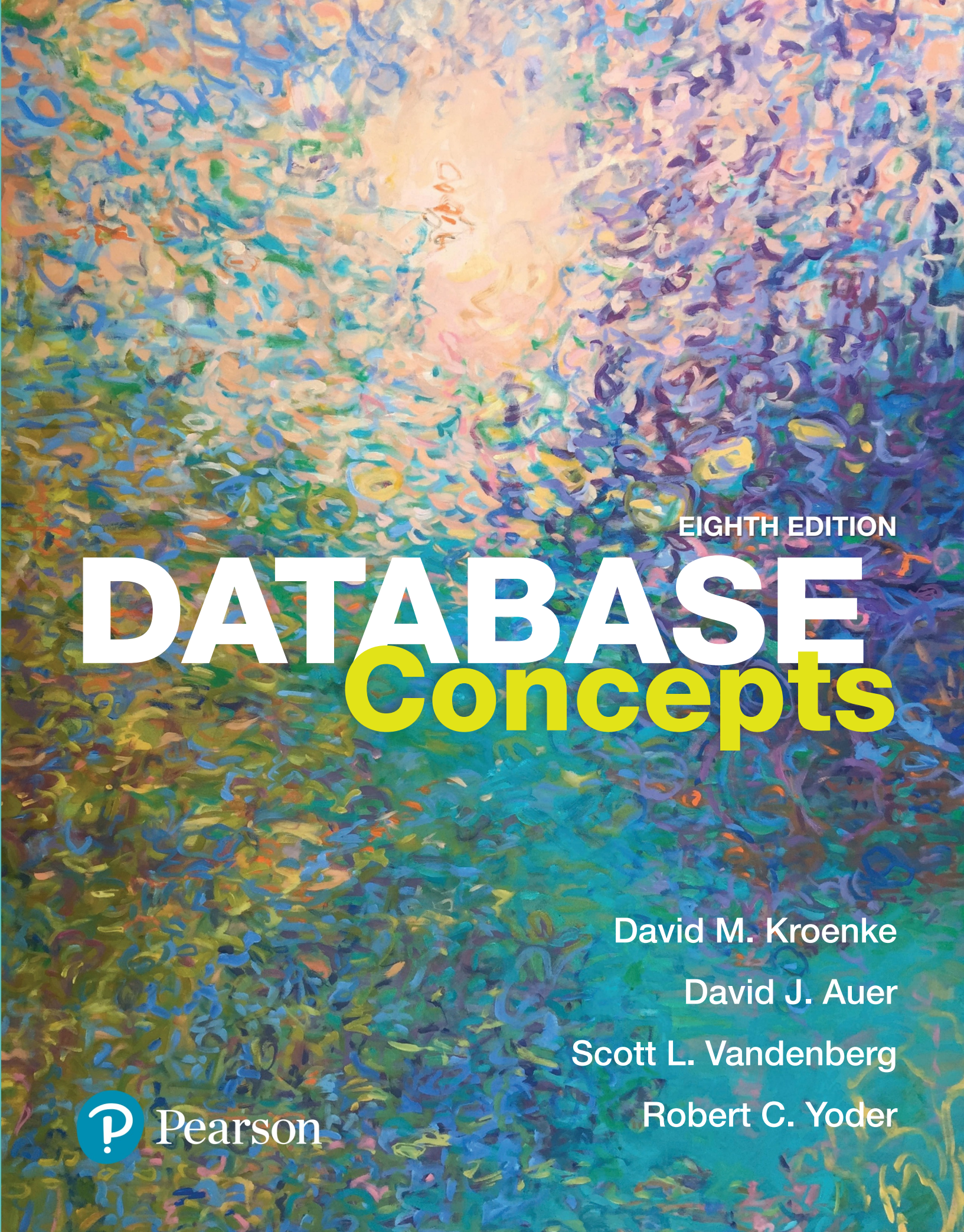
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Brief Contents

ONLINE APPENDICES: SEE PAGE 541 FOR INSTRUCTIONS

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Preface

Colin Johnson is a production supervisor for a small manufacturer in Seattle. Several years ago, Colin wanted to build a database to keep track of components in product packages. At the time, he was using a spreadsheet to perform this task, but he could not get the reports he needed from the spreadsheet. Colin had heard about Microsoft Access, and he tried to use it to solve his problem. After several days of frustration, he bought several popular Microsoft Access books and attempted to learn from them. Ultimately, he gave up and hired a consultant who built an application that more or less met his needs. Over time, Colin wanted to change his application, but he did not dare try.

Colin was a successful businessperson who was highly motivated to achieve his goals. A seasoned Windows user, he had been able to teach himself how to use Microsoft Excel, Microsoft PowerPoint, and a number of production-oriented application packages. He was flummoxed at his inability to use Microsoft Access to solve his problem. "I'm sure I could do it, but I just don't have any more time to invest," he thought. This story is especially remarkable because it has occurred tens of thousands of times over the past decade to many other people.

Microsoft, Oracle, IBM, and other database management system (DBMS) vendors are aware of such scenarios and have invested millions of dollars in creating better graphical interfaces, hundreds of multi-panel wizards, and many sample applications. Unfortunately, such efforts treat the symptoms and not the root of the problem. In fact, most users have no clear idea what the wizards are doing on their behalf. As soon as these users require changes to database structure or to components such as forms and queries, they drown in a sea of complexity for which they are unprepared. With little understanding of the underlying fundamentals, these users grab at any straw that appears to lead in the direction they want. The consequence is poorly designed databases and applications that fail to meet the users' requirements.

Why can people like Colin learn to use a word processor or a spreadsheet product yet fail when trying to learn to use a DBMS product? First, the underlying database concepts are unnatural to most people. Whereas everyone knows what paragraphs and margins are, no one knows what a *relation* (also called a *table*) is. Second, it seems as though using a DBMS product ought to be easier than it is. "All I want to do is keep track of something. Why is it so hard?" people ask. Without knowledge of the *relational model*, breaking a sales invoice into five separate tables before storing the data is mystifying to business users.

This book is intended to help people like Colin understand, create, and use databases in a DBMS product, whether they are individuals who found this book in a bookstore or students using this book as their textbook in a class.

NEW TO THIS EDITION

Students and other readers of this book will benefit from new content and features in this edition. These include the following:

- The material on Structured Query Lanquage in Chapter 3 has been reorganized and expanded to provide a more concise and comprehensive presentation of SQL topics. New material to illustrate the concepts of SQL joins has been added to Chapter 3 to make this material easier for students to understand.
- The discussion of SQL is continued in a revised and expanded Appendix E, which is now retitled as "Advanced SQL", and which contains a discussion of the SQL

ALTER statement, SQL set operators (UNION), SQL correlated subqueries, SQL views, and SQL/Persistent Stored Modules (SQL/PSM).

- Microsoft Office 2016, and particularly Microsoft Access 2016, is now the basic software used in the book and is shown running on Microsoft Windows 10.[1]
- DBMS software coverage has been updated to include Microsoft SQL Server 2016 Developer Edition, which is now freely available from Microsoft and which has the full functionality of the Microsoft SQL Server Enterprise edition.
- DBMS software coverage has been updated to include MySQL 5.7 Community Server.
- DBMS software coverage on Microsoft SQL Server 2016 (Appendix A), Oracle Database Express Edition (Oracle Database XE) (Appendix B), and MySQL 5.7 Community Server (Appendix C) has been extended, and now includes detailed coverage of software installation and configuration.
- The discussion of importing Microsoft Excel data into a DBMS table has been moved from Appendix E into the specific coverage of each of the DBMS products—see coverage of Microsoft SQL Server 2016 in Appendix A, of Oracle Database Express Edition (Oracle Database XE) in Appendix B, and of MySQL 5.7 Community Server in Appendix C.
- Chapter 8 has been updated to include material on cloud computing and virtualization in addition to revisions tying together the various topics of the chapter. This gives a more complete, contextualized treatment of Big Data and its various facets and relationships to the other topics.
- Appendices J, "Business Intelligence Systems," and K, "Big Data," continue to expand on Chapter 8. Coverage of decision trees is added to Appendix J at a level similar to that of the coverage of market basket analysis. Appendix K now includes coverage of JSON modeling (and retains the XML coverage) for document-based NoSQL databases. Appendix K also now includes basic coverage and examples of cloud databases and a document-based NoSQL database management system.

