FOUNDATIONS IN MICROBIOLOGY

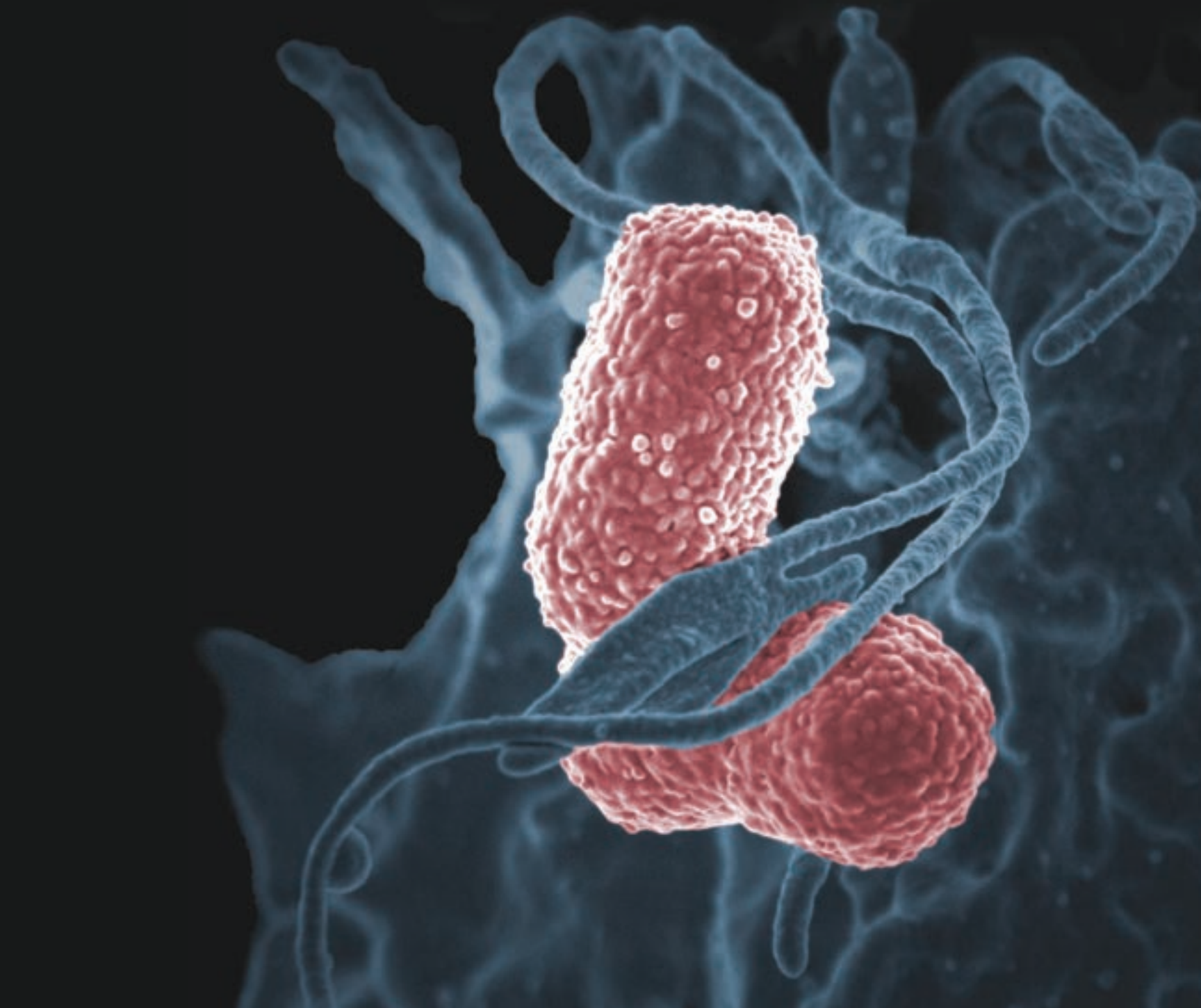
10th EDITION

KATHLEEN PARK
TALARO

BARRY
CHESS

Mc Graw Hill Education

FOUNDATIONS IN MICROBIOLOGY



TENTH EDITION

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FOUNDATIONS IN MICROBIOLOGY, TENTH EDITION

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Photo of Kathy Park Talaro (p. vi): Courtesy of Dave Bedrosian; Photo of Barry Chess (p. vi): Courtesy of Josh Chess

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Brief Contents

About the Authors

Kathleen Park Talaro is a microbiologist, educator, author, and artist. She has been nurturing her love of microbiology since her youth growing up on an Idaho farm where she was first fascinated by tiny creatures she could just barely see swimming in a pond. This interest in the microbial world led to a biology major at Idaho State University, where she worked as a teaching assistant and scientific illustrator for one of her professors. This was the beginning of an avocation that she continues today—that of lending her artistic hand to interpretation of scientific concepts. She continued her education at Arizona State University, Occidental College, California Institute of Technology, and California State University.

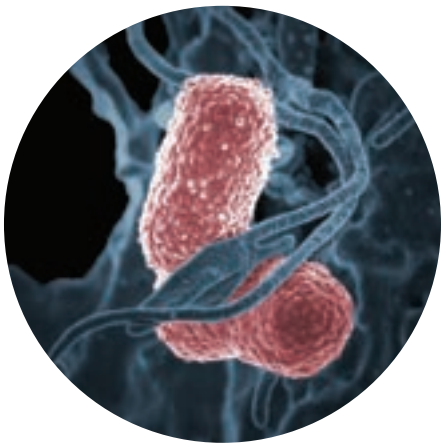
She taught microbiology and major's biology courses at Pasadena City College for 30 years, during which time she developed new curricula and refined laboratory experiments. She has been an author of, and contributor to, several publications of the William C. Brown Company and McGraw-Hill Publishers since the early 1980s, first illustrating and writing for laboratory manuals and later developing this textbook. She has also served as a coauthor with Kelly Cowan on the first two editions of *Microbiology: A Systems Approach.*

Kathy continues to make microbiology a major focus of her life and is passionate about conveying the significance and practical knowledge of the subject to students, colleagues, family, friends, and practically anyone who shows interest. In addition to her writing and illustration, she keeps current by attending conferences and participating in the American Society for Microbiology and its undergraduate educational programs. She is gratified by the many supportive notes and letters she has received over the years from devotees of microbiology and users of her book.

She lives in Altadena, California, with husband Dave Bedrosian and son David. Whenever she can, she visits her family in Idaho. In her spare time, she enjoys photography, reading true crime books, music, crossword puzzles, and playing with her rescued kitties.

Barry Chess has been teaching microbiology at Pasadena City College for 20 years. He received his Bachelor's and Master's degrees from the California State University and did postgraduate work at the University of California, where his research focused on the expression of eukaryotic genes involved in the development of muscle and bone.

At Pasadena City College, Barry developed a new course in human genetics and helped to institute a biotechnology program. He regularly teaches courses in microbiology, general biology, and genetics, and works with students completing independent research projects in biology and microbiology. Over the past several years, Barry's interests have begun to focus on innovative methods of teaching that increase student success. He has written cases for the National Center for Case Study Teaching in Science and given talks at national meetings on the effectiveness of case studies in the classroom. His laboratory manual, *Laboratory Applications in Microbiology: A Case Study Approach,* is currently in its third edition. He feels very fortunate to be collaborating with Kathy Talaro, with whom he has worked in the classroom for more than a decade, on this tenth edition. Barry is a member of the American Society for Microbiology and the American Association for the Advancement of Science and regularly attends meetings in his fields of interest, both to keep current of changes in the discipline and to exchange teaching and learning strategies with others in the field.



A major intent of this textbook has always been to promote an understanding of microbes and their intimate involvement in the lives of humans, but our other aim is to stimulate an appreciation that goes far beyond that. We want you to be awed by these tiniest creatures and the tremendous impact they have on all of the earth's natural activities. We hope you are inspired enough to embrace that knowledge throughout your lives.

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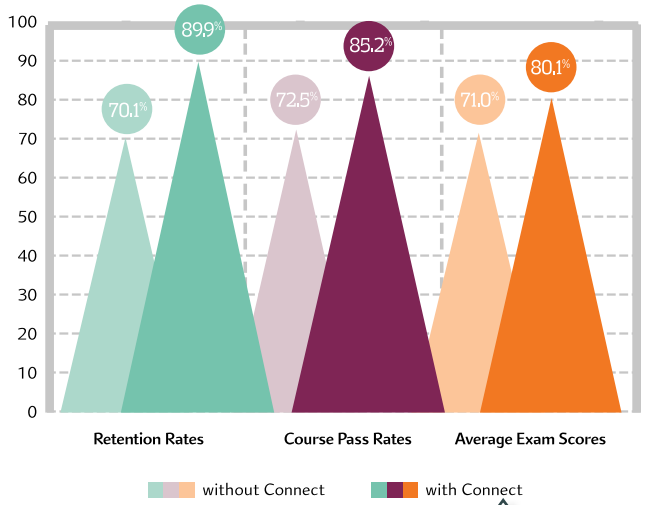

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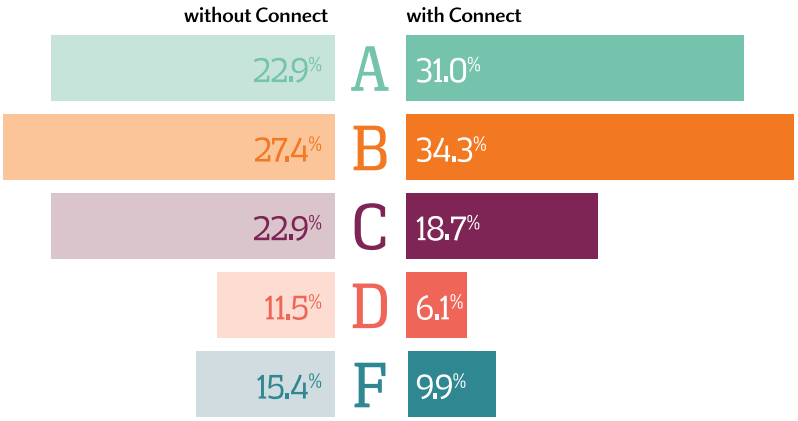

