik Fever	2009	COMEDY
What He Doesn't Know	2008	COMEDY
Constant Companion	2010	DRAMA
Richard Goodhope	2010	DRAMA
Where Hope Dies	2000	DRAMA
The Cesar Family Christmas	2009	FAMILY

SOURCE: Course Technology/Cengage Learning

-
75. Write a query to display the movie number, movie title, and price code for all movies with a title that starts with the letter *R*. (The results are shown in [Figure P7.75](#).)
-

FIGURE P7.75 Movie titles starting with *R*

Movie_Num	Movie_Title	Price_Code
1236	Richard Goodhope	2

SOURCE: Course Technology/Cengage Learning

76. Write a query to display the movie title, movie year, and movie cost for all movies that contain the word *hope* in the title. Sort the results in ascending order by title. (The results are shown in [Figure P7.76](#).)
-

FIGURE P7.76 Movies with *hope* in the title

Movie_Title	Movie_Year	Movie_Cost
Richard Goodhope	2010	59.95
Where Hope Dies	2000	25.49

SOURCE: Course Technology/Cengage Learning

77. Write a query to display the movie title, movie year, and movie genre for all action movies. (The results are shown in [Figure P7.77](#).)
-

FIGURE P7.77 Action movies

Movie_Title	Movie_Year	Movie_Genre
Smokey Mountain Wildlife	2006	ACTION
Time to Burn	2008	ACTION

SOURCE: Course Technology/Cengage Learning

-
78. Write a query to display the movie number, movie title, and movie cost for all movies that cost more than \$40. (The results are shown in [Figure P7.78](#).)
79. Write a query to display the movie number, movie title, movie cost, and movie genre for all action or comedy movies that cost less than \$50. Sort the results in ascending order by genre. (The results are shown in [Figure P7.79](#).)
-

FIGURE P7.78 Movies that cost more than \$40

Movie_Num	Movie_Title	Movie_Cost
1235	Smokey Mountain Wildlife	59.95
1236	Richard Goodhope	59.95
1238	Constant Companion	89.95
1245	Time to Burn	45.49
1246	What He Doesn't Know	58.29

SOURCE: Course Technology/Cengage Learning

FIGURE P7.79 Action or comedy movies that cost less than \$50

Movie_Num	Movie_Title	Movie_Cost	Movie_Genre
1245	Time to Burn	45.49	ACTION
1237	Beatnik Fever	29.95	COMEDY

SOURCE: Course Technology/Cengage Learning

80. Write a query to display the movie number and movie description for all movies, where the movie description is a combination of the movie title, movie year, and movie genre, with the movie year enclosed in parentheses. (The results are shown in [Figure P7.80](#).)
-

FIGURE P7.80 Movies with concatenated descriptions

Movie_Num	Movie Description
1234	The Cesar Family Christmas (2009) FAMILY
1235	Smokey Mountain Wildlife (2006) ACTION
1236	Richard Goodhope (2010) DRAMA
1237	Beatnik Fever (2009) COMEDY
1238	Constant Companion (2010) DRAMA
1239	Where Hope Dies (2000) DRAMA
1245	Time to Burn (2008) ACTION
1246	What He Doesn't Know (2008) COMEDY

SOURCE: Course Technology/Cengage Learning

81. Write a query to display the movie genre and the number of movies in each genre. (The results are shown in [Figure P7.81](#).)
82. Write a query to display the average cost of all the movies. (The results are shown in [Figure P7.82](#).)

FIGURE P7.81 Number of movies in genre

Movie_Genre	Number of Movies
ACTION	2
COMEDY	2
DRAMA	3
FAMILY	1

SOURCE: Course Technology/Cengage Learning

FIGURE P7.82 Average movie cost

Average Movie Cost

51.1275

SOURCE: Course Technology/Cengage Learning

-
- 83. Write a query to display the movie genre and average cost of movies in each genre. (The results are shown in [Figure P7.83](#).)
 - 84. Write a query to display the movie title, movie genre, price description, and price rental fee for all movies with a price code. (The results are shown in [Figure P7.84](#).)
-

FIGURE P7.83 Average movie cost by genre

Movie_Genre	Average Cost
ACTION	52.72
COMEDY	44.12
DRAMA	58.46
FAMILY	39.95

SOURCE: Course Technology/Cengage Learning

FIGURE P7.84 Rental fees for movies

Movie_Title	Movie_Genre	Price_Description	Price_RentFee
What He Doesn't Know	COMEDY	Standard	2.5
The Cesar Family Christmas	FAMILY	New Release	4
Richard Goodhope	DRAMA	New Release	4
Beatnik Fever	COMEDY	New Release	4
Smokey Mountain Wildlife	ACTION	Discount	2
Where Hope Dies	DRAMA	Discount	2
Time to Burn	ACTION	Discount	2

SOURCE: Course Technology/Cengage Learning

85. Write a query to display the movie genre and average rental fee for movies in each genre that have a price. (The results are shown in [Figure P7.85](#).)
-
-

FIGURE P7.85 Average rental fee by genre

Movie_Genre	Average Rental Fee
ACTION	2
COMEDY	3.25
DRAMA	3
FAMILY	4

SOURCE: Course Technology/Cengage Learning

86. Write a query to display the movie title, movie year, and breakeven amount for each movie that has a price. The breakeven amount is the movie cost divided by the price rental fee for each movie that has a price; it determines the number of rentals needed to break even on the purchase of the movie. (The results are shown in [Figure P7.86](#).)
-
-

FIGURE P7.86 Breakeven rentals

Movie_Title	Movie_Year	Breakeven Rentals
What He Doesn't Know	2008	23.32
The Cesar Family Christmas	2009	9.99
Richard Goodhope	2010	14.99
Beatnik Fever	2009	7.49
Smokey Mountain Wildlife	2006	29.98
Where Hope Dies	2000	12.75
Time to Burn	2008	22.75

SOURCE: Course Technology/Cengage Learning

-
87. Write a query to display the movie title and movie year for all movies that have a price code. (The results are shown in [Figure P7.87](#).)
-

FIGURE P7.87 Movies with a price

Movie_Title	Movie_Year
The Cesar Family Christmas	2009
Smokey Mountain Wildlife	2006
Richard Goodhope	2010
Beatnik Fever	2009
Where Hope Dies	2000
Time to Burn	2008
What He Doesn't Know	2008

SOURCE: Course Technology/Cengage Learning

88. Write a query to display the movie title, movie year, and movie cost for all movies that cost between \$44.99 and \$49.99. (The results are shown in [Figure P7.88](#).)
-

FIGURE P7.88 Movie costs within a range

Movie_Title	Movie_Year	Movie_Cost
Time to Burn	2008	45.49

SOURCE: Course Technology/Cengage Learning

89. Write a query to display the movie title, movie year, price description, and price rental fee for all movies that are in the genres of family, comedy, or drama. (The results are shown in [Figure P7.89](#).)
-

FIGURE P7.89 Movies with specific genres

Movie_Title	Movie_Year	Price_Description	Price_RentFee	Movie_Genre
The Cesar Family Christmas	2009	New Release	4	FAMILY
Richard Goodhope	2010	New Release	4	DRAMA
Beatnik Fever	2009	New Release	4	COMEDY
Where Hope Dies	2000	Discount	2	DRAMA
What He Doesn't Know	2008	Standard	2.5	COMEDY

SOURCE: Course Technology/Cengage Learning

90. Write a query to display the movie number, movie title, and movie year for all movies that do not have a video. (The results are shown in [Figure P7.90](#).)

FIGURE P7.90 Movies without videos

Movie_Num	Movie_Title	Movie_Year
1238	Constant Companion	2010

SOURCE: Course Technology/Cengage Learning

91. Write a query to display the membership number, first name, last name, and balance of the memberships that have a rental. (The results are shown in [Figure P7.91](#).)
92. Write a query to display the minimum balance, maximum balance, and average balance for memberships that have a rental. (The results are shown in [Figure P7.92](#).)

FIGURE P7.91 Balances of memberships with rentals

--	--	--

Mem_Num	Mem_FName	Mem_LName	Mem_Balance
102	Tami	Dawson	11
103	Curt	Knight	6
104	Jamal	Melendez	0
105	Iva	McClain	15
107	Rosario	Elliott	5
110	Lewis	Rosales	0
111	Stacy	Mann	8

SOURCE: Course Technology/Cengage Learning

FIGURE P7.92 Minimum, maximum, and average balances

Minimum Balance	Maximum Balance	Average Balance
0	15	6.43

SOURCE: Course Technology/Cengage Learning

93. Write a query to display the membership name and membership address. The membership name is a concatenation of the first name and last name with a space added between them in a single column. The membership address is a concatenation of the street, city, state, and zip code into a single column with spaces. (The results are shown in [Figure P7.93](#).)
-

FIGURE P7.93 Concatenated membership data

Membership Name	Membership Address
Tami Dawson	2632 Takli Circle, Norene, TN 37136
Curt Knight	4025 Cornell Court, Flatgap, KY 41219
Jamal Melendez	788 East 145th Avenue, Quebeck, TN 38579
Iva McClain	6045 Musket Ball Circle, Summit, KY 42783
Miranda Parks	4469 Maxwell Place, Germantown, TN 38183
Rosario Elliott	7578 Danner Avenue, Columbia, TN 38402
Mattie Guy	4390 Evergreen Street, Lily, KY 40740
Clint Ochoa	1711 Elm Street, Greenville, TN 37745
Lewis Rosales	4524 SouthWind Circle, Counce, TN 38326
Stacy Mann	2789 East Cook Avenue, Murfreesboro, TN 37132
Luis Trujillo	7267 Melvin Avenue, Heiskell, TN 37754
Minnie Gonzales	6430 Vasili Drive, Williston, TN 38076

SOURCE: Course Technology/Cengage Learning

94. Write a query to display the rental number, rental date, video number, movie title, due date, and return date for all videos that were returned after the due date. Sort the results by rental number and movie title. (The results are shown in [Figure P7.94](#).)
-

FIGURE P7.94 Late video returns

Rent_Num	Rent_Date	Vid_Num	Movie_Title	Detail_DueDate	Detail_ReturnDate
1003	02-Mar-11	54325	The Cesar Family Christmas	04-Mar-11	09-Mar-11
1003	02-Mar-11	61369	What He Doesn't Know	06-Mar-11	09-Mar-11
1003	02-Mar-11	61388	Where Hope Dies	06-Mar-11	09-Mar-11
1004	02-Mar-11	44392	Beatnik Fever	05-Mar-11	07-Mar-11
1004	02-Mar-11	34367	Richard Goodhope	05-Mar-11	07-Mar-11

SOURCE: Course Technology/Cengage Learning

95. Write a query to display the rental number, rental date, video number, movie title, due date, return date, detail fee, and number of days past due for each video that was returned after the due date. Sort the results by rental number and movie title. (The results are shown in [Figure P7.95](#).)
-

FIGURE P7.95 Number of days late

Rent_Num	Rent_Date	Vid_Num	Movie_Title	Detail_DueDate	Detail_ReturnDate	Detail_Fee	Days Past Due
1003	02-Mar-11	54325	The Cesar Family Christmas	04-Mar-11	09-Mar-11	3.5	5
1003	02-Mar-11	61369	What He Doesn't Know	06-Mar-11	09-Mar-11	2	3
1003	02-Mar-11	61388	Where Hope Dies	06-Mar-11	09-Mar-11	0	3
1004	02-Mar-11	44392	Beatnik Fever	05-Mar-11	07-Mar-11	3.5	2
1004	02-Mar-11	34367	Richard Goodhope	05-Mar-11	07-Mar-11	3.5	2

SOURCE: Course Technology/Cengage Learning

96. Write a query to display the rental number, rental date, movie title, and detail fee for each movie that was returned on or before the due date. (The results are shown in [Figure P7.96](#).)

FIGURE P7.96 Actual rental fees charged

Rent_Num	Rent_Date	Movie_Title	Detail_Fee
1001	01-Mar-11	Smokey Mountain Wildlife	2
1001	01-Mar-11	Time to Burn	2
1002	01-Mar-11	Beatnik Fever	3.5
1004	02-Mar-11	Smokey Mountain Wildlife	2
1005	02-Mar-11	Smokey Mountain Wildlife	2
1005	02-Mar-11	Beatnik Fever	3.5
1006	02-Mar-11	Richard Goodhope	3.5
1008	03-Mar-11	Richard Goodhope	3.5
1001	01-Mar-11	Richard Goodhope	3.5

SOURCE: Course Technology/Cengage Learning

97. Write a query to display the membership number, last name, first name, and total rental fees earned from that membership. (The results are shown in [Figure P7.97](#).) The total rental fee is the sum of all detail fees (without late fees) from all movies the member has rented.

FIGURE P7.97 Total rental fees paid by membership

Mem_Num	Mem_LName	Mem_FName	Rental Fee Revenue
102	Dawson	Tami	5.5
103	Knight	Curt	7.5
104	Melendez	Jamal	3.5
105	McClain	Iva	7
107	Elliott	Rosario	5.5
110	Rosales	Lewis	9
111	Mann	Stacy	9

SOURCE: Course Technology/Cengage Learning

98. Write a query to display the movie number, movie genre, average cost of movies in that genre, cost of the individual movie, and the percentage difference between the average movie cost and the individual movie cost. The results are shown in [Figure P7.98](#). The percentage difference is the cost of the individual movie minus the average cost of movies in that genre, divided by the average cost of movies in that genre multiplied by 100. For example, if the average cost of movies in the family genre is \$25 and a given family movie costs \$26, then the calculation would be $((26 - 25) / 25 * 100)$, or 4.00 percent. In this case, the individual movie costs 4 percent more than the average family movie.

FIGURE P7.98 Movie differences from genre average

Movie_Num	Movie_Genre	Average Cost	Movie_Cost	Percent Difference
1234	FAMILY	39.95	39.95	0.00
1235	ACTION	52.72	59.95	13.71
1236	DRAMA	58.46	59.95	2.54
1237	COMEDY	44.12	29.95	-32.12
1238	DRAMA	58.46	89.95	53.86
1239	DRAMA	58.46	25.49	-56.40
1245	ACTION	52.72	45.49	-13.71
1246	COMEDY	44.12	58.29	32.12

SOURCE: Course Technology/Cengage Learning

8 ADVANCED SQL

In this chapter, you will learn:

- How to use the advanced SQL JOIN operator syntax
 - About the different types of subqueries and correlated queries
 - How to use SQL functions to manipulate dates, strings, and other data
 - About the relational set operators UNION, UNION ALL, INTERSECT, and MINUS
 - How to create and use views and updatable views
 - How to create and use triggers and stored procedures
 - How to create embedded SQL
-

Preview

In [Chapter 7](#), Introduction to Structured Query Language (SQL), you learned the basic SQL data definition and data manipulation commands used to create and manipulate relational data. In this chapter, you build on that knowledge and learn how to use more advanced SQL features.

In this chapter, you will learn about the SQL relational set operators (UNION, INTERSECT, and MINUS) and how they are used to merge the results of multiple queries. Joins are at the heart of SQL, so you must learn how to use the SQL JOIN statement to extract information from multiple tables. In the previous chapter, you learned how cascading queries inside other queries can be useful in certain circumstances. In this chapter, you will also learn about the different styles of subqueries you can implement in a SELECT statement. Finally, you will learn more of SQL's many functions to extract information from data, including manipulation of dates and strings and computations based on stored or even derived data.

In the real world, business procedures require the execution of clearly defined actions when a specific event occurs, such as the addition of a new invoice or a student's enrollment in a class. Such procedures can be applied within the

DBMS through the use of triggers and stored procedures. In addition, SQL facilitates the application of business procedures when it is embedded in a programming language such as Visual Basic .NET, C#, or COBOL.



ONLINE CONTENT

Although most of the examples used in this chapter are shown in Oracle, you could also use MS SQL Server. The Website for this book, www.cengagebrain.com, provides you with the **ADVSQldbInit.SQL** script file (Oracle and MS SQL versions) to create the tables and load the data used in this chapter. There you will also find additional SQL script files to demonstrate each of the commands shown in this chapter.

8.1 SQL JOIN OPERATORS

The relational join operation merges rows from two tables and returns the rows with one of the following conditions:

- Have common values in common columns (natural join).
- Meet a given join condition (equality or inequality).
- Have common values in common columns or have no matching values (outer join).

In [Chapter 7](#), you learned how to use the SELECT statement in conjunction with the WHERE clause to join two or more tables. For example, you can join the PRODUCT and VENDOR tables through their common V_CODE by writing the following:

```
SELECT P_CODE, P_DESCRIP, P_PRICE, V_NAME  
FROM   PRODUCT, VENDOR  
WHERE  PRODUCT.V_CODE = VENDOR.V_CODE;
```

The preceding SQL join syntax is sometimes referred to as an “old-style” join.

Note that the FROM clause contains the tables being joined and that the WHERE clause contains the condition(s) used to join the tables.

Note the following points about the preceding query:

- The FROM clause indicates which tables are to be joined. If three or more tables are included, the join operation takes place two tables at a time, from left to right. For example, if you are joining tables [T1](#), [T2](#), and [T3](#), the first join is table [T1](#) with [T2](#); the results of that join are then joined to table [T3](#).
- The join condition in the WHERE clause tells the SELECT statement which rows will be returned. In this case, the SELECT statement returns all rows for which the V_CODE values in the PRODUCT and VENDOR tables are equal.
- The number of join conditions is always equal to the number of tables being joined minus one. For example, if you join three tables ([T1](#), [T2](#), and [T3](#)), you will have two join conditions (j1 and j2). All join conditions are connected through an AND logical operator. The first join condition (j1) defines the join criteria for [T1](#) and [T2](#). The second join condition (j2) defines the join criteria for the output of the first join and [T3](#).
- Generally, the join condition will be an equality comparison of the primary key in one table and the related foreign key in the second table.

Join operations can be classified as inner joins and outer joins. The [**inner join**](#) is the traditional join in which only rows that meet a given criterion are selected. The join criterion can be an equality condition (also called a natural join or an equijoin) or an inequality condition (also called a theta join). An [**outer join**](#) returns not only the matching rows but the rows with unmatched attribute values for one table or both tables to be joined. The SQL standard also introduces a special type of join, called a cross join, that returns the same result as the Cartesian product of two sets or tables.

In this section, you will learn various ways to express join operations that meet the ANSI SQL standard, as outlined in [Table 8.1](#). Remember that not all DBMS vendors provide the same level of SQL support and that some do not support the

join styles shown in this section. Oracle 11g is used to demonstrate the following queries; refer to your DBMS manual if you are using a different DBMS.

TABLE 8.1 SQL Join Expression Styles

JOIN CLASSIFICATION	JOIN TYPE	SQL SYNTAX EXAMPLE	DESCRIPTION
CROSS	CROSS JOIN	SELECT * FROM T1, T2	Returns the Cartesian product of T1 and T2 (old style)
		SELECT * FROM T1 CROSS JOIN T2	Returns the Cartesian product of T1 and T2
INNER	Old-style JOIN	SELECT * FROM T1, T2 WHERE T1.C1=T2.C1	Returns only the rows that meet the join condition in the WHERE clause (old style); only rows with matching values are selected
	NATURAL JOIN	SELECT * FROM T1 NATURAL JOIN T2	Returns only the rows with matching values in the matching columns; the matching columns must have the same names and similar data types
	JOIN USING	SELECT * FROM T1 JOIN T2 USING (C1)	Returns only the rows with matching values in the columns indicated in the USING clause
OUTER	JOIN ON	SELECT * FROM T1 JOIN T2 ON T1.C1=T2.C1	Returns only the rows that meet the join condition indicated in the ON clause
	LEFT JOIN	SELECT * FROM T1 LEFT OUTER JOIN T2 ON T1.C1=T2.C1	Returns rows with matching values and includes all rows from the left table (T1) with unmatched values
OUTER	RIGHT JOIN	SELECT * FROM T1 RIGHT OUTER JOIN T2 ON T1.C1=T2.C1	Returns rows with matching values and includes all rows from the right table (T2) with unmatched values
	FULL JOIN	SELECT * FROM T1 FULL OUTER JOIN T2 ON T1.C1=T2.C1	Returns rows with matching values and includes all rows from both tables (T1 and T2) with unmatched values

8.1.1 CROSS JOIN

A [cross join](#) performs a relational product (also known as the Cartesian product) of two tables. The cross join syntax is:

`SELECT column-list FROM table1 CROSS JOIN table2`

For example, the following command:

`SELECT * FROM INVOICE CROSS JOIN LINE;`

performs a cross join of the INVOICE and LINE tables that generates 144 rows.

(There are 8 invoice rows and 18 line rows, yielding $8 \times 18 = 144$ rows.)

You can also perform a cross join that yields only specified attributes. For example, you can specify:

```
SELECT    INVOICE.INV_NUMBER, CUS_CODE, INV_DATE, P_CODE  
FROM      INVOICE CROSS JOIN LINE;
```

The results generated through that SQL statement can also be generated by using the following syntax:

```
SELECT    INVOICE.INV_NUMBER, CUS_CODE, INV_DATE, P_CODE  
FROM      INVOICE, LINE;
```

8.1.2 NATURAL JOIN

Recall from [Chapter 3](#) that a natural join returns all rows with matching values in the matching columns and eliminates duplicate columns. This style of query is used when the tables share one or more common attributes with common names. The natural join syntax is:

```
SELECT column-list FROM table1 NATURAL JOIN table2
```

The natural join will perform the following tasks:

- Determine the common attribute(s) by looking for attributes with identical names and compatible data types.
- Select only the rows with common values in the common attribute(s).
- If there are no common attributes, return the relational product of the two tables.

The following example performs a natural join of the CUSTOMER and INVOICE tables and returns only selected attributes:

```
SELECT    CUS_CODE, CUS_LNAME, INV_NUMBER, INV_DATE  
FROM      CUSTOMER NATURAL JOIN INVOICE;
```

The SQL code and its results are shown at the top of [Figure 8.1](#).

You are not limited to two tables when performing a natural join. For example, you can perform a natural join of the INVOICE, LINE, and PRODUCT tables

and project only selected attributes by writing the following:

```
SELECT      INV_NUMBER, P_CODE, P_DESCRIP, LINE_UNITS,  
LINE_PRICE  
FROM      INVOICE NATURAL JOIN LINE NATURAL JOIN PRODUCT;
```

The SQL code and its results are shown at the bottom of [Figure 8.1](#).

One important difference between the natural join and the old-style join syntax is that the natural join does not require the use of a table qualifier for the common attributes. In the first natural join example, you projected CUS_CODE. However, the projection did not require any table qualifier, even though the CUS_CODE attribute appears in both the CUSTOMER and INVOICE tables. The same can be said of the INV_NUMBER attribute in the second natural join example.

FIGURE 8.1 NATURAL JOIN results

```

SQL> SELECT CUS_CODE, CUS_LNAME, INU_NUMBER, INU_DATE
  2  FROM CUSTOMER NATURAL JOIN INVOICE;

CUS_CODE CUS_LNAME      INU_NUMBER INU_DATE
-----  -----
10011  Dunne            1008 17-JAN-12
10011  Dunne            1004 17-JAN-12
10011  Dunne            1002 16-JAN-12
10012  Smith             1003 16-JAN-12
10014  Orlando           1006 17-JAN-12
10014  Orlando           1001 16-JAN-12
10015  O'Brian            1007 17-JAN-12
10018  Farris             1005 17-JAN-12

8 rows selected.

SQL> SELECT INU_NUMBER, P_CODE, P_DESCRPT, LINE_UNITS, LINE_PRICE
  2  FROM INVOICE NATURAL JOIN LINE NATURAL JOIN PRODUCT;

INU_NUMBER P_CODE      P_DESCRPT        LINE_UNITS LINE_PRICE
-----  -----
1001 13-Q2/P2    7.25-in. pwr. saw blade      1       14.99
1001 23109-HB    Claw hammer                   1       9.95
1002 54778-2T    Rat-tail file, 1/8-in. fine     2       4.99
1003 2238/QPD    B&D cordless drill, 1/2-in.      1       38.95
1003 1546-QQ2    Hrd. cloth, 1/4-in., 2x50        1       39.95
1003 13-Q2/P2    7.25-in. pwr. saw blade      5       14.99
1004 54778-2T    Rat-tail file, 1/8-in. fine     3       4.99
1004 23109-HB    Claw hammer                   2       9.95
1005 PUC23DRT    PUC pipe, 3.5-in., 8-ft        12      5.87
1006 SN-18277    1.25-in. metal screw, 25       3       6.99
1006 2232/QTY    B&D jigsaw, 12-in. blade       1      109.92
1006 23109-HB    Claw hammer                   1       9.95
1006 89-WRE-0    Hicut chain saw, 16 in.        1      256.99
1007 13-Q2/P2    7.25-in. pwr. saw blade      2       14.99
1007 54778-2T    Rat-tail file, 1/8-in. fine     1       4.99
1008 PUC23DRT    PUC pipe, 3.5-in., 8-ft        5       5.87
1008 WR3/TT3     Steel matting, 4'x8'x1/6", .5" mesh 3      119.95
1008 23109-HB    Claw hammer                   1       9.95

18 rows selected.

SQL>

```

SOURCE: Course Technology/Cengage Learning

8.1.3 JOIN USING CLAUSE

A second way to express a join is through the **USING** keyword. The query returns only the rows with matching values in the column indicated in the **USING** clause—and that column must exist in both tables. The syntax is:

SELECT column-list FROM table1 JOIN table2 USING (common-column)

To see the **JOIN USING** query in action, perform a join of the **INVOICE** and **LINE** tables by writing the following:

```

SELECT           INV_NUMBER, P_CODE, P_DESCRIP, LINE_UNITS,
LINE_PRICE
FROM      INVOICE JOIN LINE USING (INV_NUMBER) JOIN PRODUCT
USING (P_CODE);

```

The SQL statement produces the results shown in [Figure 8.2](#).

FIGURE 8.2 JOIN USING results

INV_NUMBER	P_CODE	P_DESCRIP	LINE_UNITS	LINE_PRICE
1001	13-Q2/P2	7.25-in. pwr. saw blade	1	14.99
1001	23109-HB	Claw hammer	1	9.95
1002	54778-2T	Rat-tail file, 1/8-in. fine	2	4.99
1003	2238/QPD	B&D cordless drill, 1/2-in.	1	38.95
1003	1546-QQ2	Hrd. cloth, 1/4-in., 2x50	1	39.95
1003	13-Q2/P2	7.25-in. pwr. saw blade	5	14.99
1004	54778-2T	Rat-tail file, 1/8-in. fine	3	4.99
1004	23109-HB	Claw hammer	2	9.95
1005	PUC23DRT	PUC pipe, 3.5-in., 8-ft	12	5.87
1006	SM-18277	1.25-in. metal screw, 25	3	6.99
1006	2232/QTY	B&D jigsaw, 12-in. blade	1	109.92
1006	23109-HB	Claw hammer	1	9.95
1006	89-WRE-Q	Hicut chain saw, 16 in.	1	256.99
1007	13-Q2/P2	7.25-in. pwr. saw blade	2	14.99
1007	54778-2T	Rat-tail file, 1/8-in. fine	1	4.99
1008	PUC23DRT	PUC pipe, 3.5-in., 8-ft	5	5.87
1008	WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	3	119.95
1008	23109-HB	Claw hammer	1	9.95

18 rows selected.

SQL>

SOURCE: Course Technology/Cengage Learning

As with the NATURAL JOIN command, the JOIN USING operand does not require table qualifiers. As a matter of fact, Oracle will return an error if you specify the table name in the USING clause.

8.1.4 JOIN ON CLAUSE

The previous two join styles use common attribute names in the joining tables.

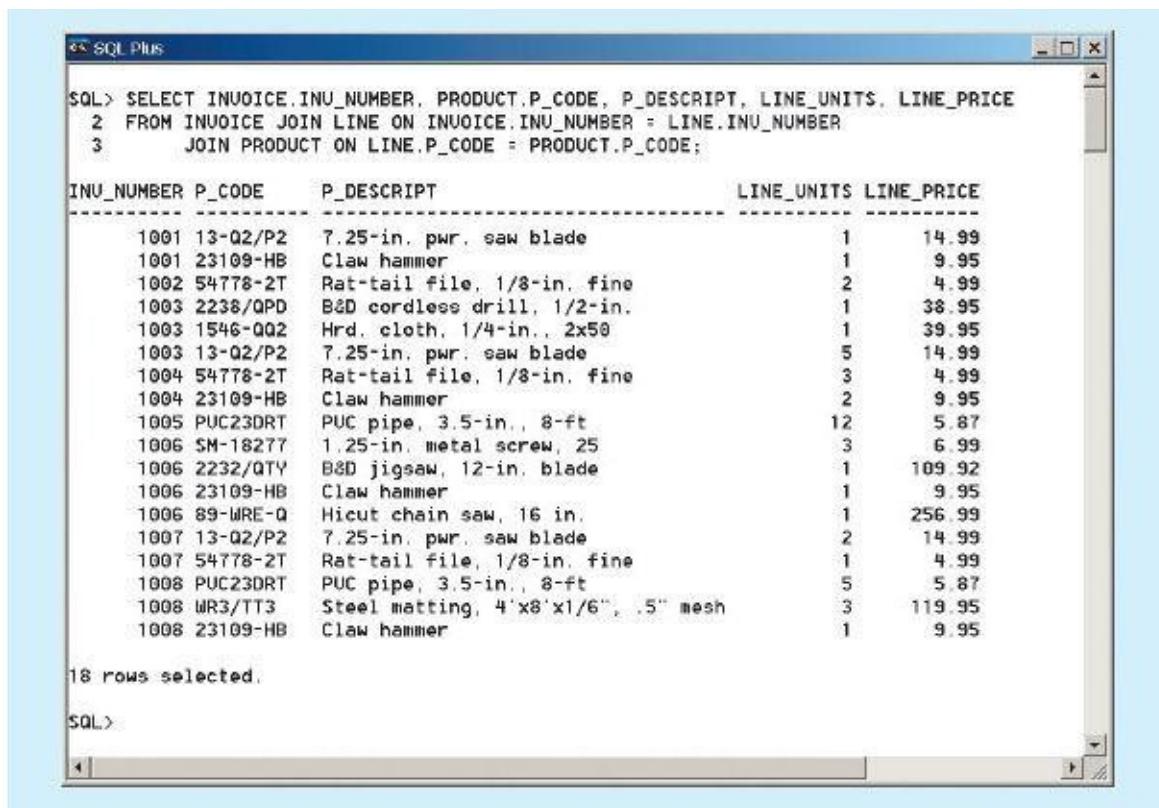
Another way to express a join when the tables have no common attribute names is to use the JOIN ON operand. The query will return only the rows that meet the indicated join condition. The join condition will typically include an equality comparison expression of two columns. (The columns may or may not share the same name, but obviously they must have comparable data types.) The syntax is:

`SELECT column-list FROM table1 JOIN table2 ON join-condition`

The following example performs a join of the INVOICE and LINE tables using the ON clause. The result is shown in [Figure 8.3](#).

```
SELECT      INVOICE.INV_NUMBER, PRODUCT.P_CODE, P_DESCRIP,
LINE_UNITS, LINE_PRICE
FROM          INVOICE JOIN LINE ON INVOICE.INV_NUMBER =
LINE.INV_NUMBER
                JOIN PRODUCT ON LINE.P_CODE = PRODUCT.P_CODE;
```

FIGURE 8.3 JOIN ON results



The screenshot shows the SQL Plus command-line interface. The command entered is:

```
SQL> SELECT INVOICE.INV_NUMBER, PRODUCT.P_CODE, P_DESCRIP,
2   FROM INVOICE JOIN LINE ON INVOICE.INV_NUMBER = LINE.INV_NUMBER
3   JOIN PRODUCT ON LINE.P_CODE = PRODUCT.P_CODE;
```

The resulting output is a table with the following data:

INV_NUMBER	P_CODE	P_DESCRIP	LINE_UNITS	LINE_PRICE
1001	13-Q2/P2	7.25-in. pwr. saw blade	1	14.99
1001	23109-HB	Claw hammer	1	9.95
1002	54778-2T	Rat-tail file, 1/8-in. fine	2	4.99
1003	2238/QPD	B&D cordless drill, 1/2-in.	1	38.95
1003	1546-QQ2	Hrd. cloth, 1/4-in., 2x50	1	39.95
1003	13-Q2/P2	7.25-in. pwr. saw blade	5	14.99
1004	54778-2T	Rat-tail file, 1/8-in. fine	3	4.99
1004	23109-HB	Claw hammer	2	9.95
1005	PUC23DRT	PUC pipe, 3.5-in., 8-ft	12	5.87
1006	SM-18277	1.25-in. metal screw, 25	3	6.99
1006	2232/QTY	B&D jigsaw, 12-in. blade	1	109.92
1006	23109-HB	Claw hammer	1	9.95
1006	89-WRE-Q	Hicut chain saw, 16 in.	1	256.99
1007	13-Q2/P2	7.25-in. pwr. saw blade	2	14.99
1007	54778-2T	Rat-tail file, 1/8-in. fine	1	4.99
1008	PUC23DRT	PUC pipe, 3.5-in., 8-ft	5	5.87
1008	WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	3	119.95
1008	23109-HB	Claw hammer	1	9.95

18 rows selected.

```
SQL>
```

Unlike the NATURAL JOIN and JOIN USING operands, the JOIN ON clause requires a table qualifier for the common attributes. If you do not specify the table qualifier, you will get a “column ambiguously defined” error message.

Keep in mind that the JOIN ON syntax lets you perform a join even when the tables do not share a common attribute name. For example, to generate a list of all employees with the managers’ names, you can use the following (recursive) query:

```
SELECT      E.EMP_MGR, M.EMP_LNAME, E.EMP_NUM,  
           E.EMP_LNAME  
FROM        EMP E JOIN EMP M ON E.EMP_MGR = M.EMP_NUM  
ORDER BY    E.EMP_MGR;
```

8.1.5 OUTER JOINS

An outer join returns not only the rows matching the join condition (that is, rows with matching values in the common columns), it returns the rows with unmatched values. The ANSI standard defines three types of outer joins: left, right, and full. The left and right designations reflect the order in which the tables are processed by the DBMS. Remember that join operations take place two tables at a time. The first table named in the FROM clause will be the left side, and the second table named will be the right side. If three or more tables are being joined, the result of joining the first two tables becomes the left side, and the third table becomes the right side.

The left outer join returns not only the rows matching the join condition (that is, rows with matching values in the common column), it returns the rows in the left table with unmatched values in the right table. The syntax is:

```
SELECT  column-list  
FROM    table1 LEFT [OUTER] JOIN table2 ON join-condition
```

For example, the following query lists the product code, vendor code, and vendor name for all products and includes those vendors with no matching products:

```
SELECT P_CODE, VENDOR.V_CODE, V_NAME  
FROM VENDOR LEFT JOIN PRODUCT ON VENDOR.V_CODE =  
PRODUCT.V_CODE;
```

The preceding SQL code and its results are shown in [Figure 8.4](#).

FIGURE 8.4 LEFT JOIN results

The screenshot shows an SQL Plus window with the following content:

```
SQL> SELECT P_CODE, VENDOR.V_CODE, V_NAME  
2 FROM VENDOR LEFT JOIN PRODUCT ON VENDOR.V_CODE = PRODUCT.V_CODE;  
  
P_CODE          V_CODE V_NAME  
-----  
11QER/31      25595 Rubicon Systems  
13-02/P2       21344 Gomez Bros.  
14-01/L3       21344 Gomez Bros.  
1546-QQ2      23119 Randeets Ltd.  
1558-QW1      23119 Randeets Ltd.  
2232/QTY       24288 ORDUA, Inc.  
2232/QUE       24288 ORDUA, Inc.  
2238/QPD       25595 Rubicon Systems  
23109-HB      21225 Bryson, Inc.  
54778-ZT       21344 Gomez Bros.  
89-WRE-Q       24288 ORDUA, Inc.  
SM-18277      21225 Bryson, Inc.  
SW-23116      21231 Dome Supply  
WR3/TT3       25595 Rubicon Systems  
              22567 Dome Supply  
              21226 SuperLoo, Inc.  
              24004 Brackman Bros.  
              25501 Damal Supplies  
              25443 BSK, Inc.  
  
19 rows selected.  
SQL>
```

SOURCE: Course Technology/Cengage Learning

The right outer join returns not only the rows matching the join condition (that is, rows with matching values in the common column), it returns the rows in the right table with unmatched values in the left table. The syntax is:

```
SELECT column-list  
FROM table1 RIGHT [OUTER] JOIN table2 ON join-condition
```

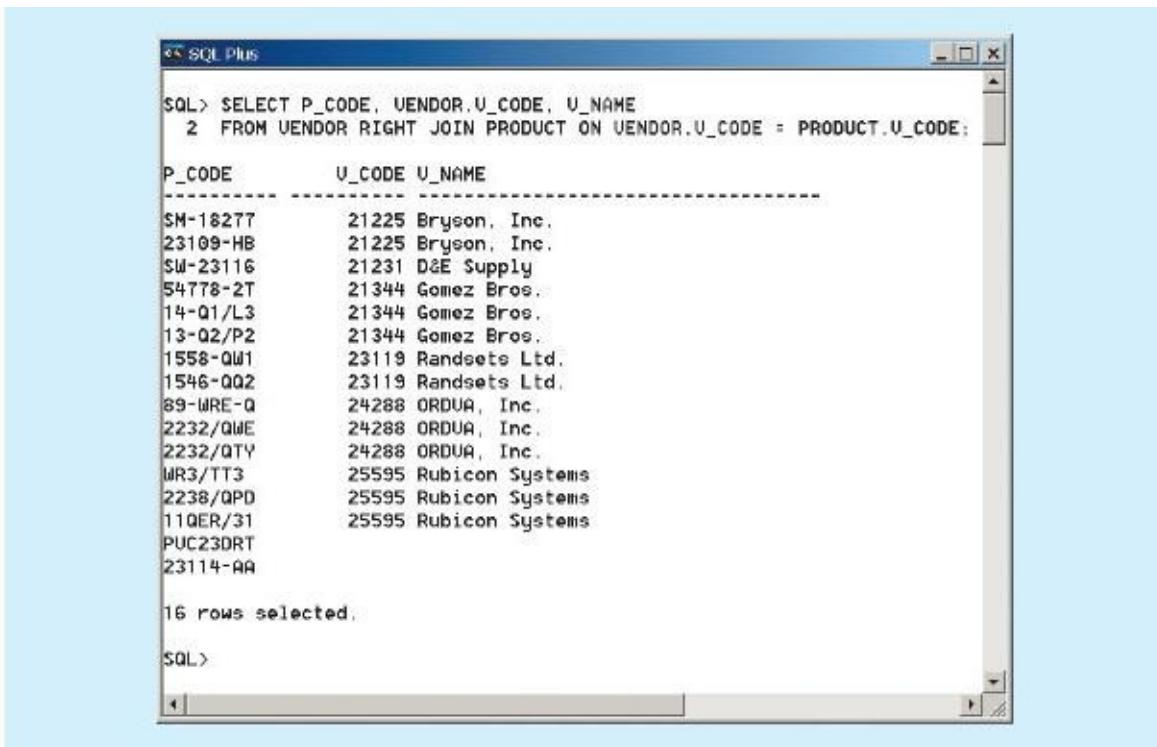
For example, the following query lists the product code, vendor code, and vendor name for all products and includes products that do not have a matching

vendor code:

```
SELECT P_CODE, VENDOR.V_CODE, V_NAME  
FROM VENDOR RIGHT JOIN PRODUCT ON VENDOR.V_CODE =  
PRODUCT.V_CODE;
```

The SQL code and its output are shown in [Figure 8.5](#).

FIGURE 8.5 RIGHT JOIN results



The screenshot shows an SQL Plus window with the following content:

```
SQL> SELECT P_CODE, VENDOR.V_CODE, V_NAME  
2 FROM VENDOR RIGHT JOIN PRODUCT ON VENDOR.V_CODE = PRODUCT.V_CODE;  
  
P_CODE      V_CODE V_NAME  
-----  
SM-18277    21225 Bryson, Inc.  
23109-HB    21225 Bryson, Inc.  
SU-23116    21231 D&E Supply  
54778-2T    21344 Gomez Bros.  
14-Q1/L3    21344 Gomez Bros.  
13-Q2/P2    21344 Gomez Bros.  
1558-QW1    23119 Randsets Ltd.  
1546-QQ2    23119 Randsets Ltd.  
89-WRE-Q    24288 ORDUA, Inc.  
2232/QWE    24288 ORDUA, Inc.  
2232/QTY    24288 ORDUA, Inc.  
WR3/TT3     25595 Rubicon Systems  
2238/QPD    25595 Rubicon Systems  
11QER/31    25595 Rubicon Systems  
PUC23DRT  
23114-AA  
  
16 rows selected.  
  
SQL>
```

SOURCE: Course Technology/Cengage Learning

The full outer join returns not only the rows matching the join condition (that is, rows with matching values in the common column), it returns all of the rows with unmatched values in the table on either side. The syntax is:

```
SELECT column-list  
FROM table1 FULL [OUTER] JOIN table2 ON join-condition
```

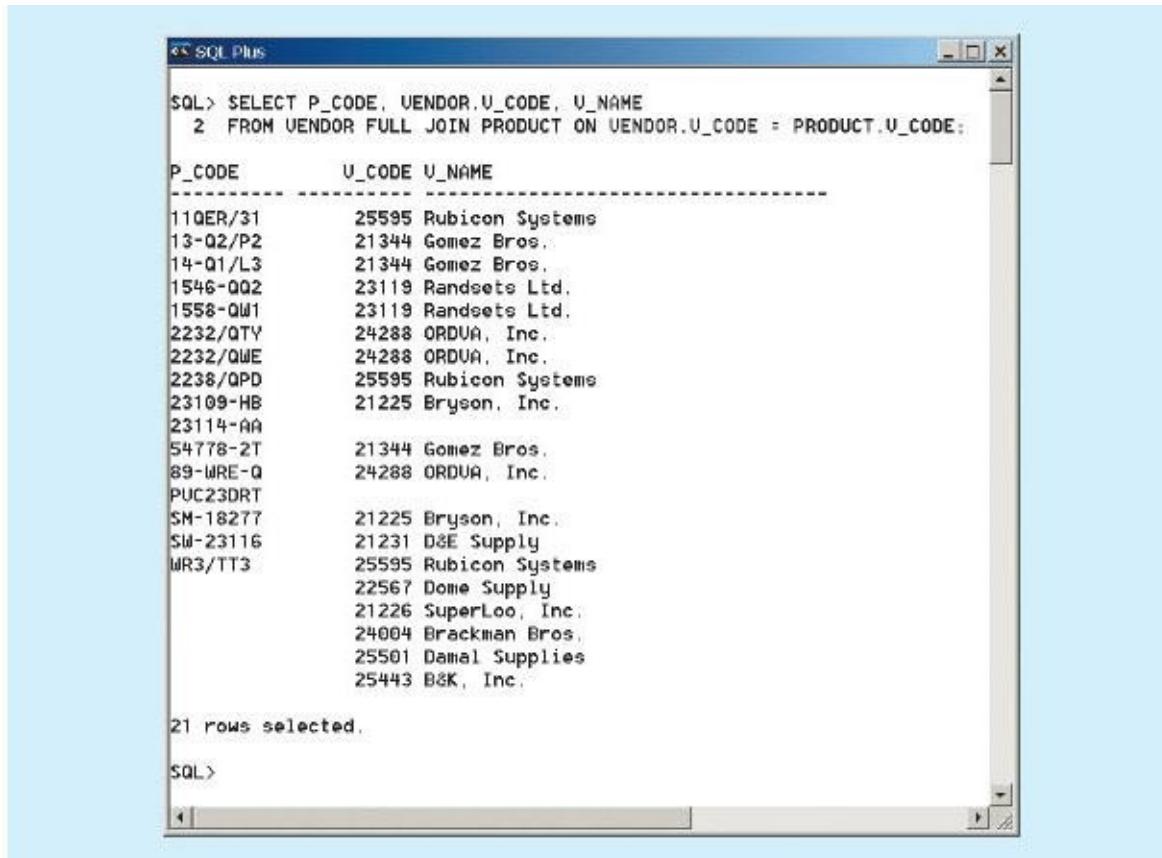
For example, the following query lists the product code, vendor code, and vendor name for all products and includes all product rows (products without

matching vendors) as well as all vendor rows (vendors without matching products):

```
SELECT P_CODE, VENDOR.V_CODE, V_NAME  
FROM VENDOR FULL JOIN PRODUCT ON VENDOR.V_CODE =  
PRODUCT.V_CODE;
```

The SQL code and its results are shown in [Figure 8.6](#).

FIGURE 8.6 FULL JOIN results



The screenshot shows an SQL Plus window with the following content:

```
SQL> SELECT P_CODE, VENDOR.V_CODE, V_NAME  
  2 FROM VENDOR FULL JOIN PRODUCT ON VENDOR.V_CODE = PRODUCT.V_CODE;  
  
P_CODE      U_CODE V_NAME  
-----  
11QER/31    25595 Rubicon Systems  
13-Q2/P2    21344 Gomez Bros.  
14-01/L3    21344 Gomez Bros.  
1546-QQ2    23119 Randsets Ltd.  
1558-QW1    23119 Randsets Ltd.  
2232/QTY    24288 ORDUA, Inc.  
2232/QWE    24288 ORDUA, Inc.  
2238/QPD    25595 Rubicon Systems  
23109-HB   21225 Bryson, Inc.  
23114-AA    21344 Gomez Bros.  
54778-2T    24288 ORDUA, Inc.  
89-WRE-Q    21225 Bryson, Inc.  
PUC23DRT  
SM-18277    21231 D&E Supply  
SW-23116    25595 Rubicon Systems  
WR3/TT3     22567 Dome Supply  
             21226 SuperLoo, Inc.  
             24004 Brackman Bros.  
             25501 Damal Supplies  
             25443 B&K, Inc.  
  
21 rows selected.  
SQL>
```

SOURCE: Course Technology/Cengage Learning

8.2 SUBQUERIES AND CORRELATED QUERIES

The use of joins in a relational database allows you to get information from two or more tables. For example, the following query allows you to get customer data with their respective invoices by joining the CUSTOMER and INVOICE tables.

```
SELECT           INV_NUMBER, INVOICE.CUS_CODE, CUS_LNAME,  
CUS_FNAME  
FROM    CUSTOMER, INVOICE  
WHERE   CUSTOMER.CUS_CODE = INVOICE.CUS_CODE;
```

In the previous query, the data from both tables (CUSTOMER and INVOICE) are processed at once, matching rows with shared CUS_CODE values.

However, it is often necessary to process data based on *other* processed data. For example, suppose that you want to generate a list of vendors who do not provide products. (Recall that not all vendors in the VENDOR table have provided products—some are only *potential* vendors.) In [Chapter 7](#), you learned that you could generate such a list by writing the following query:

```
SELECT  V_CODE, V_NAME FROM VENDOR  
WHERE   V_CODE NOT IN (SELECT V_CODE FROM PRODUCT);
```

Similarly, to generate a list of all products with a price greater than or equal to the average product price, you can write the following query:

```
SELECT  P_CODE, P_PRICE FROM PRODUCT  
WHERE   P_PRICE >= (SELECT AVG(P_PRICE) FROM PRODUCT);
```

In both queries, you needed to get information that was not previously known:

- What vendors provide products?
- What is the average price of all products?

In both cases, you used a subquery to generate the required information, which could then be used as input for the originating query.

You learned how to use subqueries in [Chapter 7](#); review their basic characteristics:

- A subquery is a query (SELECT statement) inside a query.

- A subquery is normally expressed inside parentheses.
- The first query in the SQL statement is known as the outer query.
- The query inside the SQL statement is known as the inner query.
- The inner query is executed first.
- The output of an inner query is used as the input for the outer query.
- The entire SQL statement is sometimes referred to as a nested query.

In this section, you learn more about the practical use of subqueries. You already know that a subquery is based on the use of the SELECT statement to return one or more values to another query, but subqueries have a wide range of uses. For example, you can use a subquery within a SQL data manipulation language (DML) statement such as INSERT, UPDATE, or DELETE, in which a value or list of values (such as multiple vendor codes or a table) is expected. [Table 8.2](#) uses simple examples to summarize the use of SELECT subqueries in DML statements.

TABLE 8.2 SELECT Subquery Examples

SELECT SUBQUERY EXAMPLES	EXPLANATION
<pre>INSERT INTO PRODUCT SELECT * FROM P;</pre>	Inserts all rows from Table P into the PRODUCT table. Both tables must have the same attributes. The subquery returns all rows from Table P.
<pre>UPDATE PRODUCT SET P_PRICE = (SELECT AVG(P_PRICE) FROM PRODUCT) WHERE V_CODE IN (SELECT V_CODE FROM VENDOR WHERE V_AREACODE = '615')</pre>	Updates the product price to the average product price, but only for products provided by vendors who have an area code equal to 615. The first subquery returns the average price; the second subquery returns the list of vendors with an area code equal to 615.
<pre>DELETE FROM PRODUCT WHERE V_CODE IN (SELECT V_CODE FROM VENDOR WHERE V_AREACODE = '615')</pre>	Deletes the PRODUCT table rows provided by vendors with an area code equal to 615. The subquery returns the list of vendor codes with an area code equal to 615.

Using the examples in [Table 8.2](#), note that the subquery is always on the right side of a comparison or assigning expression. Also, a subquery can return one or more values. To be precise, the subquery can return the following:

- *One single value (one column and one row).* This subquery is used anywhere a single value is expected, as in the right side of a comparison expression. An example is the preceding UPDATE subquery, in which you assigned the average price to the product's price. Obviously, when you assign a value to an attribute, you are assigning a single value, not a list of them. Therefore, the subquery must return only one value (one column, one row). If the query returns multiple values, the DBMS will generate an error.
- *A list of values (one column and multiple rows).* This type of subquery is used anywhere a list of values is expected, such as when using the IN clause—for example, when comparing the vendor code to a list of vendors. Again, in this case, there is only one column of data with multiple value instances. This type of subquery is used frequently in combination with the IN operator in a WHERE conditional expression.
- *A virtual table (multicolumn, multirow set of values).* This type of subquery can be used anywhere a table is expected, such as when using the FROM clause. You will see an example later in this chapter.

It is important to note that a subquery can return no values at all; it is a NULL. In such cases, the output of the outer query might result in an error or a null empty set, depending on where the subquery is used (in a comparison, an expression, or a table set).

In the following sections, you will learn how to write subqueries within the SELECT statement to retrieve data from the database.

8.2.1 WHERE SUBQUERIES

The most common type of subquery uses an inner SELECT subquery on the right side of a WHERE comparison expression. For example, to find all products with a price greater than or equal to the average product price, you write the following query:

```
SELECT P_CODE, P_PRICE FROM PRODUCT
```

```
WHERE    P_PRICE >= (SELECT AVG(P_PRICE) FROM PRODUCT);
```

The output of the preceding query is shown in [Figure 8.7](#). Note that this type of query, when used in a $>$, $<$, $=$, \geq , or \leq conditional expression, requires a subquery that returns only one value (one column, one row). The value generated by the subquery must be of a comparable data type; if the attribute to the left of the comparison symbol is a character type, the subquery must return a character string. Also, if the query returns more than a single value, the DBMS will generate an error.

Subqueries can also be used in combination with joins. For example, the following query lists all customers who ordered a claw hammer:

```
SELECT    DISTINCT CUS_CODE, CUS_LNAME, CUS_FNAME
FROM      CUSTOMER  JOIN INVOICE USING (CUS_CODE)
          JOIN LINE USING (INV_NUMBER)
          JOIN PRODUCT USING (P_CODE)
WHERE     P_CODE = (SELECT P_CODE FROM PRODUCT WHERE
P_DESCRIP = 'Claw hammer');
```

The result of the query is shown in [Figure 8.7](#).

FIGURE 8.7 WHERE subquery examples

```

SQL> SELECT P_CODE, P_PRICE FROM PRODUCT
2 WHERE P_PRICE >= (SELECT AVG(P_PRICE) FROM PRODUCT);

P_CODE          P_PRICE
-----          -----
11QER/31        109.99
2232/QTY        109.92
2232/QME        99.87
89-WRE-Q        256.99
MR3/TT3         119.95

SQL> SELECT DISTINCT CUS_CODE, CUS_LNAME, CUS_FNAME
2  FROM CUSTOMER JOIN INVOICE USING (CUS_CODE)
3      JOIN LINE USING (INV_NUMBER)
4      JOIN PRODUCT USING (P_CODE)
5 WHERE P_CODE = (SELECT P_CODE FROM PRODUCT WHERE P_DESCRIPTOR = 'Claw hammer');

CUS_CODE CUS_LNAME      CUS_FNAME
-----  -----
10011  Dunne           Leona
10014  Orlando         Myron

SQL>

```

SOURCE: Course Technology/Cengage Learning

In the preceding example, the inner query finds the P_CODE for the claw hammer. The P_CODE is then used to restrict the selected rows to those in which the P_CODE in the LINE table matches the P_CODE for “Claw hammer.” Note that the previous query could have been written this way:

```

SELECT    DISTINCT CUS_CODE, CUS_LNAME, CUS_FNAME
FROM      CUSTOMER  JOIN INVOICE USING (CUS_CODE)
          JOIN LINE USING (INV_NUMBER)
          JOIN PRODUCT USING (P_CODE)
WHERE    P_DESCRIPTOR = 'Claw hammer';

```

If the original query encounters the “Claw hammer” string in more than one product description, you get an error message. To compare one value to a list of values, you must use an IN operand, as shown in the next section.

8.2.2 IN SUBQUERIES

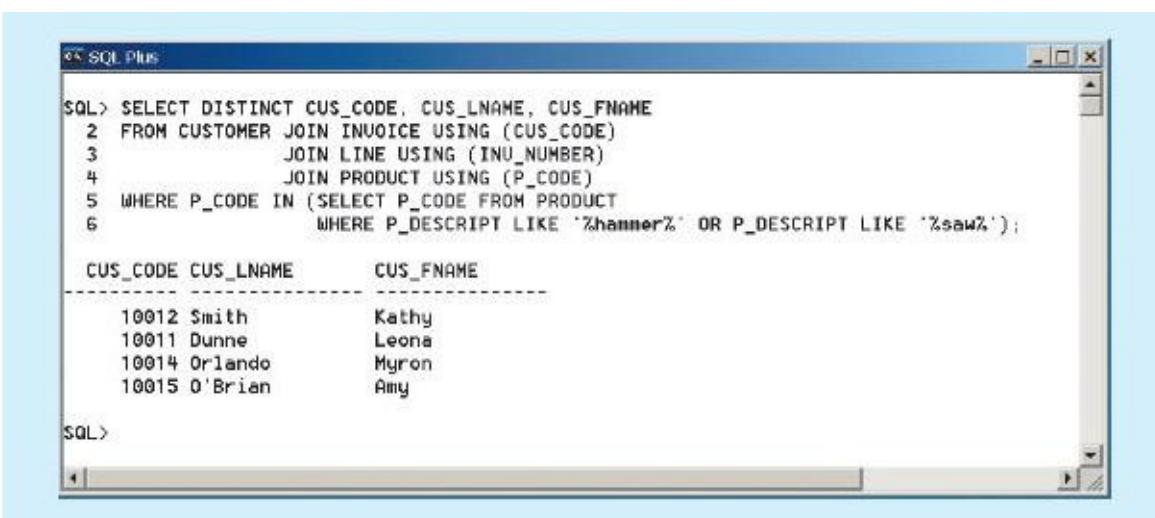
What if you wanted to find all customers who purchased a hammer or any kind of saw or saw blade? Note that the product table has two different types of hammers: a claw hammer and a sledge hammer. Also, there are multiple occurrences of products that contain “saw” in their product descriptions,

including saw blades and jigsaws. In such cases, you need to compare the P_CODE not to one product code (a single value), but to a list of product code values. When you want to compare a single attribute to a list of values, you use the IN operator. When the P_CODE values are not known beforehand, but they can be derived using a query, you must use an IN subquery. The following example lists all customers who have purchased hammers, saws, or saw blades.

```
SELECT DISTINCT CUS_CODE, CUS_LNAME, CUS_FNAME
FROM CUSTOMER JOIN INVOICE USING (CUS_CODE)
                JOIN LINE USING (INV_NUMBER)
                JOIN PRODUCT USING (P_CODE)
WHERE P_CODE IN (SELECT P_CODE FROM PRODUCT
                  WHERE P_DESCRIP LIKE '%hammer%'
                  OR P_DESCRIP LIKE '%saw%');
```

The result of the query is shown in [Figure 8.8](#).

FIGURE 8.8 IN subquery example



A screenshot of the SQL*Plus application window. The title bar says "SQL*PLUS". The main area contains the following SQL code:

```
SQL> SELECT DISTINCT CUS_CODE, CUS_LNAME, CUS_FNAME
  2  FROM CUSTOMER JOIN INVOICE USING (CUS_CODE)
  3      JOIN LINE USING (INV_NUMBER)
  4      JOIN PRODUCT USING (P_CODE)
  5 WHERE P_CODE IN (SELECT P_CODE FROM PRODUCT
  6                   WHERE P_DESCRIP LIKE '%hammer%' OR P_DESCRIP LIKE '%saw%');

CUS_CODE CUS_LNAME      CUS_FNAME
-----  -----
10012  Smith          Kathy
10011  Dunne          Leona
10014  Orlando        Myron
10015  O'Brian        Amy
```

SOURCE: Course Technology/Cengage Learning

8.2.3 HAVING SUBQUERIES

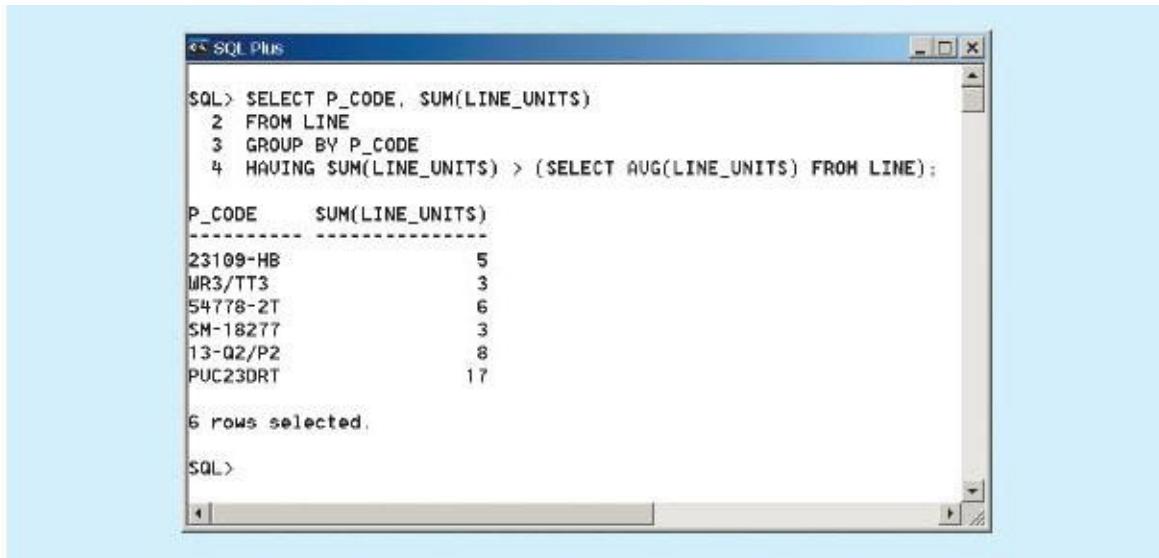
Just as you can use subqueries with the WHERE clause, you can use a subquery with a HAVING clause. The HAVING clause is used to restrict the output of a

GROUP BY query by applying conditional criteria to the grouped rows. For example, to list all products with a total quantity sold greater than the average quantity sold, you would write the following query:

```
SELECT      P_CODE, SUM(LINE_UNITS)
FROM        LINE
GROUP BY    P_CODE
HAVING      SUM(LINE_UNITS) > (SELECT AVG(LINE_UNITS) FROM
LINE);
```

The result of the query is shown in [Figure 8.9](#).

FIGURE 8.9 HAVING subquery example



The screenshot shows an Oracle SQL Plus window with the following content:

```
SQL> SELECT P_CODE, SUM(LINE_UNITS)
  2  FROM LINE
  3  GROUP BY P_CODE
  4  HAVING SUM(LINE_UNITS) > (SELECT AVG(LINE_UNITS) FROM LINE);

P_CODE      SUM(LINE_UNITS)
-----
23109-HB          5
MR3/TT3           3
S4778-2T          6
SM-18277          3
13-Q2/P2           8
PUC23DRT          17

6 rows selected.

SQL>
```

The window title is "SQL Plus". The command entered is a SELECT statement with a HAVING clause that includes a subquery to calculate the average line units. The output shows six rows of data, each with a product code and its sum of line units. The last line of the output indicates "6 rows selected".

SOURCE: Course Technology/Cengage Learning

8.2.4 MULTIROW SUBQUERY OPERATORS: ANY AND ALL

So far, you have learned that you must use an IN subquery to compare a value to a list of values. However, the IN subquery uses an equality operator; that is, it selects only those rows that are equal to at least one of the values in the list. What happens if you need to make an inequality comparison ($>$ or $<$) of one value to a list of values?

For example, suppose you want to know which products cost more than all individual products provided by vendors from Florida:

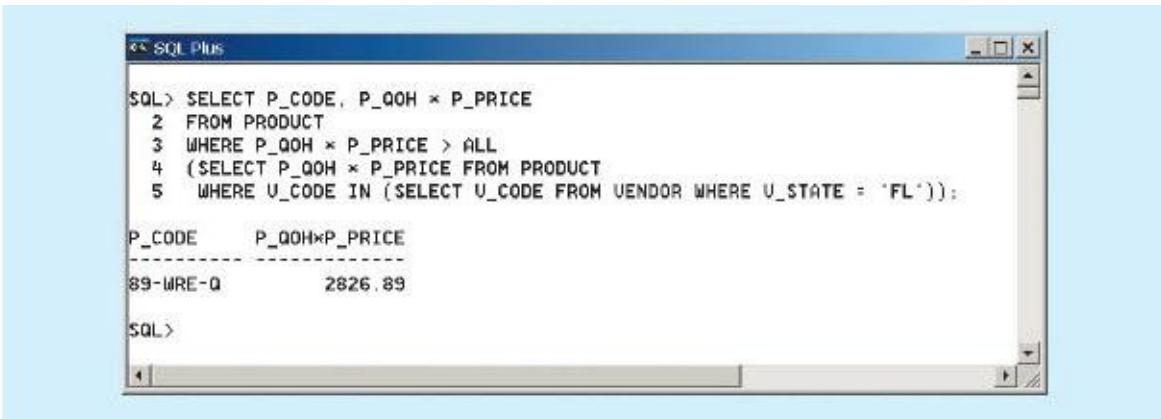
```
SELECT P_CODE, P_QOH * P_PRICE
FROM PRODUCT
WHERE P_QOH * P_PRICE > ALL (SELECT P_QOH * P_PRICE
                               FROM PRODUCT
                               WHERE V_CODE IN (SELECT V_CODE
                                                 FROM VENDOR
                                                 WHERE V_STATE = 'FL'));
```

The result of the query is shown in [Figure 8.10](#).

It is important to note the following points about the query and its output in [Figure 8.10](#):

- The query is a typical example of a nested query.
- The query has one outer SELECT statement with a SELECT subquery (call it sqA) that contains a second SELECT subquery (call it sqB).
- The last SELECT subquery (sqB) is executed first and returns a list of all vendors from Florida.
- The first SELECT subquery (sqA) uses the output of the second SELECT subquery (sqB). The sqA subquery returns the list of costs for all products provided by vendors from Florida.

FIGURE 8.10 Multirow subquery operator example



The screenshot shows a Windows application window titled "SQL Plus". Inside, a SQL command is being run:

```
SQL> SELECT P_CODE, P_QOH * P_PRICE
  2  FROM PRODUCT
  3 WHERE P_QOH * P_PRICE > ALL
  4  (SELECT P_QOH * P_PRICE FROM PRODUCT
  5  WHERE V_CODE IN (SELECT V_CODE FROM VENDOR WHERE V_STATE = 'FL'));
```

The output displays one row:

P_CODE	P_QOH*P_PRICE
89-WRE-Q	2826.89

SQL>

SOURCE: Course Technology/Cengage Learning

-
- The use of the ALL operator allows you to compare a single value ($P_QOH * P_PRICE$) with a list of values returned by the first subquery (sqA) using a comparison operator other than equals.
 - For a row to appear in the result set, it has to meet the criterion $P_QOH * P_PRICE > ALL$ of the individual values returned by the subquery sqA. The values returned by sqA are a list of product costs. In fact, “greater than ALL” is equivalent to “greater than the highest product cost of the list.” In the same way, a condition of “less than ALL” is equivalent to “less than the lowest product cost of the list.”

Another powerful operator is the ANY multirow operator, which you can consider the cousin of the ALL multirow operator. The ANY operator allows you to compare a single value to a list of values and select only the rows for which the inventory cost is greater than or less than any value in the list. You could use the equal to ANY operator, which would be the equivalent of the IN operator.

8.2.5 FROM SUBQUERIES

So far you have seen how the SELECT statement uses subqueries within WHERE, HAVING, and IN statements, and how the ANY and ALL operators are used for multirow subqueries. In all of those cases, the subquery was part of a conditional expression, and it always appeared at the right side of the expression. In this section, you will learn how to use subqueries in the FROM clause.

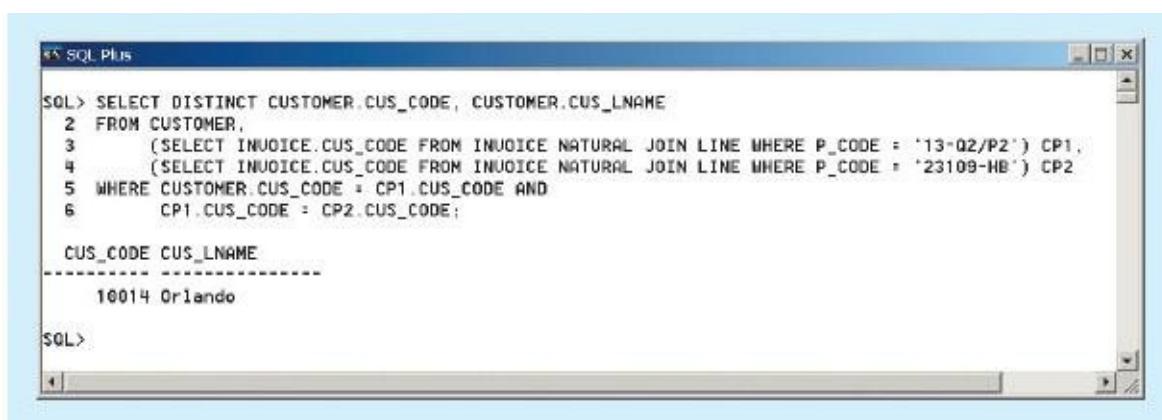
As you already know, the FROM clause specifies the table(s) from which the data will be drawn. Because the output of a SELECT statement is another table

(or more precisely, a “virtual” table), you could use a SELECT subquery in the FROM clause. For example, assume that you want to know all customers who have purchased products 13-Q2/ P2 *and* 23109-HB. All product purchases are stored in the LINE table, so you can easily find out who purchased any given product by searching the P_CODE attribute in the LINE table. In this case, however, you want to know all customers who purchased both products, not just one. You could write the following query:

```
SELECT           DISTINCT      CUSTOMER.CUS_CODE,  
CUSTOMER.CUS_LNAME  
FROM    CUSTOMER,  
        (SELECT INVOICE.CUS_CODE FROM INVOICE NATURAL  
JOIN LINE  
        WHERE P_CODE = '13-Q2/P2') CP1,  
        (SELECT INVOICE.CUS_CODE FROM INVOICE NATURAL  
JOIN LINE  
        WHERE P_CODE = '23109-HB') CP2  
WHERE          CUSTOMER.CUS_CODE  =  CP1.CUS_CODE  AND  
CP1.CUS_CODE = CP2.CUS_CODE;
```

The result of the query is shown in [Figure 8.11](#).

FIGURE 8.11 FROM subquery example



```
SQL> SELECT DISTINCT CUSTOMER.CUS_CODE, CUSTOMER.CUS_LNAME  
  2  FROM CUSTOMER,  
  3      (SELECT INVOICE.CUS_CODE FROM INVOICE NATURAL JOIN LINE WHERE P_CODE = '13-Q2/P2') CP1,  
  4      (SELECT INVOICE.CUS_CODE FROM INVOICE NATURAL JOIN LINE WHERE P_CODE = '23109-HB') CP2  
  5 WHERE CUSTOMER.CUS_CODE = CP1.CUS_CODE AND  
  6      CP1.CUS_CODE = CP2.CUS_CODE;  
  
CUS_CODE CUS_LNAME  
-----  
10014 Orlando  
  
SQL>
```

SOURCE: Course Technology/Cengage Learning

Note in [Figure 8.11](#) that the first subquery returns all customers who purchased

product 13-Q2/P2, while the second subquery returns all customers who purchased product 23109-HB. So, in this FROM subquery, you are joining the CUSTOMER table with two virtual tables. The join condition selects only the rows with matching CUS_CODE values in each table (base or virtual).

8.2.6 ATTRIBUTE LIST SUBQUERIES

The SELECT statement uses the attribute list to indicate what columns to project in the resulting set. Those columns can be attributes of base tables, computed attributes, or the result of an aggregate function. The attribute list can also include a subquery expression, also known as an inline subquery. A subquery in the attribute list must return one value; otherwise, an error code is raised. For example, a simple inline query can be used to list the difference between each product's price and the average product price:

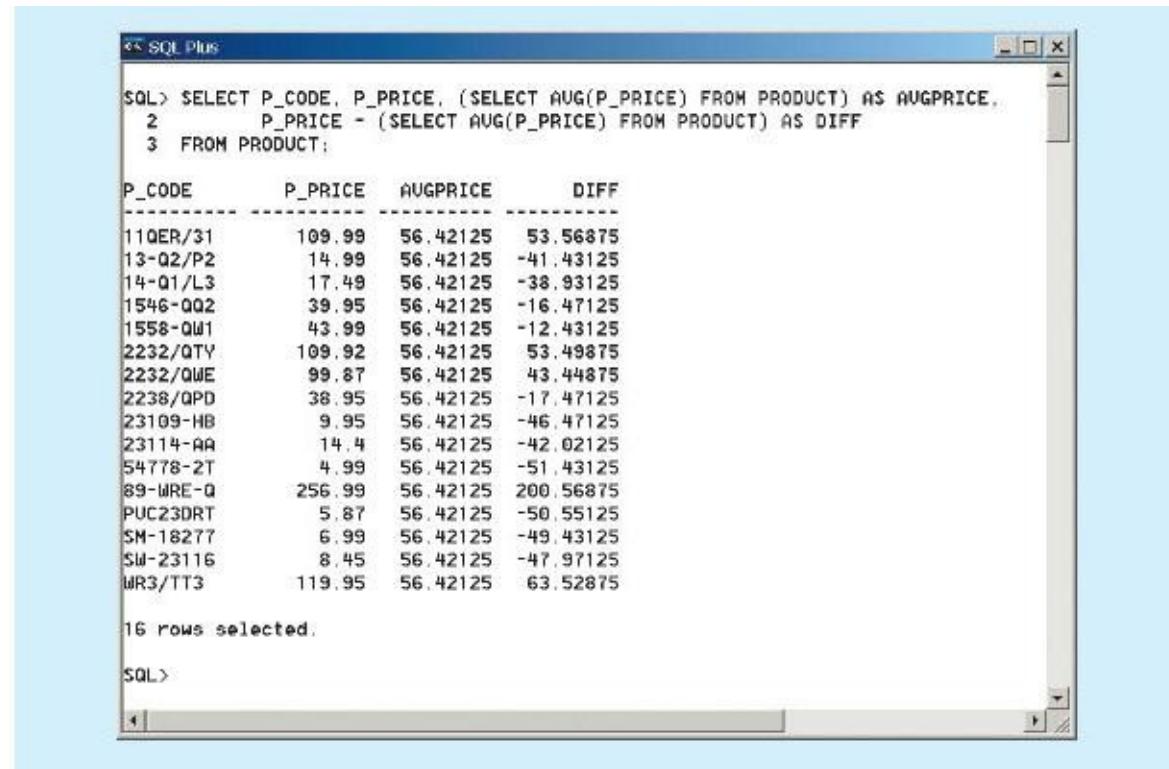
```
SELECT      P_CODE,  P_PRICE,  (SELECT  AVG(P_PRICE)  FROM
PRODUCT) AS AVGPRICE,
          P_PRICE - (SELECT AVG(P_PRICE) FROM PRODUCT) AS DIFF
FROM      PRODUCT;
```

[Figure 8.12](#) shows the result of the query.

In [Figure 8.12](#), note that the inline query output returns one value (the average product's price) and that the value is the same in every row. Note also that the query uses the full expression instead of the column aliases when computing the difference. In fact, if you try to use the alias in the difference expression, you will get an error message. The column alias cannot be used in computations in the attribute list when the alias is defined in the same attribute list. That DBMS requirement is the result of the way the DBMS parses and executes queries.

Another example will help you understand the use of attribute list subqueries and column aliases. For example, suppose that you want to know the product code, the total sales by product, and the contribution by employee of each product's sales. To get the sales by product, you need to use only the LINE table. To compute the contribution by employee, you need to know the number of employees (from the EMPLOYEE table). As you study the tables' structures, you can see that the LINE and EMPLOYEE tables do not share a common attribute. In fact, you do not need a common attribute.

FIGURE 8.12 Inline subquery example



The screenshot shows a window titled "SQL Plus". Inside, a SQL query is executed:

```
SQL> SELECT P_CODE, P_PRICE, (SELECT AVG(P_PRICE) FROM PRODUCT) AS AVGPRICE,
2      P_PRICE - (SELECT AVG(P_PRICE) FROM PRODUCT) AS DIFF
3  FROM PRODUCT;
```

The output displays 16 rows of data with columns: P_CODE, P_PRICE, AVGPRICE, and DIFF. The data includes various product codes and their prices, along with calculated average price and difference values.

P_CODE	P_PRICE	AVGPRICE	DIFF
11QER/31	109.99	56.42125	53.56875
13-Q2/P2	14.99	56.42125	-41.43125
14-Q1/L3	17.49	56.42125	-38.93125
1546-QQ2	39.95	56.42125	-16.47125
1558-QW1	43.99	56.42125	-12.43125
2232/QTY	109.92	56.42125	53.49875
2232/QWE	99.87	56.42125	43.44875
2238/QPD	38.95	56.42125	-17.47125
23109-HB	9.95	56.42125	-46.47125
23114-AA	14.4	56.42125	-42.02125
54778-2T	4.99	56.42125	-51.43125
69-WRE-Q	256.99	56.42125	200.56875
PUC23DRT	5.87	56.42125	-50.55125
SM-18277	6.99	56.42125	-49.43125
SW-23116	8.45	56.42125	-47.97125
WR3/TT3	119.95	56.42125	63.52875

16 rows selected.

SQL>

SOURCE: Course Technology/Cengage Learning

You only need to know the total number of employees, not the total employees related to each product. So, to answer the query, you would write the following code:

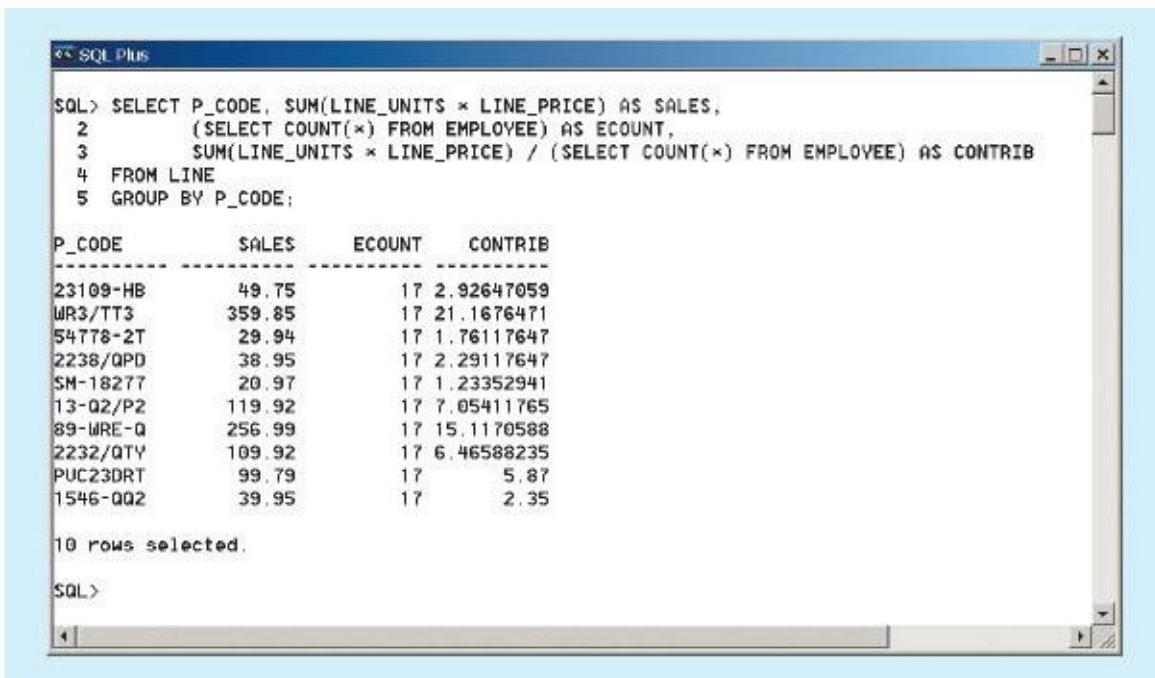
```
SELECT P_CODE, SUM(LINE_UNITS * LINE_PRICE) AS SALES,
       (SELECT COUNT(*) FROM EMPLOYEE) AS ECOUNT,
       SUM(LINE_UNITS * LINE_PRICE)/(SELECT COUNT() FROM
EMPLOYEE) AS CONTRIB
FROM   LINE
GROUP  BY P_CODE;
```

The result of the query is shown in [Figure 8.13](#).

As you can see in [Figure 8.13](#), the number of employees remains the same for each row in the result set. The use of this type of subquery is limited to certain instances when you need to include data from other tables that are not directly

related to a main table or tables in the query. The value will remain the same for each row, like a constant in a programming language. (You will learn another use of inline subqueries in [Section 8.2.7](#), Correlated Subqueries.) Note that you cannot use an alias in the attribute list to write the expression that computes the contribution per employee.

FIGURE 8.13 Another example of an inline subquery

A screenshot of a Windows application window titled "SQL*Plus". Inside the window, SQL code is entered and executed, resulting in a table of data. The SQL code is:

```
SQL> SELECT P_CODE, SUM(LINE_UNITS * LINE_PRICE) AS SALES,
  2       (SELECT COUNT(*) FROM EMPLOYEE) AS ECOUNT,
  3       SUM(LINE_UNITS * LINE_PRICE) / (SELECT COUNT(*) FROM EMPLOYEE) AS CONTRIB
  4  FROM LINE
  5 GROUP BY P_CODE;
```

The resulting data table is:

P_CODE	SALES	ECOUNT	CONTRIB
23109-HB	49.75	17	2.92647059
WR3/TT3	359.85	17	21.1676471
54778-2T	29.94	17	1.76117647
2238/QPD	38.95	17	2.29117647
SM-18277	20.97	17	1.23352941
13-QZ/PZ	119.92	17	7.05411765
89-WRE-Q	256.99	17	15.1170588
2232/QTY	109.92	17	6.46588235
PUC23DRT	99.79	17	5.87
1546-QQZ	39.95	17	2.35

10 rows selected.

SQL>

SOURCE: Course Technology/Cengage Learning

Another way to write the same query by using column aliases requires the use of a subquery in the FROM clause, as follows:

```
SELECT P_CODE, SALES, ECOUNT, SALES/ECOUNT AS CONTRIB
FROM     (SELECT P_CODE, SUM(LINE_UNITS * LINE_PRICE) AS SALES,
                  (SELECT COUNT(*) FROM EMPLOYEE) AS ECOUNT
                   FROM LINE
                   GROUP BY P_CODE);
```

In this case, you are actually using two subqueries. The subquery in the FROM

clause executes first and returns a virtual table with three columns: P_CODE, SALES, and ECOUNT. The FROM subquery contains an inline subquery that returns the number of employees as ECOUNT. Because the outer query receives the output of the inner query, you can now refer to the columns in the outer subquery by using the column aliases.

8.2.7 CORRELATED SUBQUERIES

Until now, all subqueries you have learned execute independently. That is, each subquery in a command sequence executes in a serial fashion, one after another. The inner subquery executes first; its output is used by the outer query, which then executes until the last outer query finishes (the first SQL statement in the code).

In contrast, a [correlated subquery](#) is a subquery that executes once for each row in the outer query. The process is similar to the typical nested loop in a programming language. For example:

```
FOR X = 1 TO 2
    FOR Y = 1 TO 3
        PRINT "X = "X, "Y = "Y
    END
END
```

will yield the output:

```
X = 1      Y = 1
X = 1      Y = 2
X = 1      Y = 3
X = 2      Y = 1
X = 2      Y = 2
X = 2      Y = 3
```

Note that the outer loop X = 1 TO 2 begins the process by setting X = 1, and then the inner loop Y = 1 TO 3 is completed for each X outer loop value. The relational DBMS uses the same sequence to produce correlated subquery results:

1. It initiates the outer query.

2. For each row of the outer query result set, it executes the inner query by passing the outer row to the inner query.

This process is the opposite of that of the subqueries, as you have already seen. The query is called a *correlated* subquery because the inner query is *related* to the outer query; the inner query references a column of the outer subquery.

To see the correlated subquery in action, suppose that you want to know all product sales in which the units sold value is greater than the average units sold value *for that product* (as opposed to the average for *all* products). In that case, the following procedure must be completed:

1. Compute the average units sold for a product.
2. Compare the average computed in Step 1 to the units sold in each sale row, and then select only the rows in which the number of units sold is greater.

The following correlated query completes the preceding two-step process:

```
SELECT    INV_NUMBER, P_CODE, LINE_UNITS
FROM      LINE LS
WHERE     LS.LINE_UNITS > (SELECT AVG(LINE_UNITS)
                           FROM LINE LA
                           WHERE LA.P_CODE = LS.P_CODE);
```

The first example in [Figure 8.14](#) shows the result of the query.

FIGURE 8.14 Correlated subquery examples

```
SQL> SELECT INV_NUMBER, P_CODE, LINE_UNITS
  2  FROM LINE LS
  3 WHERE LS.LINE_UNITS > (SELECT AVG(LINE_UNITS)
  4                           FROM LINE LA
  5                           WHERE LA.P_CODE = LS.P_CODE);

INV_NUMBER P_CODE      LINE_UNITS
-----  -----
1003 13-Q2/P2          5
1004 54778-2T           3
1004 23109-HB           2
1005 PUC23DRT            12

SQL> SELECT INV_NUMBER, P_CODE, LINE_UNITS,
  2        (SELECT AVG(LINE_UNITS) FROM LINE LX WHERE LX.P_CODE = LS.P_CODE) AS AUG
  3  FROM LINE LS
  4 WHERE LS.LINE_UNITS > (SELECT AVG(LINE_UNITS)
  5                           FROM LINE LA
  6                           WHERE LA.P_CODE = LS.P_CODE);

INV_NUMBER P_CODE      LINE_UNITS      AUG
-----  -----
1003 13-Q2/P2          5  2.66666667
1004 54778-2T           3              2
1004 23109-HB           2              1.25
1005 PUC23DRT            12             8.5
```

SOURCE: Course Technology/Cengage Learning

In the top query and its result in [Figure 8.14](#), note that the LINE table is used more than once, so you must use table aliases. In this case, the inner query computes the average units sold of the product that matches the P_CODE of the outer query P_CODE. That is, the inner query runs once, using the first product code found in the outer LINE table, and returns the average sale for that product. When the number of units sold in the outer LINE row is greater than the average computed, the row is added to the output. Then the inner query runs again, this time using the second product code found in the outer LINE table. The process repeats until the inner query has run for all rows in the outer LINE table. In this case, the inner query will be repeated as many times as there are rows in the outer query.

To verify the results and to provide an example of how you can combine subqueries, you can add a correlated inline subquery to the previous query. (See the second query and its results in [Figure 8.14](#).) As you can see, the new query contains a correlated inline subquery that computes the average units sold for each product. You not only get an answer, you can also verify that the answer is correct.

Correlated subqueries can also be used with the EXISTS special operator. For example, suppose that you want to know the names of all customers who have placed an order lately. In that case, you could use a correlated subquery like the first one shown in [Figure 8.15](#):

```
SELECT CUS_CODE, CUS_LNAME, CUS_FNAME
FROM CUSTOMER
WHERE EXISTS (SELECT CUS_CODE FROM INVOICE
               WHERE INVOICE.CUS_CODE =
                     CUSTOMER.CUS_CODE);
```

FIGURE 8.15 EXISTS correlated subquery examples

The screenshot shows a Windows application window titled "SQL*Plus". Inside, two SQL queries are run against a database:

```
SQL> SELECT CUS_CODE, CUS_LNAME, CUS_FNAME
  2  FROM CUSTOMER
  3 WHERE EXISTS (SELECT CUS_CODE FROM INVOICE
  4                   WHERE INVOICE.CUS_CODE = CUSTOMER.CUS_CODE);

    CUS_CODE CUS_LNAME      CUS_FNAME
    -----  -----
  10014  Orlando        Myron
  10011  Dunne          Leona
  10012  Smith          Kathy
  10018  Farriss        Anne
  10015  O'Brian        Amy

SQL> SELECT U_CODE, U_NAME FROM VENDOR
  2 WHERE EXISTS (SELECT x FROM PRODUCT
  3                   WHERE P_QOH < P_MIN * 2 AND
  4                   U_VENDOR.U_CODE = PRODUCT.U_CODE);

    U_CODE U_NAME
    ----- 
  21344 Gomez Bros.
  23119 Randsets Ltd.
  24288 ORDUA, Inc.
  25595 Rubicon Systems
```

SOURCE: Course Technology/Cengage Learning

The second example in [Figure 8.15](#) will help you understand how to use correlated queries. For example, suppose that you want to know what vendors you must contact to order products that are approaching the minimum quantity-on-hand value. In particular, you want to know the vendor code and vendor name for products with a quantity on hand that is less than double the minimum

quantity. The query that answers the question is as follows:

```
SELECT V_CODE, V_NAME
FROM VENDOR
WHERE EXISTS (SELECT *
               FROM PRODUCT
              WHERE P_QOH < P_MIN * 2
                AND VENDOR.V_CODE = PRODUCT.V_CODE);
```

In the second query in [Figure 8.15](#), note that:

1. The inner correlated subquery runs using the first vendor.
 2. If any products match the condition (the quantity on hand is less than double the minimum quantity), the vendor code and name are listed in the output.
 3. The correlated subquery runs using the second vendor, and the process repeats itself until all vendors are used.
-

8.3 SQL FUNCTIONS

The data in databases are the basis of critical business information. Generating information from data often requires many data manipulations. Sometimes such data manipulation involves the decomposition of data elements. For example, an employee's date of birth can be subdivided into a day, a month, and a year. A product manufacturing code (for example, SE-05-2-09-1234-1-3/12/04-19:26:48) can be designed to record the manufacturing region, plant, shift, production line, employee number, date, and time. For years, conventional programming languages have had special functions that enabled programmers to perform data transformations like the preceding data decompositions. If you know a modern programming language, it is very likely that the SQL functions in this section will look familiar.

SQL functions are very useful tools. You'll need to use functions when you want to list all employees ordered by year of birth, or when your marketing department wants you to generate a list of all customers ordered by zip code and the first three digits of their telephone numbers. In both of these cases, you'll need to use data elements that are not present as such in the database; instead, you will need a SQL function that can be derived from an existing attribute. Functions always use a numerical, date, or string value. The value may be part of

the command itself (a constant or literal) or it may be an attribute located in a table. Therefore, a function may appear anywhere in a SQL statement where a value or an attribute can be used.

There are many types of SQL functions, such as arithmetic, trigonometric, string, date, and time functions. This section will not explain all of these functions in detail, but it will give you a brief overview of the most useful ones.

NOTE

Although the main DBMS vendors support the SQL functions covered here, the syntax or degree of support will probably differ. In fact, DBMS vendors invariably add their own functions to products to lure new customers. The functions covered in this section represent just a small portion of functions supported by your DBMS. Read your DBMS SQL reference manual for a complete list of available functions.

8.3.1 DATE AND TIME FUNCTIONS

All SQL-standard DBMSs support date and time functions. All date functions take one parameter of a date or character data type and return a value (character, numeric, or date type). Unfortunately, date/time data types are implemented differently by different DBMS vendors. The problem occurs because the ANSI SQL standard defines date data types, but it does not specify how those data types are to be stored. Instead, it lets the vendor deal with that issue.

Because date/time functions differ from vendor to vendor, this section will cover basic date/time functions for MS Access, SQL Server, and Oracle. [Table 8.3](#) shows a list of selected MS Access and SQL Server date/time functions.

TABLE 8.3 Selected MS Access and SQL Server Date/Time Functions

FUNCTION	EXAMPLE(S)
YEAR Returns a four-digit year Syntax: <code>YEAR(date_value)</code>	Lists all employees born in 1966: <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_DOB, YEAR(EMP_DOB) AS YEAR FROM EMPLOYEE WHERE YEAR(EMP_DOB) = 1966;</pre>
MONTH Returns a two-digit month code Syntax: <code>MONTH(date_value)</code>	Lists all employees born in November: <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_DOB, MONTH(EMP_DOB) AS MONTH FROM EMPLOYEE WHERE MONTH(EMP_DOB) = 11;</pre>
DAY Returns the number of the day Syntax: <code>DAY(date_value)</code>	Lists all employees born on the 14th day of the month: <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_DOB, DAY(EMP_DOB) AS DAY FROM EMPLOYEE WHERE DAY(EMP_DOB) = 14;</pre>

DATE() MS Access GETDATE() SQL Server Returns today's date	<p>Lists how many days are left until Christmas:</p> <pre>SELECT #25-Dec-2012# - DATE();</pre> <p>Note two features:</p> <ul style="list-style-type: none"> • There is no <code>FROM</code> clause, which is acceptable in MS Access. • The Christmas date is enclosed in number signs (#) because you are doing date arithmetic. <p>In MS SQL Server:</p> <p>Use <code>GETDATE()</code> to get the current system date. To compute the difference between dates, use the <code>DATEDIFF</code> function (see below).</p>
DATEADD SQL Server Adds a number of selected time periods to a date Syntax: <code>DATEADD(datepart, number, date)</code>	<p>Adds a number of dateparts to a given date. Dateparts can be minutes, hours, days, weeks, months, quarters, or years. For example:</p> <pre>SELECT DATEADD(day,90, P_INDATE) AS DueDate FROM PRODUCT;</pre> <p>The preceding example adds 90 days to <code>P_INDATE</code>.</p> <p>In MS Access, use the following:</p> <pre>SELECT P_INDATE+90 AS DueDate FROM PRODUCT;</pre>
DATEDIFF SQL Server Subtracts two dates Syntax: <code>DATEDIFF(datepart, startdate, enddate)</code>	<p>Returns the difference between two dates expressed in a selected datepart.</p> <p>For example:</p> <pre>SELECT DATEDIFF(day, P_INDATE, GETDATE()) AS DaysAgo FROM PRODUCT;</pre> <p>In MS Access, use the following:</p> <pre>SELECT DATE() - P_INDATE AS DaysAgo FROM PRODUCT;</pre>

[Table 8.4](#) shows the equivalent date/time functions used in Oracle. Note that Oracle uses the same function (`TO_CHAR`) to extract the various parts of a date. Also, another function (`TO_DATE`) is used to convert character strings to a valid Oracle date format that can be used in date arithmetic.

TABLE 8.4 Selected Oracle Date/Time Functions

FUNCTION	EXAMPLE(S)
TO_CHAR Returns a character string or a formatted string from a date value Syntax: <code>TO_CHAR(date_value, fmt)</code> fmt = format used; can be: MONTH: name of month MON: three-letter month name MM: two-digit month name D: number for day of week DD: number for day of month DAY: name of day of week YYYY: four-digit year value YY: two-digit year value	<p>Lists all employees born in 1982:</p> <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_DOB, TO_CHAR(EMP_DOB, 'YYYY') AS YEAR FROM EMPLOYEE WHERE TO_CHAR(EMP_DOB, 'YYYY') = '1982';</pre> <p>Lists all employees born in November:</p> <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_DOB, TO_CHAR(EMP_DOB, 'MM') AS MONTH FROM EMPLOYEE WHERE TO_CHAR(EMP_DOB, 'MM') = '11';</pre> <p>Lists all employees born on the 14th day of the month:</p> <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_DOB, TO_CHAR(EMP_DOB, 'DD') AS DAY FROM EMPLOYEE WHERE TO_CHAR(EMP_DOB, 'DD') = '14';</pre>
TO_DATE Returns a date value using a character string and a date format mask; also used to translate a date between formats Syntax: <code>TO_DATE(char_value, fmt)</code> fmt = format used; can be: MONTH: name of month MON: three-letter month name MM: two-digit month name D: number for day of week DD: number for day of month DAY: name of day of week YYYY: four-digit year value YY: two-digit year value	<p>Lists the approximate age of employees on the company's tenth anniversary date (11/25/2012):</p> <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_DOB, '11/25/2012' AS ANIV_DATE, (TO_DATE('11/25/2002','MM/DD/YYYY') - EMP_DOB)/365 AS YEARS FROM EMPLOYEE ORDER BY YEARS;</pre> <p>Note the following:</p> <ul style="list-style-type: none"> • '11/25/2012' is a text string, not a date. • The TO_DATE function translates the text string to a valid Oracle date used in date arithmetic. <p>How many days are there between Thanksgiving and Christmas 2012?</p> <pre>SELECT TO_DATE('2012/12/25','YYYY/MM/DD') - TO_DATE('NOVEMBER 27, 2012','MONTH DD, YYYY') FROM DUAL;</pre> <p>Note the following:</p> <ul style="list-style-type: none"> • The TO_DATE function translates the text string to a valid Oracle date used in date arithmetic. • DUAL is Oracle's pseudo-table, used only for cases in which a table is not really needed.

SYSDATE Returns today's date	<p>Lists how many days are left until Christmas:</p> <pre>SELECT TO_DATE('25-Dec-2012','DD-MON-YYYY') - SYSDATE FROM DUAL;</pre> <p>Notice two things:</p> <ul style="list-style-type: none"> • DUAL is Oracle's pseudo-table, used only for cases in which a table is not really needed. • The Christmas date is enclosed in a TO_DATE function to translate the date to a valid date format.
ADD_MONTHS Adds a number of months or years to a date Syntax: <code>ADD_MONTHS(date_value, n)</code> n = number of months	<p>Lists all products with their expiration date (two years from the purchase date):</p> <pre>SELECT P_CODE, P_INDATE, ADD_MONTHS(P_INDATE,24) FROM PRODUCT ORDER BY ADD_MONTHS(P_INDATE,24);</pre>
LAST_DAY Returns the date of the last day of the month given in a date Syntax: <code>LAST_DAY(date_value)</code>	<p>Lists all employees who were hired within the last seven days of a month:</p> <pre>SELECT EMP_LNAME, EMP_FNAME, EMP_HIRE_DATE FROM EMPLOYEE WHERE EMP_HIRE_DATE >= LAST_DAY(EMP_HIRE_DATE)-7;</pre>

8.3.2 NUMERIC FUNCTIONS

Numeric functions can be grouped in many different ways, such as algebraic, trigonometric, and logarithmic. In this section, you will learn two very useful functions. Do not confuse the SQL aggregate functions you saw in the previous chapter with the numeric functions in this section. The first group operates over a set of values (multiple rows—hence, the name *aggregate functions*), while the numeric functions covered here operate over a single row. Numeric functions take one numeric parameter and return one value. [Table 8.5](#) shows a selected group of available numeric functions.

TABLE 8.5 Selected Numeric Functions

FUNCTION	EXAMPLE(S)
ABS Returns the absolute value of a number Syntax: <code>ABS(numeric_value)</code>	In Oracle, use the following: <pre>SELECT 1.95, -1.93, ABS(1.95), ABS(-1.93) FROM DUAL;</pre> In MS Access and SQL Server, use the following: <pre>SELECT 1.95, -1.93, ABS(1.95), ABS(-1.93);</pre>
ROUND Rounds a value to a specified precision (number of digits) Syntax: <code>ROUND(numeric_value, p)</code> <code>p = precision</code>	Lists the product prices rounded to one and zero decimal places: <pre>SELECT P_CODE, P_PRICE, ROUND(P_PRICE,1) AS PRICE1, ROUND(P_PRICE,0) AS PRICE0 FROM PRODUCT;</pre>
CEIL/CEILING/FLOOR Returns the smallest integer greater than or equal to a number or returns the largest integer equal to or less than a number, respectively Syntax: <code>CEIL(numeric_value)</code> Oracle <code>CEILING(numeric_value)</code> SQL Server <code>FLOOR(numeric_value)</code>	Lists the product price, the smallest integer greater than or equal to the product price, and the largest integer equal to or less than the product price. In Oracle, use the following: <pre>SELECT P_PRICE, CEIL(P_PRICE), FLOOR(P_PRICE) FROM PRODUCT;</pre> In SQL Server, use the following: <pre>SELECT P_PRICE, CEILING(P_PRICE), FLOOR(P_PRICE) FROM PRODUCT;</pre> MS Access does not support these functions.

8.3.3 STRING FUNCTIONS

String manipulations are among the most-used functions in programming. If you have ever created a report using any programming language, you know the importance of properly concatenating strings of characters, printing names in uppercase, or knowing the length of a given attribute. [Table 8.6](#) shows a subset of useful string manipulation functions.

TABLE 8.6 Selected String Functions

FUNCTION	EXAMPLE(S)
Concatenation $\ $ Oracle + MS Access and SQL Server Concatenates data from two different character columns and returns a single column Syntax: strg_value $\ $ strg_value strg_value + strg_value	Lists all employee names (concatenated). In Oracle, use the following: <pre>SELECT EMP_LNAME ', ' EMP_FNAME AS NAME FROM EMPLOYEE;</pre> In MS Access and SQL Server, use the following: <pre>SELECT EMP_LNAME + ', ' + EMP_FNAME AS NAME FROM EMPLOYEE;</pre>
UPPER and LOWER Returns a string in all capital or all lowercase letters Syntax: UPPER(strg_value) LOWER(strg_value)	Lists all employee names in all capital letters (concatenated). In Oracle, use the following: <pre>SELECT UPPER(EMP_LNAME) ', ' UPPER(EMP_FNAME) AS NAME FROM EMPLOYEE;</pre> In SQL Server, use the following: <pre>SELECT UPPER(EMP_LNAME) + ', ' + UPPER(EMP_FNAME) AS NAME FROM EMPLOYEE;</pre> Lists all employee names in all lowercase letters (concatenated). In Oracle, use the following: <pre>SELECT LOWER(EMP_LNAME) ', ' LOWER(EMP_FNAME) AS NAME FROM EMPLOYEE;</pre> In SQL Server, use the following: <pre>SELECT LOWER(EMP_LNAME) + ', ' + LOWER(EMP_FNAME) AS NAME FROM EMPLOYEE;</pre> Not supported by MS Access.

SUBSTRING Returns a substring or part of a given string parameter Syntax: SUBSTR(strg_value, p, l) Oracle SUBSTRING(strg_value,p,l) SQL Server p = start position l = length of characters	Lists the first three characters of all employee phone numbers. In Oracle, use the following: <pre>SELECT EMP_PHONE, SUBSTR(EMP_PHONE,1,3) AS PREFIX FROM EMPLOYEE;</pre> In SQL Server, use the following: <pre>SELECT EMP_PHONE, SUBSTRING(EMP_PHONE,1,3) AS PREFIX FROM EMPLOYEE;</pre> Not supported by MS Access.
LENGTH Returns the number of characters in a string value Syntax: LENGTH(strg_value) Oracle LEN(strg_value) SQL Server	Lists all employee last names and the length of their names in descending order by last name length. In Oracle, use the following: <pre>SELECT EMP_LNAME, LENGTH(EMP_LNAME) AS NAMESIZE FROM EMPLOYEE;</pre> In MS Access and SQL Server, use the following: <pre>SELECT EMP_LNAME, LEN(EMP_LNAME) AS NAMESIZE FROM EMPLOYEE;</pre>

8.3.4 CONVERSION FUNCTIONS

Conversion functions allow you to take a value of a given data type and convert it to the equivalent value in another data type. In [Section 8.3.1](#), you learned about two basic Oracle SQL conversion functions: TO_CHAR and TO_DATE. Note that the TO_CHAR function takes a date value and returns a character

string representing a day, a month, or a year. In the same way, the TO_DATE function takes a character string representing a date and returns an actual date in Oracle format. SQL Server uses the CAST and CONVERT functions to convert one data type to another. A summary of the selected functions is shown in [Table 8.7](#).

TABLE 8.7 Selected Conversion Functions

FUNCTION	EXAMPLE(S)
Numeric to Character: TO_CHAR Oracle CAST SQL Server CONVERT SQL Server Returns a character string from a numeric value. Syntax: Oracle: TO_CHAR(numeric_value, fmt) SQL Server: CAST (numeric AS varchar(length)) CONVERT(varchar(length), numeric)	Lists all product prices, quantity on hand, percent discount, and total inventory cost using formatted values. In Oracle, use the following: <pre>SELECT P_CODE, TO_CHAR(P_PRICE,'999.99') AS PRICE, TO_CHAR(P_QOH,'9,999.99') AS QUANTITY, TO_CHAR(P_DISCOUNT,'0.99') AS DISC, TO_CHAR(P_PRICE*P_QOH,'99,999.99') AS TOTAL_COST FROM PRODUCT;</pre> In SQL Server, use the following: <pre>SELECT P_CODE, CAST(P_PRICE AS VARCHAR(8)) AS PRICE, CONVERT(VARCHAR(4),P_QOH) AS QUANTITY, CAST(P_DISCOUNT AS VARCHAR(4)) AS DISC, CAST(P_PRICE*P_QOH AS VARCHAR(10)) AS TOTAL_COST FROM PRODUCT; Not supported in MS Access.</pre>
Date to Character: TO_CHAR Oracle CAST SQL Server CONVERT SQL Server Returns a character string or a formatted character string from a date value Syntax: Oracle: TO_CHAR(date_value, fmt) SQL Server: CAST (date AS varchar(length)) CONVERT(varchar(length), date)	Lists all employee dates of birth, using different date formats. In Oracle, use the following: <pre>SELECT EMP_LNAME, EMP_DOB, TO_CHAR(EMP_DOB, DAY, MONTH DD, YYYY) AS DATEOFBIRTH FROM EMPLOYEE;</pre> In SQL Server, use the following: <pre>SELECT EMP_LNAME, EMP_DOB, TO_CHAR(EMP_DOB, YYYY/MM/DD) AS DATEOFBIRTH FROM EMPLOYEE; Not supported in MS Access.</pre>

<p>String to Number:</p> <p>TO_NUMBER</p> <p>Returns a formatted number from a character string, using a given format</p> <p>Syntax: Oracle: <code>TO_NUMBER(char_value, fmt)</code> fmt = format used; can be: 9 = displays a digit 0 = displays a leading zero ,</p> <p>= displays the comma . = displays the decimal point \$ = displays the dollar sign B = leading blank S = leading sign MI = trailing minus sign</p>	<p>Converts text strings to numeric values when importing data to a table from another source in text format; for example, the query shown below uses the TO_NUMBER function to convert text formatted to Oracle default numeric values using the format masks given.</p> <p>In Oracle, use the following:</p> <pre>SELECT TO_NUMBER('-123.99', 'S999.99'), TO_NUMBER('99.78','B999.99MI') FROM DUAL;</pre> <p>In SQL Server, use the following:</p> <pre>SELECT CAST('-123.99' AS NUMERIC(8,2)), CAST('-99.78' AS NUMERIC(8,2))</pre> <p>The SQL Server CAST function does not support the trailing sign on the character string.</p> <p>Not supported in MS Access.</p>
---	---

<p>CASE SQL Server</p> <p>DECODE Oracle</p> <p>Compares an attribute or expression with a series of values and returns an associated value or a default value if no match is found</p> <p>Syntax: Oracle: <code>DECODE(e, x, y, d)</code> e = attribute or expression x = value with which to compare e y = value to return in e = x d = default value to return if e is not equal to x SQL Server: <code>CASE When condition THEN value1 ELSE value2 END</code></p>	<p>The following example returns the sales tax rate for specified states:</p> <ul style="list-style-type: none"> • Compares V_STATE to 'CA'; if the values match, it returns .08. • Compares V_STATE to 'FL'; if the values match, it returns .05. • Compares V_STATE to 'TN'; if the values match, it returns .085. <p>If there is no match, it returns 0.00 (the default value).</p> <pre>SELECT V_CODE, V_STATE, DECODE(V_STATE,'CA',.08,'FL',.05, 'TN',.085, 0.00) AS TAX FROM VENDOR;</pre> <p>In SQL Server, use the following:</p> <pre>SELECT V_CODE, V_STATE, CASE WHEN V_STATE = 'CA' THEN .08 WHEN V_STATE = 'FL' THEN .05 WHEN V_STATE = 'TN' THEN .085 ELSE 0.00 END AS TAX FROM VENDOR</pre> <p>Not supported in MS Access.</p>
--	--

8.4 RELATIONAL SET OPERATORS

In [Chapter 3](#), The Relational Database Model, you learned about the eight general relational operators. In this section, you will learn how to use three SQL commands (UNION, INTERSECT, and MINUS) to implement the union, intersection, and difference relational operators.

In previous chapters, you learned that SQL data manipulation commands are [set-oriented](#); that is, they operate over entire sets of rows and columns (tables) at once. You can combine two or more sets to create new sets (or relations). That is precisely what the UNION, INTERSECT, and MINUS statements do. In

relational database terms, you can use the words *sets*, *relations*, and *tables* interchangeably because they all provide a conceptual view of the data set as it is presented to the relational database user.

NOTE

The SQL standard defines the operations that all DBMSs must perform on data, but it leaves the implementation details to the DBMS vendors. Therefore, some advanced SQL features might not work on all DBMS implementations. Also, some DBMS vendors might implement additional features not found in the SQL standard. UNION, INTERSECT, and MINUS are the names of the SQL statements implemented in Oracle. The SQL standard uses the keyword EXCEPT to refer to the difference (MINUS) relational operator. Other RDBMS vendors might use a different command name or might not implement a given command at all. To learn more about the ANSI/ISO SQL standards and find out how to obtain the latest standard documents in electronic form, check the ANSI Website (www.ansi.org). As of this writing, the most recent fully approved standard is SQL-2003, which made revisions and additions to the previous standard; most notable is its support for XML data. The SQL-2006 standard extended support for XML and multimedia data. The SQL-2008 standard added INSTEAD OF triggers and the TRUNCATE statement.

UNION, INTERSECT, and MINUS work properly only if relations are [union-compatible](#), which means that the number of attributes must be the same and their corresponding data types must be alike. In practice, some RDBMS vendors require the data types to be compatible but not exactly the same. For example, compatible data types are VARCHAR (35) and CHAR (15). Both attributes store character (string) values; the only difference is the string size. Another example of compatible data types is NUMBER and SMALLINT. Both data types are used to store numeric values.

NOTE

Some DBMS products might require union-compatible tables to have *identical* data types.



ONLINE CONTENT

The Website for this book, www.cengagebrain.com, provides SQL script files (Oracle and MS SQL Server) to demonstrate the UNION, INTERSECT, and MINUS commands. It also provides the **Ch08_SaleCo** MS Access database, which contains supported set operator alternative queries.

8.4.1 UNION

Suppose that SaleCo has bought another company. SaleCo's management wants to make sure that the acquired company's customer list is properly merged with its own customer list. Because some customers might have purchased goods from both companies, the two lists might contain common customers. SaleCo's management wants to make sure that customer records are not duplicated when the two customer lists are merged. The UNION query is a perfect tool for generating a combined listing of customers—one that excludes duplicate records.

The UNION statement combines rows from two or more queries *without including duplicate rows*. The syntax of the UNION statement is:

query UNION query

In other words, the UNION statement combines the output of two SELECT queries. (Remember that the SELECT statements must be union-compatible. That is, they must return the same number of attributes and similar data types.)

To demonstrate the use of the UNION statement in SQL, use the CUSTOMER and CUSTOMER_2 tables in the Ch08_SaleCo database. To show the combined CUSTOMER and CUSTOMER_2 records without duplicates, the UNION query is written as follows:

```
SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE,  
      CUS_PHONE  
FROM   CUSTOMER  
UNION
```

```

SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE,
CUS_PHONE
FROM CUSTOMER_2;

```

[Figure 8.16](#) shows the contents of the CUSTOMER and CUSTOMER_2 tables and the result of the UNION query. Although MS Access is used to show the results here, similar results can be obtained with Oracle.

Note the following in [Figure 8.16](#):

- The CUSTOMER table contains 10 rows, while the CUSTOMER_2 table contains seven rows.
- Customers Dunne and Olowski are included in the CUSTOMER table as well as the CUSTOMER_2 table.
- The UNION query yields 15 records because the duplicate records of customers Dunne and Olowski are not included. In short, the UNION query yields a unique set of records.

FIGURE 8.16 UNION query results

Table name: CUSTOMER							Query name: qryUNION-of-CUSTOMER-and-CUSTOMER_2				
CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_BALANCE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE
10010	Ramas	Alfred	A	615	844-2573	0.00	Brown	James	G	615	297-1228
10011	Dunne	Leona	K	713	894-1238	0.00	Durrie	Leona	K	713	894-1238
10012	Smith	Kathy	W	615	894-2285	345.86	Faniss	Anne	G	713	382-7185
10013	Olowksi	Paul	F	615	894-2180	536.75	Hernandez	Carlos	J	723	123-7654
10014	Orlando	Myron		615	222-1672	0.00	Lewis	Marie	J	734	332-1789
10015	O'Brian	Amy	B	713	442-3381	0.00	McDowell	George		723	123-7768
10016	Brown	James	G	615	297-1228	221.19	O'Brian	Amy	B	713	442-3381
10017	Williams	George		615	290-2556	768.93	Olowski	Paul	F	615	894-2180
10018	Ferriss	Anne	G	713	382-7185	216.55	Orlando	Myron		615	222-1672
10019	Smith	Olette	K	615	297-3809	0.00	Ramas	Alfred	A	615	844-2573

Table name: CUSTOMER_2					
CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE
345	Terrell	Justine	H	615	322-9870
347	Olowksi	Paul	F	615	894-2180
351	Hernandez	Carlos	J	723	123-7654
352	McDowell	George		723	123-7768
365	Tirpin	Khaleed	G	723	123-9876
368	Lewis	Marie	J	734	332-1789
369	Dunne	Leona	K	713	894-1238

SOURCE: Course Technology/Cengage Learning

NOTE

The SQL standard calls for the elimination of duplicate rows when the UNION SQL statement is used. However, some DBMS vendors might not adhere to that standard. Check your DBMS manual to see if the UNION statement is supported, and if so, *how* it is supported.

The UNION statement can be used to unite more than just two queries. For example, assume that you have four union-compatible queries named T1, T2, T3, and T4. With the UNION statement, you can combine the output of all four queries into a single result set. The SQL statement will be similar to this:

```
SELECT column-list FROM T1
UNION
SELECT column-list FROM T2
UNION
SELECT column-list FROM T3
UNION
SELECT column-list FROM T4;
```

8.4.2 UNION ALL

If SaleCo's management wants to know how many customers are on *both* the CUSTOMER and CUSTOMER_2 lists, a UNION ALL query can be used to produce a relation that retains the duplicate rows. Therefore, the following query will keep all rows from both queries (including the duplicate rows) and return 17 rows.

```
SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL,
FROM CUS_AREACODE, CUS_PHONE CUSTOMER
UNION
ALL
SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL,
FROM CUS_AREACODE, CUS_PHONE CUSTOMER_2;
```

Running the preceding UNION ALL query produces the result shown in [Figure 8.17](#).

FIGURE 8.17 UNION ALL query results

Table name: CUSTOMER

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_BALANCE
10010	Ramas	Alfred	A	615	844-2573	0.00
10011	Dunne	Leona	K	713	894-1238	0.00
10012	Smith	Kathy	W	615	894-2265	345.86
10013	Ołowski	Paul	F	615	894-2180	536.75
10014	Orlando	Myron		615	222-1672	0.00
10015	O'Brian	Amy	B	713	442-3381	0.00
10016	Brown	James	G	615	297-1228	221.19
10017	Williams	George		615	290-2566	768.93
10018	Farris	Anne	G	713	382-7185	216.55
10019	Smith	Olette	K	615	297-3809	0.00

Query name: qryUNION-ALL-of-CUSTOMER-and-CUSTOMER_2

CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE
Ramas	Alfred	A	615	844-2573
Dunne	Leona	K	713	894-1238
Smith	Kathy	W	615	894-2265
Ołowski	Paul	F	615	894-2180
Orlando	Myron		615	222-1672
O'Brian	Amy	B	713	442-3381
Brown	James	G	615	297-1228
Williams	George		615	290-2566
Farris	Anne	G	713	382-7185
Smith	Olette	K	615	297-3809
Terrell	Justine	H	615	322-9870
Ołowski	Paul	F	615	894-2180
Hernandez	Carlos	J	723	123-7654
McDowell	George		723	123-7768
Tirpin	Khaled	G	723	123-9876
Lewis	Marie	J	734	332-1789
Dunne	Leona	K	713	894-1238

Table name: CUSTOMER_2

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE
345	Terrell	Justine	H	615	322-9870
347	Ołowski	Paul	F	615	894-2180
351	Hernandez	Carlos	J	723	123-7654
352	McDowell	George		723	123-7768
365	Tirpin	Khaled	G	723	123-9876
368	Lewis	Marie	J	734	332-1789
369	Dunne	Leona	K	713	894-1238

Database name: CH08_SaleCo

CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE
Ramas	Alfred	A	615	844-2573
Dunne	Leona	K	713	894-1238
Smith	Kathy	W	615	894-2265
Ołowski	Paul	F	615	894-2180
Orlando	Myron		615	222-1672
O'Brian	Amy	B	713	442-3381
Brown	James	G	615	297-1228
Williams	George		615	290-2566
Farris	Anne	G	713	382-7185
Smith	Olette	K	615	297-3809
Terrell	Justine	H	615	322-9870
Ołowski	Paul	F	615	894-2180
Hernandez	Carlos	J	723	123-7654
McDowell	George		723	123-7768
Tirpin	Khaled	G	723	123-9876
Lewis	Marie	J	734	332-1789
Dunne	Leona	K	713	894-1238

SOURCE: Course Technology/Cengage Learning

Like the UNION statement, the UNION ALL statement can be used to unite more than just two queries.

8.4.3 INTERSECT

If SaleCo's management wants to know which customer records are duplicated in the CUSTOMER and CUSTOMER_2 tables, the INTERSECT statement can be used to combine rows from two queries, returning only the rows that appear in both sets. The syntax for the INTERSECT statement is:

query INTERSECT *query*

To generate the list of duplicate customer records, you can use the following commands:

```
SELECT      CUS_LNAME, CUS_FNAME, CUS_INITIAL,
            CUS_AREACODE, CUS_PHONE
FROM        CUSTOMER
INTERSECT
            CUS_LNAME, CUS_FNAME, CUS_INITIAL,
```

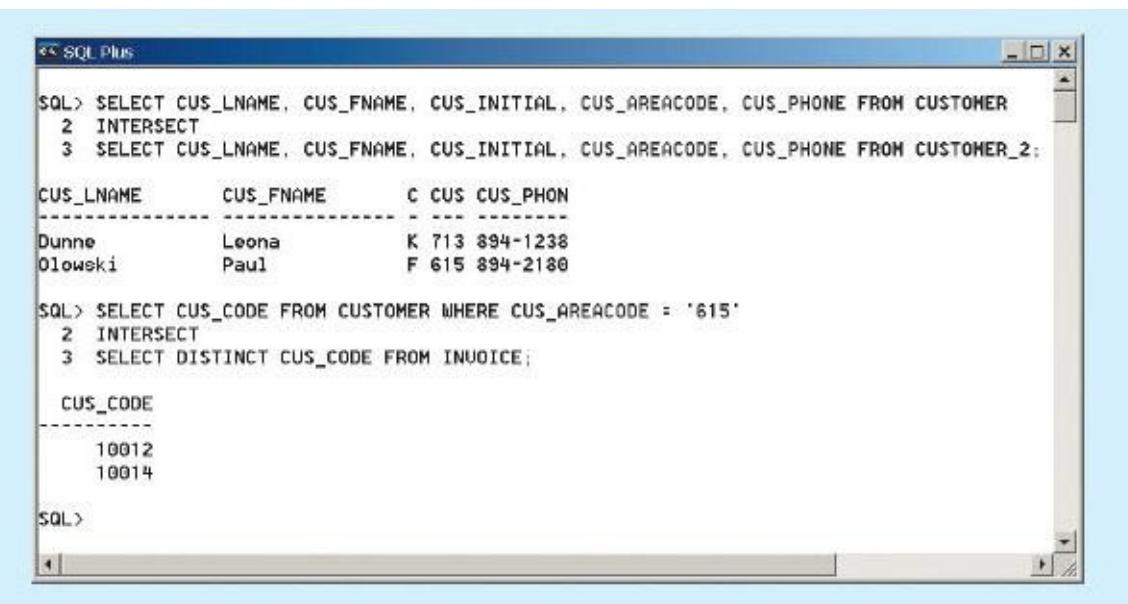
```
SELECT      CUS_AREACODE, CUS_PHONE  
FROM        CUSTOMER_2;
```

The INTERSECT statement can be used to generate additional useful customer information. For example, the following query returns the customer codes for all customers who are in area code 615 and who have made purchases. (If a customer has made a purchase, there must be an invoice record for that customer.)

```
SELECT      CUS_CODE FROM CUSTOMER WHERE CUS_AREACODE  
= '615'  
INTERSECT  
SELECT      DISTINCT CUS_CODE FROM INVOICE;
```

[Figure 8.18](#) shows both sets of SQL statements and their output.

FIGURE 8.18 INTERSECT query results



The screenshot shows an SQL Plus window with the following content:

```
SQL> SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, CUS_PHONE FROM CUSTOMER  
2 INTERSECT  
3 SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, CUS_PHONE FROM CUSTOMER_2;  
  
CUS_LNAME      CUS_FNAME      CUS_INITIAL    CUS_AREACODE    CUS_PHONE  
-----  
Dunne          Leona          K             713 894-1238  
Olowski        Paul           F             615 894-2180  
  
SQL> SELECT CUS_CODE FROM CUSTOMER WHERE CUS_AREACODE = '615'  
2 INTERSECT  
3 SELECT DISTINCT CUS_CODE FROM INVOICE;  
  
CUS_CODE  
-----  
10012  
10014  
  
SQL>
```

SOURCE: Course Technology/Cengage Learning

NOTE

MS Access does not support the INTERSECT query, nor does it support other complex queries you will explore in this chapter. At least in some cases, Access might be able to give you the desired results if you use an alternative query format or procedure. For example, although Access does not support SQL triggers and stored procedures, you can use Visual Basic code to perform similar actions. However, the objective here is to explain some important standard SQL features.

8.4.4 MINUS

The MINUS statement in SQL combines rows from two queries and returns only the rows that appear in the first set but not in the second. The syntax for the MINUS statement is:

query MINUS *query*

For example, if the SaleCo managers want to know which customers in the CUSTOMER table are not found in the CUSTOMER_2 table, they can use the following commands:

```
SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE,  
      CUS_PHONE  
FROM   CUSTOMER;  
MINUS  
SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE,  
      CUS_PHONE  
FROM   CUSTOMER_2;
```

If the managers want to know which customers in the CUSTOMER_2 table are not found in the CUSTOMER table, they merely switch the table designations:

```
SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE,  
      CUS_PHONE  
FROM   CUSTOMER_2  
MINUS  
      CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE,  
SELECT CUS_PHONE
```

```
FROM CUSTOMER;
```

You can extract useful information by combining MINUS with various clauses such as WHERE. For example, the following query returns the customer codes for all customers in area code 615 minus the ones who have made purchases, leaving the customers in area code 615 who have not made purchases.

```
SELECT CUS_CODE FROM CUSTOMER WHERE CUS_AREACODE =
  '615'
MINUS
SELECT DISTINCT CUS_CODE FROM INVOICE;
```

[Figure 8.19](#) shows the preceding three SQL statements and their output.

NOTE

Some DBMS products do not support the INTERSECT or MINUS statements, while others might implement the difference relational operator in SQL as EXCEPT. Consult your DBMS manual to see if the statements illustrated here are supported by your DBMS.

FIGURE 8.19 MINUS query results

The screenshot shows an SQL Plus window with three distinct SQL statements. The first statement uses MINUS to find names unique to the first table:

```
SQL> SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, CUS_PHONE FROM CUSTOMER
2 MINUS
3 SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, CUS_PHONE FROM CUSTOMER_2;
```

The output is a table with columns CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, and CUS_PHONE. The data includes rows for Brown, Farries, O'Brian, Orlando, Ramas, Smith, Smith, and Williams.

The second statement uses MINUS to find names unique to the second table:

```
SQL> SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, CUS_PHONE FROM CUSTOMER_2
2 MINUS
3 SELECT CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, CUS_PHONE FROM CUSTOMER;
```

The output is a table with columns CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, and CUS_PHONE. The data includes rows for Hernandez, Lewis, McDowell, Terrell, and Tirpin.

The third statement finds codes where the area code is 615:

```
SQL> SELECT CUS_CODE FROM CUSTOMER WHERE CUS_AREACODE = '615'
2 MINUS
3 SELECT DISTINCT CUS_CODE FROM INVOICe;
```

The output is a table with column CUS_CODE, listing values 10010, 10013, 10016, 10017, and 10019.

SOURCE: Course Technology/Cengage Learning

8.4.5 SYNTAX ALTERNATIVES

If your DBMS does not support the INTERSECT or MINUS statements, you can use the IN and NOT IN subqueries to obtain similar results. For example, the following query will produce the same results as the INTERSECT query shown in [Section 8.4.3](#):

```
SELECT CUS_CODE FROM CUSTOMER
WHERE CUS_AREACODE = '615' AND
CUS_CODE IN (SELECT DISTINCT CUS_CODE FROM
```

INVOICE);

Figure 8.20 shows the use of the INTERSECT alternative.

FIGURE 8.20 INTERSECT alternative

Table name: CUSTOMER							Database name: CH08_SaleCo		
CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_BALANCE	INV_NUMBER	CUS_CODE	INV_DATE
10010	Ramas	Alfred	A	615	844-2573	0.00	1001	10014	16-Jan-12
10011	Dunne	Leona	K	713	894-1238	0.00	1002	10011	16-Jan-12
10012	Smith	Kathy	W	615	894-2285	345.86	1003	10012	16-Jan-12
10013	Olowksi	Paul	F	615	894-2180	536.75	1004	10011	17-Jan-12
10014	Orlando	Myron		615	222-1672	0.00	1005	10018	17-Jan-12
10015	O'Brian	Amy	B	713	442-3381	0.00	1006	10014	17-Jan-12
10016	Brown	James	G	615	297-1228	221.19	1007	10015	17-Jan-12
10017	Williams	George		615	290-2566	768.93	1008	10011	17-Jan-12
10018	Farris	Anne	G	713	382-7185	216.55			
10019	Smith	Olette	K	615	297-3809	0.00			

Query name: qry-INTERSECT-Alternative

CUS_CODE
10012
10014

NOTE

MS Access will generate an input request for the CUS_AREACODE if you use apostrophes around the area code. (If you supply the 615 area code, the query will execute properly.) You can eliminate the problem by using standard double quotation marks, writing the WHERE clause in the second line of the preceding SQL statement as:

WHERE CUS_AREACODE = "615" AND

MS Access will also accept single quotation marks.

Using the same alternative to the MINUS statement, you can generate the output for the third MINUS query shown in [Section 8.4.4](#) by entering the following:

```
SELECT CUS_CODE FROM CUSTOMER  
WHERE CUS_AREACODE = '615' AND
```

CUS_CODE NOT IN (SELECT DISTINCT CUS_CODE FROM INVOICE);

The results of the query are shown in [Figure 8.21](#). Note that the query output includes only the customers in area code 615 who have not made any purchases and therefore have not generated invoices.

FIGURE 8.21 MINUS alternative

Database name: CH08_SaleCo

Table name: CUSTOMER

CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_BALANCE
10010	Ramas	Alfred	A	615	844-2573	0.00
10011	Dunne	Leona	K	713	894-1238	0.00
10012	Smith	Kathy	W	615	894-2285	345.86
10013	Olowksi	Paul	F	615	894-2180	536.75
10014	Orlando	Myron		615	222-1672	0.00
10015	O'Brian	Amy	B	713	442-3381	0.00
10016	Brown	James	G	615	297-1228	221.19
10017	Williams	George		615	290-2556	768.93
10018	Farris	Anne	G	713	382-7185	216.55
10019	Smith	Olette	K	615	297-3809	0.00

Table name: INVOICE

INV_NUMBER	CUS_CODE	INV_DATE
1001	10014	16-Jan-12
1002	10011	16-Jan-12
1003	10012	16-Jan-12
1004	10011	17-Jan-12
1005	10018	17-Jan-12
1006	10014	17-Jan-12
1007	10015	17-Jan-12
1008	10011	17-Jan-12

Query name: qry-MINUS-Alternative

CUS_CODE
10010
10013
10016
10017
10019

SOURCE: Course Technology/Cengage Learning

8.5 VIRTUAL TABLES: CREATING A VIEW

As you learned earlier, the output of a relational operator such as SELECT is another relation (or table). Suppose that at the end of each day, you would like to have a list of all products to reorder—that is, products with a quantity on hand that is less than or equal to the minimum quantity. Instead of typing the same query at the end of each day, wouldn't it be better to permanently save that query in the database? That is the function of a relational view. A [view](#) is a virtual table based on a SELECT query. The query can contain columns, computed columns, aliases, and aggregate functions from one or more tables. The tables on which the view is based are called [base tables](#).

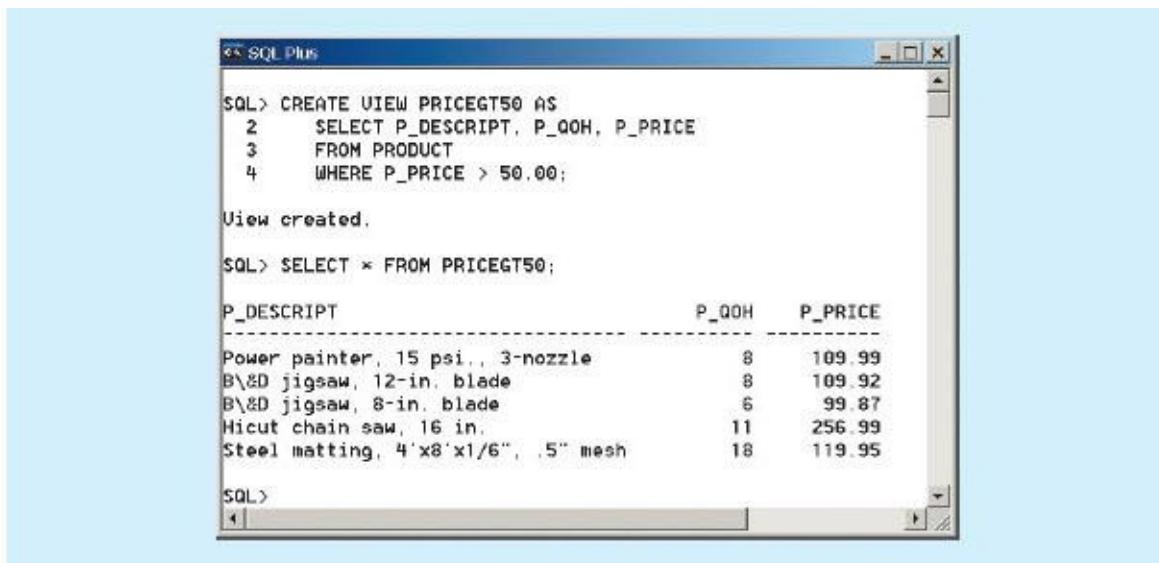
You can create a view by using the [CREATE VIEW](#) command:

`CREATE VIEW viewname AS SELECT query`

The CREATE VIEW statement is a data definition command that stores the subquery specification—the SELECT statement used to generate the virtual table—in the data dictionary.

The first SQL command set in [Figure 8.22](#) shows the syntax used to create a view named PRICEGT50. This view contains only the designated three attributes (P_DESCRIFT, P_QOH, and P_PRICE) and only rows in which the price is over \$50. The second SQL command sequence in [Figure 8.22](#) shows the rows that make up the view.

FIGURE 8.22 Creating a virtual table with the CREATE VIEW command



The screenshot shows an Oracle SQL Plus window with the following content:

```
SQL> CREATE VIEW PRICEGT50 AS
  2   SELECT P_DESCRIFT, P_QOH, P_PRICE
  3   FROM PRODUCT
  4   WHERE P_PRICE > 50.00;

View created.

SQL> SELECT * FROM PRICEGT50;

P_DESCRIFT          P_QOH    P_PRICE
-----  -----  -----
Power painter, 15 psi., 3-nozzle      8    109.99
B&D jigsaw, 12-in. blade             8    109.92
B&D jigsaw, 8-in. blade              6    99.87
Hicut chain saw, 16 in.            11    256.99
Steel matting, 4'x8'x1/6", .5" mesh 18    119.95
```

SOURCE: Course Technology/Cengage Learning

NOTE

Note To Ms Access Users

The CREATE VIEW command is not directly supported in MS Access. To

create a view in MS Access, you simply create a SQL query and then save it.

A relational view has several special characteristics:

- You can use the name of a view anywhere a table name is expected in a SQL statement.
- Views are dynamically updated. That is, the view is re-created on demand each time it is invoked. Therefore, if new products are added or deleted to meet the criterion `P_PRICE > 50.00`, those new products will automatically appear or disappear in the `PRICEGT50` view the next time the view is invoked.
- Views provide a level of security in the database because they can restrict users to seeing only specified columns and rows in a table. For example, if you have a company with hundreds of employees in several departments, you could give each department secretary a view of certain attributes only for the employees who belong to that secretary's department.
- Views may also be used as the basis for reports. For example, if you need a report that shows a summary of total product cost and quantity-on-hand statistics grouped by vendor, you could create a `PROD_STATS` view as:

```
SELECT V_CODE, SUM(P_QOH*P_PRICE) AS TOTCOST, MAX(P_QOH)
      AS MAXQTY,
      MIN(P_QOH) AS MINQTY, AVG(P_QOH) AS AVGQTY
   FROM PRODUCT
  GROUP BY V_CODE;
```

8.5.1 UPDATABLE VIEWS

One of the most common operations in production database environments is to use batch update routines to update a master table attribute (field) with transaction data. As the name implies, a [batch update routine](#) pools multiple

transactions into a single batch to update a master table field *in a single operation*. For example, a batch update routine is commonly used to update a product's quantity on hand based on summary sales transactions. Such routines are typically run as overnight batch jobs to update the quantity on hand of products in inventory. For example, the sales transactions performed by traveling salespeople can be entered during periods when the system is offline.



ONLINE CONTENT

For MS Access users, the PRODMASTER and PRODSALES tables are in the **Ch08_UV** database, which is available at www.cengagebrain.com.



ONLINE CONTENT

For Oracle users, all SQL commands you see in this section are available at www.cengagebrain.com. After you locate the script files (**uv-01.sql** through **uv-04.sql**), you can copy and paste the command sequences into your SQL*Plus program.

To perform a batch update routine, begin by defining the master product table (PRODMASTER) and the product monthly sales totals table (PRODSALES) shown in [Figure 8.23](#). Note the 1:1 relationship between the two tables.

FIGURE 8.23 The PRODMASTER and PRODSALES tables

Database name: CH08_UV		
Table name: PRODMASTER		
PROD_ID	PROD_DESC	PROD_QOH
A123	SCREWS	67
BX34	NUTS	37
C583	BOLTS	50

Table name: PRODSALES	
PROD_ID	PS_QTY
A123	7
BX34	3

Using the tables in [Figure 8.23](#), update the PRODMASTER table by subtracting the PRODSALES table's product monthly sales quantity (PS_QTY) from the PRODMASTER table's PROD_QOH. To produce the required update, the update query would be written like this:

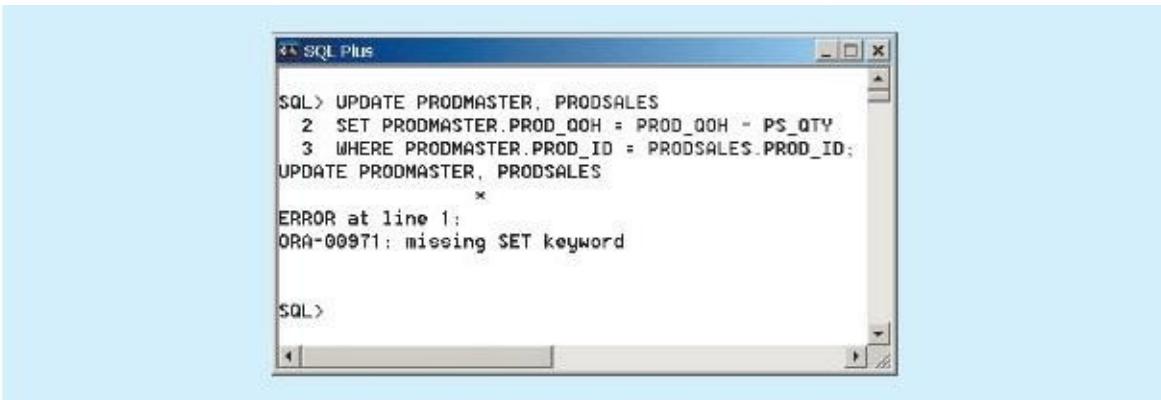
```
UPDATE PRODMASTER, PRODSALES
SET PRODMASTER.PROD_QOH =
    PROD_QOH - PS_QTY
WHERE PRODMASTER.PROD_ID =
    PRODSALES.PROD_ID;
```

Note that the update statement reflects the following sequence of events:

- Join the PRODMASTER and PRODSALES tables.
- Update the PROD_QOH attribute (using the PS_QTY value in the PRODSALES table) for each row of the PRODMASTER table with matching PROD_ID values in the PRODSALES table.

To be used in a batch update, the PRODSALES data must be stored in a base table rather than in a view. The query will work in Access, but Oracle will return the error message shown in [Figure 8.24](#).

FIGURE 8.24 The Oracle UPDATE error message

A screenshot of a Windows application window titled "SQL Plus". Inside the window, there is a single-line text input field. A user has typed the following SQL command:

```
SQL> UPDATE PRODMaster, PRODsales
  2 SET PRODMaster.PROD_QOH = PROD_QOH - PS_QTY
  3 WHERE PRODMaster.PROD_ID = PRODsales.PROD_ID;
UPDATE PRODMaster, PRODsales
      *
```

After pressing Enter, the application displays an error message:

ERROR at line 1:
ORA-00971: missing SET keyword

SOURCE: Course Technology/Cengage Learning

Oracle produced the error message because it expected to find a single table name in the UPDATE statement. In fact, you cannot join tables in the UPDATE statement in Oracle. To solve that problem, you have to create an *updatable* view. As its name suggests, an [updatable view](#) can be used to update attributes in any base table(s) used in the view. You must realize that *not all views are updatable*. Actually, several restrictions govern updatable views, and some of them are vendor-specific.

NOTE

Keep in mind that the examples in this section are generated in Oracle. To see what restrictions are placed on updatable views by the DBMS you are using, check the appropriate DBMS documentation.

The most common updatable view restrictions are as follows:

- GROUP BY expressions or aggregate functions cannot be used.
- You cannot use set operators such as UNION, INTERSECT, and MINUS.
- Most restrictions are based on the use of JOINs or group operators in views.

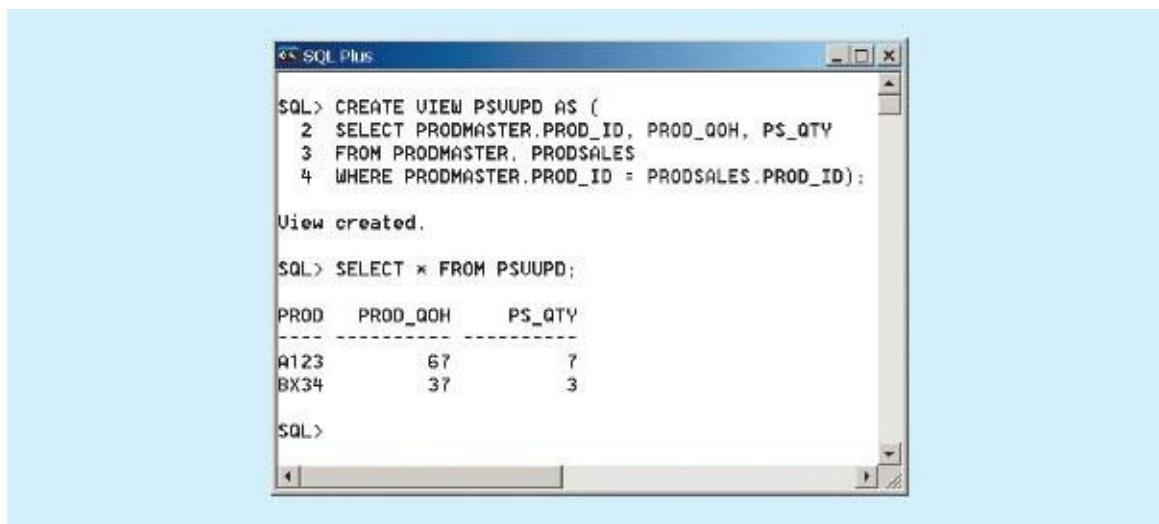
To meet the Oracle limitations, an updatable view named PSVUPD has been created, as shown in [Figure 8.25](#).

One easy way to determine whether a view can be used to update a base table is to examine the view's output. If the primary key columns of the base table you want to update still have unique values in the view, the base table is updatable. For example, if the PROD_ID column of the view returns the A123 or BX34 values more than once, the PRODMASTER table cannot be updated through the view.

After creating the updatable view shown in [Figure 8.25](#), you can use the UPDATE command to update the view, thereby updating the PRODMASTER table. [Figure 8.26](#) shows how the UPDATE command is used and shows the final contents of the PRODMASTER table after the UPDATE has been executed.

Although the batch update procedure just illustrated meets the goal of updating a master table with data from a transaction table, the preferred real-world solution to the update problem is to use procedural SQL, which you will learn about later in this chapter.

FIGURE 8.25 Creating an updatable view in Oracle



```
SQL> CREATE VIEW PSUUPD AS (
  2  SELECT PRODMASTER.PROD_ID, PROD_QOH, PS_QTY
  3  FROM PRODMASTER, PRODSALES
  4  WHERE PRODMASTER.PROD_ID = PRODSALES.PROD_ID);

View created.

SQL> SELECT * FROM PSUUPD;

PROD      PROD_QOH      PS_QTY
-----  -----
A123          67            7
BX34          37            3

SQL>
```

SOURCE: Course Technology/Cengage Learning

FIGURE 8.26 PRODMASTER table update, using an updatable view

The screenshot shows a Windows application window titled "SQL*Plus". Inside, a series of SQL statements are run against a database:

```
SQL> SELECT * FROM PRODMASTER;
PROD PROD_DESC          PROD_QOH
-----
A123 SCREWS              67
BX34 NUTS                 37
C583 BOLTS                50

SQL> SELECT * FROM PRODSALES;
PROD      PS_QTY
-----
A123                  7
BX34                  3

SQL> UPDATE PSUUPD
  2 SET PROD_QOH = PROD_QOH - PS_QTY;
2 rows updated.

SQL> SELECT * FROM PRODMASTER;
PROD PROD_DESC          PROD_QOH
-----
A123 SCREWS              60
BX34 NUTS                 34
C583 BOLTS                50

SQL> _
```

SOURCE: Course Technology/Cengage Learning

8.6 ORACLE SEQUENCES

If you use MS Access, you might be familiar with the AutoNumber data type, which you can use to define a column in your table that will be automatically populated with unique numeric values. In fact, if you create a table in MS Access and forget to define a primary key, MS Access will offer to create a primary key column; if you accept, you will notice that MS Access creates a column named “ID” with an AutoNumber data type. After you define a column as an AutoNumber type, every time you insert a row in the table, MS Access will automatically add a value to that column, starting with 1 and increasing the value by 1 in every new row you add. Also, you cannot include that column in your INSERT statements—Access will not let you edit that value at all. MS SQL Server uses the Identity column property to serve a similar purpose. In MS SQL

Server, a table can have at most one column defined as an Identity column. This column behaves similarly to an MS Access column with the AutoNumber data type.

Oracle does not support the AutoNumber data type or the Identity column property. Instead, you can use a “sequence” to assign values to a column on a table. However, an Oracle sequence is very different from the Access AutoNumber data type and deserves close scrutiny:

- Oracle sequences are an independent object in the database. (Sequences are not a data type.)
- Oracle sequences have a name and can be used anywhere a value is expected.
- Oracle sequences are not tied to a table or a column.
- Oracle sequences generate a numeric value that can be assigned to any column in any table.
- The table attribute to which you assigned a value based on a sequence can be edited and modified.
- An Oracle sequence can be created and deleted anytime.

The basic syntax to create a sequence in Oracle is:

```
CREATE SEQUENCE name [START WITH n] [INCREMENT BY n] [CACHE  
| NOCACHE]
```

where:

- *name* is the name of the sequence.
- *n* is an integer value that can be positive or negative.
- *START WITH* specifies the initial sequence value. (The default value is 1.)
- *INCREMENT BY* determines the value by which the sequence is

incremented. (The default increment value is 1. The sequence increment can be positive or negative to enable you to create ascending or descending sequences.)

- The *CACHE* or *NOCACHE* clause indicates whether Oracle will preallocate sequence numbers in memory. (Oracle preallocates 20 values by default.)

For example, you could create a sequence to automatically assign values to the customer code each time a new customer is added, and create another sequence to automatically assign values to the invoice number each time a new invoice is added. The SQL code to accomplish those tasks is:

```
CREATE SEQUENCE CUS_CODE_SEQ START WITH 20010 NOCACHE;
CREATE SEQUENCE INV_NUMBER_SEQ START WITH 4010 NOCACHE;
```

You can check all of the sequences you have created by using the following SQL command, as illustrated in [Figure 8.27](#):

```
SELECT * FROM USER_SEQUENCES;
```

FIGURE 8.27 Oracle sequence

The screenshot shows an Oracle SQL Plus window with the following content:

```
SQL> CREATE SEQUENCE CUS_CODE_SEQ START WITH 20010 NOCACHE;
Sequence created.

SQL> CREATE SEQUENCE INV_NUMBER_SEQ START WITH 4010 NOCACHE;
Sequence created.

SQL> SELECT * FROM USER_SEQUENCES;

SEQUENCE_NAME          MIN_VALUE  MAX_VALUE INCREMENT_BY C_O CACHE_SIZE LAST_NUMBER
-----  -----  -----  -----  -----  -----
CUS_CODE_SEQ           1 1.0000E+27      1 N N      0      20010
INV_NUMBER_SEQ         1 1.0000E+27      1 N N      0      4010

SQL>
```

SOURCE: Course Technology/Cengage Learning

To use sequences during data entry, you must use two special pseudo-columns: *NEXTVAL* and *CURRVAL*. *NEXTVAL* retrieves the next available value from a sequence, and *CURRVAL* retrieves the current value of a sequence. For

example, you can use the following code to enter a new customer:

```
INSERT INTO CUSTOMER  
VALUES (CUS_CODE_SEQ.NEXTVAL,'Connery', 'Sean', NULL, '615',  
'898-2007', 0.00);
```

The preceding SQL statement adds a new customer to the CUSTOMER table and assigns the value 20010 to the CUS_CODE attribute. Examine some important sequence characteristics:

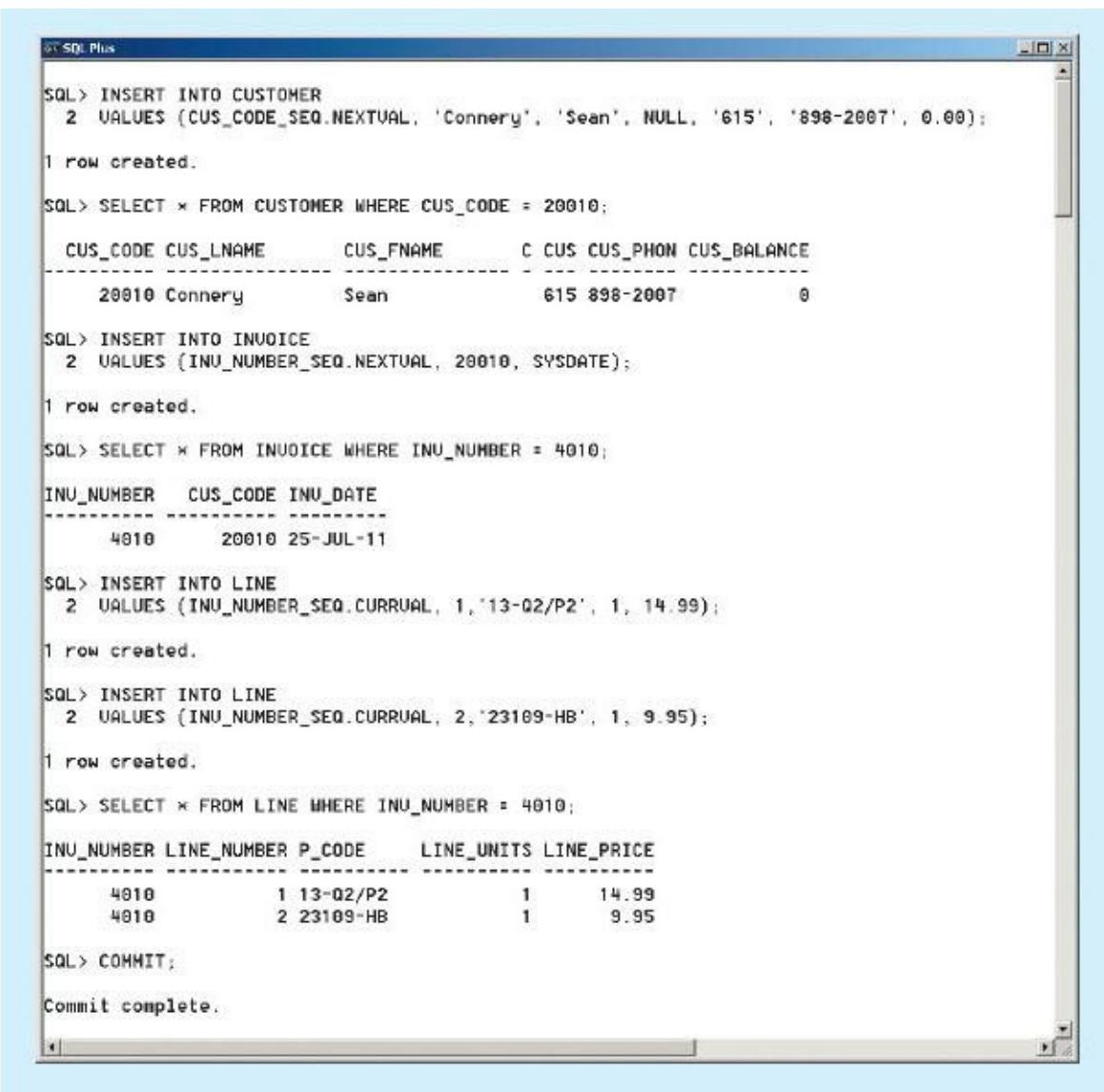
- CUS_CODE_SEQ.NEXTVAL retrieves the next available value from the sequence.
- Each time you use NEXTVAL, the sequence is incremented.
- Once a sequence value is used (through NEXTVAL), it cannot be used again. If your SQL statement rolls back for some reason, *the sequence value does not roll back*. If you issue another SQL statement (with another NEXTVAL), the next available sequence value will be returned to the user—it will look like the sequence skips a number.
- You can issue an INSERT statement without using the sequence.

CURRVAL retrieves the current value of a sequence—that is, the last sequence number used, which was generated with a NEXTVAL. You cannot use CURRVAL unless a NEXTVAL was issued previously in the same session. The main use for CURRVAL is to enter rows in dependent tables. For example, the INVOICE and LINE tables are related in a one-to-many relationship through the INV_NUMBER attribute. You can use the INV_NUMBER_SEQ sequence to automatically generate invoice numbers. Then, using CURRVAL, you can get the latest INV_NUMBER used and assign it to the related INV_NUMBER foreign key attribute in the LINE table. For example:

```
INSERT INTO INVOICE VALUES (INV_NUMBER_SEQ.NEXTVAL, 20010, SYSDATE);  
INSERT INTO LINE VALUES (INV_NUMBER_SEQ.CURRVAL, 1,'13-Q2/P2', 1, 14.99);  
INSERT INTO LINE VALUES (INV_NUMBER_SEQ.CURRVAL, 2,'23109-HB', 1, 9.95);  
COMMIT;
```

The results are shown in [Figure 8.28](#).

FIGURE 8.28 Oracle sequence examples



The screenshot shows an Oracle SQL Plus window with the following session history:

```
SQL> INSERT INTO CUSTOMER
  2  VALUES (CUS_CODE_SEQ.NEXTVAL, 'Connery', 'Sean', NULL, '615', '898-2007', 0.00);
1 row created.

SQL> SELECT * FROM CUSTOMER WHERE CUS_CODE = 20010;
      CUS_CODE CUS_LNAME      CUS_FNAME      C CUS_CUS_PHON CUS_BALANCE
-----  -----
    20010 Connery        Sean           615 898-2007          0

SQL> INSERT INTO INVOICE
  2  VALUES (INU_NUMBER_SEQ.NEXTVAL, 20010, SYSDATE);
1 row created.

SQL> SELECT * FROM INVOICE WHERE INU_NUMBER = 4010;
      INU_NUMBER   CUS_CODE INU_DATE
-----  -----
     4010          20010 25-JUL-11

SQL> INSERT INTO LINE
  2  VALUES (INU_NUMBER_SEQ.CURRVAL, 1, '13-02/P2', 1, 14.99);
1 row created.

SQL> INSERT INTO LINE
  2  VALUES (INU_NUMBER_SEQ.CURRVAL, 2, '23109-HB', 1, 9.95);
1 row created.

SQL> SELECT * FROM LINE WHERE INU_NUMBER = 4010;
      INU_NUMBER LINE_NUMBER P_CODE      LINE_UNITS LINE_PRICE
-----  -----
     4010          1 13-02/P2            1       14.99
     4010          2 23109-HB           1        9.95

SQL> COMMIT;
Commit complete.
```

SOURCE: Course Technology/Cengage Learning

In the example shown in [Figure 8.28](#), INV_NUMBER_SEQ.NEXTVAL retrieves the next available sequence number (4010) and assigns it to the INV_NUMBER column in the INVOICE table. Also note the use of the SYSDATE attribute to automatically insert the current date in the INV_DATE attribute. Next, the following two INSERT statements add the products being

sold to the LINE table. In this case, INV_NUMBER_SEQ.CURRVAL refers to the last-used INV_NUMBER_SEQ sequence number (4010). In this way, the relationship between INVOICE and LINE is established automatically. The COMMIT statement at the end of the command sequence makes the changes permanent. Of course, you can also issue a ROLLBACK statement, in which case the rows you inserted in the INVOICE and LINE tables would be rolled back (but remember that the sequence number would not). Once you use a sequence number with NEXTVAL, there is no way to reuse it! This “no-reuse” characteristic is designed to guarantee that the sequence will always generate unique values.

Remember these points when you think about sequences:

- The use of sequences is optional. You can enter the values manually.
- A sequence is not associated with a table. As in the examples in [Figure 8.28](#), two distinct sequences were created (one for customer code values and one for invoice number values), but you could have created just one sequence and used it to generate unique values for both tables.

NOTE

The SQL standard defines the use of Identity columns and sequence objects. However, some DBMS vendors might not adhere to the standard. Check your DBMS documentation.

Finally, you can drop a sequence from a database with a DROP SEQUENCE command. For example, to drop the sequences created earlier, you would type:

```
DROP SEQUENCE CUS_CODE_SEQ;  
DROP SEQUENCE INV_NUMBER_SEQ;
```

Dropping a sequence does not delete the values you assigned to table attributes (CUS_CODE and INV_NUMBER); it deletes only the sequence object from the database. The *values* you assigned to the table columns (CUS_CODE and INV_NUMBER) remain in the database.

Because the CUSTOMER and INVOICE tables are used in the following

examples, you will want to keep the original data set. Therefore, you can delete the customer, invoice, and line rows you just added by using the following commands:

```
DELETE FROM INVOICE WHERE INV_NUMBER = 4010;  
DELETE FROM CUSTOMER WHERE CUS_CODE = 20010;  
COMMIT;
```

Those commands delete the recently added invoice, all of the invoice line rows associated with the invoice (the LINE table's INV_NUMBER foreign key was defined with the ON DELETE CASCADE option), and the recently added customer. The COMMIT statement saves all changes to permanent storage.

NOTE

At this point, you need to re-create the CUS_CODE_SEQ and INV_NUMBER_SEQ sequences, as they will be used again later in the chapter. Enter:

```
CREATE SEQUENCE CUS_CODE_SEQ START WITH 20010  
NOCACHE;
```

```
CREATE SEQUENCE INV_NUMBER_SEQ START WITH 4010  
NOCACHE;
```

8.7 PROCEDURAL SQL

Thus far, you have learned to use SQL to read, write, and delete data in the database. For example, you learned to update values in a record, to add records, and to delete records. Unfortunately, SQL does not support the *conditional* execution of procedures that are typically supported by a programming language using the general format:

```
IF <condition>  
    THEN <perform procedure>  
    ELSE <perform alternate procedure>  
END IF
```

SQL also fails to support looping operations in programming languages that permit the execution of repetitive actions typically encountered in a programming environment. The typical format is:

```
DO WHILE  
    <perform procedure>  
END DO
```

Traditionally, if you wanted to perform a conditional or looping type of operation (that is, a procedural type of programming using an IF-THEN-ELSE or DO-WHILE statement), you would use a programming language such as Visual Basic .NET, C#, or COBOL. This explains why many older (so-called legacy) business applications are based on enormous numbers of COBOL program lines. Although that approach is still common, it usually involves the duplication of application code in many programs. Therefore, when procedural changes are required, modifications must be made in many different programs. An environment characterized by such redundancies often creates data management problems.

A better approach is to isolate critical code and then have all application programs call the shared code. The advantage of this modular approach is that the application code is isolated in a single program, thus yielding better maintenance and logic control. In any case, the rise of distributed databases and object-oriented databases required that more application code be stored and executed within the database. (For more information on these databases, see [Chapter 12](#), Distributed Database Management Systems, and Appendix G at www.cengagebrain.com, respectively.) To meet that requirement, most RDBMS vendors created numerous programming language extensions. Those extensions include:

- Flow-control procedural programming structures (IF-THEN-ELSE, DO-WHILE) for logic representation
- Variable declaration and designation within the procedures
- Error management

To remedy the lack of procedural functionality in SQL and to provide some standardization within the many vendor offerings, the SQL-99 standard defined the use of persistent stored modules. A [persistent stored module \(PSM\)](#) is a block of code containing standard SQL statements and procedural extensions that is stored and executed at the DBMS server. The PSM represents business logic that

can be encapsulated, stored, and shared among multiple database users. A PSM lets an administrator assign specific access rights to a stored module to ensure that only authorized users can use it. Support for persistent stored modules is left to each vendor to implement. In fact, for many years, some RDBMSs (such as Oracle, SQL Server, and DB2) supported stored procedure modules within the database before the official standard was promulgated.

MS SQL Server implements persistent stored modules via Transact-SQL and other language extensions, the most notable of which are the .NET family of programming languages. Oracle implements PSMs through its procedural SQL language. [Procedural Language SQL \(PL/SQL\)](#) is a language that makes it possible to use and store procedural code and SQL statements within the database and to merge SQL and traditional programming constructs, such as variables, conditional processing (IF-THEN-ELSE), basic loops (FOR and WHILE loops), and error trapping. The procedural code is executed as a unit by the DBMS when it is invoked (directly or indirectly) by the end user. End users can use PL/SQL to create:

- Anonymous PL/SQL blocks
- Triggers (covered in [Section 8.7.1](#))
- Stored procedures (covered in [Section 8.7.2](#) and [Section 8.7.3](#))
- PL/SQL functions (covered in [Section 8.7.4](#))

Do not confuse PL/SQL functions with SQL's built-in aggregate functions such as MIN and MAX. SQL built-in functions can be used only within SQL statements, while PL/SQL functions are mainly invoked within PL/SQL programs such as triggers and stored procedures. Functions can also be called within SQL statements, provided that they conform to very specific rules that are dependent on your DBMS environment.

NOTE

PL/SQL, triggers, and stored procedures are illustrated within the context of an Oracle DBMS. All examples in the following sections assume the use of Oracle RDBMS.

Using Oracle SQL*Plus, you can write a PL/SQL code block by enclosing the

commands inside BEGIN and END clauses. For example, the following PL/SQL block inserts a new row in the VENDOR table, as shown in [Figure 8.29](#).

```
BEGIN  
    INSERT INTO VENDOR  
        VALUES (25678,'Microsoft Corp.', 'Bill Gates', '765', '546-  
8484', 'WA', 'N');  
END;
```

FIGURE 8.29 Anonymous PL/SQL block examples

```
SQL> BEGIN  
2  INSERT INTO VENDOR  
3  VALUES (25678, 'Microsoft Corp.', 'Bill Gates', '765', '546-8484', 'WA', 'N');  
4  END;  
5 /  
  
PL/SQL procedure successfully completed.  
  
SQL> SET SERVEROUTPUT ON  
SQL>  
SQL> BEGIN  
2  INSERT INTO VENDOR  
3  VALUES (25772, 'Clue Store', 'Issac Hayes', '456', '323-2009', 'WA', 'N');  
4  DBMS_OUTPUT.PUT_LINE('New Vendor Added!');  
5  END;  
6 /  
New Vendor Added!  
  
PL/SQL procedure successfully completed.  
  
SQL> SELECT * FROM VENDOR;  
  
U_CODE U_NAME          U_CONTACT      U_A U_PHONE  U_U  
-----  
25678 Microsoft Corp.   Bill Gates    765 546-8484 WA N  
25772 Clue Store       Issac Hayes   456 323-2009 WA N  
21225 Bryson, Inc.     Smithson     615 223-3234 TN Y  
21226 SuperLoo, Inc.   Flushing     904 215-8995 FL N  
21231 D&E Supply      Singh        615 228-3245 TN Y  
21344 Gomez Bros.     Ortega       615 889-2546 KY N  
22567 Dome Supply     Smith        901 678-1419 GA N  
23119 Randsets Ltd.   Anderson    901 678-3998 GA Y  
24004 Brackman Bros.  Browning    615 228-1410 TN N  
24288 ORDURA, Inc.     Hakford     615 898-1234 TN Y  
25443 B&K, Inc.        Smith        904 227-0093 FL N  
25501 Damal Supplies   Smythe      615 890-3529 TN N  
25595 Rubicon Systems  Orton       904 456-0092 FL Y  
  
13 rows selected.  
  
SQL>
```

The PL/SQL block shown in [Figure 8.29](#) is known as an [anonymous PL/SQL block](#) because it has not been given a specific name. The block's last line uses a forward slash (/) to indicate the end of the command-line entry. This type of PL/SQL block executes as soon as you press Enter after typing the forward slash. Following the PL/SQL block's execution, you will see the message "PL/SQL procedure successfully completed."

Suppose that you want a more specific message displayed on the SQL*Plus screen after a procedure is completed, such as "New Vendor Added." To produce a more specific message, you must do two things:

1. At the SQL > prompt, type SET SERVEROUTPUT ON. This SQL*Plus command enables the client console (SQL*Plus) to receive messages from the server side (Oracle DBMS). Remember, just like standard SQL, the PL/SQL code (anonymous blocks, triggers, and procedures) are executed at the server side, not at the client side. To stop receiving messages from the server, you would enter SET SERVEROUTPUT OFF.

2. To send messages from the PL/SQL block to the SQL*Plus console, use the DBMS_OUTPUT.PUT_LINE function.

The following anonymous PL/SQL block inserts a row in the VENDOR table and displays the message "New Vendor Added!" (see [Figure 8.29](#)).

```
BEGIN  
    INSERT INTO VENDOR  
        VALUES (25772,'Clue Store', 'Issac Hayes', '456', '323-2009', 'VA',  
    'N');  
    DBMS_OUTPUT.PUT_LINE('New Vendor Added!');  
END;  
/
```

In Oracle, you can use the SQL*Plus command SHOW ERRORS to help you diagnose errors found in PL/SQL blocks. The SHOW ERRORS command yields additional debugging information whenever you generate an error after creating or executing a PL/SQL block.

The following example of an anonymous PL/SQL block demonstrates several of the constructs supported by the procedural language. Remember that the exact syntax of the language is vendor-dependent; in fact, many vendors enhance their products with proprietary features.

```
DECLARE
  W_P1 NUMBER(3) := 0;
  W_P2 NUMBER(3) := 10;
  W_NUM NUMBER(2) := 0;
BEGIN
  WHILE W_P2 < 300 LOOP
    SELECT COUNT(P_CODE) INTO W_NUM FROM PRODUCT
    WHERE P_PRICE BETWEEN W_P1 AND W_P2;
    DBMS_OUTPUT.PUT_LINE('There are' || W_NUM || 'Products
with price between' || W_P1 ||
                     'and' || W_P2);
    W_P1 := W_P2 + 1;
    W_P2 := W_P2 + 50;
  END LOOP;
END;
/
```

The block's code and execution are shown in [Figure 8.30](#).

FIGURE 8.30 Anonymous PL/SQL block with variables and loops

```

SQL> DECLARE
  2   M_P1  NUMBER(3) := 0;
  3   M_P2  NUMBER(3) := 10;
  4   M_NUM NUMBER(2) := 0;
  5   BEGIN
  6   WHILE M_P2 < 300 LOOP
  7     SELECT COUNT(P_CODE) INTO M_NUM FROM PRODUCT
  8     WHERE P_PRICE BETWEEN M_P1 AND M_P2;
  9     DBMS_OUTPUT.PUT_LINE('There are ' || M_NUM || ' Products with price between ' || M_P1 || ' and ' || M_P2);
10    M_P1 := M_P2 + 1;
11    M_P2 := M_P2 + 10;
12  END LOOP;
13  END;
14 /
There are 5 Products with price between 0 and 10
There are 6 Products with price between 11 and 20
There are 3 Products with price between 21 and 30
There are 1 Products with price between 31 and 40
There are 0 Products with price between 41 and 50
There are 1 Products with price between 51 and 60
PL/SQL procedure successfully completed.

SQL>

```

SOURCE: Course Technology/Cengage Learning

The PL/SQL block shown in [Figure 8.30](#) has the following characteristics:

- The PL/SQL block starts with the DECLARE section, in which you declare the variable names, the data types, and, if desired, an initial value. Supported data types are shown in [Table 8.8](#).

TABLE 8.8 PL/SQL Basic Data Types

DATA TYPE	DESCRIPTION
CHAR	Character values of a fixed length; for example: W_ZIP CHAR(5)
VARCHAR2	Variable-length character values; for example: W_FNAME VARCHAR2(15)
NUMBER	Numeric values; for example: W_PRICE NUMBER(6,2)
DATE	Date values; for example: W_EMP_DOB DATE
	Inherits the data type from a variable that you declared previously or from an attribute of a database table; for example:
%TYPE	W_PRICE PRODUCT.P_PRICE%TYPE
	Assigns W_PRICE the same data type as the P_PRICE column in the PRODUCT table

-
- A WHILE loop is used. Note the syntax:

```
WHILE condition LOOP
    PL/SQL statements;
END LOOP
```
 - The SELECT statement uses the INTO keyword to assign the output of the query to a PL/SQL variable. You can use the INTO keyword only inside a PL/SQL block of code. If the SELECT statement returns more than one value, you will get an error.
-
- Note the use of the string concatenation symbol (||) to display the output.
 - Each statement inside the PL/SQL code must end with a semicolon (;).

NOTE

PL/SQL blocks can contain only standard SQL data manipulation language (DML) commands such as SELECT, INSERT, UPDATE, and DELETE. The use of data definition language (DDL) commands is not directly supported in a PL/SQL block.

The most useful feature of PL/SQL blocks is that they let you create code that can be named, stored, and executed—either implicitly or explicitly—by the DBMS. That capability is especially desirable when you need to use triggers and stored procedures, which you will explore next.

8.7.1 TRIGGERS

Automating business procedures and automatically maintaining data integrity and consistency are critical in a modern business environment. One of the most critical business procedures is proper inventory management. For example, you want to make sure that current product sales can be supported with sufficient product availability. Therefore, you must ensure that a product order is written to a vendor when that product's inventory drops below its minimum allowable quantity on hand. Better yet, how about ensuring that the task is completed automatically?

To automate product ordering, you first must make sure the product's quantity on hand reflects an up-to-date and consistent value. After the appropriate product availability requirements have been set, two key issues must be addressed:

1. Business logic requires an update of the product quantity on hand each time there is a sale of that product.
2. If the product's quantity on hand falls below its minimum allowable inventory level, the product must be reordered.

To accomplish these two tasks, you could write multiple SQL statements: one to update the product quantity on hand and another to update the product reorder flag. Next, you would have to run each statement in the correct order each time there was a new sale. Such a multistage process would be inefficient because a series of SQL statements must be written and executed each time a product is sold. Even worse, this SQL environment requires that someone must remember to perform the SQL tasks.

A [trigger](#) is procedural SQL code that is *automatically* invoked by the RDBMS upon the occurrence of a given data manipulation event. It is useful to remember that:

- A trigger is invoked before or after a data row is inserted, updated, or deleted.
- A trigger is associated with a database table.
- Each database table may have one or more triggers.
- A trigger is executed as part of the transaction that triggered it.

Triggers are critical to proper database operation and management. For example:

- Triggers can be used to enforce constraints that cannot be enforced at the DBMS design and implementation levels.
- Triggers add functionality by automating critical actions and providing

appropriate warnings and suggestions for remedial action. In fact, one of the most common uses for triggers is to facilitate the enforcement of referential integrity.

- Triggers can be used to update table values, insert records in tables, and call other stored procedures.

Triggers play a critical role in making the database truly useful; they also add processing power to the RDBMS and to the database system as a whole. Oracle recommends triggers for:

- Auditing purposes (creating audit logs)
- Automatic generation of derived column values
- Enforcement of business or security constraints
- Creation of replica tables for backup purposes

To see how a trigger is created and used, examine a simple inventory management problem. For example, if a product's quantity on hand is updated when the product is sold, the system should automatically check whether the quantity on hand falls below its minimum allowable quantity. To demonstrate that process, use the PRODUCT table in [Figure 8.31](#). Note the use of the minimum order quantity (P_MIN_ORDER) and product reorder flag (P_REORDER) columns. The P_MIN_ORDER indicates the minimum quantity for restocking an order. The P_REORDER column is a numeric field that indicates whether the product needs to be reordered (1 = Yes, 0 = No). The initial P_REORDER values are set to 0 (No) to serve as the basis for the initial trigger development.

