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Carlos Coronel • Steven Morris

Database Systems

Design, Implementation, & Management

14TH Edition

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***Database Systems: Design, Implementation, and Management*, 14th Edition**
Carlos Coronel and Steven Morris

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Dedication

To the treasures in my life: To Victoria, for 31 wonderful years. Thank you for your unending support and for being my angel, my sweetie, and, most importantly, my best friend. To Carlos Anthony, who has become a remarkable man, pride of his father, and husband to our beautiful, sweet, and brilliant daughter-in-law, Jered. Thank you for your words of wisdom, hard-working attitude, and for giving us reasons to be happy. You are still young; your best times are still to come. To Cerila Reyan, our beautiful granddaughter, whose smiles give us so much hope and happiness. To Gabriela Victoria, who is the image of brilliance, beauty, and faithfulness. The way you give your time and talents in the service of others is an inspiration to all of us. Thank you for being my sunshine on cloudy days. Your future is bright and endless. To Christian Javier, who is smarter than all of us. Thank you for being the youthful reminder of life's simple beauties. Keep challenging yourself to new highs and keep working hard to achieve your dreams. 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 nearly 30 years of marriage, you are 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, your depth of character is without measure. You are my pride and joy. To my daughter, Lauren, your beauty and intensity take my breath away. You are my heart and soul. To my daughter-in-law, Blakley, whom I could not love more if you were my flesh and blood. To my granddaughter, Daphne, a bundle of joy brought into a world that does not deserve someone so precious. To my mother, Florence, and to the memory of my father, Alton, together they instilled in me the desire to learn and the passion to achieve. To my mother-in-law, Connie, and to the memory of my father-in-law, Wayne, they taught me to find joy in all things. To all of you, with all my love, I dedicate this book.

Steven Morris

For Peter

To longtime colleague and friend, Peter Rob: Your drive and dedication to your students started this book. Your depth of knowledge, attention to detail, and pursuit of excellence made it succeed. Your patience and guidance continue to light our path. It is our sincere hope that, as we move forward, we can continue to live up to your standard. Enjoy your retirement, my friend; you have surely earned it.

Carlos Coronel and Steven Morris

Brief Contents

The following appendices are included on the Instructor and Student Resource Sites at www.cengage.com.

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The following appendices are included on the Instructor and Student Resource Sites at www.cengage.com.

About the Authors

Carlos Coronel is currently the IT Resources Director for the Jones College of Business at Middle Tennessee State University. He has more than 30 years of experience in various fields as a Database Administrator, Network Administrator, Web Manager, and Technology Entrepreneur and Innovator. He has taught courses in web development, database design and development, and data communications at the undergraduate and graduate levels.

Steven Morris earned the Ph.D. in Management Information Systems from Auburn University. He is Professor of Information Systems and Analytics in the Jones College of Business at Middle Tennessee State University. He has over 20 years of experience working with and teaching database systems and is actively engaged with consulting and professional database training with businesses in the Middle Tennessee and Nashville areas. He primarily teaches courses at the graduate and undergraduate levels in database design, advanced database programming, and Big Data for analytics.

Preface

It is our great pleasure to present the fourteenth edition of *Database Systems*. We are grateful and humbled that so many of our colleagues around the world have chosen this text to support their classes. 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 resource has been successful through thirteen editions because the authors, editors, and the publisher paid attention to the impact of technology and to adopters' questions and suggestions. We believe that the fourteenth edition successfully reflects the same attention to such factors.

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 a 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.

Prerequisites

Students using these materials are expected to be familiar with basic system concepts and know the difference between hardware and software. Familiarity with basic productivity software such as MS Excel and MS Access is useful. Prior programming experience is not required.

Instructors can configure their classes as best suits their resources and pedagogical approach. Data modeling can be done with a number of computer resources, some of which are free to use, or drawn by hand. Coding problems will require a DBMS. The MindTap resources include hands-on programming activities with an embedded MySQL database sandbox for students to work in. Other instructors may choose to have each student run their own individual DBMS, while still others may choose an instructor-administered central DBMS to which all students connect to work. The text supports all of these approaches.

Target Market

The text is written in a comprehensive manner that allows usage at a wide range of academic levels. The skills covered in the text are in high demand and are applicable in programs from two-year degrees, four-year degrees, graduate degrees, and adult continuing education. They are even taught in some specialized high school programs. We have reports of the text being used at all of these types of academic venues. The text is written in an easily approachable style that starts with the most basic concepts and builds to advanced topics. The modular nature of the chapters makes it easy for instructors to adapt the coverage to the level of sophistication that is most appropriate for their students.

Changes to the Fourteenth Edition

In many respects, revising a resource like this is more difficult than writing it the first time. If the text 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.

In this fourteenth edition, we have responded to the requests and suggestions of numerous adopters. The database arena is vast, wonderful, and in constant change. The role of data in society and industry is ever increasing, and database and data management technologies are constantly changing to address new challenges. To help you address changing learning needs as efficiently as possible, we've prioritized the following changes in this edition.

Streamlined Coverage

Scope creep is a real challenge because the ingenuity of our industry continually finds new ways to solve data problems. In this edition, we have streamlined many tangential topics that, while important, are not suitable for the depth of coverage previously provided.

Reorganized SQL

We have reorganized the SQL coverage to make sure basics are covered before introducing more advanced topics. This ensures the presentation is easier to follow and avoids overwhelming students. We start with simple SQL statements to familiarize students with the basic SQL syntax and environment. This approach helps students build the confidence to transition to the more advanced SQL features and commands. These changes provide a better flow of material.

MySQL Examples

We continue our tradition of supporting multiple DBMS products (MS Access, Oracle, SQL Server, and MySQL). In cases where code or concepts are the same in all of these products, we have shifted many of the illustrations and examples into MySQL to provide a more consistent appearance. In cases where the code is different across products, we have multiple notes and alternative examples to clarify the concepts for other DBMS products. It is our intention that faculty using any of these products, or none of them, can use this edition seamlessly in their

classes. All students will benefit from consistency in the presentation. Faculty that support the text by using the coding resources available in MindTap can also integrate the coding problems more easily with the text.

