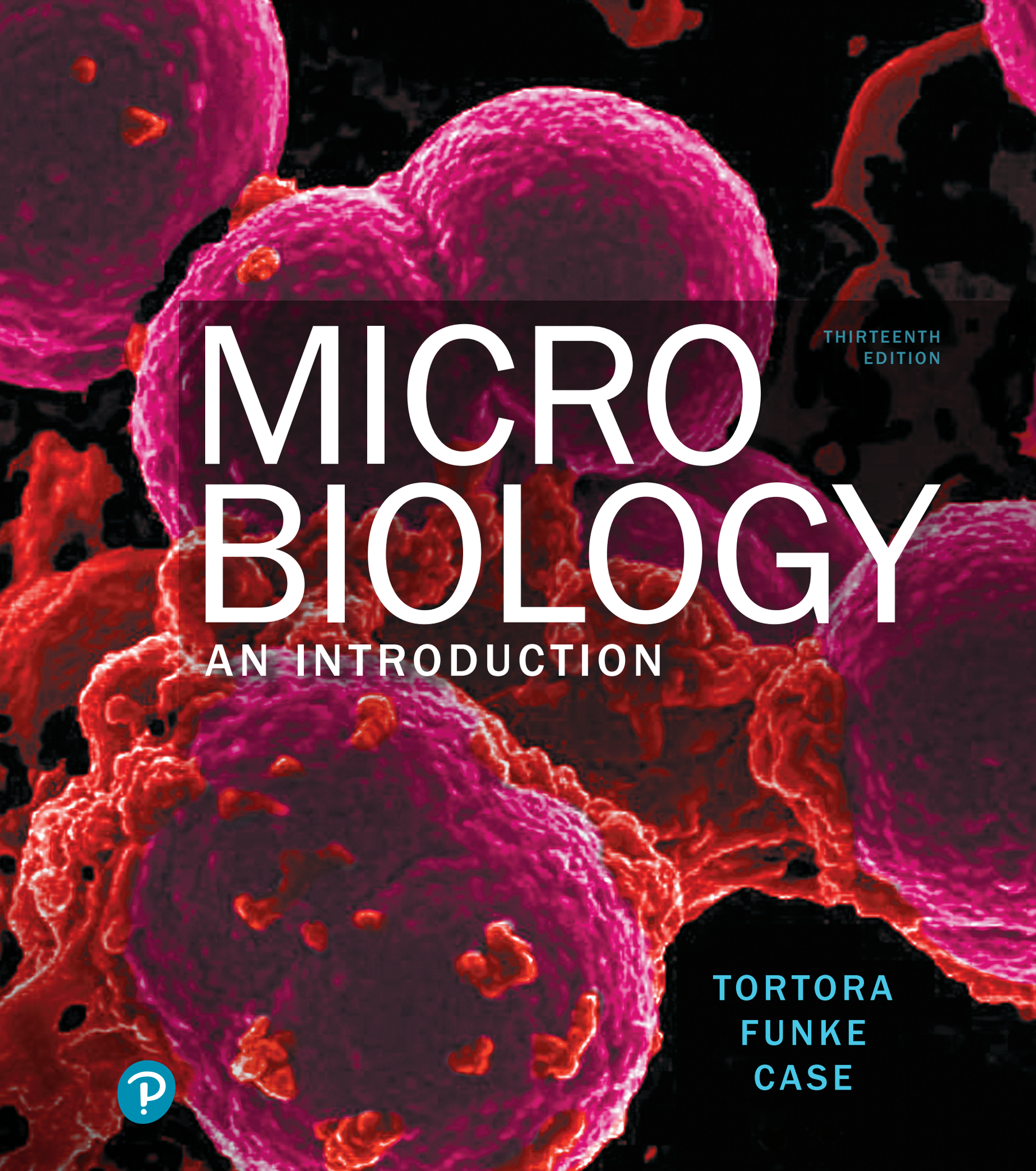
