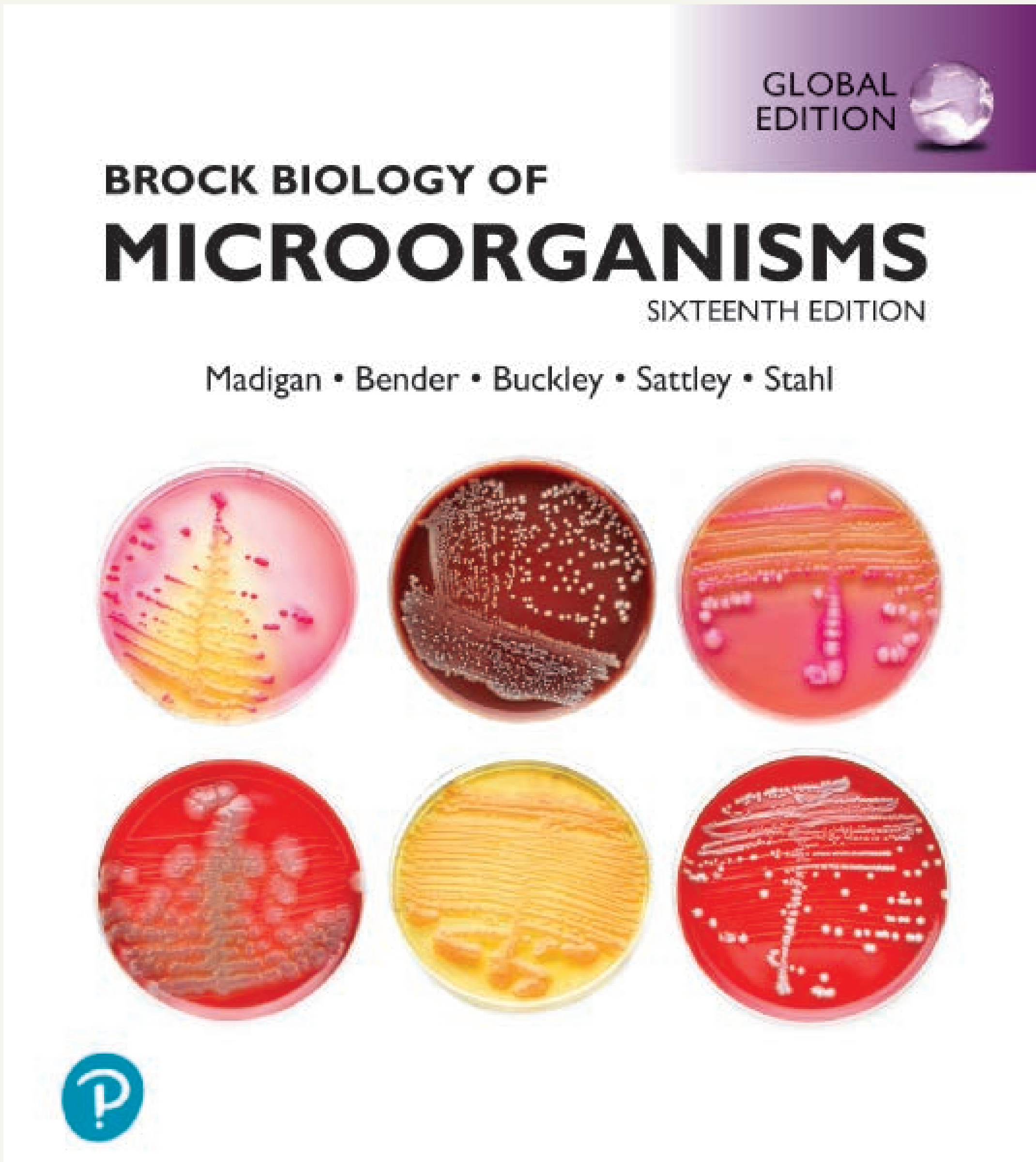
Authoritative. Accurate. Accessible.

Brock Biology of Microorganisms **is the leading microbiology text for majors, setting the standard for impeccable scholarship, accuracy, a visually stunning art program, and the use of cutting-edge research to illustrate basic concepts.**



Pearson

Making Connections Across

UPDATED! Each chapter is carefully cross-referenced to connect students with related material found earlier (◀) or later (▶) in the book.

NEW! Key Concept statements at the start of each key topic of a chapter give students a big-picture view of the content to come before they dive in and immerse themselves in the details.

I • Bacterial Cell Division

Prokaryotic cell division is preceded by chromosome replication and the synthesis of new cell wall material in a way that defines cell shape. Cell division is orchestrated in a carefully controlled fashion by protein complexes whose activities can be visualized by powerful light microscopic techniques.

