PREFACE

In the third edition of *Genetics: Analysis & Principles,* the content has been updated to reflect current trends in the field. In addition, the presentation of the content has been improved in a way that fosters active learning. As an author, researcher, and teacher, I want a textbook that gets students actively involved in learning genetics. To achieve this goal, I have worked with a talented team of editors, illustrators, and media specialists who have helped me to make the third edition of *Genetics: Analysis & Principles* a fun learning tool. The features that we feel are most appealing to students, and which have been added to or improved upon in the third edition, are the following.

- **Interactive exercises** Education specialists have crafted interactive exercises in which the students can make their own choices in problem-solving activities, and predict what the outcomes will be. These exercises often focus on inheritance patterns and human genetic diseases. (For example, see Chapters 4 and 22.)
- **Animations** Our media specialists have created over 50 animations for a variety of genetic processes. These animations were made specifically for this textbook, and use the art from the textbook. The animations literally make many of the figures in the textbook "come to life."
- **Experiments** As in the previous editions, each chapter (beginning with Chapter 2) incorporates one or two experiments that are presented according to the scientific method. These experiments are not "boxed off" from the rest of the chapter. Rather, they are integrated within the chapters and flow with the rest of the text. As you are reading the experiments, you will simultaneously explore the scientific method and the genetic principles that have been discovered using this approach. For students, I hope this textbook will help you to see the fundamental connection between scientific analysis and principles. For both students and instructors, I expect that this strategy will make genetics much more fun to explore.
- **Art** The art has been further refined for clarity and completeness. This makes it easier and more fun for students to study the illustrations without having to go back and forth between the art and the text.
- **Engaging text** A strong effort has been made in the third edition to pepper the text with questions. Sometimes these are questions that scientists considered when they were conducting their research. Sometimes they are questions that the students might ask themselves when they are learning about genetics.

Overall, an effective textbook needs to accomplish three goals. First, it needs to provide comprehensive, accurate, and up-to-date content in its field. Second, it needs to provide students with an exposure to the techniques and skills that are needed for them to become successful in that field. And finally, it should inspire students so they want to pursue that field as a career. The hard work that has gone into the third edition of *Genetics: Analysis & Principles* has been aimed at achieving all three of these goals.

HOW WE EVALUATED YOUR NEEDS

ORGANIZATION

In surveying many genetics instructors, it became apparent that most people fall into two camps: **Mendel first** versus **Molecular first.** I have taught genetics both ways. As a teaching tool, this textbook has been written with these different teaching strategies in mind. The organization and content lend themselves to various teaching formats.

Chapters 2 through 8 are largely inheritance chapters, while Chapters 24 through 26 examine population and quantitative genetics. The bulk of the molecular genetics is found in Chapters 9 through 23, although I have tried to weave a fair amount of molecular genetics into Chapters 2 through 8 as well. The information in

Chapters 9 through 23 *does not assume* that a student has already covered Chapters 2 through 8. Actually, each chapter is written with the perspective that instructors may want to vary the order of their chapters to fit their students' needs.

For those who like to discuss inheritance patterns first, a common strategy would be to cover Chapters 1 through 8 first, and then possibly 24 through 26. (However, many instructors like to cover quantitative and population genetics at the end. Either way works fine.) The more molecular and technical aspects of genetics would then be covered in Chapters 9 through 23. Alternatively, if you like the "Molecular first" approach, you would probably cover Chapter 1, then skip to Chapters 9 through 23, then return to Chapters 2 through 8, and then cover Chapters 24 through 26 at the end of the course. This textbook was written in such a way that either strategy works just fine.

ACCURACY

Both the publisher and I acknowledge the fact that inaccuracies can be a source of frustration for both the instructor and students. Therefore, throughout the writing and production of this textbook we have worked very hard to catch and correct errors during each phase of development and production.