FIGURE 8.31 The PRODUCT table

SQL> SELECT * FROM PRODUCT;

P_CODE	P_DESCRIP	P_INDATE	P_QOH	P_MIN	P_PRICE	P_DISCOUNT	V_CODE	P_MIN_ORDER	P_REORDER
110ER/31	Power painter, 15 psi., 3-nozz	03-NOV-11	8	5	109.99	0.00	25595	25	0
13-Q2/P2	7.25-in. pwr. saw blade	13-DEC-11	32	15	16.99	0.05	21344	50	0
14-Q1/L3	9.00-in. pwr. saw blade	13-NOV-11	18	12	17.49	0.00	21344	50	0
15H6-Q02	Hrd. cloth, 1/4-in., 2x50	15-JAN-12	15	8	39.95	0.00	23119	35	0
1558-QW1	Hrd. cloth, 1/2-in., 3x50	15-JAN-12	23	5	43.99	0.00	23119	25	0
2232-QTY	B&D jigsaw, 12-in. blade	30-DEC-11	8	5	109.92	0.05	24288	15	0
2232-QWE	B&D jigsaw, 8-in. blade	24-DEC-11	6	5	99.87	0.05	24288	15	0
2238-QPD	B&D cordless drill, 1/2-in.	20-JAN-12	12	5	38.95	0.05	25595	12	0
23109-HB	Claw hammer	20-JAN-12	23	18	9.95	0.10	21225	25	0
23114-AA	Sledge hammer, 12 lb.	02-JAN-12	8	5	14.40	0.05		12	0
54778-ZT	Rat-tail file, 1/8-in. fine	15-DEC-11	43	28	4.99	0.00	21344	25	0
89-MRE-Q	Hicut chain saw, 16 in.	07-FEB-12	11	5	256.99	0.05	24288	10	0
PUC23DRT	PUC pipe, 3.5-in., 8-ft	20-FEB-12	188	75	5.87	0.00		50	0
SM-18277	1.25-in. metal screw, 25	01-MAR-12	172	75	6.99	0.00	21225	50	0
SM-23116	2.5-in. wd. screw, 50	24-FEB-12	237	100	8.45	0.00	21231	100	0
MR3/TT3	Steel matting, 4'x8"x1/8", .5"	17-JAN-12	18	5	119.95	0.10	25595	10	0

16 rows selected.

SQL>

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

Oracle users can run the **PRODLIST.SQL** script file to format the output of the **PRODUCT** table shown in [Figure 8.31](#). The script file is available at www.cengagebrain.com.

Given the **PRODUCT** table listing shown in [Figure 8.31](#), create a trigger to evaluate the product's quantity on hand, **P_QOH**. If the quantity on hand is below the minimum quantity shown in **P_MIN**, the trigger will set the **P_REORDER** column to 1, which represents “Yes.” The syntax to create a trigger in Oracle is:

CREATE OR REPLACE TRIGGER *trigger_name*

[BEFORE AFTER] [DELETE INSERT / UPDATE OF *column_name* **] ON** *table_name*

[FOR EACH ROW]

[DECLARE]

[variable_name] *data type*[:=initial_value]]

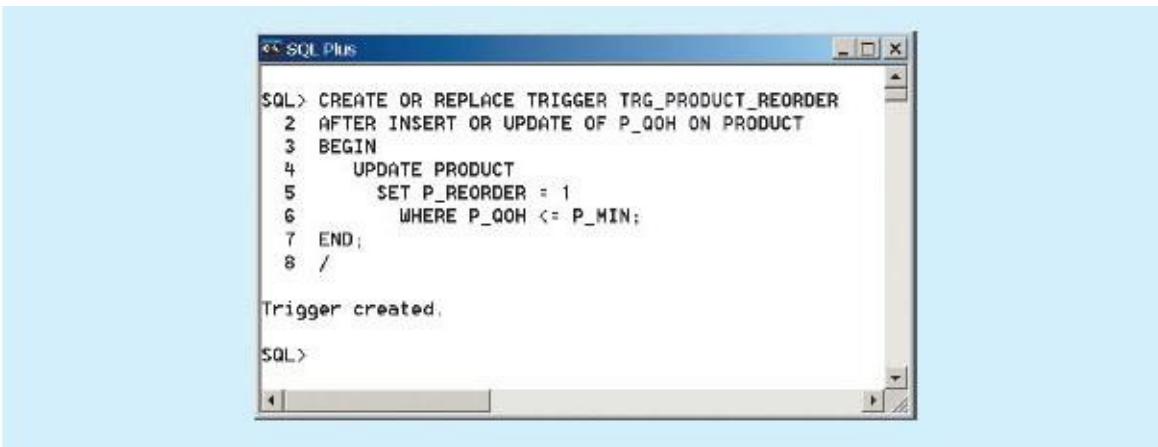
```
BEGIN  
PL/SQL instructions;  
.....  
END;
```

As you can see, a trigger definition contains the following parts:

- *The triggering timing:* BEFORE or AFTER. This timing indicates when the trigger's PL/SQL code executes—in this case, before or after the triggering statement is completed.
- *The triggering event:* The statement that causes the trigger to execute (INSERT, UPDATE, or DELETE).
- *The triggering level:* The two types of triggers are statement-level triggers and row-level triggers.
 - A [statement-level trigger](#) is assumed if you omit the FOR EACH ROW keywords. This type of trigger is executed once, before or after the triggering statement is completed. This is the default case.
 - A [row-level trigger](#) requires use of the FOR EACH ROW keywords. This type of trigger is executed once for each row affected by the triggering statement. (In other words, if you update 10 rows, the trigger executes 10 times.)
- *The triggering action:* The PL/SQL code enclosed between the BEGIN and END keywords. Each statement inside the PL/SQL code must end with a semicolon (;).

In the PRODUCT table's case, you will create a statement-level trigger that is implicitly executed AFTER an UPDATE of the P_QOH attribute for an existing row or AFTER an INSERT of a new row in the PRODUCT table. The trigger action executes an UPDATE statement that compares the P_QOH with the P_MIN column. If the value of P_QOH is equal to or less than P_MIN, the trigger updates the P_REORDER to 1. To create the trigger, Oracle's SQL*Plus will be used. The trigger code is shown in [Figure 8.32](#).

FIGURE 8.32 Creating the TRG_PRODUCT_REORDER trigger



The screenshot shows a window titled "SQL*Plus". Inside, the following SQL code is being run:

```
SQL> CREATE OR REPLACE TRIGGER TRG_PRODUCT_REORDER
  2  AFTER INSERT OR UPDATE OF P_QOH ON PRODUCT
  3  BEGIN
  4      UPDATE PRODUCT
  5          SET P_REORDER = 1
  6          WHERE P_QOH <= P_MIN;
  7  END;
  8 /
```

After the code is executed, the message "Trigger created." is displayed.

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The source code for the triggers in this section is available at www.cengagebrain.com.

To test the TRG_PRODUCT_REORDER trigger, update the quantity on hand of product '11QER/31' to 4. After the UPDATE completes, the trigger is automatically fired and the UPDATE statement inside the trigger code sets the P_REORDER to 1 for all products that are below the minimum. (See [Figure 8.33](#).)

FIGURE 8.33 Verifying the TRG_PRODUCT_REORDER trigger execution

The screenshot shows a SQL*Plus session with the following commands and output:

```

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '110ER/31';
P_CODE      P_DESCRIP          P_INDATE  P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_REORDER
110ER/31 Power painter, 15 poi., 3-nozz 03-NOV-11    8      5  109.99      0.00  25595        25      0

SQL> UPDATE PRODUCT
2 SET P_QOH = 4
3 WHERE P_CODE = '110ER/31';
1 row updated.

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '110ER/31';
P_CODE      P_DESCRIP          P_INDATE  P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_REORDER
110ER/31 Power painter, 15 poi., 3-nozz 03-NOV-11    4      5  109.99      0.00  25595        25      1

SQL>

```

SOURCE: Course Technology/Cengage Learning

The trigger shown in [Figure 8.33](#) seems to work, but what happens if you reduce the minimum quantity of product ‘2232/QWE’? [Figure 8.34](#) shows that when you update the minimum quantity, the quantity on hand of the product ‘2232/QWE’ falls below the new minimum, but the reorder flag is still 0. Why?

FIGURE 8.34 The P_REORDER value mismatch after update of the P_MIN attribute

The screenshot shows a SQL*Plus session with the following commands and output:

```

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '2232/QWE';
P_CODE      P_DESCRIP          P_INDATE  P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_REORDER
2232/QWE B&D jigsaw, 8-in. blade  24-DEC-11    6      5  99.87      0.05  24288        15      0

SQL> UPDATE PRODUCT
2 SET P_MIN = 7
3 WHERE P_CODE = '2232/QWE';
1 row updated.

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '2232/QWE';
P_CODE      P_DESCRIP          P_INDATE  P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_REORDER
2232/QWE B&D jigsaw, 8-in. blade  24-DEC-11    6      7  99.87      0.05  24288        15      0

SQL>

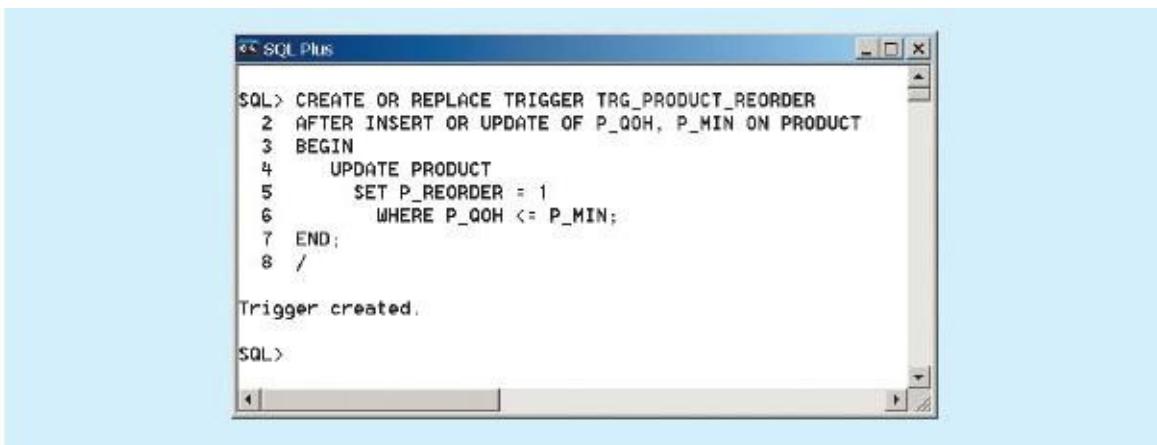
```

SOURCE: Course Technology/Cengage Learning

The answer is simple: you updated the P_MIN column, but the trigger is never

executed. TRG_PRODUCT_ REORDER executes only after an update of the P_QOH column! To avoid that inconsistency, you must modify the trigger event to execute after an update of the P_MIN field, too. The updated trigger code is shown in [Figure 8.35](#).

FIGURE 8.35 Second version of the TRG_PRODUCT_REORDER trigger



The screenshot shows a window titled "SQL*Plus". Inside, the following SQL code is being run:

```
SQL> CREATE OR REPLACE TRIGGER TRG_PRODUCT_REORDER
  2  AFTER INSERT OR UPDATE OF P_QOH, P_MIN ON PRODUCT
  3  BEGIN
  4    UPDATE PRODUCT
  5      SET P_reordered = 1
  6      WHERE P_QOH <= P_Min;
  7  END;
  8 /
```

After the code is executed, the message "Trigger created." is displayed.

SOURCE: Course Technology/Cengage Learning

To test this new trigger version, change the minimum quantity for product '23114-AA' to 10. After that update, the trigger makes sure that the reorder flag is properly set for all of the products in the PRODUCT table. (See Figure 8.36.)

FIGURE 8.36 Successful trigger execution after the P_MIN value is updated

The screenshot shows a SQL*Plus window with the following session history:

```

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '23114-AA';
P_CODE      P_DESCRIP          P_INDATE    P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_Reorder
23114-AA Sledge hammer, 12 lb.     02-JAN-12    8     5    14.40     0.05            12        8

SQL> UPDATE PRODUCT
  2 SET P_MIN = 10
  3 WHERE P_CODE = '23114-AA';

1 row updated.

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '23114-AA';
P_CODE      P_DESCRIP          P_INDATE    P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_Reorder
23114-AA Sledge hammer, 12 lb.     02-JAN-12    8    10    14.40     0.05            12        1
SQL>

```

SOURCE: Course Technology/Cengage Learning

This second version of the trigger seems to work well, but nothing happens if you change the P_QOH value for product ‘11QER/31’, as shown in [Figure 8.37!](#) (Note that the reorder flag is *still* set to 1.) Why didn’t the trigger change the reorder flag to 0?

The answer is that the trigger does not consider all possible cases. Examine the second version of the TRG_PRODUCT_ REORDER trigger code ([Figure 8.35](#)) in more detail:

- The trigger fires after the triggering statement is completed. Therefore, the DBMS always executes two statements (INSERT plus UPDATE or UPDATE plus UPDATE). That is, after you update P_MIN or P_QOH or you insert a new row in the PRODUCT table, the trigger executes another UPDATE statement automatically.
-

FIGURE 8.37 The P_Reorder value mismatch after increasing the P_QOH value

The screenshot shows an Oracle SQL*Plus session titled "SQL*PLUS". The user runs a SELECT statement to find a product with code "110ER/31". The result shows one row: P_CODE "110ER/31", P_DESCRIP "Power painter, 15 psi., 3-nozz", P_INDATE "83-NOV-11", P_QOH "4", P_MIN "5", P_PRICE "109.99", P_DISCOUNT "0.00", U_CODE "25595", P_MIN_ORDER "25", and P_Reorder "1". The user then runs an UPDATE statement to set P_QOH = P_QOH + P_Min_Order where P_CODE = "110ER/31". A message "1 row updated." is displayed. Finally, another SELECT statement is run, showing the same product row with P_QOH now updated to 29.

```

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '110ER/31';
P_CODE      P_DESCRIP          P_INDATE    P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_Reorder
110ER/31    Power painter, 15 psi., 3-nozz 83-NOV-11    4      5   109.99      0.00  25595           25      1
SQL> UPDATE PRODUCT
2  SET P_QOH = P_QOH + P_Min_Order
3  WHERE P_CODE = '110ER/31';
1 row updated.
SQL> SELECT * FROM PRODUCT WHERE P_CODE = '110ER/31';
P_CODE      P_DESCRIP          P_INDATE    P_QOH P_MIN P_PRICE P_DISCOUNT U_CODE P_MIN_ORDER P_Reorder
110ER/31    Power painter, 15 psi., 3-nozz 83-NOV-11    29     5   109.99      0.00  25595           25      1
SQL>

```

SOURCE: Course Technology/Cengage Learning

- The triggering action performs an UPDATE of *all* the rows in the PRODUCT table, *even if the triggering statement updates just one row!* This can affect the performance of the database. Imagine what will happen if you have a PRODUCT table with 519,128 rows and you insert just one product. The trigger will update all 519,129 rows, including the rows that do not need an update!
- The trigger sets the P_Reorder value only to 1; it does not reset the value to 0, even if such an action is clearly required when the inventory level is back to a value greater than the minimum value.

In short, the second version of the TRG_PRODUCT_Reorder trigger still does not complete all of the necessary steps. Now modify the trigger to handle all update scenarios, as shown in [Figure 8.38](#).

The trigger in [Figure 8.38](#) sports several new features:

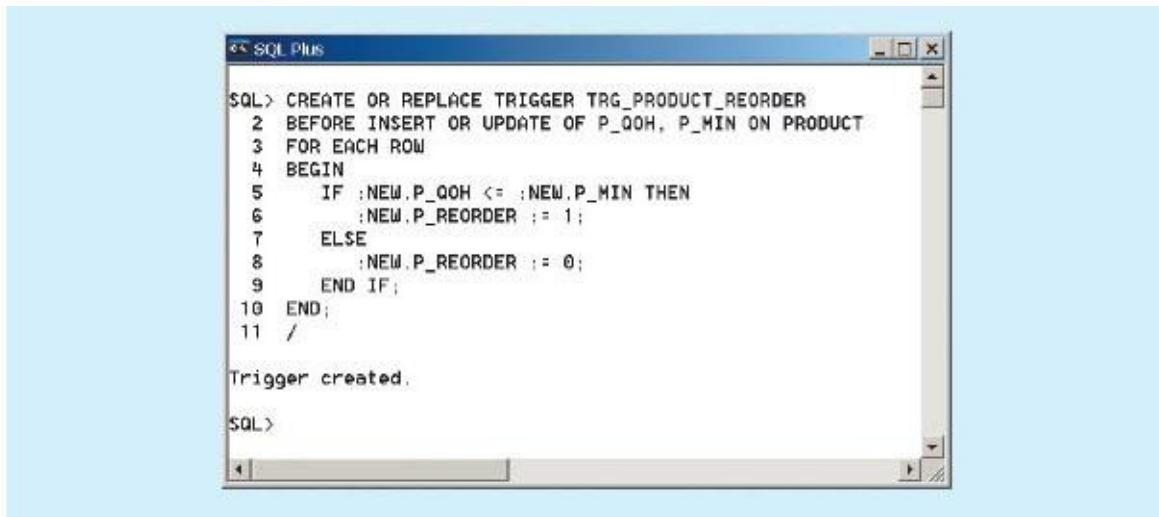
- The trigger is executed *before* the actual triggering statement is completed. In [Figure 8.38](#), the triggering timing is defined in line 2, BEFORE INSERT OR UPDATE. This clearly indicates that the triggering statement is executed before the INSERT or UPDATE completes, unlike the previous trigger examples.
- The trigger is a row-level trigger instead of a statement-level trigger. The

FOR EACH ROW keywords make the trigger a row-level trigger. Therefore, this trigger executes once for each row affected by the triggering statement.

- The trigger action uses the :NEW attribute reference to change the value of the P_REORDER attribute.

The use of the :NEW attribute references deserves a more detailed explanation. To understand its use, you must first consider a basic computing tenet: *all changes are done first in primary memory, then transferred to permanent memory*. In other words, the computer cannot change anything directly in permanent storage (on disk). It must first read the data from permanent storage to primary memory, then make the change in primary memory, and finally write the changed data back to permanent memory (on disk).

FIGURE 8.38 Third version of the TRG_PRODUCT_REORDER trigger



The screenshot shows an SQL*Plus window with the title 'SQL*PLUS'. The command entered is:

```
SQL> CREATE OR REPLACE TRIGGER TRG_PRODUCT_REORDER
2 BEFORE INSERT OR UPDATE OF P_QOH, P_MIN ON PRODUCT
3 FOR EACH ROW
4 BEGIN
5     IF :NEW.P_QOH <= :NEW.P_MIN THEN
6         :NEW.P_REORDER := 1;
7     ELSE
8         :NEW.P_REORDER := 0;
9     END IF;
10 END;
11 /
```

After executing the command, the message 'Trigger created.' is displayed.

SOURCE: Course Technology/Cengage Learning

The DBMS operates in the same way, with one addition. Because ensuring data integrity is critical, the DBMS makes two copies of every row being changed by a DML (INSERT, UPDATE, or DELETE) statement. You will learn more about this in [Chapter 10](#), Transaction Management and Concurrency Control. The first copy contains the original (“old”) values of the attributes before the changes. The second copy contains the changed (“new”) values of the attributes that will

be permanently saved to the database after any changes made by an INSERT, UPDATE, or DELETE. You can use :OLD to refer to the original values; you can use :NEW to refer to the changed values (the values that will be stored in the table). You can use :NEW and :OLD attribute references only within the PL/SQL code of a database trigger action. For example:

- IF :NEW.P_QOH < = :NEW.P_MIN compares the quantity on hand with the minimum quantity of a product. Remember that this is a row-level trigger. Therefore, this comparison is made for each row that is updated by the triggering statement.
- Although the trigger is a BEFORE trigger, this does not mean that the triggering statement has not executed yet. To the contrary, the triggering statement has already taken place; otherwise, the trigger would not have fired and the :NEW values would not exist. Remember, BEFORE means *before* the changes are permanently saved to disk, but *after* the changes are made in memory.
- The trigger uses the :NEW reference to assign a value to the P_REORDER column before the UPDATE or INSERT results are permanently stored in the table. The assignment is always made to the :NEW value (never to the :OLD value), and the assignment always uses the := assignment operator. The :OLD values are *read-only* values; you cannot change them. Note that :NEW.P_REORDER := 1; assigns the value 1 to the P_REORDER column and :NEW.P_REORDER := 0; assigns the value 0 to the P_REORDER column.
- This new trigger version does not use any DML statements!

Before testing the new trigger, note that product ‘11QER/31’ currently has a quantity on hand that is above the minimum quantity, yet the reorder flag is set to 1. Given that condition, the reorder flag must be 0. After creating the new trigger, you can execute an UPDATE statement to fire it, as shown in [Figure 8.39](#).

FIGURE 8.39 Execution of the third trigger version

The screenshot shows an Oracle SQL Plus session. The user runs a SELECT query to view all rows from the PRODUCT table. The results show various products like power tools and hardware items with their respective codes, descriptions, and prices. After selecting 16 rows, the user runs an UPDATE statement to set P_QOH to P_MIN for all selected rows. Finally, a SELECT query is run again for the specific product with code 11QER/31, which now shows the updated P_QOH value.

```

SQL> SELECT * FROM PRODUCT;
P_CODE      P_DESCRIP          P_INDATE    P_QOH   P_MIN   P_PRICE  P_DISCOUNT U_CODE  P_MIN_ORDER P_REORDER
11QER/31  Power painter, 15 psi., 3-nozz 03-NOV-11    29      5  189.99    0.00  25595      25      1
13-Q2/P2  7.25-in. pwr. saw blade    13-DEC-11    32      15  14.99    0.05  21344      50      0
14-Q1/L3  9.00-in. pwr. saw blade    13-NOV-11    18      12  17.49    0.00  21344      50      0
1546-Q02  Hrd. cloth, 1/4-in., 2x50  15-JAN-12    15      8  39.95    0.00  23119      35      0
1558-QW1  Hrd. cloth, 1/2-in., 3x50  15-JAN-12    23      5  43.99    0.00  23119      25      0
2232/QTY  B&D jigsaw, 12-in. blade  30-DEC-11    8       5  109.92    0.05  24288      15      0
2232/QWE  B&D jigsaw, 8-in. blade   24-DEC-11    6       7  99.87    0.05  24288      15      1
2238/QPD  B&D cordless drill, 1/2-in. 20-JAN-12    12      5  38.95    0.05  25595      12      0
23109-HB  Claw hammer                20-JAN-12    23      10  9.95    0.10  21225      25      0
23114-QA  Sledge hammer, 12 lb.     02-JAN-12    8       8  18.48    0.05  21225      12      1
54770-2T  Rat-tail file, 1/8-in. fine 15-DEC-11    43      20  4.99    0.00  21344      25      0
89-WRE-Q  Hicut chain saw, 16 in.    07-FEB-12    11      5  256.99    0.05  24288      10      0
PUC23DRT  PUC pipe, 3.5-in., 8-ft    20-FEB-12    188     75  5.87    0.00  50          50      0
SM-18277  1.25-in. metal screw, 25  01-MAR-12    172     75  6.99    0.00  21225      50      0
SU-23116  2.5-in. wd. screw, 50     29-FEB-12    237     100  8.45    0.00  21231      100     0
MR3/TT3   Steel matting, 4'x8"x1/8", .5" 17-JAN-12    18      5  119.95    0.10  25595      10      0
16 rows selected.

SQL> UPDATE PRODUCT SET P_QOH = P_MIN;

16 rows updated.

SQL> SELECT * FROM PRODUCT WHERE P_CODE = '11QER/31';

P_CODE      P_DESCRIP          P_INDATE    P_QOH   P_MIN   P_PRICE  P_DISCOUNT U_CODE  P_MIN_ORDER P_REORDER
11QER/31  Power painter, 15 psi., 3-nozz 03-NOV-11    29      5  189.99    0.00  25595      25      0
SQL>

```

SOURCE: Course Technology/Cengage Learning

Note the following important features of the code in [Figure 8.39](#):

- The trigger is automatically invoked for each affected row—in this case, all rows of the PRODUCT table. If your triggering statement would have affected only three rows, not all PRODUCT rows would have the correct P_REORDER value set, which is why the triggering statement was set up as shown in [Figure 8.38](#).
- The trigger will run only if you insert a new product row or update P_QOH or P_MIN. If you update any other attribute, the trigger will not run.

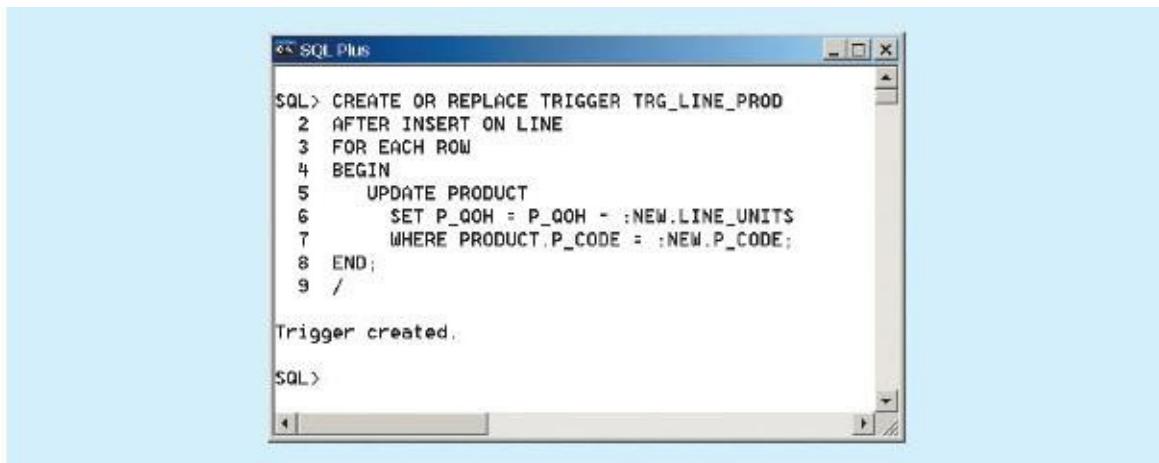
You can also use a trigger to update an attribute in a table other than the one being modified. For example, suppose that you would like to create a trigger that automatically reduces the quantity on hand of a product with every sale. To accomplish that task, you must create a trigger for the LINE table that updates a

row in the PRODUCT table. The sample code for that trigger is shown in [Figure 8.40](#).

Note that the TRG_LINE_PROD row-level trigger executes after inserting a new invoice's LINE and reduces the quantity on hand of the recently sold product by the number of units sold. This row-level trigger updates a row in a different table (PRODUCT), using the :NEW values of the recently added LINE row.

A third trigger example shows the use of variables within a trigger. In this case, you want to update the customer balance (CUS_BALANCE) in the CUSTOMER table after inserting every new LINE row. This trigger code is shown in [Figure 8.41](#).

FIGURE 8.40 TRG_LINE_PROD trigger to update the PRODUCT quantity on hand



The screenshot shows an SQL Plus window with the following SQL code:

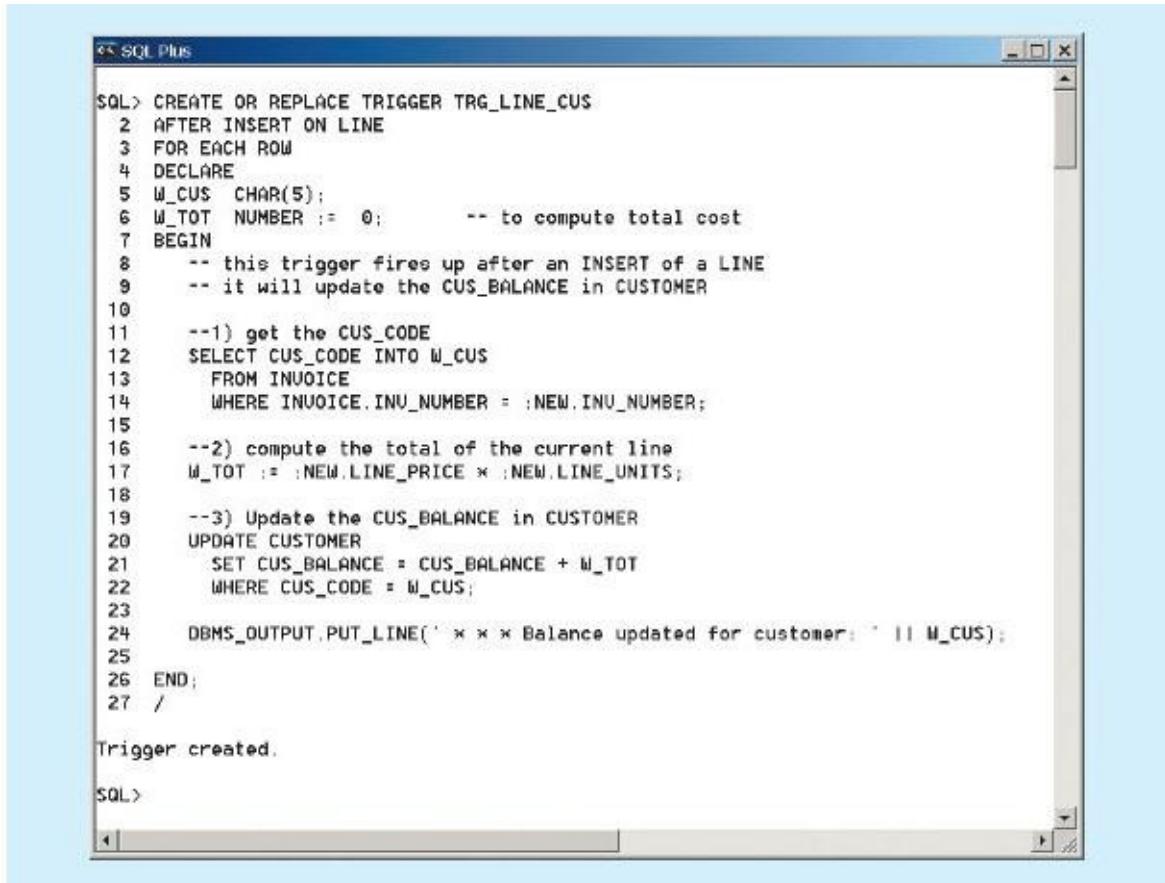
```
SQL> CREATE OR REPLACE TRIGGER TRG_LINE_PROD
  2  AFTER INSERT ON LINE
  3  FOR EACH ROW
  4  BEGIN
  5    UPDATE PRODUCT
  6      SET P_QOH = P_QOH - :NEW.LINE_UNITS
  7      WHERE PRODUCT.P_CODE = :NEW.P_CODE;
  8  END;
  9 /
```

Trigger created.

SQL>

SOURCE: Course Technology/Cengage Learning

FIGURE 8.41 TRG_LINE_CUS trigger to update the customer balance



The screenshot shows a window titled "SQL*Plus" with the following PL/SQL code:

```
SQL> CREATE OR REPLACE TRIGGER TRG_LINE_CUS
  2  AFTER INSERT ON LINE
  3  FOR EACH ROW
  4  DECLARE
  5    W_CUS CHAR(5);
  6    W_TOT NUMBER := 0;      -- to compute total cost
  7    BEGIN
  8      -- this trigger fires up after an INSERT of a LINE
  9      -- it will update the CUS_BALANCE in CUSTOMER
 10
 11      --1) get the CUS_CODE
 12      SELECT CUS_CODE INTO W_CUS
 13        FROM INVOICE
 14       WHERE INVOICE.INU_NUMBER = :NEW.INU_NUMBER;
 15
 16      --2) compute the total of the current line
 17      W_TOT := :NEW.LINE_PRICE * :NEW.LINE_UNITS;
 18
 19      --3) Update the CUS_BALANCE in CUSTOMER
 20      UPDATE CUSTOMER
 21        SET CUS_BALANCE = CUS_BALANCE + W_TOT
 22       WHERE CUS_CODE = W_CUS;
 23
 24      DBMS_OUTPUT.PUT_LINE(' * * * Balance updated for customer: ' || W_CUS);
 25
 26  END;
 27 /
```

Trigger created.

SQL>

SOURCE: Course Technology/Cengage Learning

Carefully examine the trigger in [Figure 8.41](#).

- The trigger is a row-level trigger that executes after each new LINE row is inserted.
- The DECLARE section in the trigger is used to declare any variables used inside the trigger code.
 - You can declare a variable by assigning a name, a data type, and (optionally) an initial value, as in the case of the W_TOT variable.
- The first step in the trigger code is to get the customer code (CUS_CODE) from the related INVOICE table. Note that the SELECT statement returns only one attribute (CUS_CODE) from the INVOICE table. Also

note that the attribute returns only one value as specified by the use of the WHERE clause, *to restrict the query output to a single value*.

- Note the use of the INTO clause within the SELECT statement. You use the INTO clause to assign a value from a SELECT statement to a variable (W_CUS) used within a trigger.
- The second step in the trigger code computes the total of the line by multiplying :NEW.LINE_UNITS by :NEW. LINE_PRICE and assigning the result to the W_TOT variable.
- The final step updates the customer balance by using an UPDATE statement and the W_TOT and W_CUS trigger variables.
- Double dashes (--) are used to indicate comments within the PL/SQL block.

To summarize the triggers created in this section:

- TRG_PRODUCT_REORDER is a row-level trigger that updates P_REORDER in PRODUCT when a new product is added or when the P_QOH or P_MIN columns are updated.
- TRG_LINE_PROD is a row-level trigger that automatically reduces the P_QOH in PRODUCT when a new row is added to the LINE table.
- TRG_LINE_CUS is a row-level trigger that automatically increases the CUS_BALANCE in CUSTOMER when a new row is added in the LINE table.

The use of triggers facilitates the automation of multiple data management tasks. Although triggers are independent objects, they are associated with database tables. When you delete a table, all its trigger objects are deleted with it. However, if you needed to delete a trigger without deleting the table, you could use the following command:

```
DROP TRIGGER trigger_name
```

Trigger Action Based on Conditional DML Predicates

You could also create triggers whose actions depend on the type of DML statement (INSERT, UPDATE, or DELETE) that fires the trigger. For example, you could create a trigger that executes after an INSERT, an UPDATE, or a DELETE on the PRODUCT table. But how do you know which one of the three statements caused the trigger to execute? In those cases, you could use the following syntax:

```
IF INSERTING THEN ... END IF;  
IF UPDATING THEN ... END IF;  
IF DELETING THEN ... END IF;
```

8.7.2 STORED PROCEDURES

A [stored procedure](#) is a named collection of procedural and SQL statements. Just like database triggers, stored procedures are stored in the database. One of the major advantages of stored procedures is that they can be used to encapsulate and represent business transactions. For example, you can create a stored procedure to represent a product sale, a credit update, or the addition of a new customer. By doing that, you can encapsulate SQL statements within a single stored procedure and execute them as a single transaction. There are two clear advantages to the use of stored procedures:

- Stored procedures substantially reduce network traffic and increase performance. Because the procedure is stored at the server, there is no transmission of individual SQL statements over the network. The use of stored procedures improves system performance because all transactions are executed locally on the RDBMS, so each SQL statement does not have to travel over the network.
- Stored procedures help reduce code duplication by means of code isolation and code sharing (creating unique PL/SQL modules that are called by application programs), thereby minimizing the chance of errors and the cost of application development and maintenance.

To create a stored procedure, you use the following syntax:

```
CREATE OR REPLACE PROCEDURE procedure_name [(argument [IN/OUT]  
data-type, ... )]
```

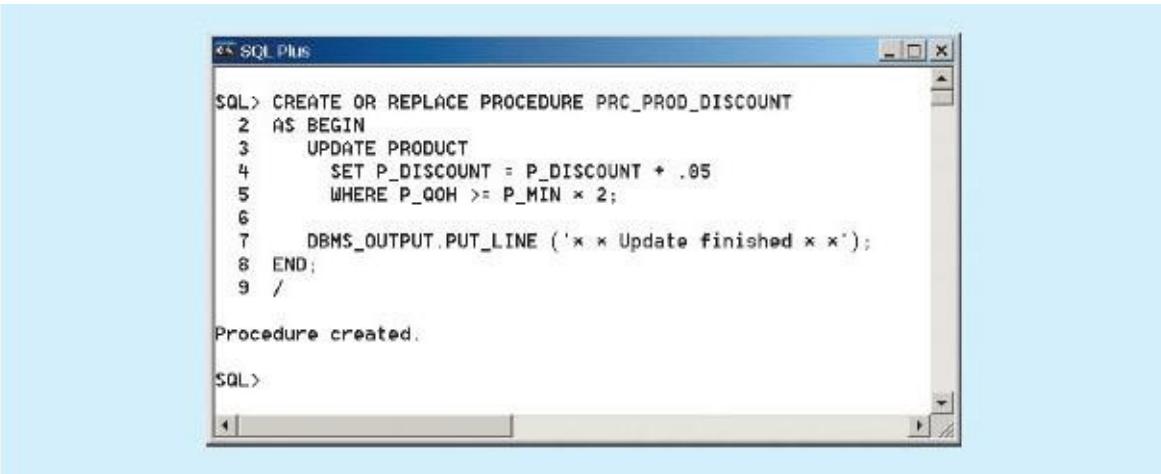
```
[IS/AS]
[variable_name data type[:=initial_value] ]
BEGIN
    PL/SQL or SQL statements;
    ...
END;
```

Note the following important points about stored procedures and their syntax:

- *argument* specifies the parameters that are passed to the stored procedure. A stored procedure could have zero or more arguments or parameters.
- *IN/OUT* indicates whether the parameter is for input, output, or both.
- *data-type* is one of the procedural SQL data types used in the RDBMS. The data types normally match those used in the RDBMS table creation statement.
- Variables can be declared between the keywords IS and BEGIN. You must specify the variable name, its data type, and (optionally) an initial value.

To illustrate stored procedures, assume that you want to create a procedure (PRC_PROD_DISCOUNT) to assign an additional 5 percent discount for all products when the quantity on hand is more than or equal to twice the minimum quantity. [Figure 8.42](#) shows how the stored procedure is created.

FIGURE 8.42 Creating the PRC_PROD_DISCOUNT stored procedure



The screenshot shows a Windows application window titled "SQL*Plus". Inside, SQL code is being entered and executed. The code creates a stored procedure named "PRC_PROD_DISCOUNT". The procedure begins with a BEGIN block, updates the "PRODUCT" table by setting "P_DISCOUNT" to its current value plus 0.05 where "P_QOH" is greater than or equal to twice "P_MIN", and then uses the DBMS_OUTPUT.PUT_LINE function to print a message ("* * Update finished * *"). The procedure ends with an END; statement and a final slash. After executing the code, the message "Procedure created." is displayed. The SQL prompt "SQL>" appears again at the bottom.

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The source code for the stored procedures in this section is available at www.cengagebrain.com.

Note in [Figure 8.42](#) that the PRC_PROD_DISCOUNT stored procedure uses the DBMS_OUTPUT.PUT_LINE function to display a message when the procedure executes. (This action assumes that you previously ran SET SERVEROUTPUT ON.)

To execute the stored procedure, you must use the following syntax:

EXEC procedure_name[(parameter_list)];

For example, to see the results of running the PRC_PROD_DISCOUNT stored procedure, you can use the EXEC PRC_PROD_DISCOUNT command shown in [Figure 8.43](#).

FIGURE 8.43 Results of the PRC_PROD_DISCOUNT stored procedure

```

SQL> SELECT * FROM PRODUCT;
P_CODE P_DESCRIP P_INDATE P_QOH P_MIN P_PRICE P_DISCOUNT V_CODE P_MIN_ORDER P_Reorder
110ER/31 Power painter, 15 psi., 3-nozz 03-NOV-11 29 5 109.99 0.00 25595 25 0
13-Q2/P2 7.25-in. pwr. saw blade 13-DEC-11 32 15 14.99 0.05 21344 50 0
14-Q1/L3 9.00-in. pwr. saw blade 13-NOV-11 18 12 17.49 0.00 21344 50 0
1546-QQ2 Hrd. cloth, 1/4-in., 2x50 15-JAN-12 15 8 39.95 0.00 23119 35 0
1558-CW1 Hrd. cloth, 1/2-in., 3x50 15-JAN-12 23 5 41.99 0.00 23119 25 0
2232/OTY B&D jigsaw, 12-in. blade 30-DEC-11 8 5 109.92 0.05 24288 15 0
2232/CWE B&D jigsaw, 8-in. blade 24-DEC-11 6 7 99.87 0.05 24288 15 1
2238/QPD B&D cordless drill, 1/2-in. 20-JAN-12 12 5 38.95 0.05 25595 12 0
23109-HB Claw hammer 20-JAN-12 23 10 9.95 0.10 21225 25 0
23114-AA Sledge hammer, 12 lb. 02-3-JAN-12 8 10 14.40 0.05 21344 12 1
54778-2T Rat-tail file, 1/8-in. Fine 15-DEC-11 43 20 4.99 0.00 21344 25 0
89-WKE-Q Hicut chain saw, 18 in. 07-FEB-12 11 5 256.99 0.05 24288 10 0
PVC23DRT PVC pipe, 3.5-in., 8-ft. 20-FEB-12 188 75 5.87 0.00 24288 50 0
SM-18277 1.25-in. metal screw, 25 01-MAR-12 172 75 6.99 0.00 21225 50 0
SW-23116 2.5-in. wd. screw, 50 24-FEB-12 237 100 8.45 0.00 21231 100 0
MR3/TTS Steel matting, 4'x8'x1/6", .5" 17-JAN-12 18 5 119.95 0.10 25595 10 0
16 rows selected.

SQL> EXEC PRC_PROD_DISCOUNT;
* * Update finished *

PL/SQL procedure successfully completed.

SQL> SELECT * FROM PRODUCT;
P_CODE P_DESCRIP P_INDATE P_QOH P_MIN P_PRICE P_DISCOUNT V_CODE P_MIN_ORDER P_Reorder
110ER/31 Power painter, 15 psi., 3-nozz 03-NOV-11 29 5 109.99 0.05 25595 25 0
13-Q2/P2 7.25-in. pwr. saw blade 13-DEC-11 32 15 14.99 0.10 21344 50 0
14-Q1/L3 9.00-in. pwr. saw blade 13-NOV-11 18 12 17.49 0.00 21344 50 0
1546-QQ2 Hrd. cloth, 1/4-in., 2x50 15-JAN-12 15 8 39.95 0.00 23119 35 0
1558-CW1 Hrd. cloth, 1/2-in., 3x50 15-JAN-12 23 5 41.99 0.00 23119 25 0
2232/OTY B&D jigsaw, 12-in. blade 30-DEC-11 8 5 109.92 0.05 24288 15 0
2232/CWE B&D jigsaw, 8-in. blade 24-DEC-11 6 7 99.87 0.05 24288 15 1
2238/QPD B&D cordless drill, 1/2-in. 20-JAN-12 12 5 38.95 0.10 25595 12 0
23109-HB Claw hammer 20-JAN-12 23 10 9.95 0.15 21225 25 0
23114-AA Sledge hammer, 12 lb. 02-3-JAN-12 8 10 14.40 0.05 21344 12 1
54778-2T Rat-tail file, 1/8-in. Fine 15-DEC-11 43 20 4.99 0.05 21344 25 0
89-WKE-Q Hicut chain saw, 18 in. 07-FEB-12 11 5 256.99 0.10 24288 10 0
PVC23DRT PVC pipe, 3.5-in., 8-ft. 20-FEB-12 188 75 5.87 0.05 24288 50 0
SM-18277 1.25-in. metal screw, 25 01-MAR-12 172 75 6.99 0.05 21225 50 0
SW-23116 2.5-in. wd. screw, 50 24-FEB-12 237 100 8.45 0.05 21231 100 0
MR3/TTS Steel matting, 4'x8'x1/6", .5" 17-JAN-12 18 5 119.95 0.15 25595 10 0
16 rows selected.

SQL>

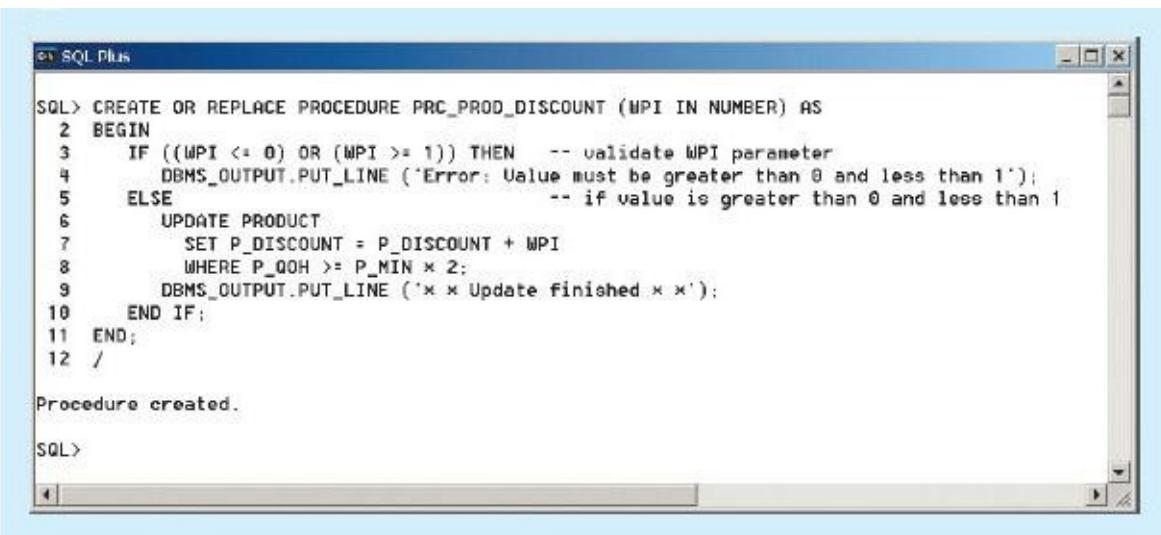
```

SOURCE: Course Technology/Cengage Learning

Using [Figure 8.43](#) as your guide, you can see how the product discount attribute was increased by 5 percent for all products with a quantity on hand that was more than or equal to twice the minimum quantity. (Compare the first PRODUCT table listing to the second PRODUCT table listing.)

One of the main advantages of procedures is that you can pass values to them. For example, the previous PRC_PROD_DISCOUNT procedure worked well, but what if you want to make the percentage increase an input variable? In that case, you can pass an argument to represent the rate of increase to the procedure. [Figure 8.44](#) shows the code for that procedure.

FIGURE 8.44 Second version of the PRC_PROD_DISCOUNT stored procedure



```
SQL> CREATE OR REPLACE PROCEDURE PRC_PROD_DISCOUNT (WPI IN NUMBER) AS
 2 BEGIN
 3   IF ((WPI <= 0) OR (WPI >= 1)) THEN -- validate WPI parameter
 4     DBMS_OUTPUT.PUT_LINE ('Error: Value must be greater than 0 and less than 1');
 5   ELSE                                -- if value is greater than 0 and less than 1
 6     UPDATE PRODUCT
 7       SET P_DISCOUNT = P_DISCOUNT + WPI
 8     WHERE P_QOH >= P_MIN * 2;
 9     DBMS_OUTPUT.PUT_LINE ('* * Update finished * *');
10   END IF;
11 END;
12 /
```

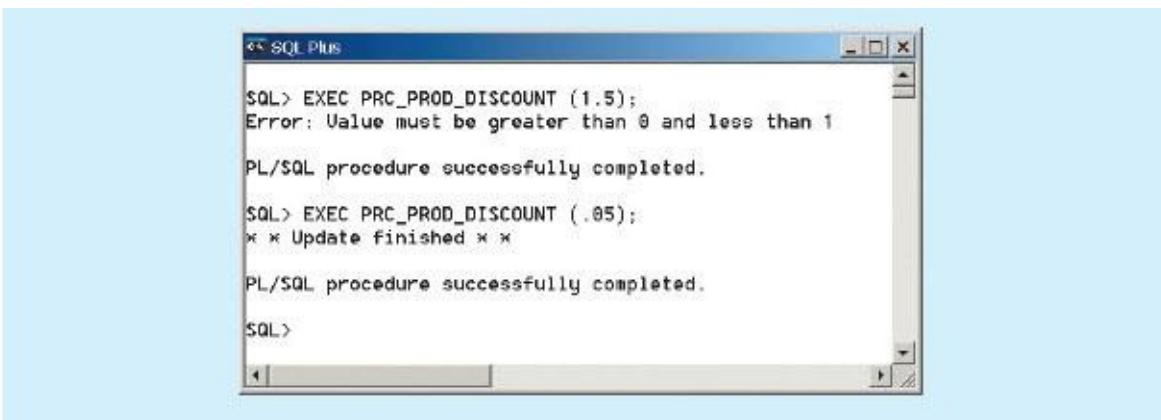
Procedure created.

SQL>

SOURCE: Course Technology/Cengage Learning

[Figure 8.45](#) shows the execution of the second version of the PRC_PROD_DISCOUNT stored procedure. Note that if the procedure requires arguments, they must be enclosed in parentheses and separated by commas.

FIGURE 8.45 Results of the second version of the PRC_PROD_DISCOUNT stored procedure



```
SQL> EXEC PRC_PROD_DISCOUNT (1.5);
Error: Value must be greater than 0 and less than 1
PL/SQL procedure successfully completed.

SQL> EXEC PRC_PROD_DISCOUNT (.05);
* * Update finished * *

PL/SQL procedure successfully completed.

SQL>
```

SOURCE: Course Technology/Cengage Learning

Stored procedures are also useful to encapsulate shared code to represent business transactions. For example, you can create a simple stored procedure to add a new customer. By using a stored procedure, all programs can call it by

name each time a new customer is added. Naturally, if new customer attributes are added later, you will need to modify the stored procedure. However, the programs that use the stored procedure will not need to know the name of the newly added attribute; they will need to add only a new parameter to the procedure call. (Notice the PRC_CUS_ADD stored procedure shown in [Figure 8.46](#).)

FIGURE 8.46 The PRC_CUS_ADD stored procedure

The screenshot shows a Windows application window titled "SQL*Plus". Inside, SQL commands are being run against a database. The session starts with creating the stored procedure PRC_CUS_ADD, which takes five parameters: M_LN, M_FN, M_INIT, M_AC, and M_PH, all of type VARCHAR. The procedure uses the CUS_CODE_SEQ sequence to generate a customer code. It inserts the new customer into the CUSTOMER table and outputs a message confirming the addition. After creation, it executes the procedure with values 'Walker', 'James', NULL, '615', and '84-HORSE', resulting in a customer record being added. A SELECT statement then retrieves the customer record for 'Walker'. Finally, an attempt is made to execute the procedure again with the same values, but it fails due to a constraint violation (ORA-01400) because the CUS_CODE_SEQ sequence has already generated the customer code '20030'.

```
SQL> CREATE OR REPLACE PROCEDURE PRC_CUS_ADD
  2  (M_LN IN VARCHAR, M_FN IN VARCHAR, M_INIT IN VARCHAR, M_AC IN VARCHAR, M_PH IN VARCHAR)
  3  AS
  4  BEGIN
  5  -- note that the procedure uses the CUS_CODE_SEQ sequence created earlier
  6  -- attribute names are required when not giving values for all table attributes
  7  INSERT INTO CUSTOMER (CUS_CODE, CUS_LNAME, CUS_FNAME, CUS_INITIAL, CUS_AREACODE, CUS_PHONE)
  8    VALUES (CUS_CODE_SEQ.NEXTVAL, M_LN, M_FN, M_INIT, M_AC, M_PH);
  9  DBMS_OUTPUT.PUT_LINE ('Customer ' || M_LN || ', ' || M_FN || ' added.');
10 END;
11 /  

Procedure created.  

SQL> EXEC PRC_CUS_ADD('Walker', 'James', NULL, '615', '84-HORSE');
Customer Walker, James added.  

PL/SQL procedure successfully completed.  

SQL> SELECT * FROM CUSTOMER WHERE CUS_LNAME = 'Walker';
  CUS_CODE CUS_LNAME      CUS_FNAME      C CUS_CUS_PHONE CUS_BALANCE
-----  -----  -----  -----  -----
      20030 Walker          James        615 84-HORSE           0  

SQL> EXEC PRC_CUS_ADD ('Lowery', 'Denisee', NULL, NULL, NULL);
BEGIN PRC_CUS_ADD ('Lowery', 'Denisee', NULL, NULL, NULL); END;  

*
ERROR at line 1:
ORA-01400: cannot insert NULL into ("BOOK","CUSTOMER","CUS_AREACODE")
ORA-06512: at "BOOK.PRC_CUS_ADD", line 7
ORA-06512: at line 1  

SQL>
```

SOURCE: Course Technology/Cengage Learning

As you examine [Figure 8.46](#), note these features:

- The PRC_CUS_ADD procedure uses several parameters, one for each required attribute in the CUSTOMER table.

- The stored procedure uses the CUS_CODE_SEQ sequence to generate a new customer code.
- The required parameters—those specified in the table definition—must be included and can be null *only* when the table specifications permit nulls for that parameter. For example, note that the second customer addition was unsuccessful because the CUS_AREACODE is a required attribute and cannot be null.
- The procedure displays a message in the SQL*Plus console to let the user know that the customer was added.

The next two examples further illustrate the use of sequences within stored procedures. In this case, create two stored procedures:

1. The PRC_INV_ADD procedure adds a new invoice.
2. The PRC_LINE_ADD procedure adds a new product line row for a given invoice.

Both procedures are shown in [Figure 8.47](#). Note the use of a variable in the PRC_LINE_ADD procedure to get the product price from the PRODUCT table.

FIGURE 8.47 The PRC_INV_ADD and PRC_LINE_ADD stored procedures

The screenshot shows a window titled "SQL Plus" with two SQL statements being run:

```
SQL> CREATE OR REPLACE PROCEDURE PRC_INV_ADD (W_CUS_CODE IN VARCHAR2, W_DATE IN DATE)
  2 AS BEGIN
  3   INSERT INTO INVVOICE
  4     VALUES (INV_NUMBER_SEQ.NEXTVAL, W_CUS_CODE, W_DATE);
  5   DBMS_OUTPUT.PUT_LINE ('Invoice added');
  6 END;
  7 /
Procedure created.

SQL> CREATE OR REPLACE PROCEDURE PRC_LINE_ADD (W_LN IN NUMBER, W_P_CODE IN VARCHAR2, W_LU IN NUMBER)
  2 AS
  3   W_LP NUMBER := 0.00;
  4 BEGIN
  5   -- get the product price
  6   SELECT P_PRICE INTO W_LP
  7   FROM PRODUCT
  8   WHERE PRODUCT.P_CODE = W_P_CODE;
  9
 10  -- adds the new line row
 11  INSERT INTO LINE
 12    VALUES (INV_NUMBER_SEQ.CURRVAL, W_LN, W_P_CODE, W_LU, W_LP);
 13  DBMS_OUTPUT.PUT_LINE ('Invoice line ' || W_LN || ' added');
 14 END;
 15 /
Procedure created.
```

SOURCE: Course Technology/Cengage Learning

To test the procedures shown in [Figure 8.47](#):

1. Call the PRC_INV_ADD procedure with the new invoice data as arguments.

2. Call the PRC_LINE_ADD procedure and pass the product line arguments.

That process is illustrated in [Figure 8.48](#).

FIGURE 8.48 Testing the PRC_INV_ADD and PRC_LINE_ADD procedures

The screenshot shows a Windows application window titled "SQL*Plus". Inside, several SQL statements are executed:

```
SQL> EXEC PRC_INU_ADD (20010, '09-APR-2012');
Invoice added
PL/SQL procedure successfully completed.

SQL> EXEC PRC_LINE_ADD (1, '13-Q2/P2', 1);
x x x Balance updated for customer: 20010
Invoice line 1 added
PL/SQL procedure successfully completed.

SQL> EXEC PRC_LINE_ADD (2, '23109-HB', 1);
x x x Balance updated for customer: 20010
Invoice line 2 added
PL/SQL procedure successfully completed.

SQL> SELECT * FROM INUOICE WHERE CUS_CODE = 20010;
INU_NUMBER  CUS_CODE INU_DATE
-----
4010        20010 09-APR-12

SQL> SELECT * FROM LINE WHERE INU_NUMBER = (SELECT INU_NUMBER FROM INUOICE WHERE CUS_CODE = 20010);
INU_NUMBER LINE_NUMBER P_CODE    LINE_UNITS LINE_PRICE
-----
4010          1 13-Q2/P2      1       14.99
4010          2 23109-HB      1       9.95

SQL> SELECT * FROM PRODUCT WHERE P_CODE IN ('13-Q2/P2','23109-HB');
P_CODE  P_DESCRPT          P_INDATE P_QOH P_MIN P_PRICE P_DISCOUNT V_CODE P_MIN_ORDER P_REORDER
13-Q2/P2 7.25-in. pwr. saw blade 13-DEC-11 29   15   14.99  0.15  21344     50   0
23109-HB Claw hammer            20-JAN-12 20   10   9.95   0.20  21225     25   0

SQL> SELECT * FROM CUSTOMER WHERE CUS_CODE = 20010;
CUS_CODE CUS_LNAME    CUS_FNAME    C CUS CUS_PHONE CUS_BALANCE
20010 Connery      Sean          615 898-2007    24.94

SQL>
```

SOURCE: Course Technology/Cengage Learning

8.7.3 PL/SQL PROCESSING WITH CURSORS

Until now, all of the SQL statements you have used inside a PL/SQL block (trigger or stored procedure) have returned a single value. If the SQL statement returns more than one value, you will generate an error. If you want to use a SQL statement that returns more than one value inside your PL/SQL code, you need to use a cursor. A [cursor](#) is a special construct used in procedural SQL to hold the data rows returned by a SQL query. You can think of a cursor as a reserved area of memory in which the output of the query is stored, like an array holding columns and rows. Cursors are held in a reserved memory area in the DBMS server, not in the client computer.

There are two types of cursors: implicit and explicit. An [implicit cursor](#) is automatically created in procedural SQL when the SQL statement returns only

one value. Up to this point, all of the examples created an implicit cursor. An [explicit cursor](#) is created to hold the output of a SQL statement that may return two or more rows (but could return zero rows or only one). To create an explicit cursor, you use the following syntax inside a PL/SQL DECLARE section:

```
CURSOR cursor_name IS select-query;
```

Once you have declared a cursor, you can use specific PL/SQL cursor processing commands (OPEN, FETCH, and CLOSE) anywhere between the BEGIN and END keywords of the PL/SQL block. [Table 8.9](#) summarizes the main use of each command.

TABLE 8.9 Cursor Processing Commands

CURSOR COMMAND	EXPLANATION
OPEN	<p>Opening the cursor executes the SQL command and populates the cursor with data, opening the cursor for processing. The cursor declaration command only reserves a named memory area for the cursor; it does not populate the cursor with the data. Before you can use a cursor, you need to open it. For example:</p> <pre>OPEN <i>cursor_name</i></pre> <p>Once the cursor is opened, you can use the FETCH command to retrieve data from the cursor and copy it to the PL/SQL variables for processing. The syntax is:</p> <pre>FETCH <i>cursor_name</i> INTO <i>variable1</i> [, <i>variable2</i>, ...]</pre> <p>The PL/SQL variables used to hold the data must be declared in the DECLARE section and must have data types compatible with the columns retrieved by the SQL command. If the cursor's SQL statement returns five columns, there must be five PL/SQL variables to receive the data from the cursor.</p>
FETCH	<p>This type of processing resembles the one-record-at-a-time processing used in previous database models. The first time you fetch a row from the cursor, the first row of data from the cursor is copied to the PL/SQL variables; the second time you fetch a row from the cursor, the second row of data is placed in the PL/SQL variables; and so on.</p>

CLOSE The CLOSE command closes the cursor for processing.

Cursor-style processing involves retrieving data from the cursor one row at a time. Once you open a cursor, it becomes an active data set. That data set contains a “current” row pointer. Therefore, after opening a cursor, the current row is the first row of the cursor.

When you fetch a row from the cursor, the data from the “current” row in the cursor is copied to the PL/SQL variables. After the fetch, the “current” row pointer moves to the next row in the set and continues until it reaches the end of the cursor.

How do you know what number of rows are in the cursor? Or how do you know when you have reached the end of the cursor data set? You know because cursors have special attributes that convey important information. [Table 8.10](#) summarizes the cursor attributes.

TABLE 8.10 Cursor Attributes

ATTRIBUTE DESCRIPTION

%ROWCOUNT Returns the number of rows fetched so far. If the cursor is not OPEN, it returns an error. If no FETCH has been done but the cursor is OPEN, it returns 0.

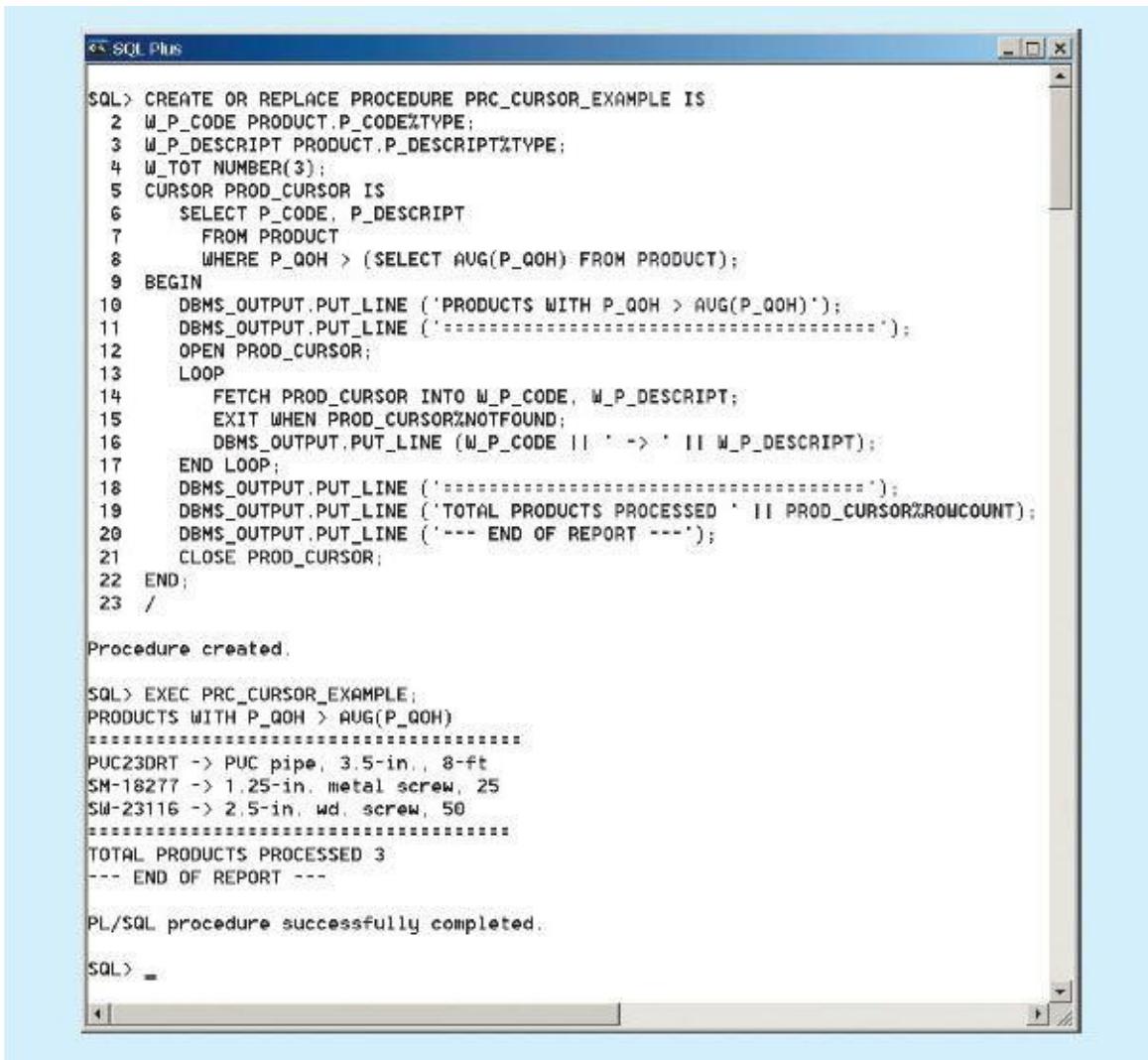
%FOUND Returns TRUE if the last FETCH returned a row, and FALSE if not. If the cursor is not OPEN, it returns an error. If no FETCH has been done, it contains NULL.

%NOTFOUND Returns TRUE if the last FETCH did not return any row, and FALSE if it did. If the cursor is not OPEN, it returns an error. If no FETCH has been done, it contains NULL.

%ISOPEN Returns TRUE if the cursor is open (ready for processing) or FALSE if the cursor is closed. Remember, before you can use a cursor, you must open it.

To illustrate the use of cursors, use a simple stored procedure example to list the products that have a greater quantity on hand than the average quantity on hand for all products. The code is shown in [Figure 8.49](#).

FIGURE 8.49 A simple PRC_CURSOR_EXAMPLE



The screenshot shows a Windows-style window titled "SQL*Plus". Inside, PL/SQL code is being entered and executed. The code creates a procedure named "PRC_CURSOR_EXAMPLE" that selects products with a quantity on hand (P_QOH) greater than the average (AUG) of P_QOH from the "PRODUCT" table. It uses DBMS_OUTPUT.PUT_LINE to print the results and a cursor loop to process each row. The output shows the procedure was created successfully, then executed, displaying three rows of product information, and finally completed.

```
SQL> CREATE OR REPLACE PROCEDURE PRC_CURSOR_EXAMPLE IS
  2   W_P_CODE PRODUCT.P_CODE%TYPE;
  3   W_P_DESCRPT PRODUCT.P_DESCRPT%TYPE;
  4   W_TOT NUMBER(3);
  5   CURSOR PROD_CURSOR IS
  6     SELECT P_CODE, P_DESCRPT
  7       FROM PRODUCT
  8      WHERE P_QOH > (SELECT AVG(P_QOH) FROM PRODUCT);
  9   BEGIN
10     DBMS_OUTPUT.PUT_LINE ('PRODUCTS WITH P_QOH > AVG(P_QOH)');
11     DBMS_OUTPUT.PUT_LINE ('-----');
12     OPEN PROD_CURSOR;
13     LOOP
14       FETCH PROD_CURSOR INTO W_P_CODE, W_P_DESCRPT;
15       EXIT WHEN PROD_CURSOR%NOTFOUND;
16       DBMS_OUTPUT.PUT_LINE (W_P_CODE || ' -> ' || W_P_DESCRPT);
17     END LOOP;
18     DBMS_OUTPUT.PUT_LINE ('-----');
19     DBMS_OUTPUT.PUT_LINE ('TOTAL PRODUCTS PROCESSED ' || PROD_CURSOR%ROWCOUNT);
20     DBMS_OUTPUT.PUT_LINE ('--- END OF REPORT ---');
21     CLOSE PROD_CURSOR;
22   END;
23 /
```

Procedure created.

```
SQL> EXEC PRC_CURSOR_EXAMPLE;
PRODUCTS WITH P_QOH > AVG(P_QOH)
-----
PUC23DRT -> PUC pipe, 3.5-in., 8-ft
SM-18277 -> 1.25-in. metal screw, 25
SM-23116 -> 2.5-in. wd. screw, 50
-----
TOTAL PRODUCTS PROCESSED 3
--- END OF REPORT ---
```

```
PL/SQL procedure successfully completed.
```

```
SQL> _
```

SOURCE: Course Technology/Cengage Learning

As you examine the stored procedure code shown in [Figure 8.49](#), note the following important characteristics:

- Lines 2 and 3 use the %TYPE data type in the variable definition section. As indicated in [Table 8.8](#), the %TYPE data type indicates that the given variable inherits the data type from a previously declared variable or from an attribute of a database table. In this case, you are using the

`%TYPE` to indicate that the `W_P_CODE` and `W_P_DESCRIPTOR` will have the same data type as the respective columns in the `PRODUCT` table. This way, you ensure that the PL/SQL variable will have a compatible data type.

- Line 5 declares the `PROD_CURSOR` cursor.
- Line 12 opens the `PROD_CURSOR` cursor and populates it.
- Line 13 uses the `LOOP` statement to loop through the data in the cursor, fetching one row at a time.
- Line 14 uses the `FETCH` command to retrieve a row from the cursor and place it in the respective PL/SQL variables.
- Line 15 uses the `EXIT` command to evaluate when there are no more rows in the cursor (using the `%NOTFOUND` cursor attribute) and to exit the loop.
- Line 19 uses the `%ROWCOUNT` cursor attribute to obtain the total number of rows processed.
- Line 21 issues the `CLOSE PROD_CURSOR` command to close the cursor.

The use of cursors, combined with standard SQL, makes working with relational databases very desirable because programmers can work in the best of both worlds: set-oriented processing and record-oriented processing. Any experienced programmer knows to use the tool that best fits the job. Sometimes you will be better off manipulating data in a set-oriented environment; at other times, it might be better to use a record-oriented environment. Procedural SQL lets you have your proverbial cake and eat it too. Procedural SQL provides functionality that enhances the capabilities of the DBMS while maintaining a high degree of manageability.

8.7.4 PL/SQL STORED FUNCTIONS

Using programmable or procedural SQL, you can also create your own stored functions. Stored procedures and functions are very similar. A [stored function](#) is basically a named group of procedural and SQL statements that returns a value, as indicated by a RETURN statement in its program code. To create a function, you use the following syntax:

```
CREATE FUNCTION function_name (argument IN data-type, ...) RETURN data-type [IS]
BEGIN
    PL/SQL statements;
    ...
    RETURN (value or expression);
END;
```

Stored functions can be invoked only from within stored procedures or triggers, and cannot be invoked from SQL statements unless the function follows some very specific compliance rules. Remember not to confuse built-in SQL functions (such as MIN, MAX, and AVG) with stored functions.

8.8 EMBEDDED SQL

There is little doubt that SQL's popularity as a data manipulation language is due in part to its ease of use and its powerful data-retrieval capabilities. In the real world, however, database systems are related to other systems and programs, and you still need a conventional programming language such as Visual Basic .NET, C#, or COBOL to integrate database systems with other programs and systems. If you are developing Web applications, you are most likely familiar with Visual Studio .NET, Java, ASP, or ColdFusion. Yet, almost regardless of the programming tools you use, if your Web application or Windows-based GUI system requires access to a database such as MS Access, SQL Server, Oracle, or DB2, you will likely need to use SQL to manipulate the data in the database.

[Embedded SQL](#) is a term used to refer to SQL statements contained within an application programming language such as Visual Basic .NET, C#, COBOL, or Java. The program being developed might be a standard binary executable in Windows or Linux, or it might be a Web application designed to run over the

Internet. No matter what language you use, if it contains embedded SQL statements, it is called the [host language](#). Embedded SQL is still the most common approach to maintaining procedural capabilities in DBMS-based applications. However, mixing SQL with procedural languages requires that you understand some key differences between the two.

- *Run-time mismatch.* Remember that SQL is a nonprocedural, interpreted language; that is, each instruction is parsed, its syntax is checked, and it is executed one instruction at a time.¹ All of the processing takes place at the server side. Meanwhile, the host language is generally a binary-executable program (also known as a compiled program). The host program typically runs at the client side in its own memory space, which is different from the DBMS environment.
- *Processing mismatch.* Conventional programming languages (COBOL, ADA, FORTRAN, Pascal, C++, and PL/I) process one data element at a time. Although you can use arrays to hold data, you still process the array elements one row at a time. This is especially true for file manipulation, where the host language typically manipulates data one record at a time. However, newer programming environments such as Visual Studio .NET have adopted several object-oriented extensions that help the programmer manipulate data sets in a cohesive manner.
- *Data type mismatch.* SQL provides several data types, but some of them might not match data types used in different host languages (for example, the DATE and VARCHAR2 data types).

To bridge the differences, the Embedded SQL standard defines a framework to integrate SQL within several programming languages. The Embedded SQL framework defines the following:

- A standard syntax to identify embedded SQL code within the host language (EXEC SQL/END-EXEC).
- A standard syntax to identify host variables, which are variables in the host language that receive data from the database (through the embedded SQL code) and process the data in the host language. All host variables are preceded by a colon (:).

- A communication area used to exchange status and error information between SQL and the host language. This communication area contains two variables—SQLCODE and SQLSTATE.

Another way to interface host languages and SQL is through the use of a call-level interface (CLI), in which the programmer writes to an application programming interface (API). A common CLI in Windows is provided by the Open Database Connectivity (ODBC) interface.



ONLINE CONTENT

Additional coverage of CLIs and ODBC is available in **Appendix F, Client/Server Systems**, and **Appendix J, Web Database Development with ColdFusion**, at www.cengagebrain.com.

Before continuing, you should explore the process required to create and run an executable program with embedded SQL statements. If you have ever programmed in COBOL or C++, you are familiar with the multiple steps required to generate the final executable program. Although the specific details vary among language and DBMS vendors, the following general steps are standard:

1. The programmer writes embedded SQL code within the host language instructions. The code follows the standard syntax required for the host language and embedded SQL.
2. A preprocessor is used to transform the embedded SQL into specialized procedure calls that are DBMS-and language-specific. The preprocessor is provided by the DBMS vendor and is specific to the host language.
3. The program is compiled using the host language compiler. The compiler creates an object code module for the program containing the DBMS procedure calls.
4. The object code is linked to the respective library modules and generates the

executable program. This process binds the DBMS procedure calls to the DBMS run-time libraries. Additionally, the binding process typically creates an “access plan” module that contains instructions to run the embedded code at run time.

5. The executable is run, and the embedded SQL statement retrieves data from the database.

Note that you can embed individual SQL statements or even an entire PL/SQL block. Up to this point in the book, you have used a DBMS-provided application (SQL*Plus) to write SQL statements and PL/SQL blocks in an interpretive mode to address one-time or ad hoc data requests. However, it is extremely difficult and awkward to use ad hoc queries to process transactions inside a host language. Programmers typically embed SQL statements within a host language that is compiled once and executed as often as needed. To embed SQL into a host language, follow this syntax:

```
EXEC SQL
    SQL statement;
END-EXEC.
```

The preceding syntax will work for SELECT, INSERT, UPDATE, and DELETE statements. For example, the following embedded SQL code will delete employee 109, George Smith, from the EMPLOYEE table:

```
EXEC SQL
    DELETE FROM EMPLOYEE WHERE EMP_NUM = 109;
END-EXEC.
```

Remember, the preceding embedded SQL statement is compiled to generate an executable statement. Therefore, the statement is fixed permanently and cannot change (unless, of course, the programmer changes it). Each time the program runs, it deletes the same row. In short, the preceding code is good only for the first run; all subsequent runs will likely generate an error. Clearly, this code would be more useful if you could specify a variable to indicate the employee number to be deleted.

In embedded SQL, all host variables are preceded by a colon (:). The host variables may be used to send data from the host language to the embedded SQL, or they may be used to receive the data from the embedded SQL. To use a

host variable, you must first declare it in the host language. Common practice is to use similar host variable names as the SQL source attributes. For example, if you are using COBOL, you would define the host variables in the Working Storage section. Then you would refer to them in the embedded SQL section by preceding them with a colon. For example, to delete an employee whose employee number is represented by the host variable W_EMP_NUM, you would write the following code:

```
EXEC SQL
      DELETE FROM EMPLOYEE WHERE EMP_NUM =
:W_EMP_NUM;
END-EXEC.
```

At run time, the host variable value will be used to execute the embedded SQL statement. What happens if the employee you are trying to delete does not exist in the database? How do you know that the statement has been completed without errors? As mentioned previously, the embedded SQL standard defines a SQL communication area to hold status and error information. In COBOL, such an area is known as the SQLCA area and is defined in the Data Division as follows:

```
EXEC SQL
      INCLUDE SQLCA
END-EXEC.
```

The SQLCA area contains two variables for status and error reporting. [Table 8.11](#) shows some of the main values returned by the variables and their meaning.

TABLE 8.11 SQL Status and Error Reporting Variables

VARIABLE NAME	VALUE EXPLANATION
SQLCODE	Old-style error reporting supported for backward compatibility only; returns an integer value (positive or negative)
0	Successful completion of command

100	No data; the SQL statement did not return any rows and did not select, update, or delete any rows
-999	Any negative value indicates that an error occurred
SQLSTATE	Added by SQL-92 standard to provide predefined error codes; defined as a character string (5 characters long)

00000 Successful completion of command

Multiple values in the format XXYYYY where:
XX-> represents the class code
YYY-> represents the subclass code

The following embedded SQL code illustrates the use of the SQLCODE within a COBOL program.

```

EXEC SQL
    SELECT    EMP_LNAME, EMP_LNAME INTO :W_EMP_FNAME,
:W_EMP_LNAME
                WHERE EMP_NUM = :W_EMP_NUM;
END-EXEC.
IF SQLCODE = 0 THEN
    PERFORM DATA_ROUTINE
ELSE
    PERFORM ERROR_ROUTINE
END-IF.
```

In this example, the SQLCODE host variable is checked to determine whether the query completed successfully. If it did, the DATA_ROUTINE is performed; otherwise, the ERROR_ROUTINE is performed.

Just as with PL/SQL, embedded SQL requires the use of cursors to hold data from a query that returns more than one value. If COBOL is used, the cursor can be declared either in the Working Storage section or in the Procedure Division.

The cursor must be declared and processed, as you learned earlier in [Section 8.7.3](#). To declare a cursor, you use the syntax shown in the following example:

```
EXEC SQL
    DECLARE PROD_CURSOR FOR
        SELECT P_CODE, P_DESCRIFT FROM PRODUCT
        WHERE P_QOH > (SELECT AVG(P_QOH) FROM PRODUCT);
END-EXEC.
```

Next, you must open the cursor to make it ready for processing:

```
EXEC SQL
    OPEN PROD_CURSOR;
END-EXEC.
```

To process the data rows in the cursor, you use the `FETCH` command to retrieve one row of data at a time and place the values in the host variables. The `SQLCODE` must be checked to ensure that the `FETCH` command completed successfully. This section of code typically constitutes part of a routine in the COBOL program. Such a routine is executed with the `PERFORM` command. For example:

```
EXEC SQL
    FETCH PROD_CURSOR INTO :W_P_CODE, :W_P_DESCRIFT;
END-EXEC.
IF SQLCODE = 0 THEN
    PERFORM DATA_ROUTINE
ELSE
    PERFORM ERROR_ROUTINE
END-IF.
```

When all rows have been processed, you close the cursor as follows:

```
EXEC SQL
    CLOSE PROD_CURSOR;
END-EXEC.
```

Thus far, you have seen examples of embedded SQL in which the programmer used predefined SQL statements and parameters. Therefore, the end users of the programs are limited to the actions that were specified in the application programs. That style of embedded SQL is known as [static SQL](#), meaning that the SQL statements will not change while the application is running. For example, the SQL statement might read like this:

```
SELECT P_CODE, P_DESCRIFT, P_QOH, P_PRICE
```

```
FROM PRODUCT  
WHERE P_PRICE > 100;
```

Note that the attributes, tables, and conditions are known in the preceding SQL statement. Unfortunately, end users seldom work in a static environment. They are more likely to require the flexibility of defining their data access requirements on the fly. Therefore, the end user requires that SQL be as dynamic as the data access requirements.

Dynamic SQL is a term used to describe an environment in which the SQL statement is not known in advance; instead, the SQL statement is generated at run time. At run time in a dynamic SQL environment, a program can generate the SQL statements that are required to respond to ad hoc queries. In such an environment, neither the programmer nor the end user is likely to know precisely what kind of queries will be generated or how they will be structured. For example, a dynamic SQL equivalent of the preceding example could be:

```
SELECT :W_ATTRIBUTE_  
FROM   :W_TABLE  
WHERE  :W_CONDITION;
```

Note that the attribute list and the condition are not known until the end user specifies them. W_TABLE, W_ATTRIBUTE_LIST, and W_CONDITION are text variables that contain the end-user input values used in the query generation. Because the program uses the end-user input to build the text variables, the end user can run the same program multiple times to generate varying outputs. For example, in one instance, the end user might want to know which products cost less than \$100; in another case, the end user might want to know how many units of a given product are available for sale at any given moment.

Although dynamic SQL is clearly flexible, such flexibility carries a price. Dynamic SQL tends to be much slower than static SQL. Dynamic SQL also requires more computer resources (overhead). Finally, you are more likely to find inconsistent levels of support and incompatibilities among DBMS vendors.

SUMMARY

- Operations that join tables can be classified as inner joins and outer joins. An inner join is the traditional join in which only rows that meet a given criterion are selected. An outer join returns the matching rows as well as the

rows with unmatched attribute values for one table or both tables to be joined.

- A natural join returns all rows with matching values in the matching columns and eliminates duplicate columns. This style of query is used when the tables share a common attribute with a common name. One important difference between the syntax for a natural join and for the old-style join is that the natural join does not require the use of a table qualifier for the common attributes.
- Joins may use keywords such as USING and ON. If the USING clause is used, the query will return only the rows with matching values in the column indicated in the USING clause; that column must exist in both tables. If the ON clause is used, the query will return only the rows that meet the specified join condition.
- Subqueries and correlated queries are used when it is necessary to process data based on *other* processed data. That is, the query uses results that were previously unknown and that are generated by another query. Subqueries may be used with the FROM, WHERE, IN, and HAVING clauses in a SELECT statement. A subquery may return a single row or multiple rows.
- Most subqueries are executed in a serial fashion. That is, the outer query initiates the data request, and then the inner subquery is executed. In contrast, a correlated subquery is a subquery that is executed once for each row in the outer query. That process is similar to the typical nested loop in a programming language. A correlated subquery is so named because the inner query is related to the outer query—the inner query references a column of the outer subquery.
- SQL functions are used to extract or transform data. The most frequently used functions are date and time functions. The results of the function output can be used to store values in a database table, to serve as the basis for the computation of derived variables, or to serve as a basis for data comparisons. Function formats can be vendor-specific. Aside from time and date functions, there are numeric and string functions as well as conversion

functions that convert one data format to another.

- SQL provides relational set operators to combine the output of two queries to generate a new relation. The UNION and UNION ALL set operators combine the output of two or more queries and produce a new relation with all unique (UNION) or duplicate (UNION ALL) rows from both queries. The INTERSECT relational set operator selects only the common rows. The MINUS set operator selects only the rows that are different. UNION, INTERSECT, and MINUS require union-compatible relations.

- Oracle sequences may be used to generate values to be assigned to a record. For example, a sequence may be used to number invoices automatically. MS Access uses an AutoNumber data type to generate numeric sequences. MS SQL Server uses the Identity column property to designate the column that will have sequential numeric values automatically assigned to it. There can only be one Identity column per SQL Server table.
- Procedural Language SQL (PL/SQL) can be used to create triggers, stored procedures, and PL/SQL functions. A trigger is procedural SQL code that is automatically invoked by the DBMS upon the occurrence of a specified data manipulation event (UPDATE, INSERT, or DELETE). Triggers are critical to proper database operation and management. They help automate various transaction and data management processes, and they can be used to enforce constraints that are not enforced at the DBMS design and implementation levels.

- A stored procedure is a named collection of SQL statements. Just like database triggers, stored procedures are stored in the database. One of the major advantages of stored procedures is that they can be used to encapsulate and represent complete business transactions. Use of stored procedures substantially reduces network traffic and increases system performance. Stored procedures also help reduce code duplication by creating unique PL/SQL modules that are called by the application programs, thereby minimizing the chance of errors and the cost of application development and maintenance.
- When SQL statements are designed to return more than one value inside the PL/SQL code, a cursor is needed. You can think of a cursor as a reserved

area of memory in which the output of the query is stored, like an array holding columns and rows. Cursors are held in a reserved memory area in the DBMS server, rather than in the client computer. There are two types of cursors: implicit and explicit.

- Embedded SQL refers to the use of SQL statements within an application programming language such as Visual Basic .NET, C#, COBOL, or Java. The language in which the SQL statements are embedded is called the host language. Embedded SQL is still the most common approach to maintaining procedural capabilities in DBMS-based applications.

KEY TERMS

[anonymous PL/SQL block](#)
[base table](#)
[batch update routine](#)
[correlated subquery](#)
[CREATE VIEW](#)
[cross join](#)
[cursor](#)
[dynamic SQL](#)
[embedded SQL](#)
[explicit cursor](#)
[host language](#)
[implicit cursor](#)
[inner join](#)
[outer join](#)
[persistent stored module \(PSM\)](#)
[Procedural Language SQL \(PL/SQL\)](#)
[row-level trigger](#)
[set-oriented](#)
[statement-level trigger](#)
[static SQL](#)
[stored function](#)

[stored procedure](#)
[trigger](#)
[union-compatible](#)
[updatable view](#)
[view](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at
www.cengagebrain.com.

REVIEW QUESTIONS

1. What is a CROSS JOIN? Give an example of its syntax.

2. What three join types are included in the OUTER JOIN classification?
3. Using tables named T1 and T2, write a query example for each of the three join types you described in Question 2. Assume that T1 and T2 share a common column named C1.

4. What is a subquery, and what are its basic characteristics?
5. What are the three types of results that a subquery can return?

6. What is a correlated subquery? Give an example.
7. Explain the difference between a regular subquery and a correlated subquery.

8. What does it mean to say that SQL operators are set-oriented?
9. The relational set operators UNION, INTERSECT, and MINUS work properly only when the relations are union-compatible. What does union-compatible mean, and how would you check for this condition?
10. What is the difference between UNION and UNION ALL? Write the syntax for each.
11. Suppose you have two tables: EMPLOYEE and EMPLOYEE_1. The EMPLOYEE table contains the records for three employees: Alice Cordoza, John Cretchakov, and Anne McDonald. The EMPLOYEE_1 table contains the records for employees John Cretchakov and Mary Chen. Given that information, list the query output for the UNION query.
12. Given the employee information in Question 11, list the query output for the UNION ALL query.
13. Given the employee information in Question 11, list the query output for the INTERSECT query.
14. Given the employee information in Question 11, list the query output for the MINUS query of EMPLOYEE to EMPLOYEE_1.
15. Why does the order of the operands (tables) matter in a MINUS query but not in a UNION query?
16. What MS Access and SQL Server function should you use to calculate the number of days between your birth date and the current date?
17. What Oracle function should you use to calculate the number of days between your birth date and the current date?
18. Suppose a PRODUCT table contains two attributes, PROD_CODE and VEND_CODE. Those two attributes have values of ABC, 125, DEF, 124, GHI, 124, and JKL, 123, respectively. The VENDOR table contains a

single attribute, VEND_CODE, with values 123, 124, 125, and 126, respectively. (The VEND_CODE attribute in the PRODUCT table is a foreign key to the VEND_CODE in the VENDOR table.) Given that information, what would be the query output for:

- a. A UNION query based on the two tables?
 - b. A UNION ALL query based on the two tables?
 - c. An INTERSECT query based on the two tables?
 - d. A MINUS query based on the two tables?
19. What string function should you use to list the first three characters of a company's EMP_LNAME values? Give an example using a table named EMPLOYEE. Provide examples for Oracle and SQL Server.
20. What is an Oracle sequence? Write its syntax.
21. What is a trigger, and what is its purpose? Give an example.
22. What is a stored procedure, and why is it particularly useful? Give an example.
23. What is embedded SQL, and how is it used?
24. What is dynamic SQL, and how does it differ from static SQL?

PROBLEMS

Use the database tables in [Figure P8.1](#) as the basis for [Problems 1-18](#).

FIGURE P8.1 Ch08_SimpleCo database tables

Database name: CH08_SimpleCo

Table name: CUSTOMER

CUST_NUM	CUST_LNAME	CUST_FNAME	CUST_BALANCE
1000	Smith	Jeanne	1050.11
1001	Ortega	Juan	840.92

Table name: CUSTOMER_2

CUST_NUM	CUST_LNAME	CUST_FNAME
2000	McPherson	Anne
2001	Ortega	Juan
2002	Kowalski	Jan
2003	Chen	George

Table name: INVOICE

INV_NUM	CUST_NUM	INV_DATE	INV_AMOUNT
8000	1000	23-Mar-12	235.89
8001	1001	23-Mar-12	312.82
8002	1001	30-Mar-12	528.10
8003	1000	12-Apr-12	194.78
8004	1000	23-Apr-12	619.44

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The **Ch08_SimpleCo** database is available at www.cengagebrain.com, as are the script files to duplicate this data set in Oracle.

1. Create the tables. (Use the MS Access example shown in [Figure P8.1](#) to see what table names and attributes to use.)
2. Insert the data into the tables you created in [Problem 1](#).
3. Write the query that will generate a combined list of customers from the tables CUSTOMER and CUSTOMER_2 that do not include the duplicate customer records. Only the customer named Juan Ortega shows up in both customer tables.
4. Write the query that will generate a combined list of customers to include the duplicate customer records.

FIGURE P8.3 Combined list of customers without duplicates

CUST_LNAME	CUST_FNAME
Chen	George
Kowalski	Jan
McPherson	Anne
Ortega	Juan
Smith	Jeanne

SOURCE: Course Technology/Cengage Learning

FIGURE P8.4 Combined list of customers with duplicates

CUST_LNAME	CUST_FNAME
Smith	Jeanne
Ortega	Juan
McPherson	Anne
Ortega	Juan
Kowalski	Jan
Chen	George

SOURCE: Course Technology/Cengage Learning

5. Write the query that will show only the duplicate customer records.

 6. Write the query that will generate only the records that are unique to the CUSTOMER_2 table.
-
-

FIGURE P8.5 Duplicate customer records

CUST_LNAME	CUST_FNAME
Ortega	Juan

SOURCE: Course Technology/Cengage Learning

FIGURE P8.6 Customers unique to the CUSTOMER_2 table

CUST_LNAME	CUST_FNAME
McPherson	Anne
Kowalski	Jan
Chen	George

SOURCE: Course Technology/Cengage Learning

-
7. Write the query to show the invoice number, the customer number, the customer name, the invoice date, and the invoice amount for all customers in the CUSTOMER table with a balance of \$1,000 or more.
-

FIGURE P8.7 Invoices of customers with a balance over \$1,000

INV_NUM	CUST_NUM	CUST_LNAME	CUST_FNAME	INV_DATE	INV_AMOUNT
8000	1000	Smith	Jeanne	23-Mar-12	235.89
8003	1000	Smith	Jeanne	12-Apr-12	194.78
8004	1000	Smith	Jeanne	23-Apr-12	619.44

SOURCE: Course Technology/Cengage Learning

-
8. Write the query for all the invoices that will show the invoice number, the invoice amount, the average invoice amount, and the difference between the average invoice amount and the actual invoice amount.
-

FIGURE P8.8 Invoice amounts compared to the average invoice amount

INV_NUM	INV_AMOUNT	AVG_INV	DIFF
8000	235.89	378.21	-142.32
8001	312.82	378.21	-65.39
8002	528.10	378.21	149.89
8003	194.78	378.21	-183.43
8004	619.44	378.21	241.23

SOURCE: Course Technology/Cengage Learning

-
9. Write the query that will write Oracle sequences to produce automatic customer number and invoice number values. Start the customer numbers at 1000 and the invoice numbers at 5000.

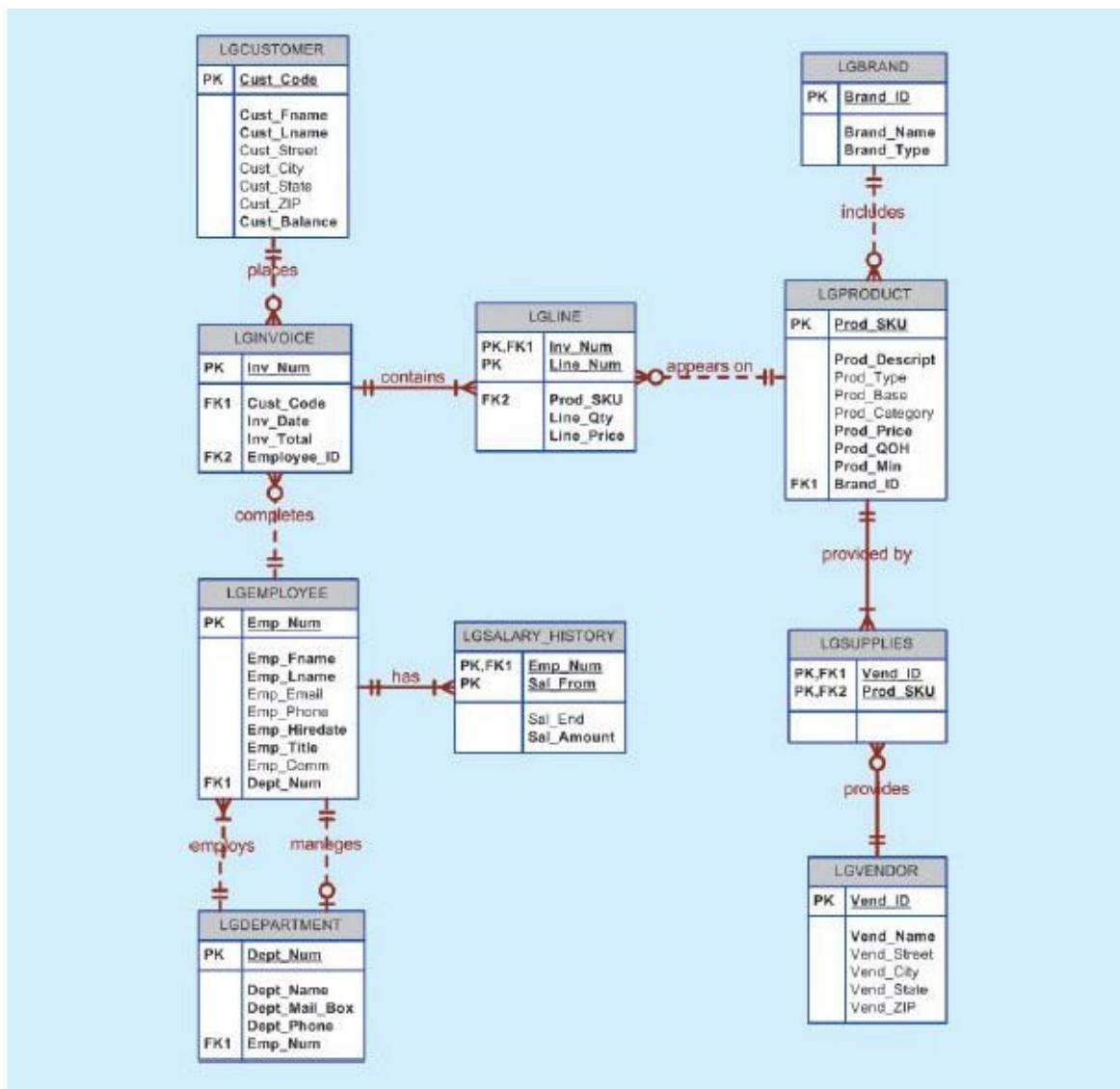
 10. Modify the CUSTOMER table to include two new attributes: CUST_DOB and CUST_AGE. Customer 1000 was born on March 15, 1979, and customer 1001 was born on December 22, 1988.
 11. Assuming that you completed [Problem 10](#), write the query that will list the names and ages of your customers.
 12. Assuming that the CUSTOMER table contains a CUST_AGE attribute, write the query to update the values in that attribute. (*Hint:* Use the results of the previous query.)
 13. Write the query that lists the average age of your customers. (Assume that the CUSTOMER table has been modified to include the CUST_DOB and the derived CUST_AGE attribute.)
 14. Write the trigger to update the CUST_BALANCE in the CUSTOMER table when a new invoice record is entered. (Assume that the sale is a credit sale.)
Test the trigger using the following new INVOICE record:
8005, 1001, '27-APR-12', 225.40
Name the trigger trg_updatecustbalance.
 15. Write a procedure to add a new customer to the CUSTOMER table. Use the following values in the new record:
1002, 'Rauthor', 'Peter', 0.00
Name the procedure prc_cust_add. Run a query to see if the record has been added.

 16. Write a procedure to add a new invoice record to the INVOICE table. Use the following values in the new record:
8006, 1000, '30-APR-12', 301.72
Name the procedure prc_invoice_add. Run a query to see if the record has been added.
 17. Write a trigger to update the customer balance when an invoice is deleted.
Name the trigger trg_updatecustbalance2.

18. Write a procedure to delete an invoice, giving the invoice number as a parameter. Name the procedure prc_inv_delete. Test the procedure by deleting invoices 8005 and 8006.

Use the Ch08_LargeCo database shown in [Figure P8.19](#) to work [Problems 19–27](#). For problems with very large result sets, only the first several rows of output are shown in the following figures.

FIGURE P8.19 The LargeCo ERD



SOURCE: Course Technology/Cengage Learning

19. Write a query to display the products that have a price greater than \$50.

 20. Write a query to display the current salary for each employee in department 300. Assume that only current employees are kept in the system, and therefore the most current salary for each employee is the entry in the salary history with a NULL end date. Sort the output in descending order by salary amount.
 21. Write a query to display the starting salary for each employee. The starting salary would be the entry in the salary history with the oldest salary start date for each employee. Sort the output by employee number.
-

FIGURE P8.20 Current salary for employees in department 300

Emp_Num	Emp_LName	Emp_FName	Sal_Amount
83746	RANKIN	SEAN	95550
84328	CARPENTER	FERN	94090
83716	RIVERA	HENRY	85920
84432	JAMISON	MERLE	85360
83902	VARGAS	ROCKY	79540
83695	MENDEZ	CARROLL	79200
84500	WESTON	CHRISTINE	78690
84594	TIDWELL	ODELL	77400
83910	AVERY	LAUREN	76110
83359	WATTS	MERLE	72240
83790	ACEVEDO	LAVINA	72000

SOURCE: Course Technology/Cengage Learning

FIGURE P8.21 Starting salary for each employee

Emp_Num	Emp_LName	Emp_FName	Sal_Amount
83304	MCDONALD	TAMARA	19770
83308	LOVE	CONNIE	11230
83312	BAKER	ROSALBA	39260
83314	DAVID	CHAROLETTE	15150
83318	PECK	DARCIE	22330
83321	FARMER	ANGELINA	18250
83332	LONG	WILLARD	23380
83341	CORTEZ	CHRISTINE	14510
83347	WINN	QUINTIN	17010
83349	SINGH	JENNIFFER	21220
83359	WATTS	MERLE	25370
83366	BLEDSOE	PHOEBE	23200

SOURCE: Course Technology/Cengage Learning

-
22. Write a query to display the invoice number, line numbers, product SKUs, product descriptions, and brand ID for sales of sealer and top coat products of the same brand on the same invoice.
-

FIGURE P8.22 Invoices for sealer and top coat of the same brand

Inv_Num	Lino_Num	p_Prod_Sku	p_Prod_Descript	I2_Line_Num	p2_Prod_Sku	p2_Prod_Descript	Brand_ID
116	2	5140-RTG	Fire Resistant Sealer, for Exterior Wood (ULC Approved)	1	1203-AIS	Fire Retardant Coating, Latex, Interior, Flat (ULC Approved)	36
118	2	5140-RTG	Fire Resistant Sealer, for Exterior Wood (ULC Approved)	5	5046-TTC	Aluminum Paint, Heat Resistant (Up to 427°C - 800°F)	36
135	5	3036-PCT	Sealer, for Knots	2	1074-VVJ	Light Industrial Coating, Exterior, Water Based ('eggshell-like'- MPI Gloss Level 3)	25
153	2	3701-YAW	Sealer, Solvent Based, for Concrete Floors	1	3555-NAD	Water Repellant, Clear (Not Paintable)	30
222	1	1336-FVM	Alkyd, Sanding Sealer, Clear	3	8199-YRF	Varnish, Exterior, Water Based, (Satin-Like) MPI Gloss Level 4	33
234	4	5736-ZPO	Shop Coat, Quick Dry, for Interior Steel	3	9772-LTP	Varnish, Marine Spar, Exterior, Gloss (MPI Gloss Level 5)	27
234	4	5726-ZPO	Shop Coat, Quick Dry, for Interior Steel	2	9126-PWF	Latex, Recycled (Consolidated), Interior (MPI Gloss Level 3)	27
243	1	4072-SWV	Sealer, Solvent Based, for Concrete Floors	3	5053-RTU	Aluminum Paint	23
287	1	8994-LUR	Lacquer, Sanding Sealer, Clear	5	9838-FUF	Fire Retardant Top-Coat, Clear, Alkyd, Interior (ULC Approved)	27
333	1	3701-YAW	Sealer, Solvent Based, for Concrete Floors	6	2584-CJU	Stain, for Exterior Wood Decks	30
333	1	3701-YAW	Sealer, Solvent Based, for Concrete Floors	5	4764-SLU	Lacquer, Clear, Flat	30
369	2	1404-TUY	Sealer, Water Based, for Concrete Floors	1	8726-ZNM	Floor Paint, Alkyd, Low Gloss	29

SOURCE: Course Technology/Cengage Learning

-
23. The Binder Prime Company wants to recognize the employee who sold the most of their products during a specified period. Write a query to display the employee number, employee first name, employee last name, e-mail address, and total units sold for the employee who sold the most Binder Prime brand products between November 1, 2011, and December 5, 2011. If there is a tie for most units sold, sort the output by employee last name.

FIGURE P8.23 Employees with most Binder Prime units sold

Emp_Num	Emp_FName	Emp_LName	Emp_Email	Total
84134	ROSALIE	GARLAND	G.ROSALI98@LGCOMPANY.COM	23
83850	RUSTY	MILES	M.RUSTY95@LGCOMPANY.COM	23

SOURCE: Course Technology/Cengage Learning

24. Write a query to display the customer code, first name, and last name of all customers who have had at least one invoice completed by employee 83649 and at least one invoice completed by employee 83677. Sort the output by customer last name and then first name.

25. LargeCo is planning a new promotion in Alabama (AL) and wants to know about the largest purchases made by customers in that state. Write a query to display the customer code, customer first name, last name, full address, invoice date, and invoice total of the largest purchase made by each customer in Alabama. Be certain to include any customers in Alabama who have never made a purchase; their invoice dates should be NULL and the invoice totals should display as 0.

FIGURE P8.24 Customers with invoices filled by employees 83649 and 83677

Cust_Code	Cust_FName	Cust_LName
684	WENDI	BEAN
340	MARCIA	BURRIS
211	GERALD	CAUDILL
292	VALARIE	DILLARD
293	CLAIR	ERICKSON
416	TATIANA	HOWE
996	EZRA	LYON
98	VALENTIN	MARINO
121	PETER	SMALL
1157	LUCIO	STALEY
617	CESAR	TALLEY
457	SHAUNA	WERNER
131	SAL	WHALEY

SOURCE: Course Technology/Cengage Learning

FIGURE P8.25 Largest purchases of customers in Alabama

Cust_Code	Cust_FName	Cust_LName	Cust_Street	Cust_City	Cust_State	Cust_ZIP	Inv_Date	Largest_Invoice
903	ROBIN	ADDISON	323 LORETTA PLACE	Mobile	AL	36693	8/26/2011	230.63
643	NINA	ALLEN	680 RED TALON DRIVE	Robertsdale	AL	36574	6/21/2011	11.99
295	DORTHY	AUSTIN	829 BIG BEND LOOP	Diamond Shamrock	AL	36614	4/24/2011	589.75
393	FOSTER	BERNAL	1299 EAST 3RD AVENUE	Birmingham	AL	35280		0
853	GAYLORD	BOLTON	1069 LUGENE LANE	Montgomery	AL	36131	11/25/2011	372.68
925	ALANA	BOOKER	1874 I STREET	Mccullough	AL	36502	12/12/2011	208.85
1248	LISA	BRADY	491 LOWLAND AVENUE	Daphne	AL	36577	12/5/2011	414.47
538	CHIQUITA	CALDWELL	1501 BRIGGS COURT	Normal	AL	35762	5/26/2011	143.9
89	MONICA	CANTRELL	697 ADAK CIRCLE	Loachapoka	AL	36865	3/31/2011	516.58
1233	NATHALIE	CHURCH	1802 SNOWY OWL CIRCLE	Napier Field	AL	36303	11/24/2011	160.96
304	GERTRUDE	CONNORS	1042 PLEASANT DRIVE	Georgiana	AL	36033	12/29/2011	376.32
1131	CARMA	CORNETT	767 CHISANA WAY	Killen	AL	35645	10/25/2011	265.12

SOURCE: Course Technology/Cengage Learning

26. One of the purchasing managers is interested in the impact of product prices on the sale of products of each brand. Write a query to display the brand name, brand type, average price of products of each brand, and total units sold of products of each brand. Even if a product has been sold more than once, its price should only be included once in the calculation of the average price. However, you must be careful because multiple products of

the same brand can have the same price, and each of those products must be included in the calculation of the brand's average price.

FIGURE P8.26 Average price and total units sold of products by brand

Brand_Name	Brand_Type	Average Price	Units Sold
BINDER PRIME	PREMIUM	16.12	3753
BUSTERS	VALUE	22.59	3727
FORESTERS BEST	VALUE	20.94	2086
HOME COMFORT	CONTRACTOR	21.8	4842
LE MODE	PREMIUM	19.22	5284
LONG HAUL	CONTRACTOR	20.12	5728
OLDE TYME QUALITY	CONTRACTOR	18.33	3614
STUTTENFURST	CONTRACTOR	16.47	3671
VALU-MATTE	VALUE	16.84	2485

SOURCE: Course Technology/Cengage Learning

27. The purchasing manager is still concerned about the impact of price on sales. Write a query to display the brand name, brand type, product SKU, product description, and price of any products that are not a premium brand, but that cost more than the most expensive premium brand products.
-

FIGURE P8.27 Non-premium products that are more expensive than premium products

Brand_Name	Brand_Type	Prod_Sku	Prod_Descript	Prod_Price
LONG HAUL	CONTRACTOR	1964-OUT	Fire Resistant Top Coat, for Interior Wood	78.49

SOURCE: Course Technology/Cengage Learning

Use the Ch08_SaleCo2 database shown in [Figure P8.28](#) to work [Problems 28-31](#).

FIGURE P8.28 Ch08_SaleCo2 database tables

Table name: CUSTOMER						
CUS_CODE	CUS_LNAME	CUS_FNAME	CUS_INITIAL	CUS_AREACODE	CUS_PHONE	CUS_BALANCE
10010	Ramas	Alfred	A	615	844-2573	0.00
10011	Duane	Leona	K	713	854-1238	0.00
10012	Smith	Kathy	W	615	854-2395	345.00
10013	Olewski	Paul	F	615	854-2183	526.75
10014	Orlando	Myron		615	222-1672	0.00
10015	O'Brien	Amy	B	713	442-3381	0.00
10016	Brown	James	G	615	251-1228	221.19
10017	Williams	George		615	290-2566	768.93
10018	Fariss	Asma	G	713	382-7185	216.55
10019	Smith	Obette	K	615	297-3809	0.00

Table name: PRODUCT							
P_CODE	P_DESCRPT	P_INDATE	P_DOH	P_MIN	P_PRICE	P_DISCOUNT	V_CODE
110ER01	Power painter, 15 µm, 3-nozzle	03-Nov-11	6	5	109.99	0.00	25595
13-Q2P2	7.25-in. gear saw blade	13-Dec-11	32	15	14.99	0.05	21344
14-Q1A3	9.0-in gear saw blade	13-Nov-11	18	12	17.49	0.00	21344
1546-002	Hrt. cloth, 1/4-in., 2x50	15-Jan-12	15	6	39.95	0.00	23119
155B-GW1	Hrt. cloth, 1/2-in., 3x50	15-Jan-12	23	6	43.99	0.00	23119
2232-QTY	BAD grinder, 12-in. blade	30-Dec-11	8	5	109.92	0.05	34288
2232-QWE	BAD grinder, 6-in. blade	24-Dec-11	6	5	99.07	0.05	34288
2238-QPD	B&D cordless drill, 1/2-in.	20-Jan-12	12	8	38.95	0.00	26896
29109HB	Claw hammer	20-Jan-12	23	10	9.95	0.10	21226
27114-AA	Sledge hammer, 12-lb.	02-Jan-12	6	5	14.40	0.05	
54778-2T	Putty knife, 1/8-in. blade	15-Dec-11	43	28	4.99	0.00	21344
05-WIRE-0	Heat chain saw, 16-in.	07-Feb-12	11	6	268.99	0.05	34288
PVC230RT	PVC pipe, 3/5-in., 8-ft	20-Feb-12	109	75	5.07	0.00	
SM 18277	1.25-in. metal screw, 26	01-Mar-12	172	75	6.99	0.00	21226
SW-29116	2.5-in. set screw, 50	24-Feb-12	237	100	8.45	0.00	21231
WR3/TIT3	Steel matting, 4'x9'x1/8", 5' mesh	17-Jan-12	18	5	119.95	0.10	25595

Table name: VENDOR						
V_CODE	V_NAME	V_CONTACT	V_AREACODE	V_PHONE	V_STATE	V_ORDER
21225	Bryant, Inc.	Senthilan	615	223-3234	TN	Y
21226	Supertech, Inc.	Flushing	904	215-8995	FL	N
21231	D&E Supply	Siegh	615	226-3245	TN	Y
21344	Gomez Bros.	Ortega	615	859-2548	KY	N
22567	Dome Supply	Smith	901	670-1419	GA	N
22119	Randarts Ltd.	Anderstan	901	678-3998	GA	Y
24004	Brackman Bros.	Browning	615	228-1410	TN	N
24288	ORDNA, Inc.	Hakred	615	898-1234	TN	Y
25443	BMIC, Inc.	Smith	904	227-0099	FL	N
25901	Dental Supplies	Senthila	615	850-3629	TN	N
25595	Rubicon Systems	Ortiz	904	456-0092	FL	Y

Database name: CH08_SaleCo2

Table name: INVOICE						
INV_NUMBER	CUS_CODE	INV_DATE	INV_SUBTOTAL	INV_TAX	INV_TOTAL	
1001	10014	16-Jan-12	24.90	1.99	26.09	
1002	10011	16-Jan-12	9.98	0.80	10.78	
1003	10012	16-Jan-12	153.85	12.31	166.16	
1004	10011	17-Jan-12	34.97	2.80	37.77	
1005	10018	17-Jan-12	70.44	5.64	76.08	
1006	10014	17-Jan-12	397.83	31.83	429.66	
1007	10015	17-Jan-12	34.97	2.80	37.77	
1008	10011	17-Jan-12	399.15	31.93	431.08	

Table name: LINE						
INV_NUMBER	LINE_NUMBER	P_CODE	LINE_UNITS	LINE_PRICE	LINE_TOTAL	
1001	1-13-Q2P2	1	14.99	14.99		
1001	2-2109HB	1	9.95	9.95		
1002	1-54778-2T	2	4.99	9.98		
1003	1-2238-QPD	1	38.95	38.95		
1003	2-1546-002	1	39.95	39.95		
1003	3-13-Q2P2	5	14.99	74.95		
1004	1-54778-2T	3	4.99	14.97		
1004	2-2109HB	2	9.95	19.90		
1005	1-PVC230RT	12	5.67	70.44		
1006	1-5M-18277	3	6.99	20.97		
1006	2-2250-QTY	1	109.92	109.92		
1007	3-2109HB	1	9.95	9.95		
1008	4-BB-WIRE-Q	1	256.99	256.99		
1007	1-13-Q2P2	2	14.99	29.98		
1007	2-54778-2T	1	4.99	4.99		
1008	1-PVC230RT	5	5.67	29.35		
1008	2-WM3/T13	3	119.95	359.85		
1008	3-2109HB	1	9.95	9.95		

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The **Ch08_SaleCo2** database used in [Problems 28-31](#) is available at www.cengagebrain.com, as are the script files to duplicate this data set in Oracle.

28. Create a trigger named `trg_line_total` to write the `LINE_TOTAL` value in the `LINE` table every time you add a new `LINE` row. (The `LINE_TOTAL` value is the product of the `LINE_UNITS` and `LINE_PRICE` values.)
29. Create a trigger named `trg_line_prod` that automatically updates the quantity on hand for each product sold after a new `LINE` row is added.
30. Create a stored procedure named `prc_inv_amounts` to update the `INV_SUBTOTAL`, `INV_TAX`, and `INV_TOTAL`. The procedure takes the

invoice number as a parameter. The INV_SUBTOTAL is the sum of the LINE_TOTAL amounts for the invoice, the INV_TAX is the product of the INV_SUBTOTAL and the tax rate (8 percent), and the INV_TOTAL is the sum of the INV_SUBTOTAL and the INV_TAX.

31. Create a procedure named prc_cus_balance_update that will take the invoice number as a parameter and update the customer balance. (*Hint:* You can use the DECLARE section to define a TOTINV numeric variable that holds the computed invoice total.)

Use the Ch08_AviaCo database shown in [Figure P8.32](#) to work [Problems 32-43](#).

FIGURE P8.32 Ch08_AviaCo database tables

SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The **Ch08_AviaCo** database used for [Problems 32-43](#) is available at www.cengagebrain.com, as are the script files to duplicate this data set in Oracle.

32. Modify the MODEL table to add the attribute and insert the values shown in the following table.

ATTRIBUTE NAME	ATTRIBUTE DESCRIPTION	ATTRIBUTE TYPE	ATTRIBUTE VALUES
MOD_WAIT_CHG	Waiting charge per hour for each model	Numeric	\$100 for C-90A \$50 for PA23-250 \$75 for PA31-350

33. Write the queries to update the MOD_WAIT_CHG attribute values based on [Problem 32](#).

34. Modify the CHARTER table to add the attributes shown in the following table.
-

ATTRIBUTE NAME	ATTRIBUTE DESCRIPTION	ATTRIBUTE TYPE
CHAR_WAIT_CHG	Waiting charge for each model (copied from the MODEL table)	Numeric
CHAR_FLT_CHG_HR	Flight charge per mile for each model (copied from the MODEL table using the MOD_CHG_MILE attribute)	Numeric
CHAR_FLT_CHG	Flight charge (calculated by CHAR_HOURS_FLOWN × CHAR_FLT_CHG_HR)	Numeric
CHAR_TAX_CHG	CHAR_FLT_CHG × tax rate (8%)	Numeric
CHAR_TOT_CHG	CHAR_FLT_CHG + CHAR_TAX_CHG	Numeric
CHAR_PYMT	Amount paid by customer	Numeric
CHAR_BALANCE	Balance remaining after payment	Numeric

-
35. Write the sequence of commands required to update the CHAR_WAIT_CHG attribute values in the CHARTER table. (*Hint:* Use either an updatable view or a stored procedure.)
36. Write the sequence of commands required to update the CHAR_FLT_CHG_HR attribute values in the CHARTER table. (*Hint:* Use either an updatable view or a stored procedure.)
37. Write the command required to update the CHAR_FLT_CHG attribute values in the CHARTER table.

38. Write the command required to update the CHAR_TAX_CHG attribute values in the CHARTER table.
 39. Write the command required to update the CHAR_TOT_CHG attribute values in the CHARTER table.
40. Modify the PILOT table to add the attribute shown in the following table.
-

ATTRIBUTE NAME	ATTRIBUTE DESCRIPTION	ATTRIBUTE TYPE
PIL_PIC_HRS	Pilot in command (PIC) hours; updated by adding the CHARTER TABLE's CHAR_HOURS_FLOWN to the PIL_PIC_HRS when the CREW table shows the CREW_JOB to be Pilot	Numeric

41. Create a trigger named trg_char_hours that automatically updates the AIRCRAFT table when a new CHARTER row is added. Use the CHARTER table's CHAR_HOURS_FLOWN to update the AIRCRAFT table's AC_TTAF, AC_TTEL, and AC_TTER values.
 42. Create a trigger named trg_pic_hours that automatically updates the PILOT table when a new CREW row is added and the CREW table uses a Pilot CREW_JOB entry. Use the CHARTER table's CHAR_HOURS_FLOWN to update the PILOT table's PIL_PIC_HRS only when the CREW table uses a Pilot CREW_JOB entry.
 43. Create a trigger named trg_cust_balance that automatically updates the CUSTOMER table's CUS_BALANCE when a new CHARTER row is added. Use the CHARTER table's CHAR_TOT_CHG as the update source. (Assume that all charter charges are charged to the customer balance.)
-
-

CASES

The following problems expand on the TinyVideo case from [Chapter 7](#). To complete the following problems, you must have first completed the table creation and data-entry requirements specified in [Problems 65](#) and [66](#) in [Chapter 7](#).

44. Alter the DETAILRENTAL table to include a derived attribute named DETAIL_DAYSLATE to store integers of up to three digits. The attribute should accept null values.
45. Alter the VIDEO table to include an attribute named VID_STATUS to store character data up to four characters long. The attribute should not accept null values. The attribute should have a constraint to enforce the domain (“IN”, “OUT”, and “LOST”) and have a default value of “IN”.
46. Update the VID_STATUS attribute of the VIDEO table using a subquery to set the VID_STATUS to “OUT” for all videos that have a null value in the DETAIL_RETURNDATE attribute of the DETAILRENTAL table.
47. Alter the PRICE table to include an attribute named PRICE_RENTDAYS to store integers of up to two digits. The attribute should not accept null values, and it should have a default value of 3.
48. Update the PRICE table to place the values shown in the following table in the PRICE_RENTDAYS attribute.

PRICE CODE PRICE RENTDAYS

1 5

2 3

3 5

49. Create a trigger named `trg_late_return` that will write the correct value to `DETAIL_DAYSLATE` in the `DETAILENTAL` table whenever a video is returned. The trigger should execute as a BEFORE trigger when the `DETAIL_RETURNDATE` or `DETAIL_DUEDATE` attributes are updated. The trigger should satisfy the following conditions:
 - a. If the return date is null, then the days late should also be null.
 - b. If the return date is not null, then the days late should determine if the video is returned late.
 - c. If the return date is noon of the day after the due date or earlier, then the video is not considered late, and the days late should have a value of zero (0).
 - d. If the return date is past noon of the day after the due date, then the video is considered late, so the number of days late must be calculated and stored.
50. Create a trigger named `trg_mem_balance` that will maintain the correct value in the membership balance in the `MEMBERSHIP` table when videos are returned late. The trigger should execute as an AFTER trigger when the due date or return date attributes are updated in the `DETAILENTAL` table. The trigger should satisfy the following conditions:
 - a. Calculate the value of the late fee prior to the update that triggered this execution of the trigger. The value of the late fee is the days late multiplied by the daily late fee. If the previous value of the late fee was null, then treat it as zero (0).
 - b. Calculate the value of the late fee after the update that triggered this execution of the trigger. If the value of the late fee is now null, then treat it as zero (0).
 - c. Subtract the prior value of the late fee from the current value of the late fee to determine the change in late fee for this video rental.
 - d. If the amount calculated in Part c is not zero (0), then update the membership balance by the amount calculated for the membership associated with this rental.
51. Create a sequence named `rent_num_seq` to start with 1100 and increment by

1. Do not cache any values.
52. Create a stored procedure named prc_new_rental to insert new rows in the RENTAL table. The procedure should satisfy the following conditions:
 - a. The membership number will be provided as a parameter.
 - b. Use a Count() function to verify that the membership number exists in the MEMBERSHIP table. If it does not exist, then a message should be displayed that the membership does not exist and no data should be written to the database.
 - c. If the membership does exist, then retrieve the membership balance and display a message that the balance amount is the previous balance. (For example, if the membership has a balance of \$5.00, then display “Previous balance: \$5.00”.)
 - d. Insert a new row in the rental table using the sequence created in Case 51 to generate the value for RENT_NUM, the current system date for the RENT_DATE value, and the membership number provided as the value for MEM_NUM.
53. Create a stored procedure named prc_new_detail to insert new rows in the DETAILRENTAL table. The procedure should satisfy the following requirements:
 - a. The video number will be provided as a parameter.
 - b. Verify that the video number exists in the VIDEO table. If it does not exist, then display a message that the video does not exist, and do not write any data to the database.
 - c. If the video number does exist, then verify that the VID_STATUS for the video is “IN”. If the status is not “IN”, then display a message that the video’s return must be entered before it can be rented again, and do not write any data to the database.
 - d. If the status is “IN”, then retrieve the values of the video’s PRICE_RENTFEE, PRICE_DAILYLATEFEE, and PRICE_RENTDAYS from the PRICE table.
 - e. Calculate the due date for the video rental by adding the number of days in PRICE_RENTDAYS to 11:59:59PM (hours:minutes:seconds) in the current system date.

- f. Insert a new row in the DETAILRENTAL table using the previous value returned by RENT_NUM_SEQ as the RENT_NUM, the video number provided in the parameter as the VID_NUM, the PRICE_RENTFEE as the value for DETAIL_FEE, the due date calculated above for the DETAIL_DUEDATE, PRICE_DAILYLATEFEE as the value for DETAIL_DAILYLATEFEE, and null for the DETAIL_RETURNDATE.
54. Create a stored procedure named prc_return_video to enter data about the return of videos that have been rented. The procedure should satisfy the following requirements.
- The video number will be provided as a parameter.
 - Verify that the video number exists in the VIDEO table. If it does not exist, display a message that the video number provided was not found and do not write any data to the database.
 - If the video number does exist, then use a Count() function to ensure that the video has only one record in DETAILRENTAL for which it does not have a return date. If more than one row in DETAILRENTAL indicates that the video is rented but not returned, display an error message that the video has multiple outstanding rentals and do not write any data to the database.
 - If the video does not have any outstanding rentals, then update the video status to “IN” for the video in the VIDEO table, and display a message that the video had no outstanding rentals but is now available for rental. If the video has only one outstanding rental, then update the return date to the current system date, and update the video status to “IN” for that video in the VIDEO table. Then display a message that the video was successfully returned.

¹ The authors are particularly grateful for the thoughtful comments provided by Emil T. Cipolla.

9 DATABASE DESIGN

In this chapter, you will learn:

- That successful database design must reflect the information system of which the database is a part
- That successful information systems are developed within a framework known as the Systems Development Life Cycle (SDLC)
- That within the information system, the most successful databases are subject to frequent evaluation and revision within a framework known as the Database Life Cycle (DBLC)
- How to conduct evaluation and revision within the SDLC and DBLC frameworks
- About database design strategies: top-down vs. bottom-up design and centralized vs. decentralized design

Preview

Databases are a part of a larger picture called an information system. Database designs that fail to recognize this fact are not likely to be successful. Database designers must recognize that the database is a critical means to an end rather than an end in itself. Managers want the database to serve their management needs, but too many databases seem to force managers to alter their routines to fit the database requirements.

Information systems don't just happen; they are the product of a carefully staged development process. Systems analysis is used to determine the need for an information system and to establish its limits. Within systems analysis, the actual information system is created through a process known as systems development.

The creation and evolution of information systems follows an iterative pattern called the Systems Development Life Cycle (SDLC), which is a continuous process of creation, maintenance, enhancement, and replacement of the information system. A similar cycle applies to databases: the database is created, maintained, and enhanced. When enhancement can no longer stretch the database's usefulness and it can no longer perform its functions adequately, it might have to be replaced. The Database Life Cycle (DBLC) is carefully traced in this chapter, and is shown in the context of the larger Systems Development Life Cycle.

At the end of the chapter, you will be introduced to some classical approaches to database design: top-down vs. bottom-up and centralized vs. decentralized.

9.1 THE INFORMATION SYSTEM

Basically, a database is a carefully designed and constructed repository of facts. The database is part of a larger whole known as an information system, which provides for data collection, storage, and retrieval. The [information system](#) also helps transform data into information, and it allows for the management of both data and information. Thus, a complete information system is composed of people, hardware, software, the database(s), application programs, and procedures. [Systems analysis](#) is the process that establishes the need for an

information system and its extent. The process of creating an information system is known as [systems development](#).

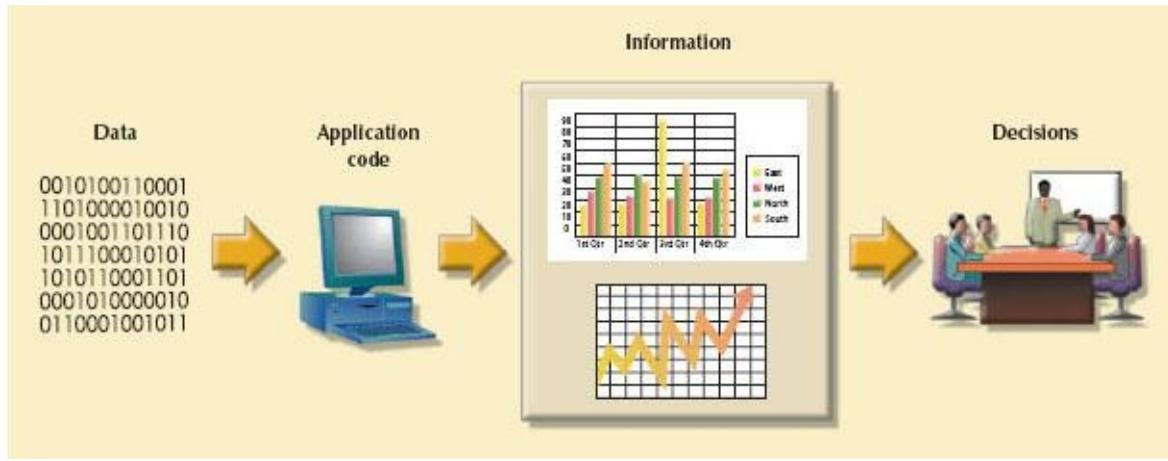
One key characteristic of current information systems is the strategic value of information in the age of global business. Therefore, information systems should always be aligned with strategic business goals; the view of isolated and independent information systems is no longer valid. Current information systems should always be integrated with the company's enterprise-wide information systems architecture.

NOTE

This chapter does not mean to cover all aspects of systems analysis and development, which are usually covered in a separate course or book. However, this chapter should help you better understand the issues associated with database design, implementation, and management, all of which are affected by the information system in which the database is a critical component.

Within the framework of systems development, applications transform data into the information that forms the basis for decision making. Applications usually generate formal reports, tabulations, and graphic displays designed to produce insight from the information. [Figure 9.1](#) illustrates that every application is composed of two parts: the data and the code (program instructions) by which the data are transformed into information. The data and code work together to represent real-world business functions and activities. At any given moment, physically stored data represent a snapshot of the business, but the picture is not complete without an understanding of the business activities represented by the code.

FIGURE 9.1 Generating information for decision making



SOURCE: Course Technology/Cengage Learning

The performance of an information system depends on three factors:

- Database design and implementation
- Application design and implementation
- Administrative procedures

This book emphasizes the database design and implementation segment of the triad—arguably the most important of the three. However, failure to address the other two segments will likely yield a poorly functioning information system. Creating a sound information system is hard work: systems analysis and development require extensive planning to ensure that all of the activities will interface with each other, that they will complement each other, and that they will be completed on time.

In a broad sense, the term [database development](#) describes the process of database design and implementation. The primary objective in database design is to create complete, normalized, nonredundant (to the greatest extent possible), and fully integrated conceptual, logical, and physical database models. The implementation phase includes creating the database storage structure, loading data into the database, and providing for data management.

To make the procedures discussed in this chapter broadly applicable, the chapter focuses on the elements that are common to all information systems. Most of the processes and procedures described in this chapter do not depend on the size, type, or complexity of the database being implemented. However, the procedures that would be used to design a small database, such as one for a neighborhood

shoe store, do not precisely scale up to the procedures that would be needed to design a database for a large corporation or even a segment of such a corporation. To use an analogy, building a small house requires a blueprint, just as building the Golden Gate Bridge did, but the bridge required far more complex planning, analysis, and design.

The next sections will trace the overall Systems Development Life Cycle and the related Database Life Cycle. Once you are familiar with those processes and procedures, you will learn about various approaches to database design, such as top-down vs. bottom-up and centralized vs. decentralized design.

NOTE

The Systems Development Life Cycle is a general framework through which you can track and understand the activities required to develop and maintain information systems. Within that framework, there are several ways to complete various tasks specified in the SDLC. For example, this book focuses on ER modeling and on relational database design and implementation, and that focus is maintained in this chapter. However, there are alternative methodologies:

- Unified Modeling Language (UML) provides object-oriented tools to support the tasks associated with the development of information systems. UML is covered in **Appendix H, Unified Modeling Language (UML)**, at www.cengagebrain.com.
- Rapid Application Development (RAD)¹ is an iterative software development methodology that uses prototypes, CASE tools, and flexible management to develop application systems. RAD started as an alternative to traditional structured development, which suffered from long deliverable times and unfulfilled requirements.
- Agile Software Development² is a framework for developing software applications that divides the work into smaller subprojects to obtain valuable deliverables in shorter times and with better cohesion. This method emphasizes close communication among all users and continuous evaluation with the purpose of increasing customer satisfaction.

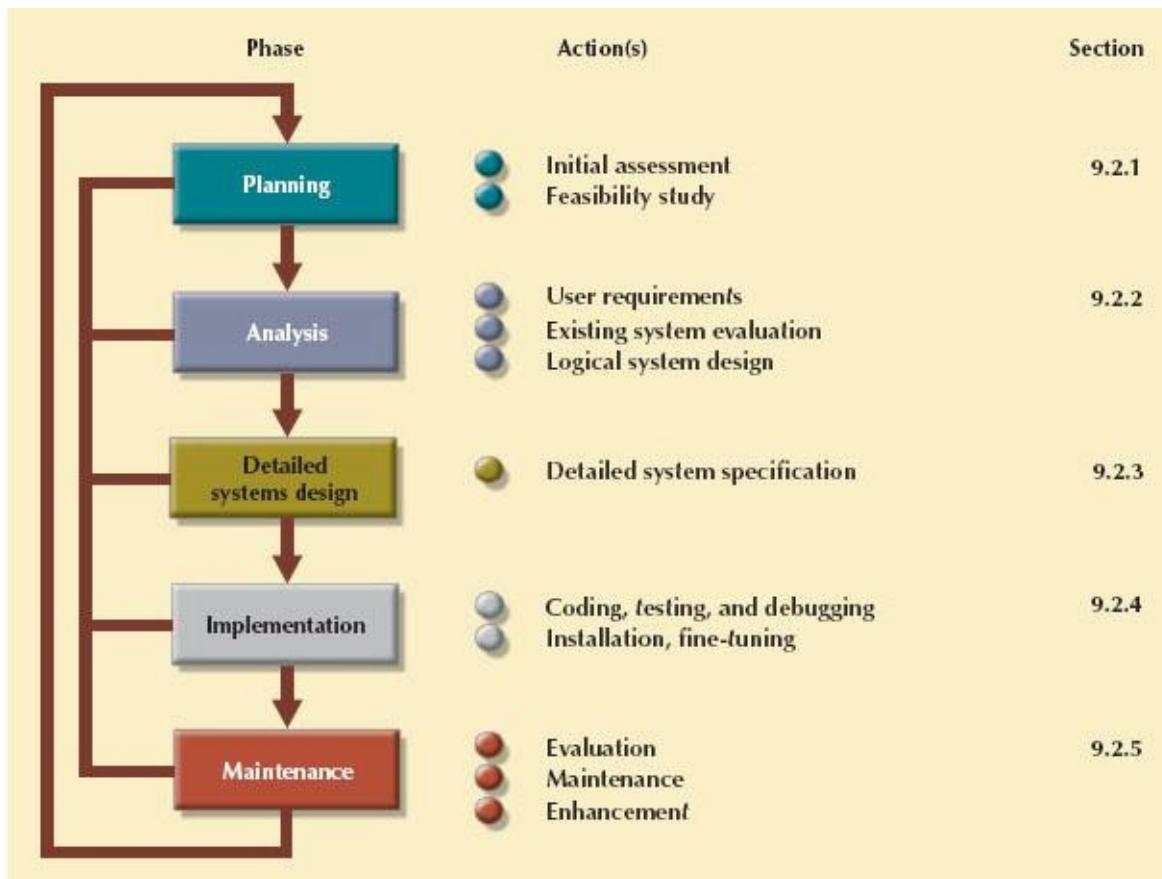
Although the development *methodologies* may change, the basic framework within which they are used does not change.

9.2 THE SYSTEMS DEVELOPMENT LIFE CYCLE

The [Systems Development Life Cycle \(SDLC\)](#) traces the history of an information system. Perhaps more important to the system designer, the SDLC provides the big picture within which the database design and application development can be mapped out and evaluated.

As illustrated in [Figure 9.2](#), the traditional SDLC is divided into five phases: planning, analysis, detailed systems design, implementation, and maintenance. The SDLC is an iterative process rather than a sequential process. For example, the details of the feasibility study might help refine the initial assessment, and the details discovered during the user requirements portion of the SDLC might help refine the feasibility study.

FIGURE 9.2 The Systems Development Life Cycle



SOURCE: Course Technology/Cengage Learning

Because the Database Life Cycle fits into and resembles the SDLC, a brief description of the SDLC is in order.

9.2.1 PLANNING

The SDLC planning phase yields a general overview of the company and its objectives. An initial assessment of the information flow-and-extent requirements must be made during this discovery portion of the SDLC. Such an assessment should answer some important questions:

- *Should the existing system be continued?* If the information generator does its job well, there is no point in modifying or replacing it. To quote an old saying, “If it ain’t broke, don’t fix it.”
- *Should the existing system be modified?* If the initial assessment indicates deficiencies in the extent and flow of the information, minor (or even major) modifications might be needed. When considering modifications,

the participants in the initial assessment must remember the distinction between wants and needs.

- *Should the existing system be replaced?* The initial assessment might indicate that the current system's flaws are beyond fixing. Given the effort required to create a new system, a careful distinction between wants and needs is perhaps even more important in this case than it is when modifying the system.

Participants in the SDLC's initial assessment must begin to study and evaluate alternative solutions. If a new system is necessary, the next question is whether it is feasible. The feasibility study must address the following:

- *The technical aspects of hardware and software requirements.* The decisions might not yet be vendor-specific, but they must address the nature of the hardware requirements (desktop computer, multiprocessor computer, mainframe, or supercomputer) and the software requirements (single-or multiuser operating systems, database type and software, programming languages to be used by the applications, and so on).
- *The system cost.* The admittedly mundane question “Can we afford it?” is crucial. The answer might force a careful review of the initial assessment. A million-dollar solution to a thousand-dollar problem is not defensible.
- *The operational cost.* Does the company possess the human, technical, and financial resources to keep the system operational? Should the feasibility study include the cost of management and end-user support needed to implement operational procedures to ensure the success of this system?

9.2.2 ANALYSIS

Problems defined during the planning phase are examined in greater detail during the analysis phase. A macro analysis must be made both of individual needs and organizational needs, addressing questions such as:

- What are the requirements of the current system's end users?

- Do those requirements fit into the overall information requirements?

The analysis phase of the SDLC is, in effect, a thorough *audit* of user requirements.

The existing hardware and software systems are also studied during the analysis phase. The result of the analysis should be a better understanding of the system's functional areas, actual and potential problems, and opportunities.

End users and the system designer(s) must work together to identify processes and uncover potential problem areas. Such cooperation is vital to defining the appropriate performance objectives by which the new system can be judged.

Along with a study of user requirements and the existing systems, the analysis phase also includes the creation of a logical systems design. The logical design must specify the appropriate conceptual data model, inputs, processes, and expected output requirements.

When creating a logical design, the designer might use tools such as data flow diagrams (DFDs), hierarchical input process output (HIPO) diagrams, and entity relationship (ER) diagrams. The database design's data-modeling activities take place at this point to discover and describe all entities and their attributes, and the relationships among the entities within the database.

Defining the logical system also yields functional descriptions of the system's components (modules) for each process within the database environment. All data transformations (processes) are described and documented, using systems analysis tools such as DFDs. The conceptual data model is validated against those processes.

9.2.3 DETAILED SYSTEMS DESIGN

In the detailed systems design phase, the designer completes the design of the system's processes. The design includes all the necessary technical specifications for the screens, menus, reports, and other devices that might help make the system a more efficient information generator. The steps are laid out for conversion from the old system to the new system. Training principles and methodologies are also planned and must be submitted for management's approval.

NOTE

Because this book has focused on the details of systems design, it has not explicitly recognized until now that management approval is needed at all stages of the process. Such approval is needed because a “go” decision requires funding. There are many go and “no go” decision points along the way to a completed systems design!

9.2.4 IMPLEMENTATION

During the implementation phase, the hardware, DBMS software, and application programs are installed, and the database design is implemented. During the initial stages of the implementation phase, the system enters into a cycle of coding, testing, and debugging until it is ready to be delivered. The actual database is created, and the system is customized by the creation of tables and views, user authorizations, and so on.

The database contents might be loaded interactively or in batch mode, using a variety of methods and devices:

- Customized user programs
- Database interface programs
- Conversion programs that import the data from a different file structure, using batch programs, a database utility, or both

The system is subjected to exhaustive testing until it is ready for use. Traditionally, the implementation and testing of a new system took 50 to 60 percent of the total development time. However, the advent of sophisticated application generators and debugging tools has substantially decreased coding and testing time. After testing is concluded, the final documentation is reviewed and printed and end users are trained. The system is in full operation at the end of this phase, but it will be continuously evaluated and fine-tuned.

9.2.5 MAINTENANCE

Almost as soon as the system is operational, end users begin to request changes in it. Those changes generate system maintenance activities, which can be grouped into three types:

- *Corrective maintenance* in response to systems errors
- *Adaptive maintenance* due to changes in the business environment
- *Perfective maintenance* to enhance the system

Because every request for structural change requires retracing the SDLC steps, the system is, in a sense, always at some stage of the SDLC.

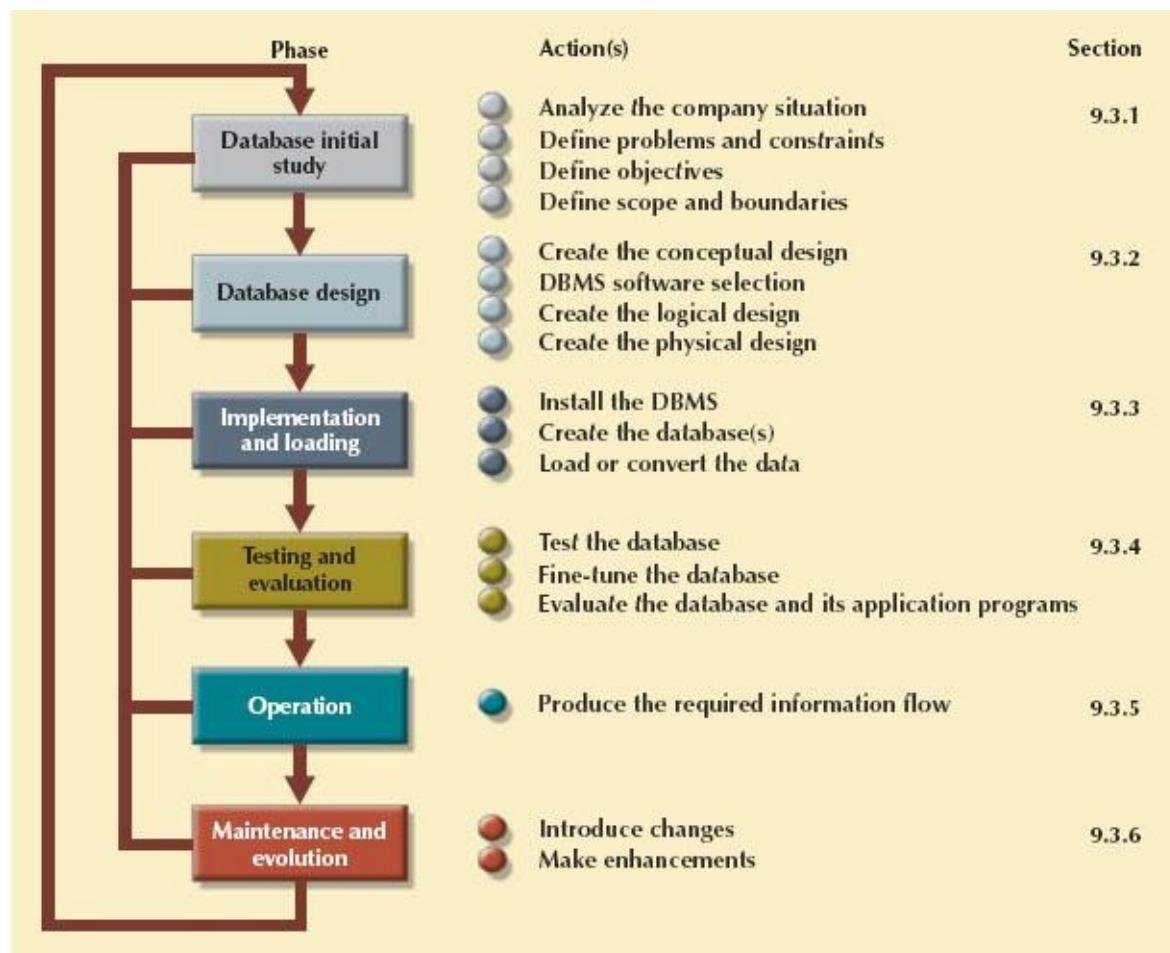
Each system has a predetermined operational life span, but its actual life span depends on its perceived utility. There are several reasons for reducing the operational life of certain systems. Rapid technological change is one reason, especially for systems based on processing speed and expandability. Another common reason is the cost of maintaining a system.

If the system's maintenance cost is high, its value becomes suspect. [Computer-aided systems engineering \(CASE\)](#) tools, such as System Architect or Visio Professional, help produce better systems within a reasonable amount of time and at a reasonable cost. In addition, CASE-produced applications are more structured, better documented, and especially *standardized*, which tends to prolong the operational life of systems by making them easier and cheaper to update and maintain.

9.3 THE DATABASE LIFE CYCLE

Within the larger information system, the database is subject to a life cycle as well. The [Database Life Cycle \(DBLC\)](#) contains six phases, as shown in [Figure 9.3](#): database initial study, database design, implementation and loading, testing and evaluation, operation, and maintenance and evolution.

FIGURE 9.3 The Database Life Cycle



SOURCE: Course Technology/Cengage Learning

9.3.1 THE DATABASE INITIAL STUDY

If a designer has been called in, chances are that the current system has failed to perform functions deemed vital by the company. (You don't call the plumber unless the pipes leak.) Therefore, in addition to examining the current system's operation within the company, the designer must determine how and why the current system fails. That means spending a lot of time talking and listening to end users. Although database design is a technical business, it is also people-oriented. Database designers must be excellent communicators and must have finely tuned interpersonal skills.

Depending on the complexity and scope of the database environment, the database designer might be a lone operator or part of a systems development team composed of a project leader, one or more senior systems analysts, and one or more junior systems analysts. The word *designer* is used generically here to

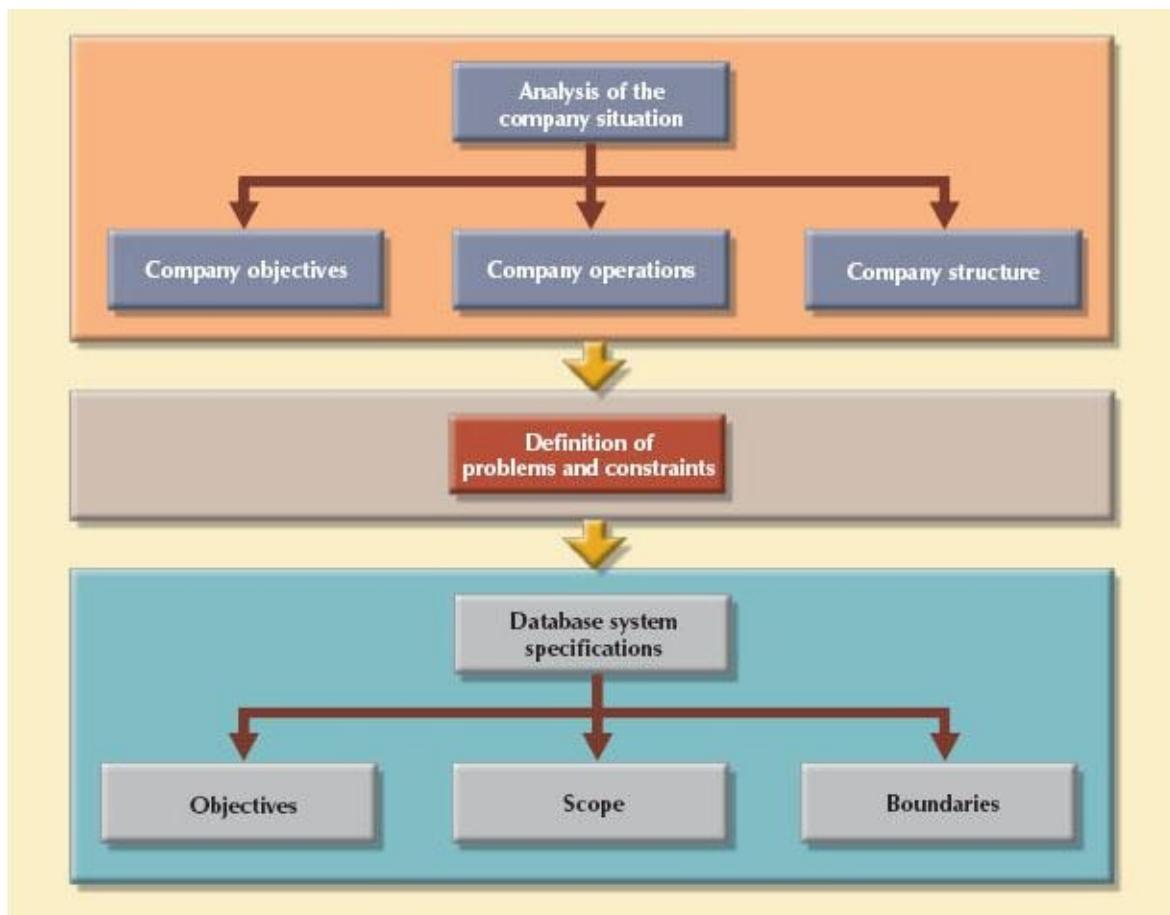
cover a wide range of design team compositions.

The overall purpose of the database initial study is to:

- Analyze the company situation.
- Define problems and constraints.
- Define objectives.
- Define scope and boundaries.

[Figure 9.4](#) depicts the interactive and iterative processes required to complete the first phase of the DBLC successfully. Note that the database initial study phase leads to the development of database system objectives. Using [Figure 9.4](#) as a discussion template, examine each of its components in greater detail.

FIGURE 9.4 A summary of activities in the database initial study



SOURCE: Course Technology/Cengage Learning

Analyze the Company Situation

The *company situation* describes the general conditions in which a company operates, its organizational structure, and its mission. To analyze the company situation, the database designer must learn the company's operational components, how they function, and how they interact.

The following issues must be resolved:

- *What is the organization's general operating environment, and what is its mission within that environment?* The design must satisfy the operational demands created by the organization's mission. For example, a mailorder business probably has operational requirements for its database that are quite different from those of a manufacturing business.
- *What is the organization's structure?* Knowing who controls what and

who reports to whom is quite useful when you need to define required information flows, specific report and query formats, and so on.

Define Problems and Constraints

The designer has both formal and informal sources of information. If the company has existed for any length of time, it already has a system in place (either manual or computer-based). How does the existing system function? What input does the system require? What documents does the system generate? By whom and how is the system output used? Studying the paper trail can be very informative. In addition to the official version of the system's operation, there is also the more informal, perhaps more real version; the designer must be shrewd enough to see how these differ.

The process of defining problems might initially appear to be unstructured. Company end users often cannot precisely describe the larger scope of company operations or identify the real problems encountered during company operations. Often the managerial view of a company's operation and its problems is different from that of the end users, who perform the actual routine work.

During the initial problem definition process, the designer is likely to collect very broad problem descriptions. For example, note the following concerns expressed by the president of a fast-growing, transnational manufacturing company:

Although the rapid growth is gratifying, members of the management team are concerned that such growth is beginning to undermine the ability to maintain a high customer service standard, and perhaps worse, to diminish manufacturing standards control.

The problem definition process quickly leads to a host of general problem descriptions. For example, the marketing manager comments:

I'm working with an antiquated filing system. We manufacture more than 1,700 specialty machine parts. When a regular customer calls in, we can't get a very quick inventory scan. If a new customer calls in, we can't do a current parts search by using a simple description, so we often do a machine setup for a part that we have in inventory. That's wasteful. And of course, some new customers get irritated when we can't give a quick response.

The production manager comments:

At best, it takes hours to generate the reports I need for scheduling purposes. I

don't have hours for quick turnarounds. It's difficult to manage what I don't have information about.

I don't get quick product request routing. Take machine setup. Right now I've got operators either waiting for the right stock or getting it themselves when a new part is scheduled for production. I can't afford to have an operator doing chores that a much lower-paid worker ought to be doing. There's just too much waiting around with the current scheduling. I'm losing too much time, and my schedules back up. Our overtime bill is ridiculous.

I sometimes produce parts that are already in inventory because we don't seem to be able to match what we've got in inventory with what we have scheduled. Shipping yells at me because I can't turn out the parts, and often they've got them in inventory one bay down. That's costing us big bucks sometimes.

New reports can take days or even weeks to get to my office. And I need a ton of reports to schedule personnel, downtime, training, etc. I can't get new reports that I need NOW. What I need is the ability to get quick updates on percent defectives, percent rework, the effectiveness of training, you name it. I need such reports by shift, by date, by any characteristic I can think of to help me manage scheduling, training, you name it.

A machine operator comments:

It takes a long time to set my stuff up. If I get my schedule banged up because John doesn't get the paperwork on time, I wind up looking for setup specs, startup material, bin assignments, and other stuff. Sometimes I spend two or three hours just setting up. Now you know why I can't meet schedules. I try to be productive, but I'm spending too much time getting ready to do my job.

After the initial declarations, the database designer must continue to probe carefully to generate additional information that will help define the problems within the larger framework of company operations. How does the problem of the marketing manager's customer fit within the broader set of marketing department activities? How does the solution to the customer's problem help meet the objectives of the marketing department and the rest of the company? How do the marketing department's activities relate to those of the other departments? That last question is especially important. Note that there are common threads in the problems described by the marketing and production department managers. If the inventory query process can be improved, both departments are likely to find simple solutions to at least some of their problems.

Finding precise answers is important, especially concerning the operational relationships among business units. If a proposed system will solve the marketing department's problems but exacerbate those of the production department, not much progress will have been made. Using an analogy, suppose that your home water bill is too high. You have determined the problem: the faucets leak. The solution? You step outside and cut off the water supply to the house. However, is that an adequate solution, or would the replacement of faucet washers do a better job of solving the problem? You might find this scenario simplistic, yet almost any experienced database designer can find similar instances of database problem solving, although they are admittedly more complicated.

Even the most complete and accurate problem definition does not always lead to the perfect solution. The real world usually intrudes to limit the design of even the most elegant database by imposing constraints such as time, budget, and personnel. If you must have a solution within a month and within a \$12,000 budget, you cannot take two years to develop a database at a cost of \$100,000. *The designer must learn to distinguish between what's perfect and what's possible.*

Define Objectives

A proposed database system must be designed to help solve at least the major problems identified during the problem discovery process. As the list of problems unfolds, several common sources are likely to be discovered. In the previous example, both the marketing manager and the production manager seem to be plagued by inventory inefficiencies. If the designer can create a database that sets the stage for more efficient parts management, both departments gain. The initial objective, therefore, might be to create an efficient inventory query and management system.

NOTE

When trying to develop solutions, the database designer must look for the *source* of the problems. Many database systems have failed to satisfy the end users because they were designed to treat the *symptoms* of the problems rather than their source.

Note that the initial study phase also yields proposed problem solutions. The

designer's job is to make sure that his or her database system objectives correspond to those envisioned by the end user(s). In any case, the database designer must begin to address the following questions:

- What is the proposed system's initial objective?
- Will the system interface with other existing or future systems in the company?
- Will the system share the data with other systems or users?

Define Scope and Boundaries

The designer must recognize two sets of limits: scope and boundaries. The system's [scope](#) defines the extent of the design according to operational requirements. Will the database design encompass the entire organization, one or more departments within the organization, or one or more functions of a single department? The designer must know the "size of the ballpark." Knowing the scope helps define the required data structures, the type and number of entities, the physical size of the database, and so on.

The proposed system is also subject to limits known as [boundaries](#), which are external to the system. Has any designer ever been told, "We have all the time in the world" or "Use an unlimited budget and as many people as needed to make the design come together"? Boundaries are also imposed by existing hardware and software. Ideally, the designer can choose the hardware and software that will best accomplish the system goals. In fact, software selection is an important aspect of the Systems Development Life Cycle. Unfortunately, in the real world, a system must often be designed around existing hardware. Thus, the scope and boundaries become the factors that force the design into a specific mold, and the designer's job is to design the best system possible within those constraints. (Note that problem definitions and the objectives must sometimes be reshaped to meet the system scope and boundaries.)

9.3.2 DATABASE DESIGN

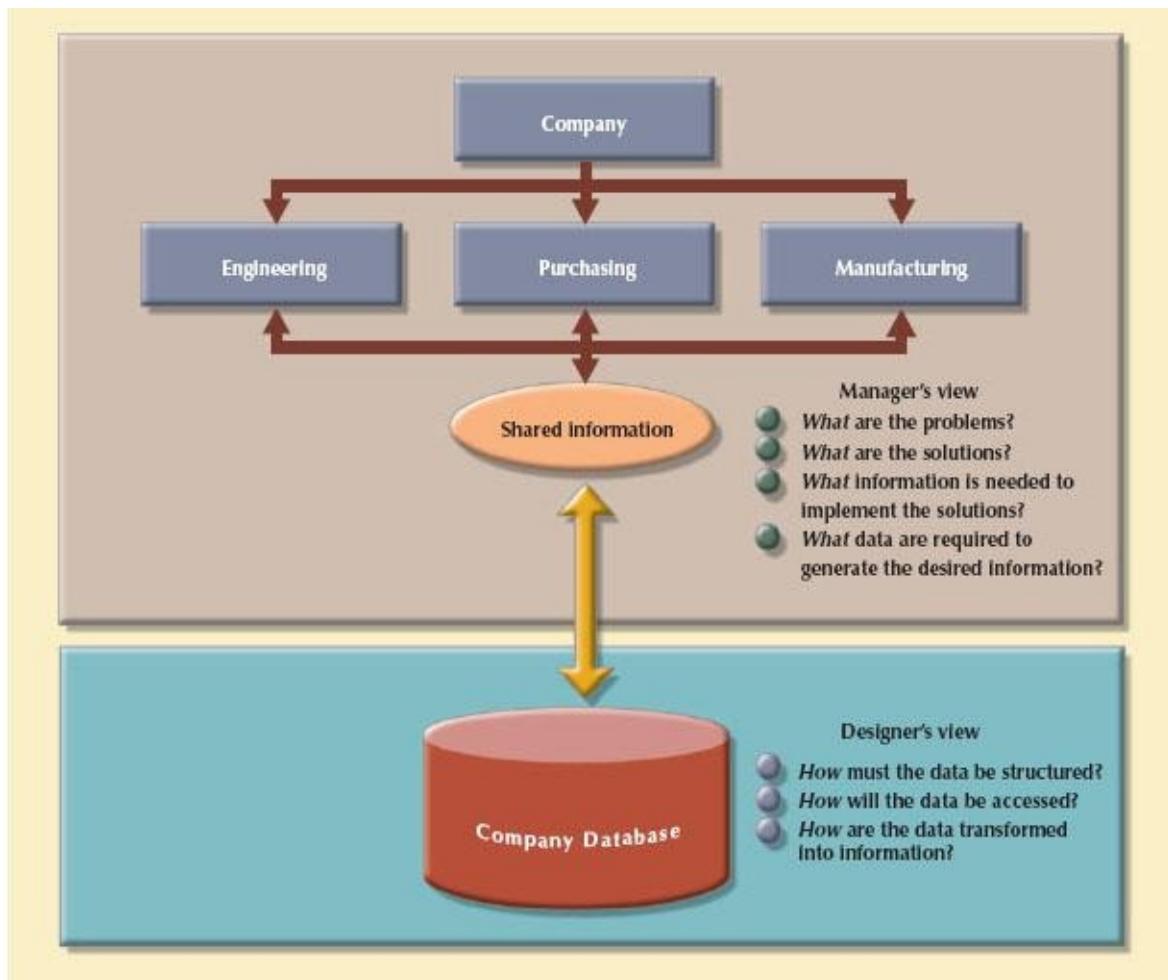
The second phase of the DBLC focuses on the design of the database model that will support company operations and objectives. This is arguably the most critical DBLC phase: making sure that the final product meets user and system requirements. In the process of database design, you must concentrate on the

data characteristics required to build the database model. At this point, there are two views of the data within the system: the business view of data as a source of information and the designer's view of the data structure, its access, and the activities required to transform the data into information. [Figure 9.5](#) contrasts those views. Note that you can summarize the different views by looking at the terms *what* and *how*. Defining data is an integral part of the DBLC's second phase.

As you examine the procedures required to complete the design phase in the DBLC, remember these points:

- The process of database design is loosely related to the analysis and design of a larger system. The data component is only one element of a larger information system.
- The systems analysts or systems programmers are in charge of designing the other system components. Their activities create the procedures that will help transform the data within the database into useful information.
- The database design does not constitute a sequential process. Rather, it is an iterative process that provides continuous feedback designed to trace previous steps.

FIGURE 9.5 Two views of data: business manager and database designer



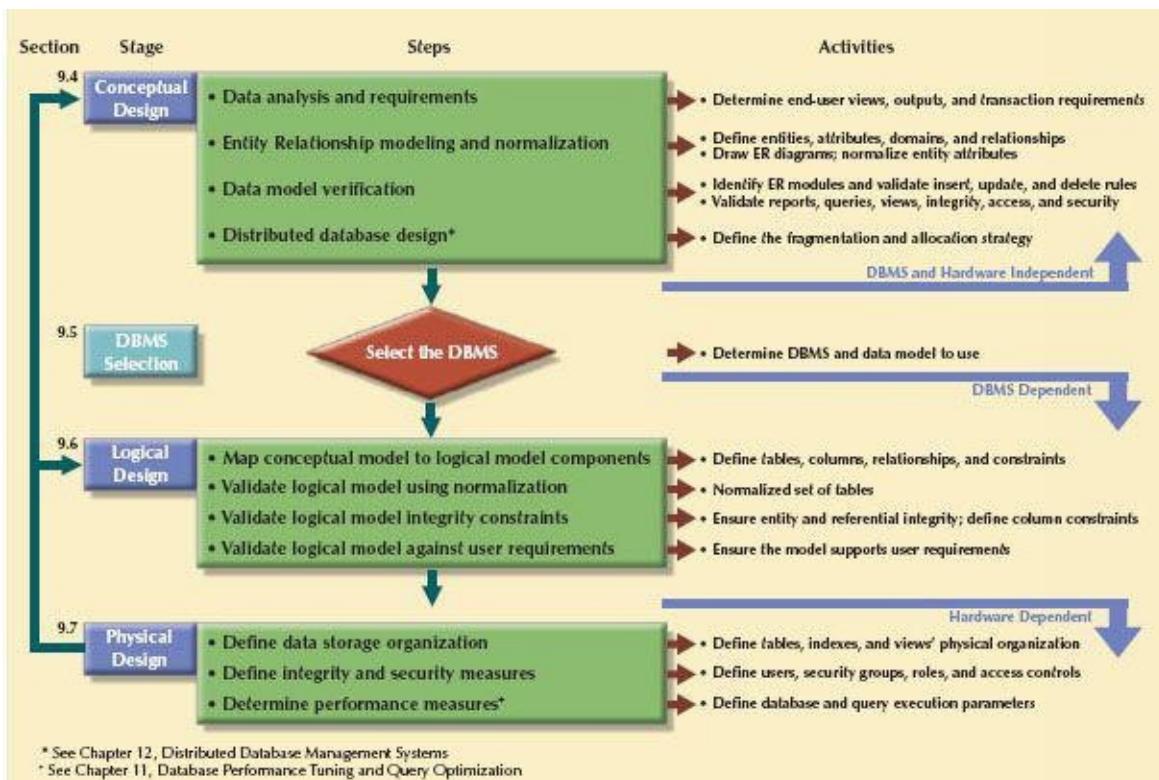
SOURCE: Course Technology/Cengage Learning

The database design process is depicted in [Figure 9.6](#). The figure shows that there are three essential stages: conceptual, logical, and physical design, plus the DBMS selection decision, which is critical to determine the type of logical and physical designs to be created. The design process starts with conceptual design and moves to the logical and physical design stages. At each stage, more details about the data model design are determined and documented. You could think of the conceptual design as the overall data as seen by the end user, the logical design as the data as seen by the DBMS, and the physical design as the data as seen by the operating system's storage management devices.

It is important to note that the overwhelming majority of database designs and implementations are based on the relational model, and therefore use the relational model constructs and techniques. When you finish the design activities, you will have a complete database design ready to be implemented.

Database design activities are covered in detail in [Sections 9.4](#) (Conceptual Design), [9.5](#) (DBMS Software Selection), [9.6](#) (Logical Design), and [9.7](#) (Physical Design).

FIGURE 9.6 Database design process



SOURCE: Course Technology/Cengage Learning

* See [Chapter 12](#), Distributed Database Management Systems

+ See [Chapter 11](#), Database Performance Tuning and Query Optimization



ONLINE CONTENT

Two appendixes at www.cengagebrain.com provide a concise example of simple real-world database development: **Appendix B, The University Lab:**

Conceptual Design, and Appendix C, The University Lab: Conceptual Design Verification, Logical Design, and Implementation.

9.3.3 IMPLEMENTATION AND LOADING

The output of the database design phase is a series of instructions detailing the creation of tables, attributes, domains, views, indexes, security constraints, and storage and performance guidelines. In this phase, you actually implement all these design specifications.

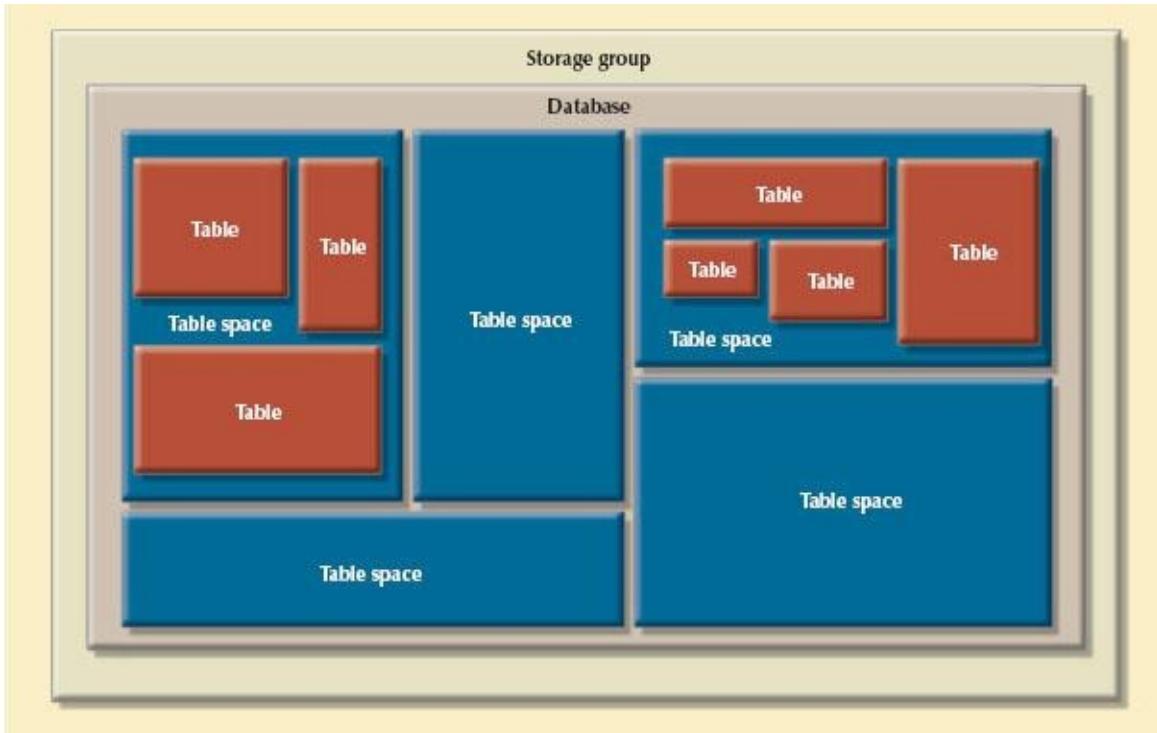
Install the DBMS

This step is required only when a new dedicated instance of the DBMS is necessary for the system. In many cases, the organization will have made a particular DBMS the standard to leverage investments in the technology and the skills that employees have already developed. The DBMS may be installed on a new server or on existing servers. One current trend is called virtualization. [Virtualization](#) is a technique that creates logical representations of computing resources that are independent of the underlying physical computing resources. This technique is used in many areas of computing, such as the creation of virtual servers, virtual storage, and virtual private networks. In a database environment, database virtualization refers to the installation of a new instance of the DBMS on a virtual server running on shared hardware. This is normally a task that involves system and network administrators to create appropriate user groups and services in the server configuration and network routing.

Create the Database(s)

In most modern relational DBMSs, a new database implementation requires the creation of special storage-related constructs to house the end-user tables. The constructs usually include the storage group (or file groups), the table spaces, and the tables. [Figure 9.7](#) shows that a storage group can contain more than one table space and that a table space can contain more than one table.

FIGURE 9.7 Physical organization of a DB2 database environment



SOURCE: Course Technology/Cengage Learning

For example, the implementation of the logical design in IBM's DB2 would require the following:

1. The system administrator (SYSADM) would create the database storage group. This step is mandatory for such mainframe databases as DB2. Other DBMS software may create equivalent storage groups automatically when a database is created. (See Step 2.) Consult your DBMS documentation to see if you must create a storage group, and if so, what the command syntax must be.
 2. The SYSADM creates the database within the storage group.
 3. The SYSADM assigns the rights to use the database to a database administrator (DBA).
 4. The DBA creates the table space(s) within the database.
 5. The DBA creates the table(s) within the table space(s).

6. The DBA assigns access rights to the table spaces and to the tables within specified table spaces. Access rights may be limited to views rather than to whole tables. The creation of views is not required for database access in the relational environment, but views are desirable from a security standpoint. For example, using the following command, access rights to a table named PROFESSOR may be granted to the user Shannon Scott, whose identification code is SSCOTT:

```
GRANT SELECT ON PROFESSOR TO USER SSCOTT;
```

Load or Convert the Data

After the database has been created, the data must be loaded into the database tables. Typically, the data will have to be migrated from the prior version of the system. Often, data to be included in the system must be aggregated from multiple sources. In a best-case scenario, all of the data will be in a relational database so that it can be readily transferred to the new database. However, in some cases data may have to be imported from other relational databases, nonrelational databases, flat files, legacy systems, or even manual paper-and-pencil systems. If the data format does not support direct importing into the new database, conversion programs may have to be created to reformat the data for importing. In a worst-case scenario, much of the data may have to be manually entered into the database. Once the data have been loaded, the DBA works with the application developers to test and evaluate the database.