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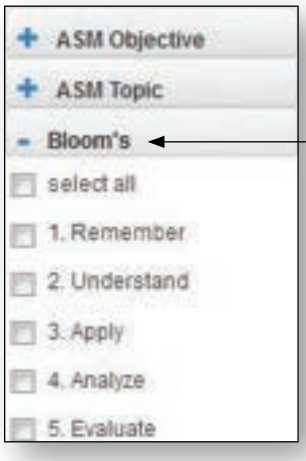

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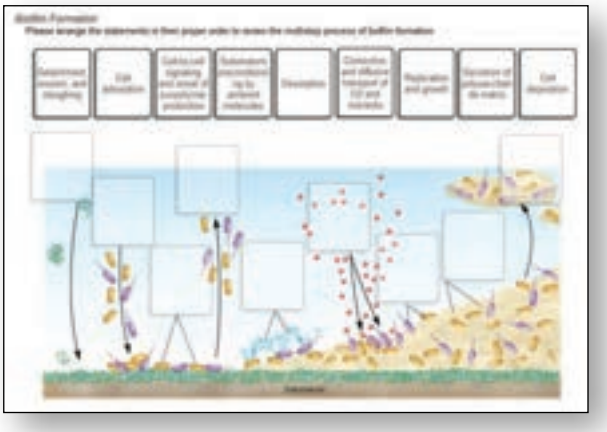

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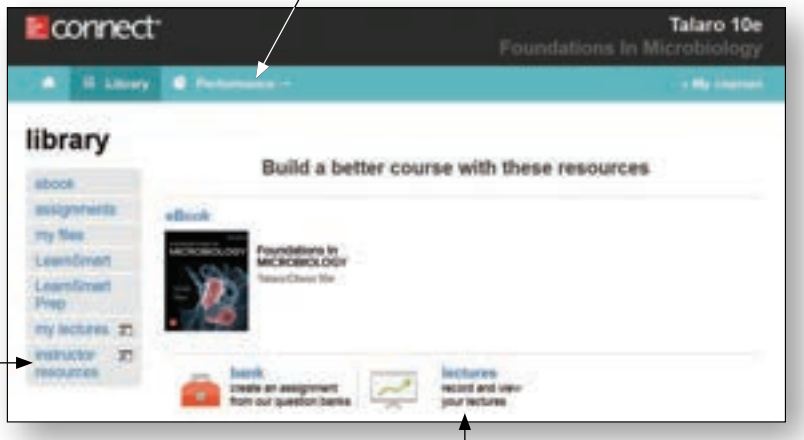

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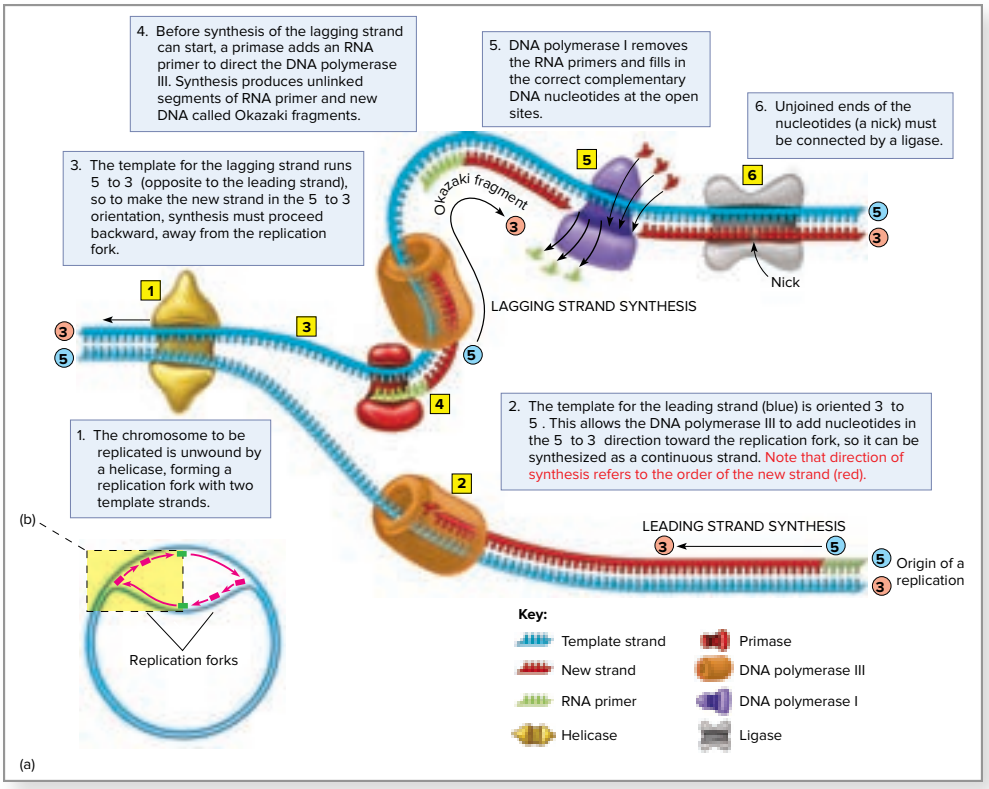
LearnSmart® Prep is an adaptive learning tool that prepares students for college-level work in Microbiology. LearnSmart Prep individually identifies concepts the student does not fully understand and provides learning resources to teach essential concepts so he or she enters the classroom prepared. Data-driven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

The Profile of a Student Success Learning Tool

Art and organization of content make this book unique

Carefully crafting a textbook to be a truly useful learning tool for students takes time and dedication. Every line of text and every piece of art in this book is scrutinized for instructional usefulness, placement, and pedagogy, and then reexamined with each revision. In this tenth edition, the authors have gone through the book page by page, with more depth than ever before, to make sure it maintains its instructional quality, fantastic art program, relevant and current material, and engaging, user-friendly writing style. Since the first edition, the goals of this book have been to explain complex topics clearly and vividly, and to present the material in a straightforward way that students can understand. The tenth edition continues to meet these goals with the most digitally integrated, up-to-date, and pedagogically important revision yet.

Like a great masterpiece hanging in a museum, *Foundations in Microbiology* is not only beautiful but also tells a story, composed of many pieces. A great textbook must be carefully constructed to place art where it makes the most sense in the flow of the narrative; create process figures that break down complex processes into their simplest parts; provide explanations at the correct level for the student audience; and offer pedagogical tools that help all types of learners. Many textbook authors write the narrative of their book and call it a day. It is the rare author team, indeed, that examines each page and makes changes based on what will help the students the most, so that when the pieces come together, the result is an expertly crafted learning tool—a story of the microbial world.

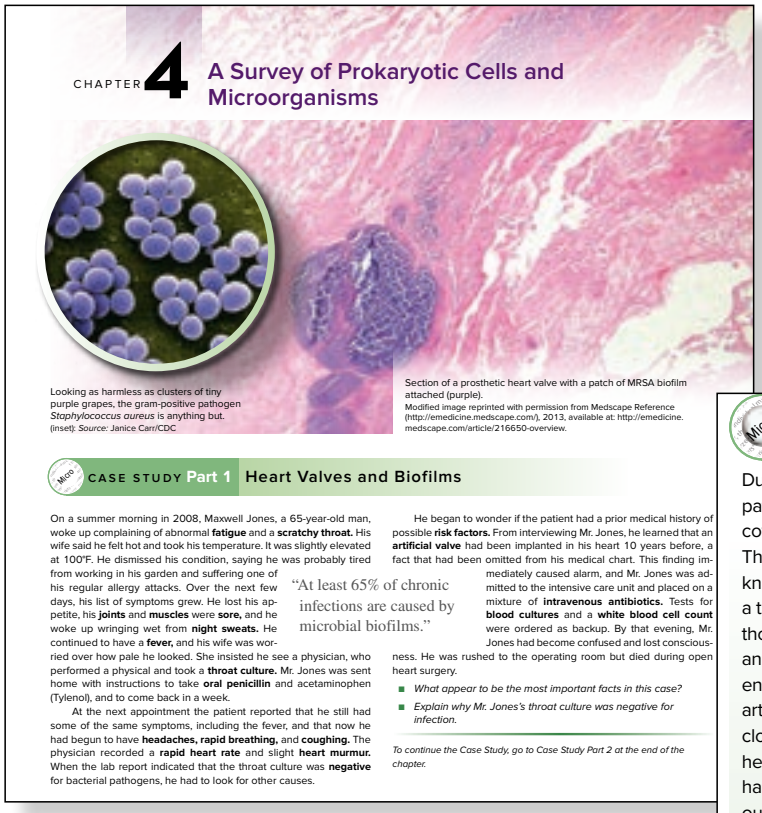


Kathy Talaro introduces new art to a revision by carefully sketching out what she envisions in precise detail, with accompanying instructions to the illustrator. The result is accurate, beautifully rendered art that helps difficult concepts come to life.

The Structure of a Student Success Learning Tool

Chapter-Opening Case Studies

Each chapter opens with a Case Study Part 1, which helps the students appreciate and understand how microbiology impacts their lives. Appropriate line art, micrographs, and quotes have been added to the chapter-opening page to help the students pull together the big picture and grasp the relevance of the material they're about to learn. The questions that directly follow Parts 1 and 2 of the Case Study challenge students to begin to think critically about relevant text references that will help them answer the questions as they work through the chapter. The Case Study Perspective wraps up the case and can be found on the Connect website.



