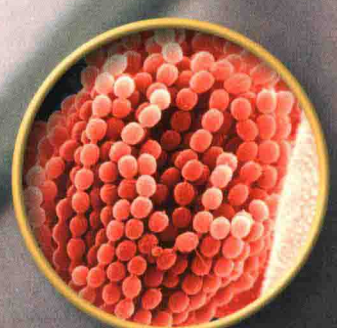
Marjorie Kelly Cowan
with Jennifer Bunn, RN

Microbiology FUNDAMENTALS

Second Edition

A Clinical Approach



Clinical Insights
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NCLEX®-Style Questions
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The Interconnected Health of the Environment, Humans, and Other Animals

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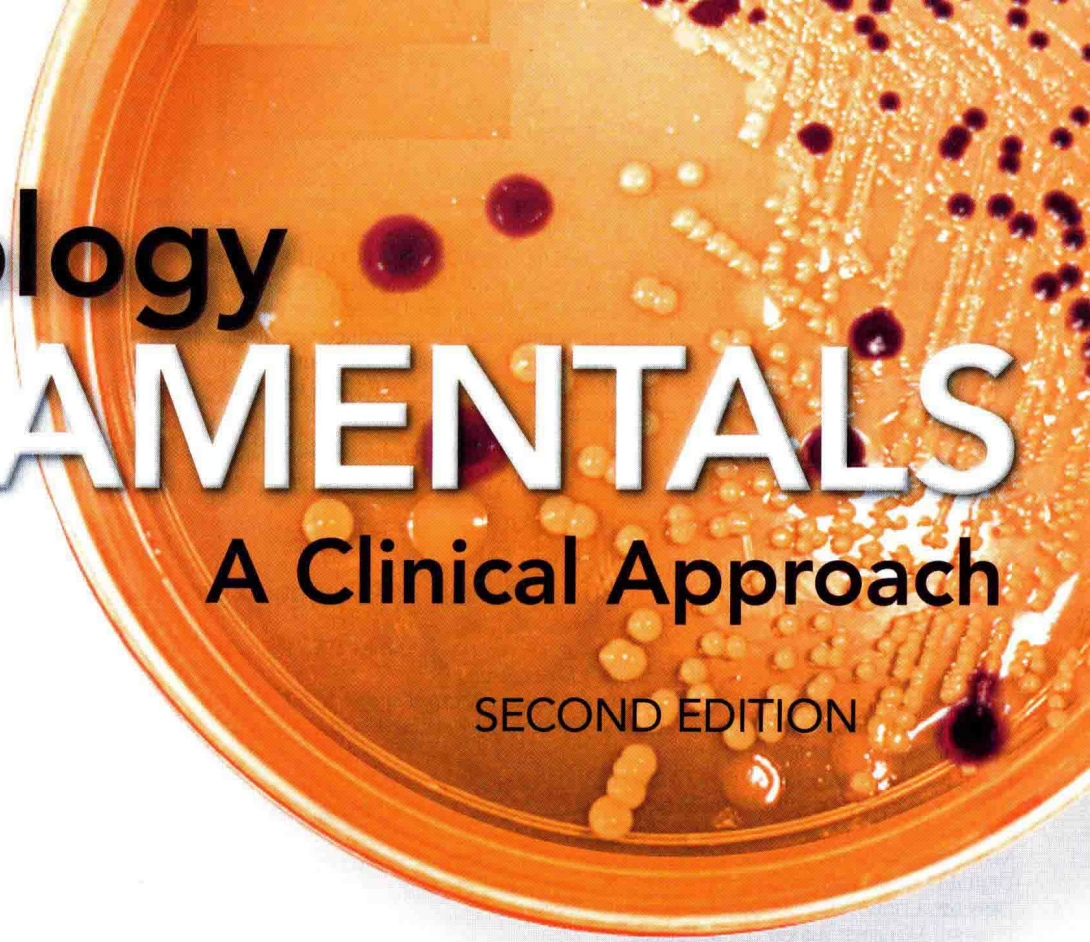

