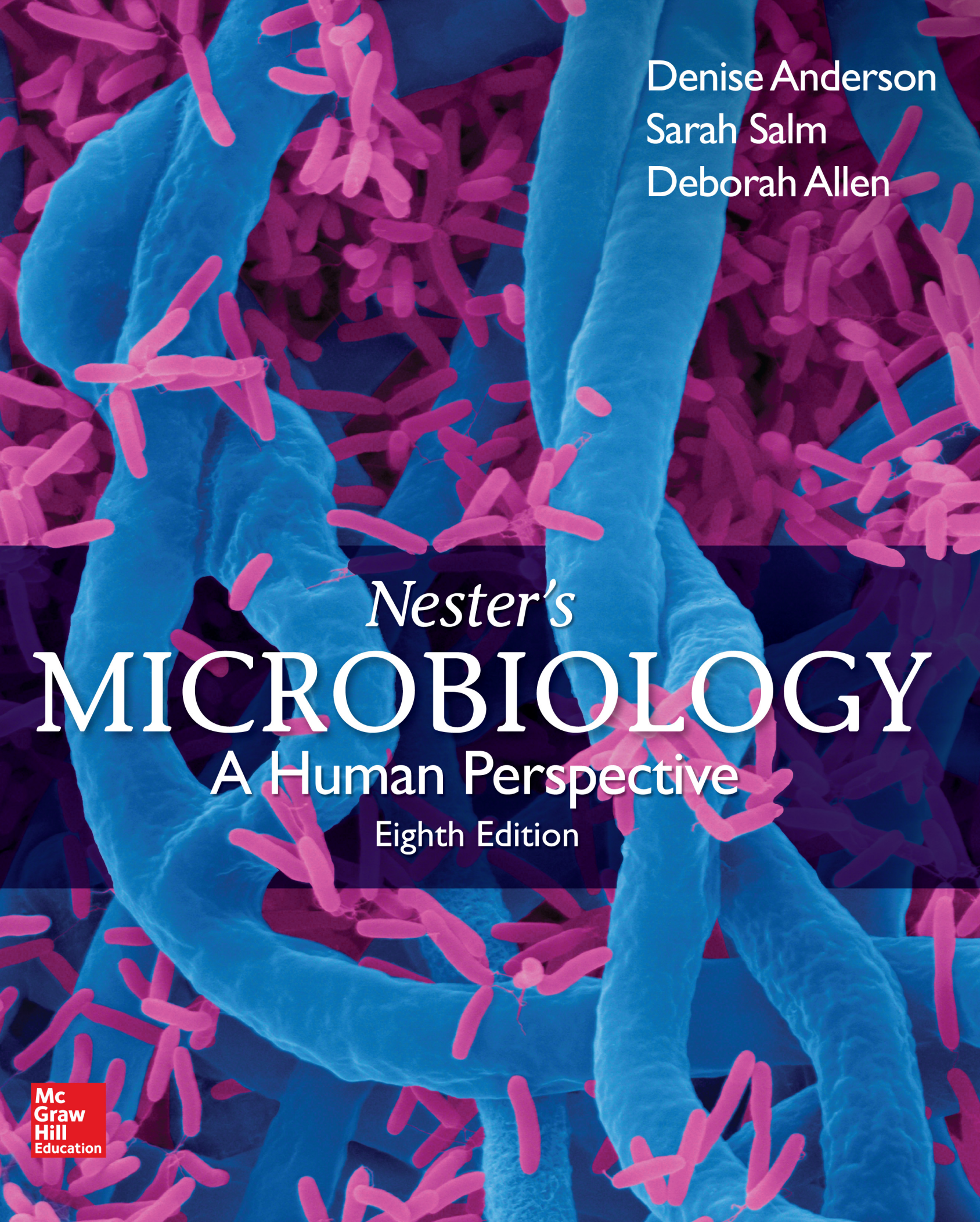

Denise Anderson
Sarah Salm
Deborah Allen

Nester's MICROBIOLOGY

A Human Perspective

Eighth Edition

Mc Graw Hill Education

Nester's Microbiology

A Human Perspective

EIGHTH EDITION

Denise G. Anderson
UNIVERSITY OF WASHINGTON

Sarah N. Salm
BOROUGH OF MANHATTAN
COMMUNITY COLLEGE

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Mc Graw Hill Education

NESTER'S MICROBIOLOGY: A HUMAN PERSPECTIVE, EIGHTH EDITION

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About the Authors

Introducing The Nester Team:

Three Perspectives, One Vision, One Voice

The three authors on this edition—Denise Anderson, Sarah Salm, and Deborah Allen—may be a set of individuals with different insights and unique experiences, but their cooperative relationship defines the word "team." What drives them is a single shared goal: To create the most learning-friendly introductory microbiology textbook available.

To ensure a consistent writing style throughout the text, each author took "voice lessons" early in the process, writing and rewriting a section until it was consistent with "the Nester style." Then each author carefully read all the chapters, looking for parts that could be tweaked for clarity. They did this with students in mind, suggesting simpler words where appropriate while maintaining the scientific rigor so important for today's healthcare professionals.

Meanwhile Gene Nester served as "team member emeritus," keeping an eagle eye out for updates that could be incorporated into the text. His work established the text's reputation for excellence over the decades, and it lives on in this edition.

Denise Anderson

Denise Anderson is a Senior Lecturer in the Department of Microbiology at the University of Washington, where she teaches a variety of courses including general microbiology, medical bacteriology laboratory, and medical mycology/parasitology laboratory. Equipped with a diverse educational background, including undergraduate work in nutrition and graduate work in food science and in microbiology, she first discovered a passion for teaching when she taught microbiology laboratory courses as part of her graduate training. Her enthusiastic teaching style, fueled by regular doses of Seattle's famous coffee, receives high reviews by her students.

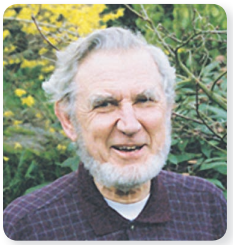
Outside of academic life, Denise relaxes in the Phinney Ridge neighborhood of Seattle, where she lives with her husband, Richard Moore, and dog, Dudley (neither of whom are well trained). When not planning lectures, grading papers, or writing textbook chapters, she can usually be found chatting with the neighbors, fighting the weeds in her garden, or enjoying a fermented beverage at the local pub.

Sarah Salm

Sarah Salm is a Professor at the Borough of Manhattan Community College (BMCC) of the City University of New York, where she teaches microbiology, anatomy and physiology, and general biology. She earned her undergraduate and doctoral degrees at the University of the Witwatersrand in Johannesburg, South Africa. She later moved to New York, working first as a postdoctoral fellow and then an Assistant Research Professor at NYU Langone Medical Center. Her research has covered a range of subjects, from plant virus identification through prostate stem cell characterization. When not focused on the textbook and her classes, Sarah loves to read, hike, and travel.

Deborah Allen

Deborah Allen is a Professor at Jefferson College in Missouri, where she teaches microbiology as well as several other courses for students entering allied health careers. Her graduate work was in zoology at the University of Oklahoma and in neurobiology and behavior at Cornell University. She participated in cancer research at the University of Arkansas Medical Center before embarking on a career in publishing, working in acquisitions and development for books in the life sciences. She is now thrilled to be working on the other end of the desk with the Nester team. Away from campus, Deborah reads or listens to her favorite Eve Dallas novels, floats the rivers and listens to folk music in the Ozarks, and fully appreciates the local microbes while visiting Missouri wineries.



Eugene Nester

Although no longer an active member of the author team, Eugene (Gene) Nester wrote the original version of the present text with Evans Roberts and Nancy Pearsall more than 30 years ago. That text, *Microbiology: Molecules, Microbes and Man,* pioneered the organ system approach to the study of infectious disease, and was developed specifically for allied health sciences.

Gene did his undergraduate work at Cornell and received his Ph.D. in microbiology from Case Western University. He then did postdoctoral work in the Department of Genetics at Stanford University with Joshua Lederberg. Following that, he joined the faculty in the Department of Microbiology at the University of Washington, where he remains active as an emeritus member. His laboratory demonstrated that *Agrobacterium* transfers DNA into plant cells—the basis for the disease crown gall—a system of gene transfer that has become a cornerstone of plant biotechnology. In recognition of his work, he was awarded the Australia Prize and the Cetus Prize in Biotechnology, and was elected to fellowship in the National Academy of Sciences, the American Academy for the Advancement of Science, the American Academy of Microbiology, and the National Academy of Sciences in India.

Message from Denise Anderson

Students:

Welcome to the amazing world of microbiology! This edition of *Nester's Microbiology* marks the official beginning of my role as the textbook's lead author. I'm not entirely a newbie—I've been a coauthor for over a decade, so I was the logical choice to take over when Eugene Nester retired. It's an honor as well as an incredible responsibility, but I truly love sharing my passion for the subject with students.

When I teach my introductory microbiology course, I always start with comments I've received from previous students. Why student opinions? Because I'm admittedly biased by my love of microbiology, so my students' words might have more influence that first day. I've decided to do the same here because, well, I want you to be as excited about microbiology as I am!

First of all, I cannot believe that people actually graduate from college with no knowledge of the microbiology that is taught in your class. I'm starting to see it and the effects of microorganisms wherever I go (because let's face it, they're everywhere) and I'm just shocked that not everyone is required to know something so basic and essential to human life.

~ Bailey Clopp

It's not just that I want you to look forward to learning about microbiology—I also want you to succeed. So that leads me from my "pep talk" to my "stern talk." To do well in a microbiology course, you have to approach your studying with the intent to understand the information rather than just memorize it. That's where the textbook comes in. My coauthors and I have spent countless hours making every explanation clear and logical—so read your book! You'll be amazed at the information that's at your fingertips! Work to understand the various processes and learn the vocabulary required to explain them to someone else. It's not just about passing your class—it's about building a strong foundation of knowledge that will serve you well in all aspects of life.

I cannot thank you enough for teaching me to think and study in a different way, rather than memorize and recall information for the test and then forget it the next day. Your class definitely was not easy, but the information and skills that I learned under your instruction will undoubtedly help me succeed in the classes that I take in the future, and as a student in the nursing program here at UW!

~ Samantha Rowley

My aim as a teacher and an author is excellence, so I welcome feedback. In fact, I've set up a special email account for you to use just for that purpose: feedback@nestertext.com. I look forward to hearing your comments about the book!

Denise Anderson

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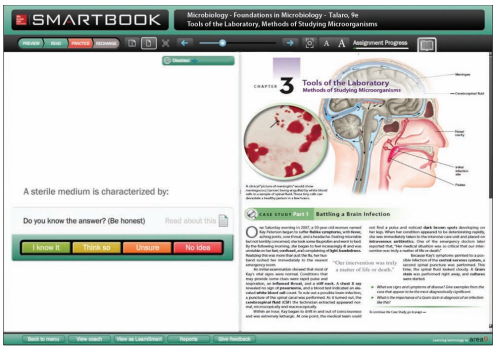

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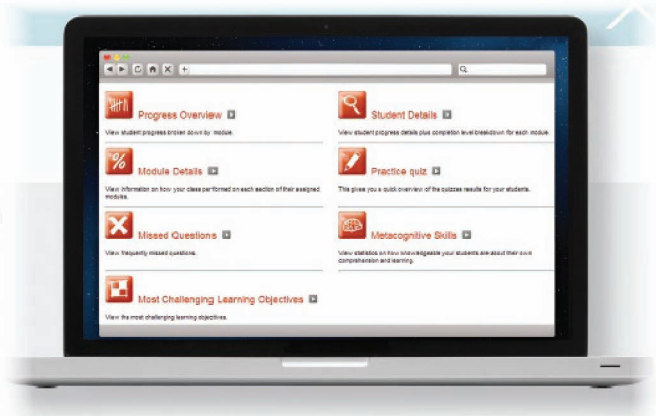

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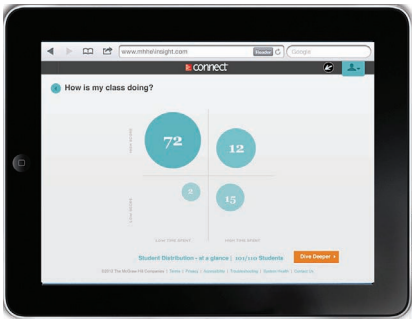

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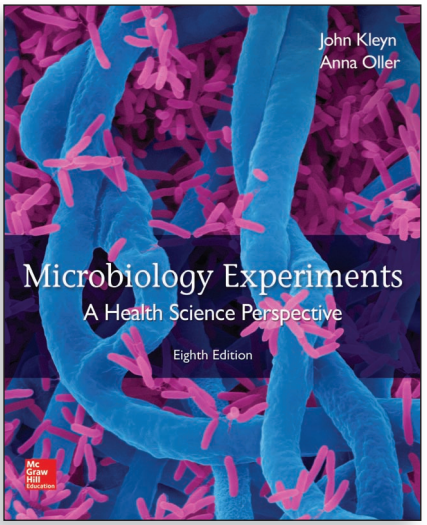

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—William Hoover, Bunker Hill Community College

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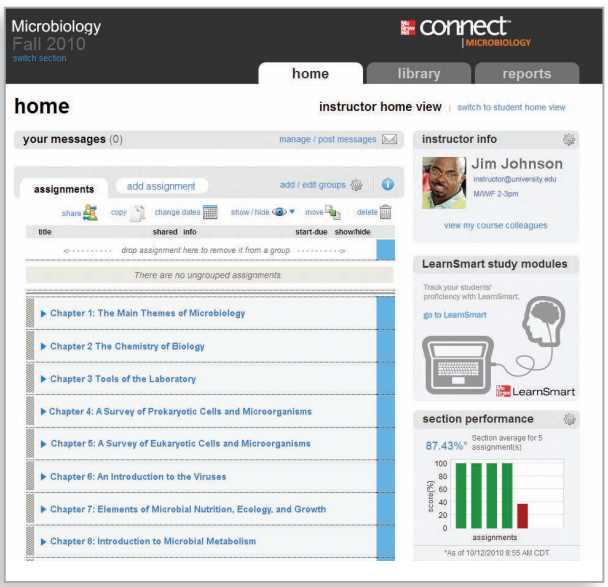

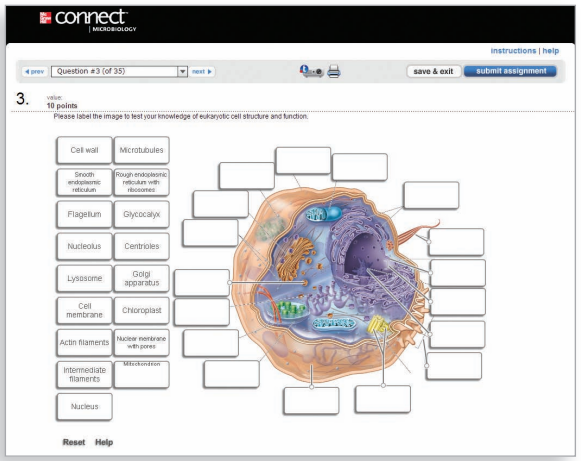

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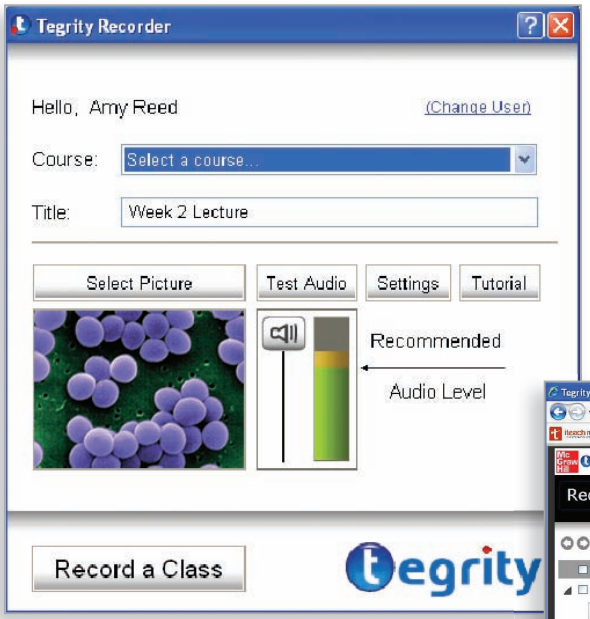

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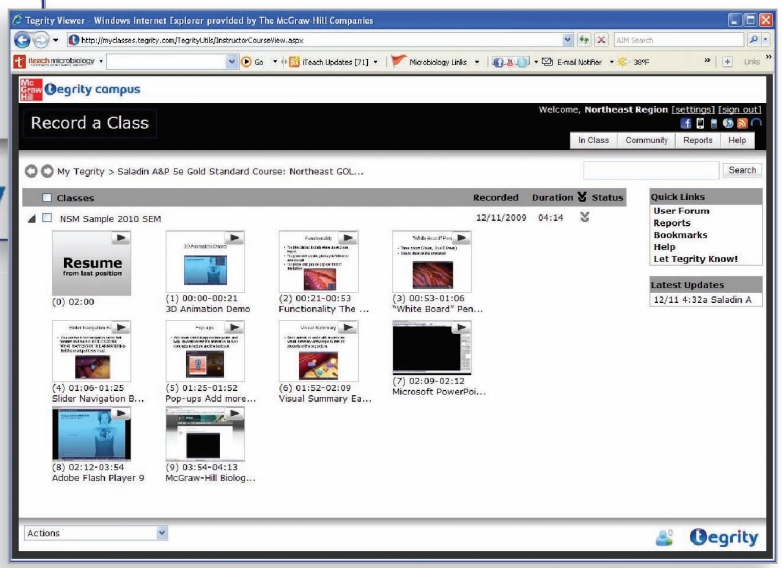


Focus on Understanding . . .

