Sixth Edition

Microbiology

A Systems Approach

Marjorie Kelly Cowan
Heidi Smith

Mc Graw Hill

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MICROBIOLOGY: A SYSTEMS APPROACH, SIXTH EDITION

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Brief Contents

About the Authors

©Greg Zoeller

Kelly Cowan has taught microbiology to pre-nursing and allied health students for over 20 years. She received her PhD from the University of Louisville and held postdoctoral positions at the University of Maryland and the University of Groningen in the Netherlands. Her campus, Miami University Middletown, is an open admissions regional campus of Miami University in Ohio. She has also authored over 25 basic research papers with her undergraduate and graduate students. For the past several years, she has turned her focus to studying pedagogical techniques that narrow the gap between underresourced students and well-resourced students. She is past chair of the American Society for Microbiology's Undergraduate Education committee and past chair of ASM's education division, Division W.

Having a proven educator as an integrated digital author makes a *proven* learning system even better.

We are pleased to have Heidi Smith on the team. Heidi works hand-in-hand with the textbook author, creating online tools that truly complement and enhance the book's content. Because of Heidi, we offer you a robust digital learning program, tied to Learning Outcomes, to enhance your lecture and lab, whether you run a traditional, hybrid, or fully online course.

Heidi Smith

Heidi Smith leads the microbiology department at Front Range Community College in Fort Collins, Colorado. Collaboration with other faculty across the nation, the development and implementation of new digital learning tools, and her focus on student learning outcomes have revolutionized Heidi's face-to-face and online teaching approaches and student performance in her classes. The use of digital technology has given Heidi the ability to teach courses driven by real-time student data and with a focus on active learning and critical thinking activities.

Heidi is an active member of the American Society for Microbiology and participated as a task force member for the development of their Curriculum Guidelines for Undergraduate Microbiology Education. At FRCC, Heidi directs a federal grant program designed to increase student success in transfer and completion of STEM degrees at the local university as well as facilitate undergraduate research opportunities for underrepresented students.

Off campus, Heidi spends as much time as she can enjoying the beautiful Colorado outdoors with her husband and four children.

Preface

Students:

Welcome to the microbial world! I think you will find it fascinating to understand how microbes interact with us and with our environment. The interesting thing is that each of you has already had a lot of experience with microbiology. For one thing, you are thoroughly populated with microbes right now, and much of your own genetic material actually came from viruses and other microbes. And while you have probably had some bad experiences with quite a few microbes in the form of diseases, you have certainly been greatly benefited by them as well.

This book is suited for all kinds of students and doesn't require any prerequisite knowledge of biology or chemistry. If you are interested in entering the health care profession in some way, this book will give you a strong background in the biology of microorganisms without overwhelming you with unnecessary details. Don't worry if you're not in the health professions. A grasp of this topic is important for everyone—and can be attained with this book.

—Kelly Cowan

FOR INSTRUCTORS

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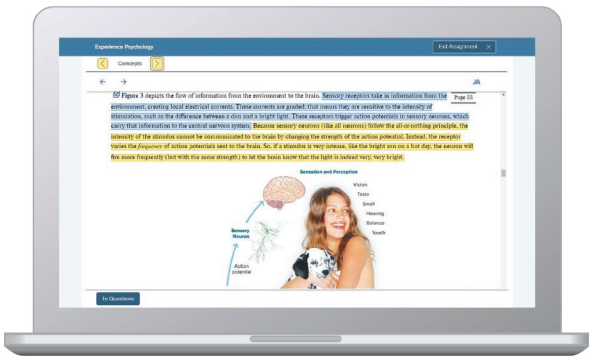

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FOR STUDENTS

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> ***"I really liked this app—it made it easy to study when you don't have your textbook in front of you."***
>
> - Jordan Cunningham, Eastern Washington University

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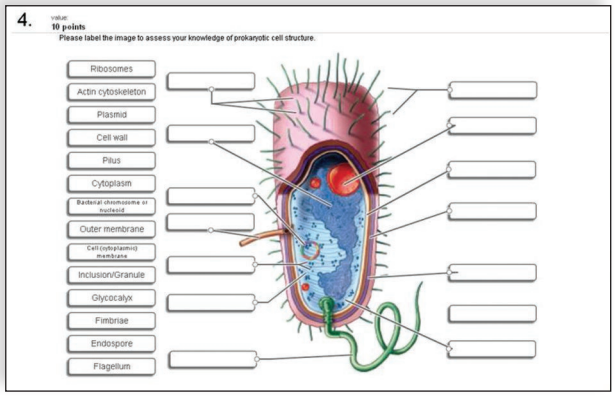
Top: Jenner Images/Getty Images, Left: Hero Images/Getty Images, Right: Hero Images/Getty Images

Digital Tools for Your Success

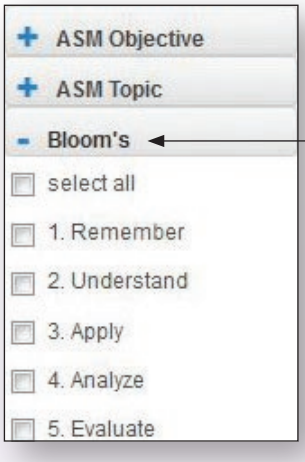
Save time with auto-graded assessments. Gather powerful performance data.

McGraw-Hill Connect for Cowan's Microbiology provides online presentation, assignment, and assessment solutions, connecting your students with the tools and resources they'll need to achieve success.



Homework and Assessment

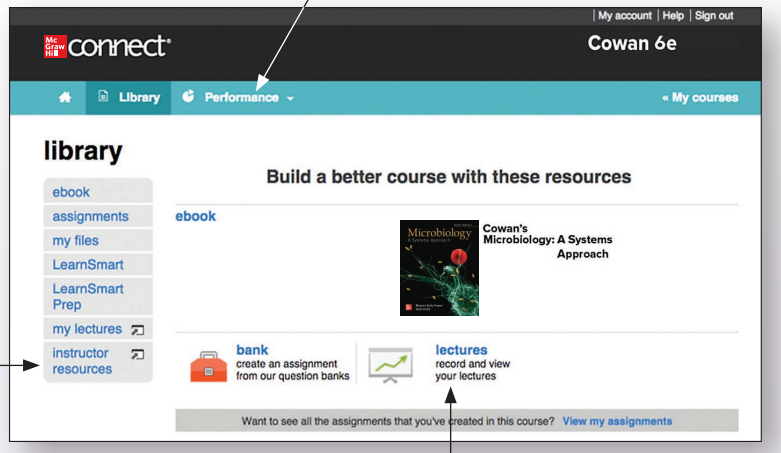
With **Connect for Cowan's Microbiology,** you can deliver auto-graded assignments, quizzes, and tests online. Choose from a robust set of interactive questions and activities using high-quality art from the textbook and animations. Assignable content is available for every Learning Outcome in the book and is categorized according to the **ASM Curriculum Guidelines.** As an instructor, you can edit existing questions and author entirely new ones.



Significant faculty demand for content at higher Bloom's levels led us to examine assessment quality and consistency of our Connect content, to develop a scientific approach to systemically increase critical-thinking levels, and develop balanced digital assessments that promote student learning. The increased challenge at higher Bloom's levels will help the student grow intellectually and be better prepared to contribute to society.