CHAPTER 4 A Survey of Prokaryotic Cells and Microorganisms

Looking as harmless as clusters of tiny purple grapes, the gram-positive pathogen *Staphylococcus aureus* is anything but.
(inset): Source: Janice Carr/CDC

Section of a prosthetic heart valve with a patch of MRSA biofilm attached (purple).
Modified image reprinted with permission from Medscape Reference (http://emedicine.medscape.com/), 2013, available at: http://emedicine.medscape.com/article/216650-overview.

MICRO CASE STUDY Part 1 Heart Valves and Biofilms

On a summer morning in 2008, Maxwell Jones, a 65-year-old man, woke up complaining of abnormal **fatigue** and a **scratchy throat.** His wife said he felt hot and took his temperature. It was slightly elevated at 100°F. He dismissed his condition, saying he was probably tired from working in his garden and suffering one of his regular allergy attacks. Over the next few days, his list of symptoms grew. He lost his appetite, his **joints** and **muscles** were **sore,** and he woke up wringing wet from **night sweats.** He continued to have a **fever,** and his wife was worried over how pale he looked. She insisted he see a physician, who performed a physical and took a **throat culture.** Mr. Jones was sent home with instructions to take **oral penicillin** and acetaminophen (Tylenol), and to come back in a week.

At the next appointment the patient reported that he still had some of the same symptoms, including the fever, and that now he had begun to have **headaches, rapid breathing,** and **coughing.** The physician recorded a **rapid heart rate** and slight **heart murmur.** When the lab report indicated that the throat culture was **negative** for bacterial pathogens, he had to look for other causes.

"At least 65% of chronic infections are caused by microbial biofilms."

He began to wonder if the patient had a prior medical history of possible **risk factors.** From interviewing Mr. Jones, he learned that an **artificial valve** had been implanted in his heart 10 years before, a fact that had been omitted from his medical chart. This finding immediately caused alarm, and Mr. Jones was admitted to the intensive care unit and placed on a mixture of **intravenous antibiotics.** Tests for **blood cultures** and a **white blood cell count** were ordered as backup. By that evening, Mr. Jones had become confused and lost consciousness. He was rushed to the operating room but died during open heart surgery.

- *What appear to be the most important facts in this case?*
- *Explain why Mr. Jones's throat culture was negative for infection.*

To continue the Case Study, go to Case Study Part 2 at the end of the chapter.

MICRO CASE STUDY Part 2

During an autopsy of Mr. Jones's body, the pathologist observed that the prosthetic valve was covered with small patches he called vegetations. The later blood cultures grew a strain of *Staphylococcus aureus** known as MRSA. Microscopic examination of the valve revealed a thick biofilm coating containing that same bacterium. The pathologist concluded that the patient had infective endocarditis,* and that vegetations on the valve lesions had broken loose and entered the circulation. This event created emboli that blocked arteries in his brain and gave rise to a massive stroke. Upon closer review of Mr. Jones's case, the physician discovered that he had suffered from a skin infection the previous spring that had been treated and cured by a different physician. It turned out to be caused by the MRSA type of *Staphylococcus aureus*.

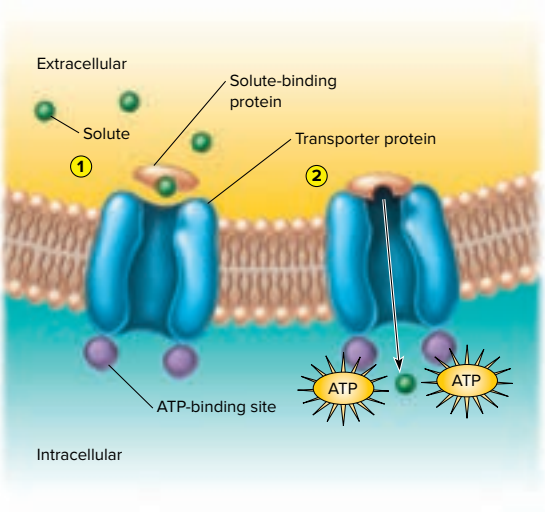
Most bacteria can form structured multicellular communities, or biofilms, on objects in a moist environment. This is even true of bacterial pathogens in the body. The CDC estimates that at least 65% of chronic infections are caused by microbial biofilms. In this case, the MRSA bacteria in the patient's skin infection must have entered the circulation and colonized the artificial valve over several weeks to months. Most cases of chronic endocarditis are caused by biofilms on valves. When the biofilm grows into larger vegetations, portions of it break loose into the circulation. These infect the blood and are spread into organs, causing fever and other signs and symptoms, including the ones that were fatal. MRSA is an emerging pathogen that started as a problem in the hospital but is now prominent in nonhospital settings as well.

- *What does the acronym MRSA mean, and what is its significance?*

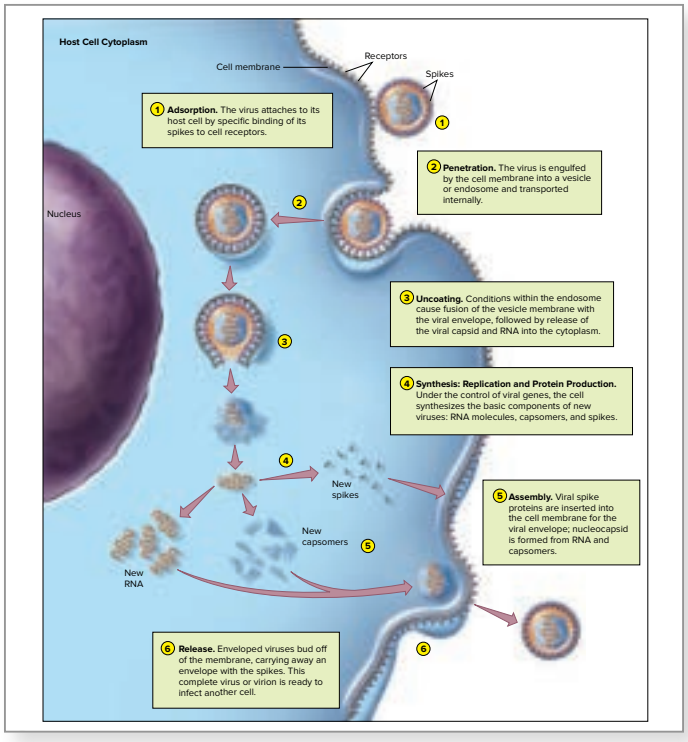
The Art of a Student Success Learning Tool

Author's experience and talent transforms difficult concepts

Truly instructional artwork has always been a hallmark feature of *Foundations in Microbiology*. Kathy Talaro's experiences as a teacher, microbiologist, and illustrator have given her a unique perspective and the ability to transform abstract concepts into scientifically accurate and educational illustrations. Powerful artwork that paints a conceptual picture for students is more important than ever for today's visual learners. *Foundations in Microbiology's* art program combines vivid colors, multidimensionality, and self-contained narrative to help students study the challenging concepts of microbiology.



(a) **Carrier-mediated active transport.** (1) Membrane-bound transporter proteins (permeases) interact with nearby solute binding proteins that carry essential solutes (sodium, iron, sugars). (2) Once a binding protein attaches to a specific site, an ATP is activated and generates energy to pump the solute into the cell's interior through a special channel in the permease.

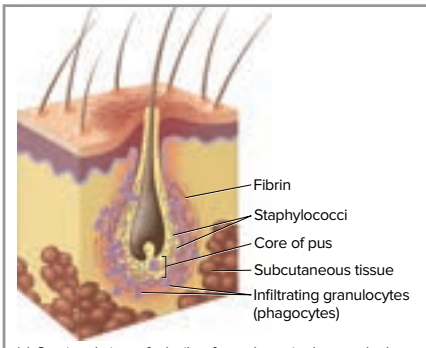


Process Figures

Many difficult microbiological concepts are best portrayed by breaking them down into stages that students will find easy to follow. These process figures show each step clearly numbered within a yellow circle and correlated to accompanying narrative to benefit all types of learners. A distinctive process icon precedes the figure number. The accompanying legend provides additional explanation.

The Relevance of a Student Success Learning Tool

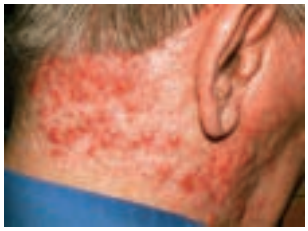
Real clinical photos help students visualize



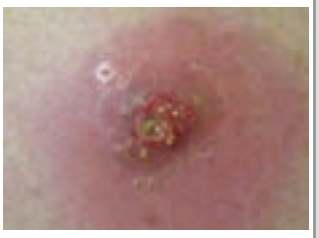
(a) Sectional view of a boil or furuncle, a single pustule that develops in a hair follicle or gland and is the classic lesion of the species. The inflamed infection site becomes abscessed when masses of phagocytes, bacteria, and fluid are walled off by fibrin.

resolved with no complications, they can lead to infections of subcutaneous tissues. A **furuncle*** (boil) results when the inflammation of a single hair follicle or sebaceous gland progresses into a

* *furuncle* (fur′-unkl) L. *furunculus*, little thief.



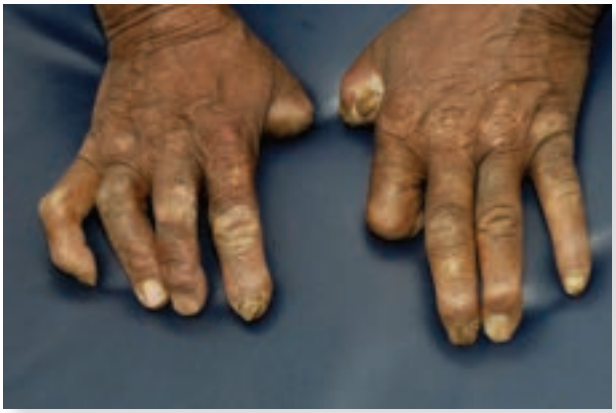
(b) Appearance of folliculitis caused by *S. aureus*. Note the clusters of inflamed papules and pustules.

