UNIT 6 Diversity of Life

Crosscutting Concepts The great diversity of animal life presents many solutions to the challenges of staying alive. The tissues, organs, and systems of animals are structured in ways that enable them to function in an ever-changing environment.

BOUNCE TO ACTIVATE **VIDEO**

Author Ken Miller discusses Scale and Proportion as he explains why an elephant can't jump like a grasshopper.

UNIT 6 PROBLEM-BASED LEARNING

Recovery

PLANS FOR ENDANGERED SPECIES

The bald eagle, the timber wolf, and the American alligator are all species that teetered on the brink of extinction due to human activities such as pollution, overhunting, and habitat destruction. For the bald eagle, loss of habitat, illegal hunting, and contamination of the animals' food source with the pesticide DDT nearly wiped out the population. In the 1960s fewer than 500 nesting pairs remained. Intentional actions designed to protect bald eagle habitats and eliminate DDT from the environment have resulted in an impressive recovery. The bald eagle is an example of a species saved by a successful recovery plan.

PROBLEM LAUNCH
Conduct research and develop a recovery plan on an endangered species in your region.

VIDEO SAFARI

BOUNCE TO ACTIVATE

Watch a video about the contributing factors that might lead to a species becoming endangered.

PROBLEM: How can you develop a species recovery plan?

TO SOLVE THIS PROBLEM, perform these activities as they come up in the unit and record your findings in your Explorer's Journal.

INTERACTIVITY

Explore captive breeding and reintroduction of endangered species.

LAB INVESTGATION

Investigate the effect of environmental conditions on plants.

AUTHENTIC READING

Read an article about how climate change impacts the growth of walnut trees.

STEM PROJECT

Research your endangered species and design a plan for its recovery.

INTERACTIVITY

Investigate how pollution can affect an animal's body systems.

PROBLEM WRAP-UP

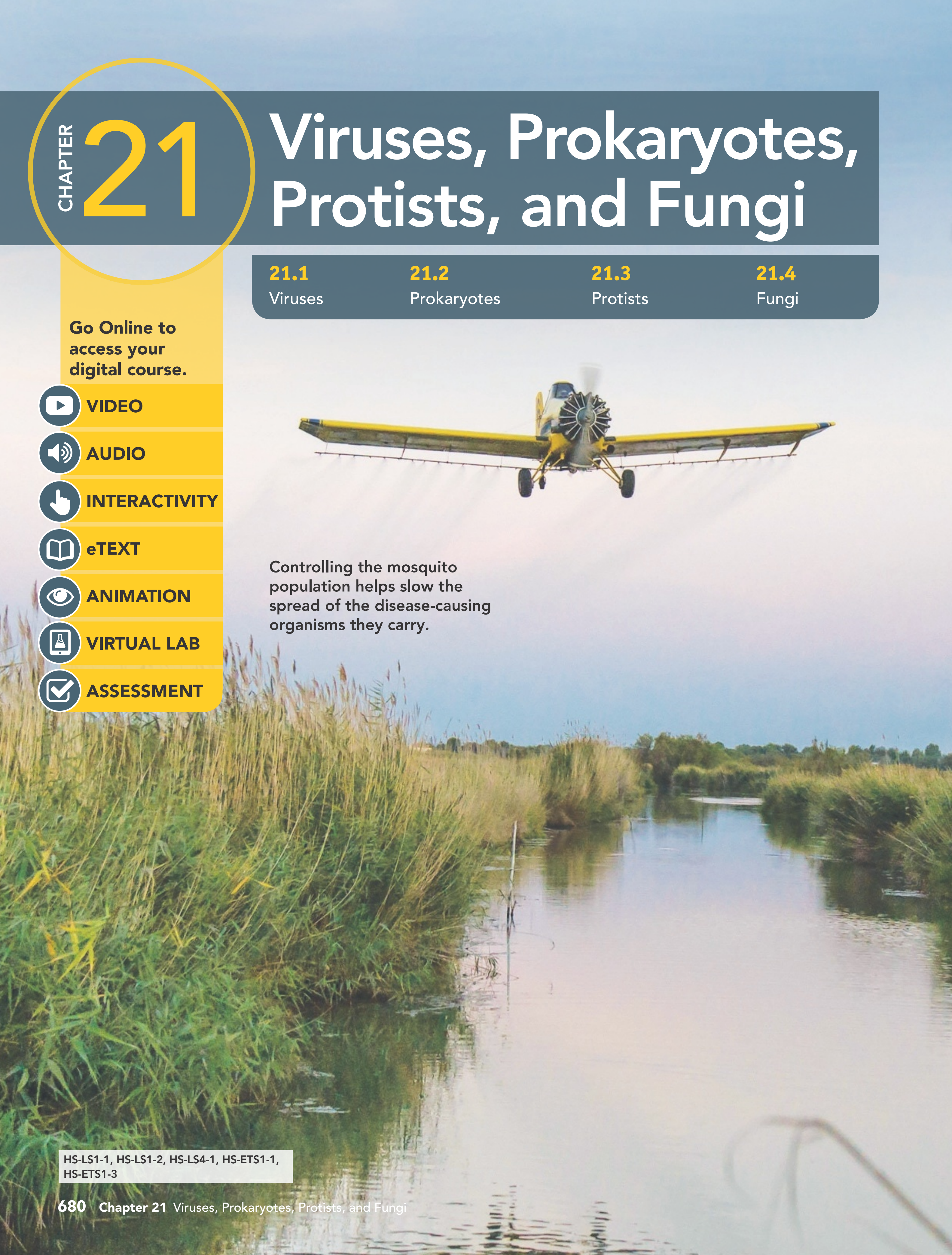
Evaluate and revise your recovery plan, and then present your findings as a report.

CHAPTER 21

Viruses, Prokaryotes, Protists, and Fungi

Go Online to access your digital course.

- VIDEO
- AUDIO
- INTERACTIVITY
- eTEXT
- ANIMATION
- VIRTUAL LAB
- ASSESSMENT



Controlling the mosquito population helps slow the spread of the disease-causing organisms they carry.

HS-LS1-1, HS-LS1-2, HS-LS4-1, HS-ETS1-1, HS-ETS1-3

CASE STUDY

Preventing the next epidemic

The plot could come from a horror movie. *They* are silent, invisible, always in the background. At first, they do no harm. Then something small happens. Perhaps a new animal arrives in the neighborhood, one that becomes their ideal host, and they stop being harmless.

They are the microscopic organisms, or microbes, with whom we share this planet. In fact, these organisms actually *dominate* the planet. They are found everywhere, from the cleanest home to the most extreme environments on earth.

Most of the time, their actions are harmless or even helpful. In nature, they help to recycle dead organic material, such as when they break down a dead tree to help enrich the soil. Microbes known as bacteria also live closely with plants and animals. In fact, the human body may be home to more bacterial cells than human cells!

Centuries ago, Europeans first made their way into North and South America. They brought horses and guns, both of which were unknown to the native peoples. Unwittingly, they also brought along microscopic cargo that was to prove far deadlier than any weapon. For the first time, Native Americans were exposed to the infectious diseases smallpox, cholera, and influenza. The Europeans had lived with these diseases for centuries, but the native peoples had not, and had no immunity to them. The toll was devastating. These microscopic pathogens laid waste to indigenous civilizations in just decades.

Some diseases, such as Zika and Ebola, are caused by viruses. Others, such as cholera, are caused by bacteria that infect food and drinking water. Malaria—among the deadliest killers of children—is the result of a unicellular eukaryote carried by mosquitoes in tropical regions.

In many cases, modern medicine has developed effective ways to cure or prevent these diseases. Yet that has not always prevented these diseases from breaking out of the background to produce mass epidemics. Sometimes a disease spreads so quickly that it is out of control before public health authorities realize it has become a problem. For others, preventive measures like vaccines have become so effective that people lose sight of just how dangerous these diseases can be. And tragically, many poor and underdeveloped regions of the world lack the resources to prevent the spread of disease and to react effectively when an epidemic threatens.

What are the types of microscopic organisms responsible for such diseases and how do they differ from one another? Just as importantly, how can understanding these microbes help us to control them and to prevent new outbreaks of disease?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

LESSON 21.1

Viruses


Leaf infected with tobacco mosaic virus

KEY QUESTIONS

- *How do viruses reproduce?*
- *What happens after a virus infects a cell?*
- *How do viruses cause disease?*
- *Can viruses be considered living things?*

HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

VOCABULARY

virus
capsid
lytic infection
bacteriophage
lysogenic infection
prophage
retrovirus

READING TOOL

After you read this lesson, make notes of the similarities and differences between viruses and cells. Create a Venn diagram in your **Biology Foundations Workbook.**

CASE STUDY

VIDEO

Discover how vaccines can prevent the flu.

Imagine that you have been presented with a great puzzle. Farmers have begun to lose their valuable tobacco crop to a disease that causes infected leaves to wither and die, killing the plants. You take leaves from a diseased plant and crush them to produce a liquid extract. You place a few drops of that liquid on the leaves of healthy plants. A few days later, these leaves also turn yellow and die.

You use a light microscope to look for a germ that might cause the disease, but none can be seen. In fact, when even the tiniest of cells are filtered out of the liquid, a drop of it still causes the disease. You figure the liquid must contain disease-causing agents so small that they are not visible under the microscope and can pass right through the filter. What do you do next? How do you deal with something invisible but deadly?

What Is a Virus?

If you think you know the answer to this puzzle, congratulations! You're walking in the footsteps of a 28-year-old Russian biologist, Dmitri Ivanovski. In 1892, Ivanovski showed that the cause of this plant disease—called tobacco mosaic disease—was found in the liquid extracted from infected plants. But what was in the liquid?

Discovery of Viruses In 1897, Dutch scientist Martinus Beijerinck suggested that tiny particles in the juice caused the disease, and he named these particles *viruses*, after a Latin word for "poison." Then, in 1935, the American biochemist Wendell Stanley isolated crystals of tobacco mosaic virus. Living organisms do not crystallize, so Stanley inferred that viruses were not truly alive. This is a conclusion that biologists still recognize as being valid today. A **virus** is a nonliving particle made of proteins, nucleic acids, and sometimes lipids. ***Viruses can reproduce only by infecting living cells.***