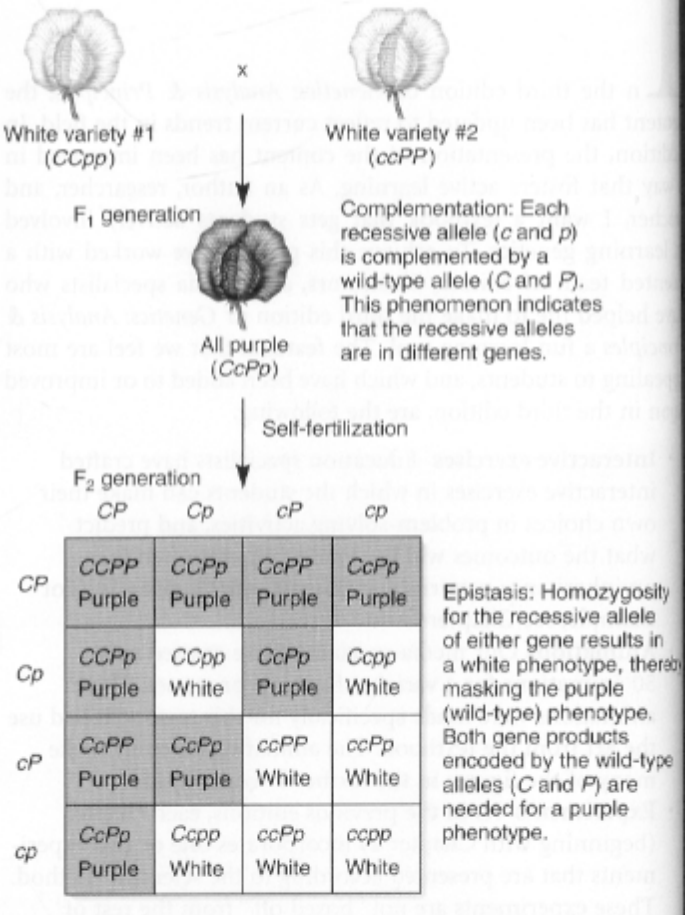
Each chapter has been reviewed by a minimum of ten people. At least eight of these people were faculty members who teach the course and/or conduct research in genetics. In addition, two development editors have gone through the material, at least twice, to check for accuracy in art, and consistency between the text and art. We also had a team of students work through all the problem sets and one development editor also checked them. The author personally checked every question and answer when the chapters were completed.

PEDAGOGY

Based on our discussions with instructors from many institutions, some common goals have emerged. Instructors want a broad textbook that clearly explains concepts in a way that is interesting, accurate, concise, and up-to-date. Likewise, most instructors want students to understand the experimentation that revealed these genetic concepts. In this textbook, concepts and experimentation are woven together to provide a story that enables students to learn the important genetic concepts that they will need in their future careers, and also to be able to explain the types of experiments that allowed researchers to derive such concepts. The end-of-chapter problem sets are categorized according to their main focus, either conceptual or experimental, although some problems contain a little of both. The problems are meant to strengthen students' abilities in a wide variety of ways.

- By bolstering their understanding of genetic principles.
- By enabling students to apply genetic concepts to new situations.
- By analyzing scientific data.
- By organizing their thoughts regarding a genetic topic.
- By improving their writing skills.

Finally, since genetics is such a broad discipline rangi from the molecular to the populational levels, many instructo have told us that it is a challenge for students to see both "t forest and the trees." It is commonly mentioned that studen often have trouble connecting the concepts they have learn in molecular genetics with the traits that occur at the level of whole organism (i.e., What does transcription have to do wi blue eyes?). To try to make this connection more meaningfu certain figure legends in each chapter, designated **Genes→ Trait** remind students that molecular and cellular phenomena ult mately lead to the traits that are observed in each species (fo example, see Figure 4.20).



INTERACTIVE EXERCISE

FIGURE 4.20 A cross between two different white varieties of the sweet pea.

Genes → Traits The color of the sweet pea flower is controlled by two genes, which are epistatic to each other and show complementation. Each gene is necessary for the production of an enzyme required for pigment synthesis. The recessive allele of either gene encodes a defective enzyme. If an individual is homozygous recessive for either of the two genes, the purple pigment cannot be synthesized. This results in a white phenotype.