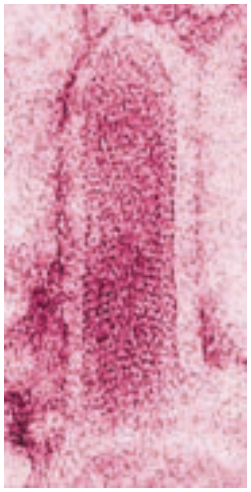


(c) An abscess on the knee caused by methicillin-resistant *Staphylococcus aureus* (MRSA).

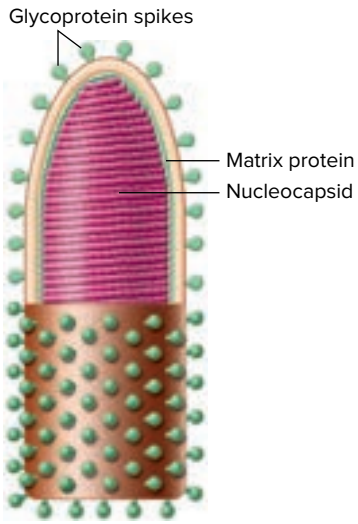
Clinical Photos

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





(a)



(b)

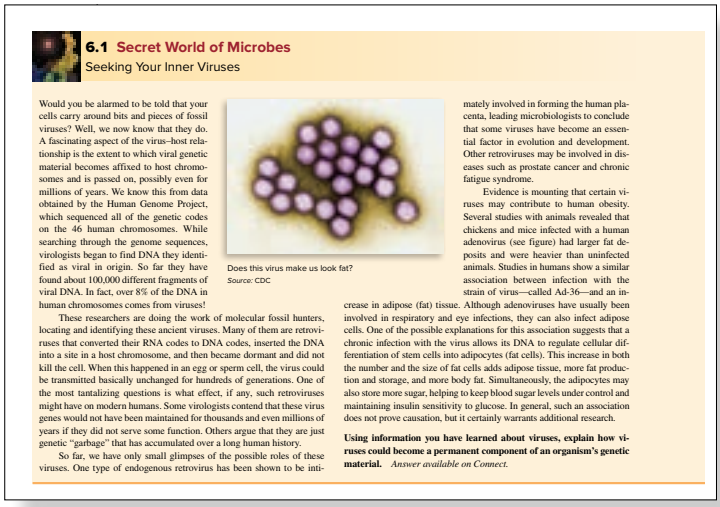
Combination Figures

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.

The Purpose of a Student Success Learning Tool

Secret World of Microbes

The living world abounds with incredible, fascinating microbes that have yet to be discovered or completely understood. This feature enriches our coverage of the latest research discoveries and applications in the field of microbiology. Almost like reading a mystery novel, *The Secret World of Microbes* reveals little-known and surprising facts about this hidden realm.



6.1 Secret World of Microbes
Seeking Your Inner Viruses

Would you be alarmed to be told that your cells carry around bits and pieces of fossil viruses? Well, we now know that they do. A fascinating aspect of the virus–host relationship is the extent to which viral genetic material becomes affixed to host chromosomes and is passed on, possibly even for millions of years. We know this from data obtained by the Human Genome Project, which sequenced all of the genetic codes on the 46 human chromosomes. While searching through the genome sequences, virologists began to find DNA they identified as viral in origin. So far they have found about 100,000 different fragments of viral DNA. In fact, over 8% of the DNA in human chromosomes comes from viruses!

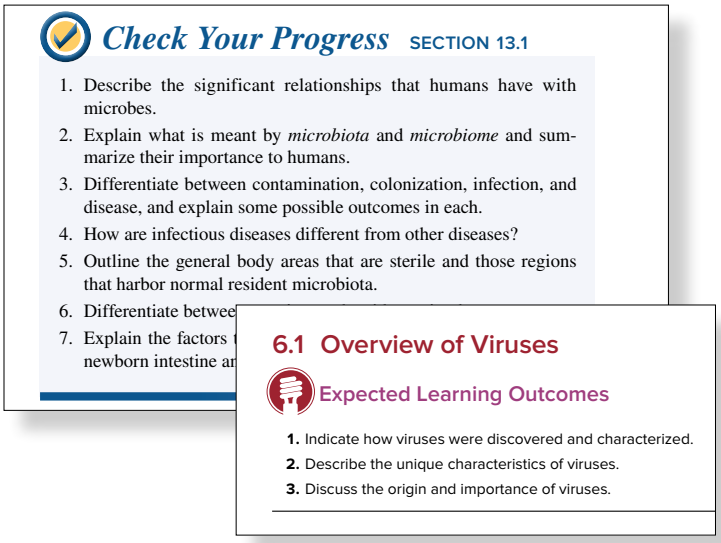
These researchers are doing the work of molecular fossil hunters, locating and identifying these ancient viruses. Many of them are retroviruses that converted their RNA codes to DNA codes, inserted the DNA into a site in a host chromosome, and then became dormant and did not kill the cell. When this happened in an egg or sperm cell, the virus could be transmitted basically unchanged for hundreds of generations. One of the most tantalizing questions is what effect, if any, such retroviruses might have on modern humans. Some virologists contend that these virus genes would not have been maintained for thousands and even millions of years if they did not serve some function. Others argue that they are just genetic "garbage" that has accumulated over a long human history.

So far, we have only small glimpses of the possible roles of these viruses. One type of endogenous retrovirus has been shown to be intimately involved in forming the human placenta, leading microbiologists to conclude that some viruses have become an essential factor in evolution and development. Other retroviruses may be involved in diseases such as prostate cancer and chronic fatigue syndrome.

Does this virus make us look fat?
Source: CDC

Evidence is mounting that certain viruses may contribute to human obesity. Several studies with animals revealed that chickens and mice infected with a human adenovirus (see figure) had larger fat deposits and were heavier than uninfected animals. Studies in humans show a similar association between infection with the strain of virus—called Ad-36—and an increase in adipose (fat) tissue. Although adenoviruses have usually been involved in respiratory and eye infections, they can also infect adipose cells. One of the possible explanations for this association suggests that a chronic infection with the virus allows its DNA to regulate cellular differentiation of stem cells into adipocytes (fat cells). This increase in both the number and the size of fat cells adds adipose tissue, more fat production and storage, and more body fat. Simultaneously, the adipocytes may also store more sugar, helping to keep blood sugar levels under control and maintaining insulin sensitivity to glucose. In general, such an association does not prove causation, but it certainly warrants additional research.

Using information you have learned about viruses, explain how viruses could become a permanent component of an organism's genetic material. *Answer available on Connect.*



Check Your Progress SECTION 13.1

1. Describe the significant relationships that humans have with microbes.
2. Explain what is meant by *microbiota* and *microbiome* and summarize their importance to humans.
3. Differentiate between contamination, colonization, infection, and disease, and explain some possible outcomes in each.
4. How are infectious diseases different from other diseases?
5. Outline the general body areas that are sterile and those regions that harbor normal resident microbiota.
6. Differentiate betwee
7. Explain the factors
newborn intestine ar

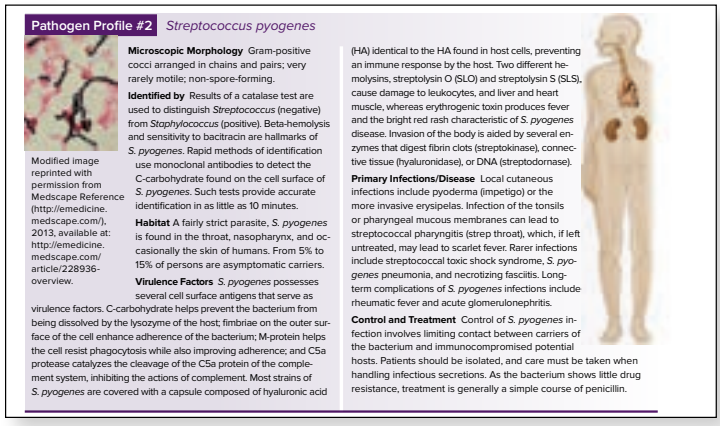
6.1 Overview of Viruses

Expected Learning Outcomes

1. Indicate how viruses were discovered and characterized.
2. Describe the unique characteristics of viruses.
3. Discuss the origin and importance of viruses.

Learning Outcomes and Check Your Progress

Every numbered section in the book opens with Expected Learning Outcomes and closes with assessment questions (Check Your Progress). 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. You can also assign Check Your Progress questions to students through McGraw-Hill Connect.



Pathogen Profile #2 *Streptococcus pyogenes*

Modified image reprinted with permission from Medscape Reference (http://emedicine.medscape.com/), 2013, available at: http://emedicine.medscape.com/article/228936-overview.

Microscopic Morphology Gram-positive cocci arranged in chains and pairs; very rarely motile; non-spore-forming.

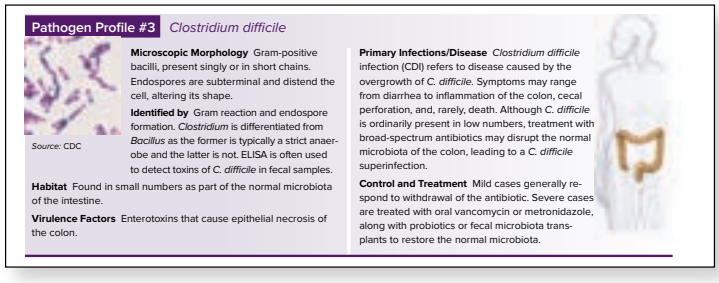
Identified by Results of a catalase test are used to distinguish *Streptococcus* (negative) from *Staphylococcus* (positive). Beta-hemolysis and sensitivity to bacitracin are hallmarks of *S. pyogenes*. Rapid methods of identification use monoclonal antibodies to detect the C-carbohydrate found on the cell surface of *S. pyogenes*. Such tests provide accurate identification in as little as 10 minutes.