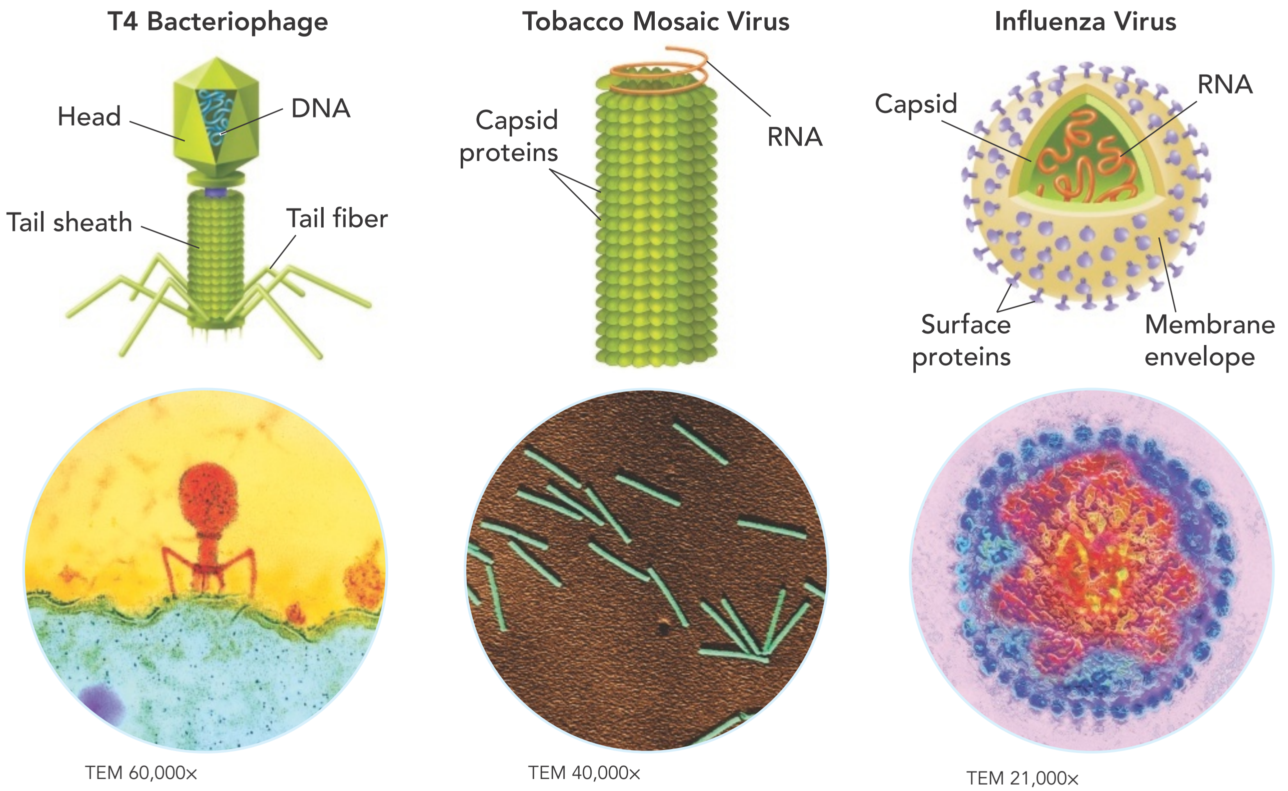
Structure and Composition Viruses are very different from living cells, and are so small they can be seen only with the aid of a powerful electron microscope. Viruses differ widely in terms of size and structure, as you can see in **Figure 21-1**. Viruses contain genetic information in the form of RNA or DNA, surrounded by a protein coat known as a **capsid**. Some viruses, such as the influenza virus, also have a membrane surrounding the capsid. The simplest viruses contain only a few genes, whereas the most complex may have hundreds.

READING CHECK **Explain** How did scientists conclude that viruses are not alive?

Figure 21-1

Diversity of Viral Forms

Viruses come in a wide variety of sizes and shapes. Three types of viruses are shown here. **Interpret Diagrams** What kind of nucleic acid does each virus type have?



Quick Lab | Guided Inquiry

How Do Viruses Differ in Structure?

1. Make models of two of the viruses shown in **Figure 21-1**.
2. Label the parts of each of your virus models.
3. Measure and record the length of each of your virus models in centimeters. Convert the length of each model into nanometers by using the following formula:
   1 cm = 10 million nm.
4. Measure the actual length of each virus you modeled. Divide the length of each model by the length of the actual virus to determine how much larger each model is than the virus it represents.

ANALYZE AND CONCLUDE

1. **Use Models** Which structures of your models are found in all viruses?
2. **Identify Patterns** Which characteristics of one or both of your models are found in only some viruses?
3. **Reason Quantitatively** How many times larger are your models than the viruses they represent?

CASE STUDY

INTERACTIVITY

Design a vaccine for preventing a viral infection.

Viral Infections

If you have access to a personal computer, you may know that they can easily be infected by pieces of code known as computer viruses. These usually enter a computer system by trickery, masquerading as an email attachment or an application program. Once they gain entry to a system, they can "reproduce" by making copies of their own code, and can even spread to other computers by instructing the operating system to send these copies to other computers on a network. The viruses that infect living cells work in ways that are remarkably similar to this, as described in **Figure 21-2**.

To enter a host cell, most viruses have proteins on their surfaces that bind to receptors on a cell. These proteins "trick" the cell to take in the virus. Once inside the cell, the virus makes copies of itself that can spread to other cells, sometimes destroying the host cell in the process. Nearly every type of organism, whether plant, animal, or bacterium, can be infected by viruses.

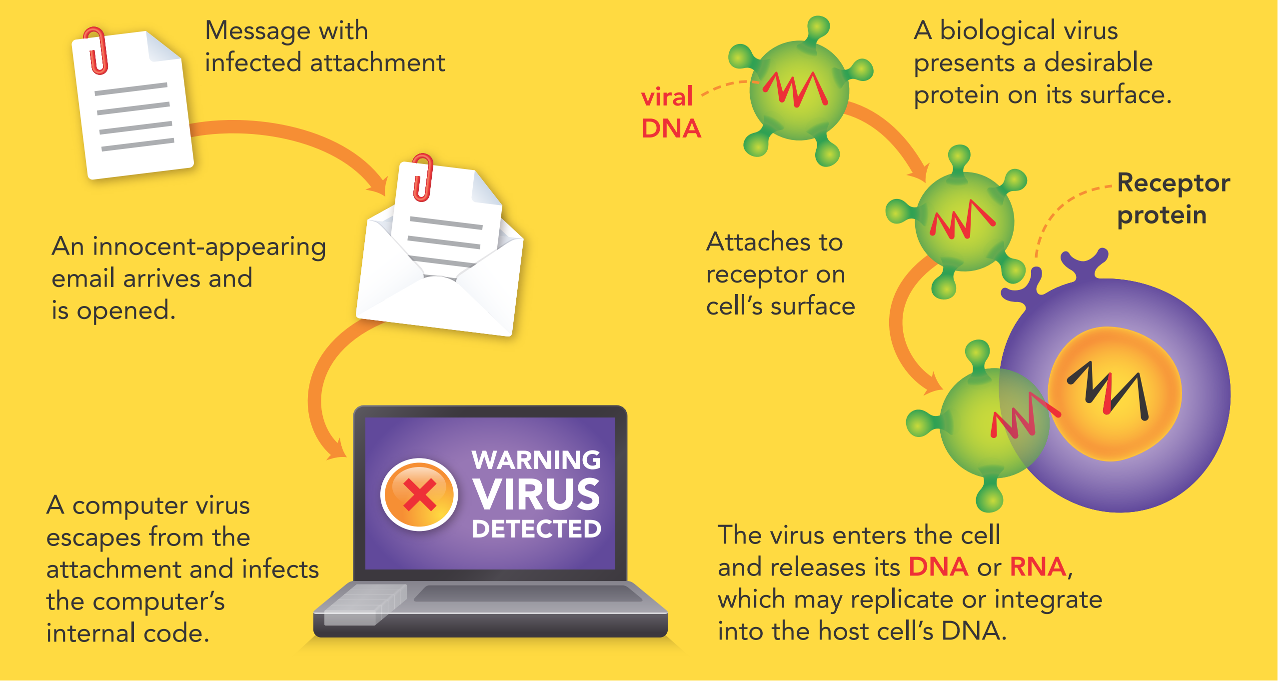
After a virus has entered a host cell, what happens? ***Inside living cells, viruses use their genetic information to reproduce. Some viruses replicate immediately, while others initially persist in an inactive state within the host.*** These two patterns of infection are called lytic infection and lysogenic infection.

Visual Analogy

Figure 21-2

How Viruses Enter Living Cells

Viruses gain entry to cells by "tricking" their hosts. First the host cell takes in the virus, and then it follows the harmful instructions the virus contains.



Lytic Infection In a **lytic infection**, a virus enters a bacterial cell, makes copies of itself, and causes the cell to burst, or lyse. *T4*, a bacterial virus, or **bacteriophage**, causes just such an infection. The virus binds to the surface of a bacterium, injects its DNA into the cell, and then begins to make messenger RNA (mRNA) from its own genes. These mRNAs are translated into proteins that act like a molecular wrecking crew, chopping up the cell's DNA.

Under the control of viral genes, the host cell now makes thousands of copies of viral nucleic acid and capsid proteins, enabling the virus to reproduce. Before long, the infected cell lyses, releasing hundreds of virus particles that may go on to infect other cells.

Lysogenic Infection Some bacterial viruses, including the bacteriophage *lambda*, cause a **lysogenic infection**, in which a host cell is not immediately taken over. Instead, the viral nucleic acid is inserted into the host cell's DNA, where it is replicated along with the host DNA without damaging the host.

Bacteriophage DNA that becomes embedded in the bacterial host's DNA is called a **prophage**. That DNA may remain in the host genome for many generations. Influences from the environment—including radiation, heat, and certain chemicals—trigger the prophage to become active. It then removes itself from the host cell DNA and reproduces by forming new virus particles. The lysogenic infection now becomes an active lytic infection, as shown in **Figure 21-3**. The details of viral infection in eukaryotic cells differ in many ways from infections of bacteria. However, the basic patterns are similar.

READING TOOL

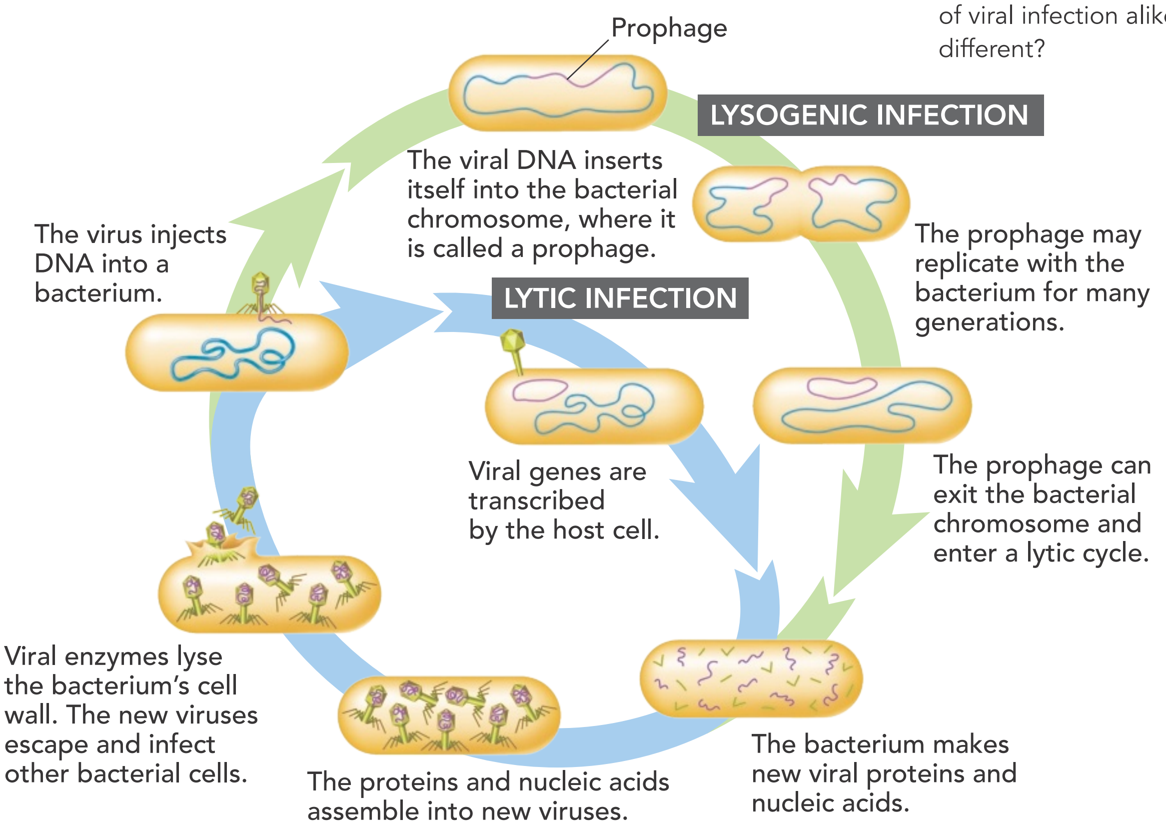
As you read this section, complete a two-column chart to compare and contrast a lytic infection with a lysogenic infection.

