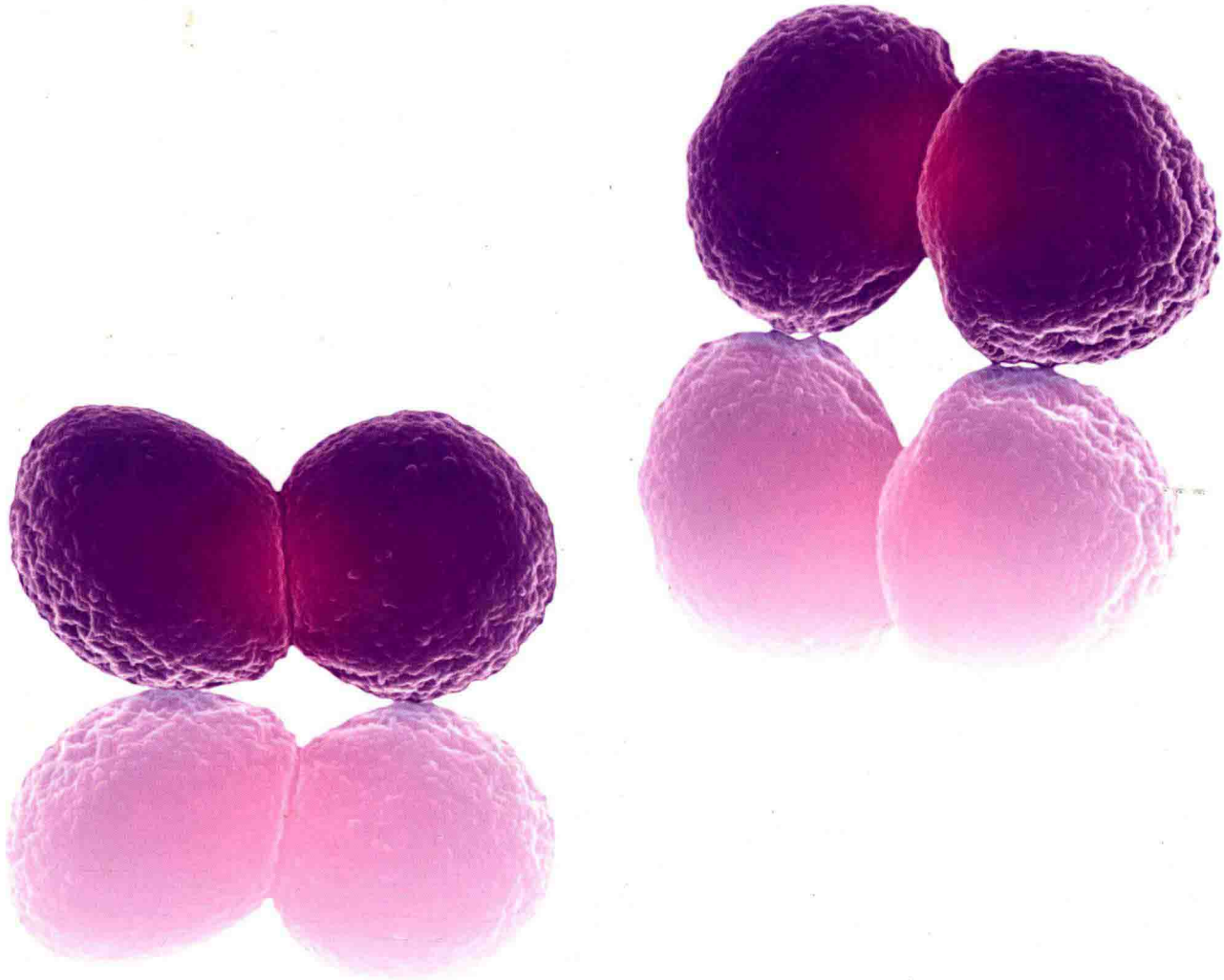
FOURTH EDITION

Microbiology

A Systems Approach



Marjorie Kelly Cowan

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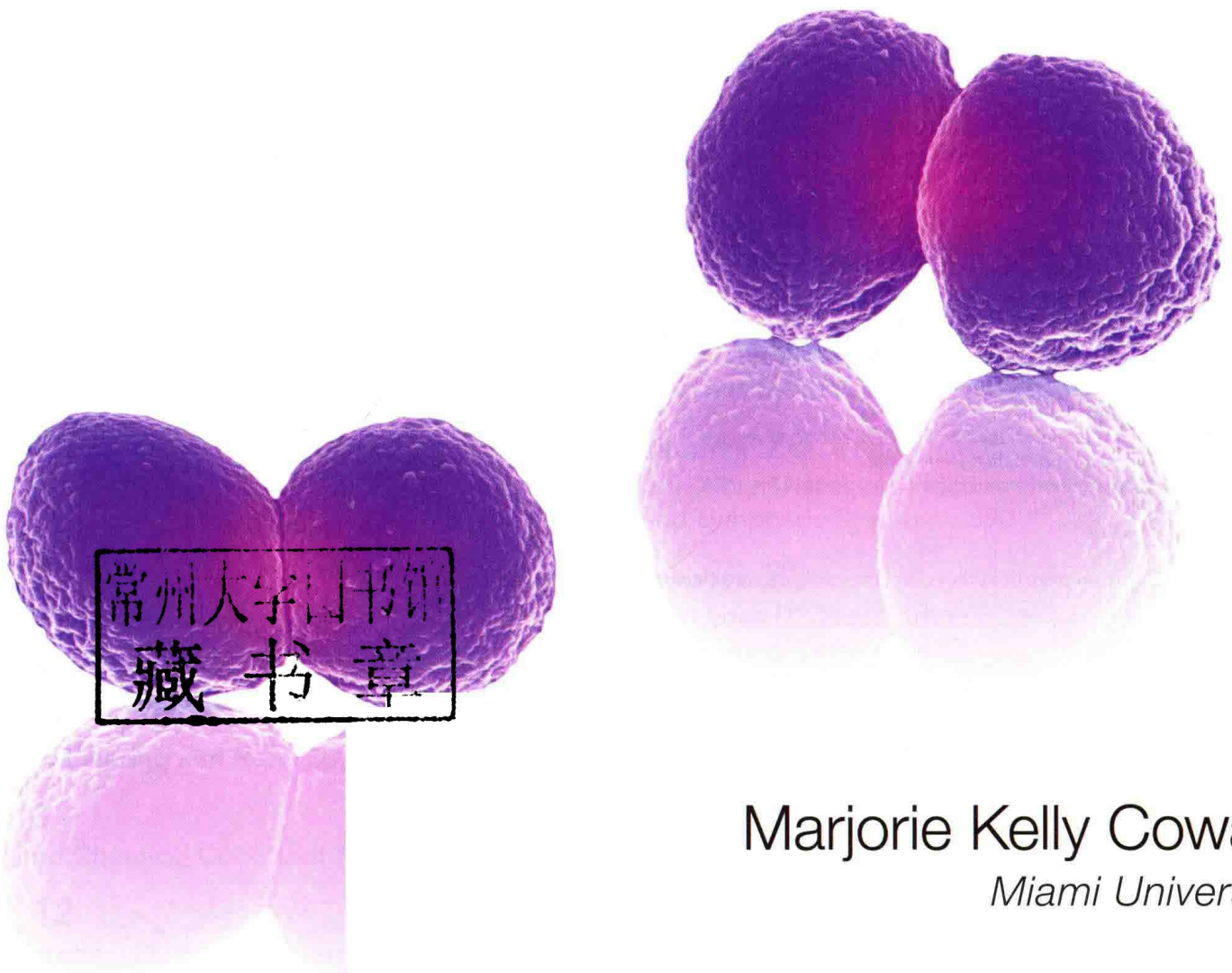