Microbiology FUNDAMENTALS

A Clinical Approach

SECOND EDITION

Marjorie Kelly Cowan
Miami University Middletown

WITH

Jennifer Bunn
RN, Clinical Advisor

Ronald M. Atlas
University of Louisville
Contributor

Heidi Smith
Front Range Community College
Digital Author

Mc Graw Hill Education

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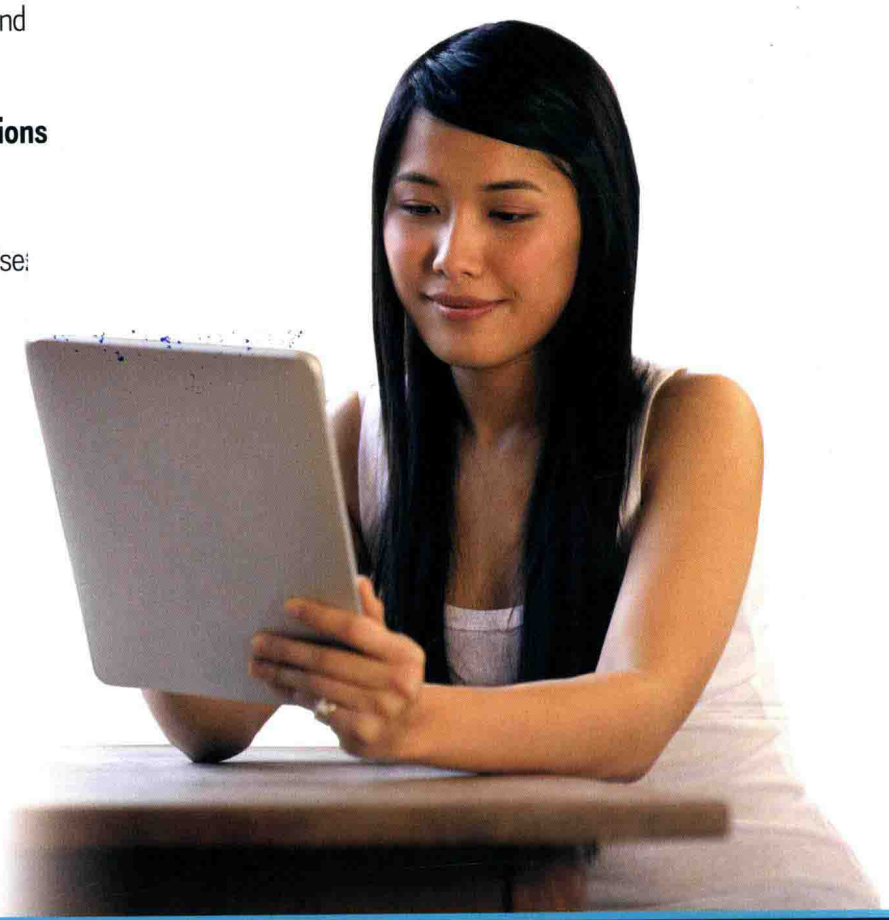

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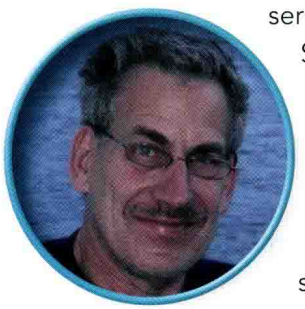
About the Authors

Kelly Cowan, PhD, has been a microbiologist at Miami University since 1993, where she teaches microbiology for pre-nursing/allied health students at the university's Middletown campus, a regional commuter campus that accepts first-time college students with a high school diploma or GED, at any age. She started life as a dental hygienist. She then went on to attain her PhD at the University of Louisville, and later worked at the University of Maryland's Center of Marine Biotechnology and the University of Groningen in The Netherlands. Kelly has published (with her students) 24 research articles stemming from her work on bacterial adhesion mechanisms and plant-derived antimicrobial compounds. But her first love is teaching—both doing it and studying how to do it better. She is past chair of the Undergraduate Education Committee of the American Society for Microbiology (ASM). When she is not teaching or writing, Kelly hikes, reads, and still tries to (s)mother her three grown kids.

Jennifer Bunn, RN, is a registered nurse, having spent most of her career in rural medicine, where she has had the opportunity to interact with patients of all ages. Her experience includes emergency medicine and critical care, pediatrics, acute care, long-term care, and labor and delivery. Currently, Jennifer works on an acute care unit. Over the span of her career, she has enjoyed mentoring and precepting LPN and RN students. Jennifer writes medical content for websites, apps, and blogs.



Ronald M. Atlas is Professor of Biology at the University of Louisville. He was a postdoctoral fellow at the Jet Propulsion Laboratory where he worked on Mars Life Detection. He has served as President of the American Society for Microbiology, as cochair of the American Society for Microbiology Biodefense Committee, as a member of the DHS Homeland Security Science and Technology Advisory Committee, and as chair of the Board of Directors of the One Health Commission. He is author of nearly 300 manuscripts and 20 books. His research on hydrocarbon biodegradation has helped pioneer the field of petroleum bioremediation. He has performed extensive studies on oil biodegradation and has worked for both Exxon and the U.S. EPA as a consultant on the *Exxon Valdez* spill and for BP on the *Deepwater Horizon* spill in the Gulf of Mexico.

Heidi Smith leads the microbiology department at Front Range Community College, Fort Collins, Colorado. Student success is a strategic priority at FRCC and a personal passion of Heidi's. 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 her face-to-face and online teaching approaches and student performance in her classes. Outside of the classroom, Heidi served as the director of the FRCC Honors Program for six years, working with other faculty to build the program from the ground up. She is also 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. Off campus, Heidi spends as much time as she can enjoying the beautiful Colorado outdoors with her husband and three young children.

Preface

Students:

Welcome! I am so glad you are here. I am very excited for you to try this book. I wrote it after years of frustration, teaching from books that didn't focus on the right things that my students needed. My students (and, I think, you) need a solid but not overwhelming introduction to microbiology and infectious diseases. I asked myself: What are the major concepts I want my students to remember 5 years from now? And then I worked backward from there, making sure everything pointed to the big picture.

While this book has enough detail to give you context, there is not so much detail that you will lose sight of the major principles. Biological processes are described right next to the illustrations that illustrate them. The format is easier to read than most books, because there is only one column of text on a page and wider margins. The margins gave me space to add interesting illustrations and clinical content. My coauthor, Jennifer Bunn, is a nurse who brings her years of experience to life on the page and shows you how this information will matter to you when you are working as a health care provider. We have interesting and up-to-the-moment Case Files, Medical Moments, Inside the Clinic selections, and NCLEX® questions in every chapter. Also be sure to use the Connect content—this is where you can really take control of your success in the class by making use of as many of the tools as you need.

I really wanted this to be a different kind of book. I started using it in my own classes and my students love it! Well, maybe they have to say that, but I hope that you truly do enjoy it and find that it is a refreshing kind of science book.

