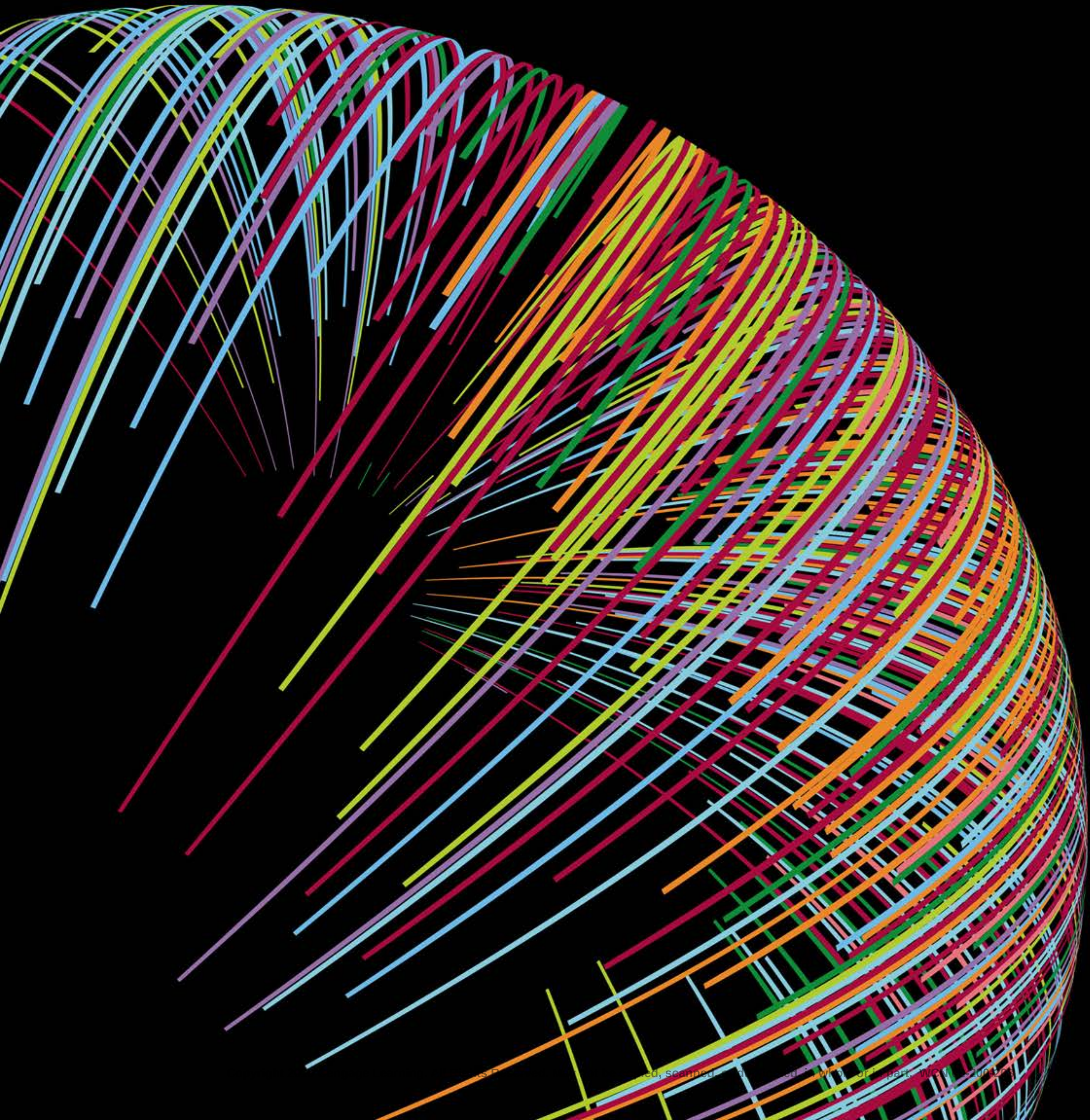
DATABASE SYSTEMS

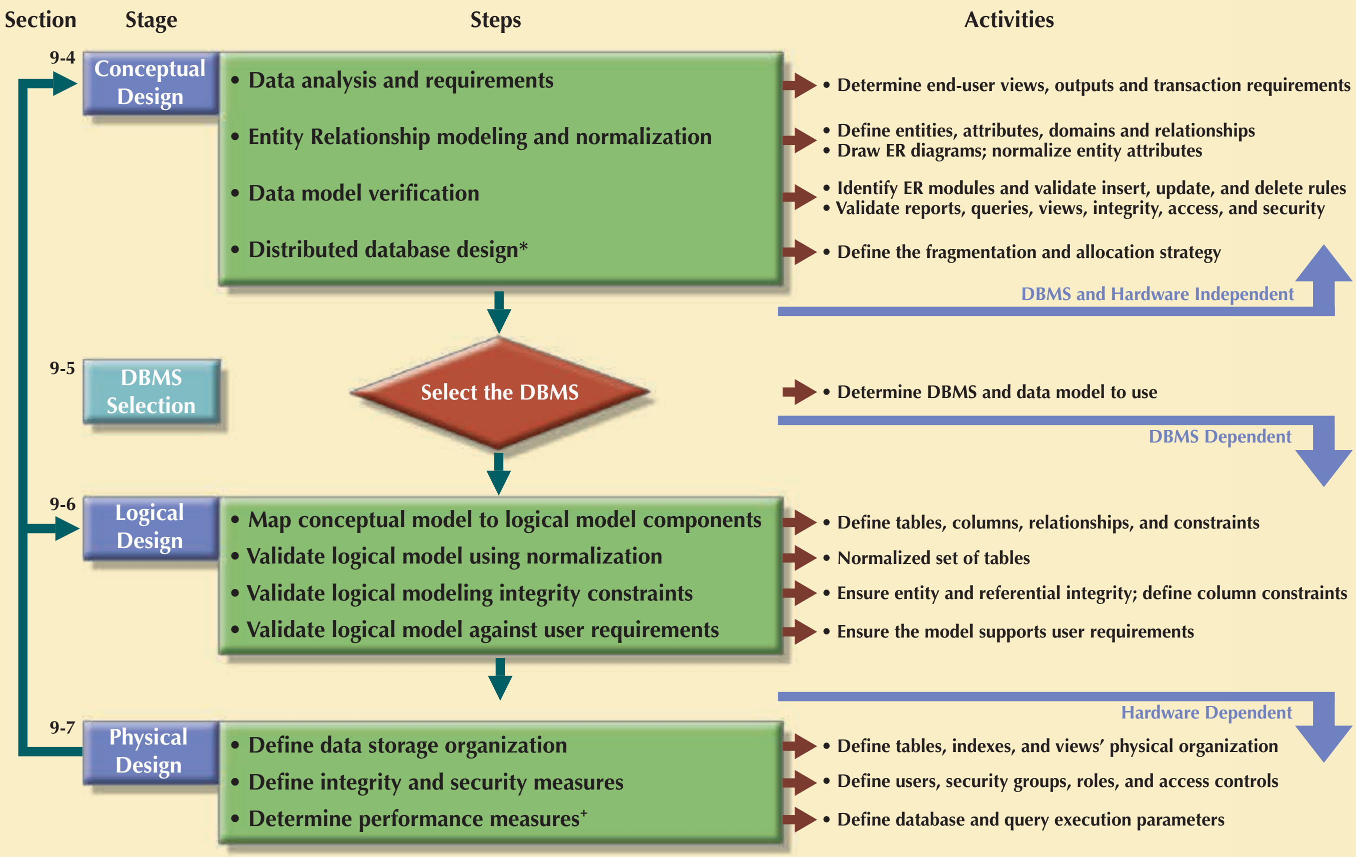
DESIGN, IMPLEMENTATION, & MANAGEMENT

CARLOS CORONEL • STEVEN MORRIS

13TH EDITION



Database Design Process



* See Chapter 12, Distributed Database Management Systems

+ See Chapter 11, Database Performance Tuning and Query Optimization

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 is clearly defined and supports the selected data granularity.