Marjorie Kelly Cowan
Miami University

Mc Graw Hill Education

MICROBIOLOGY: A SYSTEMS APPROACH, FOURTH EDITION

This book is printed on acid-free paper.

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Brief Contents

About the Authors

Kelly Cowan just celebrated her 20th anniversary at Miami University Middletown, an open admissions campus in Ohio. She received her Ph.D. at the University of Louisville, and later worked at the University of Maryland and the University of Groningen in the Netherlands. She specializes in teaching microbiology to nonmajors, and especially to pre-nursing and allied health students. She herself fell in love with microbiology while pursuing an undergraduate degree in dental hygiene. She has made it her personal mission to hear nurses and dental hygienists she encounters in everyday situations exclaim, "I *loved* my microbiology class!"

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

With this fourth edition, we are pleased to continue to have Jennifer Herzog on the team. Jen works hand-in-hand with the textbook author, creating online tools that truly complement and enhance the book's content. Because of Jen we now 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.

Jennifer Herzog, M.S., M. Phil., is an assistant professor of biology at Herkimer County Community College, Herkimer, New York, where she regularly teaches biology and microbiology to nonmajors and allied health students. She has been an active member of the American Society for Microbiology for nearly 20 years, most recently serving as Chair of the ASM Conference for Undergraduate Education and serving as Chair-Elect for the ASM's Education Division. In addition, she currently authors the "Journal Watch" section of the ASM's *Journal of Microbiology & Biology Education* and serves on the ASM's Microbe Library Editorial Review Board.

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.

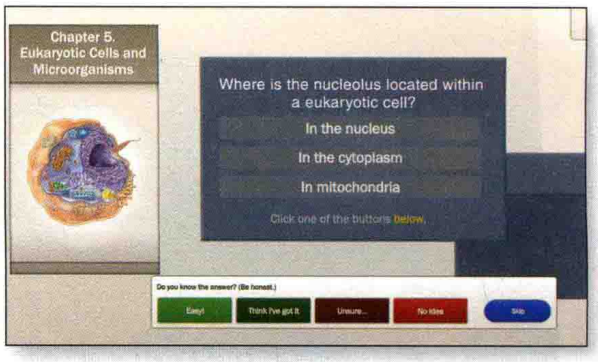
—Kelly Cowan

I dedicate this book to all public health workers who devote their lives to bringing the advances and medicines enjoyed by the industrialized world to *all* humans.

LEARNSMART™ ADVANTAGE

LearnSmart® is one of the most effective and successful adaptive learning resources available on the market today. More than 2 million students have answered more than 1.3 billion questions in LearnSmart since 2009, making it the most widely used and intelligent adaptive study tool that's proven to strengthen memory recall, keep students in class, and boost grades. Students using LearnSmart are 13% more likely to pass their classes, and 35% less likely to drop out.

LearnSmart continuously adapts to each student's needs by building an individual learning path so students study smarter and retain more knowledge. Turnkey reports provide valuable insight to instructors, so precious class time can be spent on higher-level concepts and discussion.



Fueled by LearnSmart—the most widely used and intelligent adaptive learning resource—**SmartBook™** is the first and only adaptive reading experience available today.

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LearnSmart Prep™ The primary goal of LearnSmart Prep is to help students who are unprepared to take college-level courses. Using super-adaptive technology, the program identifies what a student doesn't know, and then provides "teachable moments" designed to mimic the office hour experience. When combined with a personalized learning plan, an unprepared or struggling student has all the tools they need to quickly and effectively learn the foundational knowledge and skills necessary to be successful in a college-level course.

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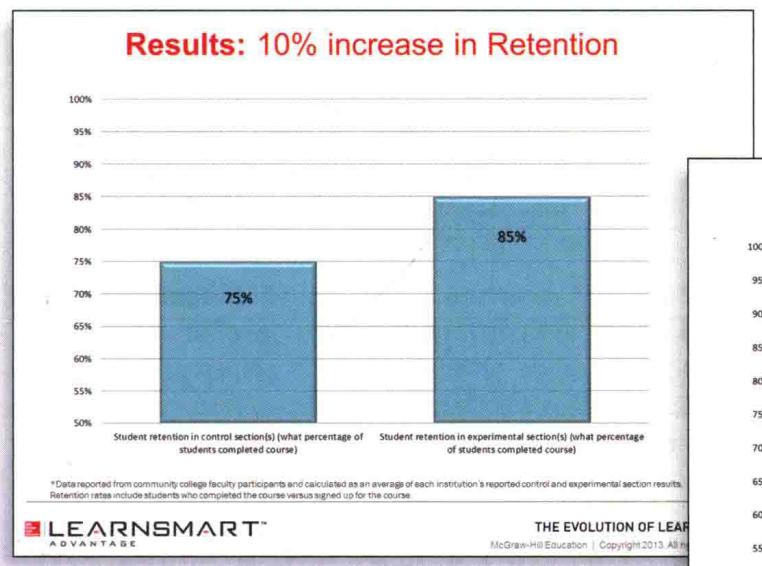
Digital efficacy study shows results!