INTERACTIVITY

Figure 21-3

Comparing Two Types of Bacteriophage Infection

Viruses that infect bacteria, called bacteriophages, may infect cells in one of two ways: lytic infection or lysogenic infection. **Compare** How are the two main patterns of viral infection alike and different?



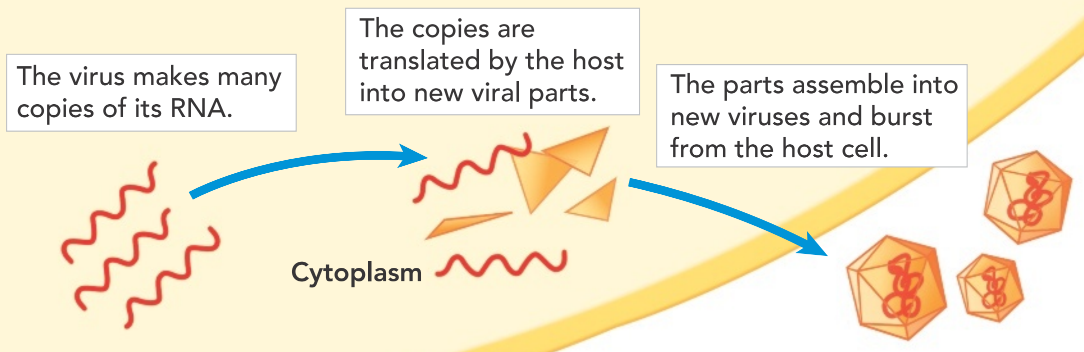


Figure 21-4

Common Cold Infection Mechanism

Once the cold virus has penetrated the host's cells, it uses the host's cellular machinery to replicate itself.

Figure 21-5

HIV Infection Mechanism

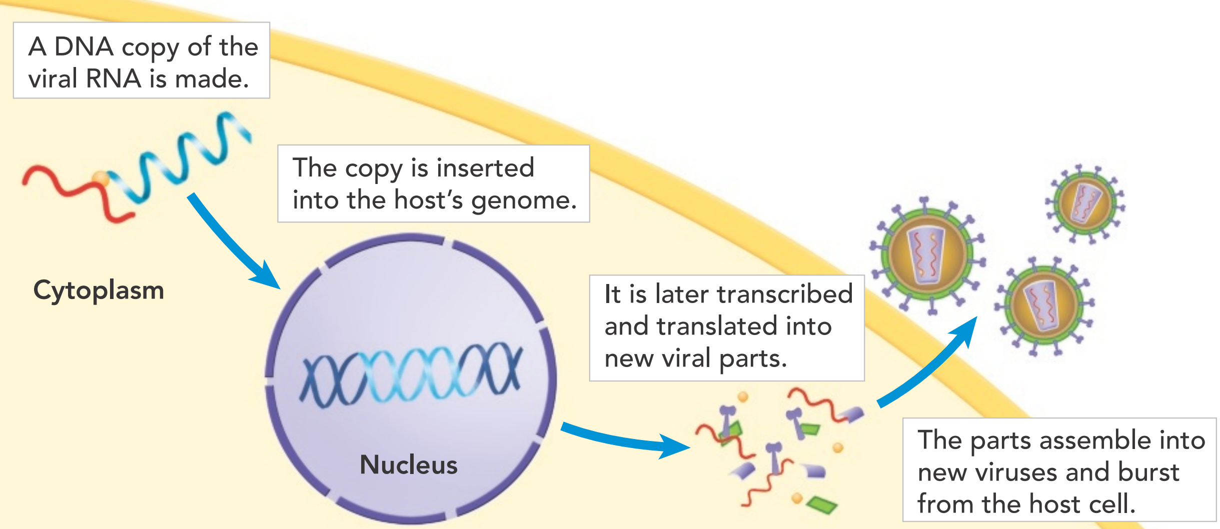
In contrast to the cold virus, a retrovirus such as HIV makes a DNA copy of itself that inserts into the host's DNA. There, it may remain inactive for many cell cycles.

A Closer Look at Two RNA Viruses

About 70 percent of viruses contain RNA rather than DNA. In humans, RNA viruses cause a wide range of infections, from relatively mild colds to influenza and AIDS. Certain kinds of cancer also begin with an infection by viral RNA.

The Common Cold What happens when you get a cold? Cold viruses attack with a very simple, fast-acting infection, as shown in **Figure 21-4**. A virus settles on a cell, often in the lining of the nose, and is brought inside the cell. The host cell's ribosomes translate the viral RNA into capsids and other viral proteins. These proteins assemble around copies of viral RNA, and within eight hours, the host cell releases hundreds of new virus particles to infect other cells.

HIV The deadly disease called acquired immune deficiency syndrome (AIDS) is caused by an RNA virus called human immunodeficiency virus (HIV), shown in **Figure 21-5**. HIV belongs to a group of RNA viruses that are called **retroviruses**. The genetic information of a retrovirus is copied from RNA to DNA, and may become inserted into the DNA of the host cell. Retroviral infections are similar to lysogenic infections of bacteria. The viral genes may remain inactive for many cell cycles before making new virus particles and damaging the cells of the host's immune system. Once activated, HIV begins to destroy the very cells that would normally fight infections.



Viral Diseases

Viruses produce disease by disrupting the body's normal homeostasis. **Figure 21-6** lists some common human diseases caused by viruses. Viruses produce serious animal and plant diseases as well.

Disease Mechanism

In many viral infections, viruses attack and destroy certain cells in the body, causing the symptoms of the associated disease. Poliovirus, for example, destroys cells in the nervous system, producing paralysis. Other viruses cause infected cells to change their patterns of growth and development, sometimes leading to cancer. ***Viruses cause disease by directly destroying living cells or by affecting cellular processes in ways that upset homeostasis.***

Prevention and Treatment

Many viral diseases can be prevented by vaccines prepared from weakened or inactivated virus particles. Vaccines stimulate the body's immune system to recognize and destroy such viruses before they can cause disease. Personal hygiene matters, too. Studies show that cold and flu viruses are often transmitted by hand-to-mouth contact, so washing your hands as well as controlling coughs and sneezes can help prevent the spread of viruses.

While viral diseases are very difficult to treat, in recent years limited progress has been made in developing a handful of antiviral drugs that attack specific viral enzymes that host cells do not have. These treatments include an antiviral medication that can help speed recovery from the flu virus, and others that have helped prolong the lives of people infected with HIV.

READING CHECK **Explain** How do viruses cause disease?

Figure 21-6

Common Human Viral Diseases

Some common viral diseases are shown in the table below.

Common Human Viral Diseases

Disease	Effect on Body	Transmission
Common cold	Sneezing, sore throat, fever, headache, muscle aches	Contact with contaminated objects; droplet inhalation
Influenza	Body aches, fever, sore throat, headache, dry cough, fatigue, nasal congestion	Flu viruses spread in respiratory droplets caused by coughing and sneezing.
AIDS (HIV)	Helper T cells, which are needed for normal immune-system function, are destroyed.	Sexual contact; contact with contaminated blood or body fluids; can be passed to babies during delivery or during breastfeeding
Hepatitis B	Jaundice, fatigue, abdominal pain, nausea, vomiting, joint pain	Contact with contaminated blood or bodily fluids
West Nile Virus	Fever, headache, body ache	Bite from an infected mosquito
Ebola	Fever and body aches, followed by rash and digestive symptoms impacting kidney and liver function	Contact with contaminated blood or bodily fluids
Zika	Fever, rash, joint pain, reddened eyes; can interfere with fetal development in pregnant women	Bite from an infected mosquito

INTERACTIVITY

Investigate the structure of a virus and compare its traits to a living organism.

Viruses and Cells

Viruses must infect living cells in order to grow and reproduce, taking advantage of the nutrients and cellular machinery of their hosts. This means that all viruses are parasites. Parasites depend entirely upon other living organisms for their existence, harming these organisms in the process.

Despite the fact that they are not alive, viruses have many of the characteristics of living things. After infecting living cells, viruses can reproduce, regulate gene expression, and even evolve. In fact, viral evolution is one of the reasons we need a new flu shot every year. A comparison of the principal differences between cells and viruses is shown in **Figure 21-7**.

Although viruses are smaller and simpler than the smallest cells, it is unlikely that they were the first organisms. Because viruses are dependent upon living organisms, it seems more likely that viruses developed after living cells. In fact, the first viruses may have evolved from the genetic material of living cells. Viruses have continued to evolve, along with the cells they infect, for billions of years.

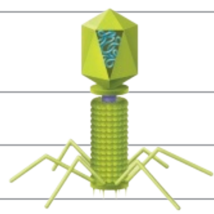
Figure 21-7

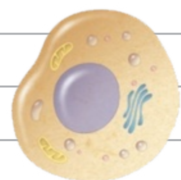
Comparing Viruses and Cells

The differences between viruses and cells are listed in this chart. **Form an Opinion** Based on this information, would you classify viruses as living or nonliving? Explain

Viruses and Cells

Characteristic	Virus	Cell
Structure	DNA or RNA in capsid, some with envelope	Cell membrane, cytoplasm; eukaryotes also contain nucleus and many organelles
Reproduction	Only within a host cell	Independent cell division, either asexually or sexually
Genetic Code	DNA or RNA	DNA
Growth and Development	No	Yes; in multicellular organisms, cells increase in number and differentiate
Obtain and Use Energy	No	Yes
Response to Environment	No	Yes
Change Over Time	Yes	Yes





HS-ETS1-1

LESSON 21.1 Review

KEY QUESTIONS

1. What do viruses depend on for their reproduction?
2. Describe each of the two paths viruses may follow once they have entered a cell.
3. Name three human diseases caused by viruses.
4. What characteristics of living things do viruses have?

CRITICAL THINKING

5. **Compare and Contrast** How is viral reproduction different from that of cell-based organisms?
6. **Compare and Contrast** Compare the structure of a virus to the structure of both a prokaryotic cell and a eukaryotic cell. Use a graphic organizer of your choice to organize the information. You may wish to use primary scientific references or to refer to Chapter 8, which discusses the structures of cells in detail.

Prokaryotes

LESSON 21.2

Colonies of *E. coli* in petri dish

KEY QUESTIONS

- *How are prokaryotes classified?*
- *How do prokaryotes vary in their structure and function?*
- *What roles do prokaryotes play in the living world?*
- *How do bacteria cause disease?*
- *What are emerging diseases?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

VOCABULARY
prokaryote
binary fission
endospore
conjugation
pathogen
vaccine
antibiotic

READING TOOL

As you read this lesson, explain the many different ways that prokaryotes function on our planet. Fill in the graphic organizer in your **Biology Foundations Workbook.**

Imagine living all your life as a member of what you believe is the only family on your street. Then, one morning, you open the front door and see neighbors tending their gardens and children walking to school. Where did all the people come from? What if the answer turned out to be that they had always been there—you just hadn't seen them? When the microscope was first invented, we humans had just such a shock. Suddenly, the street was very crowded! Microorganisms like bacteria are all around us—in fact, they even live inside our bodies.