Attributes:

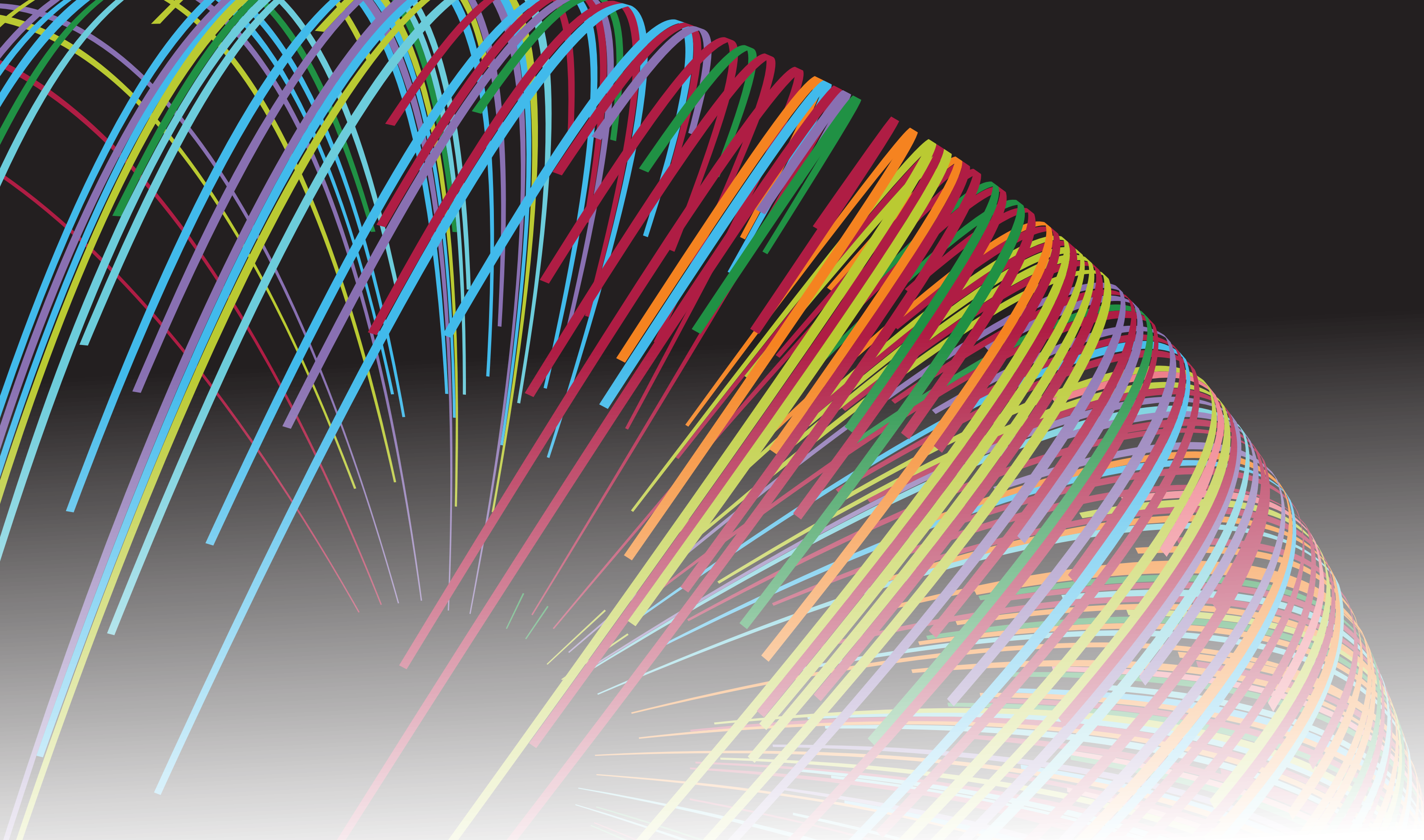
- Should be simple and single-valued (atomic data)
- Should document default values, constraints, synonyms, and aliases
- Derived attributes should be clearly identified and include source(s)
- Should not be redundant unless they are justified for transaction accuracy, performance, or maintaining a history
- 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."