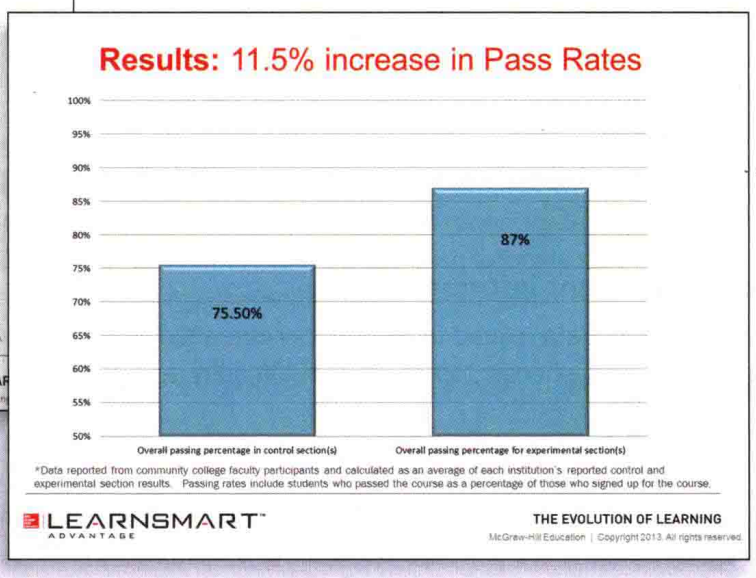
Digital efficacy study final analysis shows students experience higher success rates when required to use LearnSmart.

- Passing rates increased by an average of **11.5%** across the schools and by a weighted average of **7%** across all students.
- Retention rates increased an average of **10%** across the schools and by a weighted average of **8%** across all students.

Study details:

- Included two state universities and four community colleges.
- Control sections assigned chapter assignments consisting of testbank questions and the experimental sections assigned LearnSmart, both through McGraw-Hill Connect®.
- Both types of assignments were counted as a portion of the grade, and all other course materials and assessments were consistent.
- 358 students opted into the LearnSmart sections and 332 into the sections where testbank questions were assigned.





"LearnSmart has helped me to understand exactly what concepts I do not yet understand. I feel like after I complete a module I have a deeper understanding of the material and a stronger base to then build on to apply the material to more challenging concepts."

—Student

"After collecting data for five semesters, including two 8-week intensive courses, the trend was very clear: students who used LearnSmart scored higher on exams and tended to achieve a letter grade higher than those who did not."

—Gabriel Guzman, Triton College

"LearnSmart is intuitive and analyzes where the students' strengths and weaknesses are and develops a strategy to properly tutor the student. Connect Microbiology gives the students examples of test questions in several different formats and provides other materials to help them study and review the chapters."

—Stephen Wagner, Stephen F. Austin State University

Connecting to Core Concepts

McGraw-Hill ConnectPlus® Microbiology

McGraw-Hill Connect Microbiology is a digital teaching and learning environment that saves students and instructors time while improving performance over a variety of critical outcomes.

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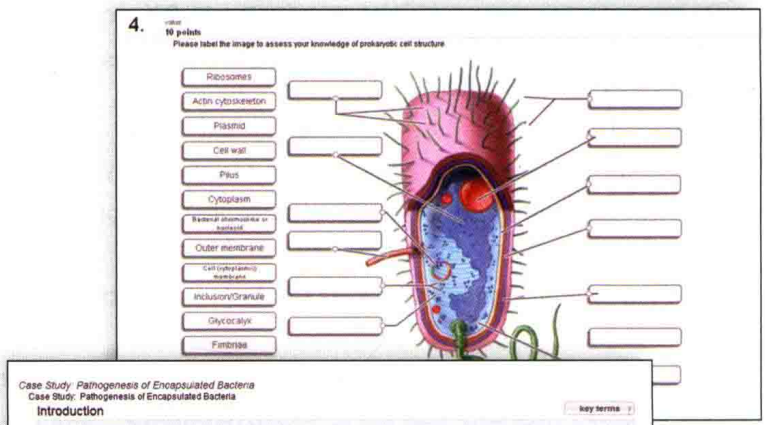
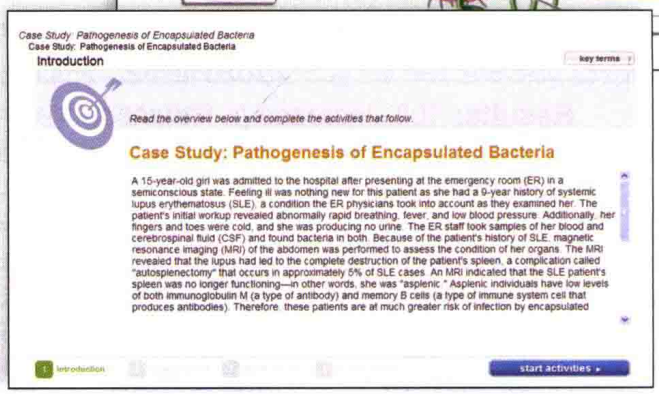
- Digital Lecture Capture: Get Connected. Get McGraw-Hill Tegrity Campus™. Capture your lectures for students. Easy access outside of class anytime, anywhere, on just about any device.

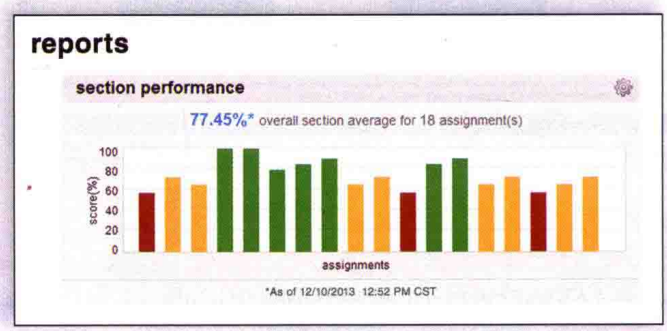




Gather assessment information

Generate powerful data related to student performance against Learning Outcomes, specific topics, level of difficulty, and more.