Most cells divide by binary fission (◀ Section 4.6 and Figure 4.8), and this process occurs in a defined series of steps such that each daughter cell obtains a copy of the genome. During the division cycle, the cell must also produce new peptidoglycan and cytoskeleton elements to prevent bursting from osmotic forces. This cytoskeleton gives the cell its distinct morphology (◀ Figure 1.8). To successfully orchestrate all of these events, various regulatory cascades are put into play. In this first part of the chapter we focus on the molecular mechanisms employed by two well-studied gram-negative bacteria, *Escherichia coli* and *Caulobacter crescentus*, and introduce advanced microscopic techniques that have revealed the major molecular events that underlie cell division and cell morphology.

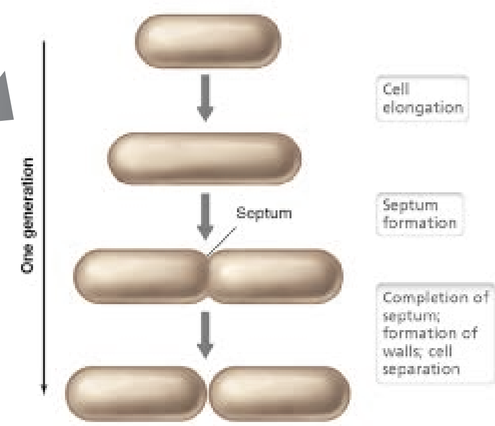


Figure 4.8 Binary fission in a rod-shaped bacterium. Cell numbers (and all components of the cells) double every generation.

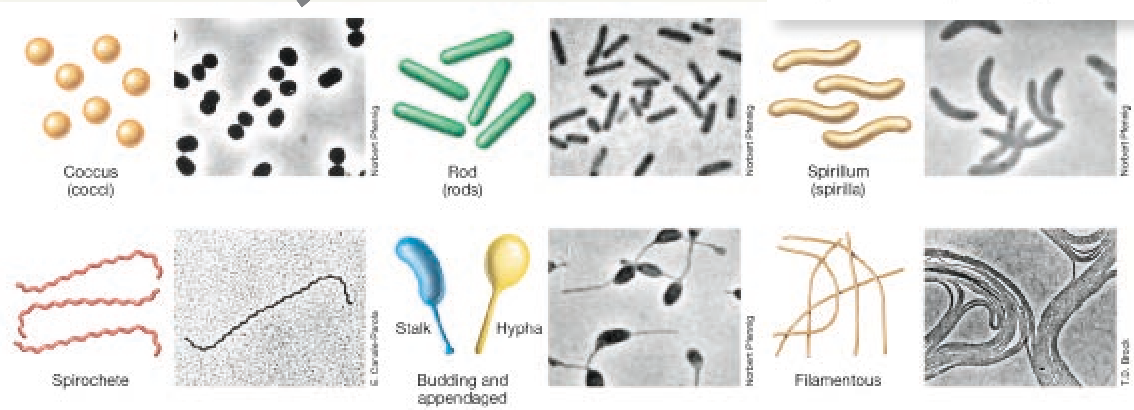


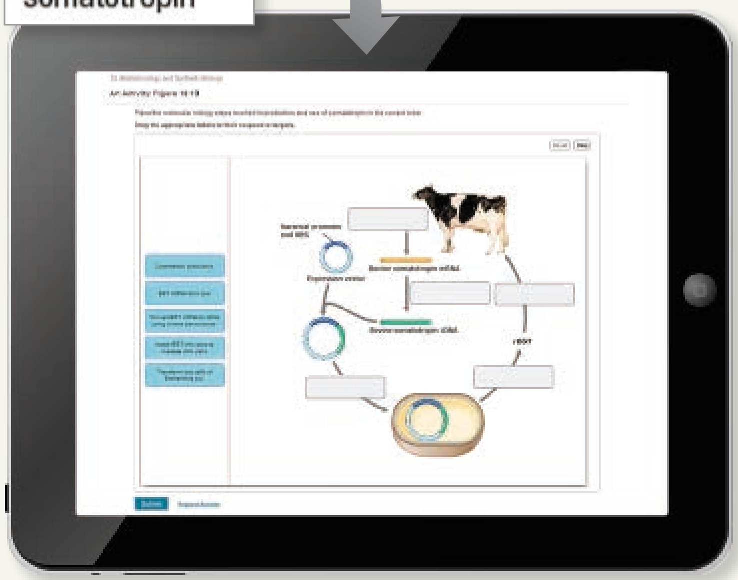
Figure 1.8 Cell morphologies. Beside each drawing is a phase-contrast photomicrograph of cells showing that morphology. Coccus (cell diameter in photomicrograph, 1.5 µm); rod (1 µm); spirillum (1 µm); spirochete (0.25 µm); budding (1.2 µm); filamentous (0.8 µm). All photomicrographs are of species of *Bacteria*. Not all of these morphologies are known among the *Archaea*, but cocci, rods, and spirilla are common.