What Are Prokaryotes?

Microscopic life covers nearly every square centimeter of Earth. The smallest and most abundant of these microorganisms are **prokaryotes** (pro KAR ee ohts)—unicellular organisms that lack a nucleus. Unlike eukaryotes, the DNA of prokaryotes is located directly in the cytoplasm.

For many years, most prokaryotes were simply called "bacteria." Today, however, biologists divide prokaryotes into two very distinct groups: Bacteria and Archaea. These groups are as different from each other as both are from eukaryotes. ***Prokaryotes are classified as Bacteria or Archaea—two of the three domains of life.*** Eukarya is the third domain. The domain Bacteria corresponds to the kingdom Eubacteria. The domain Archaea corresponds to the kingdom Archaebacteria.

Bacteria The larger of the two domains of prokaryotes is Bacteria. Bacteria include a range of organisms with lifestyles so different that biologists do not agree on exactly how to classify them within the group. Bacteria live almost everywhere, in fresh water, in salt water, on land, and on and within the bodies of humans and other eukaryotes.

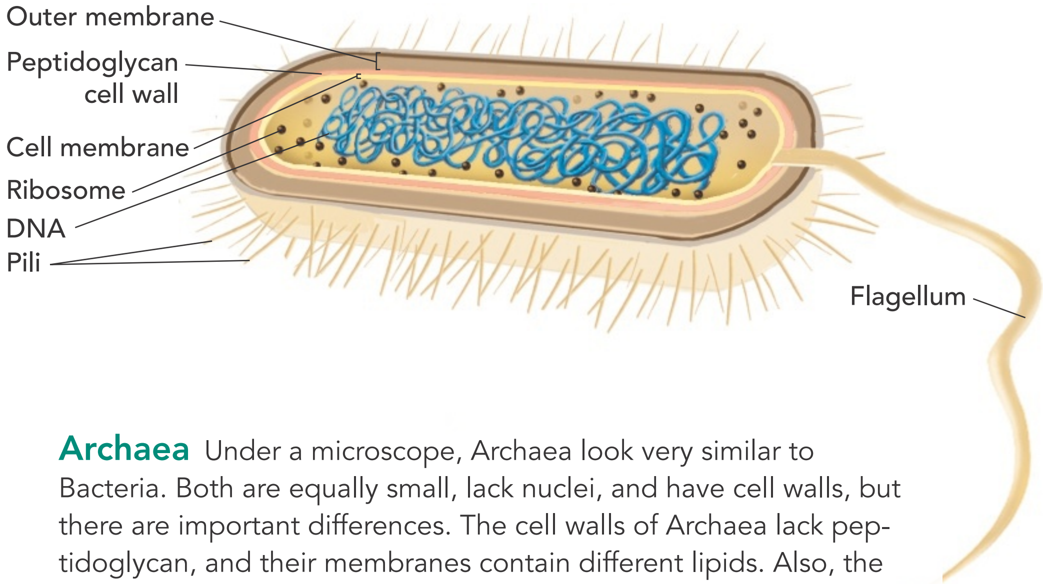
Bacteria are usually surrounded by a cell wall that protects the cell from injury and determines its shape. The cell walls of bacteria contain peptidoglycan—a polymer of sugars and amino acids that surrounds the cell membrane. Some bacteria, such as *E. coli*, shown in **Figure 21-8**, have a second membrane outside the peptidoglycan wall that makes the cell especially resistant to damage. In addition, some prokaryotes have flagella that they use for movement, or pili (singular: pilus), which in *E. coli* serve mainly to anchor the bacterium to a surface or to other bacteria.

INTERACTIVITY

Figure 21-8

Typical Bacterial Structure

A bacterium such as *E. coli* has the basic structure typical of most prokaryotes. *E. coli* also has an outer membrane composed of lipids. This outer membrane is not present in all bacteria.



Archaea Under a microscope, Archaea look very similar to Bacteria. Both are equally small, lack nuclei, and have cell walls, but there are important differences. The cell walls of Archaea lack peptidoglycan, and their membranes contain different lipids. Also, the DNA sequences of key Archaea genes are more like those of eukaryotes than those of bacteria.

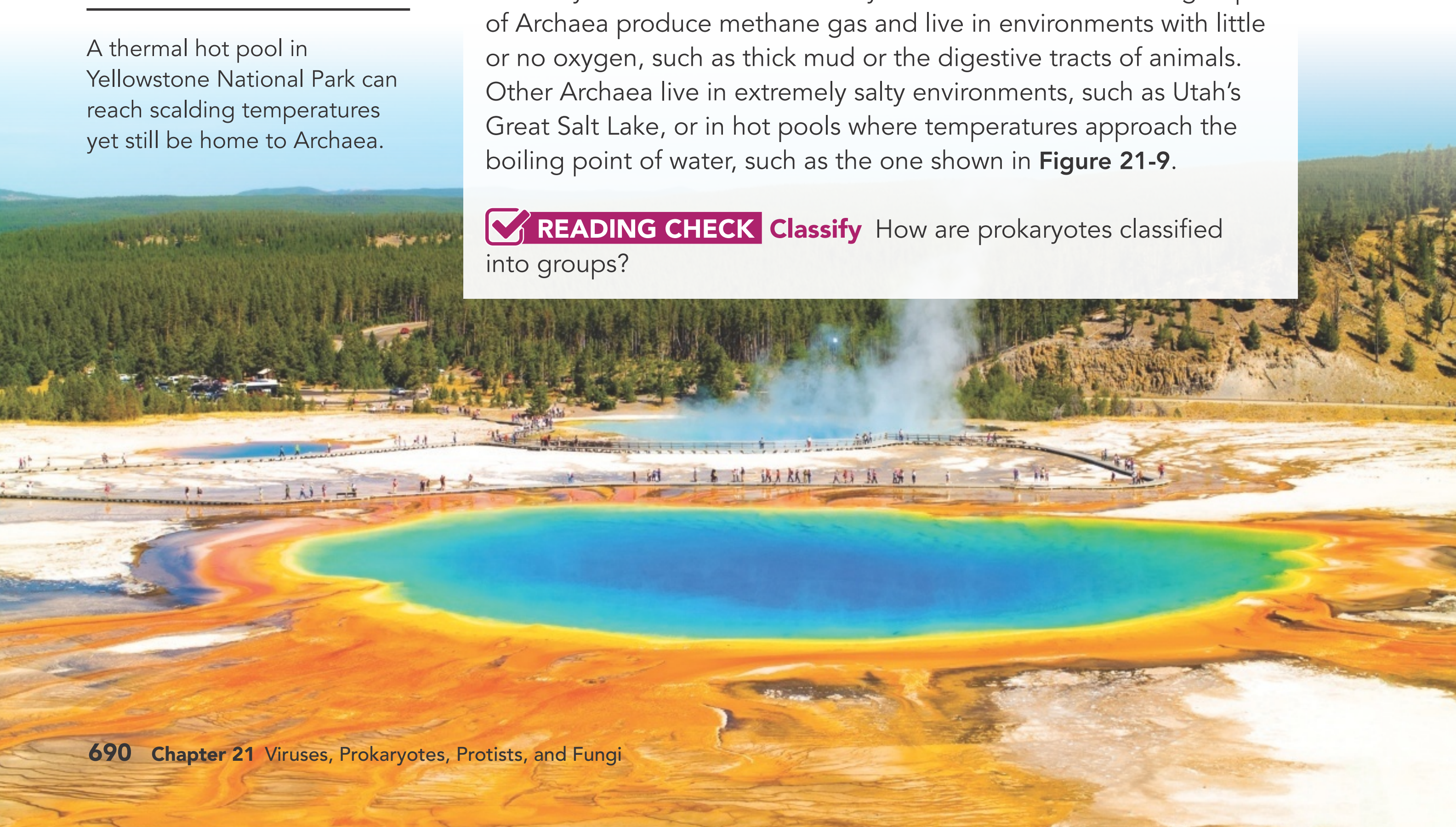
Many Archaea live in extremely harsh environments. One group of Archaea produce methane gas and live in environments with little or no oxygen, such as thick mud or the digestive tracts of animals. Other Archaea live in extremely salty environments, such as Utah's Great Salt Lake, or in hot pools where temperatures approach the boiling point of water, such as the one shown in **Figure 21-9**.

READING CHECK **Classify** How are prokaryotes classified into groups?

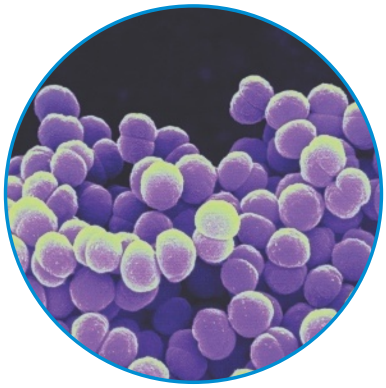
Figure 21-9

Archaea

A thermal hot pool in Yellowstone National Park can reach scalding temperatures yet still be home to Archaea.



Bacilli (SEM 8500×)



Cocci (SEM 9200×)

Spirilla (SEM 3000×)

Figure 21-10

Prokaryotic Shapes

Prokaryotes usually have one of these three basic shapes: bacilli, cocci, or spirilla.

Structure and Function of Prokaryotes

Because prokaryotes are so small, it may seem hard to tell them apart. ***Prokaryotes vary in their size and shape, in the way they move, and in the way they obtain and release energy.***

Prokaryotes range in size from 1 to 5 micrometers, making them much smaller than most eukaryotic cells. Prokaryotes come in a variety of shapes, as shown in **Figure 21-10**. Rod-shaped prokaryotes are called bacilli (buh SIL eye). Spherical prokaryotes are called cocci (KAHK sy). Spiral and corkscrew-shaped prokaryotes are called spirilla (spy RIL uh). You can also distinguish prokaryotes by whether they move and how they move. Some prokaryotes do not move at all. Others are propelled by flagella. Some glide slowly along a layer of slimelike material they secrete.

INTERACTIVITY

Investigate the structure and function of prokaryotes.

Nutrition and Metabolism

Like all organisms, prokaryotes need a supply of chemical energy, or food. They release energy from food molecules by cellular respiration, fermentation, or both. The diverse ways prokaryotes obtain and release energy are compared in **Figure 21-11**.

Figure 21-11

Energy Capture and Release by Prokaryotes

Prokaryotes vary in the way they capture energy and in the way they release it.

Energy Capture by Prokaryotes

Mode of Nutrition	How Energy Is Captured
Heterotroph "other feeder"	Take in organic molecules from environment or other organisms to use as both energy and carbon supply
Photoheterotroph "light and other feeder"	Like basic heterotrophs, but also use light energy
Photoautotroph "light self-feeder"	Use light energy to convert CO_2 into carbon compounds
Chemoautotroph "chemical self-feeder"	Use energy released by chemical reactions involving ammonia, hydrogen sulfide, etc.

Energy Release by Prokaryotes

Mode of Metabolism	How Energy Is Released
Obligate aerobe "requiring oxygen"	Cellular respiration; must have ready supply of oxygen to release fuel energy
Obligate anaerobe "requiring a lack of oxygen"	Fermentation; die in presence of oxygen
Facultative anaerobe "surviving without oxygen when necessary"	Can use either cellular respiration or fermentation as necessary

READING TOOL

As you read about prokaryotes, recall your prior knowledge about life at the cellular level. Relate bacterial growth and reproduction to similar processes in plant and animal cells.