Visit www.mcgrawhillconnect.com.



Connect seamlessly integrates with every learning management system out there through McGraw-Hill Campus, so you can easily combine your course resources into a single platform. Instructors and students benefit from universal single sign-on, automatic registration, and gradebook synchronization.

"The clear explanation of complex topics with adequate graphic resources (in text and online) are its greatest strength. This is really enhanced with the Connect and LearnSmart materials. The online materials are the best available."

—Clifton Franklund, Ferris State University

Self-study resources are also available at **www.mhhe.com/cowan4e.**

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

1. **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. Pre- and post-testing allow instructors and students to assess their overall comprehension of the activity.
2. **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.
3. **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.
4. **Animations:** Animation quizzes pair our high-quality animations with questions designed to probe student understanding of the illustrated concepts.
5. **Tutorial Animation Learning Modules:** Making use of McGraw-Hill's collection of videos and animations, this question type presents an interactive, self-grading, and assessable activity. Pre- and post-testing is used to assess shifts in student comprehension. Integrated questions force students to stop, think, and evaluate their understanding of the process being presented. These tutorials take a stand-alone, static animation and turn it into an interactive learning experience for your students with real-time remediation.
6. **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!
7. **Classification:** Ask students to organize concepts or structures into categories by placing them in the correct "bucket."
8. **Sequencing:** Challenge students to place the steps of a complex process in the correct order.
9. **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 ConnectPlus 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.

INSTRUCTORS
Presentation and Lecture Capture Tools

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Enhanced Lecture Presentations contain lecture outlines, art, photos, tables, and animations embedded where appropriate. Fully customizable, but complete and ready to use, these presentations will enable you to spend less time preparing for lecture!

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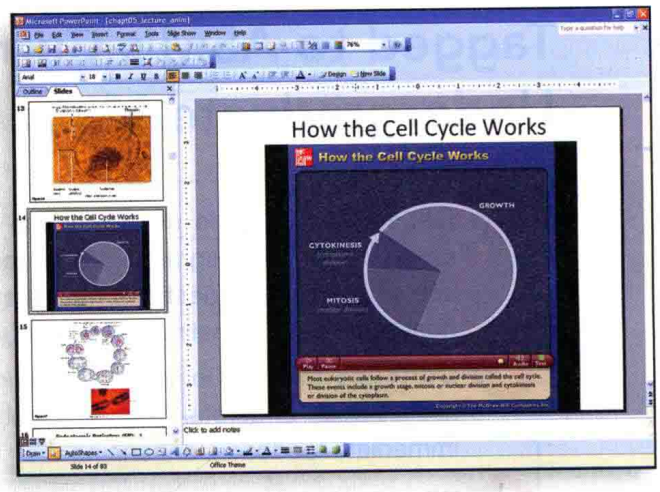

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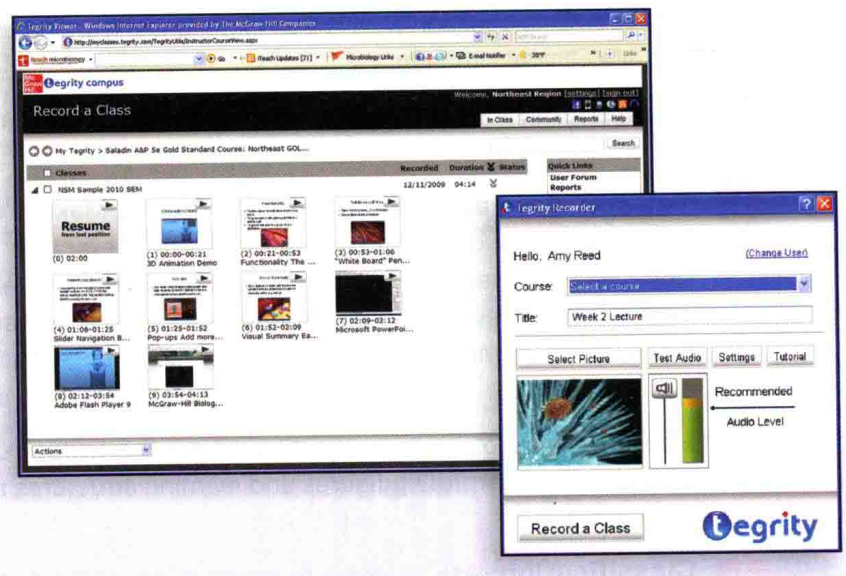

"This text is the complete package. It is well written and is supplemented with superior digital content."

—Nahel W. Awadallah, Johnston Community College

Be sure to visit Kelly's blog, www.microbiologymaven.com, where she and her guest bloggers tackle science and science teaching, as well as the occasional off-the-wall topic. If you subscribe (for free) you'll get emails once or twice a week with new entries: just enough to relieve stress and renew your sense of camaraderie with fellow instructors around the country.

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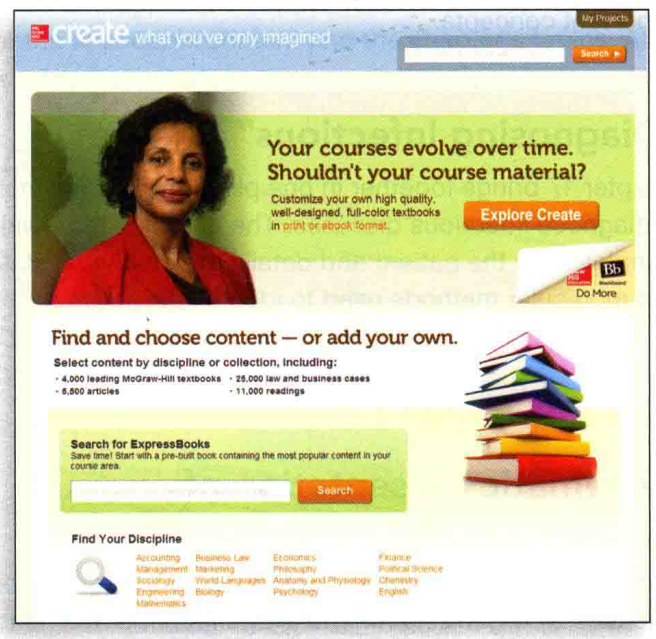