ILLUSTRATIONS

In surveying students whom I teach, I often hear it said that most of their learning comes from studying the figures. Likewise, instructors frequently use the illustrations from a textbook as a central teaching tool. For these reasons, the greatest amount of effort in improving the third edition has gone into the illustrations. The illustrations have been refined with four goals in mind:

1. **Completeness** For most figures, it should be possible to understand an experiment or genetic concept by looking at the illustration alone. Students have complained that it is difficult to understand the content of an illustration if they have to keep switching back and forth between the figure and text. In cases where an illustration shows the steps in a scientific process, the steps are described in brief statements that allow the students to understand the whole process (for example, see Figure 12.10). Likewise, such illustrations should make it easier for instructors to explain these processes in the classroom.
2. **Clarity** The figures have been extensively reviewed by students and instructors. This has helped us to avoid drawing things that may be confusing or unclear. I hope that no one looks at an element in any figure and wonders, "What is that thing?" Aside from being unmistakably drawn, all new elements within each figure are clearly labeled.
3. **Consistency** Before we began to draw the figures for the second edition, we generated a style sheet that contained recurring elements that are found in many places in the textbook. Examples include the DNA double helix, DNA polymerase, and fruit flies. We agreed upon the best way(s) to draw these elements and also what colors they should be. Therefore, as students and instructors progress through this textbook, they become accustomed to the way things should look.
4. **Realism** An important goal of this and previous editions is to make each figure as realistic as possible. When drawing macroscopic elements (for example, fruit flies, pea plants), the illustrations are based on real images, not on cartoonlike simplifications. Our most challenging goal, and one that we feel has been achieved most successfully, is the realism of our molecular drawings. Whenever possible, we have tried to depict molecular elements according to their actual structures, if such structures are known. For example, the ways we have drawn RNA polymerase, DNA polymerase, DNA helicase, and ribosomes are based on their crystal structures. When a student sees a figure in this textbook that illustrates an event in transcription, RNA polymerase is depicted in a way that is as realistic as possible (for example, see Figure 12.10).