Note

If instructors want students to complete the hands-on data manipulation assignments provided in the text, they need to ensure that students have access to a DBMS product. Further, some exercises involving MS Excel or MS Access require a complete version of that product. The hands-on coding exercises for MongoDB and Neo4j also require students to have access to that software.

Coding Labs in MindTap

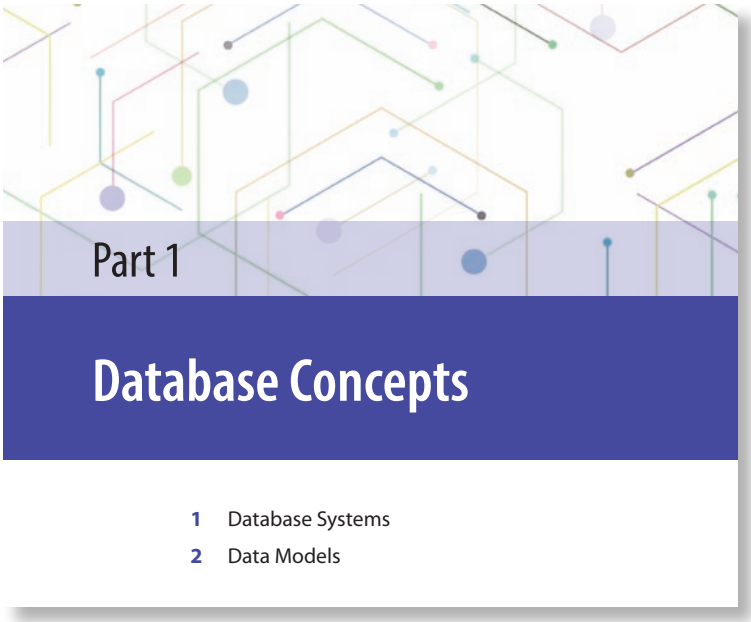
The fourteenth edition presents a major step forward in the integration of digital content with this resource by providing automatically graded coding labs through the MindTap available for this product. The labs allow students to write SQL code in an interactive environment that provides immediate feedback on problems.

Here is a summary of key changes in the fourteenth edition:

- Streamlined topic coverage, including Big Data technologies
- Reorganization of SQL to ensure basics are covered before more advanced topics
- Enhanced consistency and support for multiple DBMS products

Topical Organization

The fourteenth 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.

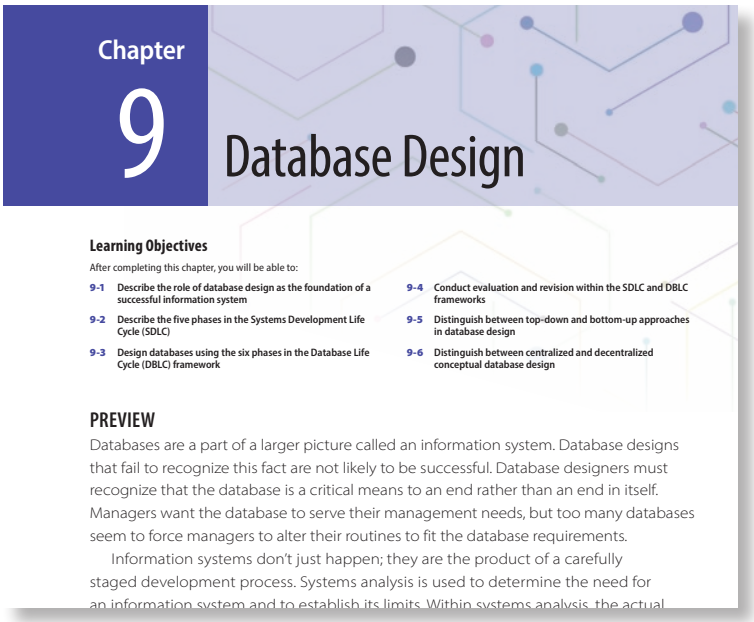


The Systems View

The title for this text 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 Appendices 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), new technologies for Big Data (Chapter 14), database connectivity and web technologies (Chapter 15), and database administration and security (Chapter 16).

Database Design

The first item in our 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 Appendices B and C. Appendix A is a good introductory tutorial on designing databases with Lucidchart.


Chapter 9
Database Design

Learning Objectives

After completing this chapter, you will be able to:

9-1 Describe the role of database design as the foundation of a successful information system
9-2 Describe the five phases in the Systems Development Life Cycle (SDLC)
9-3 Design databases using the six phases in the Database Life Cycle (DBLC) framework
9-4 Conduct evaluation and revision within the SDLC and DBLC frameworks
9-5 Distinguish between top-down and bottom-up approaches in database design
9-6 Distinguish between centralized and decentralized conceptual database design

PREVIEW

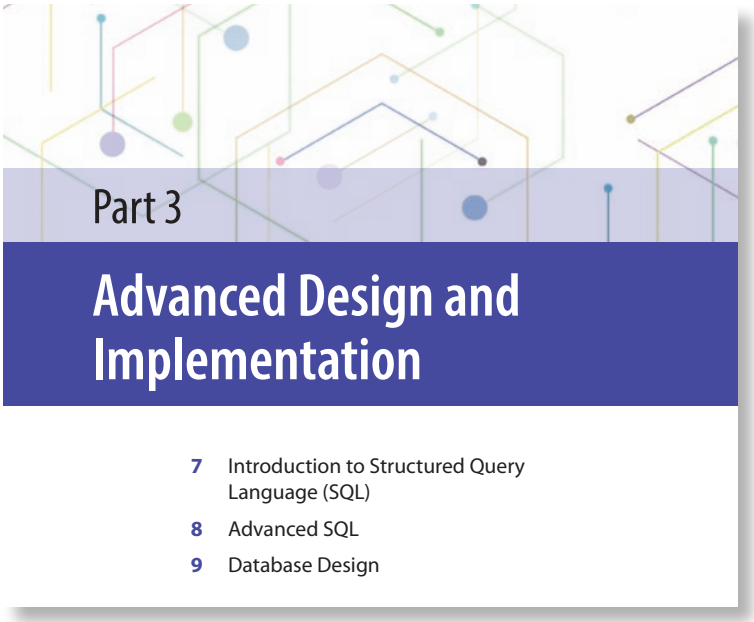
Databases are a part of a larger picture called an information system. Database designs that fail to recognize this fact are not likely to be successful. Database designers must recognize that the database is a critical means to an end rather than an end in itself. Managers want the database to serve 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

