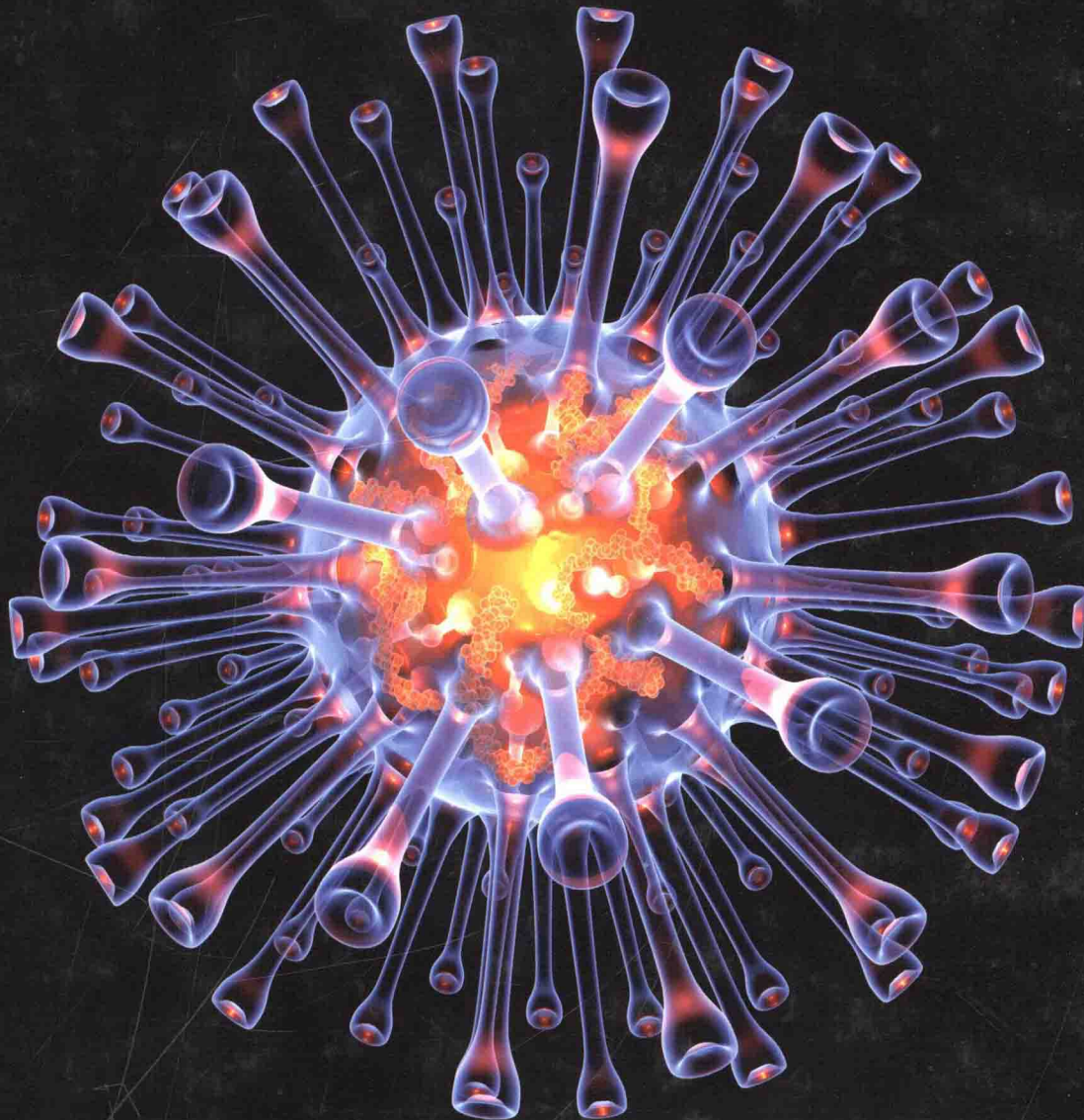


MICROBIOLOGY

PRINCIPLES AND EXPLORATIONS

9th
EDITION



JACQUELYN G. BLACK : LAURA J. BLACK

WILEY

MICROBIOLOGY

PRINCIPLES AND EXPLORATIONS

9TH
EDITION

JACQUELYN G. BLACK

Marymount University, Arlington, Virginia

LAURA J. BLACK

Laura Black has been working on this book since she was ten years old. She has been a contributing author for the past two editions and is now a coauthor of this ninth edition.