DATABASE SYSTEMS

Design, Implementation, and Management

13e

Carlos Coronel | Steven Morris

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Database Systems: Design, Implementation, and Management, **13th Edition**
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Dedication

To the treasures in my life: To Victoria, for 28 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 smart 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 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 of 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 Logan, your depth of character is without measure. You are my pride and joy. To my daughter, Lauren Elizabeth, your 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, together they 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, 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 Companion Sites at ***www.cengagebrain.com***.

Contents

The following appendices are included on the Instructor and Student Companion Sites at ***www.cengagebrain.com***.

Preface

It is our great pleasure to present the thirteenth 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 book has been successful through twelve editions because the authors, editors, and the publisher paid attention to the impact of technology and to adopters' questions and suggestions. We believe that this thirteenth 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 Thirteenth Edition

In this thirteenth edition, we have responded to the requests and suggestions of numerous adopters. We have substantially reorganized the SQL coverage to make the presentation easier to follow and easier to reference. We start with simple SQL statements to familiarize students with the basic SQL syntax and environment. This provides students the confidence to transition to the more advanced SQL features and commands. These changes provide a better flow of material. Additionally, more SQL examples and figures have been added to help students better visualize and understand the code that is presented.

Aside from enhancing the already strong coverage of database design, we made other improvements in the topical coverage. In particular, the continued growth of Big Data and NoSQL technologies continue to challenge the status quo in the database industry. Therefore, we have added two new online appendices on MongoDB and Neo4j, two of the most important of the NoSQL offerings. This new material provides coding examples and data files to allow students to gain hands-on experience using two of the most popular NoSQL databases. The thirteenth edition also presents a major step forward in the integration of digital content with the text through online, automatically graded coding labs that allow students to write SQL code in an interactive environment that can grade and provide feedback on problems. Here are a few of the highlights of changes in the thirteenth edition:

- Streamlined and reorganized coverage of normalization for enhanced clarity
- Complete reorganization of SQL and Advanced SQL chapters to improve flow and make references to keywords and techniques easier to access
- Expanded coverage of MongoDB with hands-on exercises for querying MongoDB databases (Appendix P)
- Expanded coverage of Neo4j with hands-on exercises for querying graph databases using Cypher (Appendix Q)
- New and expanded coverage of data visualization tools and techniques

This thirteenth 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.

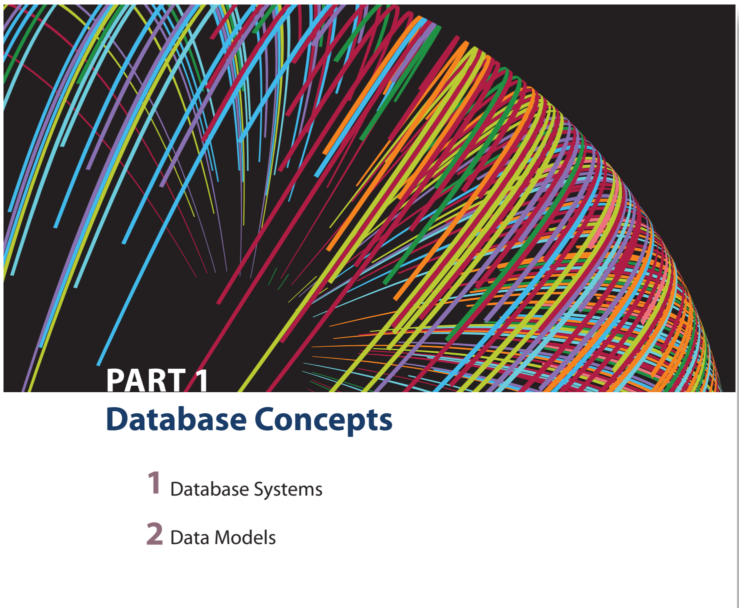
- The availability of excellent database software enables people with little experience to create databases and database applications. Unfortunately, the "create without design" approach usually paves the road to a number of database disasters. In our experience, many database system failures are traceable 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.

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 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).