We kept all the main innovations included in DBC e06 and DBC e07, including:

- The coverage of Web database applications in Chapter 7 now includes data input Web form pages. This allows Web database applications to be built with both data-input and data-reading Web pages.
- The coverage of Microsoft Access 2016 now includes Microsoft Access switchboard forms (covered in Appendix H, "The Access Workbench—Section H—Microsoft Access 2016 Switchboards"), which are used to build menus for database applications. Switchboard forms can be used to build database applications that have a user-friendly main menu that users can use to display forms, print reports, and run queries.
- Each chapter now features an independent Case Question set. The Case Question sets are problem sets that generally do not require the student to have completed work on the same case in a previous chapter (there is one intentional exception that ties data modeling and database design together). Although in some instances the same basic named case may be used in different chapters, each instance is still completely independent of any other instance.
- Material on SQL programming via SQL/Persistent Stored Modules (SQL/PSM) has been added to Appendix E to provide a better-organized discussion and expanded discussion of this material, which had previously been spread among other parts of the book.

[1]Microsoft recommends installing and using the 32-bit version of Microsoft Office 2016, even on 64-bit versions of the Microsoft Windows operating system. We also recommend that you install and use the 32-bit version. The reason for this is that the 64-bit version of Microsoft Office 2016 does not have certain components (particularly ODBC drivers [discussed in Chapter 7]) needed to implement the Web sites discussed and illustrated in Chapter 7. While this omission by Microsoft makes no sense to us, there is nothing we can do about it, and so we will stick with the 32-bit version of Microsoft Office 2016. Hopefully Microsoft will eventually add the missing pieces to the 64-bit version!

THE NEED FOR ESSENTIAL CONCEPTS

With today's technology, it is impossible to utilize a DBMS successfully without first learning fundamental concepts. After years of developing databases with business users, we believe that the following database concepts are essential:

- Fundamentals of the relational model
- Structured Query Language (SQL)
- Data modeling
- Database design
- Database administration

And because of the increasing use of the Internet, the World Wide Web, commonly available analysis tools, and the emergence of the NoSQL movement, four more essential concepts need to be added to the list:

- Web database processing
- Data warehouse structures
- Business intelligence (BI) systems
- Nonrelational structured data storage (Big Data)

Users like Colin—and students who will perform jobs similar to his—need not learn these topics to the same depth as future information systems professionals. Consequently, this textbook presents only essential concepts—those that are necessary for users like Colin who want to create and use small databases. Many of the discussions in this book are rewritten and simplified explanations of topics that you will find fully discussed in David M. Kroenke and David J. Auer's *Database Processing: Fundamentals, Design, and Implementation*.[2] However, in creating the material for this text, we have endeavored to ensure that the discussions remain accurate and do not mislead. Nothing here will need to be unlearned if students take more advanced database courses.

TEACHING CONCEPTS INDEPENDENT OF DBMS PRODUCTS

This book does not assume that students will use any particular DBMS product. The book does illustrate database concepts with Microsoft Access, Microsoft SQL Server Developer edition, Oracle Database Express Edition (Oracle Database XE), and MySQL Community Server so that students can use these products as tools and actually try out the material, but all the concepts are presented in a DBMS-agnostic manner. When students learn the material this way, they come to understand that the fundamentals pertain to any database, from the smallest Microsoft Access database to the largest Microsoft SQL Server or Oracle Database database. Moreover, this approach avoids a common pitfall. When concepts and products are taught at the same time, students frequently confound concepts with product features and functions. For example, consider referential integrity constraints. When they are taught from a conceptual standpoint, students learn that there are times when the values of a column in one table must always be present as values of a column in a second table. Students also learn how this constraint arises in the context of relationship definition and how either the DBMS or the application must enforce this constraint. If taught in the context of a DBMS—say, in the context of Microsoft Access—students will only learn that in some cases you check a check box and in other cases you do not. The danger is that the underlying concept will be lost in the product feature.

[2]David M. Kroenke and David J. Auer, *Database Processing: Fundamentals, Design, and Implementation*, 14th ed. (Upper Saddle River, NJ: Pearson/Prentice Hall, 2016).

All this is not to say that a DBMS should not be used in this class. On the contrary, students can best master these concepts by applying them using a commercial DBMS product. This edition of the book was written to include enough basic information about Microsoft Access, SQL Server Express edition, Oracle Database Express Edition, and MySQL so that you can use these products in your class without the need for a second book or other materials. Microsoft Access is covered in some depth because of its popularity as a personal database and its inclusion in the Microsoft Office Professional suite of applications. However, if you want to cover a particular DBMS in depth or use a DBMS product not discussed in the book, you need to supplement this book with another text or additional materials. Pearson provides a number of books for Microsoft Access 2016 and other DBMS products, and many of them can be packaged with this text.

THE ACCESS WORKBENCH

This new edition of the text continues using "The Access Workbench," a feature first introduced in the third edition. Because Microsoft Access is widely used in introductory database classes, we feel it is important to include specific information on using Microsoft Access. Each chapter has an accompanying section of "The Access Workbench," which illustrates the chapter's concepts and techniques using Microsoft Access. "The Access Workbench" topics start with creating a database and a single table in Chapter 1 and move through various topics, finishing with Web database processing against a Microsoft Access database in Chapter 7 and using Microsoft Access (together with Microsoft Excel) to produce PivotTable OLAP reports in Chapter 8. This material is not intended to provide comprehensive coverage of Microsoft Access, but all the necessary basic Microsoft Access topics are covered so that your students can learn to effectively build and use Microsoft Access databases.

KEY TERMS, REVIEW QUESTIONS, EXERCISES, CASES, AND PROJECTS

Because it is important for students to apply the concepts they learn, each chapter concludes with sets of key terms, review questions, exercises (including exercises tied to "The Access Workbench"), Case Question sets, and three projects that run throughout the book. Students should know the meaning of each of the key terms and be able to answer the review questions if they have read and understood the chapter material. Each of the exercises requires students to apply the chapter concepts to a small problem or task.

The first of the projects, Garden Glory, concerns the development and use of a database for a partnership that provides gardening and yard maintenance services to individuals and organizations. The second project, James River Jewelry, addresses the need for a database to support a frequent-buyer program for a retail store. The third project, The Queen Anne Curiosity Shop, concerns the sales and inventory needs of a retail business. These three projects appear in all of the book's chapters (although the actual text of the James River Jewelry project is found in online Appendix D). In each instance, students are asked to apply the project concepts from the chapter. Instructors will find more information on the use of these projects in the instructor's manual and can obtain databases and data from the password-protected instructor's portion of this book's Web site (**www.pearsonhighered.com/kroenke**).

SOFTWARE USED IN THE BOOK

Just as we have treated our discussions in a DBMS-agnostic way, whenever possible, we have selected software to be as operating system independent as possible. It is amazing how much excellent software is available online. Many major DBMS vendors provide free versions of their premier products (for example, Microsoft's SQL Server Developer edition and Express edition, Oracle Corporation's Oracle Database Express Edition (Oracle Database XE), and MySQL Community Server). Web editors and integrated development

environments (IDEs) are also available (for example, Eclipse, NetBeans, and Visual Studio Express edition). PHP, considered the fourth most commonly used programming language, is downloadable for use with many operating systems and Web servers.