Because database design is affected by real-world transactions, the way data is 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-size 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, including coverage of data visualization and data analytics. Chapter 14, Big Data and NoSQL, explores the challenges of leveraging nonrelational databases to use vast global stores of unstructured data. Chapter 15, 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 relational databases are implemented and managed. Appendix M, MS Access Tutorial, provides a quick but comprehensive guide to implementing an MS Access database. Appendices B and C demonstrate the design of a database that was fully implemented; these appendices 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. While relational databases are still the appropriate database technology to use in the vast majority


Part 3

Advanced Design and Implementation

7 Introduction to Structured Query Language (SQL)
8 Advanced SQL
9 Database Design

of situations, Big Data issues have created an environment in which special requirements can call for the use of new, nonrelational technologies. Chapter 14, Big Data and NoSQL, describes the types of data that are appropriate for these new technologies and the array of options available in these special cases. Appendix P, Working with MongoDB, and Appendix Q, Working with Neo4j, provide hands-on coverage of using MongoDB and Neo4j, some of the most popular NoSQL options. The special issues encountered in an Internet database environment are addressed in Chapter 15, 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 16, 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, walks you through the process of setting up a new database.

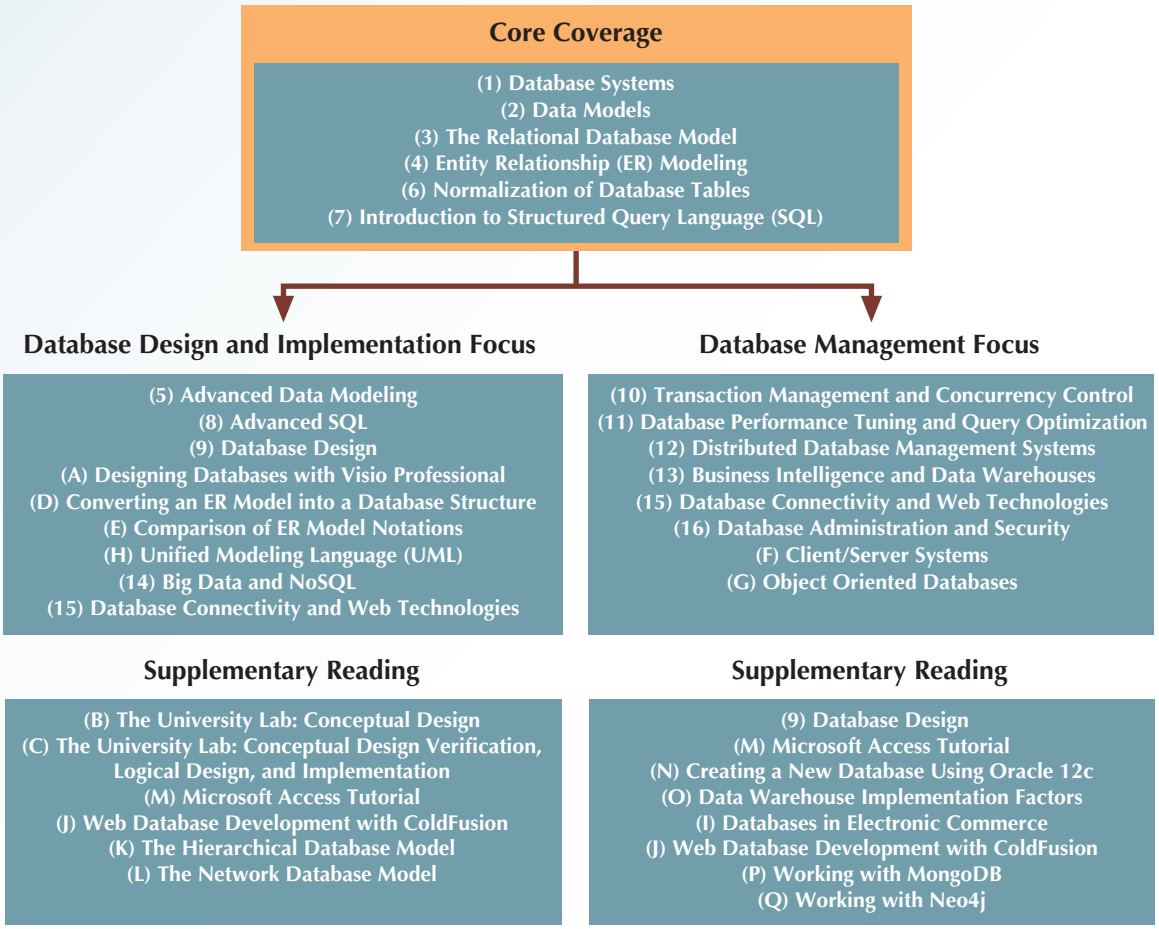
Teaching Database: A Matter of Focus

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 in which students use instructor-selected software to prototype a system that 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 make 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.

Figure 1



Text Features

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

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.cengage.com.