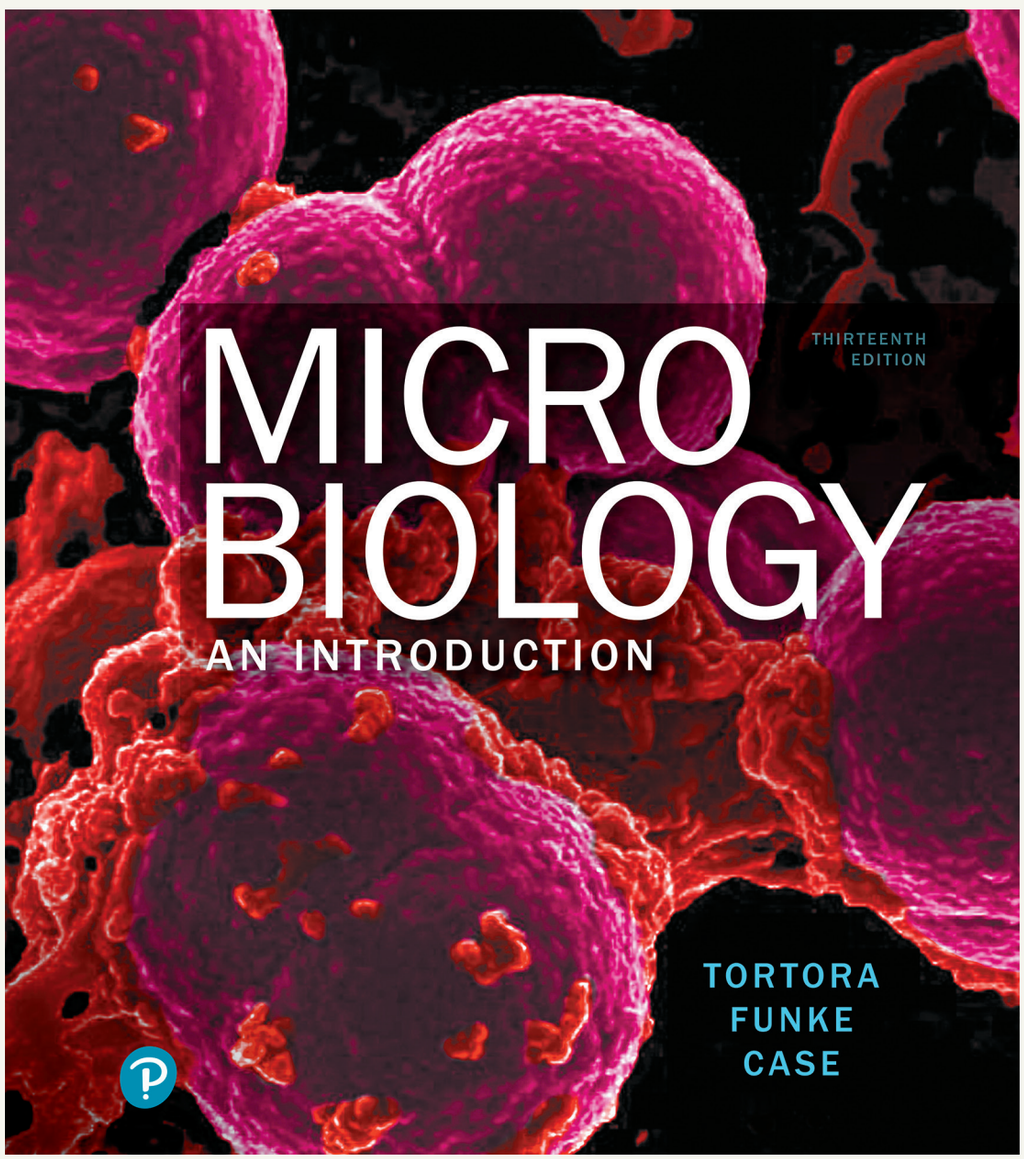