Chapter 9

Database Design

After completing this chapter, you will be able to:

- Describe the role of database design as the foundation of a successful information system
- Describe the five phases in the Systems Development Life Cycle (SDLC)
- Design databases using the six phases in the Database Life Cycle (DBLC) framework
- Conduct evaluation and revision within the SDLC and DBLC frameworks
- Distinguish between top-down and bottom-up approaches in database design
- 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 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, enhanced, and eventually 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 versus bottom-up and centralized versus decentralized.

Data Files Available on cengagebrain.com

Note
Because it is purely conceptual, this chapter does not reference any data files.

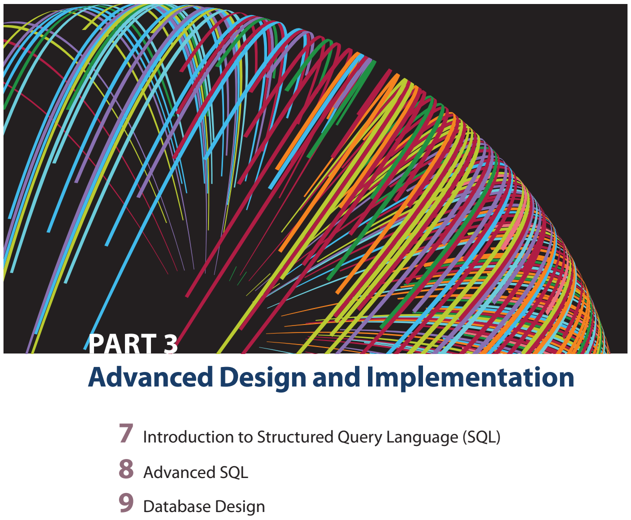
Database Design

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 Appendices B and C. Appendices A1 and A2 are good introductory tutorials on designing databases with Visio Professional 2010 and Visio 2013, respectively.

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, Microsoft 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 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

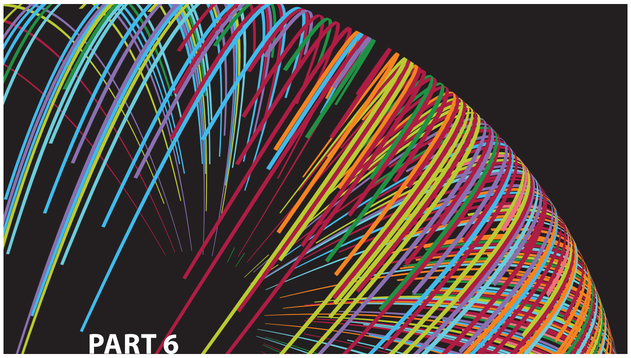

PART 3

Advanced Design and Implementation

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 12c, walks you through the process of setting up a new database.



PART 6
Database Administration

16 Database Administration and Security

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

Core Coverage

(1) Database Systems
(2) Data Models
(3) The Relational Database Model
(4) Entity Relationship (ER) Modeling
(6) Normalization of Database Tables
(7) Introduction to Structured Query Language (SQL)

Database Design and Implementation Focus

(5) Advanced Data Modeling
(8) Advanced SQL
(9) Database Design
(A) Designing Databases with Visio Professional
(D) Converting an ER Model into a Database Structure
(E) Comparison of ER Model Notations
(H) Unified Modeling Language (UML)
(14) Big Data and NoSQL
(15) Database Connectivity and Web Technologies

Supplementary Reading

(B) The University Lab: Conceptual Design
(C) The University Lab: Conceptual Design Verification, Logical Design, and Implementation
(M) Microsoft Access Tutorial
(J) Web Database Development with ColdFusion
(K) The Hierarchical Database Model
(L) The Network Database Model

Database Management Focus

(10) Transaction Management and Concurrency Control
(11) Database Performance Tuning and Query Optimization
(12) Distributed Database Management Systems
(13) Business Intelligence and Data Warehouses
(15) Database Connectivity and Web Technologies
(16) Database Administration and Security
(F) Client/Server Systems
(G) Object Oriented Databases

Supplementary Reading

(9) Database Design
(M) Microsoft Access Tutorial
(N) Creating a New Database Using Oracle 12c
(O) Data Warehouse Implementation Factors
(I) Databases in Electronic Commerce
(J) Web Database Development with ColdFusion
(P) Working with MongoDB
(Q) Working with Neo4j

Text Features

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

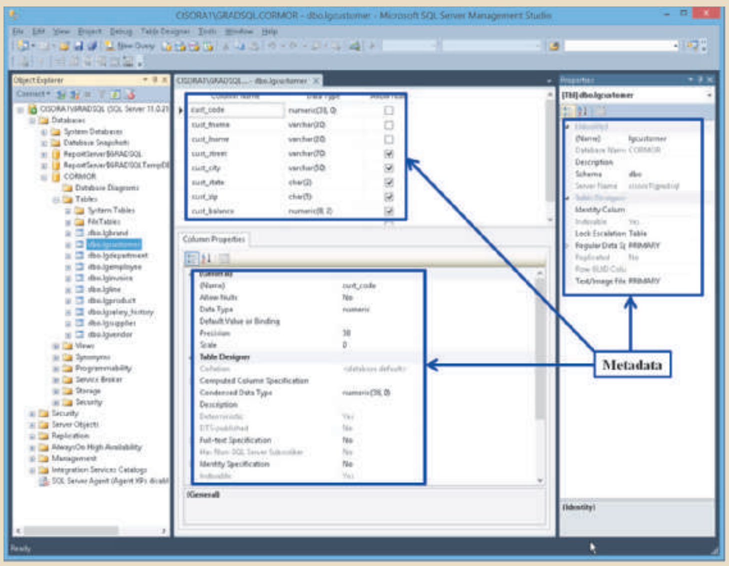
> **Online Content**
>
> All of the databases used to illustrate the material in this chapter (see the Data Files list at the beginning of the chapter) are available at *www.cengagebrain.com*. The database names match the database names shown in the figures.