9.3.4 TESTING AND EVALUATION

In the design phase, decisions were made to ensure integrity, security, performance, and recoverability of the database. During implementation and loading, these plans were put into place. In testing and evaluation, the DBA tests and fine-tunes the database to ensure that it performs as expected. This phase occurs in conjunction with application programming. Programmers use database tools to *prototype* the applications during coding of the programs. Tools such as report generators, screen painters, and menu generators are especially useful to application programmers.

Test the Database

During this step, the DBA tests the database to ensure that it maintains the integrity and security of the data. Data integrity is enforced by the DBMS through the proper use of primary and foreign key rules. Many DBMSs also

support the creation of domain constraints and database triggers. Testing will ensure that these constraints were properly designed and implemented. Data integrity is also the result of properly implemented data management policies, which are part of a comprehensive data administration framework. For a more detailed study of this topic, see The DBA's Managerial Role section in [Chapter 15](#), Database Administration and Security.

Previously, users and roles were created to grant users access to the data. In this stage, not only must those privileges be tested, the broader view of data privacy and security must be addressed. Data stored in the company database must be protected from access by unauthorized users. (It does not take much imagination to predict the likely results if students have access to a student database or if employees have access to payroll data!) Consequently, you must test for at least the following:

- *Physical security* allows only authorized personnel physical access to specific areas. Depending on the type of database implementation, however, establishing physical security might not always be practical. For example, a university student research database is not a likely candidate for physical security.
- *Password security* allows the assignment of access rights to specific authorized users. Password security is usually enforced at login time at the operating system level.
- *Access rights* can be established through the use of database software. The assignment of access rights may restrict operations (CREATE, UPDATE, DELETE, and so on) on predetermined objects such as databases, tables, views, queries, and reports.
- *Audit trails* are usually provided by the DBMS to check for access violations. Although the audit trail is an after-the-fact device, its mere existence can discourage unauthorized use.
- *Data encryption* can render data useless to unauthorized users who might have violated some of the database security layers.

- *Diskless workstations* allow end users to access the database without being able to download the information from their workstations.

For a more detailed discussion of security issues, refer to [Chapter 15](#), Database Administration and Security.

Fine-Tune the Database

Database performance can be difficult to evaluate because there are no standards for measuring it, but it is typically one of the most important factors in database implementation. Different systems will place different performance requirements on the database. Systems that support rapid transactions will require the database to be implemented so that they provide superior performance during high volumes of inserts, updates, and deletes. Other systems, like decision support systems, may require superior performance for complex data retrieval tasks. Many factors can affect the database's performance on various tasks, including the hardware and software environment in which the database exists. Naturally, the characteristics and volume of the data also affect database performance: a search of 10 tuples is faster than a search of 100,000 tuples. Other important factors in database performance include system and database configuration parameters such as data placement, access path definition, the use of indexes, and buffer size. For a more in-depth discussion of database performance issues, see [Chapter 11](#), Database Performance Tuning and Query Optimization.

Evaluate the Database and Its Application Programs

As the database and application programs are created and tested, the system must also be evaluated using a more holistic approach. Testing and evaluation of the individual components should culminate in a variety of broader system tests to ensure that all of the components interact properly to meet the needs of the users. At this stage, integration issues and deployment plans are refined, user training is conducted, and system documentation is finalized. Once the system receives final approval, it must be a sustainable resource for the organization. To ensure that the data contained in the database are protected against loss, backup and recovery plans are tested.

Timely data availability is crucial for almost every database. Unfortunately, the database can lose data through unintended deletions, power outages, and other causes. Data backup and recovery procedures create a safety valve, ensuring the availability of consistent data. Typically, database vendors encourage the use of fault-tolerant components such as uninterruptible power supply (UPS) units, RAID storage devices, clustered servers, and data replication technologies to

ensure the continuous operation of the database in case of a hardware failure. Even with these components, backup and restore functions constitute a very important part of daily database operations. Some DBMSs provide functions that allow the database administrator to schedule automatic database backups to permanent storage devices such as disks, DVDs, tapes, and online storage. Database backups can be performed at different levels:

- A [full backup](#), or *dump*, of the entire database. In this case, all database objects are backed up in their entirety.
- A [differential backup](#) of the database, in which only the objects that have been updated or modified since the last full backup are backed up.
- A [transaction log backup](#), which backs up only the transaction log operations that are not reflected in a previous backup copy of the database. In this case, no other database objects are backed up. (For a complete explanation of the transaction log, see [Chapter 10](#), Transaction Management and Concurrency Control.)

The database backup is stored in a secure place, usually in a different building from the database itself, and is protected against dangers such as fire, theft, flood, and other potential calamities. The main purpose of the backup is to guarantee database restoration following a hardware or software failure.

Failures that plague databases and systems are generally induced by software, hardware, programming exemptions, transactions, or external factors. [Table 9.1](#) summarizes the most common sources of database failure.

TABLE 9.1 Common Sources of Database Failure

SOURCE	DESCRIPTION	EXAMPLE
Software	Software-induced failures may be traceable to the operating system, the DBMS software, application programs, or viruses.	The SQL Slammer worm affected many unpatched MS SQL Server systems in 2003, causing millions of dollars in damages.

Hardware	Hardware-induced failures may include memory chip errors, disk crashes, bad disk sectors, and disk-full errors.	A bad memory module or a multiple hard disk failure in a database system can bring it to an abrupt stop.
Programming exemptions	Application programs or end users may roll back transactions when certain programming conditions are defined. Programming exemptions can also be caused by malicious or improperly tested code that can be exploited by hackers.	Hackers constantly search for ways to exploit unprotected Web database systems.
Transactions	The system detects deadlocks and aborts one of the transactions. (See Chapter 10 .)	Deadlock occurs when executing multiple simultaneous transactions.
External factors	Backups are especially important when a system suffers complete destruction from fire, earthquake, flood, or other natural disaster.	In 2005, Hurricane Katrina in New Orleans caused data losses worth millions of dollars.

Depending on the type and extent of the failure, the recovery process ranges from a minor short-term inconvenience to a major long-term rebuild. Regardless of the extent of the required recovery process, recovery is not possible without a usable backup.

Database recovery generally follows a predictable scenario. First, the type and extent of the required recovery are determined. If the entire database needs to be recovered to a consistent state, the recovery uses the most recent backup copy of the database in a known consistent state. The backup copy is then rolled forward to restore all subsequent transactions by using the transaction log information. If the database needs to be recovered but the committed portion of the database is still usable, the recovery process uses the transaction log to “undo” all of the transactions that were not committed (see [Chapter 10](#), Transaction Management and Concurrency Control).

At the end of this phase, the database completes an iterative process of testing, evaluation, and modification that continues until the system is certified as ready to enter the operational phase.

9.3.5 OPERATION

Once the database has passed the evaluation stage, it is considered operational. At that point, the database, its management, its users, and its application programs constitute a complete information system.

The beginning of the operational phase invariably starts the process of system evolution. As soon as all of the targeted end users have entered the operations phase, problems that could not have been foreseen during the testing phase begin to surface. Some of the problems are serious enough to warrant emergency “patchwork,” while others are merely minor annoyances. For example, if the database design is implemented to interface with the Web, the sheer volume of transactions might cause even a well-designed system to bog down. In that case, the designers have to identify the source of the bottleneck and produce alternative solutions. Those solutions may include using load-balancing software to distribute the transactions among multiple computers, increasing the available cache for the DBMS, and so on. The demand for change is the designer’s constant concern, which leads to phase 6, maintenance and evolution.

9.3.6 MAINTENANCE AND EVOLUTION

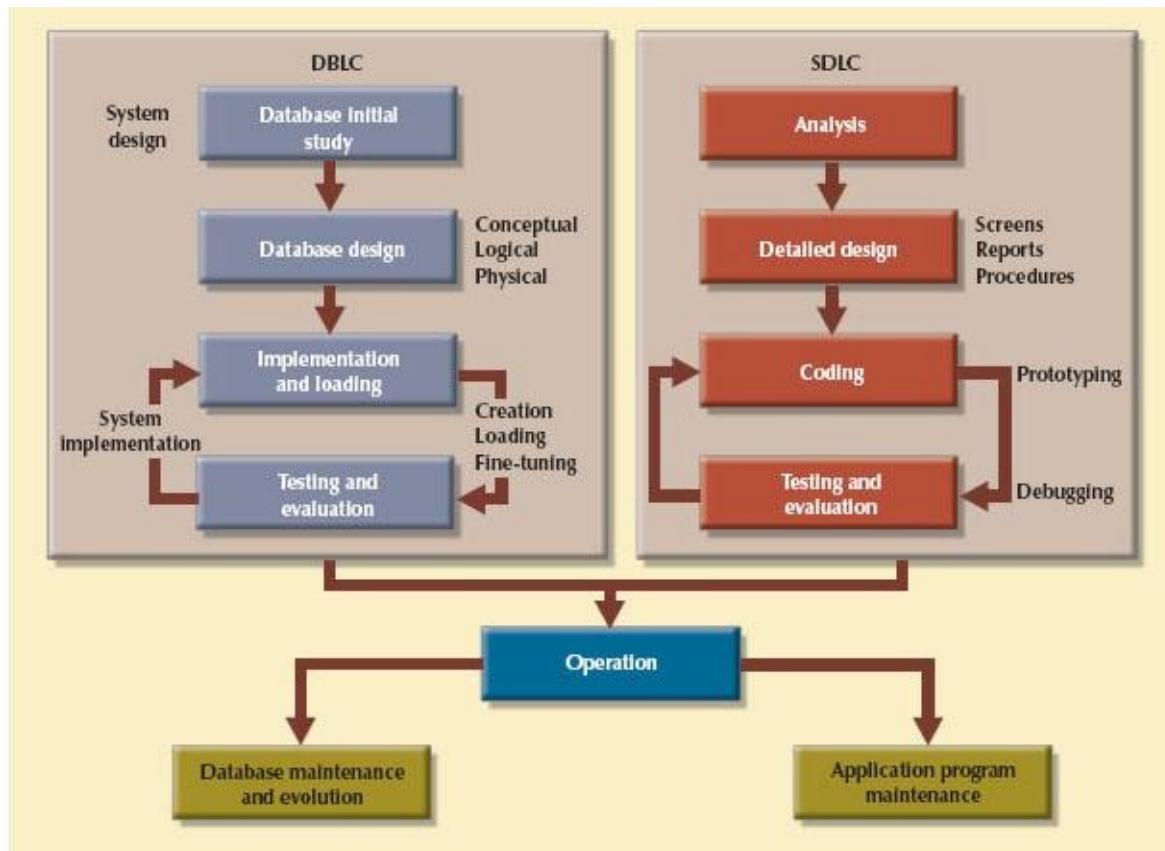
The database administrator must be prepared to perform routine maintenance activities within the database. Some of the required periodic maintenance activities include:

- Preventive maintenance (backup)
- Corrective maintenance (recovery)
- Adaptive maintenance (enhancing performance, adding entities and attributes, and so on)
- Assignment of access permissions and their maintenance for new and old users
- Generation of database access statistics to improve the efficiency and usefulness of system audits and to monitor system performance
- Periodic security audits based on the system-generated statistics
- Monthly, quarterly, or yearly system usage summaries for internal billing or budgeting purposes

The likelihood of new information requirements and the demand for additional reports and new query formats require application changes and possible minor changes in the database components and contents. These changes can be easily implemented only when the database design is flexible and when all documentation is updated and online. Eventually, even the best-designed database environment will no longer be capable of incorporating such evolutionary changes, and then the whole DBLC process begins anew.

As you can see, many of the activities described in the DBLC are similar to those in the SDLC. This should not be surprising, because the SDLC is the framework within which the DBLC activities take place. A summary of the parallel activities that occur within the SDLC and DBLC is shown in [Figure 9.8](#).

FIGURE 9.8 Parallel activities in the DBLC and the SDLC



SOURCE: Course Technology/Cengage Learning

9.4 CONCEPTUAL DESIGN

Recall that the second phase of the DBLC is database design, which comprises three stages: conceptual design, logical design, and physical design, plus the critical decision of DBMS selection. [Conceptual design](#) is the first stage in the database design process. The goal at this stage is to design a database that is independent of database software and physical details. The output of this process is a conceptual data model that describes the main data entities, attributes, relationships, and constraints of a given problem domain. This design is descriptive and narrative in form. In other words, it is generally composed of a graphical representation as well as textual descriptions of the main data elements, relationships, and constraints.

In this stage, data modeling is used to create an abstract database structure that represents real-world objects in the most realistic way possible. The conceptual model must embody a clear understanding of the business and its functional areas. At this level of abstraction, the type of hardware and database model to be used might not have been identified yet. Therefore, the design must be software- and hardware-independent so that the system can be set up within any platform chosen later.

Keep in mind the following [minimal data rule](#):

All that is needed is there, and all that is there is needed.

In other words, make sure that all data needed are in the model and that all data in the model are needed. All data elements required by the database transactions must be defined in the model, and all data elements defined in the model must be used by at least one database transaction.

However, as you apply the minimal data rule, avoid excessive short-term bias. Focus not only on the immediate data needs of the business but on future data needs. Thus, the database design must leave room for future modifications and additions, ensuring that the business's investment in information resources will endure.

The conceptual design has four steps, which are listed in [Table 9.2](#).

TABLE 9.2 Conceptual Design Steps

STEP ACTIVITY

1 Data analysis and requirements

2 Entity relationship modeling and normalization

3 Data model verification

4 Distributed database design

The following sections cover these steps in more detail.

9.4.1 DATA ANALYSIS AND REQUIREMENTS

The first step in conceptual design is to discover the characteristics of the data elements. An effective database is an information factory that produces key ingredients for successful decision making. Appropriate data element characteristics are those that can be transformed into appropriate information. Therefore, the designer's efforts are focused on:

- *Information needs.* What kind of information is needed? That is, what output (reports and queries) must be generated by the system, what information does the current system generate, and to what extent is that information adequate?
- *Information users.* Who will use the information? How is the information to be used? What are the various end-user data views?
- *Information sources.* Where is the information to be found? How is the

information to be extracted once it is found?

- *Information constitution.* What data elements are needed to produce the information? What are the data attributes? What relationships exist among the data? What is the data volume? How frequently are the data used? What data transformations will be used to generate the required information?

The designer obtains the answers to those questions from a variety of sources to compile the necessary information:

- *Developing and gathering end-user data views.* The database designer and the end user(s) jointly develop a precise description of end-user data views, which in turn are used to help identify the database's main data elements.
- *Directly observing the current system: existing and desired output.* The end user usually has an existing system in place, whether it is manual or computer-based. The designer reviews the existing system to identify the data and their characteristics. The designer examines the input forms and files (tables) to discover the data type and volume. If the end user already has an automated system in place, the designer carefully examines the current and desired reports to describe the data required to support the reports.
- *Interfacing with the systems design group.* As noted earlier in this chapter, the database design process is part of the SDLC. In some cases, the systems analyst in charge of designing the new system will also develop the conceptual database model. (This is usually true in a decentralized environment.) In other cases, the database design is considered part of the DBA's job. The presence of a DBA usually implies the existence of a formal data-processing department. The DBA designs the database according to the specifications created by the systems analyst.

To develop an accurate data model, the designer must have a thorough understanding of the company's data types and their extent and uses. But data do not, by themselves, yield the required understanding of the total business. From

a database point of view, the collection of data becomes meaningful only when business rules are defined. Remember from [Chapter 2](#), Data Models, that a *business rule* is a brief and precise description of a policy, procedure, or principle within a specific organization's environment. Business rules, derived from a detailed description of an organization's operations, help to create and enforce actions within that organization's environment. When business rules are written properly, they define entities, attributes, relationships, connectivities, cardinalities, and constraints.

To be effective, business rules must be easy to understand and they must be widely disseminated to ensure that every person in the organization shares a common interpretation of the rules. Using simple language, business rules describe the main and distinguishing characteristics of the data *as viewed by the company*. Examples of business rules are as follows:

- A customer may make many payments on an account.
- Each payment on an account is credited to only one customer.
- A customer may generate many invoices.
- Each invoice is generated by only one customer.

Given their critical role in database design, business rules must not be established casually. Poorly defined or inaccurate business rules lead to database designs and implementations that fail to meet the needs of the organization's end users.

Ideally, business rules are derived from a formal [description of operations](#), which is a document that provides a precise, up-to-date, and thoroughly reviewed description of the activities that define an organization's operating environment. (To the database designer, the operating environment is both the data sources and the data users.) Naturally, an organization's operating environment is dependent on the organization's mission. For example, the operating environment of a university would be quite different from that of a steel manufacturer, an airline, or a nursing home. Yet, no matter how different the organizations may be, the *data analysis and requirements* component of the database design is enhanced when the data environment and data use are described accurately and precisely

within a description of operations.

In a business environment, the main sources of information for the description of operations—and therefore of business rules—are company managers, policy makers, department managers, and written documentation such as company procedures, standards, and operations manuals. A faster and more direct source of business rules is direct interviews with end users. Unfortunately, because perceptions differ, the end user can be a less reliable source when it comes to specifying business rules. For example, a maintenance department mechanic might believe that any mechanic can initiate a maintenance procedure, when actually only mechanics with inspection authorization should perform such a task. This distinction might seem trivial, but it has major legal consequences. Although end users are crucial contributors to the development of business rules, it pays to verify end-user perceptions. Often, interviews with several people who perform the same job yield very different perceptions of their job components. While such a discovery might point to “management problems,” that general diagnosis does not help the database designer. Given the discovery of such problems, the database designer’s job is to reconcile the differences and verify the results of the reconciliation to ensure that the business rules are appropriate and accurate.

Knowing the business rules enables the designer to fully understand how the business works and what role the data play within company operations. Consequently, the designer must identify the company’s business rules and analyze their impact on the nature, role, and scope of data.

Business rules yield several important benefits in the design of new systems:

- They help standardize the company’s view of data.
- They constitute a communications tool between users and designers.
- They allow the designer to understand the nature, role, and scope of the data.
- They allow the designer to understand business processes.
- They allow the designer to develop appropriate relationship participation rules and foreign key constraints. See [Chapter 4](#), Entity Relationship

(ER) Modeling.

The last point is especially noteworthy: whether a given relationship is mandatory or optional is usually a function of the applicable business rule.

9.4.2 ENTITY RELATIONSHIP MODELING AND NORMALIZATION

Before creating the ER model, the designer must communicate and enforce appropriate standards to be used in the documentation of the design. The standards include the use of diagrams and symbols, documentation writing style, layout, and any other conventions to be followed during documentation. Designers often overlook this very important requirement, especially when they are working as members of a design team. Failure to standardize documentation often means a failure to communicate later, and communications failures often lead to poor design work. In contrast, well-defined and enforced standards make design work easier and promise (but do not guarantee) a smooth integration of all system components.

Because the business rules usually define the nature of the relationship(s) among the entities, the designer must incorporate them into the conceptual model. The process of defining business rules and developing the conceptual model using ER diagrams can be described using the steps shown in [Table 9.3](#).³

TABLE 9.3 Developing the Conceptual Model Using ER Diagrams

STEP ACTIVITY

- 1** Identify, analyze, and refine the business rules.

- 2** Identify the main entities, using the results of Step 1.

- 3** Define the relationships among the entities, using the results of Steps 1 and 2.

- 4** Define the attributes, primary keys, and foreign keys for each of the entities.
 - 5** Normalize the entities. (Remember that entities are implemented as tables in an RDBMS.)
 - 6** Complete the initial ER diagram.
 - 7** Validate the ER model against the end users' information and processing requirements.
 - 8** Modify the ER model, using the results of Step 7.
-

Some of the steps listed in [Table 9.3](#) take place concurrently, and some, such as the normalization process, can generate a demand for additional entities and/or attributes, thereby causing the designer to revise the ER model. For example, while identifying two main entities, the designer might also identify the composite bridge entity that represents the many-to-many relationship between the two main entities.

To review, suppose that you are creating a conceptual model for the JollyGood Movie Rental Corporation, whose end users want to track customers' movie rentals. The simple ER diagram presented in [Figure 9.9](#) shows a composite entity that helps track customers and their video rentals. Business rules define the optional nature of the relationships between the entities VIDEO and CUSTOMER. For example, customers are not required to check out a video. A video need not be checked out in order to exist on the shelf. A customer may rent many videos, and a video may be rented by many customers. In particular, note the composite RENTAL entity that connects the two main entities.

FIGURE 9.9 JollyGood movie rental ERD



SOURCE: Course Technology/Cengage Learning

As you will likely discover, the initial ER model may be subjected to several revisions before it meets the system's requirements. Such a revision process is quite natural. Remember that the ER model is a communications tool as well as a design blueprint. Therefore, when you meet with the proposed system users, the initial ER model should give rise to questions such as, "Is this really what you meant?" For example, the ERD shown in [Figure 9.9](#) is far from complete. Clearly, many more attributes must be defined and the dependencies must be checked before the design can be implemented. In addition, the design cannot yet support typical video rental transactions. For example, each video is likely to have many copies available for rental purposes. However, if the VIDEO entity shown in [Figure 9.9](#) is used to store the titles as well as the copies, the design triggers the data redundancies shown in [Table 9.4](#).

TABLE 9.4 Data Redundancies in the VIDEO Table

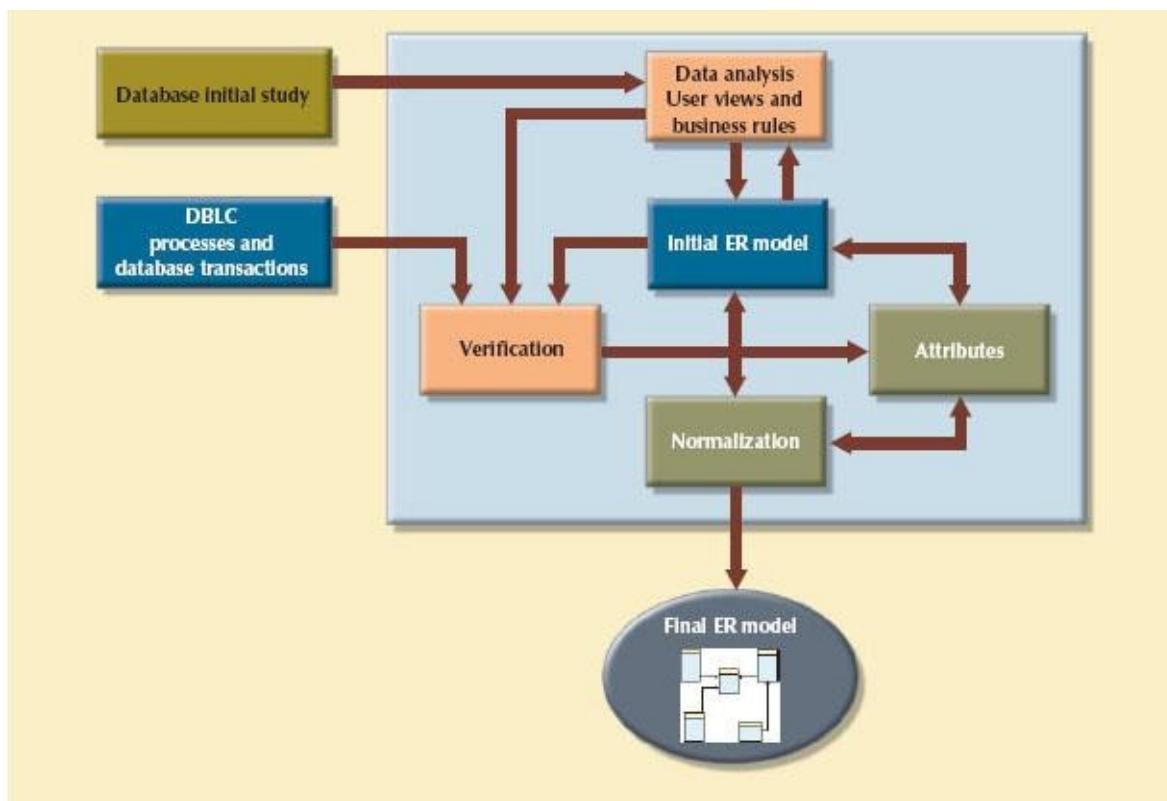
VIDEO_ID	VIDEO_TITLE	VIDEO_COPY	VIDEO_CHG	VIDEO_DAYS
SF-12345FT-1	Adventures on Planet III	1	\$4.50	1
SF-12345FT-2	Adventures on Planet III	2	\$4.50	1
SF-12345FT-3	Adventures on Planet III	3	\$4.50	1
WE-5432GR-1	TipToe Canu and Tyler 2: A Journey	1	\$2.99	2
WE-5432GR-2	TipToe Canu and Tyler 2: A Journey	2	\$2.99	2

The initial ERD shown in [Figure 9.9](#) must be modified to reflect the answer to the question, "Is more than one copy available for each title?" Also, payment transactions must be supported. (You will have an opportunity to modify this initial design in [Problem 5](#) at the end of the chapter.)

From the preceding discussion, you might get the impression that ER modeling activities such as entity and attribute definition, normalization, and verification take place in a precise sequence. In fact, once you have completed the initial ER

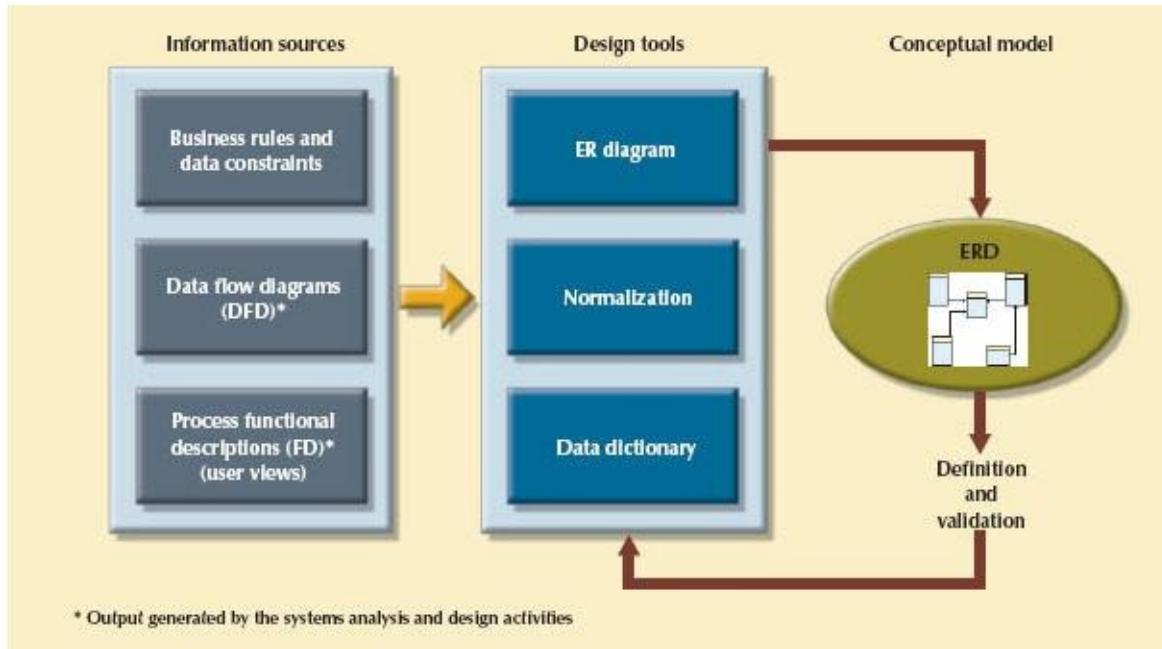
model, chances are that you will move back and forth among the activities until you are satisfied that the ER model accurately represents a database design that can meet the required system demands. The activities often take place in parallel, and the process is iterative. [Figure 9.10](#) summarizes the ER modeling interactions. [Figure 9.11](#) summarizes the array of design tools and information sources that the designer can use to produce the conceptual model.

FIGURE 9.10 ER modeling is an iterative process based on many activities



SOURCE: Course Technology/Cengage Learning

FIGURE 9.11 Conceptual design tools and information sources



SOURCE: Course Technology/Cengage Learning

* Output generated by the systems analysis and design activities

All objects (entities, attributes, relations, views, and so on) are defined in a data dictionary, which is used in tandem with the normalization process to help eliminate data anomalies and redundancy problems. During this ER modeling process, the designer must:

- Define entities, attributes, primary keys, and foreign keys. (The foreign keys serve as the basis for the relationships among the entities.)
- Make decisions about adding new primary key attributes to satisfy end-user and processing requirements.
- Make decisions about the treatment of composite and multivalued attributes.
- Make decisions about adding derived attributes to satisfy processing requirements.
- Make decisions about the placement of foreign keys in 1:1 relationships.

- Avoid unnecessary ternary relationships.
- Draw the corresponding ER diagram.
- Normalize the entities.
- Include all data element definitions in the data dictionary.
- Make decisions about standard naming conventions.

The naming conventions requirement is important, yet it is frequently ignored at the designer's risk. Real database design is generally accomplished by teams. Therefore, it is important to ensure that team members work in an environment in which naming standards are defined and enforced. Proper documentation is crucial to the successful completion of the design, and adherence to the naming conventions serves database designers well. In fact, a common refrain from users seems to be: "I didn't know why you made such a fuss over naming conventions, but now that I'm doing this stuff for real, I've become a true believer."

9.4.3 DATA MODEL VERIFICATION

Data model verification is one of the last steps in the conceptual design stage, and it is one of the most critical. In this step, the ER model must be verified against the proposed system processes to corroborate that they can be supported by the database model. Verification requires that the model be run through a series of tests against:

- End-user data views
- All required transactions: SELECT, INSERT, UPDATE, and DELETE operations
- Access rights and security
- Business-imposed data requirements and constraints

Because real-world database design is generally done by teams, the database design is probably divided into major components known as modules. A [module](#) is an information system component that handles a specific business function,

such as inventory, orders, or payroll. Under these conditions, each module is supported by an ER segment that is a subset or fragment of an enterprise ER model. Working with modules accomplishes several important ends:

- The modules (and even the segments within them) can be delegated to design groups within teams, greatly speeding up the development work.
- The modules simplify the design work. The large number of entities within a complex design can be daunting. Each module contains a more manageable number of entities.
- The modules can be prototyped quickly. Implementation and application programming trouble spots can be identified more readily. Quick prototyping is also a great confidence builder.
- Even if the entire system cannot be brought online quickly, the implementation of one or more modules will demonstrate that progress is being made and that at least part of the system is ready to begin serving the end users.

As useful as modules are, they represent a loose collection of ER model fragments that could wreak havoc in the database if left unchecked. For example, the ER model fragments:

- Might present overlapping, duplicated, or conflicting views of the same data
- Might not be able to support all processes in the system's modules

To avoid these problems, it is better if the modules' ER fragments are merged into a single enterprise ER model. This process starts by selecting a central ER model segment and iteratively adding more ER model segments one at a time. At each stage, for each new entity added to the model, you need to validate that the new entity does not overlap or conflict with a previously identified entity in the enterprise ER model.

Merging the ER model segments into an enterprise ER model triggers a careful reevaluation of the entities, followed by a detailed examination of the attributes that describe those entities. This process serves several important purposes:

- The emergence of the attribute details might lead to a revision of the entities themselves. Perhaps some of the components first believed to be entities will instead turn out to be attributes within other entities. Or, a component that was originally considered an attribute might turn out to contain a sufficient number of subcomponents to warrant the introduction of one or more new entities.
- The focus on attribute details can provide clues about the nature of relationships as they are defined by the primary and foreign keys. Improperly defined relationships lead to implementation problems first and to application development problems later.
- To satisfy processing and end-user requirements, it might be useful to create a new primary key to replace an existing primary key. For example, in the example illustrated in Figure 9.9, a surrogate primary key (RENTAL_ID) could be introduced to replace the original primary key composed of VIDEO_ID and CUST_NUM.
- Unless the entity details (the attributes and their characteristics) are precisely defined, it is difficult to evaluate the extent of the design's normalization. Knowledge of the normalization levels helps guard against undesirable redundancies.
- A careful review of the rough database design blueprint is likely to lead to revisions. Those revisions will help ensure that the design is capable of meeting end-user requirements.

After finishing the merging process, the resulting enterprise ER model is verified against each of the module's processes. The ER model verification process is detailed in [Table 9.5](#).

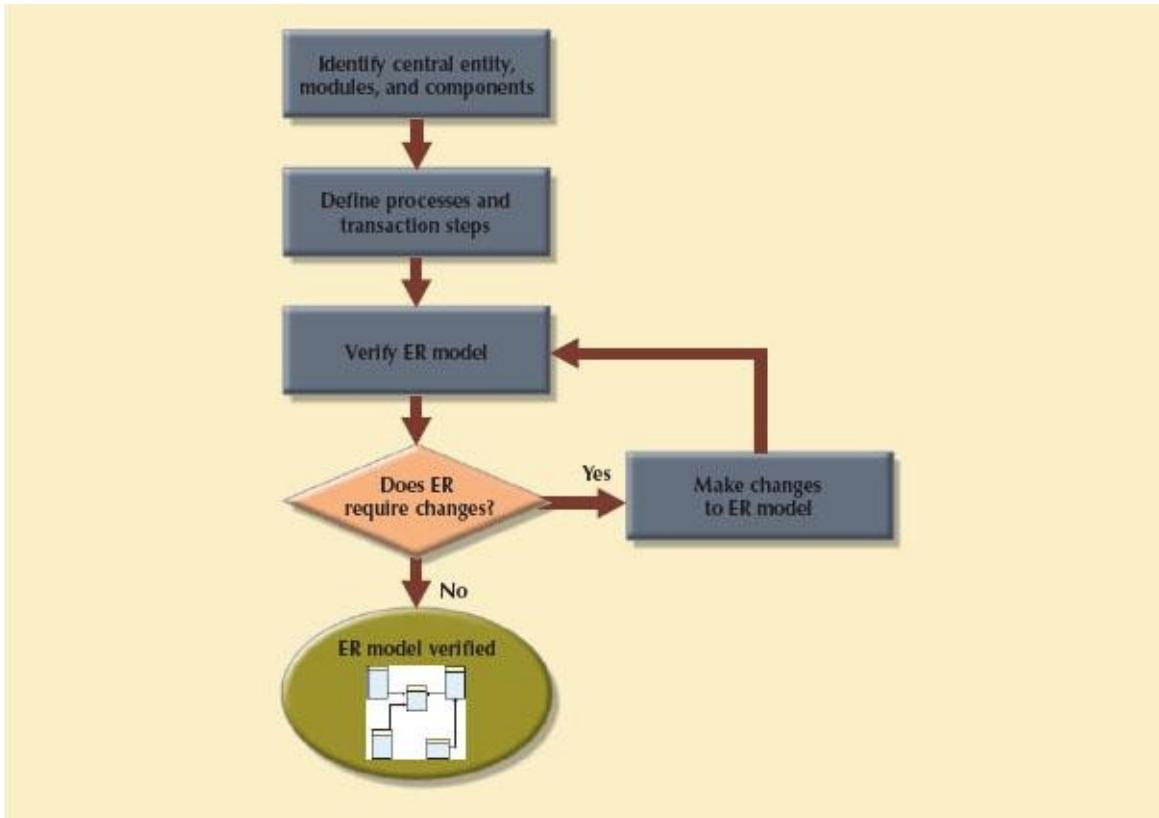
TABLE 9.5 The ER Model Verification Process

STEP ACTIVITY

- 1** Identify the ER model's central entity.
 - 2** Identify each module and its components.
 - 3** Identify each module's transaction requirements:
Internal: updates/inserts/deletes/queries/reports
External: module interfaces
 - 4** Verify all processes against system requirements.
 - 5** Make all necessary changes suggested in Step 4.
 - 6** Repeat Steps 2-5 for all modules.
-
-

Keep in mind that this process requires the continuous verification of business transactions as well as system and user requirements. The verification sequence must be repeated for each of the system's modules. [Figure 9.12](#) illustrates the iterative nature of the process.

FIGURE 9.12 Iterative ER model verification process



SOURCE: Course Technology/Cengage Learning

The verification process starts with selecting the central (most important) entity, which is the focus for most of the system's operations. To identify the central entity, the designer selects the entity involved in the greatest number of the model's relationships. In the ER diagram, it is the entity with more lines connected to it than any other.

The next step is to identify the module or subsystem to which the central entity belongs and to define that module's boundaries and scope. The entity belongs to the module that uses it most frequently. Once each module is identified, the central entity is placed within the module's framework to let you focus on the module's details.

Within the central entity/module framework, you must:

- *Ensure the module's cohesivity.* The term [cohesivity](#) describes the strength of the relationships found among the module's entities. A module must display *high cohesivity*—that is, the entities must be strongly related, and the module must be complete and self-sufficient.

- *Analyze each module's relationships with other modules to address module coupling.* [Module coupling](#) describes the extent to which modules are independent of one another. Modules must display *low coupling*, indicating that they are independent of other modules. Low coupling decreases unnecessary intermodule dependencies, thereby allowing the creation of a truly modular system and eliminating unnecessary relationships among entities.

Processes may be classified according to their:

- Frequency (daily, weekly, monthly, yearly, or exceptions)
- Operational type (INSERT or ADD, UPDATE or CHANGE, DELETE, queries and reports, batches, maintenance, and backups)

All identified processes must be verified against the ER model. If necessary, appropriate changes are implemented. The process verification is repeated for all of the model's modules. You can expect that additional entities and attributes will be incorporated into the conceptual model during its validation.

At this point, a conceptual model has been defined as hardware-and software-independent. Such independence ensures the system's portability across platforms. Portability can extend the database's life by making it possible to migrate to another DBMS and hardware platform.

9.4.4 DISTRIBUTED DATABASE DESIGN

Although not a requirement for most databases, some may need to be distributed among multiple geographical locations. Processes that access the database may also vary from one location to another. For example, a retail process and a warehouse storage process are likely to be found in different physical locations. If the database data and processes will be distributed across the system, portions of a database, known as database fragments, may reside in several physical locations. A [database fragment](#) is a subset of a database that is stored at a given location. The database fragment may be a subset of rows or columns from one or multiple tables.

Distributed database design defines the optimum allocation strategy for database fragments to ensure database integrity, security, and performance. The allocation strategy determines how to partition the database and where to store each

fragment. The design implications introduced by distributed processes are examined in detail in [Chapter 12](#), Distributed Database Management Systems.

9.5 DBMS SOFTWARE SELECTION

The selection of DBMS software is critical to the information system's smooth operation. Consequently, the advantages and disadvantages of the proposed DBMS software should be carefully studied. To avoid false expectations, the end user must be made aware of the limitations of both the DBMS and the database.

Although the factors that affect the purchasing decision vary from company to company, some of the most common are:

- *Cost.* This includes the original purchase price, along with maintenance, operational, license, installation, training, and conversion costs.
 - *DBMS features and tools.* Some database software includes a variety of tools that facilitate application development. For example, the availability of query by example (QBE), screen painters, report generators, application generators, and data dictionaries helps to create a more pleasant work environment for both the end user and the application programmer. Database administrator facilities, query facilities, ease of use, performance, security, concurrency control, transaction processing, and third-party support also influence DBMS software selection.
 - *Underlying model.* This can be hierarchical, network, relational, object relational, or object-oriented.
 - *Portability.* A DBMS can be portable across platforms, systems, and languages.
 - *DBMS hardware requirements.* Items to consider include processor(s), RAM, disk space, and so on.
-

9.6 LOGICAL DESIGN

Logical design is the second stage in the database design process. The logical design goal is to design an enterprise-wide database that is based on a specific data model but independent of physical-level details. Logical design requires that all objects in the conceptual model be mapped to the specific constructs used by the selected database model. For example, the logical design for a relational DBMS includes the specifications for the relations (tables), relationships, and constraints (in other words, domain definitions, data validations, and security views).

The logical design is generally performed in four steps, which are listed in [Table 9.6](#).

TABLE 9.6 Logical Design Steps

STEP ACTIVITY

- 1** Map the conceptual model to logical model components.

 - 2** Validate the logical model using normalization.

 - 3** Validate the logical model integrity constraints.

 - 4** Validate the logical model against user requirements.
-

Such steps, like most of the data-modeling process, are not necessarily performed sequentially, but in an iterative fashion. The following sections cover these steps in more detail.

9.6.1 MAP THE CONCEPTUAL MODEL TO THE LOGICAL MODEL

The first step in creating the logical design is to map the conceptual model to the chosen database constructs. Because this book deals primarily with relational databases, and because most current database design projects are based on the relational database model, this section focuses on logical design using relational constructs. In the real world, logical design generally involves translating the ER model into a set of relations (tables), columns, and constraint definitions. The process of translating the conceptual model into a set of relations is depicted in [Table 9.7](#).

TABLE 9.7 Mapping the Conceptual Model to the Relational Model

STEP ACTIVITY

- 1** Map strong entities.

- 2** Map supertype/subtype relationships.

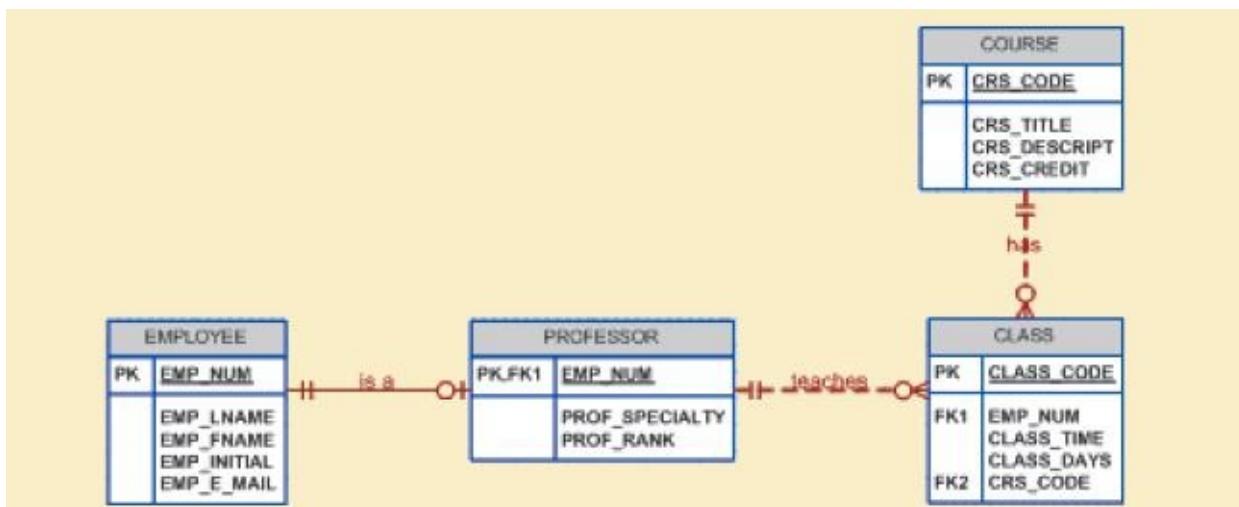
- 3** Map weak entities.

- 4** Map binary relationships.

- 5** Map higher-degree relationships.

To illustrate this process, use the example of the Simple College ER model shown in [Figure 9.13](#). Remember, the steps indicated in [Table 9.7](#) are not sequential but iterative.

FIGURE 9.13 The Simple College conceptual model



SOURCE: Course Technology/Cengage Learning

As indicated in [Table 9.7](#), the first step in the logical design stage is to map strong entities to tables. Recall from [Chapter 4](#) that a strong entity is one that resides in the “1” side of all its relationships—that is, an entity that does not have a mandatory attribute that is a foreign key to another table. Therefore, the first entities to be translated into tables would be the EMPLOYEE and COURSE entities. In this case, you define the table name, its columns, and their characteristics. For example, the relation definitions for the strong entities of Simple College would be:

COURSE (CRS_CODE, CRS_TITLE, CRS_DESCRPT, CRS_CREDIT)

 PRIMARY KEY: CRS_CODE

EMPLOYEE (EMP_NUM, EMP_LNAME, EMP_FNAME, EMP_INITIAL, EMP_E_MAIL)

 PRIMARY KEY: EMP_NUM

Once all strong entities are mapped, you are ready to map any entities involved in a supertype/subtype relationship or any weak entities. In the case of Simple College, the PROFESSOR entity is a subtype of the EMPLOYEE entity. PROFESSOR is also a weak entity because it inherits its primary key from EMPLOYEE and is existence-dependent on EMPLOYEE. At this point, you could also start defining the relationships between supertype and subtype.

entities. For example:

PROFESSOR (EMP_NUM, PROF_SPECIALTY, PROF_RANK)

PRIMARY KEY: EMP_NUM

FOREIGN KEY: EMP_NUM REFERENCES EMPLOYEE

Next, you start mapping all binary relationships. In the previous example you defined the supertype/subtype relationship between EMPLOYEE and PROFESSOR. This is an instance that demonstrates the iterative nature of the process. Continuing with the Simple College ER model, you would define the CLASS relation and define its 1:M relationships with PROFESSOR and COURSE:

CLASS (CLASS_CODE, EMP_NUM, CLASS_TIME, CLASS_DAYS, CRS_CODE)

PRIMARY KEY: CLASS_CODE

FOREIGN KEYS: EMP_NUM REFERENCES PROFESSOR
CRS_CODE REFERENCES COURSE

Next, you will proceed with all relationships between three or more entities until all relationships in the model are clearly defined. The logical design's tables must correspond to the entities (EMPLOYEE, PROFESSOR, COURSE, and CLASS) shown in the conceptual design of [Figure 9.13](#), and the table columns must correspond to the attributes specified in the conceptual design. The final outcome of this process is a list of relations, attributes, and relationships that will be the basis for the next step.

9.6.2 VALIDATE THE LOGICAL MODEL USING NORMALIZATION

The logical design should contain only properly normalized tables. The process of mapping the conceptual model to the logical model may unveil some new attributes or the discovery of new multivalued or composite attributes. Therefore, it's very likely that new attributes may be added to tables, or that entire new tables may be added to the logical model. For each identified table (old and new), you must ensure that all attributes are fully dependent on the identified primary key and that the tables are in at least third normal form (3NF).

As indicated throughout this section, database design is an iterative process. Activities such as normalization take place at different stages in the design process. Each time you reiterate a step, the model is further refined and better documented. New attributes may be created and assigned to the proper entities.

Functional dependencies among determinant and dependent attributes are evaluated and data anomalies are prevented via normalization.

9.6.3 VALIDATE LOGICAL MODEL INTEGRITY CONSTRAINTS

The translation of the conceptual model into a logical model also requires definition of the attribute domains and appropriate constraints. For example, the domain definitions for the CLASS_CODE, CLASS_DAYS, and CLASS_TIME attributes displayed in the CLASS entity in [Figure 9.13](#) are written this way:

CLASS_CODE is a valid class code.

Type: numeric

Range: low value = 1000 high value = 9999

Display format: 9999

Length: 4

CLASS_DAYS is a valid day code.

Type: character

Display format: XXX

Valid entries: MWF, TR, M, T, W, R, F, S

Length: 3

CLASS_TIME is a valid time.

Type: character

Display format: 99:99 (24-hour clock)

Display range: 06:00 to 22:00

Length: 5

All these defined constraints must be supported by the logical data model. In this stage, you must map these constraints to the proper relational model constraints. For example, the CLASS_DAYS attribute is character data that should be restricted to a list of valid character combinations. Here, you define this attribute to have a CHECK IN constraint to enforce that the only allowed values are “MWF”, “TR”, “M”, “T”, “W”, “R”, “F”, and “S”. During this step, you also define which attributes are mandatory and which are optional, and ensure that all entities maintain entity and referential integrity.

The right to use the database is also specified during the logical design phase.

Who will be allowed to use the tables and what portions of the tables will be available to which users? Within a relational framework, the answers to those questions require the definition of appropriate views. For example, a given process may require the creation of the following view to get data about the class schedules:

```
CREATE VIEW vSCHEDULE AS
    SELECT EMP_LNAME, EMP_FNAME, CLASS_CODE, CRS_TITLE, CLASS_TIME, CLASS_DAYS
    FROM PROFESSOR, CLASS, COURSE
    WHERE PROFESSOR.EMP_NUM = CLASS.EMP_NUM AND
          CLASS.CRS_CODE = COURSE.CRS_CODE
```

Special attention is needed at this stage to ensure that all views can be resolved and that security is enforced to ensure the privacy of the data. Additionally, if you are working with a distributed database design, data could be stored at multiple locations, and each location may have different security restrictions. After validating the logical model integrity constraints, you are ready to validate the model against the end-user requirements.

9.6.4 VALIDATE THE LOGICAL MODEL AGAINST USER REQUIREMENTS

The logical design translates the software-independent conceptual model into a software-dependent model. The final step in the logical design process is to validate all logical model definitions against all end-user data, transaction, and security requirements. A process similar to the one depicted in [Table 9.5](#) takes place again to ensure the correctness of the logical model. The stage is now set to define the physical requirements that allow the system to function within the selected DBMS/hardware environment.

9.7 PHYSICAL DESIGN

[Physical design](#) is the process of determining the data storage organization and data access characteristics of the database to ensure its integrity, security, and performance. This is the last stage in the database design process. The storage characteristics are a function of the types of devices supported by the hardware, the type of data access methods supported by the system, and the DBMS. Physical design can become a very technical job that affects not only the accessibility of the data in the storage device(s) but the performance of the system.

The physical design stage consists of the steps in [Table 9.8](#).

TABLE 9.8 Physical Design Steps

STEP ACTIVITY

1 Define data storage organization.

2 Define integrity and security measures.

3 Determine performance measurements.

The following sections cover these steps in more detail.

9.7.1 DEFINE DATA STORAGE ORGANIZATION

Before you can define the data storage organization, you must determine the volume of data to be managed and the data usage patterns.

- Knowing the data volume will help you determine how much storage space to reserve for the database. To do this, the designer follows a process similar to the one used during ER model verification. For each table, identify all possible transactions, their frequency, and volume. For each transaction, you determine the amount of data to be added or deleted from the database. This information will help you determine the amount of data to be stored in the related table.
- Conversely, knowing how frequently the new data are inserted, updated, and retrieved will help the designer determine the data usage patterns. Usage patterns are critical, particularly in distributed database design. For example, are there any weekly batch uploads or monthly aggregation

reports to be generated? How frequently are new data added to the system?

Equipped with the two previous pieces of information, the designer must:

- *Determine the location and physical storage organization for each table.* As you saw in [Section 9.3.3](#), tables are stored in table spaces, and a table space can hold data from multiple tables. In this step, the designer assigns which tables will use which table spaces, and assigns the location of the table spaces. For example, a useful technique available in most relational databases is the use of clustered tables. The [clustered tables](#) storage technique stores related rows from two related tables in adjacent data blocks on disk. This ensures that the data are stored in sequentially adjacent locations, thereby reducing data access time and increasing system performance.
- *Identify indexes and the type of indexes to be used for each table.* As you saw in previous chapters, indexes are useful for ensuring the uniqueness of data values in a column and to facilitate data lookups. You also know that the DBMS automatically creates a unique index for the primary key of each table. You will learn in [Chapter 11](#) about the various types of index organization. In this step, you identify all required indexes and determine the best type of organization to use based on the data usage patterns and performance requirements.
- *Identify the views and the type of views to be used on each table.* As you learned in [Chapter 8](#), a view is useful to limit access to data based on user or transaction needs. Views can also be used to simplify processing and end-user data access. In this step the designer must ensure that all views can be implemented and that they provide only the required data. The designer must also become familiar with the types of views supported by the DBMS and how they could help meet system goals.

9.7.2 DEFINE INTEGRITY AND SECURITY MEASURES

Once the physical organization of the tables, indexes, and views are defined, the database is ready for the end users. However, before users can access the data in the database, they must be properly authenticated. In this step of physical design, two tasks must be addressed:

- *Define user and security groups and roles.* User management is more a function of database administration than database design. However, as a designer you must know the different types of users and groups of users to properly enforce database security. Most DBMS implementations support the use of database roles. A [database role](#) is a set of database privileges that could be assigned as a unit to a user or group. For example, you could define an Advisor role that has Read access to the vSCHEDE view.
- *Assign security controls.* The DBMS also allows administrators to assign specific access rights for database objects to a user or group of users. For example, you could assign the SELECT and UPDATE access rights to the user sscott on the CLASS table. An access right could also be revoked from a specific user or groups of users. This feature could come in handy during database backups or scheduled maintenance events.

9.7.3 DETERMINE PERFORMANCE MEASURES

Physical design becomes more complex when data are distributed at different locations because the performance is affected by the communication media's throughput. Given such complexities, it is not surprising that designers favor database software that hides as many of the physical-level activities as possible. Despite the fact that relational models tend to hide the complexities of the computer's physical characteristics, the performance of relational databases is affected by physical storage properties. For example, performance can be affected by characteristics of the storage media, such as seek time, sector and block (page) size, buffer pool size, and the number of disk platters and read/write heads. In addition, factors such as the creation of an index can have a considerable effect on the relational database's performance—that is, data access speed and efficiency.

In summary, physical design performance measurement deals with fine-tuning the DBMS and queries to ensure that they will meet end-user performance requirements.

NOTE

For a detailed discussion of database performance and query optimization techniques that could be used here, see [**Chapter 11, Database Performance Tuning and Query Optimization**](#).

The preceding sections have separated the discussions of logical and physical design activities. In fact, logical and physical design can be carried out in parallel, on a table-by-table basis. Such parallel activities require the designer to have a thorough understanding of the software and hardware to take full advantage of their characteristics.



ONLINE CONTENT

Physical design is particularly important in the older hierarchical and network models described in **Appendices K and L, The Hierarchical Database Model and The Network Database Model**, respectively. Both appendixes are available at www.cengagebrain.com. Relational databases are more insulated from physical details than the older hierarchical and network models.

9.8 DATABASE DESIGN STRATEGIES

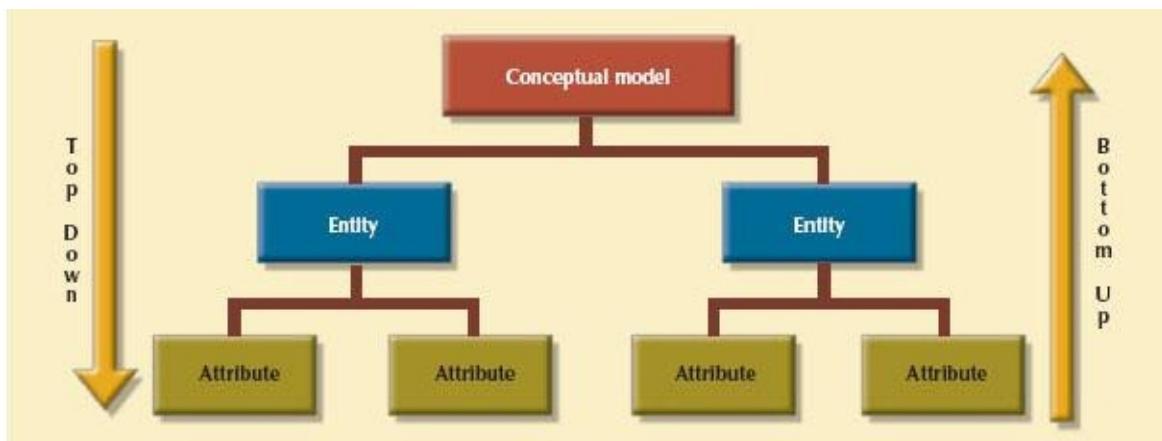
There are two classical approaches to database design:

- [**Top-down design**](#) starts by identifying the data sets and then defines the data elements for each of those sets. This process involves the identification of different entity types and the definition of each entity's attributes.
- [**Bottom-up design**](#) first identifies the data elements (items) and then groups them together in data sets. In other words, it first defines attributes, and then groups them to form entities.

The two approaches are illustrated in [**Figure 9.14**](#). Selecting a primary emphasis

on top-down or bottom-up procedures often depends on the scope of the problem or on personal preferences. Although the two methodologies are complementary rather than mutually exclusive, a primary emphasis on a bottom-up approach may be more productive for small databases with few entities, attributes, relations, and transactions. For situations in which the number, variety, and complexity of entities, relations, and transactions is overwhelming, a primarily top-down approach may be easier. Most companies have standards for systems development and database design already in place.

FIGURE 9.14 Top-down vs. bottom-up design sequencing



SOURCE: Course Technology/Cengage Learning

NOTE

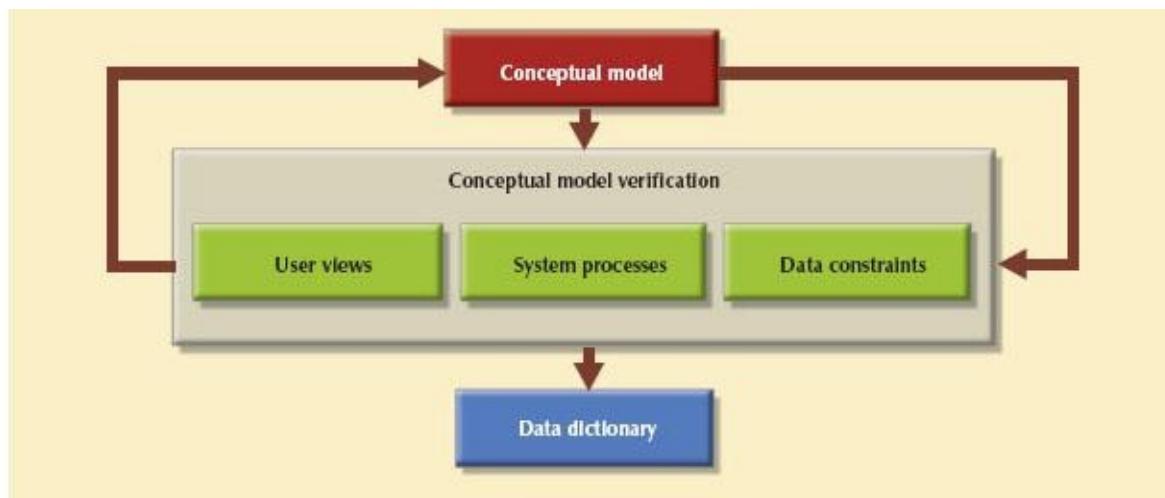
Even when a primarily top-down approach is selected, the normalization process that revises existing table structures is inevitably a bottom-up technique. ER models constitute a top-down process even when the selection of attributes and entities can be described as bottom-up. Because both the ER model and normalization techniques form the basis for most designs, the top-down vs. bottom-up debate may be based on a theoretical distinction rather than an actual difference.

9.9 CENTRALIZED Vs. DECENTRALIZED DESIGN

The two general approaches to database design (bottom-up and top-down) can be influenced by factors such as the scope and size of the system, the company's management style, and the company's structure (centralized or decentralized). Depending on these factors, the database design may be based on two very different design philosophies: centralized and decentralized.

Centralized design is productive when the data component has a relatively small number of objects and procedures. The design can be carried out and represented in a fairly simple database. Centralized design is typical of relatively simple, small databases and can be successfully done by a single database administrator or by a small, informal design team. The company operations and the scope of the problem are sufficiently limited to allow even a single designer to define the problem(s), create the conceptual design, verify the conceptual design with the user views, define system processes and data constraints to ensure the efficacy of the design, and ensure that the design will comply with all the requirements. (Although centralized design is typical for small companies, do not make the mistake of assuming that it is limited to small companies. Even large companies can operate within a relatively simple database environment.) [Figure 9.15](#) summarizes the centralized design option. Note that a single conceptual design is completed and then validated in the centralized design approach.

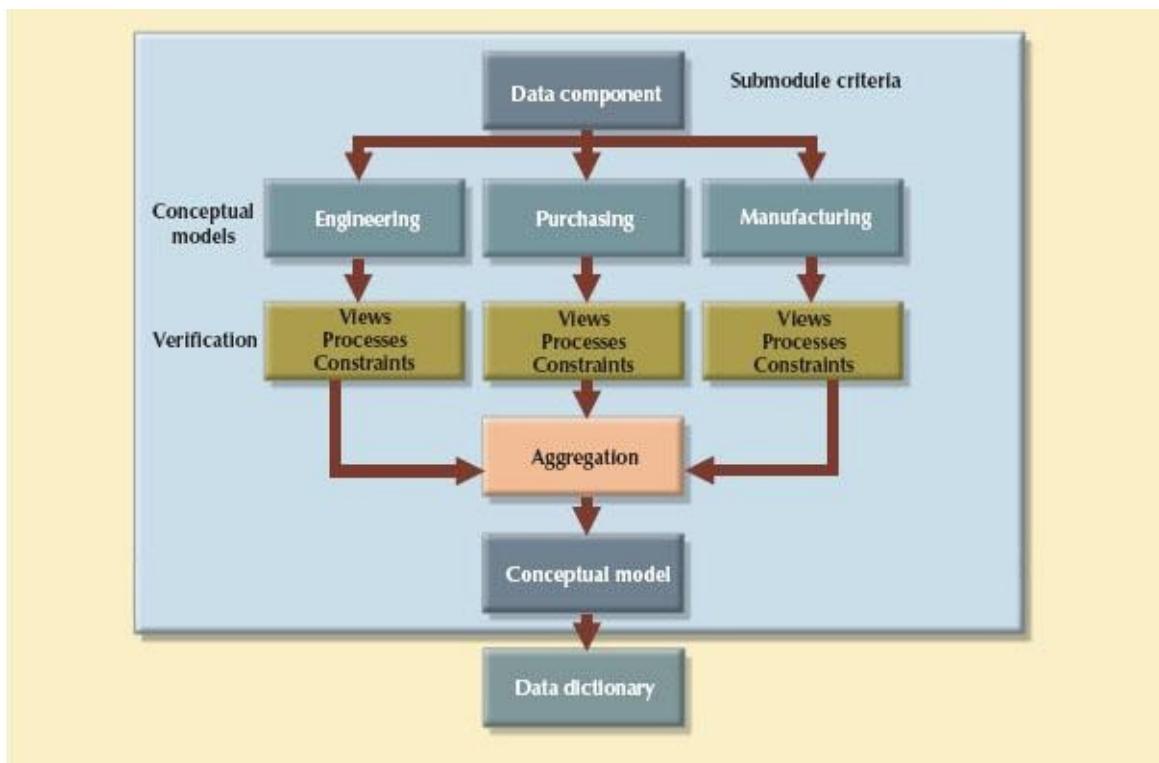
FIGURE 9.15 Centralized design



SOURCE: Course Technology/Cengage Learning

[Decentralized design](#) might be used when the system's data component has a considerable number of entities and complex relations on which very complex operations are performed. Decentralized design is also often used when the problem itself is spread across several operational sites and each element is a subset of the entire data set. (See [Figure 9.16.](#))

FIGURE 9.16 Decentralized design



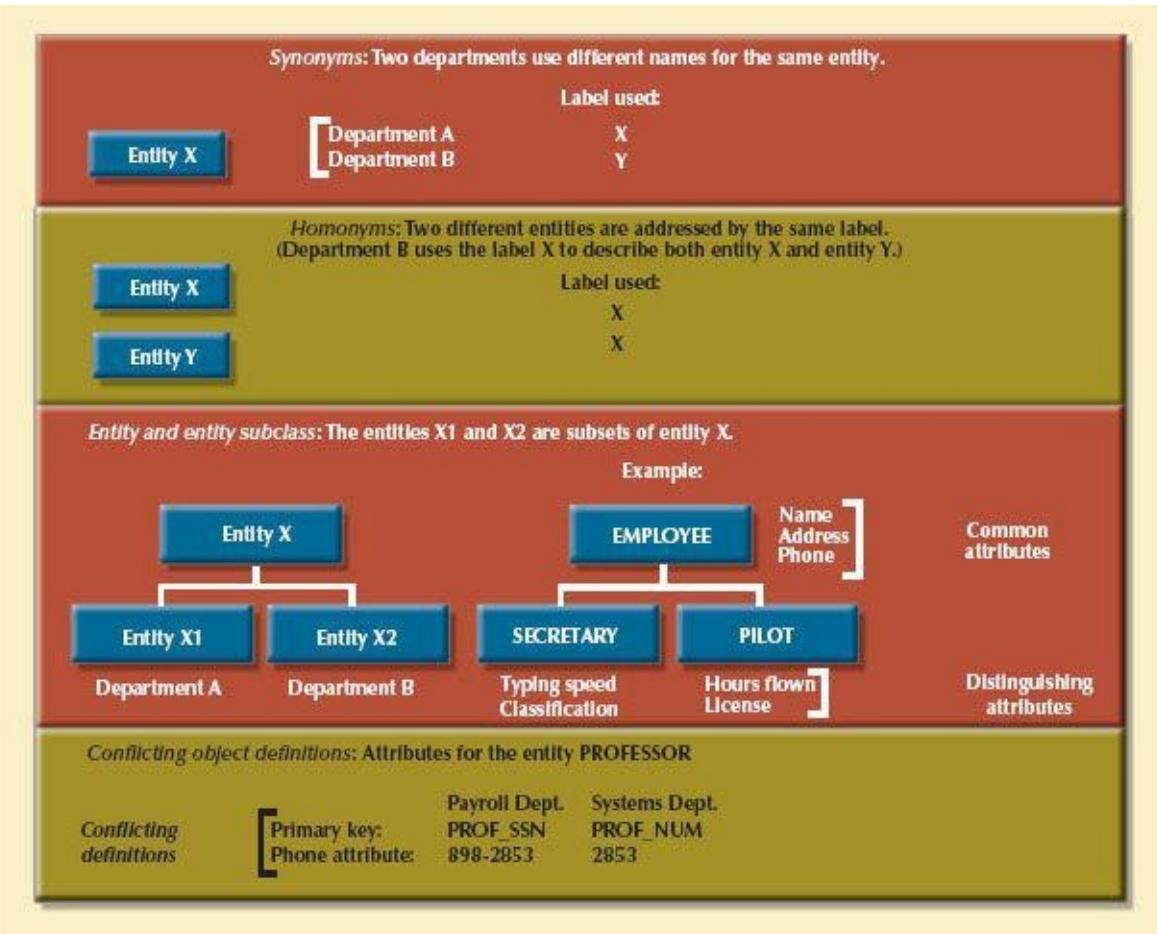
SOURCE: Course Technology/Cengage Learning

In large and complex projects, the database typically cannot be designed by only one person. Instead, a carefully selected team of database designers tackles a complex database project. Within the decentralized design framework, the database design task is divided into several modules. Once the design criteria have been established, the lead designer assigns design subsets or modules to design groups within the team.

Because each design group focuses on modeling a subset of the system, the definition of boundaries and the interrelation among data subsets must be very precise. Each design group creates a conceptual data model corresponding to the subset being modeled. Each conceptual model is then verified individually against the user views, processes, and constraints for each of the modules. After the verification process has been completed, all modules are integrated into one conceptual model. Because the data dictionary describes the characteristics of all objects within the conceptual data model, it plays a vital role in the integration process. Naturally, after the subsets have been aggregated into a larger conceptual model, the lead designer must verify that it still can support all of the required transactions.

Keep in mind that the aggregation process requires the designer to create a single model in which various aggregation problems must be addressed. (See [Figure 9.17](#).)

FIGURE 9.17 Summary of aggregation problems



SOURCE: Course Technology/Cengage Learning

- *Synonyms and homonyms.* Various departments might know the same object by different names (synonyms), or they might use the same name to address different objects (homonyms). The object can be an entity, an attribute, or a relationship.
- *Entity and entity subtypes.* An entity subtype might be viewed as a separate entity by one or more departments. The designer must integrate such subtypes into a higher-level entity.
- *Conflicting object definitions.* Attributes can be recorded as different types (character, numeric), or different domains can be defined for the same attribute. Constraint definitions can vary as well. The designer must remove such conflicts from the model.

SUMMARY

- An information system is designed to help transform data into information and to manage both data and information. Thus, the database is a very important part of the information system. Systems analysis is the process that establishes the need for an information system and its extent. Systems development is the process of creating an information system.

- The Systems Development Life Cycle (SDLC) traces the history of an application within the information system. The SDLC can be divided into five phases: planning, analysis, detailed systems design, implementation, and maintenance. The SDLC is an iterative process rather than a sequential process.
- The Database Life Cycle (DBLC) describes the history of the database within the information system. The DBLC is composed of six phases: database initial study, database design, implementation and loading, testing and evaluation, operation, and maintenance and evolution. Like the SDLC, the DBLC is iterative rather than sequential.

- The conceptual portion of the design may be subject to several variations based on two basic design philosophies: bottom-up vs. top-down and centralized vs. decentralized.

KEY TERMS

[bottom-up design](#)
[boundaries](#)
[centralized design](#)
[clustered tables](#)
[cohesivity](#)
[computer-aided systems engineering \(CASE\)](#)
[conceptual design](#)
[database development](#)

[database fragment](#)
[Database Life Cycle \(DBLC\)](#)
[database role](#)
[decentralized design](#)
[description of operations](#)
[differential backup](#)
[full backup](#)
[information system](#)
[logical design](#)
[minimal data rule](#)
[module](#)
[module coupling](#)
[physical design](#)
[scope](#)
[systems analysis](#)
[systems development](#)
[Systems Development Life Cycle \(SDLC\)](#)
[top-down design](#)
[transaction log backup](#)
[virtualization](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at
www.cengagebrain.com.

REVIEW QUESTIONS

1. What is an information system? What is its purpose?

2. How do systems analysis and systems development fit into a discussion about information systems?
 3. What does the acronym SDLC mean, and what does an SDLC portray?
 4. What does the acronym DBLC mean, and what does a DBLC portray?
 5. Discuss the distinction between centralized and decentralized conceptual database design.
 6. What is the minimal data rule in conceptual design? Why is it important?
 7. Discuss the distinction between top-down and bottom-up approaches in database design.
 8. What are business rules? Why are they important to a database designer?
 9. What is the data dictionary's function in database design?
 10. What steps are required in the development of an ER diagram? (*Hint: See [Table 9.3](#).*)
 11. List and briefly explain the activities involved in the verification of an ER model.
 12. What factors are important in a DBMS software selection?
 13. List and briefly explain the four steps performed during the logical design stage.
 14. List and briefly explain the three steps performed during the physical design stage.
 15. What three levels of backup may be used in database recovery management? Briefly describe what each backup level does.
-

PROBLEMS

1. The ABC Car Service & Repair Centers are owned by the Silent Car Dealership; ABC services and repairs only Silent cars. Three ABC centers provide service and repair for the entire state.

Each of the three centers is independently managed and operated by a shop manager, a receptionist, and at least eight mechanics. Each center maintains a fully stocked parts inventory.

Each center also maintains a manual file system in which each car's maintenance history is kept: repairs made, parts used, costs, service dates, owner, and so on. Files are also kept to track inventory, purchasing, billing, employees' hours, and payroll.

You have been contacted by one of the center's managers to design and implement a computerized database system. Given the preceding information, do the following:

- a. Indicate the most appropriate sequence of activities by labeling each of the following steps in the correct order. (For example, if you think that "Load the database." is the appropriate first step, label it "1.")

- _____ Normalize the conceptual model.
- _____ Obtain a general description of company operations.
- _____ Load the database.
- _____ Create a description of each system process.
- _____ Test the system.
- _____ Draw a data flow diagram and system flowcharts.
- _____ Create a conceptual model using ER diagrams.
- _____ Create the application programs.
- _____ Interview the mechanics.
- _____ Create the file (table) structures.
- _____ Interview the shop manager.

- b. Describe the various modules that you believe the system should include.

- c. How will a data dictionary help you develop the system? Give examples.

- d. What general (system) recommendations might you make to the shop manager? For example, if the system will be integrated, what modules will be integrated? What benefits would be derived from such an integrated

system? Include several general recommendations.

- e. What is the best approach to conceptual database design? Why?
 - f. Name and describe at least four reports the system should have. Explain their use. Who will use those reports?
2. Suppose that you have been asked to create an information system for a manufacturing plant that produces nuts and bolts of many shapes, sizes, and functions. What questions would you ask, and how would the answers affect the database design?
 - a. What do you envision the SDLC to be?
 - b. What do you envision the DBLC to be?
 3. Suppose that you perform the same functions noted in [Problem 2](#) for a larger warehousing operation. How are the two sets of procedures similar? How and why are they different?
-
4. Using the same procedures and concepts employed in [Problem 1](#), how would you create an information system for the Tiny College example in [Chapter 4](#)?
 5. Write the proper sequence of activities for the design of a video rental database. (The initial ERD was shown in [Figure 9.9](#).) The design must support all rental activities, customer payment tracking, and employee work schedules, as well as track which employees checked out the videos to the customers. After you finish writing the design activity sequence, complete the ERD to ensure that the database design can be successfully implemented. (Make sure that the design is normalized properly and that it can support the required transactions.)

¹ See *Rapid Application Development*, James Martin, Prentice-Hall, Macmillan College Division, 1991.

² For more information about Agile Software Development, go to www.agilealliance.org.

³ See “Linking Rules to Models,” Alice Sandifer and Barbara von Halle, *Database Programming and Design*, 4(3), March 1991. Although the source seems dated, it remains the current standard. The technology has changed substantially, but the process has not.

PART
IV
ADVANCED DATABASE CONCEPTS

TRANSACTION MANAGEMENT AND CONCURRENCY CONTROL **10**

DATABASE PERFORMANCE TUNING AND QUERY OPTIMIZATION **11**

DISTRIBUTED DATABASE MANAGEMENT SYSTEMS **12**

BUSINESS INTELLIGENCE AND DATA WAREHOUSES **13**

Business Vignette

In 1981, the Marciano brothers sold their first pair of jeans in the United States. Their idea was to combine Americans' passion for denim with innovative, sensual European style. By 1982, their company, GUESS, boasted an annual sales growth of \$6 million. By 2010, the now global company had branched out from men's and women's clothing into accessories like jewelry, shoes, eyewear, bathing suits, watches, wallets, and bags.¹ That same year, the company boasted net sales of almost \$2.5 billion.²

A key to the company's success is its team of designers, who work with company executives to search out global fashion trends and integrate them into the distinct GUESS image. To support this effort, the GUESS information systems department decided that the company needed a way to deliver timely business intelligence to its mobile workforce. The company has 25 regional directors in the field and 30 executives and corporate directors at headquarters. The company chose MicroStrategy, a product that could deliver mobile business intelligence through RIM BlackBerry devices.³

MicroStrategy Report Services conducts analysis, monitoring, and reporting. It uses a wide variety of scorecards, dashboards, and enterprise reports, and it features intuitive, self-service document creation. This tool can drill across multiple sources of data and has OLAP capabilities. The services can be delivered through a variety of mobile devices, including Blackberries, iPads, and iPhones.⁴

The GUESS database is 2 terabytes and runs on Oracle. About 500 users access it through an intranet, but different employees access the database in different ways. GUESS salespeople use their Blackberries to open PDFs and get a quick snapshot of sales to make immediate decisions. They can quickly view summarized information about margins, sales performance by region, trend information, and "pain points." The company also extended the use of its dynamic dashboard to buyers and planners, giving these lower-level decision makers access to business intelligence. Executives and division managers access "daily flash sales" dashboards that report profitability margins, sales trends, traffic conversion, comparative store sales, or store sales this year versus last year.

The company designers are also excited about using the mobile business information system. They can use a Flash-enabled dashboard to track their

products in real time. They can see how items are selling as soon as they hit the stores. They can find out if one color or design feature is outselling another. They can track buying patterns for their items and thus become more competitive and take advantage of opportunities for business growth.

The decision to adopt a mobile business intelligence system has paid off for GUESS. The year after the system was implemented, GUESS enjoyed a 20 percent increase in global sales despite the economic downturn. When many businesses were closing their doors, GUESS opened new stores in Asia, Europe, and the United States. In 2010, sales continued to grow, jumping 17 percent.⁵ A GUESS spokesperson said, “Deploying dynamic dashboards to our traditional and nontraditional users of business intelligence was a huge opportunity for us to contribute to our revenues and global sales growth, and it wasn’t that hard to do.” Mobile business intelligence helped GUESS take the guesswork out of the decision-making process.

¹ “Scrutinizing the Trend of Highly Acclaimed U.S. Brand,” *The Textile Icon*, May 13, 2011, www.thetextileicon.com/blog/2011/05/scrutinizing-the-trend-of-highly-acclaimed-us-brand/.

² Annual Income Statement, Investor’s Info, GUESS Web site, <http://investors.guess.com/phoenix.zhtml?c=92506&p=irol-fundIncomeA>.

³ “Success Story: GUESS?, Inc. — Using Mobile Business Intelligence and Dynamic Dashboards to Influence Business Decisions that Drive Revenue Growth,” MicroStrategy Web site, www.microstrategy.com/Customers/Succesess/detail.asp?ID=265.

⁴ MicroStrategy Business Intelligence, Products, MicroStrategy Web site, www.microstrategy.com/Software/businessintelligence/index.asp.

⁵ Annual Income Statement, Investor’s Info, GUESS Web site, <http://investors.guess.com/phoenix.zhtml?c=92506&p=irol-fundIncomeA>.

10 TRANSACTION MANAGEMENT AND CONCURRENCY CONTROL

In this chapter, you will learn:

- About database transactions and their properties
 - What concurrency control is and what role it plays in maintaining the database's integrity
 - What locking methods are and how they work
 - How stamping methods are used for concurrency control
 - How optimistic methods are used for concurrency control
 - How database recovery management is used to maintain database integrity
-

Preview

Database transactions reflect real-world transactions that are triggered by events such as buying a product, registering for a course, or making a deposit in a checking account. Transactions are likely to contain many parts. For example, a sales transaction might require updating the customer's account, adjusting the product inventory, and updating the seller's accounts receivable. All parts of a transaction must be successfully completed to prevent data integrity problems. Therefore, executing and managing transactions are important database system activities.

The main database transaction properties are atomicity, consistency, isolation, and durability. In addition, serializability is a characteristic of the schedule of operations for executing concurrent transactions. After defining the transaction properties, the chapter shows how SQL can be used to represent transactions and how transaction logs can ensure the DBMS's ability to recover transactions.

When many transactions take place at the same time, they are called concurrent transactions. Managing the execution of such transactions is called concurrency control. As you can imagine, concurrency control is especially important in a multiuser database environment. Just imagine the number of transactions routinely handled by companies that conduct sales and provide services via the

Web! This chapter discusses some of the problems that can occur with concurrent transactions—lost updates, uncommitted data, and inconsistent retrievals. You will discover that such problems can be solved when a DBMS scheduler enforces concurrency control.

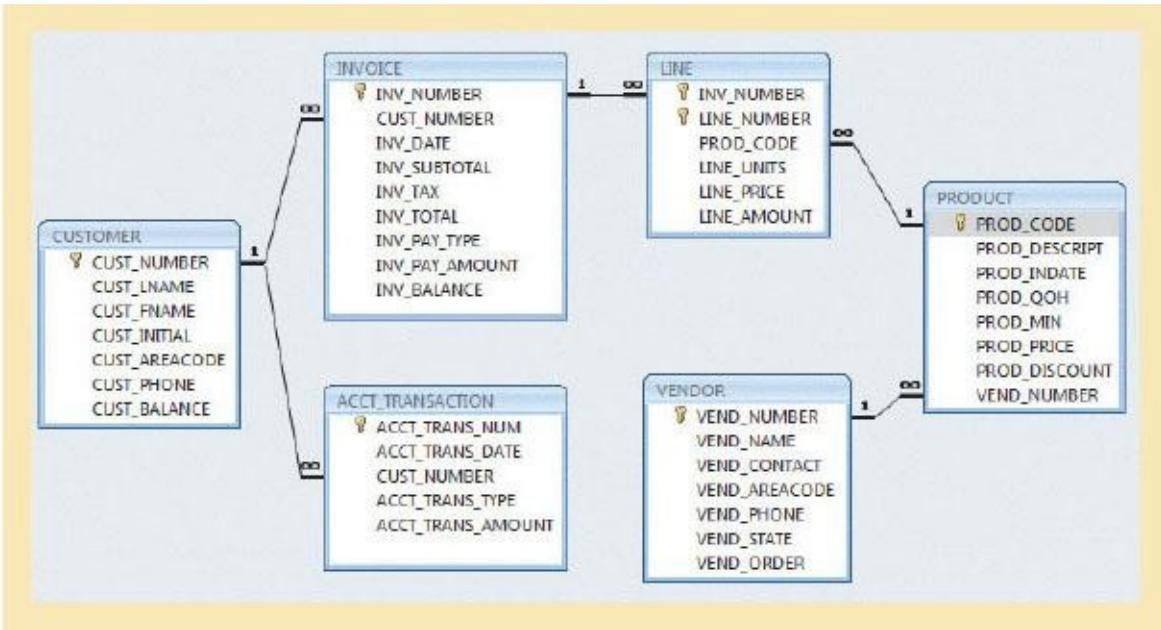
In this chapter you will learn about the most common algorithms for concurrency control: locks, timestamping, and optimistic methods. Because locks are the most widely used method, you will examine various levels and types of locks. Locks can also create deadlocks, so you will learn about strategies for managing deadlocks.

Database contents can be damaged or destroyed by critical operation errors, including transaction management failures. Therefore, this chapter also explains how database recovery management maintains a database's contents.

10.1 WHAT IS A TRANSACTION ?

To illustrate what transactions are and how they work, use the Ch10_SaleCo database. The relational diagram for the database is shown in [Figure 10.1](#).

FIGURE 10.1 The Ch10_SaleCo database relational diagram



SOURCE: Course Technology/Cengage Learning



ONLINE CONTENT

The **Ch10_SaleCo** database used to illustrate the material in this chapter is available at www.cengagebrain.com.

NOTE

Although SQL commands illustrate several transaction and concurrency control issues, you should be able to follow the discussions even if you have not studied **Chapter 7, Introduction to Structured Query Language (SQL)**, and **Chapter 8, Advanced SQL**. If you don't know SQL, ignore the SQL commands and focus on the discussions. If you have a working knowledge of SQL, you can use the **Ch10_SaleCo** database to generate your own SELECT and UPDATE examples and to augment the material in **Chapters 7** and **8** by writing your own triggers and stored procedures.

As you examine the relational diagram in [Figure 10.1](#), note the following

features:

- The design stores the customer balance (CUST_BALANCE) value in the CUSTOMER table to indicate the total amount owed by the customer. The CUST_BALANCE attribute is increased when the customer makes a purchase on credit, and it is decreased when the customer makes a payment. Including the current customer account balance in the CUSTOMER table makes it easy to write a query to determine the current balance for any customer and to generate important summaries such as total, average, minimum, and maximum balances.
- The ACCT_TRANSACTION table records all customer purchases and payments to track the details of customer account activity.

You could change the design of the Ch10_SaleCo database to reflect accounting practice more precisely, but the implementation provided here will enable you to track the transactions well enough to understand the chapter's discussions.

To understand the concept of a transaction, suppose that you sell a product to a customer. Furthermore, suppose that the customer may charge the purchase to his or her account. Given that scenario, your sales transaction consists of at least the following parts:

- You must write a new customer invoice.
- You must reduce the quantity on hand in the product's inventory.
- You must update the account transactions.
- You must update the customer balance.

The preceding sales transaction must be reflected in the database. In database terms, a [transaction](#) is any action that reads from or writes to a database. A transaction may consist of the following:

- A simple SELECT statement to generate a list of table contents
- A series of related UPDATE statements to change the values of attributes

in various tables

- A series of INSERT statements to add rows to one or more tables
- A combination of SELECT, UPDATE, and INSERT statements

The sales transaction example includes a combination of INSERT and UPDATE statements.

Given the preceding discussion, you can augment the definition of a transaction. A transaction is a *logical* unit of work that must be entirely completed or entirely aborted; no intermediate states are acceptable. In other words, a multicomponent transaction, such as the previously mentioned sale, must not be partially completed. Updating only the inventory or only the accounts receivable is not acceptable. All of the SQL statements in the transaction must be completed successfully. If any of the SQL statements fail, the entire transaction is rolled back to the original database state that existed before the transaction started. A successful transaction changes the database from one consistent state to another. A [consistent database state](#) is one in which all data integrity constraints are satisfied.

To ensure consistency of the database, every transaction must begin with the database in a known consistent state. If the database is not in a consistent state, the transaction will yield an inconsistent database that violates its integrity and business rules. For that reason, subject to limitations discussed later, all transactions are controlled and executed by the DBMS to guarantee database integrity.

Most real-world database transactions are formed by two or more database requests. A [database request](#) is the equivalent of a single SQL statement in an application program or transaction. For example, if a transaction is composed of two UPDATE statements and one INSERT statement, the transaction uses three database requests. In turn, each database request generates several input/output (I/O) operations that read from or write to physical storage media.

10.1.1 EVALUATING TRANSACTION RESULTS

Not all transactions update the database. Suppose that you want to examine the CUSTOMER table to determine the current balance for customer number 10016. Such a transaction can be completed by using the following SQL code:

```
SELECT CUST_NUMBER, CUST_BALANCE
```

```
FROM    CUSTOMER  
WHERE   CUST_NUMBER = 10016;
```

Although the query does not make any changes in the CUSTOMER table, the SQL code represents a transaction because it *accesses* the database. If the database existed in a consistent state before the access, the database remains in a consistent state after the access because the transaction did not alter the database.

Remember that a transaction may consist of a single SQL statement or a collection of related SQL statements. Revisit the previous sales example to illustrate a more complex transaction, using the Ch10_SaleCo database. Suppose that on January 18, 2012, you register the credit sale of one unit of product 89-WRE-Q to customer 10016 for \$277.55. The required transaction affects the INVOICE, LINE, PRODUCT, CUSTOMER, and ACCT_TRANSACTION tables. The SQL statements that represent this transaction are as follows:

```
INSERT INTO INVOICE  
          VALUES (1009, 10016,'18-Jan-2012', 256.99, 20.56, 277.55,  
'cred', 0.00, 277.55);
```

```
INSERT INTO LINE  
          VALUES (1009, 1, '89-WRE-Q', 1, 256.99, 256.99);
```

```
UPDATE PRODUCT  
SET     PROD_QOH = PROD_QOH - 1  
WHERE   PROD_CODE = '89-WRE-Q';
```

```
UPDATE CUSTOMER  
SET     CUST_BALANCE = CUST_BALANCE + 277.55  
WHERE   CUST_NUMBER = 10016;
```

```
INSERT INTO ACCT_TRANSACTION  
          VALUES (10007, '18-Jan-12', 10016, 'charge', 277.55);  
COMMIT;
```

The results of the successfully completed transaction are shown in [Figure 10.2](#). (All records involved in the transaction are outlined in red.)

To better understand the transaction results, note the following:

- A new row 1009 was added to the INVOICE table. In this row, derived

attribute values were stored for the invoice subtotal, the tax, the invoice total, and the invoice balance.

- The LINE row for invoice 1009 was added to reflect the purchase of one unit of product 89-WRE-Q with a price of \$256.99. In this row, the derived attribute values for the line amount were stored.
- Product 89-WRE-Q's quantity on hand (PROD_QOH) in the PRODUCT table was reduced by one, from 12 to 11.
- The customer balance (CUST_BALANCE) for customer 10016 was updated by adding \$277.55 to the existing balance (the initial value was \$0.00).
- A new row was added to the ACCT_TRANSACTION table to reflect the new account transaction number 10007.
- The COMMIT statement was used to end a successful transaction. (See [Section 10.1.3](#).)

Now suppose that the DBMS completes the first three SQL statements. Furthermore, suppose that during the execution of the fourth statement (the UPDATE of the CUSTOMER table's CUST_BALANCE value for customer 10016), the computer system loses electrical power. If the computer does not have a backup power supply, the transaction cannot be completed. Therefore, the INVOICE and LINE rows were added, and the PRODUCT table was updated to represent the sale of product 89-WRE-Q, but customer 10016 was not charged, nor was the required record written in the ACCT_TRANSACTION table. The database is now in an inconsistent state, and it is not usable for subsequent transactions. Assuming that the DBMS supports transaction management, *the DBMS will roll back the database to a previous consistent state*

FIGURE 10.2 Tracing the transaction in the Ch10_SaleCo database

Database name: Ch10_SaleCo

Table name: INVOICE

INV_NUMBER	CUST_NUMBER	INV_DATE	INV_GROSS_TOTAL	INV_TAX	INV_TOTAL	INV_PAY_TYPE	INV_PAY_AMOUNT	INV_BALANCE
1001	10014	15-Jan-12	24.92	4.95	29.87	00	0.00	0.00
1002	70001	15-Jan-12	4.99	0.99	50.78	00	0.00	0.00
1003	30007	15-Jan-12	27.99	5.59	32.58	00	0.00	0.00
1004	30001	17-Jan-12	28.63	5.79	34.42	00	0.00	0.00
1005	30008	17-Jan-12	20.98	4.94	26.06	00	7.08	0.00
1006	30005	17-Jan-12	96.62	19.32	115.94	00	100.00	20.00
1007	30005	17-Jan-12	96.62	19.32	115.94	00	100.00	20.00
1008	30001	17-Jan-12	102.00	20.40	122.40	00	60.00	0.00
1009	30005	19-Jan-12	269.99	53.99	323.98	used	0.00	271.00

Table name: PRODUCT

PROD_CODE	PROD_DESCRIPTION	PROD_INDATE	PROD_COH	PROD_MN	PROD_PRICE	PROD_DISCOUNT	VEND_NUMBER
110ER01	Power hammer, 15-lb., 3-1/2"ode	03-Nov-11	8	5	109.99	0.00	25995
13-G0R2	7.25-in. prw saw blade	13-Dec-11	32	15	14.99	0.05	21344
14-Q1L1	6.00-in. prw saw blade	13-Nov-11	18	12	17.49	0.00	21344
15H6-002	Hrd. cloth, 14-in., 25sf	15-Jan-12	15	8	39.95	0.00	23112
1598-WWY	Hrd. cloth, 12-in., 30sf	15-Jan-12	23	5	43.99	0.00	23119
223Q9TY	BMS jigsaw, 12-in. blade	30-Dec-11	5	5	109.92	0.05	24299
23200ME	B&G jigsaw, 8-in. blade	24-Dec-11	6	5	99.97	0.05	24398
23286P0	BMS cordless drill, 1/2-in.	20-Jan-12	12	5	38.95	0.05	25995
23108-HB	Olav hammer	20-Jan-12	23	10	9.95	0.10	21225
23114-AA	Sledge hammer, 12lb.	02-Jan-12	8	5	14.40	0.05	21224
54778-2T	Potlhl file, 16-in. file	15-Dec-11	43	20	4.99	0.00	21344
89-WRE-Q	Hdcl chisel, 16-in	07-Jan-12	11	5	228.99	0.05	24299
PVC-230R1	PVC pipe, 3/4-in., 8-ft	09-Jan-12	186	75	5.07	0.00	
SM-10277	1.25-in. metal screw, 25	01-Mar-12	172	75	8.99	0.00	21225
SM-23116	2.5-in. wd. screw, 50	24-Feb-12	237	100	8.45	0.00	21201
VIN3FT3	Steel nailng, 4x6x18", 57' mesh	17-Jan-12	16	5	119.95	0.10	25995

Table name: CUSTOMER

CUST_NUMBER	CUST_LNAME	CUST_FNAME	CUST_INITIAL	CUST_AREACODE	CUST_PHONE	CUST_BALANCE
10010	Ramer	Alfred	A	615	844-3573	0.00
10011	Dunne	Laura	K	713	894-1230	615.73
10012	Smith	Kathy	W	615	894-2395	0.00
10013	Overly	Paul	F	615	894-2190	0.00
10014	Orlando	Myst		615	222-1872	0.00
10015	Obrien	Ann	B	713	442-3301	0.00
10016	Brown	James	G	615	297-1238	271.55
10017	Williams	George		615	280-2596	0.00
10018	Fairchild	Anne	G	713	302-1185	0.00
10019	Smith	Olivia	K	615	207-3809	0.00

Table name: ACCT_TRANSACTION

ACCT_TRANS_NUM	ACCT_TRANS_DATE	CUST_NUMBER	ACCT_TRANS_TYPE	ACCT_TRANS_AMOUNT
10003	17-Jan-12	10014	charge	329.99
10004	17-Jan-12	10011	charge	615.73
10005	23-Jan-12	10013	payment	348.66
10007	18-Jan-12	10016	charge	271.55
10009	18-Jan-12	10014	charge	329.99
10010	21-Jan-12	10011	charge	615.73
10012	24-Jan-12	10013	payment	479.00
10013	23-Jan-12	10016	charge	329.99
10014	18-Jan-12	10011	charge	615.73
10015	18-Jan-12	10013	payment	271.55

SOURCE: Course Technology/Cengage Learning

NOTE

By default, MS Access does not support transaction management as discussed here. More sophisticated DBMSs, such as Oracle, SQL Server, and DB2, support the transaction management components discussed in this chapter.

Although the DBMS is designed to recover a database to a previous consistent state when an interruption prevents the completion of a transaction, the transaction itself is defined by the end user or programmer and must be semantically correct. *The DBMS cannot guarantee that the semantic meaning of the transaction truly represents the real-world event.* For example, suppose that following the sale of 10 units of product 89-WRE-Q, the inventory UPDATE commands were written this way:

UPDATE PRODUCT

```
SET      PROD_QOH = PROD_QOH + 10  
WHERE    PROD_CODE = '89-WRE-Q';
```

The sale should have *decreased* the PROD_QOH value for product 89-WRE-Q by 10. Instead, the UPDATE *added* 10 to product 89-WRE-Q's PROD_QOH value.

Although the UPDATE command's syntax is correct, its use yields incorrect results. Yet, the DBMS will execute the transaction anyway. The DBMS cannot evaluate whether the transaction represents the real-world event correctly; that is the end user's responsibility. End users and programmers are capable of introducing many errors in this fashion. Imagine the consequences of reducing the quantity on hand for product 1546-QQ2 instead of product 89-WRE-Q, or of crediting the CUST_BALANCE value for customer 10012 rather than customer 10016.

Clearly, improper or incomplete transactions can have a devastating effect on database integrity. Some DBMSs—especially the relational variety—provide means by which the user can define enforceable constraints based on business rules. Other integrity rules, such as those governing referential and entity integrity, are enforced automatically by the DBMS when the table structures are properly defined, thereby letting the DBMS validate some transactions. For example, if a transaction inserts a new customer number into a customer table and the number already exists, the DBMS will end the transaction with an error code to indicate a violation of the primary key integrity rule.

10.1.2 TRANSACTION PROPERTIES

Each individual transaction must display *atomicity*, *consistency*, *isolation*, and *durability*. These properties are sometimes referred to as the ACID test. In addition, when executing multiple transactions, the DBMS must schedule the concurrent execution of the transaction's operations. The schedule of such transaction operations must exhibit the property of *serializability*. Look briefly at each of the properties.

- [Atomicity](#) requires that *all* operations (SQL requests) of a transaction be completed; if not, the transaction is aborted. If a transaction T1 has four SQL requests, all four requests must be successfully completed; otherwise, the entire transaction is aborted. In other words, a transaction is treated as a single, indivisible, logical unit of work.

- **Consistency** indicates the permanence of the database's consistent state. A transaction takes a database from one consistent state to another. When a transaction is completed, the database must be in a consistent state; if any of the transaction parts violates an integrity constraint, the entire transaction is aborted.
- **Isolation** means that the data used during the execution of a transaction cannot be used by a second transaction until the first one is completed. In other words, if transaction T1 is being executed and is using the data item X, that data item cannot be accessed by any other transaction (T2 ... Tn) until T1 ends. This property is particularly useful in multiuser database environments because several users can access and update the database at the same time.
- **Durability** ensures that once transaction changes are done and committed, they cannot be undone or lost, even in the event of a system failure.
- **Serializability** ensures that the schedule for the concurrent execution of the transactions yields consistent results. This property is important in multiuser and distributed databases in which multiple transactions are likely to be executed concurrently. Naturally, if only a single transaction is executed, serializability is not an issue.

A single-user database system automatically ensures serializability and isolation of the database because only one transaction is executed at a time. The atomicity, consistency, and durability of transactions must be guaranteed by single-user DBMSs. (Even a single-user DBMS must manage recovery from errors created by OS-induced interruptions, power interruptions, and improper application execution.)

Multiuser databases are typically subject to multiple concurrent transactions. Therefore, the multiuser DBMS must implement controls to ensure serializability and isolation of transactions—in addition to atomicity and durability—to guard the database's consistency and integrity. For example, if several concurrent transactions are executed over the same data set and the second transaction updates the database before the first transaction is finished, the isolation property is violated and the database is no longer consistent. The

DBMS must manage the transactions by using concurrency control techniques to avoid undesirable situations.

10.1.3 TRANSACTION MANAGEMENT WITH SQL

The American National Standards Institute (ANSI) has defined standards that govern SQL database transactions. Transaction support is provided by two SQL statements: COMMIT and ROLLBACK. The ANSI standards require that when a transaction sequence is initiated by a user or an application program, the sequence must continue through all succeeding SQL statements until one of the following four events occurs:

- A COMMIT statement is reached, in which case all changes are permanently recorded within the database. The COMMIT statement automatically ends the SQL transaction.
- A ROLLBACK statement is reached, in which case all changes are aborted and the database is rolled back to its previous consistent state.
- The end of a program is successfully reached, in which case all changes are permanently recorded within the database. This action is equivalent to COMMIT.
- The program is abnormally terminated, in which case the database changes are aborted and the database is rolled back to its previous consistent state. This action is equivalent to ROLLBACK.

The use of COMMIT is illustrated in the following simplified sales example, which updates a product's quantity on hand (PROD_QOH) and the customer's balance when the customer buys two units of product 1558-QW1 priced at \$43.99 per unit (for a total of \$87.98) and charges the purchase to the customer's account:

```
UPDATE PRODUCT
SET     PROD_QOH = PROD_QOH - 2
WHERE   PROD_CODE = '1558-QW1';
UPDATE CUSTOMER
```

```
SET      CUST_BALANCE = CUST_BALANCE + 87.98  
WHERE   CUST_NUMBER = '10011';  
COMMIT;
```

(Note that the example is simplified to make it easy to trace the transaction. In the Ch10_SaleCo database, the transaction would involve several additional table updates.)

The COMMIT statement used in the preceding example is not necessary if the UPDATE statement is the application's last action and the application terminates normally. However, good programming practice dictates that you include the COMMIT statement at the end of a transaction declaration.

A transaction begins implicitly when the first SQL statement is encountered. Not all SQL implementations follow the ANSI standard; some (such as SQL Server) use transaction management statements such as the following to indicate the beginning of a new transaction:

```
BEGIN TRANSACTION;
```

Other SQL implementations allow you to assign characteristics for the transactions as parameters to the BEGIN statement. For example, the Oracle RDBMS uses the SET TRANSACTION statement to declare the start of a new transaction and its properties.

10.1.4 THE TRANSACTION LOG

A DBMS uses a [transaction log](#) to keep track of all transactions that update the database. The DBMS uses the information stored in this log for a recovery requirement triggered by a ROLLBACK statement, a program's abnormal termination, or a system failure such as a network discrepancy or a disk crash. Some RDBMSs use the transaction log to recover a database *forward* to a currently consistent state. After a server failure, for example, Oracle automatically rolls back uncommitted transactions and rolls forward transactions that were committed but not yet written to the physical database. This behavior is required for transactional correctness and is typical of any transactional DBMS.

While the DBMS executes transactions that modify the database, it also automatically updates the transaction log. The transaction log stores the following:

- A record for the beginning of the transaction
- For each transaction component (SQL statement):
 - The type of operation being performed (INSERT, UPDATE, DELETE)
 - The names of the objects affected by the transaction (the name of the table)
 - The “before” and “after” values for the fields being updated
 - Pointers to the previous and next transaction log entries for the same transaction
- The ending (COMMIT) of the transaction

Although using a transaction log increases the processing overhead of a DBMS, the ability to restore a corrupted database is worth the price.

[Table 10.1](#) illustrates a simplified transaction log that reflects a basic transaction composed of two SQL UPDATE statements. If a system failure occurs, the DBMS will examine the transaction log for all uncommitted or incomplete transactions and restore (ROLLBACK) the database to its previous state on the basis of that information. When the recovery process is completed, the DBMS will write in the log all committed transactions that were not physically written to the database before the failure occurred.

TABLE 10.1 A Transaction Log

TRL_ID	TRX_NUM	PREV_PTR	NEXT_PTR	OPERATION	TABLE	ROW_ID	ATTRIBUTE	BEFORE_VALUE	AFTER_VALUE
341	101	Null	352	START	****Start Transaction				
352	101	341	363	UPDATE	PRODUCT	1558-QW1	PROD_QOH	25	23
363	101	352	365	UPDATE	CUSTOMER	10011	CUST_BALANCE	525.75	615.73
365	101	363	Null	COMMIT	**** End of Transaction				

↑ TRL_ID = Transaction log record ID
 TRX_NUM = Transaction number
 PTR = Pointer to a transaction log record ID
 (Note: The transaction number is automatically assigned by the DBMS.)

If a ROLLBACK is issued before the termination of a transaction, the DBMS will restore the database only for that particular transaction, rather than for all of them, to maintain the *durability* of the previous transactions. In other words,

committed transactions are not rolled back.

The transaction log is a critical part of the database, and it is usually implemented as one or more files that are managed separately from the actual database files. The transaction log is subject to common dangers such as disk-full conditions and disk crashes. Because the transaction log contains some of the most critical data in a DBMS, some implementations support logs on several different disks to reduce the consequences of a system failure.

10.2 CONCURRENCY CONTROL

Coordinating the simultaneous execution of transactions in a multiuser database system is known as [concurrency control](#). The objective of concurrency control is to ensure the serializability of transactions in a multiuser environment. Concurrency control is important because the simultaneous execution of transactions over a shared database can create several data integrity and consistency problems. The three main problems are lost updates, uncommitted data, and inconsistent retrievals.

10.2.1 LOST UPDATES

The [lost update](#) problem occurs when two concurrent transactions, T1 and T2, are updating the same data element and one of the updates is lost (overwritten by the other transaction). To see an illustration of lost updates, examine a simple PRODUCT table. One of the table's attributes is a product's quantity on hand (PROD_QOH). Assume that you have a product whose current PROD_QOH value is 35. Also assume that two concurrent transactions, T1 and T2, occur and update the PROD_QOH value for some item in the PRODUCT table. The transactions are shown in [Table 10.2](#).

Table 10.2 Two Concurrent Transactions to Update QOH

TRANSACTION	COMPUTATION
-------------	-------------

T1: Purchase 100 units $\text{PROD_QOH} = \text{PROD_QOH} + 100$

T2: Sell 30 units

$$\text{PROD_QOH} = \text{PROD_QOH} - 30$$

[Table 10.3](#) shows the serial execution of the transactions under normal circumstances, yielding the correct answer $\text{PROD_QOH} = 105$.

TABLE 10.3 Serial Execution of Two Transactions

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T1	$\text{PROD_QOH} = 35 + 100$	
3	T1	Write PROD_QOH	135
4	T2	Read PROD_QOH	135
5	T2	$\text{PROD_QOH} = 135 - 30$	
6	T2	Write PROD_QOH	105

However, suppose that a transaction can read a product's PROD_QOH value from the table *before* a previous transaction has been committed, using the *same* product. The sequence depicted in [Table 10.4](#) shows how the lost update problem can arise. Note that the first transaction (T1) has not yet been committed when the second transaction (T2) is executed. Therefore, T2 still operates on the value 35, and its subtraction yields 5 in memory. In the meantime, T1 writes the value 135 to disk, which is promptly overwritten by T2. In short, the addition of 100 units is "lost" during the process.

TABLE 10.4 Lost Updates

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T2	Read PROD_QOH	35
3	T1	$\text{PROD_QOH} = 35 + 100$	
4	T2	$\text{PROD_QOH} = 35 - 30$	
5	T1	Write PROD_QOH (Lost update)	135
6	T2	Write PROD_QOH	5

10.2.2 UNCOMMITTED DATA

The phenomenon of [uncommitted data](#) occurs when two transactions, T1 and T2, are executed concurrently and the first transaction (T1) is rolled back after the second transaction (T2) has already accessed the uncommitted data—thus violating the isolation property of transactions. To illustrate that possibility, use the same transactions described during the lost updates discussion. T1 has two atomic parts, one of which is the update of the inventory; the other possible part is the update of the invoice total (not shown). T1 is forced to roll back due to an error during the updating of the invoice’s total; it rolls back all the way, undoing the inventory update as well. This time the T1 transaction is rolled back to eliminate the addition of the 100 units. (See [Table 10.5](#).) Because T2 subtracts 30 from the original 35 units, the correct answer should be 5.

TABLE 10.5 Transactions Creating an Uncommitted Data Problem

TRANSACTION	COMPUTATION
T1: Purchase 100 units	$\text{PROD_QOH} = \text{PROD_QOH} + 100$ (Rolled back)
T2: Sell 30 units	$\text{PROD_QOH} = \text{PROD_QOH} - 30$

[Table 10.6](#) shows how the serial execution of these transactions yields the correct answer under normal circumstances.

TABLE 10.6 Correct Execution of Two Transactions

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T1	PROD_QOH = 35 + 100	
3	T1	Write PROD_QOH	135
4	T1	*****ROLLBACK *****	35
5	T2	Read PROD_QOH	35
6	T2	PROD_QOH = 35 - 30	
7	T2	Write PROD_QOH	5

[Table 10.7](#) shows how the uncommitted data problem can arise when the ROLLBACK is completed after T2 has begun its execution.

TABLE 10.7 An Uncommitted Data Problem

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T1	PROD_QOH = 35 + 100	
3	T1	Write PROD_QOH	135
4	T2	Read PROD_QOH (Read uncommitted data)	135
5	T2	PROD_QOH = 135 - 30	
6	T1	***** ROLLBACK *****	35
7	T2	Write PROD_QOH	105

10.2.3 INCONSISTENT RETRIEVALS

[Inconsistent retrievals](#) occur when a transaction accesses data before and after one or more other transactions finish working with such data. For example, an inconsistent retrieval would occur if transaction T1 calculated some summary (aggregate) function over a set of data while another transaction (T2) was updating the same data. The problem is that the transaction might read some data before they are changed and other data *after* they are changed, thereby yielding inconsistent results.

To illustrate the problem, assume the following conditions:

1. T1 calculates the total quantity on hand of the products stored in the PRODUCT table.
2. At the same time, T2 updates the quantity on hand (PROD_QOH) for two of

the PRODUCT table's products.

The two transactions are shown in [Table 10.8](#).

TABLE 10.8 Retrieval During Update

TRANSACTION T1

SELECT SUM(PROD_QOH) UPDATE PRODUCT

FROM PRODUCT

TRANSACTION T2

SET PROD_QOH = PROD_QOH + 10

WHERE PROD_CODE = 1546-QQ2

UPDATE PRODUCT

SET PROD_QOH = PROD_QOH - 10

WHERE PROD_CODE = 1558-QW1

COMMIT;

While T1 calculates the total quantity on hand (PROD_QOH) for all items, T2 represents the correction of a typing error: the user added 10 units to product 1558-QW1's PROD_QOH but *meant* to add the 10 units to product 1546-QQ2's PROD_QOH. To correct the problem, the user adds 10 to product 1546-QQ2's PROD_QOH and subtracts 10 from product 1558-QW1's PROD_QOH. (See the two UPDATE statements in [Table 10.8](#).) The initial and final PROD_QOH values are reflected in [Table 10.9](#). (Only a few PROD_CODE values are shown for the PRODUCT table. To illustrate the point, the sum for the PROD_QOH values is shown for these few products.)

TABLE 10.9 Transaction Results: Data Entry Correction

PROD_CODE	BEFORE		AFTER	
	PROD_QOH		PROD_QOH	
11QER/31	8		8	
13-Q2/P2	32		32	
1546-QQ2	15		(15 + 10) → 25	
1558-QW1	23		(23 – 10) → 13	
2232-QTY	8		8	
2232-QWE	6		6	
Total	92		92	

Although the final results shown in [Table 10.9](#) are correct after the adjustment, [Table 10.10](#) demonstrates that inconsistent retrievals are possible during the transaction execution, making the result of T1's execution incorrect. The "After" summation shown in [Table 10.10](#) reflects that the value of 25 for product 1546-QQ2 was read *after* the WRITE statement was completed. Therefore, the "After" total is $40 + 25 = 65$. The "Before" total reflects that the value of 23 for product 1558-QW1 was read *before* the next WRITE statement was completed to reflect the corrected update of 13. Therefore, the "Before" total is $65 + 23 = 88$.

TABLE 10.10 Inconsistent Retrievals

TIME	TRANSACTION	ACTION	VALUE	TOTAL
1	T1	Read PROD_QOH for PROD_CODE = '11QER/31'	8	8
2	T1	Read PROD_QOH for PROD_CODE = '13-Q2/P2'	32	40
3	T2	Read PROD_QOH for PROD_CODE = '1546-QQ2'	15	
4	T2	PROD_QOH = 15 + 10		
5	T2	Write PROD_QOH for PROD_CODE = '1546-QQ2'	25	
6	T1	Read PROD_QOH for PROD_CODE = '1546-QQ2'	25	(After) 65
7	T1	Read PROD_QOH for PROD_CODE = '1558-QW1'	23	(Before) 88
8	T2	Read PROD_QOH for PROD_CODE = '1558-QW1'	23	
9	T2	PROD_QOH = 23 – 10		
10	T2	Write PROD_QOH for PROD_CODE = '1558-QW1'	13	
11	T2	***** COMMIT *****		
12	T1	Read PROD_QOH for PROD_CODE = '2232-QTY'	8	96
13	T1	Read PROD_QOH for PROD_CODE = '2232-QWE'	6	102

The computed answer of 102 is obviously wrong because you know from [Table 10.9](#) that the correct answer is 92. Unless the DBMS exercises concurrency control, a multiuser database environment can create havoc within the information system.

10.2.4 THE SCHEDULER

You now know that severe problems can arise when two or more concurrent transactions are executed. You also know that a database transaction involves a series of database I/O operations that take the database from one consistent state to another. Finally, you know that database consistency can be ensured only before and after the execution of transactions. A database always moves through an unavoidable temporary state of inconsistency during a transaction's execution if such a transaction updates multiple tables and rows. (If the transaction contains only one update, then there is no temporary inconsistency.) The temporary inconsistency exists because a computer executes the operations serially, one after another. During this serial process, the isolation property of transactions prevents them from accessing the data not yet released by other transactions. This consideration is even more important today, with the use of multicore processors that can execute several instructions at the same time. What would happen if two transactions executed concurrently and they were accessing the same data?

In previous examples, the operations within a transaction were executed in an arbitrary order. As long as two transactions, T1 and T2, access *unrelated* data, there is no conflict and the order of execution is irrelevant to the final outcome. However, if the transactions operate on related data or the same data, conflict is possible among the transaction components and the selection of one execution order over another might have some undesirable consequences. So, how is the correct order determined, and who determines that order? Fortunately, the DBMS handles that tricky assignment by using a built-in scheduler.

The [scheduler](#) is a special DBMS process that establishes the order in which the operations are executed within concurrent transactions. The scheduler *interleaves* the execution of database operations to ensure serializability and isolation of transactions. To determine the appropriate order, the scheduler bases its actions on concurrency control algorithms, such as locking or timestamping methods, which are explained in the next sections. However, it is important to understand that not all transactions are serializable. The DBMS determines what transactions are serializable and proceeds to interleave the execution of the transaction's operations. Generally, transactions that are not serializable are executed on a first-come, first-served basis by the DBMS. The scheduler's main job is to create a [serializable schedule](#) of a transaction's operations, in which the interleaved execution of the transactions (T1, T2, T3, etc.) yields the same results as if the transactions were executed in serial order (one after another).

The scheduler also makes sure that the computer's central processing unit (CPU)

and storage systems are used efficiently. If there were no way to schedule the execution of transactions, all of them would be executed on a first-come, first-served basis. The problem with that approach is that processing time is wasted when the CPU waits for a READ or WRITE operation to finish, thereby losing several CPU cycles. In short, first-come, first-served scheduling tends to yield unacceptable response times within the multiuser DBMS environment. Therefore, some other scheduling method is needed to improve the efficiency of the overall system.

Additionally, the scheduler facilitates data isolation to ensure that two transactions do not update the same data element at the same time. Database operations might require READ and/or WRITE actions that produce conflicts. For example, [Table 10.11](#) shows the possible conflict scenarios when two transactions, T1 and T2, are executed concurrently over the same data. Note that in [Table 10.11](#), two operations are in conflict when they access the same data and at least one of them is a WRITE operation.

TABLE 10.11 Read/Write Conflict Scenarios: Conflicting Database Operations Matrix

		TRANSACTIONS		RESULT
		T1	T2	
Operations	Read	Read	Read	No conflict
	Read	Write	Read	Conflict
	Write	Read	Write	Conflict
	Write	Write	Read	Conflict

Several methods have been proposed to schedule the execution of conflicting operations in concurrent transactions. These methods are classified as locking, timestamping, and optimistic. Locking methods, discussed next, are used most frequently.

10.3 CONCURRENCY CONTROL WITH LOCKING METHODS

A [lock](#) guarantees exclusive use of a data item to a current transaction. In other words, transaction T2 does not have access to a data item that is currently being used by transaction T1. A transaction acquires a lock prior to data access; the lock is released (unlocked) when the transaction is completed so that another

transaction can lock the data item for its exclusive use. This series of locking actions assumes that concurrent transactions might attempt to manipulate the same data item at the same time. The use of locks based on the assumption that conflict between transactions is likely is often referred to as [pessimistic locking](#).

Recall from [Sections 10.1.1](#) and [10.1.2](#) that data consistency cannot be guaranteed *during* a transaction; the database might be in a temporary inconsistent state when several updates are executed. Therefore, locks are required to prevent another transaction from reading inconsistent data.

Most multiuser DBMSs automatically initiate and enforce locking procedures. All lock information is handled by a [lock manager](#), which is responsible for assigning and policing the locks used by the transactions.

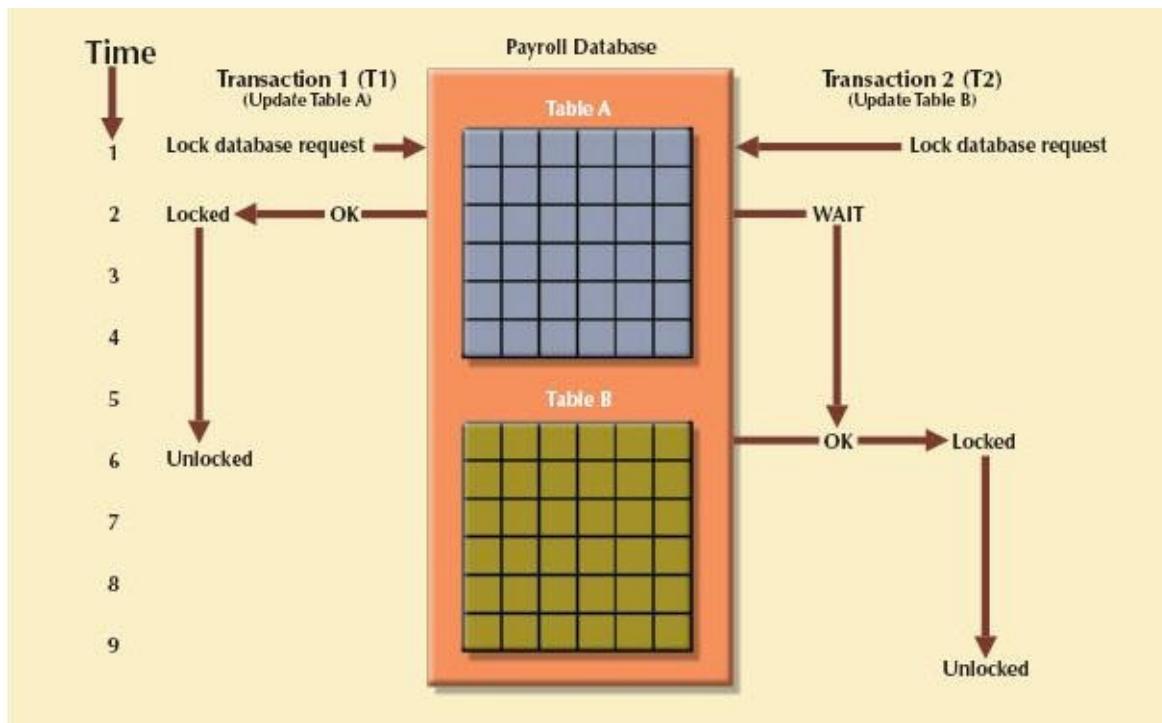
10.3.1 LOCK GRANULARITY

[Lock granularity](#) indicates the level of lock use. Locking can take place at the following levels: database, table, page, row, or even field (attribute).

Database Level

In a [database-level lock](#), the entire database is locked, thus preventing the use of any tables in the database by transaction T2 while transaction T1 is being executed. This level of locking is good for batch processes, but it is unsuitable for multiuser DBMSs. You can imagine how s-l-o-w data access would be if thousands of transactions had to wait for the previous transaction to be completed before the next one could reserve the entire database. [Figure 10.3](#) illustrates the database-level lock; because of it, transactions T1 and T2 cannot access the same database concurrently *even when they use different tables*.

FIGURE 10.3 Database-level locking sequence



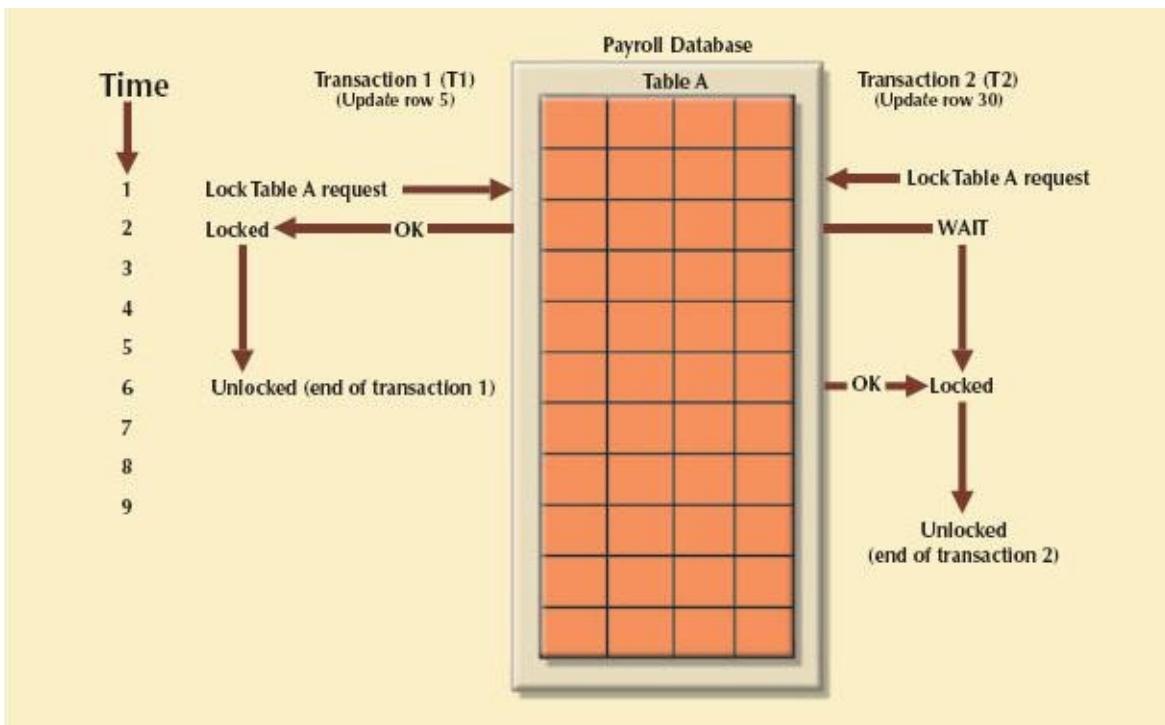
SOURCE: Course Technology/Cengage Learning

Table Level

In a [table-level lock](#), the entire table is locked, preventing access to any row by transaction T2 while transaction T1 is using the table. If a transaction requires access to several tables, each table may be locked. However, two transactions can access the same database as long as they access different tables.

Table-level locks, while less restrictive than database-level locks, cause traffic jams when many transactions are waiting to access the same table. Such a condition is especially irksome if the lock forces a delay when different transactions require access to different parts of the same table—that is, when the transactions would not interfere with each other. Consequently, table-level locks are not suitable for multiuser DBMSs. [Figure 10.4](#) illustrates the effect of a table-level lock. Note that transactions T1 and T2 cannot access the same table even when they try to use different rows; T2 must wait until T1 unlocks the table.

FIGURE 10.4 An example of a table-level lock

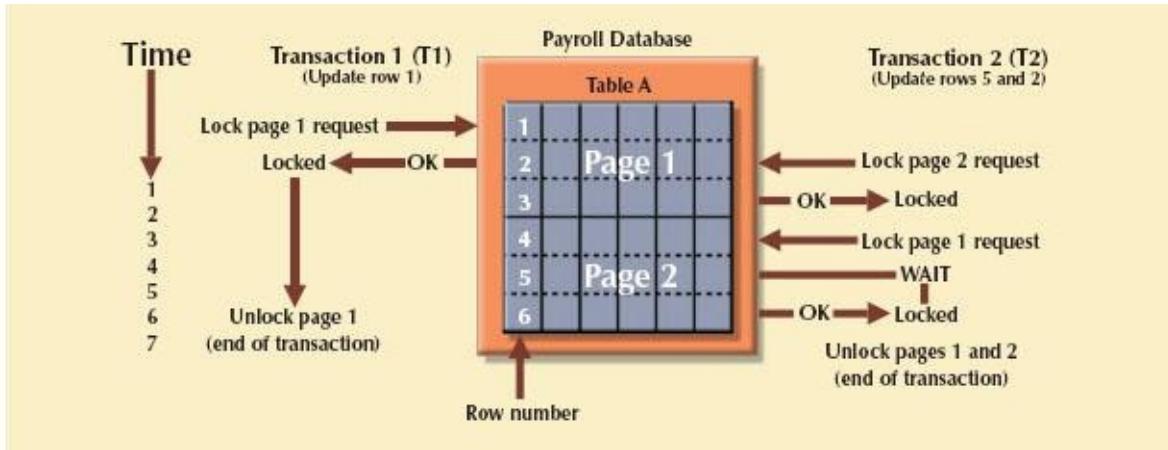


SOURCE: Course Technology/Cengage Learning

Page Level

In a [page-level lock](#), the DBMS locks an entire diskpage. A [diskpage](#), or [page](#), is the equivalent of a *diskblock*, which can be described as a directly addressable section of a disk. A page has a fixed size, such as 4K, 8K, or 16K. For example, if you want to write only 73 bytes to a 4K page, the entire 4K page must be read from disk, updated in memory, and written back to disk. A table can span several pages, and a page can contain several rows of one or more tables. Page-level locks are currently the most frequently used locking method for multiuser DBMSs. An example of a page-level lock is shown in [Figure 10.5](#). Note that T1 and T2 access the same table while locking different diskpages. If T2 requires the use of a row located on a page that is locked by T1, T2 must wait until T1 unlocks the page.

FIGURE 10.5 An example of a page-level lock

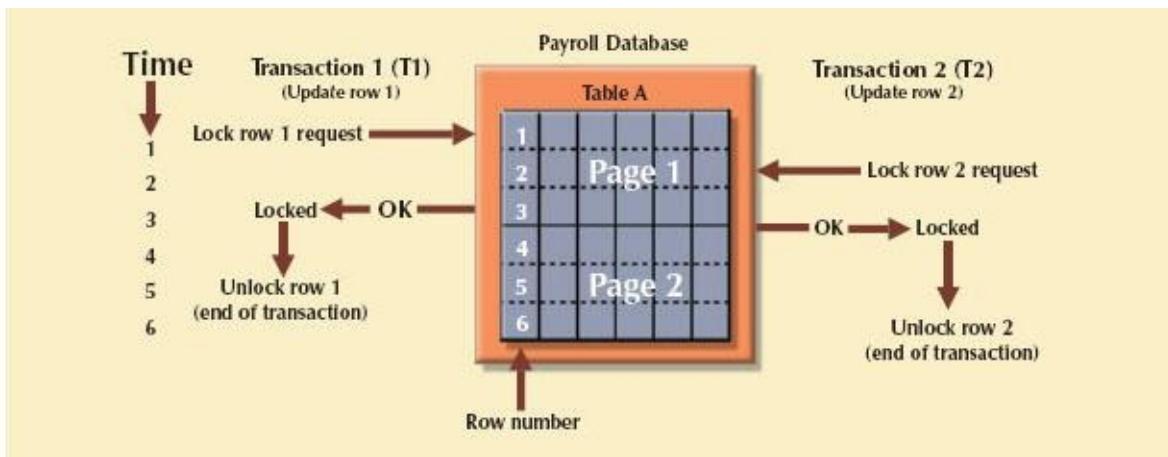


SOURCE: CourseTechnology/Cengage Learning

Row Level

A **row-level lock** is much less restrictive than the locks discussed earlier. The DBMS allows concurrent transactions to access different rows of the same table even when the rows are located on the same page. Although the row-level locking approach improves the availability of data, its management requires high overhead because a lock exists for each row in a table of the database involved in a conflicting transaction. Modern DBMSs automatically escalate a lock from a row level to a page level when the application session requests multiple locks on the same page. [Figure 10.6](#) illustrates the use of a row-level lock.

FIGURE 10.6 An example of a row-level lock



SOURCE: Course Technology/Cengage Learning

Note in [Figure 10.6](#) that both transactions can execute concurrently, even when the requested rows are on the same page. T2 must wait only if it requests the same row as T1.

Field Level

The [field-level lock](#) allows concurrent transactions to access the same row as long as they require the use of different fields (attributes) within that row. Although field-level locking clearly yields the most flexible multiuser data access, it is rarely implemented in a DBMS because it requires an extremely high level of computer overhead and because the row-level lock is much more useful in practice.

10.3.2 LOCK TYPES

Regardless of the level of locking, the DBMS may use different lock types: binary or shared/exclusive.

Binary Locks

A [binary lock](#) has only two states: locked (1) or unlocked (0). If an object such as a database, table, page, or row is locked by a transaction, no other transaction can use that object. If an object is unlocked, any transaction can lock the object for its use. Every database operation requires that the affected object be locked. As a rule, a transaction must unlock the object after its termination. Therefore, every transaction requires a lock and unlock operation for each accessed data item. Such operations are automatically managed and scheduled by the DBMS; the user does not lock or unlock data items. (Every DBMS has a default locking mechanism. If the end user wants to override the default settings, the LOCK TABLE command and other SQL commands are available for that purpose.)

The binary locking technique is illustrated in [Table 10.12](#), using the lost update problem you encountered in [Table 10.4](#). Note that the lock and unlock features eliminate the lost update problem because the lock is not released until the WRITE statement is completed. Therefore, a PROD_QOH value cannot be used until it has been properly updated. However, binary locks are now considered too restrictive to yield optimal concurrency conditions. For example, the DBMS will not allow two transactions to read the same database object even though neither transaction updates the database, and therefore no concurrency problems can occur. Remember from [Table 10.11](#) that concurrency conflicts occur only when

two transactions execute concurrently and one of them updates the database.

TABLE 10.12 An Example of a Binary Lock

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Lock PRODUCT	
2	T1	Read PROD_QOH	15
3	T1	PROD_QOH = 15 + 10	
4	T1	Write PROD_QOH	25
5	T1	Unlock PRODUCT	
6	T2	Lock PRODUCT	
7	T2	Read PROD_QOH	23
8	T2	PROD_QOH = 23 - 10	
9	T2	Write PROD_QOH	13
10	T2	Unlock PRODUCT	

Shared/Exclusive Locks

An [exclusive lock](#) exists when access is reserved specifically for the transaction that locked the object. The exclusive lock must be used when the potential for conflict exists (see [Table 10.11](#)). A [shared lock](#) exists when concurrent transactions are granted read access on the basis of a common lock. A shared lock produces no conflict as long as all the concurrent transactions are read-only.

A shared lock is issued when a transaction wants to read data from the database and no exclusive lock is held on that data item. An exclusive lock is issued when a transaction wants to update (write) a data item and no locks are currently held on that data item by any other transaction. Using the shared/exclusive locking concept, a lock can have three states: unlocked, shared (read), and exclusive (write).

As shown in [Table 10.11](#), two transactions conflict only when at least one is a write transaction. Because the two read transactions can be safely executed at once, shared locks allow several read transactions to read the same data item concurrently. For example, if transaction T1 has a shared lock on data item X and transaction T2 wants to read data item X, T2 may also obtain a shared lock on data item X.

If transaction T2 updates data item X, an exclusive lock is required by T2 over data item X. *The exclusive lock is granted if and only if no other locks are held on the data item.* Therefore, if a shared or exclusive lock is already held on data

item X by transaction T1, an exclusive lock cannot be granted to transaction T2, and T2 must wait to begin until T1 commits. This condition is known as the [mutual exclusive rule](#): only one transaction at a time can own an exclusive lock on an object.

Although the use of shared locks renders data access more efficient, a shared/exclusive lock schema increases the lock manager's overhead for several reasons:

- The type of lock held must be known before a lock can be granted.
- Three lock operations exist: READ_LOCK to check the type of lock, WRITE_LOCK to issue the lock, and UNLOCK to release the lock.
- The schema has been enhanced to allow a lock upgrade from shared to exclusive and a lock downgrade from exclusive to shared.

Although locks prevent serious data inconsistencies, they can lead to two major problems:

- The resulting transaction schedule might not be serializable.
- The schedule might create deadlocks. A [deadlock](#) occurs when two transactions wait indefinitely for each other to unlock data. A database deadlock, which is similar to traffic gridlock in a big city, is caused when two or more transactions wait for each other to unlock data.

Fortunately, both problems can be managed: serializability is guaranteed through a locking protocol known as two-phase locking, and deadlocks can be managed by using deadlock detection and prevention techniques. Those techniques are examined in the next two sections.

10.3.3 TWO-PHASE LOCKING TO ENSURE SERIALIZABILITY

[Two-phase locking](#) defines how transactions acquire and relinquish locks. Two-phase locking guarantees serializability, but it does not prevent deadlocks. The two phases are:

1. A growing phase, in which a transaction acquires all required locks without unlocking any data. Once all locks have been acquired, the transaction is in

its locked point.

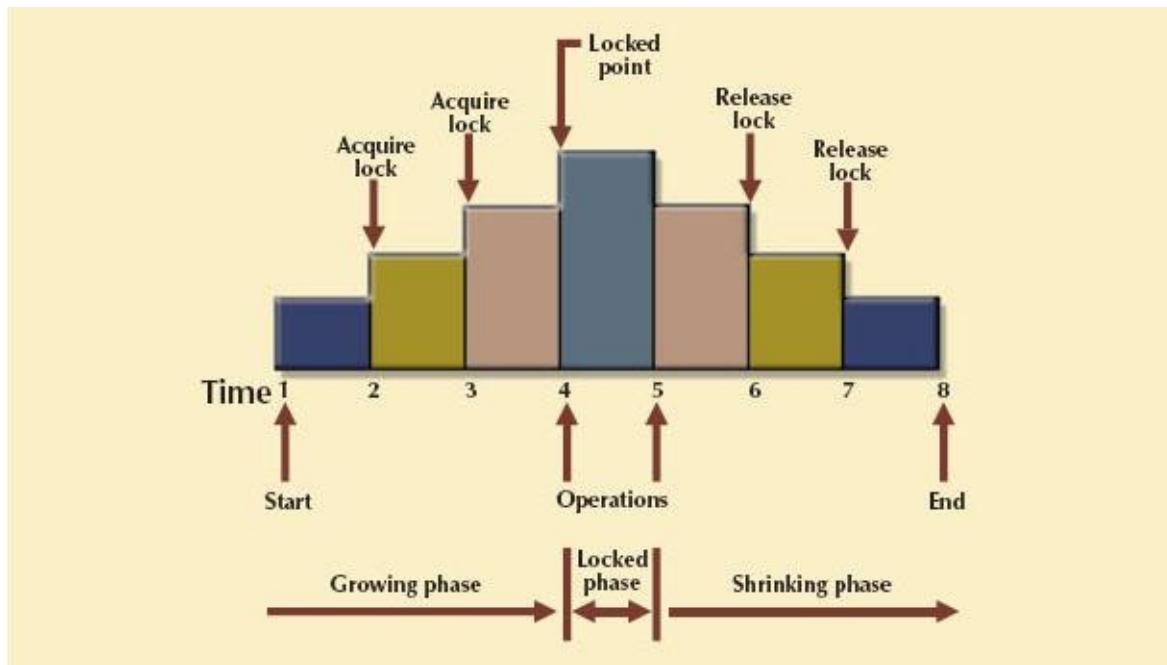
2. A shrinking phase, in which a transaction releases all locks and cannot obtain a new lock.

The two-phase locking protocol is governed by the following rules:

- Two transactions cannot have conflicting locks.
- No unlock operation can precede a lock operation in the same transaction.
 - No data are affected until all locks are obtained—that is, until the transaction is in its locked point.

[Figure 10.7](#) depicts the two-phase locking protocol.

FIGURE 10.7 Two-phase locking protocol



SOURCE: Course Technology/Cengage Learning

In this example, the transaction first acquires the two locks it needs. When it has the two locks, it reaches its locked point. Next, the data are modified to conform to the transaction's requirements. Finally, the transaction is completed as it releases all of the locks it acquired in the first phase.

Two-phase locking increases the transaction processing cost and might cause additional undesirable effects, such as deadlocks.

10.3.4 DEADLOCKS

A deadlock occurs when two transactions wait indefinitely for each other to unlock data. For example, a deadlock occurs when two transactions, T1 and T2, exist in the following mode:

T1 = access data items X and Y

T2 = access data items Y and X

If T1 has not unlocked data item Y, T2 cannot begin; if T2 has not unlocked data item X, T1 cannot continue. Consequently, T1 and T2 each wait for the other to unlock the required data item. Such a deadlock is also known as a [deadly embrace](#). [Table 10.13](#) demonstrates how a deadlock condition is created.

TABLE 10.13 How a Deadlock Condition Is Created

TIME	TRANSACTION	REPLY	LOCK STATUS	
0			Data X	Data Y
1	T1:LOCK(X)	OK	Unlocked	Unlocked
2	T2: LOCK(Y)	OK	Locked	Unlocked
3	T1:LOCK(Y)	WAIT	Locked	Locked
4	T2:LOCK(X)	WAIT	Locked	Locked
5	T1:LOCK(Y)	WAIT	Locked	Locked
6	T2:LOCK(X)	WAIT	Locked	Locked
7	T1:LOCK(Y)	WAIT	Locked	Locked
8	T2:LOCK(X)	WAIT	Locked	Locked
9	T1:LOCK(Y)	WAIT	Locked	Locked
...
...
...
...

The preceding example used only two concurrent transactions to demonstrate a

deadlock condition. In a real-world DBMS, many more transactions can be executed simultaneously, thereby increasing the probability of generating deadlocks. Note that deadlocks are possible only when one of the transactions wants to obtain an exclusive lock on a data item; no deadlock condition can exist among *shared* locks.

The three basic techniques to control deadlocks are:

- *Deadlock prevention.* A transaction requesting a new lock is aborted when there is the possibility that a deadlock can occur. If the transaction is aborted, all changes made by this transaction are rolled back and all locks obtained by the transaction are released. The transaction is then rescheduled for execution. Deadlock prevention works because it avoids the conditions that lead to deadlocking.
- *Deadlock detection.* The DBMS periodically tests the database for deadlocks. If a deadlock is found, the “victim” transaction is aborted (rolled back and restarted) and the other transaction continues.
- *Deadlock avoidance.* The transaction must obtain all of the locks it needs before it can be executed. This technique avoids the rolling back of conflicting transactions by requiring that locks be obtained in succession. However, the serial lock assignment required in deadlock avoidance increases action response times.

The choice of which deadlock control method to use depends on the database environment. For example, if the probability of deadlocks is low, deadlock detection is recommended. However, if the probability of deadlocks is high, deadlock prevention is recommended. If response time is not high on the system’s priority list, deadlock avoidance might be employed. All current DBMSs support deadlock detection in transactional databases, while some DBMSs use a blend of prevention and avoidance techniques for other types of data, such as data warehouses or XML data.

10.4 CONCURRENCY CONTROL WITH TIMESTAMPING METHODS

The [timestamping](#) approach to scheduling concurrent transactions assigns a global, unique timestamp to each transaction. The timestamp value produces an

explicit order in which transactions are submitted to the DBMS. Timestamps must have two properties: uniqueness and monotonicity. [Uniqueness](#) ensures that no equal timestamp values can exist, and [monotonicity¹](#) ensures that timestamp values always increase.

All database operations (read and write) within the same transaction must have the same timestamp. The DBMS executes conflicting operations in timestamp order, thereby ensuring serializability of the transactions. If two transactions conflict, one is stopped, rolled back, rescheduled, and assigned a new timestamp value.

The disadvantage of the timestamping approach is that each value stored in the database requires two additional timestamp fields: one for the last time the field was read and one for the last update. Timestamping thus increases memory needs and the database's processing overhead. Timestamping demands a lot of system resources because many transactions might have to be stopped, rescheduled, and restamped.

10.4.1 WAIT/DIE AND WOUND/WAIT SCHEMES

Timestamping methods are used to manage concurrent transaction execution. In this section, you will learn about two schemes used to decide which transaction is rolled back and which continues executing: the wait/die scheme and the wound/wait scheme.² An example illustrates the difference. Assume that you have two conflicting transactions: T1 and T2, each with a unique timestamp. Suppose that T1 has a timestamp of 11548789 and T2 has a timestamp of 19562545. You can deduce from the timestamps that T1 is the older transaction (the lower timestamp value) and T2 is the newer transaction. Given that scenario, the four possible outcomes are shown in [Table 10.14](#).

TABLE 10.14 Wait/Die and Wound/Wait Concurrency Control Schemes

TRANSACTION REQUESTING LOCK	TRANSACTION OWNING LOCK	WAIT/DIE SCHEME	WOUND/WAIT SCHEME
T1 (11548789)	T2 (19562545)	<ul style="list-style-type: none">T1 waits until T2 is completed and T2 releases its locks.	<ul style="list-style-type: none">T1 preempts (rolls back) T2.T2 is rescheduled using the same timestamp.
T2 (19562545)	T1 (11548789)	<ul style="list-style-type: none">T2 dies (rolls back).T2 is rescheduled using the same timestamp.	<ul style="list-style-type: none">T2 waits until T1 is completed and T1 releases its locks.

Using the wait/die scheme:

- If the transaction requesting the lock is the older of the two transactions, it will *wait* until the other transaction is completed and the locks are released.
- If the transaction requesting the lock is the younger of the two transactions, it will *die* (roll back) and is rescheduled using the same timestamp.

In short, in the [wait/die](#) scheme, the older transaction waits for the younger one to complete and release its locks.

In the wound/wait scheme:

- If the transaction requesting the lock is the older of the two transactions, it will preempt (*wound*) the younger transaction by rolling it back. T1 preempts T2 when T1 rolls back T2. The younger, preempted transaction is rescheduled using the same timestamp.
- If the transaction requesting the lock is the younger of the two transactions, it will wait until the other transaction is completed and the locks are released.

In short, in the [wound/wait](#) scheme, the older transaction rolls back the younger transaction and reschedules it.

In both schemes, one of the transactions waits for the other transaction to finish and release the locks. However, in many cases, a transaction requests multiple locks. How long does a transaction have to wait for each lock request? Obviously, that scenario can cause some transactions to wait indefinitely, causing a deadlock. To prevent a deadlock, each lock request has an associated time-out value. If the lock is not granted before the time-out expires, the transaction is rolled back.

10.5 CONCURRENCY CONTROL WITH OPTIMISTIC METHODS

The [optimistic approach](#) is based on the assumption that the majority of database operations do not conflict. The optimistic approach requires neither locking nor timestamping techniques. Instead, a transaction is executed without restrictions until it is committed. Using an optimistic approach, each transaction moves through two or three phases, referred to as *read*, *validation*, and *write*.³

- During the *read phase*, the transaction reads the database, executes the needed computations, and makes the updates to a private copy of the database values. All update operations of the transaction are recorded in a temporary update file, which is not accessed by the remaining transactions.
- During the *validation phase*, the transaction is validated to ensure that the changes made will not affect the integrity and consistency of the database. If the validation test is positive, the transaction goes to the write phase. If the validation test is negative, the transaction is restarted and the changes are discarded.
- During the *write phase*, the changes are permanently applied to the database.

The optimistic approach is acceptable for most read or query database systems that require few update transactions.

In a heavily used DBMS environment, the management of deadlocks—their prevention and detection—constitutes an important DBMS function. The DBMS will use one or more of the techniques discussed here, as well as variations on those techniques. However, it may be necessary sometimes to employ database recovery techniques to restore the database to a consistent state.

10.6 DATABASE RECOVERY MANAGEMENT

[Database recovery](#) restores a database from a given state (usually inconsistent) to a previously consistent state. Recovery techniques are based on the [atomic transaction property](#): all portions of the transaction must be treated as a single, logical unit of work in which all operations are applied and completed to produce a consistent database. If a transaction operation cannot be completed for

some reason, the transaction must be aborted and any changes to the database must be rolled back (undone). In short, transaction recovery reverses all of the changes that the transaction made to the database before the transaction was aborted.

Although this chapter has emphasized the recovery of *transactions*, recovery techniques also apply to the *database* and to the *system* after some type of critical error has occurred. Critical events can cause a database to stop working and compromise the integrity of the data. Examples of critical events are:

- *Hardware/software failures.* A failure of this type could be a hard disk media failure, a bad capacitor on a motherboard, or a failing memory bank. Other causes of errors under this category include application program or operating system errors that cause data to be overwritten, deleted, or lost. Some database administrators argue that this is one of the most common sources of database problems.

- *Human-caused incidents.* This type of event can be categorized as unintentional or intentional.
 - An unintentional failure is caused by a careless end user. Such errors include deleting the wrong rows from a table, pressing the wrong key on the keyboard, or shutting down the main database server by accident.
 - Intentional events are of a more severe nature and normally indicate that the company data are at serious risk. Under this category are security threats caused by hackers trying to gain unauthorized access to data resources and virus attacks caused by disgruntled employees trying to compromise the database operation and damage the company.
- *Natural disasters.* This category includes fires, earthquakes, floods, and power failures.

Whatever the cause, a critical error can render the database into an inconsistent state. The following section introduces the various techniques used to recover the database from an inconsistent state to a consistent state.

10.6.1 TRANSACTION RECOVERY

In [Section 10.1.4](#), you learned about the transaction log and how it contains data

for database recovery purposes. Database transaction recovery uses data in the transaction log to recover a database from an inconsistent state to a consistent state.

Before continuing, examine four important concepts that affect the recovery process:

- The [write-ahead-log protocol](#) ensures that transaction logs are always written *before* any database data are actually updated. This protocol ensures that, in case of a failure, the database can later be recovered to a consistent state using the data in the transaction log.
- [Redundant transaction logs](#) (several copies of the transaction log) ensure that a physical disk failure will not impair the DBMS's ability to recover data.
- Database [buffers](#) are temporary storage areas in primary memory used to speed up disk operations. To improve processing time, the DBMS software reads the data from the physical disk and stores a copy of it on a “buffer” in primary memory. When a transaction updates data, it actually updates the copy of the data in the buffer because that process is much faster than accessing the physical disk every time. Later, all buffers that contain updated data are written to a physical disk during a single operation, thereby saving significant processing time.
- Database [checkpoints](#) are operations in which the DBMS writes all of its updated buffers to disk. While this is happening, the DBMS does not execute any other requests. A checkpoint operation is also registered in the transaction log. As a result of this operation, the physical database and the transaction log will be in sync. This synchronization is required because update operations update the copy of the data in the buffers and not in the physical database. Checkpoints are automatically scheduled by the DBMS several times per hour. As you will see next, checkpoints also play an important role in transaction recovery.

The database recovery process involves bringing the database to a consistent state after a failure. Transaction recovery procedures generally make use of deferred-write and write-through techniques.

When the recovery procedure uses a [deferred-write technique](#) (also called a [deferred update](#)), the transaction operations do not immediately update the physical database. Instead, only the transaction log is updated. The database is physically updated only after the transaction reaches its commit point, using information from the transaction log. If the transaction aborts before it reaches its commit point, no changes (no ROLLBACK or undo) need to be made to the database because it was never updated. The recovery process for all started and committed transactions (before the failure) follows these steps:

1. Identify the last checkpoint in the transaction log. This is the last time transaction data were physically saved to disk.
2. For a transaction that started and was committed before the last checkpoint, nothing needs to be done because the data are already saved.
3. For a transaction that performed a commit operation after the last checkpoint, the DBMS uses the transaction log records to redo the transaction and update the database, using the “after” values in the transaction log. The changes are made in ascending order, from oldest to newest.
4. For any transaction that had a ROLLBACK operation after the last checkpoint or that was left active (with neither a COMMIT nor a ROLLBACK) before the failure occurred, nothing needs to be done because the database was never updated.

When the recovery procedure uses a [write-through technique](#) (also called an [immediate update](#)), the database is immediately updated by transaction operations during the transaction’s execution, even before the transaction reaches its commit point. If the transaction aborts before it reaches its commit point, a ROLLBACK or undo operation needs to be done to restore the database to a consistent state. In that case, the ROLLBACK operation will use the transaction log “before” values. The recovery process follows these steps:

1. Identify the last checkpoint in the transaction log. This is the last time transaction data were physically saved to disk.

2. For a transaction that started and was committed before the last checkpoint, nothing needs to be done because the data are already saved.
3. For a transaction that was committed after the last checkpoint, the DBMS redoing the transaction, using the “after” values of the transaction log. Changes are applied in ascending order, from oldest to newest.

4. For any transaction that had a ROLLBACK operation after the last checkpoint or that was left active (with neither a COMMIT nor a ROLLBACK) before the failure occurred, the DBMS uses the transaction log records to ROLLBACK or undo the operations, using the “before” values in the transaction log. Changes are applied in reverse order, from newest to oldest.

Use the transaction log in [Table 10.15](#) to trace a simple database recovery process. To make sure you understand the recovery process, the simple transaction log includes three transactions and one checkpoint. This transaction log includes the transaction components used earlier in the chapter, so you should already be familiar with the basic process. Given the transaction, the transaction log has the following characteristics:

- Transaction 101 consists of two UPDATE statements that reduce the quantity on hand for product 54778-2T and increase the customer balance for customer 10011 for a credit sale of two units of product 54778-2T.

- Transaction 106 is the same credit sales event you saw in [Section 10.1.1](#). This transaction represents the credit sale of one unit of product 89-WRE-Q to customer 10016 for \$277.55. This transaction consists of five SQL DML statements: three INSERT statements and two UPDATE statements.

- Transaction 155 represents a simple inventory update. This transaction consists of one UPDATE statement that increases the quantity on hand of product 2232/QWE from 6 units to 26 units.

- A database checkpoint writes all updated database buffers to disk. The

checkpoint event writes only the changes for all previously committed transactions. In this case, the checkpoint applies all changes made by transaction 101 to the database data files.

TABLE 10.15 A Transaction Log for Transaction Recovery Examples

TRL_ID	TRX_NUM	PREV_PTR	NEXT_PTR	OPERATION	TABLE	ROW_ID	ATTRIBUTE	BEFORE_VALUE	AFTER_VALUE
341	101	Null	352	START	****Start Transaction				
352	101	341	363	UPDATE	PRODUCT	54778-2T	PROD_QOH	45	43
363	101	352	365	UPDATE	CUSTOMER	10011	CUST_BALANCE	615.73	675.62
365	101	363	Null	COMMIT	**** End of Transaction				
397	106	Null	405	START	****Start Transaction				
405	106	397	415	INSERT	INVOICE	1009			1009,10016, ...
415	106	405	419	INSERT	LINE	1009,1			1009,1, 89-WRE-Q,1, ...
419	106	415	427	UPDATE	PRODUCT	89-WRE-Q	PROD_QOH	12	11
423				CHECKPOINT					
427	106	419	431	UPDATE	CUSTOMER	10016	CUST_BALANCE	0.00	277.55
431	106	427	457	INSERT	ACCT_TRANSACTION	10007			1007,18-JAN-2012, ...
457	106	431	Null	COMMIT	**** End of Transaction				
521	155	Null	525	START	****Start Transaction				
525	155	521	528	UPDATE	PRODUCT	2232/QWE	PROD_QOH	6	26
528	155	525	Null	COMMIT	**** End of Transaction				
***** C *R*A* S*H *****									

Using [Table 10.15](#), you can now trace the database recovery process for a DBMS, using the deferred update method as follows:

1. Identify the last checkpoint—in this case, TRL ID 423. This was the last time database buffers were physically written to disk.
2. Note that transaction 101 started and finished before the last checkpoint. Therefore, all changes were already written to disk, and no additional action needs to be taken.
3. For each transaction committed after the last checkpoint (TRL ID 423), the DBMS will use the transaction log data to write the changes to disk, using the “after” values. For example, for transaction 106:
 - a. Find COMMIT (TRL ID 457).
 - b. Use the previous pointer values to locate the start of the transaction (TRL ID 397).
 - c. Use the next pointer values to locate each DML statement, and apply the changes to disk using the “after” values. (Start with TRL ID 405, then 415, 419, 427, and 431.) Remember that TRL ID 457 was the COMMIT statement for this transaction.

- d. Repeat the process for transaction 155.
4. Any other transactions will be ignored. Therefore, for transactions that ended with ROLLBACK or that were left active (those that do not end with a COMMIT or ROLLBACK), nothing is done because no changes were written to disk.

SUMMARY

- A transaction is a sequence of database operations that access the database. A transaction represents a real-world event, and it must be a logical unit of work; that is, no portion of the transaction can exist by itself. Either all parts are executed or the transaction is aborted. A transaction takes a database from one consistent state to another. A consistent database state is one in which all data integrity constraints are satisfied.
- Transactions have four main properties: atomicity, consistency, isolation, and durability. Atomicity means that all parts of the transaction must be executed; otherwise, the transaction is aborted. Consistency means that the database's consistent state is maintained, and isolation means that data used by one transaction cannot be accessed by another transaction until the first one is completed. Durability means that changes made by a transaction cannot be rolled back once the transaction is committed. In addition, transaction schedules have the property of serializability—the result of the concurrent execution of transactions is the same as that of the transactions being executed in serial order.
- SQL provides support for transactions through the use of two statements: COMMIT, which saves changes to disk, and ROLLBACK, which restores the previous database state.
- SQL transactions are formed by several SQL statements or database requests. Each database request originates several I/O database operations.
- The transaction log keeps track of all transactions that modify the database. The information stored in the transaction log is used for recovery (ROLLBACK) purposes.

- Concurrency control coordinates the simultaneous execution of transactions. The concurrent execution of transactions can result in three main problems: lost updates, uncommitted data, and inconsistent retrievals.
 - The scheduler is responsible for establishing the order in which the concurrent transaction operations are executed. The transaction execution order is critical and ensures database integrity in multiuser database systems. The scheduler uses locking, timestamping, and optimistic methods to ensure the serializability of transactions.
-
- A lock guarantees unique access to a data item by a transaction. The lock prevents one transaction from using the data item while another transaction is using it. There are several levels of locks: database, table, page, row, and field.
 - Two types of locks can be used in database systems: binary locks and shared/exclusive locks. A binary lock can have only two states: locked (1) or unlocked (0). A shared lock is used when a transaction wants to read data from a database and no other transaction is updating the same data. Several shared or “read” locks can exist for a particular item. An exclusive lock is issued when a transaction wants to update (write to) the database and no other locks (shared or exclusive) are held on the data.
-
- Serializability of schedules is guaranteed through the use of two-phase locking. The two-phase locking schema has a growing phase, in which the transaction acquires all of the locks that it needs without unlocking any data, and a shrinking phase, in which the transaction releases all of the locks without acquiring new locks.
 - When two or more transactions wait indefinitely for each other to release a lock, they are in a deadlock, also called a deadly embrace. There are three deadlock control techniques: prevention, detection, and avoidance.
-
- Concurrency control with timestamping methods assigns a unique timestamp to each transaction and schedules the execution of conflicting transactions

in timestamp order. Two schemes are used to decide which transaction is rolled back and which continues executing: the wait/die scheme and the wound/wait scheme.

- Concurrency control with optimistic methods assumes that the majority of database transactions do not conflict and that transactions are executed concurrently, using private, temporary copies of the data. At commit time, the private copies are updated to the database.

- Database recovery restores the database from a given state to a previous consistent state. Database recovery is triggered when a critical event occurs, such as a hardware error or application error.

KEY TERMS

[atomicity](#)
[atomic transaction property](#)
[binary lock](#)
[buffers](#)
[checkpoints](#)
[concurrency control](#)
[consistency](#)
[consistent database state](#)
[database-level lock](#)
[database recovery](#)
[database request](#)
[deadlock](#)
[deadly embrace](#)
[deferred update](#)
[deferred-write technique](#)
[diskpage](#)
[durability](#)
[exclusive lock](#)
[field-level lock](#)
[immediate update](#)

[inconsistent retrievals](#)
[isolation](#)
[lock](#)
[lock granularity](#)
[lock manager](#)
[lost update](#)
[monotonicity](#)
[mutual exclusive rule](#)
[optimistic approach](#)
[page](#)
[page-level lock](#)
[pessimistic locking](#)
[redundant transaction logs](#)
[row-level lock](#)
[scheduler](#)
[serializable schedule](#)
[serializability](#)
[shared lock](#)
[table-level lock](#)
[timestamping](#)
[transaction](#)
[transaction log](#)
[two-phase locking](#)
[uncommitted data](#)
[uniqueness](#)
[wait/die](#)
[wound/wait](#)
[write-ahead-log protocol](#)
[write-through technique](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at

REVIEW QUESTIONS

1. Explain the following statement: a transaction is a logical unit of work.

2. What is a consistent database state, and how is it achieved?
3. The DBMS does not guarantee that the semantic meaning of the transaction truly represents the real-world event. What are the possible consequences of that limitation? Give an example.

4. List and discuss the five transaction properties.
5. What does serializability of transactions mean?

6. What is a transaction log, and what is its function?
7. What is a scheduler, what does it do, and why is its activity important to concurrency control?

8. What is a lock, and how does it work in general?
9. What are the different levels of lock granularity?

10. Why might a page-level lock be preferred over a field-level lock?
11. What is concurrency control, and what is its objective?

12. What is an exclusive lock, and under what circumstances is it granted?
13. What is a deadlock, and how can it be avoided? Discuss several strategies for dealing with deadlocks.

14. What are some disadvantages of timestamping methods for concurrency control?
15. Why might it take a long time to complete transactions when using an optimistic approach to concurrency control?

16. What are the three types of database-critical events that can trigger the database recovery process? Give some examples for each one.

PROBLEMS

1. Suppose that you are a manufacturer of product ABC, which is composed of parts A, B, and C. Each time a new product ABC is created, it must be added to the product inventory, using the PROD_QOH in a table named PRODUCT. Also, each time the product is created, the parts inventory, using PART_QOH in a table named PART, must be reduced by one each of parts A, B, and C. The sample database contents are shown in the following tables.

TABLE P10.1

TABLE NAME: PRODUCT

PROD_CODE	PROD_QOH
ABC	1,205

TABLE NAME: PART

PART_CODE	PART_QOH
A	567
B	98
C	549

Given the preceding information, answer Questions a through e.

- a. How many database requests can you identify for an inventory update for both PRODUCT and PART?
 - b. Using SQL, write each database request you identified in Step a.
 - c. Write the complete transaction(s).
 - d. Write the transaction log, using [Table 10.1](#) as your template.
 - e. Using the transaction log you created in Step d, trace its use in database recovery.
2. Describe the three most common problems with concurrent transaction execution. Explain how concurrency control can be used to avoid those problems.
 3. What DBMS component is responsible for concurrency control? How is this feature used to resolve conflicts?
 4. Using a simple example, explain the use of binary and shared/exclusive locks in a DBMS.
 5. Suppose that your database system has failed. Describe the database recovery process and the use of deferred-write and write-through techniques.



ONLINE CONTENT

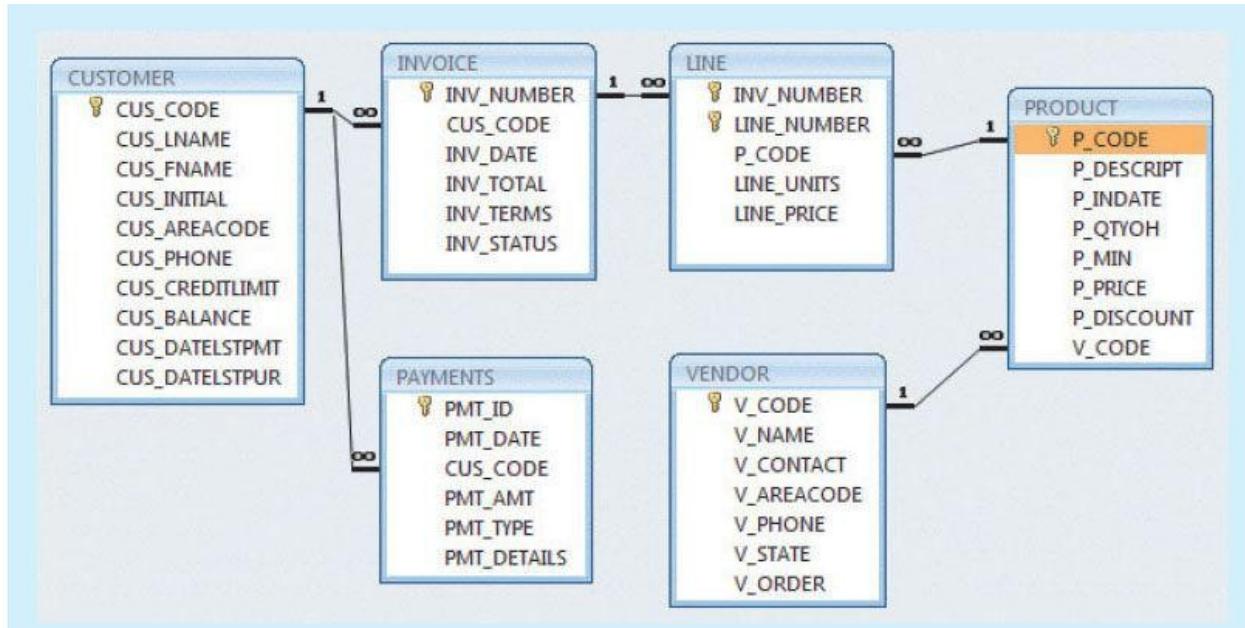
The **Ch10_ABC_Markets** database is available at www.cengagebrain.com. Use this database to provide solutions for [Problems 6-11](#).

6. ABC Markets sell products to customers. The relational diagram shown in Figure P10.6 represents the main entities for ABC's database. Note the following important characteristics:
 - A customer may make many purchases, each one represented by an invoice.
 - The CUS_BALANCE is updated with each credit purchase or payment and represents the amount the customer owes.
 - The CUS_BALANCE is increased (+) with every credit purchase and

decreased (–) with every customer payment.

- The date of last purchase is updated with each new purchase made by the customer.
- The date of last payment is updated with each new payment made by the customer.
- An invoice represents a product purchase by a customer.
- An INVOICE can have many invoice LINES, one for each product purchased.
- The INV_TOTAL represents the total cost of the invoice, including taxes.
- The INV_TERMS can be “30,” “60,” or “90” (representing the number of days of credit) or “CASH,” “CHECK,” or “CC.”
- The invoice status can be “OPEN,” “PAID,” or “CANCEL.”
- A product’s quantity on hand (P_QTYOH) is updated (decreased) with each product sale.
- A customer may make many payments. The payment type (PMT_TYPE) can be one of the following:
 - “CASH” for cash payments
 - “CHECK” for check payments
 - “CC” for credit card payments
- The payment details (PMT_DETAILS) are used to record data about check or credit card payments:
- The bank, account number, and check number for check payments
- The issuer, credit card number, and expiration date for credit card payments

FIGURE P10.6 The ABC Markets relational diagram



SOURCE: Course Technology/Cengage Learning

Note: Not all entities and attributes are represented in this example. Use only the attributes indicated.

Using this database, write the SQL code to represent each of the following transactions. Use BEGIN TRANSACTION and COMMIT to group the SQL statements in logical transactions.

- On May 11, 2012, customer 10010 makes a credit purchase (30 days) of one unit of product 11QER/31 with a unit price of \$110.00; the tax rate is 8 percent. The invoice number is 10983, and this invoice has only one product line.
- On June 3, 2012, customer 10010 makes a payment of \$100 in cash. The payment ID is 3428.
- Create a simple transaction log (using the format shown in [Table 10.14](#)) to represent the actions of the transactions in [Problems 6a](#) and [6b](#).
- Assuming that pessimistic locking is being used but the two-phase locking protocol is not, create a chronological list of the locking, unlocking, and data manipulation activities that would occur during the complete processing of the transaction described in [Problem 6a](#).
- Assuming that pessimistic locking is being used with the two-phase locking protocol, create a chronological list of the locking, unlocking, and data manipulation activities that would occur during the complete

processing of the transaction described in [Problem 6a](#).

10. Assuming that pessimistic locking is being used but the two-phase locking protocol is not, create a chronological list of the locking, unlocking, and data manipulation activities that would occur during the complete processing of the transaction described in [Problem 6b](#).
 11. Assuming that pessimistic locking with the two-phase locking protocol is being used with row-level lock granularity, create a chronological list of the locking, unlocking, and data manipulation activities that would occur during the complete processing of the transaction described in [Problem 6b](#).
-

¹ The term *monotonicity* is part of the standard concurrency control vocabulary. The authors' first introduction to this term and its proper use was in an article written by W. H. Kohler, "A Survey of Techniques for Synchronization and Recovery in Decentralized Computer Systems," *Computer Surveys* 3(2), June 1981.

² The procedure was first described by R. E. Stearnes and P. M. Lewis II in "System-level Concurrency Control for Distributed Database Systems," *ACM Transactions on Database Systems*, No. 2, June 1978.

³ The optimistic approach to concurrency control is described in an article by H. T. King and J. T. Robinson, "Optimistic Methods for Concurrency Control," *ACM Transactions on Database Systems* 6(2), June 1981. Even the most current software is built on conceptual standards that were developed more than two decades ago.

11 DATABASE PERFORMANCE TUNING AND QUERY OPTIMIZATION

In this chapter, you will learn:

- Basic database performance-tuning concepts
 - How a DBMS processes SQL queries
 - About the importance of indexes in query processing
 - About the types of decisions the query optimizer has to make
 - Some common practices used to write efficient SQL code
 - How to formulate queries and tune the DBMS for optimal performance
-

Preview

Database performance tuning is a critical topic, yet it usually receives minimal coverage in the database curriculum. Most databases used in classrooms have only a few records per table. As a result, the focus is often on making SQL queries perform an intended task, without considering the efficiency of the query process. In fact, even the most efficient query environment yields no visible performance improvements over the least efficient query environment when only 20 or 30 table rows (records) are queried. Unfortunately, that lack of attention to query efficiency can yield unacceptably slow results in the real world when queries are executed over tens of millions of records. In this chapter, you will learn what it takes to create a more efficient query environment.

NOTE

Because this book focuses on databases, this chapter covers only the factors that directly affect *database* performance. Also, because performance-tuning techniques can be DBMS-specific, the material in this chapter might not be applicable under all circumstances, nor will it necessarily pertain to all DBMS types. This chapter is designed to build a foundation for the general understanding of database performance-tuning issues and to help

you choose appropriate performance-tuning strategies. (For the most current information about tuning your database, consult the vendor's documentation.)

11.1 DATABASE PERFORMANCE-TUNING CONCEPTS

One of the main functions of a database system is to provide timely answers to end users. End users interact with the DBMS through the use of queries to generate information, using the following sequence:

1. The end-user (client-end) application generates a query.
2. The query is sent to the DBMS (server end).
3. The DBMS (server end) executes the query.
4. The DBMS sends the resulting data set to the end-user (client-end) application.

End users expect their queries to return results as quickly as possible. How do you know that the performance of a database is good? Good database performance is hard to evaluate. How do you know if a 1.06-second query response time is good enough? It is easier to identify bad database performance than good database performance—all it takes is end-user complaints about slow query results. Unfortunately, the same query might perform well one day and not so well two months later. Regardless of end-user perceptions, *the goal of database performance is to execute queries as fast as possible*. Therefore, database performance must be closely monitored and regularly tuned. **Database performance tuning** refers to a set of activities and procedures designed to reduce the response time of the database system—that is, to ensure that an end-user query is processed by the DBMS in the minimum amount of time.

The time required by a query to return a result set depends on many factors, which tend to be wide-ranging and to vary among environments and among vendors. The performance of a typical DBMS is constrained by three main factors: CPU processing power, available primary memory (RAM), and

input/output (hard disk and network) throughput. [Table 11.1](#) lists some system components and summarizes general guidelines for achieving better query performance.

TABLE 11.1 General Guidelines for Better System Performance

	SYSTEM RESOURCES	CLIENT	SERVER
Hardware	CPU	The fastest possible Dual-core CPU or higher	The fastest possible Multiple processors (quad-core technology)
	RAM	The maximum possible	The maximum possible
	Hard disk	Fast SATA/EIDE hard disk with sufficient free hard disk space	Multiple high-speed, high-capacity hard disks (SCSI/SATA/Firewire/Fibre Channel) in RAID configuration
Software	Network	High-speed connection	High-speed connection
	Operating system	Fine-tuned for best client application performance	Fine-tuned for best server application performance
	Network	Fine-tuned for best throughput	Fine-tuned for best throughput
	Application	Optimize SQL in client application	Optimize DBMS server for best performance

Naturally, the system will perform best when its hardware and software resources are optimized. However, in the real world, unlimited resources are not the norm; internal and external constraints always exist. Therefore, the system components should be optimized to obtain the best throughput possible with existing (and often limited) resources, which is why database performance tuning is important.

Fine-tuning the performance of a system requires a holistic approach. That is, *all* factors must be checked to ensure that each one operates at its optimum level and has sufficient resources to minimize the occurrence of bottlenecks. Because database design is such an important factor in determining the database system's performance efficiency, it is worth repeating this book's mantra:

Good database performance starts with good database design. No amount of fine-tuning will make a poorly designed database perform as well as a well-designed database. This is particularly true when redesigning existing databases, where the end user expects unrealistic performance gains from older databases.

What constitutes a good, efficient database design? From the performance-tuning point of view, the database designer must ensure that the design makes

use of features in the DBMS that guarantee the integrity and optimal performance of the database. This chapter provides fundamental knowledge that will help you optimize database performance by selecting the appropriate database server configuration, using indexes, understanding table storage organization and data locations, and implementing the most efficient SQL query syntax.

11.1.1 PERFORMANCE TUNING: CLIENT AND SERVER

In general, database performance-tuning activities can be divided into those on the client side and those on the server side.

- On the client side, the objective is to generate a SQL query that returns the correct answer in the least amount of time, using the minimum amount of resources at the server end. The activities required to achieve that goal are commonly referred to as **SQL performance tuning**.
 - On the server side, the DBMS environment must be properly configured to respond to clients' requests in the fastest way possible, while making optimum use of existing resources. The activities required to achieve that goal are commonly referred to as **DBMS performance tuning**.
-



ONLINE CONTENT

If you want to learn more about clients and servers, check **Appendix F, Client/Server Systems**, at www.cengagebrain.com.