Growth, Reproduction, and Recombination

Most prokaryotes reproduce by the process of **binary fission**, shown in **Figure 21-12**. In this process, the cell replicates its DNA and then divides in half to produce two identical cells. Because binary fission does not involve the exchange or recombination of genetic information, it is a form of asexual reproduction. When conditions are favorable, some prokaryotes can grow and divide as often as once every 20 minutes!

When growth conditions become unfavorable, many prokaryotic cells form an **endospore**—a thick internal wall that encloses the DNA and a portion of the cytoplasm. Endospores can remain dormant for months or even years. The ability to form endospores makes it possible for some prokaryotes to survive very harsh conditions. The bacterium *Bacillus anthracis*, which causes the disease anthrax, is one such bacterium.

As in any organism, adaptations that increase the survival and reproduction of a particular prokaryote are favored. Recall that in organisms that reproduce sexually, genes are shuffled and recombined during meiosis. But many prokaryotes reproduce asexually. So, how do their populations evolve?

Mutations Mutations are one of the main ways prokaryotes evolve. Recall that mutations are heritable changes in DNA. In prokaryotes, mutations are inherited by daughter cells produced by binary fission.

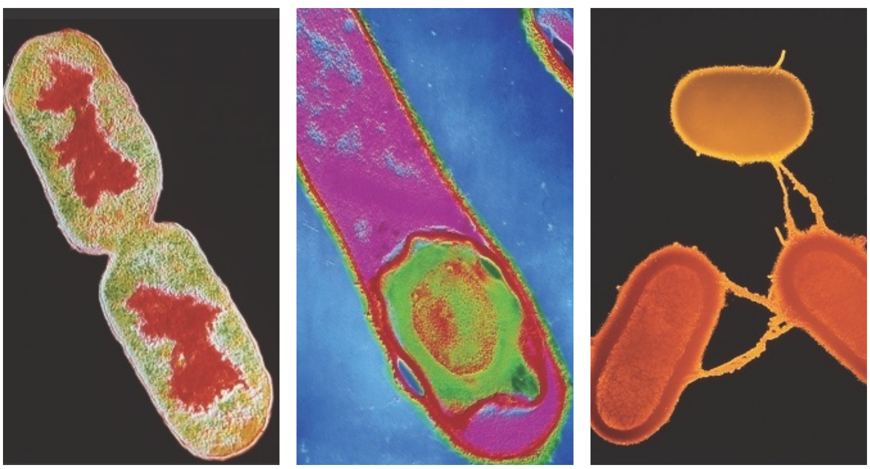
Conjugation Many prokaryotes exchange genetic information by a process called conjugation. During **conjugation**, a hollow bridge forms between two bacterial cells, and genetic material, usually in the form of a plasmid, moves from one cell to the other. Many plasmids carry genes that enable bacteria to survive in new environments or to resist antibiotics that might otherwise prove fatal. This transfer of genes increases genetic diversity in populations of prokaryotes.

READING CHECK **Explain** How is forming an endospore useful for many bacteria?

Figure 21-12

Binary Fission, Endospores, and Conjugation

An *E. coli* bacterium has almost completed the process of binary fission (left.) Another bacterium has developed an endospore, the green region (middle.) In conjugation, tiny bridges allow bacteria to transfer genetic information (right.) All three micrographs have been false-colored.



Binary fission (TEM 38,000×) Endospore (TEM 20,000×) Conjugation (TEM 11,000×)

Prokaryotes in the Environment

You may remember the star actors in the last movie you saw, but have you ever thought about a film's behind-the-scene production crew? Prokaryotes are just like those unseen workers. ***Prokaryotes are essential in maintaining every aspect of the ecological balance of the living world. In addition, some species have specific uses in human industry.***

Decomposers Every living thing depends on a supply of raw materials for its survival. By breaking down, or decomposing, dead organisms, prokaryotes supply raw materials to the environment. Bacterial decomposers are also essential to industrial sewage treatment, helping to produce purified water and chemicals that can be used as fertilizers.

Producers Photosynthetic prokaryotes are among the most important producers on the planet. The tiny cyanobacterium *Prochlorococcus* **(Figure 21-13)** alone may account for more than half of the primary production in the open ocean. Food chains everywhere are dependent upon prokaryotes as producers of food and biomass.

Nitrogen Fixers All organisms need nitrogen to grow. But while nitrogen gas (N_2) makes up 80 percent of Earth's atmosphere, only a few organisms—all of them prokaryotes—can convert N_2 into useful forms. This process, known as nitrogen fixation, provides up to 90 percent of the nitrogen used by other organisms. Some plants have vital symbiotic relationships with nitrogen-fixing prokaryotes. As shown in **Figure 21-13**, the bacterium *Rhizobium* grows in nodules, or knobs, on the roots of legume plants such as clover and soybean. The *Rhizobium* bacteria within these nodules convert nitrogen in the air into the nitrogen compounds essential for plant growth. In effect, these plants have fertilizer factories in their roots!

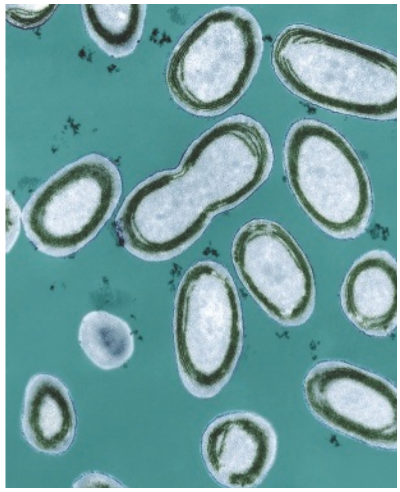
Human Uses of Prokaryotes Prokaryotes, especially bacteria, are used in the production of a wide variety of foods and other commercial products. For example, yogurt is produced by the bacterium *Lactobacillus*. Some bacteria can even digest petroleum and remove human-made waste products and poisons from water. Others are used to synthesize drugs and chemicals through the techniques of genetic engineering.

The Microbiome Bacteria live just about everywhere, but one of their favorite places turns out to be the human body. Bacteria live on the skin, on the hair, inside the mouth and nose, and especially inside our digestive systems. In a typical human intestine there may be as many as 30 trillion bacteria belonging to 150 different species. Throughout the body these organisms form what scientists now call the "microbiome," a huge collection of prokaryotic genomes that rivals the human genome in size and complexity.

Figure 21-13

Ecological Roles Played by Prokaryotes

Prokaryotes play many important roles in the environment. Cyanobacteria in the ocean (top) provide oxygen to the atmosphere and food for ocean food chains. *Rhizobium* nodules on soybean roots (bottom) convert atmospheric nitrogen into useful compounds.



TEM 23,000×

This great diversity of microorganisms helps us to digest food, synthesizes certain vitamins, and maintains a balance that is important to good health. There is growing evidence that disorders such as diabetes, obesity, and even cancer can be linked to abnormal microbiomes. An emerging area of medical science is now dedicated to understanding and correcting imbalances in the microbiome.

INTERACTIVITY

Conduct a simulation of an outbreak of cholera, a deadly bacterial disease.

Bacterial Diseases

We share this planet with prokaryotes and viruses, and most of the time we are never aware of our relationships with them. Often, these relationships are highly beneficial, but in a few cases, sharing simply doesn't work—and disease is the result.

Disease-causing agents are called **pathogens**. Although pathogens can come from any taxonomic group, nearly all known prokaryotic pathogens are bacteria. The French chemist Louis Pasteur was the first person to show convincingly that bacteria cause disease. Pasteur helped to establish what has become known as the *germ theory of disease* when he showed that bacteria were responsible for a number of human and animal diseases.

Disease Mechanisms Bacteria produce disease in one of two general ways. ***Bacteria disrupt health and cause disease by destroying living cells or by releasing chemicals that upset homeostasis.*** Some bacteria destroy living cells and tissues of the infected organism directly, while some cause the immune system to overreact, causing it to attack the body's own tissues. Other bacteria release toxins (poisons) that interfere with the normal activity of the host. **Figure 21-14** lists some common human diseases caused by bacteria.

Figure 21-14

Common Human Bacterial Diseases

Some common bacterial diseases are shown in the table below. **Infer** Why do bacterial meningitis outbreaks sometimes occur in college dormitories?

Some Human Bacterial Diseases

Disease	Effect on Body	Transmission
Lyme disease	"Bull's-eye" rash at site of tick bite, fever, fatigue, headache	Ticks transmit the bacterium *Borrelia burdorferi*.
Tetanus	Lockjaw, stiffness in neck and abdomen, difficulty swallowing, fever, elevated blood pressure, severe muscle spasms	Bacteria enter the body through a break in the skin.
Tuberculosis	Fatigue, weight loss, fever, night sweats, chills, appetite loss, bloody sputum from lungs	Bacteria particles are inhaled.
Bacterial meningitis	High fever, headache, stiff neck, nausea, fatigue	Bacteria are spread in respiratory droplets caused by coughing and sneezing; close or prolonged contact with someone infected with meningitis
Strep throat	Fever, sore throat, headache, fatigue, nausea	Direct contact with mucus from an infected person or direct contact with infected wounds or breaks in the skin

Controlling Bacteria	
Method	**Description**
Physical Removal	Washing hands or other surfaces with soap under running water doesn't kill pathogens, but it helps dislodge both bacteria and viruses.
Disinfectants	Chemical solutions that kill bacteria can be used to clean bathrooms, kitchens, hospital rooms, and other places where bacteria may flourish.
Food Storage	Low temperatures slow the growth of bacteria and keep most foods fresher for a longer period of time than room temperature.
Sanitation	Well-designed sanitary sewage and septic systems can protect drinking water and prevent the spread of disease.
Food Processing	Boiling, frying, or steaming can sterilize many kinds of food by raising the temperature of the food to a point where bacteria are killed.
Sterilization by Heat	Sterilization of objects such as medical instruments at temperatures well above 100° Celsius can prevent the growth of potentially dangerous bacteria. Most bacteria cannot survive such temperatures.

Figure 21-15

Controlling Bacteria

Bacteria cannot—and should not—be eliminated from the environment, but many methods will control their growth.

Controlling Bacteria Although most bacteria are harmless, and many are beneficial, the everyday risks of any person acquiring a bacterial infection are great enough to warrant efforts to control bacterial growth. Some methods of controlling bacteria are shown in **Figure 21-15**.

Preventing Bacterial Diseases Many bacterial diseases can be prevented by stimulating the body's immune system with vaccines. A **vaccine** is a preparation of weakened or killed pathogens or inactivated toxins. When injected into the body, a vaccine prompts the body to produce immunity to a specific disease. Immunity is the body's ability to recognize and destroy pathogens before they cause disease.

Treating Bacterial Diseases A number of drugs can be used to attack a bacterial infection. These drugs include **antibiotics**, such as penicillin and tetracycline, that block the growth and reproduction of bacteria. Antibiotics disrupt proteins or cell processes that are specific to bacterial cells. In this way, they do not harm the host's cells.

BUILD VOCABULARY

Root Words The prefix *anti-* means "opposed," and *biotic* refers to "life." However, antibiotics fight bacterial life only, and not other types of living things.