So although the examples in this book were created using a Microsoft operating system, SQL Server 2016 Developer edition, Microsoft Access 2016, Microsoft Excel 2016, and the IIS Web Server, most of them could just as easily be accomplished using Linux, MySQL Server Community edition, Apache OpenOffice Base, Apache OpenOffice Calc, and the Apache Web server. Some software products used in the book, such as PHP and NetBeans, are available for multiple operating systems.

Important Note: We are using the Microsoft Windows 10 operating system, and Microsoft recently released the Windows 10 Anniversary Update (Feature update to Windows 10, version 1607). As noted in Chapter 7's section of "The Access Workbench," in order to successfully complete all the work in this book, you need to be using the Windows 10 Anniversary Update version of Windows 10, patched with at least the Windows 10 Version 1607 update for August 23, 2016 (KB3176936), and the Windows 10 Version 1607 cumulative update for September 29, 2016 (KB3194496).

Over the past 30-plus years, we have found the development of databases and database applications to be an enjoyable and rewarding activity. We believe that the number, size, and importance of databases will increase in the future and that the field will achieve even greater prominence. It is our hope that the concepts, knowledge, and techniques presented in this book will help students to participate successfully in database projects now and for many years to come.

CHANGES FROM THE SEVENTH EDITION

The most significant changes in this edition are:

- The framing of database topic discussions within today's Internet and mobile applications based networked environment and economy. Today, databases are no longer isolated entities found somewhere in obscure server rooms, but rather are ubiquitous parts of Web sites and tablet and smart phone apps. We are literally dependent upon databases in our lives, whether exchanging email messages, posting to our Facebook pages, or shopping online.
- The revised discussion of Structured Query Lanaguage (SQL) in Chapter 3 and Appendix E, "Advanced SQL." Taken together, this material provides a better organized and easier to understand coverage of SQL topics previously included in the book, and also adds a set of new SQL topics into the mix.
- The revised coverage of the rapidly evolving use of *Big Data* and the associated *NoSQL movement*. The need to be able to store and process extremely large datasets is transforming the database world. Although these developments leave the database fundamentals covered in this book unchanged, they do require us to put the relational databases that are the core of this text into the context of the overall database picture and to provide the reader with an understanding of the nonrelational structured storage used in the Big Data environment. Therefore, Chapter 8 is now organized around the topic of Big Data, and the topics of data warehouses, clustered database servers, distributed databases, and an introduction to business intelligence (BI) systems find a natural home in that chapter. To provide additional coverage of Big Data, Appendix K, "Big Data," contains a more in-depth discussion than the page limitations of the book itself allow. For those wanting more coverage of BI than found in Chapter 8, Appendix J, "Business Intelligence Systems," contains a current and updated discussion of the topic in depth.
- The extension of coverage of Microsoft SQL Server 2016 Developer edition (Appendix A), Oracle Database XE (Appendix B), and MySQL 5.7 Community Server (Appendix C). Complete installation instructions are now included, as well as other new topics.

Finally, we have maintained the chapter-independent Case Question sets we added in the sixth edition. Although the chapter projects tie the topics in each chapter together, the case questions do not require the student to have completed work on the same case in a previous chapter or chapters. There is one intentional exception that spans Chapters 4 and 5 that ties data modeling and database design together, but each of these chapters also includes a standalone case. Although in some instances the same basic named case may be used in different chapters, each instance is still completely independent of any other instance, and we provide needed Microsoft Access 2016 database and SQL scripts at the text Web site at **www.pearsonhighered.com/kroenke**.

We have kept and improved upon several features introduced in earlier editions of the book:

- The use of "The Access Workbench" sections in each chapter to provide coverage of Microsoft Access fundamentals now includes Microsoft Access switchboards (Appendix H, "The Access Workbench—Section H—Microsoft Access 2016 Switchboards," available online).
- Introductions to the use of Microsoft SQL Server 2016 Developer edition (Appendix A, "Getting Started with Microsoft SQL Server 2016," available online), Oracle Database XE (Appendix B, "Getting Started with Oracle Database XE," available online) and Oracle MySQL 5.7 Community Server (Appendix C, "Getting Started with MySQL 5.7 Community Server," available online).
- The use of fully developed datasets for the three example databases that run throughout various portions of the book—Wedgewood Pacific, Heather Sweeney Designs, and Wallingford Motors.
- The use of the PHP scripting language, now used in the NetBeans IDE, in the Web database processing topics now includes code for Web page input forms.
- Coverage of the dimensional database model is maintained in the restructured Chapter 8, together with coverage of OLAP.
- In order to make room for this new material, we have had to move some valuable material previously found in the book itself to online appendices. This includes the James River Jewelry set of project questions, which is now in online Appendix D, "James River Jewelry Project Questions." The material on SQL views is now in online Appendix E, "Advanced SQL," with additional material on SQL Persistent Stored Modules (SQL/PSM). Discussions of how to import Microsoft Excel data into the DBMS products are now found in each related appendix— for Microsoft SQL Server 2016 Developer Edition, see online Appendix A, "Getting Started with Microsoft SQL Server 2016"; for Oracle Database XE, see online Appendix B, "Getting Started with Oracle Database XE"; and for MySQL 5.7 Community Server, see online Appendix C, "Getting Started with MySQL 5.7 Community Server."
- The business intelligence systems material on reporting systems and data mining is now in online Appendix J, "Business Intelligence Systems."

BOOK OVERVIEW

This textbook consists of 8 chapters and 11 appendices (all of which are readily available online at **www.pearsonhighered.com/kroenke**). Chapter 1 explains why databases are used, what their components are, and how they are developed. Students will learn the purpose of databases and their applications as well as how databases differ from and improve on lists in spreadsheets. Chapter 2 introduces the relational model and defines basic relational terminology. It also introduces the fundamental ideas that underlie normalization and describes the normalization process.

Chapter 3 presents fundamental SQL statements. Basic SQL statements for data definition are described, as are SQL SELECT and data modification statements. No attempt is made to present advanced SQL statements; only the essential statements are described.

Online Appendix E, "Advanced SQL," adds coverage of advanced SQL topics, such as the SQL ALTER TABLE statement, SQL set operators (UNION), SQL views, and SQL/Persistent Stored Modules (SQL/PSM).

The next two chapters consider database design. Chapter 4 addresses data modeling using the entity-relationship (E-R) model. This chapter describes the need for data modeling, introduces basic E-R terms and concepts, and presents a short case application (Heather Sweeney Designs) of E-R modeling. Chapter 5 describes database design and explains the essentials of normalization. The data model from the case example in Chapter 4 is transformed into a relational design in Chapter 5.

In this edition, we continue to use the prescriptive procedure for normalizing relations through the use of a four-step process. This approach not only makes the normalization task easier, it also makes normalization principles easier to understand. For instructors who want a bit more detail on normal forms, short definitions of most normal forms are included in Chapter 5.

The last three chapters consider database management and the uses of databases in applications. Chapter 6 provides an overview of database administration. The case example database is built as a functioning database, and it serves as the example for a discussion of the need for database administration. The chapter surveys concurrency control, security, and backup and recovery techniques. Database administration is an important topic because it applies to all databases, even personal, single-user databases. In fact, in some ways this topic is more important for those smaller databases because no professional database administrator is present to ensure that critical tasks are performed.

Chapter 7 introduces the use of Web-based database processing, including a discussion of Open Database Connectivity (ODBC) and the use of the PHP scripting language. It also discusses the emergence and basic concepts of Extensible Markup Language (XML), and introduces Java Script Object Notation (JSON).

