

## About the Authors



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Above all, Jerry is devoted to his students and their aspirations. In recognition of this commitment, MACUB presented Jerry with the organization's 1992 President's Memorial Award. In 1995, he was selected as one of the finest faculty scholars of Bergen Community College and was named Distinguished Faculty Scholar. In 1996, he received a National Institute for Staff and Organizational Development (NISOD) excellence award from the University of Texas and was selected to represent Bergen Community College in a campaign to increase awareness of the contributions of community colleges to higher education.

Jerry is the author of several best-selling science textbooks and laboratory manuals, a calling that often requires an additional 40 hours per week beyond his full-time teaching responsibilities. Nevertheless, he still makes time for four or five weekly aerobic workouts. He also enjoys attending opera performances at the Metropolitan Opera House, Broadway plays, and concerts. He spends his quiet time at his beach home on the New Jersey Shore.

To all my children, the most important gift I have: Lynne, Gerard Jr., Kenneth, Anthony, and Drew, whose love and support have been such an important part of my personal life and professional career.



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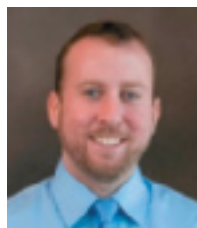
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I owe my deepest gratitude to Don Biederman and our three children, Daniel, Jonathan, and Andrea, for their unconditional love and unwavering support.

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# Preface

Since the publication of the first edition nearly 30 years ago, well over 1 million students have used *Microbiology: An Introduction* at colleges and universities around the world, making it the leading microbiology textbook for non-majors. The thirteenth edition continues to be a comprehensive beginning text, assuming no previous study of biology or chemistry. The text is appropriate for students in a wide variety of programs, including the allied health sciences, biological sciences, environmental science, animal science, forestry, agriculture, nutrition science, and the liberal arts.

The thirteenth edition has retained the features that have made this book so popular:

- **An appropriate balance between microbiological fundamentals and applications, and between medical applications and other applied areas of microbiology.** Basic microbiological principles are given greater emphasis, and health-related applications are featured.
- **Straightforward presentation of complex topics.** Each section of the text is written with the student in mind.
- **Clear, accurate, and pedagogically effective illustrations and photos.** Step-by-step diagrams that closely coordinate with narrative descriptions aid student comprehension of concepts.
- **Flexible organization.** We have organized the book in what we think is a useful fashion while recognizing that the material might be effectively presented in other sequences. For instructors who wish to use a different order, we have made each chapter as independent as possible and have included numerous cross-references. The Instructor's Guide provides detailed guidelines for organizing the material in several other ways.
- **Clear presentation of data regarding disease incidence.** Graphs and other disease statistics include the most current data available.
- **Big Picture core topic features.** These two-page spreads focus on the most challenging topics for students to master: metabolism (Chapter 5), genetics (Chapter 8), and immunology (Chapter 16). Each spread breaks down these important concepts into manageable steps and gives students a clear learning framework for the related chapters. Each refers the student to a related MicroFlix video accessible through MasteringMicrobiology.
- **Big Picture disease features.** These two-page spreads appear within each chapter in Part Four, Microorganisms and Human Disease (Chapters 21–26), as well as Chapters 18 (Practical Applications of Immunology) and 19 (Disorders of the Immune System). Each spread focuses on one significant public health aspect of microbiology.
- **ASM guidelines.** The American Society for Microbiology has released six underlying concepts and 27 related topics to provide a framework for key microbiological topics deemed to be of lasting importance beyond the classroom. The thirteenth edition explains the themes and competencies at the beginning of the book and incorporates callouts when chapter content matches one of these 27 topics. Doing so addresses two key challenges: it helps students and instructors focus on the enduring principles of the course, and it provides another pedagogical tool for instructors to assess students' understanding and encourage critical thinking.
- **Cutting-edge media integration.** MasteringMicrobiology ([www.masteringmicrobiology.com](http://www.masteringmicrobiology.com)) provides unprecedented, cutting-edge assessment resources for instructors as well as self-study tools for students. Big Picture Coaching Activities are paired with the book's Core Topics and Clinical Features. Interactive Microbiology is a dynamic suite of interactive tutorials and animations that teach key concepts in microbiology; and MicroBoosters are brief video tutorials that cover key concepts that some students may need to review or relearn.