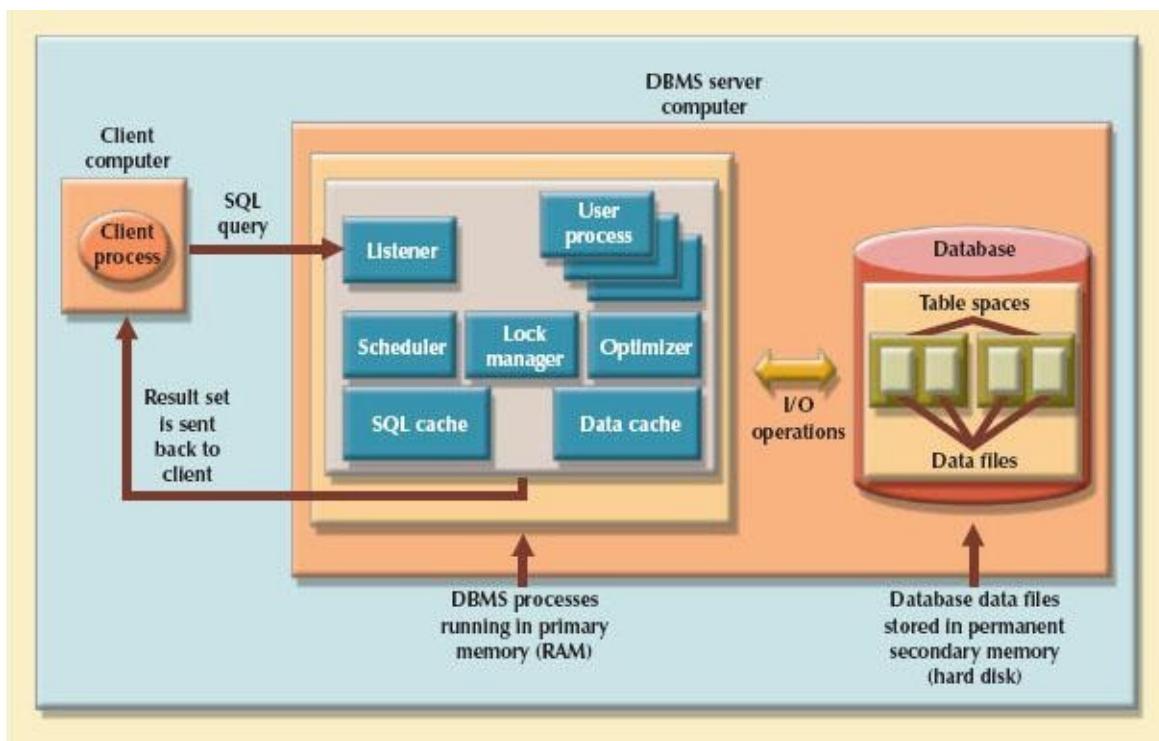
Keep in mind that DBMS implementations are typically more complex than just a two-tier client/server configuration. However, even in multitier client/server environments that consist of a client front end, application middleware, and database server back end, performance-tuning activities are frequently divided into subtasks to ensure the fastest possible response time between any two component points.

This chapter covers SQL performance-tuning practices on the client side and DBMS performance-tuning practices on the server side. However, before you start learning about the tuning processes, you must first learn more about the DBMS architectural components and processes, and how those processes interact to respond to end users' requests.

11.1.2 DBMS ARCHITECTURE

The architecture of a DBMS is represented by the processes and structures (in memory and permanent storage) used to manage a database. Such processes collaborate with one another to perform specific functions. [Figure 11.1](#) illustrates the basic DBMS architecture.

FIGURE 11.1 Basic DBMS architecture



SOURCE: Course Technology/Cengage Learning

Note the following components and functions in [Figure 11.1](#):

- All data in a database are stored in **data files**. A typical enterprise database is normally composed of several data files. A data file can contain rows from a single table, or it can contain rows from many different tables. A database administrator (DBA) determines the initial size of the data files that make up the database; however, the data files can automatically expand as required in predefined increments known as **extends**. For example, if more space is required, the DBA can define that

each new extend will be in 10 KB or 10 MB increments.

- Data files are generally grouped in file groups or table spaces. A [**table space**](#) or [**file group**](#) is a logical grouping of several data files that store data with similar characteristics. For example, you might have a *system* table space where the data dictionary table data are stored, a *user data* table space to store the user-created tables, an *index* table space to hold all indexes, and a *temporary* table space to do temporary sorts, grouping, and so on. Each time you create a new database, the DBMS automatically creates a minimum set of table spaces.
- The [**data cache**](#) or [**buffer cache**](#) is a shared, reserved memory area that stores the most recently accessed data blocks in RAM. The data read from the data files are stored in the data cache after the data have been read or before the data are written to the data files. The data cache also caches system catalog data and the contents of the indexes.
- The [**SQL cache**](#), or [**procedure cache**](#), is a shared, reserved memory area that stores the most recently executed SQL statements or PL/SQL procedures, including triggers and functions. (To learn more about PL/SQL procedures, triggers, and SQL functions, study [Chapter 8](#), Advanced SQL.) The SQL cache does not store the SQL written by the end user. Rather, the SQL cache stores a “processed” version of the SQL that is ready for execution by the DBMS.
- To work with the data, the DBMS must retrieve the data from permanent storage and place them in RAM. In other words, the data are retrieved from their data files and placed in the data cache.
- To move data from permanent storage (data files) to RAM (data cache), the DBMS issues I/O requests and waits for the replies. An [**input/output \(I/O\) request**](#) is a low-level data access operation that reads or writes data to and from computer devices, such as memory, hard disks, video, and printers. Note that an I/O disk read operation retrieves an entire physical disk block, generally containing multiple rows, from permanent

storage to the data cache, even if you will use only one attribute from only one row. The physical disk block size depends on the operating system and could be 4K, 8K, 16K, 32K, 64K, or even larger. Furthermore, depending on the circumstances, a DBMS might issue a single-block read request or a multiblock read request.

- Working with data in the data cache is many times faster than working with data in the data files because the DBMS does not have to wait for the hard disk to retrieve the data; no hard disk I/O operations are needed to work within the data cache.
- Most performance-tuning activities focus on minimizing the number of I/O operations because using I/O operations is many times slower than reading data from the data cache. For example, as of this writing, RAM access times range from 5 to 70 nanoseconds, while hard disk access times range from 5 to 15 milliseconds. This means that hard disks are about six orders of magnitude (a million times) slower than RAM.

[Figure 11.1](#) also illustrates some typical DBMS processes. Although the number of processes and their names vary from vendor to vendor, the functionality is similar. The following processes are represented in [Figure 11.1](#):

- *Listener*. The listener process listens for clients' requests and handles the processing of the SQL requests to other DBMS processes. Once a request is received, the listener passes the request to the appropriate user process.
- *User*. The DBMS creates a user process to manage each client session. Therefore, when you log on to the DBMS, you are assigned a user process. This process handles all requests you submit to the server. There are many user processes—at least one per logged-in client.
- *Scheduler*. The scheduler process organizes the concurrent execution of SQL requests. (See [Chapter 10](#), Transaction Management and Concurrency Control.)
- *Lock manager*. This process manages all locks placed on database objects, including disk pages. (See [Chapter 10](#).)

- *Optimizer*. The optimizer process analyzes SQL queries and finds the most efficient way to access the data. You will learn more about this process later in the chapter.

11.1.3 DATABASE QUERY OPTIMIZATION MODES

Most of the algorithms proposed for query optimization are based on two principles:

- The selection of the optimum execution order
- The selection of sites to be accessed to minimize communication costs

Within those two principles, a query optimization algorithm can be evaluated on the basis of its *operation mode* or the *timing of its optimization*.

Operation modes can be classified as manual or automatic. **Automatic query optimization** means that the DBMS finds the most cost-effective access path without user intervention. **Manual query optimization** requires that the optimization be selected and scheduled by the end user or programmer. Automatic query optimization is clearly more desirable from the end user's point of view, but the cost of such convenience is the increased overhead that it imposes on the DBMS.

Query optimization algorithms can also be classified according to when the optimization is done. Within this timing classification, query optimization algorithms can be static or dynamic.

- **Static query optimization** takes place at compilation time. In other words, the best optimization strategy is selected when the query is compiled by the DBMS. This approach is common when SQL statements are embedded in procedural programming languages such as C# or Visual Basic .NET. When the program is submitted to the DBMS for compilation, it creates the plan necessary to access the database. When the program is executed, the DBMS uses that plan to access the database.
- **Dynamic query optimization** takes place at execution time. Database access strategy is defined when the program is executed. Therefore, access strategy is dynamically determined by the DBMS at run time,

using the most up-to-date information about the database. Although dynamic query optimization is efficient, its cost is measured by run-time processing overhead. The best strategy is determined every time the query is executed; this could happen several times in the same program.

Finally, query optimization techniques can be classified according to the type of information that is used to optimize the query. For example, queries may be based on statistically based or rule-based algorithms.

- A **statistically based query optimization** algorithm uses statistical information about the database. The statistics provide information about database characteristics such as size, number of records, average access time, number of requests serviced, and number of users with access rights. These statistics are then used by the DBMS to determine the best access strategy. Within statistically based optimizers, some DBMSs allow setting a goal to specify that the optimizer should attempt to minimize the time to retrieve the first row or the last row. Minimizing the time to retrieve the first row is often used in transaction systems and interactive client environments. In these cases, the goal is to present the first several rows to the user as quickly as possible. Then, while the DBMS waits for the user to scroll through the data, it can fetch the other rows for the query. Setting the optimizer goal to minimize retrieval of the last row is typically done in embedded SQL and inside stored procedures. In these cases, the control will not pass back to the calling application until all of the data have been retrieved; therefore, it is important to retrieve all of the data to the last row as quickly as possible so control can be returned.
- The statistical information is managed by the DBMS and is generated in one of two different modes: dynamic or manual. In the **dynamic statistical generation mode**, the DBMS automatically evaluates and updates the statistics after each access. In the **manual statistical generation mode**, the statistics must be updated periodically through a user-selected utility such as IBM's RUNSTAT command, which is used by DB2 DBMSs.
- A **rule-based query optimization algorithm** is based on a set of user-defined rules to determine the best query access strategy. The rules are entered by the end user or database administrator, and they are typically

general in nature.

Because database statistics play a crucial role in query optimization, this topic is explored in more detail in the next section.

11.1.4 DATABASE STATISTICS

Another DBMS process that plays an important role in query optimization is gathering database statistics. The term **database statistics** refers to a number of measurements about database objects, such as number of processors used, processor speed, and temporary space available. Such statistics provide a snapshot of database characteristics.

As you will learn later in this chapter, the DBMS uses these statistics to make critical decisions about improving query processing efficiency. Database statistics can be gathered manually by the DBA or automatically by the DBMS. For example, many DBMS vendors support the ANALYZE command in SQL to gather statistics. In addition, many vendors have their own routines to gather statistics. For example, IBM's DB2 uses the RUNSTATS procedure, while Microsoft's SQL Server uses the UPDATE STATISTICS procedure and provides the Auto-Update and Auto-Create Statistics options in its initialization parameters. A sample of measurements that the DBMS may gather about various database objects is shown in [Table 11.2](#).

TABLE 11.2 Sample Database Statistics Measurements

DATABASE OBJECT SAMPLE MEASUREMENTS

Tables Number of rows, number of disk blocks used, row length, number of columns in each row, number of distinct values in each column, maximum value in each column, minimum value in each column, and columns that have indexes

Number and name of columns in the index key, number of key values
Indexes in the index, number of distinct key values in the index key, histogram
of key values in an index, and number of disk pages used by the index

Environment Resources	Logical and physical disk block size, location and size of data files, and number of extends per data file
-----------------------	--

If the object statistics exist, the DBMS will use them in query processing. Most newer DBMSs (such as Oracle, SQL Server, and DB2) automatically gather statistics; others require the DBA to gather statistics manually. To generate the database object statistics manually, you could use the following syntax:

`ANALYZE <TABLE/INDEX> object_name COMPUTE STATISTICS;`

In SQL Server, use `UPDATE STATISTICS <object_name>`, where `object_name` refers to a table or a view.

For example, to generate statistics for the VENDOR table, you would use the following command:

`ANALYZE TABLE VENDOR COMPUTE STATISTICS;`

In SQL Server, use `UPDATE STATISTICS VENDOR;`

When you generate statistics for a table, all related indexes are also analyzed. However, you could generate statistics for a single index by using the following command:

`ANALYZE INDEX VEND_NDX COMPUTE STATISTICS;`

In the preceding example, `VEND_NDX` is the name of the index.

In SQL Server, use `UPDATE STATISTICS <table_name> <index_name>`. An example command would be `UPDATE STATISTICS VENDOR VEND_NDX;`

Database statistics are stored in the system catalog in specially designated tables. It is common to periodically regenerate the statistics for database objects, especially database objects that are subject to frequent change. For example, if you own a video store and you have a video rental DBMS, your system will likely use a RENTAL table to store the daily video rentals. That RENTAL table and its associated indexes would be subject to constant inserts and updates as you record daily rentals and returns. Therefore, the RENTAL table statistics you generated last week do not accurately depict the table as it exists today. The more current the statistics are, the better the chances that the DBMS will properly select the fastest way to execute a given query.

Now that you know the basic architecture of DBMS processes and memory

structures, and the importance and timing of the database statistics gathered by the DBMS, you are ready to learn how the DBMS processes a SQL query request.

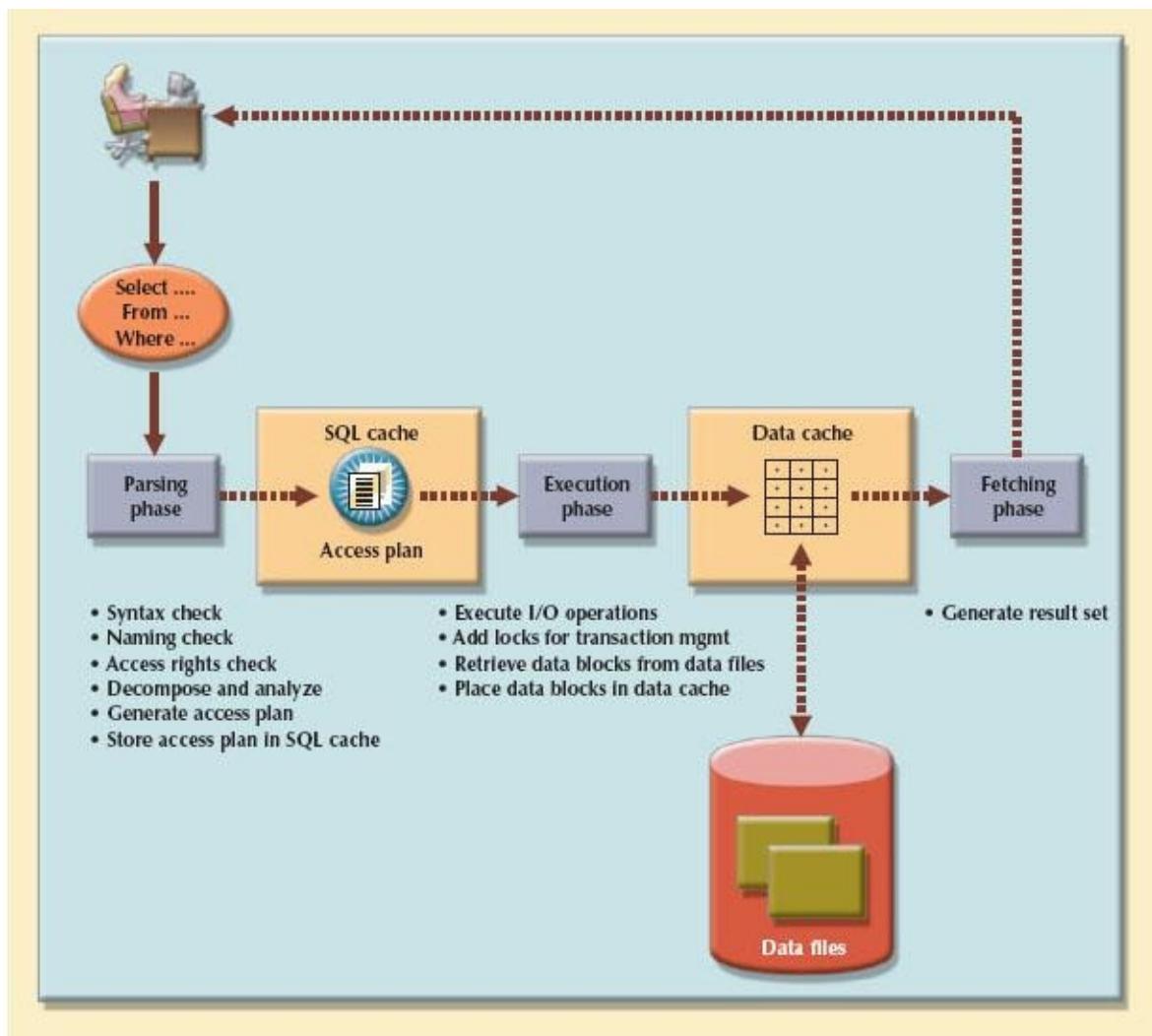
11.2 QUERY PROCESSING

What happens at the DBMS server end when the client's SQL statement is received? In simple terms, the DBMS processes a query in three phases:

1. *Parsing*. The DBMS parses the SQL query and chooses the most efficient access/execution plan.
2. *Execution*. The DBMS executes the SQL query using the chosen execution plan.
3. *Fetching*. The DBMS fetches the data and sends the result set back to the client.

The processing of SQL DDL statements (such as CREATE TABLE) is different from the processing required by DML statements. The difference is that a DDL statement actually updates the data dictionary tables or system catalog, while a DML statement (SELECT, INSERT, UPDATE, or DELETE) mostly manipulates end-user data. [Figure 11.2](#) shows the general steps required for query processing. Each step will be discussed in the following sections.

FIGURE 11.2 Query processing



SOURCE: Course Technology/Cengage Learning

11.2.1 SQL PARSING PHASE

The optimization process includes breaking down—parsing—the query into smaller units and transforming the original SQL query into a slightly different version of the original SQL code, but one that is fully equivalent and more efficient. *Fully equivalent* means that the optimized query results are always the same as the original query. *More efficient* means that the optimized query will almost always execute faster than the original query. (Note that it *almost* always executes faster because many factors affect the performance of a database, as explained earlier. Those factors include the network, the client computer's resources, and other queries running concurrently in the same database.) To determine the most efficient way to execute the query, the DBMS may use the

database statistics you learned about earlier.

The SQL parsing activities are performed by the [query optimizer](#), which analyzes the SQL query and finds the most efficient way to access the data. This process is the most time-consuming phase in query processing. Parsing a SQL query requires several steps, in which the SQL query is:

- Validated for syntax compliance
 - Validated against the data dictionary to ensure that table names and column names are correct
 - Validated against the data dictionary to ensure that the user has proper access rights
- Analyzed and decomposed into more atomic components
 - Optimized through transformation into a fully equivalent but more efficient SQL query
 - Prepared for execution by determining the most efficient execution or access plan

Once the SQL statement is transformed, the DBMS creates what is commonly known as an access plan or execution plan. An [access plan](#) is the result of parsing a SQL statement; it contains the series of steps a DBMS will use to execute the query and return the result set in the most efficient way. First, the DBMS checks to see if an access plan already exists for the query in the SQL cache. If it does, the DBMS reuses the access plan to save time. If it does not, the optimizer evaluates various plans and then decides which indexes to use and how to best perform join operations. The chosen access plan for the query is then placed in the SQL cache and made available for use and future reuse.

Access plans are DBMS-specific and translate the client's SQL query into the series of complex I/O operations required to read the data from the physical data files and generate the result set. [Table 11.3](#) illustrates some I/O operations for an Oracle RDBMS. Most DBMSs perform similar types of operations when accessing and manipulating data sets.

TABLE 11.3 Sample DBMS Access Plan I/O Operations

OPERATION DESCRIPTION

Table scan (full)	Reads the entire table sequentially, from the first row to the last, one row at a time (slowest)
Table access (row ID)	Reads a table row directly, using the row ID value (fastest)
Index scan (range)	Reads the index first to obtain the row IDs and then accesses the table rows directly (faster than a full table scan)
Index access (unique)	Used when a table has a unique index in a column

Nested loop Reads and compares a set of values to another set of values, using a nested loop style (slow)

Merge Merges two data sets (slow)

Sort Sorts a data set (slow)

In [Table 11.3](#), note that a table access using a row ID is the fastest method. A row ID is a unique identification for every row saved in permanent storage; it can be used to access the row directly. Conceptually, a row ID is similar to a slip you get when you park your car in an airport parking lot. The parking slip contains the section number and lot number. Using that information, you can go directly to your car without searching every section and lot.

11.2.2 SQL EXECUTION PHASE

In this phase, all I/O operations indicated in the access plan are executed. When the execution plan is run, the proper locks—if needed—are acquired for the data to be accessed, and the data are retrieved from the data files and placed in the DBMS’s data cache. All transaction management commands are processed during the parsing and execution phases of query processing.

11.2.3 SQL FETCHING PHASE

After the parsing and execution phases are completed, all rows that match the specified condition(s) are retrieved, sorted, grouped, and aggregated (if required). During the fetching phase, the rows of the resulting query result set are returned to the client. The DBMS might use temporary table space to store temporary data. In this stage, the database server coordinates the movement of the result set rows from the server cache to the client cache. For example, a given query result set might contain 9,000 rows; the server would send the first 100 rows to the client and then wait for the client to request the next set of rows, until the entire result set is sent to the client.

11.2.4 QUERY PROCESSING BOTTLENECKS

The main objective of query processing is to execute a given query in the fastest way possible with the least amount of resources. As you have seen, the execution of a query requires the DBMS to break down the query into a series of interdependent I/O operations to be executed in a collaborative manner. The more complex a query is, the more complex the operations are, which means that bottlenecks are more likely. A [**query processing bottleneck**](#) is a delay introduced in the processing of an I/O operation that causes the overall system to slow down. In the same way, the more components a system has, the more

interfacing is required among the components, increasing the likelihood of bottlenecks. Within a DBMS, five components typically cause bottlenecks:

- *CPU*. The CPU processing power of the DBMS should match the system's expected work load. A high CPU utilization might indicate that the processor speed is too slow for the amount of work performed. However, heavy CPU utilization can be caused by other factors, such as a defective component, not enough RAM (the CPU spends too much time swapping memory blocks), a badly written device driver, or a rogue process. A CPU bottleneck will affect not only the DBMS but all processes running in the system.
- *RAM*. The DBMS allocates memory for specific usage, such as data cache and SQL cache. RAM must be shared among all running processes, including the operating system and DBMS. If there is not enough RAM available, moving data among components that are competing for scarce RAM can create a bottleneck.
- *Hard disk*. Other common causes of bottlenecks are hard disk speed and data transfer rates. Current hard disk storage technology allows for greater storage capacity than in the past; however, hard disk space is used for more than just storing end-user data. Current operating systems also use the hard disk for *virtual memory*, which refers to copying areas of RAM to the hard disk as needed to make room in RAM for more urgent tasks. Therefore, more hard disk storage space and faster data transfer rates reduce the likelihood of bottlenecks.
- *Network*. In a database environment, the database server and the clients are connected via a network. All networks have a limited amount of bandwidth that is shared among all clients. When many network nodes access the network at the same time, bottlenecks are likely.
- *Application code*. Not all bottlenecks are caused by limited hardware resources. Two of the most common sources of bottlenecks are inferior application code and poorly designed databases. Inferior code can be improved with code optimization techniques, as long as the underlying database design is sound. However, no amount of coding will make a

poorly designed database perform better.

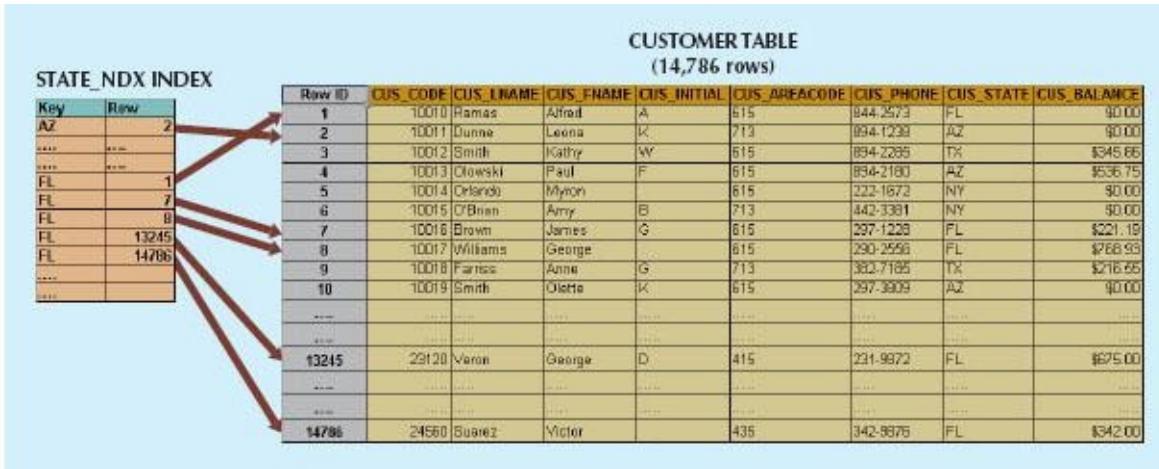
Learning how to avoid these bottlenecks and optimize database performance is the main focus of this chapter.

11.3 INDEXES AND QUERY OPTIMIZATION

Indexes are crucial in speeding up data access because they facilitate searching, sorting, and using aggregate functions and even join operations. The improvement in data access speed occurs because an index is an ordered set of values that contains the index key and pointers. The pointers are the row IDs for the actual table rows. Conceptually, a data index is similar to a book index. When you use a book index, you look up a word, which is similar to the index key. The word is accompanied by one or more page numbers where the word is used; these numbers are similar to pointers.

An index scan is more efficient than a full table scan because the index data are preordered and the amount of data is usually much smaller. Therefore, when performing searches, it is almost always better for the DBMS to use the index to access a table than to scan all rows in a table sequentially. For example, [Figure 11.3](#) shows the index representation of a CUSTOMER table with 14,786 rows and the index STATE_NDX on the CUS_STATE attribute.

FIGURE 11.3 Index representation for the CUSTOMER table



SOURCE: Course Technology/Cengage Learning

Suppose you submit the following query:

```
SELECT CUS_NAME, CUS_STATE
FROM CUSTOMER
WHERE CUS_STATE = 'FL';
```

If there is no index, the DBMS will perform a full table scan and read all 14,786 customer rows. Assuming that the index STATE_NDX is created (and analyzed), the DBMS will automatically use the index to locate the first customer with a state equal to 'FL' and then proceed to read all subsequent CUSTOMER rows, using the row IDs in the index as a guide. Assuming that only five rows meet the condition CUS_STATE = 'FL', there are five accesses to the index and five accesses to the data, for a total of 10 I/O accesses. The DBMS would save approximately 14,776 I/O requests for customer rows that do not meet the criteria. That is a lot of CPU cycles!

If indexes are so important, why not index every column in every table? The simple answer is that it is not practical to do so. Indexing every column in every table overtaxes the DBMS in terms of index-maintenance processing, especially if the table has many attributes and rows, or requires many inserts, updates, and deletes.

One measure that determines the need for an index is the data *sparsity* of the column you want to index. **Data sparsity** refers to the number of different values a column could have. For example, a STU_SEX column in a STUDENT table can have only two possible values, M or F; therefore, that column is said to

have low sparsity. In contrast, the STU_DOB column that stores the student date of birth can have many different date values; therefore, that column is said to have high sparsity. Knowing the sparsity helps you decide whether the use of an index is appropriate. For example, when you perform a search in a column with low sparsity, you are likely to read a high percentage of the table rows anyway; therefore, index processing might be unnecessary work. In [Section 11.5](#), you learn how to determine when an index is recommended.

Most DBMSs implement indexes using one of the following data structures:

- **[Hash index](#).** A hash index is based on an ordered list of hash values. A hash algorithm is used to create a hash value from a key column. This value points to an entry in a hash table, which in turn points to the actual location of the data row. This type of index is good for simple and fast lookup operations based on equality conditions—for example, LNAME=“Scott” and FNAME=“Shannon”.
- **[B-tree index](#).** The B-tree index is an ordered data structure organized as an upside-down tree. (See [Figure 11.4](#).) The index tree is stored separately from the data. The lower-level leaves of the B-tree index contain the pointers to the actual data rows. B-tree indexes are “self-balanced,” which means that it takes approximately the same amount of time to access any given row in the index. This is the default and most common type of index used in databases. The B-tree index is used mainly in tables in which column values repeat a relatively small number of times.
- **[Bitmap index](#).** A bitmap index uses a bit array (0s and 1s) to represent the existence of a value or condition. These indexes are used mostly in data warehouse applications in tables with a large number of rows in which a small number of column values repeat many times. (See [Figure 11.4](#).) Bitmap indexes tend to use less space than B-tree indexes because they use bits instead of bytes to store their data.

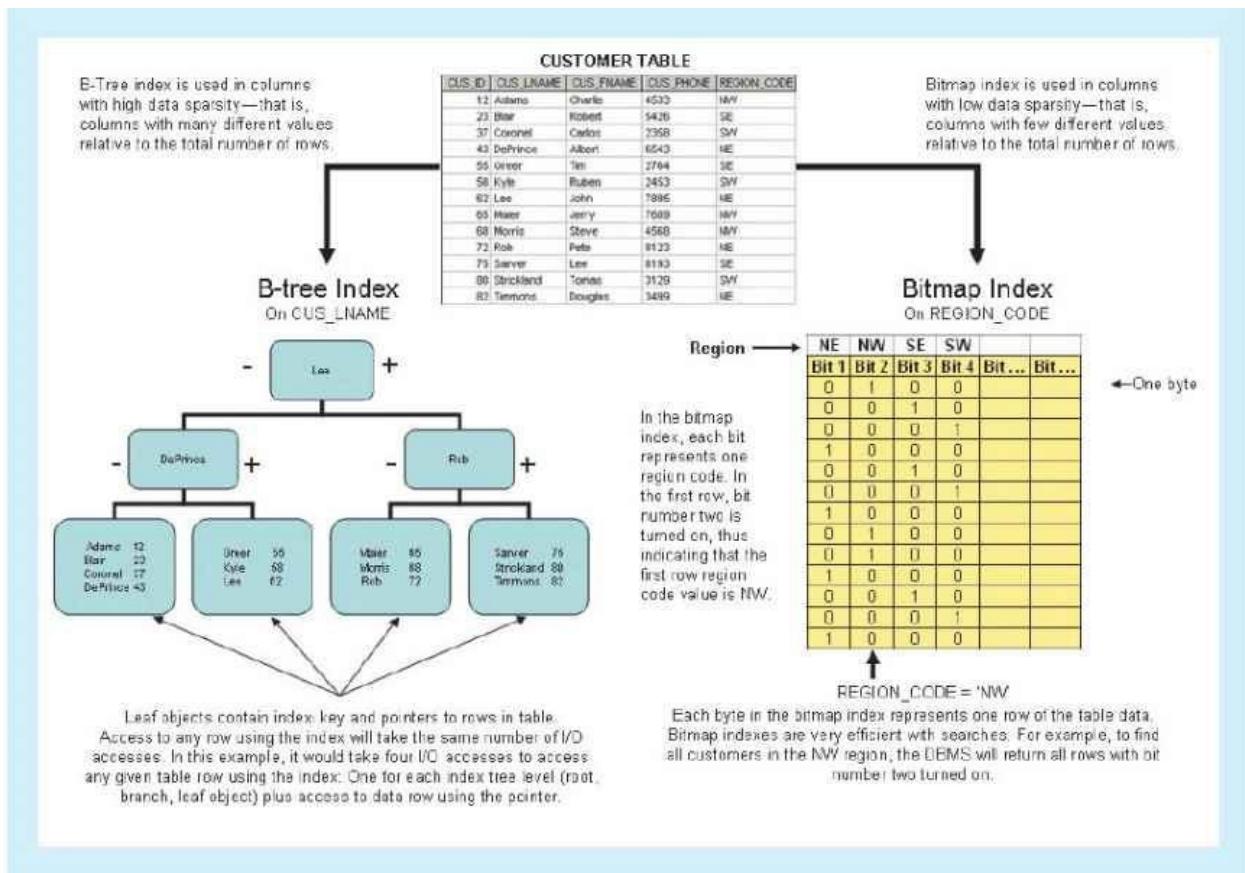
Using the preceding index characteristics, a database designer can determine the best type of index to use. For example, assume that a CUSTOMER table has several thousand rows. The CUSTOMER table has two columns that are used

extensively for query purposes: CUS_LNAME, which represents a customer's last name, and REGION_CODE, which can have one of four values (NE, NW, SW, and SE). Based on this information, you could conclude that:

- Because the CUS_LNAME column contains many different values that repeat a relatively small number of times compared to the total number of rows in the table, a B-tree index will be used.
- Because the REGION_CODE column contains only a few different values that repeat a relatively large number of times compared to the total number of rows in the table, a bitmap index will be used. [Figure 11.4](#) shows the B-tree and bitmap representations for the CUSTOMER table used in the previous discussion.

Current-generation DBMSs are intelligent enough to determine the best type of index to use under certain circumstances, provided that the DBMS has updated database statistics. Regardless of which index is chosen, the DBMS determines the best plan to execute a given query. The next section guides you through a simplified example of the type of choices the query optimizer must make.

FIGURE 11.4 B-tree and bitmap index representation



SOURCE: Course Technology/Cengage Learning

11.4 OPTIMIZER CHOICES

Query optimization is the central activity during the parsing phase in query processing. In this phase, the DBMS must choose what indexes to use, how to perform join operations, which table to use first, and so on. Each DBMS has its own algorithms for determining the most efficient way to access the data. The query optimizer can operate in one of two modes:

- **A rule-based optimizer** uses preset rules and points to determine the best approach to execute a query. The rules assign a “fixed cost” to each SQL operation; the costs are then added to yield the cost of the execution plan. For example, a full table scan has a set cost of 10, while a table access by row ID has a set cost of 3.

- A **cost-based optimizer** uses sophisticated algorithms based on statistics about the objects being accessed to determine the best approach to execute a query. In this case, the optimizer process adds up the processing cost, the I/O costs, and the resource costs (RAM and temporary space) to determine the total cost of a given execution plan.

The optimizer's objective is to find alternative ways to execute a query—to evaluate the “cost” of each alternative and then to choose the one with the lowest cost. To understand the function of the query optimizer, consider a simple example. Assume that you want to list all products provided by a vendor based in Florida. To acquire that information, you could write the following query:

```
SELECT      P_CODE, P_DESCRIP, P_PRICE, V_NAME, V_STATE
FROM        PRODUCT, VENDOR
WHERE          PRODUCT.V_CODE = VENDOR.V_CODE AND
VENDOR.V_STATE = 'FL';
```

Furthermore, assume that the database statistics indicate the following:

- The PRODUCT table has 7,000 rows.
- The VENDOR table has 300 rows.
- Ten vendors are located in Florida.
- One thousand products come from vendors in Florida.

It is important to point out that only the first two items are available to the optimizer. The second two items are assumed to illustrate the choices that the optimizer must make. Armed with the information in the first two items, the optimizer would try to find the most efficient way to access the data. The primary factor in determining the most efficient access plan is the I/O cost. (Remember, the DBMS always tries to minimize I/O operations.) [Table 11.4](#) shows two sample access plans for the previous query and their respective I/O costs.

TABLE 11.4 Comparing Access Plans and I/O Costs

PLAN	STEP	OPERATION	I/O OPERATIONS	I/O COST	RESULTING SET ROWS	TOTAL I/O COST
A	A1	Cartesian product (PRODUCT, VENDOR)	7,000 + 300	7,300	2,100,000	7,300
	A2	Select rows in A1 with matching vendor codes	2,100,000	2,100,000	7,000	2,107,300
	A3	Select rows in A2 with V_STATE = 'FL'	7,000	7,000	1,000	2,114,300
B	B1	Select rows in VENDOR with V_STATE = 'FL'	300	300	10	300
	B2	Cartesian Product (PRODUCT, B1)	7,000 + 10	7,010	70,000	7,310
	B3	Select rows in B2 with matching vendor codes	70,000	70,000	1,000	77,310

To make the example easier to understand, the I/O Operations and I/O Cost columns in [Table 11.4](#) estimate only the number of I/O disk reads the DBMS must perform. For simplicity's sake, it is assumed that there are no indexes and that each row read has an I/O cost of 1. For example, in step A1, the DBMS must calculate the Cartesian product of PRODUCT and VENDOR. To do that, the DBMS must read all rows from PRODUCT (7,000) and all rows from VENDOR (300), yielding a total of 7,300 I/O operations. The same computation is done in all steps. In [Table 11.4](#), you can see how plan A has a total I/O cost that is almost 30 times higher than plan B. In this case, the optimizer will choose plan B to execute the SQL.

NOTE

Not all DBMSs optimize SQL queries the same way. As a matter of fact, Oracle parses queries differently from the methods described in several sections in this chapter. Always read the documentation to examine the optimization requirements for your DBMS implementation.

Given the right conditions, some queries could be answered entirely by using only an index. For example, assume that you are using the PRODUCT table and the index P_QOH_NDX in the P_QOH attribute. Then a query such as SELECT MIN(P_QOH) FROM PRODUCT could be resolved by reading only the first entry in the P_QOH_NDX index, without the need to access any of the data blocks for the PRODUCT table. (Remember that the index defaults to ascending

order.)

You learned in [Section 11.3](#) that columns with low sparsity are not good candidates for index creation. However, in some cases an index in a low-sparsity column would be helpful. For example, assume that the EMPLOYEE table has 122,483 rows. If you want to find out how many female employees work at the company, you would write a query such as:

```
SELECT COUNT(EMP_SEX) FROM EMPLOYEE WHERE EMP_SEX = 'F';
```

If you do not have an index for the EMP_SEX column, the query would have to perform a full table scan to read all EMPLOYEE rows—and each full row includes attributes you do not need. However, if you have an index on EMP_SEX, the query can be answered by reading only the index data, without the need to access the employee data at all.

11.4.1 USING HINTS TO AFFECT OPTIMIZER CHOICES

Although the optimizer generally performs very well under most circumstances, in some instances the optimizer might not choose the best execution plan. Remember, the optimizer makes decisions based on the existing statistics. If the statistics are old, the optimizer might not do a good job in selecting the best execution plan. Even with current statistics, the optimizer's choice might not be the most efficient one. Sometimes the end user would like to change the optimizer mode for the current SQL statement. To do that, you need to use hints. [Optimizer hints](#) are special instructions for the optimizer that are embedded inside the SQL command text. [Table 11.5](#) summarizes a few of the most common optimizer hints used in standard SQL.

TABLE 11.5 Optimizer Hints

HINT

USAGE

	Instructs the optimizer to minimize the overall execution time—that is, to minimize the time needed to return all rows in the query result set. This hint is generally used for batch mode processes. For example:
ALL_ROWS	<pre>SELECT /*+ ALL_ROWS / FROM PRODUCT WHERE P_QOH < 10;</pre>
FIRST_ROWS	Instructs the optimizer to minimize the time needed to process the first set of rows—that is, to minimize the time needed to return only the first set of rows in the query result set. This hint is generally used for interactive mode processes. For example:
	<pre>SELECT /*+ FIRST_ROWS / FROM PRODUCT WHERE P_QOH < 10;</pre>
INDEX(name)	Forces the optimizer to use the P_QOH_NDX index to process this query. For example:
	<pre>SELECT /*+ INDEX(P_QOH_NDX) / FROM PRODUCT WHERE P_QOH < 10;</pre>

Now that you are familiar with the way the DBMS processes SQL queries, you can turn your attention to some general SQL coding recommendations to facilitate the work of the query optimizer.

11.5 SQL PERFORMANCE TUNING

SQL performance tuning is evaluated from the client perspective. Therefore, the goal is to illustrate some common practices used to write efficient SQL code. A few words of caution are appropriate:

- Most current-generation relational DBMSs perform automatic query optimization at the server end.
- Most SQL performance optimization techniques are DBMS-specific and

therefore are rarely portable, even across different versions of the same DBMS. Part of the reason for this behavior is the constant advancement in database technologies.

Does this mean that you should not worry about how a SQL query is written because the DBMS will always optimize it? No, because there is considerable room for improvement. (The DBMS uses *general* optimization techniques rather than focusing on specific techniques dictated by the special circumstances of the query execution.) A poorly written SQL query can, *and usually will*, bring the database system to its knees from a performance point of view. The majority of current database performance problems are related to poorly written SQL code. Therefore, although a DBMS provides general optimizing services, a carefully written query almost always outperforms a poorly written one.

Although SQL data manipulation statements include many different commands such as INSERT, UPDATE, DELETE, and SELECT, most recommendations in this section are related to the use of the SELECT statement, and in particular, the use of indexes and how to write conditional expressions.

11.5.1 INDEX SELECTIVITY

Indexes are the most important technique used in SQL performance optimization. The key is to know when an index is used. As a general rule, indexes are likely to be used:

- When an indexed column appears by itself in the search criteria of a WHERE or HAVING clause.
- When an indexed column appears by itself in a GROUP BY or ORDER BY clause.
- When a MAX or MIN function is applied to an indexed column.
- When the data sparsity on the indexed column is high.

Indexes are very useful when you want to select a small subset of rows from a large table based on a given condition. If an index exists for the column used in the selection, the DBMS may choose to use it. The objective is to create indexes

with high selectivity. **Index selectivity** is a measure of the likelihood that an index will be used in query processing. Here are some general guidelines for creating and using indexes:

- *Create indexes for each single attribute used in a WHERE, HAVING, ORDER BY, or GROUP BY clause.* If you create indexes in all single attributes *used in search conditions*, the DBMS will access the table using an index scan instead of a full table scan. For example, if you have an index for P_PRICE, the condition P_PRICE > 10.00 can be solved by accessing the index instead of sequentially scanning all table rows and evaluating P_PRICE for each row. Indexes are also used in join expressions, such as in CUSTOMER.CUS_CODE = INVOICE.CUS_CODE.
- *Do not use indexes in small tables or tables with low sparsity.* Remember, small tables and low-sparsity tables are not the same thing. A search condition in a table with low sparsity may return a high percentage of table rows anyway, making the index operation too costly and making the full table scan a viable option. Using the same logic, do not create indexes for tables with few rows and few attributes—*unless you must ensure the existence of unique values in a column*.
- *Declare primary and foreign keys so the optimizer can use the indexes in join operations.* All natural joins and old-style joins will benefit if you declare primary keys and foreign keys because the optimizer will use the available indexes at join time. (The declaration of a PK or FK will automatically create an index for the declared column.) Also, for the same reason, it is better to write joins using the SQL JOIN syntax. (See [Chapter 8](#), Advanced SQL.)
- *Declare indexes in join columns other than PK or FK.* If you perform join operations on columns other than the primary and foreign keys, you might be better off declaring indexes in those columns.

You cannot always use an index to improve performance. For example, using the data shown in [Table 11.6](#) in the next section, the creation of an index for P_MIN will not help the search condition P_QOH > P_MIN * 1.10. The reason is that in some DBMSs, *indexes are ignored when you use functions in the table*

attributes. However, major databases such as Oracle, SQL Server, and DB2 now support function-based indexes. A **function-based index** is an index based on a specific SQL function or expression. For example, you could create an index on YEAR(INV_DATE). Function-based indexes are especially useful when dealing with derived attributes. For example, you could create an index on EMP_SALARY + EMP_COMMISION.

How many indexes should you create? It bears repeating that you should not create an index for every column in a table. Too many indexes will slow down INSERT, UPDATE, and DELETE operations, especially if the table contains many thousands of rows. Furthermore, some query optimizers will choose only one index to be the driving index for a query, even if your query uses conditions in many different indexed columns. Which index does the optimizer use? If you use the cost-based optimizer, the answer will change with time as new rows are added to or deleted from the tables. In any case, you should create indexes in all search columns and then let the optimizer choose. It is important to constantly evaluate the index usage—monitor, test, evaluate, and improve it if performance is not adequate.

11.5.2 CONDITIONAL EXPRESSIONS

A conditional expression is normally placed within the WHERE or HAVING clauses of a SQL statement. Also known as conditional criteria, a conditional expression restricts the output of a query to only the rows that match the conditional criteria. Generally, the conditional criteria have the form shown in [Table 11.6](#).

TABLE 11.6 Conditional Criteria

OPERAND1 CONDITIONAL OPERATOR OPERAND2

P_PRICE > **10.00**

V_STATE =

FL

V_CONTACT

LIKE Smith%
P_QOH > P_MIN * 1.10

In [Table 11.6](#), note that an operand can be:

- A simple column name such as P_PRICE or V_STATE
- A literal or a constant such as the value 10.00 or the text 'FL'
- An expression such as P_MIN * 1.10

Most of the query optimization techniques mentioned next are designed to make the optimizer's work easier. The following common practices are used to write efficient conditional expressions in SQL code.

- *Use simple columns or literals as operands in a conditional expression—avoid the use of conditional expressions with functions whenever possible.* Comparing the contents of a single column to a literal is faster than comparing to expressions. For example, P_PRICE > 10.00 is faster than P_QOH > P_MIN * 1.10 because the DBMS must evaluate the P_MIN * 1.10 expression first. The use of functions in expressions also adds to the total query execution time. For example, if your condition is UPPER (V_NAME) = 'JIM', try to use V_NAME = 'JIM' if all names in the V_NAME column are stored with proper capitalization.
- *Numeric field comparisons are faster than character, date, and NULL comparisons.* In search conditions, comparing a numeric attribute to a numeric literal is faster than comparing a character attribute to a character literal. In general, the CPU handles numeric comparisons (integer and decimal) faster than character and date comparisons. Because indexes do not store references to null values, NULL conditions involve additional processing, and therefore tend to be the slowest of all conditional operands.
- *Equality comparisons are generally faster than inequality comparisons.* For example, P_PRICE = 10.00 is processed faster because the DBMS can do a direct search using the index in the column. If there are no exact matches, the condition is evaluated as false. However, if you use an inequality symbol (>, >=, <, <=), the DBMS must perform additional

processing to complete the request, because there will almost always be more “greater than” or “less than” values in the index than “equal” values. With the exception of NULL, the slowest of all comparison operators is LIKE with wildcard symbols, as in V_CONTACT LIKE “%glo%”. Also, using the “not equal” symbol (\neq) yields slower searches, especially when the sparsity of the data is high—that is, when there are many more different values than there are equal values.

- *Whenever possible, transform conditional expressions to use literals.* For example, if your condition is P_PRICE - 10 = 7, change it to read P_PRICE = 17. Also, if you have a composite condition such as:

P_QOH < P_MIN AND P_MIN = P_REORDER AND P_QOH = 10

change it to read:

P_QOH = 10 AND P_MIN = P_REORDER AND P_MIN > 10

- *When using multiple conditional expressions, write the equality conditions first.* Note that this was done in the previous example. Remember, equality conditions are faster to process than inequality conditions. Although most RDBMSs will automatically do this for you, paying attention to this detail lightens the load for the query optimizer. The optimizer will not have to do what you have already done.

- *If you use multiple AND conditions, write the condition most likely to be false first.* If you use this technique, the DBMS will stop evaluating the rest of the conditions as soon as it finds a conditional expression that is evaluated as false. Remember, for multiple AND conditions to be found true, all conditions must be evaluated as true. If one of the conditions evaluates to false, the whole set of conditions will be evaluated as false. If you use this technique, the DBMS will not waste time unnecessarily evaluating additional conditions. Naturally, the use of this technique implies knowledge of the sparsity of the data set. For example, look at the following condition list:
- P_PRICE > 10 AND V_STATE = 'FL'

If you know that only a few vendors are located in Florida, you could rewrite this condition as:

V_STATE = 'FL' AND P_PRICE > 10

- *When using multiple OR conditions, put the condition most likely to be true first.* By doing this, the DBMS will stop evaluating the remaining conditions as soon as it finds a conditional expression that is evaluated as true. Remember, for multiple OR conditions to evaluate to true, only one of the conditions must be evaluated as true.
-

NOTE

Oracle does not evaluate queries as described here. Instead, Oracle evaluates conditions from last to first.

- *Whenever possible, try to avoid the use of the NOT logical operator.* It is best to transform a SQL expression that contains a NOT logical operator into an equivalent expression. For example:

NOT (P_PRICE > 10.00) can be written as P_PRICE <= 10.00.

Also, NOT (EMP_SEX = 'M') can be written as EMP_SEX = 'F'.

11.6 QUERY FORMULATION

Queries are usually written to answer questions. For example, if an end user gives you a sample output and tells you to match that output format, you must write the corresponding SQL. To get the job done, you must carefully evaluate what columns, tables, and computations are required to generate the desired output. To do that, you must have a good understanding of the database environment and the database that will be the focus of your SQL code.

This section focuses on SELECT queries because they are the queries you will find in most applications. To formulate a query, you would normally follow these steps:

1. *Identify what columns and computations are required.* The first step is needed to clearly determine what data values you want to return. Do you

want to return just the names and addresses, or do you also want to include some computations? Remember that all columns in the SELECT statement should return single values.

- a. Do you need simple expressions? For example, do you need to multiply the price by the quantity on hand to generate the total inventory cost? You might need some single attribute functions such as DATE(), SYSDATE(), or ROUND().
 - b. Do you need aggregate functions? If you need to compute the total sales by product, you should use a GROUP BY clause. In some cases, you might need to use a subquery.
 - c. Determine the granularity of the raw data required for your output. Sometimes, you might need to summarize data that are not readily available in any table. In such cases, you might consider breaking the query into multiple subqueries and storing those subqueries as views. Then you could create a top-level query that joins those views and generates the final output.
2. *Identify the source tables.* Once you know what columns are required, you can determine the source tables used in the query. Some attributes appear in more than one table. In those cases, try to use the least number of tables in your query to minimize the number of join operations.
 3. *Determine how to join the tables.* Once you know what tables you need in your query statement, you must properly identify how to join the tables. In most cases, you will use some type of natural join, but in some instances, you might need to use an outer join.
 4. *Determine what selection criteria are needed.* Most queries involve some type of selection criteria. In this case, you must determine what operands and operators are needed in your criteria. Ensure that the data type and granularity of the data in the comparison criteria are correct.
 - a. *Simple comparison.* In most cases, you will be comparing single values—for example, P_PRICE > 10.
 - b. *Single value to multiple values.* If you are comparing a single value to multiple values, you might need to use an IN comparison operator—for example, V_STATE IN ('FL', 'TN', 'GA').
 - c. *Nested comparisons.* In other cases, you might need to have some

nested selection criteria involving subqueries—for example, $P_PRICE \geq (\text{SELECT AVG}(P_PRICE) \text{ FROM PRODUCT})$.

- d. *Grouped data selection.* On other occasions, the selection criteria might apply not to the raw data but to the aggregate data. In those cases, you need to use the HAVING clause.
5. *Determine the order in which to display the output.* Finally, the required output might be ordered by one or more columns. In those cases, you need to use the ORDER BY clause. Remember that the ORDER BY clause is one of the most resource-intensive operations for the DBMS.
-
-

11.7 DBMS PERFORMANCE TUNING

DBMS performance tuning includes global tasks such as managing the DBMS processes in primary memory (allocating memory for caching purposes) and managing the structures in physical storage (allocating space for the data files).

Fine-tuning the performance of the DBMS also includes applying several practices examined in the previous section. For example, the DBA must work with developers to ensure that the queries perform as expected—creating the indexes to speed up query response time and generating the database statistics required by cost-based optimizers.

DBMS performance tuning at the server end focuses on setting the parameters used for:

- *Data cache.* The data cache size must be set large enough to permit as many data requests as possible to be serviced from the cache. Each DBMS has settings that control the size of the data cache; some DBMSs might require a restart. This cache is shared among all database users. The majority of primary memory resources will be allocated to the data cache.
- *SQL cache.* The SQL cache stores the most recently executed SQL statements (after the SQL statements have been parsed by the optimizer). Generally, if you have an application with multiple users accessing a database, the *same* query will likely be submitted by many different

users. In those cases, the DBMS will parse the query only once and execute it many times, using the same access plan. In that way, the second and subsequent SQL requests for the same query are served from the SQL cache, skipping the parsing phase.

- *Sort cache.* The sort cache is used as a temporary storage area for ORDER BY or GROUP BY operations, as well as for index-creation functions.
- *Optimizer mode.* Most DBMSs operate in one of two optimization modes: cost-based or rule-based. Others automatically determine the optimization mode based on whether database statistics are available. For example, the DBA is responsible for generating the database statistics that are used by the cost-based optimizer. If the statistics are not available, the DBMS uses a rule-based optimizer.

Managing the physical storage details of the data files also plays an important role in DBMS performance tuning. Note the following general recommendations for physical storage of databases:

- Use **RAID** (redundant array of independent disks) to provide both performance improvement and fault tolerance, and a balance between them. Fault tolerance means that in case of failure, data can be reconstructed and retrieved. RAID systems use multiple disks to create virtual disks (storage volumes) formed by several individual disks. [Table 11.7](#) describes the most common RAID configurations.

TABLE 11.7 Common RAID Levels

RAID LEVEL **DESCRIPTION**

- | | |
|----------|---|
| 0 | The data blocks are spread over separate drives. Also known as striped array. Provides increased performance but no fault tolerance. Requires a minimum of two drives. |
| 1 | The same data blocks are written (duplicated) to separate drives. Also referred to as mirroring or duplexing. Provides increased read performance and fault tolerance via data redundancy. Requires a |

- minimum of two drives.
- The data are striped across separate drives, and parity data are computed and stored in a dedicated drive. (Parity data are specially generated data that permit the reconstruction of corrupted or missing data.) Provides good read performance and fault tolerance via parity data. Requires a minimum of three drives.
- 3 The data and the parity data are striped across separate drives. Provides good read performance and fault tolerance via parity data. Requires a minimum of three drives.
-

- Minimize disk contention. Use multiple, independent storage volumes with independent spindles (rotating disks) to minimize hard disk cycles. Remember, a database is composed of many table spaces, each with a particular function. In turn, each table space is composed of several data files in which the data are actually stored. A database should have at least the following table spaces:
 - *System table space*. This is used to store the data dictionary tables. It is the most frequently accessed table space and should be stored in its own volume.
 - *User data table space*. This is used to store end-user data. You should create as many user data table spaces and data files as are required to balance performance and usability. For example, you can create and assign a different user data table space for each application and each distinct group of users, but this is not necessary for each user.
 - *Index table space*. This is used to store indexes. You can create and assign a different index table space for each application and each group of users. The index table space data files should be stored on a storage volume that is separate from user data files or system data files.
 - *Temporary table space*. This is used as a temporary storage area for merge, sort, or set aggregate operations. You can create and assign a different temporary table space for each application and each group of users.
 - *Rollback segment table space*. This is used for transaction-recovery purposes.
- Put high-usage tables in their own table spaces so the database minimizes

conflict with other tables.

- Assign separate data files in separate storage volumes for the indexes, system, and high-usage tables. This ensures that index operations will not conflict with end-user data or data dictionary table access operations. Another advantage of this approach is that you can use different disk block sizes in different volumes. For example, the data volume can use a 16 K block size, while the index volume can use an 8 K block size. Remember that the index record size is generally smaller, and by changing the block size you will reduce contention and minimize I/O operations. This is very important; many database administrators overlook indexes as a source of contention. By using separate storage volumes and different block sizes, the I/O operations on data and indexes will happen asynchronously (at different times); more importantly, the likelihood of write operations blocking read operations is reduced, as page locks tend to lock fewer records.
- Take advantage of the various table storage organizations available in the database. For example, in Oracle consider the use of index-organized tables (IOT); in SQL Server, consider clustered index tables. An **index-organized table** (or **clustered index table**) is a table that stores the end-user data and the index data in consecutive locations on permanent storage. This type of storage organization provides a performance advantage to tables that are commonly accessed through a given index order, because the index contains the index key as well as the data rows. Therefore, the DBMS tends to perform fewer I/O operations.
- Partition tables based on usage. Some RDBMSs support the horizontal partitioning of tables based on attributes. (See [Chapter 12](#), Distributed Database Management Systems.) By doing so, a single SQL request can be processed by multiple data processors. Put the table partitions closest to where they are used the most.
- Use denormalized tables where appropriate. In other words, you might be able to improve performance by taking a table from a higher normal form to a lower normal form—typically, from third to second normal form.

This technique adds data duplication, but it minimizes join operations. (Denormalization was discussed in [Chapter 6](#), Normalization of Database Tables.)

- Store computed and aggregate attributes in tables. In short, use derived attributes in your tables. For example, you might add the invoice subtotal, the amount of tax, and the total in the INVOICE table. Using derived attributes minimizes computations in queries and join operations.

11.8 QUERY OPTIMIZATION EXAMPLE

Now that you have learned the basis of query optimization, you are ready to test your new knowledge. A simple example illustrates how the query optimizer works and how you can help it work. The example is based on the QOVENDOR and QOPRODUCT tables, which are similar to tables you used in previous chapters. However, the QO prefix is used for the table name to ensure that you do not overwrite previous tables.



ONLINE CONTENT

The databases and scripts used in this chapter are available at www.cengagebrain.com.

To perform this query optimization example, you will use the Oracle SQL*Plus interface. Some preliminary work must be done before you can start testing query optimization, as explained in the following steps:

1. Log in to Oracle SQL*Plus using the username and password provided by your instructor.
2. Create a fresh set of tables, using the QRYOPTDATA.SQL script file at www.cengagebrain.com. This step is necessary so that Oracle has a new set of tables and the new tables contain no statistics. At the SQL> prompt, type:

```
@path\QRYOPTDATA.SQL
```

where *path* is the location of the file in your computer.

3. Create the PLAN_TABLE, which is a special table used by Oracle to store the access plan information for a given query. End users can then query the PLAN_TABLE to see how Oracle will execute the query. To create the PLAN_TABLE, run the UTLXPLAN.SQL script file in the RDBMS\ADMIN folder of your Oracle RDBMS installation. The UTLXPLAN.SQL script file is also available at www.cengagebrain.com. At the SQL prompt, type:

```
@path\UTLXPLAN.SQL
```

You use the EXPLAIN PLAN command to store the execution plan of a SQL query in the PLAN_TABLE. Then, you use the SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY) command to display the access plan for a given SQL statement.

NOTE

Oracle 11g automatically defaults to cost-based optimization without giving you a choice. Oracle versions prior to Oracle 10g default to the Choose optimization mode, which implies that the DBMS will choose either rule-based or cost-based optimization, depending on the availability of table statistics.

To see the access plan used by the DBMS to execute your query, use the EXPLAIN PLAN and SELECT statements, as shown in [Figure 11.5](#). Note that the first SQL statement generates the statistics for the QOVENDOR table. Also, the initial access plan in [Figure 11.5](#) uses a full table scan on the QOVENDOR table, and the cost of the plan is 4.

FIGURE 11.5 Initial explain plan

The screenshot shows a Windows application window titled "Oracle SQL*Plus". The menu bar includes "File", "Edit", "Search", "Options", and "Help". The main area contains the following SQL statements:

```
SQL> ANALYZE TABLE QOVENDOR COMPUTE STATISTICS;
Table analyzed.

SQL> EXPLAIN PLAN FOR SELECT * FROM QOVENDOR WHERE V_NAME LIKE 'B%' ORDER BY V_AREACODE;
Explained.

SQL> SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY);

PLAN_TABLE_OUTPUT
-----
Plan hash value: 1837703589

| Id  | Operation          | Name      | Rows  | Bytes | Cost (%CPU) | Time      |
| 0   | SELECT STATEMENT   |           |       1 |    38 |     4 (25)  | 00:00:01  |
| 1   |  SORT ORDER BY     |           |       1 |    38 |     4 (25)  | 00:00:01  |
|* 2  |  TABLE ACCESS FULL | QOVENDOR  |       1 |    38 |     3 (0)   | 00:00:01  |

Predicate Information (identified by operation id):
PLAN_TABLE_OUTPUT
-----
2 - Filter("V_NAME" LIKE 'B%')
14 rows selected.

SQL> |
```

SOURCE: Course Technology/Cengage Learning

Now create an index on V_AREACODE (note that V_AREACODE is used in the ORDER BY clause) and see how it affects the access plan generated by the cost-based optimizer. The results are shown in [Figure 11.6](#).

FIGURE 11.6 Explain plan after index on V_AREACODE

The screenshot shows the Oracle SQL*Plus interface with the following session history:

```
SQL> ANALYZE TABLE QOVENDOR COMPUTE STATISTICS;
Table analyzed.

SQL> EXPLAIN PLAN FOR SELECT * FROM QOVENDOR WHERE V_NAME LIKE 'B%' ORDER BY V_AREACODE;
Explained.

SQL> SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY);

PLAN_TABLE_OUTPUT
-----
Plan hash value: 1837703589

| Id  | Operation          | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
| 0   | SELECT STATEMENT   |           | 1    | 38   | 4 (25)  | 00:00:01 |
| 1   |  SORT ORDER BY     |           | 1    | 38   | 4 (25)  | 00:00:01 |
|* 2  |  TABLE ACCESS FULL | QOVENDOR | 1    | 38   | 3 (0)   | 00:00:01 |

Predicate Information (identified by operation id):
PLAN_TABLE_OUTPUT
-----
2 - Filter("V_NAME" LIKE 'B%')

14 rows selected.

SQL>
```

SOURCE: Course Technology/Cengage Learning

In [Figure 11.6](#), note that the new access plan cuts the cost of executing the query by half! Also note that this new plan scans the QOV_NDX1 index and accesses the QOVENDOR rows, using the index row ID. (Remember that access by row ID is one of the fastest access methods.) In this case, the creation of the QOV_NDX1 index had a positive impact on overall query optimization results.

At other times, indexes do not necessarily help in query optimization, such as when you have indexes on small tables or when the query accesses a great percentage of table rows anyway. Note what happens when you create an index on V_NAME. The new access plan is shown in [Figure 11.7](#). (Note that V_NAME is used on the WHERE clause as a conditional expression operand.)

FIGURE 11.7 Explain plan after index on V_NAME

The screenshot shows a Windows-based Oracle SQL*Plus window. The session starts with creating an index:

```
SQL> CREATE INDEX QOV_NDX1 ON QOVENDOR(V_AREACODE);
```

Index created.

```
SQL> ANALYZE TABLE QOVENDOR COMPUTE STATISTICS;
```

Table analyzed.

```
SQL> EXPLAIN PLAN FOR SELECT * FROM QOVENDOR WHERE V_NAME LIKE 'B%' ORDER BY V_AREACODE;
```

Explained.

```
SQL> SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY);
```

PLAN_TABLE_OUTPUT

Plan hash value: 2305289760

Id	Operation	Name	Rows	Bytes	Cost (%CPU)	Time
0	SELECT STATEMENT		1	38	2 (0)	00:00:01
1	TABLE ACCESS BY INDEX ROWID	QOVENDOR	1	38	2 (0)	00:00:01
2	INDEX FULL SCAN	QOV_NDX1	15		1 (0)	00:00:01

Predicate Information (identified by operation id):

```
1 - filter("V_NAME" LIKE 'B%')
```

14 rows selected.

```
SQL> |
```

SOURCE: Course Technology/Cengage Learning

As you can see in [Figure 11.7](#), creation of the second index did not help the query optimization. However, on some occasions an index might be used by the optimizer, but it is not executed because of the way the query is written. For example, [Figure 11.8](#) shows the access plan for a different query using the V_NAME column.

FIGURE 11.8 Access plan using index on V_NAME

```

Oracle SQL*Plus
File Edit Search Options Help
SQL> EXPLAIN PLAN FOR SELECT V_NAME, P_CODE FROM QOVENDOR V, QOPRODUCT P
2      WHERE V.V_CODE = P.V_CODE AND V_NAME = 'ORDUA, Inc.';
Explained.

SQL> SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY);

PLAN_TABLE_OUTPUT
-----
Plan hash value: 3956542569

| Id  | Operation          | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
|---|---|---|---|---|---|---|
| 0  | SELECT STATEMENT   |             |       |       | 6  (17) | 00:00:01 |
|* 1 | HASH JOIN          |             |       |       | 6  (17) | 00:00:01 |
| 2  | TABLE ACCESS BY INDEX ROWID | QOVENDOR | 1    | 74   | 2  (0)  | 00:00:01 |
|* 3  | INDEX RANGE SCAN   | QOV_NDX2  | 1    | 17   | 1  (0)  | 00:00:01 |
| 4  | TABLE ACCESS FULL  | QOPRODUCT | 16   | 320  | 3  (0)  | 00:00:01 |

Predicate Information (identified by operation id):
-----
1 - access("V"."V_CODE"="P"."V_CODE")
3 - access("V_NAME"='ORDUA, Inc.')

Note
-----
- dynamic sampling used for this statement

21 rows selected.

SQL>

```

SOURCE: Course Technology/Cengage Learning

In [Figure 11.8](#), note that the access plan for this new query uses the QOV_NDX2 index on the V_NAME column. What would happen if you wrote the same query, using the UPPER function on V_NAME? The results are illustrated in [Figure 11.9](#).

FIGURE 11.9 Access plan using functions on indexed columns

The screenshot shows the Oracle SQL*Plus interface with the following content:

```

SQL> EXPLAIN PLAN FOR SELECT V_NAME, P_CODE FROM QOVENDOR V, QOPRODUCT P
2      WHERE V.V_CODE = P.V_CODE AND UPPER(V_NAME) = 'ORDUA, INC.';

Explained.

SQL> SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY);

PLAN_TABLE_OUTPUT
Plan hash value: 4061476548

| Id | Operation          | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
|---|---|---|---|---|---|---|
| 0 | SELECT STATEMENT   |             | 1    | 37   | 7  (15) | 00:00:01 |
|* 1 | HASH JOIN          |             | 1    | 37   | 7  (15) | 00:00:01 |
|* 2 |   VIEW              | index$_join$_001 | 1    | 17   | 3  (0)  | 00:00:01 |
|* 3 |     HASH JOIN       |             | 1    | 17   | 1  (0)  | 00:00:01 |
|* 4 |       INDEX FAST FULL SCAN | QOU_NDX2 | 1    | 17   | 1  (0)  | 00:00:01 |
|* 5 |       INDEX FAST FULL SCAN | SYS_C005802 | 1    | 17   | 1  (0)  | 00:00:01 |
| 6 |     TABLE ACCESS FULL | QOPRODUCT  | 16   | 320  | 3  (0)  | 00:00:01 |

Predicate Information (identified by operation id):
-----
1 - access("V"."V_CODE"="P"."V_CODE")
2 - filter(UPPER("V_NAME")='ORDUA, INC.')
3 - access(ROWID=ROWID)
4 - filter(UPPER("V_NAME")='ORDUA, INC.')

Note
-----
- dynamic sampling used for this statement

25 rows selected.

SQL>

```

SOURCE: Course Technology/Cengage Learning

As [Figure 11.9](#) shows, the use of a function on an indexed column caused the DBMS to perform additional operations that increased the cost of the query. The same query might produce different costs if your tables contain many more rows and if the index sparsity is different.

Now use the QOPRODUCT table to demonstrate how an index can help when aggregate function queries are being run. For example, [Figure 11.10](#) shows the access plan for a SELECT statement using the MAX(P_PRICE) aggregate function. This plan uses a full table scan with a total cost of 3.

FIGURE 11.10 First explain plan: aggregate function on a non-indexed column

The screenshot shows a window titled "Oracle SQL*Plus". The menu bar includes "File", "Edit", "Search", "Options", and "Help". The command line area contains the following SQL statements:

```
SQL> ANALYZE TABLE QOPRODUCT COMPUTE STATISTICS;
Table analyzed.

SQL> EXPLAIN PLAN FOR SELECT MAX(P_PRICE) FROM QOPRODUCT;
Explained.

SQL> SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY);
```

The output of the last command is a table titled "PLAN_TABLE_OUTPUT" with the following data:

Id	Operation	Name	Rows	Bytes	Cost (%CPU)	Time
0	SELECT STATEMENT		1	4	3 (0)	00:00:01
1	SORT AGGREGATE		1	4		
2	TABLE ACCESS FULL	QOPRODUCT	16	64	3 (0)	00:00:01

Below the table, it says "9 rows selected." and ends with "SQL>".

SOURCE: Course Technology/Cengage Learning

A cost of 3 is very low already, but you could improve the previous query performance by creating an index on P_PRICE. [Figure 11.11](#) shows how the plan cost is reduced by two-thirds after the index is created and the QOPRODUCT table is analyzed. Also note that the second version of the access plan uses only the index QOP_NDX2 to answer the query; *the QOPRODUCT table is never accessed*.

FIGURE 11.11 Second explain plan: aggregate function on an indexed column

The screenshot shows a Windows-based Oracle SQL*Plus window. The session starts with creating an index:

```
SQL> CREATE INDEX QOP_NDX2 ON QOPRODUCT(P_PRICE);
```

Index created.

```
SQL> ANALYZE TABLE QOPRODUCT COMPUTE STATISTICS;
```

Table analyzed.

```
SQL> EXPLAIN PLAN FOR SELECT MAX(P_PRICE) FROM QOPRODUCT;
```

Explained.

```
SQL> SELECT * FROM TABLE(DBMS_XPLAN.DISPLAY);
```

PLAN_TABLE_OUTPUT

Plan hash value: 3423609809

Id	Operation	Name	Rows	Bytes	Cost (%CPU)	Time
0	SELECT STATEMENT		1	4	1 (0)	00:00:01
1	SORT AGGREGATE		1	4	1 (0)	00:00:01
2	INDEX FULL SCAN (MIN/MAX)	QOP_NDX2	16	64	1 (0)	00:00:01

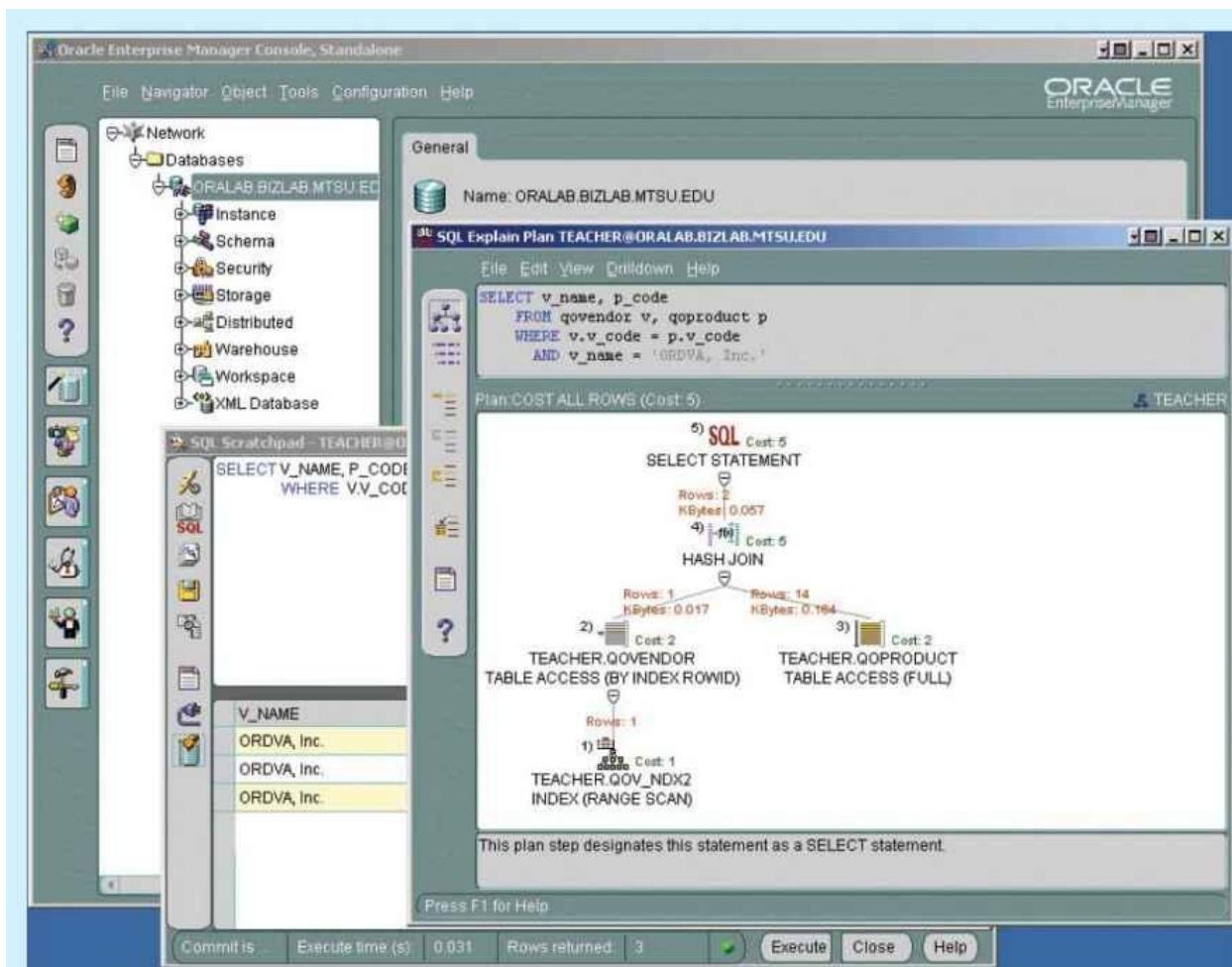
9 rows selected.

```
SQL>
```

SOURCE: Course Technology/Cengage Learning

Although the few examples in this section show the importance of proper index selection for query optimization, you also saw examples in which index creation does not improve query performance. As a DBA, you should be aware that the main goal is to optimize overall database performance—not just for a single query but for all requests and query types. Most database systems provide advanced graphical tools for performance monitoring and testing. For example, [Figure 11.12](#) shows the graphical representation of the access plan using the Oracle 9i graphical tools. (Oracle 11g does not include this interface.)

FIGURE 11.12 Oracle 9i tools for query optimization



SOURCE: Course Technology/Cengage Learning

SUMMARY

- Database performance tuning refers to a set of activities and procedures designed to ensure that an end-user query is processed by the DBMS in the least amount of time.

- SQL performance tuning refers to activities on the client side that are designed to generate SQL code that returns the correct answer in the least amount of time, using the minimum amount of resources at the server end.
- DBMS performance tuning refers to activities on the server side that are

oriented so the DBMS is properly configured to respond to clients' requests in the fastest way possible while making optimum use of existing resources.

- The DBMS architecture is represented by the many processes and structures (in memory and permanent storage) used to manage a database.
- Database statistics refer to a number of measurements gathered by the DBMS that describe a snapshot of the database objects' characteristics. The DBMS gathers statistics about objects such as tables, indexes, and available resources, which include number of processors used, processor speed, and temporary space available. The DBMS uses the statistics to make critical decisions about improving query processing efficiency.
- DBMSs process queries in three phases. In the parsing phase, the DBMS parses the SQL query and chooses the most efficient access/execution plan. In the execution phase, the DBMS executes the SQL query using the chosen execution plan. In the fetching phase, the DBMS fetches the data and sends the result set back to the client.
- Indexes are crucial in the process that speeds up data access. Indexes facilitate searching, sorting, and using aggregate functions and join operations. The improvement in data access speed occurs because an index is an ordered set of values that contains the index key and pointers. Data sparsity refers to the number of different values a column could have. Indexes are recommended in high-sparsity columns used in search conditions.
- During query optimization, the DBMS must choose what indexes to use, how to perform join operations, which table to use first, and so on. Each DBMS has its own algorithms for determining the most efficient way to access the data. The two most common approaches are rule-based and cost-based optimization.
- A rule-based optimizer uses preset rules and points to determine the best approach to execute a query. The rules assign a "fixed cost" to each SQL operation; the costs are then added to yield the cost of the execution plan.

- A cost-based optimizer uses sophisticated algorithms based on statistics about the objects being accessed to determine the best approach to execute a query. In this case, the optimizer process adds up the processing cost, the I/O costs, and the resource costs (RAM and temporary space) to determine the total cost of a given execution plan.
- Hints are used to change the optimizer mode for the current SQL statement. Hints are special instructions for the optimizer that are embedded inside the SQL command text.
- SQL performance tuning deals with writing queries that make good use of the statistics. In particular, queries should make good use of indexes. Indexes are very useful when you want to select a small subset of rows from a large table based on a condition. When an index exists for the column used in the selection, the DBMS may choose to use it. The objective is to create indexes with high selectivity. Index selectivity is a measure of the likelihood that an index will be used in query processing. It is also important to write conditional statements using some common principles.
- Query formulation deals with how to translate business questions into specific SQL code to generate the required results. To do this, you must carefully evaluate which columns, tables, and computations are required to generate the desired output.
- DBMS performance tuning includes tasks such as managing the DBMS processes in primary memory (allocating memory for caching purposes) and managing the structures in physical storage (allocating space for the data files).

KEY TERMS

[access plan](#)
[automatic query optimization](#)
[bitmap index](#)

[b-tree index](#)
[buffer cache](#)
[clustered index table](#)
[cost-based optimizer](#)
[database performance tuning](#)
[database statistics](#)
[data cache](#)
[data files](#)
[data sparsity](#)
[DBMS performance tuning](#)
[dynamic query optimization](#)
[dynamic statistical generation mode](#)
[extends](#)
[file group](#)
[function-based index](#)
[hash index](#)
[index-organized table](#)
[index selectivity](#)
[input/output \(I/O\) request](#)
[manual query optimization](#)
[manual statistical generation mode](#)
[optimizer hints](#)
[procedure cache](#)
[query optimizer](#)
[query processing bottleneck](#)
[RAID](#)
[rule-based optimizer](#)
[rule-based query optimization algorithm](#)
[static query optimization](#)
[statistically based query optimization algorithm](#)
[SQL cache](#)
[SQL performance tuning](#)
[table space](#)



ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at www.cengagebrain.com.

REVIEW QUESTIONS

1. What is SQL performance tuning?
2. What is database performance tuning?
3. What is the focus of most performance-tuning activities, and why does that focus exist?
4. What are database statistics, and why are they important?
5. How are database statistics obtained?
6. What database statistics measurements are typical of tables, indexes, and resources?
7. How is the processing of SQL DDL statements (such as CREATE TABLE) different from the processing required by DML statements?
8. In simple terms, the DBMS processes a query in three phases. What are those phases, and what is accomplished in each phase?
9. If indexes are so important, why not index every column in every table? (Include a brief discussion of the role played by data sparsity.)
10. What is the difference between a rule-based optimizer and a cost-based optimizer?
11. What are optimizer hints, and how are they used?

12. What are some general guidelines for creating and using indexes?
 13. Most query optimization techniques are designed to make the optimizer's work easier. What factors should you keep in mind if you intend to write conditional expressions in SQL code?
-
14. What recommendations would you make for managing the data files in a DBMS with many tables and indexes?
 15. What does RAID stand for, and what are some commonly used RAID levels?

PROBLEMS

[Problems 1](#) and [2](#) are based on the following query:

```
SELECT      EMP_LNAME, EMP_FNAME, EMP_AREACODE, EMP_SEX  
FROM        EMPLOYEE  
WHERE       EMP_SEX = 'F' AND EMP_AREACODE = '615'  
ORDER BY    EMP_LNAME, EMP_FNAME;
```

1. What is the likely data sparsity of the EMP_SEX column?
2. What indexes should you create? Write the required SQL commands.
3. Using [Table 11.4](#) as an example, create two alternative access plans.
Use the following assumptions:
 - a. There are 8,000 employees.
 - b. There are 4,150 female employees.
 - c. There are 370 employees in area code 615.
 - d. There are 190 female employees in area code 615.

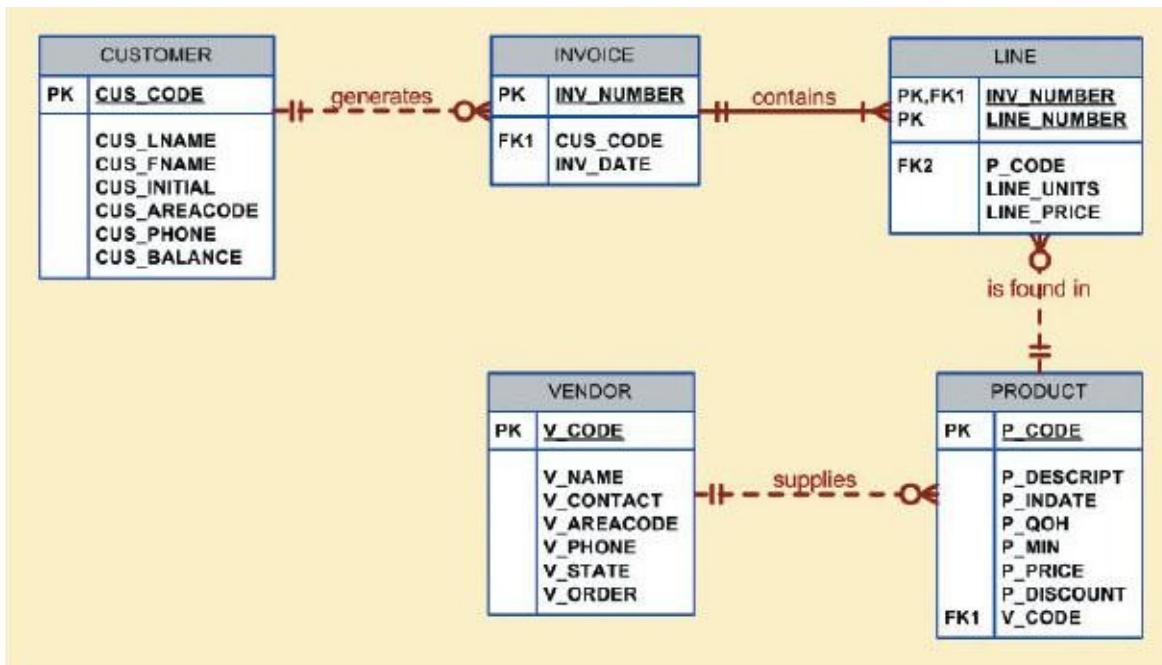
[Problems 4–6](#) are based on the following query:

```
SELECT      EMP_LNAME, EMP_FNAME, EMP_DOB, YEAR(EMP_DOB)  
AS YEAR  
FROM        EMPLOYEE  
WHERE       YEAR(EMP_DOB) = 1966;
```

4. What is the likely data sparsity of the EMP_DOB column?
5. Should you create an index on EMP_DOB? Why or why not?
6. What type of database I/O operations will likely be used by the query? (See [Table 11.3](#).)

[Problems 7-10](#) are based on the ER model shown in Figure P11.7 and on the query shown after the figure.

FIGURE P11.7 The Ch11_SaleCo ER model



SOURCE: Course Technology/Cengage Learning

- ```

SELECT P_CODE, P_PRICE
FROM PRODUCT
WHERE P_PRICE >= (SELECT AVG(P_PRICE) FROM PRODUCT);

```
7. Assuming there are no table statistics, what type of optimization will the DBMS use?
  8. What type of database I/O operations will likely be used by the query? (See [Table 11.3](#).)
  9. What is the likely data sparsity of the P\_PRICE column?

10. Should you create an index? Why or why not?

[Problems 11-14](#) are based on the following query:

```
SELECT P_CODE, SUM(LINE_UNITS)
FROM LINE
GROUP BY P_CODE
HAVING SUM(LINE_UNITS) > (SELECT MAX(LINE_UNITS) FROM
LINE);
```

11. What is the likely data sparsity of the LINE\_UNITS column?
12. Should you create an index? If so, what would the index column(s) be, and why would you create the index? If not, explain your reasoning.
13. Should you create an index on P\_CODE? If so, write the SQL command to create the index. If not, explain your reasoning.
14. Write the command to create statistics for this table.

[Problems 15](#) and [16](#) are based on the following query:

```
SELECT P_CODE, P_QOH*P_PRICE
FROM PRODUCT
WHERE P_QOH*P_PRICE > (SELECT AVG(P_QOH*P_PRICE) FROM
PRODUCT);
```

15. What is the likely data sparsity of the P\_QOH and P\_PRICE columns?
16. Should you create an index? If so, what would the index column(s) be, and why should you create the index?

[Problems 17–21](#) are based on the following query:

```
SELECT V_CODE, V_NAME, V_CONTACT, V_STATE
FROM VENDOR
WHERE V_STATE = 'TN' ORDER BY V_NAME;
```

17. What indexes should you create and why? Write the SQL command to create the indexes.
18. Assume that 10,000 vendors are distributed as shown in [Table P11.18](#). What percentage of rows will be returned by the query?

---

TABLE P11.18

---

| STATE | NUMBER OF VENDORS | STATE | NUMBER OF VENDORS |
|-------|-------------------|-------|-------------------|
| AK    | 15                | MS    | 47                |
| AL    | 55                | NC    | 358               |
| AZ    | 100               | NH    | 25                |
| CA    | 3244              | NJ    | 645               |
| CO    | 345               | NV    | 16                |
| FL    | 995               | OH    | 821               |
| GA    | 75                | OK    | 62                |
| HI    | 68                | PA    | 425               |
| IL    | 89                | RI    | 12                |
| IN    | 12                | SC    | 65                |
| KS    | 19                | SD    | 74                |
| KY    | 45                | TN    | 113               |
| LA    | 29                | TX    | 589               |
| MD    | 208               | UT    | 36                |
| MI    | 745               | VA    | 375               |
| MO    | 35                | WA    | 258               |

19. What type of I/O database operations would most likely be used to execute the query?
20. Using [Table 11.4](#) as an example, create two alternative access plans.
21. Assume that you have 10,000 different products stored in the PRODUCT table and that you are writing a Web-based interface to list all products with a quantity on hand (P\_QOH) that is less than or equal to the minimum quantity, P\_MIN. What optimizer hint would you use to ensure that your query returns the result set to the Web interface in the least time possible? Write the SQL code.

[Problems 22–24](#) are based on the following query:

```

SELECT P_CODE, P_DESCRPT, P_PRICE, P.V_CODE, V.STATE
FROM PRODUCT P, VENDOR V
WHERE P.V_CODE = V.V_CODE
 AND V.STATE = 'NY'
 AND V.AREACODE = '212'
ORDER BY P_PRICE;

```

22. What indexes would you recommend?
23. Write the commands required to create the indexes you recommended in [Problem 22](#).
24. Write the command(s) used to generate the statistics for the PRODUCT and VENDOR tables.

[Problems 25](#) and [26](#) are based on the following query:

```
SELECT P_CODE, P_DESCRIPTOR, P_QOH, P_PRICE, V_CODE
FROM PRODUCT
WHERE V_CODE = '21344'
ORDER BY P_CODE;
```

25. What index would you recommend, and what command would you use?
26. How should you rewrite the query to ensure that it uses the index you created in your solution to [Problem 25](#)?

[Problems 27](#) and [28](#) are based on the following query:

```
SELECT P_CODE, P_DESCRIPTOR, P_QOH, P_PRICE, V_CODE
FROM PRODUCT
WHERE P_QOH < P_MIN
 AND P_MIN = P_REORDER
 AND P_REORDER = 50
ORDER BY P_QOH;
```

27. Use the recommendations given in [Section 11.5.2](#) to rewrite the query and produce the required results more efficiently.
28. What indexes would you recommend? Write the commands to create those indexes.

[Problems 29–32](#) are based on the following query:

```
SELECT CUS_CODE, MAX(LINE_UNITS*LINE_PRICE)
FROM CUSTOMER NATURAL JOIN INVOICE NATURAL JOIN LINE
WHERE CUS_AREACODE = '615'
GROUP BY CUS_CODE;
```

29. Assuming that you generate 15,000 invoices per month, what recommendation would you give the designer about the use of derived attributes?
30. Assuming that you follow the recommendations you gave in [Problem 29](#), how would you rewrite the query?
31. What indexes would you recommend for the query you wrote in [Problem 30](#), and what SQL commands would you use?
32. How would you rewrite the query to ensure that the index you created in [Problem 31](#) is used?

---

## 12 DISTRIBUTED DATABASE MANAGEMENT SYSTEMS

---

In this chapter, you will learn:

- About distributed database management systems (DDBMSs) and their components
  - How database implementation is affected by different levels of data and process distribution
  - How transactions are managed in a distributed database environment
  - How distributed database design draws on data partitioning and replication to balance performance, scalability, and availability
  - About the trade-offs of implementing a distributed data system
- 

## Preview

---

In this chapter, you will learn that a single database can be divided into several fragments. The fragments can be stored on different computers within a geographically dispersed network. Processing also can be dispersed among several different network sites, or nodes. The multisite database forms the core of the distributed database system.

The growth of distributed database systems has been fostered by the increased globalization of business operations, along with the rapid pace of technological change that has made distributed network-based services practical, more reliable, and cost-effective.

Although a distributed database system requires a more sophisticated DBMS, the end user should not be burdened by increased operational complexity. That is, the greater complexity of a distributed database system should be transparent to the end user.

The distributed database management system (DDBMS) treats a distributed database as a single logical database; therefore, the basic design concepts you learned in earlier chapters apply. However, although the end user need not be aware of the distributed database's special characteristics, the distribution of data

among different sites in a computer network clearly adds to the system's complexity. For example, the design of a distributed database must consider the location of the data, the partitioning of the data into database fragments, and the replication of those fragments.

In today's Web-centric environment, any distributed data system must be highly scalable; in other words, it must grow dynamically as demand increases. As demand grows, so do the system's processing needs and inherent complexity. To accommodate such dynamic growth, trade-offs must be made to achieve some desirable properties.

---

---

## 12.1 THE EVOLUTION OF DISTRIBUTED DATABASE MANAGEMENT SYSTEMS

---

---

A **distributed database management system (DDBMS)** governs the storage and processing of logically related data over interconnected computer systems in which both data and processing are distributed among several sites. To understand how and why the DDBMS is different from the DBMS, it is useful to briefly examine the changes in the business environment that set the stage for the development of the DDBMS.

During the 1970s, corporations implemented centralized database management systems to meet their structured information needs. The use of a centralized database required that corporate data be stored in a single central site, usually a mainframe computer. Data access was provided through dumb terminals. The centralized approach, illustrated in [Figure 12.1](#), worked well to fill the structured information needs of corporations, but it fell short when quickly moving events required faster response times and equally quick access to information. The slow progression from information request to approval to specialist to user simply did not serve decision makers well in a dynamic environment. What was needed was quick, unstructured access to databases, using ad hoc queries to generate on-the-spot information.

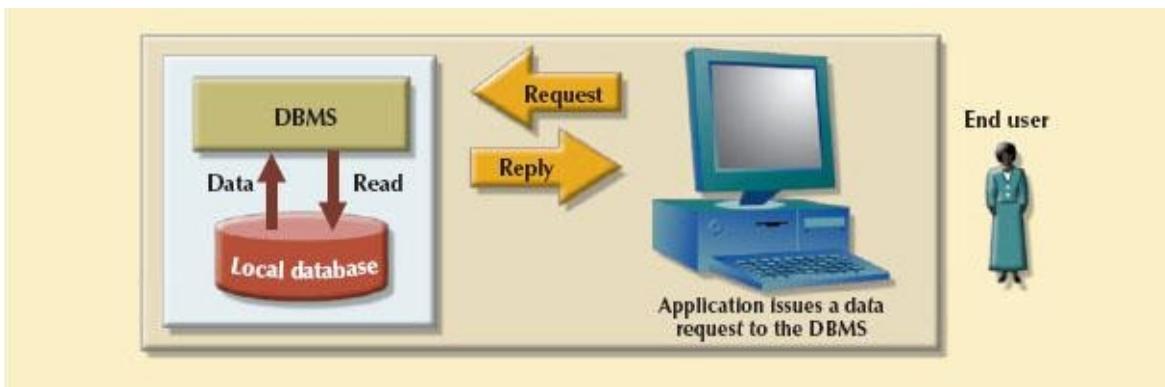
---

---

**FIGURE 12.1 Centralized database management system**

---

---



SOURCE: Course Technology/Cengage Learning

---

The last two decades gave birth to a series of crucial social and technological changes that affected the nature of the systems and the data they use:

- Business operations became global; with this change, competition expanded from the shop on the next corner to the Web store in cyberspace.
- Customer demands and market needs favored an on-demand transaction style, mostly based on Web-based services.
- Rapid social and technological changes fueled by low-cost, smart mobile devices increased the demand for complex and fast networks to interconnect them. As a consequence, corporations have increasingly adopted advanced network technologies as the platform for their computerized solutions. See [Chapter 14](#), Database Connectivity and Web Technologies, for a discussion of cloud-based services.
- Data realms are converging in the digital world more frequently. As a result, applications must manage multiple types of data, such as voice, video, music, and images. Such data tend to be geographically distributed and remotely accessed from diverse locations via location-aware mobile devices.

These factors created a dynamic business environment in which companies had to respond quickly to competitive and technological pressures. As large business

units restructured to form leaner, quickly reacting, dispersed operations, two database requirements became obvious:

- *Rapid ad hoc data access* became crucial in the quick-response decision-making environment.
- *Distributed data access* was needed to support geographically dispersed business units.

During recent years, these factors became even more firmly entrenched. However, the way they were addressed was strongly influenced by the following factors:

- *The growing acceptance of the Internet as the platform for data access and distribution.* The World Wide Web is effectively the repository for distributed data.
- *The mobile wireless revolution.* The widespread use of mobile wireless digital devices includes smart phones such as Apple's iPhone and RIM's BlackBerry and tablets such as Apple's iPad, Motorola Xoom, and Samsung Galaxy. These devices have created high demand for data access. They access data from geographically dispersed locations and require varied data exchanges in multiple formats, such as data, voice, video, music, and pictures. Although distributed data access does not necessarily imply distributed databases, performance and failure tolerance requirements often lead to the use of data replication techniques similar to those in distributed databases.
- *The accelerated growth of companies using “applications as a service.”* This new type of service provides remote applications to companies that want to outsource their application development, maintenance, and operations. The company data are generally stored on central servers and are not necessarily distributed. Just as with mobile data access, this type of service may not require fully distributed data functionality; however, other factors such as performance and failure tolerance often require the use of data replication techniques similar to those in distributed databases.

- *The increased focus on mobile business intelligence.* More and more companies are embracing mobile technologies within their business plans. As companies use social networks to get closer to customers, the need for on-the-spot decision making increases. Although a data warehouse is not usually a distributed database, it does rely on techniques such as data replication and distributed queries that facilitate data extraction and integration. (You will learn more about this topic in [Chapter 13](#), Business Intelligence and Data Warehouses.)
- 



## ONLINE CONTENT

To learn more about the Internet's impact on data access and distribution, see **Appendix I, Databases in Electronic Commerce**, at [www.cengagebrain.com](http://www.cengagebrain.com).

---

At this point, the long-term impact of the Internet and the mobile revolution on *distributed* database design and management is just starting to be felt. Perhaps the success of the Internet and mobile technologies will foster the use of distributed databases as bandwidth becomes a less troublesome bottleneck. Perhaps the resolution of bandwidth problems will simply confirm the centralized database standard. In any case, distributed database concepts and components are likely to find a place in future database development, particularly for specialized mobile and location-aware applications.

The distributed database is especially desirable because centralized database management is subject to problems such as:

- *Performance degradation* because of a growing number of remote locations over greater distances
- *High costs* associated with maintaining and operating large central (mainframe) database systems and physical infrastructure
- *Reliability problems* created by dependence on a central site (single point of failure syndrome) and the need for data replication
- *Scalability problems* associated with the physical limits imposed by a single location, such as physical space, temperature conditioning, and power consumption

- *Organizational rigidity* imposed by the database, which means it might not support the flexibility and agility required by modern global organizations

The dynamic business environment and the centralized database's shortcomings spawned a demand for applications based on accessing data from different sources at multiple locations. Such a multiple-source/multiple-location database environment is best managed by a DDBMS.

---

## 12.2 DDBMS ADVANTAGES AND DISADVANTAGES

---

Distributed database management systems deliver several advantages over traditional systems. At the same time, they are subject to some problems. [Table 12.1](#) summarizes the advantages and disadvantages associated with a DDBMS.

---

**TABLE 12.1 Distributed DBMS Advantages and Disadvantages**

---

### ADVANTAGES

- *Data are located near the site of greatest demand.* The data in a distributed database system are dispersed to match business requirements.
- *Faster data access.* End users often work with only the nearest stored subset of the data.

### DISADVANTAGES

- *Complexity of management and control.* Applications must recognize data location, and they must be able to stitch together data from various sites. Database administrators must have the ability to coordinate database activities to prevent database degradation due to data anomalies.
- *Technological difficulty.* Data integrity, transaction management, concurrency control, security, backup, recovery, and query optimization must all be addressed and resolved.

- *Faster data processing.* A distributed database system spreads out the system's workload by processing data at several sites.
- *Growth facilitation.* New sites can be added to the network without affecting the operations of other sites.
- Improved communications. Because local sites are smaller and located closer to customers, local sites foster better communication among departments and between customers and company staff.
- *Reduced operating costs.* It is more cost-effective to add nodes to a network than to update a mainframe system. Development work is done more cheaply and quickly on low-cost PCs than on mainframes.
- *User-friendly interface.* PCs and workstations are usually equipped with an easy-to-use graphical user interface (GUI). The GUI simplifies training and use for end users.
- *Less danger of a single-point failure.* When one of the computers fails, the workload
- *Security.* The probability of security lapses increases when data are located at multiple sites. The responsibility of data management will be shared by different people at several sites.
- *Lack of standards.* There are no standard communication protocols at the database level. For example, different database vendors employ different and often incompatible techniques to manage the distribution of data and processing in a DDBMS environment.
- *Increased storage and infrastructure requirements.* Multiple copies of data are required at different sites, thus requiring additional storage space.
- *Increased training cost.* Training costs are generally higher in a distributed model than they would be in a centralized model, sometimes even to the extent of offsetting operational and hardware savings.
- *Costs.* Distributed databases require duplicated infrastructure to operate, such as physical location, environment, personnel, software, and licensing.

is picked up by other workstations. Data are also distributed at multiple sites.

- Processor independence. The end user can access any available copy of the data, and an end user's request is processed by any processor at the data location.
- 

Distributed databases are being used successfully in many Web staples such as Google and Amazon, but they still have a long way to go before they yield the full flexibility and power they theoretically possess.

The remainder of this chapter explores the basic components and concepts of the distributed database. Because the distributed database is usually based on the relational database model, relational terminology is used to explain the basic concepts and components. Even though some of the most widely used distributed databases are part of the NoSQL movement (see [Chapter 2](#), Data Models), the basic concepts and fundamentals of distributed data still apply to them.

---

### 12.3 DISTRIBUTED PROCESSING AND DISTRIBUTED DATABASES

---

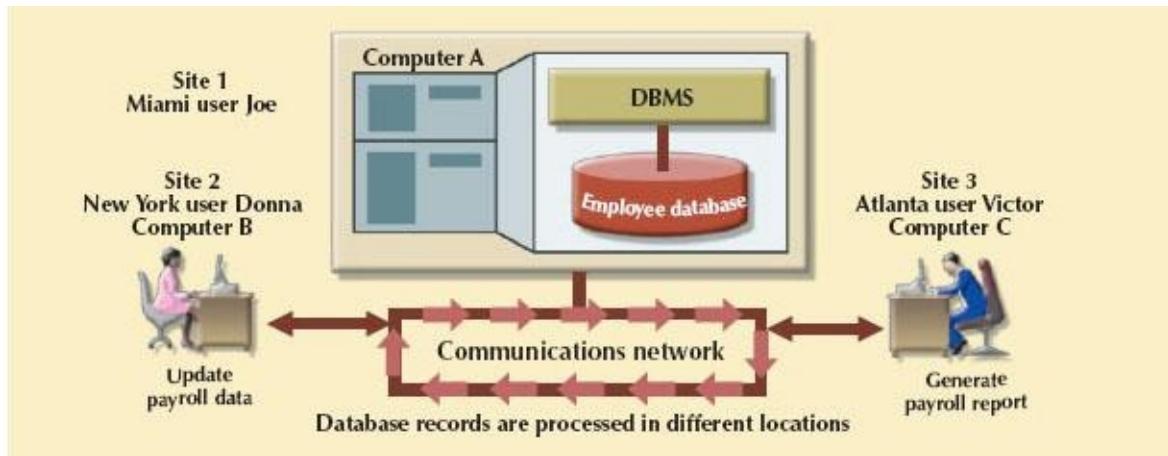
In **distributed processing**, a database's logical processing is shared among two or more physically independent sites that are connected through a network. For example, the data input/output (I/O), data selection, and data validation might be performed on one computer, and a report based on that data might be created on another computer.

A basic distributed processing environment is illustrated in [Figure 12.2](#), which shows that a distributed processing system shares the database processing chores among three sites connected through a communications network. Although the database resides at only one site (Miami), each site can access the data and update the database. The database is located on Computer A, a network computer known as the *database server*.

---

**FIGURE 12.2 Distributed processing environment**

---



SOURCE: Course Technology/Cengage Learning

---

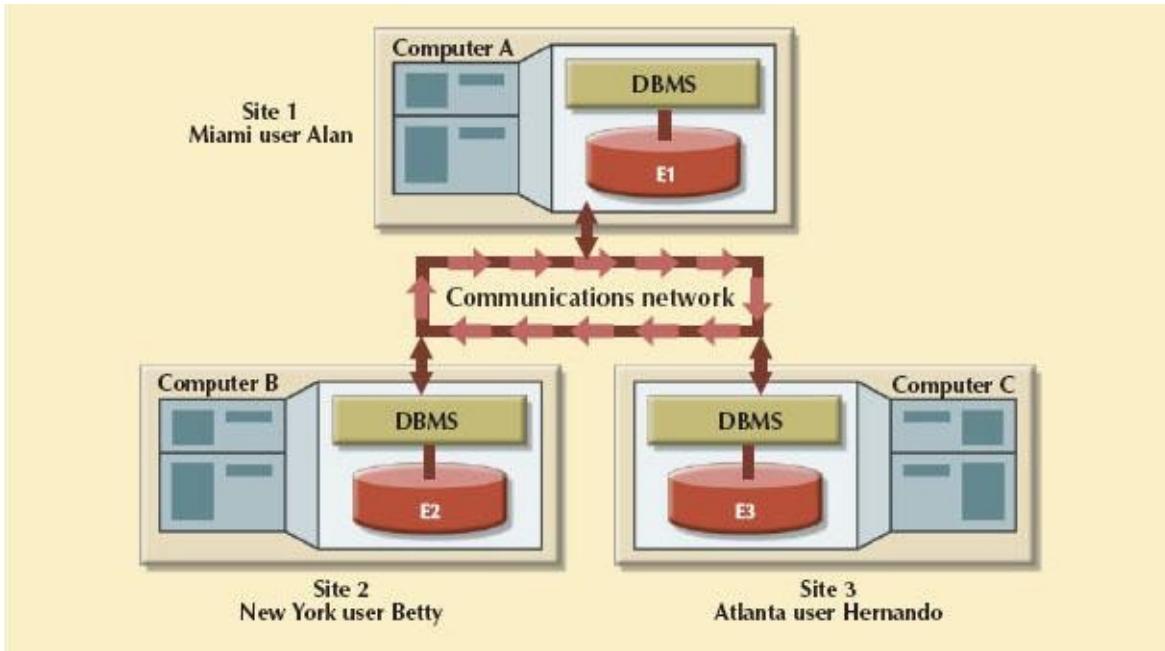
A **distributed database**, on the other hand, stores a logically related database over two or more physically independent sites. The sites are connected via a computer network. In contrast, the distributed processing system uses only a single-site database but shares the processing chores among several sites. In a distributed database system, a database is composed of several parts known as **database fragments**. The database fragments are located at different sites and can be replicated among various sites. Each database fragment is, in turn, managed by its local database process. An example of a distributed database environment is shown in [Figure 12.3](#).

---

---

**FIGURE 12.3 Distributed database environment**

---



SOURCE: Course Technology/Cengage Learning

The database in [Figure 12.3](#) is divided into three database fragments (E1, E2, and E3) located at different sites. The computers are connected through a network system. In a fully distributed database, the users Alan, Betty, and Hernando do not need to know the name or location of each database fragment in order to access the database. Also, the users might be at sites other than Miami, New York, or Atlanta and still be able to access the database as a single logical unit.

As you examine [Figures 12.2](#) and [12.3](#), keep the following points in mind:

- Distributed processing does not require a distributed database, but a distributed database requires distributed processing. (Each database fragment is managed by its own local database process.)
- Distributed processing may be based on a single database located on a single computer. For the management of distributed data to occur, copies or parts of the database processing functions must be distributed to all data storage sites.
- Both distributed processing and distributed databases require a network of interconnected components.

---

## 12.4 CHARACTERISTICS OF DISTRIBUTED DATABASE MANAGEMENT SYSTEMS

---

A DDBMS governs the storage and processing of logically related data over interconnected computer systems in which both data and processing functions are distributed among several sites. A DBMS must have at least the following functions to be classified as distributed:

- *Application interface* to interact with the end user, application programs, and other DBMSs within the distributed database
- *Validation* to analyze data requests for syntax correctness
- *Transformation* to decompose complex requests into atomic data request components
- *Query optimization* to find the best access strategy (which database fragments must be accessed by the query, and how must data updates, if any, be synchronized?)
- *Mapping* to determine the data location of local and remote fragments
- *I/O interface* to read or write data from or to permanent local storage
- *Formatting* to prepare the data for presentation to the end user or to an application program
- *Security* to provide data privacy at both local and remote databases
- *Backup and recovery* to ensure the availability and recoverability of the database in case of a failure
- *DB administration features* for the database administrator
- *Concurrency control* to manage simultaneous data access and to ensure data consistency across database fragments in the DDBMS
- *Transaction management* to ensure that the data move from one consistent state to another; this activity includes the synchronization of local and remote transactions as well as transactions across multiple distributed segments

A fully distributed database management system must perform all of the functions of a centralized DBMS, as follows:

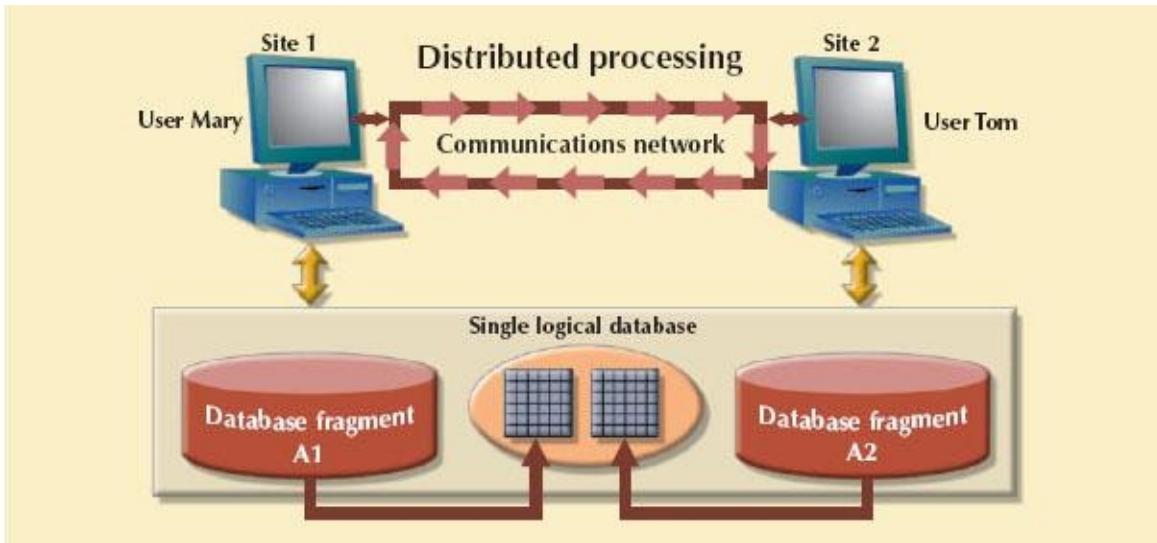
1. Receive the request of an application or end user.
2. Validate, analyze, and decompose the request. The request might include mathematical and logical operations such as the following: Select all customers with a balance greater than \$1,000. The request might require data from only a single table, or it might require access to several tables.
3. Map the request's logical-to-physical data components.
4. Decompose the request into several disk I/O operations.
5. Search for, locate, read, and validate the data.
6. Ensure database consistency, security, and integrity.
7. Validate the data for the conditions, if any, specified by the request.
8. Present the selected data in the required format.

In addition, a distributed DBMS must handle all necessary functions imposed by the distribution of data and processing, and it must perform those additional functions *transparently* to the end user. The DDBMS's transparent data access features are illustrated in [Figure 12.4](#).

---

**FIGURE 12.4 A fully distributed database management system**

---



SOURCE: Course Technology/Cengage Learning

---

The single logical database in [Figure 12.4](#) consists of two database fragments, A1 and A2, located at sites 1 and 2, respectively. Mary can query the database as if it were a local database; so can Tom. Both users “see” only one logical database and *do not need to know the names of the fragments*. In fact, the end users do not even need to know that the database is divided into fragments, *nor do they need to know where the fragments are located*.

To better understand the different types of distributed database scenarios, first consider the components of the distributed database system.

---

## 12.5 DDBMS COMPONENTS

---

The DDBMS must include at least the following components:

- *Computer workstations or remote devices* (sites or nodes) that form the network system. The distributed database system must be independent of the computer system hardware.
  
  
  
- *Network hardware and software* components that reside in each workstation or device. The network components allow all sites to interact and exchange data. Because the components—computers, operating

systems, network hardware, and so on—are likely to be supplied by different vendors, it is best to ensure that distributed database functions can be run on multiple platforms.

- *Communications media* that carry the data from one node to another. The DDBMS must be communications media-independent; that is, it must be able to support several types of communications media.
- The **transaction processor (TP)**, which is the software component found in each computer or device that requests data. The transaction processor receives and processes the application's remote and local data requests. The TP is also known as the **application processor (AP)** or the **transaction manager (TM)**.
- The **data processor (DP)**, which is the software component residing on each computer or device that stores and retrieves data located at the site. The DP is also known as the **data manager (DM)**. A data processor may even be a centralized DBMS.

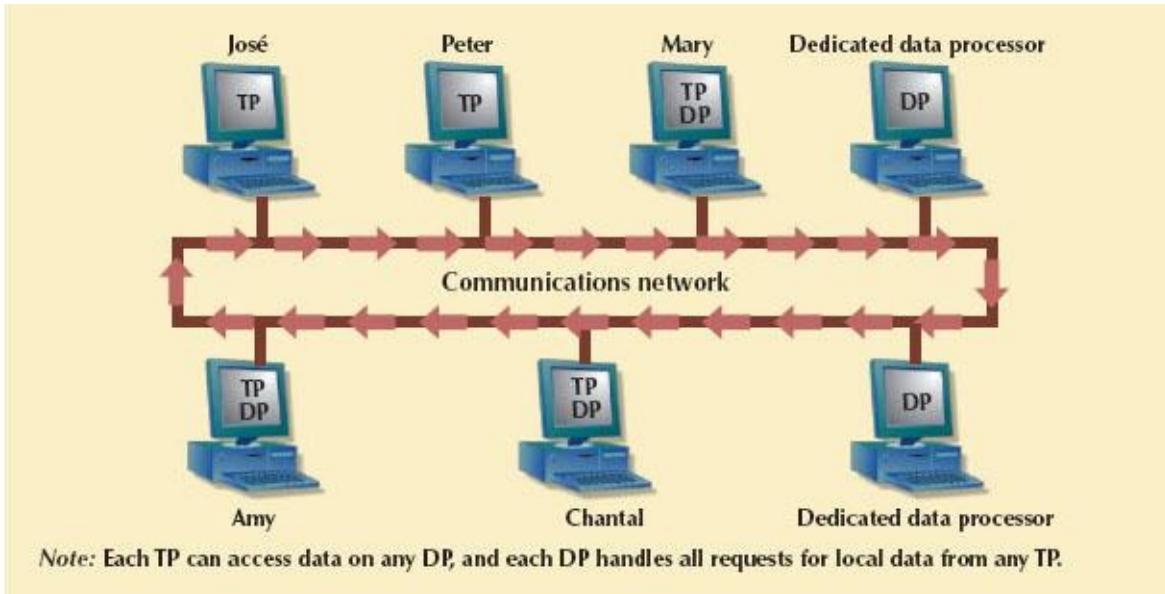
---

**Figure 12.5** illustrates the placement of the components and the interaction among them. The communication among TPs and DPs is made possible through a specific set of rules, or *protocols*, used by the DDBMS.

---

**FIGURE 12.5 Distributed database system management components**

---



SOURCE: Course Technology/Cengage Learning

The protocols determine how the distributed database system will:

- Interface with the network to transport data and commands between DPs and TPs.
- Synchronize all data received from DPs (TP side) and route retrieved data to the appropriate TPs (DP side).
- Ensure common database functions in a distributed system. Such functions include data security, transaction management and concurrency control, data partitioning and synchronization, and data backup and recovery.

DPS and TPs should be added to the system transparently without affecting its operation. A TP and a DP can reside on the same computer, allowing the end user to access both local and remote data transparently. In theory, a DP can be an independent centralized DBMS with proper interfaces to support remote access from other independent DBMSs in the network.

## 12.6 LEVELS OF DATA AND PROCESS DISTRIBUTION

---

Current database systems can be classified on the basis of how process distribution and data distribution are supported. For example, a DBMS may store data in a single site (using a centralized DB) or in multiple sites (using a distributed DB), and may support data processing at one or more sites. [Table 12.2](#) uses a simple matrix to classify database systems according to data and process distribution. These types of processes are discussed in the sections that follow.

---

TABLE 12.2 Database Systems: Levels of Data and Process Distribution

---

### SINGLE-SITE DATA      MULTIPLESITE DATA

|                      |                                              |                                                 |
|----------------------|----------------------------------------------|-------------------------------------------------|
| Single-site process  | Host DBMS                                    | Not applicable<br>(Requires multiple processes) |
| Multiplesite process | File server<br>Client/server DBMS (LAN DBMS) | Fully distributed<br>Client/server DDBMS        |

---

#### 12.6.1 SINGLE-SITE PROCESSING, SINGLE-SITE DATA

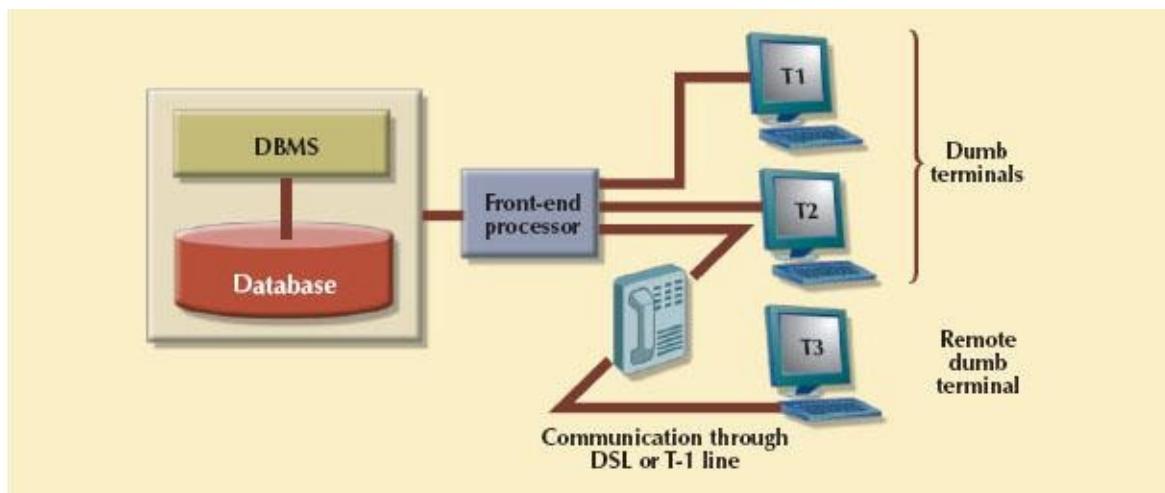
---

In the [\*\*single-site processing, single-site data \(SPSD\)\*\*](#) scenario, all processing is done on a single host computer and all data are stored on the host computer's local disk system. Processing cannot be done on the end user's side of the system. Such a scenario is typical of most mainframe and midrange UNIX/Linux server DBMSs. The DBMS is on the host computer, which is accessed by terminals connected to it (see [Figure 12.6](#)). This scenario is also typical of the first generation of single-user microcomputer databases.

---

**FIGURE 12.6 Single-site processing, single-site data (centralized)**

---



SOURCE: Course Technology/Cengage Learning

---

Using [Figure 12.6](#) as an example, you can see that the functions of the TP and DP are embedded within the DBMS on the host computer. The DBMS usually runs under a time-sharing, multitasking operating system, which allows several processes to run concurrently on a host computer accessing a single DP. All data storage and data processing are handled by a single host computer.

#### 12.6.2 MULTIPLE-SITE PROCESSING, SINGLE-SITE DATA

---

Under the [\*\*multiplesite processing, single-site data \(MPSD\)\*\*](#) scenario, multiple processes run on different computers that share a single data repository. Typically, the MPSD scenario requires a network file server running conventional applications that are accessed through a network. Many multiuser accounting applications running under a personal computer network fit such a description (see [Figure 12.7](#)).

As you examine [Figure 12.7](#), note that:

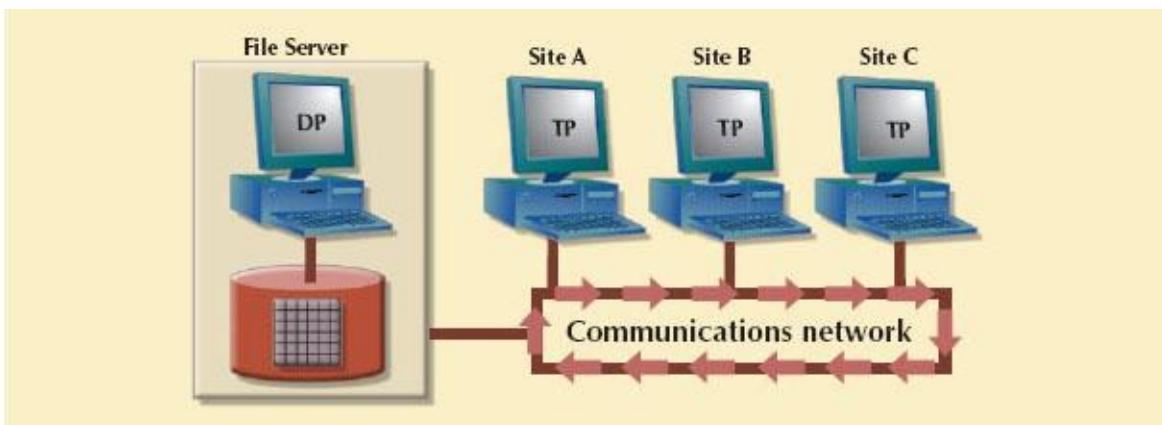
- The TP on each workstation acts only as a redirector to route all network data requests to the file server.

- The end user sees the file server as just another hard disk. Because only the data storage input/output (I/O) is handled by the file server's computer, the MPSD offers limited capabilities for distributed processing.
  - The end user must make a direct reference to the file server to access remote data. All record-and file-locking activities are performed at the end-user location.
- 
- All data selection, search, and update functions take place at the workstation, thus requiring that entire files travel through the network for processing at the workstation. Such a requirement increases network traffic, slows response time, and increases communication costs.

---

**FIGURE 12.7 Multiplesite processing, single-site data**

---



SOURCE: Course Technology/Cengage Learning

---

The inefficiency of the last condition can be illustrated easily. For example, suppose that the file server computer stores a CUSTOMER table containing 100,000 data rows, 50 of which have balances greater than \$1,000. Suppose that site A issues the following SQL query:

```
SELECT *
FROM CUSTOMER
```

WHERE CUS\_BALANCE > 1000;

All 100,000 CUSTOMER rows must travel through the network to be evaluated at site A. A variation of the multiplesite processing, single-site data approach is known as client/server architecture. **Client/server architecture** is similar to that of the network file server *except that all database processing is done at the server site, thus reducing network traffic*. Although both the network file server and the client/server systems perform multiplesite processing, the latter's processing is distributed. Note that the network file server approach requires the database to be located at a single site. In contrast, the client/server architecture is capable of supporting data at multiple sites.

---



#### ONLINE CONTENT

Appendix F, Client/Server Systems, is available at [www.cengagebrain.com](http://www.cengagebrain.com).

---

#### 12.6.3 MULTIPLE-SITE PROCESSING, MULTIPLE-SITE DATA

---

The **multiplesite processing, multiplesite data (MPMD)** scenario describes a fully distributed DBMS with support for multiple data processors and transaction processors at multiple sites. Depending on the level of support for various types of databases, DDBMSs are classified as either homogeneous or heterogeneous.

**Homogeneous DDBMSs** integrate multiple instances of the same DBMS over a network—for example, multiple instances of Oracle 11g running on different platforms. In contrast, **heterogeneous DDBMSs** integrate different types of DBMSs over a network, but all support the same data model. For example, [Table 12.3](#) lists several relational database systems that could be integrated within a DDBMS. A **fully heterogeneous DDBMS** will support different DBMSs, each one supporting a different data model, running under different computer systems.

---

**TABLE 12.3 Heterogeneous Distributed Database Scenario**

---

| PLATFORM       | DBMS     | OPERATING SYSTEM    | NETWORK COMMUNICATIONS PROTOCOL |
|----------------|----------|---------------------|---------------------------------|
| IBM 3090       | DB2      | MVS                 | APPCLU 6.2                      |
| IBM AS/400     | SQL/400  | OS/400              | 3270                            |
| RISC computer  | Informix | UNIX                | TCP/IP                          |
| Intel Xeon CPU | Oracle   | Windows Server 2008 | TCP/IP                          |

Distributed database implementations are better understood as an abstraction layer on top of a DBMS. This abstraction layer provides additional functionality that enables support for distributed database features, including straightforward data links, replication, advanced data fragmentation, synchronization, and integration. In fact, most database vendors provide for increasing levels of data fragmentation, replication, and integration. Therefore, the support for distributed databases can be better seen as a continuous spectrum that goes from homogeneous to fully heterogeneous distributed data management. Consequently, at any point on this spectrum, a DDBMS is subject to certain restrictions. For example:

- Remote access is provided on a read-only basis and does not support write privileges.
- Restrictions are placed on the number of remote tables that may be accessed in a single transaction.
- Restrictions are placed on the number of distinct databases that may be accessed.
- Restrictions are placed on the database model that may be accessed. Thus, access may be provided to relational databases but not to network or hierarchical databases.

The preceding list of restrictions is by no means exhaustive. The DDBMS technology continues to change rapidly, and new features are added frequently. (In [Chapter 2](#), you learned about the latest generation of NoSQL databases that provide high levels of data distribution.) Managing data at multiple sites leads to a number of issues that must be addressed and understood. The next section examines several key features of distributed database management systems.

---

## 12.7 DISTRIBUTED DATABASE TRANSPARENCY FEATURES

---

A distributed database system should provide some desirable transparency features that make all the system's complexities hidden to the end user. In other words, the end user should have the sense of working with a centralized DBMS. For this reason, the minimum desirable DDBMS transparency features are:

- **Distribution transparency**, which allows a distributed database to be treated as a single logical database. If a DDBMS exhibits distribution transparency, the user does not need to know:
  - That the data are partitioned—meaning the table's rows and columns are split vertically or horizontally and stored among multiple sites
  - That the data are geographically dispersed among multiple sites
  - That the data are replicated among multiple sites
- **Transaction transparency**, which allows a transaction to update data at more than one network site. Transaction transparency ensures that the transaction will be either entirely completed or aborted, thus maintaining database integrity.
- **Failure transparency**, which ensures that the system will continue to operate in the event of a node or network failure. Functions that were lost because of the failure will be picked up by another network node. This is a very important feature, particularly in organizations that depend on Web presence as the backbone for maintaining trust in their business.
- **Performance transparency**, which allows the system to perform as if it were a centralized DBMS. The system will not suffer any performance degradation due to its use on a network or because of the network's platform differences. Performance transparency also ensures that the system will find the most cost-effective path to access remote data. The system should be able to “scale out” in a transparent manner, or increase performance capacity by adding more transaction or data-processing nodes, without affecting the overall performance of the system.

- **Heterogeneity transparency**, which allows the integration of several different local DBMSs (relational, network, and hierarchical) under a common, or global, schema. The DDBMS is responsible for translating the data requests from the global schema to the local DBMS schema.

The following sections discuss each of these transparency features in greater detail.

---

## 12.8 DISTRIBUTION TRANSPARENCY

---

Distribution transparency allows a physically dispersed database to be managed as though it were a centralized database. The level of transparency supported by the DDBMS varies from system to system. Three levels of distribution transparency are recognized:

- **Fragmentation transparency** is the highest level of transparency. The end user or programmer does not need to know that a database is partitioned. Therefore, neither fragment names nor fragment locations are specified prior to data access.
- **Location transparency** exists when the end user or programmer must specify the database fragment names but does not need to specify where those fragments are located.
- **Local mapping transparency** exists when the end user or programmer must specify both the fragment names and their locations.

Transparency features are summarized in [Table 12.4](#).

---

TABLE 12.4 Summary of Transparency Features

---

| IF THE SQL STATEMENT REQUIRES: |                |                            |                                    |
|--------------------------------|----------------|----------------------------|------------------------------------|
| FRAGMENT NAME?                 | LOCATION NAME? | THEN THE DBMS SUPPORTS     | LEVEL OF DISTRIBUTION TRANSPARENCY |
| Yes                            | Yes            | Local mapping transparency | Low                                |
| Yes                            | No             | Location transparency      | Medium                             |
| No                             | No             | Fragmentation transparency | High                               |

---

#### NOTE

---

As you examine [Table 12.4](#), notice that there is no reference to a situation in which the fragment name is “No” and the location name is “Yes.” The reason is simple: you cannot have a location name that fails to reference an existing fragment. If you don’t need to specify a fragment name, its location is clearly irrelevant.

---

To illustrate the use of various transparency levels, suppose you have an EMPLOYEE table that contains the attributes EMP\_NAME, EMP\_DOB, EMP\_ADDRESS, EMP\_DEPARTMENT, and EMP\_SALARY. The EMPLOYEE data are distributed over three different locations: New York, Atlanta, and Miami. The table is divided by location; that is, New York employee data are stored in fragment E1, Atlanta employee data are stored in fragment E2, and Miami employee data are stored in fragment E3 (see [Figure 12.8](#)).

Now suppose that the end user wants to list all employees born before January 1, 1960. To focus on the transparency issues, also suppose that the EMPLOYEE table is fragmented and each fragment is unique. The **unique fragment** condition indicates that each row is unique, regardless of the fragment in which it is located. Finally, assume that no portion of the database is replicated at any other site on the network.

Depending on the level of distribution transparency support, you may examine three query cases.

---

**FIGURE 12.8 Fragment locations**

---



SOURCE: Course Technology/Cengage Learning

### **Case 1: The Database Supports Fragmentation Transparency**

The query conforms to a nondistributed database query format; that is, it does not specify fragment names or locations. The query reads:

```
SELECT *
FROM EMPLOYEE
WHERE EMP_DOB < '01-JAN-1960';
```

### **Case 2: The Database Supports Location Transparency**

Fragment names must be specified in the query, but the fragment's location is not specified. The query reads:

```
SELECT *
FROM E1
WHERE EMP_DOB < '01-JAN-1960';
```

## **UNION**

```
SELECT *
FROM E2
WHERE EMP_DOB < '01-JAN-1960';
```

## **UNION**

```
SELECT *
```

```
FROM E3
WHERE EMP_DOB < '01-JAN-1960';
```

### **Case 3: The Database Supports Local Mapping Transparency**

Both the fragment name and its location must be specified in the query. Using pseudo-SQL:

```
SELECT *
FROM E1 NODE NY
WHERE EMP_DOB < '01-JAN-1960';
```

## **UNION**

```
SELECT *
FROM E2 NODE ATL
WHERE EMP_DOB < '01-JAN-1960';
```

## **UNION**

```
SELECT *
FROM E3 NODE MIA
WHERE EMP_DOB < '01-JAN-1960';
```

---

#### **NOTE**

---

NODE indicates the location of the database fragment. NODE is used for illustration purposes and is not part of the standard SQL syntax.

---

As you examine the preceding query formats, you can see how distribution transparency affects the way end users and programmers interact with the database.

Distribution transparency is supported by a [\*\*distributed data dictionary \(DDD\)\*\*](#)

or a **distributed data catalog (DDC)**. The DDC contains the description of the entire database as seen by the database administrator. The database description, known as the **distributed global schema**, is the common database schema used by local TPs to translate user requests into subqueries (remote requests) that will be processed by different DPs. The DDC is itself distributed, and it is replicated at the network nodes. Therefore, the DDC must maintain consistency through updating at all sites.

Keep in mind that some of the current DDBMS implementations impose limitations on the level of transparency support. For instance, you might be able to distribute a database, but not a table, across multiple sites. Such a condition indicates that the DDBMS supports location transparency but not fragmentation transparency.

---

## 12.9 TRANSACTION TRANSPARENCY

---

Transaction transparency is a DDBMS property that ensures database transactions will maintain the distributed database's integrity and consistency. Remember that a DDBMS database transaction can update data stored in many different computers connected in a network. Transaction transparency ensures that the transaction will be completed only when all database sites involved in the transaction complete their part of the transaction.

Distributed database systems require complex mechanisms to manage transactions and ensure the database's consistency and integrity. To understand how the transactions are managed, you should know the basic concepts governing remote requests, remote transactions, distributed transactions, and distributed requests.

### 12.9.1 DISTRIBUTED REQUESTS AND DISTRIBUTED TRANSACTIONS<sup>1</sup>

---

Whether or not a transaction is distributed, it is formed by one or more database requests. The basic difference between a nondistributed transaction and a distributed transaction is that the latter can update or request data from several different remote sites on a network. To better understand distributed transactions, begin by learning the difference between remote and distributed transactions, using the BEGIN WORK and COMMIT WORK transaction format. Assume the existence of location transparency to avoid having to specify the data location.

A **remote request**, illustrated in [Figure 12.9](#), lets a single SQL statement access the data that are to be processed by a single remote database processor. In other words, the SQL statement (or request) can reference data at only one remote site.

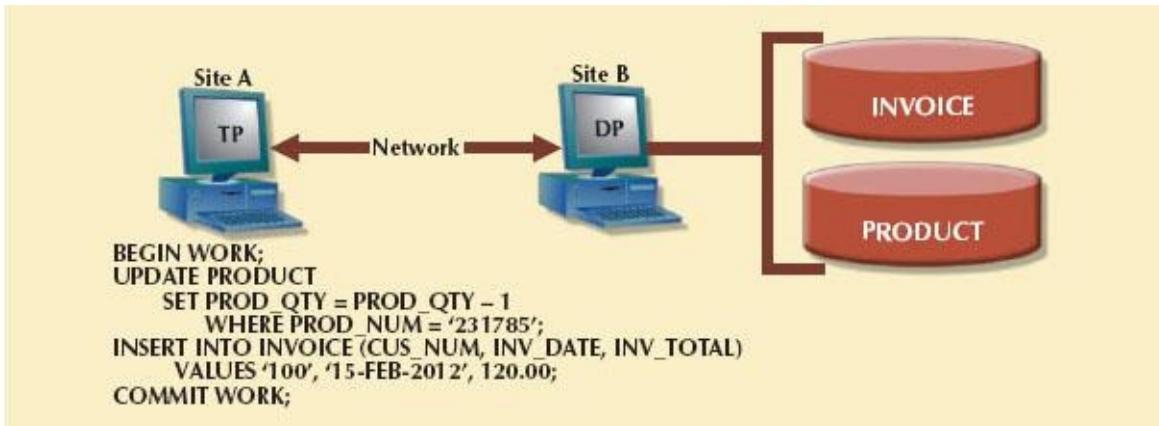
**FIGURE 12.9 A remote request**



SOURCE: Course Technology/Cengage Learning

Similarly, a **remote transaction**, composed of several requests, accesses data at a single remote site. A remote transaction is illustrated in [Figure 12.10](#).

**FIGURE 12.10 A remote transaction**



SOURCE: Course Technology/Cengage Learning

As you examine [Figure 12.10](#), note the following remote transaction features:

- The transaction updates the PRODUCT and INVOICE tables (located at

site B).

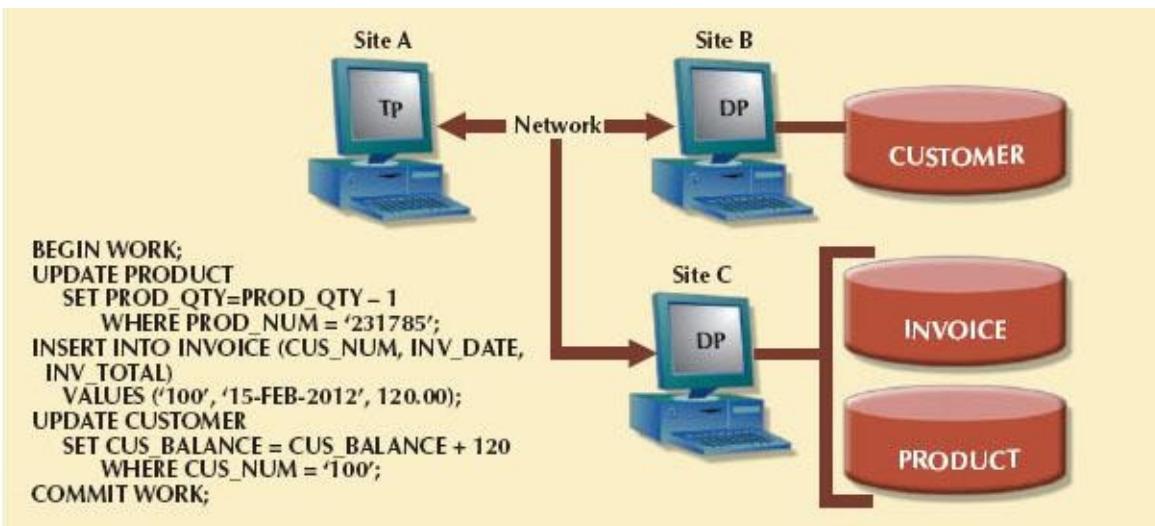
- The remote transaction is sent to the remote site B and executed there.
- The transaction can reference only one remote DP.
- Each SQL statement (or request) can reference only one (the same) remote DP at a time, and the entire transaction can reference and be executed at only one remote DP.

A **distributed transaction** can reference several different local or remote DP sites. Although each single request can reference only one local or remote DP site, the transaction as a whole can reference multiple DP sites because each request can reference a different site. The distributed transaction process is illustrated in [Figure 12.11](#).

---

**FIGURE 12.11 A distributed transaction**

---



SOURCE: Course Technology/Cengage Learning

---

Note the following features in [Figure 12.11](#):

- The transaction references two remote sites, B and C.
- The first two requests, UPDATE PRODUCT and INSERT INTO INVOICE, are processed by the DP at the remote site C, and the last request (UPDATE CUSTOMER) is processed by the DP at the remote site B.
- Each request can access only one remote site at a time.

The third characteristic may create problems. For example, suppose the PRODUCT table is divided into two fragments, PROD1 and PROD2, located at sites B and C, respectively. Given that scenario, the preceding distributed transaction cannot be executed because the following request cannot access data from more than one remote site:

```
SELECT *
FROM PRODUCT
WHERE PROD_NUM = '231785';
```

Therefore, the DBMS must be able to support a distributed request.

A **distributed request** lets a single SQL statement reference data located at several different local or remote DP sites. Because each request (SQL statement) can access data from more than one local or remote DP site, a transaction can access several sites. The ability to execute a distributed request provides fully distributed database processing because you can:

- Partition a database table into several fragments.
- Reference one or more of those fragments with only one request. In other words, there is fragmentation transparency.

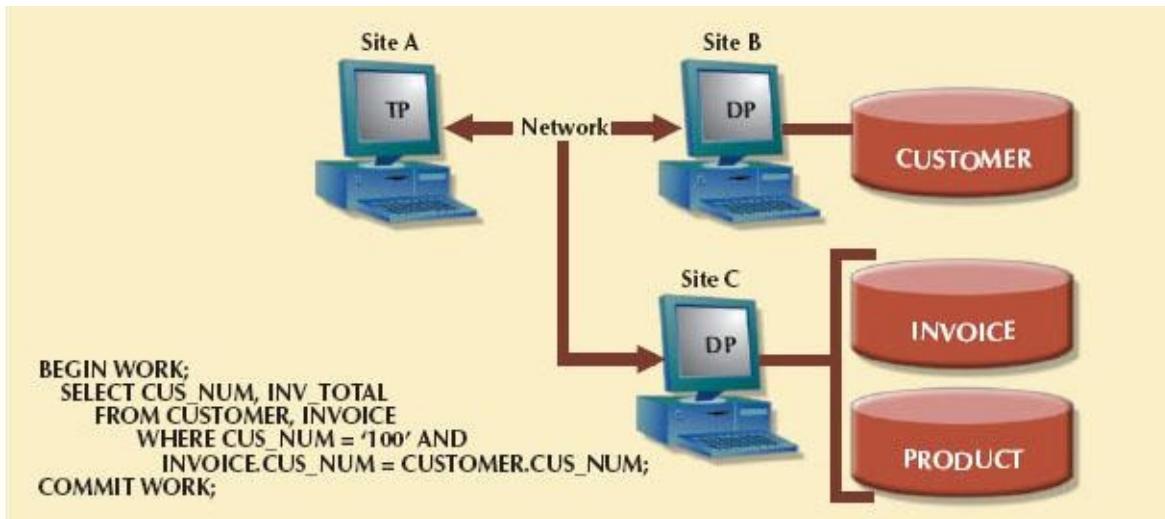
The location and partition of the data should be transparent to the end user. [Figure 12.12](#) illustrates a distributed request. As you examine the figure, note that the transaction uses a single SELECT statement to reference two tables, CUSTOMER and INVOICE. The two tables are located at two different sites, B

and C.

---

**FIGURE 12.12 A distributed request**

---



SOURCE: Course Technology/Cengage Learning

---

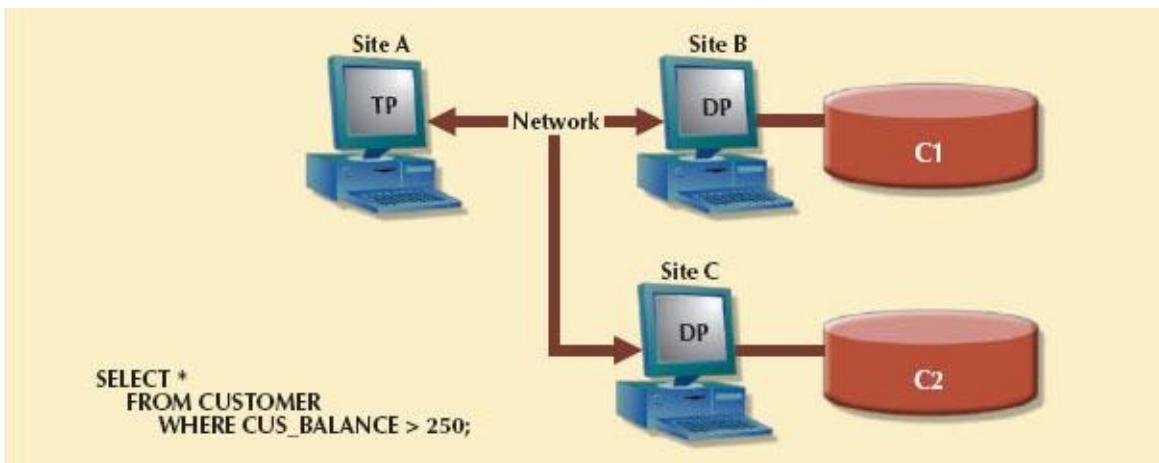
The distributed request feature also allows a single request to reference a physically partitioned table. For example, suppose that a CUSTOMER table is divided into two fragments, C1 and C2, located at sites B and C, respectively. Further suppose that the end user wants to obtain a list of all customers whose balances exceed \$250. The request is illustrated in [Figure 12.13](#). Full fragmentation transparency support is provided only by a DDBMS that supports distributed requests.

---

---

**FIGURE 12.13 Another distributed request**

---



SOURCE: Course Technology/Cengage Learning

---

Understanding the different types of database requests in distributed database systems helps you address the transaction transparency issue more effectively. Transaction transparency ensures that distributed transactions are treated as centralized transactions, ensuring their serializability. (Review [Chapter 10](#), Transaction Management and Concurrency Control, if necessary.) That is, the execution of concurrent transactions, whether they are distributed or not, will take the database from one consistent state to another.

#### 12.9.2 DISTRIBUTED CONCURRENCY CONTROL

---

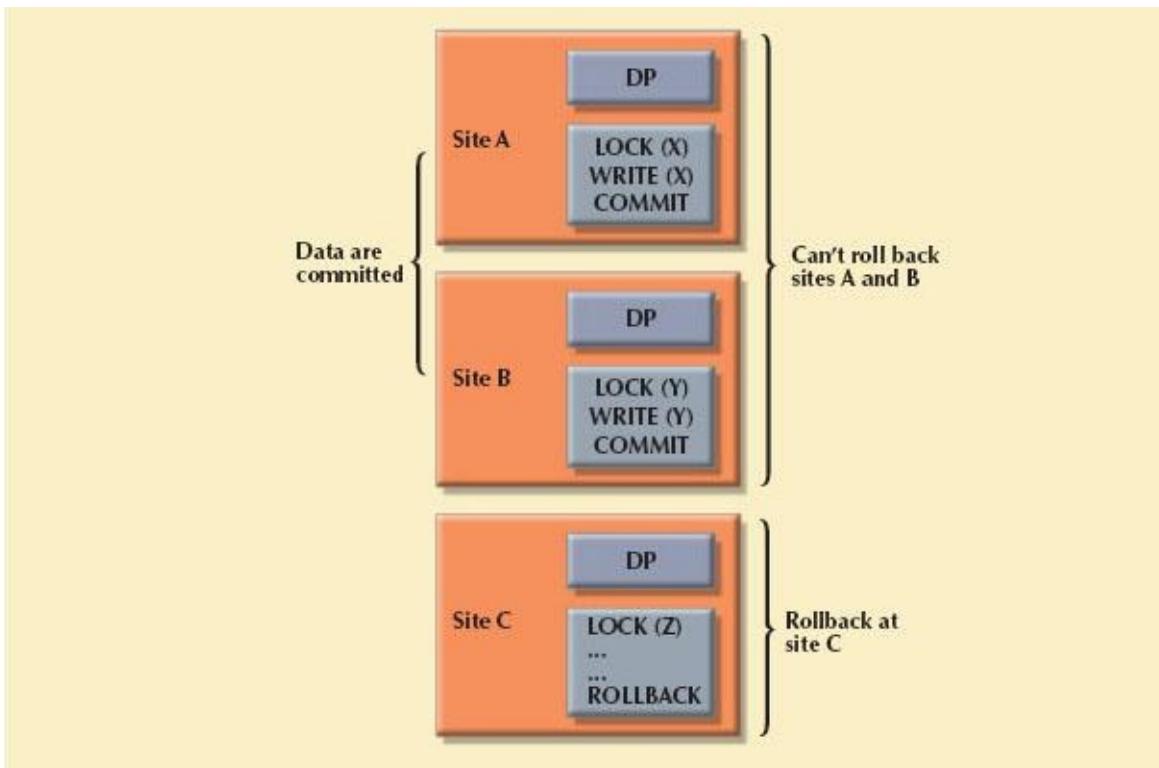
Concurrency control becomes especially important in distributed databases because multisite, multiple-process operations are more likely to create data inconsistencies and deadlocked transactions than single-site systems. For example, the TP component of a DDBMS must ensure that all parts of the transaction are completed at all sites before a final COMMIT is issued to record the transaction.

Suppose that a transaction updates data at three DP sites. The first two DP sites complete the transaction and commit the data at each local DP; however, the third DP site cannot commit the transaction. Such a scenario would yield an inconsistent database, with its inevitable integrity problems, because committed data cannot be uncommitted! This problem is illustrated in [Figure 12.14](#).

---

**FIGURE 12.14** The effect of a premature COMMIT

---



SOURCE: Course Technology/Cengage Learning

---

The solution to this problem is a *two-phase commit protocol*, which you will explore next.

---

#### 12.9.3 TWO-PHASE COMMIT PROTOCOL

---

Centralized databases require only one DP. All database operations take place at only one site, and the consequences of database operations are immediately known to the DBMS. In contrast, distributed databases make it possible for a transaction to access data at several sites. A final COMMIT must not be issued until all sites have committed their parts of the transaction. The [\*\*two-phase commit protocol \(2PC\)\*\*](#) guarantees that if a portion of a transaction operation cannot be committed, all changes made at the other sites participating in the transaction will be undone to maintain a consistent database state.

Each DP maintains its own transaction log. The two-phase commit protocol requires that the transaction log entry for each DP be written before the database fragment is actually updated (see [Chapter 10](#)). Therefore, the two-phase commit protocol requires a DO-UNDO-REDO protocol and a write-ahead protocol.

The **DO-UNDO-REDO protocol** is used by the DP to roll transactions back and forward with the help of the system's transaction log entries. The DO-UNDO-REDO protocol defines three types of operations:

- DO performs the operation and records the “before” and “after” values in the transaction log.
- UNDO reverses an operation, using the log entries written by the DO portion of the sequence.
- REDO redoing an operation, using the log entries written by the DO portion of the sequence.

To ensure that the DO, UNDO, and REDO operations can survive a system crash while they are being executed, a write-ahead protocol is used. The **write-ahead protocol** forces the log entry to be written to permanent storage before the actual operation takes place.

The two-phase commit protocol defines the operations between two types of nodes: the **coordinator** and one or more **subordinates**, or *cohorts*. The participating nodes agree on a coordinator. Generally, the coordinator role is assigned to the node that initiates the transaction. However, different systems implement various, more sophisticated election methods. The protocol is implemented in two phases, as illustrated in the following sections.

### **Phase 1: Preparation**

The coordinator sends a PREPARE TO COMMIT message to all subordinates.

1. The subordinates receive the message, write the transaction log using the write-ahead protocol, and send an acknowledgment message (YES/PREPARED TO COMMIT or NO/NOT PREPARED) to the coordinator.
2. The coordinator makes sure that all nodes are ready to commit, or it aborts the action.

If all nodes are PREPARED TO COMMIT, the transaction goes to Phase 2. If

one or more nodes reply NO or NOT PREPARED, the coordinator broadcasts an ABORT message to all subordinates.

### **Phase 2: The Final COMMIT**

1. The coordinator broadcasts a COMMIT message to all subordinates and waits for the replies.
2. Each subordinate receives the COMMIT message and then updates the database using the DO protocol.
3. The subordinates reply with a COMMITTED or NOT COMMITTED message to the coordinator.

If one or more subordinates do not commit, the coordinator sends an ABORT message, thereby forcing them to UNDO all changes.

The objective of the two-phase commit is to ensure that each node commits its part of the transaction; otherwise, the transaction is aborted. If one of the nodes fails to commit, the information necessary to recover the database is in the transaction log, and the database can be recovered with the DO-UNDO-REDO protocol. (Remember that the log information was updated using the write-ahead protocol.)

---

## **12.10 PERFORMANCE AND FAILURE TRANSPARENCY**

---

One of the most important functions of a database is its ability to make data available. Web-based distributed data systems demand high availability, which means not only that data are accessible but that requests are processed in a timely manner. For example, the average Google search has a subsecond response time. When was the last time you entered a Google query and waited more than a couple of seconds for the results?

Performance transparency allows a DDBMS to perform as if it were a centralized database. In other words, no performance degradation should be incurred due to data distribution. Failure transparency ensures that the system will continue to operate in the case of a node or network failure. Although these

are two separate issues, they are interrelated in that a failing node or congested network path could cause performance problems. Therefore, both issues are addressed in this section.

---

NOTE

---

**[Chapter 11, Database Performance Tuning and Query Optimization](#)**, provides additional details about query optimization.

---

The objective of query optimization is to minimize the total cost associated with the execution of a request. The costs associated with a request are a function of the following:

- Access time (I/O) cost involved in accessing the data from multiple remote sites
- Communication cost associated with data transmission among nodes in distributed database systems
- CPU time cost associated with the processing overhead of managing distributed transactions

Although costs are often classified either as communication or processing costs, it is difficult to separate the two. Not all query optimization algorithms use the same parameters, and not all algorithms assign the same weight to each parameter. For example, some algorithms minimize total time, others minimize the communication time, and still others do not factor in the CPU time, considering its cost insignificant relative to other costs.

As you learned in [Chapter 11](#), a centralized database evaluates every data request to find the most efficient way to access the data. This is a reasonable requirement, considering that all data are locally stored and all active transactions working on the data are known to the central DBMS. In contrast, in a DDBMS, transactions are distributed among multiple nodes; therefore, determining what data are being used becomes more complex. Hence, resolving data requests in a distributed data environment must take the following points into consideration:

- *Data distribution.* In a DDBMS, query translation is more complicated

because the DDBMS must decide which fragment to access. (Distribution transparency was explained earlier in this chapter.) In this case, a TP executing a query must choose what fragments to access, create multiple data requests to the chosen remote DPs, combine the DP responses, and present the data to the application.

- *Data replication.* In addition, the data may also be replicated at several different sites. The data replication makes the access problem even more complex because the database must ensure that all copies of the data are consistent. Therefore, an important characteristic of query optimization in distributed database systems is that it must provide replica transparency. **Replica transparency** refers to the DDBMS's ability to hide multiple copies of data from the user. This ability is particularly important with data update operations. If a read-only request is being processed, it can be satisfied by accessing any available remote DP. However, processing a write request also involves “synchronizing” all existing fragments to maintain data consistency. The two-phase commit protocol you learned about in [Section 12.9.3](#) ensures that the transaction will complete successfully. However, if data are replicated at other sites, the DDBMSs must also ensure the consistency of all the fragments—that is, all fragments should be mutually consistent. To accomplish this, a DP captures all changes and pushes them to each remote replica. This introduces delays in the system and basically means that not all data changes are immediately seen by all replicas. (The implications of this issue are explained in [Section 12.12](#), The CAP Theorem.)
- *Network and node availability.* The response time associated with remote sites cannot be easily predetermined because some nodes finish their part of the query in less time than others and network path performance varies because of bandwidth and traffic loads. Hence, to achieve performance transparency, the DDBMS should consider issues such as **network latency**, the delay imposed by the amount of time required for a data packet to make a round trip from point A to point B; or **network partitioning**, the delay imposed when nodes become suddenly unavailable due to a network failure.

Carefully planning how to partition a database and where to locate the database fragments can help ensure the performance and consistency of a distributed

database. The following section discusses issues for distributed database design.

---

## 12.11 DISTRIBUTED DATABASE DESIGN

---

Whether the database is centralized or distributed, the design principles and concepts described in [Chapters 3, 4](#), and [6](#) are still applicable. However, the design of a distributed database introduces three new issues:

- How to partition the database into fragments
- Which fragments to replicate
- Where to locate those fragments and replicas

Data fragmentation and data replication deal with the first two issues, and data allocation deals with the third issue. Ideally, data in a distributed database should be evenly distributed to maximize performance, increase availability (reduce bottlenecks), and provide location awareness, which is an ever-increasing requirement for mobile applications.

### 12.11.1 DATA FRAGMENTATION

---

**Data fragmentation** allows you to break a single object into two or more segments, or fragments. The object might be a user's database, a system database, or a table. Each fragment can be stored at any site over a computer network. Information about data fragmentation is stored in the distributed data catalog (DDC), from which it is accessed by the TP to process user requests.

Data fragmentation strategies, as discussed here, are based at the table level and consist of dividing a table into logical fragments. You will explore three types of data fragmentation strategies: horizontal, vertical, and mixed. (Keep in mind that a fragmented table can always be re-created from its fragmented parts by a combination of unions and joins.)

- **Horizontal fragmentation** refers to the division of a relation into subsets (fragments) of tuples (rows). Each fragment is stored at a different node, and each fragment has unique rows. However, the unique rows all have the same attributes (columns). In short, each fragment represents the equivalent of a SELECT statement, with the WHERE clause on a single

attribute.

- **Vertical fragmentation** refers to the division of a relation into attribute (column) subsets. Each subset (fragment) is stored at a different node, and each fragment has unique columns—with the exception of the key column, which is common to all fragments. This is the equivalent of the PROJECT statement in SQL.
- **Mixed fragmentation** refers to a combination of horizontal and vertical strategies. In other words, a table may be divided into several horizontal subsets (rows), each one having a subset of the attributes (columns).

To illustrate the fragmentation strategies, use the CUSTOMER table for the XYZ Company, as depicted in [Figure 12.15](#). The table contains the attributes CUS\_NUM, CUS\_NAME, CUS\_ADDRESS, CUS\_STATE, CUS\_LIMIT, CUS\_BAL, CUS\_RATING, and CUS\_DUE.

---

**FIGURE 12.15 A sample CUSTOMER table**

---

| Table name: CUSTOMER |               |                  |           | Database name: Ch12_Text |         |            |         |
|----------------------|---------------|------------------|-----------|--------------------------|---------|------------|---------|
| CUS_NUM              | CUS_NAME      | CUS_ADDRESS      | CUS_STATE | CUS_LIMIT                | CUS_BAL | CUS_RATING | CUS_DUE |
| 10                   | Sinex, Inc.   | 12 Main St.      | TN        | 3500.00                  | 2700.00 | 3          | 1245.00 |
| 11                   | Martin Corp.  | 321 Sunset Blvd. | FL        | 6000.00                  | 1200.00 | 1          | 0.00    |
| 12                   | Mynux Corp.   | 910 Eagle St.    | TN        | 4000.00                  | 3500.00 | 3          | 3400.00 |
| 13                   | BTBC, Inc.    | Rue du Monde     | FL        | 6000.00                  | 5890.00 | 3          | 1090.00 |
| 14                   | Victory, Inc. | 123 Maple St.    | FL        | 1200.00                  | 550.00  | 1          | 0.00    |
| 15                   | NBCC Corp.    | 909 High Ave.    | GA        | 2000.00                  | 350.00  | 2          | 50.00   |

SOURCE: Course Technology/Cengage Learning

---

---



## ONLINE CONTENT

The databases used to illustrate the material in this chapter are available at

## Horizontal Fragmentation

In this case, a table is divided into multiple subsets of rows. There are various ways to partition a table horizontally:

- *Round-robin partitioning.* Rows are assigned to a given fragment in a round-robin fashion ( $F_1, F_2, F_3, \dots, F_n$ ) to ensure an even distribution of rows among all fragments. However, this is not a good strategy if you require “location awareness”—the ability to determine which DP node will process a query based on the geospatial location of the requester. For example, you would want all queries from Florida customers to be resolved from a fragment that stores only Florida customers. Of course, you also would like this fragment to be located in a node close to Florida.
- *Range partitioning based on a partition key.* A **partition key** is one or more attributes in a table that determine the fragment in which a row will be stored. For example, if you want to provide location awareness, a good partition key would be the customer state field. This is the most common and useful data partitioning strategy.

Take a closer look at how to use a partition key to partition a table. Suppose that the XYZ Company’s corporate management requires information about its customers in all three states, but company locations in each state (TN, FL, and GA) require data regarding local customers only. Based on such requirements, you decide to distribute the data by state. Therefore, you define the horizontal fragments to conform to the structure shown in [Table 12.15](#).

---

**TABLE 12.5 Horizontal Fragmentation of the CUSTOMER Table by State**

---

| FRAGMENT NAME | LOCATION  | CONDITION        | NODE NAME | CUSTOMER NUMBERS | NUMBER OF ROWS |
|---------------|-----------|------------------|-----------|------------------|----------------|
| CUST_H1       | Tennessee | CUS_STATE = 'TN' | NAS       | 10, 12           | 2              |
| CUST_H2       | Georgia   | CUS_STATE = 'GA' | ATL       | 15               | 1              |
| CUST_H3       | Florida   | CUS_STATE = 'FL' | TAM       | 11, 13, 14       | 3              |

The partition key will be the CUS\_STATE field. Each horizontal fragment may have a different number of rows, but each fragment *must* have the same attributes. The resulting fragments yield the three tables depicted in [Figure 12.16](#).

---

**FIGURE 12.16 Table fragments in three locations**

---

| Database name: Ch12_Text |             |                     |           |           |           |            |         |
|--------------------------|-------------|---------------------|-----------|-----------|-----------|------------|---------|
| Table name: CUST_H1      |             | Location: Tennessee |           |           | Node: NAS |            |         |
| CUS_NUM                  | CUS_NAME    | CUS_ADDRESS         | CUS_STATE | CUS_LIMIT | CUS_BAL   | CUS_RATING | CUS_DUE |
| 10                       | Sinex, Inc. | 12 Main St.         | TN        | 3500.00   | 2700.00   | 3          | 1245.00 |
| 12                       | Mynux Corp. | 910 Eagle St.       | TN        | 4000.00   | 3500.00   | 3          | 3400.00 |

| Table name: CUST_H2 |            | Location: Georgia |           |           | Node: ATL |            |         |
|---------------------|------------|-------------------|-----------|-----------|-----------|------------|---------|
| CUS_NUM             | CUS_NAME   | CUS_ADDRESS       | CUS_STATE | CUS_LIMIT | CUS_BAL   | CUS_RATING | CUS_DUE |
| 15                  | NBCC Corp. | 909 High Ave.     | GA        | 2000.00   | 350.00    | 2          | 50.00   |

| Table name: CUST_H3 |               | Location: Florida |           |           | Node: TAM |            |         |
|---------------------|---------------|-------------------|-----------|-----------|-----------|------------|---------|
| CUS_NUM             | CUS_NAME      | CUS_ADDRESS       | CUS_STATE | CUS_LIMIT | CUS_BAL   | CUS_RATING | CUS_DUE |
| 11                  | Martin Corp.  | 321 Sunset Blvd.  | FL        | 6000.00   | 1200.00   | 1          | 0.00    |
| 13                  | BTBC, Inc.    | Rue du Monde      | FL        | 6000.00   | 5890.00   | 3          | 1090.00 |
| 14                  | Victory, Inc. | 123 Maple St.     | FL        | 1200.00   | 560.00    | 1          | 0.00    |

SOURCE: Course Technology/Cengage Learning

---

## Vertical Fragmentation

You may also divide the CUSTOMER relation into vertical fragments that are composed of a collection of attributes. For example, suppose that the company is divided into two departments: the service department and the collections department. Each department is located in a separate building, and each has an interest in only a few of the CUSTOMER table's attributes. In this case, the fragments are defined as shown in [Table 12.6](#).

---

**TABLE 12.6 Vertical Fragmentation of the CUSTOMER Table**

---

| FRAGMENT NAME | LOCATION         | NODE NAME | ATTRIBUTE NAMES                                  |
|---------------|------------------|-----------|--------------------------------------------------|
| CUST_V1       | Service Bldg.    | SVC       | CUS_NUM, CUS_NAME, CUS_ADDRESS, CUS_STATE        |
| CUST_V2       | Collection Bldg. | ARC       | CUS_NUM, CUS_LIMIT, CUS_BAL, CUS_RATING, CUS_DUE |

Each vertical fragment must have the same number of rows, but the inclusion of the different attributes depends on the key column. The vertical fragmentation results are displayed in [Figure 12.17](#). Note that the key attribute (CUS\_NUM) is common to both fragments CUST\_V1 and CUST\_V2.

---

**FIGURE 12.17** Vertically fragmented table contents

---

| Database name: Ch12_Text |             |                     |           |           |         |            |         |
|--------------------------|-------------|---------------------|-----------|-----------|---------|------------|---------|
| Table name: CUST_H1      |             | Location: Tennessee |           | Node: NAS |         |            |         |
| CUS_NUM                  | CUS_NAME    | CUS_ADDRESS         | CUS_STATE | CUS_LIMIT | CUS_BAL | CUS_RATING | CUS_DUE |
| 10                       | Sinex, Inc. | 12 Main St.         | TN        | 3500.00   | 2700.00 | 3          | 1245.00 |
| 12                       | Mynux Corp. | 910 Eagle St.       | TN        | 4000.00   | 3500.00 | 3          | 3400.00 |

| Table name: CUST_H2 |            | Location: Georgia |           | Node: ATL |         |            |         |
|---------------------|------------|-------------------|-----------|-----------|---------|------------|---------|
| CUS_NUM             | CUS_NAME   | CUS_ADDRESS       | CUS_STATE | CUS_LIMIT | CUS_BAL | CUS_RATING | CUS_DUE |
| 15                  | NBCC Corp. | 909 High Ave.     | GA        | 2000.00   | 350.00  | 2          | 50.00   |

| Table name: CUST_H3 |               | Location: Florida |           | Node: TAM |         |            |         |
|---------------------|---------------|-------------------|-----------|-----------|---------|------------|---------|
| CUS_NUM             | CUS_NAME      | CUS_ADDRESS       | CUS_STATE | CUS_LIMIT | CUS_BAL | CUS_RATING | CUS_DUE |
| 11                  | Martin Corp.  | 321 Sunset Blvd.  | FL        | 6000.00   | 1200.00 | 1          | 0.00    |
| 13                  | BTBC, Inc.    | Rue du Monde      | FL        | 6000.00   | 5890.00 | 3          | 1090.00 |
| 14                  | Victory, Inc. | 123 Maple St.     | FL        | 1200.00   | 550.00  | 1          | 0.00    |

SOURCE: Course Technology/Cengage Learning

---

## Mixed Fragmentation

The XYZ Company's structure requires that the CUSTOMER data be fragmented horizontally to accommodate the various company locations; within the locations, the data must be fragmented vertically to accommodate the two departments (service and collection). In short, the CUSTOMER table requires mixed fragmentation.

Mixed fragmentation requires a two-step procedure. First, horizontal fragmentation is introduced for each site based on the location within a state (CUS\_STATE). The horizontal fragmentation yields the subsets of customer tuples (horizontal fragments) that are located at each site. Because the

departments are located in different buildings, vertical fragmentation is used within each horizontal fragment to divide the attributes, thus meeting each department's information needs at each subsite. Mixed fragmentation yields the results displayed in [Table 12.7](#).

---

**TABLE 12.7 Mixed Fragmentation of the CUSTOMER Table**

---

| FRAGMENT NAME | LOCATION      | HORIZONTAL CRITERIA | NODE NAME | RESULTING ROWS AT SITE | VERTICAL CRITERIA ATTRIBUTES AT EACH FRAGMENT          |
|---------------|---------------|---------------------|-----------|------------------------|--------------------------------------------------------|
| CUST_M1       | TN-Service    | CUS_STATE = TN      | NAS-S     | 10, 12                 | CUS_NUM, CUS_NAME<br>CUS_ADDRESS,<br>CUS_STATE         |
| CUST_M2       | TN-Collection | CUS_STATE = TN      | NAS-C     | 10, 12                 | CUS_NUM, CUS_LIMIT,<br>CUS_BAL, CUS_RATING,<br>CUS_DUE |
| CUST_M3       | GA-Service    | CUS_STATE = GA      | ATL-S     | 15                     | CUS_NUM, CUS_NAME<br>CUS_ADDRESS,<br>CUS_STATE         |
| CUST_M4       | GA-Collection | CUS_STATE = GA      | ATL-C     | 15                     | CUS_NUM, CUS_LIMIT,<br>CUS_BAL, CUS_RATING,<br>CUS_DUE |
| CUST_M5       | FL-Service    | CUS_STATE = FL      | TAM-S     | 11, 13, 14             | CUS_NUM, CUS_NAME<br>CUS_ADDRESS,<br>CUS_STATE         |
| CUST_M6       | FL-Collection | CUS_STATE = FL      | TAM-C     | 11, 13, 14             | CUS_NUM, CUS_LIMIT,<br>CUS_BAL, CUS_RATING,<br>CUS_DUE |

Each fragment displayed in [Table 12.7](#) contains customer data by state and, within each state, by department location to fit each department's data requirements. The tables corresponding to the fragments listed in [Table 12.7](#) are shown in [Figure 12.18](#).

