David M. Kroenke • David J. Auer • Scott L. Vandenberg

DATABASE PROCESSING

FUNDAMENTALS, DESIGN, AND IMPLEMENTATION

SIXTEENTH EDITION

DATABASE PROCESSING
FUNDAMENTALS, DESIGN, AND IMPLEMENTATION

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Foreword to the 40th Anniversary Edition

Authors' Note: The "Foreword to the 40th Anniversary Edition" was originally written for inclusion in the 15th edition of *Database Processing*. We believe the topics covered here (including the history of the development of database systems, the story of the book itself, and the "lessons learned" during those processes) are important enough that we have retained it in this subsequent edition of the book.

David Kroenke

The publisher has asked me to write a short history of this text for this, the 40th anniversary edition. The details of each edition and how they changed are instructive, but this text and the discipline of database processing grew up together, and the story of how that happened might be more helpful to students who will work in disciplines, such as Big Data, that are emerging today.

We Didn't Know What We Were Doing

Database processing technology originated in the period 1970 to 1975, though not necessarily by that name. At the time, the U.S. government used the term *data bank*. Others used *data base* as well as *database*. I liked the latter and used it when I began work on this text in 1975.

In 1971, I was an officer in the U.S. Air Force, assigned to a Pentagon team that was building and using a simulation of World War III. It was the height of the Cold War, and the Department of Defense wanted a means to assess the efficacy of current and proposed weapons systems.

By a stroke of good luck, I was assigned to work on the data manager portion of that simulation. (The term *Database Management System [DBMS]* was not yet in use.) The logical data model of that data manager was similar to that of the set-based system that Bachmann had developed at General Electric (then a mainframe manufacturer) and that later became the CODASYL DBTG standard.[1]

Our simulation was slow and long-running; a typical run would take 10 to 12 hours. We were constrained more by input and output of data than by CPU time, and I developed low-level, re-entrant, assembly language routines for getting and putting data to and from main memory on parallel channels.

In addition to our project and Bachmann's, IBM was developing a manufacturing-oriented data manager in concert with North American Aviation. That project eventually became IBM's product IMS.[2] Another government project of that era resulted in the data manager named Total.

[1]CODASYL, the Committee on Data Systems Languages, was the committee, chaired by Grace Hopper (see *https://en.wikipedia.org/wiki/Grace_Hopper*), that developed the COBOL language standard. DBTG, the database task group, was a subcommittee tasked with developing a data modeling standard. The DBTG model was popular for a short while but was replaced by the relational model by the 1980s.

[2]IBM IMS is still a functional DBMS product—see *www.ibm.com/it-infrastructure/z/ims*.

In retrospect, I'd say the one thing we had in common was that none of us knew what we were doing. We didn't have any data models, best practices, or design principles. We didn't even know how to program. This was long before GoTo–less programming, which led to structured programming and eventually to object-oriented programming. We did know that life was easier if we developed some sort of a logic chart before we began, but that was about it. We'd pick up our coding pads (everything was done via punched cards) and start to work.

There were no debugging tools. When a job would fail, we'd receive a hexadecimal printout of the CPU registers and the contents of main memory. (The printout would be 12 to 18 inches thick.) There were no hexadecimal calculators, so we'd manually add and subtract hexadecimal numbers to navigate our way around the printout, sticking rulers in the listing as place markers. Stiff, wooden rulers were the best.

Again, though, we were just trying to solve a problem. We didn't have any idea that the technology we were developing would become an important part of the emerging world. Imagine Amazon or your college without database processing. But all of that was in the future. We were just trying to get the "darn thing" to run and somehow solve the particular problem that we'd been assigned.

For example, an important function of those early systems was to manage relationships. In our simulation, we had bombers and tankers and opposing radar sites and opposing air-to-air missiles. We needed to keep track of which of those was assigned or related to which. We just wrote programs to do that. A decade or two later someone discovered in surprise, "Hey, there's as much information in the relationships as there is in the data."

We made stuff up as we went along. The first edition of this text included no definition of *database*. When a reviewer pointed that out, I made one up for the second edition. "A self-describing collection of integrated records." Completely fabricated, but it's worked now for 35 years, so it must have been serviceable.

Situations like that were common in those early projects. We made stuff up that would help us solve our problem. Progress was slow, mistakes were frequent, failures were common. Millions of dollars and labor hours were wasted. But gradually, over time, database technology emerged.

Origin of This Text

In 1973 I completed my military commitment and following John Denver's song "Rocky Mountain High" moved my family from Washington, D.C., to Colorado State University. The business school hired me as an instructor while I attended graduate school in statistics and engineering across the street. To my delight, I was assigned to teach a course titled File Management, the predecessor of today's Database Processing course (see Figure FM-1).

As does any young instructor, I wanted to teach what I knew, and that was the rudiments of database processing. So, I began to formulate a database course, and by the spring of 1975, I was looking for a textbook. I asked the book reps if they had such a book, and none did. The sales rep for SRA, however, asked, "No, but we're looking for one. Why don't you write it?" My department chair, Bob Rademacher, encouraged me to do so, and on June 29, 1975, I signed the contract.

The draft and all the diagrams were written in number 2 pencil on the back of old coding sheets, as shown in Figure FM-2. The text would go to a typist, who'd do the best she could to decipher my writing. I'd proof the typing, and she'd produce another typed manuscript (long before word processing–pages had to be retyped to remove errors). Those pages would then go to a copy editor, and I would redo them again and send them back to the typist for a round or two. Eventually, the final typed manuscript would go to a compositor, who would produce long gray sheets (called galleys) of text to be proofed. After that, the text would be glued (I'm not kidding) to makeup pages, integrating the art that had been following a similar pathway, and then those pages would be photographed and sent to a printer.

The final draft of the first edition was completed in January 1976, and the text was published in January 1977. We were proud that it only took a year.

FIGURE FM-1

David Kroenke Loses Control of Students Excited by Database Technology

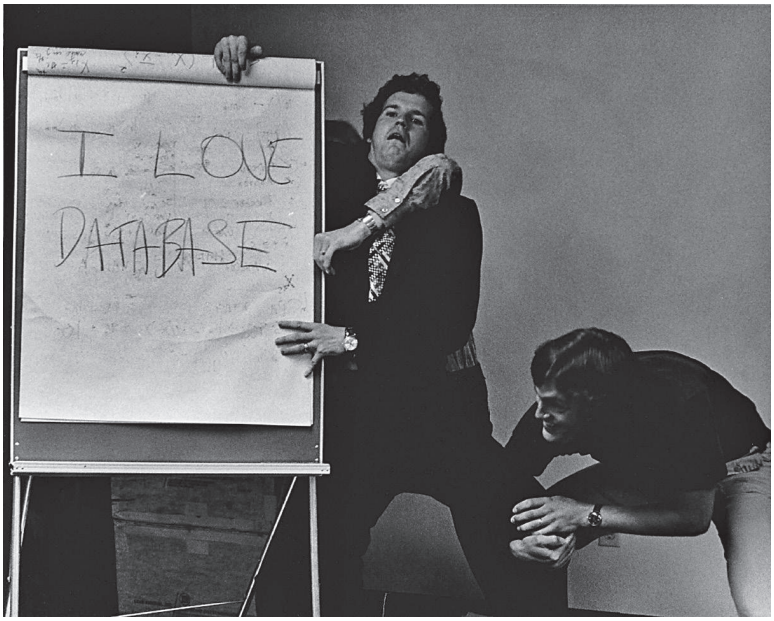
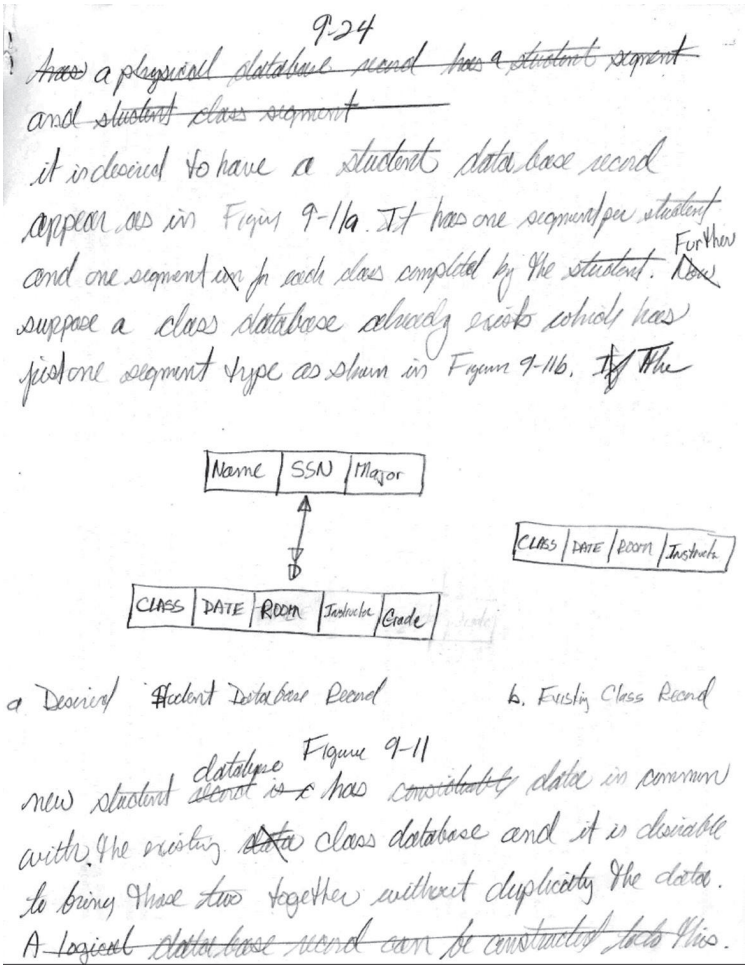


FIGURE FM-2

How Textbooks Were Written



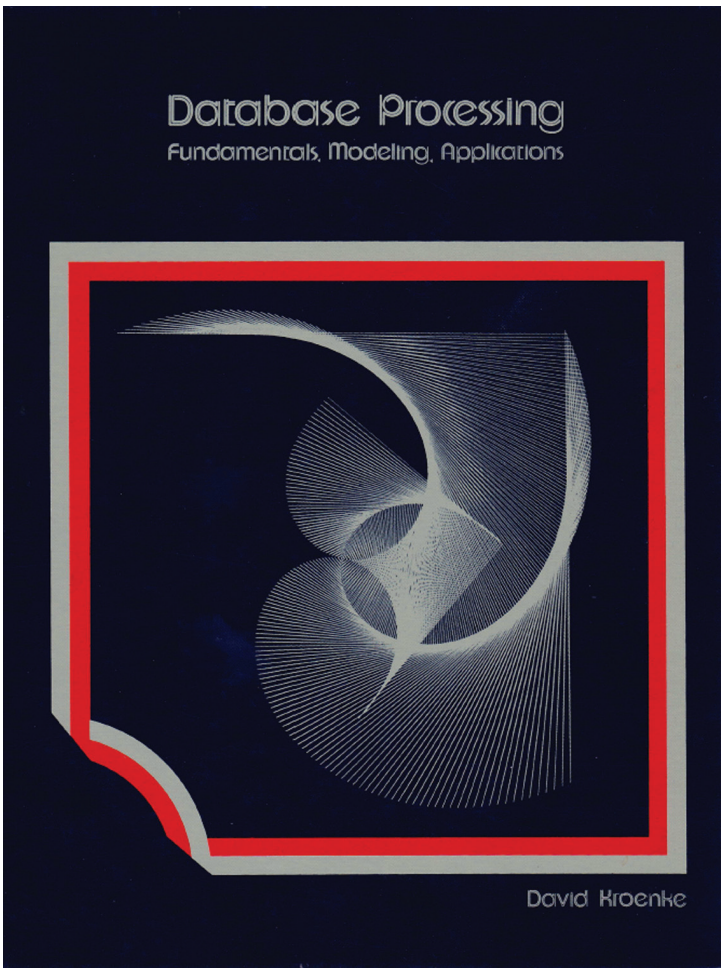
Contents of the First Edition

Database Processing was the first such textbook aimed at the information systems market. C. J. Date had produced *Database Systems* prior to this text, but his book was aimed at computer science students.[3] No one knew what should be in an information systems database book. I made it up, we sent drafts to reviewers, and they approved it. (They didn't know either.)

The first edition (see Figure FM-3) had chapters on file management and data structures. It also had chapters on hierarchical, network, and relational data models. By the way, E. F. Codd, the creator of the relational data model, was relatively unknown at that point, and he was happy to review the relational chapter. The text also featured a description of the features and functions of five DBMS products: ADABAS, System 2000, Total, IDMS, and IMS. (To my knowledge, only IMS is still in use today.) It wrapped up with a chapter on database administration.

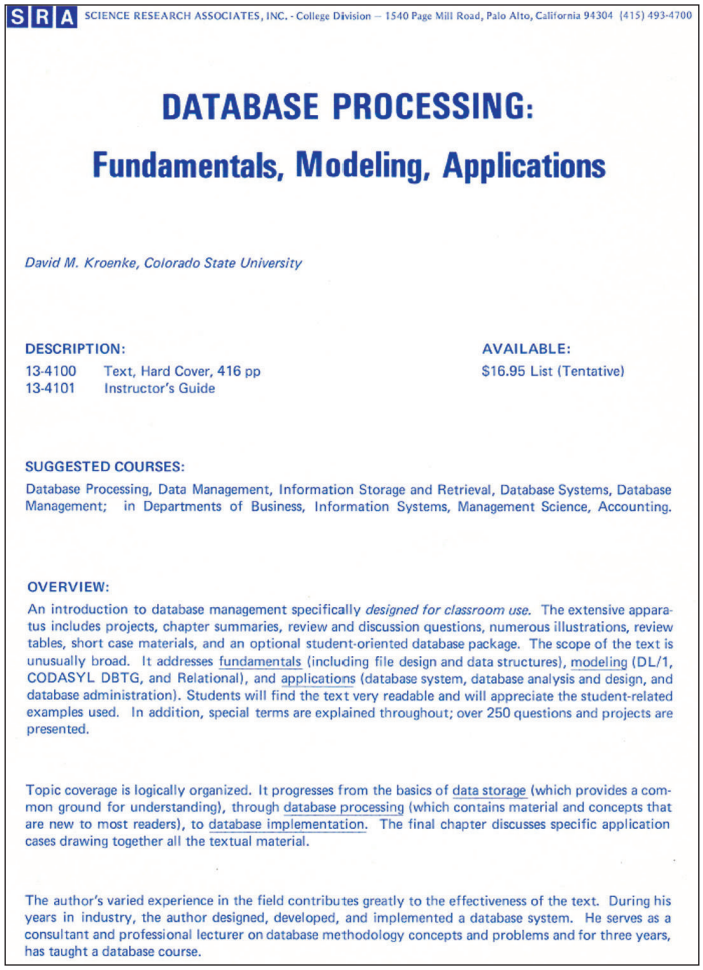
When writing that last chapter, I thought it would be a good idea to talk with an auditor to learn what auditors looked for when auditing database systems. Accordingly, I drove to Denver and met with one of the top auditors at one of the then-Big-Eight firms. I didn't learn much, just some high-level hyperbole about using commonly accepted auditing standards. The next day, the phone rang in my office and an executive in New York City invited me out

FIGURE FM-3
Cover of the First Edition of Database Processing



[3]C. J. Date's book *An Introduction to Database Systems* is currently in its eighth edition.