Student-Friendly Illustrations

Introduce the "big picture"

Focus figures provide an overview or highlight a key concept.

Keep the big picture in focus

A highlighted mini-version of the overview figure is often incorporated into the upper left corner of subsequent figures, helping students see how those figures fit into the big picture.

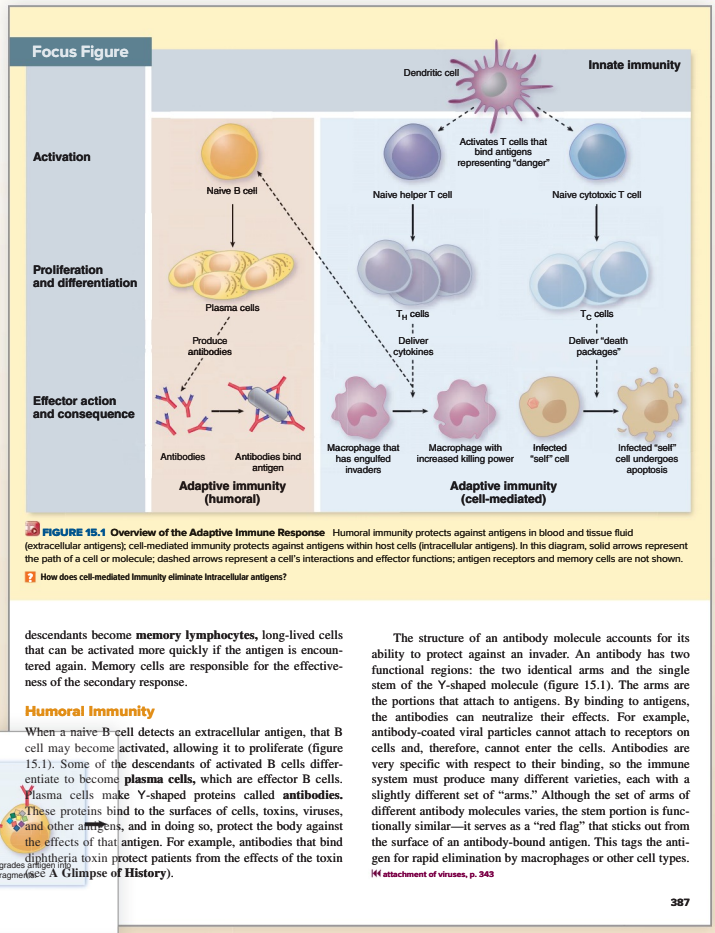


FIGURE 15.1 Overview of the Adaptive Immune Response Humoral immunity protects against antigens in blood and tissue fluid (extracellular antigens); cell-mediated immunity protects against antigens within host cells (intracellular antigens). In this diagram, solid arrows represent the path of a cell or molecule; dashed arrows represent a cell's interactions and effector functions; antigen receptors and memory cells are not shown.

? How does cell-mediated immunity eliminate intracellular antigens?

descendants become **memory lymphocytes,** long-lived cells that can be activated more quickly if the antigen is encountered again. Memory cells are responsible for the effectiveness of the secondary response.

Humoral Immunity

When a naive B cell detects an extracellular antigen, that B cell may become activated, allowing it to proliferate (figure 15.1). Some of the descendants of activated B cells differentiate to become **plasma cells,** which are effector B cells. Plasma cells make Y-shaped proteins called **antibodies.** These proteins bind to the surfaces of cells, toxins, viruses, and other antigens, and in doing so, protect the body against the effects of that antigen. For example, antibodies that bind diphtheria toxin protect patients from the effects of the toxin (see **A Glimpse of History**).

The structure of an antibody molecule accounts for its ability to protect against an invader. An antibody has two functional regions: the two identical arms and the single stem of the Y-shaped molecule (figure 15.1). The arms are the portions that attach to antigens. By binding to antigens, the antibodies can neutralize their effects. For example, antibody-coated viral particles cannot attach to receptors on cells and, therefore, cannot enter the cells. Antibodies are very specific with respect to their binding, so the immune system must produce many different varieties, each with a slightly different set of "arms." Although the set of arms of different antibody molecules varies, the stem portion is functionally similar—it serves as a "red flag" that sticks out from the surface of an antibody-bound antigen. This tags the antigen for rapid elimination by macrophages or other cell types.

attachment of viruses, p. 343

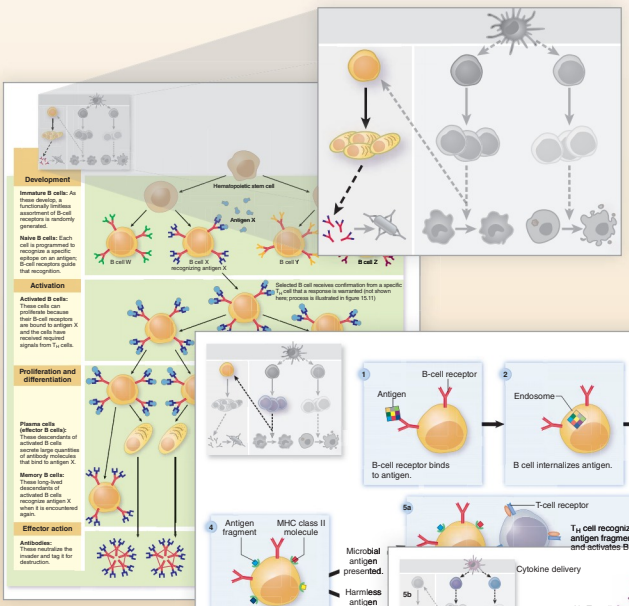


FIGURE 15.10

FIGURE 15.11

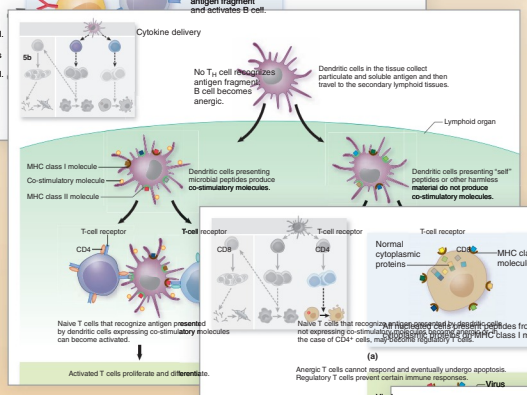


FIGURE 15.20

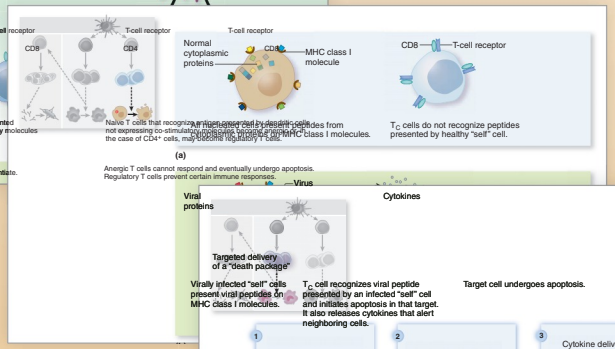


FIGURE 15.21

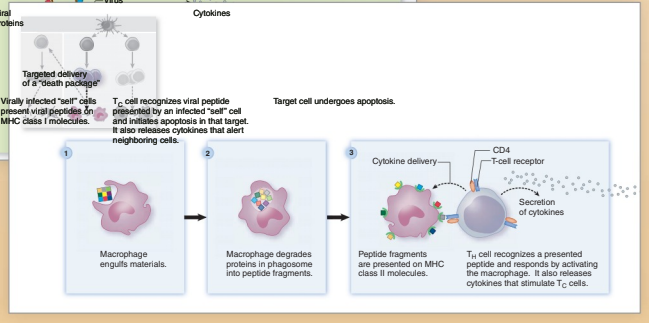


FIGURE 15.22

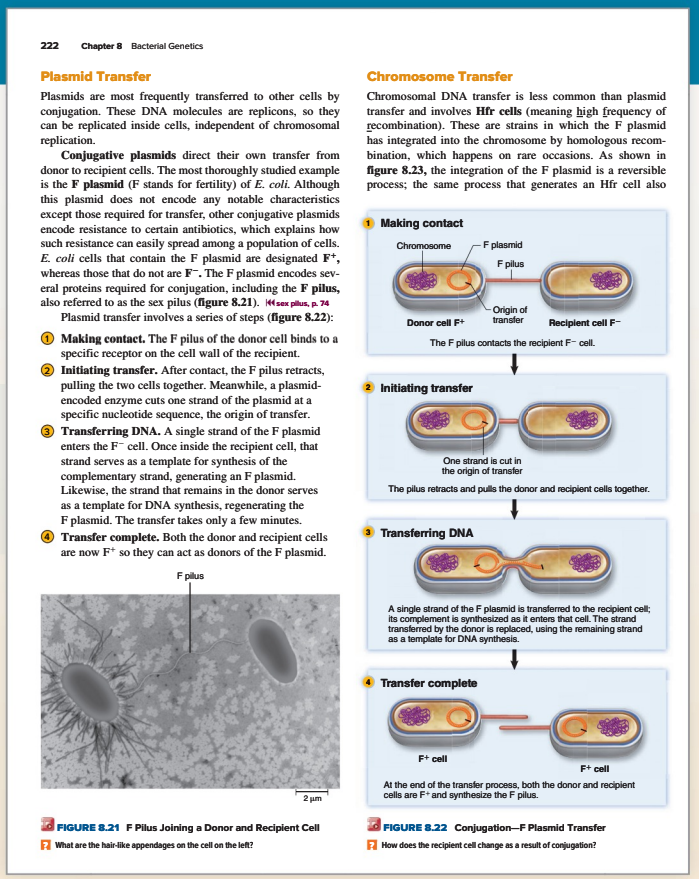
"Provides a logical unfolding conceptual framework that fosters better understanding."

—Jamal Bittar, University of Toldeo

Walk through the processes

Step-by-step figures direct the student using numbered icons, often with corresponding icons in the text.

> *"The text and illustrations are "tight" and give each other good support."*
>
> —Richard Shipee, Vincennes University



222 Chapter 8 Bacterial Genetics

Plasmid Transfer

Plasmids are most frequently transferred to other cells by conjugation. These DNA molecules are replicons, so they can be replicated inside cells, independent of chromosomal replication.

Conjugative plasmids direct their own transfer from donor to recipient cells. The most thoroughly studied example is the **F plasmid** (F stands for fertility) of *E. coli*. Although this plasmid does not encode any notable characteristics except those required for transfer, other conjugative plasmids encode resistance to certain antibiotics, which explains how such resistance can easily spread among a population of cells. *E. coli* cells that contain the F plasmid are designated **F⁺**, whereas those that do not are **F⁻**. The F plasmid encodes several proteins required for conjugation, including the **F pilus,** also referred to as the sex pilus (**figure 8.21**). ⟨◂ sex pilus, p. 74

Plasmid transfer involves a series of steps (**figure 8.22**):

1. **Making contact.** The F pilus of the donor cell binds to a specific receptor on the cell wall of the recipient.
2. **Initiating transfer.** After contact, the F pilus retracts, pulling the two cells together. Meanwhile, a plasmid-encoded enzyme cuts one strand of the plasmid at a specific nucleotide sequence, the origin of transfer.
3. **Transferring DNA.** A single strand of the F plasmid enters the F⁻ cell. Once inside the recipient cell, that strand serves as a template for synthesis of the complementary strand, generating an F plasmid. Likewise, the strand that remains in the donor serves as a template for DNA synthesis, regenerating the F plasmid. The transfer takes only a few minutes.
4. **Transfer complete.** Both the donor and recipient cells are now F⁺ so they can act as donors of the F plasmid.

F pilus

2 μm

FIGURE 8.21 F Pilus Joining a Donor and Recipient Cell

What are the hair-like appendages on the cell on the left?

Chromosome Transfer

Chromosomal DNA transfer is less common than plasmid transfer and involves **Hfr cells** (meaning high frequency of recombination). These are strains in which the F plasmid has integrated into the chromosome by homologous recombination, which happens on rare occasions. As shown in **figure 8.23,** the integration of the F plasmid is a reversible process; the same process that generates an Hfr cell also

1 Making contact
Chromosome, F plasmid, F pilus, Origin of transfer, Donor cell F⁺, Recipient cell F⁻
The F pilus contacts the recipient F⁻ cell.

2 Initiating transfer
One strand is cut in the origin of transfer
The pilus retracts and pulls the donor and recipient cells together.

3 Transferring DNA
A single strand of the F plasmid is transferred to the recipient cell; its complement is synthesized as it enters that cell. The strand transferred by the donor is replaced, using the remaining strand as a template for DNA synthesis.

4 Transfer complete
F⁺ cell, F⁺ cell
At the end of the transfer process, both the donor and recipient cells are F⁺ and synthesize the F pilus.

FIGURE 8.22 Conjugation—F Plasmid Transfer

How does the recipient cell change as a result of conjugation?

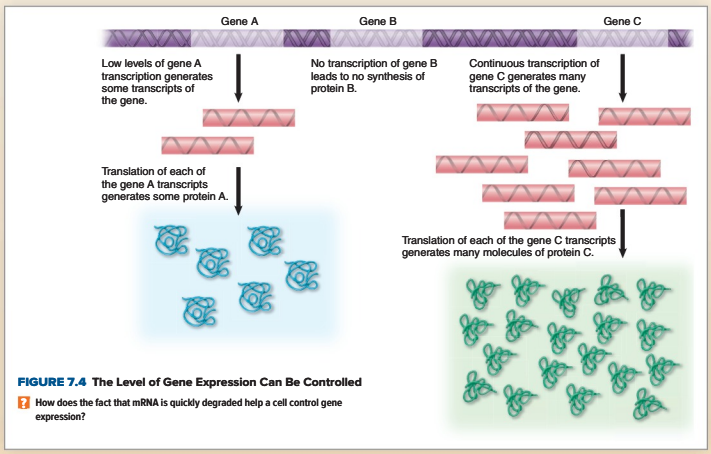


FIGURE 7.4 The Level of Gene Expression Can Be Controlled

How does the fact that mRNA is quickly degraded help a cell control gene expression?