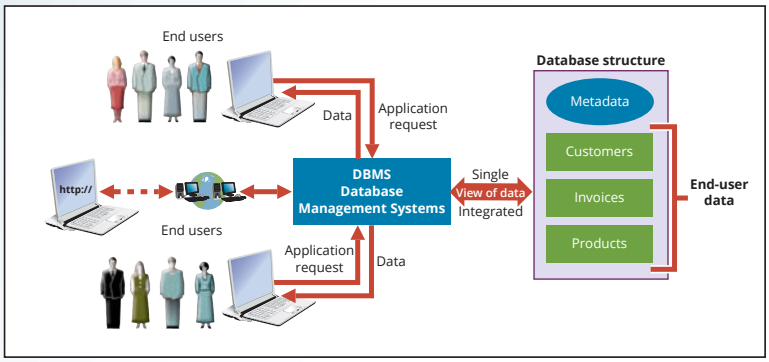
Notes highlight key facts about the concepts introduced in the chapter.

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.

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

Figure 1.4 The DBMS Manages the Interaction between the End User and the Database



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

Summary

- Data consists of raw facts. Information is the result of processing data to reveal its meaning. Accurate, relevant, and timely information is the key to good decision making, and good decision making is the key to organizational

files, each requiring its own data management program Although this method of data management is largely ou moded, understanding its characteristics makes databas design easier to comprehend.

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

Key Terms

ad hoc query
analytical database
application programming interface (API)
business intelligence
centralized database
cloud database
data
data anomaly
data dependence
data dictionary
data inconsistency
data independence
data integrity
data management

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

Review Questions

1. Define each of the following terms:
   a. data
   b. field
   c. record
   d. file
9. What are the main components of a database
10. What is metadata?
11. Explain why database design is important.
12. What are the potential costs of implementing base system?

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

Problems

Given the file structure shown in Figure P1.1, answer Problems 1–4.

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

Additional Features

MindTap® for Database Systems, Fourteenth Edition

MindTap for *Database Systems, Fourteenth Edition* is an online learning solution designed to help students master the skills they need to thrive in today's workforce. Research shows employers need critical thinkers, troubleshooters, and creative problem-solvers to stay relevant in our fast-paced, technology-driven marketplace. MindTap helps prepare you for that marketplace with relevant assignments and activities including hands-on practice. Students are guided through assignments that progress from basic knowledge and understanding to more challenging problems. MindTap activities and assignments are tied to validated learning objectives.

Additional Resources for Students and Instructors

Instructor and student resources for this product are available online. Instructor assets include an instructor manual, data files, an educator's guide, PowerPoint® slides, an image gallery, and a test bank powered by Cognero®. Student assets include data files. Sign up or sign in at www.cengage.com to search for and access this product and its online resources.

For further detail about instructor resources, read on.

Appendices

Seventeen online appendices provide additional material on a variety of important areas, such as Lucidchart® and Microsoft Access, ER model notations, UML, object-oriented databases, databases and electronic commerce, Adobe® ColdFusion®, and working with newer NoSQL databases MongoDB and Neo4j.

Database, SQL Script, JSON Documents, and ColdFusion Files

The online materials for this resource include all of the database structures and table contents used in the text. For students using Oracle®, MySQL, and Microsoft SQL Server™, SQL scripts are included to help students create and load all tables used in the SQL chapters (7 and 8). Text documents for importing JSON-formatted documents into MongoDB and a script for creating a graph database in Neo4j (Appendices P and Q) are also included. In addition, all ColdFusion scripts used to develop the web interfaces in Appendix J are included.

Instructor Manual

The instructor manual that accompanies this course provides additional instructional material to assist in class preparation, including suggestions for classroom activities, discussion topics, and additional projects.

Solutions and Answer Guide

Answers to the Review Questions, Problems, Database for Life, and Reflection activities are provided. Lab solutions are provided separately.

SQL Script Files for Instructors

The authors have provided SQL script files to allow instructors to cut and paste the SQL code into the SQL windows. (Scripts are provided for Oracle, MySQL, and MS SQL Server.) The SQL scripts, which have all been tested by Cengage Learning, 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 allows them to 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 allow instructors to illustrate the effect of design decisions. In addition, instructors have access to all the script files for Oracle, MySQL, and MS SQL Server so that all the databases and their tables can be converted easily and precisely.

Cengage Testing Powered by Cognero

Cognero is a flexible, online system that allows you to:

- Author, edit, and manage test bank content from multiple Cengage solutions.
- Create multiple test versions in an instant.
- Deliver tests from your LMS, your classroom, or wherever you want.

PowerPoint® Presentations

This course comes with Microsoft PowerPoint slides for each module. These are included as a teaching aid for classroom presentation, to make available to students on the network for module review, or to be printed for classroom distribution. Instructors, please feel at liberty to add your own slides for additional topics you introduce to the class.

Figure Files

All of the figures in the course are reproduced on the Instructor Resource Site. Similar to the PowerPoint presentations, these are included as a teaching aid for classroom presentation, to make available to students for review, or to be printed for classroom distribution.

Acknowledgments

Regardless of how many editions of *Database Systems* 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 Peter Keen to write the foreword for the first edition. Although we sometimes found Frank to be an especially demanding task master, 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 revising this resource 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 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 topic 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, Bathhurst, 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. 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 resource receives careful scrutiny by several groups of reviewers selected by the publisher. We were fortunate to benefit from 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:

Wael Jabr, Assistant Professor,
Smeal College of Business,
Pennsylvania State University

David Goldberg
San Diego State University

J. Ken. Corley II
Appalachian State University

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 Lisa Ruffolo for her help and guidance. Lisa has been a godsend. We write what we think, then Lisa helps us turn it into what we meant to say. As authors, the Development Editor is our closest point of contact with the publisher. Lisa was immediately in sync with what we were trying to do, our style of writing, and the voice for which we strive. Her precision and attention to detail were amazing, and we are deeply indebted to her for her invaluable contributions.
- After writing so many books and fourteen editions of *this* book, we know just how difficult it can be to transform the authors' work into an attractive product. The content and production teams, both at Cengage (Michele Stulga) and Straive (Arun Kumar Vasu), have done an excellent job.

