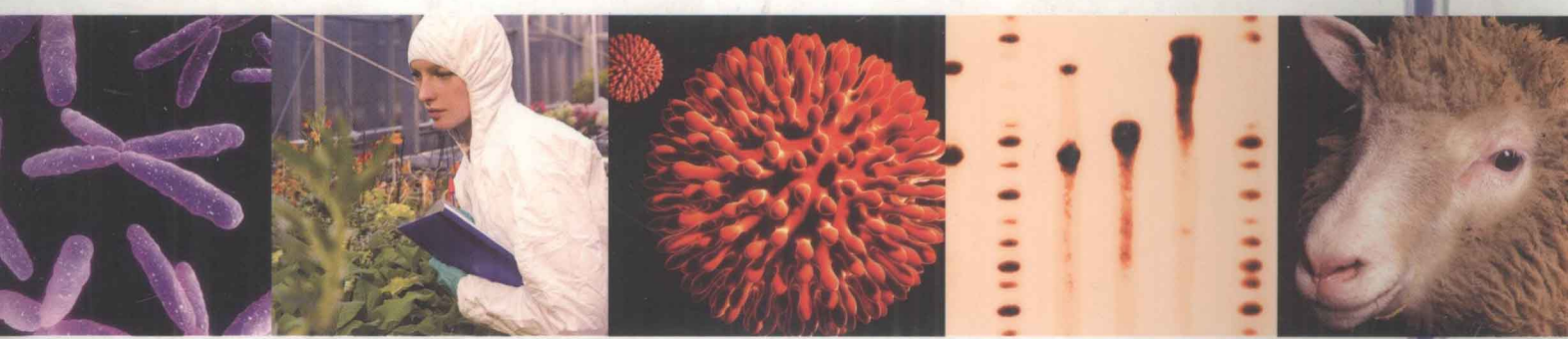
Introduction to Biotechnology

Second Edition

William J. Thieman and Michael A. Palladino



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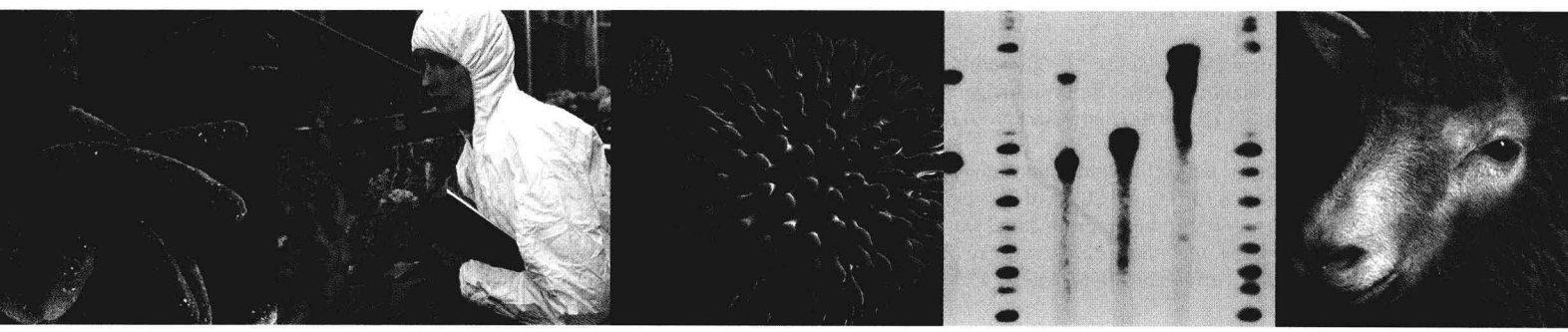

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Introduction to **Biotechnology**

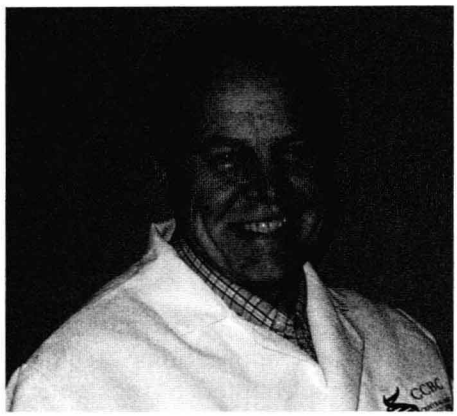
To my wife Billye, the love of my life,
and to the hundreds of biotechnology graduates
who are now doing good science at biotechnology companies
and loving every minute of it.