JACQUELYN and LAURA BLACK

WILEY

TO ROBERT . . .
*for sharing his mother and grandmother
with that greedy sibling “the book.”*

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COVER IMAGE: Pasieka/Science Source. Computer artwork of a swine influenza (flu) virus particle.

At the core of the virus is RNA (ribonucleic acid, orange) genetic material. This is surrounded by a nucleocapsid and a lipid envelope. In the envelope are two types of protein spike, hemagglutinin (H) and neuraminidase (N), which determine the strain of virus. These are used for recognizing and binding to the host cell.

AUTHOR PHOTO: Paul D. Robertson

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Preface

The development of microbiology—from Leeuwenhoek’s astonished observations of “animalcules,” to Pasteur’s first use of rabies vaccine on a human, to Fleming’s discovery of penicillin, to today’s race to develop an AIDS vaccine is one of the most dramatic stories in the history of science. To understand the roles microbes play in our lives, including the interplay between microorganisms and humans, we must examine, learn about, and study their world—the world of microbiology.

Microorganisms are everywhere. They exist in a range of environments from mountains and volcanoes to deep-sea vents and hot springs. Microorganisms can be found in the air we breathe, in the food we eat, and even within our own body. In fact, we come in contact with countless numbers of microorganisms every day. Although some microbes can cause disease, most are not disease producers; rather they play a critical role in the processes that provide energy and make life possible. Some even prevent disease, and others are used in attempts to cure disease. Because microorganisms play diverse roles in the world, microbiology continues to be an exciting and critical discipline of study. And because microbes affect our everyday lives, microbiology provides many challenges and offers many rewards. Look at your local newspaper, and you will find items concerning microbiology; to mention a few, reports on diseases such as AIDS, tuberculosis, and cancer; the resurgence of malaria and dengue fever, or “new” diseases.

Did you know that the microbes in your gut (the gut microbiome) affect you even before you are born? If your mother was obese during pregnancy, she had a low diversity of microbes in her gut, which she will pass on to you setting the stage for development of obesity and diabetes later in you. As a woman approaches her delivery date, beneficial microbes migrate down to the birth canal where they will hopefully be passed on to her baby. But if it is premature or born by Caesarian section, it won’t get them. Even the milk of C-sectioned mothers lacks proper diversity of microbes—and it won’t catch up to normal for 6 months. But if the mother has been in labor for some hours before the C-section is done, the milk will be normal from day one. Hard labor causes a leaky gut which allows microbes to get into the circulation and reach the breast milk. So when you plan to have a baby, think of the microbial implications: lose weight before you get pregnant, don’t have unnecessary C-sections, and breast feed. Those microbes are important.

One of the most exciting and controversial new developments occurred 5 years ago, when J. Craig Venter (of Human Genome fame) made a synthetic bacterium (*Synthia laboratorium*). Was he usurping the role of God?

Did we have to fear a whole new horde of man-made bacteria which would ruin the environment, create new diseases, or set off huge epidemics? Or, would they be the answer to problems such as providing biofuels that would take care of energy needs? Read about Dr. Venter’s work in Chapter 10. Incidentally, he already created the first synthetic virus a few years ago, from parts that he ordered from biological supply houses.

NAVIGATING MICROBIOLOGY

The theme that permeates this book is that microbiology is a current, relevant, exciting central science that affects all of us. I would like to share this excitement with you. Come with me as I take you, and your students, on a journey through the relevancy of microbiology. In countless areas—from agriculture to evolution, from ecology to dentistry—microbiology is contributing to scientific knowledge as well as solving human problems. Accordingly, a goal of this text is to offer a sense of the history of this science, its methodology, its many contributions to humanity, and the many ways in which it continues to be on the cutting edge of scientific advancement.

AUDIENCE AND ORGANIZATION

This book meets the needs of students in the health sciences as well as biology majors and students enrolled in other science programs who need a solid foundation in microbiology. It is designed to serve both audiences—in part by using an abundance of clinically important information to illustrate the general principles of microbiology and in part by offering a wide variety of additional applications.