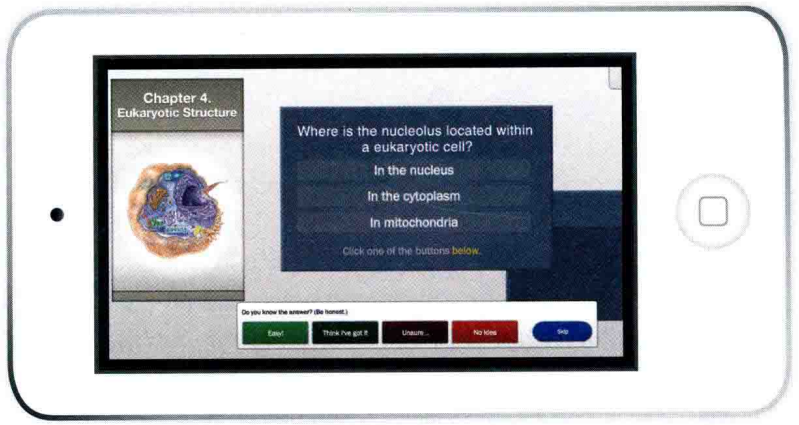
—Kelly Cowan

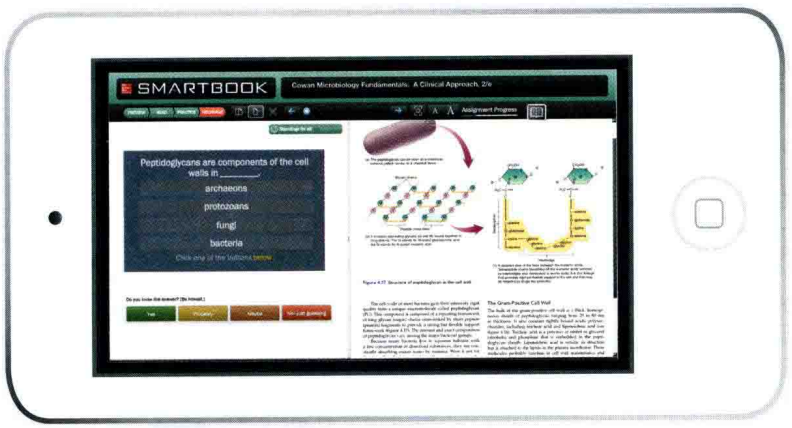
I dedicate this book to Ted.

LEARNSMART® ADVANTAGE

McGraw-Hill 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.



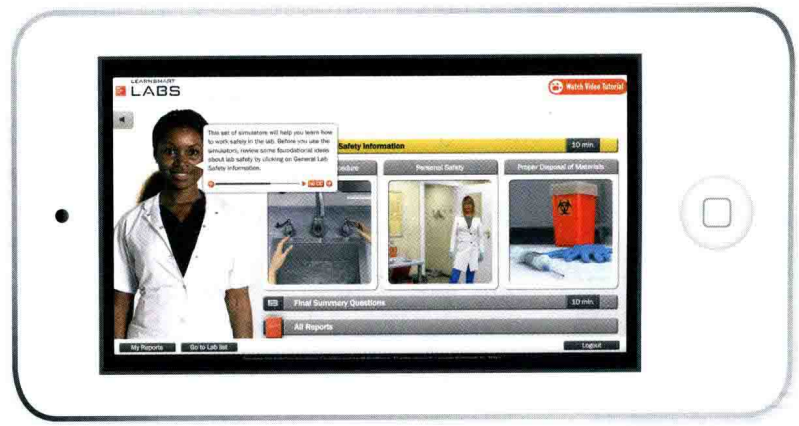


Fueled by LearnSmart—the most widely used and intelligent adaptive learning resource—**SmartBook®** is the first and only adaptive reading experience available today.

Distinguishing what students know from what they don't, and honing in on concepts they are most likely to forget, SmartBook personalizes content for each student in a continuously adapting reading experience. Reading is no longer a passive and linear experience, but an engaging and dynamic one where students are more likely to master and retain important concepts, coming to class better prepared.

As a result of the adaptive reading experience found in SmartBook, students are more likely to retain knowledge, stay in class, and get better grades.

LearnSmart Labs® is an adaptive simulated lab experience that brings meaningful scientific exploration to students. Through a series of adaptive questions, LearnSmart Labs identifies a student's knowledge gaps and provides resources to quickly and efficiently close those gaps. Once students have mastered the necessary basic skills and concepts, they engage in a highly realistic simulated lab experience that allows for mistakes and the execution of the scientific method.



LearnSmart Prep® is designed to get students ready for a forthcoming course by quickly and effectively addressing prerequisite knowledge gaps that may cause problems down the road. LearnSmart Prep maintains a continuously adapting learning path individualized for each student, and tailors content to focus on what the student needs to master in order to have a successful start in the new class.

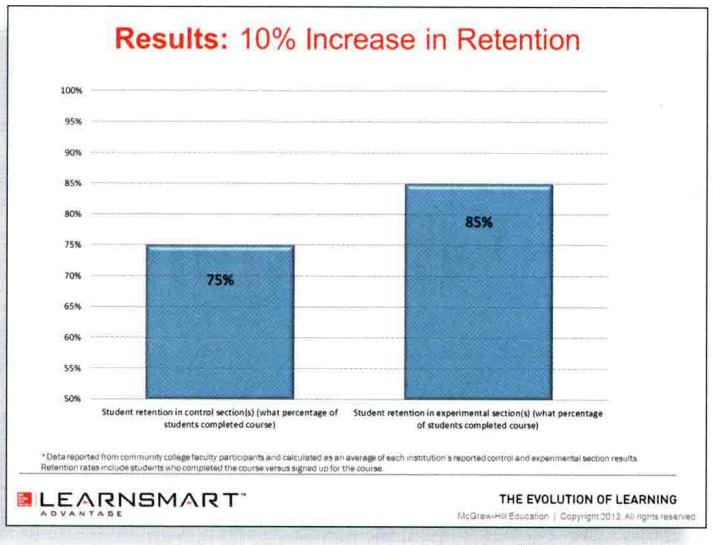
Digital efficacy study shows results!