"Superbugs" When first introduced in the 1940s, penicillin, an antibiotic derived from fungi, was a miracle drug. Conquest of bacterial diseases seemed to be in sight. Within a few decades, however, penicillin lost much of its effectiveness, as have other antibiotics. The culprit is evolution. Natural selection and the widespread use of antibiotics have led to the emergence of antibiotic resistance. Physicians now must fight "superbugs" that are resistant to multiple antibiotics.

One example is methicillin-resistant *Staphylococcus aureus*, known as MRSA (pronounced MURS uh), which can cause infections that are especially difficult to control. MRSA skin infections can be spread by close contact, including the sharing of personal items such as towels and athletic gear. In hospitals, MRSA bacteria can infect surgical wounds and spread from patient to patient.

READING CHECK Infer Why has penicillin become less useful?

CASE STUDY **Analyzing Data**

MRSA—Fighting Back

Infection by methicillin-resistant *Staphylococcus aureus* (MRSA) rose quickly in the years leading up to 2005. The table shows the incidence of MRSA infections in U.S. hospitals between 2005 and 2011.

1. **Construct Graphs** Prepare a line graph showing the number of MRSA infections in U.S. hospitals over time. Describe the trend shown by your graph.
2. **Reason Quantitatively** By what percentage did MRSA infections in U.S. hospitals increase or decrease between 2005 and 2011?
3. **Form a Hypothesis** What do you think led to the trend in the data observed between 2005 and 2011? If the average hospital stay in the United States lasted 4.6 days, while that of the average MRSA-infected patient was 10.0 days, what effect did this trend have on hospital costs?

Incidence of MRSA

Year	MRSA Infections
2005	111,261
2006	106,811
2007	100,876
2008	93,460
2009	86,041
2010	83,287
2011	80,461

Emerging Disease

A previously unknown disease that appears in a population for the first time or a well-known disease that suddenly becomes harder to control is called an emerging disease. To Native Americans, the smallpox virus that Europeans brought to the new world was just such a disease. In 1521, an epidemic of this viral disease so weakened the mighty Aztec empire that Spaniard Hernán Cortés was able to conquer what is now Mexico with just a few hundred soldiers. Similar epidemics ravaged the Native American populations of New England as well in the early 1600s.

BUILD VOCABULARY

Academic Words An epidemic is a rapid outbreak of a disease, meaning that the disease spreads quickly among many people. If the disease is fatal, many people may die in a short span of time.

The Threat Today

Emerging diseases remain a threat today. **Figure 21-16** shows locations worldwide where specific emerging diseases have broken out in recent years. Changes in lifestyle and commerce have made the health disruptions caused by emerging diseases even more of a threat. One recent example is the Zika virus, named for the forest in Uganda, Africa, where it was first discovered in monkeys. Over several decades, this mosquito-borne virus made the jump to humans, spreading across central Africa to Southeast Asia, and them to islands in the Pacific Ocean. Finally, in 2015, it emerged for the first time in South America. Because the population had no immunity to the virus, it spread quickly. In Brazil, there was a sudden increase in serious birth defects among children born to mothers who had been infected with the virus. Once the serious nature of the threat from Zika became known, public health officials moved quickly to try to stop the spread of the virus and the mosquitoes that carry it.

Because viruses replicate so quickly, their genetic makeup can change rapidly, sometimes allowing a virus to evolve in ways that enables it to jump from one species to another. Researchers have evidence that this is how the virus that causes AIDS originated, moving from nonhuman primates into humans.

Public health officials are especially worried about the flu virus. This RNA virus infects cells in the respiratory system, and can lead to severe illness and even death, especially among the elderly. Gene shuffling among different flu viruses infecting wild and domesticated bird populations has led to the emergence of a dangerous "bird flu." This bird flu is similar to the flu that spread worldwide and killed millions of people in 1918. In a few cases, bird flu has indeed infected humans, and health officials warn that a major "jump" into the human population remains possible in the future.

Prions In 1972, American scientist Stanley Prusiner became interested in scrapie, an infectious disease in sheep, the exact cause of which was unknown. At first, he suspected a viral cause, but experiments revealed clumps of tiny protein particles in the brains of infected sheep. Prusiner called these particles prions, short for "protein infectious particles." Although prions were first discovered in sheep, many animals, including humans, can become infected with prions. Prions are formed when a protein known as PrP is improperly folded. Prions themselves can cause PrP proteins to misfold, producing even more prions. An accumulation of prions can damage nerve cells.

CASE STUDY

Figure 21-16

Emerging Diseases

In recent years, new diseases such as Zika and Ebola have appeared. At the same time, some diseases thought to be under control have come back. Both examples are classified as emerging diseases.

HS-LS1-1, HS-LS4-1

LESSON 21.2 Review

KEY QUESTIONS

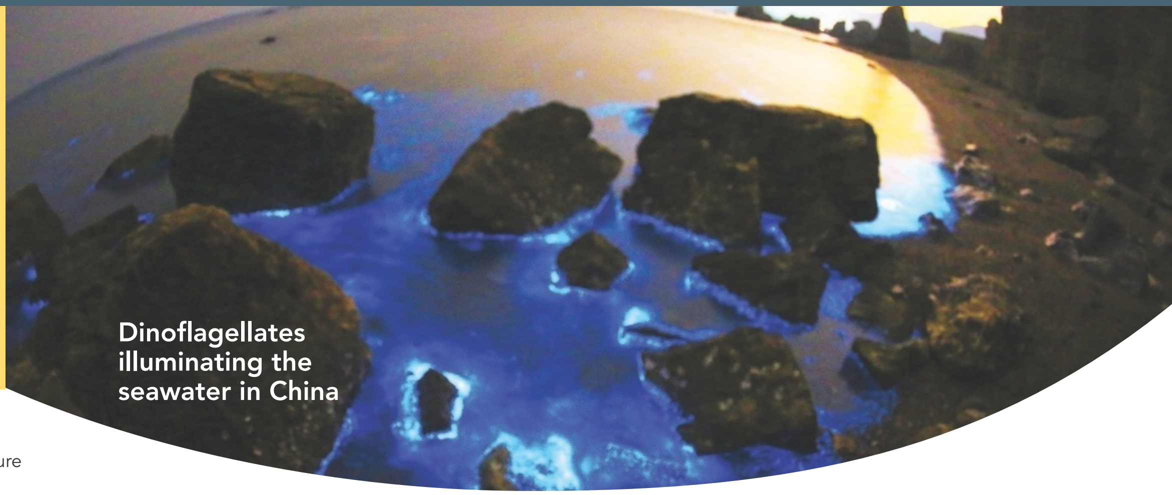
1. Describe the characteristics of the two kingdoms of prokaryotes.
2. In what ways do prokaryotes differ from one another?
3. List three ecological roles of prokaryotes.
4. What are two ways that bacteria cause disease?
5. Why are emerging diseases of particular concern?

CRITICAL THINKING

6. **Apply Scientific Reasoning** You think you might have a bacterial infection. Would you ask for a vaccination against the bacteria? Why or why not?

LESSON 21.3

Protists



Dinoflagellates illuminating the seawater in China

Key Questions

- *How are protists classified?*
- *How do protists move and reproduce?*
- *What role do protists play in the environment?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

VOCABULARY
cilium
flagellum
alternation of generations

READING TOOL

Preview the headings in this lesson to construct an outline. As you read, fill in supporting details for each heading in the outline in your **Biology Foundations Workbook.**

Some of the organisms we call "protists" live quietly on the bottom of shallow ponds, soaking up the energy of sunlight. Others sparkle like diamonds in coastal waters, but still others drift in the human bloodstream, destroying blood cells and killing nearly a million people a year. What kind of life is this, capable of such beauty and such destruction?

What Are Protists?

More than a billion years ago, a new form of organism appeared on Earth. Subtle clues in the microscopic fossils of these single cells mark them as the very first eukaryotes. Single-celled eukaryotes are still with us today and are often called "protists"—a name that means "first." ***Protists are eukaryotes that are not members of the plant, animal, or fungi kingdoms.*** Although most protists are unicellular, quite a few are not. The largest protists—brown algae called kelp—are multicellular organisms that contain millions of cells.

Protists: The First Eukaryotes Microscopic fossils of eukaryotic cells have been found in rocks as old as 1.5 billion years. Genetic and fossil evidence indicates that eukaryotes evolved from prokaryotes and are more closely related to present-day organisms in the domain Archaea than to those in the domain Bacteria. The actual split between Archaea and Eukarya may have come as early as 2.5 billion years ago. Since that time, protists have diversified into as many as 300,000 species found on every corner of the planet. Most of the major protist groups have remained unicellular, but two have produced organisms that developed true multicellularity. It is from the ancestors of these groups that plants, animals, and fungi arose. Today's protists include groups whose ancestors were among the very last to split from the organisms that gave rise to plants, animals, and fungi.

The "Protist" Dilemma In the past, scientists sorted protists into three groups: plantlike protists, animal-like protists, and fungus-like protists. But this simple solution began to fail as biologists learned that many protists do not fit into any of these groups. In fact, the so-called protists display a far greater degree of diversity than any other eukaryotic kingdom. These findings made it necessary to reclassify these remarkable organisms.

The most recent studies of protists divide them into six major clades, shown in **Figure 21-17**, each of which could be considered a living kingdom in its own right. Where would that leave the plant, animal, and fungi kingdoms? Surprisingly, they would fit right into these six clades, and two of them, animals and fungi, actually emerge from the same protist ancestors.

What "Protist" Means Today Today biologists assembling what is often called the *Tree of Life* favor the classification described. But the word *protist* remains in such common usage, even among scientists, that we continue to use it here. Bear in mind, however, that the *protist* are not a single kingdom but a collection of organisms that includes several distinct clades. This is why the term is sometimes surrounded by quotation marks.

READING CHECK **Interpret Diagrams** Which group of "protists" in **Figure 21-17** is most closely related to plants? Which group is most closely related to animals? To fungi?

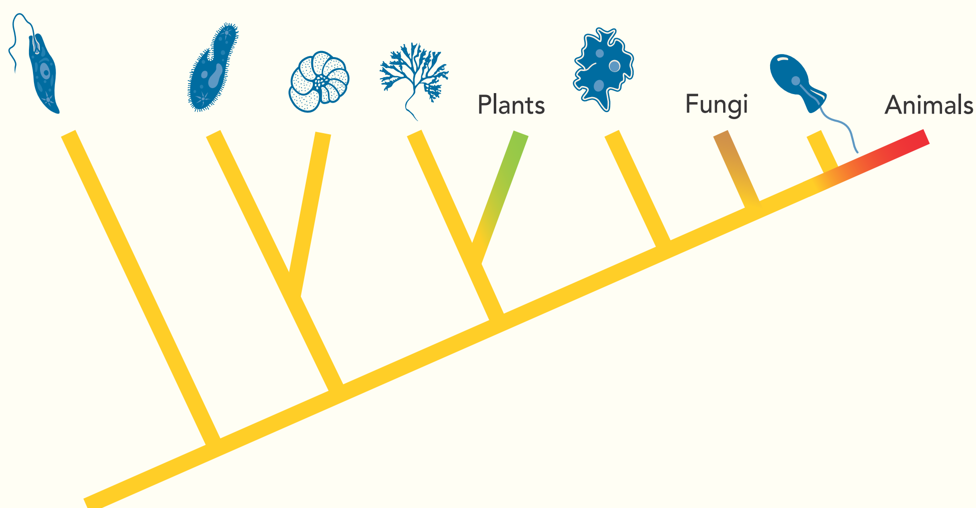
INTERACTIVITY

Figure 21-17

Protists Classification—Work in Progress

This cladogram represents an understanding of protist relationships supported by current research.