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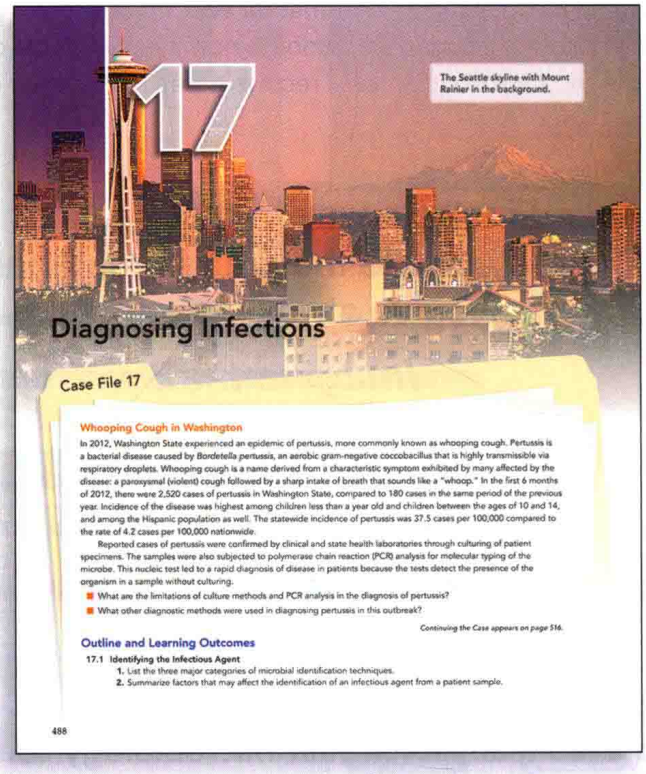
Connecting Students to Their Future Careers

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. Author Kelly Cowan has made it her goal to help all students make the connections between microbiology and the world they see around them. Her 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.


17

The Seattle skyline with Mount Rainier in the background.

Diagnosing Infections

Case File 17

Whooping Cough in Washington

In 2012, Washington State experienced an epidemic of pertussis, more commonly known as whooping cough. Pertussis is a bacterial disease caused by *Bordetella pertussis*, an aerobic gram-negative coccobacillus that is highly transmissible via respiratory droplets. Whooping cough is a name derived from a characteristic symptom exhibited by many affected by the disease: a paroxysmal (violent) cough followed by a sharp intake of breath that sounds like a "whoop." In the first 6 months of 2012, there were 2,520 cases of pertussis in Washington State, compared to 180 cases in the same period of the previous year. Incidence of the disease was highest among children less than a year old and children between the ages of 10 and 14, and among the Hispanic population as well. The statewide incidence of pertussis was 37.5 cases per 100,000 compared to the rate of 4.2 cases per 100,000 nationwide.

Reported cases of pertussis were confirmed by clinical and state health laboratories through culturing of patient specimens. The samples were also subjected to polymerase chain reaction (PCR) analysis for molecular typing of the microbe. This nucleic test led to a rapid diagnosis of disease in patients because the tests detect the presence of the organism in a sample without culturing.

- What are the limitations of culture methods and PCR analysis in the diagnosis of pertussis?
- What other diagnostic methods were used in diagnosing pertussis in this outbreak?

Continuing the Case appears on page 516.

Outline and Learning Outcomes

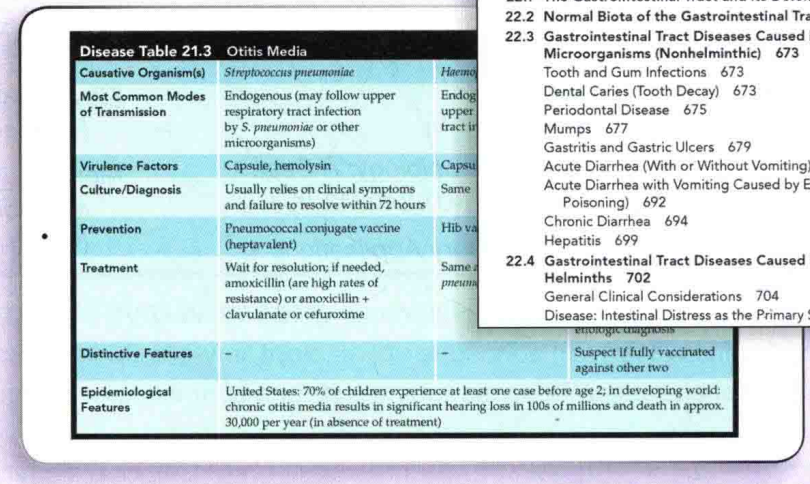
17.1 Identifying the Infectious Agent

1. List the three major categories of microbial identification techniques.
2. Summarize factors that may affect the identification of an infectious agent from a patient sample.

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. New to this edition: **Every disease table now contains national and 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.


Disease Table 21.3	Otitis Media		
Causative Organism(s)	*Streptococcus pneumoniae*	*Haemo*	
Most Common Modes of Transmission	Endogenous (may follow upper respiratory tract infection by *S. pneumoniae* or other microorganisms)	Endog upper tract i	
Virulence Factors	Capsule, hemolysin	Capsu	
Culture/Diagnosis	Usually relies on clinical symptoms and failure to resolve within 72 hours	Same	
Prevention	Pneumococcal conjugate vaccine (heptavalent)	Hib va	
Treatment	Wait for resolution; if needed, amoxicillin (are high rates of resistance) or amoxicillin + clavulanate or cefuroxime	Same *pneum*	
Distinctive Features	–	–	Suspect if fully vaccinated against other two
Epidemiological Features	United States: 70% of children experience at least one case before age 2; in developing world: chronic otitis media results in significant hearing loss in 100s of millions and death in approx. 30,000 per year (in absence of treatment)		