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

> **Note**
>
> This chapter focuses on SELECT queries to retrieve data from tables. Chapter 8 will explain how those tables are actually created and how the data is loaded into them. This reflects the experience of most entry-level database positions. As a new hire working with databases, you will likely spend quite a bit of time retrieving data from tables that already exist before you begin creating new tables and modifying the data.

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

FIGURE 1.12 ILLUSTRATING METADATA WITH MICROSOFT SQL SERVER EXPRESS



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

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

Key Terms

bottom-up design	Database Life Cycle (DBLC)	module coupling
boundaries	database role	physical design
centralized design	decentralized design	scope
clustered tables	description of operations	systems analysis
cohesivity	differential backup	systems development
computer-aided software engineering (CASE)	full backup	Systems Development Life Cycle (SDLC)
conceptual design	information system	top-down design
database development	logical design	transaction log backup
database fragment	minimal data rule	virtualization
	module	

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

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.

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

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.

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

Additional Features

MindTap® for Database Systems 13e

MindTap® combines learning tools—such as readings, multimedia, activities, and assessments—into a singular learning path that guides students through the course. You'll find a full ebook as well as a robust set of auto-gradable homework problems. Multiple-choice homework questions developed from the end-of-chapter review questions confirm students' understanding of core concepts and key terms. Higher-level assignments enable students to practice database design concepts in an automated environment, and chapter quizzes help prepare students for exams. Students will also benefit from the chapter-opening videos created by the authors, as well as study tools such as crossword puzzles and key-term flashcards.

MindTap® is designed to be fully integrated with any Learning Management System and can be used as a stand-alone product or in conjunction with a print textbook.

Appendices

Eighteen online appendices 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, Adobe® ColdFusion®, and working with newer NoSQL databases MongoDB and Neo4j.

Database, SQL Script, JSON Documents, 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®, 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 Resources

Database Systems: Design, Implementation, and Management, Thirteenth Edition, includes teaching tools to support instructors in the classroom. The ancillary material that accompanies the textbook is listed below. They are available on the web at *www.cengagebrain.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 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 teachers 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 Learning Testing Powered by Cognero

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- Cross-compatible capability. Import and export content into other systems.

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 Peter Keen 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, 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 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:

Laurie Crawford,
Franklin University

John E. MacDonald IV,
Binghamton University

Mava Wilson,
Lee 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 Deb Kaufmann for her help and guidance. Deb has been everything we could have hoped for in a development editor and more. Deb has been our editor for almost all the editions of this book, and the quality of her work shows in the attention to detail and the cohesiveness and writing style of the material in this book.
- After writing so many books and thirteen 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 Cengage (Michele Stulga) and Lumina Datamatics (Kiruthiga Sowndararajan), have done an excellent job.

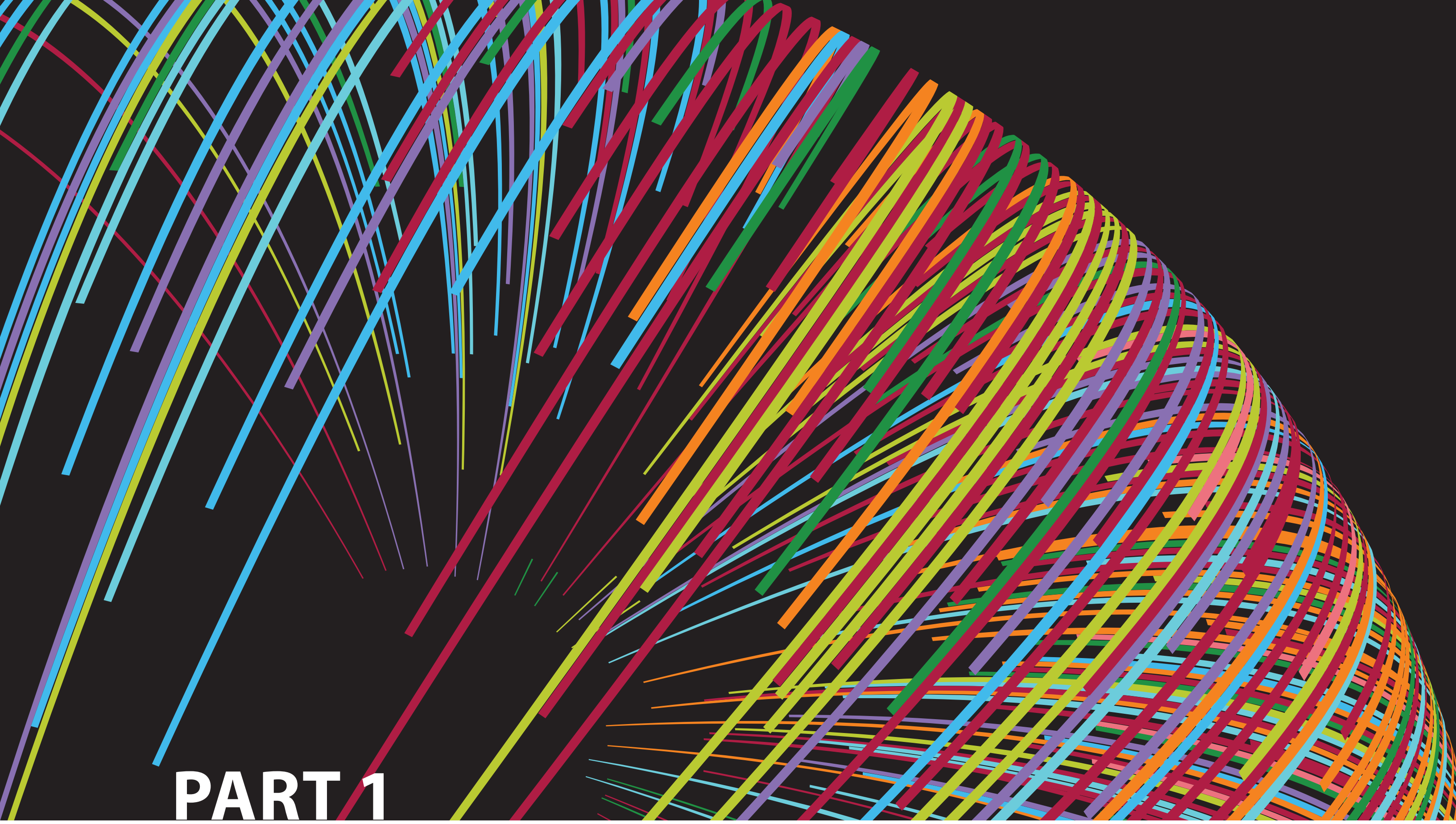
- We also owe Maria Garguilo, our Content Developer, special thanks for her ability to guide this book to a successful conclusion, and John Freitas, our technical editor, deserves many thanks for making sure all code and technical references were accurate.

