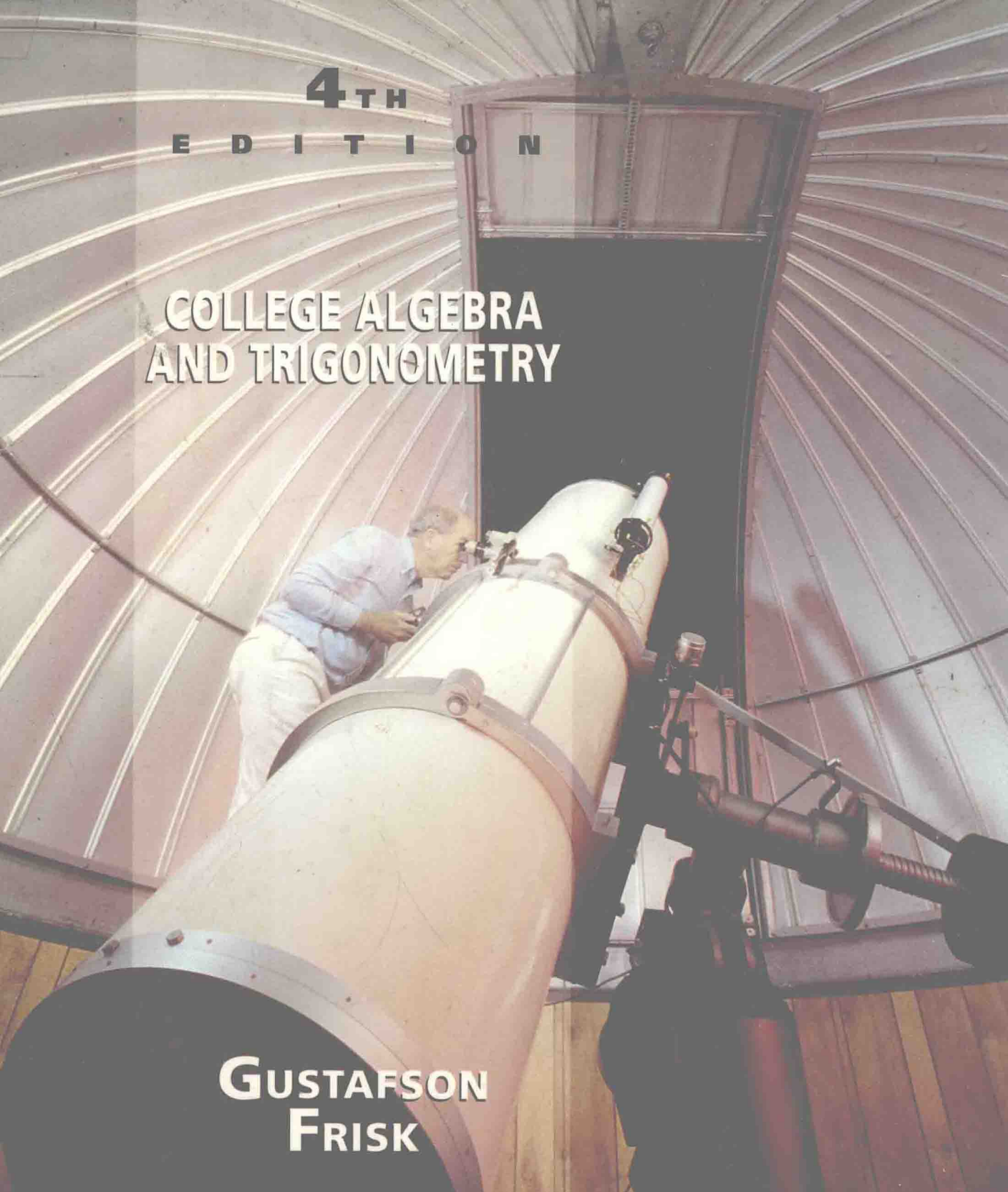
4TH EDITION

COLLEGE ALGEBRA AND TRIGONOMETRY



GUSTAFSON
FRISK

4TH EDITION

COLLEGE ALGEBRA AND TRIGONOMETRY

R. David Gustafson
Peter D. Frisk

Rock Valley College

Brooks/Cole Publishing Company
Pacific Grove, California

Brooks/Cole Publishing Company
A Division of Wadsworth, Inc.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Gustafson, R. David (Roy David), [date]
College algebra and trigonometry/R. David Gustafson, Peter D. Frisk—4th ed.
p. cm.
Includes index.
ISBN 0-534-20862-2
1. Algebra. 2. Trigonometry. I. Frisk, Peter D., [date]. II. Title.
QA154.2.G873 1993
512'.13—dc20 93-8375
CIP