## New to the Thirteenth Edition

The thirteenth edition focuses on big-picture concepts and themes in microbiology, encouraging students to visualize and synthesize more difficult topics such as microbial metabolism, immunology, and microbial genetics.

The thirteenth edition meets all students at their respective levels of skill and understanding while addressing the biggest challenges that instructors face. Updates to the thirteenth edition enhance the book's consistent pedagogy and clear explanations. Some of the highlights follow.

- **Exploring the Microbiome.** Each chapter has a new box featuring an aspect of microbiome study related to the chapter. Most feature the human microbiome. The boxes are designed to show the importance of microorganisms in health, their importance to life on Earth, and how research on the microbiome is being done.
- **In the Clinic videos accompanying each chapter opener.** In the Clinic scenarios that appear at the start of every chapter include critical-thinking questions that encourage students to think as health care professionals would in various clinical scenarios and spark student interest in the forthcoming chapter content. For the thirteenth edition, videos have been produced for the In the Clinic features for Chapters 1 through 20 and are accessible through MasteringMicrobiology.

- **New Big Picture disease features.** New Big Picture features include Vaccine-Preventable Diseases (Chapter 18), Vertical Transmission: Mother to Child (Chapter 22), and Bioterrorism (Chapter 24).
- **Reworked immunology coverage in Chapters 17, 18, and 19.** New art and more straightforward discussions make this challenging and critical material easier for students to understand and retain.

## Chapter-by-Chapter Revisions

Data in text, tables, and figures have been updated. Other key changes to each chapter are summarized below.

### Chapter 1

- The resurgence in microbiology is highlighted in sections on the Second and Third Golden Ages of Microbiology.
- The Emerging Infectious Diseases section has been updated.
- A discussion of normal microbiota and the human microbiome has been added.

### Chapter 2

- A discussion of the relationship between starch and normal microbiota has been added.

### Chapter 3

- Coverage of super-resolution light microscopy has been added.

### Chapter 4

- The description of the Gram stain method of action has been revised.
- Archaeella are now covered.

### Chapter 5

- The potential for probiotic therapy using lactic acid bacteria is introduced.
- Reoxidation of NADH in fermentation is now shown in Figure 5.18.

### Chapter 6

- Discussion has been added regarding the influence of carrying capacity on the stationary phase of microbial growth.
- Discussion of quorum sensing in biofilms is included.
- The plate-streaking figure is revised.

### Chapter 7

- A new section on plant essential oils has been added.

### Chapter 8

- The discussion of operons, induction, and repression has been revised.

- Riboswitches are defined.
- A new box about tracking Zika virus is included.

### Chapter 9

- Discussion of gene editing using CRISPR technology has been added.

### Chapter 10

- Rapid identification using mass spectrophotometry is included.

### Chapter 11

- The genus *Prochlorococcus* is now included.
- The phylum Tenericutes has been added.

### Chapter 12

- The classification of algae and protozoa is updated.

### Chapter 13

- Baltimore classification is included.
- Virusoids are defined.

### Chapter 14

- Discussions of herd immunity and the control of healthcare-associated infections are expanded.
- Clinical trials are defined.
- Congenital transmission of infection is included.
- Discussion of the emerging HAI pathogen *Elizabethkingia* is now included.
- Epidemiological data have been updated.

### Chapter 15

- Genotoxin information is updated.

### Chapter 16

- The discussion of the role of normal microbiota in innate immunity is expanded.
- A table of chemical mediators of inflammation is included.