Detailed Reports

Track individual student performance—by question, by assignment, or in relation to the class overall—with detailed grade reports. Integrate grade reports easily with your Learning Management Systems (LMS).



Instructor Resources

Customize your lecture with tools such as PowerPoint® presentations, animations, and art from the textbook. An instructor's manual for the text saves you time in developing your course.

Lecture Capture

McGraw-Hill Tegrity® Tegrity in Connect is a tool that makes class time available 24/7 by automatically capturing every lecture. With a simple one-click, start-and-stop process, you capture all computer screens and corresponding audio in a format that is easy to search, frame by frame. Students can replay any part of any class with easy-to-use, browser-based viewing on a PC, Mac, or other mobile device.

Unique Interactive Question Types in Connect® Tagged to ASM's Curriculum Guidelines for Undergraduate Microbiology and to Bloom's Taxonomy

- **Case Study:** Case studies come to life in a learning activity that is interactive, self-grading, and assessable. The integration of the cases with videos and animations adds depth to the content, and the use of integrated questions forces students to stop, think, and evaluate their understanding.
- **Media Under The Microscope:** The opening cases in the textbook help students read science articles in the popular media with a critical eye. Questions in Connect are designed to extend these cases in a manner that promotes active student learning, either at home or in the classroom.
- **Concept Maps:** Concept maps allow students to manipulate terms in a hands-on manner in order to assess their understanding of chapter-wide topics. Students become actively engaged and are given immediate feedback, enhancing their understanding of important concepts within each chapter.
- **SmartGrid Questions:** New to this edition, SmartGrid questions replace the traditional end-of-chapter questions, and all of these questions are available for assignment in Connect. These questions were carefully constructed to assess chapter material as it relates to all six concepts outlined in the American Society of Microbiology curriculum guidelines plus the competency of "Scientific Thinking." The questions are cross-referenced with Bloom's taxonomy of learning level. Seven concepts/competencies × three increasing Bloom's levels = a robust assessment tool.
- **Study Smarter: Better Together:** A new feature in every chapter, Study Smarter gives guidance for students' group study, either in person or online. No instructor intervention required! Research shows that well-structured group study benefits under-resourced learners and students with lower levels of reading ability.
- **What's the Diagnosis:** Specifically designed for the disease chapters of the text, this is an integrated learning experience designed to assess the student's ability to utilize information learned in the preceding chapters to successfully culture, identify, and treat a disease-causing microbe in a simulated patient scenario. This question type is true experiential learning and allows the students to think critically through a real-life clinical situation.
- **Animations:** Animation quizzes pair our high-quality animations with questions designed to probe student understanding of the illustrated concepts.
- **Animation Learning Modules:** Making use of McGraw-Hill Education's collection of videos and animations, this question type presents an interactive, self-grading, and assessable activity. These modules take a stand-alone, static animation and turn it into an interactive learning experience for your students with real-time remediation.
- **Labeling:** Using the high-quality art from the textbook, check your students' visual understanding as they practice interpreting figures and learning structures and relationships. Easily edit or remove any label you wish!
- **Classification:** Ask students to organize concepts or structures into categories by placing them in the correct "bucket."
- **Sequencing:** Challenge students to place the steps of a complex process in the correct order.
- **Composition:** Fill in the blanks to practice vocabulary, and then reorder the sentences to form a logical paragraph (these exercises may qualify as "writing across the curriculum" activities!).

All McGraw-Hill Connect content is tagged to Learning Outcomes for each chapter as well as topic, section, Bloom's Level, and ASM Curriculum Guidelines to assist you in customizing assignments and in reporting on your students' performance against these points. This will enhance your ability to assess student learning in your courses by allowing you to align your learning activities to peer-reviewed standards from an international organization.

Lab Resources

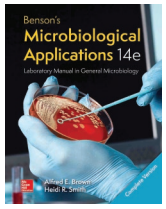
Need a lab manual for your microbiology course? Customize any of these manuals—add your text material—and *Create* your perfect solution!

McGraw-Hill Education offers several lab manuals for the microbiology course. Contact your McGraw-Hill Education learning technology representative for packaging options with any of our lab manuals.

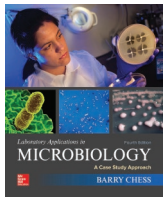
Brown/Smith: *Benson's Microbiological Applications: Laboratory Manual in General Microbiology,* 14th edition

Concise Version (978-1-259-70523-6)

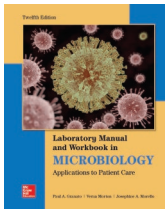
Complete Version (978-1-259-91979-4)



Chess: *Laboratory Applications in Microbiology: A Case Study Approach,* 4th edition (978-1-259-70522-9)



Morello: *Laboratory Manual and Workbook in Microbiology: Applications to Patient Care,* 12th edition (978-1-260-00218-8)



Prep for Microbiology is an adaptive learning tool that prepares students for college-level work in Microbiology. Prep for Microbiology individually identifies concepts the student does not fully understand and provides learning resources to teach essential concepts so he or she enters the classroom prepared. Data-driven reports highlight areas where students are struggling, helping to accurately identify weak areas.

Note from the Authors

This Text's Most Important Distinguishing Features:

These are the features we feel most strongly about. They represent proven methods for enabling our students to learn and we have seen them work in the classroom. The Cowan books have always been built around logical and clear organization, a factor that is critical when nonmajors are attempting to learn a science full of new vocabulary and concepts.