Six Major Groups
- Excavata
- Chromalveolata
- Cercozoa, Foraminifera, and Radiolaria
- Rhodophyta (red algae)
- Amoebozoa
- Choanozoa



READING TOOL

Use the visuals in this section to help you understand protist movement, alternation of generations, and other topics.

Structure and Function of Protists

Before they gave rise to multicellular eukaryotes, protists evolved just about every form of cellular movement known to exist. ***Some protists move by changing their cell shape, and some move by means of specialized organelles. Other protists do not move actively but are carried by wind, water, or other organisms.***

Movement Many unicellular protists move like amoebas, changing their shape in a process that makes use of cytoplasmic projections known as pseudopods (SOO doh pahdz). This type of locomotion is called amoeboid movement and is found in many protists.

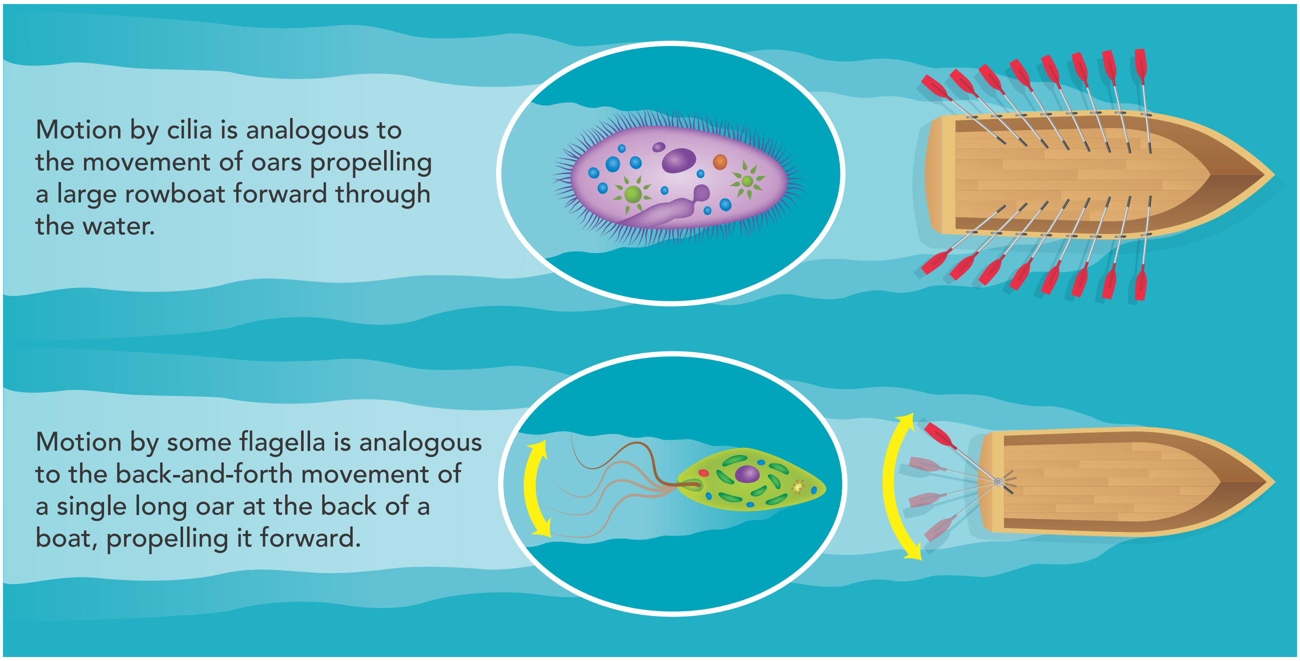
Cilia and Flagella Many protists move around by means of cilia and flagella—structures supported by microtubules. Cilia and flagella have nearly identical internal structures, but they produce cellular motion differently, as described in **Figure 21-18**. **Cilia** (singular: cilium) are short and numerous, and they move somewhat like oars on a boat. **Flagella** (singular: flagellum) are relatively long and usually number only one or two per cell. Some flagella spin like tiny propellers, but most produce a wavelike motion from base to tip.

Visual Analogy

Figure 21-18

How Cells Move Like Boats

The forward motion generated by cilia or flagella is similar to the way oars propel a boat.



Passive Movement Some of the most important protists are nonmotile—they depend on air or water currents and other organisms to carry them around. These protists form reproductive cells called spores that can enter the cells of other organisms as parasites. Spore-forming protists include *Plasmodium*, which is carried by mosquitoes and causes malaria, and *Cryptosporidium*, which spreads through contaminated drinking water and causes severe intestinal disease.

Reproduction The incredible variety of protists is reflected in their varied life cycles. ***Some protists reproduce asexually by mitosis. Others have life cycles that combine asexual and sexual forms of reproduction.***

Asexual Reproduction Most protists reproduce by mitosis: They duplicate their genetic material and then simply divide into two genetically identical cells. Other protists have phases in their life cycle in which they also produce new individuals by mitosis. Mitosis enables protists to reproduce rapidly, especially under ideal conditions, but it produces cells that are genetically identical to the parent cell, and thus limits the development of genetic diversity.

Paramecia and most ciliates also reproduce asexually by mitotic cell division. However, under stress, paramecia can remake themselves through conjugation—a process in which two organisms exchange genetic material. After conjugating, the cells then reproduce by mitosis. Paramecia have two types of nuclei: a macronucleus and one or more smaller micronuclei. The micronucleus is a bit like a reference library holding a "reserve copy" of every gene in the cell. The macronucleus is more like a lending library—it has multiple copies of the genes the cell uses in its day-to-day activities. Conjugation helps to produce and maintain genetic diversity, the raw material for evolution.

INTERACTIVITY

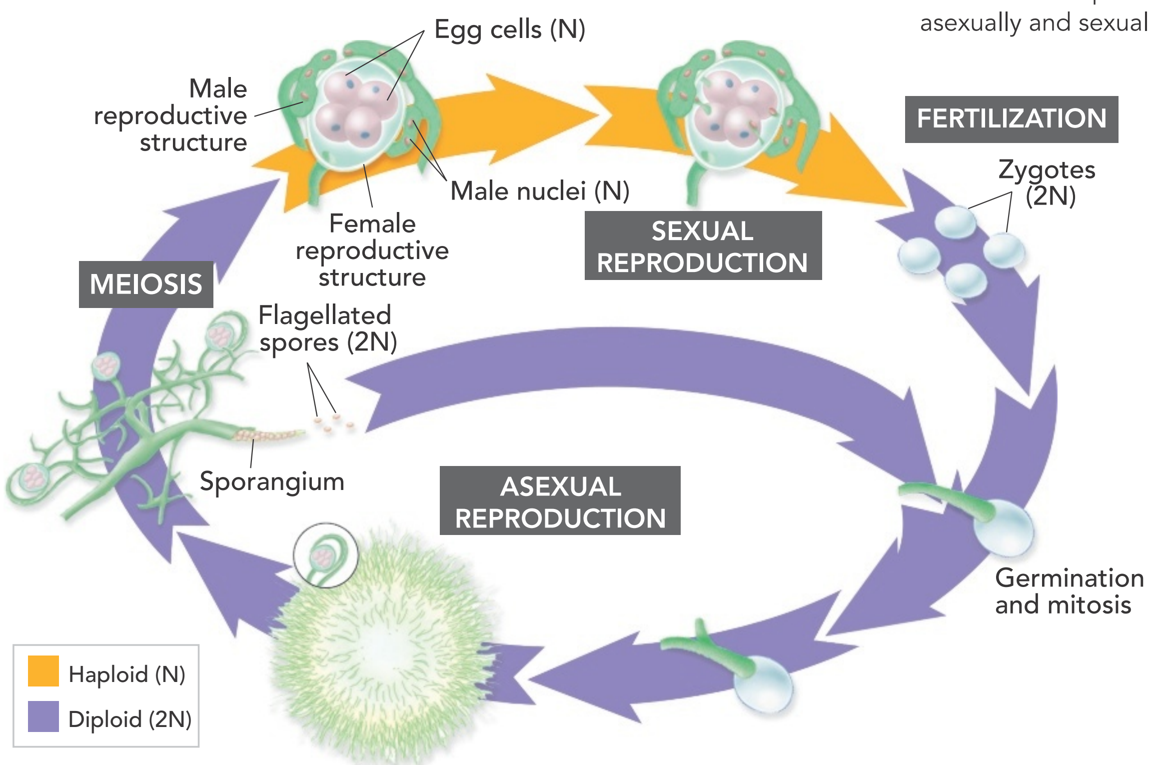
Investigate the kingdom Protista and the characteristics of each of its major groups.

Sexual Reproduction Many protists have sexual life cycles in which they switch between a diploid and a haploid phase, a process known as **alternation of generations**. An example is the life cycle of a type of protist known as a water mold. Water molds thrive on dead and decaying organic matter in water or as parasites of plants on land. The life cycle of a water mold is shown in **Figure 21-19**. Water molds—and many other protists—reproduce asexually by producing spores in a structure called a sporangium. Water molds also reproduce sexually by undergoing meiosis and producing male and female gametes. These gametes fuse during fertilization, forming a zygote that begins a new life cycle.

Figure 21-19

Water Mold Life Cycle

Water molds reproduce both asexually and sexually.



Protists in the Environment

If you've seen greenish scum growing along the banks of a pond or maybe even at the edges of a poorly maintained swimming pool, you might have called it "algae" without thinking. The organisms we call "algae" actually belong to many different groups. Some (the cyanobacteria) are prokaryotes, and some (the green algae) belong to the plant kingdom, but many are protists.

Autotrophic Protists Photosynthetic protists include many phytoplankton species and the red and brown algae, as well as euglenas and dinoflagellates. These organisms share an autotrophic lifestyle, marked by the ability to use the energy from light to make a carbohydrate food source.

Photosynthetic protists play major roles in maintaining the health and wellbeing of many organisms and ecosystems. Some examples of these ecological roles played by photosynthetic protists are shown in **Figure 21-20**. ***The position of photosynthetic protists at the base of the food chain makes much of the diversity of aquatic life possible.***

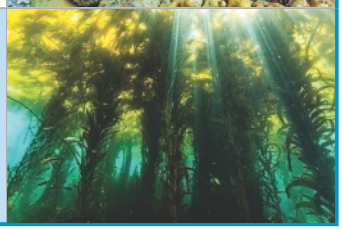
Ecological Roles of Protists		
Providing Food	Photosynthetic protists make up a large portion of phytoplankton found near the surface of oceans and lakes. About half of the photosynthesis that takes place on Earth is carried out by phytoplankton, providing nourishment for organisms as diverse as shrimp and baleen whales.	
Supporting Coral Reefs	Coral reefs provide food and shelter to large numbers of fish and other organisms. Protists known as zooxanthellae provide most of the coral's energy needs by photosynthesis. By nourishing coral animals, these algae help maintain the health and equilibrium of the coral ecosystem. Coralline red algae also help to provide calcium carbonate to stabilize growing coral reefs.	
Providing Shelter	The largest known protist is giant kelp, a brown alga. Kelp forests provide shelter for many marine species, and the kelp itself is a source of food for sea urchins.	