Sponsoring Editors: *Craig Barth, Gary Ostedt*
Editorial Assistant: *Carol Ann Benedict*
Production Editor: *Ellen Brownstein*
Production Service: *Hoyt Publishing Services*
Manuscript Editor: *David Hoyt*
Permissions Editor: *Carline Haga*
Interior and Cover Design: *Roy R. Neuhaus*
Cover and Chapter Opening Photos: *Ed Young*
Interior Illustration: *Lori Heckelman*
Typesetting: *Weimer Graphics, Inc.*
Cover Printing: *Phoenix Color Corp.*
Printing and Binding: *R. R. Donnelley & Sons, Crawfordsville*

About the Cover: The Tularcitos Observatory, a private observatory in Carmel Valley, California, uses this 18-inch Newtonian reflecting telescope as its main instrument. Its mounting is a traditional German-style equatorial mounting and its focal length is 91 inches.

Photo Credits: Cover, Courtesy of Robert Webb, Director of the Tularcitos Observatory; **page 136,** Courtesy of DeltaPoint, Monterey, California; **pages 340, 526,** Courtesy of the Maritime Museum of Monterey; **page 402,** Courtesy of the Antique Clock Shop, Pacific Grove, California; **page 456,** Courtesy of Abinante Music Store, Monterey, California; **page 599,** Courtesy of Monterey Cypress Stained Glass Studio; **page 678,** Courtesy of The Nature Company, Carmel, California; **page 713,** Courtesy of 4S Casino Party Supplies, San Carlos, California.

To our wives:
Carol and Martha
and our children:
Kristy and Steven
Sarah, Heidi, and David

PREFACE

TO THE INSTRUCTOR

College Algebra and Trigonometry, fourth edition, is an extensive revision of the successful third edition. This revision was motivated by the need to better prepare students for the mathematics of the next century.

Although the changes are substantial, our fundamental philosophy as teachers remains unchanged. Consequently, the goal of this book remains the same: to hold attrition to a minimum and to prepare students for success at the next stage, whether it be precalculus, statistics, liberal arts mathematics, calculus, or everyday life.

We believe that the fourth edition attains this goal through a successful blending of content and pedagogy. We present comprehensive, in-depth, precise coverage of the topics of college algebra and trigonometry, incorporated into a framework of tested teaching strategy combined with carefully selected pedagogical features.

Changes for the Fourth Edition

The changes we have made in the fourth edition have several effects:

1. We have increased the emphasis on learning mathematics through graphing. Although graphing calculators are incorporated throughout the book, their use is not required. All of the topics are discussed fully in traditional ways. Of course, we recommend that instructors try the graphing calculator material.
2. We emphasize and motivate problem solving through realistic applications. The variety of applications problems has been increased significantly, and all applications problems are now labeled with special headings.
3. We have fine-tuned the presentation of certain topics for better flow of ideas and greater clarity.

Some of the specific changes made to chapters include:

- Chapter 1, which is mainly review, has been condensed so that instructors can proceed to advanced topics more quickly. The work on complex numbers has been moved to Chapter 2, after a discussion of quadratic equations. Finding solutions of quadratic equations now provides the motivation for discussing complex numbers.
- The applications sections in Chapter 2 have been extensively revised to provide motivation through more authentic and varied applied problems.
- The third edition's Chapter 3 has been divided into two chapters. Chapter 3 now covers graphing lines, slope, writing equations of lines, general graphing of other relations, and ratio and proportion. Graphing calculators are introduced in Chapter 3.
- Chapter 4 covers the more formal aspects of functions and their inverses, including a new section on translations of graphs.
- Chapter 5 covers the remainder and factor theorems, synthetic division, and finding rational roots of polynomial equations. After a brief discussion of the bisection method, graphing calculators are used to find approximations for irrational roots of polynomial equations.
- Chapter 6 discusses logarithms. A thoroughly revised coverage of this topic provides a better flow of ideas. Many more applications problems have been added.
- Chapter 8 begins with an introduction to radians that has been rewritten for greater clarity. The strategy for graphing now uses a sketching point procedure, and many graphing results are confirmed with a graphing calculator.
- Chapter 9 now discusses the algebra of trigonometric expressions—how they are added, subtracted, multiplied, divided, combined, and factored. More identities in some exercise sets provide additional practice. The discussion of general solutions of trigonometric equations has been streamlined. Solving equations with a graphing calculator is now included.
- Chapter 11 covers systems of linear equations. Graphing calculators enhance the discussion of solving systems by graphing. Thoroughly revised applications problems are now more relevant. Matrix methods continue to be emphasized. The material on graphing linear inequalities in two variables has been included in the section that covers systems of linear inequalities. There is now a separate section on linear programming.
- Chapter 12 covers conic sections and quadratic systems. This chapter now contains more applications problems.

The following are some of the specific pedagogical changes:

- Cumulative review exercises follow every few chapters.
-  Warning! Students are now warned about common errors by a special symbol.
- All sections are now divided into subsections with headings. When a section deals with more than one topic, the headings help students focus on each specific topic.
-  All exercises requiring scientific calculators are marked with a special logo.
-  All exercises requiring graphing calculators are marked with a different logo.

At the same time, we have kept the pedagogical features that made previous editions of the book so successful:

Solid Mathematics The treatment of college algebra and trigonometry is direct and straightforward. Although the treatment is mathematically sound, it is not so rigorous that it will confuse students. Every effort has been made to ensure the accuracy of the mathematics and of the answers to the exercises. The book has been critiqued by dozens of reviewers. Both authors and a problem checker have worked every exercise. Although the exercise sets are designed primarily to provide practice and drill, they also contain problems that will challenge the best students. The book contains more than 5000 exercises.

Accessibility to Students The book is written for students to read and understand. The numerous problems within each exercise set are carefully keyed to more than 500 worked examples in which author's notes explain many of the steps used in the problem-solving process. Appendix III contains the answers to the odd-numbered exercises, as well as all the answers to the chapter review exercises, chapter tests, and cumulative review exercises.

Review is an integral part of the book: There are chapter summaries, review exercises at the end of each chapter, cumulative review exercises, and endpapers that list (in order of presentation) the important formulas developed in the book.

Emphasis on Applications To show that mathematics is useful, we include a large number of word problems and applications throughout the book.