Concepts in Microbiology

NEW! Marginal annotations highlight some of the best material available for instructors to assign in Mastering Microbiology, guiding students along their journey with insightful materials that support and strengthen the learning experience.

Mastering Microbiology

Art Activity: Figure 12.19 Cloning and expression of bovine somatotropin



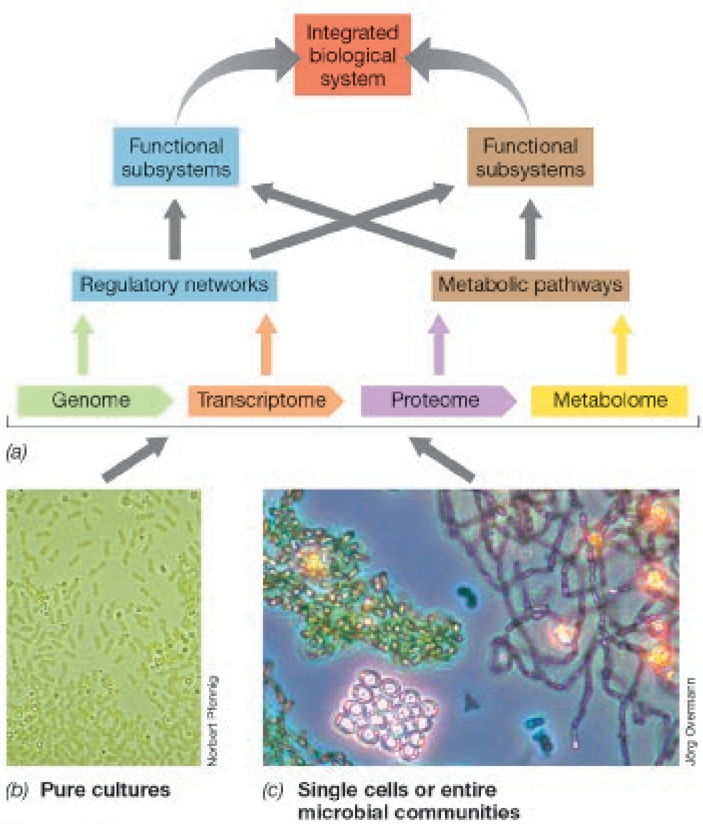


Figure 10.29 The components of systems biology. *(a)* The results of various "omics" analyses are combined and successively integrated into higher-level views of the entire biology of a pure culture, such as *(b)* that of the green sulfur bacterium *Chlorobium*; or of a mixed microbial community, such as *(c)* that of phototrophic sulfur bacteria obtained from a lake; or of a single cell isolated from a microbial community (see Figure 10.30).

Genomics, and the various "omics" it has spawned, is woven into every chapter of the text, providing students with concrete examples of how powerful tools have allowed microbiologists to probe deeper and farther into the microbial world than ever before.

Cutting-Edge Content

MICROBIOLOGYNOW

When Antibiotics Fail, Bacteriophage Therapy to the Rescue

Acquiring an antibiotic-resistant infection or "superbug" is one of medicine's biggest nightmares. What can medical practitioners do to treat the patient? Besides drugs, viruses known as bacteriophages have been recruited to specifically target and kill bacteria.

Despite microbiologists' tinkering with using bacteriophages as antimicrobials for decades, their actual application in medicine has been minimal. However, the emergence of antibiotic resistance has led to renewed focus on using these tiny microbes as therapeutic agents. The photo above shows Ella Balasa (right side of photo), a microbiologist who has cystic fibrosis. Cystic fibrosis is a genetic disease that results in a buildup of thick mucus in the lungs. This mucus allows bacteria to flourish in the lungs, which results in infections and subsequent lung damage that can be fatal. Ella had been treated numerous times with strong antibiotics specific for a respiratory infection caused by the bacterial pathogen *Pseudomonas aeruginosa*, but the microbial cells had become unresponsive to the drugs. At the time of this photo, the recurrent infection had decreased her lung function to the point where she required constant supplemental oxygen.