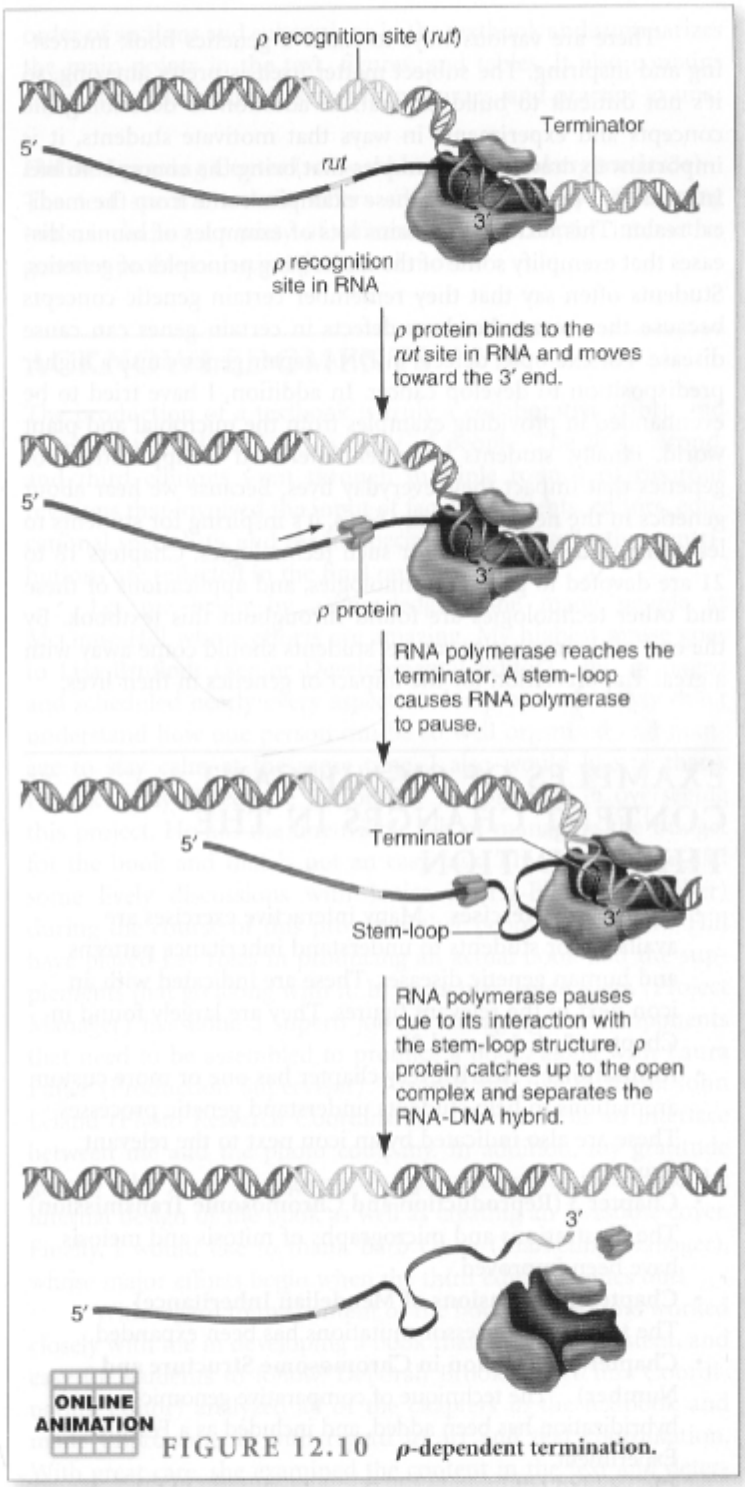


FIGURE 12.10 **ρ-dependent termination.**

WRITING STYLE

Motivation in learning often stems from enjoyment. If someone enjoys what they're reading, they are more likely to spend longer amounts of time with it and focus their attention more crisply. The writing style of this book is meant to be interesting, down to earth, and easy to follow. Each section of every chapter begins with an overview of the contents of that section, usually with a table or figure that summarizes the broad points. The section then examines how those broad points were discovered experimentally, as well as explaining many of the finer scientific details. Important terms are introduced in a boldface font. These terms are also found in the glossary.

There are various ways to make a genetics book interesting and inspiring. The subject matter itself is pretty amazing, so it's not difficult to build on that. In addition to describing the concepts and experiments in ways that motivate students, it is important to draw upon examples that bring the concepts to life. In a genetics book, many of these examples come from the medical realm. This textbook contains lots of examples of human diseases that exemplify some of the underlying principles of genetics. Students often say that they remember certain genetic concepts because they remember how defects in certain genes can cause disease. For example, defects in DNA repair genes cause a higher predisposition to develop cancer. In addition, I have tried to be evenhanded in providing examples from the microbial and plant world. Finally, students are often interested in applications of genetics that impact their everyday lives. Because we hear about genetics in the news on a daily basis, it's inspiring for students to learn the underlying basis for such technologies. Chapters 18 to 21 are devoted to genetic technologies, and applications of these and other technologies are found throughout this textbook. By the end of their genetics course, students should come away with a greater appreciation for the impact of genetics in their lives.

EXAMPLES OF SIGNIFICANT CONTENT CHANGES IN THE THIRD EDITION

- **Interactive Exercises** Many interactive exercises are available for students to understand inheritance patterns and human genetic diseases. These are indicated with an icon next to the relevant figures. They are largely found in Chapters 2, 4, 5, 7, and 22.
- **Animations** Nearly every chapter has one or more custom animations to help students understand genetic processes. These are also indicated by an icon next to the relevant figure.
- **Chapter 3 (Reproduction and Chromosome Transmission)** The illustrations and micrographs of mitosis and meiosis have been improved.
- **Chapter 4 (Extensions of Mendelian Inheritance)** The topic of suppressor mutations has been expanded.
- **Chapter 8 (Variation in Chromosome Structure and Number)** The technique of comparative genomic hybridization has been added, and included as a Feature Experiment.
- **Chapter 10 (Chromosome Organization and Molecular Structure)** An illustration and expanded discussion has been added for SMC proteins, which are involved with chromosome condensation and sister chromatid cohesion. Also, the histone code hypothesis is discussed and illustrated.
- **Chapter 11 (DNA Replication)** Illustrations in this chapter now depict the step-by-step formation of Okazaki fragments (for example, see Figure 11.10).
- **Chapter 13 (Translation of mRNA)** This chapter has undergone some reorganization to bring the basic concepts of translation to the first section.
- **Chapter 15 (Gene Regulation in Eukaryotes)** The topic of RNA interference has been expanded, including a Feature Experiment of the work of Fire and Mellow.
- **Chapter 16 (Gene Mutation and DNA Repair)** To complement some new material in Chapter 4, several examples of suppressor mutations are described. In addition, homologous recombination repair and nonhomologous end joining repair are illustrated and discussed within the context of repairing double-stranded DNA breaks.
- **Chapter 19 (Biotechnology)** Some new topics in biotechnology have been added including GloFish® and Bt corn.
- **Chapter 20 (Genomics I: Analysis of DNA)** The approach of shotgun DNA sequencing is greatly expanded along with complementary illustrations.
- **Chapter 21 (Genomics II: Functional Genomics, Proteomics, and Bioinformatics)** The method of chromatin immunoprecipitation (ChIP) has been added.
- **Chapter 22 (Medical Genetics and Cancer)** Several new topics have been added including the use of molecular markers in the mapping of human genetic diseases, and the molecular profiling of cancer cells using DNA microarrays.
- **Chapter 24 (Population Genetics)** This chapter contains an expanded discussion of natural selection with graphical representations of the various types. An entire new section on Sources of Genetic Variation has been added so students can appreciate how/why genetic variation is so prevalent.
- **Chapter 26 (Evolutionary Genetics)** The cladistic approach has been greatly expanded. In addition, an entire section on Evolutionary Developmental Biology (Evo-Devo) has been added.