CHAPTER 22

Infectious Diseases Affecting the Gastrointestinal Tract 670

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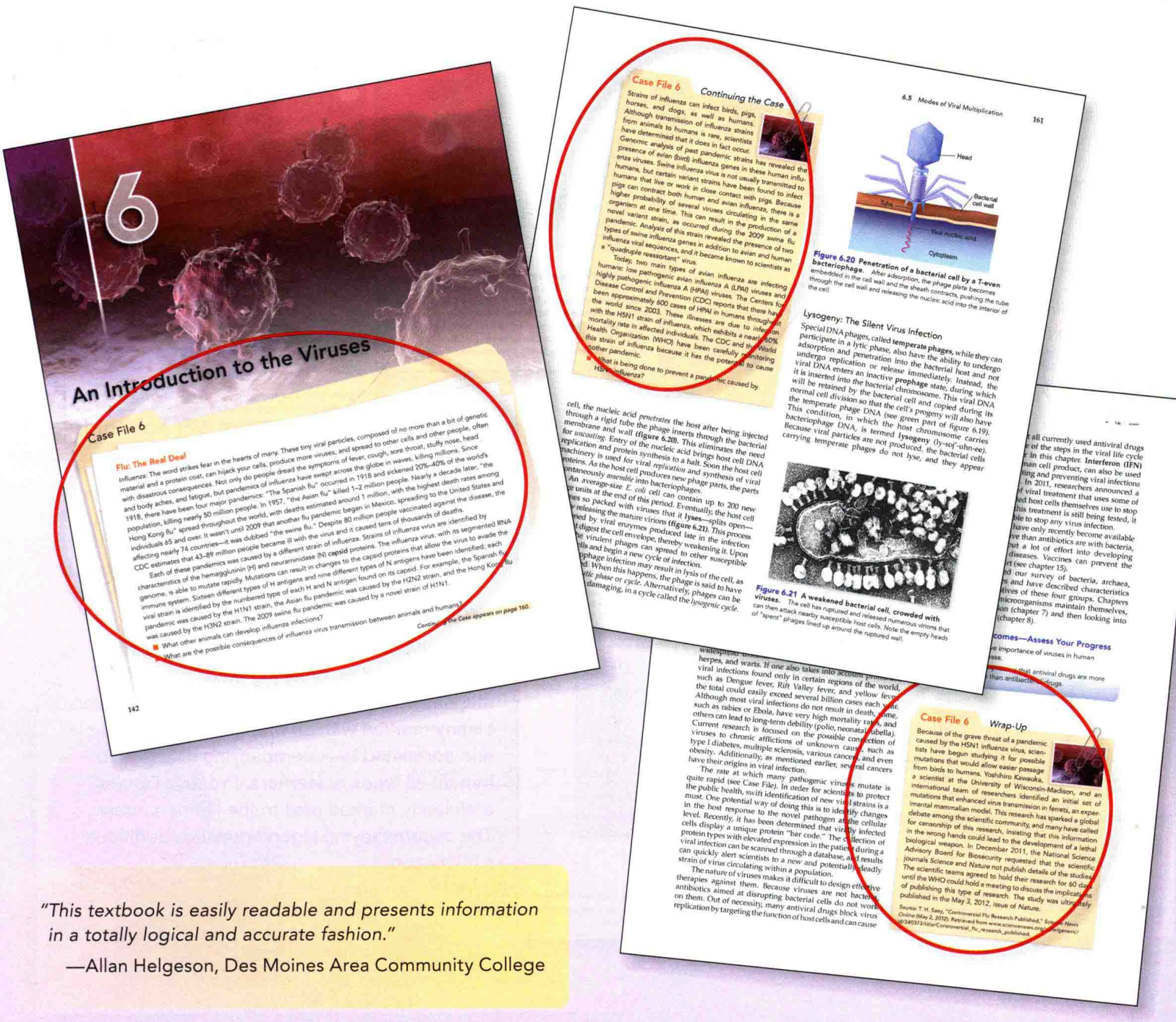
Chapter Opening Case Files!

Each chapter opens with a Case File, which helps students grasp the relevance of the material they're about to learn. The questions that directly follow the Case File challenge students to begin to think critically about what they are going to read, expecting that they'll be able to answer them once they've worked through the chapter. The Continuing the Case feature appears within the chapter where relevant, to help students follow the real-world application of the case. The Case File Wrap-Up summarizes the case at the end of the chapter, pulling together the applicable content and the chapter's topics. All of the case files are new in the fourth edition, including hot microbiological topics that are making news headlines today.



"This textbook is easily readable and presents information in a totally logical and accurate fashion."

—Allan Helgeson, Des Moines Area Community College

Connecting Students to the Content with Truly Instructional Art

Effective science illustrations not only look pretty, but help students visualize complex concepts and processes and paints a conceptual picture for them. The art combines vivid colors, multi-dimensionality, 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.

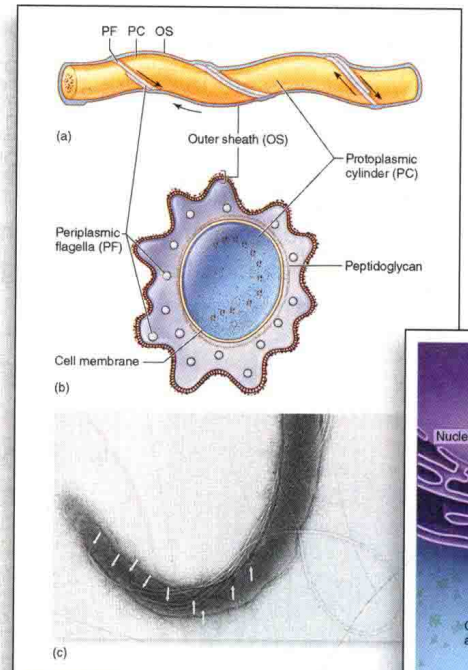


Figure 4.10 The orientation of periplasmic flagella c spirochete cell. **(a)** Longitudinal section. **(b)** Cross section (view). Contraction of the filaments imparts a spinning and undul pattern of locomotion. **(c)** Electron micrograph captures the dets of periplasmic flagella and their insertion points (arrows) in *Borre burgdorferi*, the cause of Lyme disease. One flagellum has escap outer sheath, probably during preparation for EM. (Bar = 0.2 mi