Habitat A fairly strict parasite, *S. pyogenes* is found in the throat, nasopharynx, and occasionally the skin of humans. From 5% to 15% of persons are asymptomatic carriers.

Virulence Factors *S. pyogenes* possesses several cell surface antigens that serve as virulence factors. C-carbohydrate helps prevent the bacterium from being dissolved by the lysozyme of the host; fimbriae on the outer surface of the cell enhance adherence of the bacterium; M-protein helps the cell resist phagocytosis while also improving adherence; and C5a protease catalyzes the cleavage of the C5a protein of the complement system, inhibiting the actions of complement. Most strains of *S. pyogenes* are covered with a capsule composed of hyaluronic acid (HA) identical to the HA found in host cells, preventing an immune response by the host. Two different hemolysins, streptolysin O (SLO) and streptolysin S (SLS), cause damage to leukocytes, and liver and heart muscle, whereas erythrogenic toxin produces fever and the bright red rash characteristic of *S. pyogenes* disease. Invasion of the body is aided by several enzymes that digest fibrin clots (streptokinase), connective tissue (hyaluronidase), or DNA (streptodornase).

Primary Infections/Disease Local cutaneous infections include pyoderma (impetigo) or the more invasive erysipelas. Infection of the tonsils or pharyngeal mucous membranes can lead to streptococcal pharyngitis (strep throat), which, if left untreated, may lead to scarlet fever. Rarer infections include streptococcal toxic shock syndrome, *S. pyogenes* pneumonia, and necrotizing fasciitis. Long-term complications of *S. pyogenes* infections include rheumatic fever and acute glomerulonephritis.

Control and Treatment Control of *S. pyogenes* infection involves limiting contact between carriers of the bacterium and immunocompromised potential hosts. Patients should be isolated, and care must be taken when handling infectious secretions. As the bacterium shows little drug resistance, treatment is generally a simple course of penicillin.



Pathogen Profile #3 *Clostridium difficile*

Source: CDC

Microscopic Morphology Gram-positive bacilli, present singly or in short chains. Endospores are subterminal and distend the cell, altering its shape.

Identified by Gram reaction and endospore formation. *Clostridium* is differentiated from *Bacillus* as the former is typically a strict anaerobe and the latter is not. ELISA is often used to detect toxins of *C. difficile* in fecal samples.

Habitat Found in small numbers as part of the normal microbiota of the intestine.

Virulence Factors Enterotoxins that cause epithelial necrosis of the colon.

Primary Infections/Disease *Clostridium difficile* infection (CDI) refers to disease caused by the overgrowth of *C. difficile*. Symptoms may range from diarrhea to inflammation of the colon, cecal perforation, and, rarely, death. Although *C. difficile* is ordinarily present in low numbers, treatment with broad-spectrum antibiotics may disrupt the normal microbiota of the colon, leading to a *C. difficile* superinfection.

Control and Treatment Mild cases generally respond to withdrawal of the antibiotic. Severe cases are treated with oral vancomycin or metronidazole, along with probiotics or fecal microbiota transplants to restore the normal microbiota.

Pathogen Profiles

Pathogen Profiles are abbreviated snapshots of the major pathogens in each disease chapter. The pathogen is featured in a micrograph, along with a description of the microscopic morphology, identification descriptions, habitat information, and virulence factors. Artwork displays the primary infections/disease, as well as the organs and systems primarily impacted.

The Framework of a Student Success Learning Tool

Pedagogy created to promote active learning

CLINICAL CONNECTIONS

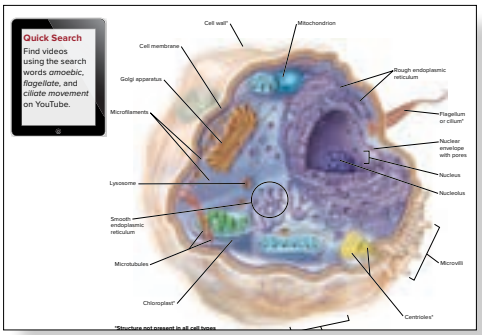
An Outbreak of Fungal Meningitis

Most fungi are not invasive and do not ordinarily cause serious infections unless a patient's immune system is compromised or the fungus is accidentally introduced into sterile tissues. In 2012 we witnessed how a simple medical procedure could turn into a medical nightmare because a common, mostly harmless fungus got into the wrong place at the wrong time. It all started when a small compounding pharmacy in Massachusetts unknowingly sent out hundreds of mold-contaminated vials of medication to medical facilities for injections to control pain. These vials were sent to 23 states and used to inject the drug into the spinal columns or joints of around 14,000 patients. By the time any problems were reported, several hundred cases of infection had occurred, half of which settled in the meninges. The most drastic outcome was the deaths of 39 patients from complications of meningitis. After months of investigation, the CDC isolated a black mold, *Exserohilum rostratum*, from both the patients and the drug vials.

This mold resides in plants and soil, from which it spreads into the air and many human habitats. But it is not considered a human pathogen, and infections with it are very rare. Examination of the compounding facility uncovered negligence and poor quality controls, along with dirty preparation rooms. Mold spores were introduced during filling of the vials, and because the medication lacked preservatives, they survived and grew. The owner of the compounding pharmacy and the head pharmacist were each charged with 25 counts of second-degree murder, their trial is expected to start in late 2016.

This case drives home several important facts about fungi: (1) They can grow rapidly even in low nutrient environments; (2) just a single spore introduced into a sterile environment, whether it is a vial of medicine or the human body, can easily multiply into millions of fungal cells; and (3) even supposedly "harmless" fungi are often opportunistic, meaning that they will infect tissues "if given an opportunity." This case also emphasizes the need for zero tolerance for microbes of any kind in a drug that is being injected—such a procedure demands sterility. When you think of it, the patients were actually being inoculated in a way that assured the development of serious mycoses.

Explain how a supposedly harmless, airborne mold could get all the way into the brain and cause meningitis. ***Answer available on Connect.***



Quick Search

This feature reminds students that videos, animation, and pictorial displays that provide further information on the topic are just a "click" away using their smart-phone, tablet, or computer. This integration of learning via technology helps students become more engaged and empowered in their study of the featured topic.

Tables

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

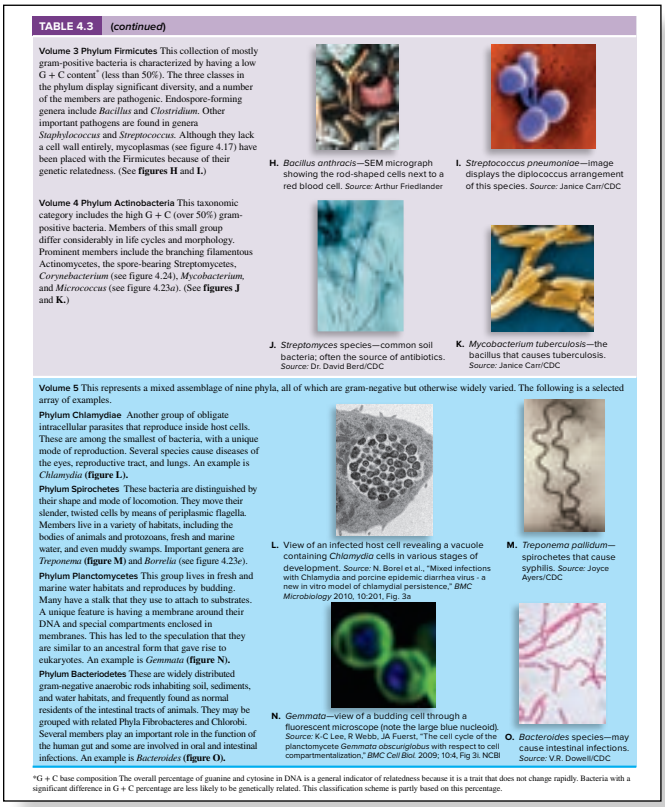


TABLE 4.3 (*continued*)

Volume 3 Phylum Firmicutes This collection of mostly gram-positive bacteria is characterized by having a low G + C content* (less than 50%). The three classes in the phylum display significant diversity, and a number of the members are pathogenic. Endospore-forming genera include *Bacillus* and *Clostridium*. Other important pathogens are found in genera *Staphylococcus* and *Streptococcus*. Although they lack a cell wall entirely, mycoplasmas (see figure 4.17) have been placed with the Firmicutes because of their genetic relatedness. (See **figures H** and **I.**)

Volume 4 Phylum Actinobacteria This taxonomic category includes the high G + C (over 50%) gram-positive bacteria. Members of this small group differ considerably in life cycles and morphology. Prominent members include the branching filamentous Actinomycetes, the spore-bearing Streptomycetes, *Corynebacterium* (see figure 4.24), *Mycobacterium*, and *Micrococcus* (see figure 4.23*a*). (See **figures J** and **K.**)

H. *Bacillus anthracis*—SEM micrograph showing the rod-shaped cells next to a red blood cell. *Source:* Arthur Friedlander

I. *Streptococcus pneumoniae*—image displays the diplococcus arrangement of this species. *Source:* Janice Carr/CDC

J. *Streptomyces* species—common soil bacteria; often the source of antibiotics. *Source:* Dr. David Berd/CDC

K. *Mycobacterium tuberculosis*—the bacillus that causes tuberculosis. *Source:* Janice Carr/CDC

Volume 5 This represents a mixed assemblage of nine phyla, all of which are gram-negative but otherwise widely varied. The following is a selected array of examples.

