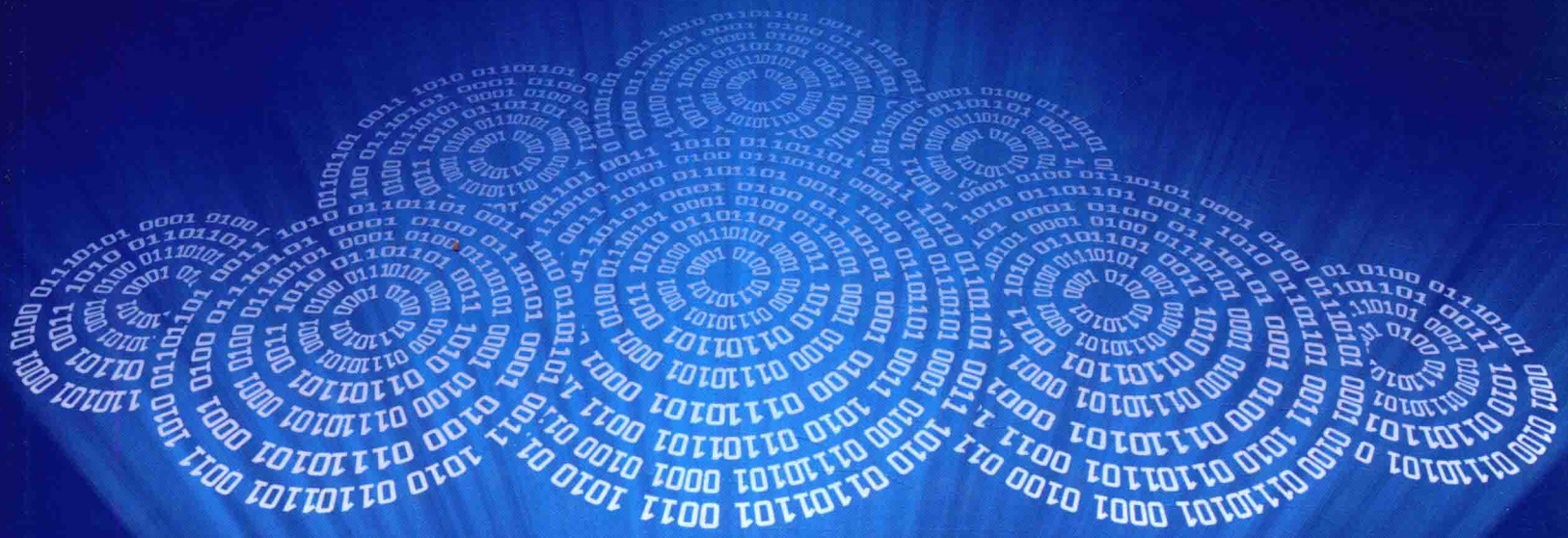


Coronel / Morris

Database Systems

Design, Implementation,
and Management 11e



DATABASE SYSTEMS

DESIGN, IMPLEMENTATION, AND MANAGEMENT



CARLOS CORONEL • STEVEN MORRIS



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**Database Systems: Design, Implementation,
and Management, Eleventh Edition**

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**D**edication

To the treasures in my life: To Victoria, for 23 wonderful years. Thank you for your unending support, for being my angel, my sweetie, and most importantly, my best friend. To Carlos Anthony for the many good times you have given us; you show us the way. Thank you for your words of wisdom, contagious happiness, and for bringing us shining days. You are still young; your best times are still to come. To Gabriela Victoria, who is the image of brilliance, beauty, and faithfulness. Thank you for being the sunshine in my cloudy days. To Christian Javier, whose endless energy and delightful smiles keep us going every day. Thank you for being the youthful reminder of life's simple beauties. To my parents, Sarah and Carlos, thank you for your sacrifice and example. To all of you, you are all my inspiration. "TQTATA."