FIGURE FM-4
Hot Marketing Handout 1977—Note Text Price



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DATABASE PROCESSING:

Fundamentals, Modeling, Applications

David M. Kroenke, Colorado State University

DESCRIPTION:

13-4100 Text, Hard Cover, 416 pp
13-4101 Instructor's Guide

AVAILABLE:

$16.95 List (Tentative)

SUGGESTED COURSES:

Database Processing, Data Management, Information Storage and Retrieval, Database Systems, Database Management; in Departments of Business, Information Systems, Management Science, Accounting.

OVERVIEW:

An introduction to database management specifically *designed for classroom use.* The extensive apparatus includes projects, chapter summaries, review and discussion questions, numerous illustrations, review tables, short case materials, and an optional student-oriented database package. The scope of the text is unusually broad. It addresses fundamentals (including file design and data structures), modeling (DL/1, CODASYL DBTG, and Relational), and applications (database system, database analysis and design, and database administration). Students will find the text very readable and will appreciate the student-related examples used. In addition, special terms are explained throughout; over 250 questions and projects are presented.

Topic coverage is logically organized. It progresses from the basics of data storage (which provides a common ground for understanding), through database processing (which contains material and concepts that are new to most readers), to database implementation. The final chapter discusses specific application cases drawing together all the textual material.

The author's varied experience in the field contributes greatly to the effectiveness of the text. During his years in industry, the author designed, developed, and implemented a database system. He serves as a consultant and professional lecturer on database methodology concepts and problems and for three years, has taught a database course.

to that firm for a job interview for a position to develop and teach database auditing standards to their staff. None of us knew what we were doing!

I had no idea of how incredibly fortunate I was to stumble into a discipline that would become one of the most important in the information systems field, to have experience and knowledge to put into a text, to have a supportive department, and, finally, to have what was at that time a superb publisher with an outstanding sales and marketing team (see Figure FM-4). Because it was all I had known, I thought it was normal. Ah, youth.

Lessons Learned

At age 71, I'm not quite consigned to watching the daytime weather channel but have reached the stage when people start listing lessons learned. I'll try to keep it brief. Here are my five lessons learned, developed as both a database technology bystander and participant.

Don't Confuse Luck with Exceptional Ability

According to an independent study at the time, the second edition of this text had 91 percent of the market. It was the first, and it had a great publisher with a superb sales force. That success was due, truly, to lucky timing and good fortune. At that point I should have doubled down and made sure that the 91 percent were satisfied while sending Thanksgiving turkeys to the 9 percent not in the fold.

Instead, what did I do? Ignored the book and joined Microrim to help develop the R:Base products.[4] Five years later when I returned to the book, numerous competitors had emerged, and the book had lost half of its market. I'd thought I could jump back in and regain that early success, but the market had a hard lesson for me.

I mention this because I've seen it elsewhere as well. Microsoft was built and managed by superior business professionals like Bill Gates, Steve Ballmer, Jon Shirley, Steve Okey, and, in the database domain, David Kaplan. Between 1985 and 2000, hundreds of employees joined the firm and were issued stock options. They were largely competent professionals, but no different from the same level of professionals one would have found at 3M, Procter and Gamble, Boeing, and so on. The difference was that during that interval, their Microsoft stock split seven times.

Many of those competent professionals understood that they had been very, very lucky to get on the Microsoft bus when they did. They took their stock proceeds and reinvested in index funds or something else safe and have been enjoying life on the golf course with their families ever since. However, some of the just-competent professionals confused their good luck with exceptional personal ability and founded their own companies or started venture capital firms. Most lost their money. They were good, but they weren't of the same caliber as Gates et al.

Joseph Conrad said it: "It is the mark of an inexperienced man not to believe in luck."

Marketing Trumps Technology

If you have a chance to invest in an average technology with superb marketing or superb technology with average marketing, take the former. Marketing is far more important than technology.

IBM's IMS uses a hierarchical data model. Representing many-to-many relationships with hierarchies is a pain. With IMS the database developer is forced to write all sorts of design and coding machinations that should have been done by the DBMS or avoided by using a different DBMS. In the early days, I watched an IBM technical sales representative present those machinations as a skill that every good database developer must already have. "Surely you know how to do the XYZ?" (I don't remember the name they'd given that dance). Because none of us in the audience knew any better, we all assumed that we were deficient if we didn't know how to do the XYZ. The deficiency was in the product, not us, but we were duped by good marketing.

Developed by Wayne Ratcliff, Ashton-Tate's dBase[5] was the most successful relational microcomputer DBMS product until Microsoft entered the picture with Microsoft Access. In fact, dBase was neither a DBMS nor relational—it was a file management system. However, Ashton-Tate's marketing convinced Osborne to place a free copy of dBase on every one of its Osborne II computers. The Osborne II was the micro or personal computer (PC) of choice for a new cadre of application developers, and they wrote millions of lines of dBase code. They used what they had and thought it was fine. When better products came along, there was no way that any small developer was going to rewrite existing code or learn new products. The new graphical user interface in Microsoft Windows, the Microsoft Office package, and cheap Microsoft Access pricing was the only force strong enough to push Ashton-Tate off its leading position.

Salsa, a product that I helped Wall Data develop, implemented the semantic object model[6] and was selected as the runner-up to Netscape Navigator for product of the year in 1996. (The other runner-up was Internet Explorer.) Salsa failed—not because of the technology but because of the marketing. We tried to sell it as an end-user product, and it was a developer product. It was as if we'd invented Gore-Tex and we were out trying to sell it to people standing in the rain. We should have sold it to the clothing manufacturers. Marketing 101. I still have nightmares about the superior technology that washed down that drain.

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[4]For more information on R:Base, see the Wikipedia article R:Base at *https://en.wikipedia.org/wiki/R:Base* (accessed October 2020). Now called RBASE, this is still a functional DBMS product—see *www.rbase.com* (accessed October 2020).

[5]dBase is still a functional DBMS product—see *www.dbase.com* (accessed October 2020).

[6]The **semantic object model** is a data modeling methodology created by David M. Kroenke that is similar to the E-R model discussed in Chapters 5 and 6. We have included it in Database Processing through the fifteenth edition, but have dropped a discussion of it from this edition because it is not widely used.

Christensen's Model Informs

I don't know anyone who made substantial money in mainframes that did well in the microcomputer industry. Accustomed to the features and power of mainframes, we viewed microcomputers as toys. We termed the TRS-80 micro the Trash-80. I bought an early Apple, and it crashed on me, and I thought to myself, "This will never amount to anything."

This phenomenon is addressed by Clayton Christensen is his disruptive innovation model.[7] His thesis is that when a disruptive technology comes along, companies that have success in the disrupted technology are unable to capitalize on the opportunities of the new technology. Kodak could not adapt to digital photography; Swiss watch makers could not adapt to digital watches. Textbook publishers could not adapt to book rentals and used books sales by Amazon. Microsoft lost its way when it achieved its goal of "A computer on every desk and in every home." It struggled to adapt to the Internet.

Don't look for the market leaders in Big Data or robotics to come from existing, large vendors. They will come from smaller companies that can position themselves to thrive in the new environment. If you haven't learned Christensen's model, you should.

Good-Enough Fashion Will Do

For the most part, the relational model supplanted all the other data models. Because of Codd's insights on the use of functional dependencies for relational design, it provided sound design principles. Also, fixed-length records (as, in practice, they were at first) fit nicely with existing file management capabilities. It worked. Thousands of papers were written on the topic.

However, today's technology readily supports the storage and searching of multiple fields in un-normalized documents. In 1980, technology constraints required designers to take a document like a sales order and break it up into its pieces: Invoice, Salesperson, Customer, Line-item, Product. They would then store those pieces and then put them all back together with Structured Query Language (SQL) when someone wanted the original sales order. That makes no sense today. It's like driving your car into a parking garage and having staff pull off your front tires and put them in the pile of front tires, your steering wheel into a pile of steering wheels, and so on, and then, when you come back, put it all back together. Even though it's unnecessary, it's happening right now in zillions of data centers.

So why is the relational model still in use? Because it's good enough and still in fashion.

Fashion is important. Consider normalization theory. Codd's first paper addressed normalization through third normal form. However, in later papers, he and others showed that this wasn't enough. Relations in third normal form still had anomalies, which led to fourth and fifth and then Boyce-Codd (BCNF) Normal Forms. Despite this, one still hears people talk about third normal form as the be-all, end-all of relational design. Third normal form is good enough and still in fashion. It was as if progress stopped at third normal form (not in this text, though, where all of these forms are taught).

I suspect that someday soon, the whole relational mess will no longer be good enough and we'll move to XML or JSON or some other form of document storage (as we discuss in Chapter 13 and Appendix H). I've been saying that for 10 years, though, and it hasn't happened yet.

Another example of good enough and fashion is the entity-relationship (E-R) model. The E-R model is nothing more than a thin cover over the relational model. Entities are essentially logical relations, and relationships are a slim version of foreign keys. E-R operates at too low a level of abstraction. Other models like the semantic object model and other object-oriented models are better. None succeeded. The E-R model was in fashion and good enough.

[7] Christensen, Clayton M. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Reprint edition) (Brighton, MA: Harvard Business Review Press, 2016).

When It's Over, It's Over

By the turn of the century, I'd been writing and revising this text for 25 years. Although I was exceedingly grateful to the thousands of professors and students who had used this book over those years, I also knew I was done. Partly, I said to myself, because it had settled down, the early crazy days were long gone, and partly because 25 years is a long time to work on a textbook.

To my great good fortune, I found David Auer, who agreed to take over the revisions of this text. I am most grateful to David for his hard work and for his fidelity to the underlying goals and philosophy of this text. The rest of this story is his.

David Auer

I was introduced to David Kroenke while working on the Instructor's Manual for the ninth edition of *Database Processing*. Because we were both living and teaching in western Washington State, we could get together for meals and discussions. This led to my working on the companion textbook, *Database Concepts*, being a technical reader for the 10th edition of *Database Processing*, and then being asked to become a coauthor for the 11th edition of *Database Processing*.

I am very fortunate to be able to work with David on these projects. If you have read his portion of this foreword, you will have gotten a brief glimpse into the mind of a very creative and articulate person. He was also in the right place at the right time to be part of the creation of the computer-driven world that we live in and work in today. He has made many important contributions over his career, and the book you are reading is certainly one of them—the first textbook on database systems for management information systems classes and still one of the leading textbooks in the field!

David constantly revised and expanded *Database Processing* as new topics became relevant. My main contributions to the 11th and following editions were making MySQL a DBMS discussed on the same level as Microsoft SQL Server and Oracle Database; formalizing the treatment of Web database applications; and introducing new current topics such as non-relational databases, Big Data, and cloud computing. I have also revised and updated our treatment of Structured Query Language while maintaining the practical and "immediately usable on your own computer" presentation that has always been a hallmark of this book.

The main challenge now is to keep the book current with the changing technology and techniques in our app-driven, Internet, and cloud computing world of today, where databases are used ubiquitously to support applications such as Facebook, Twitter, and Instagram. To this end, we have brought two new coauthors on board for this edition: Scott Vandenberg and Robert Yoder, who are researching and teaching these topics.

Although this 15th edition of *Database Processing* marks the 40th anniversary of the book, we look forward to providing you with many more years of current, accurate, and usable knowledge about the world of databases and how they are used.

Preface

The 16th edition of *Database Processing: Fundamentals, Design, and Implementation* refines the organization and content of this classic textbook to reflect a new teaching and professional workplace environment. Students and other readers of this book will benefit from new content and features in this edition.