Chapter 8 discusses the emerging world of Big Data and the NoSQL movement, including under this umbrella business intelligence (BI) systems and the data warehouse architectures that support them, which often involve Big Data and NoSQL concepts. Chapter 8 also provides a discussion of distributed databases, object-relational databases, virtualization, and cloud computing as they relate to the continuing evolution of NoSQL systems and Big Data. Many details of BI systems have been moved to online Appendix J, "Business Intelligence Systems." More specifically, Chapter 8 discusses dimensional databases as an example of a data warehouse architecture, walking through how to build a dimensional database for Heather Sweeney Designs and then using it to produce a PivotTable online analytical processing (OLAP) report as an example of BI reporting.

Appendix A provides an introduction to Microsoft SQL Server 2016 Developer Edition, Appendix B provides an introduction for Oracle Database XE, and Appendix C provides a similar introduction for MySQL 5.7 Community Server. Microsoft Access is covered in "The Access Workbench" sections included in each chapter. Appendix D contains the James River Jewelry project questions. Appendix E covers material on advanced SQL topics such as SQL views and SQL/PSM. Appendix F provides an introduction to systems analysis and design and can be used to provide context for Chapter 4 (data modeling) and Chapter 5 (database design)—although in this book we focus on databases, databases are used in applications. Appendix F describes the application development process in more detail. Appendix G is a short introduction to Microsoft Visio 2016, which can be used as a tool for data modeling (Chapter 4). A useful database design (Chapter 4) tool is the MySQL Workbench, and this use of the MySQL Workbench is discussed in Appendix C. Appendix H extends Chapter 5's section of "The Access Workbench" by providing coverage of Microsoft Access 2016 switchboards. Appendix I provides detailed support for Chapter 7 by giving detailed instructions on getting the Microsoft IIS Web server, PHP, and the NetBeans IDE up and running. Appendix J provides additional material on business intelligence (BI) systems to supplement and support Chapter 8 by giving details on report systems and data mining. Finally, Appendix K provides additional material on Big Data and NoSQL databases to also supplement and support Chapter 8.

KEEPING CURRENT IN A RAPIDLY CHANGING WORLD

In order to keep *Database Concepts* up to date between editions, we post updates on the book's Web site at **www.pearsonhighered.com/kroenke** as needed. Instructor resources and student materials are also available on the site, so be sure to check it from time to time.

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David M. Kroenke entered the computing profession as a summer intern at the RAND Corporation in 1967. Since then, his career has spanned education, industry, consulting, and publishing.

He has taught at the University of Washington, Colorado State University, and Seattle University. Over the years, he has led dozens of teaching seminars for college professors. In 1991 the International Association of Information Systems named him Computer Educator of the Year.

In industry, Kroenke has worked for the U.S. Air Force and Boeing Computer Services, and he was a principal in the startup of three companies. He was also vice president of product marketing and development for the Microrim Corporation and was chief technologist for the database division of Wall Data, Inc. He is the father of the semantic object data model. Kroenke's consulting clients include IBM Corporation, Microsoft, Computer Sciences Corporation, and numerous other companies and organizations.

His text *Database Processing: Fundamentals, Design, and Implementation*, first published in 1977, is now in its 14th edition (coauthored with David Auer for the 11th, 12th, 13th, and 14th editions). He introduced *Database Concepts* (now in the eighth edition that you are reading) in 2003. Kroenke has published many other textbooks, including the classic *Business Computer Systems* (1981). Recently, he has authored *Using MIS* (8th edition), *Experiencing MIS* (6th edition), *MIS Essentials* (4th edition), *Processes, Systems and Information: An Introduction to MIS* (2nd edition) (coauthored with Earl McKinney), and *Essentials of Processes, Systems and Information* (coauthored with Earl McKinney).

An avid sailor, Kroenke also wrote *Know Your Boat: The Guide to Everything That Makes Your Boat Work*. Kroenke lives in Seattle, Washington. He is married and has two children and three grandchildren.

David J. Auer is a Senior Instructor Emeritus at the College of Business (CBE) of Western Washington University in Bellingham, WA. He served as the director of Information Systems and Technology Services at CBE from 1994 to 2014 and taught in CBE's Department of Decision Sciences from 1981 to 2015. He has taught CBE courses in quantitative methods, production and operations management, statistics, finance, and management information systems. Besides managing CBE's computer, network, and other technology resources, he also teaches management information systems courses. He has taught the Principles of Management Information Systems and Business Database Development courses, and he was responsible for developing CBE's network infrastructure courses, including Computer Hardware and Operating Systems, Telecommunications, and Network Administration.

He has coauthored several MIS-related textbooks, including *Database Processing: Fundamentals, Design, and Implementation*, first published in 1977, is now in its 14th edition (coauthored with David Kroenke for the 11th, 12th, 13th, and 14th editions), and *Database Concepts*, now in the eighth edition that you are reading (coauthored with David Kroenke for the 3rd, 4th, 5th, 6th, and 7th editions, and coauthored with David Kroenke, Scott Vandenberg, and Robert Yoder for this 8th edition).

Auer holds a bachelor's degree in English literature from the University of Washington, a bachelor's degree in mathematics and economics from Western Washington University, a master's degree in economics from Western Washington University, and a master's degree in

counseling psychology from Western Washington University. He served as a commissioned officer in the U.S. Air Force, and he has also worked as an organizational development specialist and therapist for an employee assistance program (EAP).

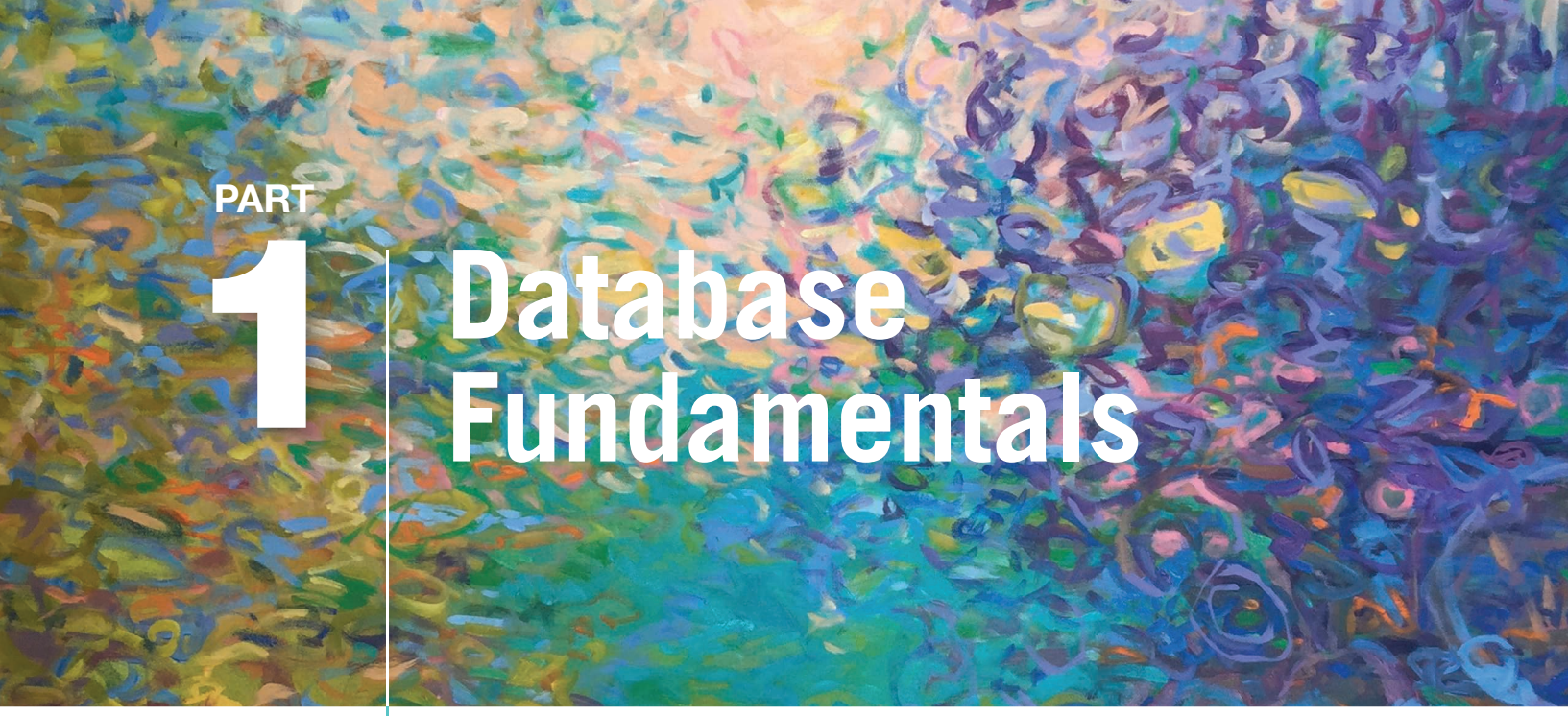
Auer and his wife, Donna, live in Bellingham, Washington. He has two children and four grandchildren.