Carlos Coronel

To Pamela, from high school sweetheart through 24 years of marriage, the beautiful love of my life who has supported, encouraged, and inspired me. More than anyone else, you are responsible for whatever successes I have achieved. To my son, Alexander Logan, whose depth of character is without measure. You are my pride and joy. To my daughter, Lauren Elizabeth, whose beauty and intensity take my breath away. You are my heart and soul. Thank you all for the sacrifices you have made that enabled me to pursue this dream. I love you so much more than I can express. To my mother, Florence Maryann, and to the memory of my father, Alton Lamar, who together instilled in me the desire to learn and the passion to achieve. To my mother-in-law, Connie Duke, and to the memory of my father-in-law, Wayne Duke, who taught me to find joy in all things. To all of you, with all my love, I dedicate this book.

Steven Morris**FOR PETER**

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

Carlos Coronel and Steven Morris

PREFACE

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

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

CHANGES TO THE ELEVENTH EDITION

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

- Expanded relational algebra coverage with formal definitions and notations
- Updated Business Vignettes showing the impact of database technologies in the real world
- Updated coverage of cloud data services
- Expanded coverage of Big Data and related Hadoop technologies
- Added coverage of data visualization
- SQL coverage expanded to include MySQL databases
- Improved readability and overall visual appeal

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

THE APPROACH: A CONTINUED EMPHASIS ON DESIGN

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

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

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

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

TOPICAL COVERAGE

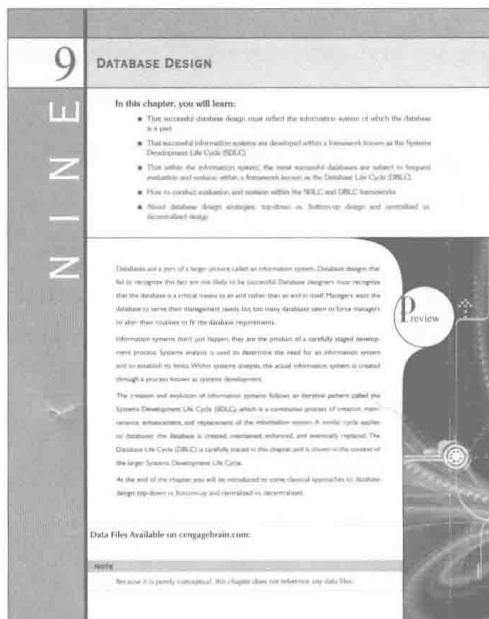
The Systems View

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



Database Design

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



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

Implementation

The second portion of the subtitle is **Implementation**. We use Structured Query Language (SQL) in Chapters 7 and 8 to show how databases are implemented and managed. Appendix M, Microsoft Access Tutorial, provides a quick but comprehensive guide to implementing an MS Access database. Appendixes B and C demonstrate the design of a database that was fully implemented; these appendixes illustrate a wide range of implementation issues. We had to deal with conflicting design goals: design elegance, information requirements, and operational speed. Therefore, we carefully audited the initial design in Appendix B to check its ability to meet end-user needs and establish appropriate implementation protocols. The result of this audit yielded the final design developed in Appendix C. The special issues encountered in an Internet database environment are addressed in Chapter 14, Database Connectivity and Web Technologies, and in Appendix J, Web Database Development with ColdFusion.

PART	
III	
ADVANCED DESIGN AND IMPLEMENTATION	
INTRODUCTION TO STRUCTURED QUERY LANGUAGE (SQL)	7
ADVANCED SQL	8
DATABASE DESIGN	9