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.

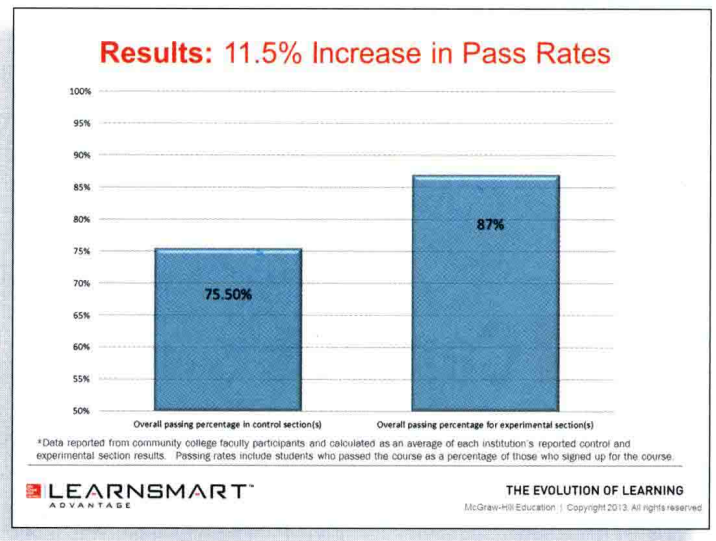
Study details:

- 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.



"Use of technology, especially LearnSmart, assisted greatly in keeping on track and keeping up with the material."

—student, Triton College



"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

"This textbook was selected due to the LearnSmart online content as well as the fact that it is geared for an allied health student. This textbook has certainly enhanced the classroom experience and I see that my students are better prepared for class after they have worked within LearnSmart."

—Jennifer Bess, Hillsborough Community College

Connecting Instructors to Students

McGraw-Hill Connect® Microbiology

connect® 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.

- Instructors have access to a variety of resources including assignable and gradable interactive questions based on textbook images, case study activities, tutorial videos, and more.
- Digital images, PowerPoint® lecture outlines, and instructor resources are also available through Connect.
- All Connect questions are tagged to a learning outcome, specific section and topic, ASM topics and curriculum guidelines, and Bloom's level for easy tracking of assessment data.

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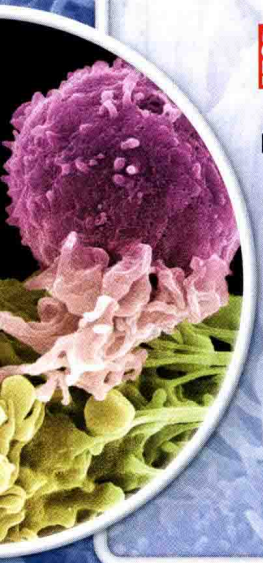
connect INSIGHT

Connect Insight® is a powerful data analytics tool that allows instructors to leverage aggregated information about their courses and students to provide a more personalized teaching and learning experience.



Campus

McGraw-Hill Campus® integrates all of your digital products from McGraw-Hill Education with your school's learning management system for quick and easy access to best-in-class content and learning tools.

Through Innovative Digital Solutions

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

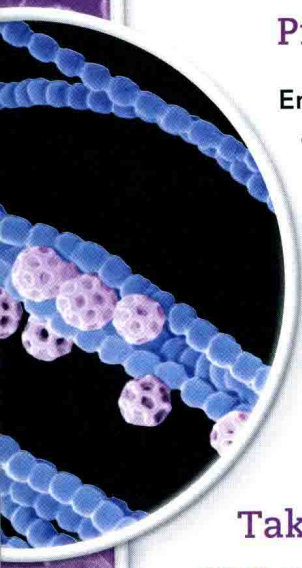
1. **Case Study:** Case studies come to life in a learning activity that is interactive, self-grading, and assessable. The integration of the cases with videos and animations adds depth to the content, and the use of integrated questions forces students to stop, think, and evaluate their understanding. 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:** Animations, videos, audio, and text all combine to help students understand complex processes. These tutorials take a stand-alone, static animation and turn it into an interactive learning experience for your students with real-time remediation. Key topics have an Animated Learning Module assignable through Connect. An icon in the text indicates when these learning modules are available.
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.
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 Connect content is tagged to Learning Outcomes for each chapter as well as topic, section, Bloom's Level, ASM topic, 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.

NCLEX®

NCLEX® Prep Questions: Sample questions are available in Connect to assign to students, and there are questions throughout the book as well.

INSTRUCTOR RESOURCES

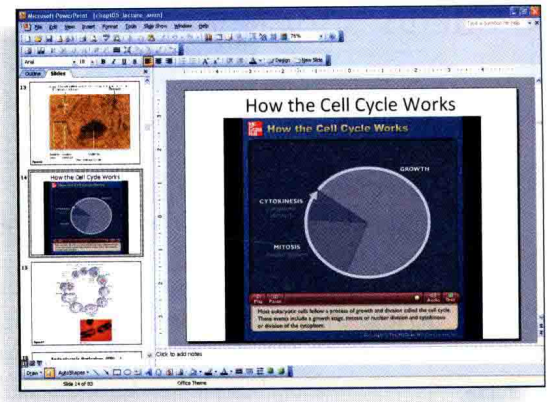


Presentation Tools allow you to customize your lectures.