THIRTEENTH
EDITION
MICRO
BIOLOGY
AN INTRODUCTION
TORTORA
FUNKE
CASE

Cutting Edge Microbiology Research for *Today's* Learners

The 13th Edition of Tortora, Funke, and Case's ***Microbiology: An Introduction*** brings a 21st-century lens to this trusted market-leading introductory textbook. New and updated features, such as **Exploring the Microbiome** boxes and **Big Picture** spreads, emphasize how our understanding of microbiology is constantly expanding. New **In the Clinic Video Tutors** in **Mastering™ Microbiology** illustrate how students can apply their learning to their future careers. Mastering Microbiology also includes new Ready-to-Go Teaching Modules that guide you through the most effective teaching tools available.



Do your students struggle to make connections between course

NEW! Exploring the Microbiome boxes illustrate how research in microbiology is revolutionizing our understanding of health and disease. These boxes highlight the possibilities in this exciting field and present insights into some of the newly identified ways that microbes influence human health. In addition, they provide examples of how research in this field is done—building on existing information, designing fair testing, drawing conclusions, and raising new questions.

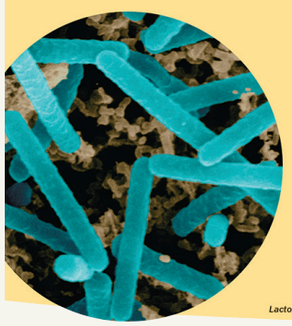
EXPLORING THE MICROBIOME

Do Artificial Sweeteners (and the Intestinal Microbiota That Love Them) Promote Diabetes?

For years, beverages made with artificial sweeteners were embraced by diabetics and weight watchers because, unlike sugar, artificial sweeteners don't impact blood glucose levels and don't provide calories. However, recent research indicates artificial sweeteners may actually increase the risk of nondiabetics developing the disease. One study published in 2009 by the American Diabetes Association found that daily consumption of diet soda was associated with a 67% greater relative risk of developing type 2 diabetes.

Undigestible by humans, artificial sweeteners provide zero calories to us when we consume them. But they are a great source of nutrients for *Bacteroides* bacteria living in the colon. As *Bacterioides* break down the sweeteners and increase in numbers, other types of microbiota simultaneously decline. Among these are *Lactobacillus* bacteria. Studies indicate that high *Lactobacillus* levels in the intestine are associated with decreased blood sugar levels. The exact mechanism remains unclear, but it is hypothesized that decreases in the population of *Lactobacillus* bacteria lead to higher blood glucose levels, thereby forcing the body to produce more insulin to control the rising blood glucose. Prolonged high insulin levels may lead to insulin resistance, a condition where the body stops responding correctly to the hormone. Insulin resistance is the hallmark sign of type 2 diabetes.

Recent and current research are exploring whether ingesting probiotics with *Lactobacillus acidophilus* and *Bifidobacterium animalis* may be a useful treatment for type 2 diabetes. Initial studies were promising, showing that these species might lower blood glucose levels. If proven effective, one day bacteria could be key weapons in preventing a deadly disease.



Lactobacillus acidophilus.

EXPLORING THE MICROBIOME

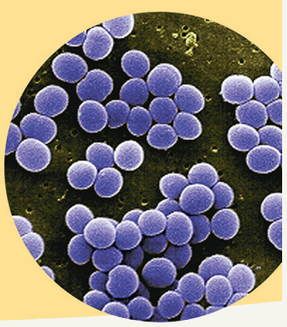
Antimicrobial Soaps: Doing More Harm Than Good?

Staphylococcus aureus is a normal member of the human microbiome, found on the skin and in the nose. *S. aureus* is also a significant cause of healthcare-associated infections in patients. The bacterium can switch from benign member of the skin community to a disease-causing pathogen if it gains entry to the body through a wound.

Since most hospital-acquired *S. aureus* infections are endogenous—that is, caused by bacteria that have colonized in or on the body before someone became a patient—hospitals have long used a disinfectant called triclosan in clinical soaps and skin lotions to prevent staphylococcal infections. Over the years, triclosan was also added to many household products, such as dishwashing detergent, toothpastes, and body washes. However, using these antimicrobial products daily seems to be a case of "too much of a good thing."

Triclosan enters the blood and is excreted in urine. Therefore, triclosan can be found in many areas of the body, including the nasal mucosa, of people who use it. The nose is the primary habitat of *S. aureus*. In an example of unintended consequences, presence of triclosan in blood is also associated with nasal colonization of the *S. aureus*. *S. aureus* is more likely to bind to host-cell-membrane proteins in the presence of triclosan. Moreover, constant exposure to triclosan selects for triclosan-resistant mutants over generations of bacterial growth. Triclosan-resistant bacteria avoid death by removing the chemical from their cells using transporter proteins. These transporters can also remove some antibiotics from the bacterial cells. Morever, methicillin-resistant *S. aureus* (MRSA) is more resistant to triclosan than methicillin-sensitive staphylococci.