- We also owe Michele Stulga, our content developer, special thanks for her ability to guide this book to a successful conclusion, and Danielle Shaw, our technical editor, deserves many thanks for making sure all code and technical references were accurate.

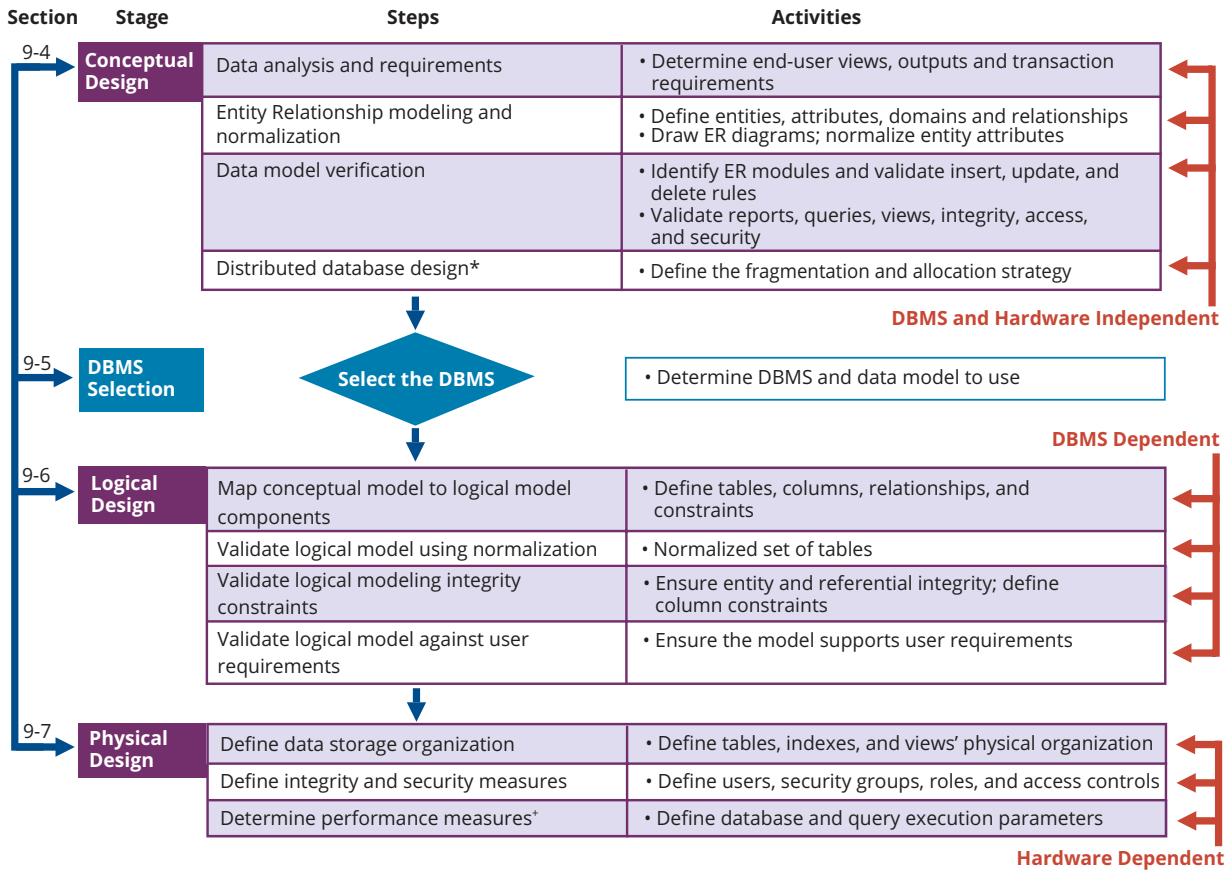
We also thank our students for their comments and suggestions. They are the reason for writing this book in the first place. One comment stands out in particular: "I majored in systems for four years, and I finally discovered why when I took your course." And one of our favorite comments by a former 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!"

Special thanks go to a unique and charismatic gentleman—for over 20 years, Peter Rob has been the driving force behind the creation and evolution of this book. This book originated as a product of his drive and dedication to excellence. For over 22 years, he was the voice of *Database Systems* and the driving force behind its advancement. We wish him peace in his retirement, time with his loved ones, and luck on his many projects.

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 and Steven Morris

Database Design Process



* See Chapter 12, Distributed Database Management Systems

+ See Chapter 11, Database Performance Tuning and Query Optimization

Database Design Process

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 is clearly defined and supports 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 they are justified 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."

Part 1

Database Concepts

Chapter

1 Database Systems

Learning Objectives

After completing this chapter, you will be able to:

- **1-1** Define the difference between data and information
- **1-2** Describe what a database is, the various types of databases, and why they are valuable assets for decision making
- **1-3** Explain the importance of database design
- **1-4** Outline how modern databases evolved from file systems
- **1-5** Identify flaws in file system data management
- **1-6** Outline the main components of the database system
- **1-7** Describe the main functions of a database management system (DBMS)

PREVIEW

Organizations use data to keep track of their day-to-day operations. Such data is used to generate information, which in turn is the basis for good decisions. Data is likely to be managed most efficiently when it is stored in a database. Databases are involved in almost all facets and activities of our daily lives: from school to work, medical care, government, nonprofit organizations, and houses of worship. 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 the need to manage large amounts of data in an organized and efficient manner. In the early days, computer file systems were used to organize such data. 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.