---

**FIGURE 12.18 Table contents after the mixed fragmentation process**

---

| Database name: Ch12_Text                                                                                                                                                                                                                                                                                                                                                                                                 |                                |                  |                    |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|------------------|--------------------|---------|---------|-----------|-------------|------------|---------|----|--------------|------------------|----|---------|----|-------------|---------------|----|---------|----|---------------|---------------|----|------|
| <b>Table name: CUST_M1</b>                                                                                                                                                                                                                                                                                                                                                                                               | <b>Location: TN-Service</b>    |                  | <b>Node: NAS-S</b> |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <table border="1"> <thead> <tr> <th>CUS_NUM</th><th>CUS_NAME</th><th>CUS_ADDRESS</th><th>CUS_STATE</th><th></th></tr> </thead> <tbody> <tr> <td>10</td><td>Sinex, Inc.</td><td>12 Main St.</td><td>TN</td><td></td></tr> <tr> <td>12</td><td>Mynux Corp.</td><td>910 Eagle St.</td><td>TN</td><td></td></tr> </tbody> </table>                                                                                           |                                |                  |                    |         | CUS_NUM | CUS_NAME  | CUS_ADDRESS | CUS_STATE  |         | 10 | Sinex, Inc.  | 12 Main St.      | TN |         | 12 | Mynux Corp. | 910 Eagle St. | TN |         |    |               |               |    |      |
| CUS_NUM                                                                                                                                                                                                                                                                                                                                                                                                                  | CUS_NAME                       | CUS_ADDRESS      | CUS_STATE          |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 10                                                                                                                                                                                                                                                                                                                                                                                                                       | Sinex, Inc.                    | 12 Main St.      | TN                 |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 12                                                                                                                                                                                                                                                                                                                                                                                                                       | Mynux Corp.                    | 910 Eagle St.    | TN                 |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <b>Table name: CUST_M2</b>                                                                                                                                                                                                                                                                                                                                                                                               | <b>Location: TN-Collection</b> |                  | <b>Node: NAS-C</b> |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <table border="1"> <thead> <tr> <th>CUS_NUM</th><th>CUS_LIMIT</th><th>CUS_BAL</th><th>CUS_RATING</th><th>CUS_DUE</th></tr> </thead> <tbody> <tr> <td>10</td><td>3500.00</td><td>2700.00</td><td>3</td><td>1245.00</td></tr> <tr> <td>12</td><td>4000.00</td><td>3500.00</td><td>3</td><td>3400.00</td></tr> </tbody> </table>                                                                                            |                                |                  |                    |         | CUS_NUM | CUS_LIMIT | CUS_BAL     | CUS_RATING | CUS_DUE | 10 | 3500.00      | 2700.00          | 3  | 1245.00 | 12 | 4000.00     | 3500.00       | 3  | 3400.00 |    |               |               |    |      |
| CUS_NUM                                                                                                                                                                                                                                                                                                                                                                                                                  | CUS_LIMIT                      | CUS_BAL          | CUS_RATING         | CUS_DUE |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 10                                                                                                                                                                                                                                                                                                                                                                                                                       | 3500.00                        | 2700.00          | 3                  | 1245.00 |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 12                                                                                                                                                                                                                                                                                                                                                                                                                       | 4000.00                        | 3500.00          | 3                  | 3400.00 |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <b>Table name: CUST_M3</b>                                                                                                                                                                                                                                                                                                                                                                                               | <b>Location: GA-Service</b>    |                  | <b>Node: ATL-S</b> |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <table border="1"> <thead> <tr> <th>CUS_NUM</th><th>CUS_NAME</th><th>CUS_ADDRESS</th><th>CUS_STATE</th><th></th></tr> </thead> <tbody> <tr> <td>15</td><td>NBCC Corp.</td><td>909 High Ave.</td><td>GA</td><td></td></tr> </tbody> </table>                                                                                                                                                                              |                                |                  |                    |         | CUS_NUM | CUS_NAME  | CUS_ADDRESS | CUS_STATE  |         | 15 | NBCC Corp.   | 909 High Ave.    | GA |         |    |             |               |    |         |    |               |               |    |      |
| CUS_NUM                                                                                                                                                                                                                                                                                                                                                                                                                  | CUS_NAME                       | CUS_ADDRESS      | CUS_STATE          |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 15                                                                                                                                                                                                                                                                                                                                                                                                                       | NBCC Corp.                     | 909 High Ave.    | GA                 |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <b>Table name: CUST_M4</b>                                                                                                                                                                                                                                                                                                                                                                                               | <b>Location: GA-Collection</b> |                  | <b>Node: ATL-C</b> |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <table border="1"> <thead> <tr> <th>CUS_NUM</th><th>CUS_LIMIT</th><th>CUS_BAL</th><th>CUS_RATING</th><th>CUS_DUE</th></tr> </thead> <tbody> <tr> <td>15</td><td>2000.00</td><td>350.00</td><td>2</td><td>50.00</td></tr> </tbody> </table>                                                                                                                                                                               |                                |                  |                    |         | CUS_NUM | CUS_LIMIT | CUS_BAL     | CUS_RATING | CUS_DUE | 15 | 2000.00      | 350.00           | 2  | 50.00   |    |             |               |    |         |    |               |               |    |      |
| CUS_NUM                                                                                                                                                                                                                                                                                                                                                                                                                  | CUS_LIMIT                      | CUS_BAL          | CUS_RATING         | CUS_DUE |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 15                                                                                                                                                                                                                                                                                                                                                                                                                       | 2000.00                        | 350.00           | 2                  | 50.00   |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <b>Table name: CUST_M5</b>                                                                                                                                                                                                                                                                                                                                                                                               | <b>Location: FL-Service</b>    |                  | <b>Node: TAM-S</b> |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <table border="1"> <thead> <tr> <th>CUS_NUM</th><th>CUS_NAME</th><th>CUS_ADDRESS</th><th>CUS_STATE</th><th></th></tr> </thead> <tbody> <tr> <td>11</td><td>Martin Corp.</td><td>321 Sunset Blvd.</td><td>FL</td><td></td></tr> <tr> <td>13</td><td>BTBC, Inc.</td><td>Rue du Monde</td><td>FL</td><td></td></tr> <tr> <td>14</td><td>Victory, Inc.</td><td>123 Maple St.</td><td>FL</td><td></td></tr> </tbody> </table> |                                |                  |                    |         | CUS_NUM | CUS_NAME  | CUS_ADDRESS | CUS_STATE  |         | 11 | Martin Corp. | 321 Sunset Blvd. | FL |         | 13 | BTBC, Inc.  | Rue du Monde  | FL |         | 14 | Victory, Inc. | 123 Maple St. | FL |      |
| CUS_NUM                                                                                                                                                                                                                                                                                                                                                                                                                  | CUS_NAME                       | CUS_ADDRESS      | CUS_STATE          |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 11                                                                                                                                                                                                                                                                                                                                                                                                                       | Martin Corp.                   | 321 Sunset Blvd. | FL                 |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 13                                                                                                                                                                                                                                                                                                                                                                                                                       | BTBC, Inc.                     | Rue du Monde     | FL                 |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 14                                                                                                                                                                                                                                                                                                                                                                                                                       | Victory, Inc.                  | 123 Maple St.    | FL                 |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <b>Table name: CUST_M6</b>                                                                                                                                                                                                                                                                                                                                                                                               | <b>Location: FL-Collection</b> |                  | <b>Node: TAM-C</b> |         |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| <table border="1"> <thead> <tr> <th>CUS_NUM</th><th>CUS_LIMIT</th><th>CUS_BAL</th><th>CUS_RATING</th><th>CUS_DUE</th></tr> </thead> <tbody> <tr> <td>11</td><td>6000.00</td><td>1200.00</td><td>1</td><td>0.00</td></tr> <tr> <td>13</td><td>6000.00</td><td>5890.00</td><td>3</td><td>1090.00</td></tr> <tr> <td>14</td><td>1200.00</td><td>550.00</td><td>1</td><td>0.00</td></tr> </tbody> </table>                   |                                |                  |                    |         | CUS_NUM | CUS_LIMIT | CUS_BAL     | CUS_RATING | CUS_DUE | 11 | 6000.00      | 1200.00          | 1  | 0.00    | 13 | 6000.00     | 5890.00       | 3  | 1090.00 | 14 | 1200.00       | 550.00        | 1  | 0.00 |
| CUS_NUM                                                                                                                                                                                                                                                                                                                                                                                                                  | CUS_LIMIT                      | CUS_BAL          | CUS_RATING         | CUS_DUE |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 11                                                                                                                                                                                                                                                                                                                                                                                                                       | 6000.00                        | 1200.00          | 1                  | 0.00    |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 13                                                                                                                                                                                                                                                                                                                                                                                                                       | 6000.00                        | 5890.00          | 3                  | 1090.00 |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |
| 14                                                                                                                                                                                                                                                                                                                                                                                                                       | 1200.00                        | 550.00           | 1                  | 0.00    |         |           |             |            |         |    |              |                  |    |         |    |             |               |    |         |    |               |               |    |      |

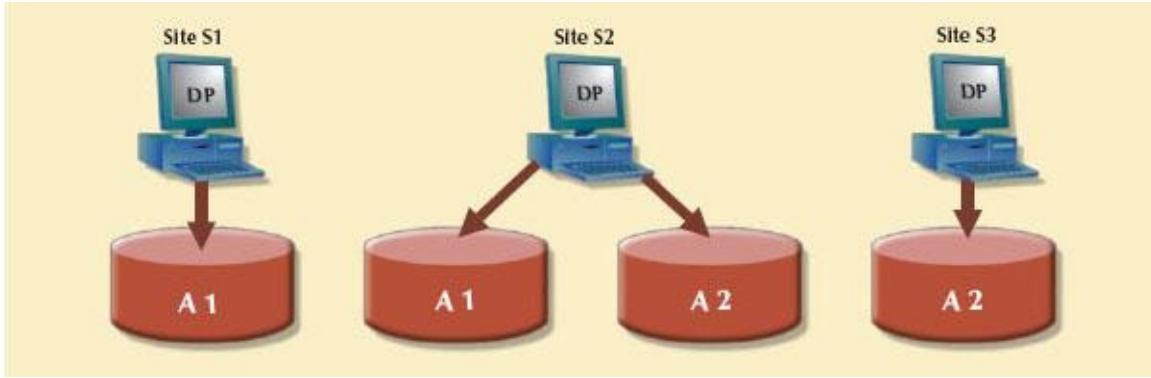
SOURCE: Course Technology/Cengage Learning

## 12.11.2 DATA REPLICATION

**Data replication** refers to the storage of data copies at multiple sites served by a computer network. Fragment copies can be stored at several sites to serve specific information requirements. Because the existence of fragment copies can enhance data availability and response time, data copies can help to reduce communication and total query costs.

Suppose database A is divided into two fragments, A1 and A2. Within a replicated distributed database, the scenario depicted in [Figure 12.19](#) is possible: fragment A1 is stored at sites S1 and S2, while fragment A2 is stored at sites S2 and S3.

**FIGURE 12.19 Data replication**



SOURCE: Course Technology/Cengage Learning

---

Replicated data are subject to the **mutual consistency rule**, which requires that all copies of data fragments be identical. Therefore, to maintain data consistency among the replicas, the DDBMS must ensure that a database update is performed at all sites where replicas exist.

There are basically two styles of replication:

- *Push replication.* After a data update, the originating DP node sends the changes to the replica nodes to ensure that data are immediately updated. This type of replication focuses on maintaining data consistency. However, it decreases data availability due to the latency involved in ensuring data consistency at all nodes.
- *Pull replication.* After a data update, the originating DP node sends “messages” to the replica nodes to notify them of the update. The replica nodes decide when to apply the updates to their local fragment. In this type of replication, data updates propagate more slowly to the replicas. The focus is on maintaining data availability. However, this style of replication allows for temporary data inconsistencies.

Although replication has some benefits, such as improved data availability, better load distribution, improved data failure tolerance, and reduced query costs, it also imposes additional DDBMS processing overhead because each data copy must be maintained by the system. Furthermore, because the data are replicated at another site, there are associated storage costs and increased transaction times (as data must be updated at several sites concurrently to comply with the mutual consistency rule). To illustrate the replica overhead

imposed on a DDBMS, consider the processes that the DDBMS must perform to use the database:

- If the database is fragmented, the DDBMS must decompose a query into subqueries to access the appropriate fragments.
- If the database is replicated, the DDBMS must decide which copy to access. A READ operation selects the *nearest copy* to satisfy the transaction. A WRITE operation requires that *all copies* be selected and updated to satisfy the mutual consistency rule.
- The TP sends a data request to each selected DP for execution.
- The DP receives and executes each request and sends the data back to the TP.
- The TP assembles the DP responses.

The problem becomes more complex when you consider additional factors such as network topology and communication throughputs.

Three replication scenarios exist: a database can be fully replicated, partially replicated, or unreplicated.

- A **fully replicated database** stores multiple copies of each database fragment at multiple sites. In this case, all database fragments are replicated. A fully replicated database can be impractical due to the amount of overhead it imposes on the system.
- A **partially replicated database** stores multiple copies of some database fragments at multiple sites. Most DDBMSs are able to handle the partially replicated database well.
- An **unreplicated database** stores each database fragment at a single site. Therefore, there are no duplicate database fragments.

Several factors influence the decision to use data replication:

- *Database size.* The amount of data replicated will have an impact on the storage requirements and the data transmission costs. Replicating large amounts of data requires a window of time and higher network bandwidth that could affect other applications.
- *Usage frequency.* The frequency of data usage determines how frequently the data need to be updated. Frequently used data should be updated more often, for example, than large data sets that are used only every quarter.
- *Costs.* Costs include those for performance, software overhead, and management associated with synchronizing transactions and their components versus fault-tolerance benefits that are associated with replicated data.

When the usage frequency of remotely located data is high and the database is large, data replication can reduce the cost of data requests. Data replication information is stored in the DDC, whose contents are used by the TP to decide which copy of a database fragment to access. The data replication makes it possible to restore lost data.

#### 12.11.3 DATA ALLOCATION

---

**Data allocation** describes the process of deciding where to locate data. Data allocation strategies are as follows:

- With **centralized data allocation**, the entire database is stored at one site.
- With **partitioned data allocation**, the database is divided into two or more disjointed parts (fragments) and stored at two or more sites.
- With **replicated data allocation**, copies of one or more database fragments are stored at several sites.

Data distribution over a computer network is achieved through data partitioning, through data replication, or through a combination of both. Data allocation is closely related to the way a database is divided or fragmented. Most data allocation studies focus on one issue: which data to locate where.

Data allocation algorithms consider a variety of factors, including:

- Performance and data availability goals
- Size, number of rows, and number of relations that an entity maintains with other entities
- Types of transactions to be applied to the database and the attributes accessed by each of those transactions
- Disconnected operation for mobile users. In some cases, the design might consider the use of loosely disconnected fragments for mobile users, particularly for read-only data that do not require frequent updates and for which the replica update windows may be longer. (A replica update window is the amount of time available to perform a data-processing task that cannot be executed concurrently with other tasks.)

Most algorithms include data such as network topology, network bandwidth and throughput, data size, and location. No optimal or universally accepted algorithm exists yet, and each database vendor implements its own version to showcase the strengths of its respective products.

---

## 12.12 THE CAP THEOREM

---

In a 2000 symposium on distributed computing, Dr. Eric Brewer stated in his presentation that “in any highly distributed data system there are three commonly desirable properties: consistency, availability, and partition tolerance. However, it is impossible for a system to provide all three properties at the same time.”<sup>2</sup> The initials *CAP* stand for the three desirable properties. Consider these three properties in more detail:

- *Consistency*. In a distributed database, consistency takes a bigger role. All

nodes should see the same data at the same time, which means that the replicas should be immediately updated. However, this involves dealing with latency and network partitioning delays, as you learned in [Section 12.10](#).

- *Availability.* Simply speaking, a request is always fulfilled by the system. No received request is ever lost. If you are buying tickets online, you do not want the system to stop in the middle of the operation. This is a paramount requirement of all Web-centric organizations.
- *Partition tolerance.* The system continues to operate even in the event of a node failure. This is the equivalent of failure transparency in distributed databases (see [Section 12.7](#)). The system will fail only if all nodes fail.

Although the CAP theorem focuses on highly distributed Web-based systems, its implications are widespread for all distributed systems, including databases.

In [Chapter 10](#), you learned that there are four database transaction properties: atomicity, consistency, isolation, and durability. The ACID properties ensure that all successful transactions result in a consistent database state—one in which all data operations always return the same results. For centralized and small distributed databases, latency is not an issue. As the business grows and the need for availability increases, database latency becomes a bigger problem. It is more difficult for a highly distributed database to ensure ACID transactions without paying a high price in network latency or data contention (delays imposed by concurrent data access).

For example, imagine that you are using Amazon to buy tickets for the Manchester United–Barcelona soccer game in Washington, D.C. You may spend a few minutes browsing through the available tickets and checking the stadium Website to see which seats have the best view. At the same time, other users from all over the world may be doing exactly the same thing. By the time you click the checkout button, the tickets you selected may already be purchased by someone else! In this case, you will start again and select other tickets until you get the ones you want. The Website is designed to work this way on purpose because Amazon prefers the small probability of having a few customers restart their transactions than to lock the database to ensure consistency and have

thousands of customers waiting for their Web pages to refresh. If you have noticed the small countdown clock when using Ticketmaster to buy concert tickets, you have seen the same principle at work.

As this example shows, when dealing with highly distributed systems, some companies tend to forfeit the consistency and isolation components of the ACID properties to achieve higher availability. This trade-off between consistency and availability has generated a new type of distributed data systems in which data are **basically available, soft state, eventually consistent (BASE)**. BASE refers to a data consistency model in which data changes are not immediate but propagate slowly through the system until all replicas are eventually consistent. For example, NoSQL databases provide a highly distributed database with eventual consistency (see [Chapter 2](#)). In practice, the emergence of NoSQL distributed databases now provides a spectrum of consistency that ranges from the highly consistent (ACID) to the eventually consistent (BASE), as shown in [Table 12.8](#).

---

**TABLE 12.8 Distributed Database Spectrum**

---

| DBMS TYPE        | CONSISTENCY | AVAILABILITY | PARTITION TOLERANCE | TRANSACTION MODEL | TRADE-OFF                                                   |
|------------------|-------------|--------------|---------------------|-------------------|-------------------------------------------------------------|
| Centralized DBMS | High        | High         | N/A                 | ACID              | No distributed data processing                              |
| Relational DDBMS | High        | Relaxed      | High                | ACID (2PC)        | Sacrifices availability to ensure consistency and isolation |
| NoSQL DDBMS      | Relaxed     | High         | High                | BASE              | Sacrifices consistency to ensure availability               |

---

### 12.13 C. J. DATE'S 12 COMMANDMENTS FOR DISTRIBUTED DATABASES

---

The notion of distributed databases has been around for at least 20 years. With the rise of relational databases, most vendors implemented their own versions of distributed databases, generally highlighting their respective product's strengths. To make comparisons easier, C. J. Date formulated 12 “commandments” or basic principles of distributed databases.<sup>3</sup> Although no current DDBMS conforms to

all of them, they constitute a useful target. The 12 rules are shown in [Table 12.9](#).

---

**TABLE 12.9 Date's 12 Commandments for Distributed Databases**

---

| RULE NUMBER | RULE NAME                                 | RULE EXPLANATION                                                                                                                                                       |
|-------------|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1           | <i>Local site independence</i>            | Each local site can act as an independent, autonomous, centralized DBMS. Each site is responsible for security, concurrency control, backup, and recovery.             |
| 2           | <i>Central site independence</i>          | No site in the network relies on a central site or any other site. All sites have the same capabilities.                                                               |
| 3           | <i>Failure independence</i>               | The system is not affected by node failures. The system is in continuous operation even in the case of a node failure or an expansion of the network.                  |
| 4           | <i>Location transparency</i>              | The user does not need to know the location of data to retrieve those data.                                                                                            |
| 5           | <i>Fragmentation transparency</i>         | Data fragmentation is transparent to the user, who sees only one logical database. The user does not need to know the name of the database fragments to retrieve them. |
| 6           | <i>Replication transparency</i>           | The user sees only one logical database. The DDBMS transparently selects the database fragment to access. To the user, the DDBMS manages all fragments transparently.  |
| 7           | <i>Distributed query processing</i>       | A distributed query may be executed at several different DP sites. Query optimization is performed transparently by the DDBMS.                                         |
| 8           | <i>Distributed transaction processing</i> | A transaction may update data at several different sites, and the transaction is executed transparently.                                                               |
| 9           | <i>Hardware independence</i>              | The system must run on any hardware platform.                                                                                                                          |
| 10          | <i>Operating system independence</i>      | The system must run on any operating system platform.                                                                                                                  |
| 11          | <i>Network independence</i>               | The system must run on any network platform.                                                                                                                           |
| 12          | <i>Database independence</i>              | The system must support any vendor's database product.                                                                                                                 |

---

## SUMMARY

---

- A distributed database stores logically related data in two or more physically independent sites connected via a computer network. The database is divided into fragments, which can be a horizontal set of rows or a vertical set of attributes. Each fragment can be allocated to a different network node.
  
- Distributed processing is the division of logical database processing among

two or more network nodes. Distributed databases require distributed processing. A distributed database management system (DDBMS) governs the processing and storage of logically related data through interconnected computer systems.

- The main components of a DDBMS are the transaction processor (TP) and the data processor (DP). The transaction processor component is the resident software on each computer node that requests data. The data processor component is the resident software on each computer that stores and retrieves data.
- Current database systems can be classified by the extent to which they support processing and data distribution. Three major categories are used to classify distributed database systems: single-site processing, single-site data (SPSD); multiplesite processing, single-site data (MPSD); and multiplesite processing, multiplesite data (MPMD).
- A homogeneous distributed database system integrates only one particular type of DBMS over a computer network. A heterogeneous distributed database system integrates several different types of DBMSs over a computer network.
- DDBMS characteristics are best described as a set of transparencies: distribution, transaction, performance, failure, and heterogeneity. All transparencies share the common objective of making the distributed database behave as though it were a centralized database system; that is, the end user sees the data as part of a single, logical centralized database and is unaware of the system's complexities.
- A transaction is formed by one or more database requests. An undistributed transaction updates or requests data from a single site. A distributed transaction can update or request data from multiple sites.
- Distributed concurrency control is required in a network of distributed databases. A two-phase COMMIT protocol is used to ensure that all parts of a transaction are completed.
- A distributed DBMS evaluates every data request to find the optimum access

path in a distributed database. The DDBMS must optimize the query to reduce associated access costs, communication costs, and CPU costs.

- The design of a distributed database must consider the fragmentation and replication of data. The designer must also decide how to allocate each fragment or replica to obtain better overall response time and to ensure data availability to the end user. Ideally, a distributed database should evenly distribute data to maximize performance, availability, and location awareness.
- A database can be replicated over several different sites on a computer network. The replication of the database fragments has the objective of improving data availability, thus decreasing access time. A database can be partially, fully, or not replicated. Data allocation strategies are designed to determine the location of the database fragments or replicas.
- The CAP theorem states that a highly distributed data system has some desirable properties of consistency, availability, and partition tolerance. However, a system can only provide two of these properties at a time.

---

#### KEY TERMS

---

[application processor \(AP\)](#)  
[basically available, soft state, eventually consistent \(BASE\)](#)  
[centralized data allocation](#)  
[client/server architecture](#)  
[coordinator](#)  
[data allocation](#)  
[database fragments](#)  
[data fragmentation](#)  
[data manager \(DM\)](#)  
[data processor \(DP\)](#)  
[data replication](#)  
[distributed database](#)

[distributed database management system \(DDBMS\)](#)  
[distributed data catalog \(DDC\)](#)  
[distributed data dictionary \(DDD\)](#)  
[distributed global schema](#)  
[distributed processing](#)  
[distributed request](#)  
[distributed transaction](#)  
[distribution transparency](#)  
[DO-UNDO-REDO protocol](#)  
[failure transparency](#)  
[fragmentation transparency](#)  
[fully heterogeneous DDBMS](#)  
[fully replicated database](#)  
[heterogeneity transparency](#)  
[heterogeneous DDBMS](#)  
[homogeneous DDBMS](#)  
[horizontal fragmentation](#)  
[local mapping transparency](#)  
[location transparency](#)  
[mixed fragmentation](#)  
[multiplesite processing, multiplesite data \(MPMD\)](#)  
[multiplesite processing, single-site data \(MPSD\)](#)  
[mutual consistency rule](#)  
[network latency](#)  
[network partitioning](#)  
[partially replicated database](#)  
[partitioned data allocation](#)  
[partition key](#)  
[performance transparency](#)  
[remote request](#)  
[remote transaction](#)  
[replica transparency](#)  
[replicated data allocation](#)  
[single-site processing, single-site data \(SPSD\)](#)  
[subordinates](#)  
[transaction manager \(TM\)](#)

[transaction processor \(TP\)](#)  
[transaction transparency](#)  
[two-phase commit protocol](#)  
[unique fragment](#)  
[unreplicated database](#)  
[vertical fragmentation](#)  
[write-ahead protocol](#)

---



## ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at [www.cengagebrain.com](http://www.cengagebrain.com).

---

---

## REVIEW QUESTIONS

---

1. Describe the evolution from centralized DBMSs to distributed DBMSs.
  
2. List and discuss some of the factors that influenced the evolution of the DDBMS.
3. What are the advantages of the DDBMS?
  
4. What are the disadvantages of the DDBMS?
5. Explain the difference between a distributed database and distributed processing.
  
6. What is a fully distributed database management system?
7. What are the components of a DDBMS?
  
8. List and explain the transparency features of a DDBMS.

9. Define and explain the different types of distribution transparency.
10. Describe the different types of database requests and transactions.
11. Explain the need for the two-phase commit protocol. Then describe the two phases.
12. What is the objective of query optimization functions?
13. To which transparency feature are the query optimization functions related?
14. What issues should be considered when resolving data requests in a distributed data environment?
15. Describe the three data fragmentation strategies. Give some examples of each.
16. What is data replication, and what are the three replication strategies?
17. What are the two basic styles of data replication?
18. What trade-offs are involved in building highly distributed data environments?
19. How does a BASE system differ from a traditional distributed database system?

---

#### PROBLEMS

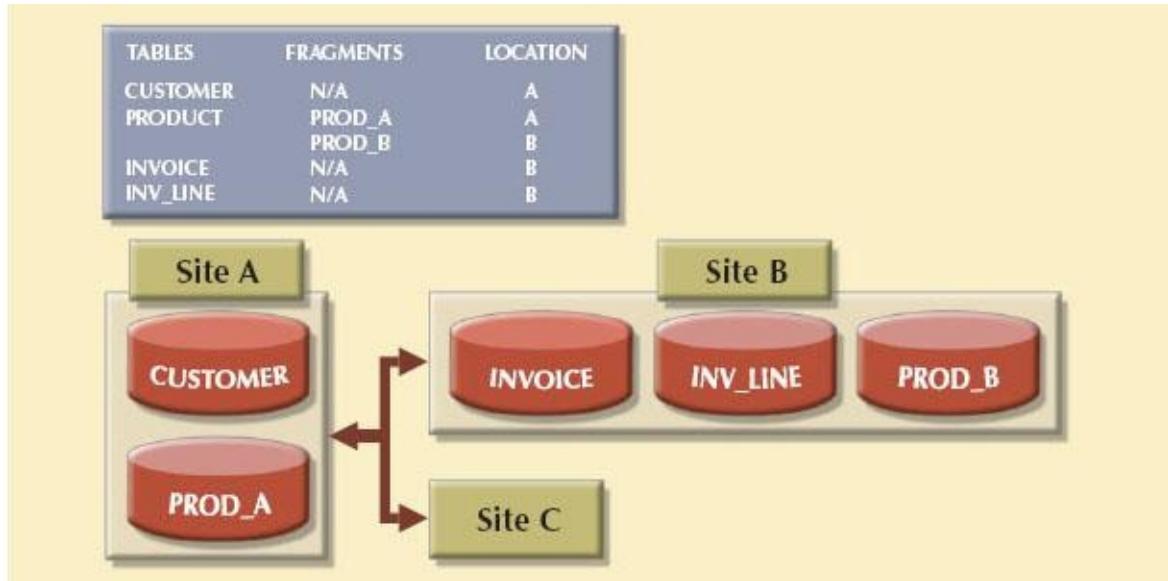
---

The first problem is based on the DDBMS scenario in [Figure P12.1](#).

---

**FIGURE P12.1** The DDBMS scenario for [Problem 1](#)

---



SOURCE: Course Technology/Cengage Learning

1. Specify the minimum types of operations the database must support to perform the following operations. These operations include remote requests, remote transactions, distributed transactions, and distributed requests.

#### **At site C**

- a. SELECT \*

**FROM CUSTOMER;**

- b. SELECT \*

**FROM INVOICE**

**WHERE INV\_TOT > 1000;**

c. SELECT

\*

**FROM PRODUCT**

**WHERE PROD\_QOH < 10;**

d. BEGIN WORK;

**UPDATE CUSTOMER**

**SET CUS\_BAL = CUS\_BAL + 100**

**WHERE CUS\_NUM = '10936';**

**INSERT INTO INVOICE(INV\_NUM, CUS\_NUM, INV\_DATE, INV\_TOTAL)**

**VALUES ('986391', '10936', '15-FEB-2012', 100);**

**INSERT INTO LINE(INV\_NUM, PROD\_NUM, LINE\_PRICE)**

**VALUES ('986391', '1023', 100);**

**UPDATE PRODUCT**

**SET** PROD\_QOH = PROD\_QOH —1

**WHERE** PROD\_NUM = ‘1023’;

COMMIT  
WORK;

e. BEGIN WORK;

**INSERT** INTO CUSTOMER(CUS\_NUM, CUS\_NAME,  
CUS\_ADDRESS, CUS\_BAL)

VALUES (‘34210’, ‘Victor Ephenor’, ‘123 Main St.’,  
0.00);

**INSERT** INTO INVOICE(INV\_NUM, CUS\_NUM, INV\_DATE,  
INV\_TOTAL)

VALUES (‘986434’, ‘34210’, ‘10-AUG-2011’, 2.00);

COMMIT  
WORK;

**At site A**

f. SELECT CUS\_NUM, CUS\_NAME, INV\_TOTAL

**FROM** CUSTOMER, INVOICE

**WHERE** CUSTOMER.CUS\_NUM = INVOICE.CUS\_NUM;

g. SELECT \*  
FROM INVOICE

WHERE INV\_TOTAL > 1000;

h. SELECT \*  
FROM PRODUCT

WHERE PROD\_QOH < 10;

**At site B**

i. SELECT \*  
FROM CUSTOMER;

j. SELECT CUS\_NAME, INV\_TOTAL  
FROM CUSTOMER, INVOICE

WHERE INV\_TOTAL > 1000 AND CUSTOMER.CUS\_NUM =  
INVOICE.CUS\_NUM;

k. SELECT \*  
FROM INVOICE

# **FROM PRODUCT**

**WHERE** PROD\_QOH < 10;

2. The following data structure and constraints exist for a magazine publishing company:

- a. The company publishes one regional magazine in each of four states: Florida (FL), South Carolina (SC), Georgia (GA), and Tennessee (TN).
- b. The company has 300,000 customers (subscribers) distributed throughout the four states listed in [Problem 2a](#).
- c. On the first day of each month, an annual subscription INVOICE is printed and sent to each customer whose subscription is due for renewal. The INVOICE entity contains a REGION attribute to indicate the customer's state of residence (FL, SC, GA, TN):

CUSTOMER (CUS\_NUM, CUS\_NAME, CUS\_ADDRESS, CUS\_CITY, CUS\_ZIP, CUS\_SUBSDATE)

INVOICE (INV\_NUM, INV\_REGION, CUS\_NUM, INV\_DATE, INV\_TOTAL)

The company is aware of the problems associated with centralized management and has decided to decentralize management of the subscriptions into the company's four regional subsidiaries. Each subscription site will handle its own customer and invoice data. The management at company headquarters, however, will have access to customer and invoice data to generate annual reports and to issue ad hoc queries such as:

- Listing all current customers by region
  - Listing all new customers by region
  - Reporting all invoices by customer and by region Given those requirements, how must you partition the database?
3. Given the scenario and requirements in [Problem 2](#), answer the following questions:
- a. What recommendations will you make regarding the type and characteristics of the required database system?

- b. What type of data fragmentation is needed for each table?
  - c. What criteria must be used to partition each database?
  - d. Design the database fragments. Show an example with node names, location, fragment names, attribute names, and demonstration data.
  - e. What type of distributed database operations must be supported at each remote site?
  - f. What type of distributed database operations must be supported at the headquarters site?
- 

1 The details of distributed requests and transactions were originally described by David McGoveran and Colin White, “Clarifying Client/Server,” *DBMS* 3(12), November 1990.

2 “Towards Robust Distributed Systems,” Eric A. Brewer, University of California at Berkeley and Inktomi Corporation, presentation at the Principles of Distributed Computing, ACM Symposium, July 2000. This theorem was later proven by Seth Gilbert and Nancy Lynch of MIT in their paper “Brewer’s Conjecture and the Feasibility of Consistent, Available, Partition-Tolerant Web Services,” *ACM SIGACT News*, vol. 33, Issue 2, 2002.

3 Date, C. J., “Twelve Rules for a Distributed Database,” *Computerworld*, June 8, 1987, 2(23).

---

## 13 BUSINESS INTELLIGENCE AND DATA WAREHOUSES

---

In this chapter, you will learn:

- How business intelligence provides a comprehensive business decision support framework
- About business intelligence architecture, its evolution, and reporting styles
  - About the relationship and differences between operational data and decision support data
- What a data warehouse is and how to prepare data for one
- What star schemas are and how they are constructed
- About data analytics, data mining, and predictive analytics
- About online analytical processing (OLAP)
- How SQL extensions are used to support OLAP-type data manipulations

---

## Preview

---

Ultimately, the reason for collecting, storing, and managing data is to generate information that becomes the basis for rational decision making. Decision support systems (DSSs) were originally developed to facilitate the decision-making process. However, as the complexity and range of information requirements increased, so did the difficulty of extracting all the necessary information from the data structures typically found in an operational database. Therefore, a new data storage facility, called a data warehouse, was developed. The data warehouse extracts or obtains its data from operational databases as well as from external sources, providing a more comprehensive data pool.

In parallel with data warehouses, new ways to analyze and present decision support data were developed. Online analytical processing (OLAP) provides advanced data analysis and visualization tools, including multidimensional data analysis. Data mining employs advanced statistical tools to analyze the wealth of data now available through data warehouses and other sources and to identify possible relationships and anomalies. Predictive analytics uses advanced

statistical and modeling techniques to predict future business outcomes with great accuracy.

Business intelligence (BI) is the collection of best practices and software tools developed to support business decision making in this age of globalization, emerging markets, rapid change, and increasing regulation. This chapter explores the main concepts and components of business intelligence and decision support systems that gather, generate, and present information for business decision makers, focusing especially on the use of data warehouses.

---

### 13.1 THE NEED FOR DATA ANALYSIS

---

Organizations tend to grow and prosper as they gain a better understanding of their environment. Most managers need to track daily transactions to evaluate how the business is performing. By tapping into the operational database, management can develop an understanding of how the company is performing and evaluate whether the current strategies meet organizational goals. In addition, analyzing the company data can provide insightful information about short-term tactical evaluations and strategic questions, such as: Are our sales promotions working? What market percentage are we controlling? Are we attracting new customers? Tactical and strategic decisions are also shaped by constant pressure from external and internal forces, including globalization, the cultural and legal environment, and technology.

Organizations are always looking for a competitive advantage through product development, market positioning, sales promotions, and customer service. Thanks to the Internet, customers are more informed than ever about the products they want and the prices they are willing to pay. Technology advances allow customers to place orders using their smart phones while they commute to work in the morning. Decision makers can no longer wait a couple of days for a report to be generated; they are compelled to make quick decisions if they want to remain competitive. Every day, TV ads offer low-price warranties, instant price matching, and so on. How can companies survive on lower margins and still make a profit? The key is in having the right data at the right time to support the decision-making process.

This process takes place at all levels of an organization. For example, transaction-processing systems, based on operational databases, are tailored to

serve the information needs of people who deal with short-term inventory, accounts payable, and purchasing. Middle-level managers, general managers, vice presidents, and presidents focus on strategic and tactical decision making. Those managers require summarized information designed to help them make decisions in a complex business environment.

Companies and software vendors addressed these multilevel decision support needs by creating autonomous applications for particular groups of users, such as those in finance, customer management, human resources, and product support. Applications were also tailored to different industries such as education, retail, health care, and finance. This approach worked well for some time, but changes in the business world, such as globalization, expanding markets, mergers and acquisitions, increased regulation, and new technologies, called for new ways of integrating and managing decision support across levels, sectors, and geographic locations. This more comprehensive and integrated decision support framework within organizations became known as business intelligence.

---

## 13.2 BUSINESS INTELLIGENCE

---

Business intelligence (BI)<sup>1</sup> is a term that describes a comprehensive, cohesive, and integrated set of tools and processes used to capture, collect, integrate, store, and analyze data with the purpose of generating and presenting information to support business decision making. This intelligence is based on learning and understanding the facts about the business environment. BI is a framework that allows a business to transform data into information, information into knowledge, and knowledge into wisdom. BI has the potential to positively affect a company's culture by creating continuous business performance improvement through active decision support at all levels in an organization. This business insight empowers users to make sound decisions based on the accumulated knowledge of the business.

BI's initial adopters were high-volume industries such as financial services, insurance, and healthcare companies. As BI technology evolved, its usage spread to other industries such as telecommunications, retail/merchandising, manufacturing, media, government, and even education. [Table 13.1](#) lists some companies that have implemented BI tools and shows how the tools benefited the companies. You will learn about these tools later in the chapter.

---

**TABLE 13.1 Solving Business Problems and Adding Value with BI Tools**

---

| COMPANY                                                                                                                                                                                 | PROBLEM                                                                                                                                                                                                                                                                      | BENEFIT                                                                                                                                                                                                                                                                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CiCi's Enterprises<br>Eighth-largest pizza chain in the U.S.; operates 650 pizza restaurants in 30 states<br>Source: Cognos Corp.<br><a href="http://www.cognos.com">www.cognos.com</a> | <ul style="list-style-type: none"><li>Information access was cumbersome and time-consuming</li><li>Needed to increase accuracy in the creation of marketing budgets</li><li>Needed an easy, reliable, and efficient way to access daily data</li></ul>                       | <ul style="list-style-type: none"><li>Provided accurate, timely budgets in less time</li><li>Provided analysts with access to data for decision-making purposes</li><li>Received in-depth view of product performance by store to reduce waste and increase profits</li></ul>                           |
| NASDAQ<br>Largest U.S. electronic stock market trading organization<br>Source: Oracle<br><a href="http://www.oracle.com">www.oracle.com</a>                                             | <ul style="list-style-type: none"><li>Inability to provide real-time, ad hoc query and standard reporting for executives, business analysts, and other users</li><li>Excessive storage costs for many terabytes of data</li></ul>                                            | <ul style="list-style-type: none"><li>Reduced storage costs by moving to a multitier storage solution</li><li>Implemented new data warehouse center with support for ad hoc query and reporting, and near real-time data access for end users</li></ul>                                                 |
| Pfizer<br>Global pharmaceutical company<br>Source: Oracle Corp.<br><a href="http://www.oracle.com">www.oracle.com</a>                                                                   | <ul style="list-style-type: none"><li>Needed a way to control costs and adjust to tougher market conditions, international competition, and increasing government regulations</li><li>Needed better analytical capabilities and flexible decision-making framework</li></ul> | <ul style="list-style-type: none"><li>Ability to get and integrate financial data from multiple sources in a reliable way</li><li>Streamlined, standards-based financial analysis to improve forecasting process</li><li>Faster and smarter decision making for business strategy formulation</li></ul> |
| Swisscom<br>Switzerland's leading telecommunications provider<br>Source: Microsoft Corp.<br><a href="http://www.microsoft.com">www.microsoft.com</a>                                    | <ul style="list-style-type: none"><li>Needed a tool to help employees monitor service-level compliance</li><li>Had a time-consuming process to generate performance reports</li><li>Needed a way to integrate data from 200 different systems</li></ul>                      | <ul style="list-style-type: none"><li>Ability to monitor performance using dashboard technology</li><li>Quick and easy access to real-time performance data</li><li>Managers have closer and better control over costs</li></ul>                                                                        |

---

Implementing BI in an organization involves capturing not only internal and external business data, but also the metadata, or knowledge about the data. In practice, BI is a complex proposition that requires a deep understanding and alignment of the business processes, business data, and information needs of users at all levels in an organization. (See Appendix O, Data Warehouse Implementation Factors.)

BI is not a product by itself, but a framework of concepts, practices, tools, and technologies that help a business better understand its core capabilities, provide snapshots of the company situation, and identify key opportunities to create

competitive advantage. In general, BI provides a framework for:

1. Collecting and storing operational data
2. Aggregating the operational data into decision support data
3. Analyzing decision support data to generate information
4. Presenting such information to the end user to support business decisions
5. Making business decisions, which in turn generate more data that are collected, stored, and so on (restarting the process)
6. Monitoring results to evaluate outcomes of the business decisions, which again provides more data to be collected, stored, and so on
7. Predicting future behaviors and outcomes with a high degree of accuracy

The seven preceding points represent a systemwide view of the flow of data, processes, and outcomes within the BI framework. In practice, the first point, collecting and storing operational data, does not fall into the realm of a BI system per se; rather, it is the function of an operational system. However, the BI system will use the operational data as input material from which information will be derived. The rest of the processes and outcomes explained in the preceding points are oriented toward generating knowledge, and they are the focus of the BI system.

In the following section, you will learn about the basic BI architecture.

### **13.2.1 BUSINESS INTELLIGENCE ARCHITECTURE**

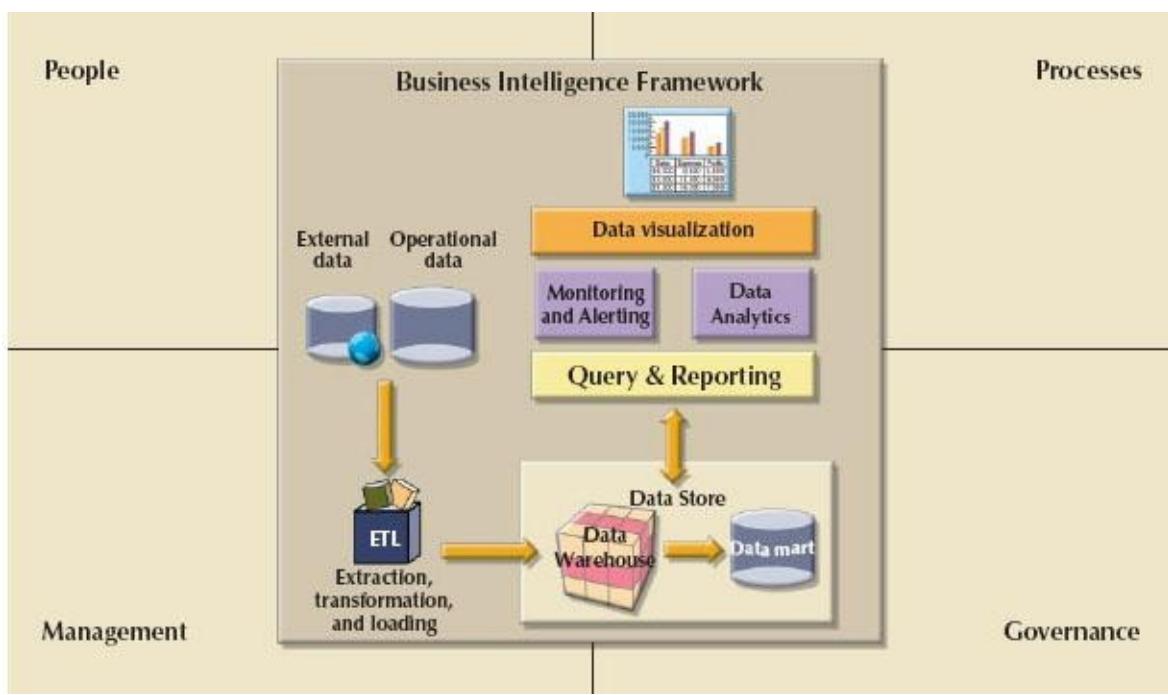
---

BI covers a range of technologies and applications to manage the entire data life cycle from acquisition to storage, transformation, integration, presentation, analysis, monitoring, and archiving. BI functionality ranges from simple data gathering and transformation to very complex data analysis and presentation. BI architecture ranges from highly integrated single-vendor systems to loosely integrated, multivendor environments. However, some common functions are expected in most BI implementations.

Like any critical business IT infrastructure, the BI architecture is composed of data, people, processes, technology, and the management of such components. [Figure 13.1](#) depicts how all these components fit together within the BI framework.

---

**FIGURE 13.1 Business intelligence framework**



SOURCE: Course Technology/Cengage Learning

The general BI framework depicted in [Figure 13.1](#) has six basic components that encompass the functionality required on most current-generation BI systems. You will learn more about these components later in this chapter. The components are briefly described in [Table 13.2](#).

**TABLE 13.2 Basic BI Architectural Components**

| COMPONENT                    | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ETL tools                    | Data extraction, transformation, and loading (ETL) tools collect, filter, integrate, and aggregate internal and external data to be saved into a data store optimized for decision support. Internal data are generated by the company during its day-to-day operations, such as product sales history, invoicing, and payments. The external data sources provide data that cannot be found within the company but are relevant to the business, such as stock prices, market indicators, marketing information (such as demographics), and competitors' data. Such data are generally located in external databases provided by industry groups or companies that market the data. |
| Data store                   | The data store is optimized for decision support and is generally represented by a <i>data warehouse</i> or a <i>data mart</i> . The data are stored in structures that are optimized for data analysis and query speed.                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Query and reporting          | This component performs data selection and retrieval, and is used by the data analyst to create queries that access the database and create the required reports. Depending on the implementation, the query and reporting tool accesses the operational database, or more commonly, the data store.                                                                                                                                                                                                                                                                                                                                                                                 |
| Data visualization           | This component presents data to the end user in a variety of meaningful and innovative ways. This tool helps the end user select the most appropriate presentation format, such as summary reports, maps, pie or bar graphs, mixed graphs, or dashboards.                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Data monitoring and alerting | This component allows real-time monitoring of business activities. The BI system will present the concise information in a single integrated view for the data analyst. This integrated view could include specific metrics about the system performance or activities, such as number of orders placed in the last four hours, number of customer complaints by product by month, and total revenue by region. Alerts can be placed on a given metric; once the value of a metric goes below or above a certain baseline, the system will perform a given action, such as e-mailing shop floor managers, presenting visual alerts, or starting an application.                      |
| Data analytics               | This component performs data analysis and data-mining tasks using the data in the data store. This tool advises the user as to which data analysis tool to select and how to build a reliable business data model. Business models are generated by special algorithms that identify and enhance the understanding of business situations and problems. Data analysis can be either explanatory or predictive. Explanatory analysis uses the existing data in the data store to discover relationships and their types, and predictive analysis creates statistical models of the data that allow predictions of future values and events.                                           |

Each BI component shown in [Table 13.2](#) has generated a fast-growing market for specialized tools. Thanks to technological advancements, the components can interact with other components to form a truly open architecture. As a matter of fact, you can integrate multiple tools from different vendors into a single BI framework. [Table 13.3](#) shows a sample of common BI tools and vendors.

---

**TABLE 13.3 Sample of Business Intelligence Tools**

---

| TOOL                                        | DESCRIPTION                                                                                                                                                                                                                                                                         | SAMPLE VENDORS                                                                     |
|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Dashboards and business activity monitoring | Dashboards use Web-based technologies to present key business performance indicators or information in a single integrated view, generally using graphics that are clear, concise, and easy to understand.                                                                          | Salesforce<br>IBM/Cognos<br>BusinessObjects<br>Information Builders<br>iDashboards |
| Portals                                     | Portals provide a unified, single point of entry for information distribution. Portals are a Web-based technology that use a Web browser to integrate data from multiple sources into a single Web page. Many different types of BI functionality can be accessed through a portal. | Oracle Portal<br>Actuate<br>Microsoft<br>SAP                                       |
| Data analysis and reporting tools           | These advanced tools are used to query multiple and diverse data sources to create integrated reports.                                                                                                                                                                              | Microsoft Reporting Services<br>MicroStrategy<br>SAS WebReportStudio               |
| Data-mining tools                           | These tools provide advanced statistical analysis to uncover problems and opportunities hidden within business data.                                                                                                                                                                | SAP<br>Teradata<br>MicroStrategy<br>MS Analytics Services                          |
| Data warehouses (DW)                        | The data warehouse is the foundation of a BI infrastructure. Data are captured from the production system and placed in the DW on a near real-time basis. BI provides company-wide integration of data and the capability to respond to business issues in a timely manner.         | Microsoft<br>Oracle<br>IBM/Cognos<br>Teradata                                      |
| OLAP tools                                  | Online analytical processing provides multidimensional data analysis.                                                                                                                                                                                                               | IBM/Cognos<br>BusinessObjects<br>Oracle<br>Microsoft                               |
| Data visualization                          | These tools provide advanced visual analysis and techniques to enhance understanding and create additional insight of business data and its true meaning.                                                                                                                           | Dundas<br>Tableau<br>QlikView<br>Actuate                                           |

---

#### NOTE

---

You will learn about data warehouses, data mining, and OLAP tools later in this chapter.

---

As depicted in [Figure 13.1](#), BI integrates people and processes using technology to add value to the business. Such value is derived from how end users apply such information in their daily activities, and particularly in their daily business decision making.

The focus of traditional information systems was on operational automation and reporting; in contrast, BI tools focus on the strategic and tactical use of information. To achieve this goal, BI recognizes that technology alone is not

enough. Therefore, BI uses an arrangement of best management practices to manage data as a corporate asset. One of the most recent developments in this area is the use of master data management techniques. [Master data management \(MDM\)](#) is a collection of concepts, techniques, and processes for the proper identification, definition, and management of data elements within an organization. MDM's main goal is to provide a comprehensive and consistent definition of all data within an organization. MDM ensures that all company resources (people, procedures, and IT systems) that work with data have uniform and consistent views of the company's data.

An added benefit of this meticulous approach to data management and decision making is that it provides a framework for business governance. [Governance](#) is a method or process of government. In this case, BI provides a method for controlling and monitoring business health and for consistent decision making. Furthermore, having such governance creates accountability for business decisions. In the present age of business flux, accountability is increasingly important. Had governance been as pivotal to business operations a few years back, crises precipitated by Enron, WorldCom, Arthur Andersen, and the 2008 financial meltdown might have been avoided.

Monitoring a business's health is crucial to understanding where the company is and where it is headed. To do this, BI makes extensive use of a special type of metrics known as key performance indicators. [Key performance indicators \(KPIs\)](#) are quantifiable numeric or scale-based measurements that assess the company's effectiveness or success in reaching its strategic and operational goals. Many different KPIs are used by different industries. Some examples of KPIs are:

- *General.* Year-to-year measurements of profit by line of business, same-store sales, product turnovers, product recalls, sales by promotion, and sales by employee
- *Finance.* Earnings per share, profit margin, revenue per employee, percentage of sales to account receivables, and assets to sales
- *Human resources.* Applicants to job openings, employee turnover, and employee longevity
- *Education.* Graduation rates, number of incoming freshmen, student retention rates, publication rates, and teaching evaluation scores

KPIs are determined after the main strategic, tactical, and operational goals are

defined for a business. To tie the KPI to the strategic master plan of an organization, a KPI is compared to a desired goal within a specific time frame. For example, if you are in an academic environment, you might be interested in ways to measure student satisfaction or retention. In this case, a sample goal would be to increase the final exam grades of graduating high school seniors by fall 2015. Another sample KPI would be to increase the returning student rate from freshman year to sophomore year from 60 percent to 75 percent by 2015. In this case, such performance indicators would be measured and monitored on a year-to-year basis, and plans to achieve such goals would be set in place.

Although BI has an unquestionably important role in modern business operations, the manager must initiate the decision support process by asking the appropriate questions. The BI environment exists to support the manager; it does not replace the management function. If the manager fails to ask the appropriate questions, problems will not be identified and solved, and opportunities will be missed. In spite of the very powerful BI presence, the human component is still at the center of business technology.

The main BI architectural components were illustrated in [Figure 13.1](#) and further explained in [Tables 13.2](#) and [13.3](#). However, the heart of the BI system is its advanced information generation and decision support capabilities. A BI system's advanced decision support functions come to life via its intuitive and informational user interface, and particularly its reporting capabilities. A modern BI system provides three distinctive reporting styles:

- *Advanced reporting.* A BI system presents insightful information about the organization in a variety of presentation formats. Furthermore, the reports provide interactive features that allow the end user to study the data from multiple points of view—from highly summarized to very detailed data. The reports present key actionable information used to support decision making.
- *Monitoring and alerting.* After a decision has been made, the BI system offers ways to monitor the decision's outcome. The BI system provides the end user with ways to define metrics and other key performance indicators to evaluate different aspects of an organization. In addition, exceptions and alerts can be set to warn managers promptly about deviations or problem areas.

- *Advanced data analytics.* A BI system provides tools to help the end user discover relationships, patterns, and trends hidden within the organization's data. These tools are used to create two types of data analysis: explanatory and predictive. Explanatory analysis provides ways to discover relationships, trends, and patterns among data, while predictive analysis provides the end user with ways to create models that predict future outcomes.

Understanding the architectural components of a BI framework is the first step in properly implementing BI in an organization. A good BI infrastructure promises many benefits to an organization, as outlined in the next section.

### **13.2.2 BUSINESS INTELLIGENCE BENEFITS**

---

As you have learned in previous sections, a properly implemented BI architecture could provide a framework for continuous performance improvements and business decision making. Improved decision making is the main goal of BI, but BI provides other benefits:

- *Integrating architecture.* Like any other IT project, BI has the potential of becoming the integrating umbrella for a disparate mix of IT systems within an organization. This architecture could support all types of company-generated data from operational to executive, as well as diverse hardware such as mainframes, servers, desktops for managers and executives, and mobile devices on the shop floor.
- *Common user interface for data reporting and analysis.* BI front ends can provide up-to-the-minute consolidated information using a common interface for all company users. IT departments no longer have to provide multiple training options for diverse interfaces. End users benefit from similar or common interfaces in different devices that use multiple clever and insightful presentation formats.
- *Common data repository fosters single version of company data.* In the past, multiple IT systems supported different aspects of an organization's operations. Such systems collected and stored data in separate data stores. Keeping the data synchronized and up to date has always been difficult. BI provides a framework to integrate such data under a common environment and present a single version of the data.

- *Improved organizational performance.* BI can provide competitive advantages in many different areas, from customer support to manufacturing processes. Such advantages can be reflected in added efficiency, reduced waste, increased sales, reduced employee and customer turnover, and most importantly, an increased bottom line for the business.

Achieving all these benefits takes a lot of human, financial, and technological resources, not to mention time. BI benefits are not achieved overnight, but are the result of a focused company-wide effort that could take a long time. As a matter of fact, as you will learn in the next section, the BI field has evolved over a long period of time itself.

### 13.2.3 BUSINESS INTELLIGENCE EVOLUTION

---

Providing useful information to end users has been a priority of IT systems since mainframe computing became an integral part of corporations. Business decision support has evolved over many decades. Following computer technology advances, business intelligence started with centralized reporting systems and evolved into today's highly integrated BI environments. [Table 13.4](#) summarizes the evolution of BI systems.

---

**TABLE 13.4 Business Intelligence Evolution**

---

| SYSTEM TYPE                                                      | DATA SOURCE      | DATA EXTRACTION/INTEGRATION PROCESS                                                                                                                  | DATA STORE                                                                              | END-USER QUERY TOOL                                                                  | END USER PRESENTATION TOOL                                                                                                        |
|------------------------------------------------------------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| Traditional mainframe-based online transaction processing (OLTP) | Operational data | None<br>Reports read and summarized data directly from operational data                                                                              | None<br>Temporary files used for reporting purposes                                     | Very basic<br>Predefined reporting formats<br>Basic sorting, totaling, and averaging | Very basic<br>Menu-driven, predefined reports, text and numbers only                                                              |
| Managerial information system (MIS)                              | Operational data | Basic extraction and aggregation<br>Read, filter, and summarize operational data into intermediate data store                                        | Lightly aggregated data in RDBMS                                                        | Same as above, in addition to some ad hoc reporting using SQL                        | Same as above, in addition to some ad hoc columnar report definitions                                                             |
| First-generation departmental decision support system (DSS)      | Operational data | Data extraction and integration process populates DSS data store<br>Run periodically                                                                 | First DSS database generation<br>Usually RDBMS                                          | Query tool with some analytical capabilities and predefined reports                  | Spreadsheet style<br>Advanced presentation tools with plotting and graphics capabilities                                          |
|                                                                  | External data    | Advanced data extraction and integration<br>Access diverse data sources, filters, aggregations, classifications, scheduling, and conflict resolution | Data warehouse<br>RDBMS technology<br>Optimized for query purposes<br>Star schema model | Same as above                                                                        | Same as above, in addition to multidimensional presentation tools with drill-down capabilities                                    |
| Second-generation BI<br><br>Online analytical processing (OLAP)  | Same as above    | Same as above                                                                                                                                        | Data warehouse stores data in MDBMS<br>Cubes with multiple dimensions                   | Adds support for end-user-based data analytics                                       | Same as above, but uses cubes and multidimensional matrixes; limited by terms of cube size<br>Dashboards<br>Scorecards<br>Portals |
| Third-generation Mobile BI and cloud-based                       | Same as above    | Same as above<br>Cloud-based                                                                                                                         | Same as above<br>Cloud based                                                            | Advanced analytics<br>Limited ad hoc interactions                                    | Mobile devices: iPhone, iPad, Blackberry, Android                                                                                 |

Using [Table 13.4](#) as a guide, you can trace business intelligence from the mainframe environment to the desktop and then to the more current cloud-based, mobile BI environments. ([Chapter 14](#), Database Connectivity and Web Technologies, provides a detailed discussion of cloud-based systems.)

The precursor of the modern BI environment was the first-generation decision support system. A [decision support system \(DSS\)](#) is an arrangement of computerized tools used to assist managerial decision making. A DSS typically has a much narrower focus and reach than a BI solution. At first, decision support systems were the realm of a few selected managers in an organization. Over time, and with the introduction of the desktop computer, decision support systems migrated to more agile platforms, such as minicomputers, high-end servers, commodity servers, appliances, and cloud-based offerings. This evolution effectively changed the reach of decision support systems; BI is no longer limited to a small group of top-level managers with training in statistical modeling. Instead, BI is now available to all users in an organization, from line managers to the shop floor to mobile agents in the field.

You can also use [Table 13.4](#) to track the evolution of information dissemination styles used in business intelligence.

- Starting in the late 1970s, the need for information distribution was filled by centralized reports running on mainframes, minicomputers, or even central server environments. Such reports were predefined and took considerable time to process.
- With the introduction of desktop computers in the 1980s, a new style of information distribution, the spreadsheet, emerged as the dominant format for decision support systems. In this environment, managers downloaded information from centralized data stores and manipulated the data in desktop spreadsheets.
- As the use of spreadsheets multiplied, IT departments tried to manage the flow of data in a more formal way using enterprise reporting systems. These systems were developed in the early 1990s and basically integrated all data into an IT umbrella that started with the first-generation DSS. The systems still used spreadsheet-like features with which end users were familiar.
- Once DSSs were established, the evolution of business intelligence flourished with the introduction of the data warehouse and online analytical processing systems (OLAPs) in the mid-1990s.

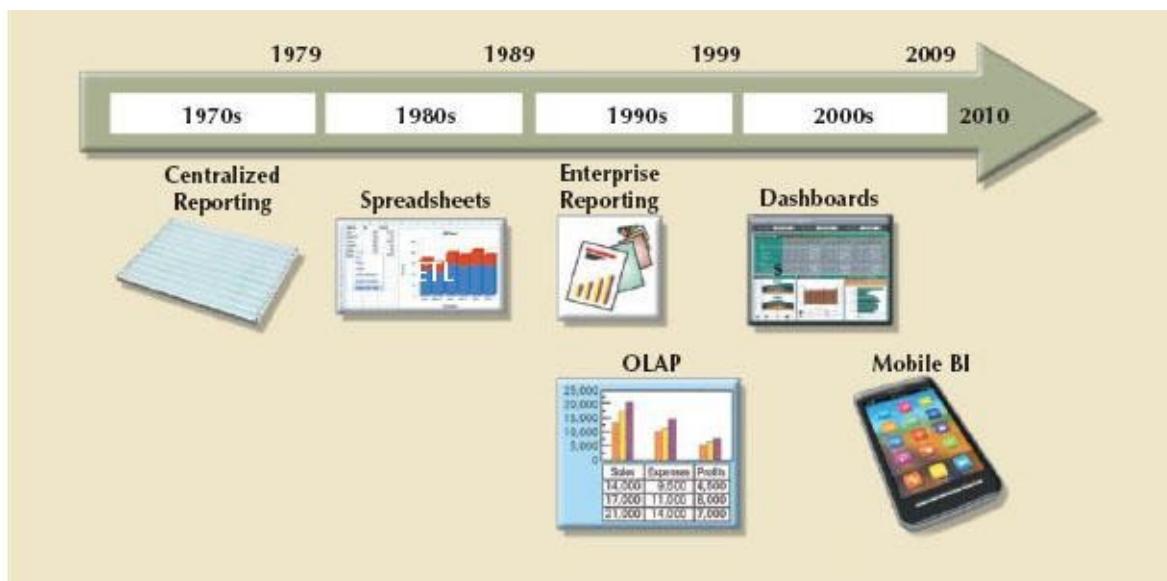
- Rapid changes in information technology and the Internet revolution led to the introduction of advanced BI systems such as Web-based dashboards in the early 2000s and mobile BI later in the decade. With mobile BI, end users access BI reports via native applications that run on a mobile smart device, such as the iPhone, Blackberry, or iPad.

[Figure 13.2](#) depicts the evolution of BI information dissemination.

---

**FIGURE 13.2 Evolution of BI information dissemination formats**

---



Credit: Oleksiy Mark / [Shutterstock.com](#)

SOURCE: Course Technology/Cengage Learning

---

#### NOTE

---

The OLAP environment is covered in [Section 13.7](#) of this chapter.

---

Although now in its infancy, mobile BI technology is poised to have a significant impact on the way BI information is disseminated and processed. If the number of students using smart phones to communicate with friends, update their Facebook status, and send tweets on Twitter is any indicator, you can expect the next generation of consumers and workers to be highly mobile. Leading corporations are therefore starting to push decision making to agents in the field

to facilitate customer relationships, sales and ordering, and product support. Such mobile technologies are so portable and interactive that some users call them “disruptive” technologies.

BI information technology has evolved from centralized reporting styles to the current, mobile BI style in just over a decade. The rate of technological change is not slowing down; to the contrary, technology advancements are accelerating the adoption of BI to new levels. The next section illustrates some BI technology trends.

#### 13.2.4 BUSINESS INTELLIGENCE TECHNOLOGY TRENDS

---

Several technological advances are driving the growth of business intelligence technologies. These advances create new generations of more affordable products and services that are faster and easier to use. In turn, such products and services open new markets and work as driving forces in the increasing adoption of business intelligence technologies within organizations. Some of the more remarkable technological trends are:

- *Data storage improvements.* New data storage technologies, such as solid state drives (SSD) and Serial Advanced Technology Attachment (SATA) drives, offer increased performance and larger capacity that make data storage faster and more affordable. Currently you can buy single drives with a capacity approaching four terabytes.
- *Business intelligence appliances.* Vendors now offer plug-and-play appliances optimized for data warehouse and BI applications. These new appliances offer improved price-performance ratios, simplified administration, rapid installation, scalability, and fast integration. Examples of these vendors include IBM, Netezza, Greenplum, and AsterData.
- *Business intelligence as a service.* Companies are starting to offer data warehouses and BI as a service. These cloud-based services allow any corporation to rapidly develop a data warehouse store without the need for hardware, software, or extra personnel. These prepackaged services offer “pay-as-you-go” models for specific industries and capacities, and they provide an opportunity for organizations to pilot-test a BI project without incurring large time or cost commitments. Such services are

offered by Netezza, AppNexus, AsterData, MicroStrategy, and Kognitio.

- *Big Data analytics.* In [Chapter 2](#), Data Models, you learned about Big Data and column-store databases. The Big Data phenomenon is creating a new market for data analytics. Organizations are turning to social media as the new source for information and knowledge to gain competitive advantages. Examples of Big Data analytics vendors include Vertica, AsterData, and Netezza.
- *Personal analytics.* OLAP brought data analytics to the desktop of every end user in an organization. Mobile BI is extending business decision making outside the walls of the organization. BI can now be deployed to mobile users who are closer to customers. The main requirement is for the BI end user to have a key understanding of the business. Examples of personal analytics vendors include MicroStrategy, QlikView, and Actuate.

One constant in this relentless technological evolution is the need for better decision support data and the importance of understanding the difference between decision support data and operational data.

---

### 13.3 DECISION SUPPORT DATA

---

Although BI is used at strategic and tactical managerial levels within organizations, *its effectiveness depends on the quality of data gathered at the operational level.* Yet, operational data are seldom well suited to the decision support tasks. The differences between operational data and decision support data are examined in the next section.

#### 13.3.1 OPERATIONAL DATA VS. DECISION SUPPORT DATA

---

Operational data and decision support data serve different purposes. Therefore, it is not surprising to learn that their formats and structures differ. Most operational data are stored in a relational database in which the structures (tables) tend to be highly normalized. Operational data storage is optimized to support transactions that represent daily operations. For example, each time an item is sold, it must be accounted for. Customer data, inventory data, and other similar data need

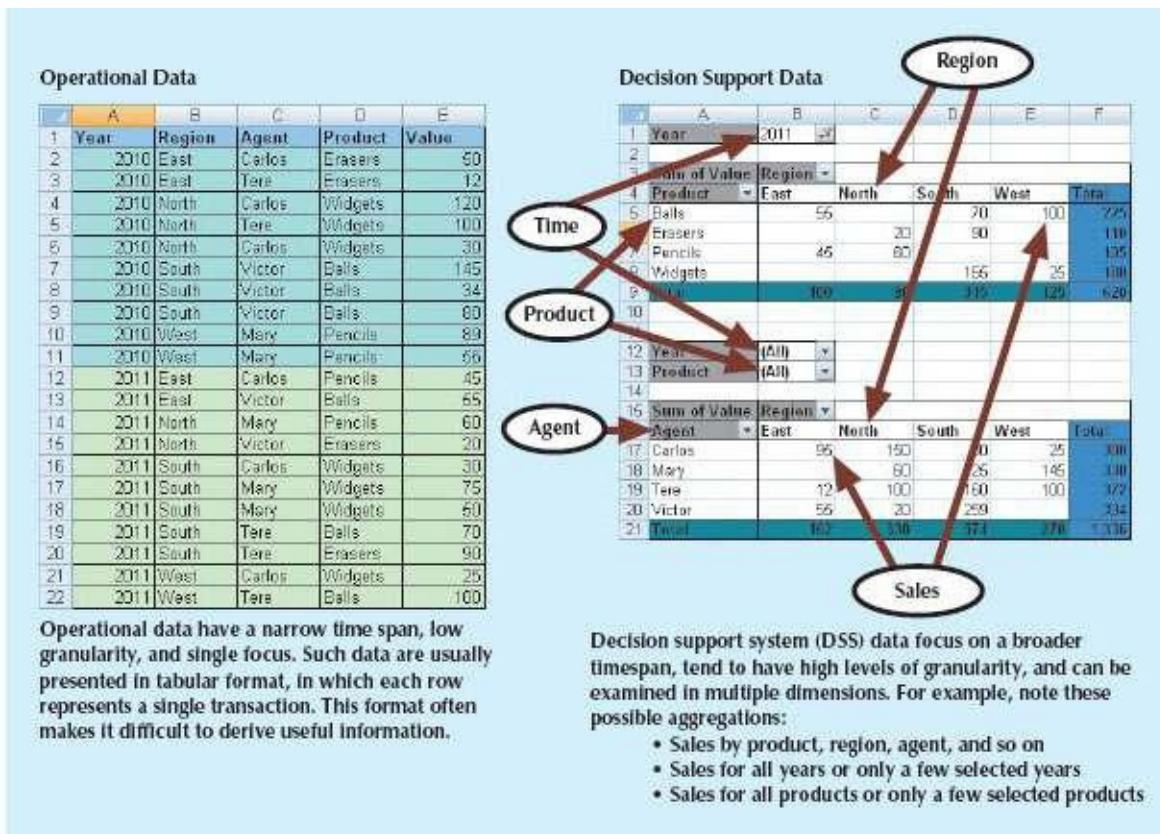
frequent updating. To provide effective update performance, operational systems store data in many tables, each with a minimum number of fields. Thus, a simple sales transaction might be represented by five or more different tables, such as INVOICE, INVOICE LINE, DISCOUNT, STORE, and DEPARTMENT. Although such an arrangement is excellent in an operational database, it is not efficient for query processing. For example, to extract a simple invoice, you would have to join several tables. Whereas operational data are useful for capturing daily business transactions, decision support data give tactical and strategic business meaning to the operational data. From the data analyst's point of view, decision support data differ from operational data in three main areas: time span, granularity, and dimensionality.

- *Time span.* Operational data cover a short time frame. In contrast, decision support data tend to cover a longer time frame. Managers are seldom interested in a specific sales invoice to customer X; rather, they tend to focus on sales generated during the last month, the last year, or the last five years.
- *Granularity (level of aggregation).* Decision support data must be presented at different levels of aggregation, from highly summarized to nearly atomic. For example, if managers analyze regional sales, they must be able to access data showing the sales by region, by city within the region, by store within the city within the region, and so on. In that case, summarized data to compare the regions is required, along with data in a structure that enables a manager to [drill down](#), or decompose, the data into more atomic components—that is, finergained data at lower levels of aggregation. In contrast, when you [roll up](#) the data, you are aggregating the data to a higher level.
- *Dimensionality.* Operational data focus on representing individual transactions rather than the effects of the transactions over time. In contrast, data analysts tend to include many data dimensions and are interested in how the data relate over those dimensions. For example, an analyst might want to know how product X fared relative to product Z during the past six months by region, state, city, store, and customer. In that case, both place and time are part of the picture.

[Figure 13.3](#) shows how decision support data can be examined from multiple dimensions such as product, region, and year, using a variety of filters to produce

each dimension. The ability to analyze, extract, and present information in meaningful ways is one of the differences between decision support data and transaction-at-a-time operational data.

**FIGURE 13.3 Transforming operational data into decision support data**



SOURCE: Course Technology/Cengage Learning



## ONLINE CONTENT

The operational data in [Figure 13.3](#) are available at [www.cengagebrain.com](http://www.cengagebrain.com). The decision support data in [Figure 13.3](#) show the output for the solution to [Problem 2](#) at the end of this chapter.

From the designer's point of view, the differences between operational and decision support data are as follows:

- Operational data represent transactions as they happen in real time. Decision support data are a snapshot of the operational data at a given point in time. Therefore, decision support data are historic, representing a time slice of the operational data.
- Operational and decision support data are different in terms of transaction *type* and transaction *volume*. Whereas operational data are characterized by update transactions, decision support data are mainly characterized by read-only transactions. Decision support data also require *periodic* updates to load new data that are summarized from the operational data. Finally, the concurrent transaction volume in operational data tends to be very high compared with the low to medium levels in decision support data.
- Operational data are commonly stored in many tables, and the stored data represent information about a given transaction only. Decision support data are generally stored in a few tables derived from the operational data. The decision support data do not include the details of each operational transaction. Instead, decision support data represent transaction *summaries*; therefore, the decision support database stores data that are integrated, aggregated, and summarized for decision support purposes.
- The degree to which decision support data are summarized is very high when contrasted with operational data. Therefore, you will see a great deal of derived data in decision support databases. For example, rather than storing all 10,000 sales transactions for a given store on a given day, the decision support database might simply store the total number of units sold and the total sales dollars generated during that day. Decision support data might be collected to monitor such aggregates as total sales for each store or for each product. The purpose of the summaries is simple: they are used to establish and evaluate sales trends and product sales comparisons, and to provide other data that serve decision needs. (How well are items selling? Should this product be discontinued? Has the advertising been effective as measured by increased sales?)
- The data models that govern operational data and decision support data are different. The operational database's frequent and rapid data updates

make data anomalies a potentially devastating problem. Therefore, the data in a relational transaction (operational) system generally require normalized structures that yield many tables, each of which contains the minimum number of attributes. In contrast, the decision support database is not subject to such transaction updates, and the focus is on querying capability. Therefore, decision support databases tend to be non-normalized and include few tables, each of which contains a large number of attributes.

- The frequency and complexity of query activity in the operational database tends to be low to allow additional processing cycles for the more crucial update transactions. Therefore, queries against operational data typically are narrow in scope and low in complexity, and high speed is critical. In contrast, decision support data exist for the sole purpose of serving query requirements. Queries against decision support data typically are broad in scope and high in complexity, and less speed is needed.
- Finally, decision support data are characterized by very large amounts of data. The large data volume is the result of two factors. First, data are stored in non-normalized structures that are likely to display many data redundancies and duplications. Second, the same data can be categorized in many different ways to represent different snapshots. For example, sales data might be stored in relation to product, store, customer, region, and manager.

[\*\*Table 13.5\*\*](#) summarizes the differences between operational and decision support data from the database designer's point of view.

---

**TABLE 13.5 Contrasting Operational and Decision Support Data Characteristics**

---

| CHARACTERISTIC | OPERATIONAL DATA                    | DECISION SUPPORT DATA                                                         |
|----------------|-------------------------------------|-------------------------------------------------------------------------------|
| Data currency  | Current operations<br>Realtime data | Historic data<br>Snapshot of company data<br>Time component (week/month/year) |

|                     |                                              |                                                                                            |
|---------------------|----------------------------------------------|--------------------------------------------------------------------------------------------|
| Granularity         | Atomic-detailed data                         | Summarized data                                                                            |
| Summarization level | Low; some aggregate yields                   | High; many aggregation levels                                                              |
| Data model          | Highly normalized<br>Mostly relational DBMSs | Non-normalized<br>Complex structures<br>Some relational, but mostly multidimensional DBMSs |
| Transaction type    | Mostly updates                               | Mostly query                                                                               |
| Transaction volumes | High update volumes                          | Periodic loads and summary calculations                                                    |
| Transaction speed   | Updates are critical                         | Retrievals are critical                                                                    |
| Query activity      | Low to medium                                | High                                                                                       |
| Query scope         | Narrow range                                 | Broad range                                                                                |
| Query complexity    | Simple to medium                             | Very complex                                                                               |
| Data volumes        | Hundreds of gigabytes                        | Terabytes to petabytes                                                                     |

---

The many differences between operational data and decision support data are good indicators of decision support database requirements, which are described in the next section.

### 13.3.2 DECISION SUPPORT DATABASE REQUIREMENTS

---

A decision support database is a specialized DBMS tailored to provide fast answers to complex queries. There are three main requirements for a decision support database: the database schema, data extraction and filtering, and database size.

#### **Database Schema**

The decision support database schema must support complex (non-normalized) data representations. As noted earlier, the decision support database must contain data that are aggregated and summarized. In addition to meeting those requirements, the queries must be able to extract multidimensional time slices. If you are using an RDBMS, the conditions suggest using non-normalized and even duplicated data. To see why this must be true, take a look at the 10-year sales history for a single store containing a single department. At this point, the

data are fully normalized within the single table, as shown in [Table 13.6](#).

---

**TABLE 13.6 Ten-Year Sales History for a Single Department, in Millions of Dollars**

---

**YEAR SALES**

**2002 8,227**

**2003 9,109**

**2004 10,104**

**2005 11,553**

**2006 10,018**

**2007 11,875**

**2008 12,699**

**2009 14,875**

**2010 16,301**

## 2011 19,986

---

This structure works well when you have only one store with only one department. However, it is very unlikely that such a simple environment has much need for a decision support database. A decision support database becomes a factor when you are dealing with more than one store, each of which has more than one department. To support all of the decision support requirements, the database must contain data for all of the stores and all of their departments—and the database must be able to support multidimensional queries that track sales by stores, by departments, and over time. For simplicity, suppose that there are only two stores (A and B) and two departments (1 and 2) within each store. Also, change the time dimension to include yearly data. [TABLE 13.7](#) shows the sales figures under the specified conditions. Only 2002, 2006, and 2011 are shown; ellipses (...) are used to indicate that data values were omitted. You can see in [Table 13.7](#) that the number of rows and attributes already multiplies quickly and that the table exhibits multiple redundancies.

---

**TABLE 13.7 Yearly Sales Summaries, Two Stores and Two Departments per Store, in Millions of Dollars**

---

| YEAR | STORE | DEPARTMENT | SALES |
|------|-------|------------|-------|
| 2002 | A     | 1          | 1,985 |
| 2002 | A     | 2          | 2,401 |
| 2002 | B     | 1          | 1,879 |
| 2002 | B     | 2          | 1,962 |
| ...  | ...   | ...        | ...   |
| 2006 | A     | 1          | 3,912 |
| 2006 | A     | 2          | 4,158 |
| 2006 | B     | 1          | 3,426 |
| 2006 | B     | 2          | 1,203 |
| ...  | ...   | ...        | ...   |
| 2011 | A     | 1          | 7,683 |
| 2011 | A     | 2          | 6,912 |
| 2011 | B     | 1          | 3,768 |
| 2011 | B     | 2          | 1,623 |

Now suppose that the company has 10 departments per store and 20 stores

nationwide, and suppose that you want to access yearly sales summaries. Now you are dealing with 200 rows and 12 monthly sales attributes per row. (Actually, there are 13 attributes per row if you add each store's sales total for each year.)

The decision support database schema must also be optimized for query (read-only) retrievals. To optimize query speed, the DBMS must support features such as bitmap indexes and data partitioning. In addition, the DBMS query optimizer must be enhanced to support the non-normalized and complex structures in decision support databases.

### **Data Extraction and Filtering**

The decision support database is created largely by extracting data from the operational database and by importing additional data from external sources. Thus, the DBMS must support advanced data extraction and data-filtering tools. To minimize the impact on the operational database, the data extraction capabilities should allow batch and scheduled data extraction, and should support different data sources: flat files and hierarchical, network, and relational databases, as well as multiple vendors. Data-filtering capabilities must include the ability to check for inconsistent data or data validation rules. Finally, to filter and integrate the operational data into the decision support database, the DBMS must support advanced data integration, aggregation, and classification.

Using data from multiple external sources also usually means having to solve data-formatting conflicts. For example, data such as Social Security numbers and dates can occur in different formats; measurements can be based on different scales, and the same data elements can have different names. In short, data must be filtered and purified to ensure that only the pertinent decision support data are stored in the database and that they are stored in a standard format.

### **Database Size**

Decision support databases tend to be very large; gigabyte and terabyte ranges are not unusual. For example, in 2008, Wal-Mart had more than four petabytes of data in its data warehouses. Therefore, the DBMS must be capable of supporting [very large databases \(VLDBs\)](#). To support a VLDB adequately, the DBMS might be required to support advanced storage technologies, and even more importantly, to support multiple-processor technologies, such as a symmetric multiprocessor (SMP) or a massively parallel processor (MPP).

The complex information requirements and the ever-growing demand for

sophisticated data analysis sparked the creation of a new type of data repository. This repository, called a data warehouse, contains data in formats that facilitate data extraction, data analysis, and decision making. It has become the foundation for a new generation of decision support systems.

---

---

## 13.4 THE DATA WAREHOUSE

---

---

Bill Inmon, the acknowledged “father” of the [data warehouse](#), defines the term as “an *integrated, subject-oriented, time-variant, nonvolatile* collection of data that provides support for decision making.”<sup>2</sup> (Italics were added for emphasis.) To understand that definition, take a more detailed look at its components.

- *Integrated.* The data warehouse is a centralized, consolidated database that integrates data derived from the entire organization and from multiple sources with diverse formats. Data integration implies that all business entities, data elements, data characteristics, and business metrics are *described in the same way throughout the enterprise*. Although this requirement sounds logical, you would be amazed to discover how many different measurements for “sales performance” can exist within an organization; the same scenario can be true for any other business element. For instance, the status of an order might be indicated with text labels such as “open,” “received,” “canceled,” and “closed” in one department and as “1,” “2,” “3,” and “4” in another department. A student’s status might be defined as “freshman,” “sophomore,” “junior,” or “senior” in the accounting department and as “FR,” “SO,” “JR,” or “SR” in the computer information systems department. To avoid the potential format tangle, the data in the data warehouse must conform to a common format that is acceptable throughout the organization. This integration can be time-consuming, but once accomplished, it enhances decision making and helps managers better understand the company’s operations. This understanding can be translated into recognition of strategic business opportunities.
- *Subject-oriented.* Data warehouse data are arranged and optimized to provide answers to questions from diverse functional areas within a company. Data warehouse data are organized and summarized by topic,

such as sales, marketing, finance, distribution, and transportation. For each topic, the data warehouse contains specific subjects of interest—products, customers, departments, regions, promotions, and so on. This form of data organization is quite different from the more functional or process-oriented organization of typical transaction systems. For example, an invoicing system designer concentrates on designing normalized data structures to support the business process by storing invoice components in two tables: INVOICE and INVLINE. In contrast, the data warehouse has a *subject* orientation. Data warehouse designers focus specifically on the data rather than on the processes that modify the data. (After all, data warehouse data are not subject to numerous realtime data updates!) Therefore, instead of storing an invoice, the data warehouse stores its “sales by product” and “sales by customer” components because decision support activities require the retrieval of sales summaries by product or customer.

- *Time-variant.* In contrast to operational data, which focus on current transactions, warehouse data represent the flow of data through time. The data warehouse can even contain projected data generated through statistical and other models. It is also time-variant in the sense that when data are periodically uploaded to the data warehouse, all time-dependent aggregations are recomputed. For example, when data for previous weekly sales are uploaded to the data warehouse, the weekly, monthly, yearly, and other time-dependent aggregates for products, customers, stores, and other variables are also updated. Because data in a data warehouse constitute a snapshot of the company history as measured by its variables, the time component is crucial. The data warehouse contains a time ID that is used to generate summaries and aggregations by week, month, quarter, year, and so on. Once the data enter the data warehouse, the time ID assigned to the data cannot be changed.
- *Nonvolatile.* Once data enter the data warehouse, they are never removed. Because the data in the warehouse represent the company’s history, the operational data, which represent the near-term history, are always added to it. Because data are never deleted and new data are continually added, the data warehouse is always growing. Therefore, the DBMS must be able to support multiterabyte or greater databases operating on multiprocessor hardware.

**Table 13.8** summarizes the differences between data warehouses and operational databases.

---

**TABLE 13.8 Characteristics of Data Warehouse Data and Operational Database Data**

---

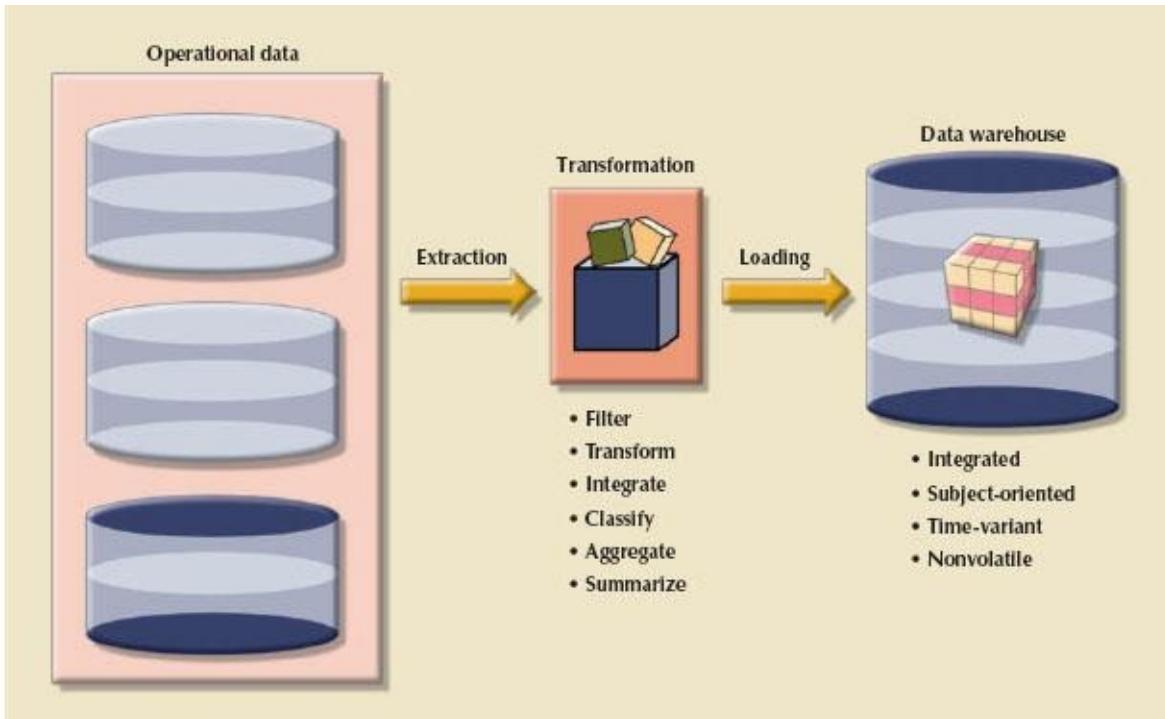
| CHARACTERISTIC   | OPERATIONAL DATABASE DATA                                                                                                                                                                                                                                            | DATA WAREHOUSE DATA                                                                                                                                                                                |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Integrated       | Similar data can have different representations or meanings. For example, Social Security numbers may be stored as ####-##-#### or as #####-####, and a given condition may be labeled as T/F or 0/1 or Y/N. A sales value may be shown in thousands or in millions. | Provide a unified view of all data elements with a common definition and representation for all business units.                                                                                    |
| Subject-oriented | Data are stored with a functional, or process, orientation. For example, data may be stored for invoices, payments, and credit amounts.                                                                                                                              | Data are stored with a subject orientation that facilitates multiple views of the data and decision making. For example, sales may be recorded by product, division, manager, or region.           |
| Time-variant     | Data are recorded as current transactions. For example, the sales data may be the sale of a product on a given date, such as \$342.78 on 12-MAY-2012.                                                                                                                | Data are recorded with a historical perspective in mind. Therefore, a time dimension is added to facilitate data analysis and various time comparisons.                                            |
| Nonvolatile      | Data updates are frequent and common. For example, an inventory amount changes with each sale. Therefore, the data environment is fluid.                                                                                                                             | Data cannot be changed. Data are added only periodically from historical systems. Once the data are properly stored, no changes are allowed. Therefore, the data environment is relatively static. |

In summary, the data warehouse is a read-only database optimized for data analysis and query processing. Typically, data are extracted from various sources and are then transformed and integrated—in other words, passed through a data filter—before being loaded into the data warehouse. As mentioned, this process is known as ETL. [Figure 13.4](#) illustrates the ETL process to create a data warehouse from operational data.

---

**FIGURE 13.4** The ETL process

---



SOURCE: Course Technology/Cengage Learning

---

Although the centralized and integrated data warehouse can be an attractive proposition that yields many benefits, managers may be reluctant to embrace this strategy. Creating a data warehouse requires time, money, and considerable managerial effort. Therefore, it is not surprising that many companies begin their foray into data warehousing by focusing on more manageable data sets that are targeted to meet the special needs of small groups within the organization. These smaller data stores are called data marts.

#### 13.4.1 DATA MARTS

---

A [data mart](#) is a small, single-subject data warehouse subset that provides decision support to a small group of people. In addition, a data mart could be created from data extracted from a larger data warehouse for the specific purpose of supporting faster data access to a target group or function. That is, data marts and data warehouses can coexist within a business intelligence environment.

Some organizations choose to implement data marts not only because of the lower cost and shorter implementation time but because of the technological advances and inevitable “people issues” that make data marts attractive. Powerful computers can provide a customized decision support system to small

groups in ways that might not be possible with a centralized system. Also, a company's culture may predispose its employees to resist major changes, but they might quickly embrace relatively minor changes that lead to demonstrably improved decision support. In addition, people at different organizational levels are likely to require data with different summarization, aggregation, and presentation formats. Data marts can serve as a test vehicle for companies exploring the potential benefits of data warehouses. By gradually migrating from data marts to data warehouses, a specific department's decision support needs can be addressed within six months to one year, as opposed to the one-to-three-year time frame usually required to implement a data warehouse. Information technology (IT) departments also benefit from this approach because their personnel can learn the issues and develop the skills required to create a data warehouse.

The only difference between a data mart and a data warehouse is the size and scope of the problem being solved. The problem definitions and data requirements are essentially the same for both. To be useful, the data warehouse must conform to uniform structures and formats to avoid data conflicts and support decision making.

#### 13.4.2 TWELVE RULES THAT DEFINE A DATA WAREHOUSE

---

In 1994, Bill Inmon and Chuck Kelley created a set of rules to define a data warehouse. These rules summarize many of the points made in this chapter about data warehouses.<sup>3</sup> The 12 rules for a data warehouse are shown in [Table 13.9](#).

---

**TABLE 13.9** Twelve Rules for a Data Warehouse

---

| <b>RULE NO.</b> | <b>DESCRIPTION</b> |
|-----------------|--------------------|
|-----------------|--------------------|

**1** The data warehouse and operational environments are separated.

**2** The data warehouse data are integrated.

- 3** The data warehouse contains historical data over a long time.
  - 4** The data warehouse data are snapshot data captured at a given point in time.
  - 5** The data warehouse data are subject oriented.
  - 6** The data warehouse data are mainly read-only with periodic batch updates from operational data. No online updates are allowed.
  - 7** The data warehouse development life cycle differs from classical systems development. Data warehouse development is data-driven; the classical approach is process-driven.
  - 8** The data warehouse contains data with several levels of detail: current detail data, old detail data, lightly summarized data, and highly summarized data.
  - 9** The data warehouse environment is characterized by read-only transactions to very large data sets. The operational environment is characterized by numerous update transactions to a few data entities at a time.
  - 10** The data warehouse environment has a system that traces data sources, transformations, and storage.
  - 11** The data warehouse's metadata are a critical component of this environment. The metadata identify and define all data elements. The metadata provide the source, transformation, integration, storage, usage, relationships, and history of each data element.
  - 12** The data warehouse contains a chargeback mechanism for resource usage that enforces optimal use of the data by end users.
-

Note how the 12 rules capture the complete data warehouse life cycle—from its introduction as an entity separate from the operational data store to its components, functionality, and management processes.

Most data warehouse implementations are based on the relational database model, and their market share suggests that their popularity will not fade anytime soon. Relational data warehouses use the star schema design technique to handle multidimensional data.

---

## 13.5 STAR SCHEMAS

---

The [star schema](#) is a data-modeling technique used to map multidimensional decision support data into a relational database. In effect, the star schema creates the near equivalent of a multidimensional database schema from the existing relational database. Star schemas yield an easily implemented model for multidimensional data analysis while preserving the relational structures on which the operational database is built. The basic star schema has four components: facts, dimensions, attributes, and attribute hierarchies.

### 13.5.1 FACTS

---

[Facts](#) are numeric measurements (values) that represent a specific business aspect or activity. For example, sales figures are numeric measurements that represent product and service sales. Facts commonly used in business data analysis are units, costs, prices, and revenues. Facts are normally stored in a [fact table](#) that is the center of the star schema. The fact table contains facts that are linked through their dimensions, which are explained in the next section.

Facts can also be computed or derived at run time. Such computed or derived facts are sometimes called [metrics](#) to differentiate them from stored facts. The fact table is updated periodically with data from operational databases.

### 13.5.2 DIMENSIONS

---

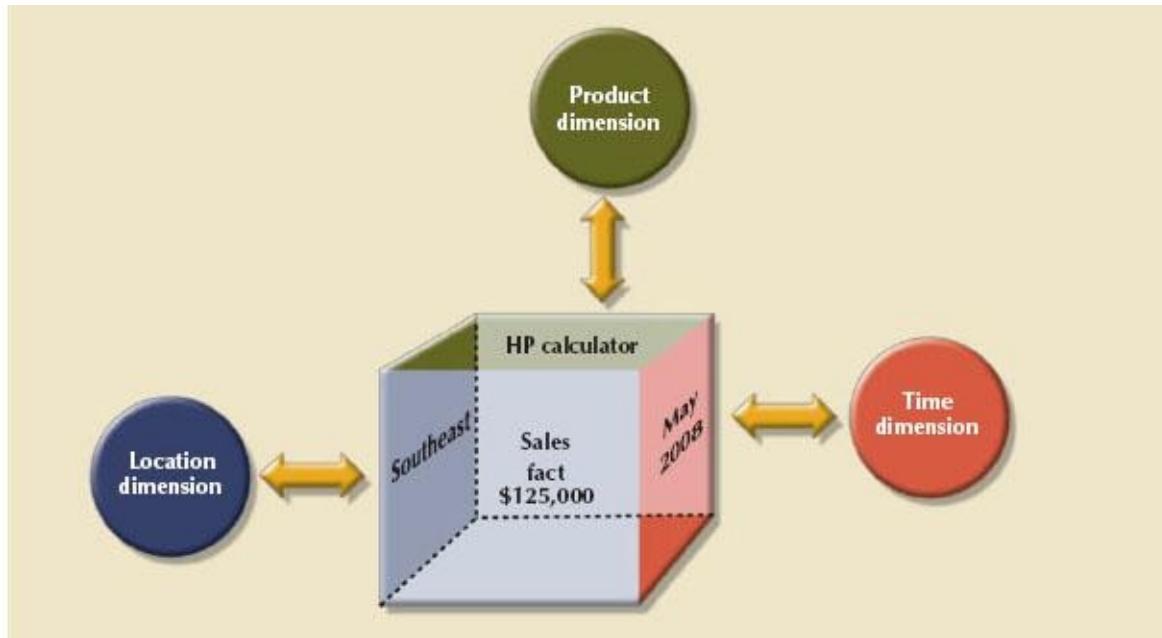
[Dimensions](#) are qualifying characteristics that provide additional perspectives to a given fact. Recall that dimensions are of interest because *decision support data are almost always viewed in relation to other data*. For instance, sales might be compared by product from region to region and from one time period to the next.

The kind of problem typically addressed by a BI system might be to compare the sales of unit X by region for the first quarters of 2002 through 2012. In that example, sales have product, location, and time dimensions. In effect, dimensions are the magnifying glass through which you study the facts. Such dimensions are normally stored in [dimension tables](#). [Figure 13.5](#) depicts a star schema for sales with product, location, and time dimensions.

---

**FIGURE 13.5 Simple star schema**

---



SOURCE: Course Technology/Cengage Learning

---

### 13.5.3 ATTRIBUTES

---

Each dimension table contains attributes. Attributes are often used to search, filter, or classify facts. *Dimensions provide descriptive characteristics about the facts through their attributes.* Therefore, the data warehouse designer must define common business attributes that will be used by the data analyst to narrow a search, group information, or describe dimensions. Using a sales example, some possible attributes for each dimension are illustrated in [Table 13.10](#).

---

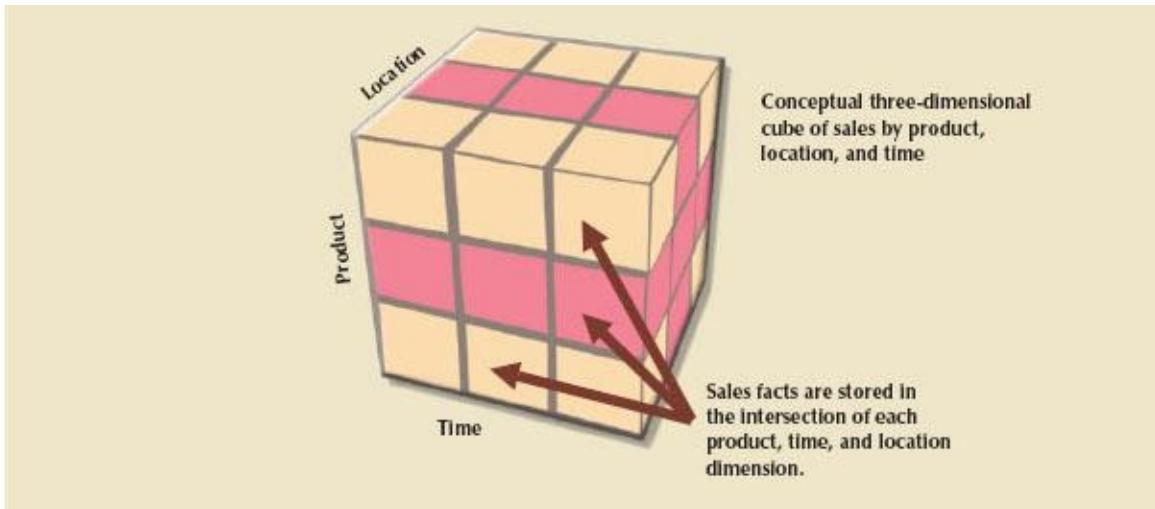
**TABLE 13.10 Possible Attributes for Sales Dimensions**

| DIMENSION NAME | DESCRIPTION                                                                                                                                              | POSSIBLE ATTRIBUTES                                                            |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Location       | Anything that provides a description of the location—for example, Nashville, Store 101, South Region, and TN                                             | Region, state, city, store, and so on                                          |
| Product        | Anything that provides a description of the product sold—for example, hair care product, shampoo, Natural Essence brand, 5.5-oz. bottle, and blue liquid | Product type, product ID, brand, package, presentation, color, size, and so on |
| Time           | Anything that provides a time frame for the sales fact—for example, the year 2012, the month of July, the date 07/29/2012, and the time 4:46 p.m.        | Year, quarter, month, week, day, time of day, and so on                        |

These product, location, and time dimensions add a business perspective to the sales facts. The data analyst can now group the sales figures for a given product, in a given region, and at a given time. The star schema, through its facts and dimensions, can provide the data in a format suited for data analysis. Also, it can do so without imposing the burden of additional and unnecessary data, such as order number, purchase order number, and status, that commonly exist in operational databases.

Conceptually, the sales example's multidimensional data model is best represented by a three-dimensional cube. Of course, this does not imply that there is a limit on the number of dimensions you can associate to a fact table. There is no mathematical limit to the number of dimensions used. However, using a three-dimensional model makes it easy to visualize the problem. The three-dimensional cube illustrated in [Figure 13.6](#) represents a view of sales with product, location, and time dimensions.

**FIGURE 13.6 Three-dimensional view of sales**



SOURCE: Course Technology/Cengage Learning

---

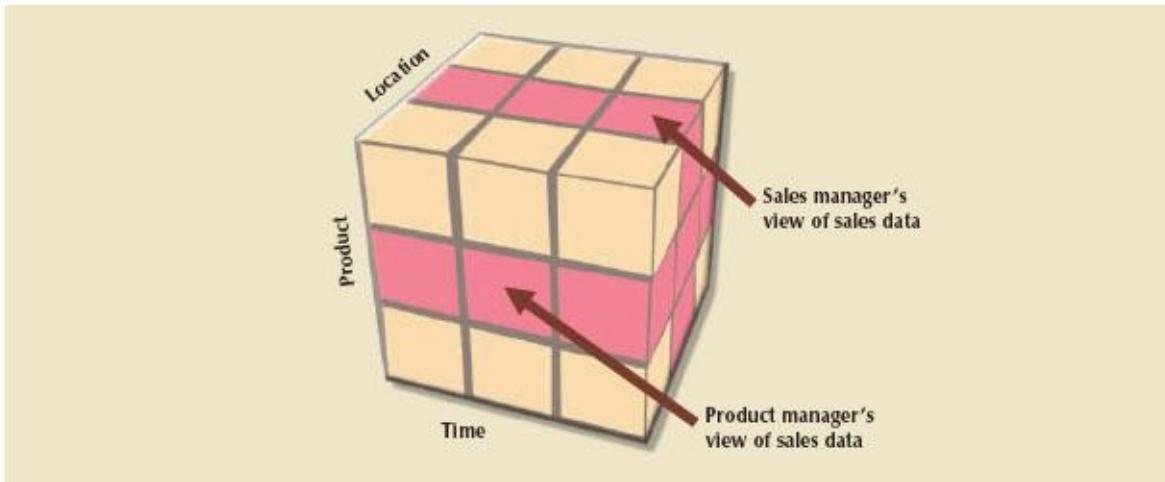
Keep in mind that this cube is only a *conceptual* representation of multidimensional data; it does not show how the data are physically stored in a data warehouse.

Whatever the underlying database technology, one of the main features of multidimensional analysis is its ability to focus on specific “slices” of the cube. For example, the product manager may be interested in examining the sales of a product while the store manager is interested in examining the sales made by a particular store. In multidimensional terms, the ability to focus on slices of the cube to perform a more detailed analysis is known as [slice and dice](#). [Figure 13.7](#) illustrates the slice-and-dice concept; note that each cut across the cube yields a slice. Intersecting slices produce small cubes that constitute the “dice” part of the slice-and-dice operation.

---

**FIGURE 13.7 Slice-and-dice view of sales**

---



SOURCE: Course Technology/Cengage Learning

---

To slice and dice, it must be possible to identify each slice of the cube. To do so, you use the values of each attribute in a given dimension. For example, to use the location dimension, you might need to define a STORE\_ID attribute to focus on a particular store.

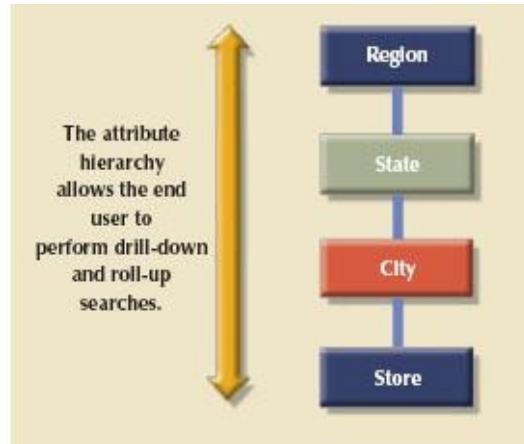
Given the requirement for attribute values in a slice-and-dice environment, reexamine [Table 13.10](#). Note that each attribute adds perspective to the sales facts, thus setting the stage for finding new ways to search, classify, and possibly aggregate information. For example, the location dimension adds a geographic perspective of where the sales took place: in which region, state, city, store, and so on. All of the attributes are selected with the objective of providing decision support data to end users so they can study sales by each of the dimension's attributes.

Time is an especially important dimension; it provides a framework from which sales patterns can be analyzed and possibly predicted. Also, the time dimension plays an important role when the data analyst is interested in studying sales aggregates by quarter, month, week, and so on. Given the importance and universality of the time dimension from a data analysis perspective, many vendors have added automatic time dimension management features to their data-warehousing products.

---

**FIGURE 13.8 Location attribute hierarchy**

---



SOURCE: Course Technology/Cengage Learning

---

#### 13.5.4 ATTRIBUTE HIERARCHIES

---

Attributes within dimensions can be ordered in a well-defined attribute hierarchy. The [attribute hierarchy](#) provides a topdown data organization that is used for two main purposes: aggregation and drilldown/roll-up data analysis. For example, [Figure 13.8](#) shows how the location dimension attributes can be organized in a hierarchy by region, state, city, and store.

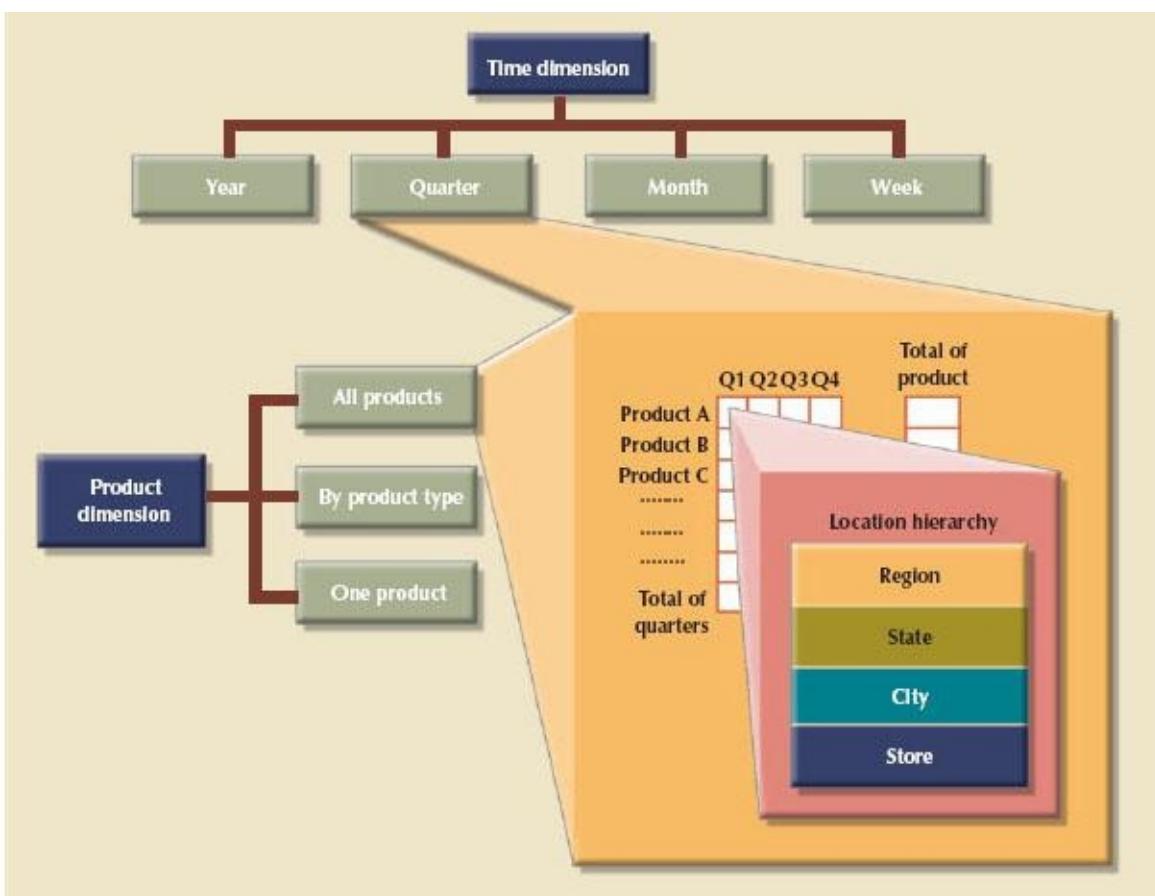
The attribute hierarchy provides the capability to perform drilldown and roll-up searches in a data warehouse. For example, suppose a data analyst looks at the answers to the following query: How does the 2011 month-to-date sales performance compare to the 2012 month-to-date sales performance? The data analyst spots a sharp sales decline for March 2012, and thus might decide to drill down inside the month of March to see how sales by regions compared to the previous year. By doing that, the analyst can determine whether the low March sales were reflected in all regions or in only a particular region. This type of drilldown operation can even be extended until the data analyst identifies the store that is performing below the norm.

The March sales scenario is possible because the attribute hierarchy allows the data warehouse and BI systems to have a defined path that identifies how data are to be decomposed and aggregated for drilldown and roll-up operations. It is not necessary for all attributes to be part of an attribute hierarchy; some attributes exist merely to provide narrative descriptions of the dimensions. However, keep in mind that the attributes from different dimensions can be grouped to form a hierarchy. For example, after you drill down from city to

store, you might want to drill down using the product dimension so the manager can identify slow-selling products in the store. The product dimension can be based on the product group (dairy, meat, and so on) or the product brand (Brand A, Brand B, and so on).

[Figure 13.9](#) illustrates a scenario in which the data analyst studies sales facts using the product, time, and location dimensions. In this example, the product dimension is set to “All products,” meaning that the data analyst will see all products on the y-axis. The time dimension (x-axis) is set to “Quarter,” meaning that the data are aggregated by quarters—for example, total sales of products A, B, and C in Q1, Q2, Q3, and Q4. Finally, the location dimension is initially set to “Region,” thus ensuring that each cell contains the total regional sales for a given product in a given quarter.

**FIGURE 13.9 Attribute hierarchies in multidimensional analysis**



SOURCE: Course Technology/Cengage Learning

The simple scenario illustrated in [Figure 13.9](#) provides the data analyst with three different information paths. On the product dimension (the y-axis), the data analyst can request to see all products, products grouped by type, or just one product. On the time dimension (the x-axis), the data analyst can request time-variant data at different levels of aggregation: year, quarter, month, or week. Each sales value initially shows the total sales, by region, of each product. When a GUI is used, clicking on the region cell enables the data analyst to drill down to see sales by states within the region. Clicking again on one of the state values yields the sales for each city in the state, and so forth.

As the preceding examples illustrate, attribute hierarchies determine how the data in the data warehouse are extracted and presented. The attribute hierarchy information is stored in the DBMS's data dictionary and is used by the BI tool to access the data warehouse properly. Once such access is ensured, query tools must be closely integrated with the data warehouse's metadata, and they must support powerful analytical capabilities.

#### 13.5.5 STAR SCHEMA REPRESENTATION

---

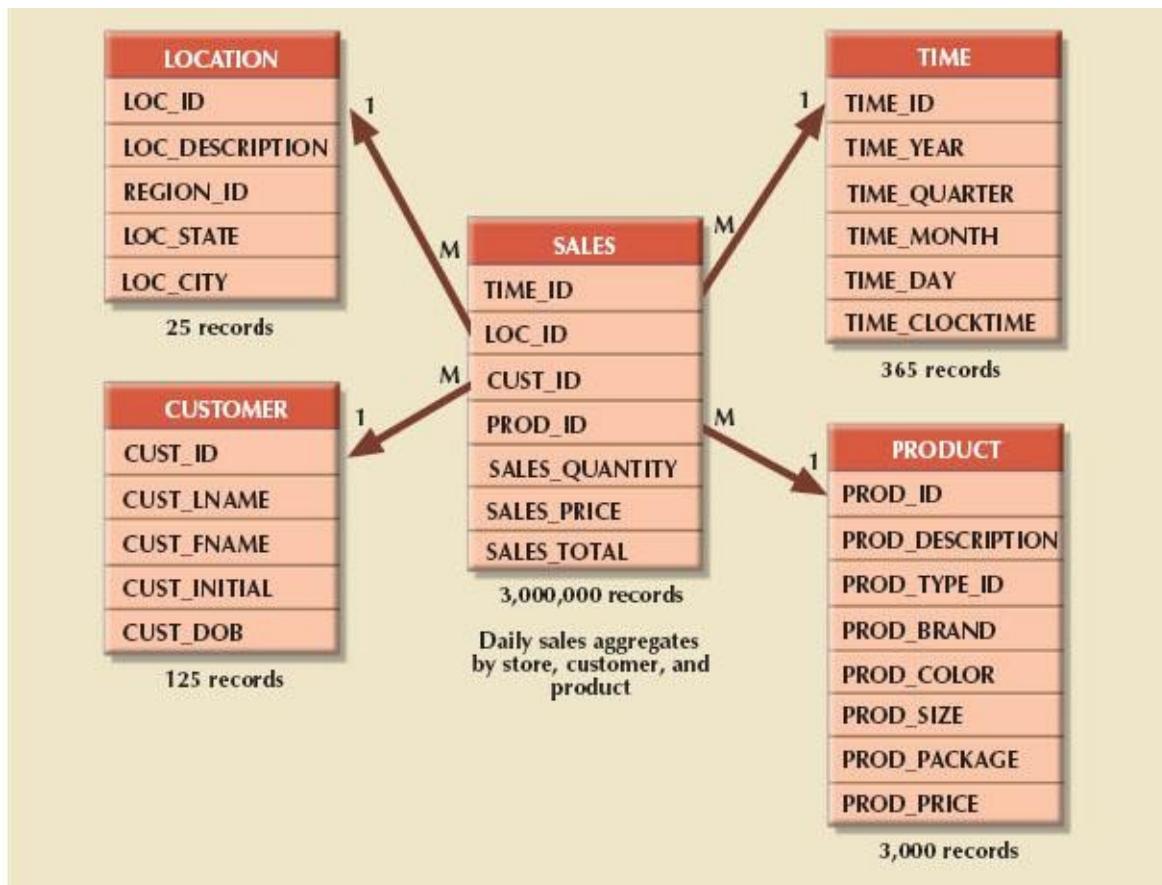
Facts and dimensions are normally represented by physical tables in the data warehouse database. The fact table is related to each dimension table in a many-to-one (M:1) relationship. In other words, many fact rows are related to each dimension row. Using the sales example, you can conclude that each product appears many times in the SALES fact table.

Fact and dimension tables are related by foreign keys and are subject to the familiar primary key and foreign key constraints. The primary key on the “1” side, the dimension table, is stored as part of the primary key on the “many” side, the fact table. *Because the fact table is related to many dimension tables, the primary key of the fact table is a composite primary key.* [Figure 13.10](#) illustrates the relationships among the sales fact table and the product, location, and time dimension tables. To show you how easily the star schema can be expanded, a customer dimension has been added to the mix. Adding the customer dimension merely required including the CUST\_ID in the SALES fact table and adding the CUSTOMER table to the database.

---

**FIGURE 13.10** Star schema for SALES

---



SOURCE: Course Technology/Cengage Learning

The composite primary key for the SALES fact table is composed of TIME\_ID, LOC\_ID, CUST\_ID, and PROD\_ID. Each record in the SALES fact table is uniquely identified by the combination of values for each of the fact table's foreign keys. *By default, the fact table's primary key is always formed by combining the foreign keys pointing to the dimension tables to which they are related.* In this case, each sales record represents each product sold to a specific customer, at a specific time, and in a specific location. In this schema, the TIME dimension table represents daily periods, so the SALES fact table represents daily sales aggregates by product and by customer. Because fact tables contain the actual values used in the decision support process, those values are repeated many times in the fact tables. Therefore, the fact tables are always the largest tables in the star schema. Because the dimension tables contain only nonrepetitive information, such as all unique salespersons and all unique products, the dimension tables are always smaller than the fact tables.

In a typical star schema, each dimension record is related to thousands of fact

records. For example, “widget” appears only once in the product dimension, but it has thousands of corresponding records in the SALES fact table. This characteristic of the star schema facilitates data retrieval because the data analyst usually looks at the facts through the dimension’s attributes. Therefore, a data warehouse DBMS that is optimized for decision support first searches the smaller dimension tables before accessing the larger fact tables.

Data warehouses usually have many fact tables. Each fact table is designed to answer specific decision support questions. For example, suppose that you develop a new interest in orders while maintaining your original interest in sales. In that scenario, you should maintain an ORDERS fact table and a SALES fact table in the same data warehouse. If orders are considered to be an organization’s key interest, the ORDERS fact table should be the center of a star schema that might have vendor, product, and time dimensions. In that case, an interest in vendors yields a new vendor dimension, represented by a new VENDOR table in the database. The product dimension is represented by the same product table used in the initial sales star schema. However, given the interest in orders as well as sales, the time dimension now requires special attention. If the orders department uses the same time periods as the sales department, time can be represented by the same time table. If different time periods are used, you must create another table, perhaps named ORDER\_TIME, to represent the time periods used by the orders department. In [Figure 13.11](#), the orders star schema shares the product, vendor, and time dimensions.

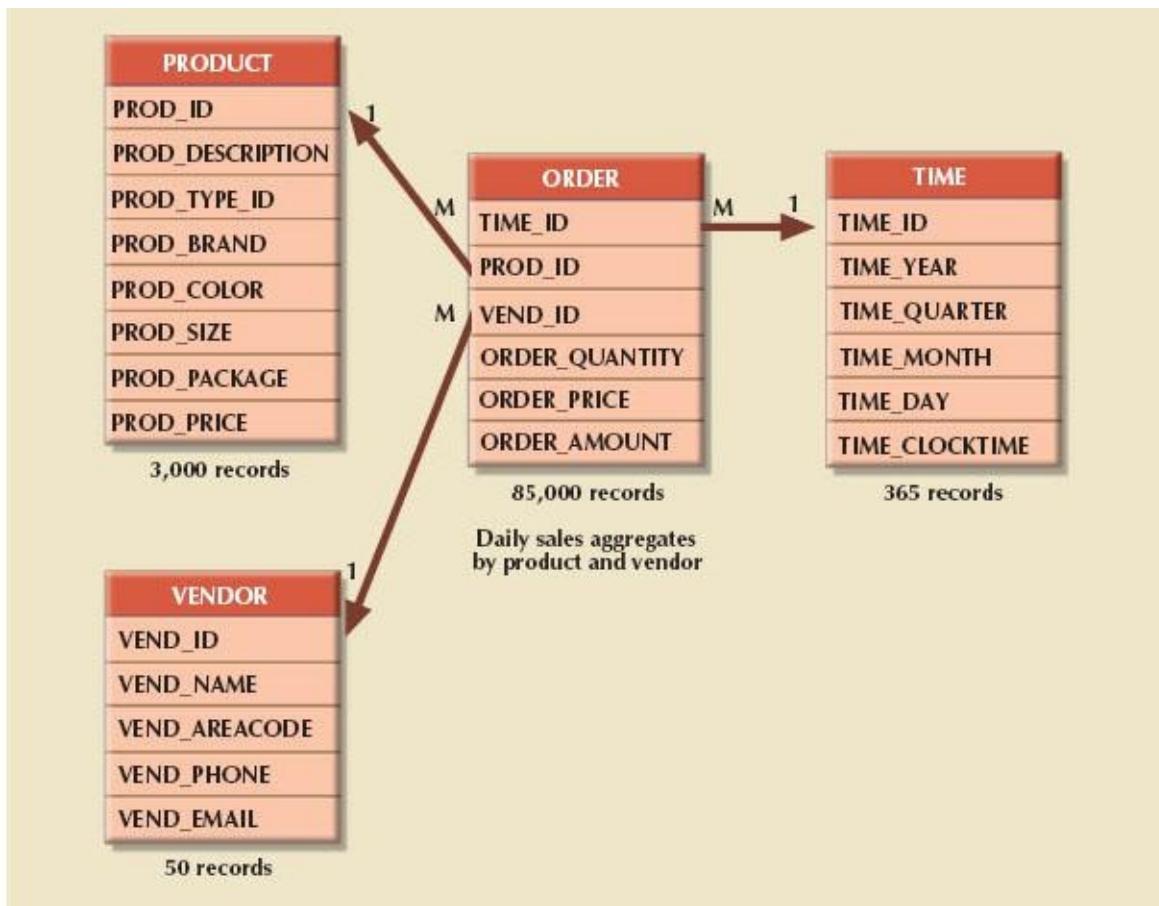
---

---

**FIGURE 13.11 Orders star schema**

---

---



SOURCE: Course Technology/Cengage Learning

---

Multiple fact tables can also be created for performance and semantic reasons. The following section explains several performance-enhancing techniques that can be used within the star schema.

#### 13.5.6 PERFORMANCE-IMPROVING TECHNIQUES FOR THE STAR SCHEMA

---

Creating a database that provides fast and accurate answers to data analysis queries is the prime objective of data warehouse design. Therefore, performance enhancement might target query speed through the facilitation of SQL code and through better semantic representation of business dimensions. The following four techniques are often used to optimize data warehouse design:

- Normalizing dimensional tables
- Maintaining multiple fact tables to represent different aggregation levels
- Denormalizing fact tables

- Partitioning and replicating tables

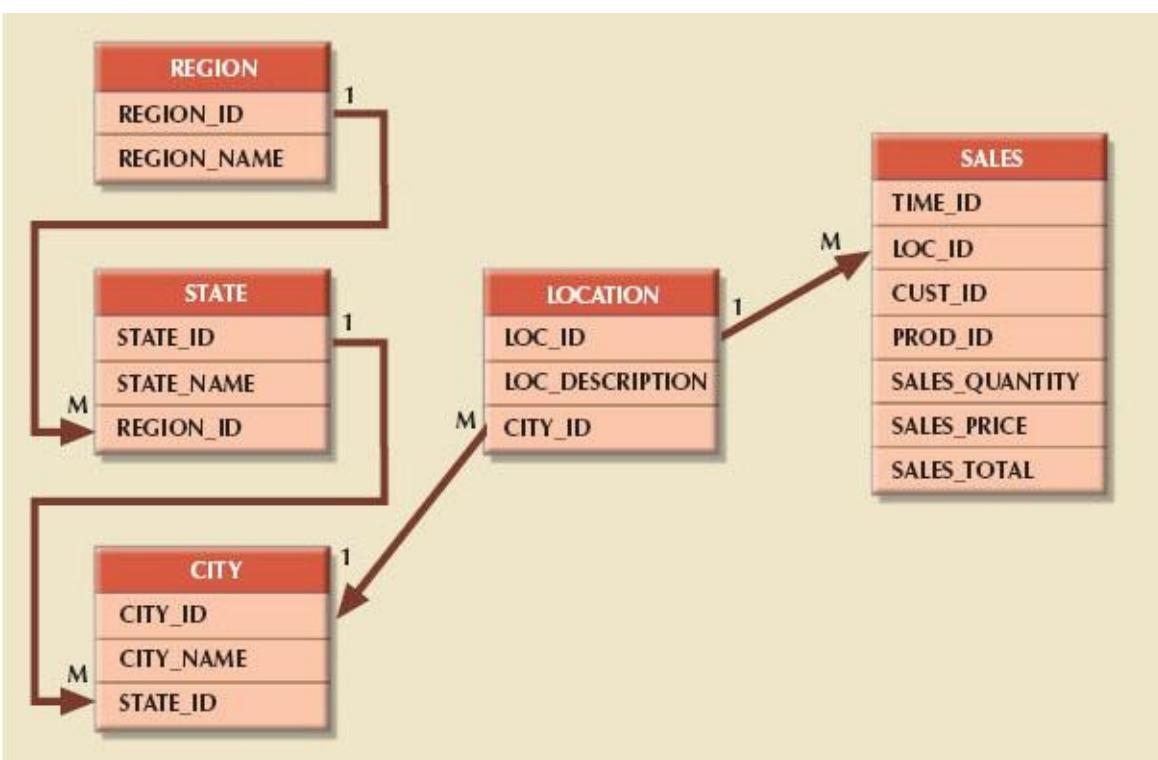
## Normalizing Dimensional Tables

Dimensional tables are normalized to achieve semantic simplicity and facilitate end-user navigation through the dimensions. For example, if the location dimension table contains transitive dependencies among region, state, and city, you can revise those relationships to the 3NF (third normal form), as shown in [Figure 13.12](#). (If necessary, review the normalization techniques in [Chapter 6](#), Normalization of Database Tables.) The star schema shown in [Figure 13.12](#) is known as a [snowflake schema](#), which is a type of star schema in which the dimension tables can have their own dimension tables. The snowflake schema is usually the result of normalizing dimension tables.

---

**FIGURE 13.12** Normalized dimension tables

---



SOURCE: Course Technology/Cengage Learning

---

By normalizing the dimension tables, you simplify the data-filtering operations related to the dimensions. In this example, the region, state, city, and location contain very few records compared to the SALES fact table. Only the location

table is directly related to the SALES fact table.

---

#### NOTE

---

Although using the dimension tables shown in [Figure 13.12](#) provides structural simplicity, there is a price to pay for that simplicity. For example, if you want to aggregate the data by region, you must use a four-table join, thus increasing the complexity of the SQL statements. The star schema in [Figure 13.10](#) uses a LOCATION dimension table that greatly facilitates data retrieval by eliminating multiple join operations. This is yet another example of the trade-offs that designers must consider.

---

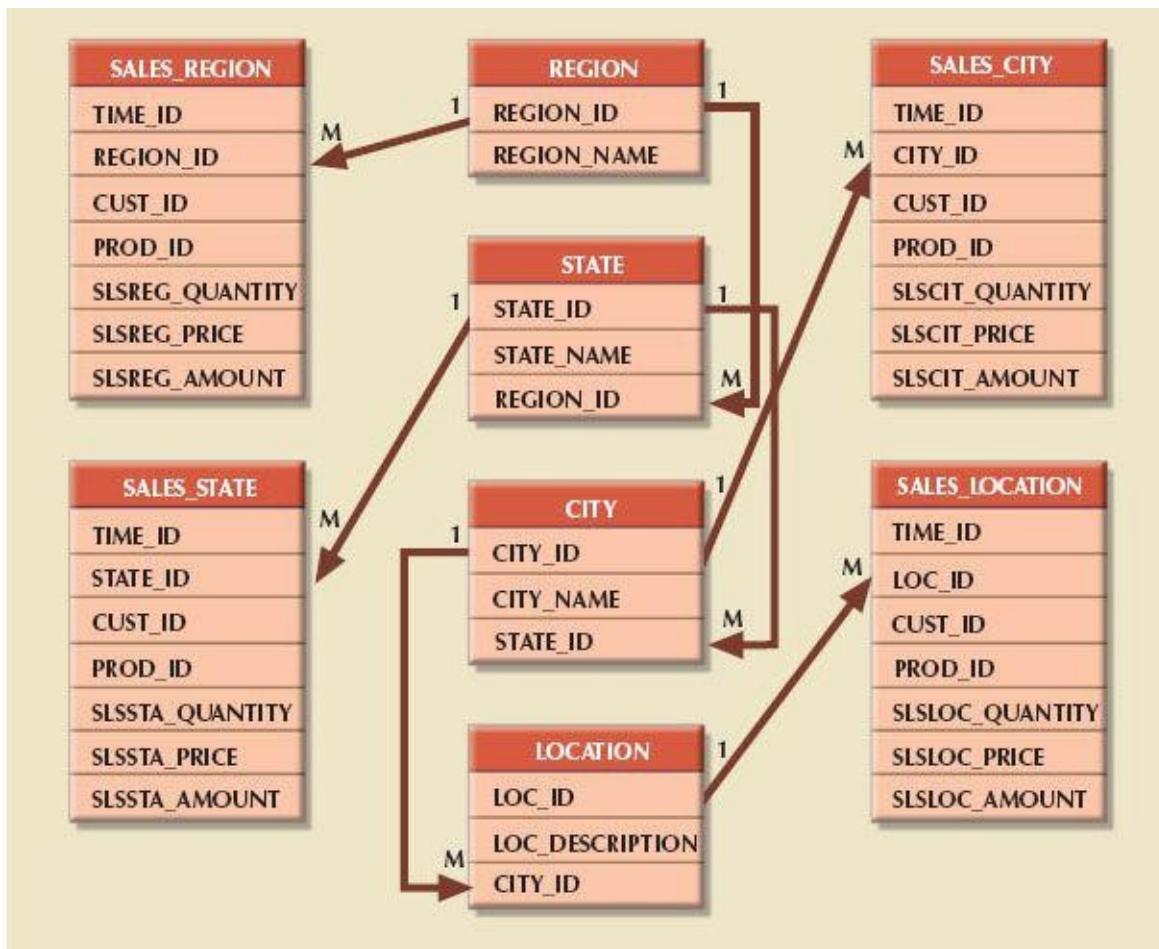
### Maintaining Multiple Fact Tables That Represent Different Aggregation Levels

You can also speed up query operations by creating and maintaining multiple fact tables related to each level of aggregation (region, state, and city) in the location dimension. These aggregate tables are precomputed at the data-loading phase rather than at run time. The purpose of this technique is to save processor cycles at run time, thereby speeding up data analysis. An end-user query tool optimized for decision analysis then properly accesses the summarized fact tables instead of computing the values by accessing a fact table at a lower level of detail. This technique is illustrated in [Figure 13.13](#), which adds aggregate fact tables for region, state, and city to the initial sales example.

---

**FIGURE 13.13** Multiple fact tables

---



SOURCE: Course Technology/Cengage Learning

The data warehouse designer must identify which levels of aggregation to precompute and store in the database. These multiple aggregate fact tables are updated during each load cycle in batch mode. Also, because the objective is to minimize access according to the expected frequency of use and to minimize the processing time required to calculate a given aggregation level at run time, the data warehouse designer must select which aggregation fact tables to create.

### Denormalizing Fact Tables

Denormalizing fact tables improves data access performance and saves data storage space. The latter objective, however, is becoming less of an issue. Data storage costs decrease almost daily, and DBMS limitations on database and table size, record size, and the maximum number of records in a single table have far more negative effects than raw storage space costs.

Denormalization improves performance by using a single record to store data

that normally take many records. For example, to compute the total sales for all products in all regions, you might have to access the region sales aggregates and summarize all of the records in this table. If you have 300,000 product sales, you could be summarizing at least 300,000 rows. Although this might not be a taxing operation for a DBMS, a comparison of 10 years' worth of previous sales begins to bog down the system. In such cases, it is useful to have special aggregate tables that are denormalized. For example, a YEAR\_TOTALS table might contain the following fields: YEAR\_ID, MONTH\_1, MONTH\_2 ... MONTH\_12, and each year's total. Such tables can easily be used to serve as a basis for year-to-year comparisons at the top month level, the quarter level, or the year level. Here again, design criteria such as frequency of use and performance requirements are evaluated against the possible overload placed on the DBMS to manage the denormalized relations.

## Partitioning and Replicating Tables

Because table partitioning and replication were covered in detail in [Chapter 12](#), Distributed Database Management Systems, those techniques are discussed here only as they specifically relate to the data warehouse. Table partitioning and replication are particularly important when a BI system is implemented in dispersed geographic areas. [Partitioning](#) splits a table into subsets of rows or columns and places the subsets close to the client computer to improve data access time. [Replication](#) makes a copy of a table or partition and places it in a different location, also to improve access time.

No matter which performance-enhancement scheme is used, time is the most common dimension used in business data analysis. Therefore, it is very common to have one fact table for each level of aggregation defined within the time dimension. In the sales example, you might have five aggregate sales fact tables: daily, weekly, monthly, quarterly, and yearly. These fact tables must have an implicit or explicit periodicity defined. [Periodicity](#), which is usually expressed as current year only, previous years, or all years, provides information about the time span of the data stored in the table.

At the end of each year, daily sales for the current year are moved to another table that contains previous years' daily sales only. This table actually contains all sales records from the beginning of operations, with the exception of the current year. The data in the current year and previous years' tables thus represent the complete sales history of the company. The previous years' sales table can be replicated at several locations to avoid having to remotely access the historic sales data, which can cause a slow response time. The possible size of

this table is enough to intimidate all but the bravest of query optimizers. Here is one case in which denormalization would be of value!

In this section you learned how the star schema design technique allows you to model data optimized for business decision making. BI tools use the data warehouse data as the raw materials for data analytics to generate business knowledge.

---

## 13.6 DATA ANALYTICS

---

Data analytics is a subset of BI functionality that encompasses a wide range of mathematical, statistical, and modeling techniques with the purpose of extracting knowledge from data. Data analytics is used at all levels within the BI framework, including queries and reporting, monitoring and alerting, and data visualization. Hence, data analytics is a “shared” service that is crucial to what BI adds to an organization. Data analytics represents what business managers really want from BI: the ability to extract actionable business insight from current events and foresee future problems or opportunities.

[Data analytics](#) discovers characteristics, relationships, dependencies, or trends in the organization’s data, and then explains the discoveries and predicts future events based on the discoveries. In practice, data analytics is better understood as a continuous spectrum of knowledge acquisition that goes from *discovery* to *explanation* to *prediction*. The outcomes of data analytics then become part of the information framework on which decisions are built. Based on the previous discussion, data analytics tools can be grouped into two separate (but closely related and often overlapping) areas:

- [Explanatory analytics](#) focuses on discovering and explaining data characteristics and relationships based on existing data. Explanatory analytics uses statistical tools to formulate hypotheses, test them, and answer the *how* and *why* of such relationships—for example, how do past sales relate to previous customer promotions?
- [Predictive analytics](#) focuses on *predicting future data outcomes* with a high degree of accuracy. Predictive analytics uses sophisticated statistical tools to help the end user create advanced models that answer questions

about future data occurrences—for example, what would next month's sales be based on a given customer promotion?

You can think of explanatory analytics as explaining the past and present, while predictive analytics forecasts the future. However, you need to understand that both sciences work together; predictive analytics uses explanatory analytics as a stepping stone to create predictive models.

Data analytics has evolved over the years from simple statistical analysis of business data to dimensional analysis with OLAP tools, and then from data mining that discovers data patterns, relationships, and trends to its current status of predictive analytics. The next sections illustrate the basic characteristics of data mining and predictive analytics.

#### 13.6.1 DATA MINING

---

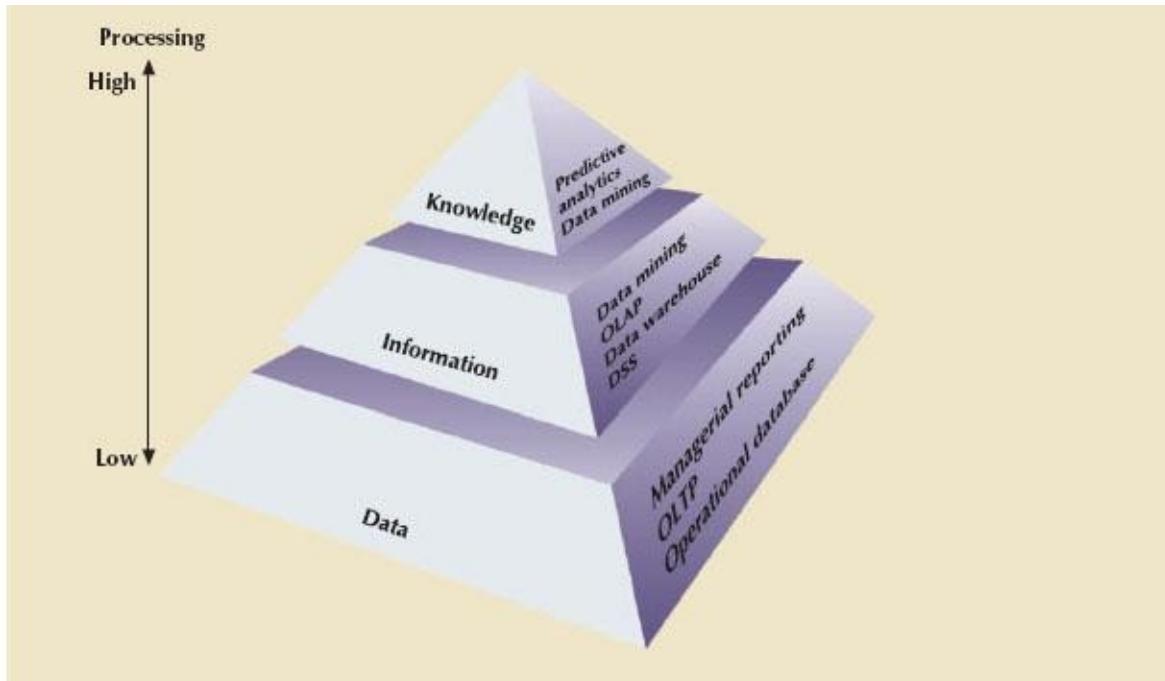
Data mining refers to analyzing massive amounts of data to uncover hidden trends, patterns, and relationships; to form computer models to simulate and explain the findings; and then to use such models to support business decision making. In other words, data mining focuses on the discovery and explanation stages of knowledge acquisition.

To put data mining in perspective, look at the pyramid in [Figure 13.14](#), which represents how knowledge is extracted from data. *Data* form the pyramid base and represent what most organizations collect in their operational databases. The second level contains *information* that represents the purified and processed data. Information forms the basis for decision making and business understanding. *Knowledge* is found at the pyramid's apex, and represents highly distilled information that provides concise, actionable business insight.

---

**FIGURE 13.14 Extracting knowledge from data**

---



SOURCE: Course Technology/Cengage Learning

---

Current-generation data-mining tools contain many design and application variations to fit specific business requirements. Depending on the problem domain, data-mining tools focus on market niches such as banking, insurance, marketing, retailing, finance, and health care. Within a given niche, data-mining tools can use certain algorithms that are implemented in different ways and applied over different data. Despite the lack of precise standards, data mining consists of four general phases:

- Data preparation
- Data analysis and classification
- Knowledge acquisition
- Prognosis

In the *data preparation phase*, the main data sets to be used by the data-mining operation are identified and cleansed of any data impurities. Because the data in the data warehouse are already integrated and filtered, the data warehouse usually is the target set for data-mining operations.

The *data analysis and classification phase* studies the data to identify common data characteristics or patterns. During this phase, the data-mining tool applies

specific [algorithms](#) to find:

- Data groupings, classifications, clusters, or sequences
- Data dependencies, links, or relationships
- Data patterns, trends, and deviations

The *knowledge acquisition phase* uses the results of the data analysis and classification phase. During the knowledge acquisition phase, the data-mining tool (with possible intervention by the end user) selects the appropriate modeling or knowledge acquisition algorithms. The most common algorithms used in data mining are based on neural networks, decision trees, rules induction, genetic algorithms, classification and regression trees, memory-based reasoning, and nearest neighbor. A data-mining tool may use many of these algorithms in any combination to generate a computer model that reflects the behavior of the target data set.

Although many data-mining tools focus on the knowledge-discovery phase, others continue to the *prognosis phase*. In that phase, the data-mining findings are used to predict future behavior and forecast business outcomes. Examples of data-mining findings can be:

- Sixty-five percent of customers who did not use a particular credit card in the last six months are 88 percent likely to cancel that account.
- Eighty-two percent of customers who bought a 42-inch or larger LCD TV are 90 percent likely to buy an entertainment center within the next four weeks.
- If  $\text{age} < 30$ ,  $\text{income} \leq 25,000$ ,  $\text{credit rating} < 3$ , and  $\text{credit amount} > 25,000$ , then the minimum loan term is 10 years.

The complete set of findings can be represented in a decision tree, a neural network, a forecasting model, or a visual presentation interface that is used to project future events or results. For example, the prognosis phase might project the likely outcome of a new product rollout or a new marketing promotion. [Figure 13.15](#) illustrates the different phases of the data-mining process.

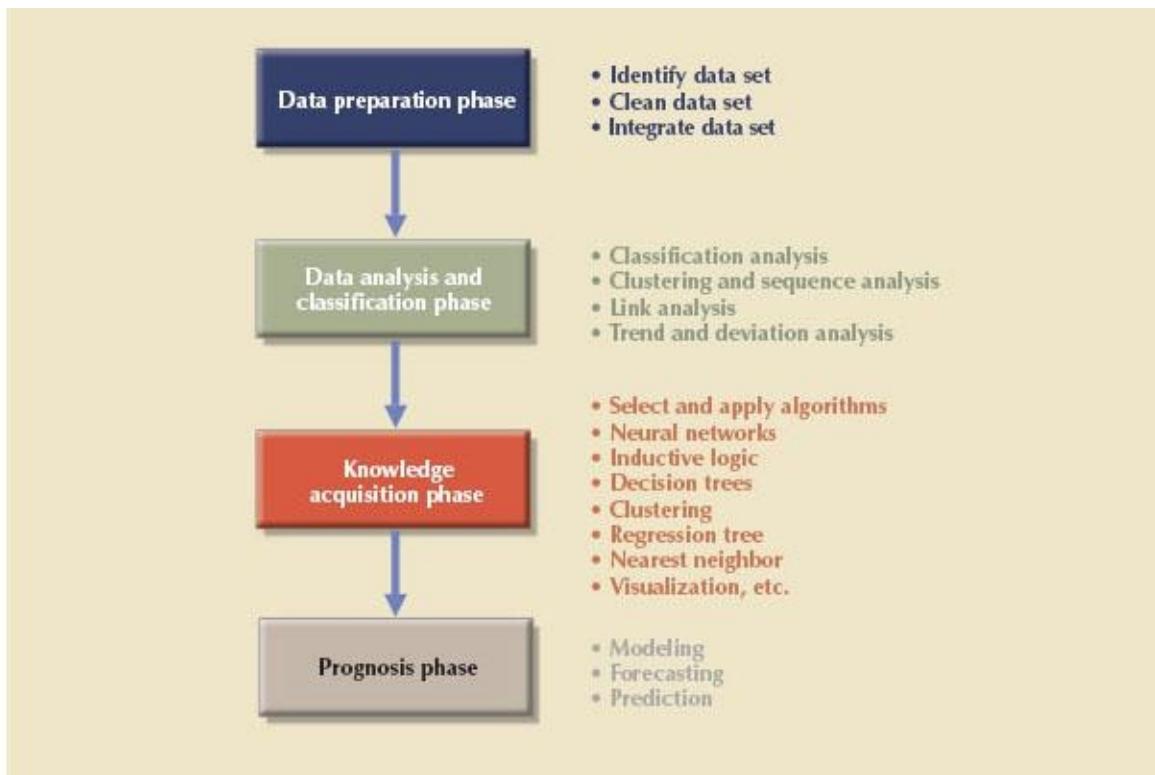
---

---

**FIGURE 13.15 Data-mining phases**

---

---



SOURCE: Course Technology/Cengage Learning

---

Because of the nature of the data-mining process, some findings might fall outside the boundaries of what business managers expect. For example, a data-mining tool might find a close relationship between a customer's favorite brand of soda and the brand of tires on the customer's car. Clearly, that relationship might not be held in high regard among sales managers. (In regression analysis, those relationships are commonly described by the label "idiot correlation.")

Fortunately, data mining usually yields more meaningful results. In fact, data mining has proven helpful in finding practical relationships among data that help define customer buying patterns, improve product development and acceptance, reduce healthcare fraud, analyze stock markets, and so on.

Data mining can be run in two modes:

- *Guided.* The end user guides the data-mining tool step by step to explore and explain known patterns or relationships. In this mode, the end user decides what techniques to apply to the data.

- *Automated.* In this mode, the end user sets up the data-mining tool to run automatically and uncover hidden patterns, trends, and relationships. The data-mining tool applies multiple techniques to find significant relationships.

As you learned in this section, data-mining methodologies focus on discovering and extracting information that describes and explains the data; for example, an explanatory model could create a customer profile that describes a given customer group. However, data mining can also be used as the basis to create advanced predictive data models. For example, a predictive model could be used to predict future customer behavior, such as a customer response to a target marketing campaign. The next section explains the use of predictive analytics in more detail.

#### 13.6.2 PREDICTIVE ANALYTICS

---

Although the term *predictive analytics* is used by many BI vendors to indicate many different levels of functionality, the promise of predictive analytics is very attractive for businesses looking for ways to improve their bottom line. Therefore, predictive analytics is receiving a lot of marketing buzz; vendors and businesses are dedicating extensive resources to this BI area. Predictive analytics refers to the use of advanced mathematical, statistical, and modeling tools to predict future business outcomes with high degrees of accuracy.

What is the difference between data mining and predictive analytics? As you learned earlier, data mining also has predictive capabilities. In fact, data mining and predictive analytics use similar and overlapping sets of tools, but with a slightly different focus. Data mining focuses on answering the “how” and “what” of *past* data, while predictive analytics focuses on creating actionable models to predict *future* behaviors and events. In some ways, you can think of predictive analytics as the next logical step after data mining; once you understand your data, you can use the data to predict future behaviors. In fact, most BI vendors are dropping the term *data mining* and replacing it with the more alluring term *predictive analytics*.

The origins of predictive analytics can be traced back to the banking and credit card industries. The need to profile customers and predict customer buying patterns in these industries was a critical driving force for the evolution of many modeling methodologies used in BI data analytics today. For example, based on your demographic information and purchasing history, a credit card company

can use data-mining models to determine what credit limit to offer, what offers you are more likely to accept, and when to send those offers.

Predictive analytics received a big stimulus with the advent of social media. Companies turned to data mining and predictive analytics as a way to harvest the mountains of data stored on social media sites. Google was one of the first companies that offered targeted ads as a way to increase and personalize search experiences. Similar initiatives were used by all types of organizations to increase customer loyalty and drive up sales. Take the example of the airline and credit card industries and their frequent flyer and affinity card programs. Nowadays, many organizations use predictive analytics to profile customers in an attempt to get and keep the right ones, which in turn will increase loyalty and sales.<sup>4</sup>

Predictive analytics employs mathematical and statistical algorithms, neural networks, artificial intelligence, and other advanced modeling tools to create actionable predictive models based on available data. The algorithms used to build the predictive model are specific to certain types of problems and work with certain types of data. Therefore, it is important that the end user, who typically is trained in statistics and understands business, applies the proper algorithms to the problem in hand. However, thanks to constant technology advances, modern BI tools automatically apply multiple algorithms to find the optimum model.

Most predictive analytics models are used in areas such as customer relationships, customer service, customer retention, fraud detection, targeted marketing, and optimized pricing. Predictive analytics can add value to an organization in many different ways; for example, it can help optimize existing processes, identify hidden problems, and anticipate future problems or opportunities. However, predictive analytics is not the “secret sauce” to fix all business problems. Managers should carefully monitor and evaluate the value of predictive analytics models to determine their return on investment.

So far, you have learned about data warehouses and star schemas to model and store decision support data, and data analytics to extract knowledge from the data. A BI system uses all the previously mentioned components to provide decision support to all organizational users. In the next section you will learn about a widely used BI style known as online analytical processing.

---

## 13.7 ONLINE ANALYTICAL PROCESSING

---

[Online analytical processing \(OLAP\)](#) is a BI style whose systems share three main characteristics:

- Multidimensional data analysis techniques
- Advanced database support
- Easy-to-use end-user interfaces

This section examines each characteristic.

### 13.7.1 MULTIDIMENSIONAL DATA ANALYSIS TECHNIQUES

---

The most distinctive characteristic of modern OLAP tools is their capacity for multidimensional analysis, in which data are processed and viewed as part of a multidimensional structure. This type of data analysis is particularly attractive to business decision makers because they tend to view business data as being related to other business data.

To better understand this view, you can examine how a business data analyst might investigate sales figures. In this case, the analyst is probably interested in the sales figures as they relate to other business variables such as customers and time. In other words, customers and time are viewed as different dimensions of sales. [Figure 13.16](#) illustrates how the operational (one-dimensional) view differs from the multidimensional view of sales.

---

**FIGURE 13.16 Operational vs. multidimensional view of sales**

---

Database name: Ch13\_Text

Table name: DW\_INVOICE

| INV_NUM | INV_DATE  | CUS_NAME    | INV_TOTAL |
|---------|-----------|-------------|-----------|
| 2034    | 15-May-12 | Dartnik     | 1400.00   |
| 2035    | 15-May-12 | Summer Lake | 1200.00   |
| 2036    | 16-May-12 | Dartnik     | 1350.00   |
| 2037    | 16-May-12 | Summer Lake | 8100.00   |
| 2038    | 16-May-12 | Trydon      | 400.00    |

Operational Data

Table name: DW\_LINE

| INV_NUM | LINE_NUM | PROD_DESCRIPTION                     | LINE PRICE | LINE QUANTITY | LINE_AMOUNT |
|---------|----------|--------------------------------------|------------|---------------|-------------|
| 2034    | 1        | Optical Mouse                        | 45.00      | 20            | 900.00      |
| 2034    | 2        | Wireless RF remote and laser pointer | 50.00      | 10            | 500.00      |
| 2035    | 1        | Everlast Hard Drive, 80 GB           | 200.00     | 6             | 1200.00     |
| 2035    | 1        | Optical Mouse                        | 45.00      | 30            | 1350.00     |
| 2037    | 1        | Optical Mouse                        | 45.00      | 10            | 450.00      |
| 2037    | 2        | Roadster 56KB Ext. Modem             | 120.00     | 5             | 600.00      |
| 2037    | 3        | Everlast Hard Drive, 80 GB           | 205.00     | 10            | 2050.00     |
| 2038    | 1        | NoTech Speaker Set                   | 50.00      | 8             | 400.00      |

Multidimensional View of Sales

(using MS Access PivotTable View)

|             |  | INV_DATE | 15-May-12  | 16-May-12  | Grand Total |
|-------------|--|----------|------------|------------|-------------|
| CUS_NAME    |  |          |            |            |             |
| Dartnik     |  |          | \$1,400.00 | \$1,350.00 | \$2,750.00  |
| Summer Lake |  |          | \$1,200.00 | \$3,100.00 | \$4,300.00  |
| Trydon      |  |          |            | \$400.00   | \$400.00    |
| Grand Total |  |          | \$2,600.00 | \$4,850.00 | \$7,450.00  |

Sales are located in the intersection  
of a customer row and date (time) column

Aggregations (grand total sales) are provided  
for both dimensions (time and customer)

SOURCE: Course Technology/Cengage Learning

Note in [Figure 13.16](#) that the operational (tabular) view of sales data is not well suited to decision support because the relationship between INVOICE and LINE does not provide a business perspective of the sales data. On the other hand, the end user's view of sales data *from a business perspective* is more closely represented by the multidimensional view of sales than by the tabular view of separate tables. Note also that the multidimensional view allows end users to consolidate or aggregate data at different levels: total sales figures by customers and by date. Finally, the multidimensional view of data allows a business data analyst to easily switch business perspectives (dimensions) from sales by customer to sales by division, by region, and so on.

Multidimensional data analysis techniques are augmented by the following functions:

- *Advanced data presentation functions.* These functions include 3D graphics, pivot tables, crosstabs, data rotation, and three-dimensional

cubes. Such tools are compatible with desktop spreadsheets, statistical packages, and query and report packages.

- *Advanced data aggregation, consolidation, and classification functions.* These allow the data analyst to create multiple data aggregation levels, slice and dice data (see [Section 13.5.3](#)), and drill down and roll up data across different dimensions and aggregation levels. For example, aggregating data by week, month, quarter, and year allows the data analyst to drill down and roll up across time dimensions.
- *Advanced computational functions.* These include business-oriented variables such as market share, period comparisons, sales margins, product margins, and percentage changes; financial and accounting ratios, including profitability, overhead, cost allocations, and returns; and statistical and forecasting functions. These functions are provided automatically, so the end user does not need to redefine the components each time they are accessed.
- *Advanced data-modeling functions.* These provide support for what-if scenarios, variable assessment, contributions to outcome, linear programming, and predictive modeling tools. Predictive modeling allows the system to build advanced statistical models to predict future values (business outcomes) with a high percentage of accuracy.

#### 13.7.2 ADVANCED DATABASE SUPPORT

---

To deliver efficient decision support, OLAP tools must have the following advanced data access features:

- Access to many different kinds of DBMSs, flat files, and internal and external data sources
- Access to aggregated data warehouse data as well as to the detail data found in operational databases
- Advanced data navigation features such as drilldown and roll-up
- Rapid and consistent query response times

- The ability to map end-user requests, expressed in either business or model terms, to the appropriate data source and then to the proper data access language (usually SQL). The query code must be optimized to match the data source, regardless of whether the source is operational or data warehouse data.
- Support for very large databases. As explained earlier, the data warehouse could easily and quickly grow to multiple terabytes in size.

To provide a seamless interface, OLAP tools map the data elements from the data warehouse and the operational database to their own data dictionaries. These metadata are used to translate end-user data analysis requests into the proper (optimized) query codes, which are then directed to the appropriate data sources.

### 13.7.3 EASY-TO-USE END-USER INTERFACES

---

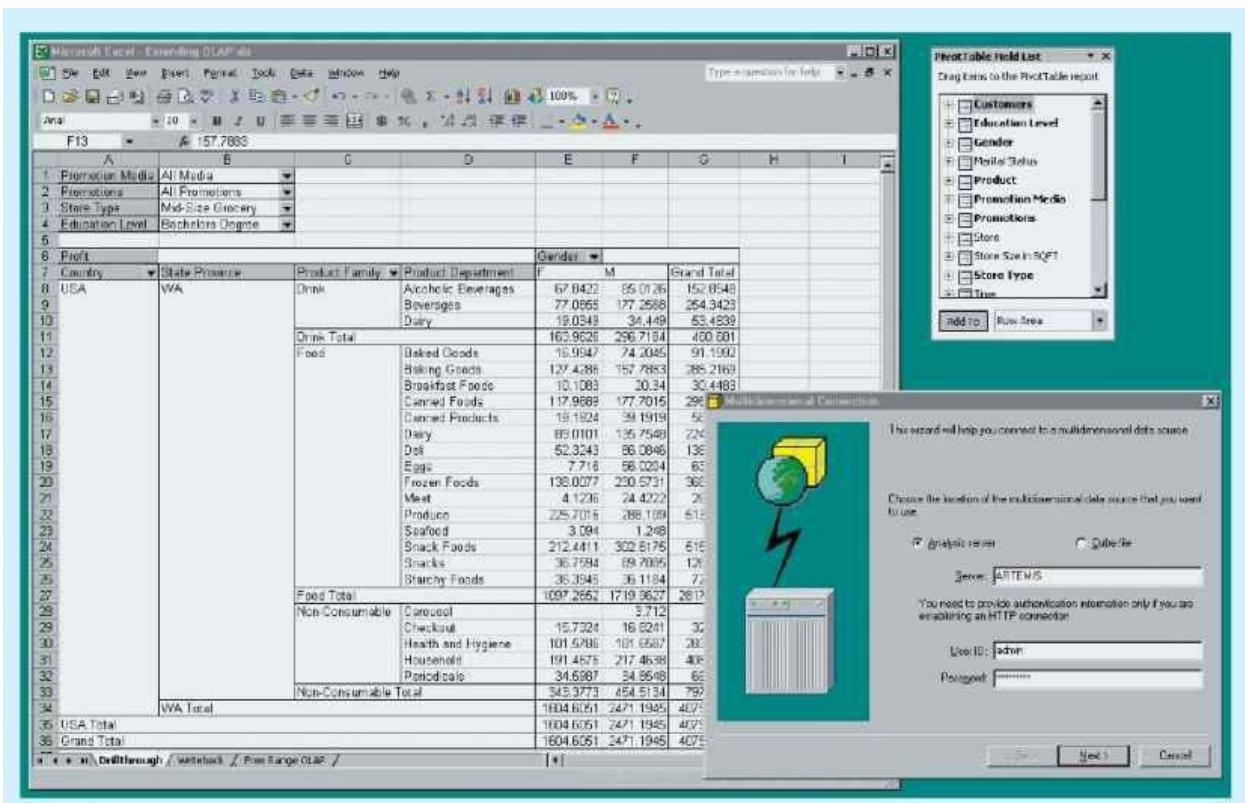
The end-user analytical interface is one of the most critical OLAP components. When properly implemented, an analytical interface permits the user to navigate the data in a way that simplifies and accelerates decision making or data analysis.

Advanced OLAP features become more useful when access to them is kept simple. OLAP tool vendors learned this lesson early and have equipped their sophisticated data extraction and analysis tools with easy-to-use graphical interfaces. Many of the interface features are “borrowed” from previous generations of data analysis tools that are already familiar to end users.

Because many analysis and presentation functions are common to desktop spreadsheet packages, most OLAP vendors have closely integrated their systems with spreadsheets such as Microsoft Excel. Using the features available in graphical end-user interfaces, OLAP simply becomes another option within the spreadsheet menu bar, as shown in [Figure 13.17](#). This seamless integration is an advantage for OLAP systems and spreadsheet vendors because end users gain access to advanced data analysis features by using familiar programs and interfaces. Therefore, additional training and development costs are minimized.

---

**FIGURE 13.17 Integration of OLAP with a spreadsheet program**



SOURCE: Course Technology/Cengage Learning

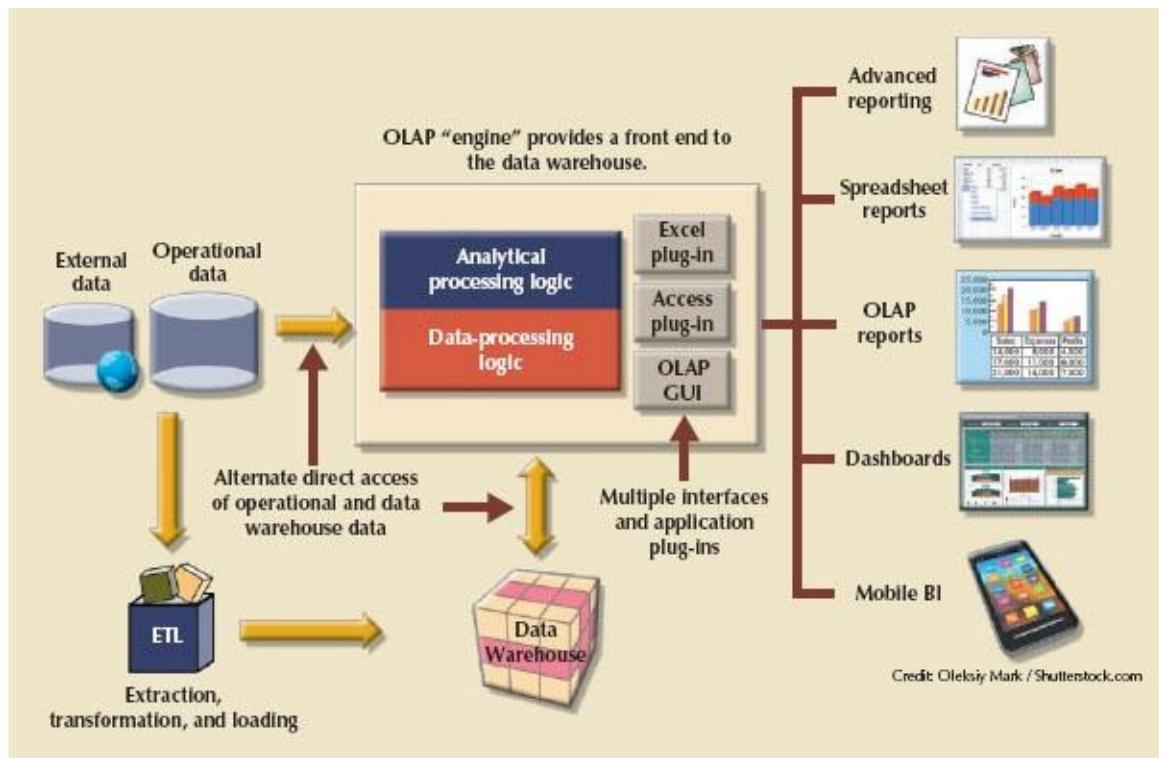
#### 13.7.4 OLAP ARCHITECTURE

The OLAP architecture is designed to meet ease-of-use requirements while keeping the system flexible. An OLAP system has three main architectural components:

- Graphical user interface (GUI)
- Analytical processing logic
- Data-processing logic

These three components can exist on the same computer or be distributed among several computers. [Figure 13.18](#) illustrates OLAP's architectural components.

**FIGURE 13.18** OLAP architecture



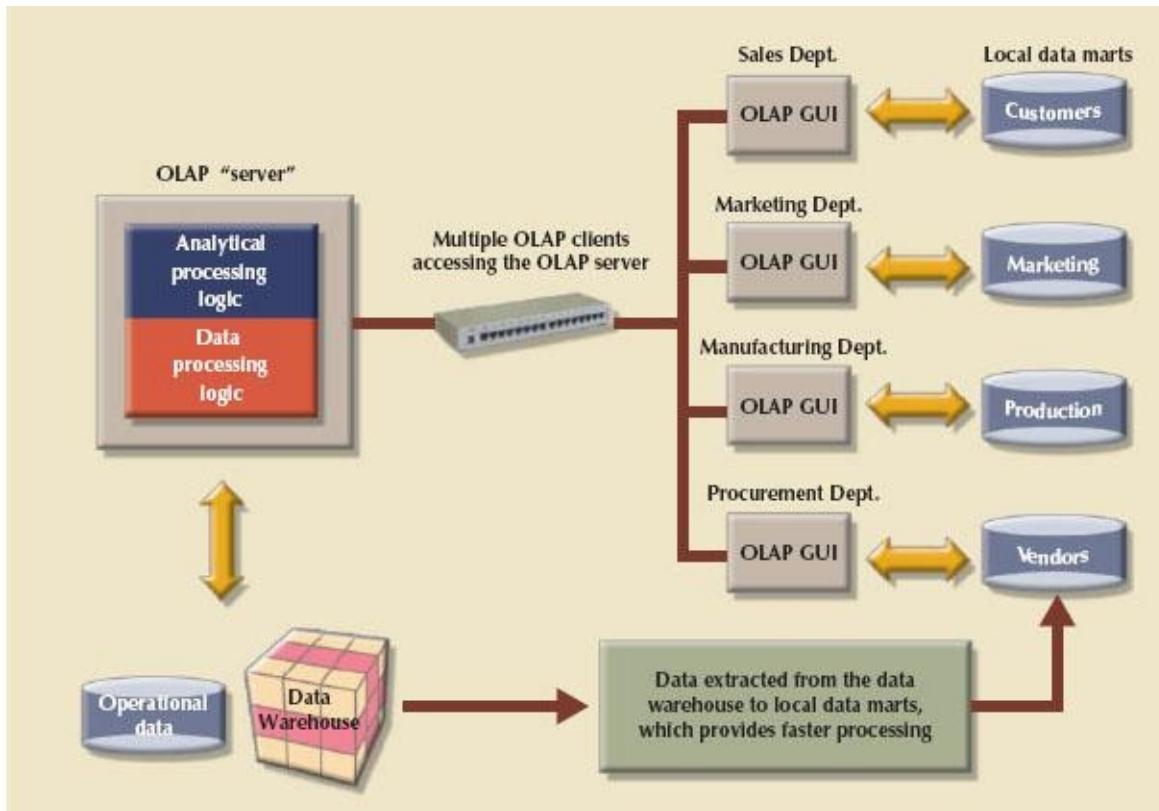
Credit: Oleksiy Mark / [Shutterstock.com](#)

SOURCE: Course Technology/Cengage Learning

As [Figure 13.18](#) illustrates, OLAP systems are designed to use both operational and data warehouse data. The figure shows the OLAP system components on a single computer, but this single-user scenario is only one of many. In fact, one problem with the installation shown here is that each data analyst must have a powerful computer to store the OLAP system and perform all data processing locally.

A more common and practical architecture is one in which the OLAP GUI runs on client workstations while the OLAP data-processing logic (or OLAP “server”) runs on a shared server computer. The OLAP analytical processing logic could be located on a client workstation, the OLAP server, or be split between the two sides. In any case, the OLAP server component acts as an intermediary between the OLAP GUI and the data warehouse. This middle layer accepts and handles the data-processing requests generated by the many end-user OLAP workstations. This flexible architecture allows for many different OLAP configurations. [Figure 13.19](#) illustrates an OLAP server with local miniature data marts.

**FIGURE 13.19 OLAP server with local miniature data marts**



SOURCE: Course Technology/Cengage Learning

As illustrated in [Figure 13.19](#), the OLAP system could merge the data warehouse and data mart approaches by storing extracts of the data warehouse at end-user workstations. The objective is to increase the speed of data access and data visualization (the graphic representations of data trends and characteristics). The logic behind this approach is the assumption that most end users usually work with fairly small, stable data warehouse subsets. For example, a sales analyst is most likely to work with sales data, whereas a customer representative is likely to work with customer data.

Whatever the arrangement of the OLAP components, one thing is certain: multidimensional data must be used. But how are multidimensional data best stored and managed? OLAP proponents are sharply divided. Some favor the use of relational databases to store multidimensional data; others argue that specialized multidimensional databases are superior. The basic characteristics of each approach are examined next.

### 13.7.5 RELATIONAL OLAP

---

[Relational online analytical processing \(ROLAP\)](#) provides OLAP functionality by using relational databases and familiar relational query tools to store and analyze multidimensional data. This approach builds on existing relational technologies and represents a natural extension to companies that already use relational database management systems within their organizations. ROLAP adds the following extensions to traditional RDBMS technology:

- Multidimensional data schema support within the RDBMS
  - Data access language and query performance optimized for multidimensional data
- Support for very large databases (VLDBs)

#### **Multidimensional Data Schema Support within the RDBMS**

Relational technology uses normalized tables to store data. The reliance on normalization as the design methodology for relational databases is seen as a stumbling block to its use in OLAP systems. Normalization divides business entities into smaller pieces to produce the normalized tables. For example, sales data components might be stored in four or five different tables. The reason for using normalized tables is to reduce redundancies, thereby eliminating data anomalies, and to facilitate data updates. Unfortunately, for decision support purposes, it is easier to understand data when they are seen with respect to other data. (See the example in [Figure 13.16](#).) Given that view of the data environment, this book has emphasized that decision support data tend to be non-normalized, duplicated, and preaggregated. Those characteristics seem to preclude the use of standard relational design techniques and RDBMSs as the foundation for multidimensional data.

Fortunately for companies heavily invested in relational technology, ROLAP uses a special design technique that enables RDBMS technology to support multidimensional data representations. This special design technique is known as a star schema, which is covered in detail in [Section 13.5](#).

The star schema is designed to optimize data query operations rather than data update operations. Naturally, changing the data design foundation means that the tools used to access such data will have to change. End users who are familiar with traditional relational query tools will discover that those tools do not work efficiently with the star schema. However, ROLAP saves the day by adding

support for the star schema when familiar query tools are used. ROLAP provides advanced data analysis functions and improves query optimization and data visualization methods.

## **Data Access Language and Query Performance Optimized for Multidimensional Data**

Another criticism of relational databases is that SQL is not suited for performing advanced data analysis. Most decision support data requests require the use of multiple-pass SQL queries or multiple nested SQL statements. To answer this criticism, ROLAP extends SQL so that it can differentiate between access requirements for data warehouse data (based on the star schema) and operational data (normalized tables). A ROLAP system therefore can generate the SQL code required to access the star schema data.

Query performance is also improved because the query optimizer is modified to identify the SQL code's intended query targets. For example, if the query target is the data warehouse, the optimizer passes the requests to the data warehouse. However, if the end user performs drilldown queries against operational data, the query optimizer identifies that operation and properly optimizes the SQL requests before passing them to the operational DBMS.

Another source of improved query performance is the use of advanced indexing techniques such as bitmapped indexes within relational databases. As the name suggests, a bitmapped index is based on 0 and 1 bits to represent a given condition. For example, if the REGION attribute in [Figure 13.3](#) has only four outcomes—North, South, East, and West—those outcomes may be represented as shown in [Table 13.11](#). Only the first 10 rows from [Figure 13.3](#) are represented in the table. The “1” represents “bit on,” and the “0” represents “bit off.” For example, to represent a row with a REGION attribute = “East,” only the “East” bit would be on. Note that each row must be represented in the index table.

---

**TABE 13.11 Bitmap Representation of Region Values**

---

NORTH SOUTH EAST WEST

**0      0      1      0**

**0      0      1      0**

**1      0      0      0**

**1      0      0      0**

**1      0      0      0**

**0      1      0      0**

**0      1      0      0**

**0      1      0      0**

**0      0      0      1**

**0      0      0      1**

---

Note that the index in [Table 13.11](#) takes a minimal amount of space. Therefore, bitmapped indexes are more efficient at handling large amounts of data than the indexes typically found in many relational databases. However, keep in mind that bitmapped indexes are primarily used when the number of possible values for an attribute is fairly small. For example, REGION has only four outcomes in

this example. Marital status—married, single, widowed, or divorced—would be another good bitmapped index candidate, as would gender—M or F.

## Support for Very Large Databases

Recall that support for VLDBs is a requirement for decision support databases. Therefore, when the relational database is used in a decision support role, it also must be able to store very large amounts of data. Both the storage capability and the process of loading data into the database are crucial. Therefore, the RDBMS must have the proper tools to import, integrate, and populate the data warehouse with data. Decision support data are normally loaded in bulk (batch) mode from the operational data. However, batch operations require that both the source and the destination databases be reserved (locked). The speed of the data-loading operations is important, especially when you realize that most operational systems run 24 hours a day, 7 days a week. Therefore, the window of opportunity for maintenance and batch loading is open only briefly, typically during slack periods.

Clearly, ROLAP is a logical choice for companies that already use relational databases for their operational data. Given the size of the relational database market, it is hardly surprising that most current RDBMS vendors have extended their products to support data warehouses and OLAP capabilities.

### 13.7.6 MULTIDIMENSIONAL OLAP

---

[Multidimensional online analytical processing \(MOLAP\)](#) extends OLAP functionality to [multidimensional database management systems \(MDBMSs\)](#). An MDBMS uses proprietary techniques to store data in matrixlike  $n$ -dimensional arrays. MOLAP's premise is that multidimensional databases are best suited to manage, store, and analyze multidimensional data. Most of the proprietary techniques used in MDBMSs are derived from engineering fields such as computer-aided design/computer-aided manufacturing (CAD/CAM) and geographic information systems (GIS). MOLAP tools store data using multidimensional arrays, row stores, or column stores. (If necessary, review the NoSQL data model in [Chapter 2](#), Data Models.)

Conceptually, MDBMS end users visualize the stored data as a three-dimensional cube known as a [data cube](#). The location of each data value in the data cube is a function of the x-, y-, and z-axes in a three-dimensional space. The three axes represent the dimensions of the data value. The data cubes can grow to  $n$  number of dimensions, thus becoming *hypercubes*. Data cubes are created

by extracting data from the operational databases or from the data warehouse. One important characteristic of data cubes is that they are static; that is, they are not subject to change and must be created before they can be used. Data cubes cannot be created by ad hoc queries. Instead, you query precreated cubes with defined axes; for example, a cube for sales will have the product, location, and time dimensions, and you can query only those dimensions. Therefore, the data cube creation process is critical and requires in-depth front-end design work. This design work may be well justified because MOLAP databases are known to be much faster than their ROLAP counterparts, especially when dealing with large data sets. To speed data access, data cubes are normally held in memory in the [cube cache](#). (A data cube is only a window to a predefined subset of data in the database. A data cube and a database are not the same thing.) Because MOLAP also benefits from a client/server infrastructure, the cube cache can be located at the MOLAP server, the MOLAP client, or both.

Because the data cube is predefined with a set number of dimensions, the addition of a new dimension requires that the entire data cube be recreated, which is time-consuming. Therefore, when data cubes are created too often, the MDBMS loses some of its speed advantage over the relational database. In addition, the MDBMS uses proprietary data storage techniques that in turn require proprietary data access methods using a multidimensional query language (review the NoSQL model in [Chapter 2](#)).

Multidimensional data analysis is also affected by how the database system handles sparsity. [Sparsity](#) measures the density of the data held in the data cube; it is computed by dividing the total number of actual values in the cube by its total number of cells. Because the data cube's dimensions are predefined, not all cells are populated. In other words, some cells are empty. Returning to the sales example, many products might not be sold during a given time period in a given location. In fact, you will often find that less than 50 percent of the data cube's cells are populated. In any case, multidimensional databases must handle sparsity effectively to reduce processing overhead and resource requirements.

#### 13.7.7 RELATIONAL VS. MULTIDIMENSIONAL OLAP

---

[Table 13.12](#) summarizes some pros and cons of ROLAP and MOLAP. Keep in mind that the selection of one or the other often depends on the evaluator's vantage point. For example, a proper evaluation of OLAP must include price, supported hardware platforms, compatibility with the existing DBMS, programming requirements, performance, and availability of administrative

tools. The summary in [Table 13.12](#) provides a useful starting point for comparison.