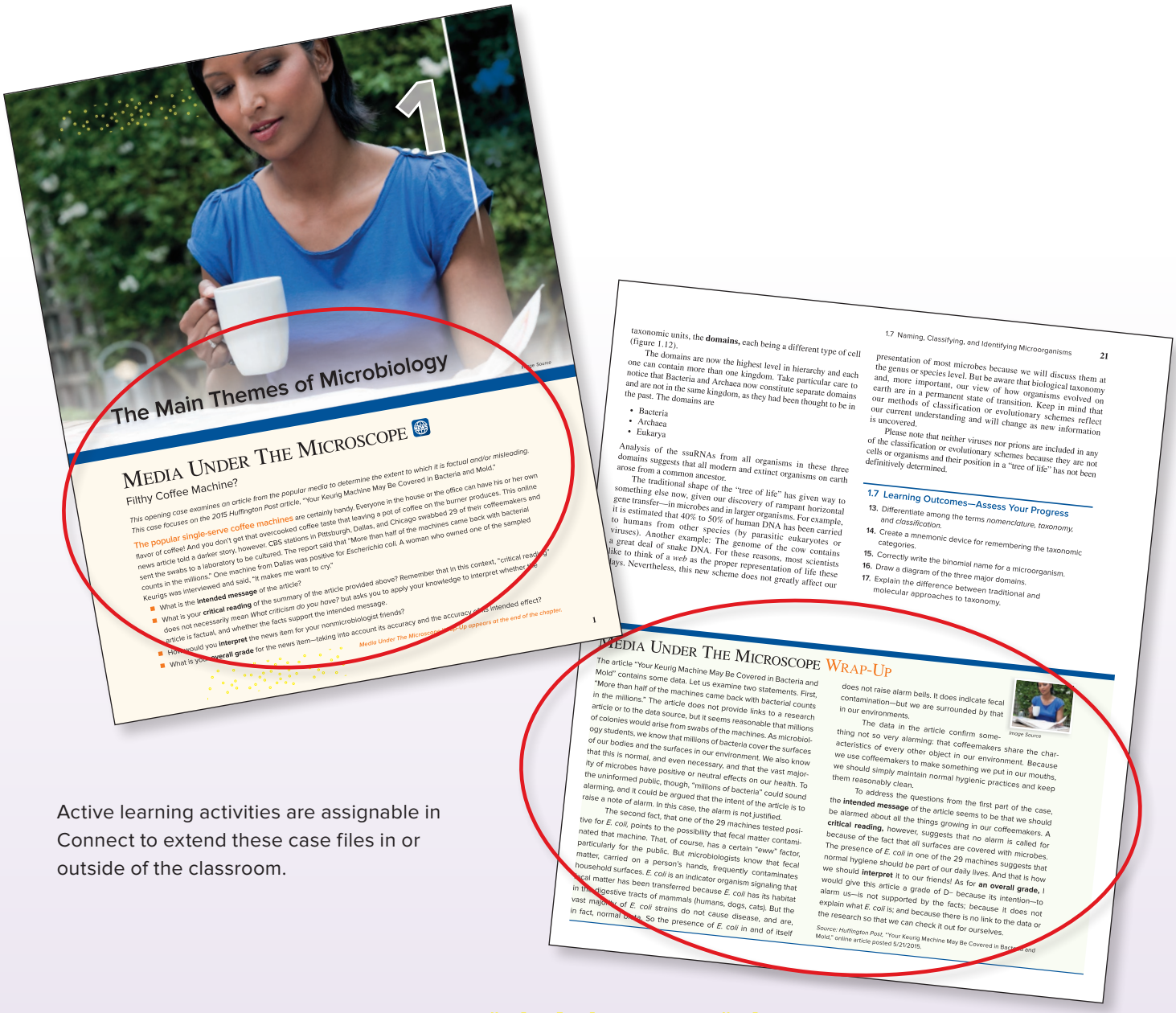
- SYSTEMATIC ORGANIZATION of the disease chapters that groups microbes by the conditions they cause.
- EPIDEMIOLOGY in every disease table.
- OPENING CASES that teach students how to read science articles in the popular media with a critical eye.
- MICROBIOME findings in all 25 chapters—in form of Microbiome Insight boxes as well as in the text. This reinforces how game-changing the microbiome findings are.
- STUDY SMARTER: BETTER TOGETHER in each chapter that provides guidance for students' group study, either in person or online. No instructor intervention required! Research shows that well-structured group study benefits under-resourced learners and students with lower levels of reading ability.
- SMARTGRIDS in each chapter. The end-of-chapter questions are dramatically reformatted into a 21-question grid that cross-references questions by their Bloom's level and the six core concepts of microbiology (plus the competency of scientific literacy) as identified by the American Society for Microbiology.
- VISUAL feature on the difference between the deadliness and the contagiousness of various microbes that appears in every disease chapter.
- CLEAN, uncluttered, and predictable sequence of chapter content.
- CONNECT UPDATES
  - CRITICAL THINKING applied through higher Bloom's level questions added to the Connect Question Bank.
  - SMARTBOOK LEARNING RESOURCES added based on heat map results from areas where students struggle the most. Help when they need it, with a library of resources available for refresher.
  - SUB-SECTION LEARNSMART assignability to allow for a more narrowed focus of chapters or further ability to assign chapter content in smaller chunks for student understanding.

—Kelly Cowan
—Heidi Smith

Capturing Students' Attention and Learning

Chapter Opening Case Files That Teach Students How to Judge Popular Media Articles About Science!

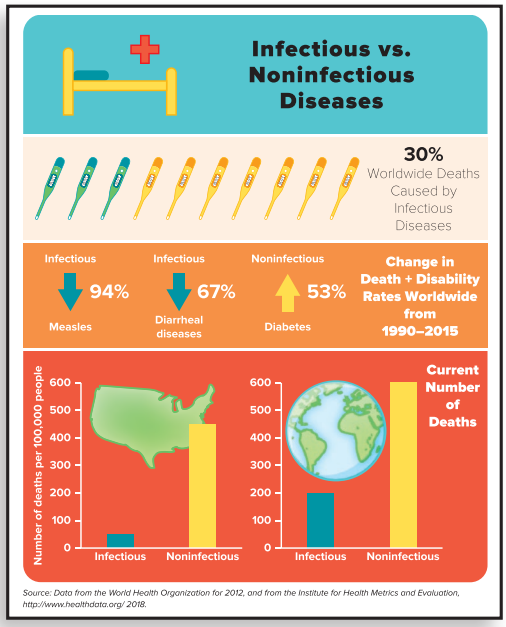
Each chapter opens with a revolutionary kind of case study. Titled "Media Under The Microscope," these are summaries of actual news items about microbiology topics. Students are walked through the steps of judging the relative accuracy of the popular media stories. Chapter by chapter, they learn how to critically assess the journalistic accounts. They encounter the principles of causation vs. correlation, biological plausibility, and the importance of not overstating experimental results. It is a critical need among the public today, and this textbook addresses it.



Active learning activities are assignable in Connect to extend these case files in or outside of the classroom.

Student-Focused Instructional Art

Effective science illustrations not only look pretty but help students visualize complex concepts and processes and paint a conceptual picture for them. The art combines vivid colors, multidimensionality, and self-contained narrative to help students study the challenging concepts of microbiology from a visual perspective. Drawings are often paired with photographs or micrographs to enhance comprehension.



Source: Data from the World Health Organization for 2012, and from the Institute for Health Metrics and Evaluation, http://www.healthdata.org/ 2018.

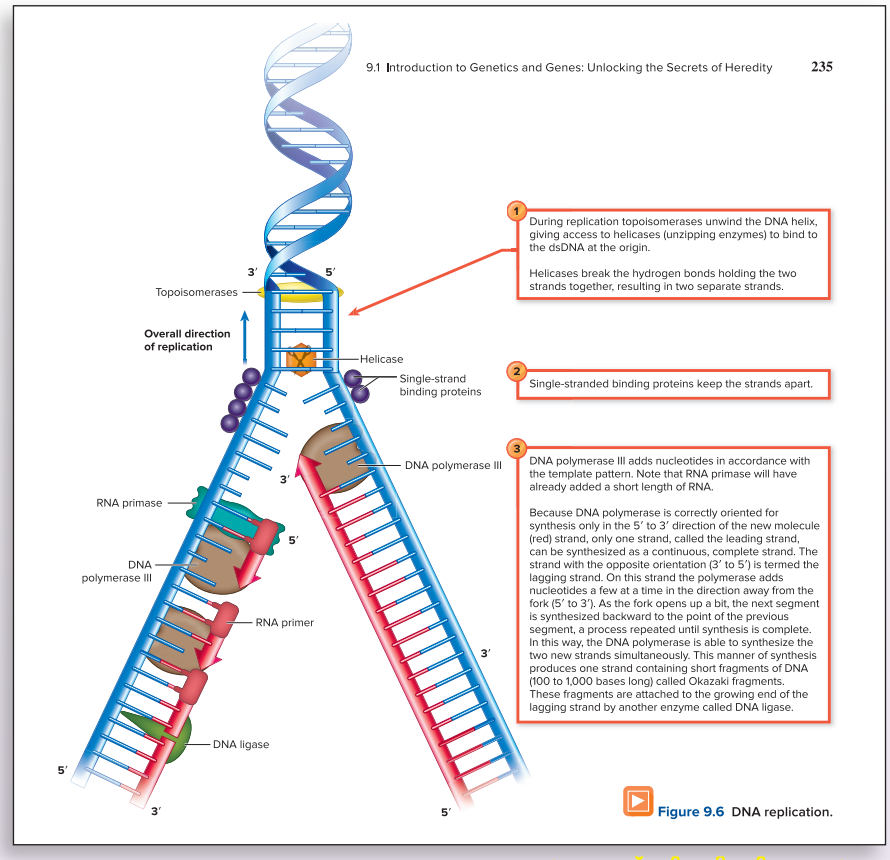


Figure 9.6 DNA replication.