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

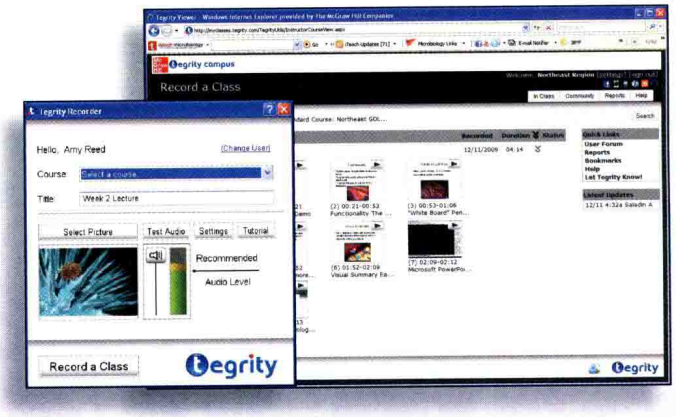
Animations Over 100 animations bring key concepts to life, available for instructors and students.

Animation PPTs Animations are embedded in PowerPoint for ultimate ease of use! Just copy and paste into your custom slide show and you're done!



Take your course online—*easily*—with one-click Digital Lecture Capture.

McGraw-Hill Tegrity® is a fully automated lecture capture solution used in traditional, hybrid, "flipped classes," and online courses to record lesson, lectures, and skills.



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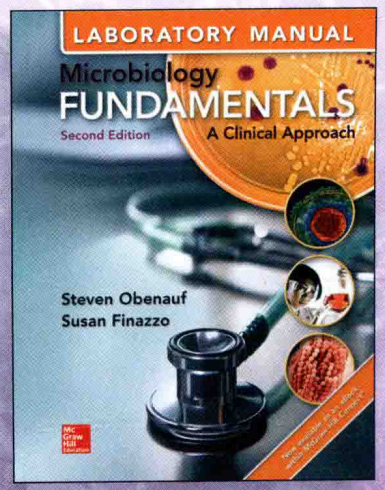
Microbiology Fundamentals Laboratory Manual, Second Edition

Steven Obenauf, Broward College
Susan Finazzo, Georgia Perimeter College

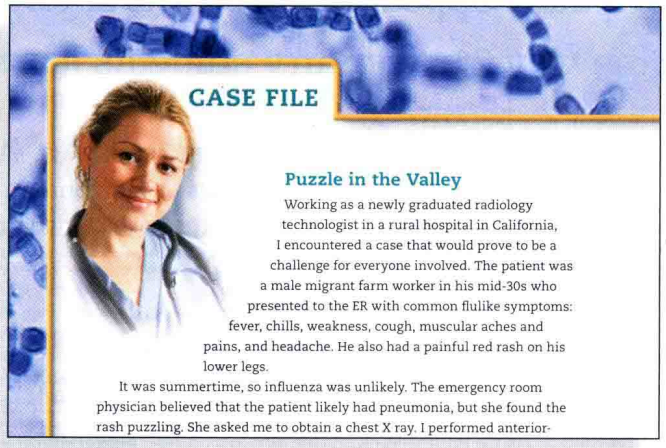
Written specifically for pre-nursing and allied health microbiology students, this manual features brief, visual exercises with a clinical emphasis.



Clinical applications help students see the relevance of microbiology.

Case File Each chapter begins with a case written from the perspective of a former microbiology student.

These high-interest introductions provide a specific example of how the chapter content is relevant to real life and future health care careers.


CASE FILE

Puzzle in the Valley

Working as a newly graduated radiology technologist in a rural hospital in California, I encountered a case that would prove to be a challenge for everyone involved. The patient was a male migrant farm worker in his mid-30s who presented to the ER with common flulike symptoms: fever, chills, weakness, cough, muscular aches and pains, and headache. He also had a painful red rash on his lower legs.

It was summertime, so influenza was unlikely. The emergency room physician believed that the patient likely had pneumonia, but she found the rash puzzling. She asked me to obtain a chest X ray. I performed anterior-

Clinical Contributor

This textbook features a clinical advisor, Jennifer Bunn, RN, who authored the following features, described on these pages:

- Added clinical relevance throughout the chapter
- Relevant case files
- Medical Moment boxes
- NCLEX® prep questions

"Jen added things that were fascinating to ME! And will enrich my own teaching. Pre-allied health students are so eager to start 'being' nurses, etc., they love these clinical details."

—Kelly Cowan

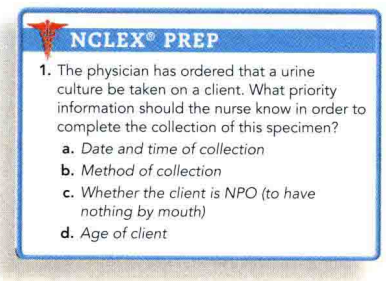
Medical Moment
These boxes give students a more detailed clinical application of a nearby concept in the chapter.


Medical Moment

Outsmarting Encapsulated Bacteria

Catheter-associated infections in critically ill patients requiring central venous access are unfortunately all too common. It has been estimated that bloodstream infection, a condition called **sepsis,** affects 3% to 8% of patients requiring an indwelling catheter for a prolonged period of time. Sepsis increases morbidity and mortality and can increase the cost of a patient's care by approximately $30,000.