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 very 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



PART 1
Database Concepts

Chapter 1

Database Systems

After completing this chapter, you will be able to:

- Define the difference between data and information
- Describe what a database is, the various types of databases, and why they are valuable assets for decision making
- Explain the importance of database design
- See how modern databases evolved from file systems
- Understand flaws in file system data management
- Outline the main components of the database system
- 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

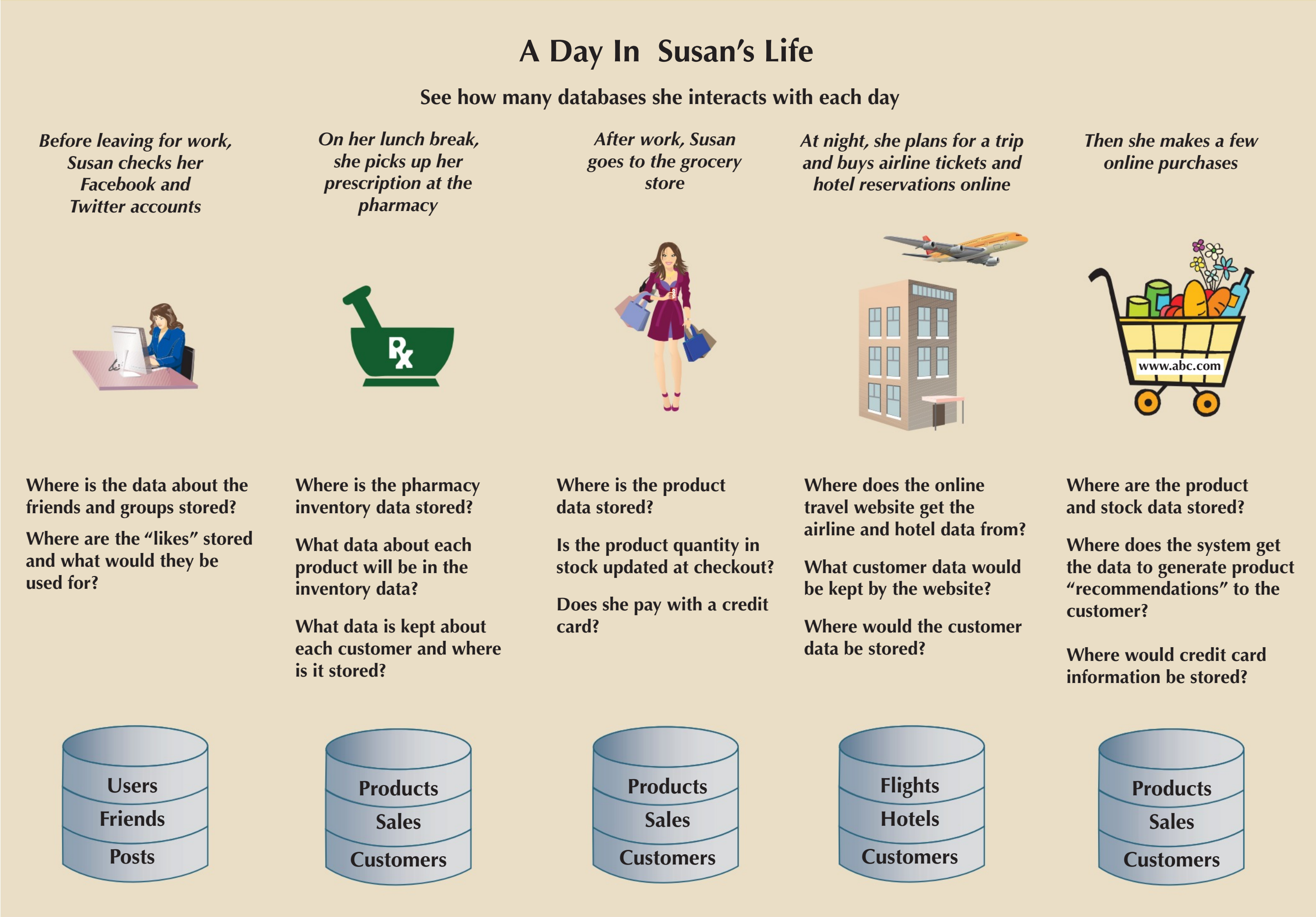
	MS Access	Oracle	MS SQL	My SQL		MS Access	Oracle	MS SQL	My SQL
CH01_Text	✓	✓	✓	✓	CH01_Problems	✓	✓	✓	✓