In this edition, boxed essay titles appear in a different color to help students easily identify the type of application.

The organization of the ninth edition continues to combine logic with flexibility. The chapters are grouped in units from the fundamentals of chemistry, cells, and microscopy; to metabolism, growth, and genetics; to taxonomy of microbes and multicellular parasites; to control of microorganisms; to host-microbe interactions; to infectious diseases of humans; and finally to environmental

CLOSE UP

Happy Hunting

Most people have heard about Dolly, the cloned sheep, or Mr. Jefferson, the cloned calf. With successful genetic discoveries and experiments like these going on, you probably assumed that most of the organisms inhabiting the Earth were well known. But that's not true. Biology is still discovering basic information about the most abundant, widely distributed, and biochemically versatile organisms on the planet—the

formations of carbon, nitrogen, and sulfur in our biosphere; and live everywhere, even in bizarre and extreme habitats, prokaryotes are probably the least understood organisms on Earth. One recent study revealed a large variety of life, doubling the number of bacterial species. In the face of this discovery, the number of bacterial species on Earth—there is still a

TRY IT

Another Evil of Tobacco

Keep smokers away from your tomato plants. Cigarette tobacco always contains some tobacco mosaic virus—enough to start an infection in tomato plants when carried there by smokers' hands or cigarette butts. Try an experiment: Is it possible for a tomato plant in which cigarette tobacco has been soaked able to transfer the virus to another tomato plant?

Smoke? We know the effects of tobacco on the human body, but what about the effects of tobacco on plants?

PUBLIC HEALTH

Red Tides

Certain species of *Gonyaulax*, *Pfiesteria piscicida*, and some other dinoflagellates produce 2 toxins. One of these is thought to be a protection against hungry zooplankton predators. Symbiotic bacteria that live on the dinoflagellates' surfaces probably help synthesize the toxins. The other toxin affects only vertebrates. When these marine organisms appear seasonally in large numbers, they cause a bloom known as a *red tide*. When the population uses up available nutrients e.g., nitrogen and phosphorus, they become 2 to 7 times more



(Bill Bachman/Science Source)

APPLICATIONS

Plant Viruses

Besides the specificity shown by some viruses for bacteria and humans, other viruses are specific to and infect plants. Most viruses enter plant cells through damaged areas of the cell wall and spread through cytoplasmic connections called *plasmodesmata*.

Because plant viruses cause serious crop losses, much research has been done on them. The tobacco mosaic virus infects tobacco plants. Other plant viruses, which have either DNA or RNA genomes, infect various ornamental plants, including carnations and tulips. Food crops are not immune to viral infections. Lettuce, potatoes, beets, cucumbers, tomatoes, beans, corn, cauliflower, and turnips are all subject to infection.



BIOTECHNOLOGY

Whose DNA Do You Have?

Eukaryotic nuclei can be removed from cells of one species (such as human) and implanted into the egg cytoplasm of another species (such as a cow) from which the original nucleus has been removed. However, the cytoplasmic mitochondria of the second species retain their own DNA. The resulting embryo can develop, but it will have DNA from two species. This gives new meaning to the lyrics of the old song "Mama,

and applied microbiology. The chapter sequence will be useful in most microbiology courses as they are usually taught. However, it is not essential that chapters be assigned in their present order; it is possible to use this book in courses organized along different lines.

STYLE AND CURRENCY

In a field that changes so quickly—with new research, new drugs, and even new diseases—it is essential that a text be as up-to-date as possible. This book incorporates the latest information on all aspects of microbiology, including geomicrobiology, phage therapy, deep hot biosphere vents, and clinical practice. Special attention has been paid to such important, rapidly evolving topics as genetic engineering, gut microbiome, fecal transplants, prions, virophages, giant Mimi viruses, cervical cancer, and immunology.

One of the most interesting ideas new to immunology is found in the opener to Chapter 18: are worms our friends? Many autoimmune diseases such as Crohn's disease and irritable bowel disease are being treated by giving the patient 2,500 whipworm eggs every 2 or 3 weeks. They hatch, but can't develop as they are in the wrong host. But they induce a win—win symbiosis: They induce a dampening of the host's inflammatory immune response, meaning that they don't get killed (their win). The human host wins by not having a huge inflammatory immune response which would lead to an autoimmune disease. Our ancestors must have all had many kinds of worms with which they could have evolved symbioses. Maybe it's time to go back to "our old friends, the worms."