W. J. T.

To Maria and Angelo, my parents,
for providing all the love and support
a family could ask for.

M. A. P.

About the Authors



Mr. Bill Thieman in the lab.

Dr. Palladino in the lab with undergraduate biology student researchers.

William J. Thieman taught biology at Ventura College for 35 years and biotechnology for 11 years before retiring from full time teaching in 2005. He continues to teach the biotechnology course at Ventura part-time. He received his B.A. in biology from California State University at Northridge in 1966 and his M.A. degree in Zoology in 1969 at UCLA. In 1993, he started a biotechnician training program at Ventura College where he has been teaching since 1970. In 1995, he added laboratory skills components to the course and articulated it as a state-approved vocational program.

Mr. Thieman has taught a broad range of undergraduate courses including general, human, and cancer biology. He received the Outstanding Teaching Award from the National Biology Teachers Association in 1996 and the 1997 and 2000 Student Success Award from the California Community Colleges Chancellor Office. The Economic Development Association presented the biotechnology training program at Ventura College its 1998 Program for Economic Development Award for its work with local biotechnology companies. His success at acquiring grants to support the program was recognized at the National Center for Resource Development Conference in 2007.

Michael A. Palladino is Dean of the School of Science, Technology and Engineering, and an Associate Professor of Biology at Monmouth University in West Long Branch, New Jersey. He received his B.S. degree in Biology from Trenton State College (now known as The College of New Jersey) in 1987, and his Ph.D. in Anatomy and Cell Biology from the University of Virginia in 1994. From 1994 to 1999, he was a faculty member at Brookdale Community College in Lincroft, New Jersey. He joined the Monmouth faculty in 1999.

Dr. Palladino has taught a wide range of undergraduate courses. He has received several awards for research and teaching including the Distinguished Teacher Award from Monmouth University, Caring Heart Award from the New Jersey Association for Biomedical Research, the New Investigator Award of the American Society of Andrology, and the Outstanding Colleague Award from Brookdale Community College. At Monmouth, he has an active lab of undergraduates involved in research on the cell and molecular biology of male reproductive organs. He is founder and director for the New Jersey Biotechnology Educators Consortium, a statewide association for biotechnology teachers.

Dr. Palladino is author of *Understanding the Human Genome Project,* the first volume in the *Benjamin Cummings Special Topics in Biology Series* for which he also serves as series editor. Dr. Palladino recently joined the writing team of W.S. Klug, M.R. Cummings and C.A. Spencer on *Concepts of Genetics* and *Essentials of Genetics*, both published by Benjamin Cummings.

Preface

It is hard to imagine a more exciting time to be studying biotechnology. Advances are occurring at a dizzying pace, and biotechnology has made an impact on many aspects of our everyday lives. *Introduction to Biotechnology* is the first biotechnology textbook written specifically for the diverse backgrounds of undergraduate students. Appropriate for students at both two- and four-year schools and vocational technical schools, *Introduction to Biotechnology* provides students with the tools for practical success in the biotechnology industry through its balanced coverage of molecular biology, details on contemporary techniques and applications, integration of ethical issues, and career guidance.

Introduction to Biotechnology was designed with several major goals in mind. The text aims to provide:

- An engaging and easy-to-understand narrative that is appropriate for a diverse student audience with varying levels of scientific knowledge.
- Assistance to instructors teaching all major areas of biotechnology and help to students learning fundamental scientific concepts without overwhelming and excessive detail.
- An overview of historic applications while emphasizing modern, cutting-edge, and emerging areas of biotechnology.
- Insights on how biotechnology applications can provide some of the tools to solve important scientific and societal problems for the benefit of humankind and the environment.
- Inspiration for students to ponder the many ethical issues associated with biotechnology.