In order to colonize a catheter, microorganisms must first adhere to the surface of the tip on this medical device. Fimbriae and glycocalyces are bacterial structures most often used for this purpose.

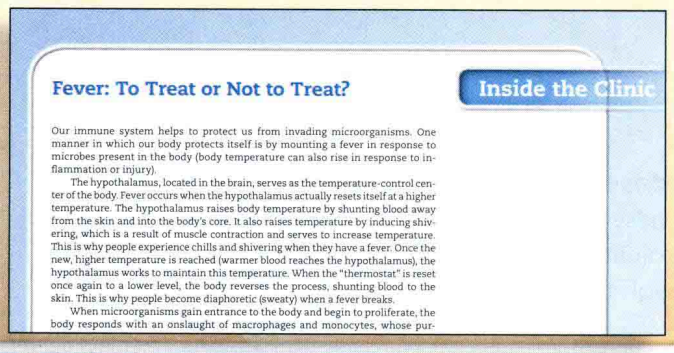

NCLEX® PREP

1. The physician has ordered that a urine culture be taken on a client. What priority information should the nurse know in order to complete the collection of this specimen?
   a. *Date and time of collection*
   b. *Method of collection*
   c. *Whether the client is NPO (to have nothing by mouth)*
   d. *Age of client*

NCLEX® Prep Questions Found throughout the chapter, these multiple-choice questions are application-oriented and designed to help students learn the microbiology information they will eventually need to pass the NCLEX examination. Students will begin learning to think critically, apply information, and over time, prep themselves for the examination.

Additional questions are available in Connect for homework and assessment.

Inside the Clinic Each chapter ends with a reading that emphasizes the nursing aspect of microbiology.


Fever: To Treat or Not to Treat?

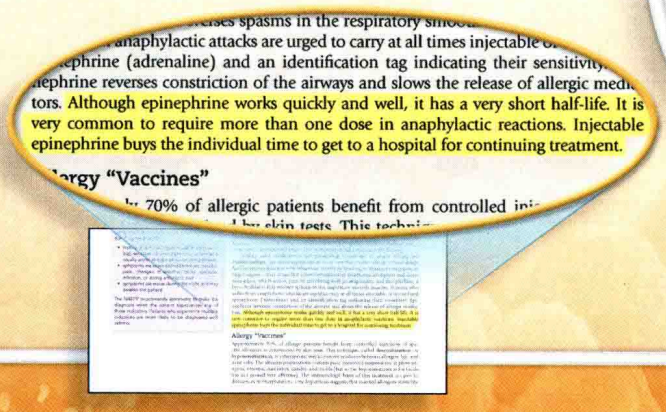
Inside the Clinic

Our immune system helps to protect us from invading microorganisms. One manner in which our body protects itself is by mounting a fever in response to microbes present in the body (body temperature can also rise in response to inflammation or injury).

The hypothalamus, located in the brain, serves as the temperature-control center of the body. Fever occurs when the hypothalamus actually resets itself at a higher temperature. The hypothalamus raises body temperature by shunting blood away from the skin and into the body's core. It also raises temperature by inducing shivering, which is a result of muscle contraction and serves to increase temperature. This is why people experience chills and shivering when they have a fever. Once the new, higher temperature is reached (warmer blood reaches the hypothalamus), the hypothalamus works to maintain this temperature. When the "thermostat" is reset once again to a lower level, the body reverses the process, shunting blood to the skin. This is why people become diaphoretic (sweaty) when a fever breaks.

When microorganisms gain entrance to the body and begin to proliferate, the body responds with an onslaught of macrophages and monocytes, whose pur-

Clinical Examples Throughout Clinical insights and examples are woven throughout the chapter—not just in boxed elements.


anaphylactic attacks are urged to carry at all times injectable
ephrine (adrenaline) and an identification tag indicating their sensitivity.
iephrine reverses constriction of the airways and slows the release of allergic medi
tors. Although epinephrine works quickly and well, it has a very short half-life. It is very common to require more than one dose in anaphylactic reactions. Injectable epinephrine buys the individual time to get to a hospital for continuing treatment.

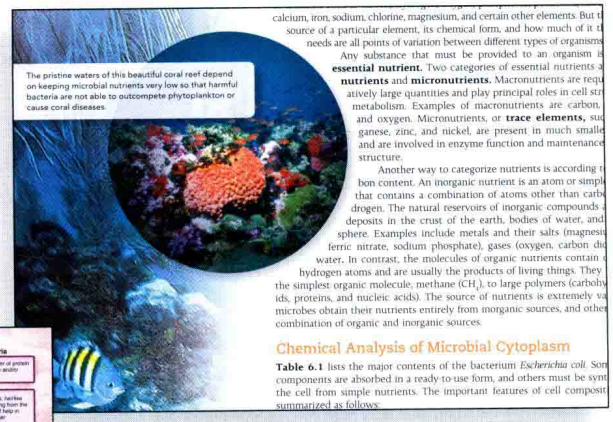
ergy "Vaccines"