New to This Edition

Content and features new to the 16th edition of *Database Processing: Fundamentals, Design, and Implementation* include the following:

- The book has been reorganized to reintegrate material previously pushed into the appendices. Chapter 12 has been split into two chapters. Chapter 12 now covers only data warehouse and business intelligence systems and integrates material previously covered in Appendix J ("Business Intelligence Systems"). This brings important topics such as data mining into the main text, and expands the coverage of reporting systems (including RFM reporting), and includes specific, extended examples of Market Basket Analysis and Decision Trees. Chapter 13 covers Big Data, NoSQL (non-relational DBMSs), and cloud computing, which integrates material previously found in Appendix K ("Big Data"). This includes coverage of the CAP theorem, more detailed and specific examples of data using all four varieties of NoSQL DBMS (key-value, graph, document, and column), and an extensive hands-on introduction to creating both relational and document data using the Microsoft Azure cloud platform. In addition, a new online Chapter 10D is dedicated to the non-relational ArangoDB DBMS, which was previously covered in Appendix L ("JSON and Document Databases"). By creating Chapter 10D, we are acknowledging the importance of non-relational DBMSs in today's mobile and app-driven world and getting them the prominence they deserve. This new chapter, in addition to introducing ArangoDB, can stand alone as an introduction to document database concepts, design, and querying: it goes beyond just describing a DBMS and necessarily includes introductory content similar to the relational content in the rest of book so that the specifics of ArangoDB can be put into context.
- Chapter 9 now includes a brief section on physical database design (expanded on in Appendix F) as well as specific examples of GRANT and REVOKE commands.
- The book has been updated to reflect the use of Microsoft SQL Server 2019, the current version of Microsoft SQL Server. Microsoft has made SQL Server Developer Edition (a one-user version of SQL Server Enterprise Edition) available for download at no cost, and therefore we use this Developer Edition instead of the Express Edition as the basis for our work with SQL Server in the book. Although most of the topics covered are backward compatible with Microsoft SQL Server 2016 and earlier versions, all material in the book now uses SQL Server 2019 in conjunction with Microsoft Office 2019 exclusively.
- Oracle's Oracle Database is now updated to use Oracle Database 18c Express Edition (Oracle Database XE) as the preferred Oracle Database product for use on personal computers (whether in the classroom or at home) and as our standard version of Oracle Database in this book. All important Oracle Database techniques can

now be covered using Oracle Database XE with the Oracle SQL Developer GUI, and Oracle recommends Oracle Database XE for instructional purposes. Specific examples of Oracle Database backup and recovery have been added. All of our discussion and examples will also apply to the current version of Oracle Database Enterprise Edition, Oracle Database 19c, if your class is using it.

- Online Chapter 10C, "Managing Databases with MySQL," has been streamlined and updated to MySQL 8.0.
- Microsoft Windows 10 is the sole operating system generally discussed and illustrated in the text. We are not using Microsoft Windows Server 2019 for any of our systems, which means that everything in the book is compatible with and can be replicated on computers running the Microsoft Windows 10 OS.
- We have updated online Appendix G, "Getting Started with Web Servers, PHP, and the NetBeans IDE" to cover current versions of the software. We are now using the NetBeans IDE instead of the Eclipse PDT IDE. This provides a better development environment with a much simpler set of product installations because the Java JDK and NetBeans are installed in one combined installation. This new material provides a simplified (but still detailed) introduction to the installation and use of the Microsoft IIS Web server, PHP, the Java JDK, and the NetBeans in Appendix G. All of these tools are then used for Web database-application development as discussed in Chapter 11.

BY THE WAY With the 16th edition of Database Processing, we say a fond farewell to our coverage of the semantic object model (SOM). David Kroenke is the creator of the semantic object model, and we have included a discussion of it since he created it. Unfortunately, as David himself writes in the "Foreword to the 40th Anniversary Edition," "marketing trumps technology," and the SOM never caught on in the industry. The extended E-R model became and remains the standard database modeling methodology. Farewell, old friend!

Fundamentals, Design, and Implementation

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 have developed what we believe to be a set of essential database concepts. These are augmented by the concepts necessitated by the increasing use of the Internet, the World Wide Web, and commonly available analysis tools. Thus, the organization and topic selection of the 16th edition are designed to:

- Present an early introduction to SQL queries.
- Use a "spiral approach" to database design.
- Use a consistent, generic Information Engineering (IE) Crow's Foot E-R diagram notation for data modeling and database design.
- Provide a detailed discussion of specific normal forms within a discussion of normalization that focuses on pragmatic normalization techniques.
- Use current DBMS technology: Microsoft Access 2019, Microsoft SQL Server 2019, Oracle Database Express Edition 18c, MySQL 8.0, and ArangoDB 3.7.
- Create Web database applications based on widely used Web development technology.
- Provide an introduction to business intelligence (BI) systems.

- Discuss the dimensional database concepts used in database designs for data warehouses and online analytical processing (OLAP).
- Discuss the emerging and important topics of server virtualization, cloud computing, Big Data, and the NoSQL (Not only SQL) movement.

These changes have been made because it has become obvious that the basic structure of the earlier editions (up to and including the 9th edition–the 10th edition introduced many of the changes we used in the 11th through 15th editions and retain in the 16th edition) was designed for a teaching environment that no longer exists. The structural changes to the book were made for several reasons:

- Unlike the early years of database processing, today's students have ready access to data modeling and DBMS products.
- Today's students are too impatient to start a class with lengthy conceptual discussions on data modeling and database design. They want to do something, see a result, and obtain feedback.
- In the current economy, students need to reassure themselves that they are learning marketable skills.

Early Introduction of SQL DML

Given these changes in the classroom environment, this book provides an early introduction to SQL data manipulation language (DML) SELECT statements. The discussion of SQL data definition language (DDL) and additional DML statements occurs in Chapters 7 and 8. By encountering SQL SELECT statements in Chapter 2, students learn early in the class how to query data and obtain results, seeing firsthand some of the ways that database technology will be useful to them.

The text assumes that students will work through the SQL statements and examples with a DBMS product. This is practical today because nearly every student has access to Microsoft Access. Therefore, Chapters 1 and 2 and Appendix A ("Getting Started with Microsoft Access 2019") are written to support an early introduction of Microsoft Access 2019 and the use of Microsoft Access 2019 for SQL queries. (Microsoft Access 2019 QBE query techniques are also covered.)

If a non-Microsoft Access-based approach is desired, versions of Microsoft SQL Server 2019, Oracle Database, and MySQL 8.0 are readily available for use. Free versions of the three major enterprise DBMS products covered in this book (SQL Server 2019 Developer Edition; Oracle Database Express Edition 18c [Oracle Database XE], and MySQL 8.0 Community Edition) are available for download. Thus, students can actively use a DBMS product by the end of the first week of class.

BY THE WAY The presentation and discussion of SQL are spread over four chapters so students can learn about this important topic in small bites. SQL SELECT statements are taught in Chapter 2. SQL data definition language (DDL) and SQL data manipulation language (DML) statements are presented in Chapter 7. Correlated subqueries and EXISTS/NOT EXISTS statements are described in Chapter 8, and SQL transaction control language (TCL) and SQL data control language (DCL) are discussed in Chapter 9. Each topic appears in the context of accomplishing practical tasks. Correlated subqueries, for example, are used to verify functional dependency assumptions, a necessary task for database redesign.

This box illustrates another feature used in this book: BY THE WAY boxes are used to separate comments from the text discussion. Sometimes they present ancillary material; other times they reinforce important concepts.

A Spiral Approach to the Database Design Process

Today, databases arise from three sources: (1) from the need to integrate existing data from spreadsheets, data files, and database extracts; (2) from the need to develop new information systems projects; and (3) from the need to redesign an existing database to adapt to changing requirements. We believe that the fact that these three sources exist presents instructors with a significant pedagogical opportunity. Rather than teach database design just once from data models, why not teach database design three times, once for each of these sources? In practice, this idea has turned out to be even more successful than expected.

Database Design Iteration 1: Databases from Existing Data

Considering the design of databases from existing data, if someone were to email us a set of tables and say, "Create a database from them," how would we proceed? We would examine the tables in light of normalization criteria and then determine whether the new database was for a production system that allows new data to be inserted for each new transaction or for a business intelligence (BI) data warehouse that allow users to only query data for use in reports and data analysis. Depending on the answer, we would normalize the data, pulling them apart (for the production transaction processing system), or denormalize the data, joining them together (for the BI system data warehouse). All of this is important for students to know and understand.

Therefore, the first iteration of database design gives instructors a rich opportunity to teach normalization not as a set of theoretical concepts but rather as a useful toolkit for making design decisions for databases created from existing data. Additionally, the construction of databases from existing data is an increasingly common task that is often assigned to junior staff members. Learning how to apply normalization to the design of databases from existing data not only provides an interesting way of teaching normalization, it is also common and useful!

We prefer to teach and use a pragmatic approach to normalization and present this approach in Chapter 3. However, we are aware that many instructors like to teach normalization in the context of a step-by-step normal form presentation (1NF, 2NF, 3NF, then BCNF), and Chapter 3 now includes additional material to provide more support for this approach as well.

In today's workplace, large organizations are increasingly licensing standardized software from vendors such as SAP, Oracle, and Siebel. Such software already has a database design component. But with every organization running the same software, many are learning that they can gain a competitive advantage only if they make better use of the data in those predesigned databases. Hence, students who know how to extract data and create read-only databases for reporting and data mining have obtained marketable skills in the world of ERP and other packaged software solutions.

Database Design Iteration 2: Data Modeling and Database Design

The second source of databases is from new systems development. Although not as common as in the past, many databases are still created from scratch. Thus, students still need to learn data modeling, and they still need to learn how to transform data models into database designs that are then implemented in a DBMS product.

The IE Crow's Foot Model as a Design Standard

This edition uses a generic, standard IE Crow's Foot notation. Your students should have no trouble understanding the symbols and using the data modeling or database design tool of your choice.

IDEF1X (which was used as the preferred E-R diagram notation in the ninth edition of this text) is explained in Appendix C, "E-R Diagrams and the IDEF1X and UML Standards," in case your students will graduate into an environment where it is used or if you prefer to use it in your classes. UML is also explained in this appendix in case you prefer to use UML in your classes.

BY THE WAY

The choice of a data modeling tool is somewhat problematic. Of the two most readily available tools, Microsoft Visio 2019 has been rewritten as a very rudimentary database design tool, whereas Oracle's MySQL Workbench is a database design tool, not a data modeling tool. MySQL Workbench cannot produce an N:M relationship as such (as a data model requires) but has to immediately break it into two 1:N relationships (as database design does). Therefore, the intersection table must be constructed and modeled. This confounds data modeling with database design in just the way that we are attempting to teach students to avoid.

To be fair to Microsoft Visio 2019, it is true that data models with N:M relationships can be drawn using the standard Microsoft Visio 2019 drawing tools. Unfortunately, Microsoft has chosen to remove many of the best database design tools that were in Microsoft Visio 2010, and Microsoft Visio 2019 lacks the tools that made it a favorite of Microsoft Access and Microsoft SQL Server users. For a full discussion of these tools, see Appendix D, "Getting Started with Microsoft Visio 2019," and Appendix E, "Getting Started with the MySQL Workbench Data Modeling Tools."

Good data modeling tools are available, but they tend to be more complex and expensive. Two examples are Visible Systems' Visible Analyst and erwin Inc.'s erwin Data Modeler. Visible Analyst is available in a student edition (at a modest price), and a free trial period is available for erwin Data Modeler. ER-Assistant is a free and simple program that uses the same notation as in this book.

Database Design from E-R Data Models

As we discuss in Chapter 6, designing a database from data models consists of three tasks: representing entities and attributes with tables and columns; representing maximum cardinality by creating and placing foreign keys; and representing minimum cardinality via constraints, triggers, and application logic.

The first two tasks are straightforward. However, designs for minimum cardinality are more difficult. Required parents are easily enforced using NOT NULL foreign keys and referential integrity constraints. Required children are more problematic. In this book, however, we simplify the discussion of this topic by limiting the use of referential integrity actions and by supplementing those actions with design documentation. See the discussion around Figure 6-29.

Although the design for required children is complicated, it is important for students to learn. It also provides a reason for students to learn about triggers as well. In any case, the discussion of these topics is much simpler than it was in prior editions because of the use of the IE Crow's Foot model and ancillary design documentation.

Database Implementation from Database Designs

Of course, to complete the process, a database design must be implemented in a DBMS product. This is discussed in Chapter 7, where we introduce SQL DDL for creating tables and SQL DML for populating the tables with data.

Database Design Iteration 3: Database Redesign

Database redesign, the third iteration of database design, is both common and difficult. As stated in Chapter 8, information systems cause organizational change. New information systems give users new behaviors, and as users behave in new ways, they require changes in their information systems.

Database redesign is, by nature, complex. Depending on your students, you may wish to skip it, and you can do so without loss of continuity. Database redesign is presented after the discussion of SQL DDL and DML in Chapter 7 because it requires the use of advanced SQL. It also provides a practical reason to teach correlated subqueries and EXISTS/NOT EXISTS statements.

Active Use of a DBMS Product

We assume that students will actively use a DBMS product. The only real question becomes "Which one?" Realistically, for relational databases most of us have at least four common alternatives to consider: Microsoft Access, Microsoft SQL Server, Oracle Database, and MySQL. You can use any of those products with this text, and tutorials for each of them are presented for Microsoft Access 2019 (Appendix A), SQL Server 2019 (Chapter 10A), Oracle Database XE 18c (Chapter 10B), and MySQL 8.0 (Chapter 10C). Any other relational DBMS can also be used with this text, but without the detailed level of support provided for the four systems covered. Given the limitations of class time, it is probably necessary to pick and use just one of these products. You can often devote a portion of a lecture to discussing the characteristics of each, but it is usually best to limit student work to one of them. The possible exception to this is starting the course with Microsoft Access and then switching to a more robust DBMS product later in the course.

For non-relational DBMS products, we have a bit of a quandary–as discussed in Chapter 13, there are four common types of non-relational DBMSs and many products. To provide the best continuity with relational models and languages, the document model is described in the most detail in Chapter 10D. Many document database concepts can be thought of as extensions to relational features, and many document query languages resemble SQL in important ways. We have chosen to use ArangoDB, which, among other advantages, supports three of the four NoSQL database models (document, key-value, and graph). The multi-model nature of ArangoDB allows you to further experiment with graph and key-value NoSQL databases on your own without having to install another DMBS. ArangoDB is also easy to download and install on a variety of platforms. Its document model is based on JSON, which is simpler than XML and is becoming more popular as the model for document databases. A simple, Web-based GUI is supplied with ArangoDB that makes administration, data creation, and querying much easier than always using the command-line interface. Finally, the ArangoDB Query Language (AQL) is easy to learn if one already knows SQL; it also provides support for joins and, if desired, ACID transactions. ArangoDB, like the other enterprise-class systems used in this book, also comes in a free ("community") edition to enable easy learning.

Using Microsoft Access 2019

The primary advantage of Microsoft Access is accessibility. Many students already have a copy, and, if not, copies are easily obtained. Many students will have used Microsoft Access in their introductory or other classes. Appendix A, "Getting Started with Microsoft Access 2019," is a tutorial on Microsoft Access 2019 for students who have not used it but who wish to use it with this book.