---

**TABLE 13.12 Relational vs. Multidimensional OLAP**

---

|               | <b>CHARACTERISTIC ROLAP</b>                                            | <b>MOLAP</b>                                                                                                                       |
|---------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Schema        | Uses star schema<br>Additional dimensions can be added dynamically     | Uses data cubes<br>Multidimensional arrays, row stores, column stores<br>Additional dimensions require recreation of the data cube |
| Database size | Medium to large                                                        | Large                                                                                                                              |
| Architecture  | Client/server<br>Standards-based                                       | Client/server<br>Open or proprietary, depending on vendor                                                                          |
| Access        | Supports ad hoc requests<br>Unlimited dimensions                       | Limited to predefined dimensions<br>Proprietary access languages                                                                   |
| Speed         | Good with small data sets; average for medium-sized to large data sets | Faster for large data sets with predefined dimensions                                                                              |

---

ROLAP and MOLAP vendors are working to integrate their respective solutions within a unified decision support framework. Many OLAP products can handle tabular and multidimensional data with the same ease. For example, if you use Excel OLAP functionality, as shown earlier in [Figure 13.17](#), you can access relational OLAP data in a SQL server as well as cube (multidimensional) data in the local computer. In the meantime, relational databases have successfully extended SQL to support many OLAP tools.

---

## 13.8 SQL EXTENSIONS FOR OLAP

---

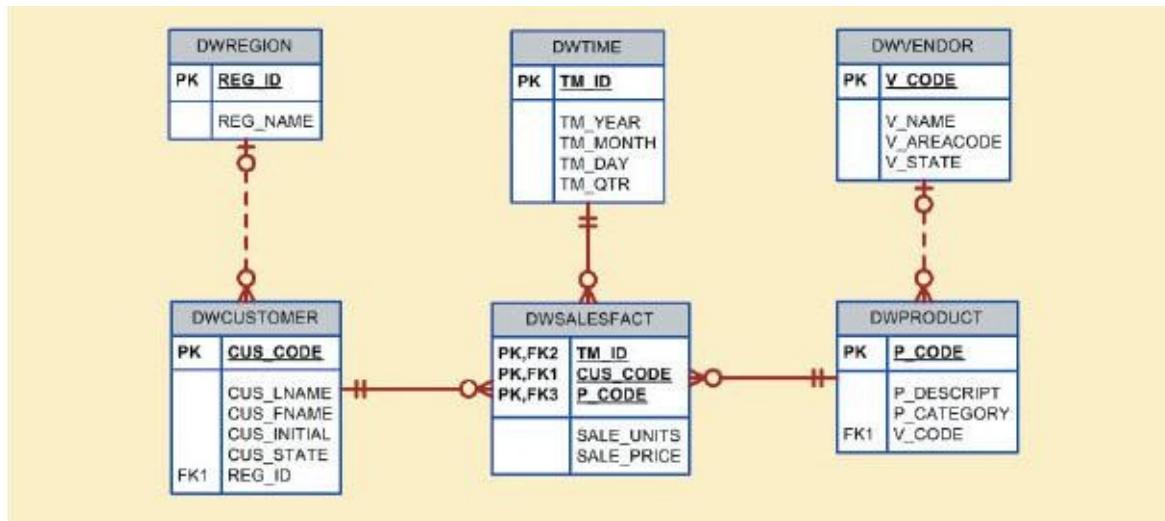
The proliferation of OLAP tools has fostered the development of SQL extensions to support multidimensional data analysis. Most SQL innovations are the result of vendor-centric product enhancements. However, many of the innovations have made their way into standard SQL. This section introduces some of the new SQL extensions that have been created to support OLAP-type data manipulations.

The SaleCo snowflake schema shown in [Figure 13.20](#) demonstrates the use of the SQL extensions. Note that this snowflake schema has a central DWSALESFACT fact table and three dimension tables: DWCUSTOMER, DWPRODUCT, and DWTIME. The central fact table represents daily sales by product and customer. However, as you examine the schema shown in [Figure 13.20](#), you will see that the DWCUSTOMER and DWPRODUCT dimension tables have their own dimension tables: DWREGION and DWVENDOR.

---

**FIGURE 13.20** SaleCo snowflake schema

---



SOURCE: Course Technology/Cengage Learning

---

Keep in mind that a database is at the core of all data warehouses. Therefore, all SQL commands (such as CREATE, INSERT, UPDATE, DELETE, and SELECT) will work in the data warehouse as expected. However, most queries you run in a data warehouse tend to include a lot of data groupings and aggregations over multiple columns. Therefore, this section introduces two extensions to the GROUP BY clause that are particularly useful: ROLLUP and

CUBE. In addition, you will learn about using materialized views to store preaggregated rows in the database.

---

---



## ONLINE CONTENT

The script files used to populate the database and run the SQL commands are available at [www.cengagebrain.com](http://www.cengagebrain.com).

---

---

## NOTE

---

This section uses the Oracle RDBMS to demonstrate the use of SQL extensions to support OLAP functionality. If you use a different DBMS, consult the documentation to verify whether the vendor supports similar functionality and what the proper syntax is for your DBMS.

---

### 13.8.1 THE ROLLUP EXTENSION

---

The ROLLUP extension is used with the GROUP BY clause to generate aggregates by different dimensions. As you know, the GROUP BY clause will generate only one aggregate for each new value combination of attributes listed in the GROUP BY clause. The ROLLUP extension goes one step further; it enables you to get a subtotal for each column listed except for the last one, which gets a grand total instead. The syntax of the GROUP BY ROLLUP command sequence is as follows:

```
SELECT column1 [, column2, ...], aggregate_function(expression)
FROM table1 [, table2, ...]
[WHERE condition]
GROUP BY ROLLUP (column1 [, column2, ...])
[HAVING condition]
[ORDER BY column1 [, column2, ...]]
```

The order of the column list within GROUP BY ROLLUP is very important. The last column in the list will generate a grand total, and all other columns will

generate subtotals. For example, [Figure 13.21](#) shows the use of the ROLLUP extension to generate subtotals by vendor and product.

FIGURE 13.21 ROLLUP extension

The screenshot shows an Oracle SQL\*Plus window with the following SQL query:

```
SQL> SELECT V_CODE, P_CODE, SUM(SALE_UNITS*SALE_PRICE) AS TOTSALES
 2 FROM DWDSALESFACT NATURAL JOIN DWPRODUCT NATURAL JOIN DWVENDOR
 3 GROUP BY ROLLUP (V_CODE, P_CODE)
 4 ORDER BY V_CODE, P_CODE;
```

The output displays the following data:

| V_CODE | P_CODE   | TOTSALES |
|--------|----------|----------|
| 21225  | 23109-HB | 99.5     |
| 21225  | PUC23DRT | 199.58   |
| 21225  | SM-18277 | 41.94    |
| 21225  |          | 341.02   |
| 21344  | 13-Q2/P2 | 239.84   |
| 21344  | 54778-2T | 59.88    |
| 21344  |          | 299.72   |
| 23119  | 1546-Q02 | 79.9     |
| 23119  |          | 79.9     |
| 24288  | 2232/QTV | 219.84   |
| 24288  | 89-WRE-Q | 513.98   |
| 24288  |          | 733.82   |
| 25595  | 2238/QPD | 77.9     |
| 25595  | WR3/TT3  | 719.7    |
| 25595  |          | 797.6    |
|        |          | 2252.06  |

Annotations in the screenshot:

- Arrows point from the subtotal rows (341.02, 299.72, 79.9, 733.82, 797.6) to the text "Subtotals by V\_CODE".
- An arrow points from the bottom row (2252.06) to the text "Grand total for all P\_CODE values".

SOURCE: Course Technology/Cengage Learning

[Figure 13.21](#) shows the subtotals by vendor code and a grand total for all product codes. Contrast that with the normal GROUP BY clause that generates only the subtotals for each vendor and product combination. The ROLLUP extension is particularly useful when you want to obtain multiple nested subtotals for a dimension hierarchy. For example, within a location hierarchy, you can use ROLLUP to generate subtotals by region, state, city, and store.

### 13.8.2 THE CUBE EXTENSION

The CUBE extension is also used with the GROUP BY clause to generate aggregates by the listed columns, including the last one. The CUBE extension enables you to get a subtotal for each column listed in the expression, in addition to a grand total for the last column listed. The syntax of the GROUP BY CUBE command sequence is as follows:

```
SELECT column1 [, column2, ...], aggregate_function(expression)
```

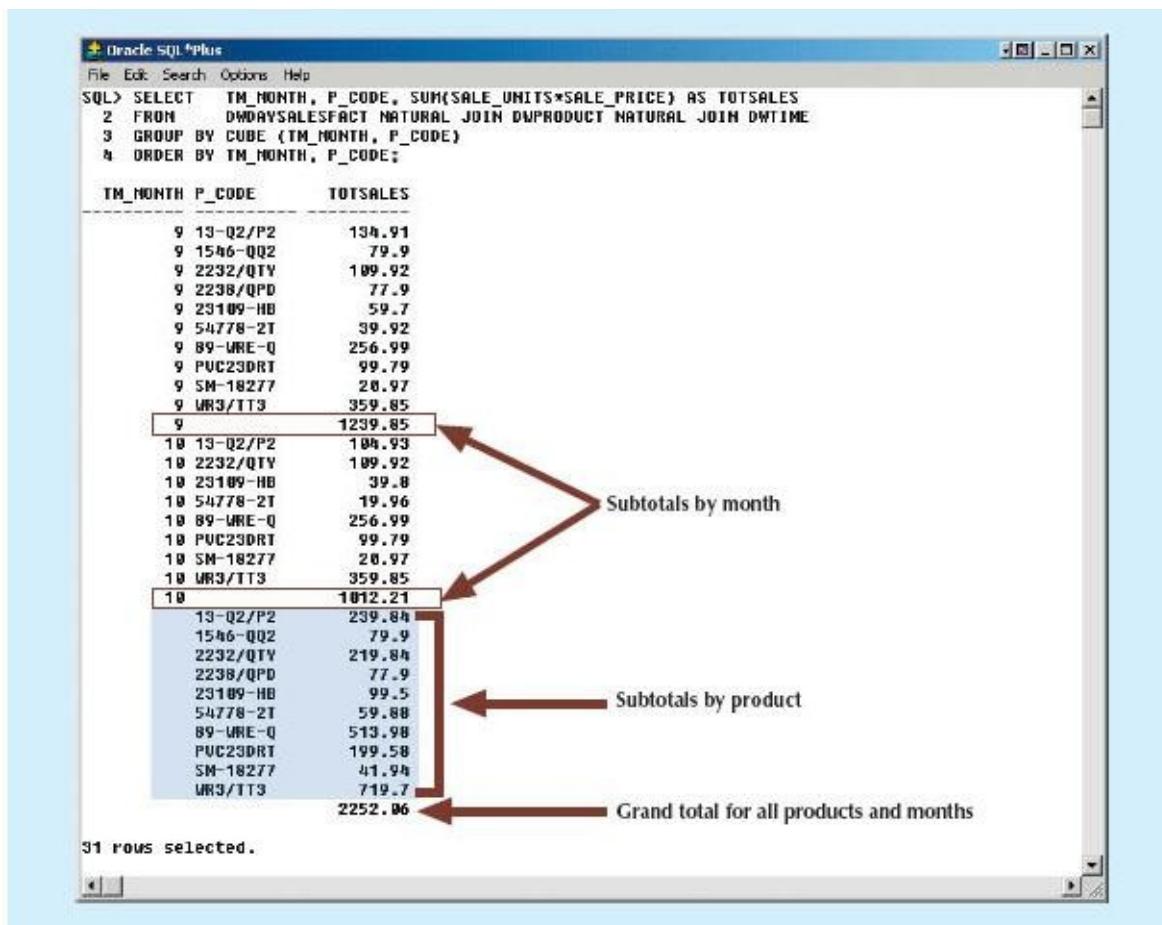
FROM table1 [, table2, ...]  
 [WHERE condition]  
 GROUP BY CUBE (column1 [, column2, ...])  
 [HAVING condition]  
 [ORDER BY column1 [, column2, ...]]

For example, [Figure 13.22](#) shows the use of the CUBE extension to compute the sales subtotals by month and by product, as well as a grand total.

---

**FIGURE 13.22 CUBE extension**

---



The screenshot shows an Oracle SQL\*Plus window with the following SQL query:

```

SQL> SELECT TM_MONTH, P_CODE, SUM(SALE_UNITS * SALE_PRICE) AS TOTSALES
 2 FROM DWDSALESFACT NATURAL JOIN DWPRODUCT NATURAL JOIN DWTIME
 3 GROUP BY CUBE (TM_MONTH, P_CODE)
 4 ORDER BY TM_MONTH, P_CODE;

```

The output displays sales data grouped by TM\_MONTH and P\_CODE, with subtotals for each group and a final grand total. Arrows point from the text labels to the corresponding rows in the output:

| TM_MONTH | P_CODE   | TOTSALES       |
|----------|----------|----------------|
| 9        | 13-Q2/P2 | 134.91         |
| 9        | 1546-QQ2 | 79.9           |
| 9        | 2232/QTY | 189.92         |
| 9        | 2238/QPD | 77.9           |
| 9        | 23109-HB | 59.7           |
| 9        | 54778-2T | 39.92          |
| 9        | 89-WRE-Q | 256.99         |
| 9        | PUC23DRT | 99.79          |
| 9        | SM-18277 | 28.97          |
| 9        | UR3/TT3  | 359.85         |
| 9        |          | <b>1239.85</b> |
| 10       | 13-Q2/P2 | 184.93         |
| 10       | 2232/QTY | 189.92         |
| 10       | 23109-HB | 39.8           |
| 10       | 54778-2T | 19.96          |
| 10       | 89-WRE-Q | 256.99         |
| 10       | PUC23DRT | 99.79          |
| 10       | SM-18277 | 28.97          |
| 10       | UR3/TT3  | 359.85         |
| 10       |          | <b>1012.21</b> |
|          | 13-Q2/P2 | 239.84         |
|          | 1546-QQ2 | 79.9           |
|          | 2232/QTY | 219.84         |
|          | 2238/QPD | 77.9           |
|          | 23109-HB | 99.5           |
|          | 54778-2T | 59.88          |
|          | 89-WRE-Q | 513.98         |
|          | PUC23DRT | 199.58         |
|          | SM-18277 | 41.94          |
|          | UR3/TT3  | 719.7          |
|          |          | <b>2252.86</b> |

31 rows selected.

Subtotals by month

Subtotals by product

Grand total for all products and months

SOURCE: Course Technology/Cengage Learning

---

In [Figure 13.22](#), the CUBE extension also generates subtotals for each

combination of month and product. The CUBE extension is particularly useful when you want to compute all possible subtotals within groupings based on multiple dimensions. Cross-tabulations are especially good candidates for application of the CUBE extension.

### 13.8.3 MATERIALIZED VIEWS

---

The data warehouse normally contains fact tables that store specific measurements of interest to an organization. Such measurements are organized by different dimensions. The vast majority of OLAP business analysis of everyday activity is based on data comparisons that are aggregated at different levels, such as totals by vendor, by product, and by store.

Because businesses normally use a predefined set of summaries for benchmarking, it is reasonable to predefine such summaries for future use by creating summary fact tables. (See [Section 13.5.6](#) for a discussion of additional performance-improving techniques.) However, creating multiple summary fact tables that use GROUP BY queries with multiple table joins could become resource-intensive. In addition, data warehouses must be able to maintain up-to-date summarized data at all times. So what happens with the summary fact tables after new sales data have been added to the base fact tables? Under normal circumstances, the summary fact tables are recreated. This operation requires that the SQL code be run again to recreate all summary rows, even when only a few rows need updating. Clearly, this is a time-consuming process.

To save query processing time, most database vendors have implemented additional functions to manage aggregate summaries more efficiently. This new functionality resembles the standard SQL views for which the SQL code is predefined in the database. However, the added difference is that the views also store the preaggregated rows, something like a summary table. For example, Microsoft SQL Server provides indexed views, while Oracle provides materialized views. This section explains the use of materialized views.

A [materialized view](#) is a dynamic table that not only contains the SQL query command to generate the rows, it stores the actual rows. The materialized view is created the first time the query is run, and the summary rows are stored in the table. The materialized view rows are automatically updated when the base tables are updated. That way, the data warehouse administrator will create the view but will not have to worry about updating the view. The use of materialized views is totally transparent to the end user. The OLAP end user can create OLAP

queries using the standard fact tables, and the DBMS query optimization feature will automatically use the materialized views if they provide better performance.

The basic syntax for the materialized view is:

```
CREATE MATERIALIZED VIEW view_name
BUILD {IMMEDIATE | DEFERRED}
REFRESH {[FAST | COMPLETE | FORCE]} ON COMMIT
[ENABLE QUERY REWRITE]
AS select_query;
```

The BUILD clause indicates when the materialized view rows are actually populated. IMMEDIATE indicates that the materialized view rows are populated right after the command is entered. DEFERRED indicates that the materialized view rows will be populated later. Until then, the materialized view is in an unusable state. The DBMS provides a special routine that an administrator runs to populate materialized views.

The REFRESH clause lets you indicate when and how to update the materialized view when new rows are added to the base tables. FAST indicates that whenever a change is made in the base tables, the materialized view updates only the affected rows. COMPLETE indicates that a complete update will be made for all rows in the materialized view when you rerun the SELECT query on which the view is based. FORCE indicates that the DBMS will first try to do a FAST update; otherwise, it will do a COMPLETE update. The ON COMMIT clause indicates that the updates to the materialized view will take place as part of the commit process of the underlying DML statement—that is, as part of the commitment of the DML transaction that updated the base tables. The ENABLE QUERY REWRITE option allows the DBMS to use the materialized views in query optimization.

To create materialized views, you must have specified privileges and you must complete specified prerequisite steps. As always, you must consult the DBMS documentation for the latest updates. In the case of Oracle, you must create materialized view logs on the base tables of the materialized view. [Figure 13.23](#) shows the steps required to create the SALES\_MONTH\_MV materialized view in the Oracle RDBMS.

---

FIGURE 13.23 Creating a materialized view

The screenshot shows a window titled "Oracle SQL\*Plus" with a menu bar (File, Edit, Search, Options, Help). The main area contains the following SQL commands and their output:

```
SQL> CREATE MATERIALIZED VIEW LOG ON DWTIME
 2 WITH ROWID, SEQUENCE INCLUDING NEW VALUES;
Materialized view log created.

SQL> CREATE MATERIALIZED VIEW LOG ON DWDAYSALESFACT
 2 WITH ROWID, SEQUENCE INCLUDING NEW VALUES;
Materialized view log created.

SQL> CREATE MATERIALIZED VIEW SALES_MONTH_MV
 2 BUILD IMMEDIATE
 3 REFRESH FORCE ON COMMIT
 4 ENABLE QUERY REWRITE
 5 AS SELECT TM_YEAR, TM_MONTH, P_CODE,
 6 SUM(SALE_UNITS), SUM(SALE_PRICE*SALE_UNITS) AS SUM_SALES
 7 FROM DWTIME T, DWDAYSALESFACT S
 8 WHERE S.TM_ID = T.TM_ID
 9 GROUP BY TM_YEAR, TM_MONTH, P_CODE;

Materialized view created.

SQL> SELECT * FROM SALES_MONTH_MV ORDER BY TM_YEAR, TM_MONTH, SUM_SALES;
-----+-----+-----+-----+-----+
 2009 | 9 | SM-18277 | 3 | 20.97
 2009 | 9 | 54778-2T | 8 | 39.92
 2009 | 9 | 23109-HB | 6 | 59.7
 2009 | 9 | 2238/QPD | 2 | 77.9
 2009 | 9 | 1546-QQ2 | 2 | 79.9
 2009 | 9 | PUC23DRT | 17 | 99.79
 2009 | 9 | 2232/QTY | 1 | 109.92
 2009 | 9 | 13-Q2/P2 | 9 | 134.91
 2009 | 9 | 89-WRE-Q | 1 | 256.99
 2009 | 9 | WR3/TT3 | 3 | 359.85
 2009 | 10 | 54778-2T | 4 | 19.96
 2009 | 10 | SM-18277 | 3 | 20.97
 2009 | 10 | 23109-HB | 4 | 39.8
 2009 | 10 | PUC23DRT | 17 | 99.79
 2009 | 10 | 13-Q2/P2 | 7 | 104.93
 2009 | 10 | 2232/QTY | 1 | 109.92
 2009 | 10 | 89-WRE-Q | 1 | 256.99
 2009 | 10 | WR3/TT3 | 3 | 359.85
-----+-----+-----+-----+-----+
18 rows selected.

SQL> COMMIT;
Commit complete.
```

SOURCE: Course Technology/Cengage Learning

The materialized view in [Figure 13.23](#) computes the monthly total units sold and the total sales aggregated by product. The SALES\_MONTH\_MV materialized view is configured to automatically update after each change in the base tables. The last row of SALES\_MONTH\_MV indicates that during October, three units of product ‘WR3/TT3’ were sold for a total of \$359.85. [Figure 13.24](#) shows the effects of updating the DWDAYSALESFACT base table.

**FIGURE 13.24 Refreshing a materialized view**

The screenshot shows a Windows-style window for Oracle SQL\*Plus. The title bar says "Oracle SQL\*Plus". The menu bar includes "File", "Edit", "Search", "Options", and "Help". The main area contains the following SQL commands and their results:

```
SQL> INSERT INTO DWDAYSALESFACT VALUES (207,10017,'WR3/TT3',1,106.99);
1 row created.

SQL> COMMIT;
Commit complete.

SQL> SELECT * FROM SALES_MONTH_MV ORDER BY TM_YEAR, TM_MONTH, SUM_SALES;
```

| TM_YEAR | TM_MONTH | P_CODE   | SUM(TRADE_UNITS) | SUM_SALES |
|---------|----------|----------|------------------|-----------|
| 2009    | 9        | SM-18277 | 3                | 20.97     |
| 2009    | 9        | 54778-2T | 8                | 39.92     |
| 2009    | 9        | 23109-HB | 6                | 59.7      |
| 2009    | 9        | 2238/QPD | 2                | 77.9      |
| 2009    | 9        | 1546-QQ2 | 2                | 79.9      |
| 2009    | 9        | PUC23DRT | 17               | 99.79     |
| 2009    | 9        | 2232/QTY | 1                | 109.92    |
| 2009    | 9        | 13-Q2/P2 | 9                | 134.91    |
| 2009    | 9        | 89-WRE-Q | 1                | 256.99    |
| 2009    | 9        | WR3/TT3  | 3                | 359.85    |
| 2009    | 10       | 54778-2T | 4                | 19.96     |
| 2009    | 10       | SM-18277 | 3                | 20.97     |
| 2009    | 10       | 23109-HB | 4                | 39.8      |
| 2009    | 10       | PUC23DRT | 17               | 99.79     |
| 2009    | 10       | 13-Q2/P2 | 7                | 104.93    |
| 2009    | 10       | 2232/QTY | 1                | 109.92    |
| 2009    | 10       | 89-WRE-Q | 1                | 256.99    |
| 2009    | 10       | WR3/TT3  | 4                | 466.84    |

18 rows selected.

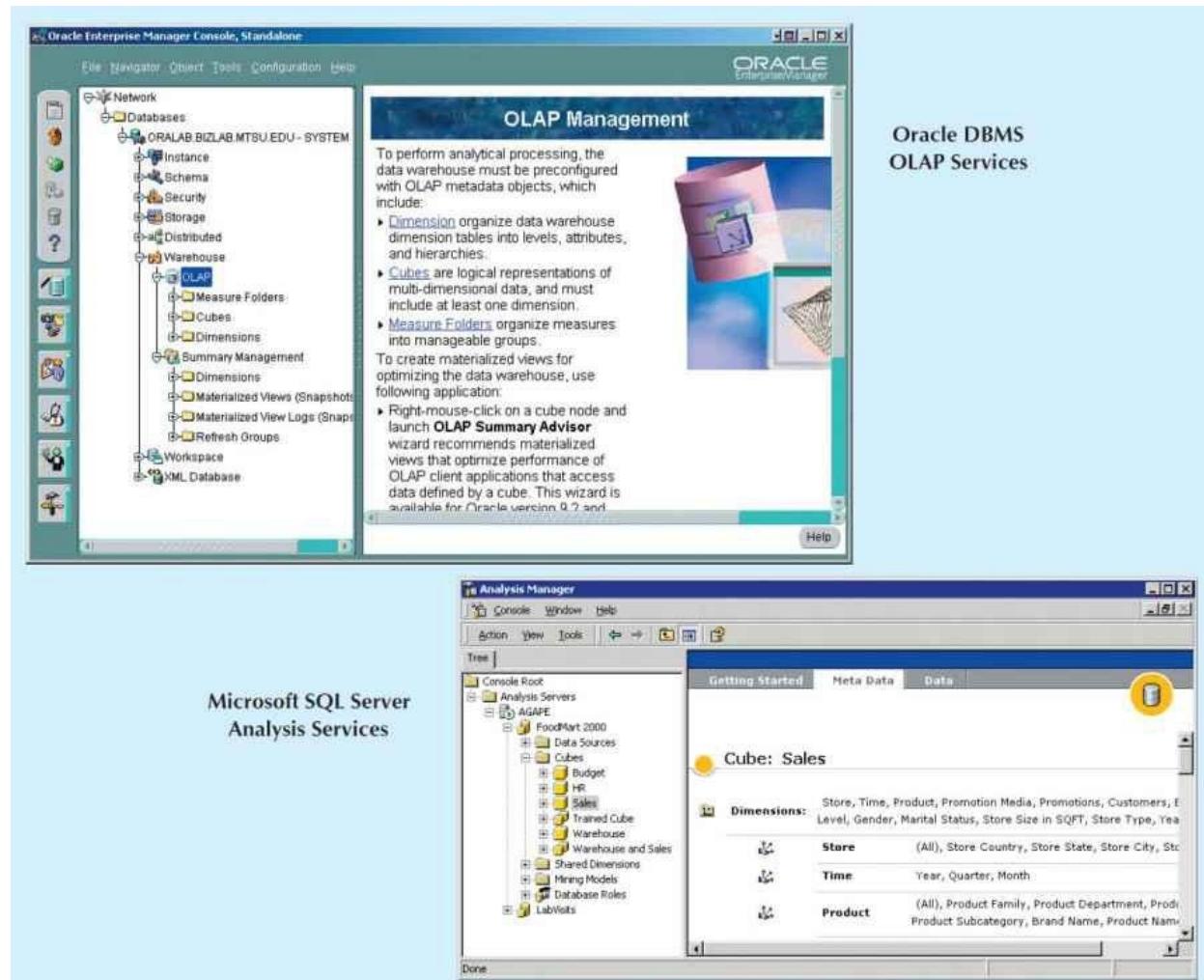
SOURCE: Course Technology/Cengage Learning

[Figure 13.24](#) shows how the materialized view was automatically updated after

the insertion of a new row in the DWDAYSALESFACT table. The last row of SALES\_MONTH\_MV now shows that in October, four units of product ‘WR3/TT3’ were sold for a total of \$466.84.

Although all of the examples in this section focus on SQL extensions to support OLAP reporting in an Oracle DBMS, you have seen just a small fraction of the many business intelligence features currently provided by most DBMS vendors. For example, most vendors provide rich graphical user interfaces to manipulate, analyze, and present the data in multiple formats. [Figure 13.25](#) shows two sample screens, one for Oracle and one for Microsoft OLAP products.

**FIGURE 13.25 Sample OLAP applications**



SOURCE: Course Technology/Cengage Learning

---

## SUMMARY

---

- Business intelligence (BI) is a term for a comprehensive, cohesive, and integrated set of applications used to capture, collect, integrate, store, and analyze data with the purpose of generating and presenting information to support business decision making.
- Decision support systems (DSSs) refer to an arrangement of computerized tools used to assist managerial decision making within a business. DSSs were the original precursor of current-generation BI systems.
- Operational data are not well suited for decision support. From the end user's point of view, decision support data differ from operational data in three main areas: time span, granularity, and dimensionality.
- The data warehouse is an integrated, subject-oriented, time-variant, nonvolatile collection of data that provides support for decision making. The data warehouse is usually a read-only database optimized for data analysis and query processing. A data mart is a small, single-subject data warehouse subset that provides decision support to a small group of people.
- The star schema is a data-modeling technique used to map multidimensional decision support data into a relational database for advanced data analysis. The basic star schema has four components: facts, dimensions, attributes, and attribute hierarchies. Facts are numeric measurements or values that represent a specific business aspect or activity. Dimensions are general qualifying categories that provide additional perspectives to facts. Conceptually, the multidimensional data model is best represented by a three-dimensional cube. Attributes can be ordered in well-defined hierarchies, which provide a topdown organization that is used for two main purposes: to permit aggregation and provide drilldown and roll-up data analysis.
- Data analytics is a subset of BI functionality that provides advanced data

analysis tools to extract knowledge from business data. Data analytics can be divided into explanatory and predictive analytics. Explanatory analytics focuses on discovering and explaining data characteristics and relationships. Predictive analytics focuses on creating models to predict future outcomes or events based on the existing data.

- Data mining automates the analysis of operational data to find previously unknown data characteristics, relationships, dependencies, and trends. The data-mining process has four phases: data preparation, data analysis and classification, knowledge acquisition, and prognosis.
  
- Predictive analytics uses the information generated in the data-mining phase to create advanced predictive models with high degrees of accuracy.
- Online analytical processing (OLAP) refers to an advanced data analysis environment that supports decision making, business modeling, and operations research.
  
- SQL has been enhanced with extensions that support OLAP-type processing and data generation.

---

#### KEY TERMS

---

[algorithms](#)

[attribute hierarchy](#)

[business intelligence \(BI\)](#)

[cube cache](#)

dashboard

[data analytics](#)

[data cube](#)

[data mart](#)

[data mining](#)

[data warehouse](#)

[decision support system \(DSS\)](#)

[dimension tables](#)

[dimensions](#)  
[drill down](#)  
[explanatory analytics](#)  
extraction, transformation, and loading (ETL)  
[fact table](#)  
[facts](#)  
[governance](#)  
[key performance indicators \(KPIs\)](#)  
[master data management \(MDM\)](#)  
[materialized view](#)  
[metrics](#)  
[multidimensional database management system \(MDBMS\)](#)  
[multidimensional online analytical processing \(MOLAP\)](#)  
[online analytical processing \(OLAP\)](#)  
[partitioning](#)  
[periodicity](#)  
[portal](#)  
[predictive analytics](#)  
[relational online analytical processing \(ROLAP\)](#)  
[replication](#)  
[roll up](#)  
[slice and dice](#)  
[snowflake schema](#)  
[sparsity](#)  
[star schema](#)  
[very large databases \(VLDBs\)](#)

---



## ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at [www.cengagebrain.com](http://www.cengagebrain.com).

---

## REVIEW QUESTIONS

---

1. What is business intelligence? Give some recent examples of BI usage, using the Internet for assistance. What BI benefits have companies found?
2. Describe the BI framework. Illustrate the evolution of BI.
3. What are decision support systems, and what role do they play in the business environment?
4. Explain how the main components of the BI architecture interact to form a system. Describe the evolution of BI information dissemination formats.
5. What are the most relevant differences between operational data and decision support data?
6. What is a data warehouse, and what are its main characteristics? How does it differ from a data mart?
7. Give three examples of likely problems when operational data are integrated into the data warehouse.

Use the following scenario to answer Questions 8-14.

While working as a database analyst for a national sales organization, you are asked to be part of its data warehouse project team.

8. Prepare a high-level summary of the main requirements for evaluating DBMS products for data warehousing.
9. Your data warehousing project group is debating whether to create a prototype of a data warehouse before its implementation. The project group members are especially concerned about the need to acquire some data warehousing skills before implementing the enterprise-wide data warehouse. What would you recommend? Explain your recommendations.
10. Suppose that you are selling the data warehouse idea to your users. How would you define multidimensional data analysis for them? How would you

explain its advantages to them?

11. The data warehousing project group has invited you to provide an OLAP overview. The group's members are particularly concerned about the OLAP client/server architecture requirements and how OLAP will fit the existing environment. Your job is to explain the main OLAP client/server components and architectures.
12. One of your vendors recommends using an MDBMS. How would you explain this recommendation to your project leader?
13. The project group is ready to make a final decision, choosing between ROLAP and MOLAP. What should be the basis for this decision? Why?
14. The data warehouse project is in the design phase. Explain to your fellow designers how you would use a star schema in the design.
15. Briefly discuss the OLAP architectural styles with and without data marts.
16. What is OLAP, and what are its main characteristics?
17. Explain ROLAP, and list the reasons you would recommend its use in the relational database environment.
18. Explain the use of facts, dimensions, and attributes in the star schema.
19. Explain multidimensional cubes, and describe how the slice-and-dice technique fits into this model.
20. In the star schema context, what are attribute hierarchies and aggregation levels, and what is their purpose?
21. Discuss the most common performance improvement techniques used in star schemas.

22. What is data analytics? Briefly explain explanatory and predictive analytics.
23. Describe and contrast the focus of data mining and predictive analytics. Give some examples.
24. How does data mining work? Discuss the different phases in the data-mining process.
25. Describe the characteristics of predictive analytics. What is the impact of Big Data (social media) in predictive analytics?



### ONLINE CONTENT

The databases used for the following problems are available at [www.cengagebrain.com](http://www.cengagebrain.com). These databases are stored in Microsoft Access 2000 format. The databases named **Ch13\_P1.mdb**, **Ch13\_P3.mdb**, and **Ch13\_P4.mdb** contain the data for [Problems 1](#), [3](#), and [4](#), respectively. The data for [Problem 2](#) are stored in Microsoft Excel 2000 format at [www.cengagebrain.com](http://www.cengagebrain.com). The spreadsheet filename is **Ch13\_P2.xls**.

---

---

### PROBLEMS

---

1. The university computer lab's director keeps track of lab usage, as measured by the number of students using the lab. This function is important for budgeting purposes. The computer lab director assigns you the task of developing a data warehouse to keep track of the lab usage statistics. The main requirements for this database are to:
  - Show the total number of users by different time periods.
  - Show usage numbers by time period, by major, and by student classification.
  - Compare usage for different majors and different semesters.

Use the Ch13\_P1.mdb database, which includes the following tables:

- USELOG contains the student lab access data.
- STUDENT is a dimension table that contains student data.

Given the three preceding requirements, and using the Ch13\_P1.mdb data, complete the following problems:

- a. Define the main facts to be analyzed. (*Hint:* These facts become the source for the design of the fact table.)
  - b. Define and describe the appropriate dimensions. (*Hint:* These dimensions become the source for the design of the dimension tables.)
  - c. Draw the lab usage star schema, using the fact and dimension structures you defined in Problems 1a and 1b.
  - d. Define the attributes for each of the dimensions in [Problem 1b](#).
  - e. Recommend the appropriate attribute hierarchies.
  - f. Implement your data warehouse design, using the star schema you created in [Problem 1c](#) and the attributes you defined in [Problem 1d](#).
  - g. Create the reports that will meet the requirements listed in this problem's introduction.
2. Victoria Ephnor manages a small product distribution company. Because the business is growing fast, she recognizes that it is time to manage the vast information pool to help guide the accelerating growth. Ephnor, who is familiar with spreadsheet software, currently employs a sales force of four people. She asks you to develop a data warehouse application prototype that will enable her to study sales figures by year, region, salesperson, and product. (This prototype will be used as the basis for a future data warehouse database.)

Using the data supplied in the Ch13\_P2.xls file, complete the following seven problems:

- a. Identify the appropriate fact table components.
- b. Identify the appropriate dimension tables.
- c. Draw a star schema diagram for this data warehouse.
- d. Identify the attributes for the dimension tables that will be required to solve this problem.
- e. Using Microsoft Excel or any other spreadsheet program that can produce pivot tables, generate a pivot table to show the sales by product and

by region. The end user must be able to specify the display of sales for any given year. The sample output is shown in the first pivot table in [Figure P13.2E](#).

---

**FIGURE P13.2E** Using a pivot table

---

|    | A            | B      | C     | D     | E    | F     |
|----|--------------|--------|-------|-------|------|-------|
| 1  | Year         | 2011   |       |       |      |       |
| 2  |              |        |       |       |      |       |
| 3  | Sum of Value | Region |       |       |      |       |
| 4  | Product      | East   | North | South | West | Total |
| 5  | Balls        | 55     |       | 70    | 100  | 225   |
| 6  | Erasers      |        | 20    | 90    |      | 110   |
| 7  | Pencils      | 45     | 80    |       |      | 105   |
| 8  | Widgets      |        |       | 155   | 25   | 180   |
| 9  | Total        | 100    | 100   | 315   | 125  | 620   |
| 10 |              |        |       |       |      |       |
| 11 |              |        |       |       |      |       |
| 12 | Year         | (All)  |       |       |      |       |
| 13 | Product      | (All)  |       |       |      |       |
| 14 |              |        |       |       |      |       |
| 15 | Sum of Value | Region |       |       |      |       |
| 16 | Agent        | East   | North | South | West | Total |
| 17 | Carlos       | 95     | 150   | 30    | 25   | 300   |
| 18 | Mary         |        | 60    | 125   | 145  | 330   |
| 19 | Tere         | 12     | 100   | 160   | 100  | 372   |
| 20 | Victor       | 55     | 20    | 259   |      | 334   |
| 21 | Total        | 162    | 330   | 514   | 270  | 1,336 |

SOURCE: Course Technology/Cengage Learning

---

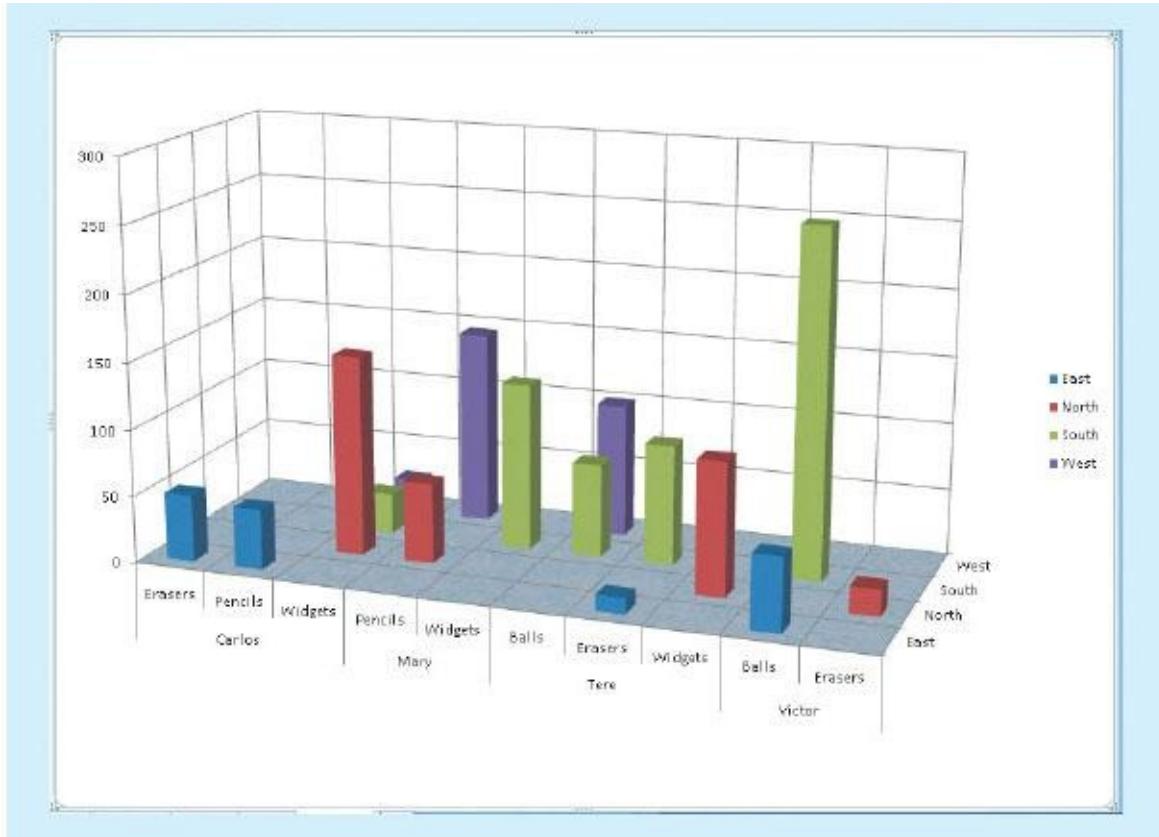
- f. Using [Problem 2e](#) as your base, add a second pivot table (see [Figure P13.2E](#)) to show the sales by salesperson and by region. The end user must be able to specify sales for a given year or for all years, and for a given product or for all products.
- g. Create a 3D bar graph to show sales by salesperson, by product, and by region. (See the sample output in [Figure P13.2G](#).)
3. David Suker, the inventory manager for a marketing research company, wants to study the use of supplies within the different company departments. Suker has heard that his friend, Victoria Ephonor, has developed a spreadsheet-based data warehouse model that she uses to analyze sales data (see [Problem 2](#)). Suker is interested in developing a data warehouse model like Ephonor's so he can analyze orders by department and by product. He will use Microsoft Access as the data warehouse DBMS and Microsoft Excel as the analysis tool.
  - a. Develop the order star schema.
  - b. Identify the appropriate dimension attributes.

- c. Identify the attribute hierarchies required to support the model.
- d. Develop a crosstab report in Microsoft Access, using a 3D bar graph to show orders by product and by department. (The sample output is shown in [Figure P13.3](#).)

---

**FIGURE P13.2G 3D bar graph showing the relationships among agent, product, and region**

---



SOURCE: Course Technology/Cengage Learning

- 
4. ROBCOR, whose sample data are contained in the database named Ch13\_P4.mdb, provides “on-demand” aviation charters using a mix of different aircraft and aircraft types. Because ROBCOR has grown rapidly, its owner has hired you as its first database manager. The company’s database, developed by an outside consulting team, is already in place to help manage all company operations. Your first critical assignment is to develop a decision support system to analyze the charter data. (Review the company’s operations in [Problems 24-31](#) of [Chapter 3](#), The Relational Database Model.) The charter operations manager wants to be able to

analyze charter data such as cost, hours flown, fuel used, and revenue. She also wants to be able to drill down by pilot, type of airplane, and time periods.

Given those requirements, complete the following:

- a. Create a star schema for the charter data.
- b. Define the dimensions and attributes for the charter operation's star schema.
- c. Define the necessary attribute hierarchies.
- d. Implement the data warehouse design using the design components you developed in Problems 4a-4c.
- e. Generate the reports to illustrate that your data warehouse meets the specified information requirements.

Using the data provided in the SaleCo snowflake schema in [Figure 13.20](#), solve the following problems. (*Hint:* In [Problems 5–11](#), use the ROLLUP command.)

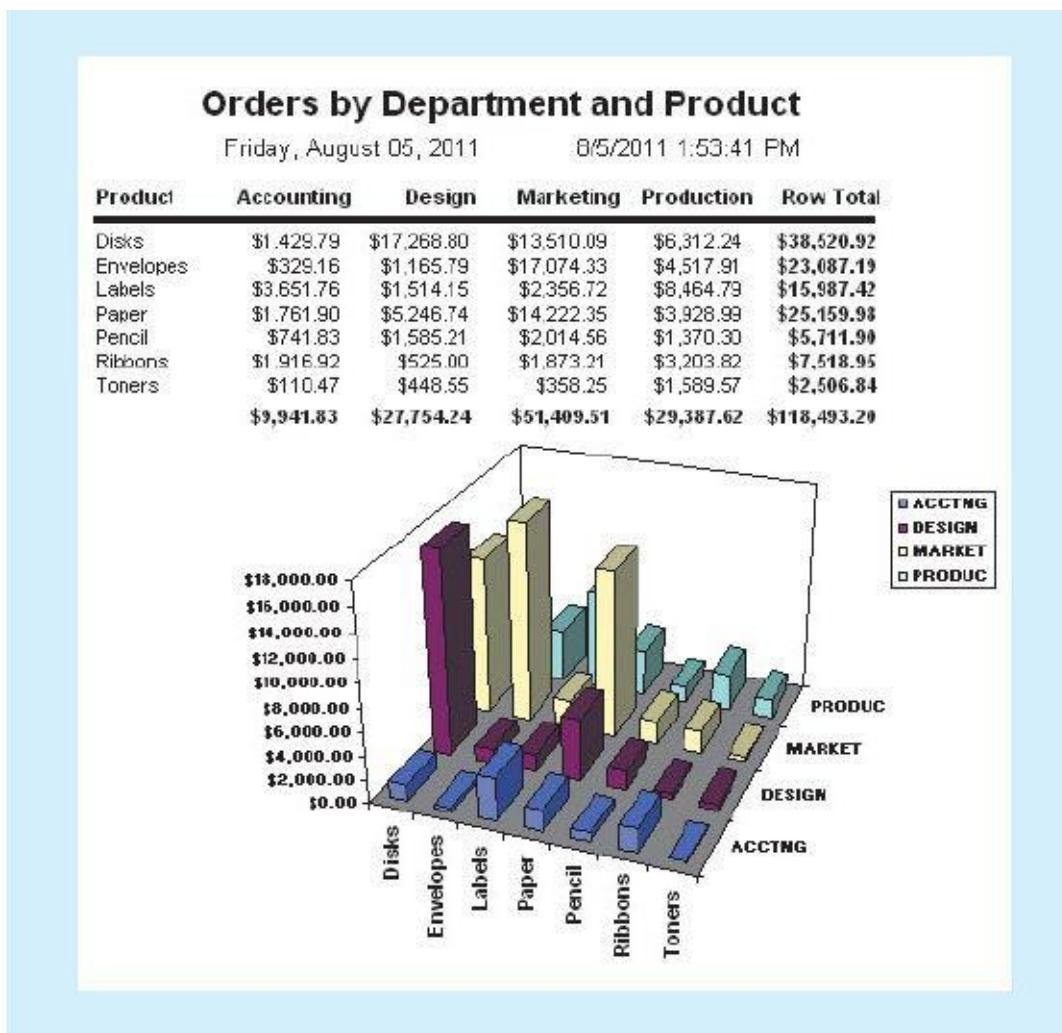
---

---

**FIGURE P13.3 Crosstab report: orders by product and department**

---

---



SOURCE: Course Technology/Cengage Learning



## ONLINE CONTENT

The script files used to populate the SaleCo database are available at [www.cengagebrain.com](http://www.cengagebrain.com). The script files assume the use of an Oracle RDBMS. If you use a different DBMS, consult the documentation to verify whether the vendor supports similar functionality and what the proper syntax is for your DBMS.

5. What is the SQL command to list the total sales by customer and by product, with subtotals by customer and a grand total for all product sales?

6. What is the SQL command to list the total sales by customer, month, and product, with subtotals by customer and by month and a grand total for all product sales?
  7. What is the SQL command to list the total sales by region and customer, with subtotals by region and a grand total for all sales?
  8. What is the SQL command to list the total sales by month and product category, with subtotals by month and a grand total for all sales?
  9. What is the SQL command to list the number of product sales (number of rows) and total sales by month, with subtotals by month and a grand total for all sales?
  10. What is the SQL command to list the number of product sales (number of rows) and total sales by month and product category, with subtotals by month and product category and a grand total for all sales?
  11. What is the SQL command to list the number of product sales (number of rows) and total sales by month, product category, and product, with subtotals by month and product category and a grand total for all sales?
  12. Using the answer to [Problem 10](#) as your base, what command would you need to generate the same output but with subtotals in all columns? (*Hint:* Use the CUBE command.)
- 

<sup>1</sup> In 1989, while working at Gartner Inc., Howard Dresner popularized BI as an umbrella term to describe a set of concepts and methods to improve business decision making by using fact-based support systems ([www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=266298](http://www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=266298)).

<sup>2</sup> Inmon, Bill and Chuck Kelley, “The Twelve Rules of Data Warehouse for a Client/Server World,” *Data Management Review*, 4(5), May 1994.

<sup>3</sup> Inmon, Bill and Chuck Kelley, “The Twelve Rules of Data Warehouse for a Client/Server World,” *Data Management Review*, 4(5), May 1994.

<sup>4</sup> “BI Home Runs: 15 Organizations making better business decisions through BI technology,” Ellen Fanning, *Computerworld*, September 18, 2006.

---

PART  
V  
DATABASES AND THE INTERNET

---

---

DATABASE CONNECTIVITY AND WEB TECHNOLOGIES **14**

---

**Business Vignette** Nealab is an Italian IT company that develops and manages social media sites such as [Freebar.com](#) and IncontraGente. [Freebar.com](#) was the first social network site established in Italy in 2003, two years prior to the social media explosion. Today, the site boasts 40,000 unique visitors and 700,000 page views per day. IncontraGente is an online dating utility with 400,000 users and about 80,000 unique visits per day. Both sites generate revenue through online advertisements and opt-in, direct e-mail marketing services.<sup>1</sup>

Nealab originally relied on dedicated servers and Web-hosting services to run its Webbased social media applications. However, the company has significant variability in its high-traffic Web applications,<sup>2</sup> so its dedicated servers often did not run at full capacity and unused processing power was wasted. Cloud computing allows one physical server to host multiple logical servers in a process called server virtualization. Server virtualization maximizes the computing resources of the physical server by allocating resources to the logical servers as needed, thus reducing the number of physical machines needed to handle fluctuations in Web traffic. This virtualization allows Nealab to save time and money on server infrastructure and maintenance.<sup>3</sup>

Nealab decided to transition to cloud computing through Amazon Web Services (AWS). Nealab runs its applications on Amazon Elastic Compute Cloud (Amazon EC2), and it also employs Amazon Relational Database Service (Amazon RDS). Amazon RDS, through its cloud capabilities, makes it simple to use replication to improve database reliability and availability, and allows users to scale out beyond normal capacity during read-heavy database workloads. Furthermore, Amazon allows its clients to pay for on-demand database instances per hour. So, a company is only charged for the database processing power it actually uses.<sup>4</sup>

“As a Web company, we operate in a very dynamic environment that requires an elastic technological infrastructure capable of adapting to its rapid changes,” says Nealab founder Stefano Pochet. “For example, we had a high peak of traffic in December 2009 on one of our applications. During this peak, our infrastructure simultaneously ran 50 Amazon EC2 instances. Thanks to the elasticity of AWS, which has completely removed server deployment and installation processing time, we were able to manage the situation.”

Nealab can integrate its open source caching system and custom, PHP-based,

object relational mapping framework with Amazon RDS. The company then employs Amazon CloudWatch to monitor its Amazon EC2 instances to provide real-time statistics and graphical views of its demand, resource usage, and performance. These cloud capabilities have enabled Nealab to run its social media platforms more effectively and efficiently; the company handles more than 6 million visitors per month through an office in the historic district of Naples with only 12 employees.

---

<sup>1</sup> Nealab Website, [www.nealab.it](http://www.nealab.it).

<sup>2</sup> AWS Case Study: Nealab Technologies, Amazon Web Services, <http://aws.amazon.com/solutions/case-studies/nealab-technologies/>.

<sup>3</sup> Jonathan Strickland, How Cloud Computing Works, [HowStuffWorks.com](http://computer.howstuffworks.com/cloud-computing1.htm), <http://computer.howstuff-works.com/cloud-computing1.htm>.

<sup>4</sup> Amazon Relational Database Service (Amazon RDS), Amazon Web Services, <http://aws.amazon.com/rds/>.

---

## 14 DATABASE CONNECTIVITY AND WEB TECHNOLOGIES

---

In this chapter, you will learn:

- About various database connectivity technologies
  - How Web-to-database middleware is used to integrate databases with the Internet
  - About Web browser plug-ins and extensions
  - What services are provided by Web application servers
  - What Extensible Markup Language (XML) is and why it is important for Web database development
  - About cloud computing and how it enables the database-as-a-service model
- 

## Preview

---

Databases are the central repository for critical data generated by business applications, including newer channels such as the Web and mobile devices. For businesses to remain competitive, such data must be readily available, anywhere and anytime, to all business users and in all types of formats: a desktop spreadsheet, a Visual Basic application, a Web front end, and newer technologies such as iPads, Playbooks, iPhones, and Android phones. In this chapter, you will learn about various architectures used to connect applications to databases.

The Internet has changed how organizations of all types operate. For example, buying goods and services via the Internet has become commonplace. This chapter examines the fundamentals of Web database technologies used to open databases to the Internet. In today's environment, interconnectivity occurs not only between an application and the database but between applications interchanging messages and data. Extensible Markup Language (XML) provides a standard way of exchanging unstructured and structured data between applications.

Companies that want to integrate database and Web technologies within their

applications portfolio can now choose from a range of Internet-based services. Therefore, you will learn how organizations can benefit from cloud computing by leveraging the database-as-a-service model within their IT environments. These cloud-based services offer a quick and cost-efficient way to provide new business services.

---

## 14.1 DATABASE CONNECTIVITY

---

*Database connectivity* refers to the mechanisms through which application programs connect and communicate with data repositories. Database connectivity software is also known as **database middleware** because it provides an interface between the application program and the database. The data repository, also known as the *data source*, represents the data management application, such as Oracle RDBMS, SQL Server DBMS, or IBM DBMS, that will be used to store the data generated by the application program. Ideally, a data source or data repository could be located anywhere and hold any type of data. For example, the data source could be a relational database, a NoSQL database, a spreadsheet, or a text data file.

The need for standard database connectivity interfaces cannot be overstated. Just as SQL has become the de facto data manipulation language, a standard database connectivity interface is necessary for enabling applications to connect to data repositories. Although there are many ways to achieve database connectivity, this section covers only the following interfaces:

- Native SQL connectivity (vendor provided)
- Microsoft's Open Database Connectivity (ODBC), Data Access Objects (DAO), and Remote Data Objects (RDO)
- Microsoft's Object Linking and Embedding for Database (OLE-DB)
- Microsoft's ActiveX Data Objects (ADO.NET)
- Sun's Java Database Connectivity (JDBC)

You should not be surprised to learn that most interfaces you are likely to encounter are Microsoft offerings. After all, client applications connect to databases, and the majority of those applications run on computers that are powered by some version of Microsoft Windows. The data connectivity

interfaces illustrated here are dominant players in the market, and more importantly, they enjoy the support of most database vendors. In fact, ODBC, OLE-DB, and ADO. NET form the backbone of Microsoft's [\*\*Universal Data Access \(UDA\)\*\*](#) architecture, a collection of technologies used to access any type of data source and manage the data through a common interface. As you will see, Microsoft's database connectivity interfaces have evolved over time: each interface builds on top of the other, thus providing enhanced functionality, features, flexibility, and support.

#### **14.1.1 NATIVE SQL CONNECTIVITY**

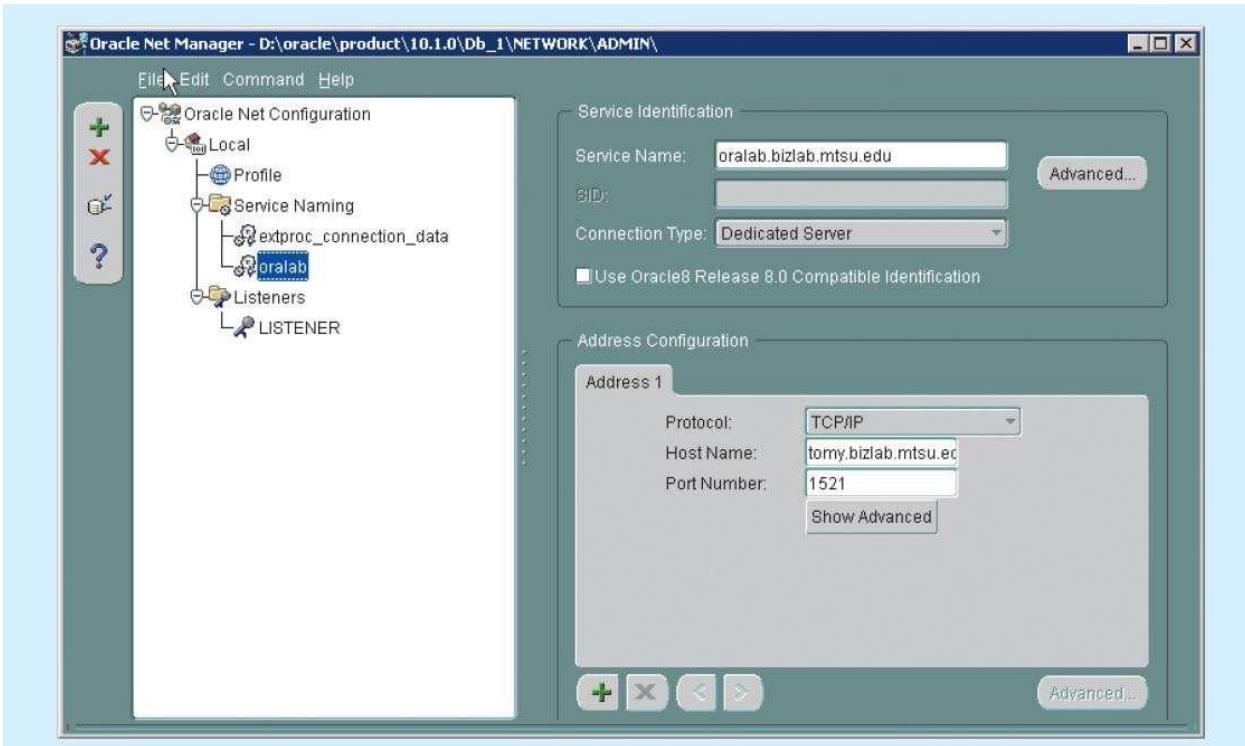
---

Most DBMS vendors provide their own methods for connecting to their databases. Native SQL connectivity refers to the connection interface that is provided by the database vendor and is unique to that vendor. The best example of this type of native interface is the Oracle RDBMS. To connect a client application to an Oracle database, you must install and configure Oracle's SQL\*Net interface in the client computer. [Figure 14.1](#) shows the configuration of the Oracle SQL\*Net interface on the client computer.

---

**FIGURE14.1 Oracle native connectivity**

---



SOURCE: Course Technology/Cengage Learning

---

Native database connectivity interfaces are optimized for “their” DBMS, and those interfaces support access to most or all of the database features. However, maintaining multiple native interfaces for different databases can become a burden for the programmer. Therefore, the need for “universal” database connectivity arises. Usually, the native database connectivity interface provided by the vendor is not the only way to connect to a database; most current DBMS products support other database connectivity standards, the most common being ODBC.

#### 14.1.2 ODBC, DAO, AND RDO

---

Developed in the early 1990s, [\*\*Open Database Connectivity \(ODBC\)\*\*](#) is Microsoft’s implementation of a superset of the SQL Access Group [\*\*Call Level Interface \(CLI\)\*\*](#) standard for database access. ODBC is probably the most widely supported database connectivity interface. ODBC allows any Windows application to access relational data sources, using SQL via a standard [\*\*application programming interface \(API\)\*\*](#). The Webopedia online dictionary ([www.webopedia.com](http://www.webopedia.com)) defines an API as “a set of routines, protocols, and tools for building software applications.” A good API makes it easy to develop a

program by providing all of the building blocks; the programmer puts the blocks together. Most operating environments, such as Windows, provide an API so that programmers can write applications consistent with the operating environment. Although APIs are designed for programmers, they are ultimately good for users because they guarantee that all programs using a common API will have similar interfaces. That makes it easy for users to learn new programs.

ODBC was the first widely adopted database middleware standard, and it enjoyed rapid adoption in Windows applications. As programming languages evolved, ODBC did not provide significant functionality beyond the ability to execute SQL to manipulate relational-style data. Therefore, programmers needed a better way to access data. To answer that need, Microsoft developed two other data access interfaces:

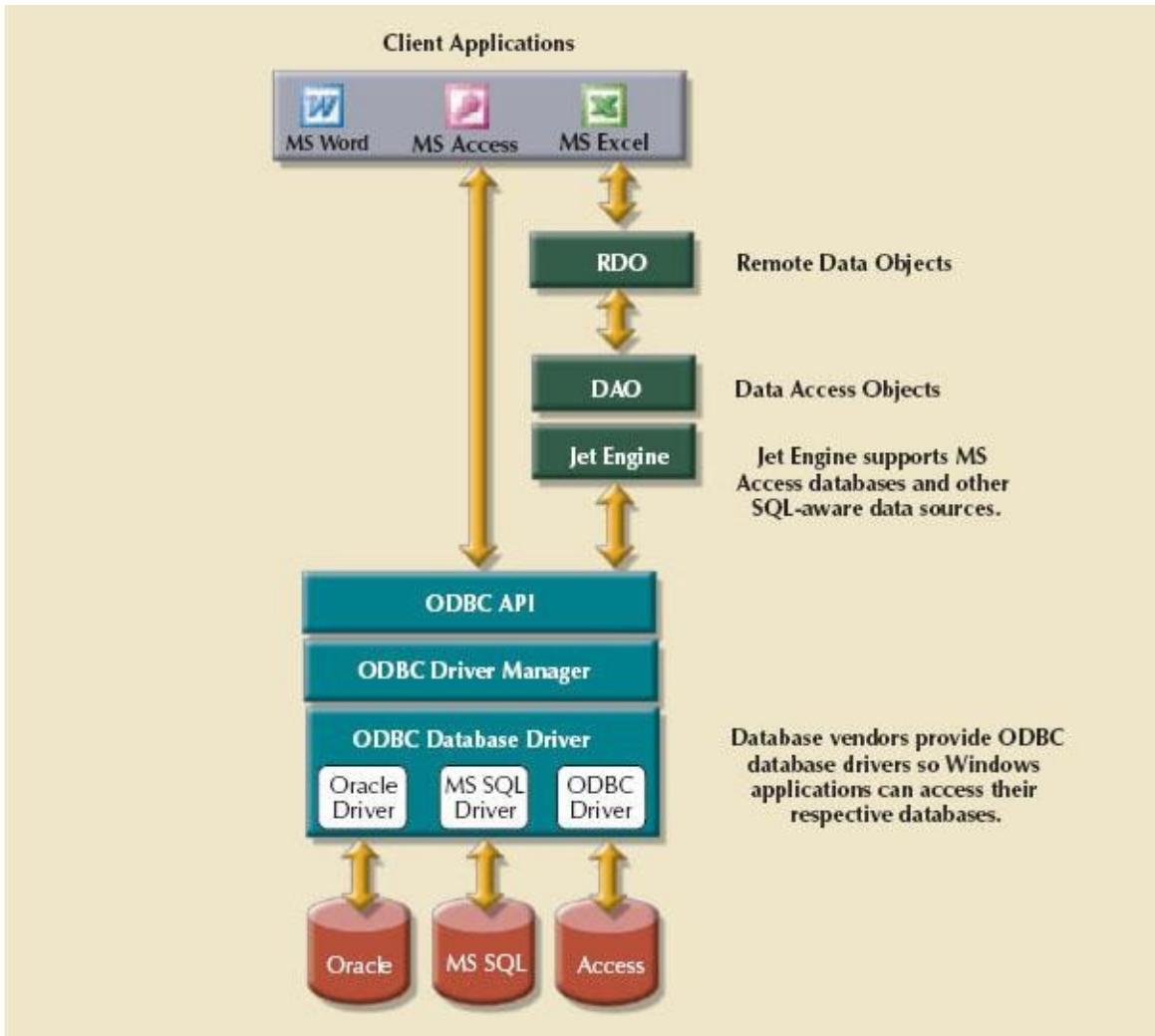
- **Data Access Objects (DAO)** is an object-oriented API used to access MS Access, MS FoxPro, and dBase databases (using the Jet data engine) from Visual Basic programs. DAO provides an optimized interface that exposes programmers to the functionality of the Jet data engine, on which the MS Access database is based. The DAO interface can also be used to access other relational-style data sources.
- **Remote Data Objects (RDO)** is a higher-level, object-oriented application interface used to access remote database servers. RDO uses the lower-level DAO and ODBC for direct access to databases. RDO is optimized to deal with server-based databases such as MS SQL Server, Oracle, and DB2.

[Figure 14.2](#) illustrates how Windows applications can use ODBC, DAO, and RDO to access local and remote relational data sources.

---

**FIGURE 14.2 Using ODBC, DAO, and RDO to access databases**

---



SOURCE: Course Technology/Cengage Learning

The DAO and RDO object interfaces provide more functionality than ODBC. DAO and RDO make use of the underlying ODBC data services. ODBC, DAO, and RDO are implemented as shared code that is dynamically linked to the Windows operating environment through [dynamic-link libraries \(DLLs\)](#), which are stored as files with a .dll extension. Running as a DLL, the code speeds up load and run times.

The basic ODBC architecture has three main components:

- A high-level *ODBC API* through which application programs access ODBC functionality
- A *driver manager* that is in charge of managing all database connections

- An *ODBC driver* that communicates directly to the DBMS

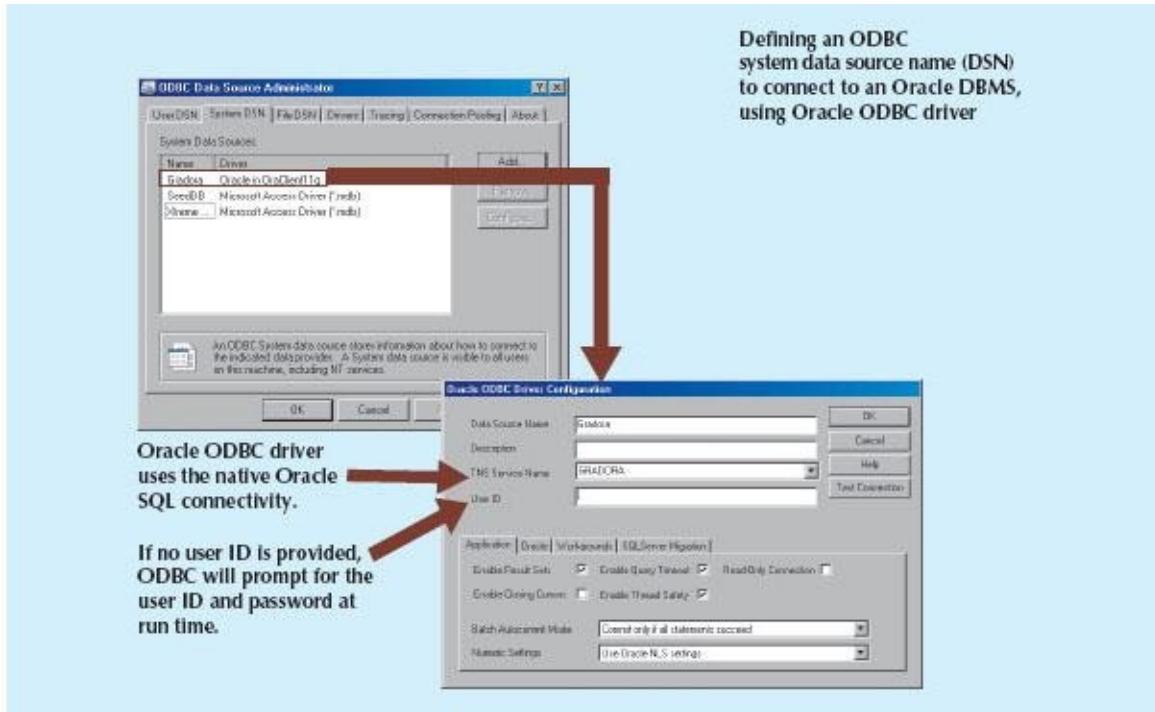
Defining a data source is the first step in using ODBC. To define a data source, you must create a [data source name \(DSN\)](#) for it. To create a DSN, you need to provide the following:

- *An ODBC driver.* You must identify the driver to use to connect to the data source. The ODBC driver is normally provided by the database vendor, although Microsoft provides several drivers that connect to most common databases. For example, if you are using an Oracle DBMS, you would select the Oracle ODBC driver provided by Oracle. Or, you could instead select the Microsoft-provided ODBC driver for Oracle.
- *A name.* This is a unique name by which the data source will be known to ODBC, and therefore to applications. ODBC offers two types of data sources: user and system. *User data sources* are available only to the user. *System data sources* are available to all users, including operating system services.
- *ODBC driver parameters.* Most ODBC drivers require specific parameters to establish a connection to the database. For example, if you are using an MS Access database, you must point to the location of the MS Access file and then provide a username and password if necessary. If you are using a DBMS server, you must provide the server name, the database name, the username, and the password needed to connect to the database. [Figure 14.3](#) shows the ODBC screens required to create a system ODBC data source for an Oracle DBMS. Note that some ODBC drivers use the native driver provided by the DBMS vendor.

---

**FIGURE 14.3 Configuring an Oracle ODBC data source**

---



SOURCE: Course Technology/Cengage Learning

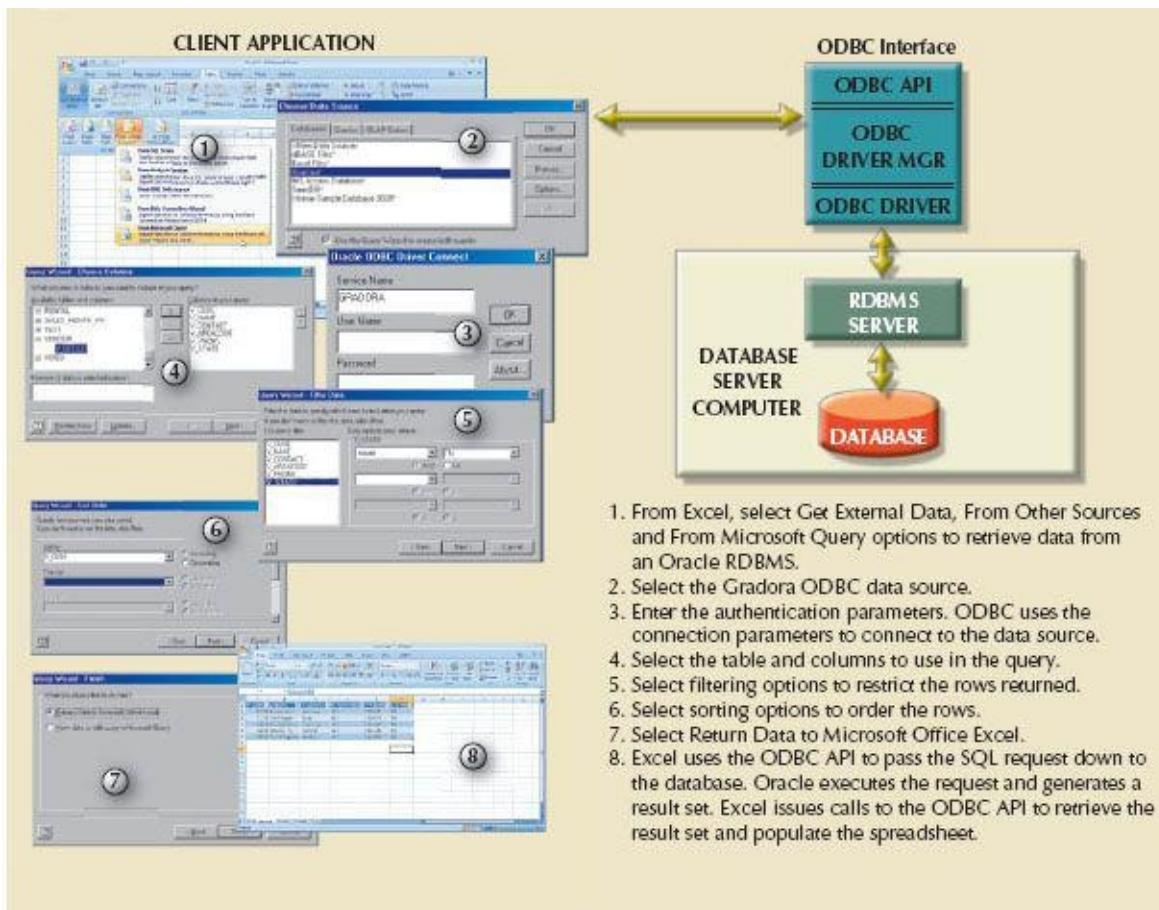
---

Once the ODBC data source is defined, application programmers can write to the ODBC API by issuing specific commands and providing the required parameters. The ODBC Driver Manager will properly route the calls to the appropriate data source. The ODBC API standard defines three levels of compliance: Core, Level-1, and Level-2, which provide increasing levels of functionality. For example, Level-1 might provide support for most SQL DDL and DML statements, including subqueries and aggregate functions, but not for procedural SQL or cursors. The database vendors can choose which level to support. However, to interact with ODBC, the database vendor must implement all of the features in the specified ODBC API support level.

[Figure 14.4](#) shows how you could use MS Excel to retrieve data from an Oracle RDBMS using ODBC. Because much of the functionality provided by these interfaces is oriented toward accessing relational data sources, the use of the interfaces was limited with other data source types. With the advent of object-oriented programming languages, it has become more important to provide access to other nonrelational data sources.

---

**FIGURE 14.4** MS Excel uses ODBC to connect to an Oracle database



SOURCE: Course Technology/Cengage Learning

#### 14.1.3 OLE-DB

Although ODBC, DAO, and RDO are used, they do not provide support for nonrelational data. To answer that need and to simplify data connectivity, Microsoft developed **Object Linking and Embedding for Database (OLE-DB)**. Based on Microsoft's Component Object Model (COM), OLE-DB is database middleware that adds object-oriented functionality for access to relational and nonrelational data. OLE-DB was the first part of Microsoft's strategy to provide a unified object-oriented framework for the development of next-generation applications.

OLE-DB is composed of a series of COM objects that provide low-level database connectivity for applications. Because OLE-DB is based on COM, the objects contain data and methods, also known as the interface. The OLE-DB model is better understood when you divide its functionality into two types of

objects:

- *Consumers* are objects (applications or processes) that request and use data. Consumers request data by invoking the methods exposed by the data provider objects (public interface) and passing the required parameters.
- *Providers* are objects that manage the connection with a data source and provide data to the consumers. Providers are divided into two categories: data providers and service providers.
  - *Data providers* provide data to other processes. Database vendors create data provider objects that expose the functionality of the underlying data source (relational, object-oriented, text, and so on).
  - *Service providers* provide additional functionality to consumers. The service provider is located between the data provider and the consumer. The service provider requests data from the data provider, transforms the data, and then provides the transformed data to the data consumer. In other words, the service provider acts like a data consumer of the data provider and as a data provider for the data consumer (end-user application). For example, a service provider could offer cursor management services, transaction management services, query processing services, and indexing services.

As a common practice, many vendors provide OLE-DB objects to augment their ODBC support, effectively creating a shared object layer on top of their existing database connectivity (ODBC or native) through which applications can interact. The OLE-DB objects expose functionality about the database; for example, there are objects that deal with relational data, hierarchical data, and flat-file text data. Additionally, the objects implement specific tasks, such as establishing a connection, executing a query, invoking a stored procedure, defining a transaction, or invoking an OLAP function. By using OLE-DB objects, the database vendor can choose what functionality to implement in a modular way, instead of being forced to include all of the functionality all of the time. [Table 14.1](#) shows a sample of the object-oriented classes used by OLE-DB and some of the methods (interfaces) exposed by the objects.

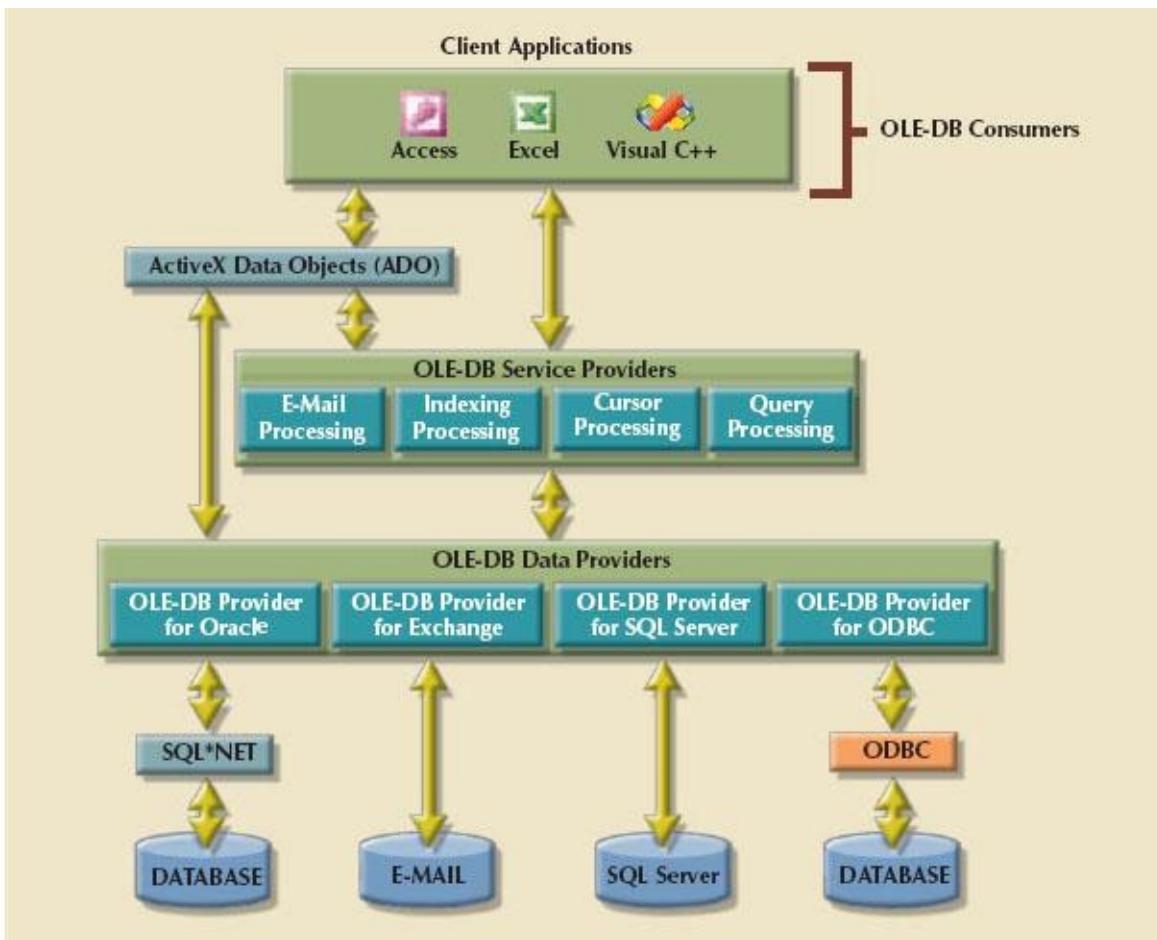
---

**TABLE 14.1 Sample OLE-DB Classes and Interfaces**

| OBJECT CLASS | USAGE                                                                                                                                                                | SAMPLE INTERFACES                           |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|
| Session      | Used to create an OLE-DB session between a data consumer application and a data provider                                                                             | IGetDataSource<br>ISessionProperties        |
| Command      | Used to process commands to manipulate a data provider's data; generally, the command object will create RowSet objects to hold the data returned by a data provider | ICommandPrepare<br>ICommandProperties       |
| RowSet       | Used to hold the result set returned by a relational-style database or a database that supports SQL; represents a collection of rows in a tabular format             | IRowsetInfo<br>IRowsetFind<br>IRowsetScroll |

OLE-DB provides additional capabilities for the applications accessing the data. However, it does not provide support for scripting languages, especially the ones used for Web development, such as Active Server Pages (ASP) and ActiveX. (A script is written in a programming language that is not compiled but is interpreted and executed at run time.) To provide that support, Microsoft developed a new object framework called **ActiveX Data Objects (ADO)**, which provides a high-level, application-oriented interface to interact with OLE-DB, DAO, and RDO. ADO provides a unified interface to access data from any programming language that uses the underlying OLE-DB objects. [Figure 14.5](#) illustrates the ADO/OLE-DB architecture and how it interacts with ODBC and native connectivity options.

**FIGURE14.5 OLE-DB architecture**



SOURCE: Course Technology/Cengage Learning

---

ADO introduced a simpler object model that was composed of only a few interacting objects to provide the data manipulation services required by the applications. Sample objects in ADO are shown in [Table 14.2](#).

---



---

**TABLE 14.2 Sample ADO Objects**

---

## OBJECT USAGE CLASS

Connection      Used to set up and establish a connection with a data source.  
                   ADO will connect OLE-DB data source. The data source can be

|           |                                                                                                                                                                                |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           | of any type.                                                                                                                                                                   |
| Command   | Used to execute commands against a specific connection (data source)                                                                                                           |
| Recordset | Contains the data generated by the execution of a command. It will also contain new data to be written to the data source. The Recordset can be disconnected from data source. |
| Fields    | Contains a collection of field descriptions for each column in the Recordset                                                                                                   |

---

Although the ADO model is a tremendous improvement over the OLE-DB model, Microsoft is actively encouraging programmers to use its newer data access framework, ADO.NET.

#### 14.1.4 ADO.NET

---

Based on ADO, [ADO.NET](#) is the data access component of Microsoft's .NET application development framework. The [Microsoft .NET framework](#) is a component-based platform for developing distributed, heterogeneous, interoperable applications aimed at manipulating any type of data using any combination of network, operating system, and programming language. Comprehensive coverage of the .NET framework is beyond the scope of this book. Therefore, this section only introduces the basic data access component of the .NET architecture, ADO.NET.

It is important to understand that the .NET framework extends and enhances the functionality provided by the ADO/ OLE-DB duo. ADO.NET introduced two new features that are critical for the development of distributed applications: DataSets and XML support.

To understand the importance of this new model, you should know that a [DataSet](#) is a disconnected, memory-resident representation of the database. That is, the DataSet contains tables, columns, rows, relationships, and constraints. Once the data are read from a data provider, they are placed in a memory-resident DataSet, which is then disconnected from the data provider. The data consumer application interacts with the data in the DataSet object to make inserts, updates, and deletes in the DataSet. Once the processing is done, the DataSet data are synchronized with the data source and the changes are made permanent.

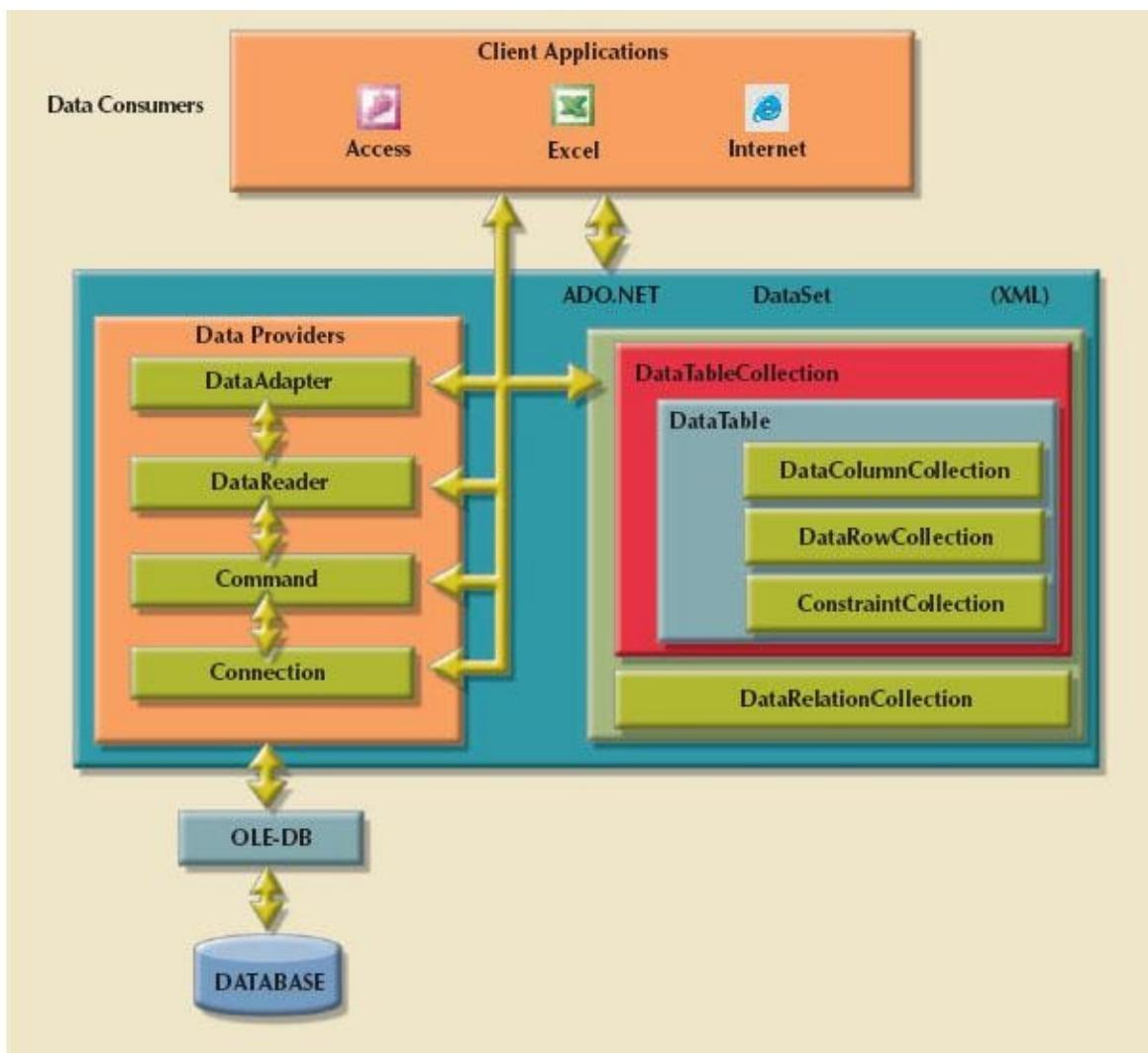
The DataSet is internally stored in XML format, and the data in the DataSet can be made persistent as XML documents. This is critical in today's distributed environments. You can think of the DataSet as an XML-based, in-memory database that represents the persistent data stored in the data source. (You will learn about XML later in this chapter.)

[Figure 14.6](#) illustrates the main components of the ADO.NET object model.

---

**FIGURE 14.6 ADO.NET framework**

---



SOURCE: Course Technology/Cengage Learning

---

The ADO.NET framework consolidates all data access functionality under one integrated object model. In this object model, several objects interact with one another to perform specific data manipulations. These objects can be grouped as data providers and consumers.

Data provider objects are provided by the database vendors. However, ADO.NET comes with two standard data providers: one for OLE-DB data sources and one for SQL Server. That way, ADO.NET can work with any previously supported database, including an ODBC database with an OLE-DB data provider. At the same time, ADO.NET includes a highly optimized data provider for SQL Server.

Whatever the data provider is, it must support a set of specific objects to manipulate the data in the data source. Some of those objects are shown in [Figure 14.6](#). A brief description of the objects follows.

- *Connection*. The Connection object defines the data source used, the name of the server, the database, and so on. This object enables the client application to open and close a connection to a database.
- *Command*. The Command object represents a database command to be executed within a specified database connection. This object contains the actual SQL code or a stored procedure call to be run by the database. When a SELECT statement is executed, the Command object returns a set of rows and columns.
- *DataReader*. The DataReader object is a specialized object that creates a read-only session with the database to retrieve data sequentially (forward only) and very quickly.
- *DataAdapter*. The DataAdapter object is in charge of managing a DataSet object, and is the most specialized object in the ADO.NET framework. The DataAdapter object contains the following objects that aid in managing the data in the DataSet: SelectCommand, InsertCommand, UpdateCommand, and DeleteCommand. The DataAdapter object uses these objects to populate and synchronize the data in the DataSet with the permanent data source data.

- *DataSet*. The DataSet object is the in-memory representation of the data in the database. This object contains two main objects. The DataTableCollection object contains a collection of DataTable objects that make up the “in-memory” database, and the DataRelationCollection object contains a collection of objects that describe the data relationships and ways to associate one row in a table to the related row in another table.
- *DataTable*. The DataTable object represents the data in tabular format. This object has one very important property: PrimaryKey, which allows the enforcement of entity integrity. In turn, the DataTable object is composed of three main objects:
  - *DataColumnCollection* contains one or more column descriptions. Each column description has properties such as column name, data type, nulls allowed, maximum value, and minimum value.
  - *DataRowCollection* contains zero rows, one row, or more than one row with data as described in the DataColumnCollection.
  - *ConstraintCollection* contains the definition of the constraints for the table. Two types of constraints are supported: ForeignKeyConstraint and UniqueConstraint.

As you can see, a DataSet is a simple database with tables, rows, and constraints. Even more importantly, the DataSet does not require a permanent connection to the data source. The DataAdapter uses the SelectCommand object to populate the DataSet from a data source. However, once the DataSet is populated, it is completely independent of the data source, which is why it is called disconnected.

Additionally, DataTable objects in a DataSet can come from different data sources. This means that you could have an EMPLOYEE table in an Oracle database and a SALES table in a SQL Server database. You could then create a DataSet that relates both tables as though they were in the same database. In short, the DataSet object paves the way for truly heterogeneous, distributed database support within applications.

The ADO.NET framework is optimized to work in disconnected environments. In a disconnected environment, applications exchange messages in request/reply format. The most common example of a disconnected system is the Internet.

Modern applications rely on the Internet as the network platform and on the Web browser as the graphical user interface. In later sections, you will learn about how Internet databases work.

#### 14.1.5 JAVA DATABASE CONNECTIVITY (JDBC)

---

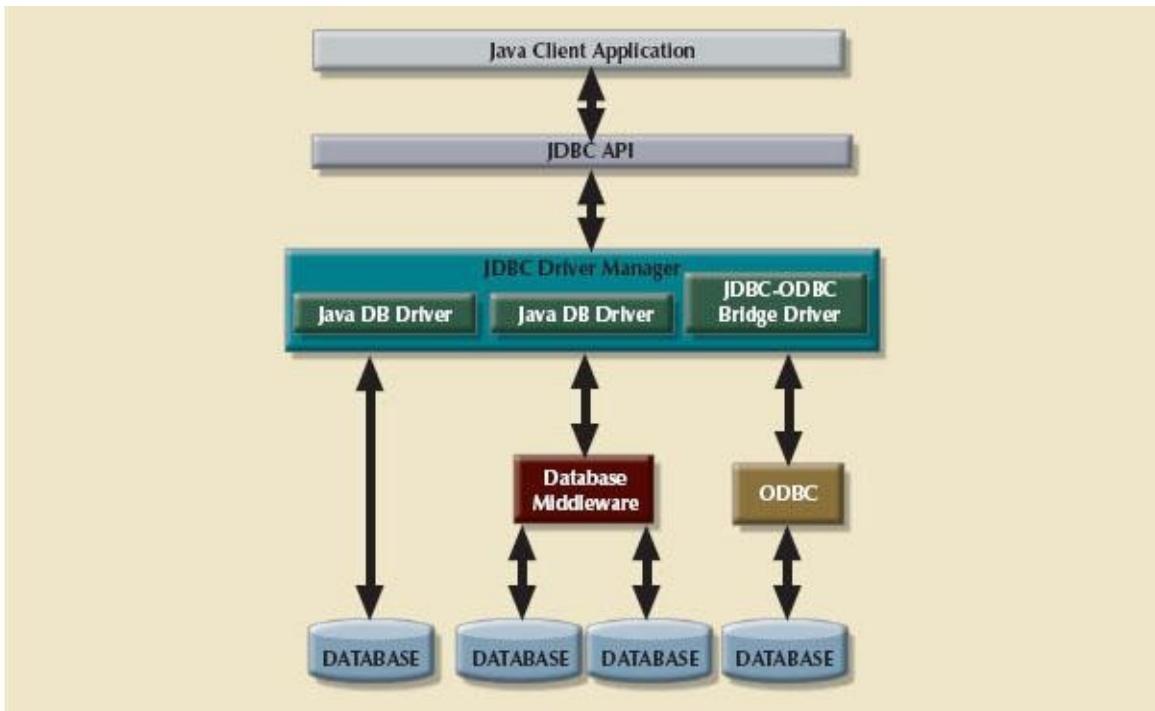
[Java](#) is an object-oriented programming language developed by Sun Microsystems that runs on top of Web browser software. Java is one of the most common programming languages for Web development. Sun Microsystems created Java as a “write once, run anywhere” environment, which means that a programmer can write a Java application once and then run it in multiple environments without any modification. The cross-platform capabilities of Java are based on its portable architecture. Java code is normally stored in preprocessed “chunks” known as applets that run in a virtual machine environment in the host operating system. This environment has well-defined boundaries, and all interactivity with the host operating system is closely monitored. Sun provides Java run-time environments for most operating systems, from computers to handheld mobile devices to TV set-top boxes. Another advantage of using Java is its “on-demand” architecture. When a Java application loads, it can dynamically download all its modules or required components via the Internet.

When Java applications need to access data outside the Java run-time environment, they use predefined application programming interfaces. [Java Database Connectivity \(JDBC\)](#) is an application programming interface that allows a Java program to interact with a wide range of data sources, including relational databases, tabular data sources, spreadsheets, and text files. JDBC allows a Java program to establish a connection with a data source, prepare and send the SQL code to the database server, and process the result set.

One main advantage of JDBC is that it allows a company to leverage its existing investment in technology and personnel training. JDBC allows programmers to use their SQL skills to manipulate the data in the company’s databases. As a matter of fact, JDBC allows direct access to a database server or access via database middleware. Furthermore, JDBC provides a way to connect to databases through an ODBC driver. [Figure 14.7](#) illustrates the basic JDBC architecture and the various database access styles.

---

**FIGURE 14.7 JDBC architecture**



SOURCE: Course Technology/Cengage Learning

As you see in [Figure 14.7](#), the database access architecture in JDBC is very similar to the ODBC/OLE/ADO.NET architecture. All database access middleware shares similar components and functionality. One advantage of JDBC over other middleware is that it requires no configuration on the client side. The JDBC driver is automatically downloaded and installed as part of the Java applet download. Because Java is a Web-based technology, applications can connect to a database directly using a simple URL. Once the URL is invoked, the Java architecture comes into play, the necessary applets are downloaded to the client (including the JDBC database driver and all configuration information), and then the applets are executed securely in the client's run-time environment.

Every day, more and more companies are investing resources to develop and expand their Web presence and are finding ways to do more business on the Internet. Such business generates increasing amounts of data to be stored in databases. Java and the .NET framework are part of the trend toward increasing reliance on the Internet as a critical business resource. In fact, the Internet is likely to become the development platform of the future. In the next section, you will learn more about Internet databases and how they are used.

---

## 14.2 DATABASE INTERNET CONNECTIVITY

---

Millions of people all over the world access the Internet and connect to databases via Web browsers or data services. For example, they can use a smart phone applet to get weather information. Internet database connectivity opens the door to new, innovative services that do the following:

- Permit rapid responses to competitive pressures by bringing new services and products to market quickly.
- Increase customer satisfaction through the creation of Web-based support services.
- Allow anywhere, anytime data access using mobile smart devices via the Internet.
- Yield fast and effective information dissemination through universal access from across the street or across the globe.

Given these advantages, many organizations rely on their IT departments to create universal data access architectures based on Internet standards. [Table 14.3](#) shows a sample of Internet technology characteristics and the benefits they provide.

---

**TABLE 14.3 Characteristics and Benefits of Internet Technologies**

---

| <b>INTERNET<br/>CHARACTERISTIC</b> | <b>BENEFIT</b> |
|------------------------------------|----------------|
|------------------------------------|----------------|

|                                               |
|-----------------------------------------------|
| Savings in equipment and software acquisition |
|-----------------------------------------------|

|                                       |                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hardware and software independence    | Ability to run on most existing equipment<br>Platform independence and portability<br>No need for multiple platform development                                                                                                                                                                                                                                                                                        |
| Common and simple user interface      | Reduced training time and cost<br>Reduced end-user support cost<br>No need for multiple platform development<br>Global access through Internet infrastructure and mobile smart                                                                                                                                                                                                                                         |
| Location independence                 | Reduced requirements (and costs!) for dedicated connections                                                                                                                                                                                                                                                                                                                                                            |
| Rapid development at manageable costs | Availability of multiple development tools<br>Plug-and-play development tools (open standards)<br>More interactive development<br>Reduced development times<br>Relatively inexpensive tools<br>Free client access tools (Web browsers)<br>Low entry costs; frequent availability of free Web servers<br>Reduced costs of maintaining private networks<br>Distributed processing and scalability using multiple servers |

---

As you will learn in the following sections, database application development—particularly the creation and management of user interfaces and database connectivity—is profoundly affected by the Web. However, having a Web-based database interface does not negate the design and implementation issues that were addressed in the previous chapters. In the final analysis, whether you make a purchase by going online or by standing in line, the system-level transaction details are essentially the same, and they require the same basic database structures and relationships. If any immediate lesson is to be learned, it is this: *The effects of bad database design, implementation, and management are magnified in an environment in which transactions might be measured in hundreds of thousands per day rather than hundreds.*

The simplicity of the Web's interface and its cross-platform functionality are at the core of its success as a data access platform. In fact, the Web has helped

create a new information dissemination standard. The following sections examine how Web-to-database middleware enables end users to interact with databases over the Web.

#### 14.2.1 WEB-TO-DATABASE MIDDLEWARE: SERVER-SIDE EXTENSIONS

---

In general, the Web server is the main hub through which all Internet services are accessed. For example, when an end user uses a Web browser to dynamically query a database, the client browser requests a Web page from the Web server. When the Web server receives the page request, it looks for the page on the hard disk; when it finds the page, the server sends it back to the client.

---



#### ONLINE CONTENT

Client/server systems are covered in detail in **Appendix F, Client/Server Systems**, at [www.cengagebrain.com](http://www.cengagebrain.com).

---

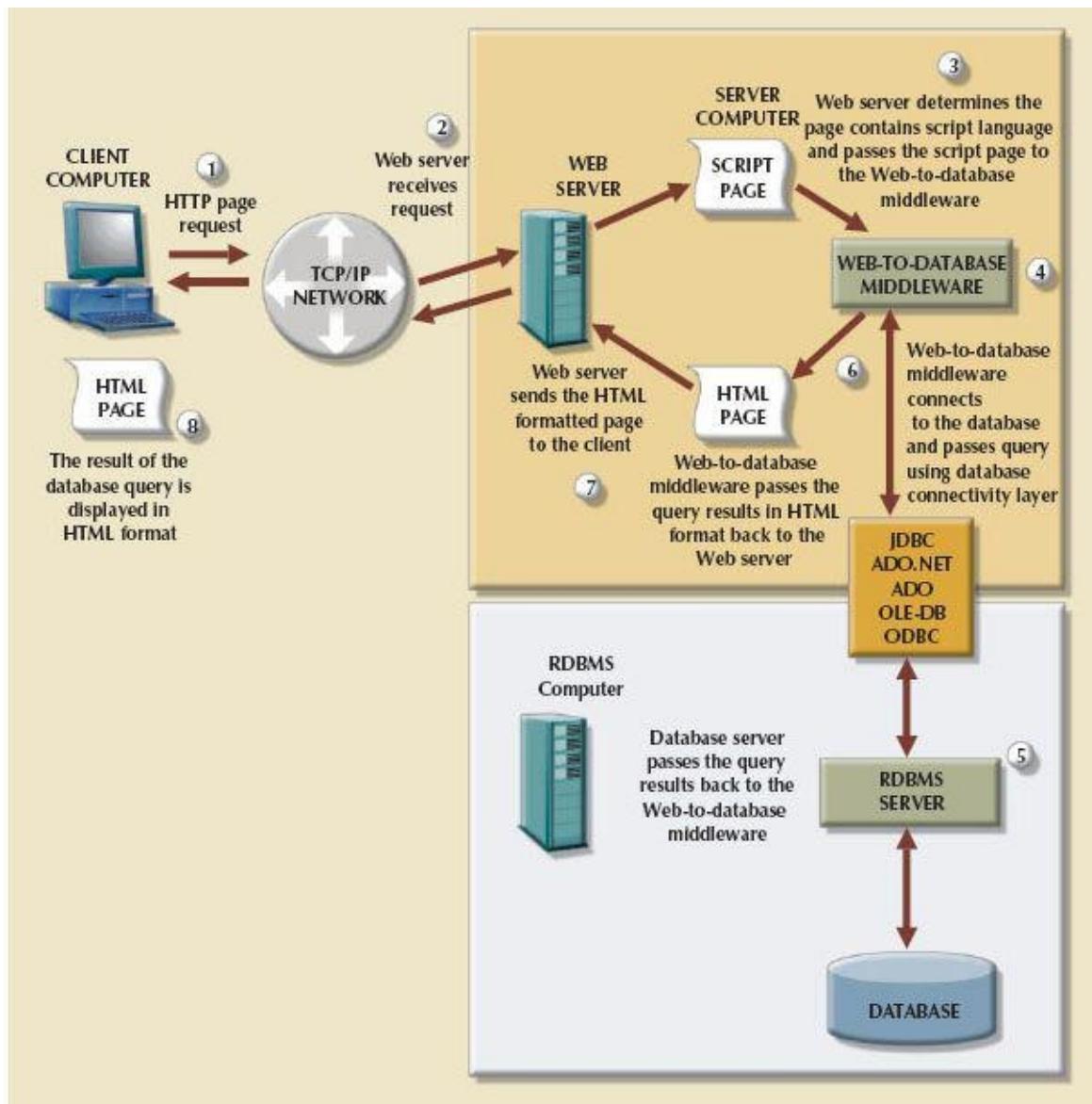
Dynamic Web pages are at the heart of current Websites. In this database query scenario, the Web server generates the Web page contents before it sends the page to the client Web browser. The only problem with the preceding query scenario is that the Web server must include the database query result on the page *before* it sends that page back to the client. Unfortunately, neither the Web browser nor the Web server knows how to connect to and read data from the database. Therefore, to support this type of request, the Web server's capability must be extended so it can understand and process database requests. This job is known as a server-side extension.

A **server-side extension** is a program that interacts directly with the Web server to handle specific types of requests. In the preceding database query example, the server-side extension program retrieves the data from databases and passes the retrieved data to the Web server, which in turn sends the data to the client's browser for display. The server-side extension makes it possible to retrieve and present the query results, but more importantly, *it provides its services to the Web server in a way that is totally transparent to the client browser*. In short, the server-side extension adds significant functionality to the Web server, and therefore to the Internet.

A database server-side extension program is also known as **Web-to-database**

**middleware.** Figure 14.8 shows the interaction between the browser, the Web server, and the Web-to-database middleware.

FIGURE 14.8 Web-to-database middleware



SOURCE: Course Technology/Cengage Learning

Trace the Web-to-database middleware actions in Figure 14.8:

- The client browser sends a page request to the Web server.

- The Web server receives and passes the request to the Web-to-database middleware for processing. Generally, the requested page contains some type of scripting language to enable the database interaction.
- The Web-to-database middleware reads, validates, and executes the script. In this case, it connects to the database and passes the query using the database connectivity layer.
- The database server executes the query and passes the result back to the Web-to-database middleware.
- The Web-to-database middleware compiles the result set, dynamically generates an HTML-formatted page that includes the data retrieved from the database, and sends it to the Web server.
- The Web server returns the just-created HTML page, which now includes the query result, to the client browser.
- The client browser displays the page on the local computer.

The interaction between the Web server and the Web-to-database middleware is crucial to the development of a successful Internet database implementation. Therefore, the middleware must integrate closely via a well-defined Web server interface.

#### 14.2.2 WEB SERVER INTERFACES

---

Extending Web server functionality implies that the Web server and the Web-to-database middleware will properly communicate with each other. (Database professionals often use the word *interoperate* to indicate that each party can respond to the communications of the other.) A Web server interface defines a standard way to exchange messages with external programs. Currently, there are two well-defined Web server interfaces:

- Common Gateway Interface (CGI)
- Application programming interface (API)

The **Common Gateway Interface (CGI)** uses script files that perform specific functions based on the client's parameters that are passed to the Web server. The script file is a small program containing commands written in a programming language—usually Perl, C#, or Visual Basic. The script file's contents can be used to connect to the database and to retrieve data from it, using the parameters passed by the Web server. Next, the script converts the retrieved data to HTML format and passes the data to the Web server, which sends the HTML-formatted page to the client.

The main disadvantage of using CGI scripts is that the script file is an external program that executes separately for each user request and therefore causes a resource bottleneck. Performance also could be degraded by using an interpreted language or by writing the script inefficiently.

An application programming interface (API) is a newer Web server interface standard that is more efficient and faster than a CGI script. APIs are more efficient because they are implemented as shared code or as dynamic-link libraries (DLLs). That means the API is treated as part of the Web server program that is dynamically invoked when needed.

APIs are faster than CGI scripts because the code resides in memory, so there is no need to run an external program for each request. Instead, the same API serves all requests. Another advantage is that an API can use a shared connection to the database instead of creating a new one every time, as is the case with CGI scripts.

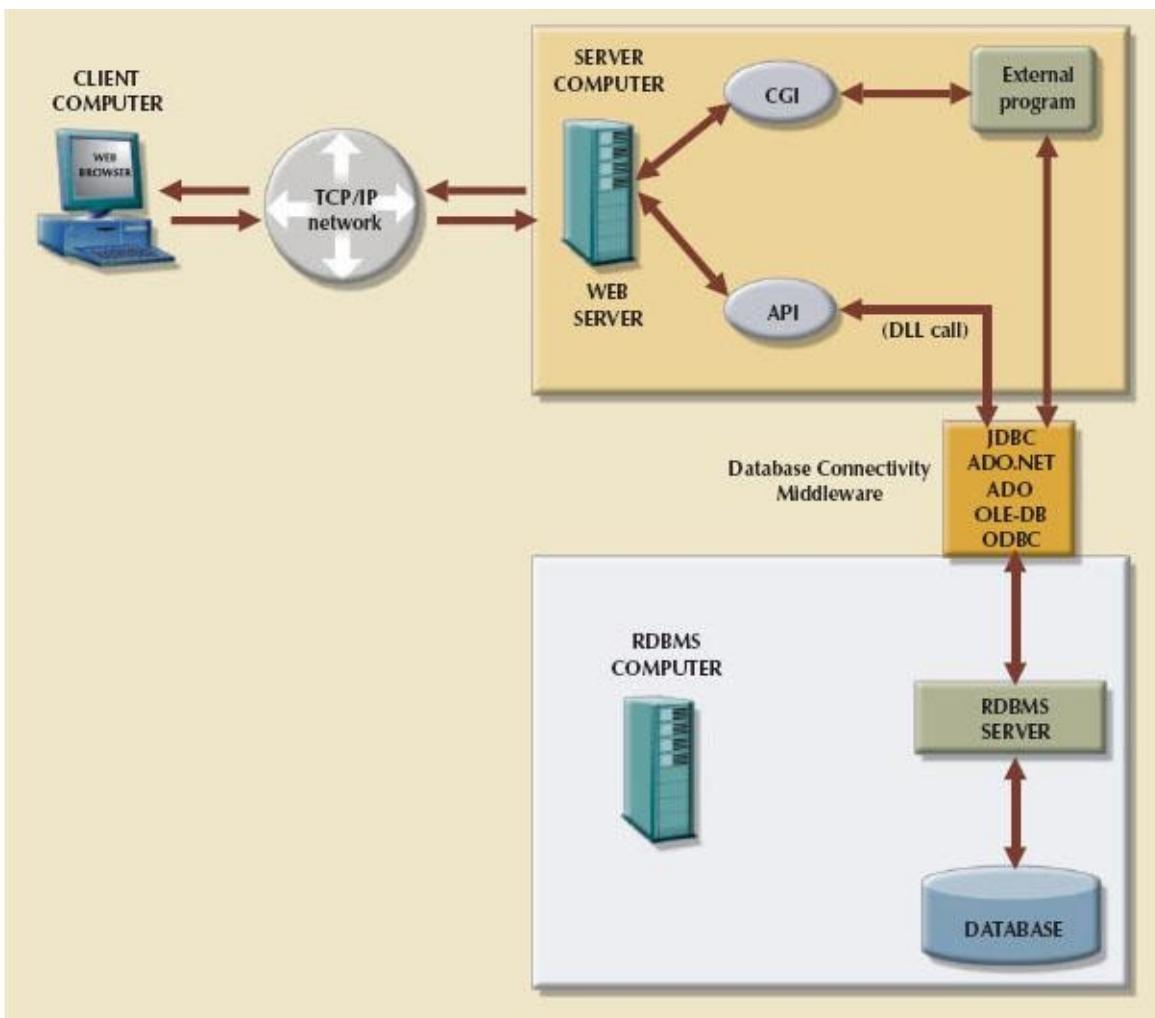
Although APIs are more efficient in handling requests, they have some disadvantages. Because the APIs share the same memory space as the Web server, an API error can bring down the Web server. Another disadvantage is that APIs are specific to the Web server and to the operating system.

The Web interface architecture is illustrated in [Figure 14.9](#).

---

**FIGURE 14.9** Web server CGI and API interfaces

---



SOURCE: Course Technology/Cengage Learning

---

Regardless of the type of Web server interface used, the Web-to-database middleware program must be able to connect with the database. That connection can be accomplished in one of two ways:

- Use the native SQL access middleware provided by the vendor. For example, you can use SQL\*Net if you are using Oracle.
- Use the services of general database connectivity standards such as ODBC, OLE-DB, ADO, ADO.NET, or JDBC.

#### 14.2.3 THE WEB BROWSER

---

The Web browser is software such as Microsoft Internet Explorer, Google Chrome, Apple Safari, or Mozilla Firefox that lets end users navigate the Web from their client computer. Each time the end user clicks a hyperlink, the browser generates an HTTP GET page request that is sent to the designated Web server using the TCP/IP Internet protocol.

The Web browser's job is to *interpret* the HTML code that it receives from the Web server and to present the various page components in a standard formatted way. Unfortunately, the browser's interpretation and presentation capabilities are not sufficient to develop Web-based applications. The Web is a **stateless system** —at any given time, a Web server does not know the status of any of the clients communicating with it. That is, there is no open communication line between the server and each client accessing it, which of course is impractical in a *worldwide* Web! Instead, client and server computers interact in very short “conversations” that follow the request-reply model. For example, the browser is concerned only with the *current* page, so there is no way for the second page to know what was done in the first page. The only time the client and server computers communicate is when the client requests a page—when the user clicks a link—and the server sends the requested page to the client. Once the client receives the page and its components, the client/server communication is ended. Therefore, although you may be browsing a page and *think* that the communication is open, you are actually just browsing the HTML document stored in the local cache (temporary directory) of your browser. The server does not have any idea what the end user is doing with the document, what data are entered in a form, what option is selected, and so on. On the Web, if you want to act on a client's selection, you need to jump to a new page (go back to the Web server), thus losing track of what was done before.

The Web browser, through its use of HTML, does not have computational abilities beyond formatting output text and accepting form field inputs. Even when the browser accepts form field data, there is no way to perform immediate data entry validation. Therefore, to perform such crucial processing in the client, the Web defers to other Web programming languages such as Java, JavaScript, and VBScript. The browser resembles a dumb terminal that displays only data and can perform only rudimentary processing such as accepting form data inputs. To improve the capabilities of the Web browser, you must use plug-ins and other client-side extensions. On the server side, Web application servers provide the necessary processing power.

#### 14.2.4 CLIENT-SIDE EXTENSIONS

---

**Client-side extensions** add functionality to the Web browser. Although client-side extensions are available in various forms, the most common are:

- Plug-ins
- Java and JavaScript
- ActiveX and VBScript

A **plug-in** is an external application that is automatically invoked by the browser when needed. The plug-in is associated with a data object—generally using the file extension—to allow the Web server to properly handle data that are not originally supported. For example, if one of the page components is a PDF document, the Web server will receive the data, recognize it as a Portable Document Format object, and launch Adobe Acrobat Reader to present the document on the client computer.

**JavaScript** is a scripting language (one that enables the execution of a series of commands or macros) that allows Web authors to design interactive sites. JavaScript code is embedded in the Web page and executed after a specific event, such as a mouse click on an object or a page being loaded from the server into memory.

**ActiveX** is Microsoft's alternative to Java. ActiveX is a specification for writing programs that run inside the Microsoft client browser, Internet Explorer. Because ActiveX is oriented toward Windows applications, it has low portability. ActiveX extends the Web browser by adding controls to Web pages, including drop-down lists, a slider, a calendar, and a calculator. Those controls are downloaded from the Web server when needed so you can manipulate data inside the browser. ActiveX controls can be created in several programming languages; C++ and Visual Basic are most commonly used. Microsoft's .NET framework allows for wider interoperability of ActiveX-based applications (such as ADO. NET) across multiple operating environments.

**VBScript** is another Microsoft product that is used to extend browser functionality. VBScript is derived from Microsoft Visual Basic. Like JavaScript, VBScript code is embedded inside an HTML page and is activated by triggering events such as clicking a link.

From the developer's point of view, using routines that permit data validation on the client side is an absolute necessity. For example, when data are entered in a Web form and no data validation is done on the client side, the entire data set

must be sent to the Web server. That scenario requires the server to perform all data validation, thus wasting valuable CPU processing cycles. Therefore, client-side data input validation is one of the most basic requirements for Web applications. Most of the data validation routines are done in Java, JavaScript, ActiveX, or VBScript.

#### **14.2.5 WEB APPLICATION SERVERS**

---

A **Web application server** is a middleware application that expands the functionality of Web servers by linking them to a wide range of services, such as databases, directory systems, and search engines. The Web application server also provides a consistent run-time environment for Web applications. Web application servers can be used to perform the following:

- Connect to and query a database from a Web page.
- Present database data in a Web page using various formats.
- Create dynamic Web search pages.
- Create Web pages to insert, update, and delete database data.
- Enforce referential integrity in the application program logic.
- Use simple and nested queries and programming logic to represent business rules.

Web application servers provide features such as:

- An integrated development environment with session management and support for persistent application variables
- Security and authentication of users through user IDs and passwords
- Computational languages to represent and store business logic in the application server

- Automatic generation of HTML pages integrated with Java, JavaScript, VBScript, ASP, and so on
- Performance and fault-tolerant features
- Database access with transaction management capabilities
  - Access to multiple services, such as file transfers (FTP), database connectivity, e-mail, and directory services

Examples of Web application servers include ColdFusion/JRun by Adobe, WebSphere Application Server by IBM, WebLogic Server by Oracle, Fusion by NetObjects, Visual Studio .NET by Microsoft, and WebObjects by Apple. All Web application servers offer the ability to connect Web servers to multiple data sources and other services. They vary in their range of available features, robustness, scalability, compatibility with other Web and database tools, and extent of the development environment.

#### 14.2.6 WEB DATABASE DEVELOPMENT

---

Web database development deals with the process of interfacing databases with the Web browser—in short, how to create Web pages that access data in a database. As you learned earlier in this chapter, multiple Web environments can be used to develop Web database applications. This section presents two simple code examples (ColdFusion and PHP). Because this is a database book, the examples focus only on the commands used to interface with the database rather than the specifics of HTML code.

---



#### ONLINE CONTENT

To see and try a particular Web-to-database interface in action, consult **Appendix J, Web Database Development with ColdFusion**, at [www.cengagebrain.com](http://www.cengagebrain.com). This appendix steps you through the process of creating and using a simple Web-to-database interface, and provides more detailed information on developing Web databases with Adobe ColdFusion middleware.

---

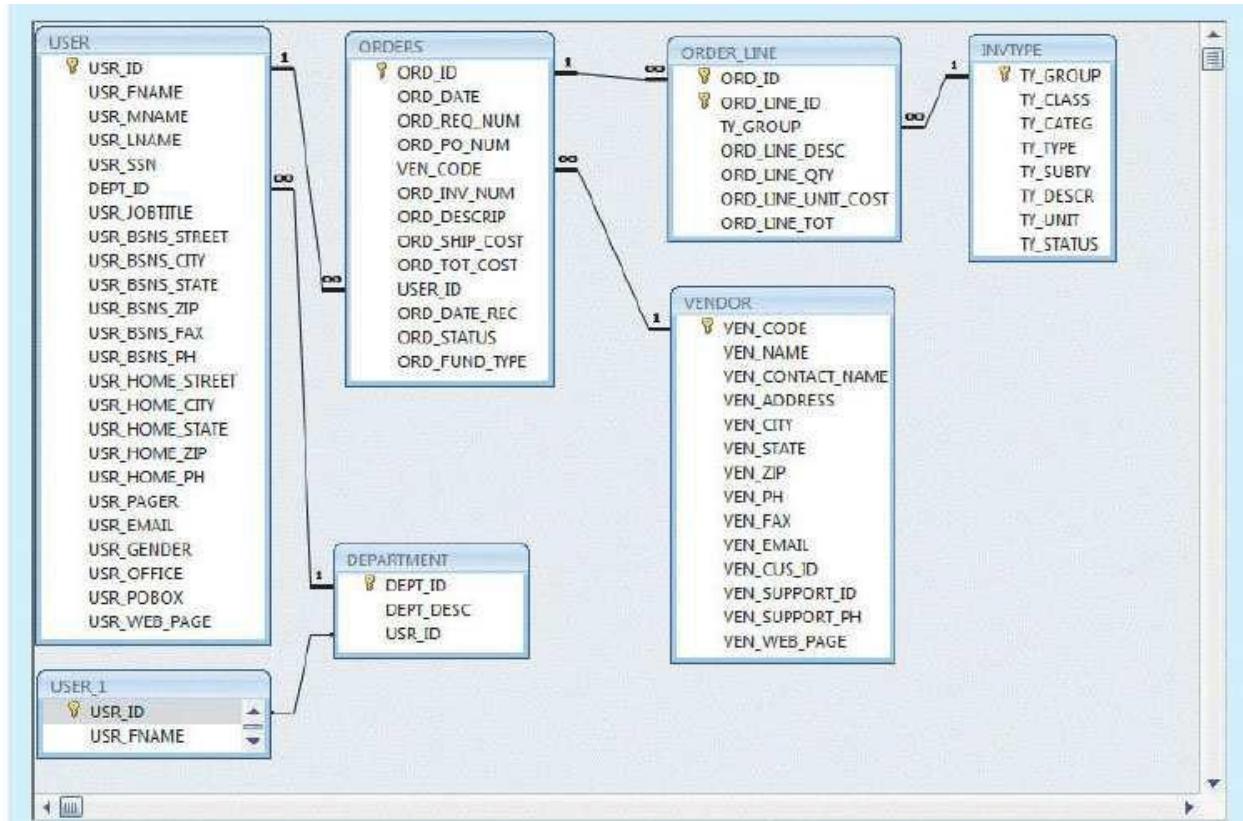
A Microsoft Access database named Orderdb is used to illustrate the Web-to-database interface examples. The Orderdb database, whose relational diagram is shown in [Figure 14.10](#), was designed to track the purchase orders placed by

users in a multidepartment company.

---

**FIGURE 14.10** The Orderdb relational diagram for the Web database development examples

---



SOURCE: Course Technology/Cengage Learning

---

The following examples explain how to use ColdFusion and PHP to create a simple Web page to list the VENDOR rows. The scripts used in these examples perform two basic tasks:

1. Query the database using standard SQL to retrieve a data set that contains all records in the VENDOR table. The examples will use an ODBC data source named RobCor. The ODBC data source was defined using the operating system tools shown in [Section 14.1.2](#).
2. Format the records generated in Step 1 in HTML so they are included in the

Web page that is returned to the client browser.

[Figure 14.11](#) shows the ColdFusion code to query the VENDOR table.

---

**FIGURE 14.11 ColdFusion code to query the VENDOR table**

---

```
1 <HTML>
2 <HEAD>
3 <TITLE>Rob & Coronel - ColdFusion Examples</TITLE>
4 <CFQUERY NAME="venlist" DATASOURCE="RobCor">
5 SELECT * FROM VENDOR ORDER BY VEN_CODE
6 </CFQUERY>
7 </HEAD>
8 <BODY BGCOLOR="LIGHTBLUE">
9 <H1>
10 <CENTER>Simple Query using CFQUERY and CFOUTPUT</CENTER>
11 <CENTER>(Vertical Output)</CENTER>
12 </H1>
13

14 <HR>
15 <CFOUTPUT>
16 Your query returned #venlist.RecordCount# records
17 </CFOUTPUT>
18 <CFOUTPUT QUERY="venlist">
19 <PRE>
20 VENDOR CODE: #VEN_CODE#
21 VENDOR NAME: #VEN_NAME#
22 CONTACT PERSON: #VEN_CONTACT_NAME#
23 ADDRESS: #VEN_ADDRESS#
24 CITY: #VEN_CITY#
25 STATE: #VEN_STATE#
26 ZIP: #VEN_ZIP#
27 PHONE: #VEN_PH#
28 FAX: #VEN_FAX#
29 E-MAIL: #VEN_EMAIL#
30 CUSTOMER ID: #VEN_CUS_ID#
31 SUPPORT ID: #VEN_SUPPORT_ID#
32 SUPPORT PHONE: #VEN_SUPPORT_PH#
33 VENDOR WEB PAGE: #VEN_WEB_PAGE#
34 <HR></PRE>
35 </CFOUTPUT>
36 </FORM>
37 </BODY>
38 </HTML>
```

SOURCE: Course Technology/Cengage Learning

---

In the code in [Figure 14.11](#), note that its ColdFusion tags are CFQUERY (to

query a database) and CFOUTPUT (to display the data returned by the query). Take a closer look at these two CFML tags:

- <CFQUERY> tag (lines 4–6). This tag sets the stage for the database connection and the execution of the enclosed SQL statement. The CFQUERY tag uses the following parameters:
  - NAME = “*queryname*”. This name uniquely identifies the record set returned by the database query.
  - DATASOURCE = “*datasourcename*”. This parameter uses the previously defined ODBC data source name.
  - The SQL statement (line 5) is the SQL code used to retrieve the data rows from the VENDOR table.
- <CFOUTPUT> tag (lines 15–17 and 18–35). This tag is used to display the results from a CFQUERY or to call other ColdFusion variables or functions. Its parameters are:
  - QUERY = “*queryname*”. This is an optional parameter (see line 18). The tag works like a loop that is executed as many times as the number of rows in the named query set. You can include any valid HTML tags or text within the opening and closing CFOUTPUT tags.
  - ColdFusion uses pound signs (#) to reference query fields in the resulting query set or to call other ColdFusion variables. For example, #venlist.RecordCount# (line 16) displays the number of rows returned by the “venlist” query result set.
  - Lines 19–34 are repeated as a loop, one for each record returned in the named query.

[Figure 14.12](#) shows the PHP code to query the VENDOR table.

---

**FIGURE 14.12 PHP code to query the VENDOR table**

---

```
1 <HTML>
2 <HEAD>
3 <TITLE>Rob & Coronel - PHP Example</TITLE>
4 </HEAD>
5 <BODY BGCOLOR="LIGHTBLUE">
6 <H1><CENTER>Simple Query using PHP and ODBC functions</CENTER>
7 <CENTER>(Vertical Output)</CENTER></H1>
8

9 <HR>
10 <?php
11 $dbc = odbc_connect("RobCor","","");
12 $sql = "SELECT * FROM VENDOR ORDER BY VEN_CODE";
13 $rs = odbc_exec($dbc, $sql);

14
15 while (odbc_fetch_row($rs))
16 {
17 $VEN_CODE = odbc_result($rs,"VEN_CODE");
18 $VEN_NAME = odbc_result($rs,"VEN_NAME");
19 $VEN_CONTACT_NAME = odbc_result($rs,"VEN_CONTACT_NAME");
20 $VEN_ADDRESS = odbc_result($rs,"VEN_ADDRESS");
21 $VEN_CITY = odbc_result($rs,"VEN_CITY");
22 $VEN_STATE = odbc_result($rs,"VEN_STATE");
23 $VEN_ZIP = odbc_result($rs,"VEN_ZIP");
24 $VEN_PH = odbc_result($rs,"VEN_PH");
25 $VEN_FAX = odbc_result($rs,"VEN_FAX");
26 $VEN_EMAIL = odbc_result($rs,"VEN_EMAIL");
27 $VEN_CUS_ID = odbc_result($rs,"VEN_CUS_ID");
28 $VEN_SUPPORT_ID = odbc_result($rs,"VEN_SUPPORT_ID");
29 $VEN_SUPPORT_PH = odbc_result($rs,"VEN_SUPPORT_PH");
30 $VEN_WEB_PAGE = odbc_result($rs,"VEN_WEB_PAGE");

31
32 echo "
";
33 echo "VENDOR CODE: ". $VEN_CODE . "
";
34 echo "VENDOR NAME: ". $VEN_NAME . "
";
35 echo "CONTACT PERSON: ". $VEN_CONTACT_NAME . "
";
36 echo "ADDRESS: ". $VEN_ADDRESS . "
";
37 echo "CITY: ". $VEN_CITY . "
";
38 echo "STATE: ". $VEN_STATE . "
";
39 echo "ZIP: ". $VEN_ZIP . "
";
40 echo "PHONE: ". $VEN_PH . "
";
41 echo "FAX: ". $VEN_FAX . "
";
42 echo "E-MAIL: ". $VEN_EMAIL . "
";
43 echo "CUSTOMER ID: ". $VEN_CUS_ID . "
";
44 echo "SUPPORT ID: ". $VEN_SUPPORT_ID . "
";
45 echo "SUPPORT PHONE: ". $VEN_SUPPORT_PH . "
";
46 echo "VENDOR WEB PAGE:". $VEN_WEB_PAGE . "
";
47 echo "<HR>";
48 }
49 odbc_close($dbc);
50 ?>
51 </BODY>
52 </HTML>
```

In the figure, note that PHP uses multiple tags to query and display the data returned by the query. Take a closer look at the PHP functions:

- The ODBC\_CONNECT function (line 11) opens a connection to the ODBC data source. A handle to this database is set in the \$dbc variable.
- The ODBC\_EXEC function (line 13) executes the SQL query stored in the \$sql variable against the \$dbc database connection. The query's result set is stored in the \$rs variable.
- The WHILE function (line 15) loops through the result set (\$rs) and uses the ODBC\_FETCH\_ROW function to get one row at a time from the result set. Notice that PHP variables start with the dollar sign (\$ ).
- The ODBC\_RESULT function (lines 17–30) gets a column value from a row in the result set and stores it in a variable. This function extracts the different values for each field to be displayed and stores them in variables.
- The ECHO function (lines 32–47) outputs text to the Web page using the variables defined in the previous lines. You can also combine text (HTML code) and PHP variables (lines 33–46) using the “.” delimiter.
- The ODBC\_CLOSE function closes the database connection.

The previous examples are just two of the many ways you can interface Web pages and databases to Web applications. These examples only scratch the surface of the multiple features that Web application servers provide.

Current-generation systems involve more than just the development of Web-enabled database applications. They also require applications that can communicate with each other and with other systems not based on the Web. Clearly, systems must be able to exchange data in a standard-based format. That is the role of XML.

---

## 14.3 EXTENSIBLE MARKUP LANGUAGE (XML)

---

Companies use the Internet to generate business transactions and integrate data to increase efficiency and reduce costs. These transactions are known as electronic commerce (e-commerce); it enables all types of organizations to sell products and services to a global market. E-commerce transactions—the sale of products or services—can take place between businesses (business-to-business, or B2B) or between a business and a consumer (business-to-consumer, or B2C).

---



### ONLINE CONTENT

To learn more about e-commerce, consult **Appendix I, Databases in Electronic Commerce**, at [www.cengagebrain.com](http://www.cengagebrain.com).

---

Most e-commerce transactions take place between businesses. Because B2B e-commerce integrates business processes among companies, it requires the transfer of business information among different business entities. However, the way in which businesses represent, identify, and use data tends to differ substantially from company to company. As a simple example, some companies use the term *product code*, while others use *item ID*.

Until recently, a purchase order traveling over the Web was expected to be in the form of an HTML document. The HTML Web page displayed on the Web browser would include formatting as well as the order details. HTML **tags** describe how something *looks* on the Web page, such as typefaces and heading styles, and they often come in pairs to start and end formatting features. For example, the following tags in angle brackets would display FOR SALE in bold Arial font:

```
FOR SALE
```

If an application needs to get the order data from the Web page, there is no easy way to extract details such as the order number, date, customer number, product code, quantity, or price from an HTML document. The HTML document can only describe how to display the order in a Web browser; it does not permit the manipulation of the order's data elements. To solve that problem, a new markup

language known as Extensible Markup Language was developed.

**Extensible Markup Language (XML)** is a metalanguage used to represent and manipulate data elements. XML is designed to facilitate the exchange of structured documents, such as orders and invoices, over the Internet. The World Wide Web Consortium (W3C) published the first XML 1.0 standard definition in 1998, setting the stage for giving XML the real-world appeal of being a true vendor-independent platform. Therefore, it is not surprising that XML has rapidly become the data exchange standard for e-commerce applications.

The XML metalanguage allows the definition of new tags, such as <ProdPrice>, to describe the data elements used in an XML document. This ability to *extend* the language explains the *X* in XML; the language is said to be *extensible*. XML is derived from the Standard Generalized Markup Language (SGML), an international standard for the publication and distribution of highly complex technical documents. For example, documents used by the aviation industry and the military services are too complex and unwieldy for the Web. Just like HTML, which was also derived from SGML, an XML document is a text file. However, it has a few important additional characteristics:

- XML allows the definition of new tags to describe data elements.
- XML is case sensitive: <ProductID> is not the same as <Productid>.
- XML must be well formed; that is, tags must be properly formatted. Most openings also have a corresponding closing. For example, a product's identification would require the format <ProductId>2345-AA</ProductId>.
- XML must be properly nested. For example, properly nested XML might look like this: <Product><ProductId>2345-AA</ProductId></Product>.
- You can use the <-- and --> symbols to enter comments in the XML document.
- The *XML* and *xml* prefixes are reserved for XML only.

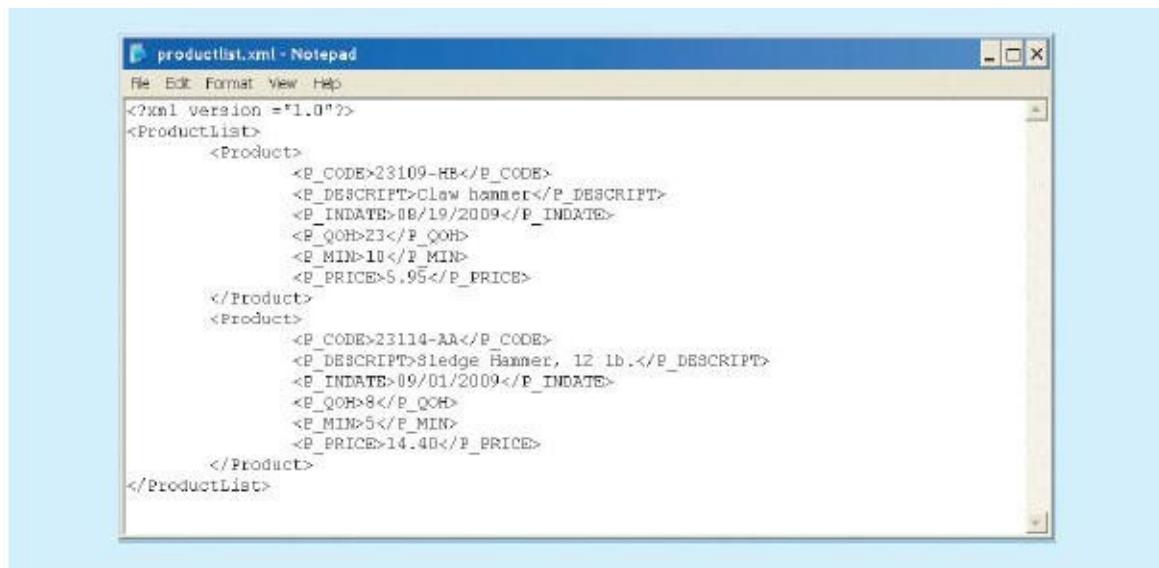
XML is *not* a new version or replacement for HTML. XML is concerned with the description and representation of the data, rather than the way the data are displayed. XML provides the semantics that facilitate the sharing, exchange, and manipulation of structured documents over organizational boundaries. XML and HTML perform complementary functions rather than overlapping functions. Extensible Hypertext Markup Language (XHTML) is the next generation of HTML based on the XML framework. The XHTML specification expands the HTML standard to include XML features. Although it is more powerful than HTML, XHTML requires strict adherence to syntax requirements.

To illustrate the use of XML for data exchange purposes, consider a B2B example in which Company A uses XML to exchange product data with Company B over the Internet. [Figure 14.13](#) shows the contents of the productlist.xml document.

---

**FIGURE 14.13** Contents of the productlist.xml document

---

A screenshot of a Windows Notepad window titled "productlist.xml - Notepad". The window displays an XML document with two products. Product 1 has code 23109-HB, description "Claw hammer", and price \$5.95. Product 2 has code 23114-AA, description "81edge Hammer, 12 lb.", and price \$14.40. Both products have an indate of 10/19/2009 and a min QOH of 5.

```
<?xml version = "1.0"?>
<ProductList>
 <Product>
 <P_CODE>23109-HB</P_CODE>
 <P_DESCRIP>Claw hammer</P_DESCRIP>
 <P_INDATE>10/19/2009</P_INDATE>
 <P_QOH>23</P_QOH>
 <P_MIN>10</P_MIN>
 <P_PRICE>5.95</P_PRICE>
 </Product>
 <Product>
 <P_CODE>23114-AA</P_CODE>
 <P_DESCRIP>81edge Hammer, 12 lb.</P_DESCRIP>
 <P_INDATE>09/01/2009</P_INDATE>
 <P_QOH>8</P_QOH>
 <P_MIN>5</P_MIN>
 <P_PRICE>14.40</P_PRICE>
 </Product>
</ProductList>
```

SOURCE: Course Technology/Cengage Learning

---

The preceding example illustrates several important XML features:

- The first line represents the XML document declaration, and it is mandatory.
- Every XML document has a *root element*. In the example, the second line

declares the ProductList root element.

- The root element contains *child elements* or subelements. In the example, line 3 declares Product as a child element of ProductList.
- Each element can contain *subelements*. For example, each Product element is composed of several child elements, represented by P\_CODE, P\_DESCRIP, P\_INDATE, P\_QOH, P\_MIN, and P\_PRICE.

Once Company B receives productlist.xml, it can process the document, assuming that it understands the tags created by Company A. The meaning of the XML in [Figure 14.13](#) is fairly self-evident, but there is no easy way to validate the data or to check whether the data are complete. For example, you could encounter a P\_INDATE value of “25/14/2009,” but is that value correct? What happens if Company B expects a Vendor element as well? How can companies share data descriptions about their business data elements? The next section shows how document type definitions and XML schemas are used to address such concerns.

#### 14.3.1 DOCUMENT TYPE DEFINITIONS (DTD) AND XML SCHEMAS

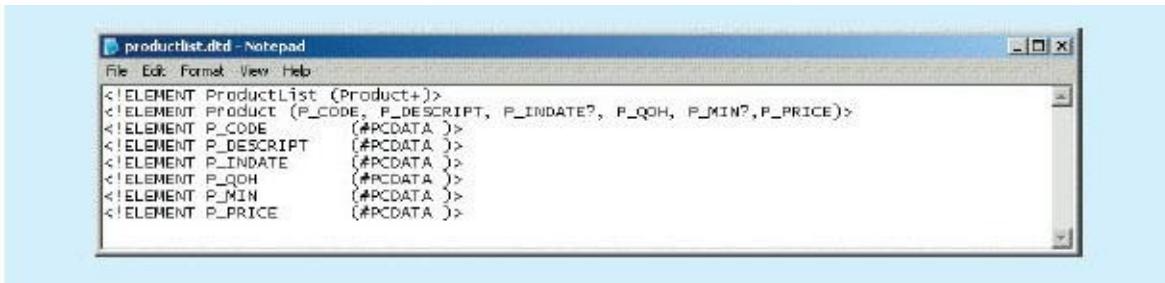
---

Companies that use B2B transactions must have a way to understand and validate each other’s tags. One way to accomplish that task is through the use of document type definitions. A [document type definition \(DTD\)](#) is a file with a .dtd extension that describes XML elements—in effect, a DTD file provides the composition of the database’s logical model and defines the syntax rules or valid elements for each type of XML document. (The DTD component is similar to having a public data dictionary for business data.) Companies that intend to engage in e-commerce transactions must develop and share DTDs. [Figure 14.14](#) shows the productlist.dtd document for the productlist.xml document shown earlier in [Figure 14.13](#).

---

**FIGURE 14.14** Contents of the productlist.dtd document

---



SOURCE: Course Technology/Cengage Learning

---

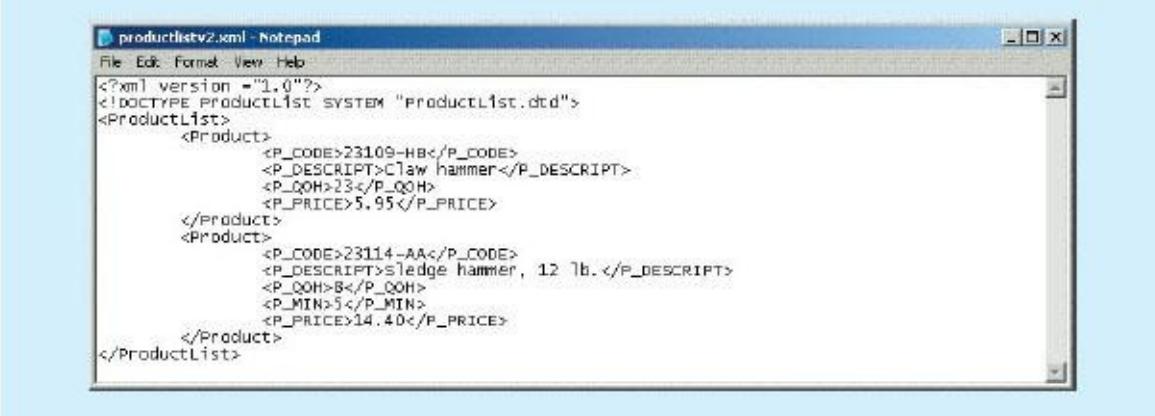
In [Figure 14.14](#), the productlist.dtd file provides definitions of the elements in the productlist.xml document. In particular, note the following:

- The first line declares the ProductList root element.
- The ProductList root element has one child, the Product element. The second line describes the Product element.
- The plus (+) symbol indicates that Product occurs one or more times within ProductList.
- An asterisk (\*) would mean that the child element occurs zero or more times.
- The question mark (?) after P\_INDATE and P\_MIN indicates that they are optional child elements.
- The #PCDATA keyword represents the actual text data.

To be able to use a DTD file to define elements within an XML document, the DTD must be referenced within that XML document. [Figure 14.15](#) shows the productlistv2.xml document that includes the reference to productlist.dtd in the second line.

---

**FIGURE 14.15** Contents of the productlistv2.xml document



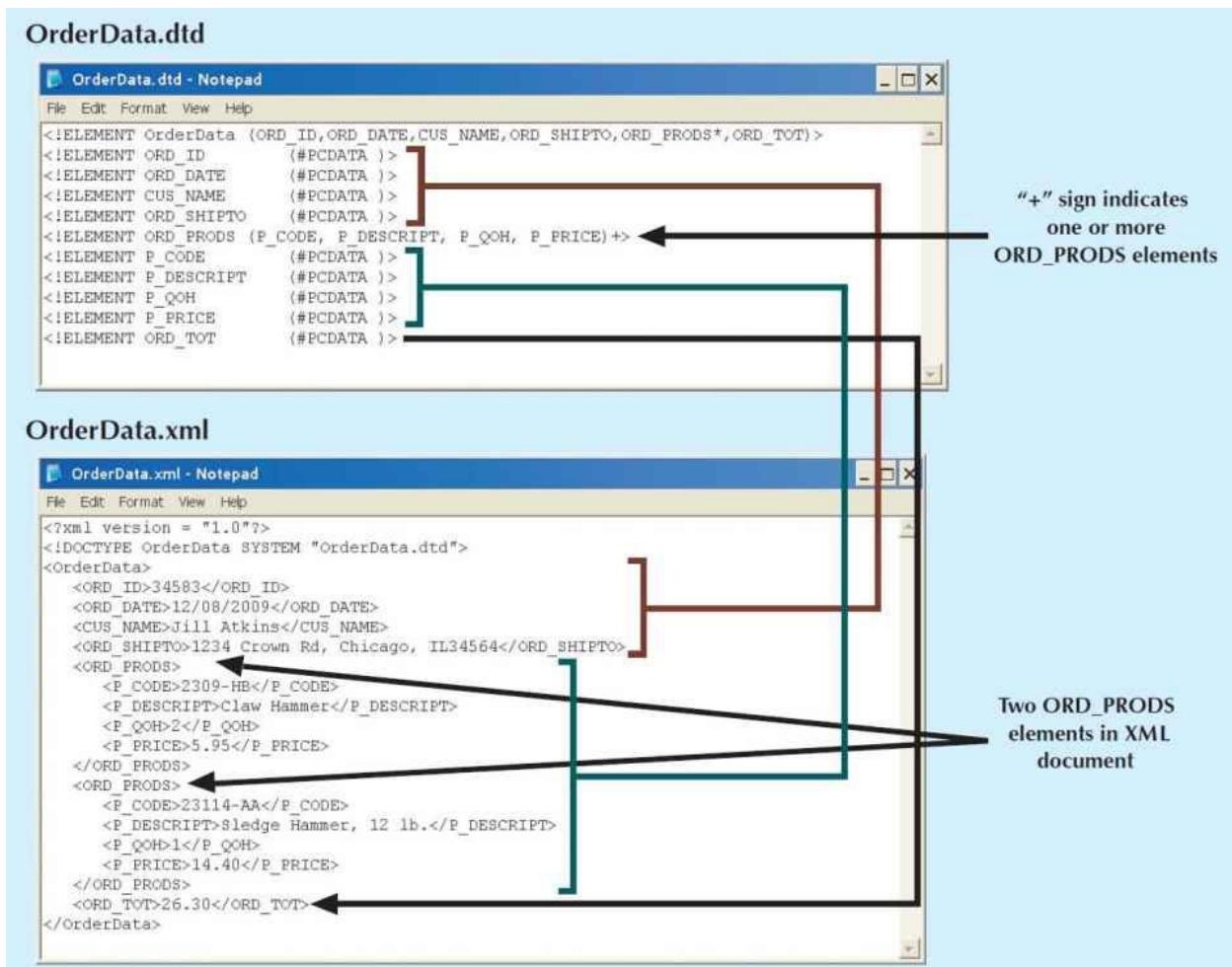
```
<?xml version = "1.0"?>
<!DOCTYPE ProductList SYSTEM "ProductList.dtd">
<ProductList>
 <Product>
 <P_CODE>23109-HB</P_CODE>
 <P_DESCRIPTOR>Claw hammer</P_DESCRIPTOR>
 <P_QOH>23</P_QOH>
 <P_PRICE>5.95</P_PRICE>
 </Product>
 <Product>
 <P_CODE>23114-AA</P_CODE>
 <P_DESCRIPTOR>sledge hammer, 12 lb.</P_DESCRIPTOR>
 <P_QOH>8</P_QOH>
 <P_MIN>5</P_MIN>
 <P_PRICE>14.40</P_PRICE>
 </Product>
</ProductList>
```

SOURCE: Course Technology/Cengage Learning

In [Figure 14.15](#), note that P\_INDATE and P\_MIN do not appear in all Product definitions because they were declared to be optional elements. The DTD can be referenced by many XML documents of the same type. For example, if Company A routinely exchanges product data with Company B, it will need to create the DTD only once. All subsequent XML documents will refer to the DTD, and Company B will be able to verify the data being received.

To further demonstrate the use of XML and DTD for e-commerce data exchanges, consider the case of two companies exchanging order data. [Figure 14.16](#) shows the DTD and XML documents for that scenario.

**FIGURE 14.16** DTD and XML documents for order data



SOURCE: Course Technology/Cengage Learning

---

Although the use of DTDs is a great improvement for data sharing over the Web, a DTD only provides descriptive information for understanding how the elements—root, parent, child, mandatory, or optional—relate to one another. A DTD provides limited additional semantic value, such as data type support or data validation rules. That information is very important for database administrators who are in charge of large e-commerce databases. To solve the DTD problem, the W3C published an XML schema standard that better describes XML data.

The [XML schema](#) is an advanced data definition language that is used to describe the structure of XML data documents. This structure includes elements, data types, relationship types, ranges, and default values. One of the main advantages of an XML schema is that it more closely maps to database terminology and features. For example, an XML schema can define common

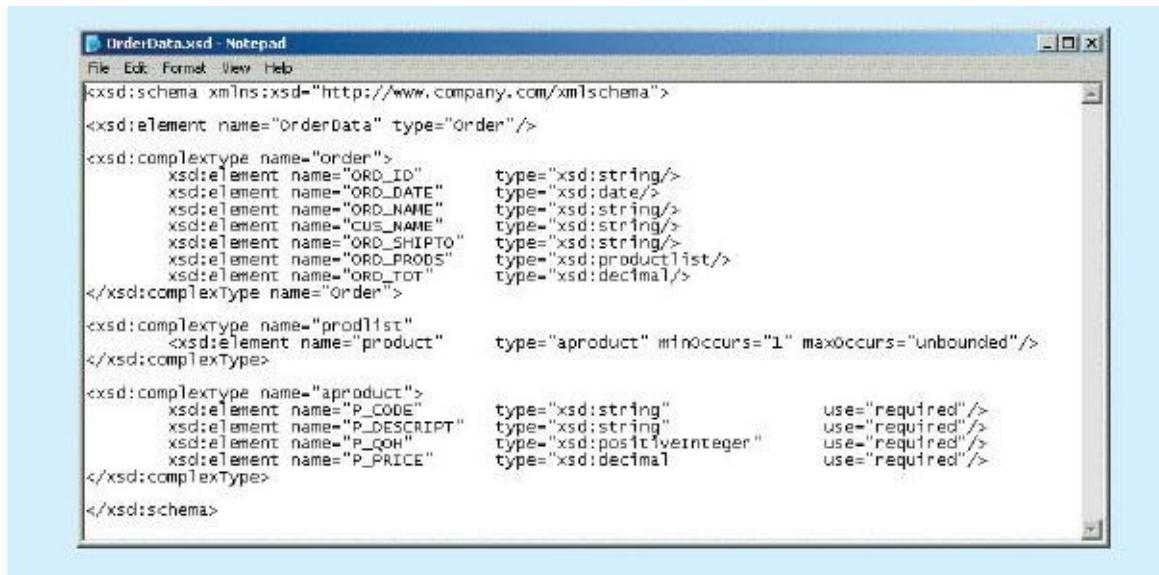
database types such as date, integer, or decimal; minimum and maximum values; a list of valid values; and required elements. Using the XML schema, a company would be able to validate data for values that may be out of range, have incorrect dates, contain invalid values, and so on. For example, a university application must be able to specify that a GPA value is between 0 and 4.0, and it must be able to detect an invalid birth date such as “14/13/1987.” (There is no 14th month.) Many vendors are adopting this new standard and are supplying tools to translate DTD documents into XML schema definition documents. It is widely expected that XML schemas will replace DTD as the method to describe XML data.

Unlike a DTD document, which uses a unique syntax, an **XML schema definition (XSD)** file uses a syntax that resembles an XML document. [Figure 14.17](#) shows the XSD document for the OrderData XML document.

---

**FIGURE 14.17** The XML schema document for the order data

---

A screenshot of a Windows Notepad window titled "OrderData.xsd - Notepad". The window displays an XML schema definition (XSD) document. The code defines an "OrderData" element as the root "order" element. It includes definitions for "order" complex type, "prodlist" complex type, and "aproduct" simple type. The "order" type contains elements for ORD\_ID, ORD\_DATE, ORD\_NAME, CUS\_NAME, ORD\_SHIPTO, ORD\_PRODS, and ORD\_TOT. The "prodlist" type contains a single "product" element. The "aproduct" type defines attributes for P\_CODE, P\_DESCRPT, P\_QOH, and P\_PRICE, with P\_CODE and P\_DESCRPT being required string attributes, P\_QOH being a required positive integer attribute, and P\_PRICE being a required decimal attribute.

```
<xsd:schema xmlns:xsd="http://www.company.com/xmlschema">
<xsd:element name="OrderData" type="order"/>
<xsd:complexType name="order">
 <xsd:element name="ORD_ID" type="xsd:string"/>
 <xsd:element name="ORD_DATE" type="xsd:date"/>
 <xsd:element name="ORD_NAME" type="xsd:string"/>
 <xsd:element name="CUS_NAME" type="xsd:string"/>
 <xsd:element name="ORD_SHIPTO" type="xsd:string"/>
 <xsd:element name="ORD_PRODS" type="xsd:productlist"/>
 <xsd:element name="ORD_TOT" type="xsd:decimal"/>
</xsd:complexType>
<xsd:complexType name="prodlist">
 <xsd:element name="product" type="aproduct" minOccurs="1" maxOccurs="unbounded"/>
</xsd:complexType>
<xsd:complexType name="aproduct">
 <xsd:element name="P_CODE" type="xsd:string" use="required"/>
 <xsd:element name="P_DESCRPT" type="xsd:string" use="required"/>
 <xsd:element name="P_QOH" type="xsd:positiveinteger" use="required"/>
 <xsd:element name="P_PRICE" type="xsd:decimal" use="required"/>
</xsd:complexType>
</xsd:schema>
```

SOURCE: Course Technology/Cengage Learning

---

The code shown in [Figure 14.17](#) is a simplified version of the XML schema document. As you can see, the XML schema syntax is similar to the XML document syntax. However, the XML schema introduces additional semantic information for the OrderData XML document, such as string, date, and decimal

data types; required elements; and minimum and maximum cardinalities for the data elements.

#### 14.3.2 XML PRESENTATION

---

One of the main benefits of XML is that it separates data structure from its presentation and processing. By separating the two, you can present the same data in different ways—which is similar to having views in SQL. The Extensible Style Language (XSL) specification provides the mechanism to display XML data. XSL is used to define the rules by which XML data are formatted and displayed. The XSL specification is divided into two parts: Extensible Style Language Transformations (XSLT) and XSL style sheets.

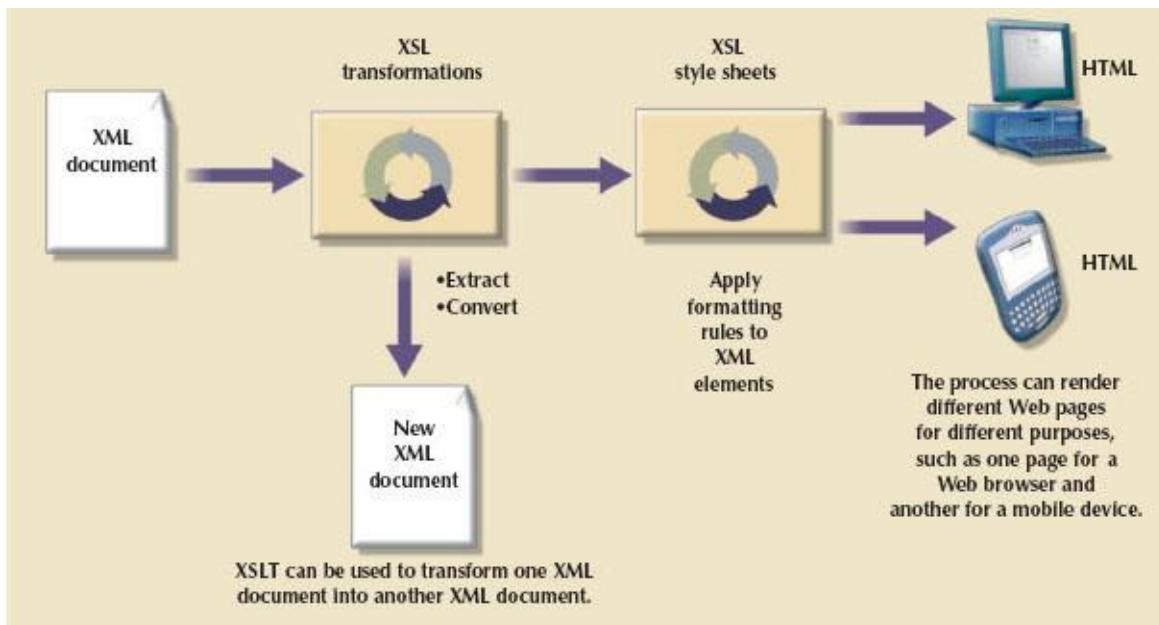
- *Extensible Style Language Transformations (XSLT)* describes the general mechanism that is used to extract and process data from one XML document and enable its transformation within another document. Using XSLT, you can extract data from an XML document and convert it into a text file, an HTML Web page, or a Web page that is formatted for a mobile device. What the user sees in those cases is actually a view (or HTML representation) of the XML data. XSLT can also be used to extract certain elements from an XML document, such as product codes and product prices, to create a product catalog. XSLT can even be used to transform one XML document into another.
- *XSL style sheets* define the presentation rules applied to XML elements—somewhat like presentation templates. The XSL style sheet describes the formatting options to apply to XML elements when they are displayed on a browser, smart phone, tablet screen, and so on.

[Figure 14.18](#) illustrates the framework used by the various components to translate XML documents into viewable Web pages, an XML document, or some other document.

---

**FIGURE 14.18 Framework for XML transformations**

---



SOURCE: Course Technology/Cengage Learning

---

To display the XML document with Windows Internet Explorer (IE) 5.0 or later, enter the URL of the XML document in the browser's address bar. [Figure 14.19](#) is based on the productlist.xml document created earlier. As you examine [Figure 14.19](#), note that IE shows the XML data in a color-coded, collapsible, treelike structure. (Actually, this is the IE default style sheet that is used to render XML documents.)

---

**FIGURE 14.19** Displaying XML documents

---



SOURCE: Course Technology/Cengage Learning

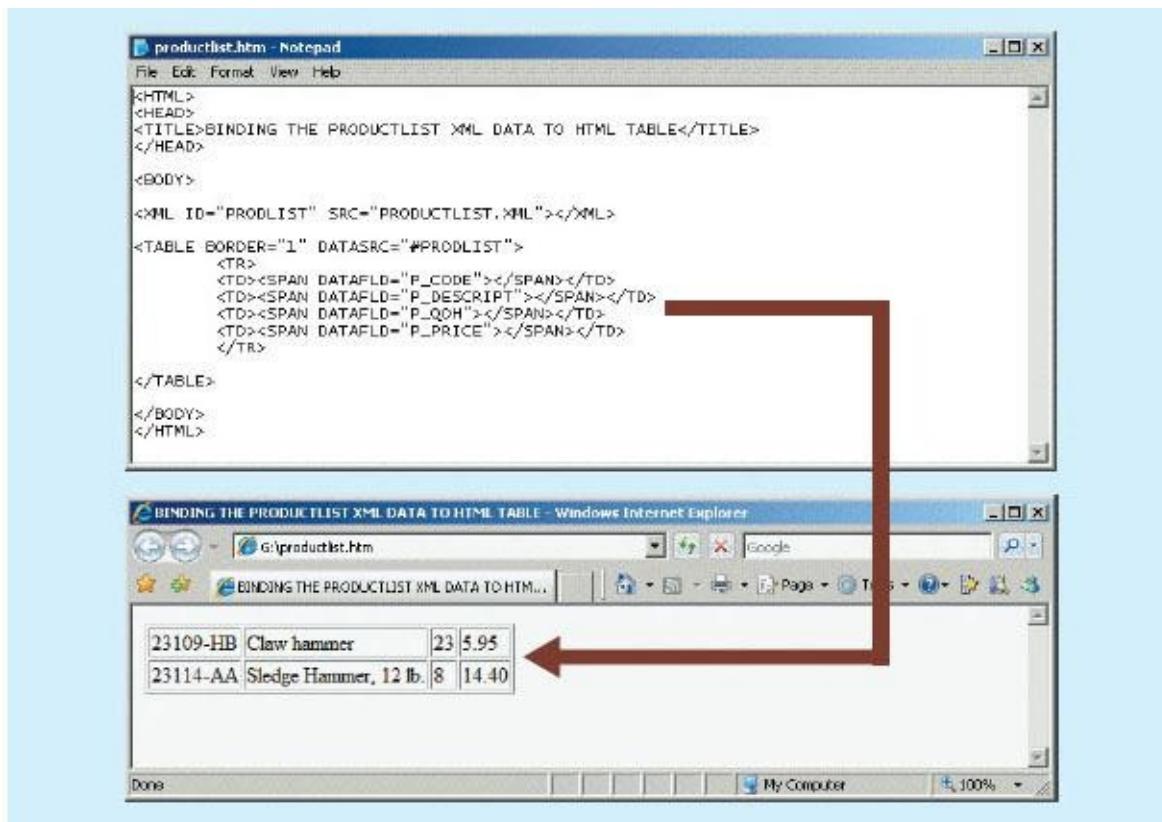
---

Internet Explorer also provides *data binding* of XML data to HTML documents. [Figure 14.20](#) shows the HTML code that is used to bind an XML document to an HTML table. The example uses the <xml> tag to include the XML data in the HTML document and later bind it to the HTML table. This example works in IE 5.0 or later.

---

**FIGURE 14.20** XML data binding

---



SOURCE: Course Technology/Cengage Learning

---

#### 14.3.3 XML APPLICATIONS

---

Now that you have some idea what XML is, how can you use it? What kinds of applications lend themselves particularly well to XML? This section lists some of the uses of XML. Keep in mind that the future use of XML is limited only by the imagination and creativity of developers, designers, and programmers.

- *B2B exchanges.* XML enables the exchange of B2B data, providing the standard for all organizations that need to exchange data with partners, competitors, the government, or customers. In particular, XML is positioned to replace EDI as the standard for automation of the supply chain because it is less expensive and more flexible.
- *Legacy systems integration.* XML provides the “glue” to integrate legacy system data with modern e-commerce Web systems. Web and XML technologies could be used to inject some new life into old but trusted

legacy applications. Another example is the use of XML to import transaction data from multiple databases to a data warehouse database.

- *Web page development.* XML provides several features that make it a good fit for certain Web development scenarios. For example, Web portals with large amounts of personalized data can use XML to pull data from multiple external sources (such as news, weather, and stock sites) and apply different presentation rules to format pages on desktop computers as well as mobile devices.
- *Database support.* A DBMS that supports XML exchanges can integrate with external systems such as the Web, mobile data, and legacy systems, thus enabling the creation of new types of systems. These databases can import or export data in XML format or generate XML documents from SQL queries while still storing the data using their native data model format. An example is the use of the FOR XML clause in the SQL SELECT statement in SQL Server. Alternatively, a DBMS can also support an XML data type to store XML data in its native format—enabling support to store treelike hierarchical structures inside a relational structure.
- *Database metadictionaries.* XML is also used to create metadictionaries, or vocabularies, for entire industries. Examples of metadictionaries include HR-XML for the human resources industry, the metadata encoding and transmission standard (METS) from the Library of Congress, the clinical accounting information (CLAIM) data exchange standard for patient data exchange in electronic medical record systems, and the extensible business reporting language (XBRL) standard for exchanging business and financial information.
- *XML databases.*<sup>1</sup> Most databases on the market support XML to manage data in some shape or form. The approaches range from simple middleware XML software to object databases with XML interfaces to full XML database engines and servers. XML databases provide for the storage of data in complex relationships. For example, an XML database would be well suited to store the contents of a book. The book's structure

would dictate its database structure: a book typically consists of chapters, sections, paragraphs, figures, charts, footnotes, endnotes, and so on. Examples of XML databases are Oracle, IBM DB2, MS SQL Server, Ipedo XML Database ([www.ipedo.com](http://www.ipedo.com)), Tamino from Software AG ([www.softwareag.com](http://www.softwareag.com)), and the open source dbXML from <http://sourceforge.net/projects/dbxml-core>.

- *XML services.* Many companies are already working to develop a new breed of services based on XML and Web technologies. These services break down the interoperability barriers among systems and companies alike. XML provides the infrastructure that helps heterogeneous systems to work together across the desk, the street, and the world. Services would use XML and other Internet technologies to publish their interfaces. Other services that want to interact with existing services would locate them and learn their vocabulary (service request and replies) to establish a “conversation.”

One area in which Internet, Web, virtualization, and XML technologies work together in innovative ways to leverage IT services is “cloud computing.”

---

## 14.4 CLOUD COMPUTING SERVICES

---

You have almost certainly heard about the “cloud” from the thousands of publications and TV ads that have used the term over the years, although it has represented different concepts. In the late 1980s, the term *cloud* was used by telecommunication companies to describe their data networks. In the late 1990s, during the peak of Internet growth, the term depicted the Internet itself. Then, in 2006, Google and Amazon began using the term *cloud computing* to describe a new set of innovative Web-based services. Google, Yahoo, eBay, and Amazon were the early adopters of this new computing paradigm.

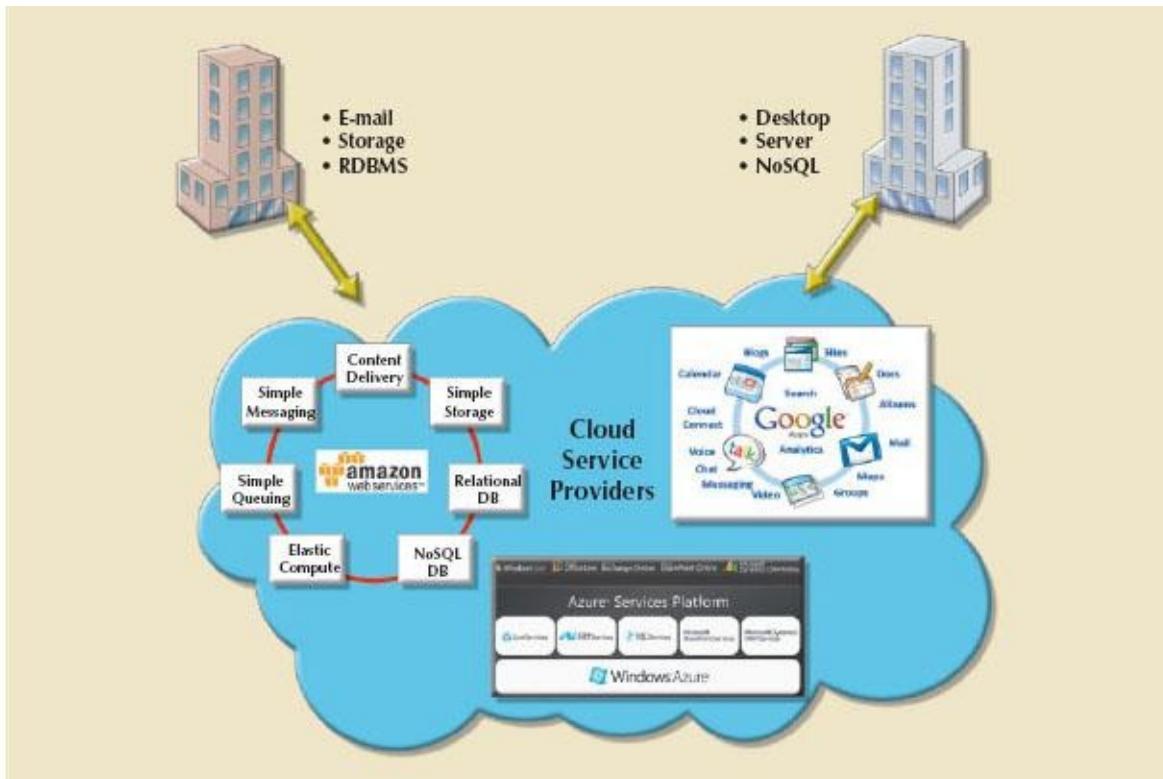
But what exactly is cloud computing? According to the National Institute of Standards and Technology (NIST),<sup>2</sup> **cloud computing** is “a computing model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computer resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” The term **cloud services** is used in this book to refer to the services provided by cloud computing. Cloud

services allow any organization to quickly and economically add information technology services such as applications, storage, servers, processing power, databases, and infrastructure to its IT portfolio. [Figure 14.21](#) shows a representation of cloud computing services on the Internet.

---

**FIGURE 14.21** Cloud services

---



SOURCE: Course Technology/Cengage Learning

---

Cloud computing allows highly specialized, IT-savvy organizations such as Amazon, Google, and Microsoft to build high-performance, fault-tolerant, flexible, and scalable IT services. These services include applications, storage, servers, processing power, databases, and e-mail, which are delivered via the Internet to individuals and organizations using a pay-as-you-go price model.

For example, imagine that the chief technology officer of a nonprofit organization wants to add e-mail services to the IT portfolio. A few years ago, this proposition would have implied building the e-mail system's infrastructure from the ground up, including hardware, software, setup, configuration,

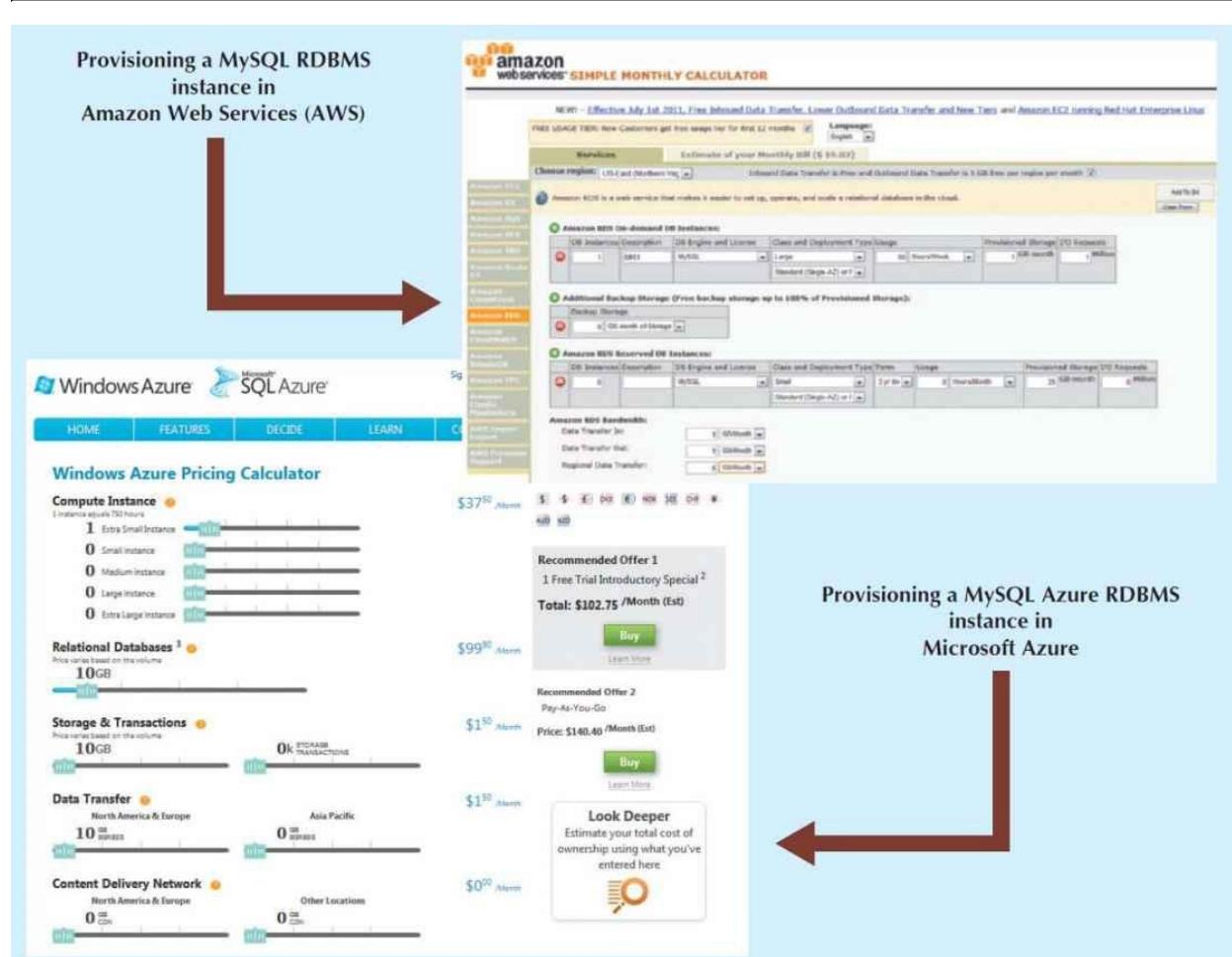
operation, and maintenance. However, in today's cloud computing era, you can use Google Apps for Business or Microsoft Exchange Online and get a scalable, flexible, and more reliable e-mail solution for a fraction of the cost. The best part is that you do not have to worry about the daily chores of managing and maintaining the IT infrastructure, such as OS updates, patches, security, fault tolerance, and recovery. What used to take months or years to implement can now be done in a matter of minutes. If you need more space, you just add another storage unit to your storage cloud. If you need more processing power to handle last-minute orders during the busy Christmas season, you simply add more processing units to your cloud servers. Even more importantly, you can scale down as easily as you scaled up. Once your need for additional processing or storage subsides, you can go back to your previous levels of usage and pay only for what you use. The beauty of cloud services is that you can scale down automatically, without an administrator's intervention.