Figures

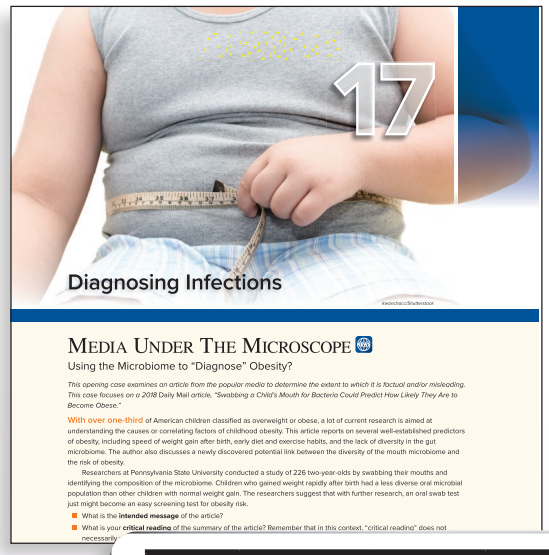
Many difficult microbiological concepts are best portrayed by breaking them down into stages. These figures show each step clearly marked with an orange, numbered circle and correlated to accompanying narrative to benefit all types of learners. The accompanying legend provides additional explanation.

Connecting Students to Their Future Careers

Many students taking this course will be entering the health care field in some way, and it is absolutely critical that they have a good background in the biology of microorganisms. Authors Kelly Cowan and Heidi Smith have made it their goal to help all students make the connections between microbiology and the world they see around them. Cowan textbooks have become known for their engaging writing style, instructional art program, and focus on active learning. The "building blocks" approach establishes the big picture first and then gradually layers concepts onto this foundation. This logical structure helps students build knowledge and ***connect*** important concepts.

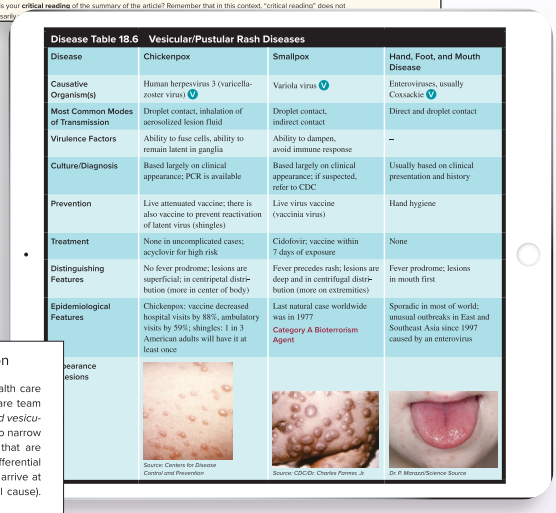
"Diagnosing Infections" Chapter

Chapter 17 brings together in one place the current methods used to diagnose infectious diseases. The chapter starts with collecting samples from the patient and details the biochemical, serological, and molecular methods used to identify causative microbes.

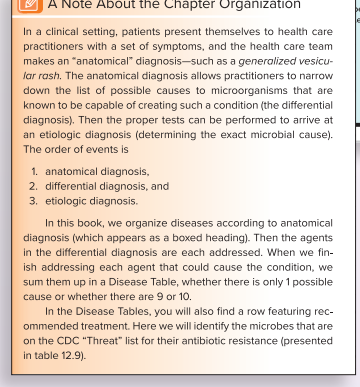


Systematic Presentation of Disease-Causing Organisms

Microbiology: A Systems Approach takes a unique approach to diseases by organizing microbial agents under the heading of the disease condition they cause. After all of them are covered, the agents are summarized in a comparative table. Every condition gets a table, whether there is one possible cause or a dozen. Through this approach, students study how diseases affect patients—the way future health care professionals will encounter them in their jobs. A summary table follows the textual discussion of each disease and summarizes the characteristics of agents that can cause that disease.



Every disease table contains national and/or worldwide epidemiological information for each causative agent.

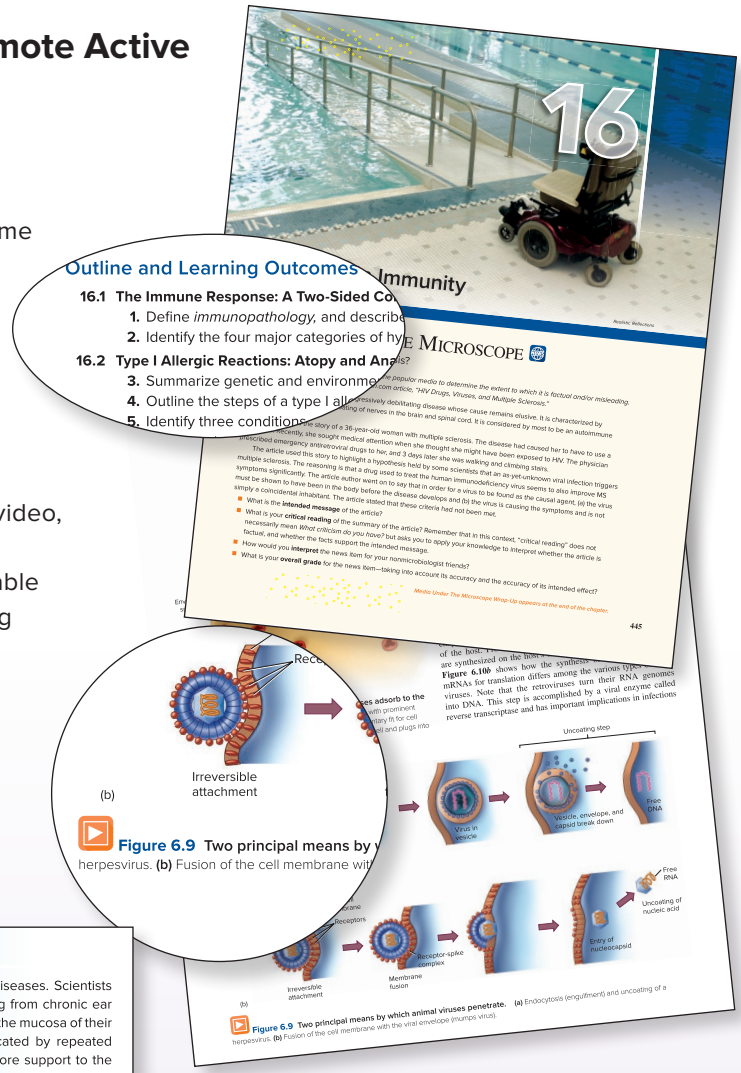


This approach is logical, systematic, and intuitive, as it encourages clinical and critical thinking in students—the type of thinking they will be using if their eventual careers are in health care. Students learn to examine multiple possibilities for a given condition and grow accustomed to looking for commonalities and differences among the various organisms that cause a given condition.