SUGGESTIONS WELCOME!

It seems very appropriate to use the word evolution to describe the continued development of this textbook. I welcome any and all comments. The refinement of any science textbook requires input from instructors and their students. These include comments regarding writing, illustrations, supplements, factual content, and topics that may need greater or less emphasis. You are invited to contact me at:

Dr. Rob Brooker
Dept. of Genetics, Cell Biology, and Development
University of Minnesota
6-160 Jackson Hall
321 Church St.
Minneapolis, MN 55455
brook005@umn.edu

TEACHING AND LEARNING SUPPLEMENTS

McGraw-Hill offers various tools and technology products to support the third edition of *Genetics: Analysis & Principles.*

FOR THE INSTRUCTOR:

Online Learning Center (www.mhhe.com/brookergenetics3e)
The text specific website offers an extensive array of learning and teaching tools. In addition to student resources, the site also includes an instructor's manual, test bank, and lecture outlines.

Presentation Center
Complete set of electronic book images and assets for instructors
Build instructional materials wherever, whenever, and however you want! Accessed from your textbook's Online Learning Center, Presentation Center is an online digital library containing photos, artwork, animations, and other media types that can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, or attractive printed support materials. All assets are copyrighted by McGraw-Hill Higher Education, but can be used by instructors for classroom purposes. The visual resources in this collection include:

- **Art** Full-color digital files of all illustrations in the book can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. In addition, all files are pre-inserted into PowerPoint slides for ease of lecture preparation.
- **Photos** The photo collection contains digital files of photographs from the text, which can be reproduced for multiple classroom uses.
- **Tables** Every table that appears in the text has been saved in electronic form for use in classroom presentations and/or quizzes.
- **Animations** Numerous full-color animations illustrating important processes are also provided. Harness the visual impact of concepts in motion by importing these files into classroom presentations or online course materials.

Also residing on your textbook's Online Learning Center are:

- **PowerPoint Lecture Outlines** Ready-made presentations that combine art and lecture notes are provided for each chapter of the text.
- **PowerPoint Slides** For instructors who prefer to create their lectures from scratch, all illustrations, photos, and tables are pre-inserted by chapter into blank PowerPoint slides.

FOR THE STUDENT:

Student Study Guide/Solutions Manual
The solutions to the end-of-chapter problems and questions will aid the students in developing their problem-solving skills by providing the steps for each solution. The Study Guide follows the order of sections and subsections in the textbook and summarizes the main points in the text, figures, and tables. It also contains concept-building exercises, self-help quizzes, and practice exams.

Online Learning Center (www.mhhe.com/brookergenetics3e)
The text specific website offers an extensive array of learning tools, including a variety of quizzes for each chapter, interactive genetics problems, animations, and more.

ACKNOWLEDGMENTS

The production of a textbook is truly a collaborative effort, and I am greatly indebted to a variety of people. The first, second, and third editions went through multiple rounds of rigorous revisions that involved the input of faculty, students, editors, educational specialists, and media specialists. Their collective contributions are reflected in the final outcome.