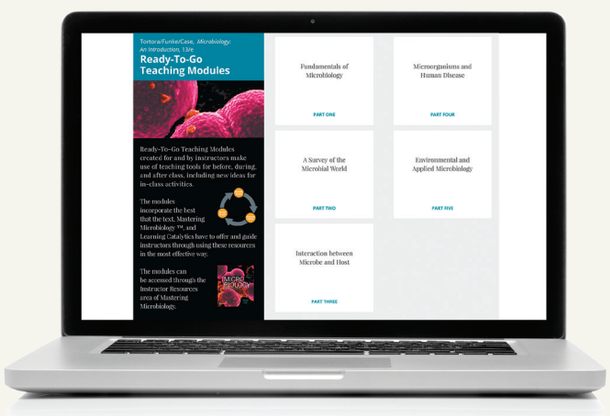
Starting in late 2016, the Federal Drug Association banned triclosan from over-the-counter consumer washing products. The American Medical Association recommends using plain soap and water and proper handwashing techniques instead—these products and techniques remove microbes without the harmful unintended consequences associated with widespread triclosan use.



Staphylococcus aureus.

content and their future careers?

New! In the Clinic Video Tutors bring to life the scenarios in the chapter-opening In the Clinic features. Concepts related to infection control, principles of disease, and antimicrobial therapies are integrated throughout the chapters, providing a platform for instructors to introduce clinically relevant topics throughout the term. Each Video Tutor has a series of assessments assignable in Mastering Microbiology that are tied to learning outcomes.

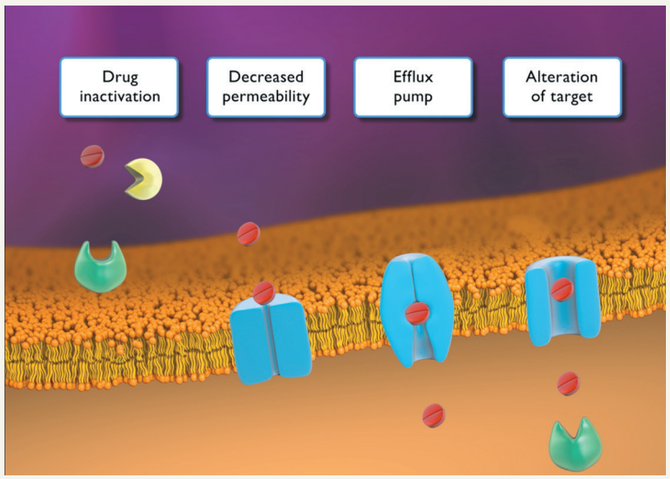


NEW! Ready-to-Go Teaching Modules in the Instructor Resources of Mastering Microbiology help instructors efficiently make use of the available teaching tools for the toughest topics in microbiology. Pre-class assignments, in-class activities, and post-class assessments are provided for ease of use.

Within the Ready-to-Go Teaching Modules, **Adopt a Microbe** modules enable instructors to select specific pathogens for additional focus throughout the text.

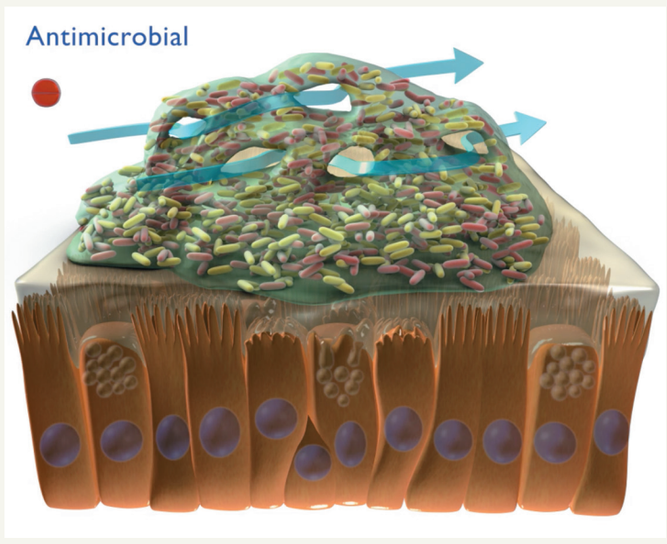
Do your students need help understanding the toughest

Interactive Microbiology is a dynamic suite of interactive tutorials and animations that teach key microbiology concepts. Students actively engage with each topic and learn from manipulating variables, predicting outcomes, and answering assessment questions that test their understanding of basic concepts and their ability to integrate and build on these concepts. These are available in Mastering Microbiology.