Encourage deeper understanding

Figures have accompanying questions that encourage students to think more carefully about the concept illustrated in the figure.

Introduce the body systems

Disease chapters include a stunning figure that introduces the students to the anatomy of the body system.

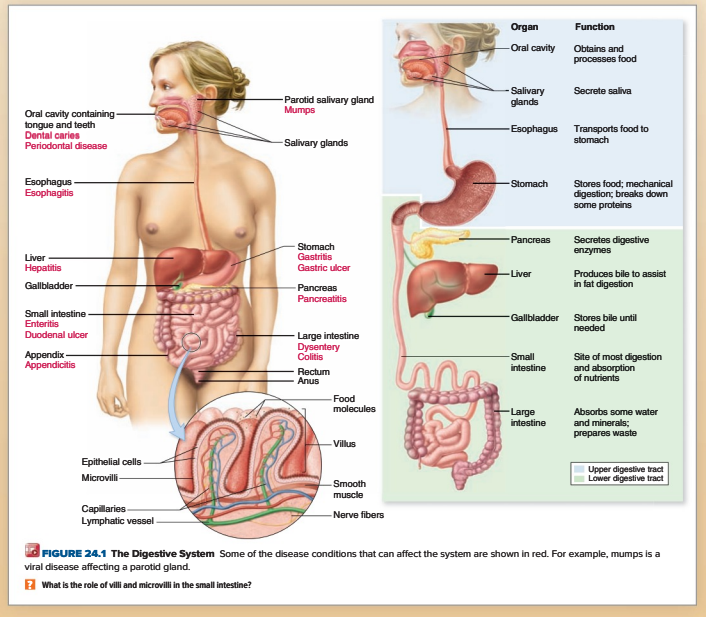


FIGURE 24.1 The Digestive System Some of the disease conditions that can affect the system are shown in red. For example, mumps is a viral disease affecting a parotid gland.

What is the role of villi and microvilli in the small intestine?

Focus on Understanding . . .

Student-Friendly Chapter Features

Provide the tools for understanding

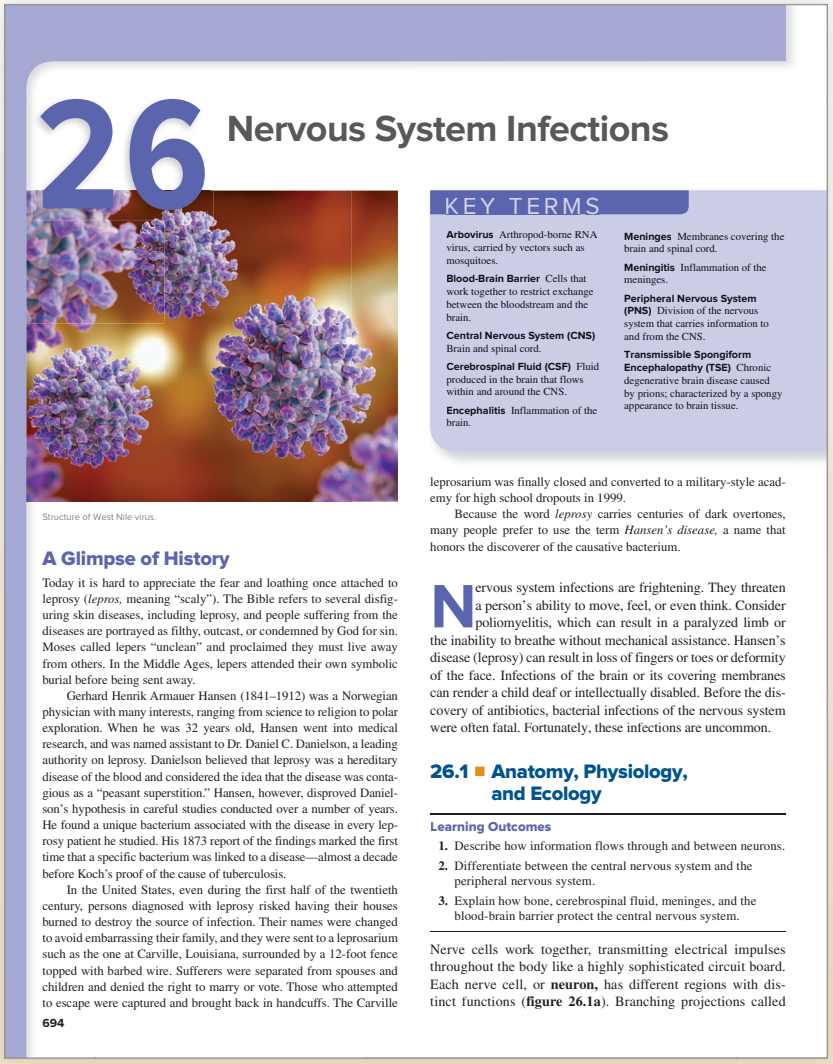
Key Terms for each chapter are defined on the opening page.

Share the history

A Glimpse of History opens each chapter, featuring engaging stories about the men and women who pioneered the field of microbiology

Define the expectations

Learning outcomes are found at the beginning of each numbered section, allowing organization, evaluation, and assessment of instruction.



26 Nervous System Infections

Structure of West Nile virus.

KEY TERMS

Arbovirus Arthropod-borne RNA virus, carried by vectors such as mosquitoes.

Blood-Brain Barrier Cells that work together to restrict exchange between the bloodstream and the brain.

Central Nervous System (CNS) Brain and spinal cord.

Cerebrospinal Fluid (CSF) Fluid produced in the brain that flows within and around the CNS.

Encephalitis Inflammation of the brain.

Meninges Membranes covering the brain and spinal cord.

Meningitis Inflammation of the meninges.

Peripheral Nervous System (PNS) Division of the nervous system that carries information to and from the CNS.

Transmissible Spongiform Encephalopathy (TSE) Chronic degenerative brain disease caused by prions; characterized by a spongy appearance to brain tissue.

A Glimpse of History

Today it is hard to appreciate the fear and loathing once attached to leprosy (*lepros,* meaning "scaly"). The Bible refers to several disfiguring skin diseases, including leprosy, and people suffering from the diseases are portrayed as filthy, outcast, or condemned by God for sin. Moses called lepers "unclean" and proclaimed they must live away from others. In the Middle Ages, lepers attended their own symbolic burial before being sent away.

Gerhard Henrik Armauer Hansen (1841–1912) was a Norwegian physician with many interests, ranging from science to religion to polar exploration. When he was 32 years old, Hansen went into medical research, and was named assistant to Dr. Daniel C. Danielson, a leading authority on leprosy. Danielson believed that leprosy was a hereditary disease of the blood and considered the idea that the disease was contagious as a "peasant superstition." Hansen, however, disproved Danielson's hypothesis in careful studies conducted over a number of years. He found a unique bacterium associated with the disease in every leprosy patient he studied. His 1873 report of the findings marked the first time that a specific bacterium was linked to a disease—almost a decade before Koch's proof of the cause of tuberculosis.

In the United States, even during the first half of the twentieth century, persons diagnosed with leprosy risked having their houses burned to destroy the source of infection. Their names were changed to avoid embarrassing their family, and they were sent to a leprosarium such as the one at Carville, Louisiana, surrounded by a 12-foot fence topped with barbed wire. Sufferers were separated from spouses and children and denied the right to marry or vote. Those who attempted to escape were captured and brought back in handcuffs. The Carville leprosarium was finally closed and converted to a military-style academy for high school dropouts in 1999.

Because the word *leprosy* carries centuries of dark overtones, many people prefer to use the term *Hansen's disease,* a name that honors the discoverer of the causative bacterium.

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Nervous system infections are frightening. They threaten a person's ability to move, feel, or even think. Consider poliomyelitis, which can result in a paralyzed limb or the inability to breathe without mechanical assistance. Hansen's disease (leprosy) can result in loss of fingers or toes or deformity of the face. Infections of the brain or its covering membranes can render a child deaf or intellectually disabled. Before the discovery of antibiotics, bacterial infections of the nervous system were often fatal. Fortunately, these infections are uncommon.

26.1 ■ Anatomy, Physiology, and Ecology

Learning Outcomes

1. Describe how information flows through and between neurons.
2. Differentiate between the central nervous system and the peripheral nervous system.
3. Explain how bone, cerebrospinal fluid, meninges, and the blood-brain barrier protect the central nervous system.

Nerve cells work together, transmitting electrical impulses throughout the body like a highly sophisticated circuit board. Each nerve cell, or **neuron,** has different regions with distinct functions (**figure 26.1a**). Branching projections called

MicroAssessment 3.2

Dyes are used to stain cells so they can be seen against an unstained background. The Gram stain is the most commonly used differential stain. The acid-fast stain is used to detect *Mycobacterium* species. Specific dyes and techniques are used to observe cell structures such as capsules, endospores, and flagella. Fluorescent dyes and tags can be used to observe total cells, a subset of cells, or cells that have certain proteins on their surface.

4. What are the functions of a primary stain and a counterstain?
5. Describe one error in the staining procedure that would result in a Gram-positive bacterium appearing pink.
6. What color would a Gram-negative bacterium be in an acid-fast stain? +

Assess understanding

A **MicroAssessment** at the end of each numbered section summarizes the concepts and includes review questions, usually featuring one that stimulates critical thinking (indicated by a plus sign).

Engage the reader

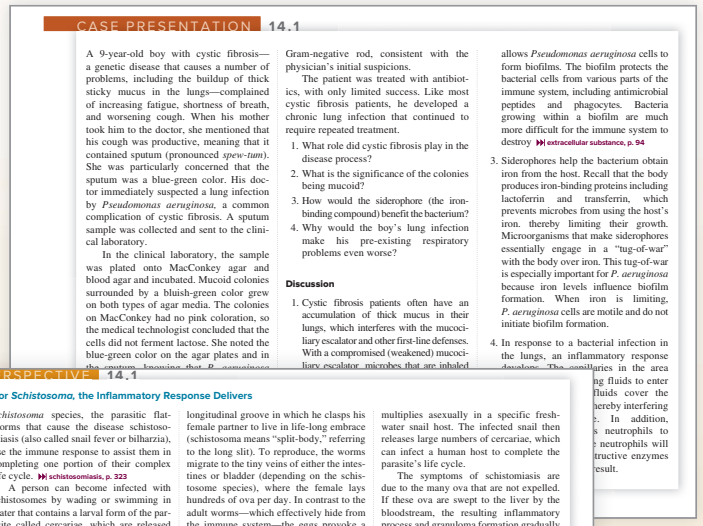
MicroBytes found throughout the chapter provide small "bytes" of information, capturing the reader's attention.

MicroByte

There are more bacteria in just one person's mouth than there are people in the world!

Highlight the relevance

Case Presentation boxes (now one in each chapter!) describe realistic clinical, veterinary, or environmental situations, along with questions and discussions designed to highlight the relevance of the information.


CASE PRESENTATION 14.1

A 9-year-old boy with cystic fibrosis—a genetic disease that causes a number of problems, including the buildup of thick sticky mucus in the lungs—complained of increasing fatigue, shortness of breath, and worsening cough. When his mother took him to the doctor, she mentioned that his cough was productive, meaning that it contained sputum (pronounced *spew-tum*). She was particularly concerned that the sputum was a blue-green color. His doctor immediately suspected a lung infection by *Pseudomonas aeruginosa*, a common complication of cystic fibrosis. A sputum sample was collected and sent to the clinical laboratory.

In the clinical laboratory, the sample was plated onto MacConkey agar and blood agar and incubated. Mucoid colonies surrounded by a bluish-green color grew on both types of agar media. The colonies on MacConkey had no pink coloration, so the medical technologist concluded that the cells did not ferment lactose. She noted the blue-green color on the agar plates and in

Gram-negative rod, consistent with the physician's initial suspicions.

The patient was treated with antibiotics, with only limited success. Like most cystic fibrosis patients, he developed a chronic lung infection that continued to require repeated treatment.

1. What role did cystic fibrosis play in the disease process?
2. What is the significance of the colonies being mucoid?
3. How would the siderophore (the iron-binding compound) benefit the bacterium?
4. Why would the boy's lung infection make his pre-existing respiratory problems even worse?

Discussion

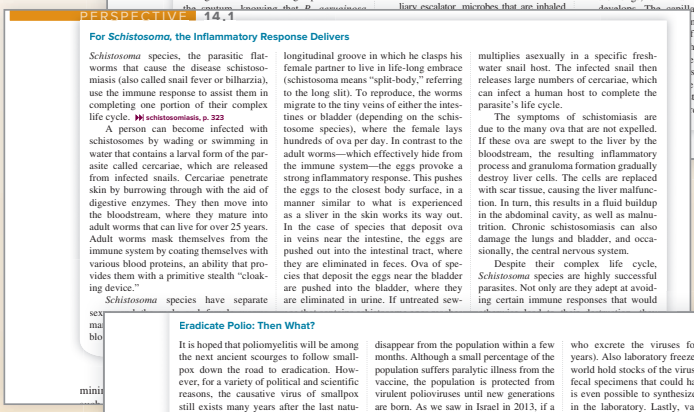
1. Cystic fibrosis patients often have an accumulation of thick mucus in their lungs, which interferes with the mucociliary escalator and other first-line defenses. With a compromised (weakened) mucociliary escalator, microbes that are inhaled

allows *Pseudomonas aeruginosa* cells to form biofilms. The biofilm protects the bacterial cells from various parts of the immune system, including antimicrobial peptides and phagocytes. Bacteria growing within a biofilm are much more difficult for the immune system to destroy ⏭ extracellular substance, p. 94

3. Siderophores help the bacterium obtain iron from the host. Recall that the body produces iron-binding proteins including lactoferrin and transferrin, which prevents microbes from using the host's iron, thereby limiting their growth. Microorganisms that make siderophores essentially engage in a "tug-of-war" with the body over iron. This tug-of-war is especially important for *P. aeruginosa* because iron levels influence biofilm formation. When iron is limiting, *P. aeruginosa* cells are motile and do not initiate biofilm formation.
4. In response to a bacterial infection in the lungs, an inflammatory response

Provide perspective

Perspective boxes show how microorganisms and their products influence our lives in many different ways.


PERSPECTIVE 14.1

For *Schistosoma*, the Inflammatory Response Delivers

Schistosoma species, the parasitic flatworms that cause the disease schistosomiasis (also called snail fever or bilharzia), use the immune response to assist them in completing one portion of their complex life cycle. ⏭ schistosomiasis, p. 323

A person can become infected with schistosomes by wading or swimming in water that contains a larval form of the parasite called cercariae, which are released from infected snails. Cercariae penetrate skin by burrowing through with the aid of digestive enzymes. They then move into the bloodstream, where they mature into adult worms that can live for over 25 years. Adult worms mask themselves from the immune system by coating themselves with various blood proteins, an ability that provides them with a primitive stealth "cloaking device."