Cloud computing is important for database technologies because it has the potential to become a "game changer." Cloud computing eliminates financial and technological barriers so organizations can leverage database technologies in their business processes with minimal effort and cost. In fact, cloud services have the potential to turn basic IT services into "commodity" services such as electricity, gas, and water, and to enable a revolution that could change not only the way that companies do business, but the IT business itself. As Nicholas Carr put it so vividly: "Cloud computing is for IT what the invention of the power grid was for electricity."<sup>3</sup>

The technologies that make cloud computing work have been around for a few years now; these technologies include the Web, messaging, virtualization, remote desktop protocols, VPN, and XML. However, cloud computing itself is still in the early years and needs to mature further before it can be widely adopted. Despite this, more and more organizations are tapping into cloud services to secure advanced database services (relational or NoSQL) for their organizations. Currently, you can log in to Amazon Web Services (AWS) or Microsoft Azure and have a relational database ready for use in a matter of minutes. Instead of spending large amounts of cash buying hardware and software, organizations can employ a pay-per-use model for their IT services. [Figure 14.22](#) depicts the cost of provisioning a relational database instance in Microsoft Azure and Amazon RDS services, respectively.

---

**FIGURE 14.22 Provisioning an RDBMS in the cloud**



SOURCE: Course Technology/Cengage Learning

Although [Figure 14.22](#) shows a cloud that requires some degree of customization on the customer's part, other cloud computing services are more transparent to the user and require less customization. For example, Dropbox is a simple cloud service that lets you synchronize your documents, photos, music, and other files transparently over the Internet across many devices. In 2011, Apple announced a similar service, known as iCloud. Both services work transparently behind the scenes with minimal end-user intervention. As you can see, cloud computing implementations vary; the next section explains the basic types.

#### 14.4.1 CLOUD IMPLEMENTATION TYPES

Cloud computing has different types of implementations based on who the target

customers are:

- **Public cloud.** This type of cloud infrastructure is built by a third-party organization to sell cloud services to the general public. The public cloud is the most common type of cloud implementation; examples include Amazon Web Services (AWS), Google Application Engine, and Microsoft Azure. In this model, cloud consumers share resources with other consumers transparently. The public cloud infrastructure is managed exclusively by the third-party provider.
- **Private cloud.** This type of internal cloud is built by an organization for the sole purpose of servicing its own needs. Private clouds are often used by large, geographically dispersed organizations to add agility and flexibility to internal IT services. The cloud infrastructure could be managed by internal IT staff or an external third party.
- **Community cloud.** This type of cloud is built by and for a specific group of organizations that share a common trade, such as agencies of the federal government, the military, or higher education. The cloud infrastructure could be managed by internal IT staff or an external third party.

Regardless of the implementation an organization uses, most cloud services share a common set of core characteristics. These characteristics are explored in the next section.

#### **14.4.2 CHARACTERISTICS OF CLOUD SERVICES**

---

Cloud computing services share a set of guiding principles. The characteristics listed in this section are shared by prominent public cloud providers such as Amazon, Google, Salesforce, SAP, and Microsoft. The prevalent characteristics are:

- *Ubiquitous access via Internet technologies.* All cloud services use Internet and Web technologies to provision, deliver, and manage the services they provide. The basic requirement is that the device has access to the Internet.

- *Shared infrastructure.* The cloud service infrastructure is shared by multiple users. Sharing is made possible by Web and virtualization technologies. Cloud services effectively provide an organization with a virtual IT infrastructure, which is locally managed by the consumer's organization as if it were the only user of the infrastructure.
- *Lower costs and variable pricing.* The initial costs of using cloud services tend to be significantly lower than building on-premise IT infrastructures. According to some studies,<sup>4</sup> the savings could range from 35 percent to 55 percent depending on company size, although more research is needed in this area. Because the Web service's usage is metered per volume and time utilization, consumers benefit from lower and flexible pricing options. These options range from pay-as-you-go to fixed pricing based on minimum levels of service.
- *Flexible and scalable services.* The cloud services are built on an infrastructure that is highly scalable, fault tolerant, and very reliable. The services can scale up and down on demand according to resource demands.
- *Dynamic provisioning.* The consumer can quickly provision any needed resources, including servers, processing power, storage, and e-mail, by accessing the Web management dashboard and then adding and removing services on demand. This process also could be automated via other services.
- *Service orientation.* Cloud computing focuses on providing consumers with specific, well-defined services that use well-known interfaces. These interfaces hide the complexity from the end user, and can be delivered anytime and anywhere.
- *Managed operations.* Cloud computing minimizes the need for extensive and expensive in-house IT staff. The system infrastructure is managed by the cloud provider. The consumer organization's IT staff is free from routine management and maintenance tasks so they can focus on other

tasks within the organization. Managed operations apply to organizations that use public clouds and that outsource cloud management to an external third party.

The preceding list is not exhaustive, but it is a starting point to understand most cloud computing offerings. Although most companies move to cloud services because of cost savings, some companies move to them because they are the best way to gain access to specific IT resources that would otherwise be unavailable. Not all cloud services are the same; in fact, there are several different types, as explained in the next section.

#### 14.4.3 TYPES OF CLOUD SERVICES

---

Cloud services come in different shapes and forms; no single type of service works for all consumers. In fact, cloud services often follow an “à la carte” model; consumers can choose multiple service options according to their individual needs. These services can build on top of each other to provide sophisticated solutions. Based on the types of services provided, cloud services can be classified by the following categories:

- **Software as a Service (SaaS)**. The cloud service provider offers turnkey applications that run in the cloud. Consumers can run the provider’s applications internally in their organizations via the Web or any mobile device. The consumer can customize certain aspects of the application but cannot make changes to the application itself. The application is actually shared among users from multiple organizations. Examples of SaaS include MS Office Live, Google Docs, Intuit’s TurboTax Online, and SCALA digital signage.
- **Platform as a Service (PaaS)**. The cloud service provider offers the capability to build and deploy consumercreated applications using the provider’s cloud infrastructure. In this scenario, the consumer can build, deploy, and manage applications using the provider’s cloud tools, languages, and interfaces. However, the consumer does not manage the underlying cloud infrastructure. Examples of PaaS include the Microsoft Azure platform with .NET and the Java development environment, and Google Application Engine with Python or Java.
- **Infrastructure as a Service (IaaS)**. In this case, the cloud service provider

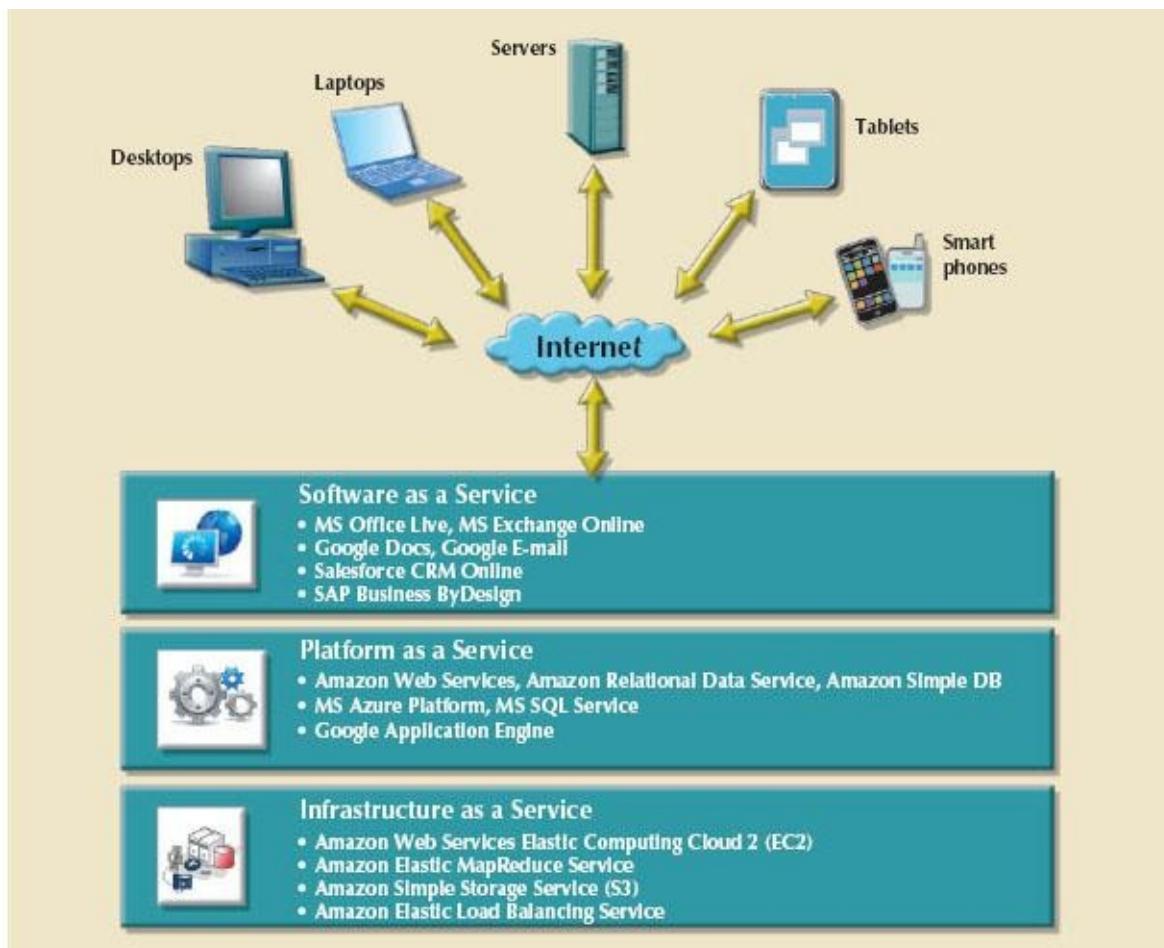
offers consumers the ability to provision their own resources on demand; these resources include storage, servers, databases, processing units, and even a complete virtualized desktop. The consumer then can add or remove the resources as needed. For example, a consumer can use AWS and provision a server computer that runs Linux and Apache Web server using 16 GB of RAM and 160 GB of storage.

[Figure 14.23](#) illustrates a sample of the different types of cloud services; these services can be accessed from any computing device.

---

**FIGURE 14.23 Types of cloud services**

---



SOURCE: Course Technology/Cengage Learning

---

Cloud computing services have evolved in their sophistication and flexibility.

The merging of new technologies has enabled the creation of new options such as “desktop as a service,” which effectively creates a virtual computer on the cloud that can be accessed from any device over the Internet. For example, you can use a service such as Desktone ([www.desktone.com](http://www.desktone.com)) and get a Windows 7 desktop running over the Web for your personal use in a matter of minutes. Moreover, you can access your virtual desktop via the Web browser or using any Remote Desktop Protocol (RDP) application.

#### 14.4.4 CLOUD SERVICES: ADVANTAGES AND DISADVANTAGES

---

Cloud computing has grown remarkably in the past few years. Companies of all sizes are enjoying the advantages of cloud computing, but its widespread adoption is still limited by several factors.<sup>5</sup> [Table 14.4](#) summarizes the main advantages and disadvantages of cloud computing.

---

**TABLE 14.4 Advantages and Disadvantages of Cloud Computing**

---

<b>ADVANTAGE</b>	<b>DISADVANTAGE</b>
<i>Low initial cost of entry.</i> Cloud computing has lower costs of entry when compared with the alternative of building in house.	<i>Issues of security, privacy, and compliance.</i> Trusting sensitive company data to external entities is difficult for most data-cautious organizations.
<i>Scalability/elasticity.</i> It is easy to add and remove resources on demand.	<i>Hidden costs of implementation and operation.</i> It is hard to estimate bandwidth and data migration costs.
<i>Support for mobile computing.</i> Cloud computing providers support multiple types of mobile computing devices.	<i>Data migration is a difficult and lengthy process.</i> Migrating large amounts of data to and from the cloud infrastructure can be difficult and time-consuming.
<i>Ubiquitous access.</i> Consumers can access the cloud resources from anywhere at any time, as long as they have Internet access.	<i>Complex licensing schemes.</i> Organizations that implement cloud services are faced with complex licensing schemes and complicated service-level agreements.

*High reliability and performance.* Cloud providers build solid infrastructures that otherwise are difficult for the average organization to leverage.

*Fast provisioning.* Resources can be provisioned on demand in a matter of minutes with minimal effort.

*Managed infrastructure.* Most cloud implementations are managed by dedicated internal or external staff. This allows the organization's IT staff to focus on other areas.

*Loss of ownership and control.* Companies that use cloud services are no longer in complete control of their data. What is the responsibility of the cloud provider if data are breached? Can the vendor use your data without your consent?

*Organization culture.* End users tend to be resistant to change. Do the savings justify being dependent on a single provider? Will the cloud provider be around in 10 years?

*Difficult integration with internal IT system.* Configuring the cloud services to integrate transparently with internal authentication and other internal services could be a daunting task.

As the table shows, the top perceived benefit of cloud computing is the lower cost of entry. At the same time, the chief concern of cloud computing is data security and privacy, particularly in companies that deal with sensitive data and are subject to high levels of regulation and compliance.<sup>6</sup> This concern leads to the perception that cloud services are mainly implemented in small to medium-sized companies where the risk of service loss is minimal. In fact, some companies that are subject to strict data security regulations tend to favor private clouds rather than public ones.<sup>7</sup>

One of the biggest growth segments in cloud services is mobile computing. For example, Netflix,<sup>8</sup> the video-on-demand trailblazer, announced in 2011 that it had moved significant parts of its IT infrastructure to AWS. Netflix decided to move to the cloud because of the challenges of building IT infrastructure fast enough to keep up with its relentless growth.

---

#### NOTE

---

#### **Cloud Reality Check: Is the Cloud Enterprise Ready?**

In April 2011, Amazon's cloud services suffered a well-publicized outage.<sup>9</sup> The cloud infrastructure in one of the main service areas slowed to a crawl. Many well-known Web companies that depend on AWS, including Reddit,

Foursquare, Quora, and HotPads, were faced with sluggish and sometimes inaccessible Websites. In a matter of hours, several Websites disappeared from the cloud! This was the biggest test of cloud reliability to date. Amazon technicians worked for the next several days to recover service to all the Websites, but questions about cloud reliability still linger.

---

Regardless of a company's size, databases remain at the center of all system development. Cloud computing brings a new dimension to data management that is within reach of any type of organization.

#### 14.4.5 SQL DATA SERVICES

---

As you have seen in this chapter, data access technologies have evolved from simple ODBC data retrieval to advanced remote data processing using ADO.NET and XML. At the same time, companies are looking for ways to better manage ever-growing amounts of data while controlling costs without sacrificing data management features. Cloud computing provides a relatively stable and reliable platform for developing and deploying business services; cloud vendors have expanded their business to offer SQL data services. [\*\*SQL data services \(SDS\)\*\*](#) refers to a cloud computing-based data management service that provides relational data storage, access, and management to companies of all sizes without the typically high costs of in-house hardware, software, infrastructure, and personnel. This type of service provides some unique benefits:

- *Hosted data management.* SDS typically uses a cluster of database servers that provide a large subset of database functionality over the Internet to database administrators and users. Typically, features such as SQL queries, indexing, stored procedures, triggers, reporting, and analytical functions are available to end users. Other features such as data synchronization, data backup and restore, and data importing and exporting are available for administrative purposes.
- *Standard protocols.* SDS uses standard data communication and relational data access protocols. Typically, these services encapsulate SQL networking protocols, such as SQL-Net for Oracle databases and Tabular Data Services (TDS) for Microsoft SQL Server databases, inside the TCP/IP networking protocol.

- *A common programming interface.* SDS is transparent to application developers. Programmers continue to use familiar programming interfaces such as ADO.NET and Visual Studio .NET to manipulate the data. Programmers write embedded SQL code in their applications and connect to the database as if the data were stored locally instead of in a remote location on the Internet. One potential disadvantage, however, is that some specialized data types may not be supported by SDS.

SQL data services offer the following advantages when compared with in-house systems:

- Highly reliable and scalable relational database for a fraction of the cost
- High level of failure tolerance because data are normally distributed and replicated among multiple servers
- Dynamic and automatic load balancing
- Automated data backup and disaster recovery included with the service
- Dynamic creation and allocation of database processes and storage

Cloud providers such as Amazon and Microsoft allow you to get your own database server running in a matter of minutes. Even better, you do not have to worry about backups, fault tolerance, scalability, and routine maintenance tasks. The use of SQL data services enables rapid application development for businesses with limited information technology resources, and allows them to rapidly deploy business solutions. A consumer of cloud services is free to use the database to create the best solution for the problem at hand. However, having access to relational database technology via a SQL data service is just the start—you still need to be knowledgeable in database design and SQL to develop high-quality applications.

---

## SUMMARY

---

- Database connectivity refers to the mechanisms through which application programs connect and communicate with data repositories. Database connectivity software is also known as *database middleware*.

- Microsoft database connectivity interfaces are dominant players in the market and enjoy the support of most database vendors. ODBC, OLE-DB, and ADO.NET form the backbone of Microsoft's Universal Data Access (UDA) architecture.
  - Native database connectivity refers to the connection interface that is provided by the database vendor and is unique to that vendor. ODBC is probably the most widely supported database connectivity interface. ODBC allows any Windows application to access relational data sources using standard SQL. Data Access Objects (DAO) is an older, object-oriented application interface. Remote Data Objects (RDO) is a higher-level, object-oriented application interface used to access remote database servers. RDO was optimized to deal with server-based databases such as MS SQL Server and Oracle.
- 
- Object Linking and Embedding for Database (OLE-DB) is database middleware developed with the goal of adding object-oriented functionality for access to relational and nonrelational data. ActiveX Data Objects (ADO) provides a high-level, application-oriented interface to interact with OLE-DB, DAO, and RDO. Based on ADO, ADO.NET is the data access component of Microsoft's .NET application development framework. Java Database Connectivity (JDBC) is the standard way to interface Java applications with data sources.
  - Database access through the Web is achieved through middleware. To improve the capabilities on the client side of the Web browser, you must use plug-ins and other client-side extensions such as Java and JavaScript, or ActiveX and VBScript. On the server side, Web application servers are middleware that expand the functionality of Web servers by linking them to a wide range of services, such as databases, directory systems, and search engines.
- 
- Extensible Markup Language (XML) facilitates the exchange of B2B and other data over the Internet. XML provides the semantics that facilitate the exchange, sharing, and manipulation of structured documents across organizational boundaries. XML produces the description and the

representation of data, thus setting the stage for data manipulation in ways that were not possible before. XML documents can be validated through the use of document type definition (DTD) documents and XML schema definition (XSD) documents.

- Cloud computing is a computing model that provides ubiquitous, on-demand access to a shared pool of configurable resources that can be rapidly provisioned. SQL data services (SDS) refers to a cloud computing-based data management service that provides relational data storage, ubiquitous access, and local management to companies of all sizes. This service enables rapid application development for businesses with limited information technology resources. SDS allows rapid deployment of business solutions using standard protocols and common programming interfaces.

---

#### KEY TERMS

---

[ActiveX](#)  
[ActiveX Data Objects \(ADO\)](#) [ADO.NET](#)  
[application programming interface \(API\)](#)  
[Call Level Interface \(CLI\)](#)  
[client-side extensions](#)  
[cloud computing](#)  
[cloud services](#)  
[Common Gateway Interface \(CGI\)](#)  
[community cloud](#)  
[Data Access Objects \(DAO\)](#)  
[data source name \(DSN\)](#)  
[database middleware](#)  
[DataSet](#)  
[document type definition \(DTD\)](#)  
[dynamic-link libraries \(DLLs\)](#)  
[Extensible Markup Language \(XML\)](#)  
[Infrastructure as a Service \(IaaS\)](#)  
[Java](#)  
[Java Database Connectivity \(JDBC\)](#)

[JavaScript](#)

[Microsoft .NET framework](#)

[Object Linking and Embedding for Database \(OLE-DB\)](#)

[Open Database Connectivity \(ODBC\)](#)

[Platform as a Service \(PaaS\)](#)

[plug-in](#)

[private cloud](#)

[public cloud](#)

[Remote Data Objects \(RDO\)](#)

[script](#)

[server-side extension](#)

[Software as a Service \(SaaS\)](#)

[SQL data services \(SDS\)](#)

[stateless system](#)

[tags](#)

[Universal Data Access \(UDA\)](#)

[VBScript](#)

[Web application server](#)

[Web-to-database middleware](#)

[XML schema](#)

[XML schema definition \(XSD\)](#)

---



## ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at [www.cengagebrain.com](http://www.cengagebrain.com).

---

## REVIEW QUESTIONS

---

1. Give some examples of database connectivity options and what they are used for.
  
2. What are ODBC, DAO, and RDO? How are they related?
3. What is the difference between DAO and RDO?

4. What are the three basic components of the ODBC architecture?
5. What steps are required to create an ODBC data source name?
6. What is OLE-DB used for, and how does it differ from ODBC?
7. Explain the OLE-DB model based on its two types of objects.
8. How does ADO complement OLE-DB?
9. What is ADO.NET, and what two new features make it important for application development?
10. What is a DataSet, and why is it considered to be disconnected?
11. What are Web server interfaces used for? Give some examples.
12. Search the Internet for Web application servers. Choose one and prepare a short presentation for your class.
13. What does this statement mean: “The Web is a stateless system.” What implications does a stateless system have for database application developers?
14. What is a Web application server, and how does it work from a database perspective?
15. What are scripts, and what is their function? (Think in terms of database application development.)
16. What is XML, and why is it important?
17. What are document type definition (DTD) documents, and what do they do?
18. What are XML schema definition (XSD) documents, and what do they do?

19. What is JDBC, and what is it used for?
  20. What is cloud computing, and why is it a “game changer”?
  21. Name and contrast the types of cloud computing implementation.
  22. Name and describe the most prevalent characteristics of cloud computing services.
  23. Using the Internet, search for providers of cloud services. Then, classify the types of services they provide (SaaS, PaaS, and IaaS).
  24. Summarize the main advantages and disadvantages of cloud computing services.
  25. Define SQL data services and list their advantages.
- 



#### ONLINE CONTENT

The databases used in the Problems for this chapter are available at [www.cengagebrain.com](http://www.cengagebrain.com).

---

---

#### PROBLEMS

---

---

In the following exercises, you will set up database connectivity using MS Excel.

1. Use MS Excel to connect to the Ch02\_InsureCo MS Access database using ODBC, and retrieve all of the AGENTS.
2. Use MS Excel to connect to the Ch02\_InsureCo MS Access database using ODBC, and retrieve all of the CUSTOMERS.

3. Use MS Excel to connect to the Ch02\_InsureCo MS Access database using ODBC, and retrieve the customers whose AGENT\_CODE is equal to 503.
  4. Create a System DSN ODBC connection called Ch02\_SaleCo using the Administrative Tools section of the Windows Control Panel.
- 
5. Use MS Excel to list all of the invoice lines for Invoice 103 using the Ch02\_SaleCo System DSN.
  6. Create a System DSN ODBC connection called Ch02\_Tinycollege using the Administrative Tools section of the Windows Control Panel.
- 
7. Use MS Excel to list all classes taught in room KLR200 using the Ch02\_TinyCollege System DSN.

To answer [Problems 8–11](#), use [Section 14.3.1](#) as your guide.

8. Create a sample XML document and DTD for the exchange of customer data.
  9. Create a sample XML document and DTD for the exchange of product and pricing data.
- 
10. Create a sample XML document and DTD for the exchange of order data.
  11. Create a sample XML document and DTD for the exchange of student transcript data. Use your college transcript as a sample.

---

<sup>1</sup> For a comprehensive analysis of XML database products, see “XML Database Products” by Ronald Bourret at [www.rpbourret.com](http://www.rpbourret.com).

<sup>2</sup>*Recommendations of the National Institute of Standards and Technology*, Peter Mell and Timothy Grance, Special Publication 800-145 (Draft), January 2011.

<sup>3</sup> Nicholas Carr, *The Big Switch: Rewiring the World, from Edison to Google*, W.W. Norton & Co., 2009.

<sup>4</sup> “The Compelling TCO Case for Cloud Computing in SMB and Mid-Market Enterprises: A 4-year

total cost of ownership (TCO) perspective comparing cloud and on-premise business application development,” Sanjeev Aggarwal, Partner; Laurie McCabe, Partner; Hurwitz & Associates, 2009.

5 “2011 Cloud Computing Outlook: Survey Results,” [www.cloud.com/cloud-computing-outlook/survey.pdf](http://www.cloud.com/cloud-computing-outlook/survey.pdf).

6 “Are security issues delaying adoption of cloud computing?,” Ellen Messmer, Network World, April 27, 2009.

7 “Lessons From FarmVille,” Charles Babcock, InformationWeek, May 16, 2011.

8 “NoSQL at Netflix,” Yuri Israilevsky, Director of Cloud and Systems Infrastructure at Netflix, January 28, 2011, <http://techblog.netflix.com/2011/nosql—at—netflix.html>.

9 “When Amazon’s Cloud Turned On Itself,” Charles Babcock, InformationWeek, May 16, 2011.

---

PART  
VI  
DATABASE ADMINISTRATION

---

---

DATABASE ADMINISTRATION AND SECURITY **15**

---

# Business Vignette

Founded in 1987, Amadeus is a leading technology provider for the travel industry. The company, based in Madrid, Spain, is the global leader in online travel reservations, processing more travel bookings than any other company in the world. A wide array of businesses rely on Amadeus technology, from ferry lines and boutique hotels to multinational travel agencies and major airlines.<sup>1</sup> Through the Amadeus Global Distribution System (GDS), airlines and agencies can book from a selection of 95 percent of all scheduled airline seats.

To avoid unscheduled interruption of its services and protect against CPU failures, Amadeus relies on Oracle Real Application clusters (RAC). RAC allows Amadeus to achieve full application service redundancy in multiple nodes. The company's data center is divided into six independent cells, each with its own cabling and power. The company maintains two independent hardware, storage, and application systems. The company also uses Data Guard Redo Apply to maintain physical copies of its Oracle databases at a remote data recovery site 30 kilometers away from the main data center.<sup>2</sup>

When Amadeus decided to upgrade from Oracle 9i to Oracle 10g, it faced a major dilemma. The Amadeus IT service agreement restricts the company to 15 minutes of planned database downtime per quarter. Yet, the migration to Oracle 10g would require at least 25 minutes. Fortunately, the Amadeus IT team developed a plan to reduce the migration time significantly, using Oracle Transportable Tablespaces and Oracle Data Guard.<sup>3</sup>

Oracle Data Guard provides for data protection and disaster recovery by creating and monitoring the integrity of standby databases. The product can maintain transactionally consistent databases in the event of planned or unplanned outages.<sup>4</sup> Transportable Tablespaces allows the simple transfer of data files through copying, exporting, and importing functions.<sup>5</sup>

Amadeus decided to carry out the first upgrade on its electronic ticketing server. The plan involved several steps. First, the Amadeus IT team created a physical standby database on a separate system that ran Oracle 9i. Next, the team created a shell of the Oracle 10g database on this standby system and shut down the primary database. The team then used Transportable Tablespaces to transfer all tablespaces from the Oracle 9i standby database to the Oracle 10g shell. The team pointed the application to the new Oracle 10g database. Finally, the team

made a hot backup of the new database and created a physical copy of it at the data recovery site. Through this process, Amadeus reduced the anticipated 25 minutes of downtime to 8 minutes, and met its contractual obligations to its large customer base.

---

1 About Us, Amadeus.net, [www.amadeus.net/plnext/meb/AboutUs.action?  
SITE=BCEUBCEU&LANGUAGE=GB](http://www.amadeus.net/plnext/meb/AboutUs.action?SITE=BCEUBCEU&LANGUAGE=GB), and Amadeus.com North America,  
[www.amadeus.com/us/us.html](http://www.amadeus.com/us/us.html).

2 OTN Case Study: Amadeus, Using Data Guard for Disaster Recovery & Rolling Upgrades, Oracle Success Stories, Oracle Website, [www.oracle.com/technetwork/database/features/availability/amadeusprofile-1-128797.pdf](http://www.oracle.com/technetwork/database/features/availability/amadeusprofile-1-128797.pdf).

3 *Ibid.*

4 Introduction to Oracle Data Guard, Oracle® Data Guard Concepts and Administration, 10g Release 2 (10.2), Oracle Website, [http://download.oracle.com/docs/cd/B19306\\_01/server.102/b14239/concepts.htm](http://download.oracle.com/docs/cd/B19306_01/server.102/b14239/concepts.htm).

5 Transportable Tablespaces, Oracle Website, <http://wiki.oracle.com/page/Transportable+Tablespaces>.

---

## 15 DATABASE ADMINISTRATION AND SECURITY

---

In this chapter, you will learn:

- That data are a valuable business asset requiring careful management
- How a database plays a critical role in an organization
- That the introduction of a DBMS has important technological, managerial, and cultural consequences for an organization
- What the database administrator's managerial and technical roles are
  - About data security, database security, and the information security framework
  - About several database administration tools and strategies
  - How various technical tasks of database administration are performed with Oracle

---

## Preview

---

This chapter shows you the basis for a successful database administration strategy. Such a strategy requires that data be treated and managed as a valuable corporate asset.

The chapter explores how a database fits within an organization, what the data views and requirements are for various management levels, and how the DBMS supports those views and requirements. Database administration must be fully understood and accepted within an organization before a sound administration strategy can be implemented. In this chapter, you will learn about important data management issues by looking at the managerial and technical roles of the database administrator (DBA). This chapter also explores database security issues, such as the confidentiality, integrity, and availability of data. In our information-based society, a key aspect of data management is ensuring that data are protected against intentional or unintentional access by unauthorized personnel. It is also essential to ensure that data are available as needed, even in the face of natural disaster or hardware failure, and to maintain the integrity of

the data in the database.

The chapter includes a discussion of database administration tools and the corporate-wide data architectural framework. You will also learn how database administration management fits within classical organizational structures. Because Oracle is the current leader in mid-to high-level corporate database markets, you will learn how a DBA manages a database in Oracle.

---

## 15.1 DATA AS A CORPORATE ASSET

---

In [Chapter 1](#), Database Systems, you learned that data are the raw material from which information is produced. Therefore, in today's information-driven environment, data are a valuable asset that requires careful management.

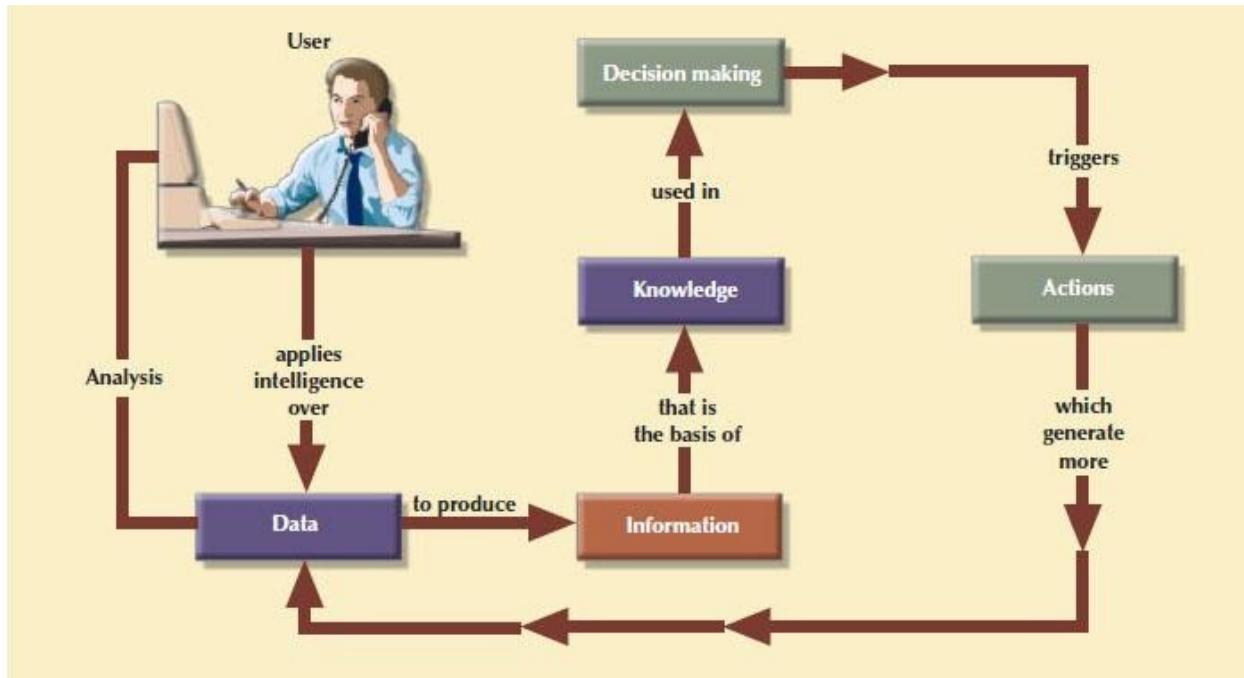
To assess data's monetary value, consider what is stored in a company database: data about customers, suppliers, inventory, operations, and so on. How many opportunities are lost if the data are lost? What is the actual cost of data loss? For example, an accounting firm that lost its entire database would incur significant direct and indirect costs. The firm's problems would be magnified if the data loss occurred during tax season. Data loss puts any company in a difficult position. The company might be unable to handle daily operations effectively, it might lose customers who require quick and efficient service, and it might lose the opportunity to gain new customers.

Data are a valuable *resource* that can translate into *information*. If the information is accurate and timely, it can enhance the company's competitive position and generate wealth. In effect, an organization is subject to a *data-information-decision cycle*; that is, the data *user* applies intelligence to data to produce information that is the basis of knowledge used in *decision making*. This cycle is illustrated in [Figure 15.1](#).

---

**FIGURE 15.1** The data-information-decision cycle

---



SOURCE: Course Technology/Cengage Learning

Note in [Figure 15.1](#) that decisions made by high-level managers trigger actions within the organization's lower levels. Such actions produce additional data to be used for monitoring company performance. In turn, the additional data must be recycled within the data-information-decision framework. Thus, data form the basis for decision making, strategic planning, control, and operations monitoring.

Efficient asset management is critical to the success of an organization. To manage data as a corporate asset, managers must understand the value of information. For some companies, such as credit reporting agencies, their only product is information, and their success is solely a function of information management.

Most organizations continually seek new ways to leverage their data resources to get greater returns. This leverage can take many forms, from data warehouses that support improved customer relationships to tighter integration with customers and suppliers in support of the electronic supply chain. As organizations become more dependent on information, its accuracy becomes more critical. **Dirty data**, or data that suffer from inaccuracies and inconsistencies, becomes an even greater threat. Data can become dirty for many reasons:

- Lack of enforcement of integrity constraints, such as not null, uniqueness, and referential integrity
- Data-entry errors and typographical errors
- Use of synonyms and homonyms across systems
- Nonstandard use of abbreviations in character data
  - Different decompositions of composite attributes into simple attributes across systems

Some causes of dirty data, such as improper implementation of constraints, can be addressed within an individual database. However, addressing other causes is more complicated. Some dirty data come from the movement of data across systems, as in the creation of a data warehouse. Efforts to control dirty data are generally referred to as data quality initiatives.

**Data quality** is a comprehensive approach to ensuring the accuracy, validity, and timeliness of data. This comprehensive approach is important, because data quality involves more than just cleaning dirty data; it also focuses on preventing future inaccuracies and building user confidence in the data. Large-scale data quality initiatives tend to be complex and expensive projects, so the alignment of these initiatives with business goals is a must, as is buy-in from top management. While data quality efforts vary greatly from one organization to another, most involve the following:

- A data governance structure that is responsible for data quality
- Measurements of current data quality
- Definition of data quality standards in alignment with business goals
- Implementation of tools and processes to ensure future data quality

A number of tools can assist in data quality initiatives. In particular, data-profiling and master data management software are available from many vendors. **Data-profiling software** gathers statistics, analyzes existing data sources and metadata to determine data patterns, and compares the patterns against standards that the organization has defined. This analysis can help to assess the quality of existing data and identify sources of dirty data. **Master data management (MDM) software** helps to prevent dirty data by coordinating common data across multiple systems. MDM software provides a “master” copy

of entities, such as customers, that appear in numerous systems throughout the organization.

While these technological approaches provide an important part of data quality, the overall solution to high-quality data within an organization still relies heavily on data administration and management.

---

## 15.2 THE NEED FOR A DATABASE AND ITS ROLE IN AN ORGANIZATION

---

Data are used by different people in different departments for various reasons. Therefore, data management must address the concept of shared data. [Chapter 1](#) showed how the need for data sharing made the DBMS almost inevitable. Used properly, the DBMS facilitates:

- *Interpretation* and *presentation* of data in useful formats by transforming raw data into information
- *Distribution* of data and information to the right people at the right time
- *Data preservation* and *monitoring* data usage for adequate periods of time
- *Control* over data duplication and use, both internally and externally

Regardless of the organization, the database's predominant role is *to support managerial decision making at all levels in the organization while preserving data privacy and security.*

An organization's managerial structure might be divided into three levels: top-level management makes strategic decisions, middle management makes tactical decisions, and operational management makes daily working decisions. Operational decisions are short term; for example, a manager might change the price of a product to clear it from inventory. Tactical decisions involve a longer time frame and affect larger-scale operations—for example, changing the price of a product in response to competitive pressures. Strategic decisions affect the long-term well-being of the company or even its survival—for example, changing the pricing strategy across product lines to capture market share.

The DBMS must give each level of management a useful view of the data and support the required level of decision making. The following activities are typical of each management level.

At the *top management* level, the database must be able to:

- Provide the information necessary for strategic decision making, strategic planning, policy formulation, and goals definition.
- Provide access to external and internal data to identify growth opportunities and to chart the direction of such growth. (Direction refers to the nature of the operations: will a company become a service organization, a manufacturing organization, or some combination of the two?)
- Provide a framework for defining and enforcing organizational policies that are translated into business rules at lower levels in the organization.
- Improve the likelihood of a positive return on investment by searching for new ways to reduce costs and boost productivity in the company.
- Provide feedback to monitor whether the company is achieving its goals.

At the *middle management* level, the database must be able to:

- Deliver the data necessary for tactical decisions and planning.
- Monitor and control the allocation and use of company resources and evaluate the performance of various departments.
- Provide a framework for enforcing and ensuring the security and privacy of the data in the database. Security means protecting the data against accidental or intentional use by unauthorized users. In the context of database administration, **privacy** is the extent to which individuals and organizations have the right to determine the details of data usage (who, what, when, where, and how).

At the *operational management* level, the database must be able to:

- Represent and support company operations as closely as possible. The data model must be flexible enough to incorporate all current and future data.

- Produce query results within specified performance levels. Keep in mind that the performance requirements increase for lower levels of management and operations. Thus, the database must support fast responses to a greater number of transactions at the operational management level.
- Enhance the company's short-term operations by providing timely information for customer support and for application development and computer operations.

A general objective for any database is to provide a seamless flow of information throughout the company.

The company's database is also known as the corporate or enterprise database. The **enterprise database** might be defined as the company's data representation that provides support for all present and expected future operations. Most of today's successful organizations depend on the enterprise database to provide support for all of their operations—from design to implementation, from sales to services, and from daily decision making to strategic planning.

---

### 15.3 INTRODUCTION OF A DATABASE: SPECIAL CONSIDERATIONS

---

Having a computerized database management system does not guarantee that the data will be properly used to provide the best solutions required by managers. A DBMS is a tool for managing data; like any tool, it must be used effectively to produce the desired results. In the hands of a carpenter, a hammer can help produce furniture, but in the hands of a child, it might do damage. The solution to company problems is not the mere existence of a computer system or its database, but its effective management and use.

The introduction of a DBMS represents a big change and challenge; throughout the organization, the DBMS is likely to have a profound impact, which might be positive or negative depending on how it is administered. For example, one key consideration is to adapt the DBMS to the organization rather than forcing the organization to adapt to the DBMS. The main issue should be the organization's needs rather than the DBMS's technical capabilities. However, the introduction of a DBMS cannot be accomplished without affecting the organization. The

flood of new information has a profound effect on the way the organization functions and therefore on its corporate culture.

The introduction of a DBMS has been described as a process that includes three important aspects:<sup>1</sup>

- *Technological*—DBMS software and hardware
- *Managerial*—Administrative functions
- *Cultural*—Corporate resistance to change

The *technological* aspect includes selecting, installing, configuring, and monitoring the DBMS to make sure that it efficiently handles data storage, access, and security. The personnel in charge of installing the DBMS must have the technical skills to provide or secure adequate support for various users of the system: programmers, managers, and end users. Therefore, database administration staffing is a key technological consideration. The selected personnel must have the right mix of technical and managerial skills to provide a smooth transition to the new shared-data environment.

The *managerial* aspect of the DBMS introduction should not be taken lightly. A high-quality DBMS does not guarantee a high-quality information system, just as having the best race car does not guarantee winning a race.

The introduction of a DBMS requires careful planning to create an appropriate organizational structure and accommodate the personnel responsible for administering the system. This structure must also be subject to well-developed monitoring and controls. The administrative personnel must have excellent interpersonal and communications skills combined with broad organizational and business understanding. Top management must be committed to the new system and must define and support data administration functions, goals, and roles within the organization.

The *cultural* impact of the new database system must be assessed carefully. The DBMS is likely to have an effect on people, functions, and interactions. For example, additional personnel might be hired, new roles might be allocated to existing personnel, and employee performance might be evaluated using new standards.

A cultural impact is likely because the database approach creates a more controlled and structured information flow. Department managers who are accustomed to handling their own data must surrender ownership and share their

data with the rest of the company. Application programmers must learn and follow new design and development standards. Managers might perceive an information overload and require time to adjust to the new environment.

When the new database comes online, people might be reluctant to use its information and might question its value or accuracy. Many might be disappointed that the information does not fit their preconceived notions and strongly held beliefs. Database administrators must be prepared to open their doors to end users, listen to their concerns, act on those concerns when possible, and explain the system's uses and benefits.

---

## 15.4 THE EVOLUTION OF DATABASE ADMINISTRATION

---

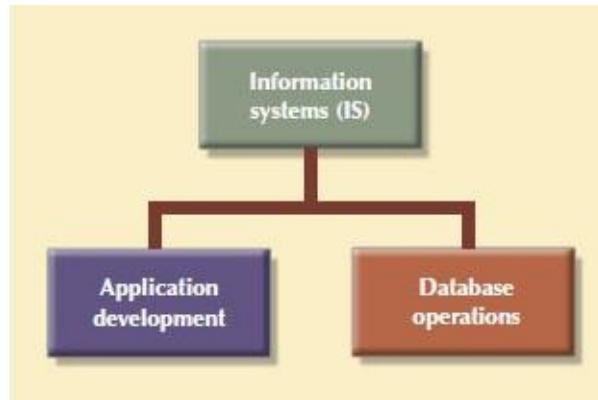
Data administration has its roots in the old, decentralized world of the file system. The cost of data and managerial duplication in these systems gave rise to centralized data administration known as the electronic data processing (EDP) or data processing (DP) department. The DP department's task was to pool all computer resources to support all departments *at the operational level*. DP administrators were given the authority to manage all company file systems as well as resolve data and managerial conflicts created by the duplication and misuse of data.

The advent of the DBMS and its shared view of data produced a new level of data management sophistication and led the DP department to evolve into an **information systems (IS) department**. The responsibilities of the IS department were broadened to include:

- A *service* function to provide end users with data management support
  - A *production* function to provide end users with solutions for their information needs through integrated application or management information systems
- 

**FIGURE 15.2 The IS department's internal organization**

---



SOURCE: Course Technology/Cengage Learning

---

The function of the IS department was reflected in its internal structure; a typical structure is shown in [Figure 15.2](#). As demand grew, the IS application development segment was subdivided by the type of system it supported: accounting, inventory, marketing, and so on. However, this development meant that database administration responsibilities were divided. The application development segment was in charge of gathering database requirements and logical database design, whereas the database operations segment took charge of implementing, monitoring, and controlling DBMS operations.

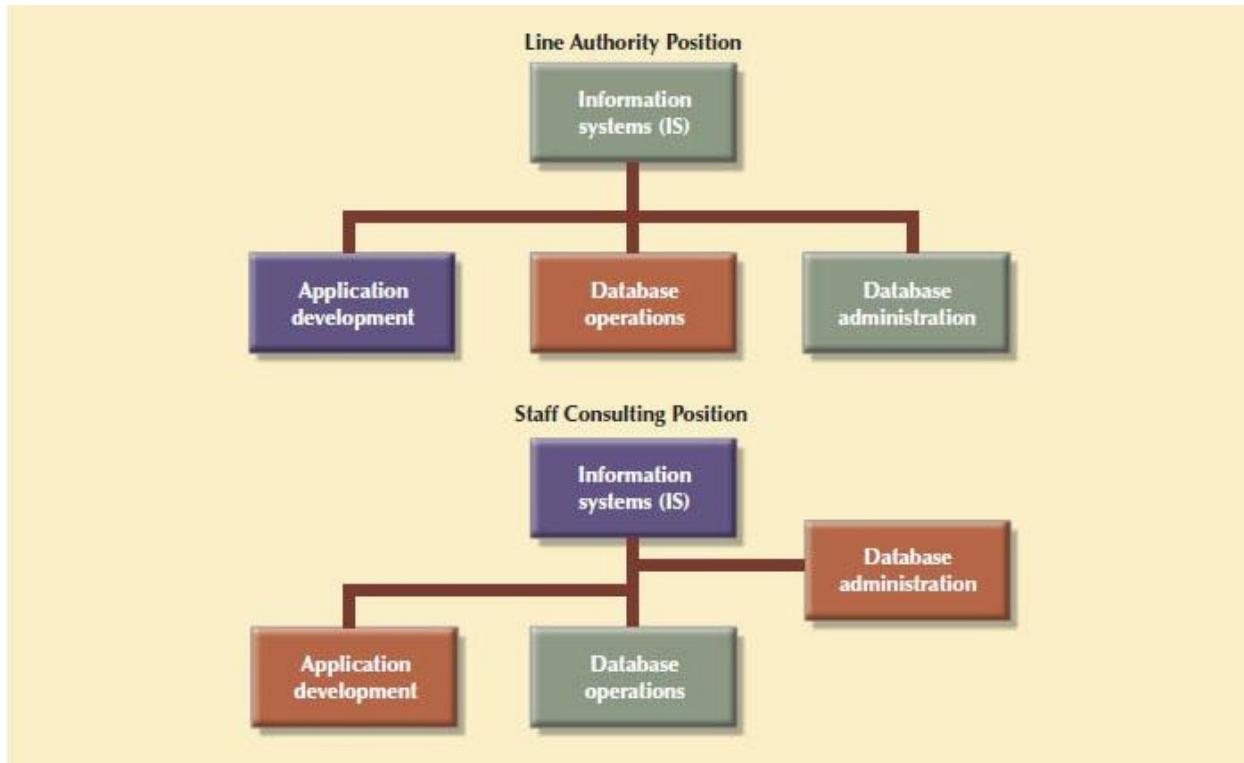
As the number of database applications grew, data management became increasingly complex, thus leading to the development of database administration. The person responsible for control of the centralized and shared database became known as the [\*\*database administrator \(DBA\)\*\*](#).

The size and role of the DBA function varies from company to company, as does its placement within the organizational structure. On the organizational chart, the DBA function might be defined as either a staff or line position. In a staff position, the DBA often takes on a consulting role; the DBA can devise the data administration strategy but does not have the authority to enforce it or resolve possible conflicts.<sup>2</sup> In a line position, the DBA has both the responsibility and authority to plan, define, implement, and enforce the policies, standards, and procedures used in data administration. The two possible DBA positions are illustrated in [Figure 15.3](#).

---

**FIGURE 15.3 The placement of the DBA function**

---



SOURCE: Course Technology/Cengage Learning

---

There is no standard for how the DBA function fits in an organization's structure, partly because the function itself is probably the most dynamic of any in an organization. In fact, the fast-paced changes in DBMS technology dictate changing organizational styles. For example:

- The development of distributed databases can force an organization to decentralize data administration further. The distributed database requires the system DBA to define and delegate the responsibilities of each local DBA, thus imposing new and more complex *coordinating* activities on the system DBA.
- The growing use of Internet-accessible data and the growing number of data warehousing applications are likely to expand the DBA's data-modeling and design activities.
- The increasing sophistication and power of microcomputer-based DBMS packages provide an easy platform for developing user-friendly, cost-effective, and efficient solutions. However, such an environment also

invites data duplication, not to mention the problems created by people who lack the technical qualifications to produce good database designs. In short, the new microcomputer environment requires the DBA to develop a new set of technical and managerial skills.

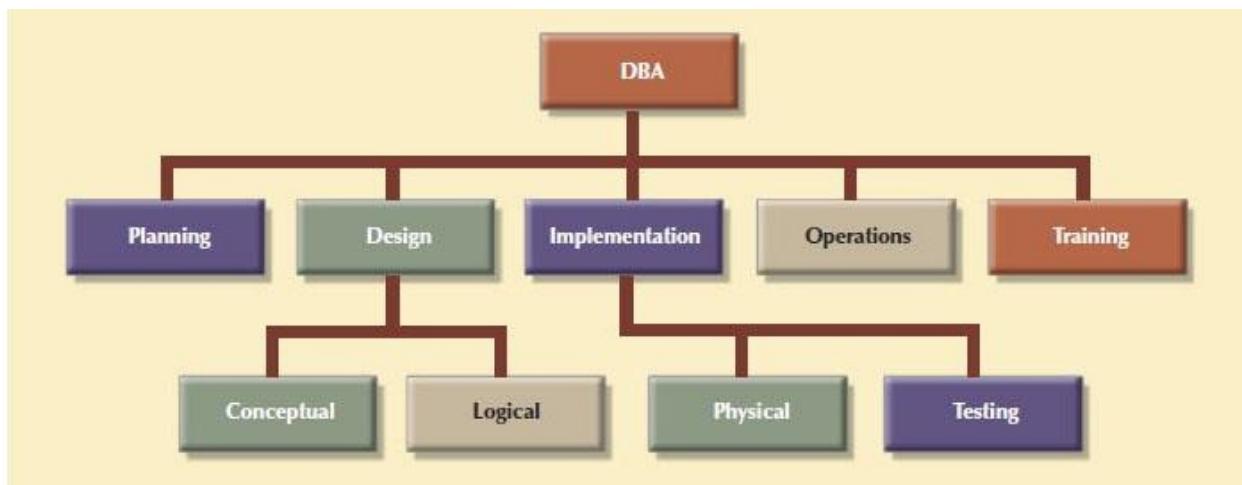
DBA operations are commonly defined and divided according to the phases of the Database Life Cycle (DBLC). If that approach is used, the DBA function requires personnel to cover the following activities:

- Database planning, including the definition of standards, procedures, and enforcement
- Database requirements gathering and conceptual design
- Database logical and transaction design
- Database physical design and implementation
- Database testing and debugging
- Database operations and maintenance, including installation, conversion, and migration
- Database training and support
- Data quality monitoring and management

---

**FIGURE 15.4 represents a DBA functional organization according to the preceding model.**

---

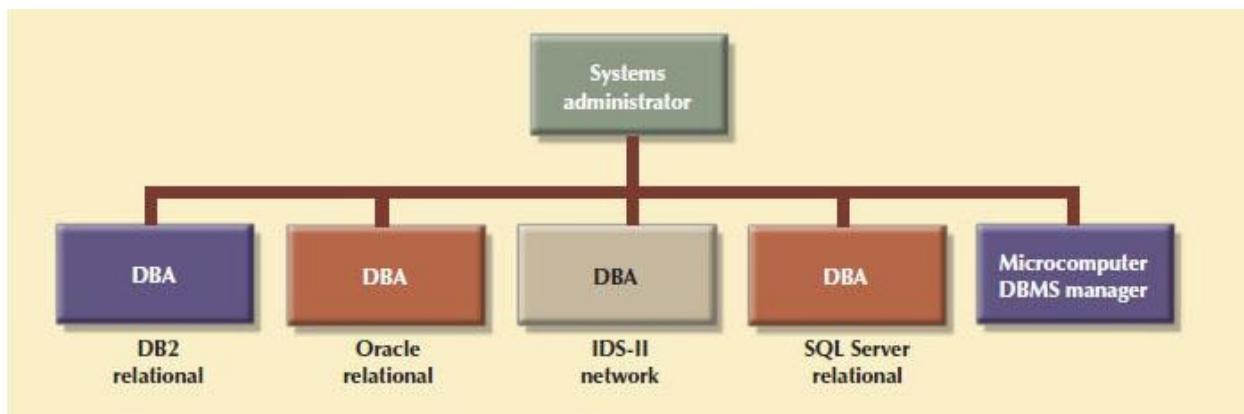


Keep in mind that a company might have several incompatible DBMSs installed to support different operations. For example, some corporations have a hierarchical DBMS to support daily transactions at the operational level and a relational database to support middle and top management's ad hoc information needs. A variety of microcomputer DBMSs might be installed in different departments. In such an environment, the company might have one DBA assigned for each DBMS. The general coordinator of all DBAs is sometimes known as the [systems administrator](#); that position is illustrated in [Figure 15.5](#).

---

**FIGURE 15.5 Multiple database administrators in an organization**

---



There is a growing trend toward specialization in data management. For example, the organizational charts used by some larger corporations make a distinction between a DBA and the [data administrator \(DA\)](#). The DA, also known as the [information resource manager \(IRM\)](#), usually reports directly to top management and is given a higher degree of responsibility and authority than the DBA, although the two roles can overlap.

The DA is responsible for controlling the overall corporate data resources, both computerized and manual. Thus, the DA's job covers more operations than the DBA's because the DA controls data outside the scope of the DBMS in addition to computerized data. Depending on an organization's structure, the DBA might report to the DA, the IRM, the IS manager, or directly to the company's CEO.

---

## 15.5 THE DATABASE ENVIRONMENT'S HUMAN COMPONENT

---

---

A substantial portion of this book is devoted to relational database design and implementation, and to DBMS features and characteristics. Thus far, the book has focused on very important technical aspects of the database. However, even the most carefully crafted database system cannot operate without human assistance. In this section, you will explore how people perform the data administration activities that make a good database design useful.

Effective data administration requires both technical and managerial skills. For example, the DA's job typically has a strong managerial orientation with company-wide scope, along with a technical orientation that has a narrower, DBMS-specific scope. However, the DBA also must have considerable people skills. For example, both the DA and DBA direct and control personnel staffing and training within their respective departments.

[\*\*Table 15.1\*\*](#) contrasts the general characteristics of both positions by summarizing typical DA and DBA activities. All of these activities are assigned to the DBA if the organization does not employ both a DA and a DBA.

---

**TABLE 15.1 Contrasting DA and DBA Activities and Characteristics**

---

<b>DATA ADMINISTRATOR (DA)</b>	<b>DATABASE ADMINISTRATOR (DBA)</b>
Performs strategic planning	Controls and supervises
Sets long-term goals	Executes plans to reach goals
Sets policies and standards	Enforces policies and procedures Enforces programming standards
Job is broad in scope	Job is narrow in scope
Focuses on the long term	Focuses on the short term (daily operations)
Has a managerial orientation	Has a technical orientation
Is DBMS-independent	Is DBMS-specific

---

Note that the DA provides a global and comprehensive administrative strategy

for the organization's data. In other words, the DA's plans must consider the entire data spectrum. Thus, the DA is responsible for the consolidation and consistency of both manual and computerized data.

The DA must also set data administration goals. Those goals are defined by issues such as:

- Data "sharability" and time availability
- Data consistency and integrity
- Data security and privacy
- Data quality standards
- Extent and type of data use

Naturally, the list can be expanded to fit an organization's specific data needs. Regardless of how data management is conducted—and despite the fact that great authority is invested in the DA or DBA to define and control the way company data are used—the DA and DBA do not own the data. Instead, their functions are defined to emphasize that data are a shared company asset.

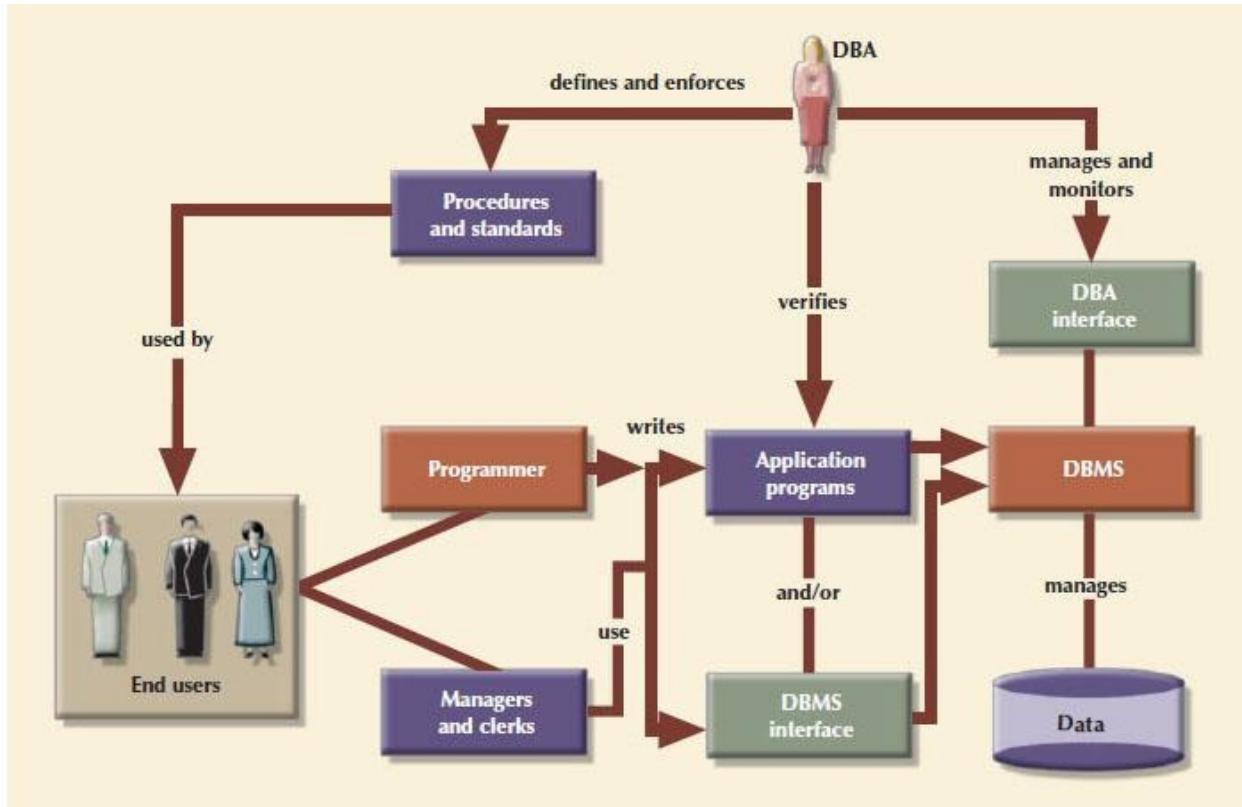
The preceding discussion should not lead you to believe that there are universally accepted DA and DBA administrative standards. The style, duties, organizational placement, and internal structure of both functions vary from company to company. For example, many companies distribute DA duties between the DBA and the manager of information systems. For simplicity and to avoid confusion, the label *DBA* is used here as a general title that encompasses all appropriate data administration.

The arbitration of interactions between the two most important assets of any organization, people and data, places the DBA in the dynamic environment portrayed in [Figure 15.6](#).

---

**FIGURE 15.6 A summary of DBA activities**

---



SOURCE: Course Technology/Cengage Learning

As you examine [Figure 15.6](#), note that the DBA is the focal point for data and user interaction. The DBA defines and enforces the procedures and standards to be used by programmers and end users during their work with the DBMS. The DBA also verifies that programmer and end-user access meets the required quality and security standards.

Database users might be classified by the following criteria:

- Type of decision-making support required (operational, tactical, or strategic)
- Degree of computer knowledge (novice, proficient, or expert)
- Frequency of access (casual, periodic, or frequent)

These classifications are not exclusive and usually overlap. For example, an operational user can be an expert with casual database access, or a top-level manager might be a strategic novice user with periodic database access. On the other hand, a database application programmer is an operational expert and frequent database user. Thus, each organization employs people whose levels of

database expertise span an entire spectrum. The DBA must be able to interact with all of them, understand their different needs, answer questions at all levels of expertise, and communicate effectively.

The DBA activities portrayed in [Figure 15.6](#) suggest the need for a diverse mix of skills. In large companies, such skills are likely to be distributed among several DBAs. In small companies, the skills might be the domain of just one DBA. The skills can be divided into two categories—managerial and technical—as summarized in [Table 15.2](#).

---

**TABLE 15.2 Desired DBA Skills**

---

## **MANAGERIAL TECHNICAL**

Broad business understanding	Broad data-processing background
Coordination skills	Knowledge of Systems Development Life Cycle Structured methodologies:
Analytical skills	<ul style="list-style-type: none"><li>• Data flow diagrams</li><li>• Structure charts</li><li>• Programming languages</li></ul>
Conflict resolution skills	Knowledge of Database Life Cycle
Communication skills (oral and written)	Database modeling and design skills <ul style="list-style-type: none"><li>• Conceptual</li><li>• Logical</li><li>• Physical</li></ul>
Negotiation skills	Operational skills: Database implementation, data dictionary management, security, and so on

---

Experience: 10 years in a large DP department

As you examine [Table 15.2](#), keep in mind that the DBA must perform two distinct roles. The DBA's managerial role is focused on personnel management and on interactions with end users. The DBA's technical role involves the use of the DBMS—database design, development, and implementation—as well as the

production, development, and use of application programs. Both roles are examined in greater detail in the following sections.

#### 15.5.1 THE DBA'S MANAGERIAL ROLE

---

As a manager, the DBA must concentrate on the control and planning of database administration. Therefore, the DBA is responsible for:

- Coordinating, monitoring, and allocating database administration resources: people and data
- Defining goals and formulating strategic plans for database administration

More specifically, the DBA's responsibilities are shown in [Table 15.3](#).

---

**TABLE 15.3 DBA Activities and Services**

---

DBA ACTIVITY	DBA SERVICE
Planning	End-user support
Organizing	Policies, procedures, and standards
Testing	Data security, privacy, and integrity
Monitoring	Data backup and recovery
Delivering	Data distribution and use

[Table 15.3](#) illustrates that the DBA is generally responsible for planning, organizing, testing, monitoring, and delivering quite a few services. Those services might be performed by the DBA, although they are more likely to be performed by the DBA's personnel. The following sections examine the services in greater detail.

#### End-User Support

The DBA interacts with end users by providing data and information support to their departments. Because end users usually have dissimilar computer backgrounds, support services include the following:

- *Gathering user requirements.* The DBA must work with end users to help gather the data required to identify and describe their present and future information needs. The DBA's communication skills are important in working closely with people who have varying computer backgrounds and communication styles.

- *Building end-user confidence.* Finding adequate solutions to end users' problems increases their trust and confidence in the DBA. The DBA also should educate end users about the services provided and how they enhance data stewardship and data security.
- *Resolving conflicts and problems.* Finding solutions to end users' problems in one department might trigger conflicts with other departments. End users are typically concerned with their own data needs rather than those of others, and they might not consider how their data affect other departments within the organization. When conflicts arise, the DBA must have the authority and responsibility to resolve them.
- *Finding solutions to information needs.* The ability and authority to resolve data conflicts enables the DBA to develop solutions that will properly fit within the data management framework and address end users' information needs. Given the growing importance of the Internet, those solutions are likely to require the development and management of Web servers to interface with the databases. In fact, the explosive growth of e-commerce requires the use of *dynamic* interfaces to facilitate interactive product queries and product sales.
- *Ensuring quality and integrity of data and applications.* Once the right solution has been found, it must be properly implemented and used. The DBA must work with application programmers and end users to teach them the database standards and procedures required for data quality, access, and manipulation. The DBA must also make sure that the database transactions do not adversely affect data quality. Likewise, certifying the quality of application programs that access the database is a crucial DBA function. Special attention must be given to DBMS Internet interfaces because they are prone to security issues, particularly when using cloud data services.
- *Managing the training and support of DBMS users.* One of the most timeconsuming DBA activities is teaching end users how to use the database. The DBA must ensure that all users understand the basic

functions of the DBMS software. The DBA coordinates and monitors all DBMS training activities.

### **Policies, Procedures, and Standards**

A successful data administration strategy requires the continuous enforcement of policies, procedures, and standards for correct data creation, usage, and distribution within the database. The DBA must define, document, and communicate the following before they can be enforced:

- **Policies** are general statements of direction or action that communicate and support DBA goals.
- **Standards** describe the minimum requirements of a given DBA activity; they are more detailed and specific than policies. In effect, standards are rules that evaluate the quality of the activity. For example, standards define the structure of application programs and the naming conventions programmers must use.
- **Procedures** are written instructions that describe a series of steps to be followed during the performance of a given activity. Procedures must be developed within existing working conditions, and they must support and enhance the work environment.

To illustrate the distinctions among policies, standards, and procedures, look at the following examples:

#### *Policies*

- All users must have passwords.
- Passwords must be changed every six months.

#### *Standards*

- A password must have a minimum of five characters.
- A password must have a maximum of 12 characters.
- Social Security numbers, names, and birth dates cannot be used as

passwords.

### *Procedures*

- To create a password, (1) the end user sends the DBA a written request for the creation of an account; (2) the DBA approves the request and forwards it to the computer operator; (3) the computer operator creates the account, assigns a temporary password, and sends the account information to the end user; (4) a copy of the account information is sent to the DBA; and (5) the user changes the temporary password to a permanent one.

Standards and procedures defined by the DBA apply to all end users who want to benefit from the database. Standards and procedures must complement each other and must constitute an extension of data administration policies. Procedures must facilitate the work of end users and the DBA. The DBA must define, communicate, and enforce procedures that cover areas such as:

- *End-user database requirements gathering.* What documentation is required? What forms must be used?
- *Database design and modeling.* What database design methodology will be used (normalization or object-oriented)? What tools will be used (CASE tools, data dictionaries, UML or ER diagrams)?
- *Documentation and naming conventions.* What documentation must be used in the definition of all data elements, sets, and programs that access the database?
- *Design, coding, and testing of database application programs.* The DBA must define the standards for application program coding, documentation, and testing. The DBA standards and procedures are given to the application programmers, and the DBA must enforce those standards.
- *Database software selection.* The selected DBMS must properly interface with existing software, have the features needed by the organization, and

provide a positive return on investment. In today's Internet environment, the DBA must also work with Web and network administrators to implement efficient and secure Web and cloud database connectivity.

- *Database security and integrity.* The DBA must define policies that govern security and integrity. Database security is especially crucial. Security standards must be clearly defined and strictly enforced. Security procedures must handle a multitude of scenarios to ensure that problems are minimized. Although no system can ever be completely secure, procedures must meet critical standards. The growing use of Internet interfaces to databases opens the door to new security threats that are far more complex and difficult to manage than those in traditional interfaces. Therefore, the DBA must work closely with Internet security specialists to ensure that the databases are properly protected from attacks.
- *Database backup and recovery.* Database backup and recovery procedures must include information that guarantees proper execution and management of the backups.
- *Database maintenance and operation.* The DBMS's daily operations must be clearly documented. Operators must keep job logs and must write operator instructions and notes. Such notes help pinpoint the causes and solutions of problems. Operational procedures must also include precise instructions for backup and recovery procedures.
- *End-user training.* A full-featured training program must be established within the organization, and training procedures must be clearly specified. Each end user must be aware of available training.

Procedures and standards must be revised at least annually to keep them up to date and to ensure that the organization can adapt quickly to changes in the work environment. Naturally, the introduction of new DBMS software, the discovery of security or integrity violations, company reorganizations, and similar changes require revision of procedures and standards.

## **Data Security, Privacy, and Integrity**

Database security, privacy, and integrity are of great concern to DBAs who

manage DBMS installations. Technology has pointed the way to greater productivity through information management, and it has enabled the distribution of data across multiple sites, making it more difficult to maintain data control, security, and integrity. Thus, the DBA must use the security and integrity mechanisms provided by the DBMS to enforce the database administration policies defined in the previous section. In addition, DBAs must team up with Internet security experts to build security mechanisms that safeguard data from possible attacks or unauthorized access. [Section 15.6](#) covers security issues in more detail.

## **Data Backup and Recovery**

When data are not readily available, companies face potentially ruinous losses. Therefore, data backup and recovery procedures are critical in all database installations. The DBA must also ensure that data can be fully recovered in case of data loss or loss of database integrity. These losses can be partial or total; therefore, backup and recovery procedures are the cheapest database insurance you can buy.

The management of database security, integrity, backup, and recovery is so critical that many DBA departments have created a position called the [\*\*database security officer \(DSO\)\*\*](#). The DSO's sole job is to ensure database security and integrity. In large organizations, the DSO's activities are often classified as *disaster management*.

[\*\*Disaster management\*\*](#) includes all of the DBA activities designed to secure data availability following a physical disaster or a database integrity failure. Disaster management includes all planning, organizing, and testing of database contingency plans and recovery procedures. The backup and recovery measures must include at least the following:

- *Periodic data and application backups.* Some DBMSs include tools to ensure automatic backup and recovery of the database. Products such as IBM's DB2 allow different types of backups: full, incremental, and concurrent. A [\*\*full backup\*\*](#), also known as a [\*\*database dump\*\*](#), produces a complete copy of the entire database. An [\*\*incremental backup\*\*](#) produces a backup of all data since the last backup date. A [\*\*concurrent backup\*\*](#) takes place while the user is working on the database.
- *Proper backup identification.* Backups must be clearly identified through

detailed descriptions and date information, thus enabling the DBA to ensure that the correct backups are used to recover the database. The most common backup medium has traditionally been tape; computer operators must diligently store and label the tapes, and the DBA must keep track of the current tape's location. However, organizations that are large enough to hire a DBA do not typically use tapes for enterprise backup. Other emerging solutions include optical and disk-based backup devices. Such backup solutions include online storage based on network-attached storage (NAS) and storage area networks (SAN). Enterprise backup solutions use a layered approach in which the data are first backed up to fast disk media for intermediate storage and fast restoration. Later, the data are transferred to tape for archival storage.

- *Convenient and safe backup storage.* Multiple backups of the same data are required, and each backup copy must be stored in a different location. The storage locations must include sites inside and outside the organization. (Keeping different backups in the same place defeats the purpose of having multiple backups.) The storage locations must be properly prepared, and they may include fire-safe and quakeproof vaults as well as humidity and temperature controls. The DBA must establish a policy to respond to two questions: (1) Where are the backups to be stored? (2) How long are backups to be stored?
- *Physical protection of both hardware and software.* Protection might include the use of closed installations with restricted access, as well as preparation of the computer sites to provide air conditioning, backup power, and fire protection. Physical protection also includes a backup computer and DBMS to be used in case of emergency. For example, when Hurricane Katrina hit the U.S. Gulf Coast in 2005, New Orleans suffered almost total destruction of its communications infrastructure. The storm served as a wake-up call for many organizations and educational institutions that did not have adequate disaster recovery plans for such an extreme level of service interruption.
- *Personal access control to the software of a database installation.* Multilevel passwords and privileges as well as hardware and software challenge/response tokens can be used to identify authorized users of resources.

- *Insurance coverage for the data in the database.* The DBA or security officer must buy an insurance policy to provide financial protection in the event of a database failure. The insurance might be expensive, but it is less expensive than the disaster created by massive data loss.

Two additional points are worth making.

- Data recovery and contingency plans must be thoroughly tested and evaluated, and they must be practiced frequently. So-called fire drills should not be disparaged, and they require top-level management's support and enforcement.
- A backup and recovery program is not likely to cover all components of an information system. Therefore, it is appropriate to establish priorities for the nature and extent of data recovery.

## **Data Distribution and Use**

Data are useful only when they reach the right users in a timely fashion. The DBA is responsible for ensuring that the data are distributed to the right people, at the right time, and in the right format. These tasks can become very timeconsuming, especially when data delivery capacity is based on a typical applications programming environment, where users depend on programmers to deliver the programs that access the database. Although the Internet and its intranet and extranet extensions have opened databases to corporate users, they have also created a new set of challenges for the DBA.

Current data distribution philosophy makes it easy for *authorized* end users to access the database. One way to accomplish this task is to facilitate the use of new, more sophisticated query tools and new Web front ends. They enable the DBA to educate end users to produce required information without being dependent on applications programmers. Naturally, the DBA must ensure that users adhere to appropriate standards and procedures.

This data-sharing philosophy is common today, and it probably will become more common as database technology marches on. Such an environment is more flexible for end users; by becoming more self-sufficient in the acquisition and use of data, they can make better decisions. Yet, this “data democracy” can also

produce some troublesome side effects. Letting end users micromanage their data subsets could inadvertently sever the connection between those users and data administrators. The DBA's job could become more complicated, and the efficiency of data administration could be compromised. Data duplication might flourish again without checks at the organizational level to ensure the uniqueness of data elements. Thus, end users who do not completely understand the nature and sources of data might use the data elements improperly.

#### 15.5.2 THE DBA'S TECHNICAL ROLE

---

The DBA's technical role requires a broad understanding of DBMS functions, configuration, programming languages, and data-modeling and design methodologies. For example, the DBA's technical activities include the selection, installation, operation, maintenance, and upgrading of the DBMS and utility software, as well as the design, development, implementation, and maintenance of application programs that interact with the database.

Many of the DBA's technical activities are a logical extension of the DBA's managerial activities. For example, the DBA deals with database security and integrity, backup and recovery, and training and support. The technical aspects of the DBA's job are rooted in the following areas of operation:

- Evaluating, selecting, and installing the DBMS and related utilities
- Designing and implementing databases and applications
- Testing and evaluating databases and applications
- Operating the DBMS, utilities, and applications
- Training and supporting users
- Maintaining the DBMS, utilities, and applications

The following sections explore the details of each area.

### **Evaluating, Selecting, and Installing the DBMS and Utilities**

One of the DBA's first and most important technical responsibilities is selecting the database management system, utility software, and supporting hardware to be used in the organization. This task requires extensive planning, which must be based on the organization's needs rather than specific software and hardware features. The DBA must recognize that the objective is solving problems rather

than buying a computer or DBMS software. Put simply, a DBMS is a management tool and not a technological toy.

The first and most important step of the plan is to determine company needs. The DBA must make sure that all end users, including top-and midlevel managers, are involved in the process. Once the needs are identified, the objectives of data administration can be clearly established and the DBMS features and selection criteria can be defined.

To match DBMS capability to the organization's needs, the DBA would be wise to develop a checklist of desired DBMS features that addresses at least the following issues:

- *DBMS model.* Are the company's needs better served by a relational, object-oriented, or object/relational DBMS? If a data warehouse application is required, should a relational or multidimensional DBMS be used? Does the DBMS support star schemas?
- *DBMS storage capacity.* What maximum disk and database sizes are required? How many disk packages must be supported? How many tape units are needed? What are other storage needs?
- *Application development support.* Which programming languages are supported? What application development tools are available? (Options include database schema design, a data dictionary, performance monitoring, and screen and menu painters.) Are end-user query tools provided? Does the DBMS provide Web front-end access?
- *Security and integrity.* Does the DBMS support referential and entity integrity rules, access rights, and so on? Does the DBMS support the use of audit trails to spot errors and security violations? Can the audit trail's size be modified?
- *Backup and recovery.* Does the DBMS provide automated backup and recovery tools? Does the DBMS support tape, optical disc, or network-based backups? Does the DBMS automatically back up the transaction logs?

- *Concurrency control.* Does the DBMS support multiple users? What levels of isolation (table, page, row) does the DBMS offer? How much manual coding is needed in the application programs?
- *Performance.* How many transactions per second does the DBMS support? Are additional transaction processors needed?
- *Database administration tools.* Does the DBMS offer some type of DBA management interface? What type of information does the DBA interface provide? Does the DBMS provide alerts to the DBA when errors or security violations occur?
- *Interoperability and data distribution.* Can the DBMS work with other DBMS types in the same environment? What coexistence or interoperability level is achieved? Does the DBMS support read and write operations to and from other DBMS packages? Does the DBMS support a client/server architecture?
- *Portability and standards.* Can the DBMS run on different operating systems and platforms? Can the DBMS run on mainframes, midrange computers, and personal computers? Can the DBMS applications run without modification on all platforms? What national and industry standards does the DBMS follow?
- *Hardware.* What hardware does the DBMS require?
- *Data dictionary.* Does the DBMS have a data dictionary? If so, what information is kept in it? Does the DBMS interface with any data dictionary tool? Does the DBMS support any CASE tools?
- *Vendor training and support.* Does the vendor offer in-house training? What type and level of support does the vendor provide? Is the DBMS documentation easy to read and helpful? What is the vendor's upgrade policy?

- *Available thirdparty tools.* What additional tools are offered by thirdparty vendors? Do they include query tools, a data dictionary, access management and control, and storage allocation management tools?
- *Costs.* What costs are involved in the acquisition of the software and hardware? How many additional personnel are required, and what level of expertise is required of them? What are the recurring costs? What is the expected payback period?

Pros and cons of several alternative solutions must be evaluated during the selection process. Available alternatives are often restricted because software must be compatible with the organization's existing computer system. Remember that a DBMS is just part of a solution; it requires support from collateral hardware, application software, and utility programs. For example, the DBMS's use is likely to be constrained by the available CPU(s), front-end processor(s), auxiliary storage devices, data communication devices, the operating system, a transaction processor system, and so on. The costs associated with the hardware and software components must be included in the estimations.

The selection process must also consider the site's preparation costs. For example, the DBA must include both onetime and recurring expenditures for preparing and maintaining the computer room installations.

The DBA must supervise the installation of all software and hardware that supports the data administration strategy, and must thoroughly understand the components being installed, including their installation, configuration, and startup procedures. The installation procedures include the location of backup and transaction log files, network configuration information, and physical storage details.

Keep in mind that installation and configuration details are DBMS-dependent. Therefore, such details cannot be addressed in this book. Consult the installation and configuration sections of your system's DBMS administration guide for details.

## **Designing and Implementing Databases and Applications**

The DBA also provides data-modeling and design services to end users. Such

services are often coordinated with an application development group within the data-processing department. Therefore, one of the primary activities of a DBA is to determine and enforce standards and procedures to be used. Once a framework of appropriate standards and procedures are in place, the DBA must ensure that the database-modeling and design activities are performed within the framework. The DBA then provides necessary assistance and support during the design of the database at the conceptual, logical, and physical levels. (Remember that the conceptual design is both DBMS-and hardware-independent, the logical design is DBMS-dependent and hardware-independent, and the physical design is both DBMS-and hardware-dependent.)

The DBA function usually requires that several people be dedicated to database modeling and design activities. Those people might be grouped according to the organizational areas covered by the application. For example, database modeling and design personnel may be assigned to production systems, financial and managerial systems, or executive and decision support systems. The DBA schedules the design jobs to coordinate the data design and modeling activities. That coordination may require reassignment of available resources based on externally determined priorities.

The DBA also works with application programmers to ensure the quality and integrity of database design and transactions. Such support services include reviewing the database application design to ensure that transactions are:

- *Correct.* The transactions mirror real-world events.
- *Efficient.* The transactions do not overload the DBMS.
- *Compliant.* Transactions comply with integrity rules and standards.

These activities require personnel with broad database design and programming skills.

The implementation of the applications requires the implementation of the physical database. Therefore, the DBA must provide assistance and oversight during the physical design, including determination and creation of storage space, data loading, conversion, and database migration services. The DBA's implementation tasks also include the generation, compilation, and storage of the application's access plan. An [\*\*access plan\*\*](#) is a set of instructions generated when the application is compiled that predetermines how the application will access

the database at run time. To be able to create and validate the access plan, the user must have the required rights to access the database (see [Chapter 11](#), Database Performance Tuning and Query Optimization).

Before an application comes online, the DBA must develop, test, and implement the operational procedures required by the new system. Such procedures include training, security, and backup and recovery plans, as well as assigning responsibility for database control and maintenance. Finally, the DBA must authorize application users to access the database from which the applications draw the required data.

The addition of a new database might require fine-tuning or reconfiguring of the DBMS. Remember that the DBMS assists all applications by managing the shared corporate data repository. Therefore, when data structures are added or modified, the DBMS might require the assignment of additional resources to serve new and original users with equal efficiency (see [Chapter 11](#)).

## **Testing and Evaluating Databases and Applications**

The DBA must also provide testing and evaluation services for all database and end-user applications. These services are the logical extension of the design, development, and implementation services described in the preceding section. Clearly, testing procedures and standards must already be in place before any application program can be approved for use in the company.

Although testing and evaluation services are closely related to database design and implementation services, they usually are maintained independently. The reason for the separation is that application programmers and designers are often too close to the problem being studied to detect errors and omissions.

Testing usually starts with the loading of the “test bed” database, which contains test data for the applications. Its purpose is to check the data definition and integrity rules of the database and application programs.

The testing and evaluation of a database application cover all aspects of the system, from the simple collection and creation of data to its use and retirement. The evaluation process covers the following:

- Technical aspects of both the applications and the database; backup and recovery, security and integrity, use of SQL, and application performance must be evaluated
- Evaluation of the written documentation and procedures to ensure that

they are accurate and easy to follow

- Observance of standards for naming, documenting, and coding
- Checking for data duplication conflicts with existing data
- The enforcement of all data validation rules

Following the thorough testing of all applications, the database, and the procedures, the system is declared operational and can be made available to end users.

## **Operating the DBMS, Utilities, and Applications**

DBMS operations can be divided into four main areas:

- System support
- Performance monitoring and tuning
- Backup and recovery
- Security auditing and monitoring

*System support* activities cover all tasks directly related to the day-to-day operations of the DBMS and its applications. These activities include filling out job logs, changing tape, and verifying the status of computer hardware, disk packages, and emergency power sources. System-related activities include periodic tasks such as running special programs and resource configurations for new and upgraded versions of database applications.

*Performance monitoring and tuning* require much of the DBA's attention and time. These activities are designed to ensure that the DBMS, utilities, and applications maintain satisfactory performance levels. To carry out performance monitoring and tuning tasks, the DBA must:

- Establish DBMS performance goals.
- Monitor the DBMS to evaluate whether the performance objectives are being met.
- Isolate the problem and find solutions if performance objectives are not met.

- Implement the selected performance solutions.

DBMSs often include performance-monitoring tools that allow the DBA to query database usage information. Performance-monitoring tools are available from many different sources: DBMS utilities are provided by thirdparty vendors, or they might be included in operating system utilities or transaction processor facilities. Most of the performance-monitoring tools allow the DBA to focus on selected system bottlenecks. The most common bottlenecks in DBMS performance tuning are related to the use of indexes, query optimization algorithms, and management of storage resources.

Because improper index selection can have a deleterious effect on system performance, most DBMS installations adhere to a carefully defined index creation and usage plan. Such a plan is especially important in a relational database environment.

To produce satisfactory performance, the DBA might train programmers and end users in the proper use of SQL statements. Typically, DBMS programming manuals and administration manuals contain useful performance guidelines and examples that demonstrate the proper use of SQL statements, both at the command line and within application programs. Because relational systems do not give the user an index choice within a query, the DBMS makes the index selection for the user. Therefore, the DBA should create indexes that can be used to improve system performance. (For examples of database performance tuning, see [Chapter 11](#).)

Query optimization routines are usually integrated into the DBMS package, allowing few tuning options. Query optimization routines are oriented toward improving concurrent access to the database. Several database packages let the DBA specify parameters for determining the desired level of concurrency. Concurrency is also affected by the types of locks used by the DBMS and requested by the applications. Because concurrency is important to the efficient operation of the system, the DBA must be familiar with the factors that influence concurrency. (See [Chapter 10](#), Transaction Management and Concurrency Control, for more information.)

During DBMS performance tuning, the DBA must also consider available storage resources in terms of both primary and secondary memory. The allocation of storage resources is determined when the DBMS is configured.

Storage configuration parameters can be used to determine:

- The number of databases that may be opened concurrently
- The number of application programs or users supported concurrently
  - The amount of primary memory (buffer pool size) assigned to each database and each database process
  - The size and location of the log file (remember that these files are used to recover the database; the log files can be located in a separate volume to reduce the disk's head movement and to increase performance)

Performance-monitoring issues are DBMS-specific. Therefore, the DBA must become familiar with the DBMS manuals to learn the technical details involved in performance monitoring (see [Chapter 11](#)).

Because data loss could be devastating to the organization, *backup and recovery activities* are of primary concern during the DBMS operation. The DBA must establish a schedule for backing up database and log files at appropriate intervals. Backup frequency is dependent on the application type and on the relative importance of the data. All critical system components—the database, the database applications, and the transaction logs—must be backed up periodically.

Most DBMS packages include utilities that schedule automated database backups, be they full or incremental. Although incremental backups are faster than full backups, an incremental backup requires the existence of a periodic full backup to be useful for recovery purposes.

Database recovery after a media or systems failure requires application of the transaction log to the correct database copy. The DBA must plan, implement, test, and enforce a “bulletproof” backup and recovery procedure.

*Security auditing and monitoring* assumes the appropriate assignment of access rights and the proper use of access privileges by programmers and end users. The technical aspects of security auditing and monitoring involve creating users, assigning access rights, and using SQL commands to grant and revoke access rights to users and database objects. The DBA also must periodically generate an audit trail report to find actual or attempted security violations. If any are found, the DBA must ascertain where the violations occurred, and if possible, who committed them. For a comprehensive discussion of database security, see [Section 15.6](#).

## **Training and Supporting Users**

Training people to use the DBMS and its tools is part of the DBA's technical activities. In addition, the DBA provides or secures technical training for applications programmers in the use of the DBMS and its utilities. Applications programmer training covers the use of the DBMS tools as well as the procedures and standards required for database programming.

Unscheduled, on-demand technical support for end users and programmers is also part of the DBA's activities. A technical troubleshooting procedure can be developed to facilitate such support. The procedure might include the development of a technical database to find solutions to common technical problems.

Part of the support is provided by interaction with DBMS vendors. Establishing good relationships with software suppliers is one way to ensure that the company has a good external support source. Vendors are the source for up-to-date information concerning new products and personnel retraining. Good vendor-company relations also are likely to give organizations an edge in determining the future direction of database development.

## **Maintaining the DBMS, Utilities, and Applications**

The maintenance activities of the DBA are an extension of the operational activities. Maintenance activities are dedicated to the preservation of the DBMS environment.

Periodic DBMS maintenance includes management of the physical or secondary storage devices. One of the most common maintenance activities is reorganizing the physical location of data in the database. (This is usually done as part of the DBMS fine-tuning activities.) The reorganization of a database might be designed to allocate contiguous disk-page locations to the DBMS to increase performance. The reorganization process also might free the space allocated to deleted data, thus providing more disk space for new data.

Maintenance activities also include upgrading the DBMS and utility software. The upgrade might require installing a new version of the DBMS software or an Internet front-end tool. Or, it might create an additional DBMS gateway to allow access to a host DBMS running on a different host computer. DBMS gateway services are very common in distributed DBMS applications running in a client/server environment. Also, new-generation databases include features such as spatial data support, data warehousing and star query support, and support for

Java programming interfaces for Internet access (see [Chapter 14](#), Database Connectivity and Web Technologies).

Quite often companies are faced with the need to exchange data in dissimilar formats or between databases. The maintenance efforts of the DBA include migration and conversion services for data in incompatible formats or for different DBMS software. Such conditions are common when the system is upgraded from one version to another or when the existing DBMS is replaced by an entirely new DBMS. Database conversion services also include downloading data from the host DBMS (mainframe-based) to an end user's personal computer to allow the user to perform a variety of activities—spreadsheet analysis, charting, statistical modeling, and so on. Migration and conversion services can be done at the logical level (DBMS-or software-specific) or at the physical level (storage media or operating systemspecific). Current-generation DBMSs support XML as a standard format for data exchange among database systems and applications (see [Chapter 14](#)).

#### 15.5.3 THE DBA'S ROLE IN THE CLOUD

---

The use of cloud-based data services does not signal the end of DBAs, but it does have a significant impact on their role. As discussed in previous chapters, services such as Microsoft Azure and AmazonRDS allow for the outsourcing of database technology as a highly scalable, capability-on-demand service. As a result, the DBA has a reduced role in installing and maintaining the DBMS. Cloud services provide:

- *DBMS installation and updates.* The DBMS is installed on a virtual server by the service provider. As the DBMS vendor releases required updates and security fixes to the DBMS software, the service provider manages the application of the updates within a specified maintenance window.
- *Server/network management.* The service provider configures and manages the server where the DBMS resides, including scaling a database across multiple servers as needed. If the database is distributed across multiple servers, the service provider can supply load balancing to ensure a high level of performance.
- *Backup and recovery operations.* The service provider performs regular backups and stores backups in secure facilities.

While these services are valuable and free the DBA from these tasks, the primary benefit of cloud-based data services is their ability to provide and manage computing hardware and software configuration at a low cost. The preceding tasks are only a small part of the DBA's responsibilities; the DBA's managerial role is largely unchanged. User requirements must still be gathered, data solutions must still be designed, end users need training, and policies, standards, and procedures must be developed and enforced.

Even the technical role of the DBA still exists with the use of cloud data services. There are several cloud data service providers, and some offer a variety of DBMS products, including some proprietary systems. Only some versions of these DBMSs are available, including multiple versions of the same DBMS. For example, a given service provider may support both MySQL 5.1 and MySQL 5.5. In this environment, the DBA evaluates different DBMSs to determine which software product to use, and evaluates from which provider to purchase the DBMS.

A variety of pricing schemes are offered by cloud data service providers. Pricing is typically based on factors such as storage space, computing resources (CPU cycles and memory), and data transfer sizes. Service users are billed monthly for the amount of resources used. Service providers have a vested interest in their clients' databases being as large as possible; it is also in their interest for database designs to be inefficient in processing queries because clients will have to buy more memory and CPU capacity. Service providers benefit if your database is filled with poorly designed tables that contain lots of unnecessarily redundant data, with every attribute in every table indexed, and queries that take a long time to run or return thousands of rows of data that must be transferred to a front-end application for additional processing. Therefore, the DBA must ensure that databases are properly designed with minimal redundancy and that database coding is efficient. Clearly, the DBA's technical role is still critical to organizations that use cloud-based data services. The DBA's efforts in efficient and effective database design, coding, monitoring database performance, and database tuning still affect the organization's ability to use data and information as a resource, and they have an immediate visible impact on the monthly data service bill.

---

## 15.6 SECURITY

---

**Security** refers to activities and measures that ensure the confidentiality, integrity, and availability of an information system and its main asset, data.<sup>3</sup> Securing data requires a comprehensive, company-wide approach. That is, you cannot secure data if you do not secure all the processes and systems around it, including hardware systems, software applications, the network and its devices, internal and external users, procedures, and the data itself. To understand the scope of data security, consider each of the three security goals in more detail:

- **Confidentiality** deals with ensuring that data are protected against unauthorized access, and if the data are accessed by an authorized user, that the data are used only for an authorized purpose. In other words, confidentiality entails safeguarding data against disclosure of any information that would violate the privacy rights of a person or organization. Data must be evaluated and classified according to the level of confidentiality: highly restricted (very few people have access), confidential (only certain groups have access), and unrestricted (can be accessed by all users). The data security officer spends a great amount of time ensuring that the organization is in compliance with desired levels of confidentiality. **Compliance** refers to activities that meet data privacy and security reporting guidelines. These guidelines are either part of internal procedures or are imposed by external regulatory agencies such as the federal government. Examples of U.S. legislation enacted to ensure data privacy and confidentiality include the Health Insurance Portability and Accountability Act (HIPAA), Gramm-Leach-Bliley Act (GLBA), and Sarbanes-Oxley Act (SOX). For more information about these laws, visit <http://library.uis.edu/findinfo/govinfo/federal/law.html>.
- **Integrity**, within the data security framework, is concerned with keeping data consistent and free of errors or anomalies. (See [Chapter 1](#) to review the concepts of data inconsistencies and data anomalies.) The DBMS plays a pivotal role in ensuring the integrity of the data in the database. However, from the security point of view, the organizational processes, users, and usage patterns also must maintain integrity. For example, a work-at-home employee using the Internet to access product costing could be considered an acceptable use; however, security standards might

require the employee to use a secure connection and follow strict procedures to manage the data at home, such as shredding printed reports and using encryption to copy data to the local hard drive. Maintaining data integrity is a process that starts with data collection and continues with data storage, processing, usage, and archiving (see [Chapter 13](#), Business Intelligence and Data Warehouses). The rationale behind integrity is to treat data as the most valuable asset in the organization and to ensure that rigorous data validation is carried out at all levels within the organization.

- **Availability** refers to the accessibility of data whenever required by authorized users and for authorized purposes. To ensure data availability, the entire system must be protected from service degradation or interruption caused by any internal or external source. Service interruptions could be very costly for companies and users alike. System availability is an important goal of security.

#### 15.6.1 SECURITY POLICIES

---

Normally, the tasks of securing the system and its main asset, the data, are performed by the database security officer and the database administrator(s), who work together to establish a cohesive data security strategy. Such a strategy begins with defining a sound and comprehensive security policy. A **security policy** is a collection of standards, policies, and procedures created to guarantee the security of a system and ensure auditing and compliance. The security audit process starts by identifying security vulnerabilities in the organization's information system infrastructure and identifying measures to protect the system and data against those vulnerabilities.

#### 15.6.2 SECURITY VULNERABILITIES

---

A **security vulnerability** is a weakness in a system component that could be exploited to allow unauthorized access or cause service disruptions. Such vulnerabilities could fall under one of the following categories:

- *Technical*. An example would be a flaw in the operating system or Web browser.
- *Managerial*. For example, an organization might not educate users about

critical security issues.

- *Cultural*. Users might hide passwords under their keyboards or forget to shred confidential reports.
- *Procedural*. Company procedures might not require complex passwords or the checking of user IDs.

When a security vulnerability is left unchecked, it could become a security threat. A **security threat** is an imminent security violation.

A **security breach** occurs when a security threat is exploited to endanger the integrity, confidentiality, or availability of the system. Security breaches can lead to a database whose integrity is either preserved or corrupted:

- *Preserved*. In these cases, action is required to avoid the recurrence of similar security problems, but data recovery may not be necessary. As a matter of fact, most security violations are produced by unauthorized and unnoticed access for information purposes, but such snooping does not disrupt the database.
- *Corrupted*. Action is required to avoid the recurrence of similar security problems, and the database must be recovered to a consistent state. Corrupting security breaches include database access by computer viruses and by hackers who intend to destroy or alter data.

Table 15.4 illustrates some security vulnerabilities of system components and typical protective measures against them.

---

**Table 15.4 Sample Security Vulnerabilities and Related Protective Measures**

---

SYSTEM COMPONENT	SECURITY VULNERABILITY	SECURITY MEASURES
People	<ul style="list-style-type: none"> <li>The user sets a blank password.</li> <li>The password is short or includes a birth date.</li> <li>The user leaves the office door open all the time.</li> <li>The user leaves payroll information on the screen for long periods of time.</li> </ul>	<ul style="list-style-type: none"> <li>Enforce complex password policies.</li> <li>Use multilevel authentication.</li> <li>Use security screens and screen savers.</li> <li>Educate users about sensitive data.</li> <li>Install security cameras.</li> <li>Use automatic door locks.</li> </ul>
Workstation and servers	<ul style="list-style-type: none"> <li>The user copies data to a flash drive.</li> <li>The workstation is used by multiple users.</li> <li>A power failure crashes the computer.</li> <li>Unauthorized personnel can use the computer.</li> <li>Sensitive data are stored on a laptop computer.</li> <li>Data are lost due to a stolen hard disk or laptop.</li> <li>A natural disaster occurs.</li> </ul>	<ul style="list-style-type: none"> <li>Use group policies to restrict the use of flash drives.</li> <li>Assign user access rights to workstations.</li> <li>Install uninterrupted power supplies (UPSs).</li> <li>Add security locks to computers.</li> <li>Implement a kill switch for stolen laptops.</li> <li>Create and test data backup and recovery plans.</li> <li>Insure the system against natural disasters—use co-location strategies.</li> </ul>
Operating system	<ul style="list-style-type: none"> <li>Buffer overflow attacks</li> <li>Virus attacks</li> <li>Root kits and worm attacks</li> <li>Denial-of-service attacks</li> <li>Trojan horses</li> <li>Spyware applications</li> <li>Password crackers</li> </ul>	<ul style="list-style-type: none"> <li>Apply OS security patches and updates.</li> <li>Apply application server patches.</li> <li>Install antivirus and antispyware software.</li> <li>Enforce audit trails on the computers.</li> <li>Perform periodic system backups.</li> <li>Install only authorized applications.</li> <li>Use group policies to prevent unauthorized installations.</li> </ul>
Applications	<ul style="list-style-type: none"> <li>Application bugs—buffer overflow</li> <li>SQL injection, session hijacking, etc.</li> <li>Application vulnerabilities—cross-site scripting, nonvalidated inputs</li> <li>E-mail attacks—spamming, phishing, etc.</li> <li>Social engineering e-mails</li> </ul>	<ul style="list-style-type: none"> <li>Test application programs extensively.</li> <li>Build safeguards into code.</li> <li>Do extensive vulnerability testing in applications.</li> <li>Install spam filters and antivirus software for e-mail systems.</li> <li>Use secure coding techniques (see <a href="http://www.owasp.org">www.owasp.org</a>).</li> <li>Educate users about social engineering attacks.</li> </ul>
Network	<ul style="list-style-type: none"> <li>IP spoofing</li> <li>Packet sniffers</li> <li>Hacker attacks</li> <li>Clear passwords on network</li> </ul>	<ul style="list-style-type: none"> <li>Install firewalls.</li> <li>Use virtual private networks (VPNs).</li> <li>Use intrusion detection systems (IDSs).</li> <li>Use network access control (NAC).</li> <li>Use network activity monitoring.</li> </ul>
Data	<ul style="list-style-type: none"> <li>Data shares are open to all users.</li> <li>Data can be accessed remotely.</li> <li>Data can be deleted from a shared resource.</li> </ul>	<ul style="list-style-type: none"> <li>Implement file system security.</li> <li>Implement share access security.</li> <li>Use access permission.</li> <li>Encrypt data at the file system or database level.</li> </ul>

### 15.6.3 DATABASE SECURITY

---

**Database security** refers to DBMS features and other related measures that comply with the organization's security requirements. From the DBA's point of view, security measures should be implemented to protect the DBMS against service degradation and to protect the database against loss, corruption, or mishandling. In short, the DBA should secure the DBMS from the point of installation through operation and maintenance.

---

#### NOTE

---

James Martin's excellent description of the desirable attributes of a database security strategy remains relevant today (*Managing the Database Environment*, Prentice-Hall, 1977). Martin's security strategy is based on the seven essentials of database security, and may be summarized as one in which data are protected, reconstructable, auditable, and tamperproof, and users are identifiable, authorized, and monitored.

---

To protect the DBMS against service degradation, some security safeguards are recommended. For example:

- Change default system passwords.
  
- Change default installation paths.
  
- Apply the latest patches.
  
- Secure installation folders with proper access rights.
  
- Make sure that only required services are running.
  
- Set up auditing logs.
  
- Set up session logging.

- Require session encryption.

Furthermore, the DBA should work closely with the network administrator to implement network security that protects the DBMS and all services running on the network. In modern organizations, one of the most critical components in the information architecture is the network.

Protecting the data in the database is a function of authorization management. **Authorization management** defines procedures to protect and guarantee database security and integrity. Those procedures include the following:

- *User access management.* This function is designed to limit access to the database; it likely includes at least the following procedures:
  - *Define each user to the database.* The DBA performs this function at the operating system level and the DBMS level. At the operating system level, the DBA can request the creation of a unique user ID for each end user who logs on to the computer system. At the DBMS level, the DBA can either create a different user ID or employ the same one to authorize the end user to access the DBMS.
  - *Assign passwords to each user.* The DBA also performs this function at both the operating system and DBMS levels. The database passwords can be assigned with predetermined expiration dates, which enable the DBA to screen end users periodically and remind them to change their passwords, thus making unauthorized access less likely.
  - *Define user groups.* Classifying users into groups according to common access needs can help the DBA control and manage the access privileges of individual users. Also, the DBA can use database roles and resource limits to minimize the impact of rogue users in the system. (See [Section 15.9.6](#) for more information about these topics.)
  - *Assign access privileges.* The DBA assigns access privileges to specific users to access certain databases. Access rights may be limited to read-only, or the authorized access might include read, write, and delete privileges. Access privileges in relational databases are assigned through SQL GRANT and REVOKE commands.
  - *Control physical access.* Physical security can prevent unauthorized users from directly accessing the DBMS installation and facilities. Common physical security for large database installations includes

secured entrances, password-protected workstations, electronic personnel badges, closed-circuit video, voice recognition, and biometric technology.

- *View definition.* The DBA must define data views to protect and control the scope of the data that are accessible to an authorized user. The DBMS must provide tools that allow the definition of views composed of one or more tables, and must assign access rights to users. The SQL CREATE VIEW command is used in relational databases to define views. Oracle DBMS offers Virtual Private Database (VPD), which allows the DBA to create customized views of the data for different users. With this feature, the DBA could restrict regular users who query a payroll database to see only the necessary rows and columns, while department managers would see only the rows and columns pertinent to their departments.
- *DBMS access control.* Database access can be controlled by placing limits on the use of DBMS query and reporting tools. The DBA must make sure the tools are used properly and only by authorized personnel.
- *DBMS usage monitoring.* The DBA must also audit the use of data in the database. Several DBMS packages contain features that allow the creation of an [\*\*audit log\*\*](#), which automatically records a brief description of database operations performed by all users. Such audit trails enable the DBA to pinpoint access violations. The audit trails can be tailored to record all database accesses or just failed ones.

The integrity of a database could be lost because of external factors beyond the DBA's control. For example, the database might be damaged or destroyed by an explosion, a fire, or an earthquake. Whatever the reason, the specter of database corruption or destruction makes backup and recovery procedures crucial to any DBA.

---

## 15.7 DATABASE ADMINISTRATION TOOLS

---

The importance of the data dictionary as a DBA tool cannot be overstated. This

section examines the data dictionary as a data administration tool, as well as the DBA's use of computer-aided systems engineering (CASE) tools to support database analysis and design.

#### 15.7.1 THE DATA DICTIONARY

---

In [Chapter 1](#), a data dictionary was defined as “a DBMS component that stores the definition of data characteristics and relationships.” You may recall that such “data about data” are called metadata. The DBMS data dictionary provides the DBMS with its self-describing characteristic. In effect, the data dictionary resembles an X-ray of the company’s entire data set, and it is a crucial element in data administration.

Two main types of data dictionaries exist: integrated and standalone. An integrated data dictionary is included with the DBMS. For example, all relational DBMSs include a built-in data dictionary or system catalog that is frequently accessed and updated by the RDBMS. Other DBMSs, especially older types, do not have a built-in data dictionary; instead, the DBA may use thirdparty standalone systems.

Data dictionaries can also be classified as active or passive. An [\*\*active data dictionary\*\*](#) is automatically updated by the DBMS with every database access to keep its access information up to date. A [\*\*passive data dictionary\*\*](#) is not updated automatically and usually requires running a batch process. Data dictionary access information is normally used by the DBMS for query optimization.

The data dictionary’s main function is to store the description of all objects that interact with the database. Integrated data dictionaries tend to limit their metadata to the data managed by the DBMS. Standalone data dictionary systems are usually more flexible, and allow the DBA to describe and manage all of the organization’s data, whether they are computerized or not. Whatever the data dictionary’s format, it provides database designers and end users with a much-improved ability to communicate. In addition, the data dictionary is the tool that helps the DBA resolve data conflicts.

Although there is no standard format for the information stored in the data dictionary, several features are common. For example, the data dictionary typically stores descriptions of the following:

- *Data elements that are defined in all tables of all databases.* Specifically, the data dictionary stores element names, data types, display format,

internal storage format, and validation rules. The data dictionary explains where an element is used, who used it, and so on.

- *Tables defined in all databases.* For example, the data dictionary is likely to store the name of the table creator, the date of creation, access authorizations, and the number of columns.
- *Indexes defined for each database table.* For each index, the DBMS stores at least the index name, the attributes used, the location, specific index characteristics, and the creation date.
- *Defined databases.* This information includes who created each database, when the database was created, where the database is located, the DBA's name, and so on.
- *End users and administrators of the database.* This information defines the users of the database.
- *Programs that access the database.* This information includes screen formats, report formats, application programs, and SQL queries.
- *Access authorizations for all users of all databases.* This information defines who can manipulate which objects and what types of operations can be performed.
- *Relationships among data elements.* This information includes which elements are involved, whether the relationships are mandatory or optional, and connectivity and cardinality requirements.

If the data dictionary can be organized to include data external to the DBMS itself, it becomes an especially flexible tool for more general corporate resource management. Such an extensive data dictionary thus makes it possible to manage the use and allocation of all of the organization's information, regardless of whether it has its roots in the database data. For this reason, some managers consider the data dictionary to be a key element of information resource

management, which is why the data dictionary can be described as the [information resource dictionary](#).

The metadata stored in the data dictionary are often the basis for monitoring database use and for assigning access rights to database users. The information stored in the data dictionary is usually based on a relational table format, thus enabling the DBA to query the database with SQL commands. For example, SQL commands can be used to extract information about the users of a specific table or the access rights of a particular user. In the following section, the IBM DB2 system catalog tables are the basis for several examples of how a data dictionary is used to derive information:

- SYSTABLES stores one row for each table or view.
- SYSCOLUMNNS stores one row for each column of each table or view.
- SYSTABAUTH stores one row for each authorization given to a user for a table or view in a database.

## **Examples of Data Dictionary Usage**

### *Example 1*

List the names and creation dates of all tables created by the user JONESVI in the current database.

**SELECT NAME, CTIME**

## **FROM SYSTABLES**

**WHERE CREATOR = 'JONESVI';**

### *Example 2*

List the names of the columns for all tables created by JONESVI in the current database.

**SELECT NAME**

**FROM SYSCOLUMNNS**

```
WHERE TBCREATOR = 'JONESVI';
```

*Example 3*

List the names of all tables for which the user JONESVI has DELETE authorization.

**SELECT TTNAME**

**FROM SYSTABAUTH**

```
WHERE GRANTEE = 'JONESVI' AND DELETEAUTH = 'Y';
```

*Example 4*

List the names of all users who have some type of authority over the INVENTORY table.

**SELECT DISTINCT GRANTEE**

**FROM SYSTABAUTH**

```
WHERE TTNAME = 'INVENTORY';
```

*Example 5*

List the user and table names for all users who can alter the database structure for any table in the database.

**SELECT GRANTEE, TTNAME**

**FROM SYSTABAUTH**

```
WHERE ALTERAUTH = 'Y'
```

```
ORDER BY GRANTEE, TTNAME;
```

As you can see in the preceding examples, the data dictionary can be a tool for monitoring database security by checking the assignment of data access privileges. Although the preceding examples targeted database tables and users, information about the application programs that access the database can also be

drawn from the data dictionary.

The DBA can use the data dictionary to support data analysis and design. For example, the DBA can create a report that lists all data elements to be used in a particular application; a list of all users who access a particular program; a report that checks for data redundancies, duplications, and the use of homonyms and synonyms; and a number of other reports that describe data users, data access, and data structure. The data dictionary can also be used to ensure that application programmers have met the naming standards for data elements in the database, and that the data validation rules are correct. Thus, the data dictionary can be used to support a wide range of data administration activities and facilitate the design and implementation of information systems. Integrated data dictionaries are also essential to the use of computer-aided systems engineering tools.

#### 15.7.2 CASE TOOLS

---

**CASE** is the acronym for **computer-aided systems engineering**. A CASE tool provides an automated framework for the Systems Development Life Cycle (SDLC). CASE uses structured methodologies and powerful graphical interfaces. Because they automate many tedious system design and implementation activities, CASE tools play an increasingly important role in information systems development.

CASE tools are usually classified according to the extent of support they provide for the SDLC. For example, **front-end CASE tools** provide support for the planning, analysis, and design phases; **back-end CASE tools** provide support for the coding and implementation phases. The benefits associated with CASE tools include:

- A reduction in development time and costs
- Automation of the SDLC
- Standardization of systems development methodologies
- Easier maintenance of application systems developed with CASE tools

One of the CASE tools' most important components is an extensive data dictionary, which keeps track of all objects created by the systems designer. For example, the CASE data dictionary stores data flow diagrams, structure charts, descriptions of all external and internal entities, data stores, data items, report

formats, and screen formats. A CASE data dictionary also describes the relationships among system components.

Several CASE tools provide interfaces that work with the DBMS and allow the CASE tool to store its data dictionary information using the DBMS. Such interaction demonstrates the interdependence that exists between systems development and database development, and it helps create a fully integrated development environment.

In a CASE development environment, database and application designers use the CASE tool to store the description of the database schema, data elements, application processes, screens, reports, and other data relevant to development. The CASE tool integrates all systems development information in a common repository, which the DBA can check for consistency and accuracy.

As an additional benefit, a CASE environment tends to improve the extent and quality of communication among the DBA, application designers, and end users. The DBA can use the CASE tool to check the definition of the application's data schema, the observance of naming conventions, the duplication of data elements, validation rules for the data elements, and a host of other developmental and managerial variables. When the CASE tool finds conflicts, rules violations, and inconsistencies, it facilitates making corrections. Better yet, the CASE tool can make a correction and then cascade its effects throughout the applications environment, which greatly simplifies the job of the DBA and the application designer.

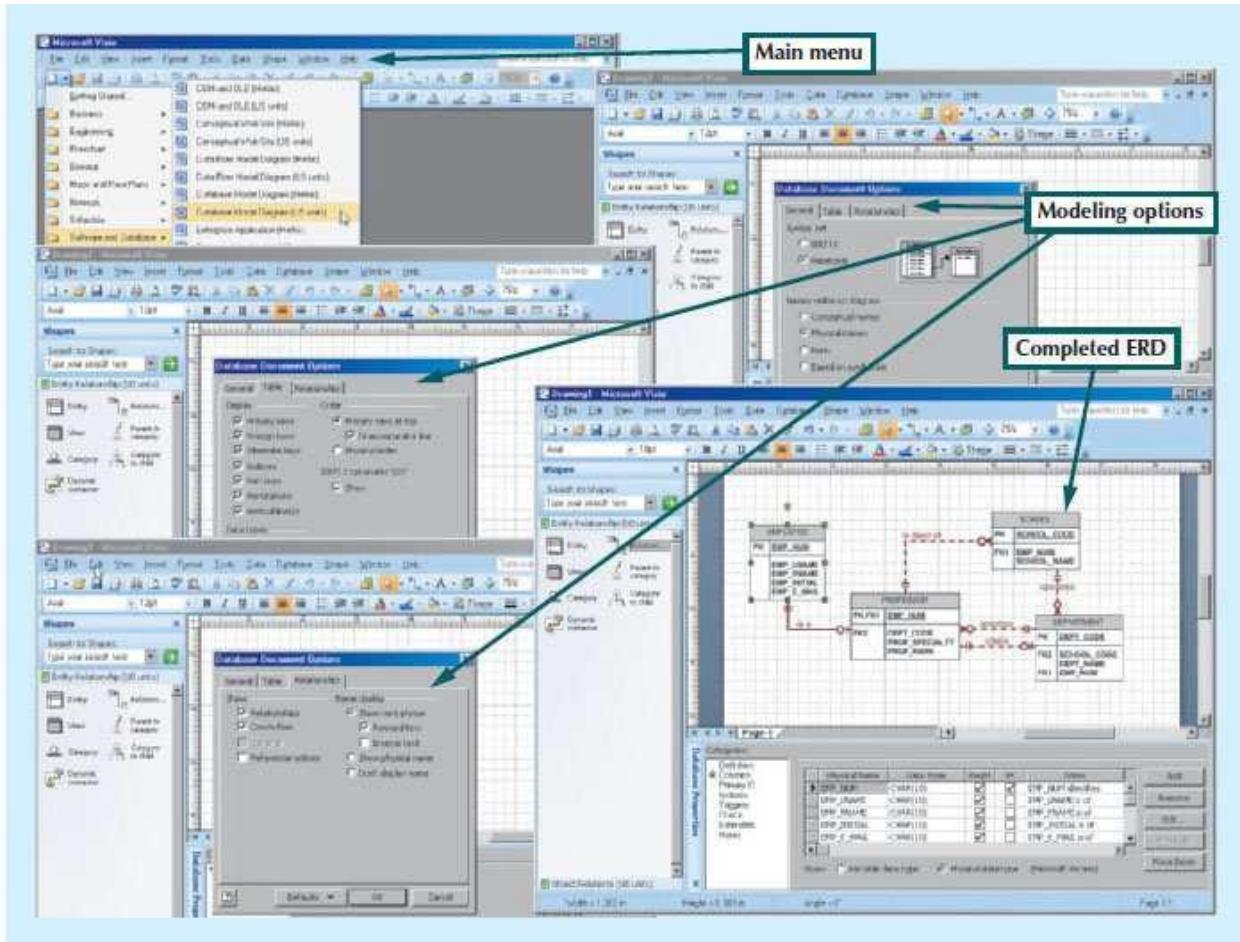
A typical CASE tool provides five components:

- Graphics designed to produce structured diagrams such as data flow diagrams, ER diagrams, class diagrams, and object diagrams
- Screen painters and report generators to produce the information system's input and output formats (for example, the end-user interface)
- An integrated repository for storing and cross-referencing the system design data; this repository includes a comprehensive data dictionary
- An analysis segment to provide a fully automated check on system consistency, syntax, and completeness
- A program documentation generator

Figure 15.7 illustrates how Microsoft Visio Professional can be used to produce

an ER diagram.

Figure 15.7 An example of a CASE tool: Visio Professional



SOURCE: Course Technology/Cengage Learning

One CASE tool, ERwin Data Modeler by Computer Associates, produces fully documented ER diagrams that can be displayed at different abstraction levels. In addition, ERwin can produce detailed relational designs. The user specifies the attributes and primary keys for each entity and describes the relations. ERwin then assigns foreign keys based on the specified relationships among the entities. Changes in primary keys are always updated automatically throughout the system. [Table 15.5](#) shows a short list of the many available CASE tool vendors.

---

**TABLE 15.5 CASE Tools**

---

COMPANY	PRODUCT	WEBSITE
Casewise	Corporate Modeler Suite	<a href="http://www.casewise.com">www.casewise.com</a>
Computer Associates	ERwin	<a href="http://www.erwin.com">www.erwin.com</a>
Embarcadero Technologies	ER/Studio	<a href="http://www.embarcadero.com/products/er-studio-data-architect">www.embarcadero.com/products/er-studio-data-architect</a>
Microsoft	Visio	<a href="http://office.microsoft.com/en-us/visio">office.microsoft.com/en-us/visio</a>
Oracle	SQL Developer Data Modeler	<a href="http://www.oracle.com/technetwork/developer-tools/datamodeler/overview/index.html">www.oracle.com/technetwork/developer-tools/datamodeler/overview/index.html</a>
IBM	Rational Software Architect	<a href="http://www-01.ibm.com/software/rational/products/swarchitect/">www-01.ibm.com/software/rational/products/swarchitect/</a>
Sybase	Power Designer	<a href="http://www.sybase.com/products/modelingdevelopment/powerdesigner">www.sybase.com/products/modelingdevelopment/powerdesigner</a>
Visible	Visible Analyst	<a href="http://www.visible.com/Products/Analyst">www.visible.com/Products/Analyst</a>

---

Major relational DBMS vendors, such as Oracle, now provide fully integrated CASE tools for their own DBMS software as well as for RDBMSs supplied by other vendors. For example, Oracle's CASE tools can be used with IBM's DB2, SQL/DS, and Microsoft's SQL Server to produce fully documented database designs. Some vendors even take nonrelational DBMSs, develop their schemas, and produce the equivalent relational designs automatically.

There is no doubt that CASE tools have enhanced the efficiency of database designers and application programmers. However, no matter how sophisticated the CASE tool, its users must be well versed in conceptual design. In the hands of database novices, CASE tools produce impressive-looking but bad designs.

---

## 15.8 DEVELOPING A DATA ADMINISTRATION STRATEGY

---

For a company to succeed, its activities must be committed to its main objectives or mission. Therefore, regardless of its size, a critical step for any organization is to ensure that its information system supports its strategic plans for each business area.

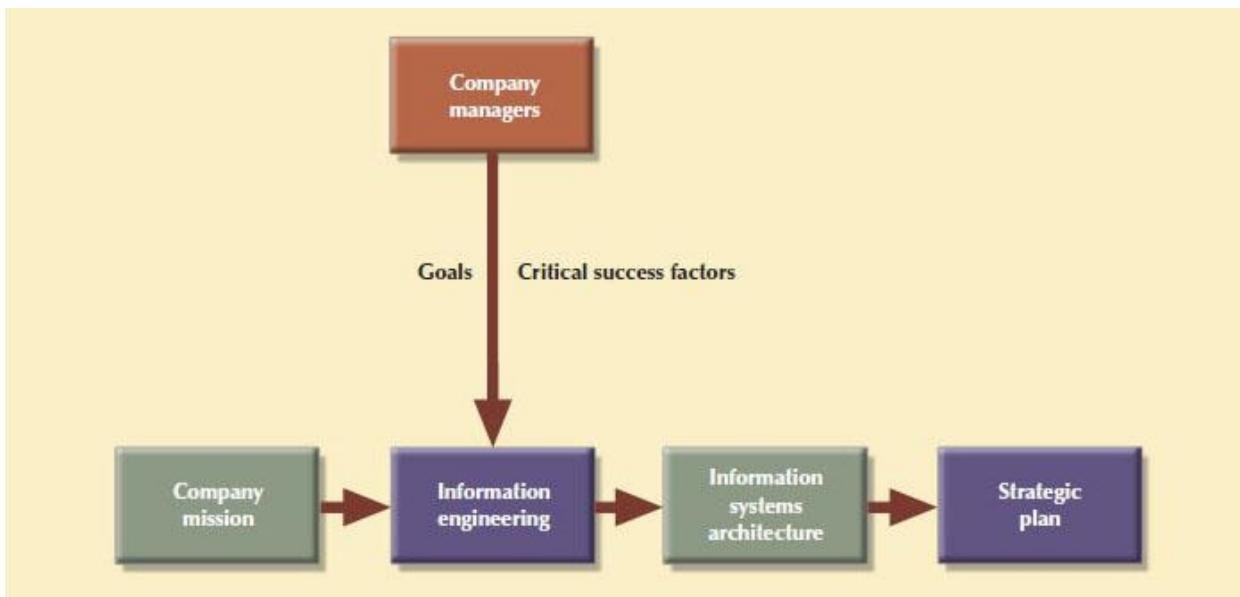
The database administration strategy must not conflict with the information systems plans. After all, these plans are derived from a detailed analysis of the company's goals, its condition or situation, and its business needs. Several methodologies are available to ensure the compatibility of data administration and information systems plans and to guide strategic plan development. The

most commonly used methodology is known as information engineering.

**Information engineering (IE)** allows for translation of the company's strategic goals into the data and applications that will help the company achieve those goals. IE focuses on the description of corporate data instead of the processes. The IE rationale is simple: business data types tend to remain fairly stable, but processes change often and thus require frequent modification of existing systems. By placing the emphasis on data, IE helps decrease the impact on systems when processes change.

The output of the IE process is an **information systems architecture (ISA)** that serves as the basis for planning, development, and control of future information systems. [Figure 15.8](#) shows the forces that affect ISA development.

#### **FIGURE 15.8 Forces affecting the development of the ISA**



SOURCE: Course Technology/Cengage Learning

Implementing IE in an organization is a costly process that involves planning, a commitment of resources, management liability, well-defined objectives, identification of critical factors, and control. An ISA provides a framework that includes computerized, automated, and integrated tools such as a DBMS and CASE tools.

The success of the overall information systems strategy and data administration strategy depends on several critical success factors that the DBA needs to understand. Critical success factors include the following managerial, technological, and corporate culture issues:

- *Management commitment.* The commitment of top-level management is necessary to enforce the use of standards, procedures, planning, and controls. The example must be set at the top.
- *Thorough analysis of the company situation.* The current state of the corporate data administration must be analyzed to understand the company's position and to have a clear vision of what must be done. For example, how are database analysis, design, documentation, implementation, standards, codification, and other issues handled? Needs and problems should be identified first and then prioritized.
- *End-user involvement.* What degree of organizational change is involved? Successful change requires that people be able to adapt to it. Users should have an open communication channel to upper management to ensure success of the implementation. Good communication is key to the overall process.
- *Defined standards.* Analysts and programmers must be familiar with appropriate methodologies, procedures, and standards. If not, they might need training.
- *Training.* The vendor must train DBA personnel in the use of the DBMS and other tools. End users must be trained to use the tools, standards, and procedures. Key personnel should be trained first so they can train others.
- *A small pilot project.* A small project is recommended to ensure that the DBMS will work in the company, that it produces expected output, and that the personnel have been trained properly.

This list of factors is not comprehensive, but it does provide the framework for developing a successful strategy. Remember that no matter how comprehensive

you make the list, it must be based on developing and implementing a data administration strategy that is tightly integrated with the organization's overall information systems planning.

---

## 15.9 THE DBA AT WORK: USING ORACLE FOR DATABASE ADMINISTRATION

---

Thus far, you have learned about the DBA's work environment and responsibilities in general terms. This section provides a more detailed look at how a DBA might handle the following technical tasks in a specific DBMS:

- Creating and expanding database storage structures
  - Managing database objects such as tables, indexes, triggers, and procedures
  - Managing the end-user database environment, including the type and extent of database access
- Customizing database initialization parameters

Many of these tasks require the DBA to use software tools and utilities that are commonly provided by the database vendor. In fact, all DBMS vendors provide a set of programs to interface with the database and to perform a wide range of database administrative tasks.

Oracle 11g for Windows is used to illustrate selected DBA tasks in this section because Oracle is typically used in organizations that are large and complex enough to employ a DBA. Also, Oracle has good market presence and is often used in small colleges and universities.

---

### NOTE

---

Although Microsoft Access is a superb DBMS, it is typically used in smaller organizations or in organizations and departments with relatively simple data environments. Access has a superior database prototyping environment, and its easy-to-use GUI tools enable rapid front-end application development. Also, Access is a component in the MS Office suite, which makes applications integration relatively simple and seamless for end users. Finally, while Access does provide some important database administration tools, an Access-based database environment does not

---

typically require a DBA, so MS Access is not a good fit for this section.

---

Most of the tasks described in this section are not particular to any DBMS or operating system. However, the *execution* of those tasks tends to be specific to the DBMS and operating system. Therefore, if you use IBM DB2 Universal Database or Microsoft SQL Server, you must adapt the procedures shown here to your DBMS. Also, these examples run under the Windows operating system, so you must adapt the procedures shown in this section if you use a different OS.

This section is not a database administration manual; it offers a brief introduction to performing typical DBA tasks in Oracle. Before learning these tasks, you should become familiar with Oracle's database administration tools and its procedures for logging on. These tools and procedures are discussed in the next two sections.

---

#### NOTE

---

Although the format of creating a database tends to be generic, its execution tends to be DBMS-specific. For a step-by-step procedure of creating a database using the Oracle Database Configuration Assistant, see **Appendix N, Creating a New Database Using Oracle 11g**.

#### 15.9.1 ORACLE DATABASE ADMINISTRATION TOOLS

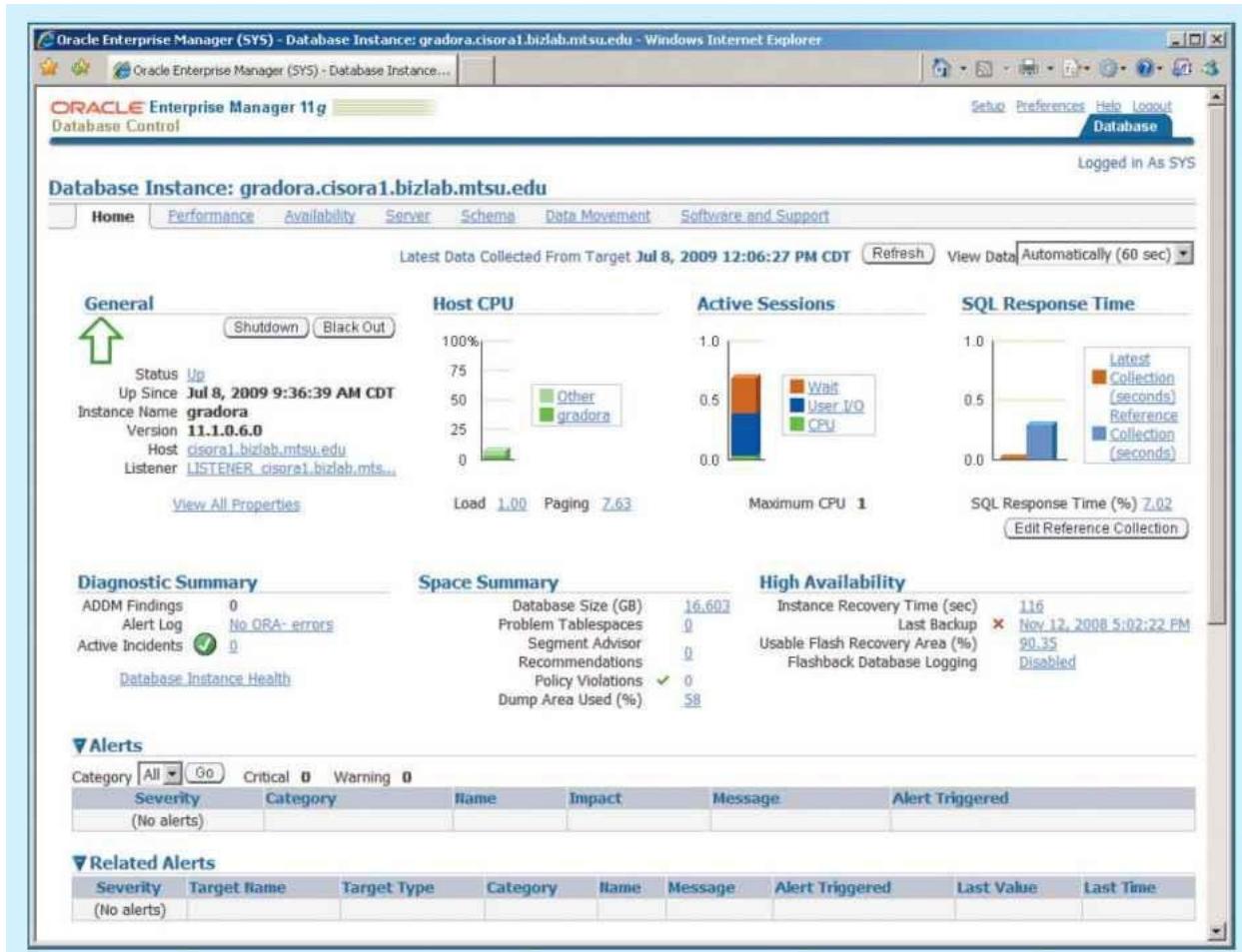
---

All database vendors supply a set of database administration tools. In Oracle, you perform most DBA tasks via the Oracle Enterprise Manager interface. (See [Figure 15.9](#).)

---

**FIGURE 15.9** The Oracle Enterprise Manager interface

---



SOURCE: Course Technology/Cengage Learning

---

Note that the interface shows the status of the current database. (This section uses the GRADORA database.) In the following sections, you examine the tasks most commonly encountered by a DBA.

#### 15.9.2 THE DEFAULT LOGIN

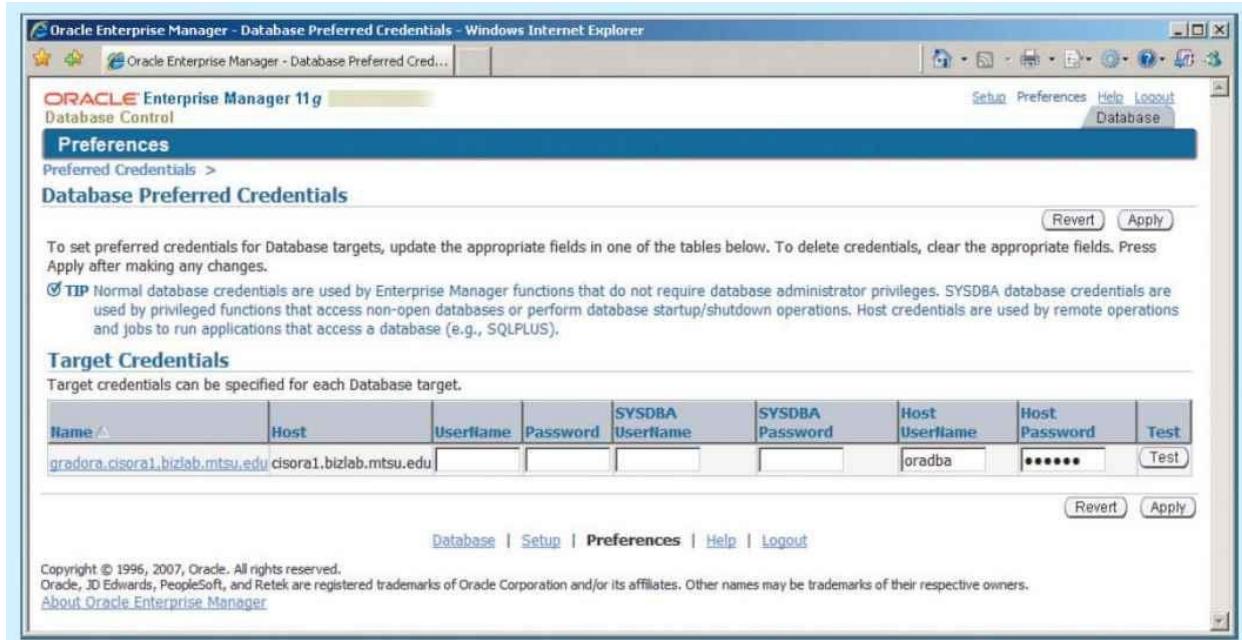
---

To perform any administrative task, you must connect to the database using a username with administrative (DBA) privileges. By default, Oracle automatically creates SYSTEM and SYS user IDs that have administrative privileges with every new database you create. You can define the preferred credentials for each database by clicking the Preferences link at the top of the page, clicking Preferred Credentials, and choosing your target username under Set Credentials. [Figure 15.10](#) shows the Edit Local Preferred Credentials page that defines the user ID (SYS) used to log on to the GRADORA database.

---

**FIGURE 15.10 The Oracle Edit Local Preferred Credentials page**

---



SOURCE: Course Technology/Cengage Learning

---

Keep in mind that usernames and passwords are database-specific. Therefore, each database can have different usernames and passwords. One of your first tasks is to change the password for the SYSTEM and SYS users. Next, you can start defining your users and assigning them database privileges.

#### 15.9.3 ENSURING THAT THE RDBMS STARTS AUTOMATICALLY

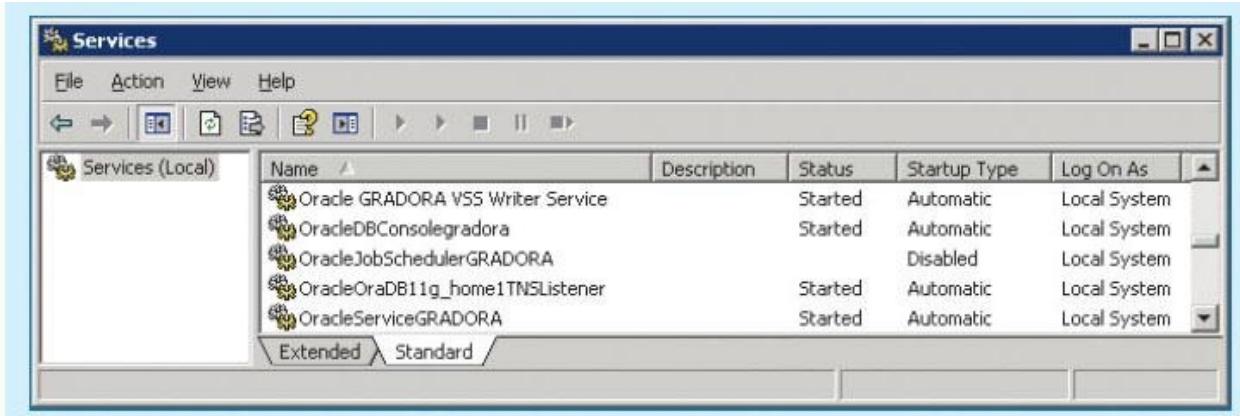
---

One of a DBA's basic tasks is to ensure that database access starts automatically when you turn on the computer. Startup procedures are different for each operating system. Oracle is used for this section's examples; if you use a different system, you need to identify the required services to ensure automatic database startup. A *service* is the Windows name for a special program that runs automatically as part of the operating system. This program ensures the availability of required services to the system and to end users on the local computer or the network. [Figure 15.11](#) shows the required Oracle services that are started automatically when Windows starts.

---

**FIGURE 15.11 Oracle RDBMS services**

---



SOURCE: Course Technology/Cengage Learning

---

As you examine [Figure 15.11](#), note the following Oracle services:

- *OracleOraDb11g\_home1TNSListener* is the process that “listens to” and processes end-user connection requests over the network. For example, when a SQL connection request such as “connect userid/password@GRADORA” is sent over the network, the listener service will validate the request and establish the connection.
- *OracleServiceGRADORA* refers to the Oracle processes running in memory that are associated with the GRADORA database instance. You can think of a [database instance](#) as a separate location in memory that is reserved to run your database. Because you can have several databases (and therefore several instances) running in memory at the same time, you need to identify each database instance uniquely, using a different suffix for each one.

#### 15.9.4 CREATING TABLESPACES AND DATAFILES

---

Each DBMS manages data storage differently. In this example, the Oracle RDBMS is used to illustrate how the database manages data storage at the logical and physical levels. In Oracle:

- A database is *logically* composed of one or more tablespaces. A **tablespace** is a logical storage space. Tablespaces are used primarily to group related data logically.
- The tablespace data are *physically* stored in one or more datafiles. A **datafile** physically stores the database's data. Each datafile is associated with only one tablespace, but each datafile can reside in a different directory on the hard disk or on multiple hard disks.

Given the preceding descriptions, you can conclude that a database has a one-to-many relationship with tablespaces and that a tablespace has a one-to-many relationship with datafiles. This set of 1:M hierarchical relationships isolates the end user from any physical details of data storage. However, *the DBA must be aware of these details to properly manage the database*.

To manage database storage, such as creating and managing tablespaces and datafiles, the DBA uses the Enterprise Manager → Server → Storage option. (See [Figure 15.12](#).)

---

---

**FIGURE 15.12 The Oracle Storage Manager**

---

---

The screenshot shows the Oracle Enterprise Manager 11g interface for managing tablespaces. The main window title is "Oracle Enterprise Manager (SYS) - Tablespaces - Windows Internet Explorer". The top menu bar includes "Setup", "Preferences", "Help", "Logout", and "Database". The sub-menu "Database Control" is selected. The URL in the address bar is "Database Instance: gradora.cisora1.bizlab.mtsu.edu > Tablespaces". The status bar indicates "Logged in As SYS".

**Tablespaces**

Object Type: Tablespace

**Search**  
Enter an object name to filter the data that is displayed in your results set.  
Object Name:  Go

By default, the search returns all uppercase matches beginning with the string you entered. To run an exact or case-sensitive match, double quote the search string. You can use the wildcard symbol (%) in a double quoted string.

Selection Mode: Single

**Actions**: Edit, View, Delete, Add Datafile, Go

Select	Name	Allocated Size(MB)	Space Used(MB)	Allocated Space Used(%)	Allocated Free Space(MB)	Status	Datafiles	Type	Extent Management	Segment Management
<input checked="" type="radio"/>	SYSAUX	899.4	852.9	94.8	46.4	✓	1	PERMANENT	LOCAL	AUTO
<input type="radio"/>	SYSTEM	710.0	703.9	99.1	6.1	✓	1	PERMANENT	LOCAL	MANUAL
<input type="radio"/>	TEMP	3,845.0	0.0	0.0	3,845.0	✓	1	TTEMPORARY	LOCAL	MANUAL
<input type="radio"/>	UNDOTBS1	6,510.0	18.2	0.3	6,491.8	✓	1	UNDO	LOCAL	MANUAL
<input type="radio"/>	USERS	5,037.2	4,710.3	93.5	326.9	✓	1	PERMANENT	LOCAL	AUTO

Total Allocated Size (MB): 17,001.6      Total Used (MB): 6,285.3      Total Allocated Free Space (MB): 10,716.2

✓ Online    ✘ Offline    📁 Read Only

[Database](#) | [Setup](#) | [Preferences](#) | [Help](#) | [Logout](#)

Copyright © 1996, 2007, Oracle. All rights reserved.  
Oracle, JD Edwards, PeopleSoft, and Retek are registered trademarks of Oracle Corporation and/or its affiliates. Other names may be trademarks of their respective owners.  
[About Oracle Enterprise Manager](#)

SOURCE: Course Technology/Cengage Learning

---

When the DBA creates a database, Oracle automatically creates the tablespaces and datafiles shown in [Figure 15.12](#). A few of them are described here.

- The *SYSTEM* tablespace is used to store the data dictionary data.
  
  
  
  
  
  
- The *USERS* tablespace stores the table data created by the end users.
- The *TEMP* tablespace stores the temporary tables and indexes created during the execution of SQL statements. For example, temporary tables are created when your SQL statement contains an ORDER BY, GROUP BY, or HAVING clause.
  
  
  
  
  
  
- The *UNDOTBS1* tablespace stores database transaction recovery information. If a transaction must be rolled back (usually to preserve database integrity), the *UNDOTBS1* tablespace stores the undo

information.

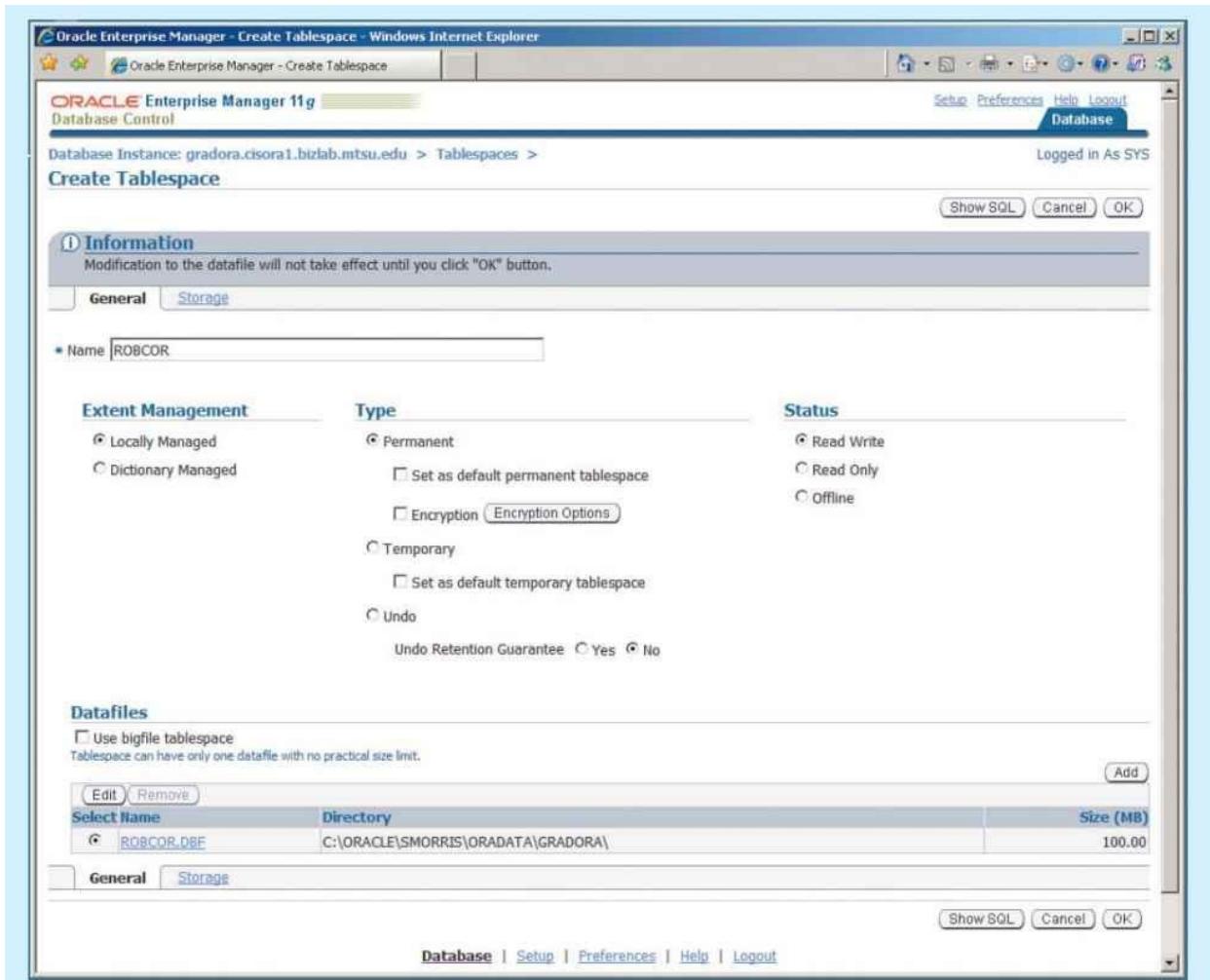
Using the Storage Manager, the DBA can:

- Create additional tablespaces to organize the data in the database. Therefore, if you have a database with several hundred users, you can create several user tablespaces to segment data storage for different types of users. For example, you might create a teacher tablespace and a student tablespace.
- Create additional tablespaces to organize the various subsystems within the database. For example, you might create different tablespaces for human resources data, payroll data, accounting data, and manufacturing data. [Figure 15.13](#) shows the page used to create a tablespace called ROBCOR that holds the tables used in this book. This tablespace is stored in the datafile named C:\ORACLE\SMORRIS\ORADATA\GRADORA\ ROBCOR.DBF, and its initial size is 100 megabytes. Note that the tablespace is available to users for data storage purposes. Also, you can click the Show SQL button at the top of the page to see the SQL code generated by Oracle to create the tablespace. (All DBA tasks can be accomplished through the direct use of SQL commands. In fact, some die-hard DBAs prefer writing their own SQL code rather than using the GUI.)
- Expand the tablespace storage capacity by creating additional datafiles. Remember that the datafiles can be stored in the same directory or on different hard disks to increase access performance. For example, you could increase storage and access performance to the USERS tablespace by creating a new datafile on a different drive.

---

**FIGURE 15.13 Creating a new tablespace**

---



SOURCE: Course Technology/Cengage Learning

---

#### 15.9.5 MANAGING THE DATABASE OBJECTS: TABLES, VIEWS, TRIGGERS, AND PROCEDURES

---

Another important aspect of managing a database is monitoring the objects that were created in the database. The Oracle Enterprise Manager gives the DBA a graphical user interface to create, edit, view, and delete objects in the database. A **database object** basically is any object created by end users—for example, tables, views, indexes, stored procedures, and triggers. [Figure 15.14](#) shows some of the types of objects listed in the Oracle Schema Manager.

---

**FIGURE 15.14** The Oracle Schema Manager

---

The screenshot shows the Oracle Enterprise Manager 11g interface. The title bar reads "Oracle Enterprise Manager (SYS) - Tables - Windows Internet Explorer". The main header says "ORACLE Enterprise Manager 11g Database Control". Below it, "Database Instance: gradora.csora1.bizlab.mtsu.edu >" is displayed. On the right, there are links for "Setup", "Preferences", "Help", "Logout", and "Database". A message "Logged In As SYS" is shown. The main content area is titled "Tables". It includes a "Search" section with fields for "Schema" (set to "SYS") and "Object Name", and a "Go" button. Below this is a note about search behavior. A "Selection Mode" dropdown is set to "Single". At the top of the table area are buttons for "Edit", "View", "Delete With Options", "Actions", "Create Like", and "Go". To the right of the table are buttons for "Previous" and "1-25". The table itself has columns: "Select Schema", "Table Name", "Tablespace", "Partitioned", "Rows", and "Last Analyzed". The "Table" option is highlighted in the dropdown menu on the right. The table lists numerous system objects, such as ACCESS, ALERT\_QT, and various APPLYS and APPROLES entries.

SOURCE: Course Technology/Cengage Learning

An Oracle **schema** is a logical section of the database that belongs to a given user; the schema is identified by the username. For example, if the user named SYSTEM creates a VENDOR table, it will belong to the SYSTEM schema. Oracle prefixes the table name with the username. Therefore, the SYSTEM's VENDOR table will be named SYSTEM.VENDOR by Oracle. Similarly, if the user PEROB creates a VENDOR table, it will be created in the PEROB schema under the name PEROB.VENDOR.

Within the schema, users can create their own tables and other objects. The database can contain as many different schemas as there are users. Because users see only their own objects, each user could get the impression that no one else uses the database.

Normally, users are authorized to access only the objects that belong to their own

schemas. Users could give other users access to their data by changing access rights. In fact, all users with DBA authorization have access to all objects in all schemas in the database.

As you can see in [Figure 15.14](#), the Schema Manager presents an organized view of all objects in the database schema. With this program, the DBA can create, edit, view, and delete any of the objects shown in the Object Type list.

#### 15.9.6 MANAGING USERS AND ESTABLISHING SECURITY

---

One of the most common database administration activities is creating and managing database users. The creation of user IDs is the first component of any well-planned database security function.

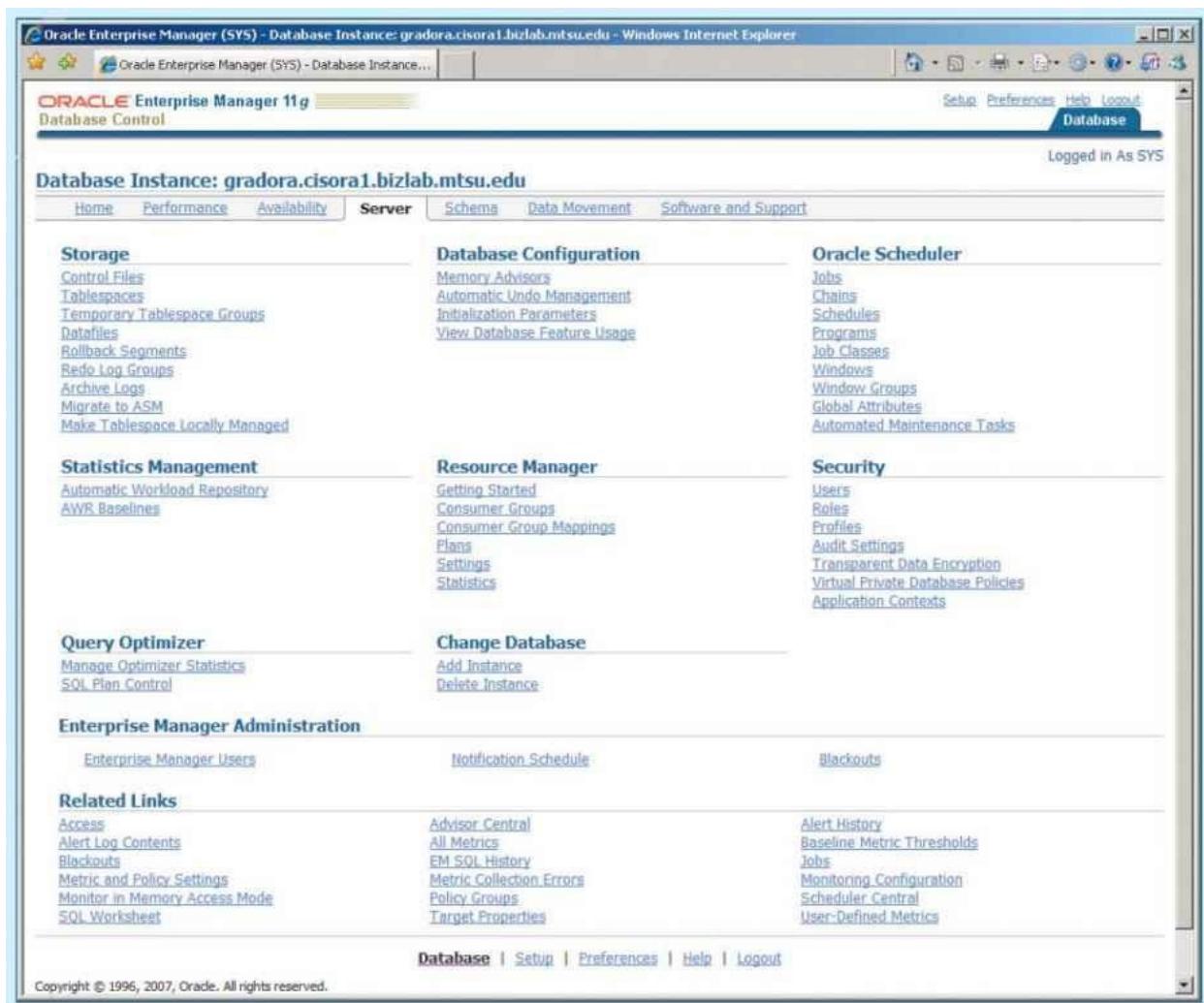
The Security section of the Oracle Enterprise Manager's Administration page enables the DBA to create users, roles, and profiles.

- A **user** is a uniquely identifiable object that allows a given person to log on to the database. The DBA assigns privileges for accessing the objects in the database. Within the privilege assignment, the DBA may specify a set of limits that define how many database resources the user can use.
  
- A **role** is a named collection of database access privileges that authorize a user to connect to the database and use its system resources. Examples of roles are as follows:
  - *CONNECT* allows a user to connect to the database and then create and modify tables, views, and other data-related objects.
  - *RESOURCE* allows a user to create triggers, procedures, and other data management objects.
  - *DBA* gives the user database administration privileges.
- A **profile** is a named collection of settings that control how much of the database resource a given user can access. For example, a runaway query could cause the database to lock up or stop responding to the user's commands, so it is important to limit access to the database resource. By specifying profiles, the DBA can limit how much storage space a user can have, how long a user can be connected, how much idle time may be used before the user is disconnected, and so on. In an ideal world, all users would have unlimited access to all resources at all times, but

realistically, such access is neither possible nor desirable.

[Figure 15.15](#) shows the Oracle Enterprise Manager Server page. From here, the DBA can manage the database and create security objects such as users, roles, and profiles.

**FIGURE 15.15** The Oracle Enterprise Manager Administration page



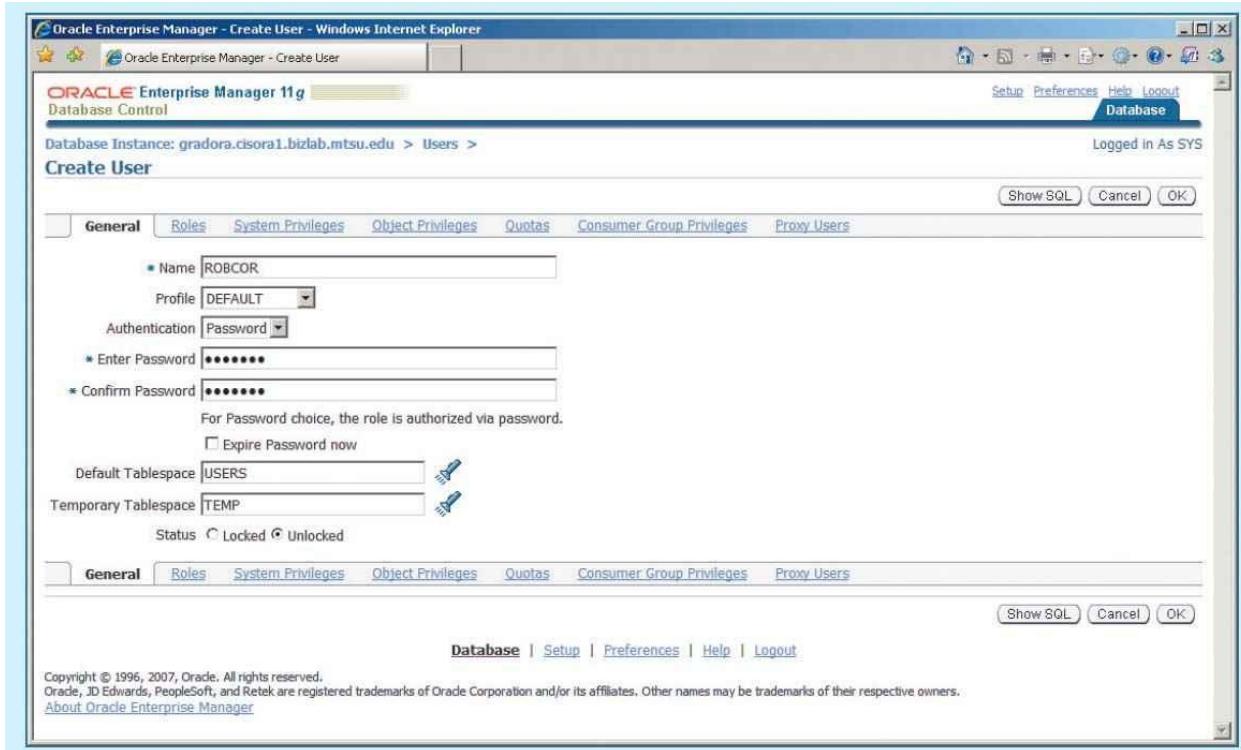
SOURCE: Course Technology/Cengage Learning

To create a new user, the DBA uses the Create User page, shown in [Figure 15.16](#).

---

**FIGURE 15.16 The Create User page**

---



SOURCE: Course Technology/Cengage Learning

---

The Create User page contains many links; the most important ones are as follows:

- The *General* link allows the DBA to assign a name, profile, and password to the new user. The DBA also uses this link to define the default tablespace to store table data and the temporary tablespace for temporary data.
- The *Roles* link allows the DBA to assign roles for a user.
- The *Object Privileges* link allows the DBA to assign specific access rights to other database objects.

- The *Quotas* link allows the DBA to specify the maximum amount of storage that the user can have in each assigned tablespace.

#### 15.9.7 CUSTOMIZING THE DATABASE INITIALIZATION PARAMETERS

---

Fine-tuning a database is another important DBA task that usually requires the modification of database configuration parameters, some of which can be changed in real time using SQL commands. Changes to other parameters require the database to be shut down and restarted. Also, some parameters may affect only the database instance, while others affect the entire RDBMS and all instances that are running. So, it is very important that the DBA become familiar with database configuration parameters, especially those that affect performance.

Each database has an associated initialization file that stores its run-time configuration parameters. The initialization file is read at instance startup and is used to set the working environment for the database. Oracle's Enterprise Manager allows the DBA to start, shut down, view, and edit the database configuration parameters of a database instance; these parameters are stored in the initialization file. The Oracle Enterprise Manager provides a GUI to modify the file, as shown in [Figure 15.17](#).

---

**FIGURE 15.17** The Oracle Enterprise Manager initialization parameters

---

The screenshot shows the Oracle Enterprise Manager (SYS) - Initialization Parameters interface in Windows Internet Explorer. The title bar reads "Oracle Enterprise Manager (SYS) - Initialization Parameters - Windows Internet Explorer". The main content area is titled "Initialization Parameters" with tabs for "Current" and "SPFILE". A message states: "The parameter values listed here are currently used by the running instance(s). You can change static parameters in SPFILE mode." Below this is a search bar with dropdowns for "Name", "Basic", "Modified", "Dynamic", and "Category" set to "All". A "Go" button and a "Filter on a name or partial name" input field are also present. A checkbox "Apply changes in current running instance(s) mode to SPFILE. For static parameters, you must restart the database." is checked. At the bottom right are "Save to File" and "Cancel" buttons. The main table lists 288 parameters, with the first few rows shown below:

Name	Type	Basic	Modified	Dynamic
audit_file_dest	String	✓	✓	Se
audit_trail	String	✓	✓	Se
diagnostic_dest	String	✓	✓	Mi
dispatchers	String	✓	✓	Sh
log_archive_format	String	✓	✓	Se
compatible	String	✓	✓	Mi
control_files	String	✓	✓	Fil
db_block_size	Integer	✓	✓	Me
db_domain	String	✓	✓	Da
db_name	String	✓	✓	Da
db_recovery_file_dest	String	✓	✓	Ba
db_recovery_file_dest_size	Big Integer	✓	✓	Re
open_cursors	Integer	✓	✓	Cu

SOURCE: Course Technology/Cengage Learning

---

One of the important functions of the initialization parameters is to reserve the resources that the database uses at run time. One of those resources is the primary memory reserved for database caching. Such caching is used to fine-tune database performance. For example, the “db\_cache\_size” parameter sets the amount of memory reserved for database caching. This parameter should be set to a value that is large enough to support all concurrent transactions. Once you modify the initialization parameters, you may be required to restart the database.

As you have seen in this brief section, the DBA is responsible for a wide range of tasks. The quality and completeness of administration tools go a long way toward making the DBA’s job easier. Even so, the DBA must become familiar with the tools and technical details of the RDBMS to perform tasks properly and efficiently.

---

## SUMMARY

---

- Data management is a critical activity for any organization, so data must be treated as a corporate asset. The value of a data set is measured by the utility of the information derived from it. Good data management is likely to produce good information, which is the basis for better decision making.
- Data quality is a comprehensive approach to ensure the accuracy, validity, and timeliness of data. Data quality focuses on correcting dirty data, preventing future inaccuracies in the data, and building user confidence in the data.
- The DBMS is the most commonly used tool for corporate data management. The DBMS supports strategic, tactical, and operational decision making at all levels of the organization. The introduction of a DBMS into an organization is a delicate job; the impact of the DBMS on the organization's managerial and cultural framework must be carefully examined.
- The database administrator (DBA) is responsible for managing the corporate database. The internal organization of database administration varies from company to company. Although no standard exists, it is common practice to divide DBA operations according to phases of the Database Life Cycle. Some companies have created a position with a broader mandate to manage computerized data and other data; this activity is handled by the data administrator (DA).
- The DA and DBA functions tend to overlap. Generally speaking, the DA has more managerial tasks than the more technically oriented DBA. Compared to the DBA function, the DA function is DBMS-independent, with a broader and longer-term focus. However, when the organization does not include a DA position, the DBA executes all of the DA's functions. In this combined role, the DBA must have a diverse mix of technical and managerial skills.
- A DBA's managerial services include supporting end users; defining and enforcing policies, procedures, and standards for the database; ensuring

data security, privacy, and integrity; providing data backup and recovery services; and monitoring distribution and use of the data in the database.

- The DBA's technical role requires involvement in at least the following activities: evaluating, selecting, and installing the DBMS; designing and implementing databases and applications; testing and evaluating databases and applications; operating and maintaining the DBMS, utilities, and applications; and training and supporting users.
  
- Security refers to activities and measures that ensure the confidentiality, integrity, and availability of an information system and its main asset, data. A security policy is a collection of standards, policies, and practices that guarantee the security of a system and ensure auditing and compliance.
- security vulnerability is a weakness in a system component that could be exploited to allow unauthorized access or service disruption. A security threat is an imminent security violation caused by an unchecked vulnerability. Security vulnerabilities exist in all components of an information system: people, hardware, software, network, procedures, and data. Therefore, it is critical to have robust database security. Database security refers to DBMS features and related measures that comply with the organization's security requirements.
  
- The development of a data administration strategy is closely related to the company's mission and objectives. Therefore, the strategic plan requires a detailed analysis of company goals, its situation, and its business needs. To guide the development of this data administration plan, an integrating methodology is required. The most commonly used integrating methodology is known as information engineering (IE).
- To help translate strategic plans into operational plans, the DBA has access to an arsenal of database administration tools, including a data dictionary and computer-aided systems engineering (CASE) tools.

---

#### KEY TERMS

---

[access plan](#)

[active data dictionary](#)  
[audit log](#)  
[authorization management](#)  
[availability](#)  
[back-end CASE tools](#)  
[CASE \(computer-aided systems engineering\)](#)  
[compliance](#)  
[concurrent backup](#)  
[confidentiality](#)  
[data administrator \(DA\)](#)  
[data-profiling software](#)  
[data quality](#)  
[database administrator \(DBA\)](#)  
[database dump](#)  
[database instance \(Oracle\)](#)  
[database object \(Oracle\)](#)  
[database security](#)  
[database security officer \(DSO\)](#)  
[datafile \(Oracle\)](#)  
[dirty data](#)  
[disaster management](#)  
[enterprise database](#)  
[front-end CASE tools](#)  
[full backup \(database dump\)](#)  
[incremental backup](#)  
[information engineering \(IE\)](#)  
[information resource dictionary](#)  
[information resource manager](#)  
[information systems architecture \(ISA\)](#)  
[information systems \(IS\) department](#)  
[integrity](#)  
[master data management \(MDM\)software](#)  
[passive data dictionary](#)  
[policies](#)  
[privacy](#)  
[procedures](#)

[profile \(Oracle\)](#)  
[role \(Oracle\)](#)  
[schema \(Oracle\)](#)  
[security](#)  
[security breach](#)  
[security policy](#)  
[security threat](#)  
[security vulnerability](#)  
[standards](#)  
[systems administrator](#)  
[tablespace \(Oracle\)](#)  
[user \(Oracle\)](#)

---



#### ONLINE CONTENT

Flashcards and crossword puzzles for key term practice are available at [www.cengagebrain.com](http://www.cengagebrain.com).

---

---

#### REVIEW QUESTIONS

---

1. Explain the difference between data and information. Give some examples of raw data and information.
  
2. Define dirty data, and identify some of its sources.
3. What is data quality, and why is it important?
  
4. Explain the interactions among end users, data, information, and decision making. Draw a diagram and explain the interactions.
5. Suppose that you are a DBA. What data dimensions would you describe to top-level managers to obtain their support for data administration?

6. How and why did database management systems become the data management standard in organizations? Discuss some advantages of the database approach over the file-system approach.
  7. Using a single sentence, explain the role of databases in organizations. Then explain your answer in more detail.
- 
8. Define *security* and *privacy*. How are the two concepts related?
  9. Describe and contrast information needs at the strategic, tactical, and operational levels of an organization. Use examples to explain your answer.
- 
10. What special considerations must you take into account when introducing a DBMS into an organization?
  11. Describe the DBA's responsibilities.
- 
12. How can the DBA function be placed within the organization chart? What effects will that placement have on the DBA function?
  13. Why and how are new technological advances in computers and databases changing the DBA's role?
- 
14. Explain the DBA department's internal organization based on the DBLC approach.
  15. Explain and contrast differences and similarities between the DBA and DA.
- 
16. Explain how the DBA plays an arbitration role between an organization's two main assets. Draw a diagram to illustrate your explanation.
  17. Describe and characterize the skills desired for a DBA.
- 
18. What are the DBA's managerial roles? Describe the managerial activities and services provided by the DBA.

19. What DBA activities support end users?
20. Explain the DBA's managerial role in the definition and enforcement of policies, procedures, and standards.
21. Protecting data security, privacy, and integrity are important database functions. What activities are required in the DBA's managerial role of enforcing those functions?
22. Discuss the importance and characteristics of database backup and recovery procedures. Then describe the actions that must be detailed in backup and recovery plans.
23. Assume that your company has assigned you the responsibility of selecting the corporate DBMS. Develop a checklist of the technical issues and other aspects involved in the selection process.
24. Describe the activities that are typically associated with the design and implementation services of the DBA's technical function. What technical skills are desirable in a DBA?
25. Why are testing and evaluation of the database and applications not done by the same people who are responsible for design and implementation? What minimum standards must be met during testing and evaluation?
26. Identify some bottlenecks in DBMS performance, and then propose some solutions used in DBMS performance tuning.
27. What are typical activities in the maintenance of the DBMS and its utilities and applications? Would you consider application performance tuning to be part of the maintenance activities? Explain your answer.
28. How do you normally define security? How is your definition similar to or different from the definition of database security in this chapter?
29. What are the levels of data confidentiality?

30. What are security vulnerabilities? What is a security threat? Give some examples of security vulnerabilities in different IS components.
31. Define the concept of a data dictionary, and discuss the different types of data dictionaries. If you managed an organization's entire data set, what characteristics would you want for the data dictionary?
32. Using SQL statements, give some examples of how you would use the data dictionary to monitor database security.
33. What characteristics do a CASE tool and a DBMS have in common? How can those characteristics be used to enhance data administration?
34. Briefly explain the concepts of information engineering (IE) and information systems architecture (ISA). How do those concepts affect the data administration strategy?
35. Identify and explain some critical success factors in the development and implementation of a good data administration strategy.
36. What tool is used in Oracle to create users?
37. In Oracle, what is a tablespace?
38. In Oracle, what is a database role?
39. In Oracle, what is a datafile? How does it differ from a file systems file?
40. In Oracle, what is a database profile?
41. In Oracle, what is a database schema?
42. In Oracle, what role is required to create triggers and procedures?

---

---

<sup>1</sup> Murray, John P., "The Managerial and Cultural Issues of a DBMS," *370/390 Database Management* 1(8), September 1991.

<sup>2</sup> For a historical perspective on the development of the DBA function, refer to Jay-Louise Weldon's classic *Data Base Administration* (New York, Plenum Press, 1981). Although you might think that the book's publication date renders it obsolete, a surprising number of its topics are relevant to current databases.

<sup>3</sup> M. Krause and H. Tipton, *Handbook of Information Security Management*, CRC Press LLC, 1999.

## GLOSSARY

---

---

---

### A

---

---

---

**access plan**—A set of instructions generated at application compilation time that is created and managed by a DBMS. The access plan predetermines how an application’s query will access the database at run time.

**active data dictionary**—A data dictionary that is automatically updated by the database management system every time the database is accessed, thereby keeping its information current. See also [data dictionary](#).