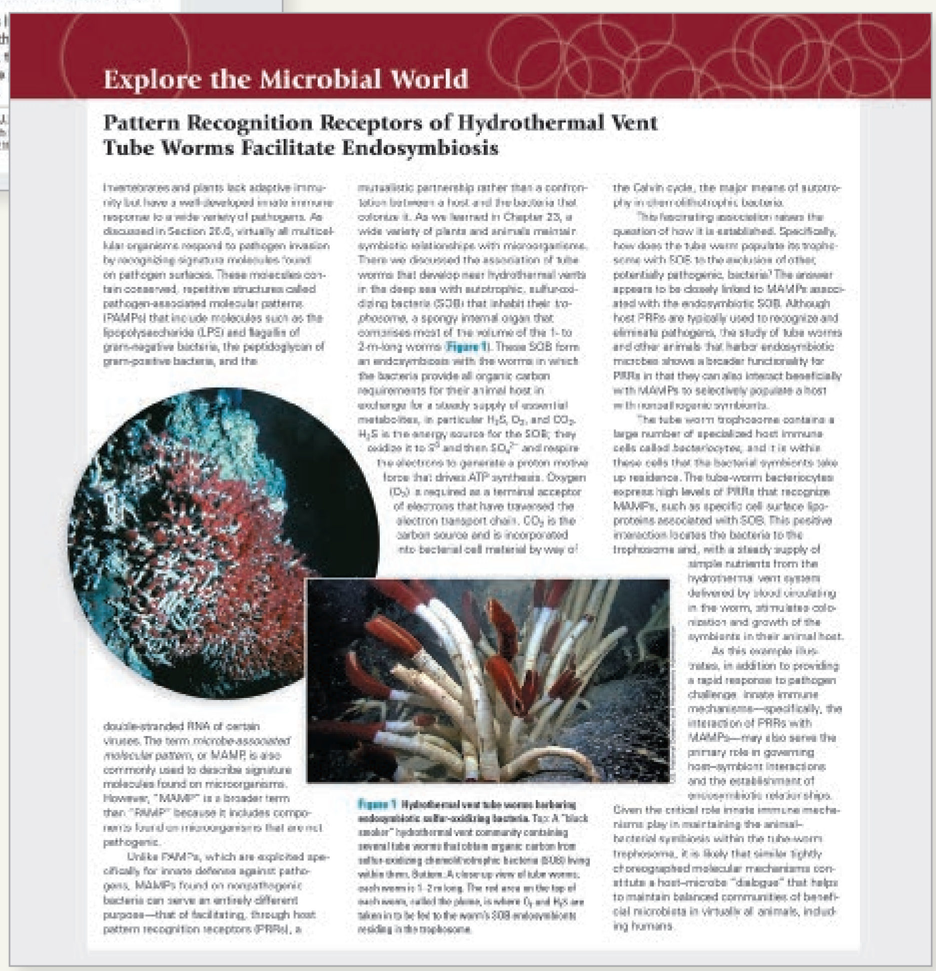
As an alternative treatment route, Dr. Benjamin Chan (on the left) took mucus from Ella's lungs infected with *P. aeruginosa* and isolated a bacteriophage that specifically killed the pathogen (see zones of clearing on Petri plate). This bacteriophage was propagated and then poured into a device so that Ella could inhale the therapy. The result of her treatment? Amazingly, the bacteriophage therapy along with a mixture of antibiotics resulted in the infection clearing a few weeks later!

While bacteriophage therapy is l
specificity and the ability of the path
become resistant to viral infection, t
success stories illustrate the future
therapy when all other options fail.

Source: Kortright, K.E., B.K. Chan, J.
Phage therapy: A renewed approach
bacteria. *Cell Host Microbe* 2021: 21

NEW! Thirty-four Microbiology Now chapter opening vignettes were composed for this edition, each designed to introduce a chapter's theme through a recent discovery in the field of microbiology. These exciting accounts will draw students into the chapter and show how the chapter content connects with real-world problems.

NEW! Several new Explore the Microbial World features provide fascinating stories that highlight how important chapter concepts have evolved from research in the microbial world.



Explore the Microbial World

Pattern Recognition Receptors of Hydrothermal Vent Tube Worms Facilitate Endosymbiosis

Invertebrates and plants lack adaptive immunity but have a well-developed innate immune response to a wide variety of pathogens. As discussed in Section 26.6, virtually all multicellular organisms respond to pathogen invasion by recognizing signature molecules found on pathogen surfaces. These molecules contain conserved, repetitive structures called pathogen-associated molecular patterns (PAMPs) that include molecules such as the lipopolysaccharide (LPS) and flagellin of gram-negative bacteria, the peptidoglycan of gram-positive bacteria, and the double-stranded RNA of certain viruses. The term *microbe-associated molecular pattern*, or MAMP, is also commonly used to describe signature molecules found on microorganisms. However, "MAMP" is a broader term than "PAMP" because it includes components found on microorganisms that are not pathogenic.

Unlike PAMPs, which are exploited specifically for innate defense against pathogens, MAMPs found on nonpathogenic bacteria can serve an entirely different purpose—that of facilitating, through host pattern recognition receptors (PRRs), a mutualistic partnership rather than a confrontation between a host and the bacteria that colonize it. As we learned in Chapter 23, a wide variety of plants and animals maintain symbiotic relationships with microorganisms. There we discussed the association of tube worms that develop near hydrothermal vents in the deep sea with autotrophic, sulfur-oxidizing bacteria (SOB) that inhabit their *trophosome*, a spongy internal organ that comprises most of the volume of the 1- to 2-m-long worms (Figure 1). These SOB form an endosymbiosis with the worms in which the bacteria provide all organic carbon requirements for their animal host in exchange for a steady supply of essential metabolites, in particular H_2S, O_2, and CO_2. H_2S is the energy source for the SOB; they oxidize it to S^0 and then SO_4^{2-} and respire the electrons to generate a proton motive force that drives ATP synthesis. Oxygen (O_2) is required as a terminal acceptor of electrons that have traversed the electron transport chain. CO_2 is the carbon source and is incorporated into bacterial cell material by way of the Calvin cycle, the major means of autotrophy in chemolithotrophic bacteria.