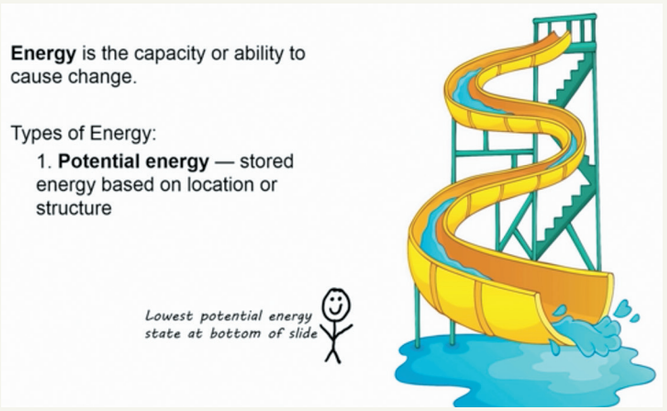
NEW! Even more Interactive Microbiology modules are available for Fall 2018. Additional titles include:

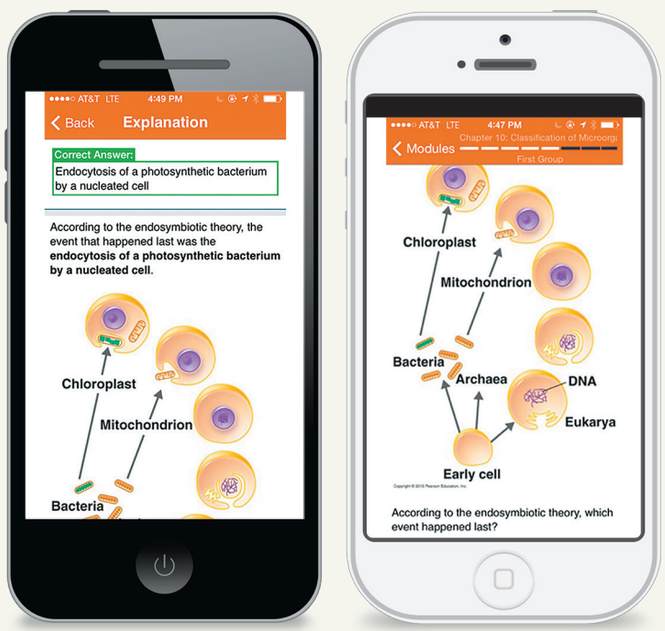
- Antimicrobial Resistance: Mechanisms
- Antimicrobial Resistance: Selection
- Aerobic Respiration in Prokaryotes
- The Human Microbiome



concepts in microbiology?

MicroBoosters are a suite of brief video tutorials that cover key concepts some students may need to review or relearn. Titles include Study Skills, Math, Scientific Terminology, Basic Chemistry, Cell Biology, and Basic Biology.





Dynamic Study Modules help students acquire, retain, and recall information faster and more efficiently than ever before. The flashcard-style modules are available as a self-study tool or can be assigned by the instructor.

NEW! Instructors can now remove questions from **Dynamic Study Modules** to better fit their course.

Do your students have trouble organizing and synthesizing

Big Picture spreads integrate text and illustrations to help students gain a broad, "big picture" understanding of important course topics.

Each Big Picture spread includes an overview that **breaks down important concepts** into manageable steps and gives students a clear learning framework for related chapters. Each spread includes Key Concepts that **help students make the connection** between the presented topic and previously learned microbiology principles. Each spread is paired with a coaching activity and assessment questions in Mastering Microbiology.

BIG PICTURE

Bioterrorism

Biological agents were first tapped by armies, and now by terrorists. Today, technology and ease of travel increase the potential damage.

History of Bioweapons

Biological weapons (bioweapons)—pathogens intentionally used for hostile purposes—are not new. The "ideal" bioweapon is one that disseminates by aerosol, spreads efficiently from human to human, causes debilitating disease, and has no readily available treatment.

The earliest recorded use of a bioweapon occurred in 1346 during the Siege of Kaffa, in what is now known as Feodosia, Ukraine. There the Tartar army catapulted their own dead soldiers' plague-ridden bodies over city walls to infect opposing troops. Survivors from that attack went on to introduce the "Black Death" to the rest of Europe, sparking the plague pandemic of 1348–1350.

In the eighteenth century, blankets contaminated with smallpox were intentionally introduced into Native American populations by the British during the French and Indian War. And during the Sino-Japanese War (1937–1945), Japanese planes dropped canisters of fleas carrying *Yersinia pestis* bacteria, the causative agent of plague, on China. In 1975, *Bacillus anthracis* endospores were accidentally released from a bioweapon production facility in Sverdlovsk.