Data Files and Available Formats

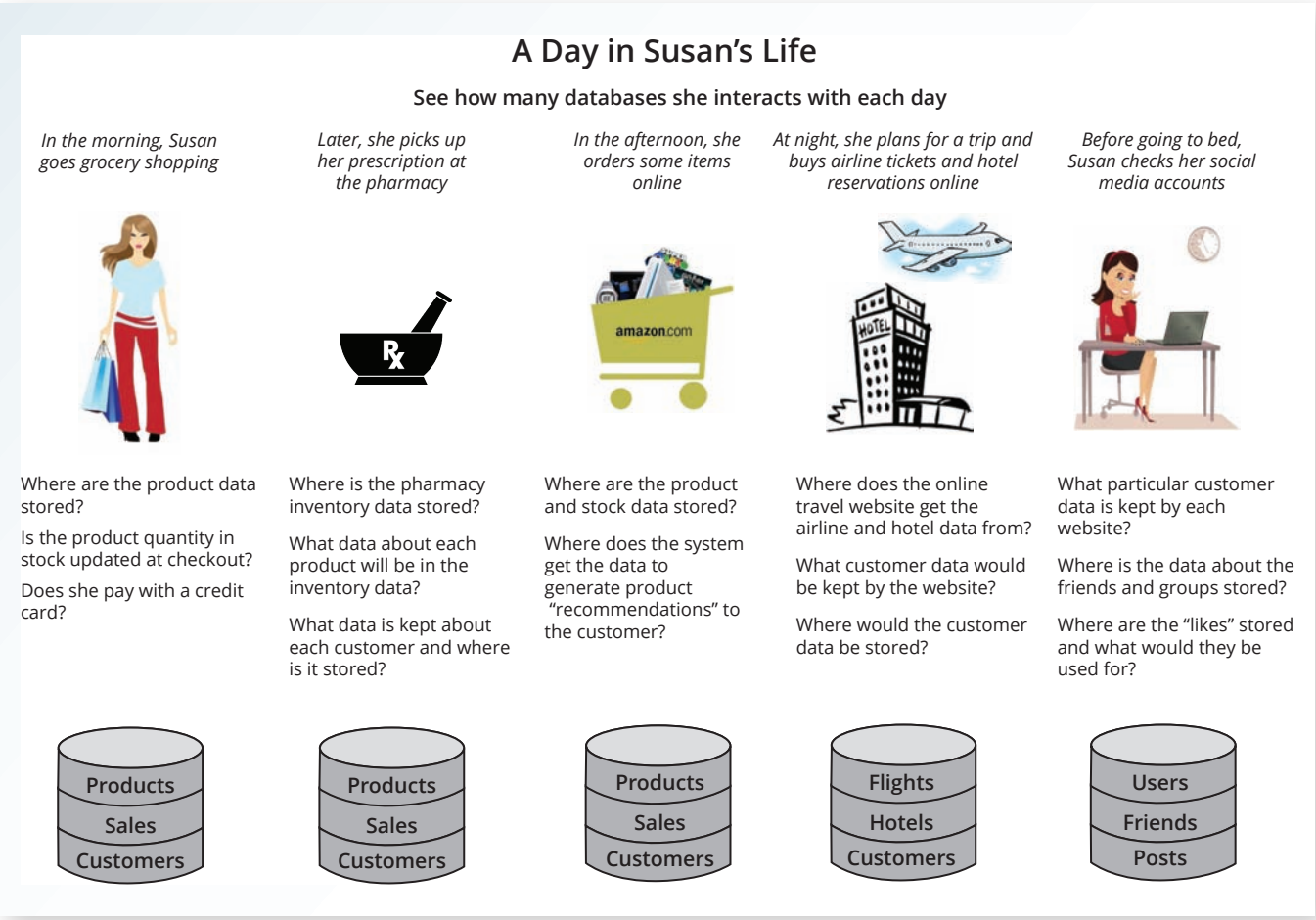
	MS Access	Oracle	MS SQL	MySQL
Ch01_Text	Yes	Yes	Yes	Yes
Ch01_Problems	Yes	Yes	Yes	Yes

Data Files available on cengage.com

1-1 Why Databases?

So, why do we need databases? In today's world, data is ubiquitous (abundant, global, everywhere) and pervasive (unescapable, prevalent, persistent). From birth to death, we generate and consume data. The trail of data starts with the birth certificate and continues all the way to a death certificate (and beyond!). In between, each individual produces and consumes enormous amounts of data. As you will see in this book, databases are the best way to store and manage data. Databases make data persistent and shareable in a secure way. As you look at Figure 1.1, can you identify some of the data generated by your own daily activities?

Figure 1.1 The Pervasive Nature of Databases



Data is not only ubiquitous and pervasive; it is also essential for organizations to survive and prosper. 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 important, they must have that 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, this data could vary from a few megabytes on just one or two topics to petabytes 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! Not only do these companies have to store and manage immense collections of data, but they must 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 of 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.

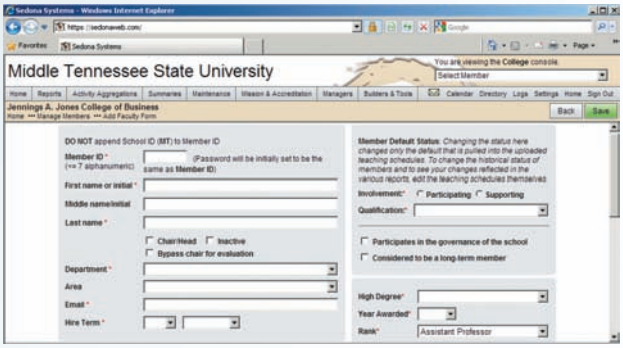
1-2 Data versus Information

To understand what drives database design, you must understand the difference between data and information. **Data** consists of 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 1.2(a) shows a simple data-entry form from a software package named Sedona. When the data is entered into the form and saved, it is placed in the underlying database as raw data, as shown in Figure 1.2(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 1.2(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 percent 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 1.2(d).

data
Raw facts, or facts that have not yet been processed to reveal their meaning to the end user.