The rapid advances being made in microbiology make teaching about—and learning about—microorganisms challenging. Therefore, every effort has been made in the ninth edition of *Microbiology: Principles and Explorations* to ensure that the writing is simple, straightforward, and functional; that microbiological concepts and methodologies are clearly and thoroughly described;

and that the information presented is as accessible as possible to students. Students who enjoy a course are likely to retain far more of its content for a longer period of time than those who take the course like a dose of medicine. There is no reason for a text to be any less interesting than the subject it describes. So, in addition to a narrative that is direct and authoritative, students will find injections of humor, engaging stories, and personal reflections that I hope impart a sense of discovery and wonder and a bit of my passion for microbial life.

Because students find courses most interesting when they can relate topics to their everyday life or to career goals, I have emphasized the connection between microbiological knowledge and student experiences. One way that this connection is made is through the many boxed essays described previously. Another is through the use of factoids, post-it type notes that are tidbits of information relating to the running text and that add an extra dimension of flavor to the discussion at hand.

Over 20 million deaths each year are due to infectious disease.

Post-it type notes give additional information in the margin.

DESIGN AND ILLUSTRATIONS

The ninth edition of *Microbiology: Principles and Explorations* has been completely redesigned with an eye toward increasing the readability, enhancing the presentation of illustrations and photographs, and making the pedagogical features more effective for use. The use of clear, attractive drawings and carefully chosen photographs can significantly contribute to the student's understanding of a scientific subject. Throughout, color has been used not just decoratively but for its pedagogic value. For example, every effort has been made to color similar molecules and structures the same way each time they appear, making them easier to recognize.

Illustrations have been carefully developed to amplify and enhance the narrative. The line art in this text is sometimes as simple as a flow diagram or just as often a

Should boys be vaccinated with Gardasil against HPV?



FIGURE 20.24 Genital warts of the penis. (Biophoto Associates/Science Source)

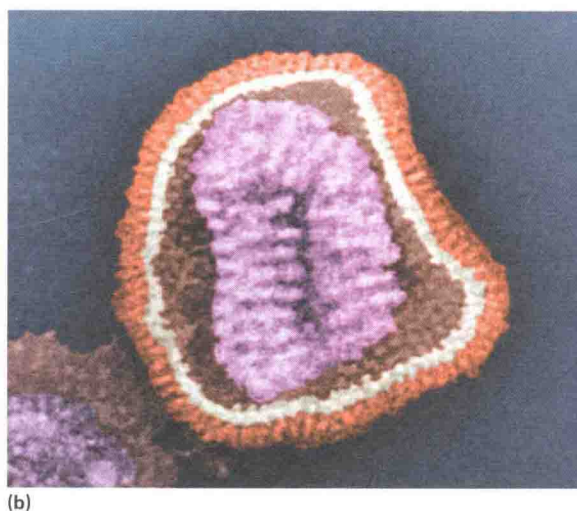
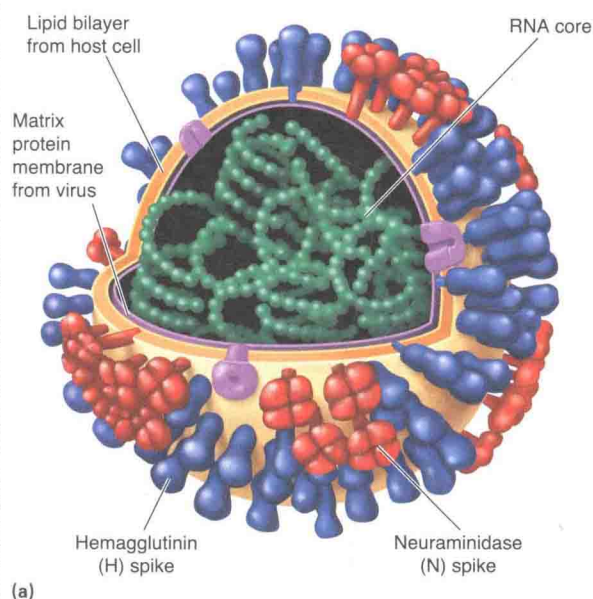


FIGURE 21.20 The influenza virus. (a) The virus shows hemagglutinin and neuraminidase spikes on its outer surface and an RNA core. (b) A colored TEM of an influenza virion (magnification unknown). (Science Source/Photo Researchers).