This fascinating association raises the question of how it is established. Specifically, how does the tube worm populate its trophosome with SOB to the exclusion of other, potentially pathogenic, bacteria? The answer appears to be closely linked to MAMPs associated with the endosymbiotic SOB. Although host PRRs are typically used to recognize and eliminate pathogens, the study of tube worms and other animals that harbor endosymbiotic microbes shows a broader functionality for PRRs in that they can also interact beneficially with MAMPs to selectively populate a host with nonpathogenic symbionts.

The tube worm trophosome contains a large number of specialized host immune cells called bacteriocytes, and it is within these cells that the bacterial symbionts take up residence. The tube-worm bacteriocytes express high levels of PRRs that recognize MAMPs, such as specific cell surface lipoproteins associated with SOB. This positive interaction locates the bacteria to the trophosome and, with a steady supply of simple nutrients from the hydrothermal vent system delivered by blood circulating in the worm, stimulates colonization and growth of the symbionts in their animal host.

As this example illustrates, in addition to providing a rapid response to pathogen challenge, innate immune mechanisms—specifically, the interaction of PRRs with MAMPs—may also serve the primary role in governing host–symbiont interactions and the establishment of endosymbiotic relationships. Given the critical role innate immune mechanisms play in maintaining the animal–bacterial symbiosis within the tube-worm trophosome, it is likely that similar tightly choreographed molecular mechanisms constitute a host–microbe "dialogue" that helps to maintain balanced communities of beneficial microbiota in virtually all animals, including humans.

Figure 1 Hydrothermal vent tube worms harboring endosymbiotic sulfur-oxidizing bacteria. Top: A "black smoker" hydrothermal vent community containing several tube worms that obtain organic carbon from sulfur-oxidizing chemolithotrophic bacteria (SOB) living within them. Bottom: A close-up view of tube worms; each worm is 1–2 m long. The red area on the top of each worm, called the plume, is where O_2 and H_2S are taken in to be fed to the worm's SOB endosymbionts residing in the trophosome.

NEW! A section on immunotherapy highlights exciting advancements in the use of genetic engineering and molecular immunology to treat cancer.

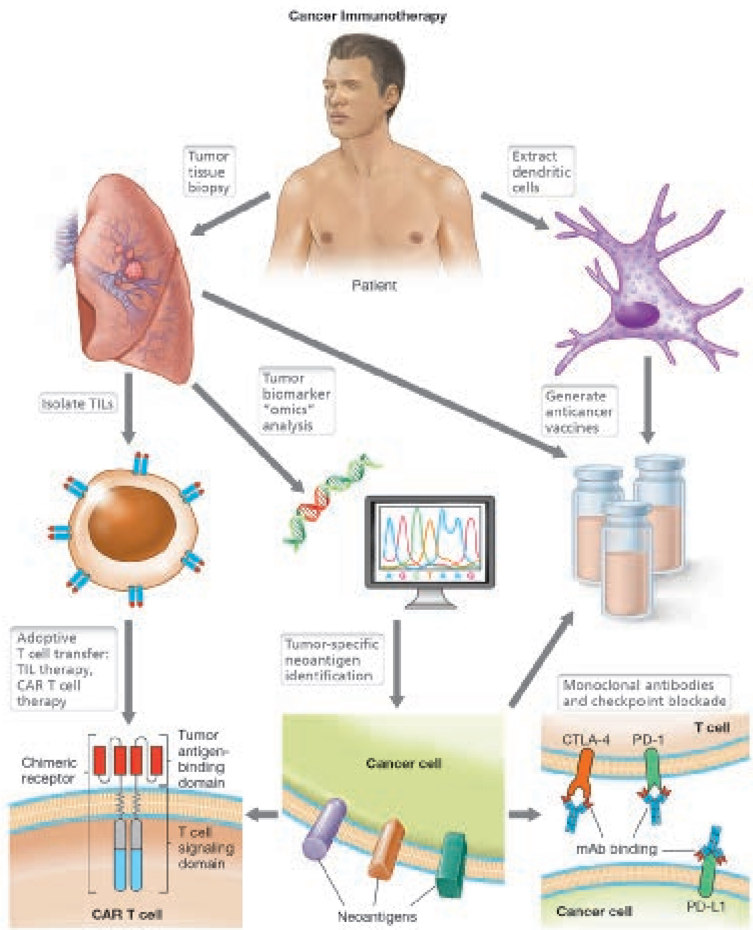


Figure 28.10 **Overview of cancer immunotherapy.** Anticancer vaccines can potentially be designed from properties of extracted tumor cells or the patient's dendritic cells. Checkpoint blockade uses monoclonal antibodies to neutralize immunosuppressive components, such as PD-1/PD-L1 and CTLA-4, in the tumor microenvironment. CARs are genetically engineered receptors that reprogram cytotoxic T cells to recognize and be directly activated by tumor-specific antigens. CAR, chimeric antigen receptor; mAb, monoclonal antibody; TIL, tumor-infiltrating lymphocyte.