Schistosoma species have separate

longitudinal groove in which he clasps his female partner to live in life-long embrace (schistosoma means "split-body," referring to the long slit). To reproduce, the worms migrate to the tiny veins of either the intestines or bladder (depending on the schistosome species), where the female lays hundreds of ova per day. In contrast to the adult worms—which effectively hide from the immune system—the eggs provoke a strong inflammatory response. This pushes the eggs to the closest body surface, in a manner similar to what is experienced as a sliver in the skin works its way out. In the case of species that deposit ova in veins near the intestine, the eggs are pushed out into the intestinal tract, where they are eliminated in feces. Ova of species that deposit the eggs near the bladder are pushed into the bladder, where they are eliminated in urine. If untreated sew-

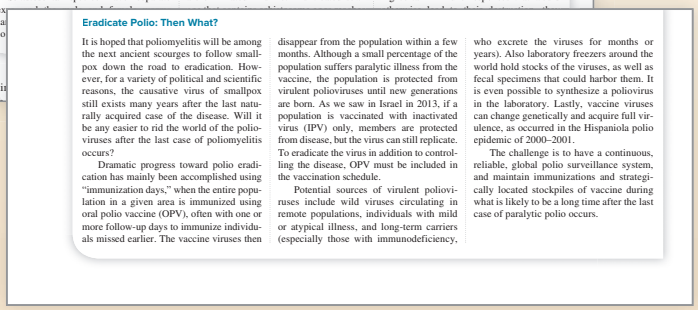
multiplies asexually in a specific freshwater snail host. The infected snail then releases large numbers of cercariae, which can infect a human host to complete the parasite's life cycle.

The symptoms of schistomiasis are due to the many ova that are not expelled. If these ova are swept to the liver by the bloodstream, the resulting inflammatory process and granuloma formation gradually destroy liver cells. The cells are replaced with scar tissue, causing the liver malfunction. In turn, this results in a fluid buildup in the abdominal cavity, as well as malnutrition. Chronic schistosomiasis can also damage the lungs and bladder, and occasionally, the central nervous system.

Despite their complex life cycle, *Schistosoma* species are highly successful parasites. Not only are they adept at avoiding certain immune responses that would

Inspire the learner

Future Opportunities boxes describe pending challenges facing current and future microbiologists.


Eradicate Polio: Then What?

It is hoped that poliomyelitis will be among the next ancient scourges to follow smallpox down the road to eradication. However, for a variety of political and scientific reasons, the causative virus of smallpox still exists many years after the last naturally acquired case of the disease. Will it be any easier to rid the world of the poliovirus after the last case of poliomyelitis occurs?

Dramatic progress toward polio eradication has mainly been accomplished using "immunization days," when the entire population in a given area is immunized using oral polio vaccine (OPV), often with one or more follow-up days to immunize individuals missed earlier. The vaccine viruses then

disappear from the population within a few months. Although a small percentage of the population suffers paralytic illness from the vaccine, the population is protected from virulent polioviruses until new generations are born. As we saw in Israel in 2013, if a population is vaccinated with inactivated virus (IPV) only, members are protected from disease, but the virus can still replicate. To eradicate the virus in addition to controlling the disease, OPV must be included in the vaccination schedule.

Potential sources of virulent polioviruses include wild viruses circulating in remote populations, individuals with mild or atypical illness, and long-term carriers (especially those with immunodeficiency,

who excrete the viruses for months or years). Also laboratory freezers around the world hold stocks of the viruses, as well as fecal specimens that could harbor them. It is even possible to synthesize a poliovirus in the laboratory. Lastly, vaccine viruses can change genetically and acquire full virulence, as occurred in the Hispaniola polio epidemic of 2000–2001.

The challenge is to have a continuous, reliable, global polio surveillance system, and maintain immunizations and strategically located stockpiles of vaccine during what is likely to be a long time after the last case of paralytic polio occurs.

- **Summary** briefly reviews the key points.
- **Short Answer** questions review major chapter concepts.
- **Multiple Choice** questions allow self-testing; answers are provided in Appendix IV.
- **Application** questions provide an opportunity to use knowledge of microbiology to solve real-world problems.
- **Critical Thinking** questions encourage practice in analysis and problem solving that can be used by the student in any subject.

Review the information

End-of-chapter review encourages students to revisit the information.

Build the story

Logical chapter order helps students understand why infectious diseases occur despite our incredible immune system, and what people can do to prevent and treat those diseases.

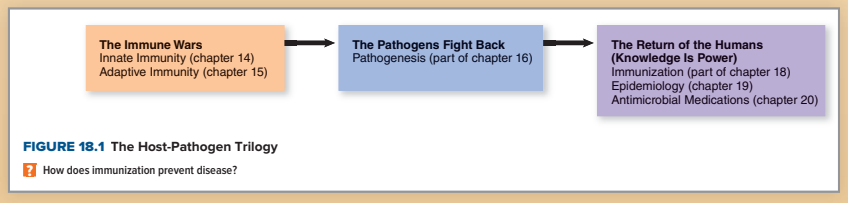


FIGURE 18.1 The Host-Pathogen Trilogy

? How does immunization prevent disease?

Focus on Understanding . . .

Student-Friendly Descriptions

Include analogies

WHY? Analogies provide students a comfortable framework for making sense of difficult topics. Here's an example from Chapter 14.

Innate Immunity *The innate immune system has three general components—first-line defenses, sensor systems, and innate effector actions. As useful analogy, think of the defense systems of a high-security building or compound: the first-line defenses are the security walls surrounding the property; the sensor systems are the security cameras scattered throughout the property, monitoring the environment for signs of invasion; and the effector actions are the security teams sent to remove any invaders that have been detected, thereby eliminating the threat* ***(figure 14.1a)****.*

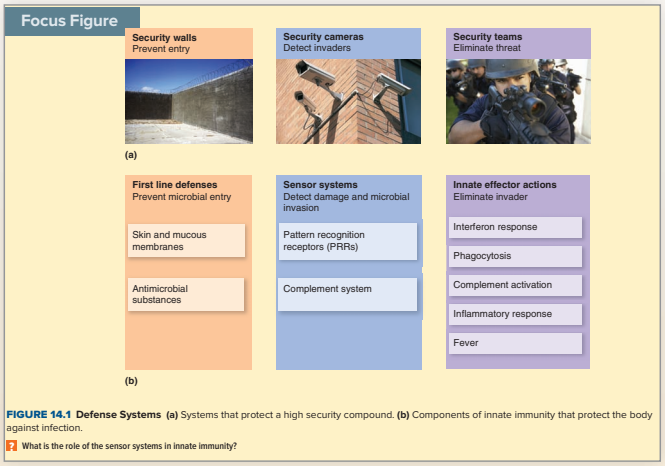


FIGURE 14.1 Defense Systems **(a)** Systems that protect a high security compound. **(b)** Components of innate immunity that protect the body against infection.

? What is the role of the sensor systems in innate immunity?

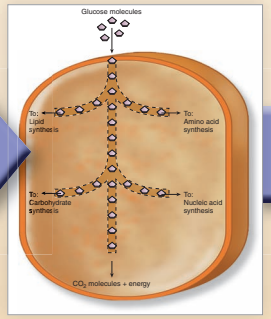
Emphasize the logic

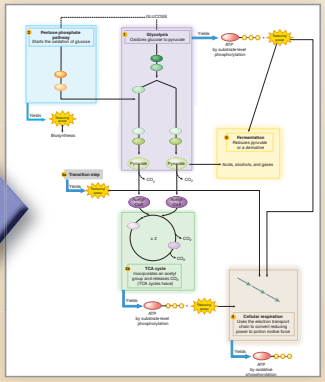
WHY? Descriptions that emphasize the logic of processes make it easier for students to understand and retain the information. Here's an example from Chapter 6.

TABLE 6.2 Precursor Metabolites

Precursor Metabolite	Pathway Generated	Biosynthetic Role
Glucose-6-phosphate	Glycolysis	Lipopolysaccharide
Fructose-6-phosphate	Glycolysis	Peptidoglycan
Dihydroxyacetone phosphate	Glycolysis	Lipids (glycerol component)
3-Phosphoglycerate	Glycolysis	Proteins (the amino acids cysteine, glycine, and serine)
Phosphoenolpyruvate	Glycolysis	Proteins (the amino acids phenylalanine, tryptophan, and tyrosine)
Pyruvate	Glycolysis	Proteins (the amino acids alanine, leucine, and valine)
Ribose-5-phosphate	Pentose phosphate cycle	Nucleic acids and proteins (the amino acid histidine)
Erythrose-4-phosphate	Pentose phosphate cycle	Proteins (the amino acids phenylalanine, tryptophan, and tyrosine)
Acetyl-CoA	Transition step	Lipids (fatty acids)
α-Ketoglutarate	TCA cycle	Proteins (the amino acids arginine, glutamate, glutamine, and proline)
Oxaloacetate	TCA cycle	Proteins (the amino acids aspartate, asparagine, isoleucine, lysine, methionine, and threonine)

Some organisms use succinyl-CoA as a precursor in heme biosynthesis; *E. coli* uses glutamate.





Introduce the players *Certain intermediates of catabolic pathways can be used in anabolic pathways. These intermediates—precursor metabolites—serve as carbon skeletons from which subunits of macromolecules can be made* ***(table 6.2)****.*

Reinforce the concept *A cell's metabolic pathways make it easy for that cell to use glucose for different purposes. Think of the cells as extensive biological recycling centers that routinely process millions of glucose molecules* ***(figure 6.9)****. Molecules that remain on the central deconstruction line are oxidized completely to CO_2, releasing the maximum amount of energy. Some breakdown intermediates, however, can exit that line to be used in biosynthesis.*

Put the pieces together *Three key metabolic pathways—the central metabolic pathways—gradually oxidize glucose to CO_2* ***(figure 6.10)****. The pathways are catabolic, but the precursor metabolites and reducing power they generate can also be diverted for use in biosynthesis.*

Student-Friendly Disease Presentations

Help students think like experts

Within each body system chapter, diseases are separated by major taxonomic category (bacteria, viruses, fungi, protozoa). This organization reflects a major consideration with respect to treatment options, an important consideration for students going into healthcare-related fields.

Treatment and Prevention

Treatment of neonatal meningitis includes intravenous dosage with a mixture of antibacterial medications such as ampicillin and gentamicin effective against both group B streptococci and *E. coli*. Other medications may be added after the causative agent is identified.

The Centers for Disease Control and Prevention (CDC) recommends that the vagina and rectum of pregnant women be tested for group B streptococci late in pregnancy. Women with positive cultures can then be treated with an appropriate antibacterial medication shortly before or during labor. Screening and subsequent treatment can decrease the incidence of serious group B streptococcal disease by more than 75%.

Listeriosis

Meningitis is the most common result of listeriosis, a foodborne disease caused by *Listeria monocytogenes*. This organism generally causes only a small percentage of meningitis cases in the United States, but epidemics may occur.

Signs and Symptoms

Listeria monocytogenes infections are generally asymptomatic or mild in most healthy people. Symptomatic listeriosis is usually characterized by fever and muscle aches, and sometimes nausea or diarrhea. Most of the cases requiring medical attention have meningitis with fever, headache, stiff neck, and vomiting. Pregnant women who become infected often miscarry or deliver terminally ill premature or full-term infants. Babies infected at birth usually develop meningitis after an incubation period of 1 to 4 weeks.

Causative Agent

Listeria monocytogenes is a motile, non-spore-forming, facultatively anaerobic, Gram-positive rod that can grow at 4°C. The organism can grow in refrigerated foods even if vacuum-packaged.

Pathogenesis

The mode of entry of *L. monocytogenes* in sporadic cases of listeriosis is usually unclear, but during epidemics it is generally via the gastrointestinal tract. Gastrointestinal symptoms may or may not occur, but the bacteria promptly penetrate the intestinal mucosa—through the M cells and into the Peyer's patches—and then enter the bloodstream. The resulting bacteremia is the source of meningeal infection. In pregnant women, *L. monocytogenes* crosses the placenta and produces widespread abscesses in tissues of the fetus.

M cells, p. 389 Peyer's patches, p. 389

Epidemiology

Listeria monocytogenes is widespread in natural waters and vegetation and can be carried in the intestines of asymptomatic humans and other animals. Pregnant women, the elderly, and those with underlying illnesses such as immunodeficiency, diabetes, cancer, and liver disease are especially susceptible to listeriosis. Outbreaks have resulted from *L. monocytogenes* contaminating foods including coleslaw, non-pasteurized milk, pork tongue in jelly, some soft cheeses, hot dogs, and canteloupe. Because the organisms can grow in commercially prepared food stored at refrigeration temperatures, thousands of infections can originate from a single food-processing plant.

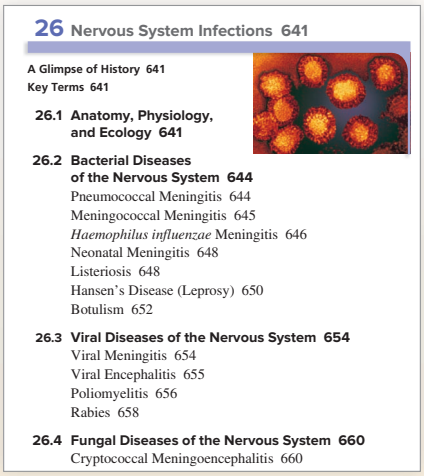
Treatment and Prevention

Most strains of *L. monocytogenes* remain susceptible to antibacterial medications such as penicillin. Even though the disease is often mild in pregnant women, prompt diagnosis and treatment are important to protect the fetus.

Listeria monocytogenes can be killed by thoroughly cooking poultry, pork, beef, and other meats. To reduce the risk of cross-contamination, uncooked meats should not be kept with other foods; countertops and utensils should be cleaned after food preparation; and raw fruits and vegetables should be thoroughly washed before eating. Pregnant women and others at high risk are advised to avoid soft cheeses, refrigerated meat spreads, and smoked seafood. They should also heat cold cuts and hot dogs before eating them and avoid the fluids that may be in the packaging. In 2006, the U.S. Food and Drug Administration approved a food additive consisting of a mixture of bacteriophage strains that lyse *L. monocytogenes* (**figure 26.7**).

FIGURE 26.7 Bacteriophage in Food Safety When sprayed onto ready-to-eat foods, bacteriophage preparations may reduce the risk of listeriosis.

? What is the source of most listeriosis infections?



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26.4 Fungal Diseases of the Nervous System 660
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Provide a consistent conceptual framework

Disease discussions are separated into consistent subsections, providing a conceptual framework and breaking the material into "bite-sized" pieces.

> *"The strength of this text is that it answers 'why' better than most texts."*
>
> —MaryAnn Mertz, West Virginia Northern Community College

Summarize each disease's characteristics

Summary tables serve as brief reminders of the important features of each disease. Major diseases are represented with an enhanced summary table that includes an outline of the disease process keyed to a human figure, showing the entry and exit of the pathogen.

Review the diseases as a group

Each disease chapter ends with a table that summarizes the key features of the diseases discussed in that chapter.