PART	
VI	
DATABASE ADMINISTRATION	
DATABASE ADMINISTRATION AND SECURITY	15

Management

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

PREFACE

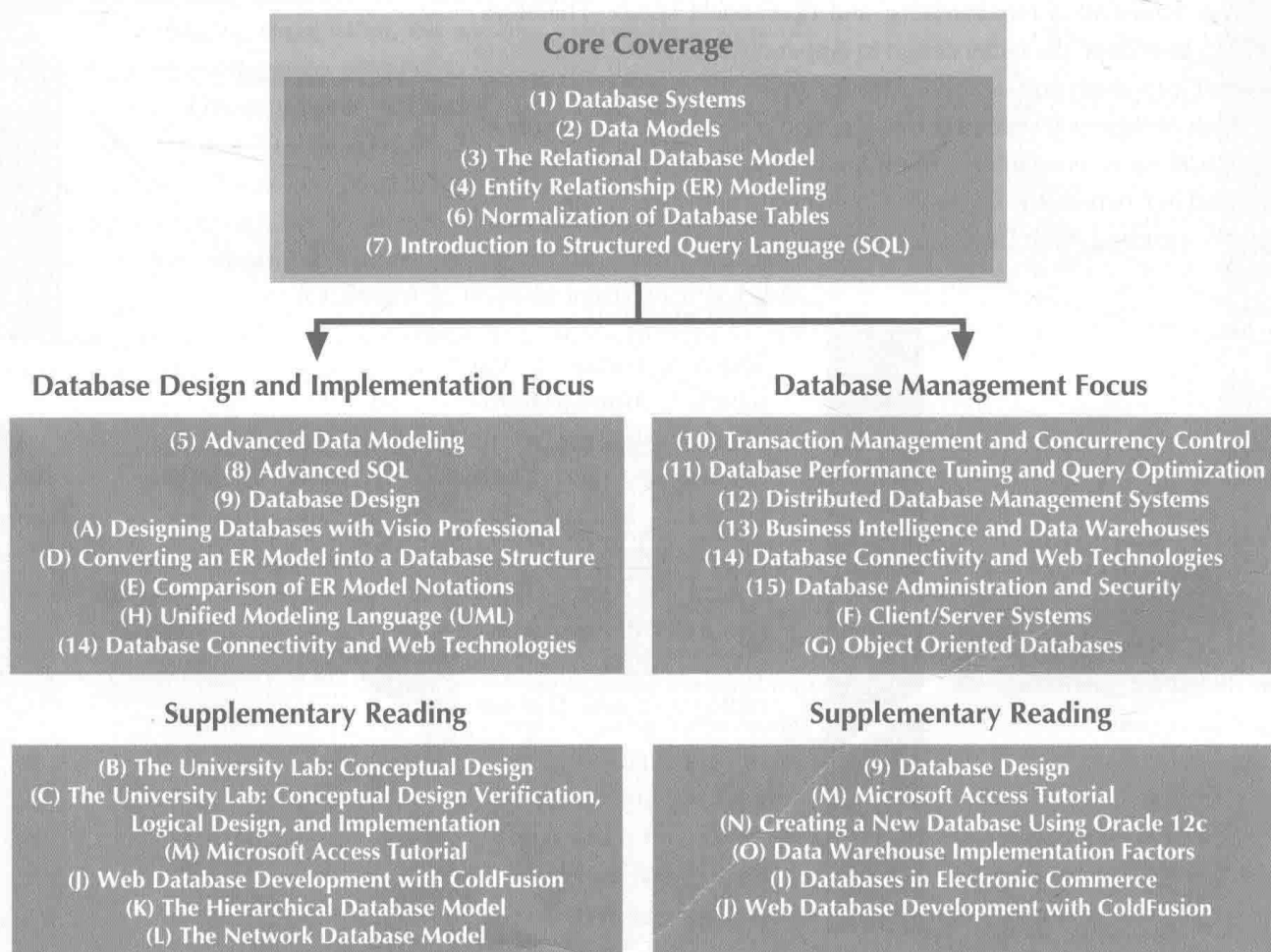
TEACHING DATABASE: A MATTER OF FOCUS

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

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

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

FIGURE 1



Business Vignettes highlight topics in a real-life setting.

THE RELATIONAL EVOLUTION AND BEYOND

For over 40 years, relational databases (RDBMS) have dominated the database market – with Oracle maintaining a leading position. In 2012, Gartner, the leading information technology research company, reported that Oracle holds a greater share of the RDBMS revenue than its four closest competitors combined.¹

Researchers, journalists, and business leaders agree, however, that the industry now stands at the brink of another database revolution. New developments have given rise to new database models. The Internet has witnessed the explosion of unstructured and semi-structured data, such as online journals, blogs, and videos. Gartner predicts that unstructured data will account for 80 percent of the new data uploaded to the Internet.² Although relational databases meet rigorous standards for data integrity and consistency, they do not scale unstructured data as well as new database models, such as NoSQL.³ As a result, social networking sites, such as Twitter and Facebook, that are home to semi-structured data and do not require high levels of data consistency and integrity have adopted noSQL databases.