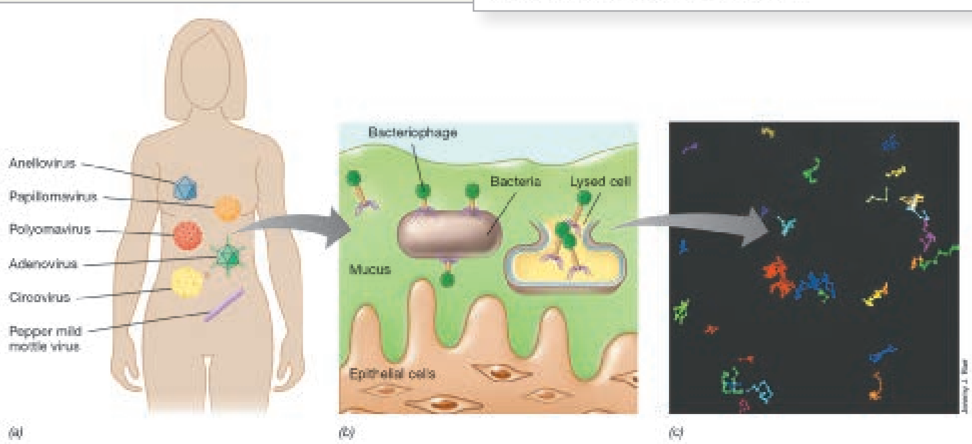
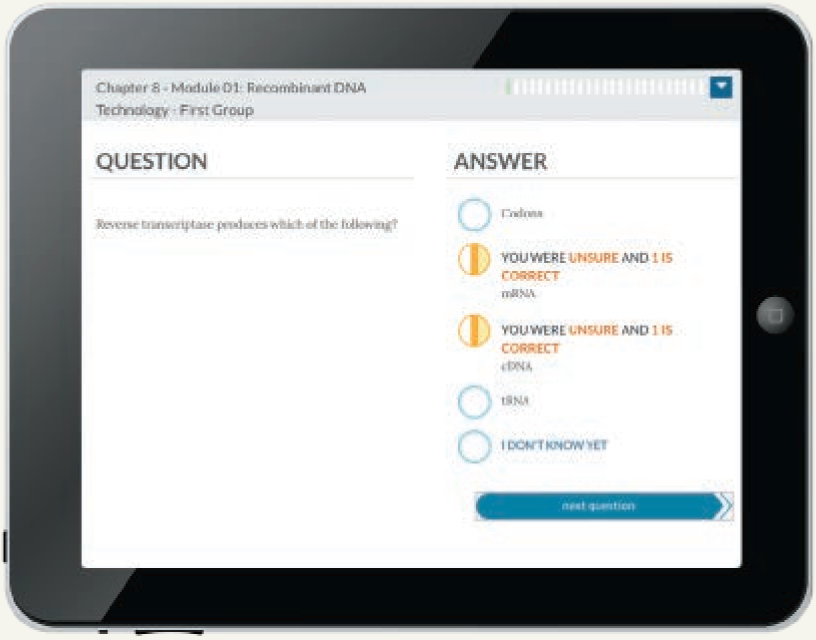