Diseases in Review 21.1

Diseases of the Respiratory System

Disease	Causative Agent	Comment	Summary Table
BACTERIAL INFECTIONS OF THE UPPER RESPIRATORY TRACT			
Streptococcal pharyngitis ("strep throat")	*Streptococcus pyogenes* (group A streptococcus)	Treated with antibiotics, partly to avoid sequelae; must be distinguished from viral pharyngitis, which cannot be treated with antibiotics.	Table 21.3, p. 537
Diphtheria	*Corynebacterium diphtheriae*	Toxin-mediated disease characterized by pseudomembrane in the upper respiratory tract. Preventable by vaccination (DTaP).	Table 21.4, p. 541
Conjunctivitis (pinkeye), otitis media (earache), sinus infection	Usually *Haemophilus influenzae* and *Streptococcus pneumoniae*	Often occur together; factors involved in the transmission are unknown.	
VIRAL INFECTIONS OF THE UPPER RESPIRATORY TRACT			
Common cold	Rhinoviruses and other viruses	Runny nose, sore throat, and cough are due to the inflammatory response and cell destruction.	Table 21.5, p. 544
Adenoviral pharyngitis	Adenovirus	Similar to the common cold but with fever; spread to the lower respiratory tract can result in severe disease.	Table 21.6, p. 545
BACTERIAL INFECTIONS OF THE LOWER RESPIRATORY TRACT			
Pneumococcal pneumonia	*Streptococcus pneumoniae*	Organism common in the throat of healthy people; causes disease when mucociliary escalator is impaired or with underlying conditions. Vaccine that protects against multiple strains is available.	Table 21.7, p. 548
***Klebsiella* pneumonia**	*Klebsiella* species, commonly *K. pneumoniae*	Common hospital-acquired bacterium; characterized by sputum resembling red current jelly. Drug resistance is a major problem.	Table 21.7, p. 548
Mycoplasmal pneumonia ("walking pneumonia")	*Mycoplasma pneumoniae*	Relatively mild pneumonia; common among college students and military recruits. Cannot be treated with medications that inhibit cell wall synthesis.	Table 21.7, p. 548
Pertussis ("whooping cough")	*Bordetella pertussis*	Characterized by frequent violent coughing. Preventable by vaccination (DTaP).	Table 21.8, p. 552
Tuberculosis ("TB")	*Mycobacterium tuberculosis*	Most infections result in latent tuberculosis infection (LTBI), but these can reactivate to cause tuberculosis disease (TB disease). Treated using combination drug therapy, but drug resistance is an increasing problem.	Table 21.9, p. 556
Legionnaires' disease	*Legionella pneumophila*	Transmitted via aerosolized water drops; smokers and those with impaired defenses are most at risk of developing disease.	Table 21.10, p. 557
VIRAL INFECTIONS OF THE LOWER RESPIRATORY TRACT			
Influenza ("flu")	Influenza A virus	New vaccine developed yearly; viruses change seasonally due to antigenic drift; antigenic shifts cause pandemics.	Table 21.11, p. 561
Respiratory syncytial virus infections	RSV	Serious disease in infants, young children, and the elderly.	Table 21.12, p. 562
Hantavirus pulmonary syndrome	Hantaviruses	Acquired via inhaled dust contaminated with rodent saliva, urine, or feces. Frequently fatal.	Table 21.13, p. 563
FUNGAL INFECTIONS OF THE RESPIRATORY TRACT			
Coccidioidomycosis ("Valley fever")	*Coccidioides immitis*	Environmental reservoir (soil in semi-arid desert areas); most infections are asymptomatic.	Table 21.14, p. 565
Histoplasmosis ("spelunker's disease")	*Histoplasma capsulatum*	Environmental reservoir (soil enriched with bird or bat droppings); most infections are asymptomatic.	Table 21.15, p. 566
Pneumocystis pneumonia (PCP)	*Pneumocystis jirovecii* (formerly *carinii*)	Organism is an opportunistic fungus that causes serious lung disease in immunocompromised people, such as those with HIV/AIDS.	Table 21.16, p. 567

UPDATES—Maintaining the Cutting Edge

Global Changes

- Improved the clarity of descriptions through extensive "wordsmithing"; also increased the spacing between letters, making the narrative easier to read
- Updated disease statistics and added incubation periods.
- Updated the terminology to be consistent with the CDC—for example, Ebola virus disease (EBV), latent tuberculosis infection (LTBI) and tuberculosis disease (TB disease), and *Clostridium difficile* infection (CDI)
- Improved the disease summary tables by making the distinction between treatment and prevention more obvious
- Simplified the treatment section of the disease summary tables by listing only the category of medication (such as antibiotic) rather than the specific type
- Replaced many of the photographs
- Changed chapter order, so that the chapter on blood and lymphatic infections comes before the chapter on nervous system infections (because nervous system infections often originate in the bloodstream)
- Eliminated one chapter by consolidating the basic information on HIV disease into the section on viral STIs (in chapter 27), moving *Pneumocystis* pneumonia to chapter 21, and moving toxoplasmosis to chapter 26. The remaining information from the chapter in now available online.

New! Every Chapter Now Includes a Case Presentation

- Chapter 1—Fecal transplantation to treat *Clostridium difficile* disease
- Chapter 2—Lactose intolerance
- Chapter 3—Methicillin-resistant *Staphylococcus aureus*
- Chapter 4—Cyanobacterial bloom due to phosphate pollution
- Chapter 5—Healthcare-associated infection
- Chapter 6—Metabolic advantage to *Salmonella enterica* in using tetrathionate
- Chapter 7—Quorum sensing in *Vibrio cholerae*
- Chapter 8—Development of vancomycin resistance in *Staphylococcus aureus*
- Chapter 9—PCR-based identification of *Neisseria meningitidis*
- Chapter 10—Tracking an *E. coli* O157:H7 outbreak
- Chapter 11—Dead zone in Lake Erie
- Chapter 12—Giardiasis in a dog
- Chapter 13—Hoof and mouth disease of cattle
- Chapter 14—*Pseudomonas aeruginosa* infection
- Chapter 15—Malaria
- Chapter 16—Whooping cough
- Chapter 17—Systemic lupus erythematosus (SLE)
- Chapter 18—Mumps outbreak at a university
- Chapter 19—Hepatitis A outbreak (includes a figure showing an "epi curve")
- Chapter 20 –Tuberculosis
- Chapter 21—Strep throat
- Chapter 22—Measles in an immunocompromised patient
- Chapter 23—*Clostridium perfringens* infection
- Chapter 24—Duodenal ulcer
- Chapter 25—Dengue
- Chapter 26—*Haemophilus influenzae* meningitis
- Chapter 27—Bacterial cystitis
- Chapter 28—"Frothy bloat" in cattle
- Chapter 29—Fecal coliforms in a lake
- Chapter 30—Foodborne botulism

Key Changes in Individual Chapters

Chapter 1 – Humans and the Microbial World

- Added a section on the scientific method
- Expanded the section "Vital Activities of Microorganisms" to include a subsection on the normal microbiota
- Updated the estimate for the ratio of microbial cells to human cells in the human body
- Extensively revised the timeline to make it more compact and to have consistent intervals (figure 1.3)
- Moved figure of historical trends of death rates to this chapter (now figure 1.4; was in the epidemiology chapter)
- Rearranged the section on medical microbiology
- Added a table on the origin of various genus and species names (table 1.1)

- Added a figure on the three domains (figure 1.7)
- Combined and rearranged the sections on members of the microbial world
- Changed the subject of the Future Opportunities to learning more about the human microbiome

Chapter 2 – The Molecules of Life

- Changed the subject of the Glimpse of History to Beijerinck and his work on nitrogen-fixing bacteria
- Created a section on types of chemical reactions
- Added a section on buffers
- Reorganized coverage of organic molecules
- Moved the coverage of ATP to the section on nucleic acids
- Consolidated the coverage of Pasteur's work with optical isomers as a new Perspective (was covered in the previous Glimpse of History and the narrative)

Chapter 3 – Microscopy and Cell Structure

- Moved endosymbiotic theory coverage into the main narrative
- Added a Perspective on pathogens hijacking host cell actin
- Rearranged the major sections for simplification
- Increased the emphasis on the differences between bacterial and archaeal cells
- Added figure to show the mechanism of the Gram stain (figure 3.34)

Chapter 4 – Dynamics of Microbial Growth

- Simplified the growth calculation explanation
- Added new information on bacteria using secretion systems to inject toxic compounds directly into competing bacteria
- Added use of calibrate loops for UTI plate counts
- Added a description of turbidity standards for antibiotic susceptibility testing
- Combined the sections on obtaining a pure culture and microbial growth in the laboratory

Chapter 5 – Control of Microbial Growth

- Simplified the explanation and figure on decimal reduction time (D value) (figure 5.2)
- Added biofilms to the environmental conditions to consider when selecting an antimicrobial procedure
- Expanded the discussion on how to choose the appropriate germicidal chemical

Chapter 6 – Metabolism: Fueling Microbial Growth

- Revised the analogy and accompanying figure (figure 6.9) to emphasize the roles of glucose in a cell (energy source AND biosynthesis)

Chapter 7 – The Blueprint of Life, from DNA to Protein

- Improved the figure that illustrates the effect of glucose on the lac operon (figure 7.25)
- Added a table that summarizes control of the *lac* operon (table 7.6)

Chapter 8 – Bacterial Genetics

- Simplified the description of the Ames test
- Added a figure that uses a Venn diagram to illustrate the genetic diversity within a species (figure 8.25)

Chapter 9 – Biotechnology and Recombinant DNA Techniques

- Simplified the figure showing the dideoxy chain termination method of sequencing DNA (figure 9.12)
- Added information on next-generation sequencing
- Added information on the Human Microbiome Project

Chapter 10 – Identifying and Classifying Microorganisms

- Added a section on MALDI-TOF, including a new figure (figure 10.7)
- Updated the example of an outbreak that involved characterizing the strain

Chapter 11 – The Diversity of Prokaryotic Organisms

- Added page reference numbers to the summary tables
- Moved coverage of *Vibrio* and added *Vibrio vulnificus*
- Added *Clostridium difficile* to the section on the genus *Clostridium*
- Added a section on the genus *Bordetella* and included *B. pertussis*
- Added the importance of *Bacteroides* species in digestion

Chapter 12 – The Eukaryotic Members of the Microbial World

- Consolidated the figures that illustrate the phylogeny of eukaryotes into single figure (figure 12.12)
- Improved description of the structure of fungi
- Clarified the medical importance of fungi
- Updated the discussion of malaria
- Increased the coverage of flukes

Chapter 13 – Viruses, Viroids, and Prions

- Added information on the newly discovered Pandoraviruses
- Simplified the explanation of gene reassortment in viruses
- Modified the virus diagrams in table 13.1
- Simplified the discussion of DNA and RNA virus replication and modified the accompanying figure (figure 13.14)
- Updated the Future Opportunities on gene therapy

Chapter 14 – The Innate Immune Response

- Added additional analogies to narrative and to figure 14.1 to help students understand the processes
- Simplified the in-art legends of figure 14.3
- Added a description of antimicrobial peptides, including the role of vitamin D in their synthesis
- Simplified the layout of table 14.1; added innate lymphoid cells to the table and narrative
- Rearranged the section on pattern recognition receptors to emphasize the location and function; also added an overview figure (14.7).
- Added information on "killer" versus "healer" macrophages

Chapter 15 – The Adaptive Immune Response

- Added additional analogies to help students understand the processes
- Revised the introductory overview so that it follows the accompanying focus figure more closely
- Added bullet lists to table 15.1 to emphasize differences in the properties/functions of the various antibody classes.
- Revised the figure that shows clonal selection of B cells to emphasize that IgM is the first antibody class made in the primary response (figure 15.10)

Chapter 16 – Host-Microbe Interactions

- Substantially expanded and updated the section "The Normal Microbiota"
- Added the term sepsis to the section on distribution of the pathogen, making it easier to distinguish that term from bacteremia
- Expanded the description of superantigens and added an additional part to the accompanying figure (figure 16.12)
- Added the capsule of *Cryptococcus* to the discussion of pathogenic mechanisms of fungi
- Added the mechanism that *Plasmodium falciparum* uses to avoid clearance of infected red blood cells in the spleen

Chapter 17 – Immunological Disorders

- New introduction lists the three general categories of immune system disorders covered in the chapter (hypersensitivities, autoimmune disorders, immunodeficiencies)
- Combined the hypersensitivity discussions into a single section with revised headings and introductions to guide students through the four different types
- Expanded the introduction to autoimmune disease
- Updated coverage of treatment of primary immune deficiencies
- Added a new table on opportunistic infections of AIDS patients

Chapter 18 – Applications of the Immune Responses

- Split the table that lists vaccines into two: (1) those used to prevent bacterial diseases (table 18.1) and (2) those used to prevent viral diseases (table 18.2); simplified and updated both tables
- Added a description of combination vaccines
- Updated the coverage of polio vaccination to include the spread of wild-type poliovirus in Israel; added the terms oral polio vaccine (OPV) and inactivated polio vaccine (IPV)
- Revised the section on principles of immunoassays, and expanded the coverage of monoclonal antibodies to include antibody-drug conjugates (section 18.3)
- Rearranged the discussion on immunological testing to focus on the most commonly used methods first (section 18.4)
- Added a table that summarizes characteristics of the common immunoassays that use labeled antibodies (table 18.5)

Chapter 19 – Epidemiology

- Revised the organization to correspond to CDC descriptions
- Added a section on chain of infection, including a new figure (figure 19.2)
- Added a section that describes how characteristics of the environment influence the epidemiology of disease
- Separated the figure showing propagated epidemic versus common-source epidemic into two parts (figure 19.9)
- Added a figure showing types of analytical studies (figure 19.11); deleted terminology referring to prospective and retrospective analytical studies

Chapter 20 – Antimicrobial Medications

- Added dysbiosis to the section "Suppression of the Normal Microbiota"
- Increased the size of two key figures: Targets of Antibacterial Medications (figure 20.3) and Common

Mechanisms of Acquired Resistance to Antibacterial Medications (figure 20.14)

- Added information about new antibacterial medications (cephalosporins effective against MRSA, pleuromutilins, and bedaquiline) and antiviral medications (protease inhibitors used to treat HCV)
- Expanded information on carbapenems and carbapenemases
- Added the term co-trimoxazole
- Added a table based on the CDC report "*Antibiotic resistant threats in the United States 2013*" (table 20.2)
- Added a figure that compares the rate of antimicrobial prescriptions by state in the United States (figure 20.5)

Chapter 21 – Respiratory System Infections

- Added information on candidate targets for a *Streptococcus pyogenes* vaccine
- Updated pneumonococcal vaccine information
- Updated information on antibiotic resistance in *Klebsiella*
- Added information on new medication (bedaquiline) for treatment of multidrug-resistant *Mycobacterium tuberculosis*
- Added information on *Mycobacterium avium* complex
- Added information on H7N9 flu of 2013
- Added information on *Pneumocystis* pneumonia, with a summary table and figure (moved from what was chapter 28)
- Updated Future Opportunities to include information on MERS-CoV

Chapter 22 – Skin Infections

- Added information about the global increase in measles cases

Chapter 23 – Wound Infections

- Added information on debridement and included MicroByte on maggot therapy
- Added summary tables for staphylococcal wound infections (table 23.2), necrotizing fasciitis (table 23.3), and *Pseudomonas* infections (table 23.4)
- Expanded discussion of neonatal tetanus

Chapter 24 – Digestive System Infections

- Updated sections on pathogenicity of *Helicobacter pylori* and *Salmonella*
- Revised and updated section on *Clostridium difficile* infection (CDI); added fecal microbiota transplant (FMT)
- New coverage of post-exposure prophylaxis (PEP) for hepatitis A and B.
- Updated coverage of treatment for hepatitis C

Chapter 25 – Blood and Lymphatic Infections (previously chapter 27)

- Combined previous sections 25.2 and 25.3 and renamed section Bacterial Diseases of the Lymphatic and Blood Vascular Systems
- Added information on *Vibrio vulnificus* infection, including summary table (table 25.3)
- Added a summary table on sepsis (table 25.2)
- Updated information on Ebola and Marburg virus disease

Chapter 26 – Nervous System Infections

- Updated coverage of vaccines against pneumococcal and meningococcal meningitis
- Revised discussion of botulism and associated summary table, clarifying differences among the various types (foodborne, intestinal/infant, and wound)
- Updated coverage of polio, including use of new terminology for polio vaccines
- Added a section on toxoplasmosis, including figure and summary table (moved from what was chapter 28)

Chapter 27 – Genitourinary Infections (previously chapter 25)

- Deleted table on common sexually transmitted infections (information is included in the "Disease in Review" table at the end of the chapter)
- Replaced SEM of *C. trachomatis* on fallopian tube mucosa with diagram of *C. trachomatis* life cycle
- Expanded HIV/AIDS coverage by moving some information from chapter 28 (now online).