Let me begin by acknowledging the many people at McGraw-Hill whose efforts are amazing. My highest praise goes to Lisa Bruflodt (Senior Developmental Editor), who managed and scheduled nearly every aspect of this project. I simply don't understand how one person can be so well organized and manage to stay calm at the same time. I also would like to thank Patrick Reidy (Executive Editor) for his patience in overseeing this project. He has the unenviable job of managing the budget for the book and that is not an easy task. I'm sure that he had some lively discussions with Janice Roerig-Blong (Publisher) during the course of this project. Other people at McGraw-Hill have played key roles in producing an actual book and the supplements that go along with it. In particular, Jayne Klein (Project Manager) has done a superb job of managing the components that need to be assembled to produce a book, along with Laura Fuller (Production Supervisor). I would also like to thank John Leland (Photo Research Coordinator), who acted as an interface between me and the photo company. In addition, my gratitude goes to John Joran (Designer), who provided much input into the internal design of the book as well as creating an awesome cover. Finally, I would like to thank Barb Owca (Marketing Manager), whose major efforts begin when the third edition comes out!

With regard to the content of the book, two editors worked closely with me in developing a book that is clear, consistent, and easy for students to follow. Deborah Brooker (Art/Text Coordinating Editor) analyzed all of the chapters in the textbook and made improvements with regard to art and text coordination. With great care, she examined the content in the text and determined if it matched what is found in the illustrations; she also checked every illustration for clarity and completeness. The high quality and pedagogy of the art are largely due to her efforts. She also scrutinized the text for clarity and logic. In addition, Joni Fraser (Freelance Development Editor) analyzed each chapter for its overall content and made many valuable suggestions for improvements. She did a great job of sharpening the writing. I am particularly grateful for her meticulous analysis of the problem sets. In her spare time, I think she may have worked all of

the problems. In addition to Deb and Joni, I would also like to thank Jane DeShaw (Freelance Copy Editor) for making grammatical improvements throughout the text and art.

I would also like to extend a special thanks to everyone at Imagineering, the art house that produced the illustrations in the second and third editions. Though we initially considered several art houses, when we saw how Imagineering could draw RNA polymerase, it was clear who the winner was. Their ability to draw three-dimensional molecular structures is outstanding. I am grateful to the many artists and contact people at Imagineering who have played important roles in developing the art for the second and third editions. Likewise, the people at Pronk & Associates have done a great job of locating many of the photograph that have been used in the third edition. Also, Lachina Publishing Services worked with great care in the paging of the book making sure that the figures and relevant text are as close to each other as possible.

Finally, I want to thank the many scientists who reviewed the chapters of this textbook. Their broad insights and constructive suggestions were an important factor that shaped its final content and organization. I am truly grateful for their time and effort