Scott L. Vandenberg has been on the Computer Science faculty at Siena College since 1993, where he regularly teaches three different database courses at several levels to both computer science and business majors. Prior to arriving at Siena, he taught undergraduate and graduate courses in database systems at the University of Massachusetts–Amherst. Since arriving at Siena, he also taught graduate and undergraduate database courses at the University of Washington–Seattle. He has developed five different database courses over this time. His other teaching experience includes introductory computer science, introductory programming, data structures, management information systems, and three years teaching Siena's required interdisciplinary freshman writing course.

Vandenberg's recent research publications are mainly in the areas of computer science education and data science applications, with earlier work on query optimization and algebraic query languages. He holds a bachelor's degree in mathematics and computer science from Cornell University and master's and PhD degrees in computer science from the University of Wisconsin–Madison. Medieval history and playing hockey are two things that can tear him away from a database. Vandenberg lives in Averill Park, NY, with his wife, Kristin, and two children.

Robert C. Yoder began his professional career at the University at Albany as a systems programmer managing mainframes and Unix servers. He has two years of research experience working on 3-D solid modeling systems. Robert holds BS and MS degrees in computer science and a PhD in information science, all from the University at Albany.

Yoder joined the Computer Science department at Siena College in 2001 and teaches Business Database, Management Information Systems, Geographic Information Systems, Data Structures, Networks, and Operating Systems courses. Yoder lives in Niskayuna, NY, with his wife, Diane, and two children and enjoys traveling, hiking, and walking his dog.



PART 1

Database Fundamentals

Part 1 introduces fundamental concepts and techniques of relational database management. Chapter 1 explains database technology, discusses why databases are used, and describes the components of a database system. Chapter 2 introduces the relational model and defines key relational database terms. It also presents basic principles of relational database design. Chapter 3 presents Structured Query Language (SQL), an international standard for creating and processing relational databases.

After you have learned these fundamental database concepts, we will focus on database modeling, design, and implementation in Part 2. Finally, we will discuss database management, Web database applications, data warehouses, business intelligence (BI) systems, cloud computing, and Big Data in Part 3.

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CHAPTER 1

Getting Started

CHAPTER OBJECTIVES

- Understand the importance of databases in Internet Web applications and mobile apps
- Understand the nature and characteristics of databases
- Understand the potential problems with lists
- Understand the reasons for using a database
- Understand how using related tables helps you avoid the problems of using lists
- Know the components of a database system
- Learn the elements of a database
- Learn the purpose of a database management system (DBMS)
- Understand the functions of a database application
- Introduce Web database applications
- Introduce data warehouses and business intelligence (BI) systems
- Introduce Big Data and cloud computing

Knowledge of database technology increases in importance every day. Databases are used everywhere: They are key components of e-commerce and other Web-based applications. They lay at the heart of organization-wide operational and decision support applications. Databases are also used by thousands of work groups and millions of individuals. It is estimated that there are more than 10 million active databases in the world today.

The purpose of this book is to teach you the essential relational database concepts, technology, and techniques that you need to begin a career as a database developer. This book does not teach everything of importance in relational database technology, but it will give you sufficient background to be able to create your own personal databases and to participate as a member of a team in the development of larger, more complicated databases. You will also be able to ask the right questions to learn more on your own.

This chapter discusses the importance of databases in the Internet world and then introduces database processing concepts. We will investigate the reasons for using a relational database. We begin by describing some of the problems that can occur when using lists. Using a series of examples, we illustrate how using sets of related tables helps you to avoid those problems. Next, we describe the components of a database system and explain the elements of a database, the purpose of a database management system (DBMS), and the functions of a database application. Finally, we introduce nonrelational databases.

THE IMPORTANCE OF DATABASES IN THE INTERNET AND MOBILE APP WORLD

Let's stop for a moment and consider the incredible information technology available for our use today.

The **personal computer (PC)** became widely available with the introduction of the **Apple II** in 1977 and the **IBM Personal Computer (IBM PC)** in 1981. PCs were networked into **Local Area Networks (LANs)** using the **Ethernet networking technology**, which was developed at the Xerox Palo Alto Research Center in the early 1970s and adopted as a national standard in 1983.

The **Internet**—the global computer network of networks—was created as the **ARPANET** in 1969 and then grew and was used to connect all the LANs (and other types of networks). The Internet became widely known and used when the **World Wide Web** (also referred to as **the Web** and **WWW**) became easily accessible in 1993. Everyone got a computer software application called a **Web browser** and starting *browsing* **Web sites**. Online retail Web sites such as Amazon.com (online since 1995) and "brick-and-mortar" stores with an online presence such as Best Buy appeared, and people started extensively *shopping online*.

In the early 2000s, **Web 2.0**[1] Web sites started to appear—allowing users to add content to Web sites that had previously held static content. Web applications such as Facebook, Wikipedia, and Twitter appeared and flourished.

In a parallel development, the **mobile phone** or **cell phone** was demonstrated and developed for commercial use in the 1970s. After decades of mobile phone and cell phone network infrastructure development, the **smartphone** appeared. Apple brought out the **iPhone** in 2007. Google created the **Android operating system**, and the first Android-based smartphone entered the market in 2008. Eight years later, in 2016 (as this is being written), smartphones and **tablet computers** (**tablets**) are widely used, and thousands of application programs known as **apps** are widely available and in daily use. Most Web applications now have corresponding smartphone and tablet apps (you can "tweet" from either your computer or your smartphone)!

What many people do not understand is that in today's Web application and smartphone app environment, most of what they do depends upon databases.

We can define **data** as recorded facts and numbers. We can initially define a *database* (we will give a better definition later in this chapter) as the structure used to hold or store that data. We process that data to provide *information* (which we also define in more detail later in this chapter) for use in the Web applications and smartphone apps.

Do you have a Facebook account? If so, all your posts, your comments, your "likes," and other data you provide to Facebook (such as photos) are stored in a *database*. When your friend posts an item, it is initially stored in the *database* and then displayed to you.

Do you have a Twitter account? If so, all your tweets are stored in a *database*. When your friend tweets something, it is initially stored in the *database* and then displayed to you.