Line drawings and photos complement each other.

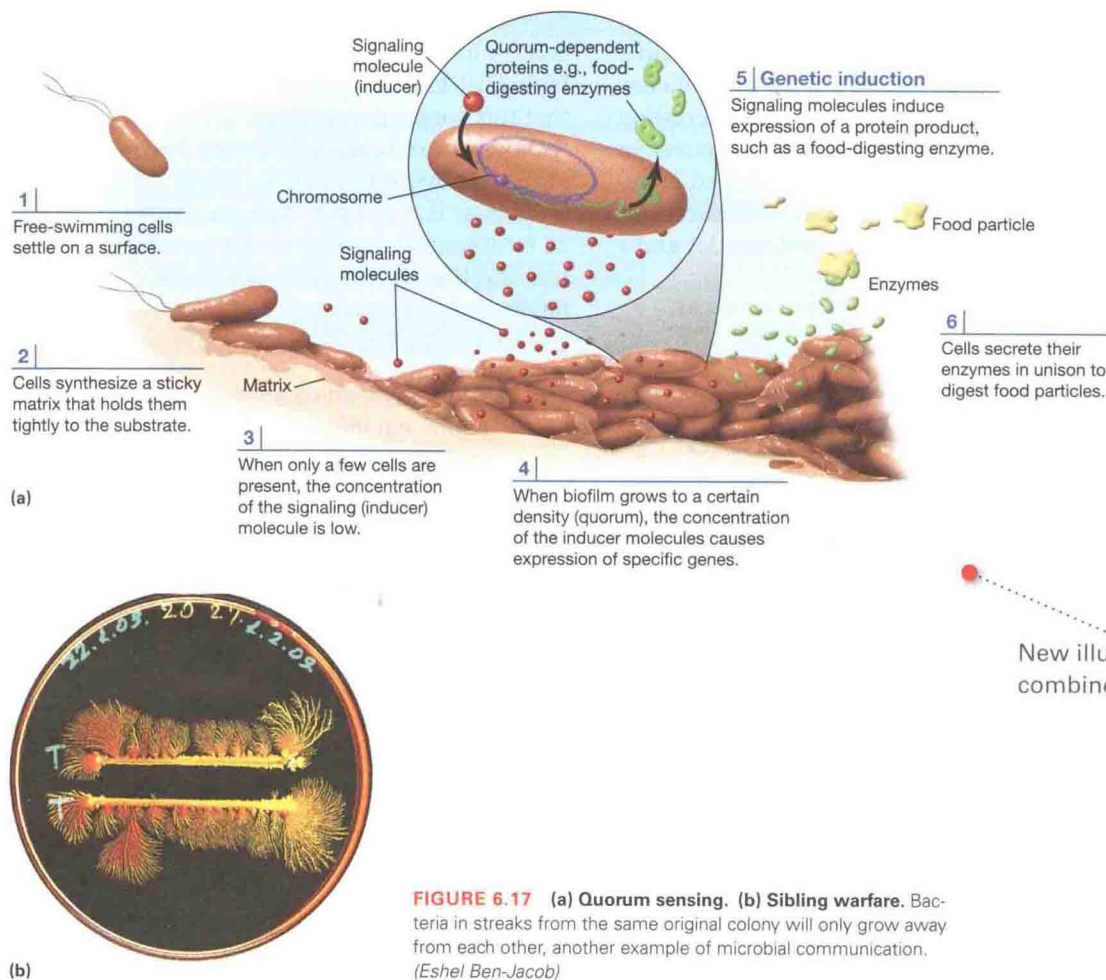


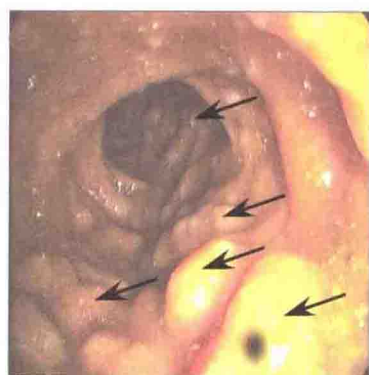
FIGURE 6.17 (a) Quorum sensing. (b) Sibling warfare. Bacteria in streaks from the same original colony will only grow away from each other, another example of microbial communication. (Eshel Ben-Jacob)

complex illustration of a structure drawn by some of the best medical illustrators working today.