Introduction to Biotechnology provides broad coverage of topics including molecular biology, bioinformatics, genomics, and proteomics. We have strived to incorporate balanced coverage of basic molecular biology with practical and contemporary applications of biotechnology to provide students with the tools and knowledge to understand the field.

In our effort to introduce students to the cutting-edge techniques and applications of biotechnology, we dedicated specific chapters to such emerging areas as agricultural biotechnology (Chapter 6), forensic biotechnology (Chapter 8), bioremediation (Chapter 9), and aquatic biotechnology (Chapter 10). Consideration of the many regulatory agencies and issues that impact the biotechnology industry are discussed in Chapter 12. In addition to the ethical issues included in each chapter as *You Decide* boxes, a separate chapter (Chapter 13) is dedicated to ethics and biotechnology.

Features

Introduction to Biotechnology is specifically designed to provide several key elements that will help students enjoy learning about biotechnology and prepare them for a career in biotechnology.

Learning Objectives

Each chapter begins with a short list of learning objectives that present key concepts that students should understand after studying each chapter.

Abundant Illustrations

Approximately 200 figures and photographs provide comprehensive coverage to support chapter content. Illustrations, instructional diagrams, tables, and flow charts present step-by-step explanations that visually help students learn about laboratory techniques and complex processes that are important in biotechnology.

Career Profiles

A special box at the end of each chapter introduces students to different job options and career paths in the biotechnology industry and provides detailed information on job functions, salaries, and guidance for preparing to enter the workforce. Experts currently working in the biotechnology industry have contributed information to many of these **Career Profile** boxes. We strongly encourage students to refer to these profiles if they are interested in learning more about careers in the industry.

You Decide

From genetically modified foods to stem cell research, there are an endless number of topics in biotechnology that provoke strong ethical, legal, and social questions and dilemmas. **You Decide** boxes stimulate discussion in each chapter by presenting students with information that relates to the social and ethical implications of biotechnology followed by a set of questions for them to consider. The goal of these boxes is to help them understand *how* to consider ethical issues and formulate their own informed decisions.

Tools of the Trade

Biotechnology is based on the application of various laboratory techniques or tools in molecular biology, biochemistry, bioinformatics, genetics, mathematics, engineering, computer science, chemistry, and other disciplines. **Tools of the Trade** boxes in each chapter present modern techniques and technologies related to the content of each chapter to help students learn about the techniques and laboratory methods that are the essence of biotechnology.

Question & Answer (Q&A) Boxes

Q & A boxes in each chapter present students with questions they might be wondering about as they read the book. The answers provide background information and enrich student learning.

Questions & Activities

Questions are included at the conclusion of each chapter to reinforce student understanding of concepts. Activities frequently include internet assignments that ask students to explore a cutting-edge topic. Answers to these questions are provided at the end of the text.

References and Further Reading

A short list of references at the end of each chapter is provided as a starting point for students to learn more about a particular topic in biotechnology. We have carefully chosen articles that will help students and motivate them to learn more about a subject. Typically these references include primary research papers, review articles, and articles from the popular literature.

Keeping Current: Web Links

Because biotechnology is such a rapidly changing discipline, it is virtually impossible to keep a textbook updated on new and exciting discoveries. To help students access the most current information available, a rich complement of high-quality web links to some of the best sites in biotechnology and related disciplines are available on the Companion Website for this text, www.pearsonhighered.com/ biotechnology. Realizing that web links may frequently change, we tried to select substantive sites that are well established. We encourage you to let us know when you encounter address changes so we may update them.

Glossary

Like any technical discipline, biotechnology has a lexicon of terms and definitions that are routinely used when discussing processes, concepts, and applications. The most important terms are shown in **boldface type** throughout the book and are defined as they appear in the text. Definitions of these key terms are included in a glossary at the end of the book.

New Features for the Second Edition

The second edition of *Introduction to Biotechnology* includes several new instructor resources and exciting features:

- Increased end-of-chapter Questions and Activities, including more Internet-based exercises.
- A computerized test bank with multiple choice questions for each chapter; electronic files for all images in the textbook; and PowerPoint Lecture Outline slides, conveniently located on the Instructor's Resource Center, www.pearsonhighered.com/educator.
- New *You Decide* entries have been added to stimulate student interest in controversial areas of biotechnology.