**ActiveX**—Microsoft’s alternative to Java. A specification for writing programs that will run inside the Microsoft client browser, Internet Explorer. Oriented mainly to Windows applications, it is not portable. It adds controls such as dropdown windows and calendars to Web pages.

**ActiveX Data Objects (ADO)**—A Microsoft object framework that provides a high-level, application-oriented interface to OLE-DB, DAO, and RDO. ADO provides a unified interface to access data from any programming language that uses the underlying OLE-DB objects.

**ad hoc query**—A “spur-of-the-moment” question.

**ADO.NET**—The data access component of Microsoft’s .NET application development framework, which is a componentbased platform for developing distributed, heterogeneous, and interoperable applications aimed at manipulating any type of data over any network using any operating system and programming language.

**algorithm**—A process or set of operations in a calculation. The most common algorithms used in data mining are based on neural networks, decision trees, rules induction, genetic algorithms, classification and regression trees, memorybased reasoning, and nearest neighbor.

**alias**—An alternative name for a column or table in a SQL statement.

**ALTER TABLE**—The SQL command used to make changes to table structure.

When the command is followed by a keyword (ADD or MODIFY), it adds a column or changes column characteristics.

**American National Standards Institute (ANSI)**—The group that accepted the DBTG recommendations and augmented database standards in 1975 through its SPARC committee.

**analytical database**—A database focused primarily on storing historical data and business metrics used exclusively for tactical or strategic decision making.

**AND**—The SQL logical operator used to link multiple conditional expressions in a WHERE or HAVING clause. It requires that all conditional expressions evaluate to true.

**anonymous PL/SQL block**—A PL/SQL block that has not been given a specific name.

**application processor**—See [\*transaction processor \(TP\)\*](#).

**application programming interface (API)**—Software through which programmers interact with middleware. An API allows the use of generic SQL code, thereby allowing client processes to be database server-independent.

**associative entity**—See [\*composite entity\*](#).

**atomic attribute**—An attribute that cannot be further subdivided to produce meaningful components. For example, a person's last name attribute cannot be meaningfully subdivided.

**atomic transaction property**—A property that requires all parts of a transaction

to be treated as a single, logical unit of work in which all operations must be completed (committed) to produce a consistent database.

**atomicity**—See [\*atomic transaction property\*](#).

**attribute**—A characteristic of an entity or object. An attribute has a name and a data type.

**attribute domain**—See [\*domain\*](#).

**attribute hierarchy**—A top-down data organization that is used for two main purposes: aggregation and drill-down/ roll-up data analysis.

**audit log**—A security feature of a database management system that automatically records a brief description of the database operations performed by all users.

**authentication**—The process through which a DBMS verifies that only registered users can access the database.

**authorization management**—Procedures that protect and guarantee database security and integrity. Such procedures include user access management, view definition, DBMS access control, and DBMS usage monitoring.

**automatic query optimization**—A method by which a DBMS finds the most efficient access path for the execution of a query.

**AVG**—A SQL aggregate function that outputs the mean average for a specified column or expression.

---

**B**

---

**b-tree index**—An ordered data structure organized as an upsidedown tree.

**back-end CASE tools**—A computer-aided software tool that provides support

for the coding and implementation phases of the SDLC. In comparison, front-end CASE tools provide support for the planning, analysis, and design phases.

**base table**—The table on which a view is based.

**basically available, soft state, eventually consistent (BASE)**—A data consistency model in which data changes are not immediate but propagate slowly through the system until all replicas are eventually consistent.

**batch update routine**—A routine that pools transactions into a single batch to update a master table in a single operation.

**BETWEEN**—In SQL, a special comparison operator used to check whether a value is within a range of specified values.

**Big Data**—A movement to find new and better ways to manage large amounts of Web-generated data and derive business insight from it, while simultaneously providing high performance and scalability at a reasonable cost.

**binary lock**—A lock that has only two states: *locked* (1) and *unlocked* (0). If a data item is locked by a transaction, no other transaction can use that data item. See also [lock](#).

**binary relationship**—An ER term for an association (relationship) between two entities. For example, PROFESSOR teaches COURSE.

**bitmap index**—An index that uses a bit array (0s and 1s) to represent the existence of a value or condition.

**Boolean algebra**—A branch of mathematics that uses the logical operators OR, AND, and NOT.

**bottom-up design**—A design philosophy that begins by identifying individual design components and then aggregates them into larger units. In database design, the process begins by defining attributes and then groups them into entities. Compare to *top-down design*.

**boundaries**—The external limits to which any proposed system is subjected. These limits include budgets, personnel, and existing hardware and software.

**Boyce-Codd normal form (BCNF)**—A special type of third normal form (3NF) in which every determinant is a candidate key. A table in BCNF must be in 3NF. See also [determinant](#).

**bridge entity**—See [composite entity](#).

**buffer**—See [buffer cache](#).

**buffer cache**—A shared, reserved memory area that stores the most recently accessed data blocks in RAM. A buffer cache takes advantage of a computer's fast primary memory compared to the slower secondary memory, minimizing the number of input/output (I/O) operations between primary and secondary memory. Also called *data cache*.

**business intelligence (BI)**—A comprehensive, cohesive, and integrated set of tools and processes used to capture, collect, integrate, store, and analyze data with the purpose of generating and presenting information to support business decision making.

**business rule**—A description of a policy, procedure, or principle within an organization. For example, a pilot cannot be on duty for more than 10 hours during a 24-hour period, or a professor may teach up to four classes during a semester.

---

C

---

**Call Level Interface (CLI)**—A standard developed by the SQL Access Group for database access.

**candidate key**—A minimal superkey; that is, a key that does not contain a subset of attributes that is itself a superkey. See [key](#).

**cardinality**—A property that assigns a specific value to connectivity and

expresses the range of allowed entity occurrences associated with a single occurrence of the related entity.

**cascading order sequence**—A nested ordering sequence for a set of rows, such as a list in which all last names are alphabetically ordered and, within the last names, all first names are ordered.

**CASE**—See [\*computer-aided systems engineering \(CASE\)\*](#).

**centralized data allocation**—A data allocation strategy in which the entire database is stored at one site. Also known as a *centralized database*.

**centralized database**—A database located at a single site.

**centralized design**—A process in which a single conceptual design is modeled to match an organization's database requirements. It is typically used when a data component consists of a relatively small number of objects and procedures. Compare to *decentralized design*.

**checkpoint**—In transaction management, an operation in which the database management system writes all of its updated buffers to disk.

**Chen notation**—See [\*entity relationship \(ER\) model\*](#).

**class**—A collection of similar objects with shared structure (attributes) and behavior (methods). A class encapsulates an object's data representation and a method's implementation. Classes are organized in a class hierarchy.

**class diagram**—A diagram used to represent data and their relationships in UML object notation.

**class diagram notation**—The set of symbols used in the creation of class diagrams.

**class hierarchy**—The organization of classes in a hierarchical tree in which

each parent class is a *superclass* and each child class is a *subclass*. See also [\*inheritance\*](#).

**client/server architecture**—The arrangement of hardware and software components to form a system composed of clients, servers, and middleware. The client/server architecture features a user of resources, or a client, and a provider of resources, or a server.

**client-side extensions**—Extensions that add functionality to a Web browser. The most common extensions are plug-ins, Java, JavaScript, ActiveX, and VBScript.

**closure**—A property of relational operators that permits the use of relational algebra operators on existing tables (relations) to produce new relations.

**cloud computing**—A computing model that provides ubiquitous, on-demand access to a shared pool of configurable resources that can be rapidly provisioned.

**cloud services**—The services provided by cloud computing. Cloud services allow any organization to quickly and economically add information technology services such as applications, storage, servers, processing power, databases, and infrastructure.

**cluster-indexed table**—See [\*index organized table\*](#).

**cluster organized table**—See [\*index organized table\*](#).

**clustered table**—A storage technique that stores related rows from two related tables in adjacent data blocks on disk.

**cohesivity**—The strength of the relationships between a module's components. Module cohesivity must be high.

**COMMIT**—The SQL command that permanently saves data changes to a database.

**Common Gateway Interface (CGI)**—A Web server interface standard that uses script files to perform specific functions based on a client’s parameters.

**community cloud**—A type of cloud built by and for a specific group of organizations that share a common trade, such as agencies of the federal government, the military, or higher education.

**completeness constraint**—A constraint that specifies whether each entity supertype occurrence must also be a member of at least one subtype. The completeness constraint can be partial or total. Partial completeness means that some supertype occurrences might not be members of any subtype. Total completeness means that every supertype occurrence must be a member of at least one subtype.

**composite attribute**—An attribute that can be further subdivided to yield additional attributes. For example, a phone number such as 615-898-2368 may be divided into an area code (615), an exchange number (898), and a fourdigit code (2368). Compare to *simple attribute*.

**composite entity**—An entity designed to transform an M:N relationship into two 1:M relationships. The composite entity’s primary key comprises at least the primary keys of the entities that it connects. Also known as a *bridge entity*. See also [\*linking table\*](#).

**composite identifier**—In ER modeling, a key composed of more than one attribute.

**composite key**—A multiple-attribute key.

**computer-aided systems engineering (CASE)**—Tools used to automate part or all of the Systems Development Life Cycle.

**conceptual design**—A process that uses data-modeling techniques to create a model of a database structure that represents realworld objects as realistically as possible. The techniques are both software-and hardware-independent.

**conceptual model**—The output of the conceptual design process. The conceptual model provides a global view of an entire database and describes the main data objects, avoiding details.

**conceptual schema**—A representation of the conceptual model, usually expressed graphically. See also [\*conceptual model\*](#).

**concurrency control**—A DBMS feature that coordinates the simultaneous execution of transactions in a multiprocessing database system while preserving data integrity.

**concurrent backup**—A backup that takes place while one or more users are working on a database.

**connectivity**—The classification of the relationship between entities. Classifications include 1:1, 1:M, and M:N.

**consistency**—A database condition in which all data integrity constraints are satisfied. To ensure consistency of a database, every transaction must begin with the database in a known consistent state. If not, the transaction will yield an inconsistent database that violates its integrity and business rules.

**consistent database state**—A database state in which all data integrity constraints are satisfied.

**constraint**—A restriction placed on data, usually expressed in the form of rules. For example, “A student’s GPA must be between 0.00 and 4.00.” Constraints are important because they help to ensure data integrity.

**coordinator**—The transaction processor (TP) node that coordinates the execution of a two-phase COMMIT in a DDBMS. See also [\*data processor \(DP\)\*](#), [\*transaction processor \(TP\)\*](#), and [\*two-phase commit protocol\*](#).

**correlated subquery**—A subquery that executes once for each row in the outer query.

**cost-based optimizer**—A query optimizer technique that uses an algorithm based on statistics about the objects being accessed, including number of rows, indexes available, index sparsity, and so on.

**COUNT**—A SQL aggregate function that outputs the number of rows containing not null values for a given column or expression, sometimes used in conjunction with the DISTINCT clause.

**CREATE INDEX**—A SQL command that creates indexes on the basis of a selected attribute or attributes.

**CREATE TABLE**—A SQL command that creates a table's structures using the characteristics and attributes given.

**CREATE VIEW**—A SQL command that creates a logical, “virtual” table based on stored enduser tables. The view can be treated as a real table.

**cross join**—A join that performs a relational product (or Cartesian product) of two tables.

**Crow's Foot notation**—A representation of the entity relationship diagram that uses a three-pronged symbol to represent the “many” sides of the relationship.

**cube cache**—In multidimensional OLAP, the shared, reserved memory area where data cubes are held. Using the cube cache assists in speeding up data access.

**cursor**—A special construct used in procedural SQL to hold the data rows returned by a SQL query. A cursor may be considered a reserved area of memory in which query output is stored, like an array holding columns and rows. Cursors are held in a reserved memory area in the DBMS server, not in the client computer.

---

**D**

---

**dashboard**—In business intelligence, a Web-based system that presents key

business performance indicators or information in a single, integrated view with clear and concise graphics.

**data**—Raw facts, or facts that have not yet been processed to reveal their meaning to the end user.

**Data Access Objects (DAO)**—An object-oriented application programming interface used to access MS Access, MS FoxPro, and dBase databases from Visual Basic programs. DAO provides an optimized programming interface that exposes the functionality of the Jet data engine, on which MS Access is based. The DAO interface can be used to access other relational-style data sources.

**data administrator (DA)**—The person responsible for managing the entire data resource, whether it is computerized or not. The DA has broader authority and responsibility than the database administrator (DBA). Also known as an *information resource manager (IRM)*.

**data allocation**—In a distributed DBMS, the process of deciding where to locate data fragments.

**data analytics**—A subset of business intelligence functions that encompasses a wide range of mathematical, statistical, and modeling techniques with the purpose of extracting knowledge from data.

**data anomaly**—A data abnormality in which inconsistent changes have been made to a database. For example, an employee moves, but the address change is not corrected in all files in the database.

**data cache**—A shared, reserved memory area that stores the most recently accessed data blocks in RAM. Also called *buffer cache*.

**data cube**—The multidimensional data structure used to store and manipulate data in a multidimensional DBMS. The location of each data value in the data cube is based on its x-, y-, and z-axes. Data cubes are static, meaning they must be created before they are used, so they cannot be created by an ad hoc query.

**data definition language (DDL)**—The language that allows a database administrator to define the database structure, schema, and subschema.

**data dependence**—A data condition in which data representation and manipulation are dependent on the physical data storage characteristics.

**data dictionary**—A DBMS component that stores metadata—data about data. Thus, the data dictionary contains the data definition as well as their characteristics and relationships. A data dictionary may also include data that are external to the DBMS. Also known as an *information resource dictionary*. See also [\*active data dictionary\*](#), [\*metadata\*](#), and [\*passive data dictionary\*](#).

**Data Encryption Standard (DES)**—The most widely used standard for private-key encryption. DES is used by the U.S. government.

**data extraction**—A process used to extract and validate data from an operational database and external data sources prior to their placement in a data warehouse.

**data file**—A named physical storage space that stores a database's data. It can reside in a different directory on a hard disk or on one or more hard disks. All data in a database are stored in data files. A typical enterprise database is normally composed of several data files. A data file can contain rows from one or more tables.

**data filtering**—See [\*data extraction\*](#).

**data fragmentation**—A characteristic of a DDBMS that allows a single object to be broken into two or more segments or fragments. The object might be a user's database, a system database, or a table. Each fragment can be stored at any site on a computer network.

**data inconsistency**—A condition in which different versions of the same data yield different (inconsistent) results.

**data independence**—A condition in which data access is unaffected by changes in the physical data storage characteristics.

**data integrity**—In a relational database, a condition in which the data in the database comply with all entity and referential integrity constraints.

**data management**—A process that focuses on data collection, storage, and retrieval. Common data management functions include addition, deletion, modification, and listing.

**data manager (DM)**—See [\*data processing \(DP\) manager\*](#).

**data manipulation language (DML)**—The set of commands that allows an end user to manipulate the data in the database. The commands include SELECT, INSERT, UPDATE, DELETE, COMMIT, and ROLLBACK.

**data mart**—A small, single-subject data warehouse subset that provides decision support to a small group of people.

**data mining**—A process that employs automated tools to analyze data in a data warehouse and other sources and to proactively identify possible relationships and anomalies.

**data model**—A representation, usually graphic, of a complex “realworld” data structure. Data models are used in the database design phase of the Database Life Cycle.

**data processing (DP) manager**—A DP specialist who evolved into a department supervisor. Roles include managing technical and human resources, supervising senior programmers, and troubleshooting the program. Also known as a *data manager (DM)*.

**data processor (DP)**—The resident software component that stores and retrieves data through a DDBMS. The DP is responsible for managing the local data in the computer and coordinating access to that data. See also

*transaction processor (TP).*

**data profiling software**—Programs that analyze data and metadata to determine patterns that can help assess data quality.

**data quality**—A comprehensive approach to ensuring the accuracy, validity, and timeliness of data.

**data redundancy**—A condition in which a data environment contains redundant (unnecessarily duplicated) data.

**data replication**—The storage of duplicated database fragments at multiple sites on a DDBMS. Duplication of the fragments is transparent to the end user. Data replication provides fault tolerance and performance enhancements.

**data source name (DSN)**—A name that identifies and defines an ODBC data source.

**data sparsity**—A column distribution of values or the number of different values a column can have.

**data store**—The component of the decision support system that acts as a database for storage of business data and business model data. The data in the data store have already been extracted and filtered from the external and operational data, and will be stored for access by the enduser query tool for the business data model.

**data warehouse**—An integrated, subject-oriented, timevariant, nonvolatile collection of data that provides support for decision making, according to Bill Inmon, the acknowledged “father of the data warehouse.”

**database**—A shared, integrated computer structure that houses a collection of related data. A database contains two types of data: enduser data (raw facts) and metadata. The metadata consist of data about data—that is, the data characteristics and relationships.

**database administrator (DBA)**—The person responsible for planning, organizing, controlling, and monitoring the centralized and shared corporate

database. The DBA is the general manager of the database administration department.

**database design**—The process that yields the description of the database structure and determines the database components. Database design is the second phase of the Database Life Cycle.

**database development**—The process of database design and implementation.

**database dump**—See [\*full backup\*](#).

**database fragment**—A subset of a distributed database. Although the fragments may be stored at different sites within a computer network, the set of all fragments is treated as a single database. See also [\*horizontal fragmentation\*](#) and [\*vertical fragmentation\*](#).

**database instance**—In an Oracle DBMS, the collection of processes and data structures used to manage a specific database.

**database-level lock**—A type of lock that restricts database access to the owner of the lock and allows only one user at a time to access the database. This lock works for batch processes but is unsuitable for online multiuser DBMSs.

**Database Life Cycle (DBLC)**—A cycle that traces the history of a database within an information system. The cycle is divided into six phases: initial study, design, implementation and loading, testing and evaluation, operation and maintenance, and evolution.

**database management system (DBMS)**—The collection of programs that manages the database structure and controls access to the data stored in the database.

**database middleware**—Database connectivity software through which application programs connect and communicate with data repositories.

**database object**—Any object in a database, such as a table, view, index, stored

procedure, or trigger.

**database performance tuning**—A set of activities and procedures designed to reduce the response time of a database system—that is, to ensure that an enduser query is processed by the DBMS in the minimum amount of time.

**database recovery**—The process of restoring a database to a previous consistent state.

**database request**—The equivalent of a single SQL statement in an application program or a transaction.

**database role**—A set of database privileges that could be assigned as a unit to a user or group.

**database security**—The use of DBMS features and other related measures to comply with the security requirements of an organization.

**database security officer (DSO)**—The person responsible for the security, integrity, backup, and recovery of the database.

**database statistics**—In query optimization, measurements about database objects, such as the number of rows in a table, number of disk blocks used, maximum and average row length, number of columns in each row, and number of distinct values in each column. Such statistics provide a snapshot of database characteristics.

**database system**—An organization of components that defines and regulates the collection, storage, management, and use of data in a database environment.

**datafile**—See [data file](#).

**DataSet**—In ADO.NET, a disconnected, memory-resident representation of the database. The DataSet contains tables, columns, rows, relationships, and constraints.

**DBMS performance tuning**—Activities to ensure that clients' requests are

addressed as quickly as possible while making optimum use of existing resources.

**deadlock**—A condition in which two or more transactions wait indefinitely for the other to release the lock on a previously locked data item. Also called *deadly embrace*. See also [lock](#).

**deadly embrace**—See [deadlock](#).

**decentralized design**—A process in which conceptual design is used to model subsets of an organization’s database requirements. After verification of the views, processes, and constraints, the subsets are then aggregated into a complete design. Such modular designs are typical of complex systems in which the data component has a relatively large number of objects and procedures. Compare to *centralized design*.

**decision support system (DSS)**—An arrangement of computerized tools used to assist managerial decision making within a business.

**deferred update**—In transaction management, a condition in which transaction operations do not immediately update a physical database. Also called *deferred write technique*.

**deferred write technique**—See [deferred update](#).

**DELETE**—A SQL command that allows data rows to be deleted from a table.

**denormalization**—A process by which a table is changed from a higher-level normal form to a lower-level normal form, usually to increase processing speed. Denormalization potentially yields data anomalies.

**dependency diagram**—A representation of all data dependencies (primary key, partial, or transitive) within a table.

**dependent**—An attribute whose value is determined by another attribute.

**derived attribute**—An attribute that does not physically exist within the entity and is derived via an algorithm. For example, the Age attribute might be derived by subtracting the birth date from the current date.

**description of operations**—A document that provides a precise, detailed, up-to-date, and thoroughly reviewed description of the activities that define an organization's operating environment.

**design trap**—A problem that occurs when a relationship is improperly or incompletely identified and therefore is represented in a way that is not consistent with the real world. The most common design trap is known as a *fan trap*.

**desktop database**—A single-user database that runs on a personal computer.

**determinant**—Any attribute in a specific row whose value directly determines other values in that row. See also [\*Boyce-Codd normal form \(BCNF\)\*](#).

**determination**—The role of a key. In the context of a database table, the statement “A determines B” indicates that knowing the value of attribute A means that the value of attribute B can be looked up.

**differential backup**—A level of database backup in which only the last modifications to the database are copied.

**dimension tables**—In a data warehouse, tables used to search, filter, or classify facts within a star schema. The fact table is in a one-to-many relationship with dimension tables.

**dimensions**—In a star schema design, qualifying characteristics that provide additional perspectives to a given fact.

**dirty data**—Data that contain inaccuracies and/or inconsistencies.

**disaster management**—The set of DBA activities dedicated to securing data availability following a physical disaster or a database integrity failure.

**discipline-specific database**—A database that contains data focused on specific subject areas.

**disjoint subtype (nonoverlapping subtype)**—In a specialization hierarchy, a unique and nonoverlapping subtype entity set.

**diskpage**—In permanent storage, the equivalent of a disk block, which can be described as a directly addressable section of a disk. A diskpage has a fixed size, such as 4K, 8K, or 16K.

**DISTINCT**—A SQL clause that produces only a list of values that are different from one another.

**distributed data catalog (DDC)**—A data dictionary that contains the description (fragment names, locations) of a distributed database. Also known as a *distributed data dictionary (DDD)*.

**distributed data dictionary (DDD)**—See [\*distributed data catalog\*](#).

**distributed database**—A logically related database that is stored in two or more physically independent sites.

**distributed database management system (DDBMS)**—A DBMS that supports a database distributed across several different sites; a DDBMS governs the storage and processing of logically related data over interconnected computer systems in which both data and processing functions are distributed among several sites.

**distributed global schema**—The database schema description of a distributed database as seen by the database administrator.

**distributed processing**—Sharing the logical processing of a database over two or more sites connected by a network.

**distributed request**—A database request that allows a single SQL statement to access data in several remote data processors (DPs) in a distributed database.

**distributed transaction**—A database transaction that accesses data in several remote data processors (DPs) in a distributed database.

**distribution transparency**—A DDBMS feature that allows a distributed database to look like a single logical database to an end user.

**document type definition (DTD)**—A file with a .dtd extension that describes XML elements; in effect, a DTD file describes a document's composition and defines the syntax rules or valid tags for each type of XML document.

**domain**—In data modeling, the construct used to organize and describe an attribute's set of possible values.

**DO-UNDO-REDO protocol**—A protocol used by a data processor (DP) to roll back or roll forward transactions with the help of a system's transaction log entries.

**drill down**—To decompose data into more atomic components—that is, data at lower levels of aggregation. This approach is used primarily in a decision support system to focus on specific geographic areas, business types, and so on. See also [roll up](#).

**DROP**—A SQL command used to delete database objects such as tables, views, indexes, and users.

**durability**—The transaction property that indicates the permanence of a database's consistent state. Transactions that have been completed will not be lost in a system failure if the database has proper durability.

**dynamic query optimization**—The process of determining the SQL access strategy at run time, using the most up-to-date information about the database. Contrast with *static query optimization*.

**dynamic SQL**—An environment in which the SQL statement is not known in advance, but instead is generated at run time. In a dynamic SQL environment,

a program can generate the SQL statements that are required to respond to ad hoc queries.

**dynamic statistical generation mode**—In a DBMS, the capability to automatically evaluate and update the database access statistics after each data access.

**dynamic-link libraries (DLLs)**—Shared code modules that are treated as part of the operating system or server process so they can be dynamically invoked at run time.

---

---

E

---

---

**EER diagram (EERD)**—The entity relationship diagram resulting from the application of extended entity relationship concepts that provide additional semantic content in the ER model.

**embedded SQL**—SQL statements contained within application programming languages such as COBOL, C++, ASP, Java, and ColdFusion.

**enduser presentation tool**—A data analysis tool that organizes and presents selected data compiled by the enduser query tool.

**enduser query tool**—A data analysis tool used to create the queries that access desired information from the data store.

**enterprise database**—The overall company data representation, which provides support for present and expected future needs.

**entity**—A person, place, thing, concept, or event for which data can be stored.  
See also [attribute](#).

**entity cluster**—A “virtual” entity type used to represent multiple entities and relationships in the ERD. An entity cluster is formed by combining multiple interrelated entities into a single abstract entity object. An entity cluster is considered “virtual” or “abstract” because it is not actually an entity in the

final ERD.

**entity instance**—In ER modeling, a specific table row. Also known as an *entity occurrence*.

**entity integrity**—The property of a relational table that guarantees each entity has a unique value in a primary key and that the key has no null values.

**entity occurrence**—See [\*entity instance\*](#).

**entity relationship diagram (ERD)**—A diagram that depicts an entity relationship model's entities, attributes, and relations.

**entity relationship (ER) model**—A data model that describes relationships (1:1, 1:M, and M:N) among entities at the conceptual level with the help of ER diagrams. The model was developed by P. Chen in 1975.

**entity set**—In a relational model, a grouping of related entities.

**entity subtype**—In a generalization/specialization hierarchy, a subset of an entity supertype. The entity supertype contains the common characteristics and the subtypes contain the unique characteristics of each entity.

**entity supertype**—In a generalization/specialization hierarchy, a generic entity type that contains the common characteristics of entity subtypes.

**equijoin**—A join operator that links tables based on an equality condition that compares specified columns of the tables.

**eventual consistency**—A model for database consistency in which updates to the database will propagate through the system so that all data copies will be consistent eventually.

**exclusive lock**—A lock that is reserved by a transaction. An exclusive lock is issued when a transaction requests permission to update a data item and no

locks are held on that data item by any other transaction. An exclusive lock does not allow other transactions to access the database. See also [\*shared lock\*](#).

**existence-dependent**—A property of an entity whose existence depends on one or more other entities. In such an environment, the existence-independent table must be created and loaded first because the existence-dependent key cannot reference a table that does not yet exist.

**existence-independent**—A property of an entity that can exist apart from one or more related entities. Such a table must be created first when referencing an existence-dependent table.

**EXISTS**—In SQL, a comparison operator that checks whether a subquery returns any rows.

**explanatory analytics**—Data analysis that provides ways to discover relationships, trends, and patterns among data.

**explicit cursor**—In procedural SQL, a cursor created to hold the output of a SQL statement that may return two or more rows, but could return zero or only one row.

**extended entity relationship model (EERM)**—Sometimes referred to as the enhanced entity relationship model; the result of adding more semantic constructs, such as entity supertypes, entity subtypes, and entity clustering, to the original entity relationship (ER) model.

**extended relational data model (ERDM)**—A model that includes the object-oriented model's best features in an inherently simpler relational database structural environment. See [\*extended entity relationship model \(EERM\)\*](#).

**extends**—In a DBMS environment, refers to the ability of data files to expand in size automatically using predefined increments.

**Extensible Markup Language (XML)**—A metalanguage used to represent and manipulate data elements. Unlike other markup languages, XML permits the

manipulation of a document's data elements. XML facilitates the exchange of structured documents such as orders and invoices over the Internet.

**external model**—The application programmer's view of the data environment. Given its business focus, an external model works with a data subset of the global database schema.

**external schema**—The specific representation of an external view; the end user's view of the data environment.

**extraction, transformation, and loading (ETL)**—In a data warehousing environment, the integrated processes of getting data from original sources into the data warehouse. ETL includes retrieving data from original data sources (extraction), manipulating the data into an appropriate form (transformation), and storing the data in the data warehouse (loading).

---

## F

---

**fact table**—In a data warehouse, the star schema table that contains facts linked and classified through their common dimensions. A fact table is in a one-to-many relationship with each associated dimension table.

**facts**—In a data warehouse, the measurements (values) that represent a specific business aspect or activity. For example, sales figures are numeric measurements that represent product or service sales. Facts commonly used in business data analysis include units, costs, prices, and revenues.

**failure transparency**—A feature that allows continuous operation of a DDBMS, even if a network node fails.

**fan trap**—A design trap that occurs when one entity is in two 1:M relationships with other entities, thus producing an association among the other entities that is not expressed in the model.

**field**—An alphabetic or numeric character or group of characters that defines a

characteristic of a person, place, or thing. For example, a person's Social Security number, address, phone number, and bank balance all constitute fields.

**field-level lock**—A lock that allows concurrent transactions to access the same row as long as they require the use of different fields (attributes) within that row. This type of lock yields the most flexible multiuser data access but requires a high level of computer overhead.

**file**—A named collection of related records.

**file group**—See [\*table space\*](#).

**first normal form (1NF)**—The first stage in the normalization process. It describes a relation depicted in tabular format, with no repeating groups and a primary key identified. All nonkey attributes in the relation are dependent on the primary key.

**flags**—Special codes implemented by designers to trigger a required response, alert end users to specified conditions, or encode values. Flags may be used to prevent nulls by bringing attention to the absence of a value in a table.

**foreign key**—An attribute or attributes in one table whose values must match the primary key in another table or whose values must be null. See [\*key\*](#).

**fourth normal form (4NF)**—A table that is in 3NF and contains no multiple independent sets of multivalued dependencies.

**fragmentation transparency**—A DDBMS feature that allows a system to treat a distributed database as a single database even though it is divided into two or more fragments.

**front-end CASE tools**—A computer-aided software tool that provides support for the planning, analysis, and design phases of the SDLC. In comparison, back-end CASE tools provide support for the coding and implementation

phases.

**full backup (database dump)**—A complete copy of an entire database saved and periodically updated in a separate memory location. A full backup ensures a full recovery of all data after a physical disaster or database integrity failure.

**full functional dependence**—A condition in which an attribute is functionally dependent on a composite key but not on any subset of the key.

**fully heterogeneous distributed database system (fully heterogeneous DDBMS)**—A system that integrates different types of database management systems (hierarchical, network, and relational) over a network. It supports different database management systems that may even support different data models running under different computer systems, such as mainframes, minicomputers, and microcomputers. See also [\*heterogeneous DDBMS\*](#) and [\*homogeneous DDBMS\*](#).

**fully replicated database**—In a DDBMS, the distributed database that stores multiple copies of each database fragment at multiple sites. See also [\*partially replicated database\*](#).

**functional dependence**—Within a relation R, an attribute B is functionally dependent on an attribute A if and only if a given value of attribute A determines exactly one value of attribute B. The relationship “B is dependent on A” is equivalent to “A determines B,” and is written as AB.

**function-based index**—A type of index based on a specific SQL function or expression.

---

G

---

**general-purpose database**—A database that contains a wide variety of data used in multiple disciplines—for example, a census database that contains general demographic data, or the LexisNexis and ProQuest databases that contain newspaper, magazine, and journal articles for a variety of topics.

**generalization**—In a specialization hierarchy, the grouping of common attributes into a supertype entity. See [\*specialization hierarchy\*](#).

**governance**—In business intelligence, the methods for controlling and monitoring business health and promoting consistent decision making.

**granularity**—The level of detail represented by the values stored in a table’s row. Data stored at their lowest level of granularity are said to be *atomic data*.

**GROUP BY**—A SQL clause used to create frequency distributions when combined with any of the aggregate functions in a SELECT statement.

---

---

## H

---

---

**hardware independence**—A condition in which a model does not depend on the hardware used in the model’s implementation. Therefore, changes in the hardware will have no effect on the database design at the conceptual level.

**hash index**—An index based on an ordered list of hash values.

**HAVING**—A clause applied to the output of a GROUP BY operation to restrict selected rows.

**heterogeneity transparency**—A feature that allows a system to integrate several centralized DBMSs into one logical DDBMS.

**heterogeneous DDBMS**—A system that integrates different types of centralized database management systems over a network. See also [\*fully heterogeneous distributed database system \(fully heterogeneous DDBMS\)\*](#) and [\*homogeneous DDBMS\*](#).

**hierarchical model**—An early database model whose basic concepts and characteristics formed the basis for subsequent database development. This model is based on an upsidedown tree structure in which each record is called a segment. The top record is the root segment. Each segment has a 1:M relationship to the segment directly below it.

**homogeneous DDBMS**—A system that integrates only one type of centralized database management system over a network. See also [heterogeneous DDBMS](#) and [fully heterogeneous distributed database system \(fully heterogeneous DDBMS\)](#).

**homonym**—The use of the same name to label different attributes. Homonyms generally should be avoided. Some relational software automatically checks for homonyms and either alerts the user to their existence or automatically makes the appropriate adjustments. See also [synonym](#).

**horizontal fragmentation**—The distributed database design process that breaks a table into subsets of unique rows. See also [database fragment](#) and [vertical fragmentation](#).

**host language**—Any language that contains embedded SQL statements.

---

---

## I

---

---

**identifiers**—In an ERM, unique names of each entity instance. In the relational model, such identifiers are mapped to primary keys in tables.

**identifying relationship**—A relationship in which related entities are existence-dependent. Also called a *strong relationship* or *strong identifying relationship* because the dependent entity's primary key contains the primary key of the parent entity.

**immediate update**—A database update that is performed immediately during a transaction's execution, even before the transaction reaches its commit point.

**implicit cursor**—A cursor that is automatically created in procedural SQL when the SQL statement returns only one value.

**IN**—In SQL, a comparison operator used to check whether a value is among a list of specified values.

**inconsistent retrievals**—A concurrency control problem that arises when a transaction-calculating summary (aggregate) functions over a set of data while other transactions are updating the data, yielding erroneous results.

**incremental backup**—A process that only backs up data that has changed in the database since the last incremental or full backup.

**index**—An ordered array of index key values and row ID values (pointers). Indexes are generally used to speed up and facilitate data retrieval. Also known as an *index key*.

**index key**—See [index](#).

**index organized table**—In a DBMS, a type of table storage organization that stores enduser data and index data in consecutive locations in permanent storage. Also known as *cluster-indexed table*.

**index selectivity**—A measure of how likely an index is to be used in query processing.

**information**—The result of processing raw data to reveal its meaning. Information consists of transformed data and facilitates decision making.

**information engineering (IE)**—A methodology that translates a company's strategic goals into helpful data and applications. IE focuses on the description of corporate data instead of the processes.

**information resource dictionary**—See [data dictionary](#).

**information resource manager (IRM)**—See [data administrator \(DA\)](#).

**information system (IS)**—A system that provides for data collection, storage, and retrieval; facilitates the transformation of data into information; and manages both data and information. An information system is composed of hardware, the DBMS and other software, database(s), people, and procedures.

**information systems architecture (ISA)**—The output of the information

engineering (IE) process that serves as the basis for planning, developing, and controlling future information systems.

**information systems (IS) department**—An evolution of the data-processing department in which responsibilities are broadened to include service and production functions.

**Infrastructure as a Service (IaaS)**—A model in which the cloud service provider offers consumers the ability to provision their own resources on demand; these resources include storage, servers, databases, processing units, and even a complete virtualized desktop.

**inheritance**—In the object-oriented data model, the ability of an object to inherit the data structure and methods of the classes above it in the class hierarchy. See also [class hierarchy](#).

**inner join**—A join operation in which only rows that meet a given criterion are selected. The join criterion can be an equality condition (natural join or equijoin) or an inequality condition (theta join). The inner join is the most commonly used type of join. Contrast with *outer join*.

**inner query**—A query that is embedded or nested inside another query. Also known as a *nested query* or a *subquery*.

**input/output (IO) request**—A low-level operation that reads or writes data to and from computer devices such as memory, hard disks, video, and printers.

**INSERT**—A SQL command that allows the insertion of one or more data rows into a table using a subquery.

**integrity**—In a data security framework, refers to keeping data consistent and free of errors or anomalies. See also [data integrity](#).

**internal model**—In database modeling, a level of data abstraction that adapts the conceptual model to a specific DBMS model for implementation. The

**internal model**—The representation of a database as “seen” by the DBMS. In other words, the internal model requires a designer to match the conceptual model’s characteristics and constraints to those of the selected implementation model.

**internal schema**—A representation of an internal model using the database constructs supported by the chosen database.

**IS NULL**—In SQL, a comparison operator used to check whether an attribute has a value.

**islands of information**—In the old file system environment, pools of independent, often duplicated, and inconsistent data created and managed by different departments.

**isolation**—A property of a database transaction in which a data item used by one transaction is not available to other transactions until the first one ends.

**iterative process**—A process based on repetition of steps and procedures.

---

---

## J

---

---

**Java**—An object-oriented programming language developed by Sun Microsystems that runs on top of the Web browser software. Java applications are compiled and stored on the Web server. Java’s main advantage is its ability to let application developers create their applications once and then run them in many environments.

**Java Database Connectivity (JDBC)**—An application programming interface that allows a Java program to interact with a wide range of data sources, including relational databases, tabular data sources, spreadsheets, and text files.

**JavaScript**—A scripting language developed by Netscape that allows Web authors to design interactive Websites. JavaScript code is embedded in Web pages, and then downloaded with the page and activated when a specific event takes place, such as a mouse click on an object.

**join columns**—Columns that join two tables. The join columns generally share similar values.

---

K

---

**key**—An entity identifier based on the concept of functional dependence; keys may be classified in several ways. See also [superkey](#), [candidate key](#), [primary key \(PK\)](#), [secondary key](#), and [foreign key](#).

**key attributes**—The attributes that form a primary key. See also [prime attribute](#).

**key performance indicators (KPIs)**—In business intelligence, quantifiable numeric or scale-based measurements that assess a company's effectiveness or success in reaching strategic and operational goals. Examples of KPI are product turnovers, sales by promotion, sales by employee, and earnings per share.

**key-value**—A data model based on a structure composed of two data elements: a key and a value, in which every key has a corresponding value or set of values. The key-value data model is also called the associative or attribute-value data model.

**knowledge**—The body of information and facts about a specific subject. Knowledge implies familiarity, awareness, and understanding of information as it applies to an environment. A key characteristic is that new knowledge can be derived from old knowledge.

---

L

---

**left outer join**—In a pair of tables to be joined, a join that yields all the rows in the left table, including those that have no matching values in the other table. For example, a left outer join of CUSTOMER with AGENT will yield all of the CUSTOMER rows, including the ones that do not have a matching AGENT row. See also [outer join](#) and [right outer join](#).

**LIKE**—In SQL, a comparison operator used to check whether an attribute's text value matches a specified string pattern.

**linking table**—In the relational model, a table that implements an M:M relationship. See also [\*composite entity\*](#).

**local mapping transparency**—A property of a DDBMS in which database access requires the end user to know both the name and location of the fragments. See also [\*location transparency\*](#).

**location transparency**—A property of a DDBMS in which database access requires the user to know only the name of the database fragments. (Fragment locations need not be known.) See also [\*local mapping transparency\*](#).

**lock**—A device that guarantees unique use of a data item in a particular transaction operation. A transaction requires a lock prior to data access; the lock is released after the operation's execution to enable other transactions to lock the data item for their own use.

**lock granularity**—The level of lock use. Locking can take place at the following levels: database, table, page, row, and field (attribute).

**lock manager**—A DBMS component that is responsible for assigning and releasing locks.

**logical data format**—The way a person views data.

**logical design**—A stage in the design phase that matches the conceptual design to the requirements of the selected DBMS and is therefore software-dependent. Logical design is used to translate the conceptual design into the internal model for a selected database management system, such as DB2, SQL Server, Oracle, IMS, Informix, Access, or Ingress.

**logical independence**—A condition in which the internal model can be changed without affecting the conceptual model. (The internal model is hardware-

independent because it is unaffected by the computer on which the software is installed. Therefore, a change in storage devices or operating systems will not affect the internal model.)

**lost updates**—A concurrency control problem in which data updates are lost during the concurrent execution of transactions.

---

---

**M**

---

---

**mandatory participation**—A relationship in which one entity occurrence must have a corresponding occurrence in another entity. For example, an EMPLOYEE works in a DIVISION. (A person cannot be an employee without being assigned to a company's division.)

**manual query optimization**—An operation mode that requires the end user or programmer to define the access path for the execution of a query.

**manual statistical generation mode**—A mode of generating statistical data access information for query optimization. In this mode, the DBA must periodically run a routine to generate the data access statistics—for example, running the RUNSTAT command in an IBM DB2 database.

**many-to-many (M:N or M:M) relationships**— Associations among two or more entities in which one occurrence of an entity is associated with many occurrences of a related entity and one occurrence of the related entity is associated with many occurrences of the first entity.

**master data management (MDM)**—In business intelligence, a collection of concepts, techniques, and processes for the proper identification, definition, and management of data elements within an organization.

**materialized view**—A dynamic table that not only contains the SQL query command to generate rows but stores the actual rows. The materialized view is created the first time the query is run and the summary rows are stored in the table. The materialized view rows are automatically updated when the base tables are updated.

**MAX**—A SQL aggregate function that yields the maximum attribute value in a given column.

**metadata**—Data about data; that is, data about data characteristics and relationships. See also [\*data dictionary\*](#).

**method**—In the objectoriented data model, a named set of instructions to perform an action. Methods represent realworld actions, and are invoked through messages.

**metrics**—In a data warehouse, numeric facts that measure a business characteristic of interest to the end user.

**Microsoft .NET framework**—A componentbased platform for the development of distributed, heterogeneous, interoperable applications aimed at manipulating any type of data over any network regardless of operating system and programming language.

**MIN**—A SQL aggregate function that yields the minimum attribute value in a given column.

**minimal data rule**—Defined as “All that is needed is there, and all that is there is needed.” In other words, all data elements required by database transactions must be defined in the model, and all data elements defined in the model must be used by at least one database transaction.

**mixed fragmentation**—A combination of horizontal and vertical strategies for data fragmentation, in which a table may be divided into several rows and each row has a subset of the attributes (columns).

**module**—(1) A design segment that can be implemented as an autonomous unit, and is sometimes linked to produce a system. (2) An information system component that handles a specific function, such as inventory, orders, or payroll.

**module coupling**—The extent to which modules are independent of one another.

**monotonicity**—A quality that ensures that timestamp values always increase. (The timestamping approach to scheduling concurrent transactions assigns a global, unique timestamp to each transaction. The timestamp value produces an explicit order in which transactions are submitted to the DBMS.)

**multidimensional database management system (MDBMS)**—A database management system that uses proprietary techniques to store data in matrixlike arrays of  $n$  dimensions known as cubes.

**multidimensional online analytical processing (MOLAP)**—An extension of online analytical processing to multidimensional database management systems.

**multiple-site processing, multiple-site data (MPMD)**—A scenario describing a fully distributed database management system with support for multiple data processors and transaction processors at multiple sites.

**multiple-site processing, single-site data (MPSD)**—A scenario in which multiple processes run on different computers sharing a single data repository.

**multiuser database**—A database that supports multiple concurrent users.

**multivalued attribute**—An attribute that can have many values for a single entity occurrence. For example, an EMP\_DEGREE attribute might store the string “BBA, MBA, PHD” to indicate three different degrees held.

**mutual consistency rule**—A data replication rule that requires all copies of data fragments to be identical.

**mutual exclusive rule**—A condition in which only one transaction at a time can own an exclusive lock on the same object.

---

---

N

---

---

**natural join**—A relational operation that links tables by selecting only the rows with common values in their common attribute(s).

**natural key (natural identifier)**—A generally accepted identifier for realworld objects. As its name implies, a natural key is familiar to end users and forms part of their day-to-day business vocabulary.

**nested query**—In SQL, a query that is embedded in another query. See [subquery](#).

**network latency**—The delay imposed by the amount of time required for a data packet to make a round trip from point A to point B.

**network model**—A data model standard created in the late 1960s that represented data as a collection of record types and relationships as predefined sets with an owner record type and a member record type in a 1:M relationship.

**non-identifying relationship**—A relationship in which the primary key of the dependent (many side) entity does not contain the primary key of the related parent entity. Also known as a *weak relationship*.

**nonkey attribute**—See [nonprime attribute](#).

**nonprime attribute**—An attribute that is not part of a key.

**normalization**—A process that assigns attributes to entities so that data redundancies are reduced or eliminated.

**NoSQL**—A new generation of database management systems that is not based on the traditional relational database model.

**NOT**—A SQL logical operator that negates a given predicate.

**null**—In SQL, the absence of an attribute value. Note that a null is not a blank.

**object**—An abstract representation of a realworld entity that has a unique identity, embedded properties, and the ability to interact with other objects and itself.

**Object Linking and Embedding for Database (OLE-DB)**—Based on Microsoft’s Component Object Model (COM), OLE-DB is database middleware that adds objectoriented functionality for accessing relational and nonrelational data. OLE-DB was the first part of Microsoft’s strategy to provide a unified objectoriented framework for the development of next-generation applications.

**objectoriented data model (OODM)**—A data model whose basic modeling structure is an object.

**objectoriented database management system (OODBMS)**—Data management software used to manage data in an objectoriented database model.

**objectoriented programming (OOP)**—An alternative to conventional programming methods based on objectoriented concepts. It reduces programming time and lines of code and increases programmers’ productivity.

**object/relational database management system (O/RDBMS)**—A DBMS based on the extended relational model (ERDM). The ERDM, championed by many relational database researchers, constitutes the relational model’s response to the OODM. This model includes many of the objectoriented model’s best features within an inherently simpler relational database structure.

**one-to-many (1:M or 1..\*) relationship**—Associations among two or more entities that are used by data models. In a 1:M relationship, one entity instance is associated with many instances of the related entity.

**one-to-one (1:1) relationship**—Associations among two or more entities that are used by data models. In a 1:1 relationship, one entity instance is associated with only one instance of the related entity.

**online analytical processing (OLAP)**—Decision support system (DSS) tools that use multidimensional data analysis techniques. OLAP creates an advanced data analysis environment that supports decision making, business modeling, and operations research.

**online transaction processing (OLTP)**—The systems that support a company's day-to-day operations. Databases that support OLTP are known as OLTP databases, transactional databases, or operational databases.

**Open Database Connectivity (ODBC)**—Database middleware developed by Microsoft to provide a database access API to Windows applications.

**operational database**—A database designed primarily to support a company's day-to-day operations. Also known as a *transactional database* or *production database*.

**optimistic approach**—In transaction management, a concurrency control technique based on the assumption that most database operations do not conflict.

**optimizer hints**—Special instructions for the query optimizer that are embedded inside the SQL command text.

**optional attribute**—In ER modeling, an attribute that does not require a value; therefore, it can be left empty.

**optional participation**—In ER modeling, a condition in which one entity occurrence does not require a corresponding entity occurrence in a particular relationship.

**OR**—The SQL logical operator used to link multiple conditional expressions in a WHERE or HAVING clause. It requires only one of the conditional expressions to be true.

**ORDER BY**—A SQL clause that is useful for ordering the output of a SELECT

query (for example, in ascending or descending order).

**outer join**—A relational algebra JOIN operation that produces a table in which all unmatched pairs are retained; unmatched values in the related table are left null. Contrast with *inner join*. See also [\*left outer join\*](#) and [\*right outer join\*](#).

---

**overlapping**—In a specialization hierarchy, a condition in which each entity instance (row) of the supertype can appear in more than one subtype.

---

**P**

---

**page**—See [\*diskpage\*](#).

**page-level lock**—In this type of lock, the database management system locks an entire diskpage, or section of a disk. A diskpage can contain data for one or more rows and from one or more tables.

**partial completeness**—In a generalization hierarchy, a condition in which some supertype occurrences might not be members of any subtype.

**partial dependency**—In normalization, a condition in which an attribute is dependent on only a portion (subset) of the primary key.

**partially replicated database**—A distributed database in which copies of only some database fragments are stored at multiple sites. See also [\*fully replicated database\*](#).

**participants**—An ER term for entities that participate in a relationship. For example, in the relationship “PROFESSOR teaches CLASS,” the *teaches* relationship is based on the participants PROFESSOR and CLASS.

**partition key**—In partitioned databases, one or more attributes in a table that determine the fragment in which a row will be stored.

**partitioned data allocation**—A data allocation strategy of dividing a database

into two or more fragments that are stored at two or more sites.

**partitioning**—The process of splitting a table into subsets of rows or columns.

**passive data dictionary**—A DBMS data dictionary that requires a command initiated by an end user to update its data access statistics. See also [data dictionary](#).

**performance transparency**—A DDBMS feature that allows a system to perform as though it were a centralized DBMS.

**performance tuning**—Activities that make a database perform more efficiently in terms of storage and access speed.

**periodicity**—Information about the time span of data stored in a table, usually expressed as current year only, previous years, or all years.

**persistent stored module (PSM)**—A block of code with standard SQL statements and procedural extensions that is stored and executed at the DBMS server.

**personalization**—Customization of a Web page for individual users.

**pessimistic locking**—The use of locks based on the assumption that conflict between transactions is likely.

**physical data format**—The way a computer “sees” (stores) data.

**physical design**—A stage of database design that maps the data storage and access characteristics of a database. Because these characteristics are a function of the types of devices supported by the hardware, the data access methods supported by the system physical design are both hardware-and software-dependent. See also [physical model](#).

**physical independence**—A condition in which the physical model can be changed without affecting the internal model.

**physical model**—A model in which physical characteristics such as location, path, and format are described for the data. The physical model is both hardware-and software-dependent. See also [\*physical design\*](#).

**Platform as a Service (PaaS)**—A model in which the cloud service provider can build and deploy consumer-created applications using the provider's cloud infrastructure.

**plug-in**—In the World Wide Web (WWW), a client-side, external application that is automatically invoked by the browser when needed to manage specific types of data.

**policies**—General statements of direction that are used to manage company operations through the communication and support of the organization's objectives.

**portal**—In terms of business intelligence, a unified, single point of entry for information distribution.

**predicate logic**—Used extensively in mathematics to provide a framework in which an assertion (statement of fact) can be verified as either true or false.

**predictive analytics**—Data analytics that use advanced statistical and modeling techniques to predict future business outcomes with great accuracy.

**primary key (PK)**—In the relational model, an identifier composed of one or more attributes that uniquely identifies a row. Also, a candidate key selected as a unique entity identifier. See also [\*key\*](#).

**prime attribute**—A key attribute; that is, an attribute that is part of a key or is the whole key. See also [\*key attributes\*](#).

**privacy**—The rights of individuals and organizations to determine access to data about themselves.

**private cloud**—A form of cloud computing in which an internal cloud is built by an organization to serve its own needs.

**Procedural Language SQL (PL/SQL)**—A type of SQL that allows the use of procedural code and in which SQL statements are stored in a database as a single callable object that can be invoked by name.

**procedure cache**—A shared, reserved memory area that stores the most recently executed SQL statements or PL/SQL procedures, including triggers and functions. Also called *SQL cache*.

**procedures**—Series of steps to be followed during the performance of an activity or process.

**production database**—The main database designed to keep track of the day-to-day operations of a company. See also [\*transactional database\*](#).

**profile**—In Oracle, a named collection of settings that controls how much of the database resource a given user can use.

**public cloud**—A form of computing in which the cloud infrastructure is built by a third-party organization to sell cloud services to the general public.

---

---

## Q

---

---

**query**—A question or task asked by an end user of a database in the form of SQL code. A specific request for data manipulation issued by the end user or the application to the DBMS.

**query language**—A nonprocedural language that is used by a DBMS to manipulate its data. An example of a query language is SQL.

**query optimizer**—A DBMS process that analyzes SQL queries and finds the most efficient way to access the data. The query optimizer generates the access or execution plan for the query.

**query processing bottleneck**—In query optimization, a delay introduced in the processing of an I/O operation that causes the overall system to slow down.

**query result set**—The collection of data rows returned by a query.

---

---

**R**

---

---

**RAID**—An acronym for Redundant Array of Independent Disks. RAID systems use multiple disks to create virtual disks (storage volumes) from several individual disks. RAID systems provide performance improvement, fault tolerance, and a balance between the two.

**record**—A collection of related (logically connected) fields.

**recursive query**—A nested query that joins a table to itself.

**recursive relationship**—A relationship found within a single entity type. For example, an EMPLOYEE is married to an EMPLOYEE or a PART is a component of another PART.

**redundant transaction logs**—Multiple copies of the transaction log kept by database management systems to ensure that the physical failure of a disk will not impair the DBMS's ability to recover data.

**referential integrity**—A condition by which a dependent table's foreign key must have either a null entry or a matching entry in the related table. Even though an attribute may not have a *corresponding* attribute, it is impossible to have an invalid entry.

**relation**—In a relational database model, an entity set. Relations are implemented as tables. Relations are related to each other through the sharing of a common entity characteristic (a value in a column).

**relational algebra**—A set of mathematical principles that form the basis for manipulating relational table contents; the eight main functions are SELECT, PROJECT, JOIN, INTERSECT, UNION, DIFFERENCE, PRODUCT, and

DIVIDE.

**relational database management system (RDBMS)**—A collection of programs that manages a relational database. The RDBMS software translates a user's logical requests (queries) into commands that physically locate and retrieve the requested data. A good RDBMS also creates and maintains a data dictionary to help provide data security, data integrity, concurrent and easy access, and system administration to the data through a query language (SQL) and application programs.

**relational diagram**—A graphical representation of a relational database's entities, the attributes within those entities, and the relationships among the entities.

**relational model**—Developed by E. F. Codd of IBM in 1970, it represented a major breakthrough for users and designers because of its conceptual simplicity. The relational model is based on mathematical set theory and represents data as independent relations. Each relation (table) is conceptually represented as a matrix of intersecting rows and columns. The relations are related to each other through the sharing of common entity characteristics (values in columns).

**relational online analytical processing (ROLAP)**— Analytical processing functions that use relational databases and familiar relational query tools to store and analyze multidimensional data.

**relational schema**—The organization of a relational database as described by the database administrator.

**relationship**—An association between entities.

**relationship degree**—The number of entities or participants associated with a relationship. A relationship degree can be unary, binary, ternary, or higher.

**Remote Data Objects (RDO)**—A higher-level, object-oriented application interface used to access remote database servers. RDO uses the lower-level DAO and ODBC for direct access to databases. RDO was optimized to deal

with server-based databases such as MS SQL Server, Oracle, and DB2.

**remote request**—A DDBMS feature that allows a single SQL statement to access data in a single remote DP. See also [remote transaction](#).

**remote transaction**—A DDBMS feature that allows a transaction (formed by several requests) to access data in a single remote DP. See also [remote request](#).

**repeating group**—In a relation, a characteristic describing a group of multiple entries of the same type for a single key attribute occurrence. For example, a car can have multiple colors for its top, interior, bottom, trim, and so on.

**replica transparency**—The DDBMS's ability to hide the existence of multiple copies of data from the user.

**replicated data allocation**—A data allocation strategy in which copies of one or more database fragments are stored at several sites.

**replication**—The process of creating and managing duplicate versions of a database. Replication is used to place copies in different locations and to improve access time and fault tolerance.

**required attribute**—In ER modeling, an attribute that must have a value. In other words, it cannot be left empty.

**reserved words**—Words used by a system that cannot be used for any other purpose. For example, in Oracle SQL, the word INITIAL cannot be used to name tables or columns.

**right outer join**—In a pair of tables to be joined, a join that yields all of the rows in the right table, including the ones with no matching values in the other table. For example, a right outer join of CUSTOMER with AGENT will yield all of the AGENT rows, including the ones that do not have a matching CUSTOMER row. See also [left outer join](#) and [outer join](#).

**role**—In Oracle, a named collection of database access privileges that authorize

a user to connect to a database and use its system resources.

**roll up**—In SQL, an OLAP extension used with the GROUP BY clause to aggregate data by different dimensions. Rolling up the data is the exact opposite of drilling down the data. See also [\*drill down\*](#).

**ROLLBACK**—A SQL command that restores the database table contents to the condition that existed after the last COMMIT statement.

**row-level lock**—A less restrictive database lock in which the DBMS allows concurrent transactions to access different rows of the same table, even when the rows are on the same page.

**row-level trigger**—A trigger that is executed once for each row affected by the triggering SQL statement. A row-level trigger requires the use of the FOR EACH ROW keywords in the trigger declaration.

**rule-based optimizer**—A query optimization mode based on the rule-based query optimization algorithm.

**rule-based query optimization algorithm**—A query optimization technique that uses preset rules and points to determine the best approach to executing a query.

**rules of precedence**—Basic algebraic rules that specify the order in which operations are performed. For example, operations within parentheses are executed first, so in the equation  $2 + (3 \times 5)$ , the multiplication portion is calculated first, making the correct answer 17.

---

---

S

---

---

**scheduler**—The DBMS component that establishes the order in which concurrent transaction operations are executed. The scheduler *interleaves* the execution of database operations in a specific sequence to ensure *serializability*.

**schema**—A logical grouping of database objects, such as tables, indexes, views, and queries, that are related to each other. Usually, a schema belongs to a single user or application.

**scope**—The part of a system that defines the extent of the design, according to operational requirements.

**script**—A programming language that is not compiled, but is interpreted and executed at run time.

**search services**—Business-enabling Web services that allow Websites to perform searches on their contents.

**second normal form (2NF)**—The second stage in the normalization process, in which a relation is in 1NF and there are no partial dependencies (dependencies in only part of the primary key).

**secondary key**—A key used strictly for data retrieval purposes. For example, customers are not likely to know their customer number (primary key), but the combination of last name, first name, middle initial, and telephone number will probably match the appropriate table row. See also [key](#).

**security**—Activities and measures to ensure the confidentiality, integrity, and availability of an information system and its main asset, data.

**security breach**—An event in which a security threat is exploited to endanger the integrity, confidentiality, or availability of the system.

**security policy**—A collection of standards, policies, and procedures created to guarantee the security of a system and ensure auditing and compliance.

**security threat**—An imminent security violation that could occur due to unchecked security vulnerabilities.

**security vulnerability**—A weakness in a system component that could be exploited to allow unauthorized access or cause service disruptions.

**segment**—In the hierarchical data model, the equivalent of a file system's record type.

**SELECT**—A SQL command that yields the values of all rows or a subset of rows in a table. The SELECT statement is used to retrieve data from tables.

**semantic data model**—The first of a series of data models that more closely represented the real world, modeling both data and their relationships in a single structure known as an object. The SDM, published in 1981, was developed by M. Hammer and D. McLeod.

**semistructured data**—Data that have already been processed to some extent.

**serializability**—A property in which the selected order of transaction operations creates the same final database state that would have been produced if the transactions had been executed in a serial fashion.

**Serializable schedule**—In transaction management, a schedule of operations in which the interleaved execution of the transactions yields the same result as if they were executed in serial order.

**server-side extension**—A program that interacts directly with the server process to handle specific types of requests. Server-side extensions add significant functionality to Web servers and intranets.

**set theory**—A part of mathematical science that deals with sets, or groups of things, and is used as the basis for data manipulation in the relational model.

**set-oriented**—Dealing with or related to sets, or groups of things. In the relational model, SQL operators are set-oriented because they operate over entire sets of rows and columns at once.

**shared lock**—A lock that is issued when a transaction requests permission to read data from a database and no exclusive locks are held on the data by another transaction. A shared lock allows other read-only transactions to

access the database. See also *exclusive lock*.

**simple attribute**—An attribute that cannot be subdivided into meaningful components. Compare to *composite attribute*.

**single-site processing, single-site data (SPSD)**—A scenario in which all processing is done on a single CPU or host computer and all data are stored on the host computer’s local disk.

**single-user database**—A database that supports only one user at a time.

**single-valued attribute**—An attribute that can have only one value.

**slice and dice**—The ability to cut slices off a data cube (drill down or drill up) to perform a more detailed analysis.

**snowflake schema**—A type of star schema in which dimension tables can have their own dimension tables. The snowflake schema is usually the result of normalizing dimension tables.

**social media**—Web and mobile technologies that enable “anywhere, anytime, always on” human interactions.

**Software as a Service (SaaS)**—A model in which the cloud service provider offers turnkey applications that run in the cloud.

**software independence**—A property of any model or application that does not depend on the software used to implement it.

**sparse data**—A case in which the number of table attributes is very large but the number of actual data instances is low.

**sparsity**—In multidimensional data analysis, a measurement of the data density held in the data cube.

**specialization**—In a specialization hierarchy, the grouping of unique attributes

into a subtype entity. See [\*specialization hierarchy\*](#).

**specialization hierarchy**—A hierarchy based on the top-down process of identifying lower-level, more specific entity subtypes from a higher-level entity supertype. Specialization is based on grouping unique characteristics and relationships of the subtypes.

**SQL cache**—A shared, reserved memory area that stores the most recently executed SQL statements or PL/SQL procedures, including triggers and functions. Also called *procedure cache*.

**SQL data services (SDS)**—Data management services that provide relational data storage, access, and management over the Internet.

**SQL performance tuning**—Activities to help generate a SQL query that returns the correct answer in the least amount of time, using the minimum amount of resources at the server end.

**standards**—A detailed and specific set of instructions that describes the minimum requirements for a given activity. Standards are used to evaluate the quality of the output.

**star schema**—A data modeling technique used to map multidimensional decision support data into a relational database. The star schema represents data using a central table known as a fact table in a 1:M relationship with one or more dimension tables.

**stateless system**—A system in which a Web server does not know the status of the clients communicating with it. The Web does not reserve memory to maintain an open communications state between the client and the server.

**statement-level trigger**—A SQL trigger that is assumed if the FOR EACH ROW keywords are omitted. This type of trigger is executed once, before or after the triggering statement completes, and is the default case.

**static query optimization**—A query optimization mode in which the access path to a database is predetermined at compilation time. Contrast with

*dynamic query optimization.*

**static SQL**—A style of embedded SQL in which the SQL statements do not change while the application is running.

**statistically based query optimization algorithm**—A query optimization technique that uses statistical information about a database. The DBMS then uses these statistics to determine the best access strategy.

**stored function**—A named group of procedural and SQL statements that returns a value, as indicated by a RETURN statement in its program code.

**stored procedure**—(1) A named collection of procedural and SQL statements. (2) Business logic stored on a server in the form of SQL code or another DBMS-specific procedural language.

**strong (identifying) relationship**—A relationship that occurs when two entities are existence-dependent; from a database design perspective, this relationship exists whenever the primary key of the related entity contains the primary key of the parent entity.

**structural dependence**—A data characteristic in which a change in the database schema affects data access, thus requiring changes in all access programs.

**structural independence**—A data characteristic in which changes in the database schema do not affect data access.

**structured data**—Unstructured data that have been formatted to facilitate storage, use, and information generation.

**Structured Query Language (SQL)**—A powerful and flexible relational database language composed of commands that enable users to create database and table structures, perform various types of data manipulation and data administration, and query the database to extract useful information.

**subordinate**—In a DDBMS, a data processor (DP) node that participates in a

distributed transaction using the two-phase COMMIT protocol.

**subquery**—A query that is embedded (or nested) inside another query. Also known as a *nested query* or an *inner query*.

**subschema**—In the network model, the portion of the database “seen” by the application programs that produce the desired information from the data in the database.

**subtype (entity set)**—An entity that contains unique characteristics (attributes) within a more broadly defined entity known as a supertype. In a generalization hierarchy, a subtype is any entity below a parent entity. For example, PILOT could be a subtype of the supertype EMPLOYEE.

**subtype discriminator**—The attribute in the supertype entity that determines to which entity subtype each supertype occurrence is related.

**SUM**—A SQL aggregate function that yields the sum of all values for a given column or expression.

**superkey**—An attribute or attributes that uniquely identify each entity in a table.  
See [key](#).

**supertype (entity set)**—An entity set that contains the commonly shared characteristics of its entities (See [subtype](#)). If the entity set can include characteristics that are not common to all entities within the set, the supertype becomes the parent to one or more subtypes in a generalization hierarchy.

**surrogate key**—A system-assigned primary key, generally numeric and auto-incremented.

**synonym**—The use of different names to identify the same object, such as an entity, an attribute, or a relationship; synonyms should generally be avoided.  
See also [homonym](#).

**system catalog**—A detailed system data dictionary that describes all objects in a

database.

**systems administrator**—The person responsible for coordinating an organization's data-processing activities.

**systems analysis**—The process that establishes the need for an information system and its extent.

**systems development**—The process of creating an information system.

**Systems Development Life Cycle (SDLC)**—The cycle that traces the history of an information system. The SDLC provides the big picture within which database design and application development can be mapped out and evaluated.

---

T

---

**table**—A matrix composed of intersecting rows (entities) and columns (attributes) that represents an entity set in the relational model. Also called a *relation*.

**table space**—In a DBMS, a logical storage space used to group related data. Also known as a *file group*.

**table-level lock**—A locking scheme that allows only one transaction at a time to access a table. A table-level lock locks an entire table, preventing access to any row by transaction T2 while transaction T1 is using the table.

**tag**—In markup languages such as HTML and XML, a command inserted in a document to specify how the document should be formatted. Tags are used in server-side markup languages and interpreted by a Web browser for presenting data.

**ternary relationship**—An ER term used to describe an association (relationship) between three entities. For example, a CONTRIBUTOR contributes money to a FUND from which a RECIPIENT receives money.

**theta join**—A join operator that links tables using an inequality comparison operator ( $,$   $>$ ,  $=$ ,  $\geq$ ) in the join condition.

**third normal form (3NF)**—A table is in 3NF when it is in 2NF and no nonkey attribute is functionally dependent on another nonkey attribute; that is, it cannot include transitive dependencies.

**timestamping**—In transaction management, a technique used in scheduling concurrent transactions that assigns a global unique timestamp to each transaction.

**timevariant data**—Data whose values are a function of time. For example, timevariant data can be seen at work when a company's history of all administrative appointments is tracked.

**top-down design**—A design philosophy that begins by defining the main structures of a system and then moves to define the smaller units within those structures. In database design, this process first identifies entities and then defines the attributes within the entities. Compare to *bottom-up design*.

**total completeness**—In a generalization/specialization hierarchy, a condition in which every supertype occurrence must be a member of at least one subtype.

**transaction**—A sequence of database requests that accesses the database. A transaction is a logical unit of work; that is, it must be *entirely* completed or aborted—no intermediate ending states are accepted. All transactions must have the properties of atomicity, consistency, isolation, and durability.

**transaction log**—A feature used by the DBMS to keep track of all transaction operations that update the database. The information stored in this log is used by the DBMS for recovery purposes.

**transaction log backup**—A backup of only the transaction log operations that are not reflected in a previous backup copy of the database.

**transaction manager (TM)**—See [\*transaction processor \(TP\)\*](#).

**transaction processor (TP)**—In a DDBMS, the software component on each computer that requests data. The TP is responsible for the execution and coordination of all databases issued by a local application that accesses data on any DP. Also called *transaction manager (TM)*. See also [\*data processor \(DP\)\*](#).

**transaction transparency**—A DDBMS property that ensures database transactions will maintain the distributed database's integrity and consistency, and that a transaction will be completed only when all database sites involved complete their part of the transaction.

**transactional database**—A database designed to keep track of the day-to-day transactions of an organization. See also [\*production database\*](#).

**transitive dependency**—A condition in which an attribute is dependent on another attribute that is not part of the primary key.

**trigger**—A procedural SQL code that is automatically invoked by the relational database management system when a data manipulation event occurs.

**tuple**—In the relational model, a table row.

**two-phase commit protocol**—In a DDBMS, an algorithm used to ensure atomicity of transactions and database consistency as well as integrity in distributed transactions.

**two-phase locking**—A set of rules that governs how transactions acquire and relinquish locks. Two-phase locking guarantees serializability, but it does not prevent deadlocks. The two-phase locking protocol is divided into two phases: (1) A *growing phase* occurs when the transaction acquires the locks it needs without unlocking any *existing* data locks. Once all locks have been acquired, the transaction is in its *locked* point. (2) A *shrinking phase* occurs when the transaction releases all locks and cannot obtain a new lock.

---

**unary relationship**—An ER term used to describe an association *within* an entity. For example, a COURSE might be a prerequisite to another COURSE.

**uncommitted data**—When you are trying to achieve concurrency control, uncommitted data cause problems with data integrity and consistency. These problems occur when two transactions are executed concurrently and the first transaction is rolled back after the second transaction has already accessed the uncommitted data, thus violating the isolation property of transactions.

**Unified Modeling Language (UML)**—A language based on object-oriented concepts that provides tools such as diagrams and symbols to graphically model a system.

**union-compatible**—Two or more tables that share the same column names and have columns with compatible data types or domains.

**unique fragment**—In a DDBMS, a condition in which each row is unique, regardless of which fragment it is located in.

**unique index**—An index in which the index key can have only one associated pointer value (row).

**uniqueness**—In concurrency control, a property of timestamping that ensures no equal timestamp values can exist.

**Universal Data Access (UDA)**—Within the Microsoft application framework, a collection of technologies used to access any type of data source and to manage the data through a common interface.

**unreplicated database**—A distributed database in which each database fragment is stored at a single site.

**unstructured data**—Data that exist in their original, raw state; that is, in the format in which they were collected.

**updatable view**—A view that can update attributes in base tables that are used in the view.

**UPDATE**—A SQL command that allows attribute values to be changed in one or more rows of a table.

**user**—In a system, a uniquely identifiable object that allows a given person or process to log on to the database.

---

---

V

---

---

**VBScript**—A client-side extension in the form of a Microsoft product that extends a browser's functionality; VBScript is derived from Visual Basic.

**vertical fragmentation**—In distributed database design, the process that breaks a table into a subset of columns from the original table. Fragments must share a common primary key. See also [\*database fragment\*](#) and [\*horizontal fragmentation\*](#).

**very large databases (VLDBs)**—Databases that contain huge amounts of data—gigabyte, terabyte, and petabyte ranges are not unusual.

**view**—A virtual table based on a SELECT query.

**virtualization**—A technique that creates logical representations of computing resources that are independent of the underlying physical computing resources.

---

---

W

---

---

**wait/die**—A concurrency control scheme in which an older transaction must wait for the younger transaction to complete and release the locks before requesting the locks itself. Otherwise, the newer transaction dies and is rescheduled.

**weak entity**—An entity that displays existence dependence and inherits the primary key of its parent entity. For example, a DEPENDENT requires the existence of an EMPLOYEE.

**weak relationship**—A relationship in which the primary key of the related entity does not contain a primary key component of the parent entity. Also known as a *non-identifying relationship*.

**Web application server**—A middleware application that expands the functionality of Web servers by linking them to a wide range of services, such as databases, directory systems, and search engines.

**Web-to-database middleware**—A database server-side extension that retrieves data from databases and passes them to the Web server, which in turn sends the data to the client's browser for display.

**wildcard character**—A symbol that can be used as a general substitute for one or more characters in a SQL LIKE clause condition. The wildcard characters used in SQL are the \_ and % symbols.

**workgroup database**—A multiuser database that usually supports fewer than 50 users or is used for a specific department in an organization.

**wound/wait**—A concurrency control scheme in which an older transaction can request the lock, preempt the younger transaction, and reschedule it. Otherwise, the newer transaction waits until the older transaction finishes.

**write-ahead protocol**—See [write-ahead-log protocol](#).

**write-ahead-log protocol**—In concurrency control, a process that ensures transaction logs are written to permanent storage before any database data are actually updated. Also called a write-ahead protocol.

**write-through technique**—In concurrency control, a process that ensures a database is immediately updated by operations during the transaction's execution, even before the transaction reaches its commit point.

---

**XML**—See [\*Extensible Markup Language \(XML\)\*](#).

**XML database**—A database system that stores and manages semistructured XML data.

**XML schema**—An advanced data definition language used to describe the elements, data types, relationship types, ranges, and default values of XML data documents. One of the main advantages of an XML schema is that it more closely maps to database terminology and features.

**XML schema definition (XSD)**—A file that contains the description of an XML document.

**XSL (Extensible Style Language)**—A specification used to define the rules by which XML data are formatted and displayed. The XSL specification is divided into two parts: Extensible Style Language Transformations (XSLT) and XSL style sheets.

**XSL style sheets**—Documents that are similar to presentation templates and that define the presentation rules applied to XML elements. The XSL style sheet describes the formatting options to apply to XML elements when they are displayed on a browser, cellular phone, PDA screen, and so on.

**XSLT (Extensible Style Language Transformations)**— The general mechanism used to extract and process data from one XML document and enable its transformation within another document.

## **INDEX**

---

---

### **SYMBOLS**

---

‘ (apostrophe): character attribute delimiter  
\* (asterisk)

wildcard character

zero or more times symbol  
|| (bars): concatenate sign (Oracle)  
O (circle): optional participation symbol  
: (colon): host variable prefix  
, (comma)

argument delimiter

table element delimiter  
-- (double dashes): comment indicator (PL/SQL)  
-> (double dashes + right angle bracket): comment indicator (in XML) " (double quotation mark):  
character attribute delimiter = (equal sign): equality comparison operator  
(forward slash): end command-line entry mark (PLSQL) > (greater than sign): greater than operator  
∞ (infinity symbol): many indicator  
<-- (left angle bracket + double dashes): comment indicator (in XML) # (number sign): date delimiter (in  
Access)  
#PCDATA keyword  
() (parentheses)

argument delimiters

table definition delimiters  
%(percent sign): wildcard character  
%FOUND cursor attribute (PL/SQL)  
%ISOPEN cursor attribute (PL/SQL)  
%NOTFOUND cursor attribute (PL/SQL)  
%ROWCOUNT cursor attribute (PL/SQL)  
%TYPE data type (PL/SQL)  
+ (plus sign)  
concatenate sign (Access/SQL Server)

one or more times symbol

? (question mark): optional element symbol

; (semicolon): end command mark

' (single quotation mark): character attribute delimiter \_ (underscore)

naming convention

wildcard character

---

---

## **NUMBERS**

---

---

1:1 (one-to-one) relationships

ERDs of

foreign keys in

implementing

as recursive relationships

usefulness  
1:M (one-to-many) relationships

creating tables in

ERDs of

fan traps in

implementing  
implementing M:N relationships with

loading data into

as recursive relationships

1NF. See first normal form 2NF. See second normal form 3NF. See third normal form 4NF. See fourth normal form 5NF (fifth normal form)

12 rules for defining a data warehouse

---

---

**A**

---

---

ABS function

absolute values: returning

abstraction levels in database design  
Access (Microsoft)

case sensitivity in search criteria

commands not supported

complex query alternatives

constraint support  
copying parts of tables into new tables

counting attribute values in

creating database structure in

creating views in

data types

date and time functions

date arithmetic

features

features not supported, commands, functions

functions not supported

joining tables with aliases

numeric functions

QBE query generator

referential constraint support

string functions

surrogate key implementation in  
access (to data). *See* data access access control: of DBMSs  
*See also* access rights (for users)  
access operations (table/index access)

access plan module  
access plans (execution plans) (of DBMSs)

comparisons of

displaying  
I/O operations  
access rights (for users)

assigning

accessing

data sources

rows

tables  
ACID properties (transaction properties)

active data dictionary  
Active Server Pages (ASP)

ActiveX

ActiveX Data Objects. *See ADO*

ad hoc queries

difficulty in host languages

in dynamic SQL

impossibility in file systems  
ADD option (ALTER TABLE command)  
ADD\_MONTHS function (Oracle)  
Administration/Server page (Oracle Enterprise Manager) ADO (ActiveX Data Objects) (Microsoft)  
vs. OLE-DB

ADO objects  
ADO.NET framework (Microsoft)

advanced data modeling  
checklist, InsideFrontCover(t)

entity clusters

extended ER model

flexible database design cases  
functions (in OLAP)

key terms

primary key selection  
problems (exercises)

review questions

summary  
advanced functions (in OLAP)  
aggregate function queries: indexes and

aggregate functions

and attribute list subqueries

with date columns

grouping data from  
vs. numeric functions  
vs. PL/SQL functions

with SQL commands

aggregation problems in database design

Agile Software Developmen

algorithms

for data allocation

for data mining

for predictive analytics

for query optimization

aliases

*See also* column aliases; table aliases

ALL subqueries

ALL\_ROWS optimizer hint (instruction)

ALTER TABLE command

Amadeus: Oracle upgrade downtime reduction process Amazon CloudWatch

Amazon EC (Amazon Elastic Compute Cloud)

Amazon RDS (Amazon Relational Database Service)

Amazon Web Services (AWS)

Netflix and

outage

provisioning cost  
Amazon's SimpleDB  
American National Standards Institute: ANSI/ SPARC data modeling framework analysis phase (SDLC)

analytical databases

analytical interface, end-user (OLAP)

ANALYZE command

AND logical operator

multiple AND conditions  
anonymous PL/SQL blocks  
ANSI SQL (ANSI/ISO standard)

clauses

commands

constraints

data types

join operations

special operators

transactions  
ANSI/SPARC data modeling framework

ANY subqueries

Apache's Cassandra

APIs (application programming interfaces)

object-oriented APIs

apostrophe (''): character attribute delimiter

application code

as a query processing bottleneck  
application databases: MSCLink  
application processors (APs)

application programming interfaces. *See APIs application programs (applications)*

.NET framework for developing  
code. *See application code*  
creating, data dictionary use in

DBA design and implementation tasks

prototyping

security vulnerabilities

as a service

SQL-based relational database application parts

testing  
APs (application processors)  
argument delimiters ((), ,)

arithmetic operators

in data updates

ASP (Active Server Pages)

associative data model. *See* key-value data model associative entities. *See* composite entities asterisk (\*)

wildcard character

zero or more times symbol  
AT&T database systems

atomic attributes

atomic data

atomicity (of entity attributes)

atomicity (of transactions)

attribute hierarchies (of fact attributes)

attribute list subqueries

attribute names in SQL command sequences

attribute values (of entity attributes)

checking for conditions for

*See also* triggers

comparing to lists of values

counting

generating aggregates

listing rows with matching values

listing rows with nulls

listing rows with unique values  
nulls. *See* nulls

passing to stored procedures  
ranges. *See* domains

returning more than one

updating

in other tables

*See also* numeric attributes; strings

attribute-value data model. *See* key-value data model attributes

of entities. *See* attributes (of entities)

of facts, hierarchies

of objects (OO model)

of PL/SQL cursors

attributes (of entities)

atomic attributes

**boldfaced** attributes  
character. *See* strings  
checklist, InsideFrontCover(t)  
common, *See also* foreign keys

composite attributes  
computed. *See* derived attributes  
constraints on (specifications for)  
data types. *See* data types

definition conflicts  
dependencies between/among. *See* dependencies

dependents  
derived. *See* derived attributes

determinants  
discriminator. *See* subtype discriminator

display formats  
domains. *See* domains

ERDs for  
functional dependence, full functional dependence

identifying

inheritance of  
key. *See* key attributes  
in the key-value data model  
multivalued attributes, implementing

naming conventions  
:NEW reference  
nonkey/nonprime attributes

not displaying in entity clusters  
numeric. *See* numeric attributes  
:OLD reference  
optional attributes, inserting rows with  
prime. *See* key attributes  
re-evaluating

refining for atomicity

relational diagrams of

repeating groups of entries for

required attributes

simple attributes  
single-valued attributes  
specifications for (constraints on)  
values. *See* attribute values

audit logs

audit trails  
authentication (of users)

authorization managemen

automatic query optimization

automatic startup in Oracle  
AutoNumber data type (in Access)

columns created as  
availability (of data)

in distributed data systems

AVG function

AWS. See Amazon Web Services Azure (Microsoft)

provisioning cost

---

---

**B**

---

---

B-tree indexes  
B2B transactions/exchanges

XML example  
back-end CASE tools

backup management

backups

Banco de Bilbao (BBVA): data modeling by

bars (||): concatenate sign (Oracle)

BASE data (basically available, soft state eventually consistent data) base tables (master tables)

updating

batch update routine  
BBVA (Banco de Bilbao): data modeling by  
BCNF. *See* Boyce-Codd normal form BEGIN clause

BETWEEN special operator

BI. *See* business intelligence BI appliances

BI tools

business problem solutions based on

Big Data analytics

Big Data challenges to the relational model

Big Data databases. *See* NoSQL databases BigTable (Google)

binary locks

binary relationships

mapping to tables

bitmap indexes

**boldfaced** attributes

Boolean algebra

bottlenecks, query processing

bottom-up design

vs. top-down design

boundaries (of systems)

boundaries and scope definition process (DBLC database initial study phase) Boyce-Codd normal form

(BCNF)

conversion to

Brewer, Eric

bridge entities. *See* composite entities browsers. *See* Web browsers B-tree indexes  
buffer cache (data cache)

buffers

BUILD clause

business governance  
business intelligence (BI)

appliances

benefits

business operations/processes framed by  
components (architecture)

decision support functions

effectiveness

evolution

management practices

reporting styles

as a service

technology trends  
tools, business problem solutions based on  
business managers' view of data  
business operations/processes framed by BI

business rules

checklist, InsideFrontCover(t)

and database design

importance

sources

SQL commands example

translating into data model components

business transactions on the Internet

(e-commerce)

*See also* B2B transactions/exchanges

business vignettes

Amadeus' Oracle upgrade downtime reduction process

BBVA's data modeling

GUESS mobile business intelligence system (Microstrategy)

MSCLink database  
Nealab's cloud services

relational database evolution  
business-to-business transactions on the Internet. *See* B2B transactions/exchanges businesses  
activity measurements. *See* facts  
data management capacity. *See* business intelligence

governance

key performance indicators (KPIs)

operations/processes framed by BI

problem solutions based on BI tools

rules. *See business rules*

*See also* business vignettes

---

---

## C

---

caches

**cube cache**

**data cache (buffer cache)**

sort cache  
SQL cache (procedure cache)  
caching (database caching)  
call level interfaces (CLIs)

candidate keys

surrogate keys and

*See also* primary keys

CAP properties of distributed data systems (CAP theorem) cardinalities (in ERDs)

career opportunities for database professionals  
Carr, Nicholas: on cloud computing

Cartesian product  
cascading order sequence: ordering listings in

CASE data dictionary

CASE development environment  
CASE function (SQL Server)

CASE interfaces

case sensitivity

in SQL searches

in XML

CASE tool vendors

CASE tools (computer-aided systems engineering tools) Cassandra (Apache)

CAST function (SQL Server)

Category symbol/shape (MS Visio)

CEIL function (Oracle)

CEILING function (SQL Server)

central entity

central processing units (CPUs): as query processing bottlenecks centralized data allocation

centralized database management systems

CAP properties

problems in

centralized databases

centralized design  
vs. decentralized design  
CGI (Common Gateway Interface)

CGI scripts

CHAR data type (PL/SQL)

character attributes. *See strings character comparisons: numeric comparisons as faster than character data*

in the data dictionary

names as

numbers as

types

*See also* strings

characters: data types

CHECK constraint

check sequences command

checklist for data modeling, InsideFrontCover(t) checkpoints (checkpoint operations)

Chen, Peter

Chen notation (ERDs)

attribute display

weak entity display

child elements in XML documents

CiCi's Enterprises: BI tool-based business problem solutions circle (O): optional participation symbol

circular join conditions

class diagrams. See UML class diagrams class hierarchy

classes (of objects)

OLE-DB classes

client/server architecture/technology

in OLAP systems

client-side activities in database performance tuning

*See also* SQL performance tuning

client-side extensions (for Web browsers)

CLIs (call level interfaces)

CLOSE command (PL/SQL)

closure property

cloud computing

growth

technologies

*See also* cloud services

cloud databases

*See also* clouds

cloud services

advantages and disadvantages

characteristics

cloud types

costs

reliability questions

simple services

types  
clouds (data networks)

customization of

implementation types

*See also* Interne

clustered tables  
Codd, E. F. (“Ted”)

relational database rules  
code. See application code cohesivity (of modules)  
ColdFusion: Web database development code example colon (:): host variable prefix

column aliases

in attribute list subqueries

in difference expressions (DIFF)

listing rows using computed columns and

column constraints  
adding/changing/deleting

column names

expressions for

*See also* column aliases

column store data model

evolution

column widths: changing

columns (in database tables)

aliases. *See* column aliases

AutoNumber data type columns

changing data types

changing widths  
constraints. *See* column constraints

copying into new tables  
data sparsity in. *See* data sparsity

deleting

identifying

indexing  
inserting (adding)

join columns  
listing rows using computed columns and column aliases  
names. *See* column names

naming conventions

projecting  
pseudo columns (in Oracle)  
ranges of values. See domains

COM (Component Object Model)

COM objects

*See also* consumers; providers  
combining tables/sets

INTERSECT queries

MINUS queries  
UNION/UNION ALL queries  
comma (,)

argument delimiter

table element delimiter  
Command objects (in ADO.NET)  
commands: ADO.NET Command objects  
*See also* SQL commands; and specific SQL commands  
comment indicator (-) (PL/SQL)  
comment indicators (<- and ->) (XML) COMMIT command (statement)  
    in transactions, premature COMMIT  
    effects, two-phase commit

protocol  
Common Gateway Interface (CGI)  
communication area in SQL (SQLCA)

community clouds

company situation analysis (DBLC database initial study phase) comparing dates

comparing strings (character/string attributes)

comparison operators

in SELECT queries join operations

COMPLETE option

completeness constraint

compliance (with data privacy and security guidelines) Component Object Model (COM)

composite attributes

composite entities (composite tables)

composite keys as identifiers of

ERDs for

composite identifiers

*See also* composite keys

composite indexes

composite keys

defining in new tables

of fact tables

problems with

uses for composite tables. *See* composite entities computational functions, advanced computed attributes. *See* derived attributes computer-aided systems engineering (CASE) technology tools. *See* CASE tools

computerized file systems  
concatenate signs (|| and +)

concatenating strings

conceptual design stage (DBLC database design phase)

data analysis and requirements step

data model verification step  
.distributed database design step  
entity relationship modeling and normalization step  
conceptual models (of data)  
in centralized vs. decentralized design

design tools and information sources  
developing, ; using ERDs  
mapping to the logical/relational model  
*See also* ER model; ER modeling

conceptual schemas  
concurrency control (of transactions)

data integrity and consistency problems

distributed concurrency control  
first-come, first-served scheduling

locking methods

optimistic methods

scheduler

concurrent backups

concurrent transactions

inconsistent retrievals problem

lost update problem  
normal/correct execution  
READ/WRITE conflict scenarios

uncommitted data problem

*See also* concurrency control

conditional expressions

evaluation order

listing rows with

*See also* join conditions

conditional operands

conditional operators

conditional procedures: programming language extensions for conditions (expressions). *See* conditional

expressions conditions (for attribute values)

    checking for *See also* triggers

confidentiality (of data)

Connection objects (in ADO.NET)

connectivity: of relationships

*See also* database connectivity

consistency (of data)

in distributed data systems

eventual consistency

mutual consistency rule

in transactions

consistent database state  
constraints (on data) (SQL constraints)

CHECK constraint  
column. *See* column constraints

DEFAULT constraint

defining

identifying

NOT NULL constraint  
referential. *See* referential constraints

table constraints

UNIQUE constraint

*See also* foreign keys; primary keys  
constraints (on entity supertypes)

completeness constraint

specialization hierarchy scenarios

*See also* disjoint subtypes; overlapping subtypes

constraints (on transactions)

consumers (COM objects)

controlled redundancy

conversion functions

*See also* string functions

CONVERT function (SQL Server)

converting dates to strings

converting numbers to strings

converting strings

to dates

to lowercase

to numbers

to uppercase  
coordinator (DDBMS node)  
copying parts of tables into new tables

correlated subqueries

with the EXISTS special operator

table aliases in

Corrupted data security breach  
cost-based optimizer  
vs. rule-based optimizer

costs

of cloud services

of data loss

of database requests

of DBMSs  
I/O cost comparisons

COUNT function

counting attribute values  
CPUs (central processing units)

as query processing bottlenecks  
READ/WRITE conflict scenarios and

CREATE INDEX command

CREATE SCHEMA AUTHORIZATION

command

CREATE TABLE command

defining constraints in Oracle  
Create User page (Oracle Enterprise Manager)

**CREATE VIEW** command  
credentials (for Oracle databases): specifying

**cross join**

*See also* PRODUCT relational operator  
Crow's Foot notation (ERDs)

attributes

cardinalities

composite entities

connectivities

ERM development

optional participation symbol

relationships strong weak

strong relationships

symbols

weak entities

weak relationships

cube cache

CUBE extension (to GROUP BY clause)

cubes, three-dimensional. *See* data cubes cultural impact of DBMS introductions

currency (of data): for operational data vs

decision support data

CURRVAL pseudo column (in Oracle)

cursors (embedded SQL)

fetching rows from  
cursors (PL/SQL)

attributes

fetching rows from

processing commands

---

---

**D**

---

---

d (disjoint constraint). *See* disjoint subtypes DA (data administrator) (information resource manager)  
position/placement/role  
tasks/responsibilities/activities  
*See also* DBAs (database administrators)  
DAO (Data Access Objects) (Microsoft)

dashboards

dashed lines in Chen ERDs

**data**  
access. *See* data access

atomic data

availability  
B2B exchanges

backups

BASE data  
business manager's view of

and code

confidentiality

consistency. *See* consistency (of data)

constraints on. *See* constraints (on data)

as a corporate asset  
current: separating from time-variant  
in data warehouses. *See* data warehouse data  
data-information-decision cycle  
database designer's view of  
decision support. *See* decision support data (DSS data)

decomposition of  
derived: denormalization and

dimensionality

dirty data

extraction of. *See* data extraction

filtering of. *See* data filtering

formats: logical vs. physical

formatting of

fragmentation of

granularity

historical accuracy. *See* historical accuracy (of data)

inconsistency. *See* data inconsistency

independence. *See* data independence

vs. information

information sources  
integration of. *See* data integration  
integrity. *See* data integrity  
loading into 1:M relationships

loading into databases  
locks on data items. *See locks*  
loss. *See data loss*  
management of. *See data management*  
mining. *See data mining*  
modeling. *See data modeling*  
models. *See data models*

multidimensional views

nonvolatile data in data warehouses  
operational. *See* operational data

periodicity

privacy

pyramid image

quality

recovery. *See* database recovery

redundant. *See* data redundancy

replicated data: mutual consistency rule *See also* data replication

rules for processing. *See* business rules

security. *See* security (of data)

semistructured data  
separating current from time-variant  
sparsity. *See* data sparsity  
storage. *See* data storage

structured data

subject-oriented data in data warehouses

time-variant. *See* time-variant data

timespan  
types. *See* data types  
uncommitted data (concurrent transactions problem)

unstructured data

updating. *See* updating of relational databases

validation of. *See* data validation

as viewed in different ways

XML. See XML data

*See also* attribute values; metadata; rows (in database tables)

data abstraction: levels in database design

data access (data retrieval)

in data models  
in DBMSs, requirements

distributed data access

file system programming requirements  
interfaces. *See* database connectivity interfaces; Internet database connectivity  
in OLAP systems, advanced features

ROLAP SQL extension

secondary keys for

*See also* queries (in SQL)

Data Access Objects (DAO) (Microsoft)

data administration. *See* database administration data administrator. *See* DA data allocation

data allocation algorithms

data analysis

data dictionary use in  
managers' need for  
multidimensional. *See* multidimensional data analysis  
proactive research approach. *See* data mining

tools

data analysis and classification phase (of data mining) data analysis and reporting tools

data analysis and requirements step (DBLC conceptual design stage) data analytics

Big Data analytics

personal analytics

*See also* data analysis; data mining

data anomalies

data redundancy and

partial dependencies and

of theoretical interest only

transitive dependencies and  
data backups. *See* backups data binding of XML data to HTML documents  
data cache (buffer cache)  
data classification functions, advanced  
data consistency. *See* consistency (of data) data consolidation functions, advanced  
data contention (network latency)  
data cubes (three-dimensional cubes)

multidimensional data analysis in  
data currency: for operational data vs. decision support data data definition commands (DDL statements)  
(in SQL)

additional commands

processing of  
data definition languages (DDLs)

SQL as a DDL

data definitions. *See* metadata data democracy

data dependence: of file systems

data dictionary

automatic creation of

CASE data dictionary

DBMS use of

descriptions stored in

functions

query use of

SQL commands example

types

data distribution

DBA tasks

levels of data and process distribution

and query optimization

data encryption

data entries: repeating groups

data entry: inserting rows

data entry errors

data extraction

extracting date parts  
from operational databases into decision support databases  
data extraction, transformation, and loading (ETL) tools data files

assigning to separate storage volumes  
groups of. *See* TABLE spaces (file groups)

transferring  
data filtering from operational databases into

decision support databases  
data formats: logical vs. physical

data fragmentation

data fragments. *See* database fragments data granularity. *See* granularity (of data) Data Guard (Oracle)

data inconsistency

concurrent transactions and

DBMSs and

data independence  
Codd's rules on

data integration

BI and

in data warehouses

DBMSs and

data integrity

concurrent transactions and

data redundancy and

DBMS management of

enforcement of

security breaches

**security measures**

*See also* entity integrity; referential integrity

data integrity management  
data loss: cost

data management

importance

via the Interne

*See also* data processing; database administration; database systems; file systems  
data managers (DMs)  
data manipulation commands (DML statements)

processing of

relational set operator implementation statements

SELECT subqueries in

trigger predicates  
data manipulation languages (DMLs)

SQL as a DML

data marts

in OLAP systems

data mining

algorithms

modes

phases

pyramid image

tools

uses

data mining tools

data model verification step (DBLC conceptual design stage) data modeling

advanced. *See* advanced data modeling

ANSI/SPARC framework

by BBVA  
checklist, InsideFrontCover(t)  
users' lack of skills in

in Visio

*See also* star schemas

data models

abstraction levels

advantages and disadvantages of various models

building blocks (data components) identifying translating business rules into characteristics, common

column store. *See column store data model*

components, *See also ... building blocks, above*

conceptual. *See conceptual models*

data access in  
data components. *See ... building  
blocks, above*

data sharing in

data storage in  
entity relationship. *See* ER model

evolution

extended ER model

extended relational. *See* extended relational

data model

external models  
hierarchical. *See* hierarchical model

implementation models

importance

internal models

key terms

key-value store. *See* key-value data model

network. *See* network model

NoSQL. *See* NoSQL data models

OO model. *See* object-oriented data model (OODM)

for operational data vs. decision support data

physical models  
problems (exercises)  
relational. *See* relational model

review questions  
semantic. *See semantic data models*

summary

**terminology**

*See also* attributes (of entities); constraints; data modeling; database models; entities; relationships

data monitoring and alerting

data networks. *See* clouds data preparation phase (data mining)

data presentation functions, advanced

data processing: file system problems

*See also* data managemen

data processing (DP)

data processing departments

data processing specialists. *See* DP specialists data processors. *See* DPs data providers (COM objects)

data quality

data recovery. *See* database recovery data redundancy

controlled redundancy

and data anomalies

and data inconsistency

and data integrity

and data security

and denormalization

foreign keys and

historical accuracy vs  
in M:N relationships wrongly implemented

partial dependencies and

relational model and

tests of

data replication

and query optimization

scenarios

in tables

usage factors

data reporting

BI styles

BI tools

database design requirements

file system delays  
data repositories. *See* data sources data retrieval. *See* data access data security. *See* security (of data) data sets

cursor sets

*See also* relations; sets; tables

data sharing

in data models

DBMSs and

file system problems  
data source names (DSNs)  
data sources (data repositories)

accessing

defining an ODBC data source  
data sparsity (sparse data)  
in columns, ; and the need for indexes

in data cubes

in NoSQL databases

data storage

BI improvements

in data models  
in DBMSs. *See* data storage management

multidimensional data

physical design

data storage management

database statistics storage

database storage groups

in Oracle

data stores

*See also* data marts; data warehouses

data transformation and presentation

data type mismatches (SQL vs. procedural languages) data types (SQL)

AutoNumber data type (in Access)

for characters

for columns: changing

compatible data types

for dates

for numbers  
PL/SQL data types

for times

data updates

arithmetic operators in

data validation

for Web applications

in XML

data visualization tools

data warehouse data  
vs. operational data

data warehouses

advanced data analysis environment. *See* OLAP systems

creating from operational data  
data in. *See* data warehouse data

data mart conversion to

data redundancies in

designing

drill down operations

fact tables in

lower normalization forms in

metadata

in OLAP systems

queries in  
roll up operations, *See also* ROLLUP extension

rules for defining  
smaller stores. *See* data marts  
data-information-decision cycle  
data-information-knowledge pyramid  
data-profiting software  
DataAdapter objects (in ADO.NET)  
database access languages (query languages)  
*See also* database languages

database administration

data processing departments  
database administrators. *See* DBAs

distributed databases and

evolution

goals

human component, *See also* DA (data administrator); DBAs (database administrators)

information systems departments

key terms

management level performance requirements

review questions

strategy

success factors

summary

tools  
using Oracle. *See* database administration using Oracle

database administration strategy

database administration using Oracle

creating databases

creating datafiles

creating tablespaces

credentials

data storage management

database object management

initialization parameters  
interface. *See* Enterprise Manager

login

startup

user management

database administrators. *See* DBAs database analysts

database applications. *See* application programs database architects

database backups. *See* backups database buffers

database caching

database checkpoints (checkpoint operations) database communication interfaces. *See* database connectivity interfaces database connectivity

key terms  
problems (exercises)

review questions

**summary**

*See also* database connectivity interfaces; Internet database connectivity; XML

database connectivity interfaces

ADO.NET framework

DAO (Data Access Objects)

JDBC (Java Database Connectivity)

native SQL connectivity

ODBC (Open Database Connectivity)

OLE-DB (Object Linking and Embedding for Database)

RDO (Remote Data Objects)

scripting language support

*See also* APIs; Internet database connectivity

database consultants

database conversion services  
database design (systems design)

abstraction levels

aggregation problems in  
approaches to (strategies)

business rules and

CASE development environment

centralized vs. decentralized design

concepts. *See* advanced data modeling; ER model; normalization; relational model

conceptual design, DBLC stage. *See* conceptual design stage

contradictory requirements/conflicting goals in

data dictionary use in

and database performance

DBA tasks

DBLC phase. *See* database design phase

decomposition of data

distributed database design

distributed processing

documentation of

ER model verification process

ERD development process

failures

flexible design cases

importance

improving

information requirements

as an iterative process

key terms  
logical. *See* logical design

management approval and  
models. *See* data models

normalization in improvements

*See also* normalization (of database tables)

objective

performance requirements  
physical. *See* physical design  
problems (exercises)  
process flow (procedure flow)

reporting requirements

review questions  
SDLC phase. *See* detailed systems design phase

standards

summary

system concepts

the Web and  
top-down vs. bottom-up design  
users' lack of skills in  
database design phase (DBLC)  
conceptual stage. *See* conceptual

design stage

## DBMS software selection

logical stage

physical stage

database designers. *See* designers database developers

database development

database implementation

new technologies

*See also* database design

database drivers. *See* ODBC drivers database dumps (full backups)

database fragments (in DDBMSs)

distribution transparency

mutual consistency rule

unique fragment condition  
database initial study phase (DBLC)

database instances

database languages

data definition/manipulation languages (DDLs/DMLs)

query languages

requirements for

scripting language connectivity support

*See also* SQL

database latency. *See* network latency (data contention) Database Life Cycle (DBLC)

DBA activities  
design phase. *See* database design phase

implementation and loading phase

initial study phase

maintenance and evolution phase

operation phase

Systems Development Life Cycle parallels

testing and evaluation phase  
database management. *See* database administration  
database management systems. *See* DBMSs

database middleware

Web-to-database middleware

*See also* database connectivity interfaces

database migration services  
database modeling. *See* data modeling

database models

SQL commands example

*See also* data models

database objects

managing in Oracle

measurement parameters

*See also* indexes; stored procedures; tables; triggers; views

database performance

database design and

mantra on

monitoring

physical storage properties and requirements. *See* database performance requirements

system performance factors  
vs. transaction consistency: in NoSQL databases  
tuning. *See* database performance tuning

database performance monitoring

database performance requirements in database design

by management level

normalization and  
*See also* reporting requirements

database performance tuning

basic concepts  
client-side activities. *See also*

SQL performance tuning

in DBMSs

key terms  
problems (exercises)

review questions

server-side activities, *See also* DBMS performance tuning

in SQL

summary

*See also* query optimization

database professionals: career opportunities

database recovery

management of

process scenario  
transaction recovery, process example

database requests

costs

distributed requests

remote requests

*See also* queries

database roles (roles)

database schemas: creating

database security

*See also* security (of data)

database security officers (DSOs)

database servers. *See* servers database statistics

generating

object measurement parameters

database storage groups

database systems

advantages

basic concepts

complexity

component installation

disadvantages  
distributed. *See* distributed database systems  
environment (components) evolution

failure sources

vs. file systems

human component, *See also* DA (data administrator); DBAs (database administrators)

key terms

levels of data and process distribution

managing  
performance factors, *See also* database performance  
problems (exercises)

review questions  
security. *See* security (of data)

summary

users. *See* users (of database systems)

database tables. *See* tables (of relational databases) database technologies, new

database transactions. *See* transactions database virtualization

database-level locks

databases

access control. *See* access rights  
accessing, *See also* database

connectivity interfaces

analytical databases  
application database (MSCLink)

backups

centralized databases  
connectivity. *See* database connectivity

consistent state

conversion services  
converting ER models into (online content)  
creating, in Oracle  
data storage. *See* data storage management  
DataSets (in ADO.NET)  
decision support. *See* decision support databases (DSS databases)  
design. *See* database design

desktop databases

development of. *See* database development

discipline-specific databases

distributed. *See* distributed databases

enterprise databases

failure sources

fine-tuning. *See* database performance tuning

fragments. *See* database fragments

general purpose databases

implementation of  
in-memory databases

inconsistent state

information systems and  
Internet connectivity. *See* Internet database connectivity  
languages. *See* database languages  
life cycle. *See* Database Life Cycle (DBLC)

loading data into management of. *See* database administration; DBMSs (database management systems)

metadictionaries for

migration services  
models. *See* database models

MSCLink database

multiuser databases

new technologies  
NoSQL databases (Big Data databases)  
operational. *See* operational databases  
partitioning of. *See* data fragmentation  
performance. *See* database performance  
policies, standards, and procedures for  
recovery of. *See* database recovery

reorganization of

replicated databases  
roles (database roles)

security

single-user databases

vs. spreadsheets

systems. *See* database systems

tables. *See* tables (of relational databases)

testing  
transactions. *See* transactions

types

usage monitoring  
users. *See* users (of database systems)  
very large databases (VLDBs) ROLAP support for

virtualization of

Web database development code examples

workgroup databases

XML databases  
datafiles (in Oracle)

creating

DataReader objects (in ADO.NET)

DataSets (in ADO.NET)

DataTables (in ADO.NET)

date arithmetic

date columns: aggregate functions with

date comparisons: numeric comparisons as faster than DATE data type (PL/SQL)

date delimiter (#) (in Access)

DATE fields

date formats

Julian format

date functions

DATE() function (Access)

Date's commandments for distributed databases

DATEADD functions (Access/SQL Server)

DATEDIFF functions (Access/SQL Server)

dates

adding time periods to

comparing

converting strings to

converting to strings

data types

entering

extracting parts

Julian dates

returning

returning the last day of the month given in

subtracting

DAY function (Access/SQL Server)

DB2 (IBM): features

DBAs (database administrators)

application design and implementation  
as arbiters between data and users

authorization management

backup and recovery management

cloud role

data dictionary usage

data distribution and use tasks

data integrity management

data security management. *See ... security management, below*

database design and implementation

database system components installation

database usage monitoring

DBLC phase activities

DBMS evaluation, selection, and installation

## DBMS operation tasks

default administrator  
end-user support services

maintenance activities

managerial role

multiple DBAs  
policies, standards, and procedures enforcement  
position/placement/role, cloud role, managerial role, technical role

security management

skills

system support activities  
tasks/responsibilities/activities

technical role

training and supporting users

user access management  
DBLC. *See* Database Life Cycle DBMS architecture

DBMS performance monitoring

DBMS performance tuning

DBMS software

selection process (DBLC database design phase)

*See also* Access (Microsoft); application programs; DB2(IBM); Oracle (RDBMS); SQL Server (Microsoft)

DBMSs (database management systems) access control

access plans. *See* access plans (execution plans)

advantages

architecture

backup management

centralized DBMSs

cultural impacts of introductions

data access in

data access needs

data dictionary usage

data formatting

data integrity management  
data storage management. *See* data

storage management  
decision support. *See* decision support  
databases (DSS databases)

## desired features checklist

disadvantages  
distributed systems. *See* distributed  
database management systems (DDBMSs)

functions

installing

introductory considerations

maintenance activities

multidimensional systems (MDBMSs)

object-oriented systems (OO DBMSs)

object/relational systems (O/R DBMSs)

operation tasks

parsing queries

performance monitoring  
performance requirements. *See* database

performance requirements

performance tuning

portability

processes

query processing in

recovery management  
relational. *See* RDBMSs (relational database management systems)  
security auditing and monitoring, data dictionary use in  
security management. *See* security management  
software. *See* DBMS software

technological changes and

transaction management support

upgrading

XML support

*See also* database systems

DDBMSs. *See* distributed database management systems DDC (distributed data catalog)

DDD (distributed data dictionary)

DDL statements. *See* data definition commands DDLs. *See* data definition languages deadlocks

control techniques  
deadly embrace (of deadlocks)  
debugging PL/SQL blocks

decentralized design  
vs. centralized design

decision making  
data-information-decision cycle

DBMSs and  
decision support data (DSS data)

characteristics  
modeling. *See* star schemas  
vs. operational data  
*See also* decision support databases  
decision support databases (DSS databases)

data extraction and filtering from

operational databases into

data in

schemas

size

*See also* data marts; data warehouses

decision support functions in BI systems

decision support systems (DSSs)

key terms  
problems (exercises)

review questions

**summary**

*See also* business intelligence; data marts; data mining; data warehouses; decision support databases; OLAP systems; star schemas

declarative languages

Codd's rule on

DECODE function (Oracle)

decomposition of data

DEFAULT constraint

**DEFERRED** statement  
deferred writes/updates

DELETE statement

deleting

columns

indexes

rows

tables

triggers

deletion anomalies  
denormalization (of database tables)

common examples

and data redundancy

fact tables

need for  
dependencies (between/among attributes)

eliminating

full functional dependence

functional dependence

identifying

multivalued dependencies

partial dependencies eliminating using with caution

transitive dependencies eliminating

dependency diagrams

Boyce-Codd normal form (BCNF)

first normal form (NF)

second normal form (NF)

third normal form (NF)

dependents (attributes)

reassignning

derived attributes

storing: advantages and disadvantages

using

derived data

in decision support databases

denormalization and  
*See also* decision support data

DESC qualifier  
descending order: ordering listings in

description of operations documents

design. *See* database design (systems design) design groups/teams

design standards (for databases)

design traps  
designers (database designers)  
groups/teams

view of data

desktop databases

detailed systems design phase (SDLC)

determinants (attributes)

as foreign keys

determination (of attribute values)

difference expressions (DIFF): column aliases in DIFFERENCE relational operator

*See also* MINUS statement

differential backups

dimension tables (dimensional tables)

and fact tables

normalization of  
trade-offs  
dimensionality (of data)  
dimensions (of facts)  
    attributes within, in hierarchies

dirty data

disaster management  
discipline-specific databases

disconnected systems

discriminator attribute. *See* subtype discriminator disjoint subtypes (disjoint constraint)

discriminator attribute for

notation for  
disk blocks (physical)  
using different sizes in different volumes

disk contention

diskless workstations

diskpages (pages)

display formats (of attributes): changing

DISTINCT clause

distributed concurrency control

distributed data access

distributed data catalog (DDC)

distributed data dictionary (DDD)

distributed data systems: properties

desirable

*See also* distributed database systems/environment

distributed database architecture: NoSQL databases distributed database design

distributed database design step (DBLC conceptual design stage) distributed database environment. *See*

distributed database systems/environment distributed database management systems (DDBMSs)

advantages and disadvantages

characteristics

components

evolution

functions

heterogeneous DDBMSs

homogeneous DDBMSs

key terms

NoSQL DDBMSs  
problems (exercises)

protocols

review questions

summary

technological changes and  
transparency features. *See* transparency features (of DDBMSs)  
distributed database systems/environment  
latency in. *See* network latency (data contention)

query optimization in

*See also* distributed data systems; distributed database management systems

distributed databases

and database administration  
Date's commandments for

design of

vs. distributed processing

*See also* distributed database systems/environment

distributed global schema

distributed processing  
vs. distributed databases  
distributed processing systems/environment

distributed requests

distributed transactions

distribution independence: Codd's rule on  
distribution transparency (of DDBMSs)

DIVIDE relational operator

DKNF (domain-key normal form)

DLLs (dynamic-link libraries)

DML statements. *See* data manipulation commands DMLs. *See* data manipulation languages DMs (data managers)

DO-UNDO-REDO protocol

Document Type Definitions. *See* DTDs documentation of database design

domain-key normal form (DKNF)

domains (of attributes/columns)

checking for values within

defining  
double dashes (--) : comment indicator (PL/SQL)  
double dashes + right angle bracket ( ->):  
comment indicator (in XML)

double lines in Chen ERDs

double quotation mark ("": character attribute delimiter DP (data processing)

DP departments

DP specialists view of file system files

DPs (data processors)

drill down operations

in data warehouses

drivers. See ODBC drivers DROP INDEX command

DROP option (ALTER TABLE command)

DROP SEQUENCE command (Oracle)

DROP TABLE command

Dropbox

dropping sequences (in Oracle)

Drucker, Peter

DSNs (data source names)

DSOs (database security officers)

DSS data. *See* decision support data DSS databases. *See* decision support databases DSSs. *See* decision support systems DTDs (Document Type Definitions) (in XML)

XML schemas vs

duplicate records problem  
durability (of transactions)

dynamic query optimization

dynamic SQL

dynamic statistical generation mode

dynamic Web pages  
dynamic-link libraries (DLLs)  
Dyson, Esther

---

---

**E**

---

---

e-commerce  
*See also* B2B transactions  
EDI: XML vs  
Edit Local Preferred Credentials page (Oracle Enterprise Manager) EER diagrams (EERDs)  
EER model (extended ER model)  
EERDs (EER diagrams)  
EERM. *See* EER model

efficiency of queries  
electronic commerce. *See* e-commerce Ellison, Larry

**embedded SQL**

creating and running executable programs with statements in

cursors in

framework  
embedding SQL statements in host languages

employee skill certification database design

ENABLE QUERY REWRITE option

END clause  
end command mark (;)  
end command-line entry mark (/) (PL/SQL)  
END statement (in PL/SQL blocks)  
end users (of database systems)

access management

access rights

authentication of

and business rules  
lack of design and data-modeling skills  
productivity (with DBMSs)

security vulnerabilities

training and supporting

view of file systems  
end-user interfaces

OLAP interfaces

of SQL-based relational database applications

end-user processes

end-user productivity tool problems. *See* personal productivity tool problems end-user requirements: in  
database design

end-user support: DBA services

enterprise databases

enterprise ER model  
Enterprise Manager (Oracle)

Create User page

Edit Local Preferred Credentials page

Initialization Parameters page  
Server/Administration page

enterprise RDBMSs

entities

attributes. *See* attributes (of entities)

central entity  
checklist, InsideFrontCover(t)  
composite. *See* composite entities

identifying  
instances. *See* entity occurrences  
integrity. *See* entity integrity

mapping to tables  
multiple (entity clusters)

as objects  
objects in the OO model as  
re-evaluating

regular entities

relational diagrams of  
relationship diagrams of. *See* ERDs  
relationships. *See* relationships (between/among entities)  
sets (entity sets)

strong entities

subtypes. *See entity subtypes*

supertypes. *See entity supertypes*

as tables

translating business rules into  
weak. *See* weak entities

entity clusters

entity instances. *See* entity occurrences entity integrity

enforcement of

violation of  
entity occurrences (instances)

cardinalities in ERDs  
groups. *See* entity subtypes; entity supertypes  
entity relationship diagrams. *See* ERDs entity relationship model. *See* ER model entity relationship modeling. *See* ER modeling entity relationship modeling and normalization step (DBLC conceptual design stage) entity sets

entity subtypes

aggregation problems with

identifying supertypes from

inheritance by

*See also* disjoint subtypes; overlapping  
subtypes; specialization hierarchies

entity supertypes

constraints on: completeness constrain

*See also* disjoin

subtypes; overlapping subtypes

identifying subtypes from

*See also* specialization hierarchies

environment resources (of relational databases): measurement parameters equal sign (=): equality comparison operator

equality comparison operator (=)

equality comparisons

as faster than inequality comparisons

equality conditions in multiple conditional expressions equijoin

equivalence (of queries)

ER diagrams. *See* ERDs

ER model (entity relationship model) (ERM)

advantages and disadvantages

business rules for  
checklist, InsideFrontCover(t)  
converting into database structure (online content)

database type independence

enterprise model

evolution

expanded model

extended model

fragmentation problems  
graphical representations of. *See* ERDs

revision process

terminology

verification process

ER model verification process  
ER modeling (entity relationship modeling)

designer tasks

as an iterative process

key terms

modular approach to

normalization and  
problems (exercises)

review questions

standards

**summary**

*See also* conceptual models; ER model; ERDs (entity relationship diagrams)

ER modeling and normalization step (DBLC conceptual design stage) ER notations

*See also* Chen notation; Crow's Foot notation; UML class diagrams (UML notation)

ERDM. *See* extended relational data model ERDs (entity relationship diagrams)

for 1:1 (one-to-one) relationships

for 1:M (one-to-many) relationships

for attributes

cardinalitiesN

for composite entities

connectivities

developing the conceptual model using

development process

tools for

fan traps in

foreign keys as not in  
for M:N (many-to-many) relationships  
notation. *See* ER notations

relationship lines in  
ERM. See ER model

error messages

from column aliases

from GROUP BY clause

from WHERE clause  
errors: in data entry

ERwin Data Modeler

ETL process

ETL tools (data extraction, transformation, and loading tools) eventual consistency (in NoSQL databases)

Excel (Microsoft): connecting to an Oracle database EXCEPT keyword

exclusive locks

EXEC command

executable programs: creating and running with embedded SQL statements executing stored procedures

execution phase of query processing  
execution plans. *See* access plans existence dependence

existence independence

EXISTS special operator correlated subqueries with expanded ER model

**EXPLAIN PLAN** command

explain plans. *See* access plans explanatory analytics

explicit cursor

extended ER model (EER model)

extended relational data model (ERDM)

DBMSs. *See* object/relational database management systems (O/R DBMSs) evolution

XML support  
extends (of data files)

Extensible Hypertext Markup Language (XHTML)

Extensible Markup Language. *See* XML

Extensible Style Language (XSL) specification

Extensible Style Language Transformations (XSLTs) external factors. *See* natural disasters external models  
(of data)

external schemas  
extraction of data. *See* data extraction

---

---

**F**

---

---

fact tables

in data warehouses

denormalization of

and dimension tables

multiple tables

summary fact tables  
facts (business activity measurements)  
    attributes of, hierarchies  
    *See also* fact tables  
failure sources (database systems)  
failure transparency (of DDBMSs)

fan traps

FAST option

FETCH command (embedded SQL)

FETCH command (PL/SQL)

fetching phase of query processing

fetching rows from cursors

in embedded SQL  
in PL/SQL  
field-level locks  
fields (of records)  
fifth normal form (5NF)  
file changes as done in memory  
file groups. *See* TABLE spaces file systems

computerized systems

data dependence

data processing problems

database systems vs

DP departments

evolution

manual systems

structural dependence

terminology

vocabulary

file terminology

file vocabulary

files

changes as done in memory

data files

tables vs.

filtering of data. *See* data filtering fine-tuning databases. *See* database performance tuning first normal form (1NF), conversion to

first-come, first-served scheduling (of transactions) FIRST\_ROWS optimizer hint (instruction)

FKs. *See* foreign keys

flags (for avoiding nulls)

flexible database design cases

FLOOR function

FORCE option  
foreign keys (FKs)  
in 1:1 relationships

automatic production of

composite primary keys and

and data redundancy  
defining/specifying in new tables from existing tables in Oracle

determinants as

primary key links with

and referential integrity

formatting of data

forward slash (/): end command-line entry mark (PL/SQL) %FOUND cursor attribute (PL/SQL)

fourth normal form (NF) conversion to

fragmentation (of data)

fragmentation problems (of ER models)

fragmentation transparency level (of distribution transparency)

query format  
fragments (of data). See database fragments [Freebar.com](#)

FROM clause

in join operations

FROM subqueries  
front-end CASE tools

full backups

full equivalence (of optimized queries)

full functional dependence

full outer join

fully heterogeneous DDBMSs

fully replicated databases  
function-based indexes

functional dependence

functions (in OLAP)

functions (in SQL)

aggregate. *See* aggregate functions

conversion functions

date functions

numeric functions  
stored functions (in PL/SQL)

string functions

time functions

---

---

**G**

---

---

GDS (Global Distribution System) (Amadeus)

general purpose databases  
generalization (identifying entity supertypes)

generalization hierarchies

generating database statistics

GETDATE() function (SQL Server)

Global Distribution System (GDS) (Amadeus)

good judgment in data modeling

Google Application Engine

Google searches  
Google's BigTable  
governance (of business)  
granularity (of data)

determining  
greater than operator ( $>$ )

GROUP BY clause

CUBE extension

HAVING clause with

ROLLUP extension

grouping data (from aggregate functions)

groups (of data): limiting/restricting

groups (of data files). *See* table spaces groups (of entity occurrences). *See* entity

subtypes; entity supertypes

guaranteed access: Codd's rule on

GUESS mobile business intelligence system (Microstrategy)

---

---

**H**

---

---

Hadoop

hard disks

contention on

as query processing bottlenecks  
hardware (of database systems)

system failures from

system performance guidelines

hardware independence

hash indexes

HAVING clause

HAVING subqueries  
heterogeneity transparency (of DDBMSs)

heterogeneous DDBMSs

hierarchical model

advantages and disadvantages

data storage

evolution

terminology  
historical accuracy (of data)  
vs. data redundancy

maintaining

homogeneous DDBMSs

homonyms: avoiding

horizontal fragmentation  
host languages (for SQL)

embedding SQL statements in

host variables

HTML (Hypertext Markup Language): and

XML

HTML documents

binding of XML data to

data problem

HTML tags

human component in database systems

*See also* DA (data administrator); DBAs (database administrators)  
human-caused system failures

hypercubes

Hypertext Markup Language. *See* HTML

---

I

---

I/O ... *See after* in..

IaaS (Infrastructure as a Service)

IBM DB. *See* DB (IBM)

iCloud

identifiers

composite identifiers

natural identifiers

*See also* primary keys

identifying entities, attributes, and relationships identifying relationships. *See* strong relationships idiot correlation label

IE (information engineering)

IE (Internet Explorer): displaying XML documents in IMMEDIATE statement

immediate updates (write-throughs)

implementation and loading phase (DBLC)

implementation models (of data)

implementation phase (SDLC)

implementing multivalued attributes

implementing relationships

1:1 (one-to-one) relationships

1:M (one-to-many) relationships

M:N (many-to-many) relationships: with

## **1:M relationships as not to be done**

implicit cursor

IN special operator

IN subqueries

in-memory databases

inconsistency of data. *See* data inconsistency inconsistent database state

inconsistent retrievals (concurrent transactions problem) IncontraGente

incremental backups

index access operation

index keys

index scan operation  
vs. table scan

index selectivity

index table space

Index(name) optimizer hint (instruction)

index-organized tables (clustered tables)

indexed views

*See also* materialized views

indexes (in relational databases) (SQL indexes)

bitmap indexes  
creating, for columns

for unnormalized tables  
data sparsity and the need for

deleting  
determining the best type to use  
function-based indexes

guidelines for using

identifying

measurement parameters

processing cost

and query optimization

scanning

selectivity

types (data structures), *See also* bitmap indexes

unique. *See* unique indexes

usefulness

indexing columns

indexing tables

unnormalized tables

inequality comparisons: equality comparisons as faster than information

data vs  
data-information-decision cycle

islands of information

pyramid image  
information dissemination: evolution  
information engineering (IE)  
information representation: Codd's rule on

information requirements

in database design

denormalization and

information resource dictionary

information resource manager (IRM). *See* DA (data administrator) information sources: on data information systems (IS)

architecture

assessment questions

and databases

departments

development methodologies

feasibility study issues  
life cycle. *See* Systems Development Life Cycle (SDLC)

operational life span

performance factors

success factors  
information systems architecture (ISA)

information systems departments  
Infrastructure as a Service (IaaS)

inheritance

in the EER model

entity clusters and

in the OO model  
initial study phase (DBLC)  
initialization parameters: customizing in Oracle

Initialization Parameters page (Oracle Enterprise Manager) inline subqueries

Inmon, Bill: twelve rules for defining a data warehouse inner joins

inner query

*See also* SELECT subqueries

input/output ... *See I/O ... after in..*

INSERT command

UPDATE command vs

*See also* inserting rows

inserting columns (in database tables)

inserting rows (in database tables)

from other tables

insertion anomalies

installing database system components

installing DBMSs

integrity. See data integrity; entity integrity; referential integrity integrity independence: Codd's rule on integrity rules (relational model)

enforcement of

*See also* entity integrity; referential integrity

interconnectivity

*See also* database connectivity interfaces; Internet database connectivity

interfaces

call level interfaces (CLIs)

CASE interfaces

Web server interfaces

*See also* APIs (application programming interfaces); database connectivity  
interfaces; end-user interfaces  
internal models (of data)

internal schemas

International Organization for Standardization (ISO)

*See also* ANSI SQL (ANSI/ISO standard)

Internet

as a business resource

business transactions on (e-commerce), *See also* B2B transactions/exchanges

data management via

and DDBMSs

*See also* Web (World Wide Web)

Internet database connectivity  
client-side extensions (for Web browsers)  
plug-ins

programming languages

uses

Web application servers

Web browsers

Web server interfaces

Web-to-database middleware

*See also* XML (Extensible Markup Language)

Internet Explorer (IE): displaying XML documents in Internet technologies

characteristics and benefits

uses of

*See also* Internet database connectivity

INTERSECT relational operator

*See also* INTERSECT statement

INTERSECT statement

syntax alternative

*See also* INTERSECT relational operator

INTO keyword/clause

invoicing system

I/O cost comparisons (of access plans)

I/O operations access plan operations

I/O requests

IRM (information resource manager). *See* DA (data administrator) IS. *See* information systems IS departments

IS NULL special operator  
"is-a" relationships  
ISA (information systems architecture)

islands of information

ISO (International Organization for Standardization)

*See also* ANSI SQL (ANSI/ISO standard)

isolation (of transactions)

%ISOPEN cursor attribute (PL/SQL)

iterative processes

database design

ER modeling

---

**J**

---

Java

Java Database Connectivity (JDBC)

JavaScript  
JDBC (Java Database Connectivity)

Jet data engine

join columns

join conditions

JOIN ON operation  
join operations (joins)

comparison operators in

cross join

equijoin

full outer join

inner joins

JOIN ON

JOIN USING

left outer joint

natural join  
old-style joins

outer joins

recursive joins

right outer join

theta join

*See also* joining tables

JOIN relational operator

JOIN USING operation

joining tables

with aliases

with subqueries

*See also* join operations

Julian date arithmetic

Julian dates/date format

---

**K**

---

Kelley, Chuck: twelve rules for defining a data warehouse key attributes (prime attributes)

in dependency diagrams

descriptive content overload in

entity clusters and

inheritance of

specifications for  
key performance indicators (KPIs) (for businesses) key relational operators

key terms

for advanced data modeling

for data models

for database administration

for database connectivity

for database design

for database performance tuning

for database systems

for decision support systems

for distributed database management systems

for ER modeling  
for normalization (of database tables)

for query optimization

for the relational model  
for SQL (Structured Query Language)

for transactions

*See also* terminology

key-value data model (key-value store DM)

evolution  
vs. relational model

keys

determinants

index keys

natural keys

partition key

secondary keys

superkeys *See also* candidate keys

types

*See also* candidate keys; composite keys; foreign keys (FKs); primary keys (PKs)

keywords (reserved words) (in SQL)

Keyworth, George

knowledge

pyramid image

knowledge-acquisition phase (data mining)

KPIs (key performance indicators) (for businesses)

---

---

L

---

LAST\_DAY function (Oracle)

latency (in distributed database systems). *See* network latency (data contention) left angle bracket + double

dashes (<--): comment indicator (in XML) left outer joint

legacy systems integration: XML and

LEN function (SQL Server)

LENGTH function (Oracle)

life span of information systems

LIKE special operator

limiting groups of data

line numbers: in Oracle

linking tables (in M:N to 1:M conversions)

links between tables

list-of-value subqueries

listener process

    Oracle service

listing rows

    based on subquery results

    with conditional restrictions

    grouping aggregate function outputs

    limiting/restricting groups

    with matching values

    with maximum/minimum values

    with nulls

    from two tables or more. *See* combining tables/sets

    with unique values

    using computed columns and column aliases

    with values within ranges

listings: ordering (sorting)

loading data into 1:M relationships

loading data into databases

local mapping transparency level (of distribution transparency) location dimension (of facts)

    attribute hierarchy

location transparency level (of distribution transparency)

    query format

lock granularity (use levels)

lock manager

locks (on data items)

    granularity (use levels)

    mutual exclusive rule for

    problems with

    types

logical conditional expressions

logical data

logical data forma

logical design

    DBLC stage. *See* logical design stage and physical design

logical design stage (DBLC database design phase) logical independence

    Codd's rule on

logical model

    mapping the conceptual model to

validating  
logical operators  
looping procedures  
    in PL/SQL blocks  
    programming language extensions for  
        *See also* correlated subqueries

lost updates (concurrent transactions problem) LOWER function  
lowercase: converting strings to

---

---

## M

---

---

M:M relationships. *See* M:N (many-to-many) relationships M:N (many-to-many) relationships  
ERDs of  
implementing: with 1:M relationships, as not to be done  
    as recursive relationships  
maintenance and evolution phase (DBLC)  
maintenance phase (SDLC)  
management approval: and systems design  
managerial aspect of DBMS introductions  
managers  
    business managers' view of data  
    data managers (DMs)  
    *See also* DA (data administrator); DBAs  
    (database administrators)  
mandatory participation (in relationships)  
mantra on database performance  
manual file systems  
manual query optimization  
manual statistical generation mode  
many-to-many relationships. *See* M:N (many-to-many) relationships mapping the conceptual model to the logical model Martin, James: seven essentials of database security master data management (MDM)  
master tables. *See* base tables matching values: listing rows with matching attribute values materialized views updating of  
mathematical symbols: naming convention against MAX function  
MDBMSs (multidimensional database management systems) MDM (master data management)  
Mediterranean Shipping Company: application database (MSCLink) memory  
    file changes as done in  
    virtual memory  
merge operation  
messages: displaying (in SQL\*Plus)  
metadata (data definitions)  
    Codd's rule on  
    in the data dictionary  
    in data warehouses  
    DTDs (in XML)  
    in the system catalog  
metadictionaries for databases  
methods (OO data model)  
    OLE-DB interfaces

metrics

Microsoft software. *See <softwareName>* (Microsoft) MicroStrategy

middleware: database middleware

*See also* database connectivity interfaces;

Web-to-database middleware

MIN function

minimal data rule

MINUS statement

syntax alternative

mixed fragmentation

mobile business intelligence

mobile business intelligence system (Microstrategy) mobile technologies

and DDBMSs

and information dissemination

models. *See* data models MODIFY option (ALTER TABLE command)

modular approach to ER modeling

modular approach to programming

module coupling

modules (ER model segments)

cohesivity

MOLAP (multidimensional online analytical processing)

vs. ROLAP

MOLAP tools

monotonicity (of time stamp values)

MONTH function (Access/SQL Server)

MPMD scenario (multiple-site processing multiple-site data scenario) MPSD scenario (multiple-site processing singlesite data scenario) MSCLink database

multidimensional data

cubic representation of

model. *See* star schemas

storage of

multidimensional data analysis

attribute hierarchies in

in data cubes

OLAP techniques

query optimization for

ROLAP systems

sparsity in

SQL and

SQL extensions for: OLAP ROLAP

multidimensional data schemas: ROLAP support for multidimensional database management systems

(MDBMSs) multidimensional databases: multidimensional

data storage in

multidimensional online analytical processing. *See* MOLAP

multidimensional views of operational data

multiple conditional expressions: equality conditions in multiple duplicate records problem

multiple entities and relationships (entity clusters) multiple fact tables

multiple-site processing, multiple-site data (MPMD) scenario multiple-site processing, singlesite data

(MPSD) scenario multirow subquery operators

multiuser access control  
multiuser databases  
    transaction controls  
multivalued attributes  
    implementing  
multivalued dependencies: eliminating problems caused by mutual consistency rule (for replicated data)  
mutual exclusive rule (for locks)  
MySQL: features

---

---

## N

---

---

names  
    as character data  
    data source names (DSNs)  
    length issue  
naming conventions  
    for attributes  
    avoiding homonyms and synonyms  
checklist, InsideFrontCover(t)  
    for columns  
    evaluating  
NASDAQ: BI tool-based business problem solutions native SQL database connectivity  
natural disasters (external factors): system failures from natural join  
natural keys (natural identifiers)  
Nealab: cloud computing  
nested loop operation  
nested queries  
    *See also* SELECT subqueries  
.NET framework (Microsoft)  
Netflix and AWS  
network latency (data contention)  
network model  
    advantages and disadvantages  
    data storage  
    evolution  
    terminology  
network partitioning  
networks  
    of data. *See* clouds  
    as query processing bottlenecks  
    security vulnerabilities  
    *See also* social media/networks  
:NEW attribute reference (in SQL\*Plus)  
NEXTVAL pseudo column (in Oracle)  
non-identifying relationships. *See* weak relationships nonkey attributes (nonprime attributes)  
non-null values: counting  
non-overlapping subtypes. *See* disjoin  
    subtypes  
nonprocedural languages  
nonsubversion: Codd's rule on

nonvolatile data in data warehouses

normal forms (of database tables)

conversion processes

higher forms

lower forms in data warehouses

*See also* Boyce-Codd normal form (BCNF);

first normal form (1NF); fourth normal

form (4NF); second normal form (2NF);

third normal form (3NF)

normalization (of database tables)

basic example

common sense and

in database design improvements

dimensional tables

eliminating partial dependencies

eliminating repeating groups

eliminating transitive dependencies

and ER modeling

key terms

need for

objective

in OLAP systems

and performance requirements

problems (exercises)

processes

review questions

stages. *See* normal forms

summary

validating the logical model using

*See also* denormalization (of database tables)

NoSQL data models

advantages and disadvantages

evolution

NoSQL databases (Big Data databases) characteristics NoSQL DDBMSs

CAP properties

“not a GROUP BY expression” error

NOT IN subqueries

NOT logical operator

avoiding the use of

syntax alternatives

NOT NULL constraint

%NOTFOUND cursor attribute (PL/SQL)

NULL comparisons: numeric comparisons as faster than NULL subqueries

nulls

avoiding

checking for

Codd’s rule on

counting non-null values

inserting rows with

IS NULL special operator

listing rows with

NOT NULL constraint

ordering of  
problems from  
from unique attributes  
NUMBER data type (PL/SQL)  
NUMBER data type (SQL)  
number sign (#) (in Access): date delimiter  
numbers  
    as character data  
    converting strings to  
    converting to strings  
    data types  
    *See also* numeric attributes  
numeric attributes  
    averaging  
    listing rows with maximum/minimum values  
    listing rows with values within ranges  
    returning absolute values  
    rounding  
    summing  
    *See also* attribute values; numbers  
numeric comparisons  
    as faster than character, date, and NULL comparisons  
    as faster than nonnumeric comparisons  
numeric data  
    in the data dictionary  
    types  
    *See also* numbers; numeric attributes  
numeric functions  
    *See also* aggregate functions

---

---

## O

---

---

o (overlapping constraint). *See* overlapping subtypes O/R DBMSs. *See* object/relational database management systems Object Linking and Embedding for Database. *See* OLE-DB  
object-oriented APIs  
object-oriented data model (OODM)  
    advantages and disadvantages  
    components  
    evolution  
    object representation  
    terminology  
    *See also* extended relational data model (ERDM)  
object-oriented database management systems (OO DBMSs)  
    vs. O/R DBMSs  
object/relational database management systems (O/R DBMSs) vs. OO DBMSs objectives definition process  
    (DBLC database initial study phase) objects  
        ADO objects  
        COM objects  
    *See also* consumers; providers

database. *See* database objects  
definition conflicts  
entities as  
in the OO model  
ODBC (Open Database Connectivity)  
(Microsoft)  
ODBC API compliance/support levels  
ODBC Driver Manager  
ODBC driver parameters  
ODBC drivers  
OLAP (online analytical processing)  
functions, advanced  
multidimensional (MOLAP), vs  
ROLAP  
multidimensional data analysis techniques  
relational. *See* ROLAP  
SQL extensions  
tools  
*See also* OLAP systems  
OLAP systems  
characteristics  
client/server architecture  
components  
data access in, advanced features  
data marts in  
data warehouses in  
end-user interfaces  
normalization in  
spreadsheet integration  
OLAP tools  
:OLD attribute reference (in SQL\*Plus)  
old-style joins  
OLE-DB (Object Linking and Embedding for Database) (Microsoft)  
ADO vs  
architecture  
OLTP databases. *See* operational databases  
ON clause: in join operations  
ON COMMIT clause  
ON DELETE CASCADE specification  
ON DELETE clause  
ON UPDATE CASCADE specification  
ON UPDATE clause  
one or more times symbol (+)  
one-to-many relationships. *See* 1:M (one-to-many) relationships  
one-to-one relationships. *See* 1:1 (one-to-one) relationships  
online analytical processing. *See* OLAP  
online transaction processing databases. *See* operational databases  
OO data model. *See* object-oriented data  
model OO DBMSs. *See* object-oriented database management systems  
OODM. *See* object-oriented data  
model OPEN command (PL/SQL)  
Open Database Connectivity. *See* ODBC  
(Open Database Connectivity)  
operating systems

- security vulnerabilities
- operation phase (DBLC)
- operational data
  - characteristics
  - creating data warehouses from
    - data warehouse data vs
    - decision support data vs
    - multidimensional views of
- operational databases (OLTP/transactional/production databases)
  - data extraction and filtering into decision
  - support databases from
    - designing, *See also* database design
    - unnormalized table defects
- operational life span of information systems
- operators
  - conditional operators
  - logical operators
  - special operators
    - See also* arithmetic operators; comparison operators; relational set operators
- optimistic approach (concurrency control)
- optimization (of queries). *See* query optimization optimization modes in Oracle
- optimizer (query optimizer)
  - I/O cost comparisons
  - modes, changing
- optimizer hints/instructions
- optional attributes
  - inserting rows with
- optional participation (in relationships)
- optional participation symbol (O)
- O/R DBMSs. *See* object/relational database
  - management systems
- OR logical operator
  - IN special operator alternative
  - multiple OR conditions
- Oracle (RDBMS)
  - attribute display formats
  - BETWEEN special operator use
  - case sensitivity in search criteria
  - CASE tools
  - column widths
  - conditions evaluation order
  - configuring an ODBC data source
  - conversion functions
  - copying parts of tables into new tables
  - CREATE TABLE command
  - creating databases in
    - credentials
  - data storage management
  - data types
  - database administration using. *See*
  - database administration using Oracle
  - database object management

datafiles  
date and time functions  
date arithmetic  
Enterprise Manager. *See* Enterprise Manager  
Excel connecting to an Oracle database  
features  
graphical tools for query optimization  
initialization parameters  
line numbers in  
listener service  
login  
market domination  
materialized views  
numeric functions  
OLAP screen  
optimization modes  
parsing in  
query optimization in  
referential constraint support  
Schema Manager  
schemas  
sequences. *See* sequences (in Oracle)  
services  
startup  
Storage Manager  
string functions  
surrogate key implementation in  
tablespaces. *See* tablespaces  
UPPER function  
user management  
Oracle Data Guard  
Oracle Real Application Clusters (RAC)  
Oracle services  
Oracle SQL\*Net interface  
Oracle Transportable Tablespaces  
ORDER BY clause  
ordering listings  
organizational performance: BI and  
outer joins  
outer query  
overlapping subtypes (overlapping constraint)  
discriminator attributes for  
notation for

---

**P**

---

PaaS (Platform as a Service)  
page-level locks  
pages (diskpages)  
parentheses (( ))  
argument delimiters  
table definition delimiters

parsing phase of query processing  
in Oracle  
*See also* query optimization

PART option (CREATE TABLE command)

partial completeness constraint

partial dependencies

- eliminating
- using with caution

partially replicated databases

participants (in relationships)

participation in relationships

- as optional or mandatory
- vs. referential integrity

partition key

partition tolerance in distributed data systems partitioned data allocation

partitioning of databases. *See* data fragmentation partitioning tables

parts of tables: copying into new tables

parts tracking

passing values to stored procedures

passive data dictionary

password security

#PCDATA keyword

percent sign (%): wildcard character

performance

- information system performance factors
- organizational performance

*See also* database performance

performance monitoring (of databases)

performance requirements. *See* database

- performance requirements; reporting requirements

performance transparency (of DDBMSs)

performance tuning. *See* database

- performance tuning; DBMS performance
- tuning; SQL performance tuning

periodicity (of data)

persistent relations. *See* tables (of relational databases) persistent stored modules (PSMs)

personal analytics

personal productivity tool problems

- See also* spreadsheets

pessimistic locking

Pfizer: BI tool-based business problem solutions PHP: Web database development code example

physical data format

physical design: logical design and

physical design stage (DBLC database design phase) physical disk blocks. *See* disk blocks physical independence

- Codd's rule on

physical models (of data)

physical security

PKs. *See* primary keys

PL/SQL (Procedural Language SQL) (Oracle)

- code blocks. *See* PL/SQL blocks

commands. *See PL/SQL commands*  
cursors  
data types  
functions (stored functions)  
procedures. *See stored procedures*  
syntax. *See PL/SQL syntax*  
triggers. *See triggers*  
uses  
PL/SQL blocks  
    comment indicator  
    debugging  
PL/SQL commands  
    cursor processing commands  
    SHOW ERRORS command  
PL/SQL data types  
PL/SQL functions (stored functions)  
PL/SQL syntax  
    explicit cursor  
    stored functions  
    stored procedures  
    triggers  
planning phase (SDLC)  
Platform as a Service (PaaS)  
Plattner, Hasso  
plug-ins (for Web browsers)  
plus sign (+)  
    concatenate sign (Access/SQL Server)  
    one or more times symbol  
Pochet, Stefano  
policies (for database usage)  
    security policies  
portability of DBMSs  
portals  
pound sign. *See number sign (#) PowerDesigner (Sybase Technology)*  
pre-aggregated data: denormalization and  
precedence rules for arithmetic operators  
predicate logic  
predictive analytics  
    algorithms  
Preserved data security breach  
primary keys (PKs) (identifiers)  
    attributes. *See key attributes*  
    candidate. *See candidate keys*  
    characteristics  
    composite. *See composite keys*  
    defining/specifying in new tables, from existing tables in Oracle  
    and entity integrity  
    evaluating  
    of fact tables  
    foreign key links with  
    functions  
    identifying/selecting

refining  
replacing  
superkeys *See also* candidate keys  
surrogate. *See* surrogate keys  
*See also* candidate keys; foreign keys (FKs)

prime attributes. *See* key attributes privacy (of data)

private clouds

problem definition process (DBLC database initial study phase) problem domain

Procedural Language SQL. *See* PL/SQL

procedural languages

    SQL vs

procedural programming: programming

    language extensions for

procedure cache (SQL cache)

procedures (for database design, management and usage) procedures, stored. *See* stored procedures process distribution: levels of data and

processing mismatches (SQL vs. procedural languages) processing speed requirements

product dimension (of facts)

PRODUCT relational operator

    creating Cartesian products

*See also* cross join

product reordering: triggering

production databases. *See* operational databases productivity of end-users (with DBMSs)

profiles

prognosis phase (data mining)

programmers: of database systems

programming

    file system requirements

    modular approach

programming exemptions: system failures from

programming interfaces

programming language extensions

programming languages

    Java

    for Web browsers

*See also* database languages; host languages; procedural languages; SQL

programs. *See* application programs PROJECT relational operator

projecting columns

properties

    CAP properties of distributed data systems

    of transactions

protocols

    DDBMS protocols

    for SQL data services (SDS)

    twophase commit protocol

    write-ahead protocol

prototyping application programs

providers (COM objects)

pseudo columns (in Oracle)

PSMs (persistent stored modules)

public clouds  
pull replication  
push replication  
pyramid image (of data mining)

---

---

## Q

---

---

QBE query generator (Access)  
queries (in SQL)  
ad hoc. *See ad hoc queries*  
aggregate function queries  
changing column data types  
changing column widths  
combining rows from. *See combining tables/sets*  
copying parts of tables into new tables  
creating indexes  
data dictionary usage  
in data warehouses  
against decision support data  
defining primary/foreign keys in new tables created from existing tables  
deleting columns  
deleting rows  
distribution transparency formats  
efficiency  
equivalence  
formulating  
fragmentation transparency forma  
inserting columns  
inserting rows, from other tables  
listing rows. *See listing rows*  
local mapping transparency forma  
location transparency forma  
against operational data  
optimization process. *See query optimization*  
parsing  
processing sequence/phases  
restoring saved changes  
result sets  
saving changes in tables  
SELECT. *See SELECT queries*  
selection criteria  
SQL commands example tables for  
subqueries. *See SELECT subqueries*  
updating rows  
on the Web  
Web database development code examples  
*See also* database requests  
query and reporting tool  
query generator (QBE) (Access)  
query languages  
*See also* SQL  
query optimization

algorithms for  
data replication and  
in distributed database systems/environment  
graphical tools for  
indexes and  
key terms  
materialized views in  
modes  
for multidimensional data analysis  
problems (exercises)  
process example  
review questions  
ROLAP and  
summary  
*See also* concurrency control; optimizer  
query optimizer. *See* optimizer query processing  
    data for  
query processing bottlenecks  
query result sets  
question mark (?): optional element  
    symbol

---

---

## R

---

---

RAC (Real Application Clusters) (Oracle)  
RAD (Rapid Application Development)  
RAID (Redundant Array of Independent Disks)  
    common configurations  
RAM (random access memory): as a query  
    processing bottleneck  
random access memory (RAM): as a query  
    processing bottleneck  
range partitioning  
ranges of attribute values. *See* domains rapid ad hoc data access  
Rapid Application Development (RAD)  
raw data. *See* data  
RDBMSs (relational database management systems)  
    advantages  
    cloud services costs  
    enterprise RDBMSs  
    evolution  
    multidimensional data schema support  
    ROLAP extensions to  
    *See also* Access (Microsoft); DB (IBM);  
    DBMSs (database management systems);  
    Oracle (RDBMS)  
RDDBMSs (relational distributed database management systems): CAP properties RDO (Remote Data  
    Objects) (Microsoft)  
READ/WRITE conflict scenarios in concurrent transactions Real Application Clusters (RAC) (Oracle)  
records: in files

*See also* time-variant data (historical data)

recovery. *See* database recovery; transaction recovery recursive queries (recursive joins)  
recursive relationships

1:1 relationships as 1:M relationships as

M:N relationships as

Redundant Array of Independent Disks. *See* RAID

redundant data: denormalization and

*See also* data redundancy

redundant relationships

redundant transaction logs (transaction log backups) referencing XML documents

referential constraints

ON DELETE CASCADE specification

ON UPDATE CASCADE specification

referential integrity

enforcement of

vs. participation in relationships

violations of

REFRESH clause

regenerating database statistics

regular entities

relational algebra

relational database management systems. *See* RDBMSs relational databases

accessing, *See also* database connectivity interfaces

advantages

Codd's rules for

evolution

indexes. *See* indexes (in relational databases)

management systems. *See* RDBMSs

(relational database management systems)

model. *See* relational model

multidimensional data storage in

operators

performance. *See* database performance

resources: measurement parameters reserving

simple example

tables. *See* tables (of relational databases)

relational DBMSs. *See* RDBMSs relational DDBMSs: CAP properties

relational diagrams

*See also* ERDs (entity relationship diagrams)

relational distributed database management systems (RDDDBMSs): CAP properties relational model

## 1:M relationship implementation in

advantages and disadvantages

Big Data challenges to

data independence

evolution

extended. *See* extended relational data model (ERDM)

integrity rules, enforcement of

key terms  
key-value data model vs  
logical model as. *See* logical model  
logical structure/view of data  
M:N relationship implementation in  
mathematical foundations  
problems (exercises)  
query language. *See* SQL  
review questions  
structural independence  
summary  
terminology  
*See also* ER model (entity relationship model)  
relational online analytical processing. *See* ROLAP  
relational operations on tables  
relational operators. *See* comparison  
operators; relational set operators  
relational schemas  
relational set operators  
closure property  
implementation statements  
key operators  
relational tables. *See* tables (of relational databases) relational views. *See* views (virtual tables) relations (in  
relational databases)  
sets as, *See also* sets (of rows and columns)  
tables as, *See also*  
tables (of relational databases)  
union-compatible tables/relations  
relationship degree types  
relationship lines in ERDs  
relationship strength  
relationships (between/among entities)  
cardinalities (in ERDs)  
checklist, InsideFrontCover(t)  
connectivity  
defining  
degree types  
diagrams of. *See* ERDs (entity relationship diagrams)  
examples  
identifying  
identifying relationships. *See* ... strong  
relationships, *below*  
implementing. *See* implementing relationships  
inheritance of  
“is-a” relationships  
in the key-value data model  
mandatory participation in  
mapping to tables  
multiple entities and (entity clusters)  
non-identifying relationships. *See* ... weak relationships, *below*  
optional participation in  
participants

participation in, as optional or mandatory  
redundant relationships  
relational diagrams of  
strength among module entities  
strong relationships weak entities in  
translating business rules into  
types  
weak relationships  
*See also* 1:1 (one-to-one) relationships; 1:M (one-to-many) relationships; M:N (many-to-many) relationships

Remote Data Objects (RDO) (Microsoft)  
remote database servers: accessing  
remote requests  
remote transactions  
repeating groups of entries (for attributes)  
eliminating  
replica transparency (of DDBMSs)  
replicated data  
    allocation of  
    mutual consistency rule  
    *See also* data replication

replicated data allocation  
replicated databases  
replication: of tables  
    *See also* data replication

report delays in file systems  
reporting requirements: in database design  
reporting styles (BI systems)  
reporting tools (BI systems)

requests: I/O requests  
    *See also* database requests

required attributes  
reserved words (keywords) (in SQL)  
resources (of relational databases)  
    measurement parameters  
    reserving

restoring saved changes  
RESTRICT relational operator  
    *See also* SELECT command

restricting groups of data  
right outer join  
ROLAP (relational online analytical processing)  
    vs. MOLAP  
    multidimensional data schema support  
    and query optimization  
    SQL extension  
    very large database support

roles (database roles)  
roll up operations  
    in data warehouses  
    *See also* ROLLUP extension

ROLLBACK command (statement)

in transactions  
rollback segment table space  
ROLLUP extension (to GROUP BY clause)  
root element in XML documents  
ROUND function  
round-robin partitioning  
rounding numbers  
row-level locks  
row-level triggers  
%ROWCOUNT cursor attribute (PL/SQL)  
rows (in database tables) (tuples)  
    accessing  
    combining. *See* combining tables/sets  
    deleting  
    fetching from cursors: in embedded SQL in PL/SQL  
    inserting from other tables  
    listing. *See* listing rows  
    updating  
        in other tables  
rule zero (Codd)  
rule-based optimizer  
rule-based query optimization algorithm  
rules  
    for defining a data warehouse  
    of precedence for arithmetic operators  
    *See also* business rules; integrity rules  
run-time mismatches (SQL vs. procedural languages)

---

## S

---

SaaS (Software as a Service)  
SAP in-memory DBMS  
saving changes in tables  
scan operations (table/index scan)  
scheduler (of transactions)  
scheduling transactions. *See* concurrency control Schema Manager (Oracle)  
schemas  
    conceptual schemas  
    database schemas  
    decision support database schemas  
    distributed global schema  
    external schemas  
    internal schemas  
    multidimensional data schemas  
    relational schemas  
    snowflake schemasN  
    star. *See* star schemas  
    XML schemas  
scope (of systems)  
scope and boundaries definition process (DBLC database initial study phase) scripting languages: database connectivity interface support for scripts (script files)

CGI scripts

SDLC. *See* Systems Development Life Cycle SDS (SQL data services)

search criteria

    adding conditional restrictions to

    case sensitivity

*See also* wildcard characters

second normal form (NF)

    conversion to

    in data warehouses

secondary keys

security (of data)

    breaches of

    controls. *See* access rights

    data redundancy and

    database security

    DBMSs and

    file system problems

    management of. *See* security management

    policies

    vulnerabilities

security auditing and monitoring (of DBMSs)

    data dictionary use in

security breaches

security controls. *See* access rights security management

    DBA tasks

    view use in

security policies

security threats

security vulnerabilities

segments in the hierarchical model

SELECT command (statement)

    clauses with. *See* FROM clause; GROUP

    BY clause; HAVING clause; ORDER BY clause; USING clause; WHERE clause

    as relational operator

    syntax

*See also* SELECT queries; SELEC

    subqueries

SELECT queries

    ad hoc. *See* ad hoc queries

    arithmetic operators in

    averaging attribute values

    comparison operators in operations

    counting attribute values

    formulating

    inner (nested). *See* SELECT subqueries

    inner query

    INTERSECT queries

    joining tables, with aliases

    listing rows. *See* listing rows

    logical operators in

    MINUS queries

    ordering listings

- outer query
- recursive queries (recursive joins)
- special operators in
  - subquery result-based
  - summing attribute values
  - UNION/UNION ALL queries
  - uniting tables
- SELECT relational operator
  - See also* SELECT command
- SELECT subqueries
  - ALL subqueries
  - ANY subqueries
  - attribute list subqueries
  - characteristics
  - correlated subqueries
  - deleting rows
  - FROM subqueries
  - HAVING subqueries
  - IN subqueries
  - inline subqueries
  - inserting rows from other tables
  - joining tables with
    - list-of-value subqueries
    - listing rows based on results of
    - multirow operators
    - NOT IN subqueries
    - NULL subqueries
    - projecting columns
    - return value types
    - single-value subqueries
    - updating rows
    - uses (examples)
    - virtual-table subqueries
    - WHERE subqueries
  - semantic data models
    - evolution
    - See also* extended relational data model (ERDM); object-oriented data model (OODM)
  - semantic errors in transactions
  - semicolon (;): end command mark
  - semistructured data
    - database models
  - sequences (in Oracle)
    - checking command
    - dropping
    - pseudo columns for
      - in stored procedures
    - syntax
  - serializability (of transactions)
    - ensuring
  - serializable schedule (of transactions)
  - server virtualization

Server/Administration page (Oracle Enterprise Manager) server-side activities in database performance tuning server-side extensions (for Web servers)  
*See also* Web-to-database middleware

servers (database servers)  
accessing remote servers  
security vulnerabilities  
*See also* Web servers

service providers (COM objects)  
services  
database conversion services  
database migration services  
Oracle services  
XML services  
*See also* cloud services

SET clause

set theory

set-level commands: Codd's rule on

set-oriented commands

sets (entity sets)

sets (of rows and columns)  
combining. *See* combining tables/sets  
as tables/relations  
*See also* relations (in relational databases); tables (of relational databases)

seven essentials of database security

SGML (Standard Generalized Markup Language)

shared locks

SHOW ERRORS command (SQL\*Plus)

simple attributes

SimpleDB (Amazon)

single quotation mark ('): character attribute delimiter

singlesite processing, singlesite data (SPSD)  
scenario

single-user databases

single-value subqueries

single-valued attributes

slice and dice operations (in data cubes)

snowflake schemas

social media/networks  
and DDBMSs  
and predictive analytics  
sites

software (of database systems)  
data-profiling software  
master data management (MDM)  
system failures from  
system performance guidelines  
*See also* application programs; DBMSs (database management systems)

Software as a Service (SaaS)

software dependence: in internal models  
software independence  
sort cache  
sort operation  
sorting listings  
SPARC (Standards Planning and Requirements Committee): ANSI/SPARC data modeling framework  
sparsity (sparse data). *See* data sparsity special operators  
correlated subqueries with the EXISTS special operator  
specialization (identifying entity subtypes)  
specialization hierarchies  
constraint scenarios  
spreadsheets  
databases vs.  
OLAP system integration with  
*See also* Excel (Microsoft)  
Sprint database systems  
SPSD scenario (singlesite processing, singlesite data scenario) SQL (Structured Query Language)  
advanced SQL  
call level interfaces (CLIs)  
commands. *See* SQL commands  
communication area (SQLCA)  
constraints. *See* constraints (on data)  
data types. *See* data types (SQL)  
dialects  
dynamic SQL  
embedded SQL  
extensions: OLAP, ROLAP  
focus  
functions. *See* functions (in SQL)  
host languages  
key terms  
language categories  
limitations  
and multidimensional data analysis  
native connectivity  
operations not supported  
performance tuning  
problems (exercises)  
procedural. *See* PL/SQL  
vs. procedural languages  
programming language extensions  
queries. *See* queries (in SQL); SELEC queries  
review questions  
standard. *See* SQL standard  
static SQL  
status and error reporting variables  
summaries  
syntax. *See* syntax (SQL)  
SQL cache (procedure cache)  
SQL commands (statements)  
aggregate functions with  
attribute names in command sequences

data definition. *See* data definition commands  
data manipulation. *See* data manipulation commands  
DDL statements. *See* data definition commands  
DML statements. *See* data manipulation commands  
embedding in host languages  
end command mark (;  
as set-oriented commands  
syntax notation  
table names in command sequences  
*See also* PL/SQL commands; *and specific SQL commands*

SQL commands example database  
    data dictionary model  
SQL communication area (SQLCA)  
SQL constraints. *See* constraints (on data) SQL data services (SDS)  
SQL engine  
SQL execution phase  
SQL fetching phase  
SQL functions. *See* functions (in SQL) SQL parsing phase  
    *See also* query optimization  
SQL performance tuning  
SQL queries. *See* queries (in SQL) SQL Server (Microsoft)  
    conversion functions  
    date and time functions  
    date arithmetic  
    features  
    indexed views  
    metadata (data definitions)  
    numeric functions  
    OLAP screen  
    referential constraint support  
    string functions  
    surrogate key implementation in  
SQL standard implementation of/support for  
    *See also* ANSI SQL (ANSI/ISO standard)

SQL statements. *See* SQL commands SQL status and error reporting variables

SQL-based relational database application parts SQL\*Net interface (Oracle)

SQL\*Plus (Oracle)  
    attribute references  
    displaying messages in  
    query optimization in  
    SHOW ERRORS command

SQLCA (SQL communication area)

SQLCODE variable

SQLSTATE variable

Standard Generalized Markup Language (SGML)

standards  
    data modeling framework  
    for database usage  
    design standards  
    ER modeling standards  
    ODBC API compliance/support levels

*See also* ANSI SQL (ANSI/ISO standard)  
SQL standard  
Standards Planning and Requirements  
Committee (SPARC): ANSI/SPARC data modeling framework  
star schemas  
    components  
    performance-improving techniques  
    representation of  
    ROLAP and  
    snowflake schemas  
    uses  
startup in Oracle  
stateless systems  
    the Web as  
statement-level triggers  
statements. *See* SQL commands (statements); *and specific SQL commands*  
static query optimization  
static SQL  
statistical information. *See* database statistics statistically based query optimization algorithm Storage Manager (Oracle)  
storage of data. *See* data storage stored functions (in PL/SQL)  
stored procedures (in PL/SQL)  
    executing  
    passing values to  
    sequences in  
    syntax  
    testing  
    uses  
strength of relationships  
    among module entities  
    string attributes. *See* strings  
string delimiters (‘,’)  
string functions  
    *See also* conversion functions  
strings (character/string attributes)  
    comparing  
    concatenating  
    converting dates to  
    converting numbers to  
    converting to dates  
    converting to lowercase  
    converting to numbers  
    converting to uppercase  
    returning length values  
    returning substrings in  
    *See also* attribute values; attributes (of entities)  
strong entities  
    mapping to tables  
strong relationships (identifying relationships)  
    weak entities in  
structural dependence: of file systems

structural independence  
of the relational model

structured data

Structured Query Language. *See SQL*

subelements in XML documents

subject-oriented data in data warehouses

subordinates (DDBMS nodes)

subqueries. *See SELECT subqueries subschemas*

SUBSTR/SUBSTRING functions

substrings: returning

subtracting dates

subtype discriminator (discriminator attribute) subtype relationships: mapping to tables

subtypes. *See entity subtypes success factors for database administration and information systems SUM function*

summary fact tables

dynamic. *See materialized views*

superkeys

*See also candidate keys*

supertype relationships: mapping to tables

supertypes. *See entity supertypes surrogate keys*

Swisscom: BI tool-based business problem solutions Sybase Technology's PowerDesigner

synonyms: avoiding

syntax (SQL)

command notation

for generating database statistics manually

for materialized views

PL/SQL. *See PL/SQL syntax*

for sequences (in Oracle)

*See also specific SQL commands clauses, and functions*

SYSADMs (systems administrators)

SYSDATE function (Oracle)

system administration: file system problems

*See also database administration*

system catalog

system security. *See security (of data) system support activities*

system table space

systems administrators (SYSADMs)

systems analysis

systems analysts

systems design. *See database design systems development*

Systems Development Life Cycle (SDLC)

Database Life Cycle parallels

tool support for. *See CASE tools*

---

---

**T**

---

---

table access operation

table aliases

in correlated subqueries

joining tables with  
table constraints  
    adding/changing/deleting  
table definition delimiters (())  
table element delimiter (.)  
table names: in SQL command sequences  
table scan operation  
    index scan vs  
table spaces (file groups)  
    for high-usage tables  
    types  
        *See also* tablespaces (in Oracle)  
table storage organizations  
table-level locks  
tables (of relational databases)  
    accessing  
    characteristics, when wellformed  
    clustered tables  
    columns. *See* columns (in database tables)  
    common attributes, *See also*  
    foreign keys  
    composite. *See* composite entities  
    conversion of. *See* normalization  
    copying parts into new tables  
    creating, defining constraints  
    when, from parts of tables  
    *See also* combining tables/sets  
    creation and load order importance  
    DataTables (in ADO.NET)  
    with decision support data  
    deleting  
    deleting columns  
    deleting rows  
    denormalization of. *See* denormalization  
    dimension. *See* dimension tables  
    entities as  
    entity sets as  
    fact. *See* fact tables  
    vs. files  
    generating attribute value aggregates  
    high-usage tables  
    index-organized tables  
    indexing ; unnormalized  
    tables  
    inserting columns in  
    inserting rows in. *See* inserting rows  
    joining, with aliases with subqueries, *See also* join operations  
    linking tables (in M:N to 1:M conversions)  
    links between  
    listing rows in. *See* listing rows  
    measurement parameters  
    merging

normal forms. *See* normal forms  
normalization of. *See* normalization  
with operational data  
operators on. *See* relational set operators  
partitioning  
relational operations on  
as relations, *See also* relations (in relational databases)  
replication of  
restoring saved changes in  
rows. *See* rows (in database tables)  
saving changes in  
scanning  
sets as, . *See also* sets (of rows and columns)  
sorting  
spaces. *See* table spaces  
SQL commands example  
structures. *See* normal forms  
union-compatible tables/relations  
uniting  
unnormalized defects  
updating base/master tables  
updating rows  
in other tables  
virtual. *See* views  
tablespaces (in Oracle)  
creating  
Transportable Tablespaces  
*See also* table spaces  
tags: HTML and XML tags  
technological aspect of DBMS introductions  
technological changes: and DDBMSs  
telephone numbers: as character data  
temporary table space  
Teorey, Toby J  
terminology  
    B2B transaction differences  
    for data models  
    *See also* key terms  
ternary relationships  
testing  
    applications  
    databases  
    stored procedures  
    triggers  
testing and evaluation phase (DBLC)  
theta join  
third normal form (NF)  
    conversion to  
    *See also* Boyce-Codd normal form (BCNF)  
three-dimensional cubes. *See* data cubes time  
    adding periods to dates  
    data types

- time dimension (of facts)
- time functions
- time IDs for warehouse data
- time stamping (of transactions)
- time-variant data (historical data)
  - in data warehouses
  - maintaining
  - separating current data from
- timespan (of data)
- TMs (transaction managers)
- TO\_CHAR function (Oracle)
- TO\_DATE function (Oracle)
- TO\_NUMBER function (Oracle)
- today's date: returning
- Toffler, Alvin
- tools
  - BI tools, business problem solutions
  - based on
  - conceptual model design tools
  - for data analysis
  - for data mining
  - for data reporting
  - for data visualization
  - for database administration
  - for ERD development
  - ETL tools
  - MOLAP tools
  - OLAP tools
- top-down design
  - vs. bottom-up design
- total completeness constraint
- TPs (transaction processors)
- training and supporting users
- transaction consistency
  - eventual consistency
- transaction log
  - backups (redundant logs)
  - example
  - write-ahead-log protocol
- transaction log backups (redundant transaction logs) transaction managers (TMs)
- transaction processors. *See* TPs transaction recovery
  - process example
- transaction speed requirements
- transaction transparency (of DBMSs)
- transactional databases. *See* operational databases transactions (business transactions). *See*
  - business transactions on the Internet
- transactions (database transactions)
  - atomicity
  - beginning
  - COMMIT statement in, premature COMMIT effects, twophase commit protocol

concurrency control. *See* concurrency control  
concurrent. *See* concurrent transactions  
consistency. *See* transaction consistency  
constraints on  
decision support data transactions  
distributed transactions  
durability  
evaluating  
first-come, first-served scheduling of  
interrupted/incomplete transactions  
isolation of  
key terms  
locks for. *See* locks (on data items)  
managing with SQL statements  
operational data transactions  
problems (exercises)  
properties  
recovery of. *See* transaction recovery  
remote transactions  
as requests. *See* database requests  
review questions  
ROLLBACK statement in  
scheduler  
scheduling. *See* concurrency control  
serializability, ensuring  
summary  
system failures from  
two-phase commit protocol  
validation of  
*See also* queries  
transitive dependencies  
eliminating  
translating XML documents  
transparency features (of DDBMSs)  
distribution transparency  
failure transparency  
heterogeneity transparency  
performance transparency  
replica transparency  
transaction transparency  
Transportable Tablespaces (Oracle)  
triggers (in PL/SQL)  
defining  
deleting  
DML statement predicates  
syntax  
testing  
types  
uses  
using variables in  
tuples. *See* rows (in database tables) twelve rules for defining a data

warehouse  
two-phase commit protocol  
two-phase locking  
%TYPE data type (PL/SQL)

---

---

## U

---

---

UDA architecture (Universal Data Access architecture) UML (Unified Modeling Language)

UML class diagrams (UML notation)

unary relationships

as recursive relationships

uncommitted data (concurrent transactions problem) underlined identifiers

underscore (\_)

naming convention

wildcard character

Unified Modeling Language (UML)

UNION ALL statement

UNION relational operator

*See also* UNION statement

UNION statement

*See also* UNION relational operator

union-compatible tables/relations

unique attributes: nulls from

unique composite indexes

UNIQUE constraint

enforcement of

unique fragment condition

unique indexes

composite indexes

creating

deleting

unique values: listing rows with

uniqueness (of time stamp values)

uniting tables

Universal Data Access architecture (UDA architecture) unnormalized tables (in production databases):

defects in unreplicated databases

unstructured data

database models

*See also* Big Data

updatable views

update anomalies

UPDATE command: updating rows

update operations

updating of materialized views

updating of relational databases

base/master tables

rows

in other tables

unnormalized tables and

upgrading DBMSs

UPPER function  
uppercase: converting strings to  
user access management (DBA tasks)  
user data table space  
user interfaces. *See* end-user interfaces user processes  
users (of database systems)  
    access management  
    access rights  
    authentication of  
    database administrators. *See* DBAs  
    database designers  
    end. *See* end users  
    managing in Oracle  
    security vulnerabilities  
    system administrators  
    system analysts and programmers  
    training and supporting  
    types/classifications  
USING clause: in join operations  
utility software

---

## V

---

validating the logical model  
values. *See* attribute values VARCHAR2 data type (PL/SQL)  
variables  
    host variables  
    SQL status and error reporting variables  
    using in triggers

VBScript  
vendor dependence in DBMSs  
verification of the ER model  
vertical fragmentation  
very large databases (VLDBs)  
    ROLAP support for  
view updating: Codd's rule on  
views (virtual tables)  
    characteristics  
    creating  
    unnormalized tables and  
    identifying  
    security management usage  
    updatable views

virtual memory  
Virtual Private Database (VPD)  
virtual tables. *See* views virtual-table subqueries  
virtualization  
    of databases  
    server virtualization  
Visio (Microsoft)  
    Category symbol/shape

data modeling in  
ERD development screens  
M:N relationship implementation in  
subtype discriminator

VLDGs. *See* very large databases VPD (Virtual Private Database)

---

## W

---

W3C (World Wide Web Consortium): XML/XML schema standards wait/die scheme

warehouses. *See* data warehouses weak entities

composite primary keys as identifiers of  
mapping to tables  
ON DELETE CASCADE as recommended for

weak relationships (non-identifying relationships) Web (World Wide Web)

as a stateless system  
business transactions on (e-commerce) *See also* B2B transactions/exchanges  
and database design  
and DDBMSs  
queries on  
*See also* Internet

Web application servers

Web applications: data validation for

Web browsers

client-side extensions

Web database connectivity. *See* Interne  
database connectivity

Web database development code examples

Web operations: NoSQL database support  
for

*See also* B2B transactions/exchanges

Web pages

development features in XML  
dynamic Web pages  
translating XML documents into

Web server interfaces

Web servers

application servers  
extensions to. *See* Web-to-database  
middleware  
interfaces  
and queries on the Web  
server-side extensions

Web-based transactions. *See* B2B transactions/  
exchanges

Web-to-database middleware

operations (actions)  
*See also* Web application servers; Web  
server interfaces

WHERE clause

error messages from

- in join operations
- logical operators with
- in row selection operations
- special operators with

WHERE subqueries

WHILE loops in PL/SQL blocks

wildcard characters

workgroup databases

workstations

- diskless
- security vulnerabilities

World Wide Web. *See* Web (World Wide Web) World Wide Web Consortium (WC): XML/XML schema

- standards wound/wait scheme

write-ahead protocol

write-ahead-log protocol

write-throughs (immediate updates)

---

X

---

XHTML (Extensible Hypertext Markup Language)

XML (Extensible Markup Language)

- B2B transactions/exchanges, example
- data presentation in
- data validation in
- DBMSs support for
- DTDs (Document Type Definitions)
- vs. EDI
- and HTML
- and legacy systems integration
- schemas
- uses (applications)
- W3C standards
- Web page development features

XML data

- binding of to HTML documents
- displaying
- validation of

XML data model: evolution

XML databases

XML documents

- characteristics
- displaying
- with DTDs
- features
- referencing
- translating

XML schemas with

- XSD documents resembling

XML schema definitions (XSDs)

XML schemas

XML services

XML tags

XSD documents

XSDs (XML schema definitions)

XSL (Extensible Style Language) specification

XSL style sheets

XSLTs (Extensible Style Language Transformations)

---

**Y**

---

YEAR function (Access/SQL Server)

---

**Z**

---

zero or more times symbol (\*)