### Chapter 17

- A new table listing cytokines and their functions has been added.
- Cells involved in cell-mediated immunity are summarized in a table.

### Chapter 18

- Vaccine-preventable diseases are discussed in a new Big Picture.
- Coverage of recombinant vector vaccines has been added.

### Chapter 19

- The discussion of autoimmune diseases has been updated.
- The discussion of HIV/AIDS has been updated.
- The Big Picture box has been revised to expand discussion of dysbiosis-linked disorders.

**Chapter 20**

- Tables have been reorganized.
- Coverage regarding the mechanisms of action of antimicrobial drugs has been updated.
- In the Clinical Focus box, data on antibiotics in animal feed have been updated.

**Chapter 21**

- All data are updated.
- The Big Picture on Neglected Tropical Diseases has been revised to include river blindness.

**Chapter 22**

- All data are updated.
- Coverage of Zika virus disease has been added.
- Discussion of Bell's palsy has been added.
- A new Big Picture covering vertical transmission of congenital infections has been added.

**Chapter 23**

- All data are updated.
- The new species of *Borrelia* are included.
- Maps showing local transmission of vector-borne diseases have been updated.

**Chapter 24**

- All data, laboratory tests, and drug treatments have been updated.
- The emerging pathogen *Enterovirus* D68 is included.
- A new Big Picture covering bioterrorism has been added.

**Chapter 25**

- All data, laboratory tests, and drug treatments are updated.
- *Salmonella* nomenclature has been revised to reflect CDC usage.
- Images of protozoan oocysts and helminth eggs have been added to illustrate laboratory identification.

**Chapter 26**

- All data, laboratory tests, and drug treatments have been updated.
- STIs that do not affect the genitourinary system are cross-referenced to the organ system affected.
- Discussion of ocular syphilis is now included.

**Chapter 27**

- The concept of the Earth microbiome is introduced.
- Discussion of hydrothermal vent communities has been added.
- The discussions of bioremediation of oil and wastewater have been updated.

**Chapter 28**

- The discussion of industrial fermentation has been updated.
- The definition of *biotechnology* is included.
- A discussion of the iChip has been added.
- A table listing fermented foods has been added.
- Discussion of microbial fuel cells is now included.



# Acknowledgments

In preparing this textbook, we have benefited from the guidance and advice of a large number of microbiology instructors across the country. These reviewers have provided constructive criticism and valuable suggestions at various stages of the revision. We gratefully acknowledge our debt to these individuals. Special thanks to retired epidemiologist Joel A. Harrison, Ph.D., M.P.H. for his thorough review and editorial suggestions.

## Contributor

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Otway edited the new In the Clinic videos. Serina Beuparant and Barbara Yien kept the project moving during a period of staff transitioning.

Michele Mangelli, Mangelli Productions, LLC, managed the book from beginning to end. She expertly guided the team through the editorial phase, managed the new design, and then oversaw the production team and process. Karen Gulliver expertly guided the text through the production process and managed the day-to-day workflow. Sally Peyrefitte's careful attention to continuity and detail in her copyedit of both text and art served to keep concepts and information clear throughout. The talented staff at Imagineering gracefully managed the high volume and complex updates of our art and photo program. Jean Lake coordinated the many complex stages of the art and photo processing and kept the entire art team organized and on-track. Our photo researcher, Kristin Piljay, made sure we had clear and striking images throughout the book. Gary Hespenheide created the elegant interior design and cover. The skilled team at iEnergizer Aptara®, Ltd moved this book through the composition process. Maureen Johnson prepared the index, Betsy Dietrich carefully proofread the art, while Martha Ghent proofread pages. Stacey Weinberger guided the book through the manufacturing process. A special thanks goes to Amy Siegesmund for her detailed review of the pages. Lucinda Bingham, Amanda Kaufmann, and Tod Regan managed this book's robust media program. Courtney Towson managed the print ancillaries through the complex production stages.