The number of data transactions has also skyrocketed in recent years. Within a decade, businesses will have to analyze 50 times more data files that are 75 times as large as they are today.⁴ Companies need databases that can process this “Big Data” so that they can obtain timely and accurate business intelligence. As a result, many Big Data companies have turned to new data models. When Visa needed



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



ONLINE CONTENT

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

NOTE

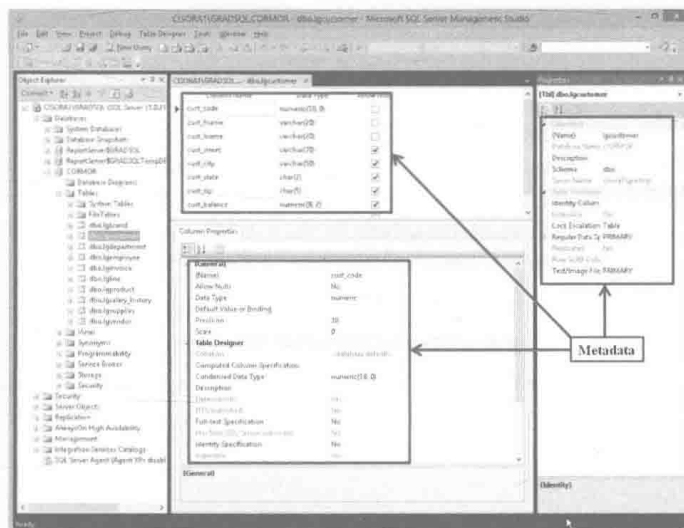
Data that display data inconsistency are also referred to as data that lack data integrity. **Data integrity** is defined as the condition in which all of the data in the database are consistent with the real-world events and conditions. In other words, data integrity means that:

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

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

FIGURE 1.10 Illustrating metadata with Microsoft SQL Server Express

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



TEXT FEATURES

S U M M A R Y

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

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

K E Y T E R M S

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

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

R E V I E W Q U E S T I O N S

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

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

P R O B L E M S

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

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

COURSEMATE

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Appendixes

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

Database, SQL Script, and ColdFusion Files

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

ADDITIONAL FEATURES

INSTRUCTOR RESOURCES

Database Systems: Design, Implementation, and Management, Eleventh Edition, includes teaching tools to support instructors in the classroom. The ancillary material that accompanies the textbook is listed below. They are available on the web at www.cengage.com.

Instructor's Manual

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

SQL Script Files for Instructors

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

ColdFusion Files for Instructors

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

Databases

For many chapters, Microsoft® Access® instructor databases are available that include features not found in the student databases. For example, the databases that accompany Chapters 7 and 8 include many of the queries that produce the problem solutions. Other Access databases, such as the ones that accompany Chapters 3, 4, 5, and 6, include implementations of the design problem solutions to let instructors illustrate the effect of design decisions. In addition, instructors have access to all the script files for Oracle, MySQL, and MS SQL Server so that all the databases and their tables can be converted easily and precisely.

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

PowerPoint® Presentations

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

Figure Files

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

ACKNOWLEDGMENTS

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

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

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

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

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

Mubarak Banisaklher, Bethune Cookman University

David Bell, Pacific Union College

Yurii Boreisha, Minnesota State University Moorhead

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- We are deeply indebted to Deb Kaufmann for her help and guidance. Deb has been everything we could have hoped for in a development editor and more. She brought fresh eyes and a new perspective that meshed wonderfully with our vision for the new edition.
- After writing so many books and ten editions of *this* book, we know just how difficult it can be to transform the authors' work into an attractive product. The production team, both at Cengage Learning (Matt Hutchinson) and GEX Publishing Services (Marisa Taylor), have done an excellent job.
- We also owe Kate Mason, our Content Developer, special thanks for her ability to guide this book to a successful conclusion. Kate's work touched on all of the publication bases, and her managerial skills protected us from publishing gremlins that might have become a major nuisance. Also, her skills in dealing with occasionally cranky authors far exceed those of any diplomat we can think of. And did we mention that Kate is, quite simply, a delightful person? We would also like to thank Anne Merrill, Content Developer, who competently shepherded the text in its later stages.

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

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

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

Carlos Coronel and Steven Morris

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