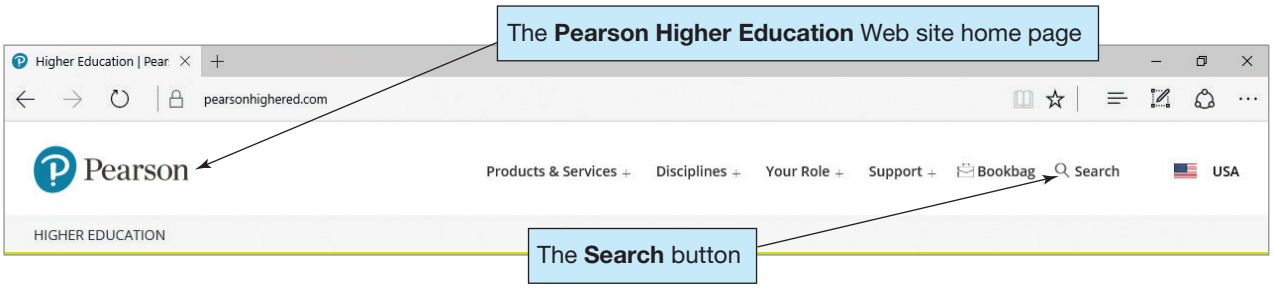
Do you shop at Amazon.com? If so, how do you find what you are looking for? You enter some words in a search text window on the Amazon home Web page (if you are using a Web browser) and click the Go button. Amazon's computers then search Amazon's *databases* and return a formatted report on-screen of the items that matched what you searched for.

The search process is illustrated in Figure 1-1, where we search the Pearson Higher Education Web site for books authored by *David Kroenke*. Figure 1-1(a) shows the upper portion of the Pearson Higher Education Web site home page. While many Web sites (including Amazon.com, REI, and Best Buy) have a text box for entering search key words on

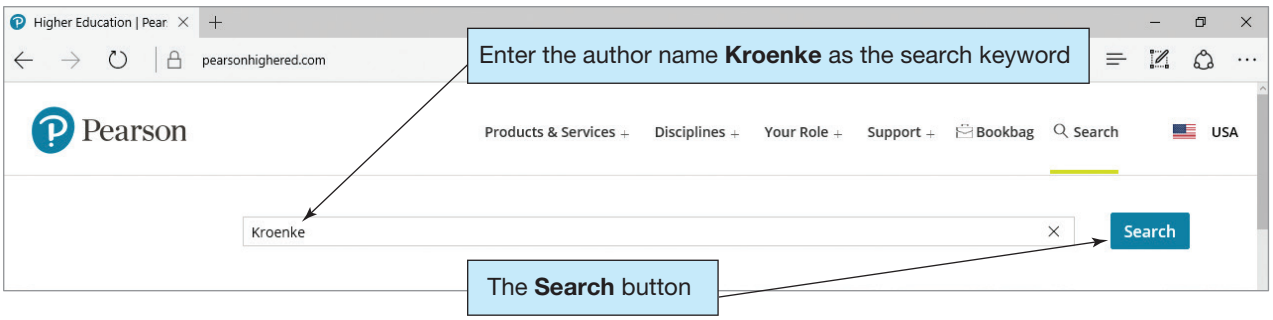
[1]Web 2.0 was originated by Darcy DiNucci in 1999 and introduced to the world at large in 2004 by publisher Tim O'Reilly. See the Wikipedia article **Web 2.0** (accessed May 2016) at https://en.wikipedia.org/wiki/Web_2.0.

FIGURE 1-1

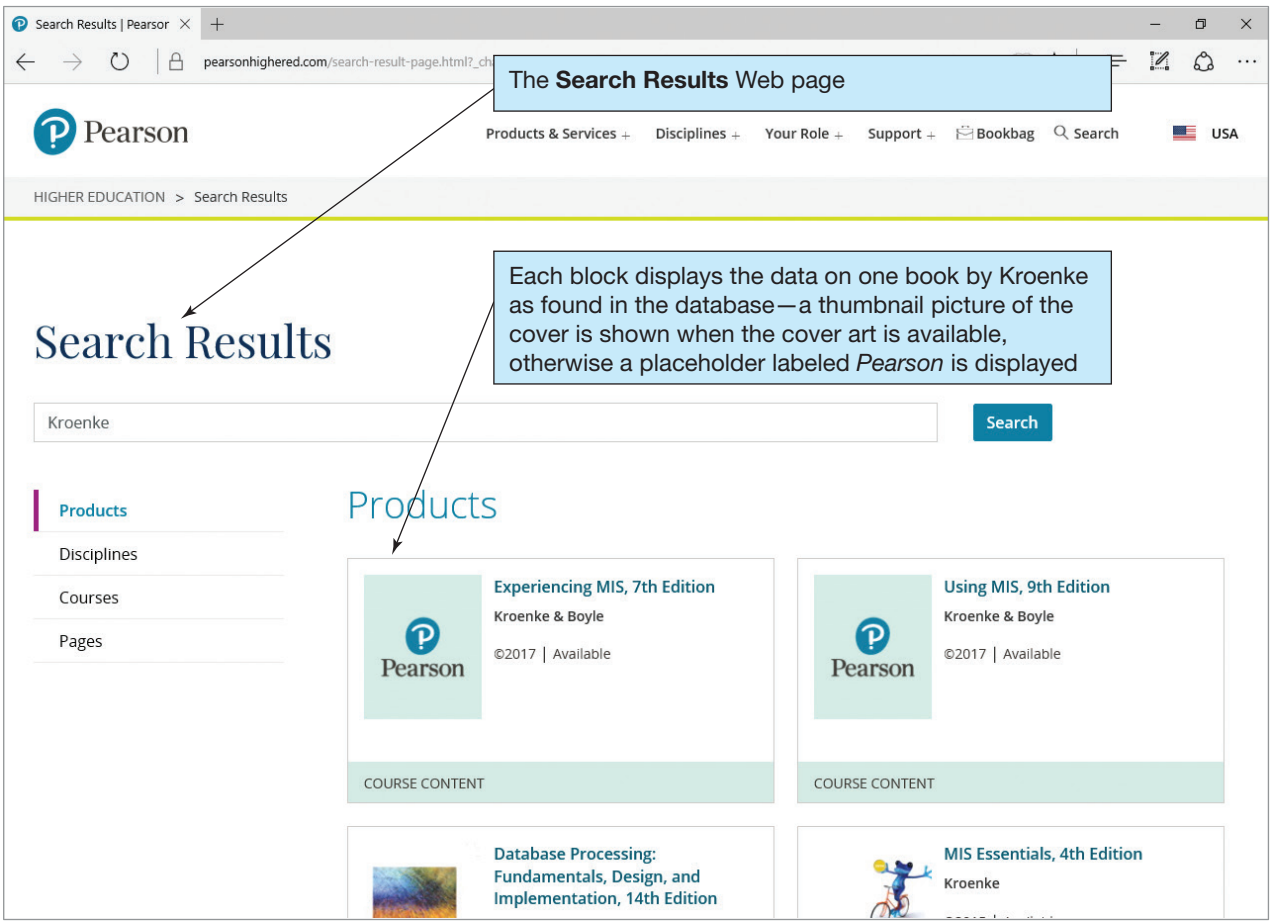
Searching a Database in a Web Browser



(a) The Pearson Higher Education Web Site Home Page



(b) Entering Author Name *Kroenke* as the Search Keyword



Pearson Education Inc, Microsoft Edge, Microsoft Corporation.

(c) Books by Author *Kroenke* Found in the Database

BTW

It is much more effective to see this process than to just read about it. Take a minute, open a Web browser, and go to Amazon.com (or any other online retailer, such as Best Buy, L.L.Bean, or REI). Search for something you are interested in, and watch the database search results be displayed for you. You just used a *database*.