However, Microsoft Access has several disadvantages. First, as explained in Chapter 1, Microsoft Access is a combination application generator and DBMS. Microsoft Access confuses students because it confounds database processing with application development. Also, Microsoft Access 2019 hides SQL behind its query processor and makes SQL appear as an afterthought rather than a foundation. Furthermore, as discussed in Chapter 2, Microsoft Access 2019 does not correctly process some of the basic SQL-92 standard statements in its default setup. Finally, Microsoft Access 2019 does not support triggers. You can simulate triggers by trapping Windows events, but that technique is nonstandard and does not effectively communicate the nature of trigger processing. Microsoft Access is not an enterprise-class DBMS.

Using Microsoft SQL Server 2019, Oracle Database, or MySQL 8.0

Choosing which of these products to use depends on your local situation. Oracle Database 19c, a superb enterprise-class DBMS product, is difficult to install and administer. However, if you have local staff to support your students, it can be an excellent choice. Fortunately, Oracle Database 18c Express Edition, commonly referred to as Oracle Database XE, is easy to install, easy to use, and freely downloadable. If you want your students to be able to install Oracle Database on their own computers, use Oracle Database XE. As shown in Chapter 10B, Oracle's SQL Developer GUI tool (or SQL*Plus if you are

dedicated to this beloved command-line tool) is a handy tool for learning SQL, triggers, and stored procedures.

Microsoft SQL Server 2019, although probably not as robust as Oracle Database, is easy to install on Windows machines, and it provides the capabilities of an enterprise-class DBMS product. The standard database administrator tool is the Microsoft SQL Server Management Studio GUI tool. As shown in Chapter 10A, SQL Server 2019 can be used to learn SQL, triggers, and stored procedures.

MySQL 8.0, discussed in Chapter 10C, is an open source DBMS product that is receiving increased attention and market share. The capabilities of MySQL are continually being upgraded, and MySQL 8.0 supports stored procedures and triggers. MySQL also has excellent GUI tools in the MySQL Workbench and an excellent command-line tool (the MySQL Command Line Client). It is the easiest of the three products for students to install on their own computers. It also works with the Linux operating system and is popular as part of the AMP (Apache–MySQL–PHP) package (known as WAMP on Windows and LAMP on Linux).

Using the Cloud and ArangoDB

As discussed in Chapter 13, many of today's cloud-based apps use a non-relational DBMS instead of a relational DBMS such as SQL Server, Oracle Database, or MySQL. In addition, many DBMS products, both relational and non-relational, are available in the cloud. Chapter 13 contains an extensive introduction to using the Microsoft Azure cloud platform, which can be used from any modern Web browser and can be used for free (up to a point, but certainly sufficient for this book, creating and querying relational and document databases). ArangoDB is a free and easy download (in its Community Edition form) and can be managed and used simply via a Web browser interface. It runs on a wide variety of platforms. ArangoDB can also be run in the cloud using ArangoDB Oasis (free for a 14-day test period).

BY THE WAY If the DBMS you use is not driven by local circumstances and you do have a choice, we recommend using Microsoft SQL Server 2019. It has all of the features of an enterprise-class DBMS product, and it is easy to install and use. Another option is to start with Microsoft Access 2019 if it is available and switch to SQL Server 2019 at Chapter 7. Chapters 1 and 2 and Appendix A are written specifically to support this approach. A variant is to use Microsoft Access 2019 as the development tool for forms and reports running against an SQL Server 2019 database.

If you prefer a different DBMS product, you can still start with Microsoft Access 2019 and switch later in the course. See the detailed discussion of the available DBMS products in Chapter 10 for a good review of your options.

Focus on Database Application Processing

In this edition, we clearly draw the line between *application development* per se and *database application processing*. Specifically, we have:

- Focused on specific database-dependent applications:
  - Web-based, database-driven applications
  - XML-based data processing
  - JSON-based data processing
  - Business intelligence (BI) systems applications
- Emphasized the use of commonly available, multiple-OS-compatible application development languages.
- Limited the use of specialized vendor-specific tools and programming languages as much as possible.

There is simply not enough room in this book to provide even a basic introduction to programming languages used for application development such as the Microsoft .NET languages and Java. Therefore, rather than attempting to introduce these languages, we leave them for other classes where they can be covered at an appropriate depth. Instead, we focus on basic tools that are relatively straightforward to learn and immediately applicable to database-driven applications. We use PHP as our Web development language, and we use the readily available NetBeans integrated development environment (IDE) as our development tool. The result is a *very* focused final section of the book, where we deal specifically with the interface between databases and the applications that use them.

BY THE WAY Although we try to use widely available software as much as possible, there are, of course, exceptions where we must use vendor-specific tools. For BI applications, for example, we draw on Microsoft Excel's PivotTable capabilities and the Microsoft PowerPivot for Microsoft Excel 2019 add-in. However, alternatives to these tools are available (OpenOffice.org DataPilot capabilities, the Palo OLAP Server), or the tools are generally available for download.

Business Intelligence Systems and Dimensional Databases

This edition maintains coverage of business intelligence (BI) systems (Chapter 12). The chapter includes a discussion of dimensional databases, which are the underlying structure for data warehouses, data marts, and OLAP servers. It still covers data management for data warehouses and data marts and also describes reporting and data mining applications, including OLAP.

Chapter 12 includes in-depth coverage of three applications that should be particularly interesting to students. The first is RFM analysis, a reporting application frequently used by mail order and e-commerce companies. The complete RFM analysis is accomplished in Chapter 12 through the use of standard SQL statements. The second, market basket analysis, is used by organizations to find patterns in purchase (or similar) data. Decision trees, the third topic covered in depth in Chapter 12, are used to automatically categorize records based on past experience (e.g., is a customer a high or low risk for insurance coverage?). Chapter 12 can be assigned at any point after Chapter 8 and could be used as a motivator to illustrate the practical applications of SQL midcourse.

Finally, Chapter 13 provides material on the current topics of Big Data, NoSQL (non-relational) databases, virtualization, and cloud computing.

Overview of the Chapters in the 16th Edition

Chapter 1 sets the stage by introducing database processing, describing basic components of database systems, and summarizing the history of database processing. If students are using Microsoft Access 2019 for the first time (or need a good review), they will also need to study Appendix A, "Getting Started with Microsoft Access 2019," at this point. Chapter 2 presents SQL SELECT statements. It also includes sections on how to submit SQL statements to Microsoft Access 2019, SQL Server 2019, Oracle Database, and MySQL 8.0.

The next four chapters, Chapters 3 through 6, present the first two iterations of database design. Chapter 3 presents the principles of normalization to Boyce-Codd Normal Form (BCNF). It describes the problems of multivalued dependencies and explains how to eliminate them. This foundation in normalization is applied in Chapter 4 to the design of databases from existing data.

Chapters 5 and 6 describe the design of new databases. Chapter 5 presents the E-R data model. Traditional E-R symbols are explained, but the majority of the chapter uses IE Crow's Foot notation. Chapter 5 provides a taxonomy of entity types, including strong,

ID-dependent, weak but not ID-dependent, supertype/subtype, and recursive. The chapter concludes with a simple modeling example for a university database.

Chapter 6 describes the transformation of data models into database designs by converting entities and attributes to tables and columns; by representing maximum cardinality by creating and placing foreign keys; and by representing minimum cardinality via carefully designed DBMS constraints, triggers, and application code. The primary section of this chapter parallels the entity taxonomy in Chapter 5.

Chapter 7 presents SQL DDL, DML, and SQL/Persistent Stored Modules (SQL/PSM). SQL DDL is used to implement the design of an example introduced in Chapter 6. INSERT, UPDATE, MERGE, and DELETE statements are discussed, as are SQL views. Additionally, the principles of embedding SQL in program code are presented, SQL/PSM is discussed, and triggers, functions, and stored procedures are explained.

Database redesign, the third iteration of database design, is described in Chapter 8. This chapter presents SQL statements using correlated subqueries and the SQL EXISTS and NOT EXISTS operators, and uses these statements in the redesign process. Reverse engineering is described, and basic redesign patterns are illustrated and discussed.

Chapters 9, 10, 10A, 10B, 10C, and 10D consider the management of multiuser organizational databases. Chapter 9 describes database administration tasks, including concurrency, security, and backup and recovery. Chapter 10 is a general introduction to the online Chapters 10A, 10B, 10C, and 10D, which describe SQL Server 2019, Oracle Database (specifically Oracle Database XE 18c), MySQL 8.0, and ArangoDB respectively. These chapters show how to use these specific products to create database structures and process SQL statements. They also explain concurrency, security, and backup and recovery with each product. The discussion in Chapters 10A, 10B, 10C, and 10D parallels the order of discussion in Chapter 9 as much as possible, though rearrangements of some topics are made, as needed, to support the discussion of a specific DBMS product.

BY THE WAY

We have maintained or extended our coverage of Microsoft Access, Microsoft SQL Server, Oracle Database, and MySQL (introduced in *Database Processing: Fundamentals, Design, and Implementation,* 11th edition) in this book. In order to keep the bound book to a reasonable length and to keep the cost of the book down, we have chosen to provide some material by download from our Web site at *www.pearsonhighered.com/kroenke*. There you will find:

- *Chapter 10A—Managing Databases with Microsoft SQL Server 2019*
- *Chapter 10B—Managing Databases with Oracle Database*
- *Chapter 10C—Managing Databases with MySQL 8.0*
- *Chapter 10D—Managing Document Databases with ArangoDB*
- *Appendix A—Getting Started with Microsoft Access 2019*
- *Appendix B—Getting Started with Systems Analysis and Design*
- *Appendix C—E-R Diagrams and the IDEF1X and UML Standards*
- *Appendix D—Getting Started with Microsoft Visio 2019*
- *Appendix E—Getting Started with the MySQL Workbench Data Modeling Tools*
- *Appendix F—Physical Database Design and Data Structures for Database Processing*
- *Appendix G—Getting Started with Web Servers, PHP, and the NetBeans IDE*
- *Appendix H—XML*

Chapters 11, 12, and 13 address standards and technologies for accessing databases. Chapter 11 presents ODBC, OLE DB, ADO.NET, ASP.NET, JDBC, and JavaServer Pages (JSP). It then introduces PHP (and the NetBeans IDE) and illustrates the use of PHP for the publication of databases via Web pages. This is followed by a description of the integration of XML and database technology. The chapter begins with a primer on XML and then shows how to use the FOR XML SQL statement in SQL Server.

Chapter 12 discusses BI systems, dimensional data models, data warehouses, data marts, reporting systems, and data mining. Chapter 13 concludes the text with a discussion of server virtualization, cloud computing, Big Data, structured storage, and the Not only SQL movement.

Supplements

This text is accompanied by a wide variety of supplements. Please visit the text's Web site at *www.pearsonhighered.com/kroenke* to access the instructor and student supplements described next. Please contact your Pearson sales representative for more details. All supplements were written by David Auer, Scott Vandenberg, Bob Yoder, and Harold Wise.

For Students

Many of the sample databases used in this text are available online in Microsoft Access, Microsoft SQL Server 2019, Oracle Database, and MySQL 8.0 formats. Some are also available in JSON format for use with ArangoDB.

For Instructors

At the Instructor Resource Center, *www.pearsonhighered.com/irc*, instructors can access a variety of print, digital, and presentation resources available with this text in downloadable format. Registration is simple and gives instructors immediate access to new titles and new editions. As a registered faculty member, you can download resource files and receive immediate access to and instructions for installing course management content on your campus server. In case you ever need assistance, our dedicated technical support team is ready to help with the media supplements that accompany this text. Visit *www.pearson.com/us/support/support-for-educator-institutions.html* for answers to frequently asked questions and toll-free user support phone numbers.

The following supplements are available for download to adopting instructors:

- Instructor's Manual (including database files and solutions)
- Test Bank
- TestGen Computerized Test Bank
- PowerPoint Presentations

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About the Authors

David M. Kroenke

Work Experience

David M. Kroenke has more than 50 years of experience in the computer industry. He began as a computer programmer for the U.S. Air Force, working both in Los Angeles and at the Pentagon, where he developed one of the world's first DBMS products while part of a team that created a computer simulation of World War III. That simulation served a key role for strategic weapons studies during a 10-year period of the Cold War.

From 1973 to 1978, Kroenke taught in the College of Business at Colorado State University. In 1977 he published the first edition of *Database Processing*, a significant and successful textbook that, more than 40 years later, you now are reading in its 16th edition. In 1978, he left Colorado State and joined Boeing Computer Services, where he managed the team that designed database management components of the IPAD project. After that, he joined with Steve Mitchell to form Mitchell Publishing and worked as an editor and author, developing texts, videos, and other educational products and seminars. Mitchell Publishing was acquired by Random House in 1986. During those years, he also worked as an independent consultant, primarily as a database disaster repairman helping companies recover from failed database projects.

In 1982, Kroenke was one of the founding directors of the Microrim Corporation. From 1984 to 1987, he served as the Vice President of Product Marketing and Development and managed the team that created and marketed the DBMS product RBASE 5000 as well as other related products.

For the next five years, Kroenke worked independently while he developed a new data modeling language called the *semantic object model*. He licensed this technology to the Wall Data Corporation in 1992 and then served as the Chief Technologist for Wall Data's Salsa line of products. He was awarded three software patents on this technology.

After 1998, Kroenke has continued consulting and writing. His current interests concern the practical applications of data mining techniques on large organizational databases. An avid sailor, he wrote *Know Your Boat: The Guide to Everything That Makes Your Boat Work*, which was published by McGraw-Hill in 2002. Now retired, Kroenke recently wrote *An Old Man and a Three Legged Dog*, a story of his travels with his dog Brie, which he published in 2020 and which is available at Amazon.com.

Consulting

Kroenke has consulted with numerous organizations during his career. In 1978, he worked for Fred Brooks, consulting with IBM on a project that became the DBMS product DB2. In 1989, he consulted for the Microsoft Corporation on a project that became Microsoft Access. In the 1990s, he worked with Computer Sciences Corporation and with General Research Corporation for the development of technology and products that were used to model all of the U.S. Army's logistical data as part of the CALS project. Additionally, he has consulted for Boeing Computer Services, the U.S. Air Force Academy, Logicon Corporation, and other smaller organizations.