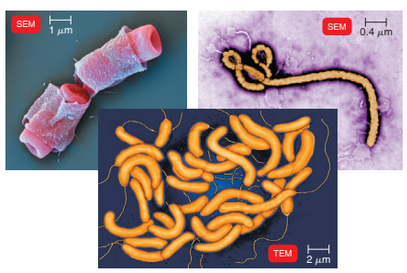
A citadel in Ukraine, location of the first known biowarfare attack in history.

Selected Diseases Identified as Potential Bioweapons

Bacterial	Viral
Anthrax (*Bacillus anthracis*)	Nonbacterial meningitis (Arenaviruses)
Psittacosis (*Chlamydophila psittaci*)	*Hantavirus* disease
Botulism (*Clostridium botulinum* toxin)	Hemorrhagic fevers (Ebola, Marburg, Lassa)
Tularemia (*Francisella tularensis*)	Monkeypox
Cholera (*Vibrio cholerae*)	Nipah virus infection
Plague (*Yersinia pestis*)	Smallpox

Biological Weapons Banned in the Twentieth Century

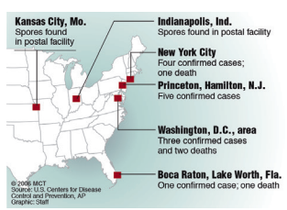
The Geneva Conventions are internationally agreed upon standards for conducting war. Written in the 1920s, they prohibited deploying bioweapons—but did not specify that possessing or creating them was illegal. As such, most powerful nations in the twentieth century continued to create bioweapons, and the growing stockpiles posed an ever-growing threat. In 1975, the Biological Weapons Convention banned both possession and development of biological weapons. The majority of the world's nations ratified the treaty, which stipulated that any existing bioweapons be destroyed and related research halted.



***(Clockwise from top left): Bacillus anthracis, Ebolavirus,* and *Vibrio cholerae* are just a few microbes identified as potential bioterrorism agents.**

Emergence of Bioterrorism

Unfortunately, the history of biowarfare doesn't end with the ratification of the Biological Weapons Convention. Since then, the main actors engaging in biowarfare have not been nations but rather radical groups and individuals. One of the most publicized bioterrorism incidents occurred in 2001, when five people died from, and many more were infected with, anthrax that an army researcher sent through the mail in letters.



Map showing location of 2001 bioterrorism anthrax attacks.

visual information?

Play MicroFlix 3D Animation
@MasteringMicrobiology

Public Health Authorities Try to Meet the Threat of Bioterrorism

One of the problems with bioweapons is that they contain living organisms, so their impact is difficult to control or even predict. However, public health authorities have created some protocols to deal with potential bioterrorism incidents.

Biological hazard symbol.

New Technologies and Techniques to Identify Bioweapons

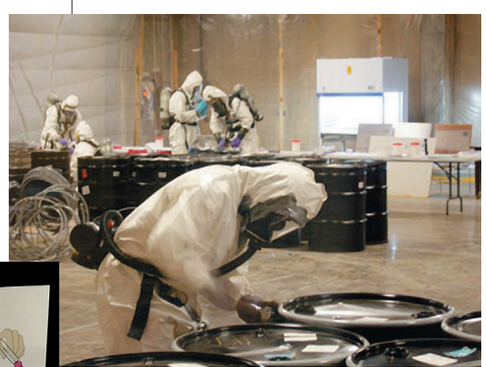
Monitoring public health, and reporting incidence of diseases of note, is the first step in any bioterrorism defense plan. The faster a potential incident is uncovered, the greater the chance for containment. Rapid tests are being investigated to detect genetic changes in hosts due to bioweapons even before symptoms develop. Early-warning systems, such as DNA chips or recombinant cells that fluoresce in the presence of a bioweapon, are also being developed.

Pro Strips Rapid Screening System, developed by ADVNT Biotechnologies LLC, is the first advanced multi-agent biowarfare detection kit that tests for anthrax, ricin toxin, botulinum toxin, plague, and SEB (staphylococcal enterotoxin B).

Vaccination: A Key Defense

When the use of biological agents is considered a possibility, military personnel and first -responders (health care personnel and others) are vaccinated—if a vaccine for the suspected agent exists. New vaccines are being developed, and existing vaccines are being stockpiled for use where needed.