Figure 1.2 Transforming Raw Data into Information

a) Data entry screen



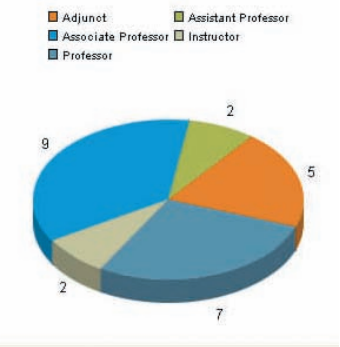
b) Raw data

Id	LastName	MidName	FirstName	DeptCode	Office	Email	Rank	HireYear	Degree
1	Washington	A.	George	MGMT	N135	gwashington@mtsu.edu	Professor	2001	Ph.D.
2	Adams		John	FIN	N313	jadams@mtsu.edu	Professor	1984	Ph.D.
3	Jefferson	L.	Thomas	ECON		tjefferson@mtsu.edu	Instructor	2002	M.B.A.
4	Madison	D.	James	FIN	N236	jmadison@mtsu.edu	Associate Professor	1994	Ph.D.
5	Monroe	N.	James	ACCT	N411	jmonroe@mtsu.edu	Assistant Professor	1995	Ph.D.
6	Adams	G.	John	ACCT	N418	jqadams@mtsu.edu	Associate Professor	1989	Ph.D.
7	Jackson	C.	Andrew	ECON	N303	ajackson@mtsu.edu	Associate Professor	1993	Ph.D.
8	Van Buren	T.	Martin	FIN	N306	mvanburen@mtsu.edu	Professor	1988	Ph.D.
9	Harrison	R.	William	MKTG	N118	wharrison@mtsu.edu	Professor	1994	Ph.D.
10	Tyler	M.	John	MGMT		JTyler@mtsu.edu	Assistant Professor	2000	Ed.D.
11	Polk		Cheryl	MKTG	N143	cpolk@mtsu.edu	Associate Professor	2002	Ph.D.
12	Taylor	G.	Zachary	ACCT	N415	ztaylor@mtsu.edu	Associate Professor	1996	Ph.D.
13	Fillmore		Millard	JCB	N219	mfillmore@mtsu.edu	Professor	1992	Ph.D.
14	Pierce	A.	Franklin	MKTG	N359	pfranklin@mtsu.edu	Instructor	2005	M.B.A.
15	Buchanan	T.	James	MGMT	N146	jbuchanan@mtsu.edu	Associate Professor	1996	D.B.A.
17	Lincoln	W.	Larry	MGMT	N150	llincoln@mtsu.edu	Associate Professor	1996	Ph.D.
18	Johnson		Andrew	ISYS	N360	ajohnson@mtsu.edu	Professor	1987	Ph.D.
19	Grant		Katie	MKTG	N120	kgrant@mtsu.edu	Assistant Professor	1989	D.B.A.
20	Rutherford		Hayes	ACCT	N408	hrutherford@mtsu.edu	Professor	1992	Ph.D.
21	Garfield	T.	Denise	ACCT		dgarfield@mtsu.edu	Assistant Professor	2018	Ph.D.
22	Arthur		Emily	ACCT	N413	earthur@mtsu.edu	Associate Professor	2003	J.D.
23	Cleveland	G.	Robert	ACCT	N401	rcleveland@mtsu.edu	Associate Professor	1997	Ph.D.
24	Harrison	X.	Patricia	BULA	N406	pharrison@mtsu.edu	Associate Professor	2001	J.D.
25	McKinley	B.	Priscilla	ISYS	N363	pmckinley@mtsu.edu	Adjunct	1994	M.S.
26	Roosevelt	F.	Hillary	MGMT	N104	hroosevelt@mtsu.edu	Associate Professor	2002	Ph.D.
27	Wilson		Laura	BCEN	N448	lwilson@mtsu.edu	Professor	1992	Ph.D.
29	Harding		Warren	MKTG	N114	wharding@mtsu.edu	Professor	1984	Ed.D.
29	Coolidge		Calvin	ECON	N316	ccoolidge@mtsu.edu	Professor	1975	Ph.D.
30	Hoover		Lisa	MGMT		lhoover@mtsu.edu	Adjunct	1978	M.B.A.
31	Truman		Betty	ACCT	N416	btruman@mtsu.edu	Professor	1971	Ed.D.
32	Johnson		Robert	BCEN	N240	rjohnson@mtsu.edu	Professor	2001	Ph.D.

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%	5.88%
Instructor	2	8.00%	18	11.11%	1.31%
Professor	7	28.00%	47	14.89%	4.58%

d) Information in graphical format



information
The result of processing raw data to reveal its meaning. Information consists of transformed data and facilitates decision making.

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.

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."[1]

Data is 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.

[1]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."

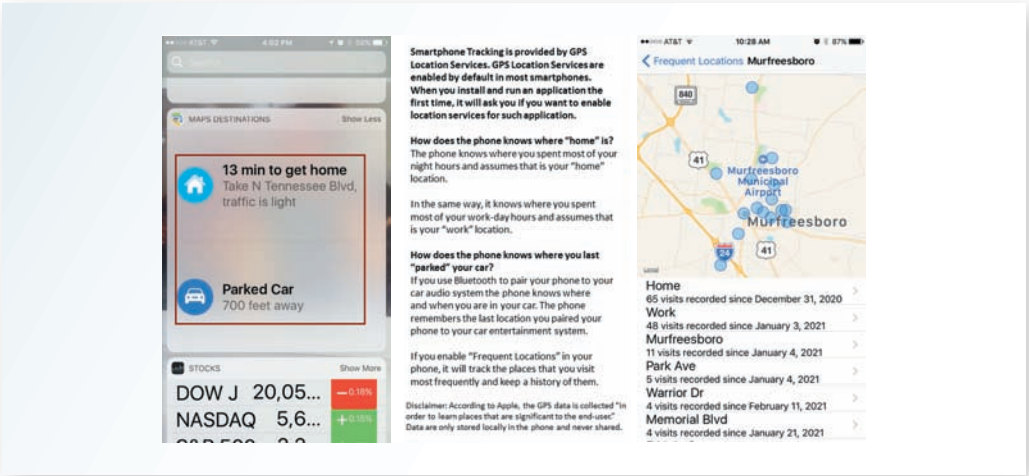
Let's summarize some key points:

- Data constitutes 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.