Student-Centered Pedagogy Created to Promote Active Learning

Learning Outcomes and Assess Your Progress Questions

Every chapter in the book opens with an outline—which is a list of Learning Outcomes. Assess Your Progress with the learning outcome questions concludes each major section of the text. The Learning Outcomes are tightly correlated to digital material. Instructors can easily measure student learning in relation to the specific Learning Outcomes used in their course.



Animated Learning Modules

Certain topics need help to come to life off the page. Animations, video, audio, and text all combine to help students understand complex processes. Key topics have an Animated Learning Module assignable through Connect. An icon in the text indicates when these learning modules are available.

Disease Connection

Sometimes it is difficult for students to see the relevance of basic concepts to their chosen professions. So the basic science chapters contain Disease Connections, very short boxes that relate esoteric topics such as pH and growth phase to clinical situations (*H. pylori* and *M. tuberculosis,* in these examples).

Disease Connection

Biofilms can play a major role in infectious diseases. Scientists have definitively shown that children suffering from chronic ear infections had biofilms of bacteria growing on the mucosa of their middle ears. These biofilms were not eradicated by repeated courses of antibiotics. This discovery gave more support to the procedure of putting tubes in the ears of children with chronic or recurrent ear infections (to drain infected fluids) instead of treating with antibiotics.

Insight Readings

Each chapter includes a Microbiome Insight box and a Clinical Insight box. The Microbiome Insight boxes are a way to emphasize the important and revolutionary ways the recent findings influence almost everything we know about human health.

INSIGHT 15.1 MICROBIOME: Cancer and the Microbiome

We know that the gut microbiome is critical to the health of its human host. One of the ways it influences health is by having a profound effect on inflammation and immunity. In turn, inflammation and immunity—in all the complexity you have studied in these two chapters—profoundly affect the initiation and progression of tumor cells. The microbiome also impacts the effectiveness of cancer therapies and the susceptibility to toxic side effects. An article that reviews the research in this field was published by two National Institutes of Health scientists, Soumen Roy and Giorgio Trinchieri, in 2017.

Image Point Fr/Shutterstock

They describe the reasons that the microbiome influences cancer occurrence and progression. One important factor is what they call the "crosstalk" among the gut microbiota, immune cells, and the mucosal surfaces. By this they mean the close association and chemical signaling that occur among the three. When the microbiome is healthy, and this crosstalk is functioning well, it is in an optimal state to prevent the initiation of tumors. Disturbances to the microbiome, which can occur because of antibiotic treatment, lifestyle, diet, and disease, can lead to a loss of immune surveillance, allowing tumor growth to begin.

Further, it has become clear that an individual's reaction to cancer treatment is also profoundly affected by the microbiome. Because the microbiota prepare immune cells to release toxic oxygen species and also to provide an effective T-cell response, when the microbiome is dysfunctional, chemotherapy that works through those two mechanisms is less effective. A disturbed microbiome has even been shown to reduce the effectiveness—and increase the side-effects—of radiation therapy. This field of research is only about 4 years old, and, as the researchers point out, has mostly been conducted in mouse models. But the prospects are good that we will eventually be able to improve the treatment of cancer, at least partially through the "engineering" of the microbiome.

Source: 2017. *Nature Reviews: Cancer.* Vol. 17, pp 27–285. DOI: 10.1038/nrc.2017.13

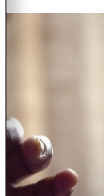
INSIGHT 12.1 CLINICAL: Using Viruses as Antibiotics

Here are two facts to consider:

- Bacteriophages, as you learned in section 6.5, are viruses that infect and kill bacteria, and they do not infect other types of cells.
- Before the middle of the 20th century, there were no effective treatments for human bacterial infections.

Does reading those two statements lead you to any speculation?

robiologist named Felix old boy who had severe ges he had isolated from ed the bacteriophages by its to remove bacteria and acteriophages. D'Herrelle ld attack the bacteria that nistering the phage "soup," e of it themselves to deter- o be.



When they administered it to the boy, his symptoms improved immediately and he recovered completely within days. This was the beginning of bacteriophage therapy. Eventually, d'Herrelle created five different commercial preparations of bacteriophages to treat respiratory infections, skin infections, intestinal infections, and so on. They were marketed by a company in France, now known as L'Oreal.

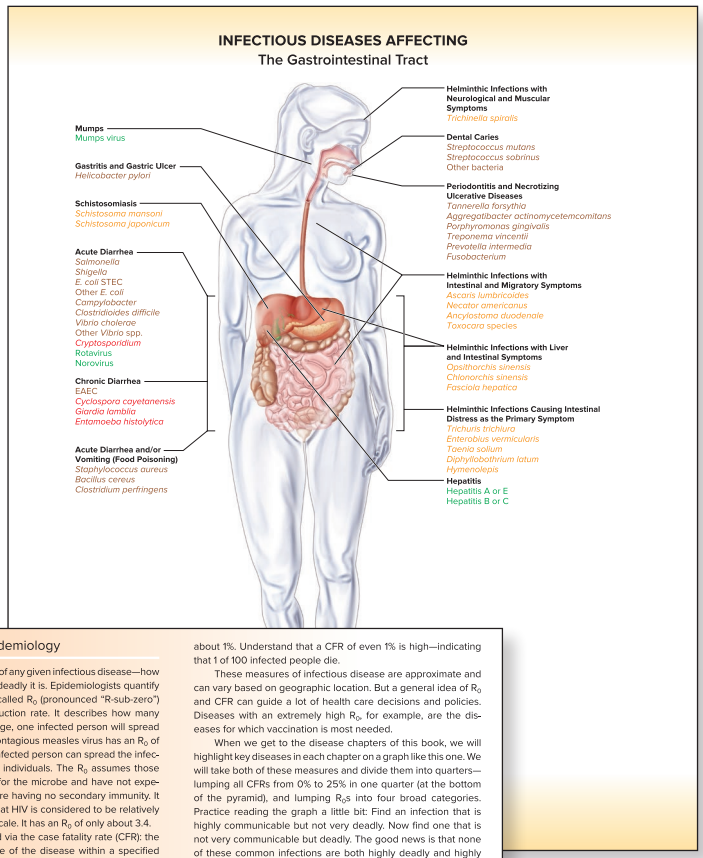
The use of bacteriophages sputtered along until the middle of the 20th century, when antibiotics were discovered. Antibiotics quickly overtook bacteriophage therapy as the treatment of choice for all bacterial infections—in the West, at least. In the Soviet Union and other Eastern bloc countries that had little or no access to antibiotics, bacteriophage use continued. It had never been rigorously vetted according to modern standards of pharmaceutical testing, but it worked effectively throughout the 20th century in those places.

In the early 21st century, we find ourselves with very few effective drug treatments for some antibiotic-resistant bacteria. European and U.S. scientists are turning again to phage therapy. The first major clinical trials of phage therapy started in Europe in summer 2015. The European Commission funded the study, which is examining the efficacy of the treatment on burn patients in France, Belgium, and Switzerland. And the United States National Institute of Allergy and Infectious Diseases in 2014 identified phage therapy as one of seven areas of emphasis in targeting antibiotic resistance. It will be at least 5 years before phage therapy passes through the rigorous testing required to bring a "drug" to market, but it still provides promise that we will have a weapon in our arsenal against drug-resistant infections.