Publications

- *Database Processing*, Pearson Prentice Hall, 16 editions, 1977–present (coauthor with David Auer, 11th, 12th, 13th, and 14th editions; coauthor with David Auer, Scott Vandenberg, and Robert Yoder 15th edition; coauthor with David Auer and Scott Vandenberg 16th edition)
- *Database Concepts*, Pearson Prentice Hall, nine editions, 2004–present (coauthor with David Auer, third, fourth, fifth, sixth, and seventh editions; coauthor with David Auer, Scott Vandenberg, and Robert Yoder eighth and ninth editions)
- *Using MIS*, Pearson Prentice Hall, 11 editions, 2006–present (coauthor with Randall J. Boyle, eighth, ninth, 10th, and 11th edition)
- *Experiencing MIS*, Pearson Prentice Hall, nine editions, 2007–present (coauthor with Randall J. Boyle, sixth, seventh, eighth, and ninth editions)
- *MIS Essentials*, Pearson Prentice Hall, four editions, 2009–present
- *Processes, Systems, and Information: An Introduction to MIS*, Pearson Prentice Hall, two editions, 2013–present (coauthor with Earl McKinney)
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- *Business Computer Systems*, Mitchell Publishing/Random House, five editions, 1981–1990
- *Managing Information for Microcomputers*, Microrim Corporation, 1984 (coauthor with Donald Nilson)
- *Database Processing for Microcomputers*, Science Research Associates, 1985 (coauthor with Donald Nilson)
- *Database: A Professional's Primer*, Science Research Associates, 1978

Teaching

Kroenke taught in the College of Business at Colorado State University from 1973 to 1978. He also has taught part time in the Software Engineering program at Seattle University. From 1990 to 1991, he served as the Hanson Professor of Management Science at the University of Washington. Most recently, he taught at the University of Washington from 2002 to 2008. During his career, he has been a frequent speaker at conferences and seminars for computer educators. In 1991, the International Association of Information Systems named him Computer Educator of the Year.

Education

B.S., Economics, U.S. Air Force Academy, 1968
M.S., Quantitative Business Analysis, University of Southern California, 1971
Ph.D., Engineering, Colorado State University, 1977

Personal

Kroenke lives on Whidbey Island in Washington State and has two grown children and three grandchildren. He enjoys skiing, sailing, and building small boats.

David J. Auer

Work Experience

David J. Auer has more than 30 years of experience teaching college-level business and information systems courses and for over 20 years has worked professionally in the field of information technology. He served as a commissioned officer in the U.S. Air Force, with

assignments to NORAD and the Alaskan Air Command in air defense operations. He later taught both business administration and music classes at Whatcom Community College and business courses for the Chapman College Residence Education Center at Whidbey Island Naval Air Station. He was a founder of the Puget Sound Guitar Workshop (now in its 41st year of operations). He worked as a psychotherapist and organizational development consultant for the Whatcom Counseling and Psychiatric Clinic's Employee Assistance Program and provided training for the Washington State Department of Social and Health Services. He taught for Western Washington University's College of Business and Economics from 1981 to June 2015 and served as the college's Director of Information Systems and Technology Services from 1994 to 2014. Now a Senior Instructor Emeritus at Western Washington University, he continues his writing projects.

Publications

- *Database Processing*, Pearson Prentice Hall, six editions, 2009–present (coauthor with David Kroenke; 15th edition coauthor with David Kroenke, Scott Vandenberg, and Robert Yoder; 16th edition coauthor with David Kroenke and Scott Vandenberg)
- *Database Concepts*, Pearson Prentice Hall, seven editions, 2007–present (coauthor with David Kroenke; eighth and ninth edition coauthor with David Kroenke, Scott Vandenberg, and Robert Yoder)
- *Network Administrator: NetWare 4.1*, Course Technology, 1997 (coauthor with Ted Simpson and Mark Ciampa)
- *New Perspectives on Corel Quattro Pro 7.0 for Windows 95*, Course Technology, 1997 (coauthor with June Jamrich Parsons, Dan Oja, and John Leschke)
- *New Perspectives on Microsoft Excel 7 for Windows 95–Comprehensive*, Course Technology, 1996 (coauthor with June Jamrich Parsons and Dan Oja)
- *New Perspectives on Microsoft Office Professional for Windows 95–Intermediate*, Course Technology, 1996 (coauthor with June Jamrich Parsons, Dan Oja, Beverly Zimmerman, Scott Zimmerman, and Joseph Adamski)
- *Microsoft Excel 5 for Windows–New Perspectives Comprehensive*, Course Technology, 1995 (coauthor with June Jamrich Parsons and Dan Oja)
- *Introductory Quattro Pro 6.0 for Windows*, Course Technology, 1995 (coauthor with June Jamrich Parsons and Dan Oja)
- *Introductory Quattro Pro 5.0 for Windows*, Course Technology, 1994 (coauthor with June Jamrich Parsons and Dan Oja)
- *The Student's Companion for Use with Practical Business Statistics*, Irwin, two editions 1991 and 1993

Teaching

Auer taught in the College of Business and Economics at Western Washington University from 1981 to June 2015. From 1975 to 1981, he taught part time for community colleges, and from 1981 to 1984, he taught part time for the Chapman College Residence Education Center System. During his career, he has taught a wide range of courses in Quantitative Methods, Production and Operations Management, Statistics, Finance, and Management Information Systems. In MIS, he has taught Principles of Management Information Systems, Business Database Development, Computer Hardware and Operating Systems, Telecommunications, Network Administration, and Fundamentals of Web Site Development.

Education

B.A., English Literature, University of Washington, 1969
B.S., Mathematics and Economics, Western Washington University, 1978
M.A., Economics, Western Washington University, 1980
M.S., Counseling Psychology, Western Washington University, 1991

Personal

Auer is married, recently moved to Whidbey Island, Washington, and has two grown children and four grandchildren. He is active in his community. Previously he has been president of his neighborhood association in Bellingham, Washington, and served on the City of Bellingham Planning and Development Commission. Now the owner of an Australian Shepard, he is on the board of directors of the organization that supports off-leash dog parks on Whidbey Island, and is also Treasurer of his community association. He enjoys music, playing acoustic and electric guitar, five-string banjo, and a bit of mandolin.

Scott L. Vandenberg

Work Experience

Scott L. Vandenberg has over 28 years' experience teaching computer science to college students in computer science and business. Before completing his PhD, he worked for brief periods at Standard Oil Research, Procter & Gamble headquarters, and IBM Research. He taught for two years at the University of Massachusetts-Amherst before joining the faculty at Siena College in 1993. His main teaching interests are in the areas of database management systems and introductory computer science, with research, consulting, and publications focused on those areas as well. Some of his earlier scholarly work included development of data models, query languages, and algebras for object-oriented databases and databases involving sequential and tree-structured data. More recent research has involved applying database technology to help solve data science problems in the areas of biology and epidemiology. He has also published several papers relating to introductory computer science curricula and was a co-principal investigator on a multiyear NSF grant to develop methods to broaden participation and increase retention in computer science. Vandenberg has published over 20 papers related to his scholarly activity.

Publications

- *Database Concepts*, Pearson Prentice Hall, eighth and ninth editions, 2017 and 2019 (coauthor with David Kroenke, David Auer, and Robert Yoder)
- *Database Processing*, Pearson Prentice Hall, 15th edition, 2018 (coauthor with David Kroenke, David Auer, and Robert Yoder)

Teaching

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 majors 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 has taught graduate and undergraduate database courses at the University of Washington in 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 interdisciplinary freshman writing course.

Education

B.A., Computer Science and Mathematics, Cornell University, 1986
M.S., Computer Science, University of Wisconsin-Madison, 1987
Ph.D., Computer Science, University of Wisconsin-Madison, 1993

Personal

Vandenberg is married; lives in Averill Park, New York; and has two children. When not playing with databases, he enjoys playing ice hockey and studying medieval history.

Getting Started

The two chapters in Part 1 provide an introduction to database processing. In Chapter 1, we discuss the importance of databases to support Internet Web applications and smartphone and other mobile apps. We then consider the characteristics of databases and describe important database applications. Chapter 1 discusses the various database components, provides a survey of the knowledge you need to learn from this text, and summarizes the history of database processing.

You will start working with a database in Chapter 2 and use that database to learn how to use Structured Query Language (SQL), a database-processing language, to query database data. You will learn how to query both single and multiple tables. Together, these two chapters will give you a sense of what databases are and how they are processed.

1 Introduction

Chapter Objectives

- To understand the importance of databases in Internet Web applications and smartphone apps
- To understand the nature and characteristics of databases
- To survey some important and interesting database applications
- To gain a general understanding of tables and relationships
- To describe the components of a Microsoft Access database system and explain the functions they perform
- To describe the components of an enterprise-class database system and explain the functions they perform
- To define the term *database management system* (DBMS) and describe the functions of a DBMS
- To define the term *database* and describe what is contained within the database
- To define the term *metadata* and provide examples of metadata
- To define and understand database design from existing data
- To define and understand database design as new systems development
- To define and understand database redesign of an existing database
- To understand the history and development of database processing

This chapter discusses the importance of databases in the Internet world and then introduces database processing concepts. We will first consider the nature and characteristics of databases and then survey a number of important and interesting database applications. Next, we will describe the components of a database system and then, in general terms, describe how databases are designed. After that, we will survey the knowledge that you need to work with databases as an application developer or as a database administrator. Finally, we conclude this introduction with a brief history of database processing.

To really understand databases and database technology, you will need to actively use some database product. Fortunately, in today's computer environment, easily obtainable versions of most major database products are available, and we will make use of them. However, this chapter assumes a minimal knowledge of database use. It assumes that you have used a basic database product such as

Microsoft Access to enter data into a form, to produce a report, and possibly to execute a query. If you have not done these things, you should obtain a copy of Microsoft Access 2019 and work through the tutorial in Appendix A.

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 (Xerox PARC)**[1] in the early 1970s and adopted as a national standard in 1983.

The **Internet**–the global computer network of networks–was created as the Department of Defense **Advanced Research Projects Agency Network (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**[2] (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* to **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**[3] Web sites started to appear–Web sites that allowed 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. Twelve years later, in 2020 (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)!

The latest development is the **Internet of Things (IoT)**,[4] where devices such as smart speakers, smart home devices (smoke detectors and thermostats), and even appliances such as refrigerators connect to the Internet and are network accessible. In particular, smart speakers such as the Amazon Echo series, Apple HomePod, the Google Home series, and Harmon Kardon INVOKE enable users to interact by voice with network-accessible apps via virtual assistants such as Amazon Alexa, Apple's Siri, Google Assistant, and Microsoft Cortana.

[1] The mouse and the multi-window graphical user interface commonly used in computer operating systems today were also developed at Xerox PARC. From there, they were adapted and popularized by Apple and Microsoft. For more information, see the Wikipedia article **PARC (company)** (accessed April 2020) at *https://en.wikipedia.org/wiki/PARC_(company)*.

[2] The World Wide Web and the first Web browser were created by Tim Berners-Lee in 1989 and 1990, respectively. For more information, see the Wikipedia articles **World Wide Web** (accessed April 2020) at *https://en.wikipedia.org/wiki/World_Wide_Web* and **World Wide Web Consortium** (accessed April 2020) at *https://en.wikipedia.org/wiki/World_Wide_Web_Consortium*. Also see the World Wide Web Consortium (W3C) Web site (accessed April 2020) at *https://www.w3.org/Consortium/*.

[3] The term *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 April 2020) at *https://en.wikipedia.org/wiki/Web_2.0*.

[4] For more information, see the Wikipedia article **Internet of Things** (accessed April 2020) at *https://en.wikipedia.org/wiki/Internet_of_things*. The article states that there were 8.4 billion network-capable IoT devices in 2017, with an expected 30 billion IoT devices by 2020!

What many people do not understand is that in today's Web application, smartphone app, and IoT 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.

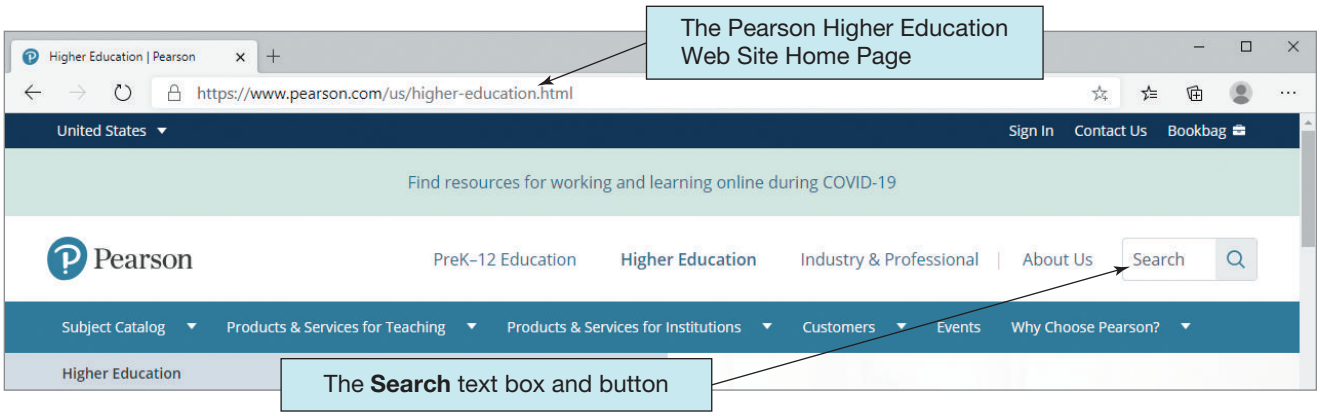
Do you have a Twitter account? If so, all your tweets are stored in a *database*. When your friend tweets something, it is initially stored in the *database* and then displayed to you.

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.