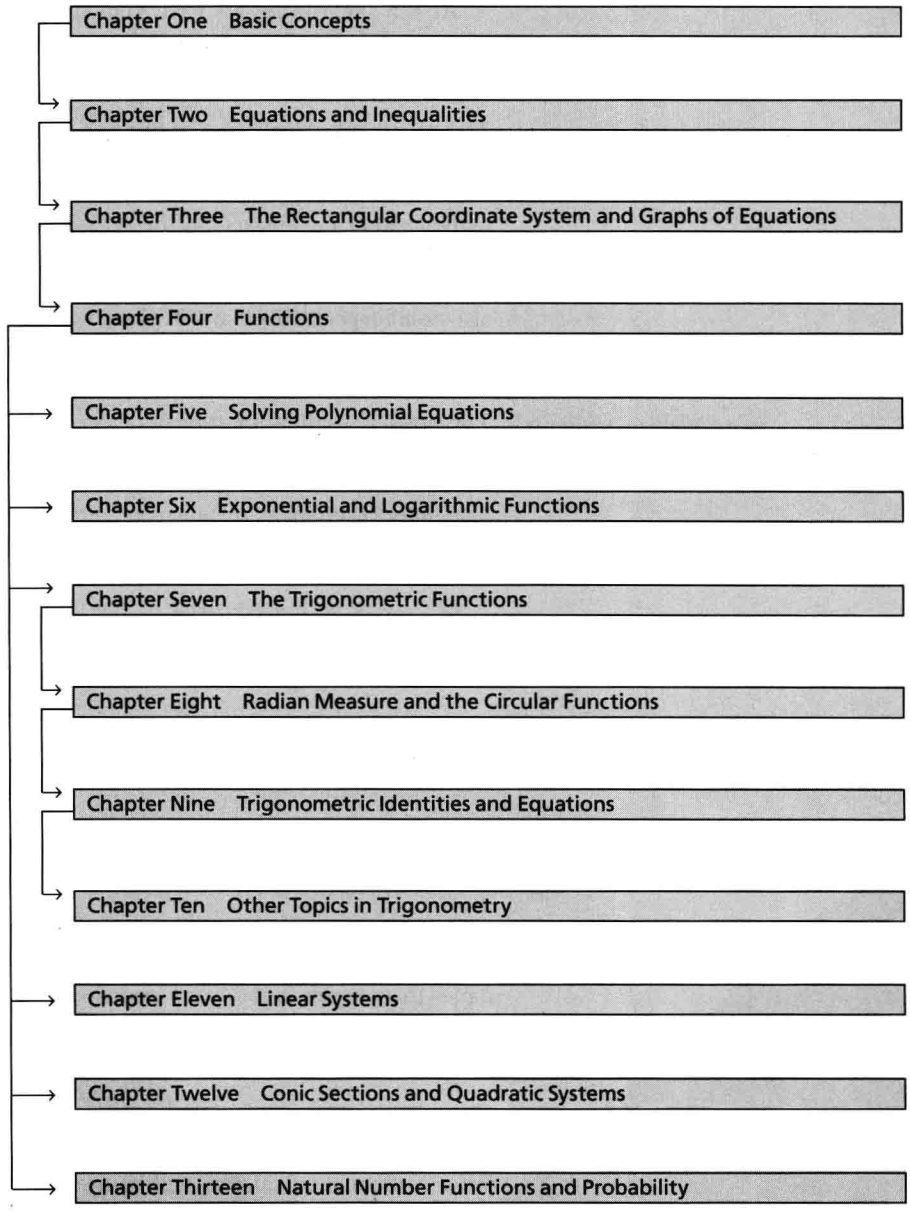
Organization and Coverage

The book can be used in a variety of ways. For optimum flexibility, many of the chapters have been designed to be independent enough that you can pick and choose topics that are relevant to your students' needs. The diagram on the next page shows how the chapters are interrelated.

Calculators

We assume that calculators will be used throughout the book. We believe that students should learn calculator skills in the mathematics classroom. They will then be prepared to use calculators in science and business classes and for nonacademic purposes. The directions within each exercise set indicate which exercises require calculators.

After much thought, we decided not to give keystrokes for any specific model of graphing calculator. Several manufacturers told us that they will soon be introducing new models that have different keystrokes from the models currently available. We do not want to confuse students by giving obsolete keystrokes. Instead, the book covers the features that are common to all graphing calculators.



Topics Covered

Review

Chapters 1 and 2 review topics from basic algebra—the real number system, exponents and radicals, polynomial arithmetic, solutions of linear and quadratic equations, complex numbers, radical equations, inequalities, and absolute value.

Inequalities
Chapter 2 covers inequalities with one variable. Rational inequalities are solved by both the test-point and sign-graph methods. Inequalities with two variables, along with their graphical interpretations, appear in Chapter 11 before the discussion of systems of inequalities.

Functions
The concept of the rectangular coordinate system is introduced in Chapter 3, with emphasis on graphing lines, writing equations of lines, and graphing various relations. Graphing calculators are also introduced in Chapter 3.

Translations of graphs and the more formal aspects of functions, function notation, rational functions, algebra of functions, composition of functions, and inverse functions are now covered in Chapter 4.

Roots of Polynomial Equations
Chapter 5 provides methods for finding rational roots of polynomial equations. Several examples illustrate the interplay between the fundamental theorem of algebra, Descartes' rule of signs, the remainder and factor theorems, the rational-root theorem, and the conjugate-pairs result. A brief discussion of the bisection method precedes using graphing calculators to find irrational roots.

Exponential and Logarithmic Functions
Chapter 6 covers exponential functions, logarithms, and many of their applications. The use of calculators is emphasized in this chapter.