Data Files Available on cengagebrain.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 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! Not only do these companies have to store and manage immense collections of data but also 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 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).

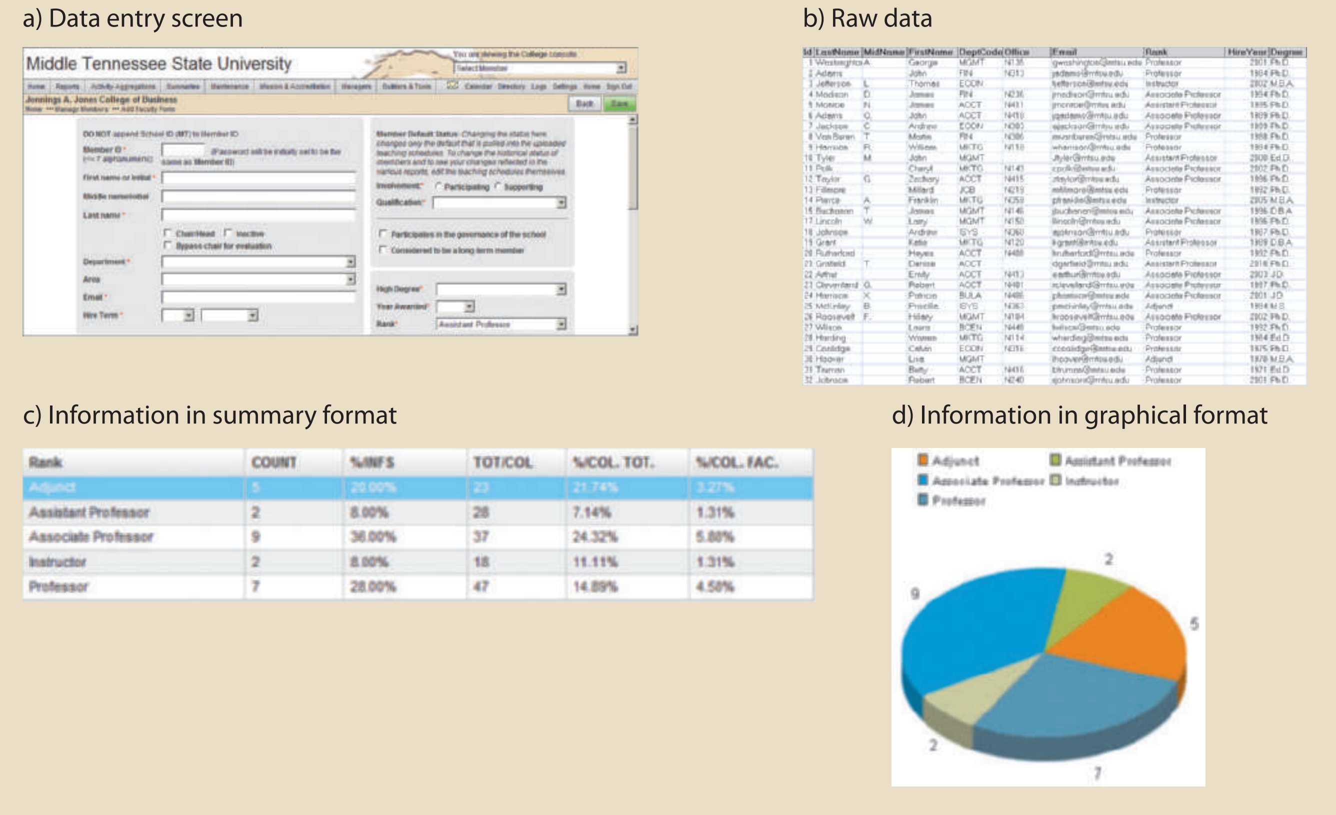
Information is the result of processing raw data to reveal its meaning. Data processing can be as simple as organizing data to reveal patterns or as complex as making forecasts or drawing inferences using statistical modeling. To reveal meaning, information requires *context*. For example, an average 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

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

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

FIGURE 1.2 TRANSFORMING RAW DATA INTO INFORMATION



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%

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.

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.