Sources: 2001. *Antimicrob. Agents. Chemother.* Vol. 45(3): 649–659. DOI: 10.1128/AAC.45.3.649-659.2001
Reuters, online article posted 7/2/15.

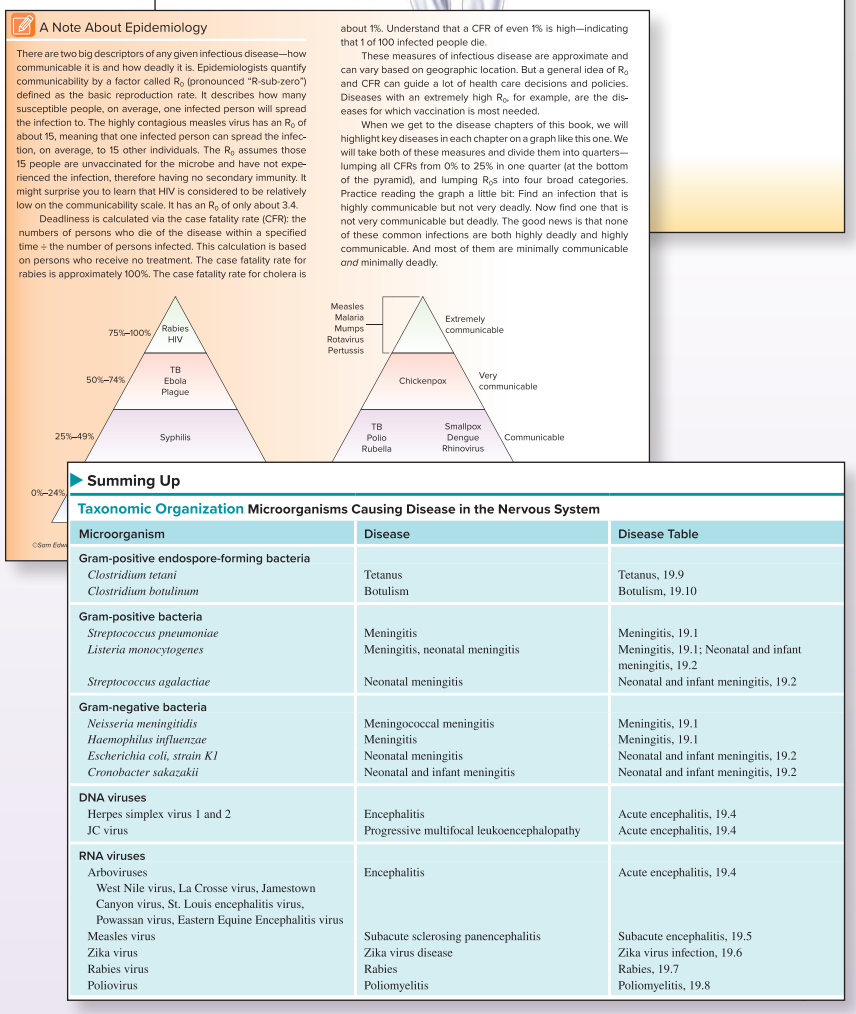
System Summary Figures

"Glass body" figures at the end of each disease chapter highlight the affected organs and list the diseases that were presented in the chapter. In addition, the microbes are color coded by type of microorganism.



Communicability vs. Deadliness Feature

Each microbe can be characterized using two important descriptors: its relative communicability and its relative deadliness. These are important epidemiologically and clinically—and usually receive only sporadic mention in textbooks—so we have created a visual feature that appears in each disease chapter, and in the epidemiology chapter.



Taxonomic List of Organisms

A taxonomic list of organisms is presented at the end of each disease chapter so students can see the taxonomic position of microbes causing diseases in that body system.

Summing Up

Taxonomic Organization Microorganisms Causing Disease in the Nervous System

Microorganism	Disease	Disease Table
Gram-positive endospore-forming bacteria		
Clostridium tetani	Tetanus	Tetanus, 19.9
Clostridium botulinum	Botulism	Botulism, 19.10
Gram-positive bacteria		
Streptococcus pneumoniae	Meningitis	Meningitis, 19.1
Listeria monocytogenes	Meningitis, neonatal meningitis	Meningitis, 19.1; Neonatal and infant meningitis, 19.2
Streptococcus agalactiae	Neonatal meningitis	Neonatal and infant meningitis, 19.2
Gram-negative bacteria		
Neisseria meningitidis	Meningococcal meningitis	Meningitis, 19.1
Haemophilus influenzae	Meningitis	Meningitis, 19.1
Escherichia coli, strain K1	Neonatal meningitis	Neonatal and infant meningitis, 19.2
Cronobacter sakazakii	Neonatal and infant meningitis	Neonatal and infant meningitis, 19.2
DNA viruses		
Herpes simplex virus 1 and 2	Encephalitis	Acute encephalitis, 19.4
JC virus	Progressive multifocal leukoencephalopathy	Acute encephalitis, 19.4
RNA viruses		
Arboviruses	Encephalitis	Acute encephalitis, 19.4
West Nile virus, La Crosse virus, Jamestown Canyon virus, St. Louis encephalitis virus, Powassan virus, Eastern Equine Encephalitis virus		
Measles virus	Subacute sclerosing panencephalitis	Subacute encephalitis, 19.5
Zika virus	Zika virus disease	Zika virus infection, 19.6
Rabies virus	Rabies	Rabies, 19.7
Poliovirus	Poliomyelitis	Poliomyelitis, 19.8

Developing Critical Thinkers

The end-of-chapter material is linked to Bloom's Taxonomy. It has been carefully planned to promote active learning and provide review for different learning styles and levels of difficulty.

SmartGrid

This innovative learning tool distributes chapter material among the American Society for Microbiology's six main curricular concepts, plus the competency of *scientific thinking*. Each of the seven areas is probed at three different Bloom's levels. The resulting 21-question grid can be assigned by column (all multiple-choice questions about each core concept, for example) or by row (all questions related to evolution, but at increasing Bloom's level). The highest Bloom's level questions can easily be assigned as a group project or presentation topic.

SmartGrid: From Knowledge to Critical Thinking

This *21 Question Grid* takes the topics from this chapter and arranges them with respect to the American Society for Microbiology's Undergraduate Curriculum guidelines—all six of the important "Concepts" as well as the important "Competency" of scientific literacy. Three questions are supplied, which cover chapter content referring to the Concept or Competency in increasing levels of Bloom's taxonomy for learning.

ASM Concept/ Competency	A. Bloom's Level 1, 2—Remember and Understand (Choose one.)	B. Bloom's Level 3, 4—Apply and Analyze	C. Bloom's Level 5, 6—Evaluate and Create
Evolution	**1.** The best descriptive term for the resident microbiota is **a.** commensal. **b.** parasitic. **c.** pathogenic. **d.** mutualistic.	**2.** In some circumstances, microbes can be quite virulent when they first infect a new species (such as in a zoonosis) but over decades of association with the new human host, cause milder and milder disease. Can you speculate about why this is evolutionarily advantageous to the pathogen?	**3.** Conduct research on germ-free mice. Use what you find to write a paragraph about the coevolution of microbes and humans.
Cell Structure and Function	**4.** Which of the following are virulence factors? **a.** toxins **b.** enzymes **c.** capsules **d.** all of the above	**5.** Why do you suppose specific adhesive structures, such as fimbriae, are critical to the disease-causing capabilities of many bacteria? Be thorough in your answer.	**6.** Discuss the role of endospores in ensuring the ongoing transmission of a bacterium in a population.