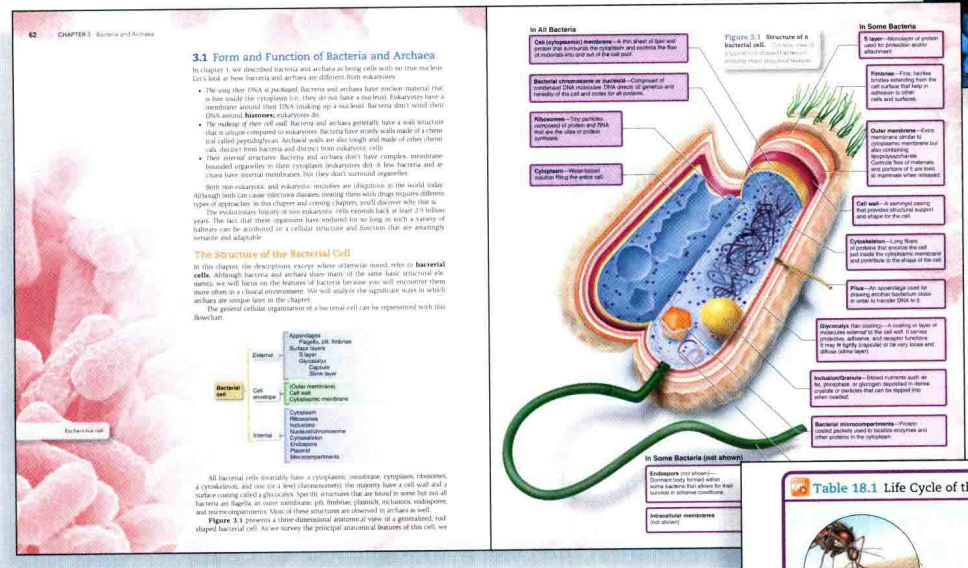
70% of allergic patients benefit from controlled

VISUAL

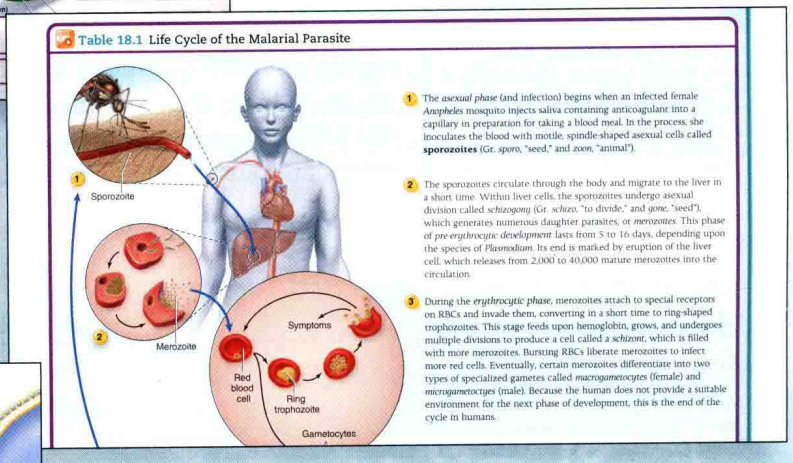
Visually appealing layouts and vivid art closely linked to narrative complement the way 21st-century students learn.

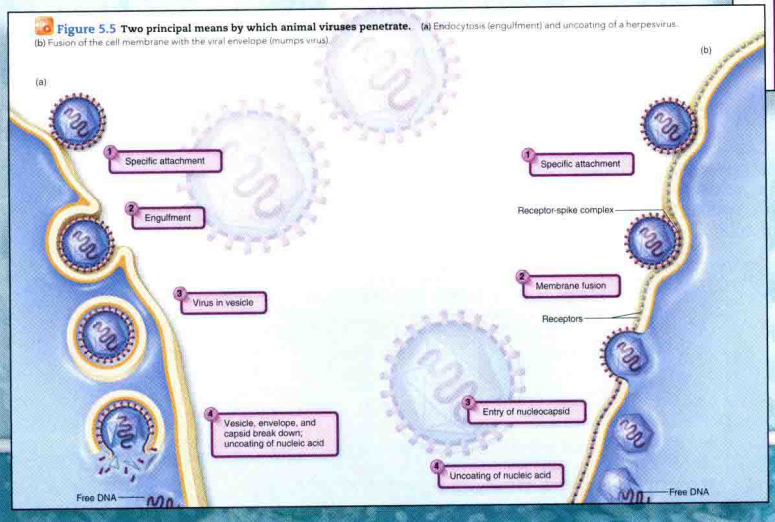
Engaging, Accurate, and Educational Art Visually appealing art and page layouts engage students in the content, while carefully constructed figures help them work through difficult concepts.





Visual Tables The most important points explaining a concept are distilled into table format and paired with explanatory art.





Process Figures Complex processes are broken into easy-to-follow steps. Numbered steps in the art coordinate with numbered text boxes to walk students through the figure.

Streamlined coverage of core concepts help students retain the information they will need for advanced courses.

Chemistry topics required for understanding microbiology are combined with the foundation content found in chapter 1.

Genetics content is synthesized into one chapter covering the concepts that are key to microbiology students.

A chapter in microbiology textbooks that is often not used in health-related classes becomes relevant because it presents the 21st-century idea of "One Health"—that the environment and animals influence human health and infections.

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Contributed by Ronald M. Atlas

"The textbook is unique in that it was written with the health science student in mind. Unlike most texts, which just claim to be appropriate for nursing students, this textbook actually incorporates real world health care using the features such as Inside the Clinic and Case Files. The textbook also incorporates critical thinking and visual connections to illustrate how a student would 'function' in the field."

—Jill Roberts, University of South Florida

Duplication Eliminated Detail is incorporated into figures so students can learn in context with the art. This allows a more concise narrative flow while still retaining core information.