Phylum Chlamydiae Another group of obligate intracellular parasites that reproduce inside host cells. These are among the smallest of bacteria, with a unique mode of reproduction. Several species cause diseases of the eyes, reproductive tract, and lungs. An example is *Chlamydia* **(figure L).**

Phylum Spirochetes These bacteria are distinguished by their shape and mode of locomotion. They move their slender, twisted cells by means of periplasmic flagella. Members live in a variety of habitats, including the bodies of animals and protozoans, fresh and marine water, and even muddy swamps. Important genera are *Treponema* **(figure M)** and *Borrelia* (see figure 4.23*e*).

Phylum Planctomycetes This group lives in fresh and marine water habitats and reproduces by budding. Many have a stalk that they use to attach to substrates. A unique feature is having a membrane around their DNA and special compartments enclosed in membranes. This has led to the speculation that they are similar to an ancestral form that gave rise to eukaryotes. An example is *Gemmata* **(figure N).**

Phylum Bacteriodetes These are widely distributed gram-negative anaerobic rods inhabiting soil, sediments, and water habitats, and frequently found as normal residents of the intestinal tracts of animals. They may be grouped with related Phyla Fibrobacteres and Chlorobi. Several members play an important role in the function of the human gut and some are involved in oral and intestinal infections. An example is *Bacteroides* **(figure O).**

L. View of an infected host cell revealing a vacuole containing *Chlamydia* cells in various stages of development. *Source:* N. Borel et al., "Mixed infections with Chlamydia and porcine epidemic diarrhea virus - a new in vitro model of chlamydial persistence," *BMC Microbiology* 2010, 10:201, Fig. 3a

M. *Treponema pallidum*—spirochetes that cause syphilis. *Source:* Joyce Ayers/CDC

N. *Gemmata*—view of a budding cell through a fluorescent microscope (note the large blue nucleoid). *Source:* K-C Lee, R Webb, JA Fuerst, "The cell cycle of the planctomycete *Gemmata obscuriglobus* with respect to cell compartmentalization," *BMC Cell Biol.* 2009; 10:4, Fig 3i. NCBI

O. *Bacteroides* species—may cause intestinal infections. *Source:* V.R. Dowell/CDC

*G + C base composition The overall percentage of guanine and cytosine in DNA is a general indicator of relatedness because it is a trait that does not change rapidly. Bacteria with a significant difference in G + C percentage are less likely to be genetically related. This classification scheme is partly based on this percentage.

5. A mnemonic device to keep track of this is *LEO* says *GER: L*ose *E*lectrons *O*xidized; *G*ain *E*lectrons *R*educed.

Footnotes

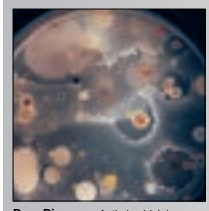
Footnotes provide the reader with additional information about the text content.

Scoping Out The Chapter

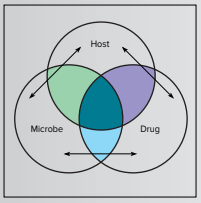
This new feature follows the opening case study in Chapters 1-17 and 26-27. Students are provided with a descriptive pictorial guide for the main topics covered within these respective chapters.

SCOPING OUT THE CHAPTER

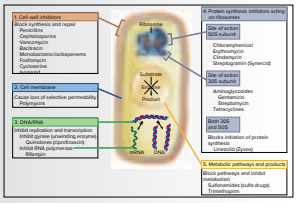
Modern antimicrobial drugs have revolutionized medical treatment. Literally billions of lives have been saved since they were first introduced 80 years ago. Having an effective drug to treat most infectious diseases is now expected, whether bacterial, viral, fungal, protozoan, or helminth. Though we may take this availability for granted, there are numerous factors that complicate their use. In this chapter we will explore "the good, the bad, and the ugly" elements of antimicrobial drug therapy.



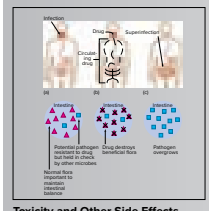
Drug Discovery Antimicrobial drugs come from many sources. Most of them, called antibiotics, are produced by certain bacteria or fungi, others are synthesized through chemical reactions alone, and some are made by combining the two methods.



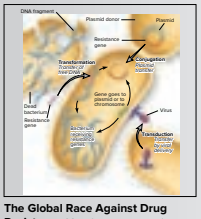
Do No Harm: Selective Toxicity Antibiotic literally means "against life", but the actual intention of these drugs is to target only microbial life. This is a very important guiding principle—that drugs do not harm humans while they are getting rid of the infectious agent.



How Antimicrobial Drugs Stop Infections Drugs are chemicals that can interfere with some specific microbial structure or function such as the cell wall, cell membrane, proteins, DNA, RNA, ribosomes, or metabolic pathways. While in contact with the drug, the microbes are either destroyed or severely inhibited and can no longer grow.



Toxicity and Other Side Effects The promise of antimicrobial therapy is spoiled by the numerous possibilities of adverse side effects. Drugs can harm body tissues and organs, disrupt the normal microbiota that help keep a balance in the body's organs, and induce allergies and hypersensitivities.



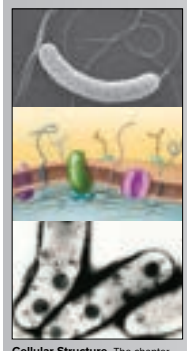
The Global Race Against Drug Resistance Microbes are very adept at rapidly altering their physiology and genetics to adapt to drugs, making them less effective. They may develop enzyme systems that dismantle the drugs, block the drug's entrance, expel the drugs, or use an alternate pathway that bypasses the drug's effects.

Choosing an Appropriate Drug Selection of an effective drug is guided by several factors. Among the most important considerations are the nature of the infectious agent, knowing which
sensitive to, the possible side effe
and the medical condition of the pa

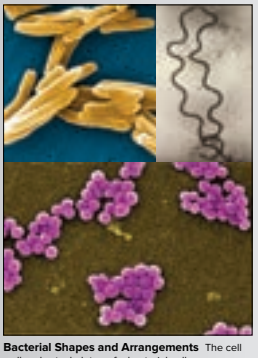
(Drug Discovery) © Kathy Park Talaro; (Choosing an Appropriate Drug) © Copyright AB BIODISK 2008. Re-printed with permission of AB BIODISK

SCOPING OUT THE CHAPTER

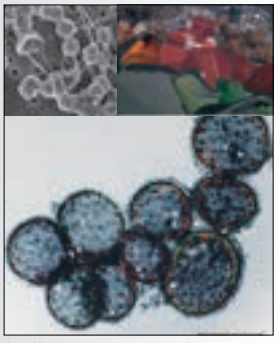
We don't need to take a course in ornithology to be able to recognize the structure of a bird's wing and describe how it functions. And even when they're too far away for us to see them clearly, we can instantly know that a group of animals flying in a "V" formation is a flock of birds, not butterflies or bats. And though they are about as different as two animals could be, we all understand intuitively that a hummingbird and a turkey are related and should be grouped together. In this chapter we will gain the same type of familiarity with bacterial cells, by studying their structure, function, and evolutionary history.



Cellular Structure The chapter opens with a discussion of what makes up a prokaryotic cell. Beginning with external structures like flagella, moving to the fluid-mosaic barrier of the cell membrane, and finally to internal structures like inclusion bodies. Understanding the anatomy of a cell is key to understanding its biology.



Bacterial Shapes and Arrangements The cell wall and cytoskeleton of a bacterial cell are responsible for its shape, and correctly recognizing the shape of a cell is one of the first steps in determining its identity. The grouping of individual cells into more complex arrangements reveals a great deal about the manner in which a cell multiplies.



Classification and Unusual Bacteria The chapter continues by explaining the ways in which prokaryotic cells may be organized based on their evolutionary relationships. Finally, we introduce several examples of novel bacteria that thrive in boiling water (top left), extraordinarily high concentrations of salt (top right), or are so big that they threaten to redefine what it means to be a bacterium (bottom).

(left: top): *Source:* Louisa Howard/Dartmouth Electron Microscope Facility; (left: bottom): © Kwangshin Kim/Science Source; (middle: top-left): *Source:* Janice Carr/CDC; (middle: top-right): *Source:* Joyce Ayers/CDC; (middle: bottom): *Source:* Jeff Hageman, M.H.S./Janice Carr/CDC; (right: top-left): *Source:* Maryland Astrobiology Consortium, NASA and STScI; (right: top-right): *Source:* NASA Johnson Space Center/ISS007E8738/ (http://eol.jsc.nasa.gov); (right: bottom): © Heide N. Schulz/Max Planck Institue for Marine Microbiology

The Planning of a Student Success Learning Tool

Pedagogy designed for varied learning styles

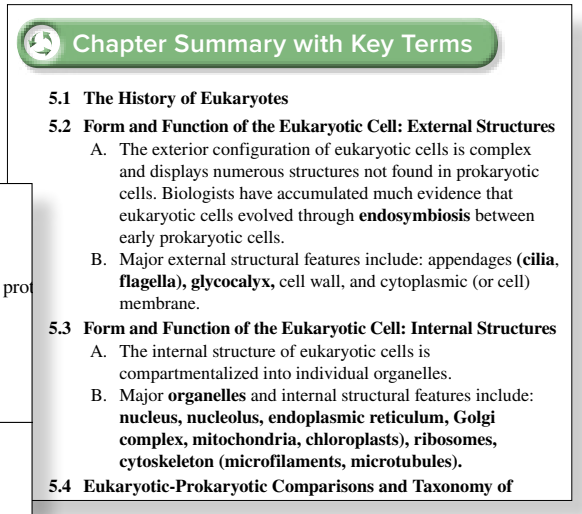
The end-of-chapter material for the tenth edition has been carefully planned and updated to promote active learning and provide review for different learning styles and levels of Bloom's Taxonomy. Questions are divided into two levels:

Level I. Knowledge and Comprehension
Level II. Application, Analysis, Evaluation, and Synthesis

The consistent layout of each chapter allows students to develop a learning strategy and gain confidence in their ability to master the concepts, leading to success in the class!