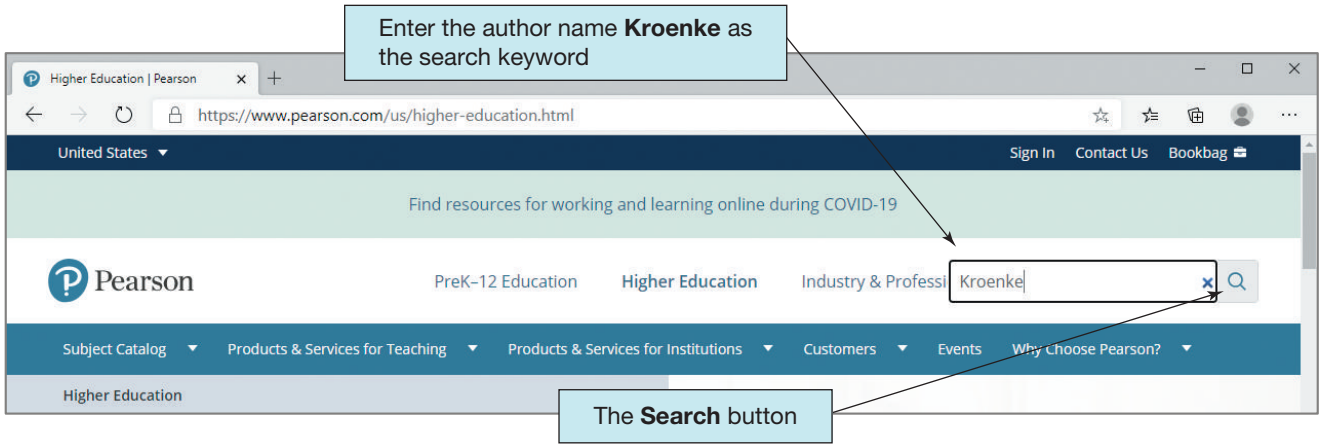
The search process is illustrated in Figure 1-1, where we search the Pearson Higher Education Web page for books authored by *David Kroenke*. Figure 1-1(a) shows the upper portion of the Pearson Higher Education Web page, with a Search text box and button in the upper right corner of the Web page. As shown in Figure 1-1(b), we enter the author name *Kroenke* in the text box and then click the **Search button**. The Pearson catalog database is searched, and the Web application returns a *Search Results Higher Education* page containing a listing of books authored by David Kroenke (with our companion book, *Database Concepts*, the second book listed) as shown in Figure 1-1(c).

FIGURE 1-1

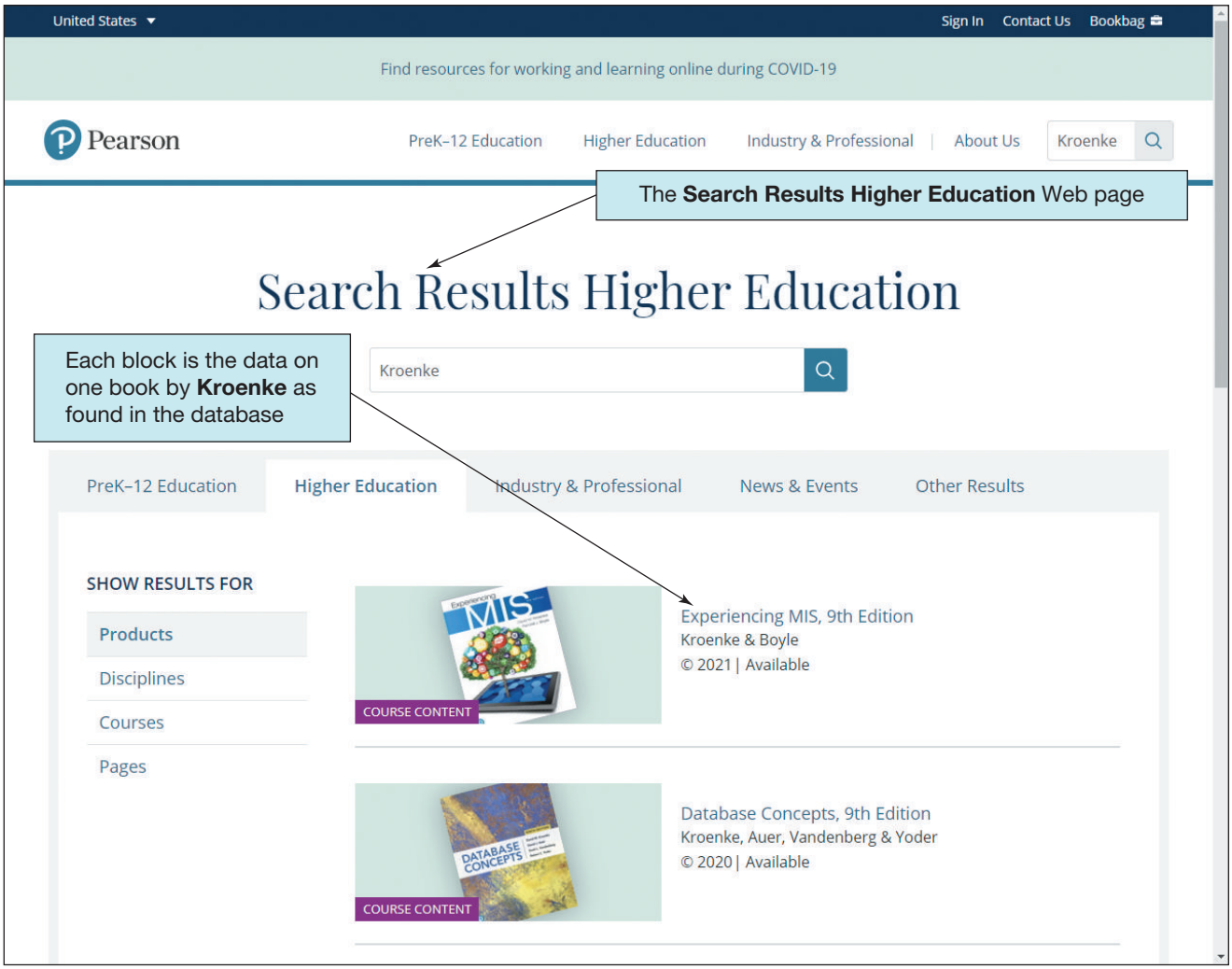
Searching a Database in a Web Browser



(a) The Pearson Higher Education Web Site Home Page



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



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

FIGURE 1-1
Continued

BY THE WAY 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, Crutchfield, or REI). Search for something you are interested in and watch the database search results be displayed for you. You just used a *database*.

BY THE WAY 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 "card holders 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 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 devices are **client** applications (Web browsers, apps) used by people to obtain **services** such as searching, browsing, online purchasing, and tweeting over the Internet or cell phone

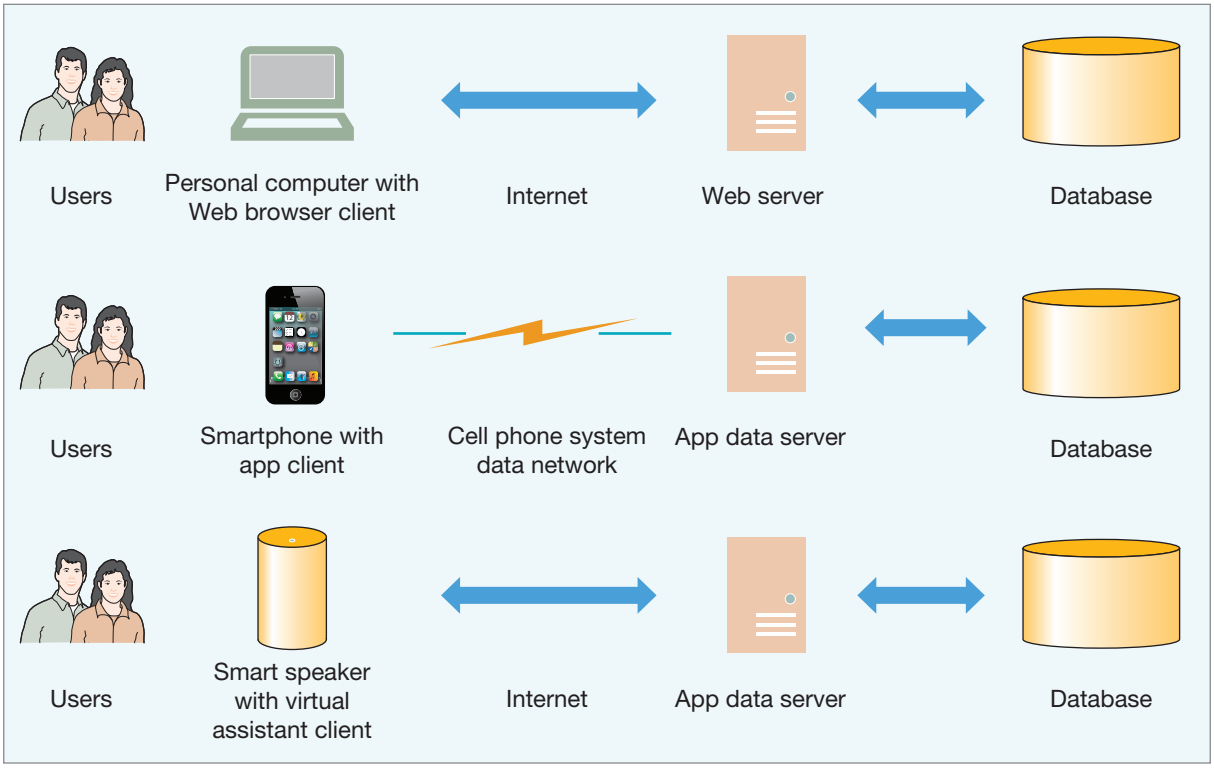


FIGURE 1-2
The Internet and Mobile Device World

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.

The Characteristics of Relational Databases

The purpose of a database is to help people keep track of things. Databases are created and controlled by software applications called database management systems (DBMSs). We can basically sort all DBMSs and the databases they manage into two categories: **relational databases** and **non-relational databases**. Historically, the first databases were non-relational databases, but when the relational database was introduced, it quickly became the most commonly used type of database, and it remains so today. We will discuss the relational database model in depth in Chapter 3, 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 should, however, be aware that Web and mobile apps such as search tools (for example, Google, Bing and DuckDuckGo), Web 2.0 social networks (for example, Facebook and Twitter), and scientific data collection tools generate enormous datasets, which are currently referred to as **Big Data**. Big Data datasets are often stored in new types of non-relational databases, and so the non-relational database is making a resurgence. We will discuss this after we complete our introduction of relational databases.

To understand how a relational database works, we start with the fact that a relational database stores data in tables. A **table** has rows and columns, like those in a spreadsheet. A database usually has multiple tables, and each table contains data about a different type of thing. For example, Figure 1-3 shows a database with two tables: the STUDENT table holds data about students, and the CLASS table holds data about classes.

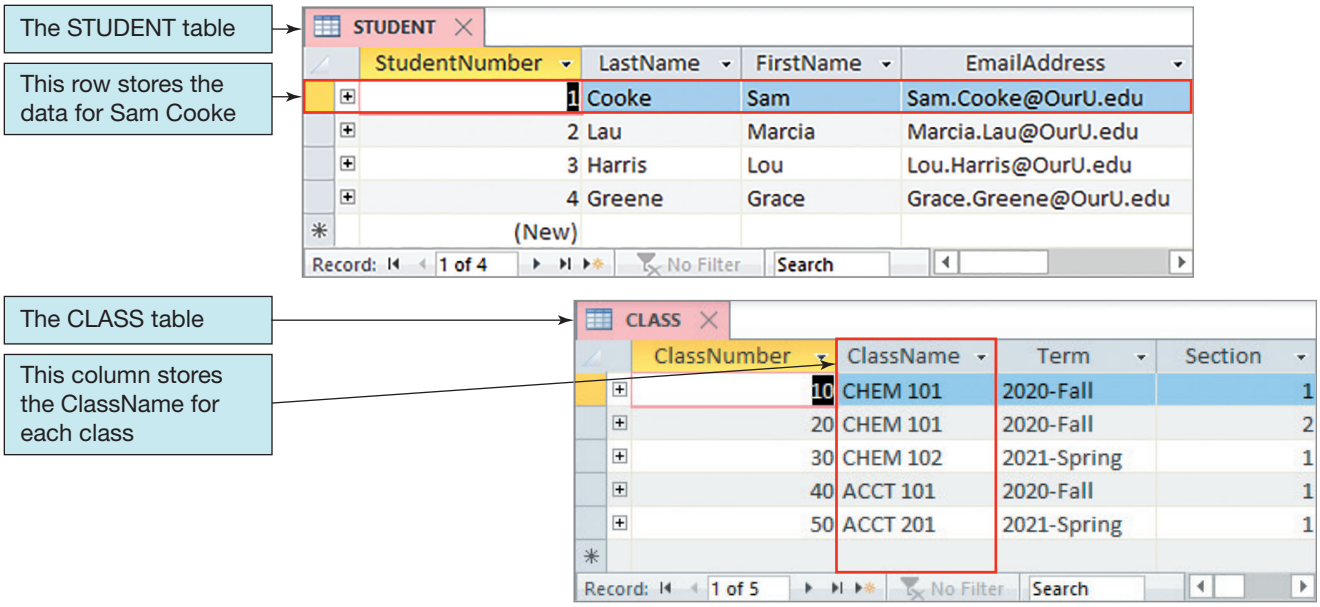


FIGURE 1-3

The STUDENT and CLASS Tables

Each **row** of a table has data about a particular occurrence, or **instance** of the thing of interest. For example, each row of the STUDENT table has data about one of four students: Cooke, Lau, Harris, and Greene. Similarly, each row of the CLASS table has data about a particular class. Because each row *records* the data for a specific instance, rows are also known as **records**. Each **column** of a table stores a characteristic common to all rows. For example, the first column of STUDENT stores StudentNumber, the second column stores LastName, and so forth. Columns are also known as **fields**.

BY THE WAY

A table and a *spreadsheet* (also known as a *worksheet*) are very similar in that you can think of both as having rows, columns, and cells. The details that define a table as something different from a spreadsheet are discussed in Chapter 3. For now, the main differences you will see are that tables have column names instead of identifying letters (for example, *Name* instead of *A*) and that the rows are not necessarily numbered.