High Impact Study Feature

Students benefit most from varied study and assessment methods. We've created a short set of "Terms" and "Concepts" that help students identify the most important 10 to 15 items in a chapter. If they understand these, they are well on their way to mastery.

High Impact Study

These terms and concepts are most critical for your understanding of this chapter—and may be the most difficult. Have you mastered them? In these disease chapters, the terms and concepts help you identify what is important in a different way than the comprehensive details in the Disease Tables. Your instructor will help you understand what is important for your class.

Concepts

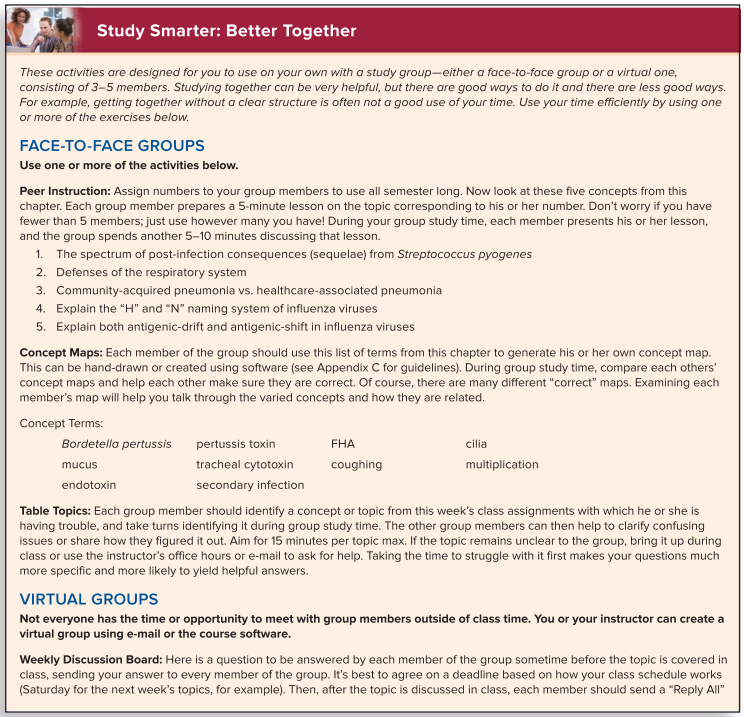
- ☐ Defenses of nervous system
- ☐ Normal microbiota of nervous system
- ☐ Four bacterial causes of meningitis
- ☐ Other causes of meningitis
- ☐ Food-borne cause of meningitis
- ☐ Meningitis vaccines
- ☐ Gram-negative diplococci vs. gram-positive diplococci
- ☐ Difference between CJD and vCJD
- ☐ Global polio eradication
- ☐ Three types of botulism
- ☐ Differences and similarities between tetanus and botulism
- ☐ Organisms in this chapter for which there are vaccines available
- ☐ Organisms in this chapter that display significant antibiotic resistance

Terms

- ☐ Meninges
- ☐ Cerebrospinal fluid
- ☐ Blood-brain barrier
- ☐ Arbovirus
- ☐ Dead-end host
- ☐ Prion
- ☐ Progressive multifocal leukoencephalopathy
- ☐ Postinfection encephalitis
- ☐ Subacute sclerosing parencephalitis

Group Study Guide

The new feature “Study Smarter: Better Together” gives students a format for their self-guided group study. We know that group study can be immensely useful for learning—but only if it is well-structured. This feature, in every chapter, helps students make the best use of their study time with their classmates, either in person or virtually, with no effort on the part of the instructor!



Study Smarter: Better Together

These activities are designed for you to use on your own with a study group—either a face-to-face group or a virtual one, consisting of 3–5 members. Studying together can be very helpful, but there are good ways to do it and there are less good ways. For example, getting together without a clear structure is often not a good use of your time. Use your time efficiently by using one or more of the exercises below.

FACE-TO-FACE GROUPS

Use one or more of the activities below.

Peer Instruction: Assign numbers to your group members to use all semester long. Now look at these five concepts from this chapter. Each group member prepares a 5-minute lesson on the topic corresponding to his or her number. Don't worry if you have fewer than 5 members; just use however many you have! During your group study time, each member presents his or her lesson, and the group spends another 5–10 minutes discussing that lesson.

1. The spectrum of post-infection consequences (sequelae) from *Streptococcus pyogenes*
2. Defenses of the respiratory system
3. Community-acquired pneumonia vs. healthcare-associated pneumonia
4. Explain the “H” and “N” naming system of influenza viruses
5. Explain both antigenic-drift and antigenic-shift in influenza viruses

Concept Maps: Each member of the group should use this list of terms from this chapter to generate his or her own concept map. This can be hand-drawn or created using software (see Appendix C for guidelines). During group study time, compare each others' concept maps and help each other make sure they are correct. Of course, there are many different “correct” maps. Examining each member's map will help you talk through the varied concepts and how they are related.

Concept Terms:

Bordetella pertussis	pertussis toxin	FHA	cilia
mucus	tracheal cytotoxin	coughing	multiplication
endotoxin	secondary infection		

Table Topics: Each group member should identify a concept or topic from this week's class assignments with which he or she is having trouble, and take turns identifying it during group study time. The other group members can then help to clarify confusing issues or share how they figured it out. Aim for 15 minutes per topic max. If the topic remains unclear to the group, bring it up during class or use the instructor's office hours or e-mail to ask for help. Taking the time to struggle with it first makes your questions much more specific and more likely to yield helpful answers.

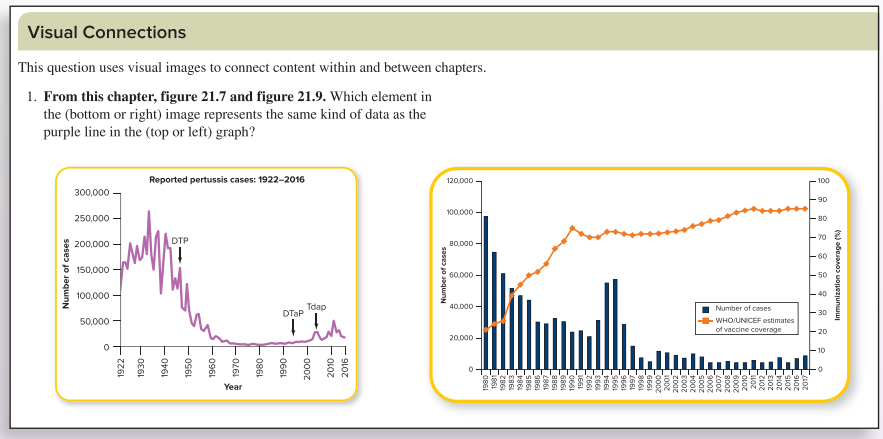
VIRTUAL GROUPS

Not everyone has the time or opportunity to meet with group members outside of class time. You or your instructor can create a virtual group using e-mail or the course software.