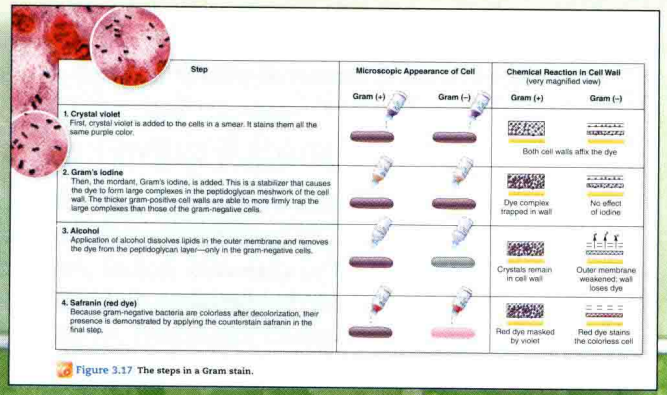
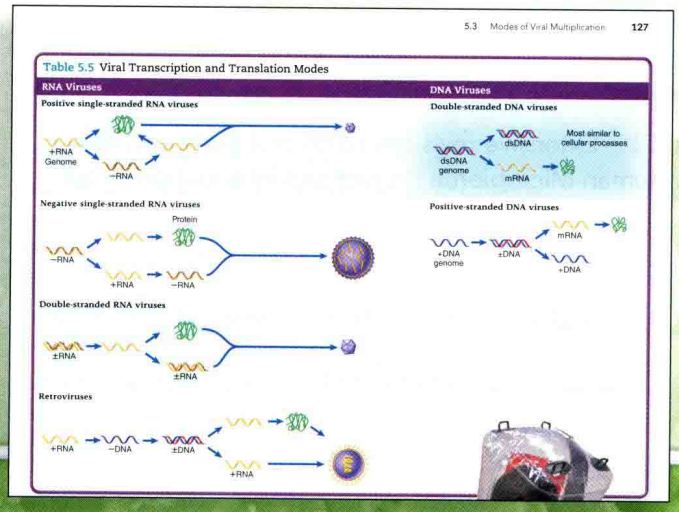


Figure 3.17 The steps in a Gram stain.

Tables Tables are used to further streamline content and help students understand relationships between concepts.



Changes to the Second Edition

Significant Changes

Epidemiological data (who, where, how common) are added for every organism in every disease table!

Twenty new chapter-opener case files include: a measles case, *C. diff*, Valley fever, Norwalk virus, gas gangrene, rheumatoid arthritis, UTI, and a bloodstream infection.

Throughout the Book

This edition has improved Learning Outcomes, new Critical Thinking questions, many new Medical Moments scattered throughout, and new Inside the Clinic scenarios at the ends of the chapters. Also, antibiotic-resistant bacteria are uniformly identified throughout the book according to CDC threat status, and neglected parasitic infections (NPIs) are highlighted.

Chapter Highlights

The Human Microbiome Project results have altered nearly every chapter. Other noteworthy changes are described here.

Chapters 1 and 4 Updates about origin of cells.

Chapter 2 New emphasis on nonculture methods.

Chapter 3 Much more information on biofilms; new material on S layers and microcompartments.

Chapter 6 Improved diffusion and osmosis discussion and exponential growth figures.

Chapter 9 Added concept of critical, semicritical disinfection.

Chapter 10 Significant changes and enhancements to the antibiotic-resistance section, incorporating information about resistance not ONLY being created in response to antibiotic presence; introduction of CDC threat report (used throughout disease chapters).

Chapter 11 Extensive revisions to normal biota sections based on Human Microbiome Project and information about normal biota in lungs, and so on; new information about polymicrobial infections, quorum sensing; added the built environment as a reservoir and the impact on epidemiology of Internet and social media.

Chapter 12 Updated to include gamma-delta T cells/NKT/NK cells as functioning in both specific and nonspecific immunity; added inflammasomes; updated discussion of interferon; complement section much clearer.

Chapter 13 Added detail on gamma-delta T cells and their important role; Medical Moment addresses Facebook group about pox parties.

Chapter 14 Updates on allergies and the microbiome.

Chapter 15 Many redrawn figures; new section titled "Breakthrough Methodologies" to discuss use of deep sequencing, mass spectrometry, and imaging as diagnostic techniques.

Chapter 16 Added *MRSA skin and soft-tissue infection* as first Highlight Disease; great emphasis on measles and recent outbreaks.

Chapter 18 Up-to-the-moment Inside the Clinic about the 2014 Ebola epidemic, including its presence in the United States.

Chapter 19 Extensive updates on influenza, TB, MDR-TB, and XDR-TB.

Chapter 20 Emphasis on neglected parasitic infections; addition of cysticercosis as a separate condition; addition of norovirus as a significant cause of diarrhea.

Chapter 21 UTI section completely rewritten to emphasize hospital and long-term-care infections.

Chapter 22 Completely new, revolutionary chapter by Ronald M. Atlas (One Health) which ties together the environment, animals and human health.

Acknowledgments

I am always most grateful to my students in my classes. They teach me every darned day how to do a better job helping them understand these concepts that are familiar to me but new to them. All the instructors who reviewed the manuscript for me were also great allies. I thank them for lending me some of their microbiological excellence. I had several contributors to the book and digital offerings—Hank Stevens, Andrea Rediske, Kimberly Harding, Kathleen Sandman and Heidi Smith chief among them. Jennifer Bunn, my coauthor, teaches me many things about many things. I would especially like to thank Ronald Atlas for the new chapter he wrote. I also am the beneficiary of the best copyediting on the planet delivered from the mind and keyboard of C. Jeanne Patterson. Amy Reed, Marija Magner, Sherry Kane, and Kristine Rellihan from McGraw-Hill Education make the wheels go round. Darlene Schueller, my day-to-day editor, is a wonderful human being and taskmaster, in that order. In short, I'm just a lucky girl surrounded by talented people.

—Kelly Cowan

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