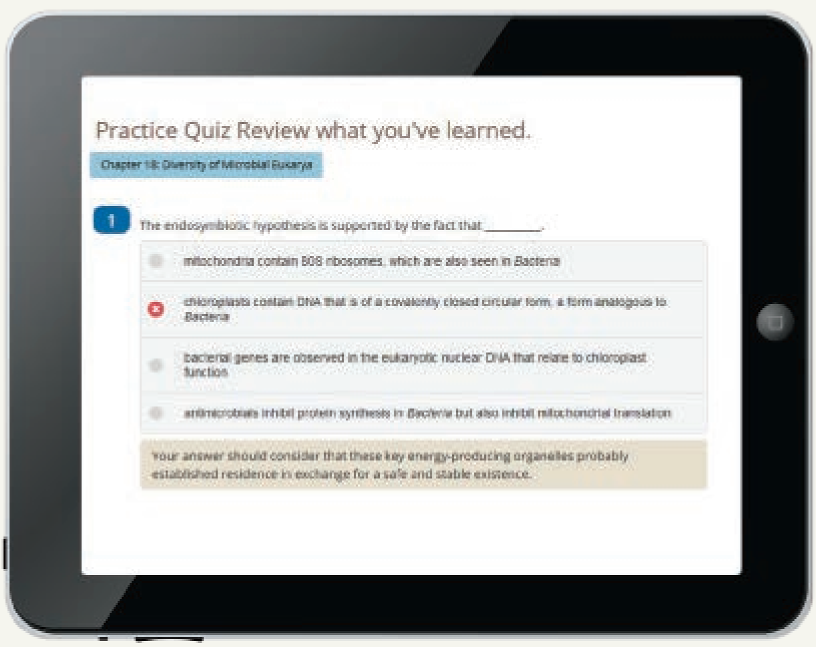
Figure 24.18 **The human virome.** *(a)* Common viruses of eukaryotes found in the virome of a healthy human. *(b)* Bacteriophages within the mucosa of the human respiratory and gastrointestinal tracts protect epithelial cells from the invasion of bacterial pathogens. *(c)* Movement of T4 bacteriophages in mucus. Tracks represent movement of fluorescently labeled individual bacteriophage virions within a microfluidic chip containing 1% mucin to simulate the mucus environment shown in part *b*.

NEW! The chapter on the human microbiome now includes a new section on the human virome, describing how metagenomics is aiding the discovery and isolation of many new viruses. Extensive coverage is provided of the impact of early life events on the development of the newborn gut microbiome and of recent successes in probiotic therapy for preventing newborn intestinal diseases.

Empower Each Learner

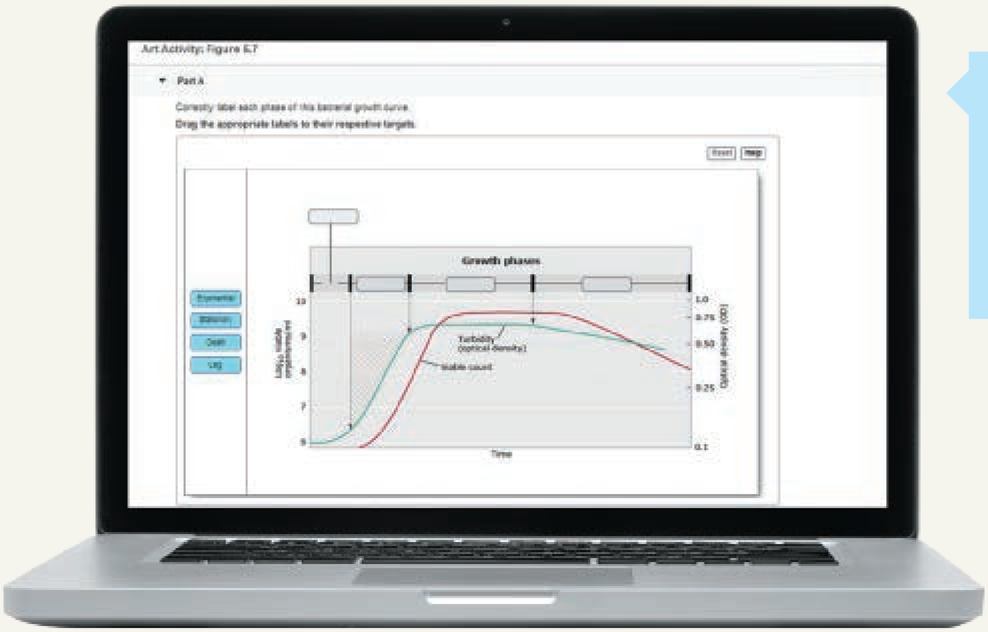


NEW! Dynamic Study Modules help students study course topics by adapting to their performance in real time. Students build the confidence they need to deepen their understanding, participate meaningfully, and perform better—in and out of class. Available on smartphones, tablets, and computers.