Chapter 28 – Microbial Ecology (previously chapter 29)

- Changed topic of Glimpse of History to Sergei Winogradsky (previous one was moved to chapter 2)
- Updated section on culture-independent methods to study microbial ecology
- Added figure showing how metagenomics is used to characterize microbial communities (figure 28.5)
- Added Future Opportunities on functional gene arrays

Chapter 29 – Environmental Microbiology: Treatment of Water, Wastes, and Pollution (previously chapter 30)

- Added information about pretreatment of industrial wastewater
- Introduced the term biosolids
- Updated information on drinking water regulations to include Revised Total Coliform rule (RTCR)

Chapter 30 – Food Microbiology (previously chapter 29)

- Expanded table on common foodborne diseases (table 30.4)

Acknowledgments

First and foremost, special thanks goes to Gene Nester, the leader of the team that wrote the first version of what became *Microbiology, A Human Perspective*. His efforts helped pioneer a new type of introductory microbiology textbook, designed specifically for students entering health-care related fields. This edition proudly builds on that original vision.

We would also like to thank the reviewers and other instructors who guided us as we developed this edition, as well as those whose input has helped the text evolve over the years. Deciding what to eliminate, what to add, and what to rearrange is always difficult, so we appreciate your suggestions.

Past students have been incredibly helpful as well. Every question helps us decide which parts of the textbook need more clarification, and every compliment lets us know when we're on the right track.

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We hope that this text will be interesting and educational for students and helpful to instructors. Our goal is excellence, so with that in mind we would appreciate any comments and suggestions from our readers.

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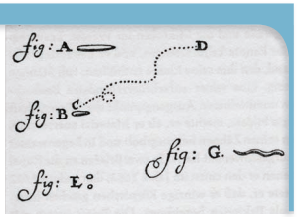

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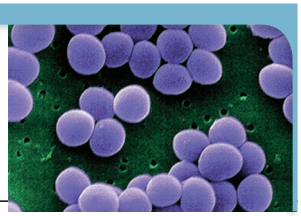

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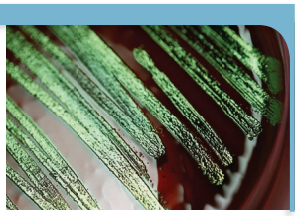

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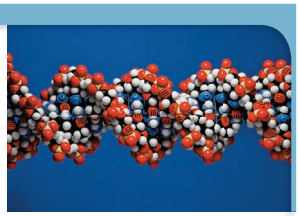

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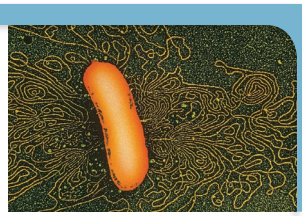

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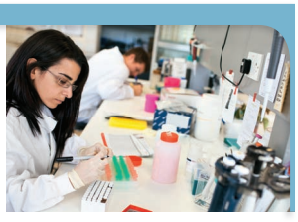

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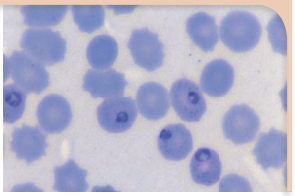

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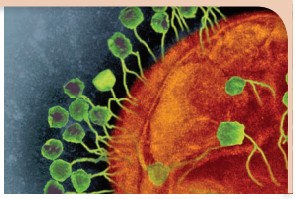

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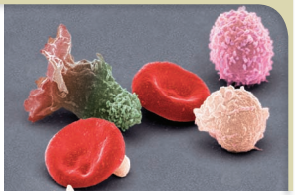

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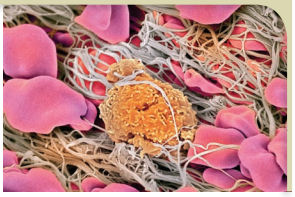

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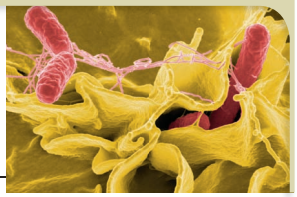

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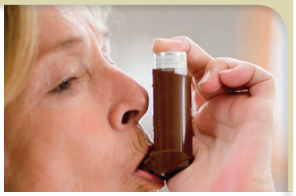

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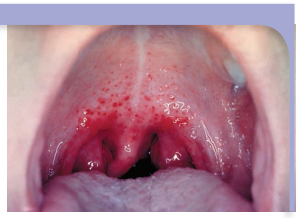

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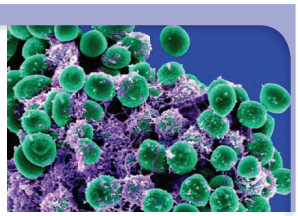

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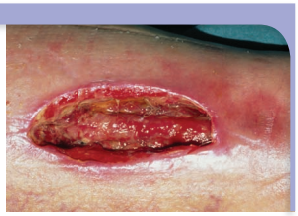

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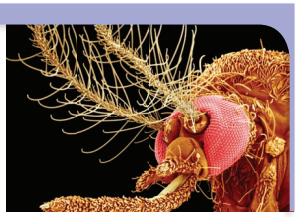

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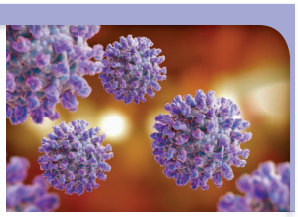

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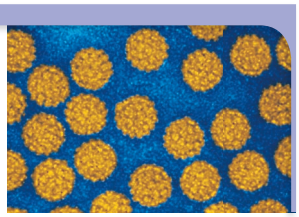

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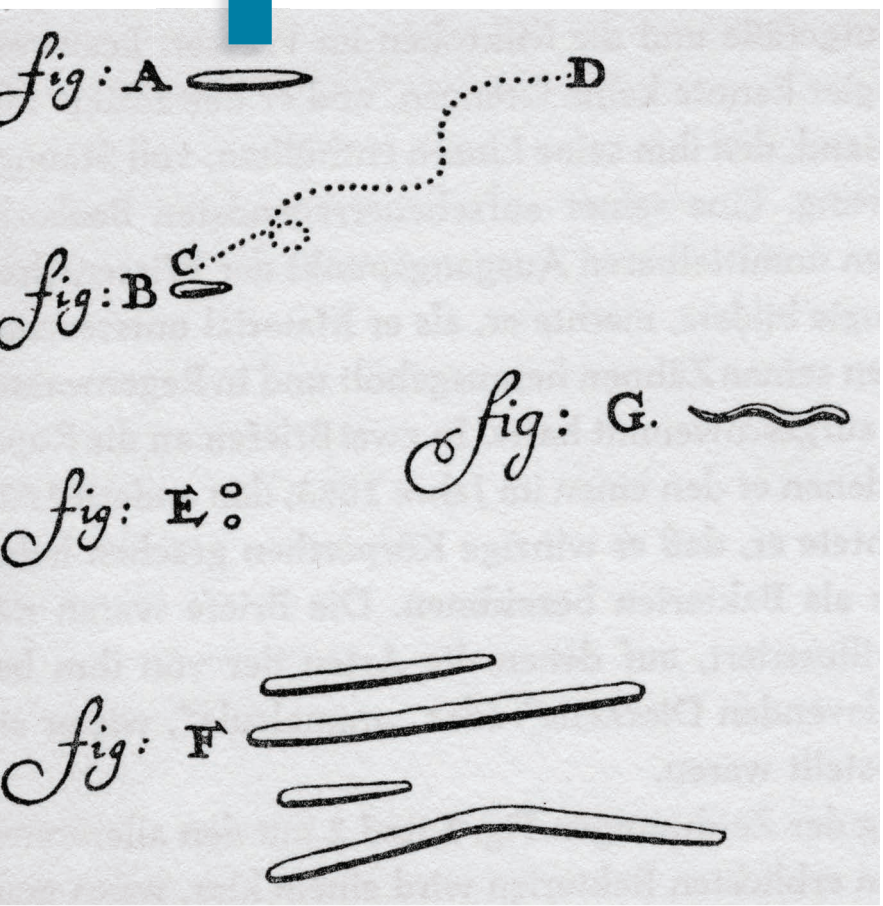
1 Humans and the Microbial World



Drawings that van Leeuwenhoek made in 1683 of microorganisms he saw through his single lens microscope. He also observed organism B moving from position C to D.

KEY TERMS

Domain The highest level in biological classification. There are three domains: *Bacteria, Archaea,* and *Eukarya.*

Eukaryote Organism composed of one or more eukaryotic cells; members of the domain *Eukarya* are eukaryotes.

Eukaryotic Cell Cell type characterized by a membrane-bound nucleus.

Prion An acellular infectious agent consisting only of protein.

Prokaryote Single-celled organism consisting of a prokaryotic cell; members of the domains *Bacteria* and *Archaea* are prokaryotes.

Prokaryotic Cell Cell type characterized by the lack of a membrane-bound nucleus.

Viroid An acellular infectious agent consisting only of RNA.

Virus An acellular infectious agent consisting of nucleic acid surrounded by a protein coat.

A Glimpse of History

Microbiology as a science was born in 1674 when Antony van Leeuwenhoek, an inquisitive Dutch fabric merchant, looked at a drop of lake water through a glass lens he had carefully made. For several centuries it was known that curved glass would magnify objects, but the skilled hands of a craftsman and his questioning mind uncovered an entirely new part of our world. What he observed through his simple magnifying glass was a startling and amazing sight—the world of microbes. As van Leeuwenhoek wrote in a letter to the Royal Society of London, he saw

> Very many little animalcules, whereof some were roundish, while others a bit bigger consisted of an oval. On these last, I saw two little legs near the head, and two little fins at the hind most end of the body. Others were somewhat longer than an oval, and these were very slow a-moving, and few in number. These animalcules had diverse colours, some being whitish and transparent; others with green and very glittering little scales, others again were green in the middle, and before and behind white; others yet were ashed grey. And the motion of most of these animalcules in the water was so swift, and so various, upwards, downwards, and round about, that 'twas wonderful to see.

Before van Leeuwenhoek made these observations, Robert Hooke, an English microscopist, saw another kind of microorganism. In 1665, he described what he called a "microscopical mushroom." His drawing was so accurate that his specimen could later be identified as a common bread mold. Hooke also described how to make the kind of microscope that van Leeuwenhoek constructed almost 10 years later. Both men deserve equal credit for revealing the world of microbes—the organisms you are about to study.

Microbiology is the study of the microbial world—an amazing world made up of members too small to be seen without the aid of a microscope. Antony van Leeuwenhoek described this world when he observed what he called "animalcules" through his simple microscope (**figure 1.1**). What he saw were **microorganisms** (organisms too small to see with the naked eye), including bacteria, protozoa, and some fungi and algae. The microbial world also includes viruses and other infectious agents that are not considered organisms because they are not composed of cells; they are acellular. When referring to general members of the microbial world, the term **microbe** is often used.

Microorganisms are the foundation for all life on Earth. They have existed on this planet for about 3.5 billion years, and over this time, plants, animals, and modern microorganisms evolved from them. Even today, they continue to be a driving force in the evolution of all living things. Microorganisms may be small, but as you are about to learn, our life depends on their activities.

FIGURE 1.1 Model of van Leeuwenhoek's Microscope The original made in 1673 could magnify the object being viewed almost 300 times. The object being viewed is brought into focus with the adjusting screws. Note the small size.

? What kinds of organisms did van Leeuwenhoek observe though his microscope?

1.1 ■ The Dispute over Spontaneous Generation

Learning Outcomes

1. Describe the key experiments of scientists who disproved spontaneous generation.
2. Explain how the successful challenge to the idea of spontaneous generation led to the Golden Age of Microbiology.
3. Describe the scientific method, using Pasteur's swan-necked flask experiment as an example.

The discovery of microorganisms in various specimens raised an interesting question: "Where did these microscopic forms originate?" Some people believed that worms and other forms of life arise from non-living material in a process referred to as **spontaneous generation.** This was challenged by an Italian biologist and physician, Francesco Redi. In 1668, he used a simple experiment to show that worms found on rotting meat originated from the eggs of flies, not from the decaying meat as supporters of spontaneous generation believed. In his experiment, Redi covered the meat with fine gauze that prevented flies from depositing their eggs. When he did this, no worms appeared.

Despite Redi's work that explained the source of worms on decaying meat, convincing evidence that microorganisms did not arise by spontaneous generation took more than 200 years and many experiments.

Early Experiments

In 1749, John Needham, a scientist and Catholic priest, showed that flasks containing various broths (made by soaking hay, chicken, or other nutrient source in water) gave rise to microorganisms even when the flasks were boiled and sealed with a cork. At that time, brief boiling was thought to kill all organisms, so this suggested that microorganisms did indeed arise spontaneously.

In 1776, the animal physiologist and priest, Lazzaro Spallanzani, obtained results that contradicted Needham's experiments; no bacteria appeared in Spallazani's broths after boiling. His experiments differed from Needham's in two significant ways: Spallanzani boiled the broths for longer periods and he sealed the flasks by melting their glass necks closed. Using these techniques, he repeatedly demonstrated that broths remained sterile (free of microorganisms). However, if the neck of the flask cracked, the broth rapidly became cloudy due to growth of the organisms. Spallanzani concluded that microorganisms had entered the broth with the air, and the corks used by Needham and other investigators did not keep them out.

Spallanzani's experiments did not stop the controversy. Some people argued that the heating process destroyed a "vital force" in the air that was necessary for spontaneous generation, and so the debate continued.

Experiments of Pasteur

One giant in science who helped disprove spontaneous generation was Louis Pasteur, the French chemist considered by many to be the father of modern microbiology. In 1861, he did a series of clever experiments. First, he demonstrated that air contains microorganisms. He did this by filtering air through a cotton plug, trapping microorganisms. He then examined the trapped microorganisms with a microscope and found that many looked identical to those described by others who had been studying broths. When Pasteur dropped the cotton plug into a sterilized broth, the broth became cloudy from the growth of these microorganisms.

Most importantly, Pasteur demonstrated that sterile broths in specially constructed swan-necked flasks remained sterile even when left open to air (**figure 1.2**). Microorganisms from the air settled in the bends of the flask necks, never reaching the broth. Only when the flasks were tipped would microorganisms enter the broth and grow. These simple and elegant experiments ended the arguments that unheated air or the broths themselves contained a "vital force" necessary for spontaneous generation. They led to the theory of **biogenesis,** the production of living things from other living things (*bio* means "life"; *genesis* means "to create").