The previous paragraphs have explained the importance of data and how the processing of data is used to reveal information that in turn generates "actionable" knowledge. Let's explore a simple example of how this works in the real world.

In today's information-centric society, you use smartphones on a daily basis. These devices have advanced GPS functionality that constantly tracks your whereabouts. This data is stored and shared with various applications. When you get a new smartphone, you can use the map application to go places and to set up your home address (now the phone knows where you live!). The GPS feature in your phone tracks your daily locations. In some cases, the information generated is very helpful: it can help you navigate to various locations and even to find where you parked your car. Figure 1.3 shows screenshots from the smartphone of one of the authors. The phone "knows" that this is about the time he goes home and tells him how long it is going to take to get there. It also tells him where he parked his car; if he clicks the Parked Car icon, it will open a map so he can locate the car.

Figure 1.3 Smartphone Tracking



Source: Morris Coronel

Furthermore, in terms of privacy issues, your smartphone may know more about your activities than you imagine. For example, suppose that every Wednesday night you go to the gym and play indoor soccer with your friends. Next Wednesday night, 20 minutes before you leave home, your phone pops up a message saying "19 minutes to [gym address]. Traffic is light." The phone has been storing GPS data on your movements to develop patterns based on days, times, and locations to generate this knowledge. It can then associate such knowledge as your daily activities provide more data points. Imagine that on Wednesday when you go to the Magic Box gym to play soccer, when you arrive you use Facebook on your phone to check in to the gym. Now, your phone also knows the name of the place where you go every Wednesday night.

As you can see from this example, knowledge and information require timely and accurate data. Such data must be properly generated and stored in a format that is easy to access and process. In addition, 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 plays, it should not surprise you that data management is a core activity for any business, government agency, service organization, or charity.

data management
A process that focuses on data collection, storage, and retrieval. Common data management functions include addition, deletion, modification, and listing.

database
A shared, integrated computer structure that houses a collection of related data. A database contains two types of data: end-user data (raw facts) and metadata.

metadata
Data about data; that is, data about data characteristics and relationships. See also *data dictionary*.

database management system (DBMS)
The collection of programs that manages the database structure and controls access to the data stored in the database.

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 the following:

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

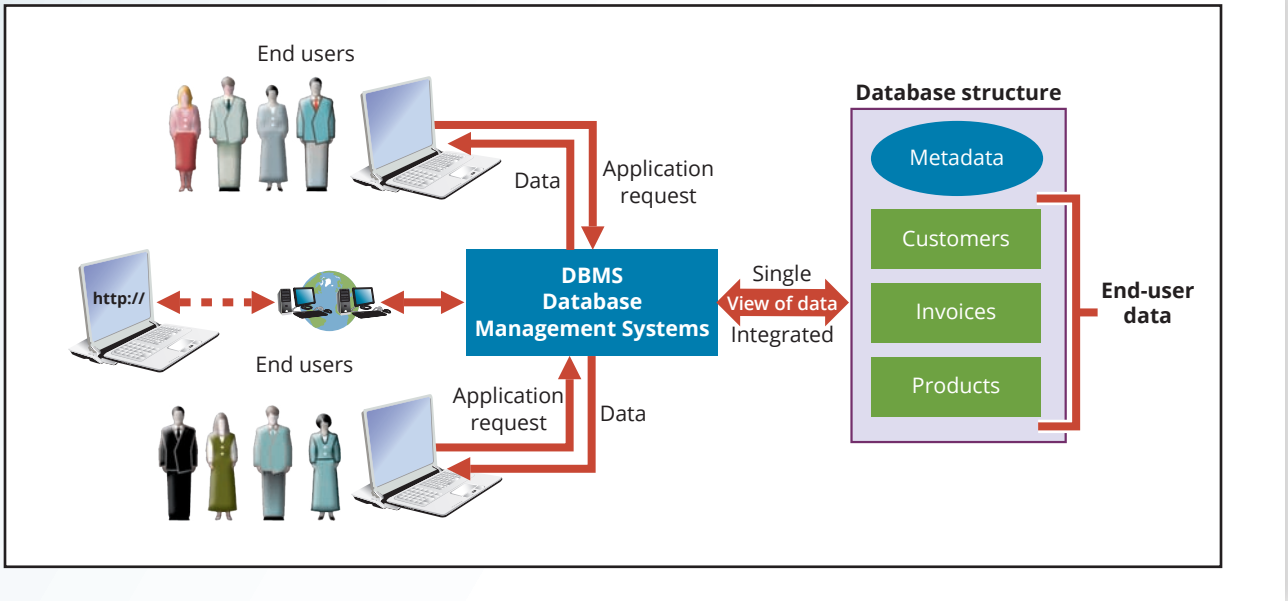
The metadata describes the data characteristics and the set of relationships that links the data found within the database. For example, the metadata component stores information such as the name of each data element, the type of values (numeric, dates, or text) stored on each data element, and whether the data element can be left empty. The metadata provides information that complements and expands the value and use of the data. In short, metadata presents 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.

1-3a 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 1.4 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

Figure 1.4 The DBMS Manages the Interaction between the End User and the Database



application programs and users. The application program might be written by a programmer using a programming language, such as Python, 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.

Because data is 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 these advantages:

- *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 is 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 are the following:
  - 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 16, 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.

data inconsistency
A condition in which different versions of the same data yield different (inconsistent) results.

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.

ad hoc query
A "spur-of-the-moment" question.

query result set
The collection of data rows returned by a query.

data quality
A comprehensive approach to ensuring the accuracy, validity, and timeliness of data.