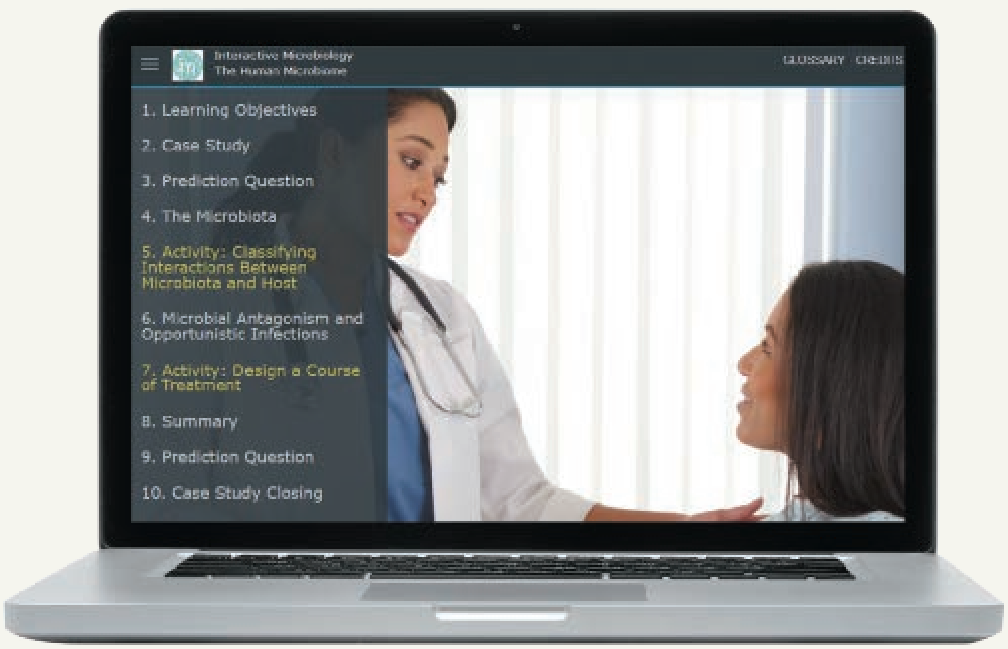
Mastering is so much more than homework. The **Pearson Study Area** allows students to access multiple study tools in one place. They don't need to search Google to find study tools that align with their course materials. Students have access to practice quizzes, videos and animations, vocabulary tools, and more.

with Mastering Microbiology



Get students engaged with content by assigning a variety of questions in Mastering Microbiology. These include:

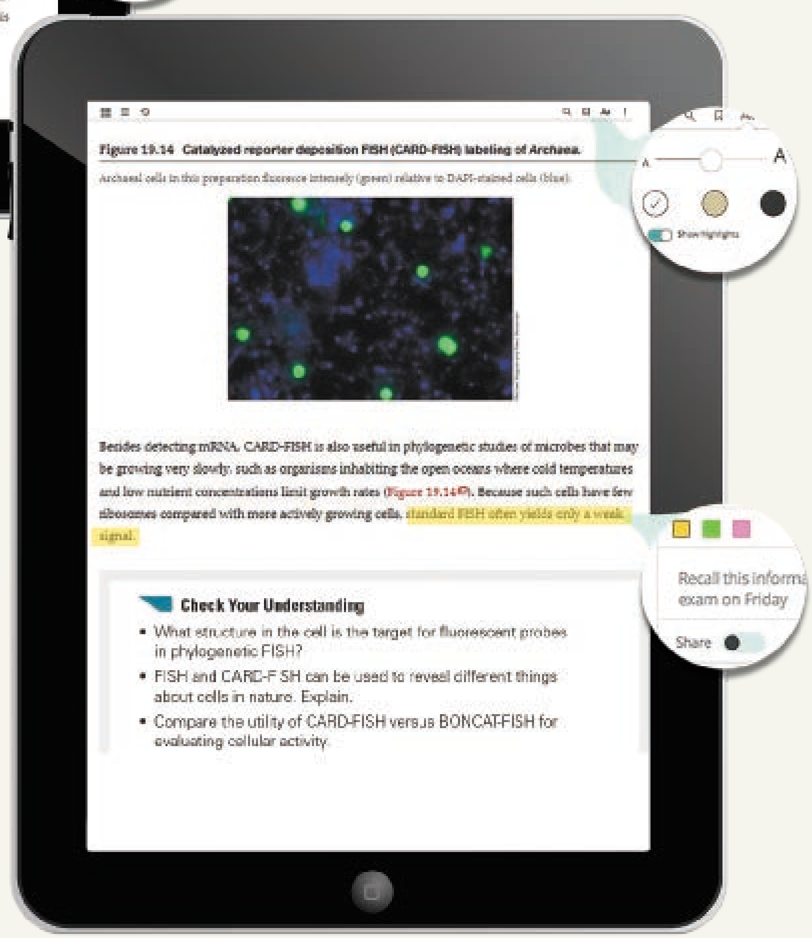
- Reading Questions
- Art-Based Activities
- Coaching Activities and more



Interactive Microbiology is a dynamic suite of interactive tutorials and animations that teach key microbiology concepts including Operons, Biofilms and Quorum Sensing, Complement, Human Microbiota, and Antibiotic Resistance. Interactive Microbiology actively engages students with each topic, enabling them to learn from manipulating variables, predicting outcomes, and answering formative and summative assessment questions. Each tutorial presents the concept within a real healthcare scenario in order to emphasize problem solving and interest students from the beginning.

Pearson eText: A Whole New Reading Experience

NEW! Pearson eText is a simple-to-use, mobile-optimized, and personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when off-line. Seamlessly integrated videos and other rich media engage students and give them access to the help they need, when they need it.



Pearson eText App now enables students to access their eText and associated study tools and notebook off-line. All they need to do is download the app!

BROCK BIOLOGY OF MICROORGANISMS

SIXTEENTH EDITION

GLOBAL EDITION

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