Trigonometry
Trigonometry is introduced by considering trigonometric functions of angles. This is the way that trigonometry developed historically, and we are convinced that this approach makes sense to students. However, we make the transition from angle domains to real number domains very early in the discussion. We have added many new applications and more preparatory work to identities. The sections on graphing have been rewritten. Calculators are used throughout.

Systems of Equations and Inequalities
Chapter 11 includes techniques for solving systems of linear equations. Matrix methods are developed, and some matrix algebra is presented. Linear programming using graphical methods has been expanded into a complete section. The topic of partial fractions is introduced as an application of systems of linear equations.

Conic Sections
Chapter 12 develops the basic forms of the equations for conic sections and provides opportunity for graphing these equations. Solutions of simultaneous second-degree equations are obtained both graphically and algebraically.

Natural Number Functions and Probability
The binomial theorem, permutations, and combinations lead to a presentation of simple and compound probabilities, odds, and mathematical expectation. The chapter includes an introduction to mathematical induction. An induction proof of the binomial theorem appears in Appendix I.

Ancillaries for the Instructor

Instructor's Solutions Manual
Cheryl Roberts

The *Instructor's Solutions Manual* contains solutions to all even-numbered problems in the text.

Test Manual
Teresa Bittner

The *Test Manual* contains three ready-to-use, free-response forms of every chapter test. Answer keys are also provided.

Computer Testing Software

Available with the text is a free-response electronic question bank. The bank contains approximately 1800 test items and is available for both IBM and compatible computers and Macintosh computers. The testing programs give you all of the features of a state-of-the-art word processor and more, including the ability to see all technical symbols, fonts, and formatting on the screen just the way they will appear when printed. The question bank can be edited.

EXPTEST™ runs on IBM and compatible computers.

ExamBuilder™ runs on Macintosh computers.

Ancillaries for the Student

Student Solutions Manual
Darrell Ropp and Michael Welden

The *Student Solutions Manual* contains worked-out solutions for all the odd-numbered exercises in the text. Available for sale to students.

Visual Precalculus
David Schneider

This fun-to-use software for IBM and compatible computers is customized to the text. *Visual Precalculus* uses animation to explore relevant exercises and examples from the text. A mouse is optional. A *Student User's Guide* accompanies the software. Available for sale to students. Site licenses are also available for sale.

Graphing Calculator Activities for Algebra
Miller, Perry, and Tveten

Graphing Calculator Activities for Algebra provides instruction, problems, exploratory exercises and projects, plus instruction and keystrokes for using the TI-81 and Casio 7700 graphing calculators. Available for sale to students.

TO THE STUDENT

Congratulations. You now own a state-of-the-art textbook that has been written especially for you. We, the authors, have tried to write a book that you can read and understand. The book is carefully written and includes an extensive number of worked examples. However, if you intend to get the most out of your algebra course, you must read and study the textbook properly. We recommend that you work the examples on paper and be sure that you understand them before attempting to work the exercises.

A *Student Solutions Manual*, available for sale, contains worked-out solutions to all of the odd-numbered exercises.

The material presented in *College Algebra and Trigonometry*, fourth edition, will be of value to you in later years. Therefore, we suggest that you keep this book after completing the course. It will be a good source of reference and will keep at your fingertips the material that you have learned here.

We wish you well.

Acknowledgments

We are grateful to the following people who reviewed the manuscript in its various stages. All of them had valuable suggestions that have been incorporated into this book.

The reviewers include:

John Adam, Old Dominion University
Daniel Anderson, University of Iowa
Richard Andrews, University of Wisconsin
James Arnold, University of Wisconsin
Wilson Banks, Illinois State University
Judy Barclay, Cuesta College
Jerry Bloomberg, Essex Community College
Elaine Bouldin, Middle Tennessee State University
Dale Boye, Schoolcraft College
Helen Burrier, Kirkwood Community College
James Choike, Oklahoma State University
Lee R. Clancy, Golden West College
Cecelia Cooper, William & Harper College
Romae J. Cormier, Northern Illinois University
Ben L. Cornelius, Oregon Institute of Technology
Gladys Crates, Chattanooga State Tech
Patricia Crawley, Wichita State University
John S. Cross, University of Northern Iowa
M. Hilary Davies, University of Alaska-Anchorage
Marvin P. Davis, Tyler Junior College
Lena Dexter, Faulkner State Junior College
Emily Dickinson, University of Arkansas
Herbert Dekhans, Indiana State University
Edward Doran, Front Range Community College
William Drezdzon, Oakton Community College
Michael Easley, University of New Orleans
Robert E. Eiken, Illinois Central College
Kevin Evans, University of Missouri
Eunice F. Everett, Seminole Community College
Ronald J. Fischer, Evergreen Valley College
Mary Jane Gates, University of Arkansas
Lane Gilliam, Davidson County Community College
Marvin Goodman, Monmouth College
Jerry Gustafson, Beloit College
Jerome Hahn, Bradley University
Douglas Hall, Michigan State University
Robert Hall, University of Wisconsin
Virginia Hanks, Western Kentucky University
David Hansen, Monterey Peninsula College
William Hinrichs, Rock Valley College
Arthur M. Hobbs, Texas A & M University
Jack E. Hofer, California Polytechnic State University
Ingrid Holzner, University of Wisconsin
Warren Jaech, Tacoma Community College
William B. Jones, University of Colorado
Barbara Juister, Elgin Community College
Maryann Justinger, Erie Community College
Robert Keicher, Delta College
Vicki J. Kijewski, Northeast Missouri State University
David Kinsey, University of Southern Indiana
Marjorie O. Labhart, University of Southern Indiana
William Lakin, Old Dominion University
Harvey W. Lambert, University of Nevada-Reno

Jimmie Lawson, Louisiana State University
Jaclyn LeFebvre, Illinois Central College
Shirley Lilge, Cleveland State University
Pamela Littleton, Tarleton State University
Judy McKinney, California Polytechnic State University
Marcus McWaters, University of Southern Florida
Donna Menard, University of Massachusetts-Dartmouth
James W. Mettler, Pennsylvania State University
Eldon L. Miller, University of Mississippi
Stuart E. Mills, Louisiana State University
Lynda Morton, University of Missouri
Diane Murray, North Harris College
Gilbert W. Nelson, North Dakota State University
Marvin Papenfuss, Lora's College
Anthony Peressini, University of Illinois
David L. Phillips, University of Southern Colorado
William H. Price, Middle Tennessee State University
Louise E. Pugh, Fergus Falls Community College
Janet P. Ray, Seattle Central Community College
Janet Ritchie, SUNY at Old Westbury
Cheryl V. Roberts, Northern Virginia Community College
Paul Schaefer, SUNY-Geneseo
Vincent P. Schielack, Jr., Texas A & M University
David Shellabarher, Lane Community College
L. Thomas Shiflett, Southwest Missouri State University
Richard Slinkman, Bemidji State University
Gerald Smith, Cayuga Community College
John Snyder, Sinclair Community College
John Spellman, Southwest Texas State University
Warren Strickland, Del Mar College
Ray Tebbetts, San Antonio College
Faye Thames, Lamar State University
Douglas Tharp, University of Houston-Downtown
Stewart Venit, California State University
Carol M. Walker, Hinds Community College
Carroll G. Wells, Western Kentucky University
William H. White, University of South Carolina-Spartanburg
Charles R. Williams, Midwestern State University
Jeffrey Willmann, Maine Maritime Academy
Clifton Whyburn, University of Houston-University Park
Albert Zechmann, University of Nebraska

We wish to thank the staff at Brooks/Cole, especially Craig Barth, Gary Ostedt, Carol Ann Benedict, Ellen Brownstein, Roy Neuhaus, Audra Silverie, and Sue Ewing for their competent work and support. We give special thanks to David Hoyt for his excellent editing of the manuscript and Lori Heckelman for rendering the art.

We also thank the following people for their skillful preparation of the ancillaries for the text: Teresa Bittner, Darrell Ropp, David Schneider, and Michael Welden. Finally, we thank Diane Koenig and Robert Hessel for their proofreading and problem checking.

R. David Gustafson
Peter D. Frisk

CONTENTS