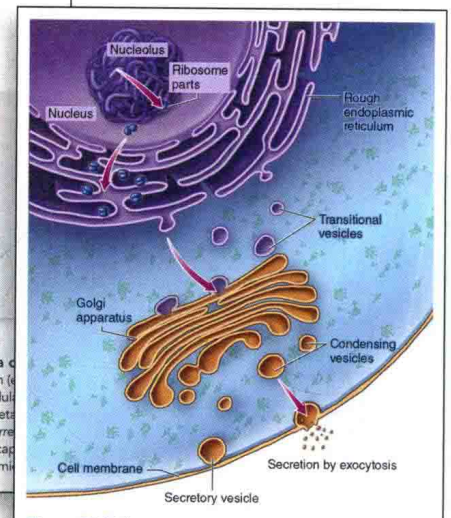
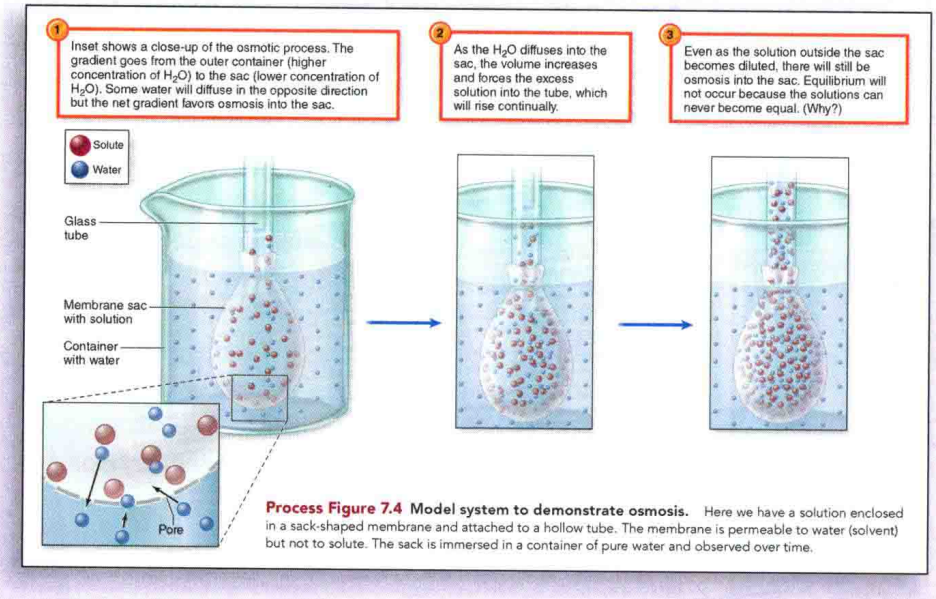


Figure 5.10 The transport process. The cooperation of organelles in protein synthesis and transport: nucleus → RER → Golgi apparatus → vesicles → secretion.

"The readabililty makes this text a winner. Excellent text!"

—Kimberly Harding, Colorado Mountain College



Process Figure 7.4 Model system to demonstrate osmosis. Here we have a solution enclosed in a sack-shaped membrane and attached to a hollow tube. The membrane is permeable to water (solvent) but not to solute. The sack is immersed in a container of pure water and observed over time.

Process Figures

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

Connecting Students to Microbiology with Relevant Examples

Real Clinical Photos Help Students Visualize Diseases

Clinical Photos

Color photos of individuals affected by disease provide students with a real life, clinical view of how microorganisms manifest themselves in the human body.

Combination Figures

Line drawings combined with photos give students two perspectives: the realism of photos and the explanatory clarity of illustrations. The authors chose this method of presentation often to help students comprehend difficult concepts.

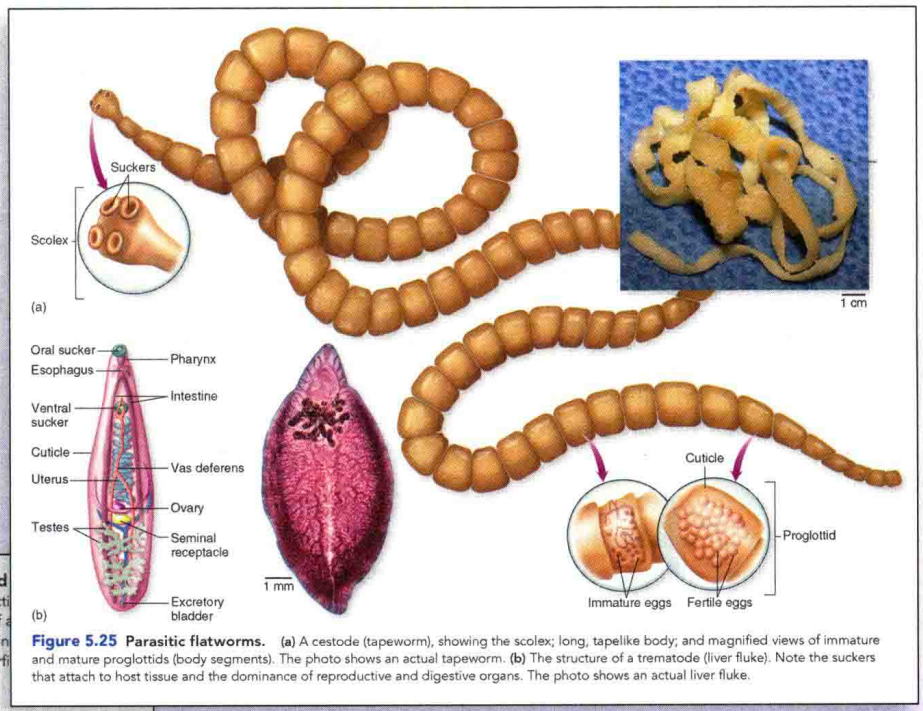


Figure 5.25 Parasitic flatworms. **(a)** A cestode (tapeworm), showing the scolex; long, tapelike body; and magnified views of immature and mature proglottids (body segments). The photo shows an actual tapeworm. **(b)** The structure of a trematode (liver fluke). Note the suckers that attach to host tissue and the dominance of reproductive and digestive organs. The photo shows an actual liver fluke.