BTW

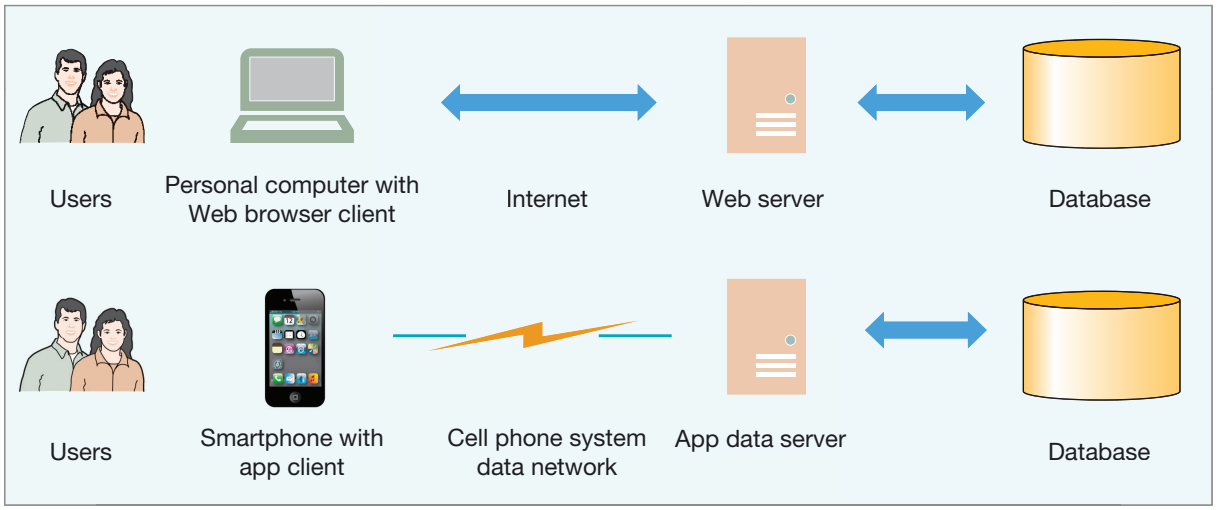
Even if you are simply shopping in a local grocery store (or a coffee shop or pizzeria), you are interacting with databases. Businesses use **Point of Sale (POS) systems** to record every purchase in a database, to monitor inventory, and, if you have a sales promotion card from the store (the one you use to get those special prices for "cardholders only"), to keep track of everything you buy for marketing purposes. All the data POS systems gather is stored in, of course, a *database*.

the home page itself for immediate use, at the Pearson site we have to click on a Search catalog button to access the search function on the *Advanced Catalog Search* page shown in Figure 1-1(b). On this page, we enter the author name *Kroenke* in the Author text box, and then click the Search button. The Pearson catalog database is searched, and the Web application returns a *Search Results* page containing a listing of books authored by David Kroenke, as shown in Figure 1-1(c).

The use of databases by Web applications and smartphone apps is illustrated in Figure 1-2. In this figure, people have computers (desktop or notebook) and smartphones, which are examples of **devices** used by people, who are referred to as *users*. On these

FIGURE 1-2

The Internet and Mobile Device World



devices are **client** applications (Web browsers, apps) used by people to obtain **services** such are searching, browsing, online purchasing, and tweeting over the Internet or cell phone networks. These services are provided by **server** computers, and these are the computers that hold the databases containing the data needed by the client applications.

This structure is known as **client-server architecture**, and it supports most of the Web applications in use today. The simple fact is that without databases, we could not have the ubiquitous Web applications and apps that are currently used by so many people.

WHY USE A DATABASE?

A database is used to help people keep track of things, and the most commonly used type of database is the *relational database*. We will discuss the relational database model in depth in Chapter 2, so for now we just need to understand a few basic facts about how a relational database helps people track things of interest to them.

You might wonder why we need a special term (and course) for such technology when a simple **list** could serve the same purpose. Many people do keep track of things by using lists, and sometimes such lists are valuable. In other cases, however, simple lists lead to data inconsistencies and other problems.

In this section, we examine several different lists and show some of these problems. As you will see, we can solve the problems by splitting lists into tables of data. Such tables are the key components of a database. A majority of this text concerns the design of such tables and techniques for manipulating the data they contain.

WHAT ARE THE PROBLEMS WITH USING LISTS?

Figure 1-3 shows a simple list of student data, named the Student List,[2] stored in a spreadsheet. The Student List is a very simple list, and for such a list a spreadsheet works quite well. Even if the list is long, you can sort it alphabetically by last name, first name, or email address to find any entry you want. You can change the data values, add data for a new student, or delete student data. With a list like the Student List in Figure 1-3, none of these actions is problematic, and a database is unnecessary. Keeping this list in a spreadsheet is just fine.

Suppose, however, we change the Student List by adding adviser data, as shown in Figure 1-4. You can still sort the new Student with Adviser List in a number of ways to find an entry, but making changes to this list causes **modification problems**. Suppose, for example, that you want to delete the data for the student Chip Marino. As shown in Figure 1-5, if you delete the eighth row (the row numbered 8—this is actually the seventh row of data because of the column headers, but it is easier to refer to the row number shown in the figure) you not only remove Chip Marino's data, you also remove the fact that

FIGURE 1-3

The Student List in a Spreadsheet

	A	B	C	D
1	SID	StudentLastName	StudentFirstName	StudentEmail
2	S0023	Andrews	Matthew	Matthew.Andrews@ourcampus.edu
3	S0065	Fischer	Douglas	Douglas.Fisher@ourcampus.edu
4	S0083	Hwang	Terry	Terry.Hwang@ourcampus.edu
5	S0132	Thompson	James	James.Thompson@ourcampus.edu
6	S0154	Brisbon	Lisa	Lis.Brisbon@ourcampus.edu
7	S0167	Lai	Tzu	Tzu.Lai@ourcampus.edu
8	S0212	Marino	Chip	Chip.Marino@ourcampus.edu

Excel 2016, Windows 10, Microsoft Corporation.

[2]In order to easily identify and reference the lists being discussed, we capitalize the first letter of each word in the list names in this chapter. Similarly, we capitalize the names of the database tables associated with the lists.

FIGURE 1-4

The Student with Adviser List

	A	B	C	D	E	F
1	SID	StudentLastName	StudentFirstName	StudentEmail	AdviserLastName	AdviserEmail
2	S0023	Andrews	Matthew	Matthew.Andrews@ourcampus.edu	Baker	Linda.Baker@ourcampus.edu
3	S0065	Fischer	Douglas	Douglas.Fisher@ourcampus.edu	Baker	Linda.Baker@ourcampus.edu
4	S0083	Hwang	Terry	Terry.Hwang@ourcampus.edu	Taing	Susan.Taing@ourcampus.edu
5	S0132	Thompson	James	James.Thompson@ourcampus.edu	Taing	Susan.Taing@ourcampus.edu
6	S0154	Brisbon	Lisa	Lis.Brisbon@ourcampus.edu	Valdez	Richard.Valdez@ourcampus.edu
7	S0167	Lai	Tzu	Tzu.Lai@ourcampus.edu	Valdez	Bill.Yeats@campus.edu
8	S0212	Marino	Chip	Chip.Marino@ourcampus.edu	Tran	Ken.Tran@ourcampus.edu

Excel 2016, Windows 10, Microsoft Corporation.

there is an adviser named Tran and that Professor Tran's email address is Ken.Tran@ourcampus.edu.

Similarly, updating a value in this list can have unintended consequences. If, for example, you change AdviserEmail in the fifth row, you will have inconsistent data. After the change, the fourth row indicates one email address for Professor Taing, and the fifth row indicates a different email address for the same professor. Or is it the same professor? From this list, we cannot tell if there is one Professor Taing with two inconsistent email addresses or whether there are two professors named Taing with different email addresses. By making this update, we add confusion and uncertainty to the list.

Finally, what do we do if we want to add data for a professor who has no advisees? For example, Professor George Green has no advisees, but we still want to record his email address. As shown in Figure 1-5, we must insert a row with incomplete values, called **null values**, in the database field. In this case, the term *null value* means a missing value, but there are other meanings of the term *null value* that are used when working with databases. We will discuss the problems of null values in detail in the next chapter, where we will show that null values are always problematic and that we want to avoid them whenever possible.

Now, what exactly happened in these two examples? We had a simple list with four columns, added two more columns to it, and thereby created several problems. The problem is not just that the list has six columns instead of four. Consider a different list that has six columns: the Student with Residence List shown in Figure 1-6. This list has five columns, yet it suffers from none of the problems of the Student with Adviser List in Figure 1-5.