Photographs also richly enhance the text. The diversity of the photo program encompasses numerous micrographs,

photographs of clinical conditions, microbiologists at work, and some laboratory techniques and results. Often, you will find a photograph accompanied by a line drawing aiding in the understanding of an unfamiliar subject.

Paired photos illustrate the text discussion.



(a)



(b)

Figure 18.24 Gastrointestinal tract endoscopy: before and a few weeks after HIV infection.

(a) The interior lining of the gut of an uninfected person showing numerous lymph node patches (GALT). (b) The gut lining stripped of lymph node Peyer's patches in an HIV-infected person. (Photographs from Brenchley et al., *Journal of Experimental Medicine*, 2004, Vol. 200, pp. 749–759 by copyright permission of The Rockefeller University Press.)

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WileyPLUS is a research-based online environment for effective teaching and learning. *WileyPLUS* is packed with interactive study tools and resources, including the complete online textbook.

WileyPLUS includes many opportunities for self-assessment linked to the relevant portions of the text. Students can take control of their own learning and practice until they master the material.

The rich variety of Microbiology resources, including Animations, Videos, and Microbiology Roadmaps ensure that students know how to study effectively, remain engaged, and stay on track.

WileyPLUS with ORION

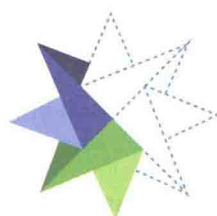
Different learning styles, different levels of proficiency, different levels of preparation—each of your students is unique. *WileyPLUS* empowers them to take advantage of their individual strengths. With *WileyPLUS*, students receive timely access to resources that address their demonstrated needs, and get immediate feedback and remediation when needed.

WileyPLUS for Microbiology 9e is now supported by an adaptive learning module called **ORION**. Based on cognitive science, ORION provides students with a personal, adaptive learning experience so they can build proficiency

in concepts and use their study time effectively. *WileyPLUS* with ORION helps students learn by learning about them.

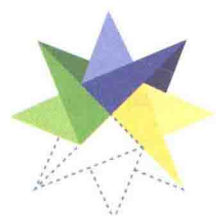
WileyPLUS with ORION is great as:

- An **adaptive pre-lecture tool** that assesses your students' conceptual knowledge so they come to class better prepared.
- A **personalized study** guide that helps students understand both strengths and areas where they need to invest more time, especially in preparation for quizzes and exams.



BEGIN

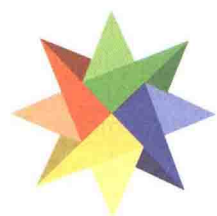
Unique to ORION, students **begin** by taking a quick **diagnostic** for any chapter. This will determine each student's baseline proficiency on each topic in the chapter. Students see their individual diagnostic report to help them decide what to do next with the help of ORION's recommendations.



PRACTICE

For each topic, students can either Study or Practice. **Study** directs the student to the specific topic they choose in *WileyPLUS*, where they can read from the e-textbook, or use the variety of relevant resources available there.

Students can also practice, using questions and feedback powered by ORION's adaptive learning engine. Based on the results of their diagnostic and ongoing practice, ORION will present students with questions appropriate for their current level of understanding, and will continuously adapt to each student, helping them build their proficiency.



MAINTAIN

ORION includes a number of reports and ongoing recommendations for students to help them maintain their proficiency over time for each topic. Students can easily access ORION from multiple places within *WileyPLUS*. It does not require any additional registration, and there will not be any additional charge for students using this adaptive learning system.