The current plan to protect civilians in the event of an attack with a microbe is illustrated by the smallpox preparedness plan. This killer disease has been eradicated from the population, but unfortunately, a cache of the virus remains preserved in research facilities, meaning that it might one day be weaponized. It's not practical to vaccinate all people against the disease. Instead, the U.S. government's strategy following a confirmed smallpox outbreak includes "ring containment and voluntary vaccination." A "ring" of vaccinated/protected individuals is built around the bioterrorism infection case and their contacts to prevent further transmission.



Examining mail for *B. anthracis*.

KEY CONCEPTS

- Vaccination is critical to preventing spread of infectious diseases, especially those that can be weaponized. **(See Chapter 18, "Principles and Effects of Vaccinations," pages 500–501.)**
- Many organisms that could be used for weapons require BSL-3 facilities. **(See Chapter 6, "Special Culture Techniques," pages 161–162.)**
- Tracking pathogen genomics provides information on its source. **(See Chapter 9, "Forensic Microbiology," pages 258–260.)**

Three Big Picture spreads focus on **important fundamental topics in microbiology:**

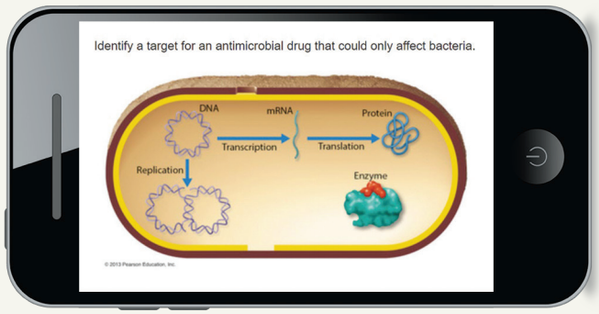
- Metabolism
- Genetics
- Immunity

Eight Big Picture spreads focus on **diseases and related public health issues that present complex real-world challenges:**

- Vaccine-Preventable Diseases
- The Hygiene Hypothesis
- Neglected Tropical Diseases
- Vertical Transmission: Mother to Child
- Climate Change and Disease
- Bioterrorism
- Cholera After Natural Disasters
- STI Home Test Kits

Additional Instructor and Student Resources

Learning Catalytics is a "bring your own device" (laptop, smartphone, or tablet) student engagement, assessment, and classroom intelligence system. With **Learning Catalytics**, instructors can assess students in real time using open-ended tasks to probe student understanding. Mastering Microbiology users may select from Pearson's library of questions designed especially for use with **Learning Catalytics**.



Instructor Resource Materials for *Microbiology: An Introduction*

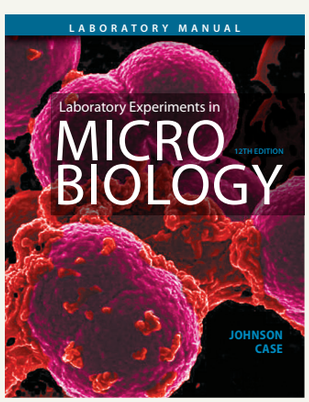
The Instructor Resource Materials organize all instructor media resources by chapter into one convenient and easy-to-use package containing:

- All figures, photos, and tables from the textbook in both labeled and unlabeled formats
- TestGen Test Bank
- MicroFlix animations
- Instructor's Guide

A wealth of additional classroom resources can be downloaded from the Instructor Resources area of Mastering Microbiology.

Laboratory Experiments in Microbiology, 12th Edition by Johnson/Case

0-134-60520-9 / 978-0-134-60520-3
Available for purchase.



Engaging, comprehensive and customizable, ***Laboratory Experiments in Microbiology*** is the perfect companion lab manual for ***Microbiology: An Introduction***, 13th Edition.

Mastering Microbiology

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MICRO BIOLOGY

AN INTRODUCTION

THIRTEENTH EDITION

Gerard J. Tortora
BERGEN COMMUNITY COLLEGE

Berdell R. Funke
NORTH DAKOTA STATE UNIVERSITY

Christine L. Case
SKYLINE COLLEGE

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About the Authors

Gerard J. Tortora Jerry Tortora is professor of biology and former biology coordinator at Bergen Community College in Paramus, New Jersey. He received his bachelor's degree in biology from Fairleigh Dickinson University and his master's degree in science education from Montclair State College. He has been a member of many professional organizations, including the American Society of Microbiology (ASM), the Human Anatomy and Physiology Society (HAPS), the American Association for the Advancement of Science (AAAS), the National Education Association (NEA), and the Metropolitan Association of College and University Biologists (MACUB).