In addition, each chapter has been thoroughly revised and updated to provide students with current information on emerging areas of biotechnology. Of special note are the following changes:

- **Chapter 1: The Biotechnology Century and Its Workforce** includes a new section on the "Business of Biotechnology" describing biotech company organization and structure, top biotechnology and pharmaceutical companies, and updated data on the biotechnology industry worldwide.
- **Chapter 2: An Introduction to Genes and Genomes** provides new content on transcription factors.
- **Chapter 3: Recombinant DNA Technology and Genomics** includes new sections on RNA interference (RNAi) and genomics and bioinformatics, updated content on the Human Genome Project, new content on comparative genomics, stone age genomics, and the "omics" revolution, and new content on high-throughput computer automated DNA sequencing, and real-time PCR.
- **Chapter 4: Proteins as Products** includes new information on mass spectrometry as the method of choice for protein sequencing and protein identification, and protein microarray studies.
- **Chapter 5: Microbial Biotechnology** includes new information on potential biological pathogens for bioweapons attacks on food sources, the use of gene microarrays for detecting host responses to pathogens and the use of protein microarrays for detecting bioweapons pathogens. New sections on metagenomics, assembling genomes to produce manufactured viruses, and new information on the human papillomavirus vaccine, Gardasil.
- **Chapter 6: Plant Biotechnology** provides updates on how genetically engineered plants have been used to replace other crops for better pest resistance, higher yields, and new applications in fiber, bioplastics, biofuels, and bioremediation. New information on plant polyploids, and using plant material to make bioethanol production economical.
- **Chapter 7: Animal Biotechnology** provides updates on using mice with partial human immune systems for testing drug responses, the use of transgenic animals to produce vaccines, and using transgenic animal bioreactors for the production of complex therapeutic proteins.
- **Chapter 8: DNA Fingerprinting and Forensic Analysis** incorporates updates on uses of DNA sequence forensic information, identification of crime and catastrophe victims, establishing or excluding paternity relationships, authenticating food products, and other interesting aspects of forensic analysis.
- **Chapter 9: Bioremediation** includes a new section on the genomics of bioremediation and updated information on microbe-powered fuel cells, phytoremediation of explosives, and a new case study example.
- **Chapter 10: Aquatic Biotechnology** includes new information on using PCR to detect oyster pathogens, and new information on emerging medical products from aquatic organisms.
- **Chapter 11: Medical Biotechnology** provides updated information on gene therapy approaches including antisense methods and RNAi, updates and new information on regenerative medicine and tissue engineering, stem cell research and legislation and recent developments, and microarrays and pharmacogenomics.
- **Chapter 12: Biotechnology Regulations** incorporates new information on patenting gene sequences and world views on cloning and human stem cell use, compared to the United States.
- **Chapter 13: Ethics and Biotechnology** was rewritten to provide updated information on genetically modified foods, the genetic information nondiscrimination act, and stem cell regulations. It also includes a new section on patient rights and biological materials and three new *You Decide* entries.

Supplemental Learning Aids

Introduction to Biotechnology Companion Website (www.pearsonhighered.com/biotechnology)

The Companion Website is designed to help students study for their exams and deepen their understanding

of the text's content. Each chapter contains learning objectives, content reviews, flashcards, glossary terms, jpegs of figures, and an extensive collection of *Keeping Current Web Links* which explore related topics in other areas.

Instructor Resource Center (IRC)

The Instructor Resource Center www.pearsonhighered.com/educator is designed to support instructors teaching biotechnology. The IRC is an online resource that supports and augments material in the textbook. New instructor supplements available for download include:

- **Computerized Test Bank:** 10-20 multiple choice test questions per chapter
- **Jpeg Art Files:** electronic files of all text tables, line drawings, and photos
- **PowerPoint Lecture Outlines:** a set of PowerPoint presentations consisting of lecture outlines for each chapter augmented by key text illustrations

Instructors using *Introduction to Biotechnology* can contact their Benjamin Cummings sales representative to access the Instructor Resource Center free of charge.