Weekly Discussion Board: Here is a question to be answered by each member of the group sometime before the topic is covered in class, sending your answer to every member of the group. It's best to agree on a deadline based on how your class schedule works (Saturday for the next week's topics, for example). Then, after the topic is discussed in class, each member should send a “Reply All”

Visual Connections

Visual Connections questions take images and concepts learned in previous chapters and ask students to apply that knowledge to concepts newly learned in the current chapter. This helps students evaluate information in new contexts and enhances learning.



Visual Connections

This question uses visual images to connect content within and between chapters.

1. **From this chapter, figure 21.7 and figure 21.9.** Which element in the (bottom or right) image represents the same kind of data as the purple line in the (top or left) graph?

Changes to the Sixth Edition

New to *Microbiology, A Systems Approach*

GLOBAL CHANGES THROUGHOUT THE SIXTH EDITION

- Many art pieces have been turned into infographics, a form of data visualization 21st-century learners are comfortable with.
- Language is simplified throughout the book. Sentences are shortened and general vocabulary is updated.
- Disease Tables now indicate the taxonomy of each microorganism.
- The end-of-chapter materials now include the SmartGrid—21 questions probing chapter content with respect to the ASM curriculum concepts *and* Bloom's taxonomy. Also, each chapter contains a simple guide for students to engage in face-to-face or virtual group study. This is called Study Smarter: Better Together.
- In all disease tables, each organism is denoted as "B, V, F, P, or H"—indicating bacterium, virus, etc. When bacterial, the table also indicates G+ or G-.

Major chapter updates or new material. Note: Each chapter contains between 400 and 700 edits, ranging from minor grammatical improvements to major insertions of content. Listed here are just the highlights.

Chapter 1: The Main Themes of Microbiology

- New infographics for better understanding of cell types
- More time on scientific methods
- Updates on evolutionary history of cell line
- Taxonomy and classification discussions clarified and simplified

Chapter 2: The Chemistry of Biology

- New elements named
- Case study on why saline might not be ideal for hydration (hint: it's the chloride!)

Chapter 3: Tools of the Laboratory

- In this chapter, there is typically a lot of terminology that is used to describe phenomena, yet the terms themselves are not defined (such as "what is growth?"); rewritten with an eye to what the students do not yet know
- New infographic to illustrate the "Five I's"

Chapter 4: Bacteria and Archaea

- New infographics that make different categories of bacteria more visual

Chapter 5: Eukaryotic Cells and Microorganisms

- Updated origins of eukaryotes narrative
- Highlighted increase in fungal opportunistic diseases
- Neglected parasitic infections (NPIs)

Chapter 6: Viruses and Prions

- Discussion of viruses in the microbiome
- New diseases caused by prions

Chapter 7: Microbial Nutrition, and Growth

- Improved the presentation of serial dilution
- Added origin of oxygen

Chapter 8: Microbial Metabolism

- Expands on electricity-eating bacteria

Chapter 9: Microbial Genetics

- Epigenetics and their connection with small RNAs

Chapter 10: Genetic Analysis and Genetic Engineering

- Pangenomes introduced
- CRISPR and gene drives updated

Chapter 11: Physical and Chemical Control of Microbes

- Added the banning by the FDA of triclosan and other chemicals in consumer products

Chapter 12: Antimicrobial Treatment

- The influence of antibiotics on the microbiome, throughout the lifespan
- New approaches to antimicrobials

Chapter 13: Microbe-Human Interactions: Health and Disease

- Added the need to negotiate the host microbiome as one of the steps required for microbes to cause disease
- Several new figures

Chapter 14: Host Defenses I: Overview and Nonspecific Defenses

- Changed overall organization to more logical sequence

Chapter 15: Host Defenses II: Specific Immunity and Immunization

- New infographic about the properties of specific immunity
- Information about vaccines for noninfectious conditions and CAR-T treatments

Chapter 16: Disorders in Immunity

- Updated discussion of causes of autoimmunity
- Several new infographics
- New information on asthma incidence

Chapter 17: Diagnosing Infections

- Point-of-care diagnostics
- More emphasis on genetic testing, qPCR, pan bacterial qPCR
- New infographics summarize the testing procedures for phenotypic, genotypic, and immunological methods in a visually consistent manner

Chapter 18: Infectious Diseases Affecting the Skin and Eyes

- Not new, but important: Retained and updated opening case study about measles transmission in an airport

Chapter 19: Infectious Diseases Affecting the Nervous System

- Zika virus disease added
- New prion described

Chapter 20: Infectious Diseases Affecting the Cardiovascular and Lymphatic Systems

- Updated the section on Rocky Mountain spotted fever to include all spotted fever rickettsias and noted their dramatic increase in the United States
- Discussion of CRISPR techniques for making mosquito populations sterile
- New figure detailing who gets AIDS in the United States

Chapter 21: Infectious Diseases Affecting the Respiratory System

- Updated differential diagnoses for pharyngitis and pneumonia

Chapter 22: Infectious Diseases Affecting the Gastrointestinal Tract

- Updated the *C. diff* genus to *Clostridioides*
- Updated foodborne disease trends

Chapter 23: Infectious Diseases Affecting the Genitourinary System

- More discussion of catheter-associated urinary tract infections
- Updated discussion on role of vaginal microbiome in high infant mortality rates
- Updated STI statistics

Chapter 24: Microbes and the Environment

- Increased emphasis on climate change

Chapter 25: Applied Microbiology and Food and Water Safety

- Clearer illustration of water purification

Acknowledgments

We are most grateful to our students who continually teach us how to more effectively communicate this subject. All the professors who reviewed manuscript or sent e-mails with feedback were our close allies as well, especially when they were liberal in their criticism. Jennifer Lusk contributed invaluable content to the text. Our minders at McGraw-Hill Education are paragons of patience and professionalism: Darlene Schueller is the best editor in the business, which makes it all the more surprising that she continues to work with us on book after book. Other members of our McGraw-Hill Education team upon whom we lean heavily are Lauren Vondra, Kristine Rellihan, Jim Connely, Jessica Portz, Beth Blech, Rachael Hillebrand, Lori Hancock, and Betsy Blumenthal.

—Kelly Cowan
—Heidi Smith

Review Process, Including Heat Maps

In the preparation of each edition, we have been guided by the collective wisdom of reviewers who are expert microbiologists and excellent teachers. They represent experience in community colleges, liberal arts colleges, comprehensive institutions, and research universities. We have followed their recommendations, while remaining true to our overriding goal of writing a readable, student-centered text. This edition has also been designed to be amenable to a variety of teaching styles. Each feature incorporated into this edition has been carefully considered in how it may be used to support student learning in both the traditional classroom and the flipped learning environment.

Also we are very pleased to have been able to incorporate real student data points and input, derived from thousands of our LearnSmart users, to help guide our revision. LearnSmart Heat Maps provided a quick visual snapshot of usage of portions of the text and the relative difficulty students experienced in mastering the content. With these data, we were able to hone not only our text content but also the LearnSmart questions.

- If the data indicated that the subject covered was more difficult than other parts of the book, as evidenced by a high proportion of students responding incorrectly, we substantively revised or reorganized the content to be as clear and illustrative as possible.
- I (Kelly) have spent some time researching student literacy levels and have found that although most students understand that there is a great deal of technical language they must master for the first time, they can have trouble with the way we (professors, textbook authors) communicate in writing. So the heat maps also point me to places where I wrote a complex sentence when a simple one would do.

Table of Contents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