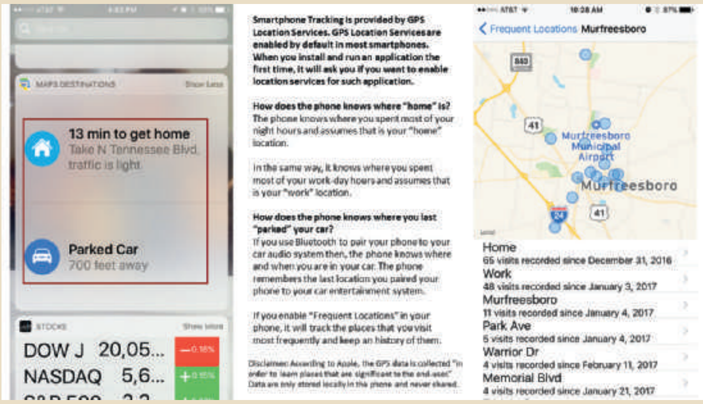
In today's information-centric society, we use smartphones on a daily basis. These devices have advanced GPS functionality that constantly tracks your whereabouts. This data is stored and shared with various applications. When you get a new smartphone,

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.

[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."

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 one of the authors' smartphone. 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



Furthermore, and maybe even scarier 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*.

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.

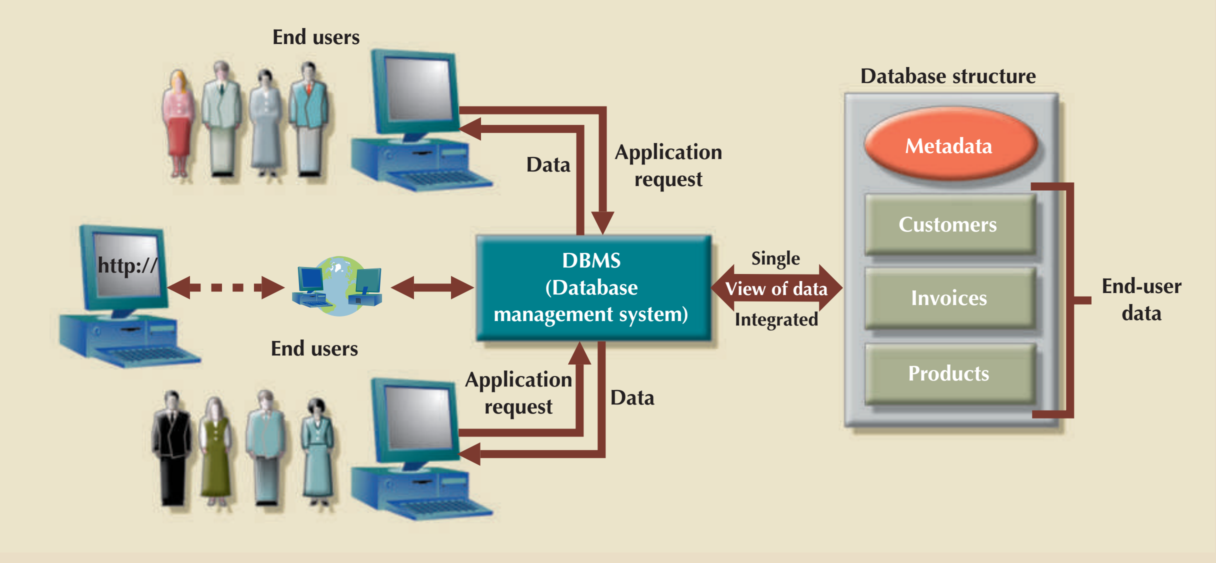
1-3a Role and Advantages of the DBMS

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 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.

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

FIGURE 1.4 THE DBMS MANAGES THE INTERACTION BETWEEN THE END USER AND THE DATABASE



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.

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.

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.

1-3b 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 is located, the type of data stored, the intended data usage, and the degree to which the data is 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.

Both centralized and decentralized (distributed) databases require a well-defined infrastructure (hardware, operating systems, network technologies, etc.) to implement and operate the database. Typically, the infrastructure is owned and maintained by the organization that creates and operates the database. But in recent years, the use of cloud databases has been growing in popularity. A **cloud database** is a database that is created and maintained using cloud data services, such as Microsoft Azure or Amazon AWS. These services, provided by third-party vendors, provide defined performance measures (data storage capacity, required throughput, and availability) for the database, but do not necessarily specify the underlying infrastructure to implement it. The data owners do not have to know, or be concerned about, what hardware and software are being used to support their databases. The performance capabilities can be renegotiated with the cloud provider as the business demands on the database change. For example, 3M Health Information Systems, the world's largest provider of health care analytics software in hospitals, used Amazon's AWS cloud database services to consolidate its multiple IT centers. 3M did not have to buy, install, configure, or maintain any hardware, operating systems, or network devices. It simply purchased storage and processing capacity for its data and applications. As the demands on the databases increased, additional processing and storage capabilities could be purchased as needed. As a result, server provisioning processes that previously took 10 weeks to complete could be done in mere minutes. This allows the company to be more responsive to the needs of customers and innovate faster.

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 is used mainly for academic or research purposes

single-user database
A database that supports only one user at a time.

desktop database
A single-user database that runs on a personal computer.

multiuser database
A database that supports multiple concurrent users.

workgroup database
A multiuser database that usually supports fewer than 50 users or is used for a specific department in an organization.

enterprise database
The overall company data representation, which provides support for present and expected future needs.

centralized database
A database located at a single site.

distributed database
A logically related database that is stored in two or more physically independent sites.

cloud database
A database that is created and maintained using cloud services, such as Microsoft Azure or Amazon AWS.

general-purpose database
A database that contains a wide variety of data used in multiple disciplines.

discipline-specific database
A database that contains data focused on specific subject areas.