Experiments of Tyndall

Although most scientists were convinced by Pasteur's experiments, some remained skeptical because they could not reproduce his results. An English physicist, John Tyndall, finally explained the conflicting data and, in turn, showed that Pasteur was correct. Tyndall found that various types of

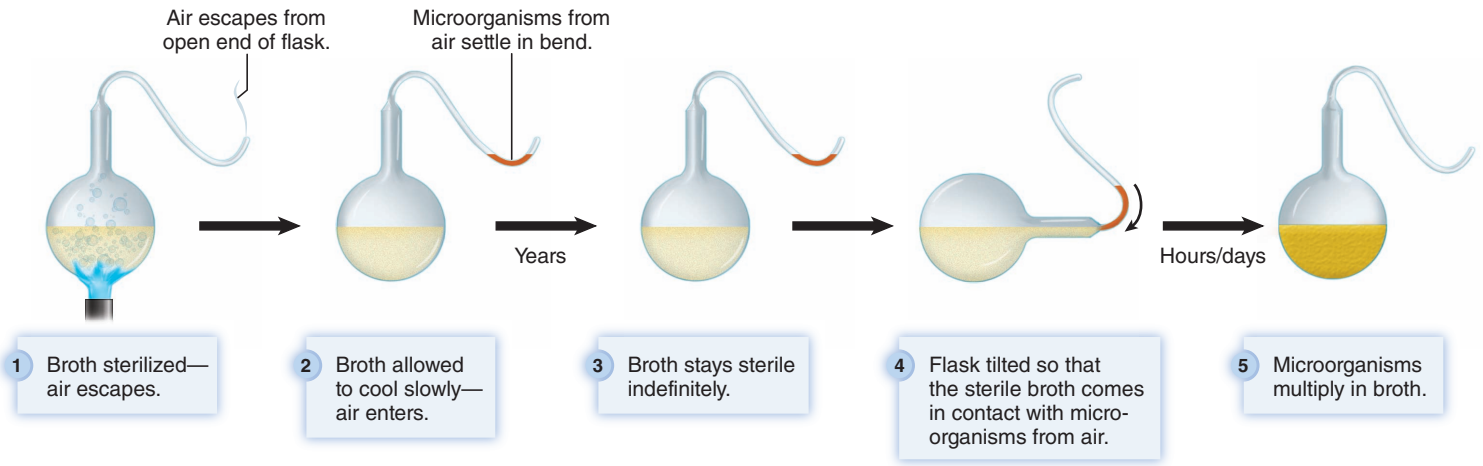


FIGURE 1.2 Pasteur's Experiment with the Swan-Necked Flask If the flask remains upright, no microbial growth occurs. If the flask is tipped, the microorganisms trapped in the neck reach the sterile broth and grow.

? If the broth in Pasteur's swan-necked flasks had contained endospores, what results would have been observed?

broths required different boiling times to be sterilized. Some materials were sterilized by boiling for 5 minutes, whereas others, most notably broths made from hay, still contained living microorganisms even after boiling for 5 hours! Even when hay was merely present in the laboratory, broths that had previously been sterilized by boiling for 5 minutes could not be sterilized by boiling for several hours. What was going on? Tyndall finally realized that hay contained heat-resistant forms of microorganisms. When hay was brought into the laboratory, dust particles must have transferred these heat-resistant forms to the broths.

Tyndall concluded that some microorganisms exist in two forms: a cell easily killed by boiling, and one that is heat resistant. In the same year (1876), a German botanist, Ferdinand Cohn, discovered **endospores,** the heat-resistant forms of some bacteria. ⏭ endospores, p. 76

The extreme heat resistance of endospores explains the differences between Pasteur's results and those of other investigators. Organisms that produce endospores are commonly found in the soil and were likely present in broths made from hay. Pasteur used only broths made with sugar or yeast extract, so his experiments probably did not have endospores. At the time, scientists did not appreciate the importance of the source of the broth, but in hindsight, the source was critical. This points out an important lesson for all scientists. In repeating an experiment, it is essential to reproduce all conditions as closely as possible. What may seem like a trivial difference may be extremely important.

The Golden Age of Microbiology

The work of Pasteur and others in disproving spontaneous generation started an era called the Golden Age of Microbiology, during which time the field of microbiology blossomed. Many important advances were made during this period, including discoveries that led to acceptance of the suggestion that microorganisms cause certain diseases, a principle now called the Germ Theory of Disease.

Figure 1.3 lists some of the important advances in microbiology made over the years in the context of other historical events. Rather than cover more history now, we will return to many of these milestones in brief stories called "A Glimpse of History" that open each chapter.

The Scientific Method

The dispute over spontaneous generation offers an excellent example of the process of science. This process, called the **scientific method,** separates science from intuition and beliefs. The scientific method involves a series of steps including:

- **Making an observation about something and asking a question about that situation.** An example from this chapter was the observation that microorganisms were present in various examined specimens. This observation led to the question "Where did the microorganisms originate?"
- **Developing an explanation and devising an experiment that tests the explanation.** A testable explanation of an observation is called a **hypothesis,** and experiments are done to test the hypothesis. The dispute over spontaneous generation led to two opposing hypotheses: biogenesis and spontaneous generation. Various people designed different experiments to test the hypotheses.
- **Doing the experiment, collecting the data, and drawing a conclusion.** Experiments such as the one illustrated in figure 1.2 provided data about the growth of microorganisms in previously sterile broths. In doing a

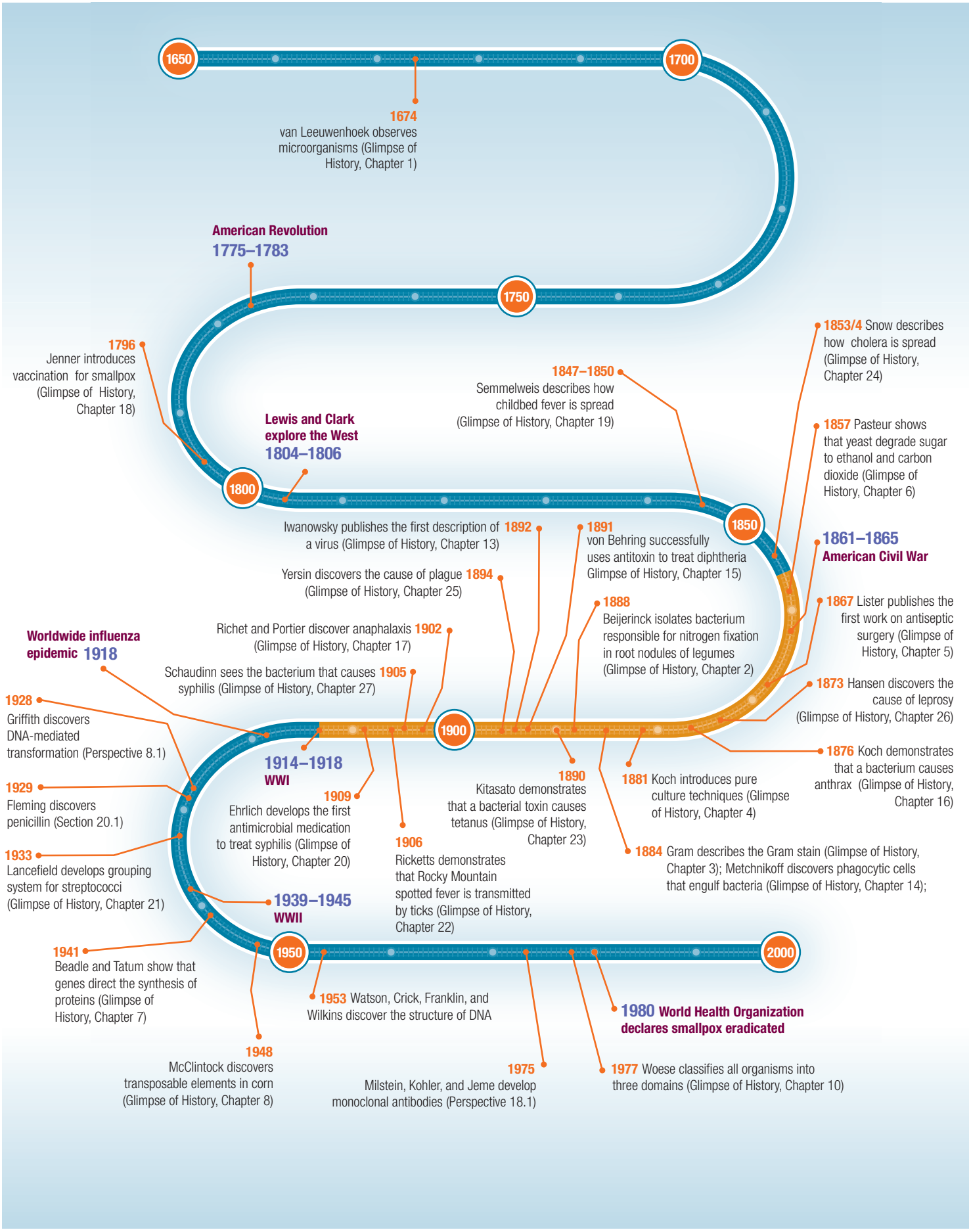


FIGURE 1.3 HIstorical Events in Microbiology Some major milestones in microbiology—and their timeline in relation to other historical events. The gold band indicates the Golden Age of Microbiology.

? What is the Golden Age of Microbiology?

scientific experiment, a critical component is a **control.** A control helps rule out alternative explanations of the results by showing that the only feature that varied in the experiment was the characteristic being tested. Pasteur's swan-necked flask experiment was brilliantly designed because his experiment provided the following control: After showing that the fluid in the swan-necked flasks remained sterile even when opened to air, he tipped the flasks so that bacteria could enter the fluid. By doing this, he showed that there was nothing in his original set-up that prevented bacteria from growing in the broth.

- **Communicating the methods, results, and conclusions.** Scientists share their work by publishing it in scientific journals. This step is particularly important because it allows other scientists to repeat the experiment to ensure the validity of the findings. Today, the respected scientific journals use a review process in which other experts in the field read communications before they are published. If deficiencies or flaws are noticed, the reviewers give suggestions for improving the experiments.

When an extensive amount of experimental evidence supports a hypothesis, that explanation may become a scientific **theory,** such as Germ Theory of Disease. Note that the scientific meaning of the word *theory* is far different from the meaning of the word in common language, which is "a speculation or guess."

As you read the information in this textbook, continually challenge yourself by asking questions about what you have learned. If you find yourself asking a question such as "How does that happen?" try to develop a hypothesis and then devise an experiment. As you do this, consider the controls you could use. Start learning to think like a scientist!

MicroAssessment 1.1

Experiments of Pasteur and Tyndall helped disprove spontaneous generation by showing that life arises from life. Many important discoveries were made during the Golden Age of Microbiology, including ones that led to the acceptance of the Germ Theory of Disease. The scientific method uses experimental evidence, including proper controls, to support or refute hypotheses.

1. Describe Pasteur's experiment that disproved the idea that a "vital force" in air was responsible for spontaneous generation.
2. How is the meaning of the word "theory" different in science versus common use?
3. Why is it important for scientists to repeat the experiments of others?

1.2 ■ Microbiology: A Human Perspective

Learning Outcomes

4. Explain why life could not exist without microorganisms.
5. List three commercial benefits of microorganisms.
6. Describe why microorganisms are useful research tools.
7. Describe the role of microbes in disease, including examples of past triumphs and remaining challenges.

Microorganisms have an enormous impact on all living things. We could not survive without them, and they also make our lives much more comfortable. At the same time, microbes can be harmful, and have killed far more people than have ever been killed in war.

Vital Activities of Microorganisms

All organisms on this planet, including humans, require the activities of microorganisms to survive.

Normal Microbiota

The surfaces of the human body are populated with characteristic communities of microorganisms, collectively called **normal microbiota,** or normal flora. Scientists have known for years that these communities play a number of essential roles, such as preventing disease by competing with disease-causing microbes, helping to degrade foods that the body otherwise could not digest, and promoting the development of the immune system.

Recent studies have given greater insight into the roles of the normal microbiota, emphasizing their importance. For example, early exposure to certain common microorganisms appears to lessen the likelihood that an individual will develop allergies, asthma, and some other diseases. According to what is sometimes referred to as the "Old Friends" hypothesis, this early exposure helps the immune system learn to distinguish "friendly" microbes from those that can cause severe disease. In addition, animal studies suggest that the composition of the normal microbiota can affect brain chemistry and behavior, as well as the tendency to gain weight. Observations such as these have led some scientists to suggest that the human body be considered a superorganism, meaning that our own cells function as a cooperative unit with the microbes that make up the normal microbiota. This is an exciting time to be a microbiologist, because there is still a great deal to learn about these interactions!

Microorganisms in the Environment

Microorganisms are the masters of recycling, and without them we would run out of certain nutrients. For instance, humans and other animals all require oxygen gas (O_2) to

breathe. However, the supply of O_2 in the atmosphere would run out if were it not continually replenished. Plants produce O_2 during photosynthesis, but so do many photosynthetic microorganisms. Another example of the importance of microorganisms in recycling involves nitrogen, an essential part of nucleic acids and proteins. A plentiful source of nitrogen is N_2—the most common gas in the atmosphere—yet neither plants nor animals can use this gas. Instead, we depend on certain microbes that convert N_2 into a form other organisms can use, a process called nitrogen fixation. Without nitrogen-fixing microbes, life as we know it would not exist.

⏭ nitrogen fixation, p. 775

Microorganisms are also important because they can degrade certain materials that other organisms cannot. As an example, humans and other animals cannot digest cellulose—an important component of plants. Certain microorganisms degrade cellulose, however, which is why leaves and fallen trees do not pile up in the environment. Many of the billions of microorganisms in the digestive tracts of a group of animals that include cattle, sheep, and deer degrade cellulose; by doing so, the microorganisms help the animals digest plant material. Without cellulose-degrading microbes in their digestive tract, these plant-eating animals would starve.

MicroByte

Your body carries at least three times more bacterial cells than human cells!

Commercial Benefits of Microorganisms

In addition to the crucial roles that microorganisms play in maintaining all life, they also have made life more comfortable for humans over the centuries.

Food Production

Egyptian bakers used yeast to make bread over 4,000 years ago. Today, bakeries use essentially the same technology.

⏭ breadmaking, p. 807

The excavation of early tombs in Egypt revealed that over 3,500 years ago, Egyptians used a complex procedure for fermenting cereal grains to produce beer. Today, brewers use the same fundamental techniques to make beer and other fermented drinks. ⏭ beer, p. 806

Virtually every population that raised milk-producing animals such as cows and goats also developed procedures to ferment milk. This allowed them to make foods such as yogurt, cheeses, and buttermilk. Today, the bacteria added to some fermented milk products are advertised as probiotics (live microorganisms that provide a health benefit), protecting against digestive disruptions. ⏭ fermented milk products, p. 803

⏭ probiotics, p. 434

Biodegradation

Microorganisms play essential roles in degrading a wide variety of environmental pollutants. These include materials in sewage and wastewater, as well as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), trichloroethylene, (a toxic solvent used in dry cleaning), and other chemicals in contaminated soil and water. Bacteria also lessen the damage from oil spills. In some cases, microorganisms are added to pollutants to hasten their decay, a process called **bioremediation.** ⏭ wastewater treatment, p. 786 ⏭ bioremediation, p. 796

Commercially Valuable Products from Microorganisms

Microorganisms synthesize a wide variety of different products, some of which are commercially valuable. Although these same products can be made in factories, microorganisms often generate them faster and cheaper. Examples include:

- **Cellulose:** used in headphones
- **Hydroxybutyric acid:** used in the manufacture of disposable diapers and plastics
- **Ethanol:** used as a biofuel
- **Hydrogen gas:** used as a possible biofuel
- **Oils:** used as a possible biofuel
- **Insect toxins:** used in insecticides
- **Antibiotics:** used in the treatment of disease
- **Amino acids:** used as dietary supplements

Biotechnology

Biotechnology—the use of microbiological and biochemical techniques to solve practical problems—depends on members of the microbial world. The study of microorganisms has led to techniques that allow scientists to genetically engineer plants to resist a variety of otherwise damaging insects, bacteria, and viruses. Biotechnology has also led to easier production of many medications such as insulin (used to treat diabetes). In the past, insulin was isolated from pancreatic glands of cattle and pigs. Now, certain microorganisms have been genetically engineered to make human insulin. The microbe-produced insulin is easier to obtain, and patients who use it have fewer allergic reactions than from the animal-derived product.

⏭ genetic engineering, p. 235

Microbes as Research Tools

Microorganisms are wonderful model organisms to study because they have the same fundamental metabolic and genetic properties as higher life forms. All cells are composed of the same chemical elements and they synthesize their cell structures by similar mechanisms. They all duplicate their DNA, and when they degrade foods to harvest energy, they do so via the same metabolic pathways. To paraphrase a

Nobel Prize–winning microbiologist, Dr. Jacques Monod—what is true of elephants is also true of bacteria, and bacteria are much easier to study! In addition, bacteria can be used to obtain results very quickly because they grow rapidly and form billions of cells per milliliter on simple inexpensive growth media. In fact, most major advances made in the last century toward understanding life have come through the study of microbes.