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.

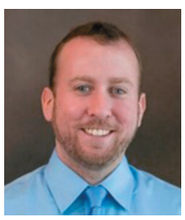
Berdell R. Funke Bert Funke received his Ph.D., M.S., and B.S. in microbiology from Kansas State University. He has spent his professional years as a professor of microbiology at North Dakota State University. He taught introductory microbiology, including laboratory sections, general microbiology, food microbiology, soil microbiology, clinical parasitology, and pathogenic microbiology. As a research scientist in the Experiment Station at North Dakota State, he has published numerous papers in soil microbiology and food microbiology.

Christine L. Case Chris Case is a professor of microbiology at Skyline College in San Bruno, California, where she has taught for the past 46 years. She received her Ed.D. in curriculum and instruction from Nova Southeastern University and her M.A. in microbiology from San Francisco State University. She was Director for the Society for Industrial Microbiology and is an active member of the ASM. She received the ASM and California Hayward outstanding educator awards. Chris received the SACNAS Distinguished Community College Mentor Award for her commitment to her students, several of whom have presented at undergraduate research conferences and won awards. In addition to teaching, Chris contributes regularly to the professional literature, develops innovative educational methodologies, and maintains a personal and professional commitment to conservation and the importance of science in society. Chris is also an avid photographer, and many of her photographs appear in this book.

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

Digital Authors

Warner B. Bair III Warner Bair is a professor of biology at Lone Star College–CyFair in Cypress, Texas. He has a bachelor of science in general biology and a Ph.D. in cancer biology, both from the University of Arizona. He has over 10 years of higher education teaching experience, teaching both general biology and microbiology classes. Warner is the recipient of multiple educational awards, including the National Institute for Staff and Organizational Development (NISOD) excellence award from the University of Texas and the League for Innovation in the Community College John and Suanne Roueche Excellence Award. Warner has previously authored Interactive Microbiology® videos and activities for the MasteringMicrobiology website and is a member of the American Society for Microbiology (ASM). He is also a certified Instructional Skill Workshop (ISW) facilitator, where he assists other professors in the development of engaging and active classroom instruction. When not working, Warner enjoys outdoor activities and travel. Warner would like to thank his wife, Meaghan, and daughter, Aisling, for their support and understanding of the many late nights and long weekends he spends pursuing his writing.



Derek Weber Derek Weber is a professor of biology and microbiology at Raritan Valley Community College in Somerville, New Jersey. He received his B.S. in chemistry from Moravian College and his Ph.D. in biomolecular chemistry from the University of Wisconsin–Madison. His current scholarly work focuses on the use of instructional technology in a flipped classroom to create a more active and engaging learning environment. Derek has received multiple awards for these efforts, including the Award for Innovative Excellence in Teaching, Learning and Technology at the International Teaching and Learning Conference. As part of his commitment to foster learning communities, Derek shares his work at state and national conferences and is a regular attendee at the annual American Society for Microbiology Conference for Undergraduate Educators (ASMCUE). He has previously authored MicroBooster Video Tutorials, available in MasteringMicrobiology, which remediate students on basic concepts in biology and chemistry as they apply to microbiology. Derek acknowledges the support of his patient wife, Lara, and his children, Andrew, James, and Lilly.

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) 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.
- Archaella 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 fuels cells is now included.

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Contributor

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Reviewers

Jason Adams, *College of DuPage*
D. Sue Katz Amburn, *Rogers State University*
Ana Maria Barral, *National University*
Anar Brahmbhatt, *San Diego Mesa College*
Carron Bryant, *East Mississippi Community College*
Luti Erbeznik, *Oakland Community College*
Tod R. Fairbanks, *Palm Beach State College*
Myriam Alhadeff Feldman, *North Seattle College*
Kathleen Finan, *College of DuPage*
Annissa Furr, *Kaplan University*
Pattie S. Green, *Tacoma Community College*
Julianne Grose, *Brigham Young University*
Amy Jo M. Hammett, *Texas Woman's College*
Justin Hoshaw, *Waubonsee Community College*
Huey-Jane Liao, *Northern Virginia Community College*
Anne Montgomery, *Pikes Peak Community College*
Jessica Parilla, *Georgia State University*
Taylor Robertson, *Snead State Community College*
Michelle Scanavino, *Moberly Area Community College*
John P. Seabolt, *University of Kentucky*
Ginny Webb, *University of South Carolina Upstate*

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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.