REVIEWERS

Shivanthi Anandan, *Drexel University*
Alan G. Atherly, *Iowa State University*
William Baird, *Clemson University*
Gail S. Begley, *Northeastern University*
Michael Benedik, *University of Houston*
Kelly Bidle, *Rider University*
Andrew J. Bohonak, *San Diego State University*
Mark A. Brick, *Colorado State University*
James J. Campanella, *Montclair State University*
Arden Campbell, *Iowa State University*
Gerard Campbell, *University of Pittsburgh*
Diane A. Caporale, *University of Wisconsin–Stevens Point*
J. Aaron Cassill, *University of Texas at San Antonio*
Richard W. Cheney, Jr., *Christopher Newport University*
Joseph P. Chinnici, *Virginia Commonwealth University*
Brian Condie, *University of Georgia*
Gregory Copenhaver, *University of North Carolina*
Stephen J. D'Surney, *University of Mississippi*
Sumana Datta, *Texas A&M University*
Jeff DeJong, *University of Texas at Dallas*
Robert S. Dotson, *Tulane University*
Johnny El-Rady, *University of South Florida*
Susan Elrod, *California Polytechnic State University*
Bert Ely, *University of South Carolina*
Les Erickson, *Salisbury University*
Michael L. Foster, *Eastern Kentucky University*
Robert G. Fowler, *San Jose State University*
Richard F. Gaber, *Northwestern University*
Sudhindra R. Gadagkar, *University of Dayton*
Matthew R. Gilg, *University of North Florida*
Jack R. Girton, *Iowa State University*
Michael A. Goldman, *San Francisco State University*
Elliott S. Goldstein, *Arizona State University*
Nels H. Granholm, *South Dakota State University*
Alison Hill, *Duke University*
Ralph Hillman, *Temple University*
David C. Hinkle, *University of Rochester*
J. Spencer Johnston, *Texas A&M University*
Gregg Jongeward, *University of the Pacific*
Christopher Kvaal, *St. Cloud State University*
Arlene T. Larson, *University of Colorado at Denver*
Elena Levine Keeling, *California Polytechnic State University*
Rebecca Lyczak, *Ursinus College*
Jocelyn Malamy, *University of Chicago*
Philip M. Mathis, *Middle Tennessee State University*
Terry R. McGuire, *Rutgers University*
Mark E. Meade, *Jacksonville State University*
Roderick M. Morgan, *Grand Valley State University*
Robert Moss, *Wofford College*
Jacqueline Peltier Horn, *Houston Baptist University*
David K. Peyton, *Morehead State University*
Chara J. Ragland, *Texas A&M University*
David H. Reed, *University of Mississippi*
Linda L. Restifo, *University of Arizona*
Inder Saxena, *University of Texas at Austin*
Deemah N. Schirf, *University of Texas at San Antonio*
Mark Schlueter, *Xavier University of Louisiana*
Ekaterina G. Sedia, *The Richard Stockton College of New Jersey*
Jeff Sekelsky, *University of North Carolina at Chapel Hill*
Richard N. Sherwin, *University of Pittsburgh*
Joan Smith Sonneborn, *University of Wyoming*
Adriana Stoica, *Georgetown University*
Martin Tracey, *Florida International University*
Carol Trent, *Western Washington University*
Sarah Ward, *Colorado State University*
Dan E. Wells, *University of Houston*
Douglas Wendell, *Oakland University*
Frederick Whipple, *California State University–Fullerton*
Mark Winey, *University of Colorado–Boulder*
David Wofford, *University of Florida*
Daniel Wang, *University of Miami*

ACCURACY CHECKERS

Ruth Ballard, *CSU–Sacramento*
Michel Baudry, *USC*
Michael Benedik, *University of Houston*
Carey Booth, *Portland State University*
Matt Bozovsky, *Loyola University*

Joel Chandlee, *University of Rhode Island*
Henry Chang, *Purdue University*
Karen Cichy, *Michigan State University*
Brian Condie, *University of Georgia*
Erin Cram, *Northeastern University*
Jeff DeJong, *University of Texas at Dallas*
Rodney Dyer, *Virginia Commonwealth University*
Kevin Edwards, *Illinois State University*
Aboubaker Elkharroubi, *Johns Hopkins University*
Cedric Feschotte, *UT–Arlington*
David Foltz, *Louisiana State University*
Michael Foster, *Eastern Kentucky University*
Thomas Fowler, *Southern Illinois University*
Anne Galbraith, *UW–Lacrosse*
Jack Girton, *Iowa State University*
Elliott Goldstein, *ASU*
Christine Gray, *University of Puget Sound*
Tara Harmer Luke, *The Richard Stockton College of NJ*
Marilyn Hart, *Mankato State University*
Daryl Henderson, *Stony Brooker University*
Adam Hrincevich, *LSU*
Michael Ibba, *Ohio State University*
Margaret Jefferson, *CSU–LA*
David Kass, *Eastern Michigan University*
Cindy Malone, *CSU–Northridge*
John Mishler, *Delaware Valley College*
James Morris, *Clemson University*
Sang-Chul Nam, *Baylor University*
Daniel Odom, *California State University–Northridge*
Michael Polymenis, *Texas A&M University*
David Reed, *University of Mississippi*
Laurie Russell, *St. Louis University*
Mark Seeger, *Ohio State University*
Theresa Spradling, *University of Northern Iowa*
JD Swanson, *University of Central Arkansas*
James Thompson, *University of Oklahoma*
John Tomkiel, *U of NC–Greensboro*
Carol Trent, *Western Washington University*
Fyodor Urnov, *University of California–Berkeley*
Harald Vaessin, *Ohio State University*
Alan Waldman, *University of South Carolina*
Daniel Wang, *University of Miami*
Sarah Ward, *Colorado State University*
Matt White, *Ohio University*
Dwayne Wise, *Mississippi State University*
Yang Yen, *South Dakota State University*
Malcolm Zellars, *Georgia State University*
Jianzhi Zhang, *University of Michigan*