Allison Rona, Kelly Galli, and the entire Pearson sales force did a stellar job presenting this book to instructors and students and ensuring its unwavering status as the best-selling microbiology textbook.

We would like to acknowledge our spouses and families, who have provided invaluable support throughout the writing process.

Finally, we have an enduring appreciation for our students, whose comments and suggestions provide insight and remind us of their needs. This text is for them.

*Gerard J. Tortora      Berdell R. Funke      Christine Case*

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# ASM Recommended Curriculum Guidelines for Undergraduate Microbiology

The American Society for Microbiology (ASM) endorses a concept-based curriculum for introductory microbiology, emphasizing skills and concepts that remain important long after students exit the course. The ASM *Curriculum Guidelines for Undergraduate Microbiology Education* provide a framework for key microbiological topics and agree with scientific literacy reports from the American Association for the Advancement of Science and Howard Hughes Medical Institute. This textbook references part one of curriculum guidelines throughout chapters. When a discussion touches on one of the concepts, readers will see the ASM icon, along with a summary of the relevant statement.



## ASM Guideline Concepts and Statements

### Evolution

- Cells, organelles (e.g., mitochondria and chloroplasts), and all major metabolic pathways evolved from early prokaryotic cells.
- Mutations and horizontal gene transfer, with the immense variety of microenvironments, have selected for a huge diversity of microorganisms.
- Human impact on the environment influences the evolution of microorganisms (e.g., emerging diseases and the selection of antibiotic resistance).
- The traditional concept of species is not readily applicable to microbes due to asexual reproduction and the frequent occurrence of horizontal gene transfer.
- The evolutionary relatedness of organisms is best reflected in phylogenetic trees.

### Cell Structure and Function

- The structure and function of microorganisms have been revealed by the use of microscopy (including brightfield, phase contrast, fluorescent, and electron).
- Bacteria have unique cell structures that can be targets for antibiotics, immunity, and phage infection.
- Bacteria and Archaea have specialized structures (e.g. flagella, endospores, and pili) that often confer critical capabilities.
- While microscopic eukaryotes (for example, fungi, protozoa, and algae) carry out some of the same processes as bacteria, many of the cellular properties are fundamentally different.
- The replication cycles of viruses (lytic and lysogenic) differ among viruses and are determined by their unique structures and genomes.

### Metabolic Pathways

- Bacteria and Archaea exhibit extensive, and often unique, metabolic diversity (e.g., nitrogen fixation, methane production, anoxygenic photosynthesis).
- The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities (e.g., quorum sensing, oxygen consumption, nitrogen transformations).
- The survival and growth of any microorganism in a given environment depend on its metabolic characteristics.
- The growth of microorganisms can be controlled by physical, chemical, mechanical, or biological means.

### Information Flow and Genetics

- Genetic variations can impact microbial functions (e.g., in biofilm formation, pathogenicity, and drug resistance).
- Although the central dogma is universal in all cells, the processes of replication, transcription, and translation differ in Bacteria, Archaea, and Eukaryotes.
- The regulation of gene expression is influenced by external and internal molecular cues and/or signals.
- The synthesis of viral genetic material and proteins is dependent on host cells.
- Cell genomes can be manipulated to alter cell function.

### Microbial Systems

- Microorganisms are ubiquitous and live in diverse and dynamic ecosystems.
- Most bacteria in nature live in biofilm communities.
- Microorganisms and their environment interact with and modify each other.
- Microorganisms, cellular and viral, can interact with both human and nonhuman hosts in beneficial, neutral, or detrimental ways.

### Impact of Microorganisms

- Microbes are essential for life as we know it and the processes that support life (e.g., in biogeochemical cycles and plant and/or animal microbiota).
- Microorganisms provide essential models that give us fundamental knowledge about life processes.
- Humans utilize and harness microorganisms and their products.
- Because the true diversity of microbial life is largely unknown, its effects and potential benefits have not been fully explored.