+ 3D Animations

To help explain “the most difficult topics in Microbiology to teach,” a new set of animations by renowned 3D Visualization artist, Janet Iwasa, University of Utah, are included in this edition. An icon accompanying key illustrations and sections of the text directs students to these animations in *WileyPLUS*. A complete set of animations is listed here:

CHAPTER 2

Acids and Bases
Chemical Bonding
Polarity and Solubility
Types of Reactions and Equilibrium

CHAPTER 3

Staining Bacteria: The Gram Stain
Wavelength Analogy

CHAPTER 4

Endocytosis and Exocytosis
Endosymbiosis
Eukaryotic Cell Structure
Mitosis and Meiosis Compared
Molecular Movement
Osmosis
Peptidoglycan
Prokaryotic Cell Structure
3D Animation: What do bacteria look like?
3D Animation: What structures are found inside of bacteria?
3D Animation: What types of cell envelopes are found in bacteria?
3D Animation: What features are found on the surface of bacteria?

CHAPTER 5

Catabolism of Fats and Proteins
Cell Respiration
Competitive and Noncompetitive Inhibition of Enzymes
Functions of Enzymes and uses of ATP
Metabolism: The Sum of Catabolism and Anabolism
3D Animation: What becomes of electrons generated by glycolysis and the TCA cycle?

CHAPTER 6

Binary Fission
Budding
Endospore Formation
Enterotube
Streak Plate Method
3D Animation: How can we grow microorganisms in the laboratory?
3D Animation: What other roles do bacteriological media perform?

3D Animation: How can a pure culture of a microorganism be obtained?

3D Animation: Besides spread and pour plate counts, how else can we measure microbial populations?

3D Animation: How do bacteria communicate with their neighbors?

CHAPTER 7

End Product Inhibition
Enzyme Induction: the Lac Operon
Eukaryotic Genes Contain Introns
Mutations
Polymerase Chain Reaction
Protein Synthesis
Thymine Dimer Repair
3D Animation: How are genome sequences determined?
3D Animation: How is gene expression measured using genomics tools?
3D Animation: How do regulatory proteins control transcription?
3D Animation: How can mRNA be controlled?

CHAPTER 8

Gene Transfer: Transformation
Recombinant DNA
Transduction
3D Animation: How do bacteria acquire free DNA from their environment?
3D Animation: How do bacteria share their DNA directly with other bacteria?
3D Animation: How do viruses help transfer DNA into bacteria?
3D Animation: How do transposable elements influence DNA variation in bacteria?
3D Animation: How can molecular biology tools be used to improve microbial strains?
3D Animation: What roles do microbes play in agricultural biotechnology?

CHAPTER 9

DNA Hybridization
Five Kingdom System of Classification

Lateral Gene Transfer
Shrub of Life

CHAPTER 10

Replication of An Enveloped dsDNA Animal Virus
Replication of (+) sense RNA viruses: HIV
Replication of (+) sense RNA viruses: poliovirus
Replication of a Virulent Bacteriophage
Replication of Temperate Bacteriophage
3D Animation: How do viruses recognize and attach to host cells?
3D Animation: How do viruses enter host cells?
3D Animation: How do viruses replicate their genome?
3D Animation: How do replicated viruses exit their host cells?
3D Animation: How do viruses interact with host cells?
3D Animation: How do some viruses become highly virulent?

CHAPTER 13

Antivirals
Effects of Premature Termination of Antibiotic Treatment

CHAPTER 16

Inflammation
Non-Specific Disease Resistance

CHAPTER 17

Antibody Mediated Immunity
Cell Mediated Immunity
Introduction to Disease Resistance
Production of Monoclonal Antibodies
3D Animation: What is the Cell-Mediated Immune Response?
3D Animation: How does humoral immunity fight infection?

CHAPTER 18

Four Types of Hypersensitivity
Myasthenia Gravis

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ALSO AVAILABLE

Laboratory Exercises in Microbiology, 4e (ISBN 9781118135259) Robert A. Pollack, Lorraine Findlay, Walter Mondschein, and R. Ronald Modesto is a publication that carefully corresponds to *Microbiology* 9e. This hands-on laboratory manual contains a variety of interactive activities and experiments that teach students the basic concepts of microbiology. It also covers methods that allow the safe movement or transfer of microbial cells from one type of growth environment to another, classification and identification of microbes, and microbial biochemistry.

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Comments and suggestions about the book are most welcome.
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Arlington, Virginia

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