Benjamin Cummings Special Topics in Biology Series

The *Benjamin Cummings Special Topics in Biology Series* is a series of booklets designed for undergraduate students. These small booklets present the basic scientific facts and the social and ethical issues surrounding current hot topics. Booklets in the series include:

- *Alzheimer's Disease*
  (ISBN 0-1318-3834-2)
- *Biology of Cancer*
  (ISBN 0-8053-4867-0)
- *Biological Terrorism*
  (ISBN 0-8053-4868-9)
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Contact your local Benjamin Cummings sales representative about bundling booklets in this series with *Introduction to Biotechnology* or visit www.pearsonhighered.com for more information.

Acknowledgments

A textbook is the collaborative result of hard work from many dedicated individuals including students, colleagues, editors and editorial staff, graphics experts, and many others. First, we thank our family and friends for their support and encouragement while we spent countless hours of our lives on this project. Without your understanding and patience, this book would not be possible.

We gratefully acknowledge the help of many talented people at Benjamin Cummings, particularly the editorial staff. Editorial duties changed several times during the preparation of this edition, but each editor provided creative talents and dedication to the book. We thank Mercedes Grandin for her guidance and help with reviews during the transition between editions. Acquistions Editor Becky Ruden has been the guiding force for the second edition and we are indebted to her for believing in the book's mission and for her vision to support and improve the text. Becky's leadership has been exactly what this project has needed, and she has been a great asset. We thank Project Editor Leata Holloway for keeping us on schedule and for her attention to detail, patience, enthusiasm, editorial suggestions, and great energy for the project.

We thank Production Supervisor Lori Newman for guiding us through the production process. Thanks go to Executive Marketing Manager Lauren Harp for her talents and creative contributions in developing promotional materials for this book. Maureen Spuhler, Photo Researcher, did a wonderful job of identifying and securing key art and suggesting alternatives. We thank Maria McColligan, Project Manager at Nesbitt Graphics, Inc., for her expert work on the first and second editions of the textbook. We'd also like to thank cover designer Rich Leeds of Big Wig Design who leant a fresh new look for the 2nd edition and Anne Lesser for expert copyediting.

Undergraduate students at Monmouth University read many drafts of the manuscript for the first and second edition and critiqued art scraps for clarity and content. We thank former students in BY 201 – Introduction to Biotechnology for their honest reviews, error finding, and suggestions from a student's perspective. In particular we thank Monica Gionet who was especially skilled at noting points of clarification prior to completing the second edition. We also thank Monmouth University graduate Robert Sexton for contributing to the Career Profile section of Chapter 3. The 2002 Introductory Biotechnology class students at Ventura College provided many useful suggestions while they tolerated the use of the "sketchy figures" in PowerPoint programs, which were the result of our first draft. Our students inspire us to strive for better ways to help us teach and to help them understand the wonders of biotechnology. We applaud you for your help in creating what we hope future students will deem to be a student-friendly textbook.

We also thank Dr. Daniel Rudolph for contributing to the Career Profile in Chapter 5 (Microbial Biotechnology) and Gef Flimlin for contributing to the Career Profile in Chapter 10 (Aquatic Biotechnology).

Finally, *Introduction to Biotechnology* has greatly benefited from valued input of many colleagues and instructors who helped us with scientific accuracy, clarity, pedagogical aspects of the book, and suggestions for improving drafts of each chapter. The many instructors who have developed biotechnology courses and programs and enthusiastically teach majors and nonmajors about biotechnology provided reviews of the text and art that have been invaluable for helping shape this textbook. Your constructive criticism helped us to revise drafts of each chapter, and your words of praise helped inspire us to move ahead. All errors or omissions in the text are our responsibility. We thank you all and look forward to your continued feedback. Reviewers of *Introduction to Biotechnology,* include:

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Whether you are a student or instructor, we invite your comments and suggestions for improving the next edition of *Introduction to Biotechnology*. Please write to us at the following addresses below or contact us via e-mail at bc.feedback@pearson.com.

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As students ourselves, we too continue to learn about biotechnology everyday. We wish you great success in your explorations of biotechnology!

W. J. T.
M. A. P.

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