Although, in theory, you could switch the rows and columns by putting instances in the columns and characteristics in the rows, this is never done. Every database in this text and 99.999999 percent of all databases throughout the world store instances in rows and characteristics in columns.

A Note on Naming Conventions

In this text, table names appear in capital letters. This convention will help you to distinguish table names in explanations. However, you are not required to set table names in capital letters. Microsoft Access and similar programs will allow you to write a table name as STUDENT, student, Student, or stuDent or in some other way.

Additionally, in this text column names begin with a capital letter. Again, this is just a convention. You could write the column name Term as term, teRm, or TERM or in any other way. To ease readability, we will sometimes create compound column names in which the first letter of each element of the compound word is capitalized. Thus, in Figure 1-3 the STUDENT table has columns StudentNumber, LastName, FirstName, and EmailAddress. Again, this capitalization is just a convenient convention. However, following these or other

consistent conventions will make interpretation of database structures easier. For example, you will always know that STUDENT is the name of a table and that Student is the name of a column of a table.

A Database Has Data and Relationships

Figure 1-3 illustrates how relational database tables are structured to store data, but a relational database is not complete unless it also shows the relationships among the rows of data. To see why this is important, examine Figure 1-4. In this figure, the database contains all of the basic data shown in Figure 1-3 together with a GRADE table. Unfortunately, the relationships among the data are missing. In this format, the GRADE data are useless. It is like the joke about the sports commentator who announced: "Now for tonight's baseball scores: 2–3, 7–2, 1–0, and 4–5." The scores are useless without knowing the teams that earned them. Thus, a database contains both data and the relationships among the data.

Figure 1-5 shows the complete database that contains not only the data about students, classes, and grades but also the relationships among the rows in those tables. For example, StudentNumber 1, who is Sam Cooke, earned a Grade of 3.7 in ClassNumber 10, which is Chem101. He also earned a Grade of 3.5 in ClassNumber 40, which is Acct101.

Figure 1-5 illustrates an important characteristic of database processing. Each row in a table is uniquely identified by a **primary key**, and the values of these keys are used to create the relationships between the tables. For example, in the STUDENT table StudentNumber serves as the primary key. Each value of StudentNumber is unique and identifies a particular student. Thus, StudentNumber 1 identifies Sam Cooke. Similarly, ClassNumber in the CLASS table identifies each class. If the numbers used in primary key columns such as StudentNumber and ClassNumber are automatically generated and assigned in the database itself, then the key is also called a **surrogate key**.

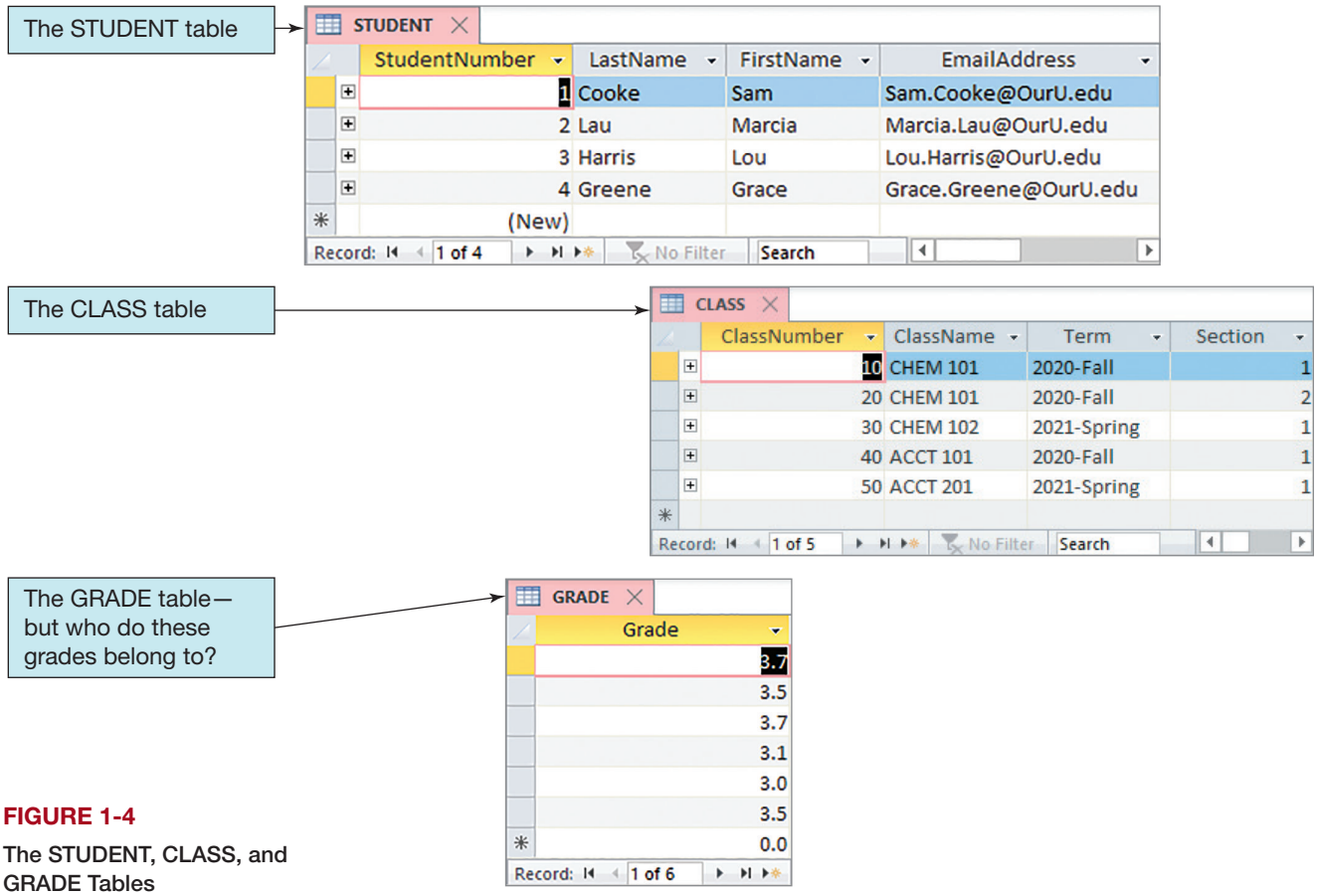


FIGURE 1-4

The STUDENT, CLASS, and GRADE Tables

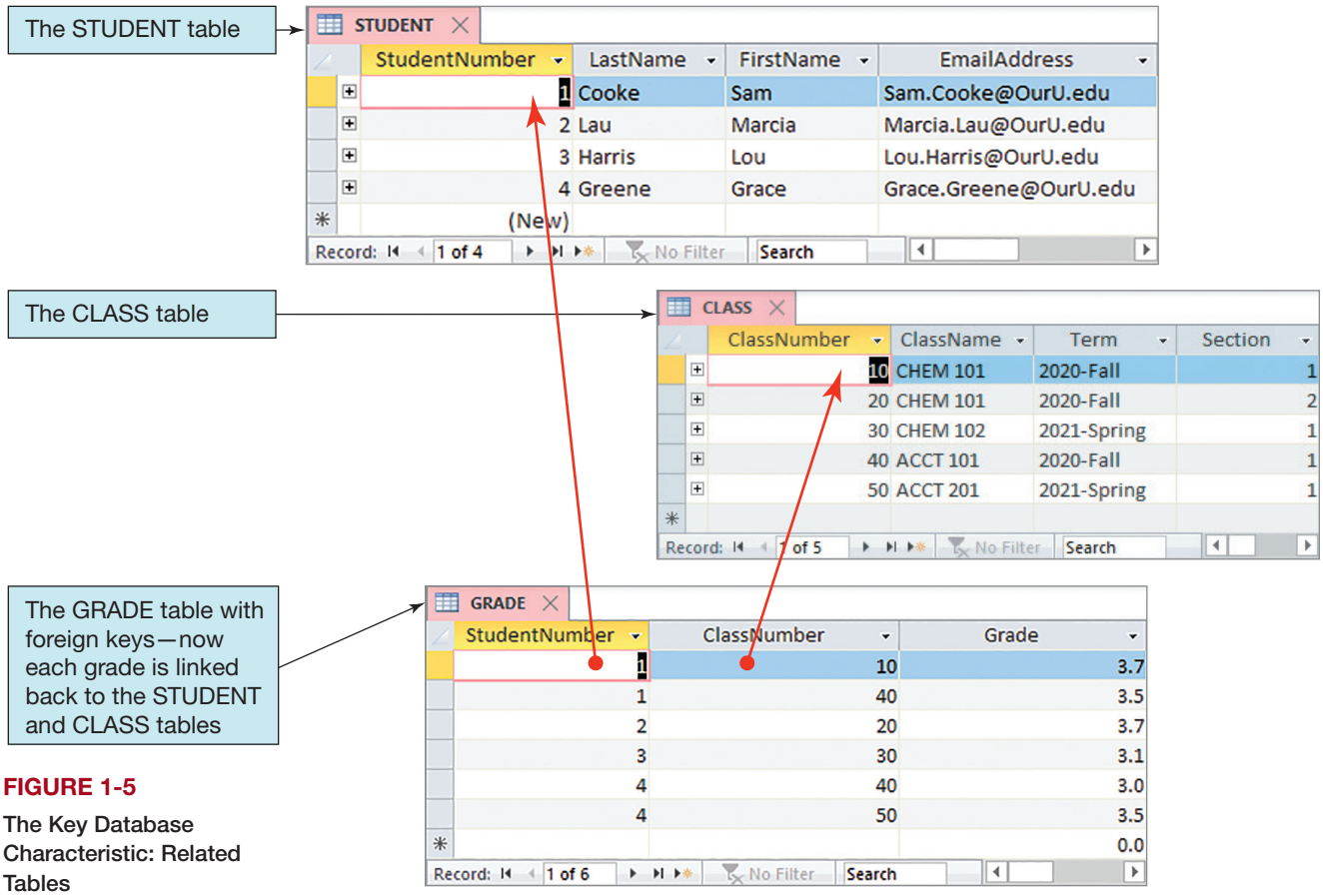


FIGURE 1-5

The Key Database Characteristic: Related Tables

Figure 1-6 shows a Microsoft Access 2019 view of the tables and relationships shown in Figure 1-5. In Figure 1-6, primary keys in each table are marked with key symbols, and connecting lines representing the relationships are drawn from the foreign keys (in GRADE) to the corresponding primary keys (in STUDENT and CLASS). The symbols on the relationship line (the number 1 and the infinity symbol) mean that, for example, one student in STUDENT can be linked to many grades in GRADE.

By comparing Figures 1-4, 1-5, and 1-6, we can see how the primary keys of STUDENT and CLASS were added to the GRADE table to provide GRADE with a primary key of (StudentNumber, ClassNumber) to uniquely identify each row. When more than one column in a table must be combined to form the primary key, we call this a **composite key**. More important, in GRADE StudentNumber and ClassNumber each now serves as a

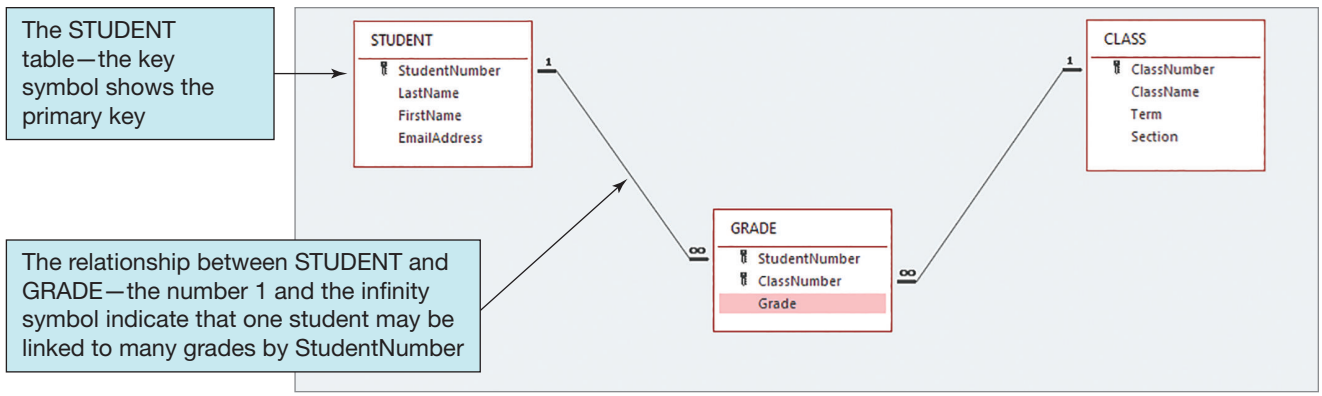


FIGURE 1-6

Microsoft Access 2019 View of Tables and Relationships

foreign key. A foreign key provides the link between two tables. By adding a foreign key, we create a **relationship** between the two tables.

Databases Create Information

In order to make decisions, we need information upon which to base those decisions. Because we have already defined *data* as recorded facts and numbers, we can now define[5] **information** as:

- Knowledge derived from data
- Data presented in a meaningful context
- Data processed by summing, ordering, averaging, grouping, comparing, or other similar operations

Databases record facts and figures, so they record data. They do so, however, in a way that enables them to produce information. The data in Figure 1-5 can be manipulated to produce a student's GPA, the average GPA for a class, the average number of students in a class, and so forth. In Chapter 2, you will be introduced to a language called Structured Query Language (SQL) that you can use to produce information from database data.

To summarize, relational databases store data in tables, and they represent the relationships among the rows of those tables. They do so in a way that facilitates the production of information. We will discuss the relational database model in depth in Part 2 of this book.

Database Examples

Today, database technology is part of almost every information system. This fact is not surprising when we consider that every information system needs to store data and the relationships among those data. Still, the vast array of applications that use this technology is staggering. Consider, for example, the applications listed in Figure 1-7.

Single-User Database Applications

In Figure 1-7, the first application is used by a single salesperson to keep track of the customers she has called and the contacts that she has had with them. Most salespeople do not build their own contact manager applications; instead, they license products such as GoldMine or Act!