Microbes and Disease

Although most microbes are beneficial or not harmful, some are **pathogens,** meaning they can cause disease (a noticeable impairment in body function). The disease symptoms result from damage to the body tissues. This damage can occur either as a direct result of the pathogen's growth and products, or as a result of the body's defense mechanisms, which can harm the host while attempting to control the pathogen.

To appreciate the effect an infectious disease can have on a population, consider that more Americans died of influenza in 1918–1919 than were killed in World Wars I and II, and the Korean, Vietnam, and Iraq wars combined. Fortunately, technological advances such as sanitation, vaccination, and antibiotic treatments have dramatically reduced the incidence of many of the most feared infectious diseases. To maintain this success, however, we must continue to develop new medications, vaccines, and disease-prevention strategies.

Past Triumphs

The Golden Age of Microbiology included an important period when scientists learned a great deal about pathogens. Between 1876 and 1918, most pathogenic bacteria were identified, and early work on viruses had begun. Once people realized that microbes could cause disease, they tried to prevent their spread. As illustrated in **figure 1.4,** the death rate due to infectious diseases has decreased dramatically over the last 100 years, due largely to preventing the spread of pathogens, developing vaccines to provide immunity, and using antibiotics to treat bacterial diseases when they do occur.

The viral disease smallpox was one of the most devastating diseases the world has ever known, killing approximately 10 million people over 4,000 years. When Europeans carried the disease to the Americas, it decimated the populations of native inhabitants who had never been exposed to the disease. In recent times, an active worldwide vaccination program eliminated the disease in nature, with no cases being reported since 1977. Laboratory stocks of the smallpox virus remain, however, raising the possibility that the virus could be used in bioterrorist attacks.

Plague has been another major killer. One-third of the population of Europe, or approximately 25 million people, died of this bacterial disease in only four years (1347–1351). We now know that rodents can carry the bacterium, and their fleas can transmit the disease, so we take measures to control the rodent population. We have also learned that the pneumonic form of the disease (meaning it is in the lungs) can spread from human to human through respiratory secretions, so special precautions are taken when a patient has pneumonic plague. In addition, the discovery of antibiotics in the twentieth century made treatment possible. As a result, less than 100 people worldwide die from plague in a typical year.

Polio can cause paralysis, leading to death of some people and disability in others. The disease was once relatively common, but it has been nearly eliminated because of vaccination. In fact, polio now occurs in relatively few countries, and the goal is to eradicate (eliminate) the disease globally.

Epidemics are not limited to human populations. The great famine in Ireland in the 1800s was due, in part, to a microbial disease of potatoes. In 2001, a catastrophic outbreak of foot-and-mouth disease of animals occurred in England. To contain this viral disease, one of the most contagious known, almost 4 million pigs, sheep, and cattle were destroyed.

Remaining Challenges

Although progress has been impressive against infectious diseases, much more still needs to be done. On a worldwide basis, infectious diseases remain too common, particularly in developing countries. Even in developed countries with sophisticated health care systems, infectious diseases remain a serious threat. In the United States, about 750 million cases of infectious diseases occur each year, leading to 200,000 deaths and costing tens of billions of dollars.

Emerging Infectious Diseases An **emerging infectious disease (EID)** is an infectious disease that has become more common in the last 35 years. Many of these are new or newly

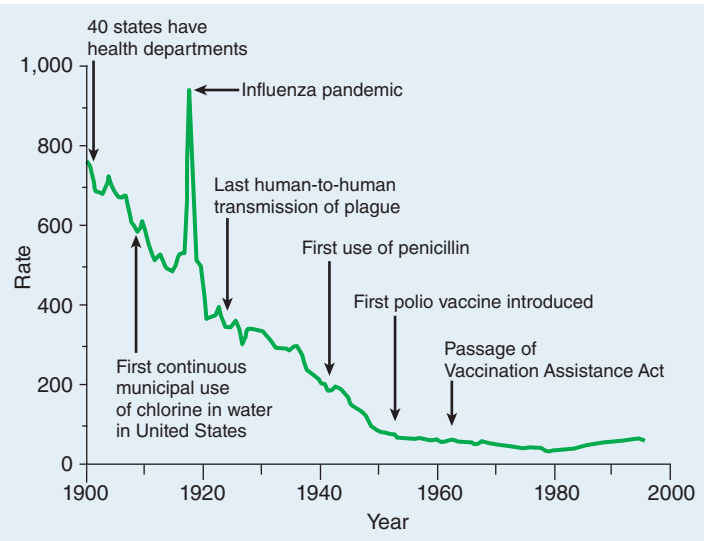


FIGURE 1.4 Trend in Death Rates Due to Infectious Diseases
Crude death rate for infectious disease, United States, per 100,000 population per year

? Why would the creation of health departments lower the disease rate?

recognized; examples of these include Ebola virus disease, MERS (Middle East respiratory syndrome), hepatitis C, severe acute respiratory syndrome (SARS), certain types of influenza, Lyme disease, acquired immunodeficiency syndrome (AIDS), hantavirus pulmonary syndrome, and mad cow disease (bovine spongiform encephalopathy) (**figure 1.5**). Others are long-established diseases such as malaria or tuberculosis that have spread or become more common in recent years.

Some diseases arise because the infectious agents gain the ability to infect new hosts. Genetic analysis indicates that HIV-1 (human immunodeficiency virus type 1), the most common type of HIV to cause AIDS, arose from a virus that infected chimpanzees. The virus causing SARS is related to viruses found in animals and may have been transmitted from animals to humans.

New pathogens can also develop by acquiring DNA from another organism, a process called horizontal gene transfer. An organism called *E. coli* O104:H4, which caused a severe foodborne diarrheal outbreak in Europe, appears to have gained the ability to make a specific toxin by acquiring genes from a related bacterium.

Changing lifestyles bring opportunities for infectious agents to spread, resulting in an emerging disease. As suburbs of cities expand into rural areas, for example, human populations come into closer contact with animals as well the mosquitoes and other arthropods that normally feed on those animals. Consequently, people are exposed to pathogens that they might not have encountered previously. An example is hantavirus, a virus that infects rodents. The infected animals usually are not ill, but they shed the virus in their urine, feces, and saliva. When a person inhales contaminated airborne particles, the virus can enter the body and cause disease.

Infectious diseases that were under control can spread again, resulting in increased numbers of cases. In some instances, the preventive measures become victims of their own success. For example, decades of vaccination have nearly eliminated measles, mumps, and whooping cough in developed countries, so that most people no longer have first-hand knowledge of the dangers of the diseases. Couple this with misinformation about vaccines, and some people develop irrational fears, falsely believing that vaccines are more harmful than the diseases they prevent. When this happens, parents often refuse to vaccinate their children appropriately, leading to a situation where the diseases become more common again.

Diseases also emerge when pathogens become resistant to antimicrobial medications, making them more difficult to treat. Tuberculosis and malaria have increased in incidence in recent years, in part because the causative organisms are resistant to many of the available medications.

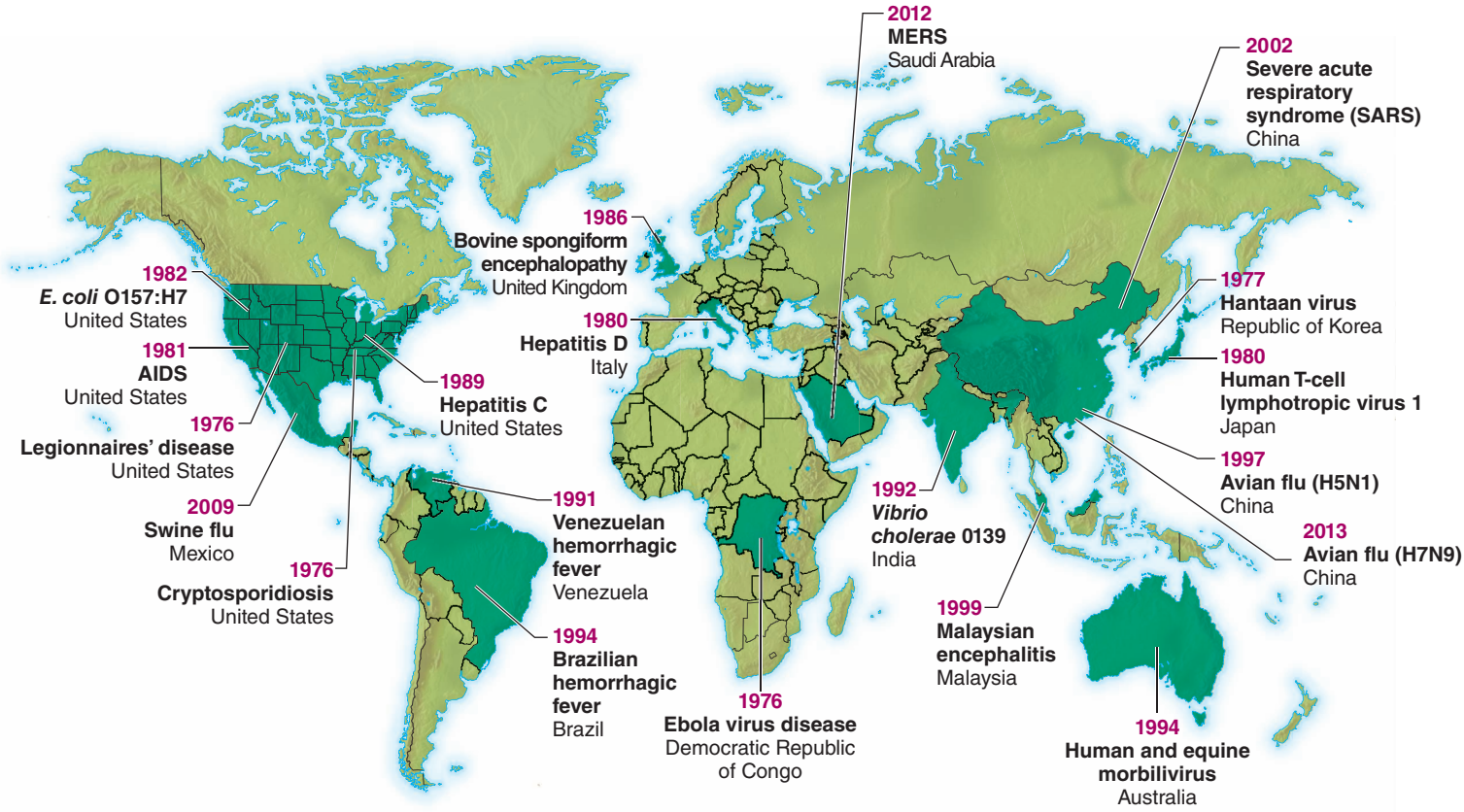


FIGURE 1.5 New and Newly Recognized Infectious Diseases or Disease Agents in Humans and Animals Since 1976 Countries where cases first appeared or were identified appear in a darker shade.

? Why might so many of the diseases first appear or be identified in the United States and Western European countries?

CASE PRESENTATION 1.1

A 24-year-old woman suffered from recurrent severe episodes of an intestinal disorder called *Clostridium difficile* infection (CDI) for the past 13 months. She routinely experienced profuse watery diarrhea, abdominal pain, and fever. In addition, she was feeling tired and hopeless because she did not seem to be getting well, despite long attempts at multiple different treatments.

As with most patients who have CDI, the woman had been taking an oral antibiotic shortly before her symptoms began—in this case to treat a tooth infection. The antibiotic had successfully killed the bacteria that caused her tooth infection, but it also killed some members of her normal intestinal microbiota. As a result, the bacterium *Clostridium difficile*—often referred to simply as "C. diff"—thrived in her intestinal tract, growing to much higher numbers than it could before. The strain that caused her infection was able to make a toxin that damaged the lining of her intestinal tract.

When the patient first started experiencing CDI, her doctor told her to stop taking the antibiotic prescribed for her tooth infection, hoping that her CDI would resolve on its own. When that did not help, the doctor prescribed a different antibiotic that is often effective in treating CDI. The patient started feeling better, but the symptoms quickly returned when she stopped taking the medication. She also tried oral supplements containing *Lactobacillus* GG, a bacterium that sometimes appears to be effective in preventing antibiotic-associated diarrhea.

Because the patient's health was declining, doctors suggested a fecal transplant, a procedure that involves inserting feces from a healthy person into the patient's intestinal tract in order to repopulate that environment with appropriate microbes. They chose to use her sister as a fecal donor, screening both the donor and the patient to ensure that neither was infected with certain infectious agents, including various intestinal pathogens and HIV. Approximately ¼ cup of fresh feces was mixed with 1 quart of water and delivered to her intestinal tract via a colonoscope. Within days after the transplant, the patient began feeling better, and soon recovered completely.

1. Why would certain oral antibiotics allow *C. difficile* to thrive in the intestinal tract?
2. Why would the doctors screen both the patient and the fecal donor for certain infectious agents?
3. Why would the doctors transplant feces rather than introducing isolated bacteria from feces to repopulate the colon?

Discussion

1. Antibiotics kill or inhibit not just pathogens, but also beneficial members of the normal microbiota, a group that protects against infection in at least two general ways. First, they quickly use nutrients that would otherwise be available to *C. difficile* and other disease-causing microorganisms. Also, some members of the normal microbiota make compounds that are toxic or inhibitory to other organisms. The environment of the intestinal tract is quite complex, however, so other factors might also be playing a role.
2. Physicians screen the fecal donor to decrease the likelihood that disease-causing microbes could be transferred to the patient via the procedure. The doctors screen the patient to ensure that she was not already infected with the pathogens. For example, if the patient developed symptoms of a *Salmonella* infection after the procedure, how would physicians know that she acquired the infection as a result of the procedure if they had not checked her beforehand?
3. Feces contain many types of bacteria that cannot yet be grown in the laboratory. In addition, scientists do not yet know which types of fecal bacteria protect against CDI.

Changes in the characteristics of a population can also cause emergence of diseases. Elderly people typically have weaker immune systems than the young, so aging populations are more susceptible to infectious agents. Individuals with AIDS are especially susceptible to a wide variety of diseases, including tuberculosis.

Travelers and immigrants can contribute to disease emergence by inadvertently carrying pathogens around the globe. Diseases such as malaria, cholera, plague, and yellow fever have largely been eliminated from developed countries, but they still exist in many parts of the world. Newly infected international travelers could theoretically circle the globe, touch down in several countries, and expose many people before becoming ill themselves.

Chronic Diseases In addition to the diseases long recognized as being caused by pathogens, some illnesses once attributed to other causes may be due to microorganisms. Perhaps the best-known example is stomach ulcers, once thought to be due to stress. We now know that stomach ulcers are often caused by a bacterium *(Helicobacter pylori)* and are treatable with antibiotics. Chronic indigestion may be caused by the same bacterium. Another example is cervical cancer, which we now know is caused by human papillomavirus (HPV) infection; a vaccine against HPV prevents that cancer. Infectious microbes may play important roles in other chronic diseases as well.

MicroAssessment 1.2

Microbial activities are essential to human life as well as being commercially valuable. Microbes are important research tools. Although most microbes are beneficial or not harmful, some cause disease. Enormous progress has been made in preventing and curing infectious diseases, but some diseases are becoming more common.

4. Describe two microbial activities essential to life and three that make our lives more comfortable.
5. Describe three factors that lead to certain infectious diseases becoming more common.
6. Why would it seem logical, even inevitable, that at least some bacteria would attack the human body and cause disease?