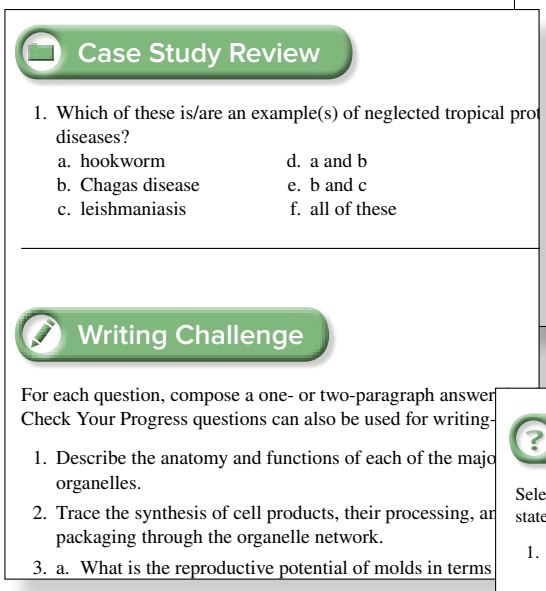
Chapter Summary with Key Terms

A brief outline of the chapter's main concepts is provided for students, with important terms highlighted. Key terms are also included in the glossary at the end of the book.



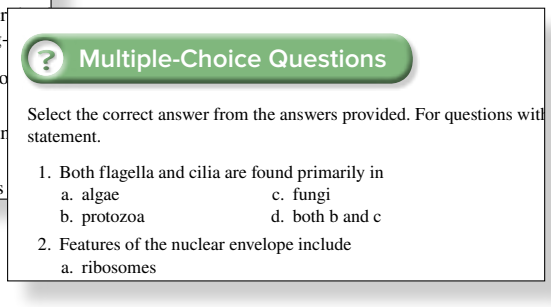
Case Study Review

These questions provide a quick check of concepts covered by the Case Study and allow instructors to assess students on the case study material.



Writing Challenge

Writing Challenge questions are suggested as a writing experience. Students are asked to compose a one- or two-paragraph response using the factual information learned in the chapter.

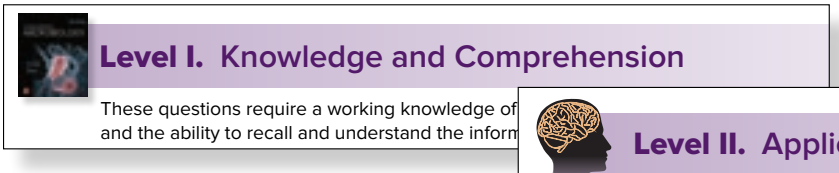


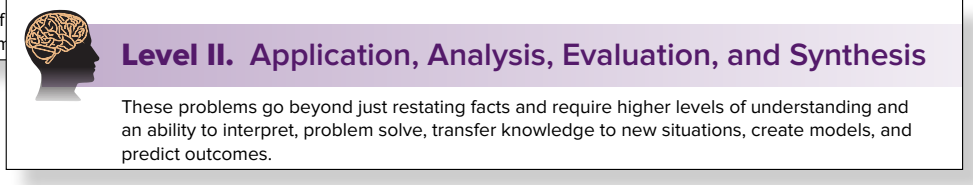
Multiple-Choice Questions

Students can assess their knowledge of basic concepts by answering these questions and looking up the correct answers in appendix D. In addition, SmartBook allows for students to quiz themselves interactively using these questions.

End-of-Chapter Questions

Questions are divided into two levels.





The Innovation of a Student Success Learning Tool

Concept Mapping

An Introduction to Concept Mapping can be found on Connect.

Concept Mapping

On Connect you can find an Introduction to Concept Mapping that provides guidance for working with concept maps along with concept-mapping activities for this chapter.

Critical Thinking

Using the facts and concepts they just studied, students must reason and problem solve to answer these specially developed questions. Questions do not have a single correct answer and thus open doors to discussion and application.

Critical Thinking

Critical thinking is the ability to reason and solve problems using facts and concepts. These questions can be approached from a number of angles, and in most cases, they do not have a single correct answer.

1. Explain the ways that mitochondria resemble rickettsias and chloroplasts resemble cyanobacteria.
2. Give the common name of a eukaryotic microbe that is unicellular, walled, nonphotosynthetic, nonmotile, and bud-forming.
3. How are the eukaryotic ribosomes and cell membranes different from those of prokaryotes?
4. What general type of multicellular parasite is composed primarily of thin sacs of reproductive organs?
5. a. Name two parasites that are transmitted in the cyst form.
   b. How must a non-cyst-forming pathogenic protozoan be transmitted? Why?
6. Explain what factors could cause opportunistic mycoses to be a growing medical problem.
7. a. How are bacterial endospores and cysts of protozoa alike?
   b. How do they differ?
8. For what reasons would a eukaryotic cell evolve an endoplasmic reticulum and a Golgi apparatus?
9. Can you think of a simple test to determine if a child is suffering from pinworms? Hint: Clear adhesive tape is involved.

Visual Challenge

1. What term is used to describe a single species exhibiting both cell types shown below, and which types of organisms would most likely have this trait?

Visual Challenge

Visual Challenge questions take images and concepts learned in other chapters and ask students to apply that knowledge to concepts covered in the current chapter.

The Revision of a Student Success Learning Tool

Changes to Foundations in Microbiology, Tenth Edition

Overall Changes:

- A new feature "Scoping Out The Chapter" has been placed after the opening case studies. This page will give readers a descriptive pictorial guide for the main topics covered in chapters 1–17 and 26–27.
- Ten chapters (6, 7, 13, 19, 21, 22, 24, 25, 26, and 27) contain new case studies chosen for their relevance to major themes in the chapter.
- Approximately 175 new and replacement photographs have been included in the revision.
- Numerous images and figures have been revised and corrected.
- Clinical Connections boxes and side notes have a tinted screen added to set them off from the regular text. Several new Clinical Corrections boxes have been added.
- Coverage of diseases, statistics, and graphic data has been updated.
- Most chapters contain new links and quick searches for exploring topics on the internet.
- Special effort has been directed towards clarifying terms, wording, and definitions to improve understanding of more difficult concepts.

Chapter-Specific Changes:

Chapter 1

- The chapter opens with a new case study featuring microorganisms living in extreme habitats
- Epidemiology statistics have been updated throughout the chapter
- New information on the spread of chikungunya virus and Zika virus has been added
- Information concerning the ongoing pertussis epidemic has been updated
- Information on the link between microorganisms and chronic disease has been updated
- The topic of microbial evolution and classification has been updated

Chapter 2

- Discussions of the manner in which electron shells are filled and the importance of valence electrons to the formation of covalent bonds have been clarified
- The section on polymeric biomolecules (DNA, RNA, lipids, proteins, starches) has been clarified

Chapter 3

- New photos have been added to illustrate differences in resolution between light microscopes and electron microscopes
- New photos have been added to the discussions of fluorescence microscopy, electron microscopy, and selective and differential media

Chapter 4

- A new discussion and figure concerning bacterial microcompartments has been added.
- New photographs for a hyperthermophile and bacterial inclusion bodies

Chapter 5

- The case study concerning neglected tropical diseases (NTDs) has been updated to include the awarding of the 2015 Nobel Prize in Physiology or Medicine to scientists working in this area
- New tables summarize the function of structures within the eukaryotic cell
- New photos of the nucleus and mitochondria emphasize the importance of these organelles
- Update on *Pseudogymnoascus destructans,* the fungus responsible for white nose syndrome in bats

Chapter 6

- The chapter opens with a new case study focused on highly pathogenic avian influenza.
- The role of Adenovirus Ad-36 in weight gain and regulation of blood sugar levels has been updated.
- New photomicrograph of an Ebola virus budding from an infected cell

Chapter 7

- A new case study "A Creature of Habitat" describes the serious problem of cystic fibrosis and its connection with recurring *Pseudomonas* infections.
- New photographs for satellitism and an anaerobic growth chamber
- New information on biofilm formation

Chapter 8

- Addition of coenzymes to table on cofactors.
- Clarification of how the term fermentation is used under different contexts

Chapter 9

- Improved figure showing input by regulatory RNA
- Revised table on types of mutations.
- Updated box on regulatory, noncoding RNA, and riboswitches
- Improved consistency of figures for conjugation and transduction

Chapter 10

- Added details of newer DNA sequencing technologies
- Updated box on the human genome
- Revised tables on genetically-engineered animals
- New graph on genetically engineered crops
- Revised and updated Clinical Connections covering gene therapy
- The term DNA fingerprinting has been replaced with DNA profiling
- Figure on standardized DNA profiling has been revised
- Reorganized section on different uses of DNA profiling
- A note describing the gene editing technology of CRSPR has been added.

Chapter 11

- Updated case study on an outbreak of hepatitis C in a colonscopy clinic
- Integrated historical aspects of microbial control into main text and removed Making Connections box 11.1.
- New Clinical Connections box discusses the sterilization of reusable medical devices
- Revised the box on use of triclosan, including new FDA ruling

Chapter 12

- Integrated Making connections 12.2 on discovery of drugs into main chapter
- Added a new figure on the chemical synthesis of penicillin drugs
- Included new categories of antibacterial and antiviral drugs
- Updated drug resistance box and added a new figure showing carbapenem-resistant enterobacteriaceae (CRE)

Chapter 13

- New case study "Fatal Filaments from Far Away Africa" that covers the Ebola epidemic in Africa and its spread to the United States.
- Introduced new information on the importance of the microbiome to general human physiology
- Coverage of the relationship of the placental microbiome to infant development and the development of the intestinal microbiome in newborns.
- New surveillance figures for HIV infection, pertussis, and Ebola fever.
- Updated figure on healthcare associated infections (HAI); replacing use of nosocomial infections with the more commonly used HAI

The Effort of a Student Success Learning Tool

- New visual challenge figures to differentiate among different epidemiological patterns for diseases

Chapter 14

- Added new information on the hygiene hypothesis
- Clarified figure on the actions of complement
- Removed discussion of fever from Clinical Connections box and integrated it into text

Chapter 15

- Reorganized the order of introduction of T cell and B cell actions and functions; T cells now are covered first, followed by B cells.
- Revised figure 15.1 to align with new order of coverage.
- Added side note to focus on the functions of T regulatory cells with new information on biologic drugs based on this type of T cell
- Updated the list of monoclonal antibody-based drugs and currently-approved vaccine schedules.
- Coverage of the breast microbiome and the role breast milk has in the development of the immune systems of infants.