In the Student with Residence List in Figure 1-6, we can delete the data for student Chip Marino and lose only data for that student. No unintended consequences occur. Similarly, we can change the value of Residence for student Tzu Lai without introducing any inconsistency. Finally, we can add data for student Garret Ingram and not have any null values.

FIGURE 1-5

Modification Problems in the Student with Adviser List

Changed row—inconsistent data

Deleted row—too much data lost

Inserted row—data missing

	A	B	C	D	E	F
1	SID	StudentLastName	StudentFirstName	StudentEmail	AdviserLastName	AdviserEmail
2	S0023	Andrews	Matthew	Matthew.Andrews@ourcampus.edu	Baker	Linda.Baker@ourcampus.edu
3	S0065	Fischer	Douglas	Douglas.Fisher@ourcampus.edu	Baker	Linda.Baker@ourcampus.edu
4	S0083	Hwang	Terry	Terry.Hwang@ourcampus.edu	Taing	Susan.Taing@ourcampus.edu
5	S0132	Thompson	James	James.Thompson@ourcampus.edu	Taing	Sue.Taing@ourcampus.edu
6	S0154	Brisbon	Lisa	Lis.Brisbon@ourcampus.edu	Valdez	Richard.Valdez@ourcampus.edu
7	S0167	Lai	Tzu	Tzu.Lai@ourcampus.edu	Valdez	Bill.Yeats@campus.edu
8	~~S0212~~	~~Marino~~	~~Chip~~	Chip.Marino@ourcampus.edu	~~Tran~~	Ken.Tran@ourcampus.edu
9	???	???	???	???	Green	George.Green@ourcampus.edu

Excel 2016, Windows 10, Microsoft Corporation.

FIGURE 1-6

The Student with Residence List

	A	B	C	D	E	F
1	SID	StudentLastName	StudentFirstName	StudentEmail	Phone	Residence
2	S0023	Andrews	Matthew	Matthew.Andrews@ourcampus.edu	301-555-2225	123 15th St Apt 21
3	S0065	Fischer	Douglas	Douglas.Fisher@ourcampus.edu	301-555-2257	McKinley Room 109
4	S0083	Hwang	Terry	Terry.Hwang@ourcampus.edu	301-555-2229	McKinley Room 208
5	S0132	Thompson	James	James.Thompson@ourcampus.edu	301-555-2245	345 17th St Apt 43
6	S0154	Brisbon	Lisa	Lis.Brisbon@ourcampus.edu	301-555-2241	Dorsett Room 201
7	S0167	Lai	Tzu	Tzu.Lai@ourcampus.edu	301-555-2231	McKinley Room 115
8	~~S0212~~	~~Marino~~	~~Chip~~	~~Chip.Marino@ourcampus.edu~~	~~301-555-2243~~	~~234 16th St Apt 32~~
9	S0213	Ingram	Garrett	Garret.Ingram@ourcampus.edu	301-555-2223	Dorsett Room 218

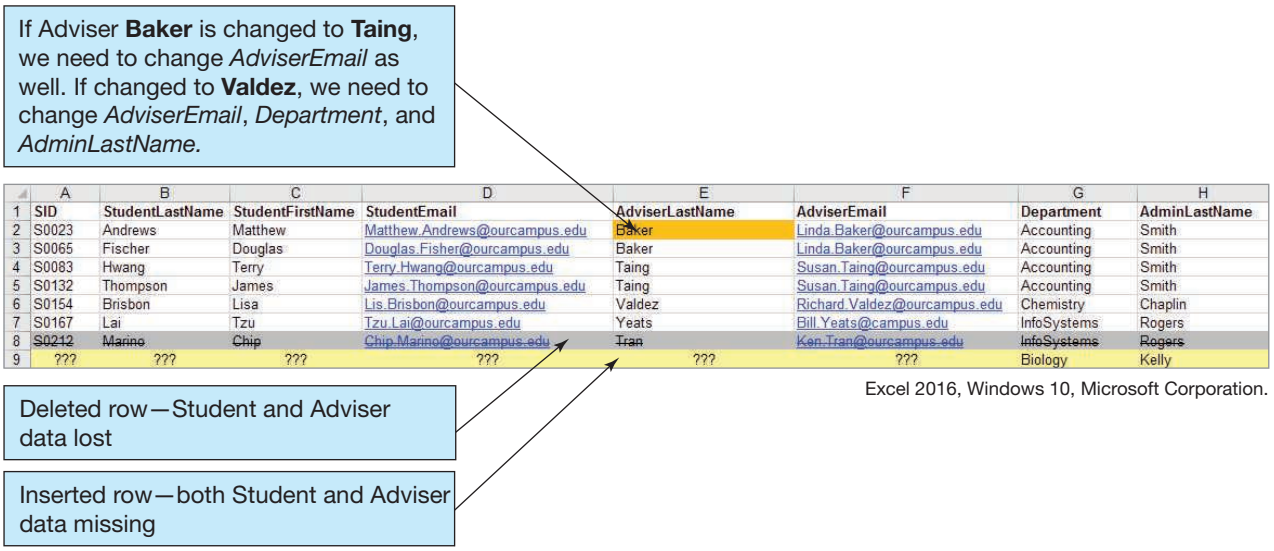
Excel 2016, Windows 10, Microsoft Corporation.

An essential difference exists between the Student with Adviser List in Figure 1-5 and the Student with Residence List in Figure 1-6. Looking at those two figures, can you determine the difference? The essential difference is that the Student with Residence List in Figure 1-6 is all about a *single thing*: All the data in that list concern *students.* In contrast, the Student with Adviser List in Figure 1-3 is about *two things*: Some of the data concern *students,* and some of the data concern *advisers.* In general, whenever a list has data about two or more different things, modification problems will result.

To reinforce this idea, examine the Student with Adviser and Department List in Figure 1-7. This list has data about three different things: *students*, *advisers*, and *departments.* As you can see in the figure, the problems with inserting, updating, and deleting data just get worse. A change in the value of AdviserLastName, for example, might necessitate a change in only AdviserEmail, or it might require a change in AdviserEmail, Department, and AdminLastName. As you can imagine, if this list is long—for example, if the list has thousands of rows—and if several people process it, the list will be a mess in a very short time.

FIGURE 1-7

The Student with Adviser and Department List



	A	B	C	D	E	F	G	H
1	SID	StudentLastName	StudentFirstName	StudentEmail	AdviserLastName	AdviserEmail	Department	AdminLastName
2	S0023	Andrews	Matthew	Matthew.Andrews@ourcampus.edu	Baker	Linda.Baker@ourcampus.edu	Accounting	Smith
3	S0065	Fischer	Douglas	Douglas.Fisher@ourcampus.edu	Baker	Linda.Baker@ourcampus.edu	Accounting	Smith
4	S0083	Hwang	Terry	Terry.Hwang@ourcampus.edu	Taing	Susan.Taing@ourcampus.edu	Accounting	Smith
5	S0132	Thompson	James	James.Thompson@ourcampus.edu	Taing	Susan.Taing@ourcampus.edu	Accounting	Smith
6	S0154	Brisbon	Lisa	Lis.Brisbon@ourcampus.edu	Valdez	Richard.Valdez@ourcampus.edu	Chemistry	Chaplin
7	S0167	Lai	Tzu	Tzu.Lai@ourcampus.edu	Yeats	Bill.Yeats@campus.edu	InfoSystems	Rogers
8	~~S0212~~	~~Marino~~	~~Chip~~	~~Chip.Marino@ourcampus.edu~~	~~Tran~~	~~Ken.Tran@ourcampus.edu~~	~~InfoSystems~~	~~Rogers~~
9	???	???	???	???	???	???	Biology	Kelly

Excel 2016, Windows 10, Microsoft Corporation.