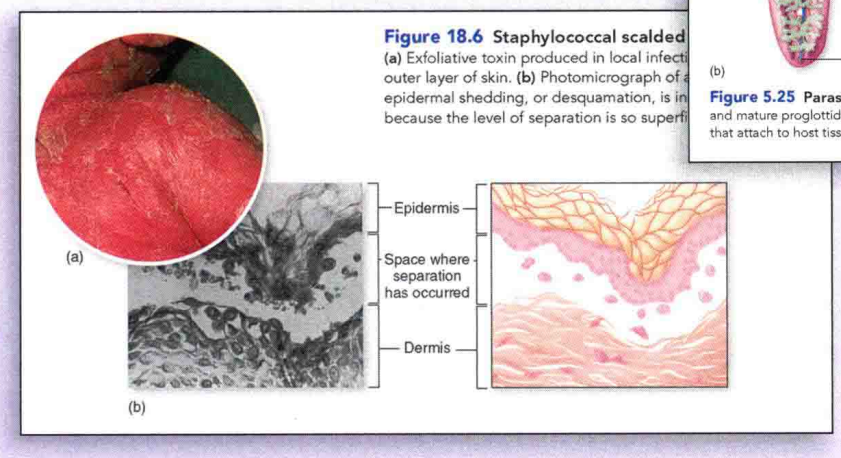


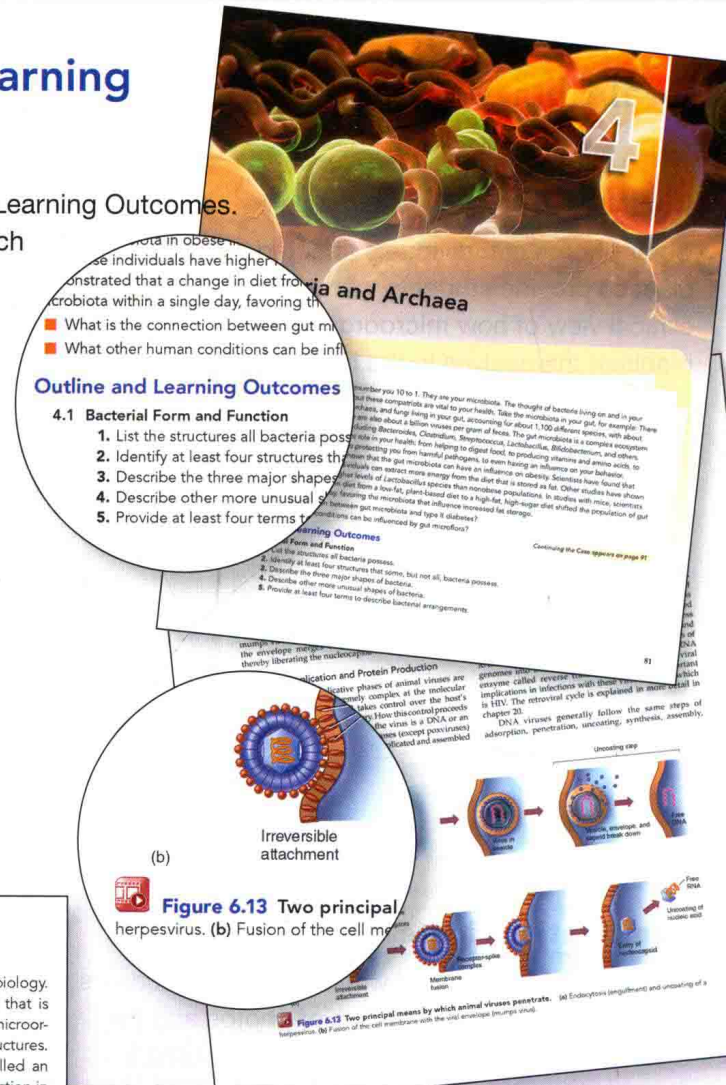
Figure 18.6 Staphylococcal scalded
(a) Exfoliative toxin produced in local infecti
outer layer of skin. **(b)** Photomicrograph of
epidermal shedding, or desquamation, is in
because the level of separation is so superfi

Connecting Students to Microbiology Through Student-Centered Pedagogy

Pedagogy Created to Promote Active Learning

Learning Outcomes and Assess Your Progress Questions

Every chapter in the book now opens with an outline—which is a list of Learning Outcomes. Assess Your Progress with the learning outcome questions conclude 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.

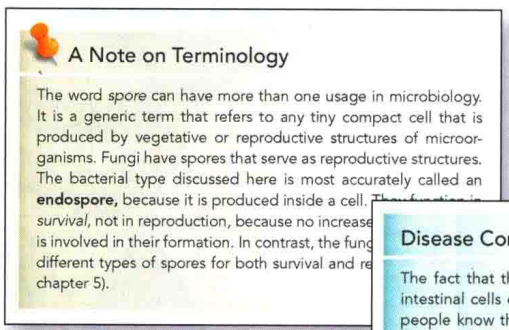


Animated Learning Modules

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.

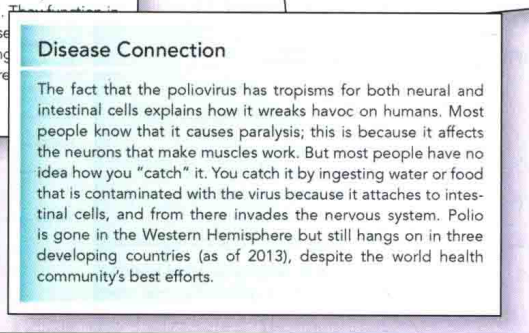
Notes

Notes appear, where appropriate, throughout the text. They give students helpful information about various terminologies, exceptions to the rule, or important clarifications.



Disease Connection

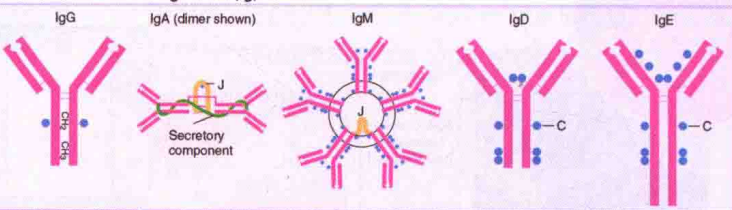
Sometimes it is difficult for students to see the relevance of basic concepts to their chosen professions. So in this edition the basic science chapters contain Disease Connections, very short boxes that relate esoteric topics such as pH and growth phase to clinical situations (*H. pylori* and *M. tuberculosis,*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



Tables

This edition contains numerous illustrated tables. Horizontal contrasting lines set off each entry, making it easy to read.

Table 15.3 Characteristics of the Immunoglobulin (Ig) Classes



	Monomer	Dimer, Monomer	Pentamer	Monomer	Monomer
Number of Antigen Binding Sites	2	4, 2	10	2	2
Molecular Weight	150,000	170,000-385,000	900,000	180,000	200,000