Chapter 16

- Revised allergen count figure
- New photographs of atopic and contact dermatitis
- New photograph of blood typing
- New photograph of rheumatoid arthritis
- Illustration of child with velocardiofacial (DiGeorge) syndrome

Chapter 17

- Updated box on point-of-care testing
- New example of the direct fluorescent antibody test
- Replacement figure for rapid identification testing
- New examples of serological test results

Chapter 18

- New electron photomicrograph of methicillin-resistant *Staphylococcus aureus* has been added
- New photos of erysipelas and limb necrosis due to meningococcemia
- Updated recommendations for treatment of bacterial infections
- Updated statistics on the prevalence of sexually transmitted diseases
- The discussion of meningococcemia and meningitis has been clarified

Chapter 19

- The chapter opens with a new case study concerning *Listeria monocytogenes*
- New photomicrographs of *Bacillus anthracis*, *Corynebacterium diphtheriae*, and fluorescently labeled *Mycobacterium tuberculosis* have been added
- New photographs for myonecrosis, erysipeloid, the Mantoux skin test for tuberculosis, paucibacillary leprosy, multibacillary leprosy, fish tank granuloma, and actinomycosis
- Expanded and updated discussion of the use of fecal microbiota transplants as a treatment of *C-difficile* infection
- New electron micrograph of *Mycobacterium tuberculosis*, updated worldwide statistics for tuberculosis, and updated treatment recommendations for both active and latent tuberculosis
- Updated classification of leprosy to match WHO standards

Chapter 20

- New photomicrograph of *Pseudomonas aeruginosa* and new photo of cutaneous *Pseudomonas* infection
- Updated treatment recommendations for *Pseudomonas* infection, *Brucellosis,* and *Tularemia*
- New information on pertactin-deficient strains of *Bordetella pertussis*
- Updated discussion of *E. coli* pathotypes
- New section on Carbepenem-resistant Enterobacteriaceae infections
- New section on naming conventions in *Salmonella*

Chapter 21

- Chapter opens with a new case study on Q fever and live cell transplantation
- New photographs of *Coxiella burnetti*, *Treponema pallidum*, *Borrelia burgdorferi*, *Vibrio cholera*, *Campylobacter jejuni*, *Orienta tsutsugamushi*, and *lxodes scapularis*
- Updated statistics on syphilis
- New treatment recommendations for cholera
- New photos of dental caries and oral bacteria

Chapter 22

- Case study has been updated to include the latest facts concerning the fungal meningitis outbreak connected to the New England Compounding Center
- Updates on antifungal drugs and epidemiological statistics
- New photographs of cutaneous blastomycosis, *Tinea pedis, Aspergillus,* and aspergillosis
- Reclassification of zygomycosis as mucormycosis

Chapter 23

- Updated drug recommendations for parasitic diseases
- New discussion on genetically engineered mosquitoes resistant to *Plasmodium sp.*
- New feature on Carlos Chagas and his importance to the field of parasitology
- The latest information about phase 3/4 trials of malaria vaccine RTS,S

Chapter 24

- The chapter begins with a new case study concerning unusual varicella zoster virus transmission
- New photos of herpes simplex type 1, neonatal herpes, and lymphocytes infected with Epstein-Barr virus
- Updated recommendations for treatment of neonatal herpes
- Update on treatment and prevention of HPV

Chapter 25

- New case study on measles and subacute sclerosing panencephalitis
- Updates include information on the Ebola outbreak of 2014–2016, the ongoing Zika virus outbreak, and widespread outbreaks of chikungunya virus
- Updated information on influenza vaccines and new chemotherapeutic treatments for influenza
- New information on the measles outbreak of 2015 along with discussion and references to online documentaries about vaccine skepticism
- Distribution maps for *Aedes* mosquitoes, the vector of dengue, chikungunya, and Zika viruses
- Feature on the *Aedes* mosquito
- Information about the recently approved vaccine to prevent dengue fever
- Updates on treatment strategies for HIV, including the use of pre-exposure prophylaxis (PrEP)

Chapter 26

- New case study on drinking water contamination as a result of harmful algae blooms
- New photos of *Rhizobium* root nodules and mycorrhizae
- New discussion concerning fracking as a potential contaminant of groundwater

Chapter 27

- New case study concerning three separate outbreaks of food poisoning

Acknowledgments

This edition marks the 24th anniversary of the first publication of Foundations in 1993. Looking back over the previous nine editions, the authors are struck by the extensive discoveries and new developments in the science of microbiology that are reflected in the changing content and character of this book. This 10th edition is no exception. The one thing that has remained constant and unchanging over these years is the outstanding collaboration we enjoy with the editorial and production staff at McGraw-Hill Education. This time around, we have been fortunate to have the able assistance and expertise of product developer Mandy Clark, keeping us on track and providing much needed moral support. We also appreciate the insights and contributions of brand manager Marija Magner and marketing manager Jessica Cannavo. Our project manager Jayne Klein has been an experienced and knowledgeable guide through the intricacies of a digital-style revision.

Other valued members of our team who have been instrumental in developing the text's visual elements are Carrie Burger, the content licensing specialist, Danny Meldung at Photo Affairs, and the designer Tara McDermott, who has produced another striking book and cover design. Some of the unsung heroes of authors are the readers who must sift through the text with a fine-tooth comb, checking for errors, grammatical usage, and consistency in style. This tedious job fell this time to copy editor Wendy Nelson. After poring over 800 plus pages of text in a few months, she may feel like she has taken a crash course in microbiology.

It takes about a year and a half to complete a textbook revision—a process that involves editing manuscript, writing new text, illustration, research, and much more. During this time, the entire text and art program are inspected at least six times by the authors and team members. Even with the keenest eyes and spell checks, some typos, errors, oversights, and other mistakes may end up on the printed page. If you find any of these or wish to make other comments, feel free to contact the publisher, sales representative, or authors (ktalaro@aol.com and bxchess@Pasadena.edu.)

We hope that you enjoy your explorations in the microbial world and that this fascinating science will leave a lasting impression on you.

—Kathy Talaro and Barry Chess

A Note to the Student

How to Maximize Your Learning Curve

Most of you are probably taking this course as a prerequisite to nursing, dental hygiene, medicine, pharmacy, optometry, physician assistant, or other health science programs. Because you are preparing for professions that involve interactions with patients, you will be concerned with infection control and precautions, which in turn requires you to think about microbes and how to manage them. This means you must not only be knowledgeable about the characteristics of bacteria, viruses, and other microbes, and their physiology and primary niches in the world, but you must also have a grasp of disease transmission, the infectious process, disinfection procedures, and drug treatments. You will need to understand how the immune system interacts with microorganisms and the effects of immunization. All of these areas bring their own vocabulary and language—much of it new to you—and mastering it will require time, motivation, and preparation. A valid question students often ask is: "How can I learn this information to increase my success in the course as well as retain it for the future?"

Right from the first, you need to be guided by how your instructor has organized your course. Because there is more information than could be covered in one semester or quarter, your instructor will select what he or she wants to emphasize and will construct reading assignments and a study outline that corresponds to lectures and discussion sessions. Many instructors have a detailed syllabus or study guide that directs the class to specific content areas and vocabulary words. Others may have their own website to distribute assignments and even sample exams. Whatever materials are provided, this should be your primary guide in preparing to study.

The next consideration involves your own learning style and what works best for you. To be successful, you must commit essential concepts and terminology to memory. A list of how we retain information called the "pyramid of learning" has been proposed by Edgar Dale: We remember about 10% of what we read; 20% of what we hear; 50% of what we see and hear; 70% of what we discuss with others; 80% of what we experience personally; and 95% of what we teach to someone else.

There are clearly many ways to go about assimilating information. Mainly, you will want to focus on more than just reading alone to gather the most important points from a chapter. Try to incorporate writing, drawing simple diagrams, and discussion or study with others. You must attend lecture and laboratory sessions to listen to your instructors or teaching assistants explain the material. You can rewrite the notes you've taken during lecture, or outline them to organize the main points. This begins the process of laying down memory. You should go over concepts with others—perhaps a tutor or study group—and even take on the role of the teacher-presenter part of the time. With these kinds of interactions, you will move beyond simple rote memorization of words and will come to *understand* the ideas and be able to apply them later.

A way to assess your understanding and level of learning is to test yourself. You may use the exam questions in the text, on the Connect website, or make up your own. LearnSmart, available within the Connect site, is an excellent way to map your own, individualized learning program. It helps to track what you know, pinpoint what you don't know, and creates personalized questions based on your progress.

Another big factor in learning is the frequency of studying. It is far more effective to spend an hour or so each day for two weeks than a marathon cramming session on one weekend. If you approach the subject in small bites and remain connected with the terminology and topics, over time it will become yours and you will find that the pieces begin to fit together. Just remember that repetition and experience are the most effective ways to acquire knowledge.

In the final analysis, the process of learning comes down to self-motivation and attitude. There is a big difference between forcing yourself to memorize something to get by and really wanting to know and understand it. Therein is the key to most success and achievement, no matter what your final goals. And though it is true that mastering the subject matter in this textbook requires time and effort, millions of students will affirm how worthwhile such knowledge has been in their professions and everyday life.

Contents