Multiuser Database Applications

The next applications in Figure 1-7 are those that involve more than one user. The patient-scheduling application, for example, may have 15 to 50 users. These users will be appointment clerks, office administrators, nurses, dentists, doctors, and so forth. A database like this one may have as many as 100,000 rows of data in perhaps 5 or 10 different tables.

When more than one user employs a database application, there is always the chance that one user's work may interfere with another's. Two appointment clerks, for example, might assign the same appointment to two different patients. Special concurrency-control mechanisms are used to coordinate activity against the database to prevent such conflicts. You will learn about these mechanisms in Chapter 9.

The third row of Figure 1-7 shows an even larger database application. A **customer relationship management (CRM)** system is an information system that manages customer contacts from initial solicitation through acceptance, purchase, continuing purchase, support, and so forth. CRM systems are used by salespeople, sales managers, customer

[5]These definitions are from David M. Kroenke's books *Using MIS*, 11th ed. (Upper Saddle River, NJ: Prentice-Hall, 2020) and *Experiencing MIS*, 8th ed. (Upper Saddle River, NJ: Prentice-Hall, 2019). See these books for a full discussion of these definitions as well as a discussion of a fourth definition, "a difference that makes a difference."

Application	Example Users	Number of Users	Typical Size	Remarks
Sales contact manager	Salesperson	1	2,000 rows	Products such as GoldMine and Act! are database-centric.
Patient appointment (doctor, dentist)	Medical office	15 to 50	100,000 rows	Vertical market software vendors incorporate databases into their software products.
Customer relationship management (CRM)	Sales, marketing, or customer service departments	500	10 million rows	Major vendors such as Microsoft and Oracle PeopleSoft Enterprise build applications around the database.
Enterprise resource planning (ERP)	An entire organization	5,000	10 million+ rows	SAP uses a database as a central repository for ERP data.
E-commerce site	Internet users	Possibly millions	1 billion+ rows	Drugstore.com has a database that grows at the rate of 20 million rows per day!
Digital dashboard	Senior managers	500	100,000 rows	Displays extractions, summaries, and consolidations of operational database data.
Data mining	Business analysts	25	100,000 to millions+	Data are extracted, reformatted, cleaned, and filtered for use by statistical data mining tools.

FIGURE 1-7
Example Database Applications

service and support staff, and other personnel. A CRM database in a larger company might have 500 users and 10 million or more rows in perhaps 50 or more tables. According to Microsoft, in 2004 Verizon had an SQL Server customer database that contained more than 15 terabytes of data. If those data were published in books, a bookshelf 450 miles long would be required to hold them.

An **enterprise resource planning (ERP)** is an information system that touches every department in a manufacturing company. It includes sales, inventory, production planning, purchasing, and other business functions. SAP is the leading vendor of ERP applications, and a key element of its product is a database that integrates data from these various business functions. An ERP system may have 5,000 or more users and perhaps 100 million rows in several hundred tables.

E-Commerce Database Applications

E-commerce is another important database application. Databases are a key component of e-commerce order entry, billing, shipping, and customer support. Surprisingly, however, the largest databases at an e-commerce site are not order-processing databases. The largest databases are those that track customer browser behavior. Most of the prominent e-commerce companies, such as Amazon.com and Drugstore.com, keep track of the Web pages and the Web page components that they send to their customers. They also track customer clicks, additions to shopping carts, order purchases, abandoned shopping carts, and so forth.

E-commerce companies use Web activity databases to determine which items on a Web page are popular and successful and which are not. They also can conduct experiments to determine if a purple background generates more orders than a blue one, and so forth. Such Web usage databases are huge. For example, Drugstore.com adds 20 million rows to its Web log database each day!

Reporting and Data Mining Database Applications

Two other example applications in Figure 1-7 are digital dashboards and data mining applications. These applications use the data generated by order processing and other operational systems to produce information to help manage the enterprise. Such applications do not generate new data but instead summarize existing data to provide insights to management. **Digital dashboards** and other reporting systems assess past and current performance. **Data mining** applications predict future performance. We will consider such applications in Chapter 12. The bottom line is that database technology is used in almost every information system and involves databases ranging in size from a few thousand rows to many millions of rows.

BY THE WAY

Do not assume that just because a database is small that its structure is simple. For example, consider parts distribution for a company that sells $1 million in parts per year and parts distribution for a company that sells $100 million in parts per year. Despite the difference in sales, the companies have similar databases. Both have the same kinds of data, about the same number of tables of data, and the same level of complexity in data relationships. Only the amount of data varies from one to the other. Thus, although a database for a small business may be small, it is not necessarily simple.

The Components of a Database System

As shown in Figure 1-8, a **database system** is typically defined to consist of four components: users, the database application, the database management system (DBMS), and the database. However, given the importance of **Structured Query Language (SQL)**, an internationally recognized standard language that is understood by all commercial relational DBMS products, in database processing and the fact that database applications typically send SQL statements to the DBMS for processing, we can refine our illustration of a database system to appear as shown in Figure 1-9.

Starting from the right of Figure 1-9, the **database** is a collection of related tables and other structures. The **database management system (DBMS)** is a computer program

FIGURE 1-8
The Components of a Database System

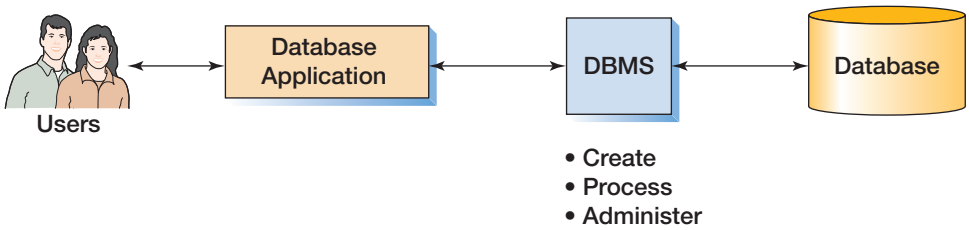
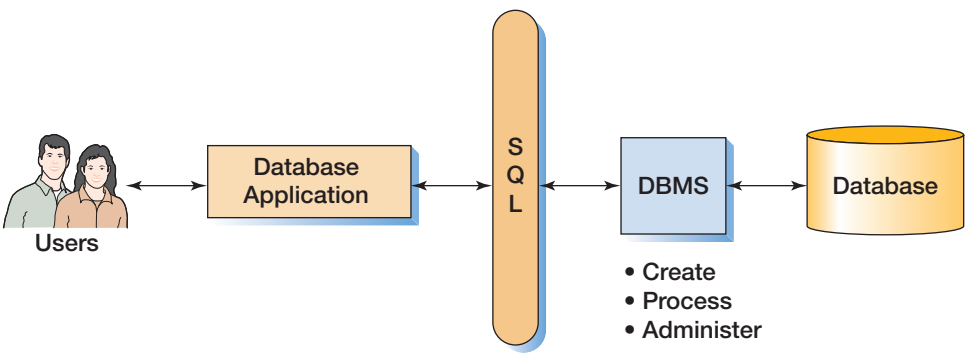


FIGURE 1-9
The Components of a Database System with SQL



used to create, process, and administer the database. The DBMS receives requests encoded in SQL and translates those requests into actions on the database. The DBMS is a large, complicated program that is licensed from a software vendor; companies almost never write their own DBMS programs.

A **database application** is a set of one or more computer programs that serves as an intermediary between the user and the DBMS. Application programs read or modify database data by sending SQL statements to the DBMS. Application programs also present data to users in the format of forms and reports. Application programs can be acquired from software vendors, and they are also frequently written in-house. The knowledge you gain from this text will help you write database applications.

Users, the final component of a database system, employ a database application to keep track of things. They use forms to read, enter, and query data, and they produce reports to convey information.

Database Applications and SQL

Figure 1-9 shows that users interact directly with database applications. Figure 1-10 lists the basic functions of database applications.

First, an application program creates and processes forms. Figure 1-11 shows a typical form for entering and processing student enrollment data for the Student-Class-Grade database shown in Figures 1-5 and 1-6. Notice that this form hides the structure of the underlying tables from the user. By comparing the tables and data in Figure 1-5 to the form in Figure 1-11, we can see that data from the CLASS table appears at the top of the form, and data from the STUDENT table is presented in a tabular section labeled Class Enrollment Data.

The goal of this form, like that for all data entry forms, is to present the data in a format that is useful for the users, regardless of the underlying table structure. Behind the form, the application processes the database in accordance with the users' actions. The application generates an SQL statement to insert, update, or delete data for any of the tables that underlie this form.

The second function of application programs is to process user queries. The application program first generates a query request and sends it to the DBMS. Results are then formatted and returned to the user. Applications use SQL statements and pass them to the DBMS for processing. To give you a taste of SQL, here is a sample SQL statement for processing the STUDENT table in Figure 1-5:

```
SELECT    LastName, FirstName, EmailAddress
FROM      STUDENT
WHERE     StudentNumber > 2;
```

This SQL statement is a query statement, which asks the DBMS to obtain specific data from a database. In this case, the query asks for the last name, first name, and email address of all students with a StudentNumber greater than 2. The results of this SQL statement are shown (as displayed in Microsoft Access 2019) in Figure 1-12 and will include the LastName, FirstName, and EmailAddress for students Harris and Greene.

FIGURE 1-10
Basic Functions of Application Programs

Basic Functions of Application Programs
Create and process forms
Process user queries
Create and process reports
Execute application logic
Control the application itself

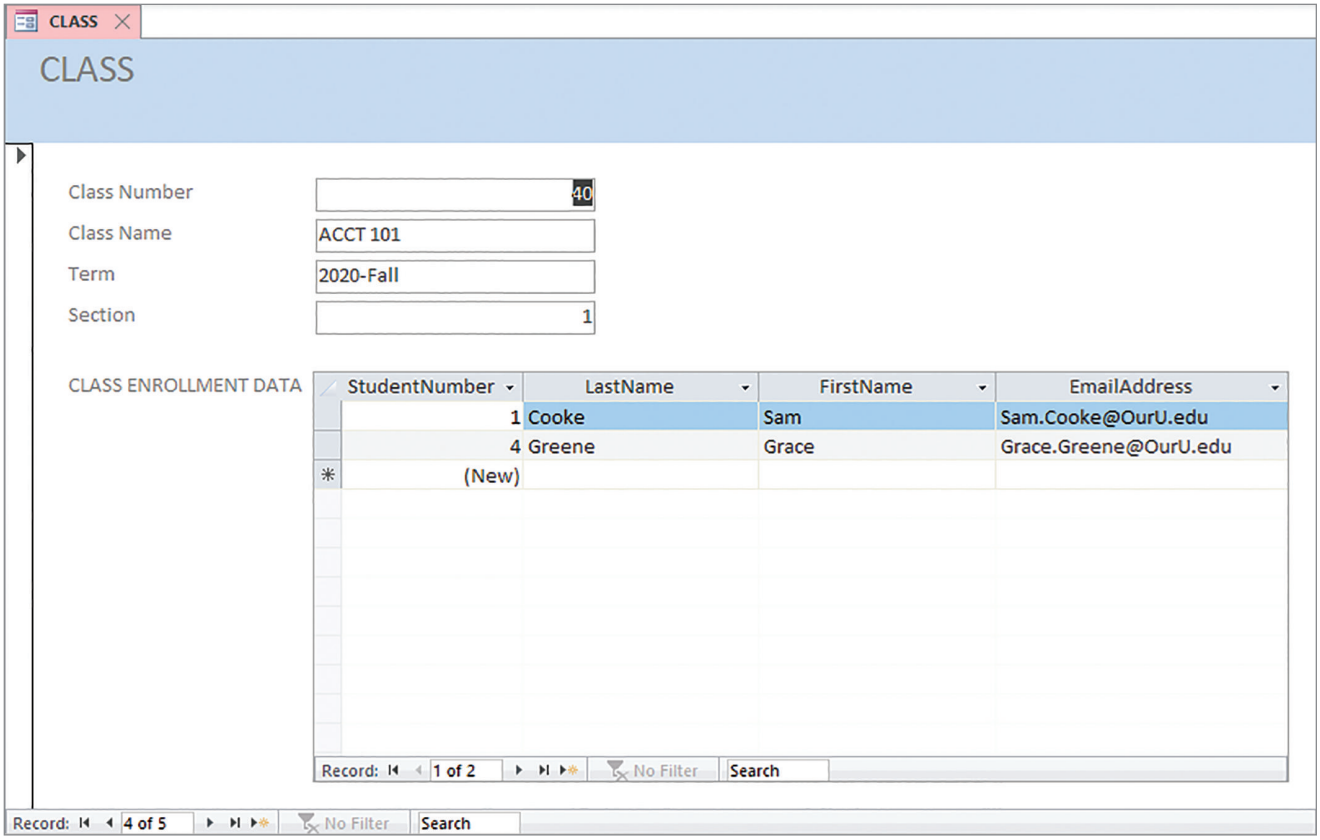


FIGURE 1-11
An Example Data Entry Form

The third function of an application is to create and process reports. This function is somewhat similar to the second because the application program first queries the DBMS for data (again using SQL). The application then formats the query results as a report. Figure 1-13 shows a report that displays all the Student-Class-Grade data shown in Figure 1-5 sorted by ClassNumber and LastName. Notice that the report, like the form in Figure 1-11, is structured according to the users' needs, not according to the underlying table structure.

In addition to generating forms, queries, and reports, the application program takes other actions to update the database in accordance with application-specific logic. For example, suppose a user using an order entry application requests 10 units of a particular item. Suppose further that when the application program queries the database (via the DBMS), it finds that only 8 units are in stock. What should happen? It depends on the logic of that particular application. Perhaps no units should be removed from inventory and the user should be notified, or perhaps the 8 units should be removed and 2 more placed on backorder. Perhaps some other action should be taken. Whatever the case, it is the job of the application program to execute the appropriate logic.

Finally, the last function for application programs listed in Figure 1-10 is to control the application. This is done in two ways. First, the application needs to be written so that only

FIGURE 1-12
Example SQL Query Results