Figure 21-20

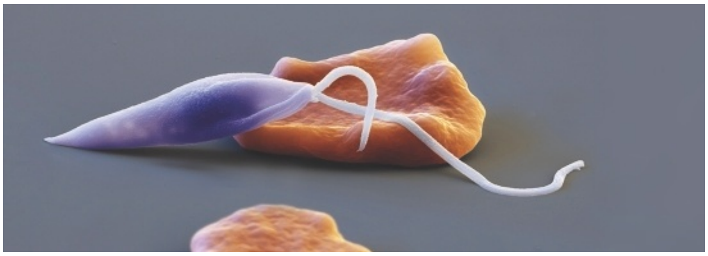
Ecological Roles of Photosynthetic Protists

Photosynthetic protists play many roles in the environment.

Mutualists Given the great diversity of protists, it should come as no surprise that many of them are involved in symbiotic relationships with other organisms. ***Many protists are involved in mutualistic symbioses, in which they and their hosts both benefit.*** One example is a mutualistic relationship involving *Trichonympha*. This protist lives within the digestive systems of termites and helps to produce enzymes that enable the termites to digest wood.

Giardia (SEM 4500×)

Trypanosoma brucei (yellow) and red blood cells (SEM 3600×)



Leishmaniasis (purple) and red blood cell (SEM 6600×)

Parasites Some protists are parasites that cause serious problems. In the United States, some streams and lakes are home to *Giardia*, a protist that causes a range of intestinal problems. ***Parasitic protists are responsible for some of the world's most deadly diseases, including several kinds of debilitating intestinal diseases, African sleeping sickness, and malaria.***

In much of the world, one of the greatest threats to human health is a disease known as malaria, caused by a protist known as *Plasmodium*. This parasite lives in the human bloodstream, and is passed from person to person by the bite of the *Anopheles* mosquito, which is common in tropical regions. In years past, malaria killed as many as a million people a year, many of them children. Developing drugs and vaccines to fight this killer has been a major effort of the World Health Organization. This effort has cut the death rate from malaria by as much as 50 percent in some regions.

Figure 21-21

Disease-Causing Protists

Protist parasites, such as *Giardia*, cause serious and sometimes deadly outbreaks of intestinal disease. Protists of the genus *Trypanosoma* cause African sleeping sickness. Leishmaniasis is caused by *Leishmania* protists and is common in tropical regions of the world.

VIDEO

Learn about malaria and how it is transmitted.

HS-LS1-1, HS-LS1-2, HS-LS4-1

LESSON 21.3 Review

KEY QUESTIONS

1. How does the updated classification of protists differ from the older classification?
2. How is movement by means of flagella different from movement by means of cilia?
3. How would ocean food chains change in the absence of photosynthetic protists?

CRITICAL THINKING

4. **Evaluate Models** Compare **Figure 21-17** with the model of the Tree of Life presented in Chapter 19. What simplification does **Figure 21-17** make? How could this simplification be misinterpreted? Explain your answer.
5. **Compare and Contrast** Compare asexual and sexual processes in paramecia. Include the terms *mitosis* and *meiosis* in your answer. You may want to refer back to Chapters 11 and 12 to review mitosis and meiosis.

LESSON 21.4

Fungi

KEY QUESTIONS

- *What are the basic characteristics of fungi?*
- *How do fungi affect homeostasis in other organisms and the environment?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

VOCABULARY

chitin
hyphae
fruiting body
mycelium
lichen
mycorrhiza

READING TOOL

As you read, complete the chart in your **Biology Foundations Workbook** that describes the form and structure of fungi.

How many organisms are shown in the photo? You might guess 50 or 60, one for each mushroom. However, the whole ring of mushrooms is actually part of a large single organism. Most of the mass of the fungus is underground, spanning at least the width of the ring of mushrooms, and extending more than 2 meters into the ground.

What Are Fungi?

Like the ring of mushrooms, many fungi grow from the ground. This once led scientists to classify them as nonphotosynthetic plants. But they aren't plants at all. Instead of carrying out photosynthesis, fungi produce powerful enzymes that digest food outside their bodies. Then they absorb the small molecules released by the enzymes. Many fungi feed by absorbing nutrients from decaying matter in the soil. Others live as parasites, absorbing nutrients from the bodies of their hosts.

Another defining characteristic of fungi is the composition of their cell walls, which contain chitin. **Chitin** is a polymer made of modified sugars that is also found in the external skeletons of insects. The presence of chitin is one of several features that show fungi are more closely related to animals than to plants. ***Fungi are heterotrophic eukaryotes with cell walls that contain chitin.***

Bracket fungi

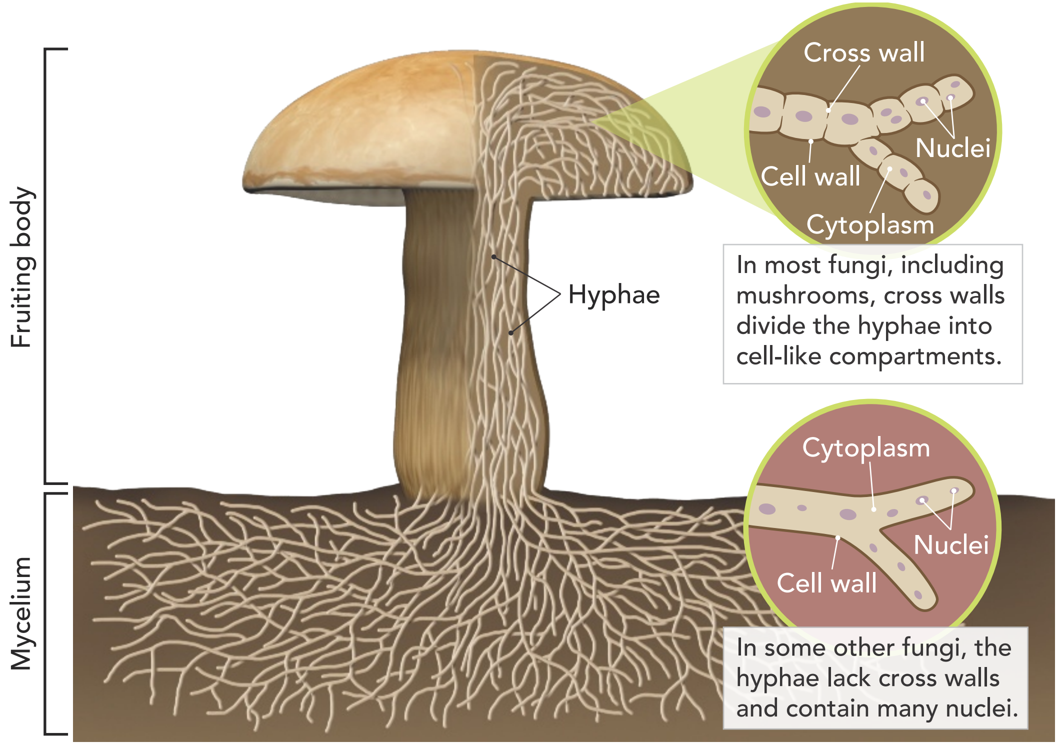
Structure and Function Some fungi, known as yeasts, live most of their lives as single cells. But mushrooms and other fungi grow much larger, their bodies made up of cells that form long, slender branching filaments called **hyphae** (singular: hypha), as shown in **Figure 21-22**. In most fungi, cross walls divide the hyphae into compartments resembling cells, each containing one or two nuclei. In the cross walls, there are openings through which cytoplasm and organelles such as mitochondria can move.

What you recognize as a mushroom is actually the **fruiting body**, the reproductive structure of the fungus. The fruiting body grows from the **mycelium** (plural: mycelia), the mass of branching hyphae below the soil. Clusters of mushrooms are often part of the same mycelium, which means that they are actually part of the same organism.

Figure 21-22

Structure of a Mushroom

The body of a mushroom is its reproductive structure, also called a fruiting body. The major portion of the organism is the mycelium, which grows underground.



Exploration Lab Open-Ended Inquiry

Mushroom Farming

Problem How does the amount of available light affect mushroom growth?

In this lab, you will design an experiment to determine the effect of light on the growth of a fruiting body. Your group will monitor one of three experimental setups and share your results. You will then analyze the pooled data from the entire class to determine the optimal conditions for mushroom growth.

You can find this lab in your digital course.

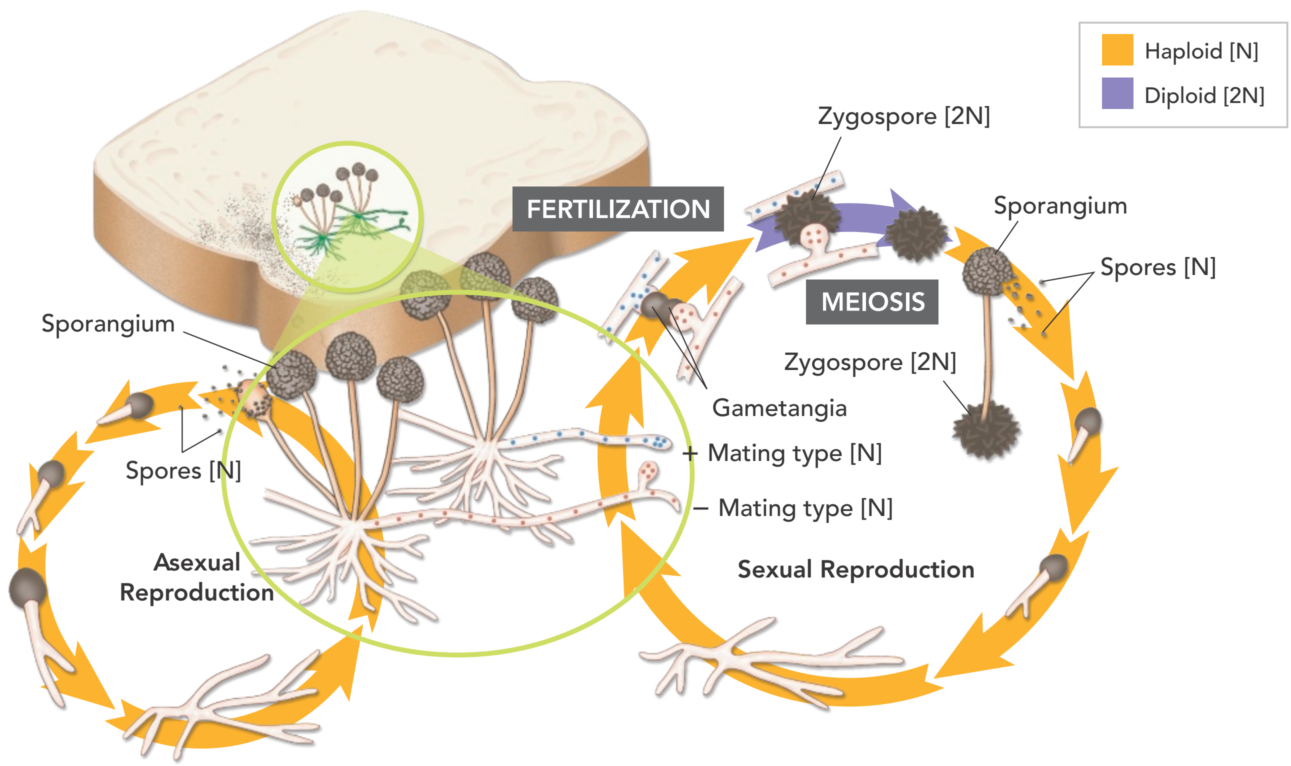


Figure 21-23

Bread Mold Life Cycle

During sexual reproduction in the black bread mold *Rhizopus stolonifer*, hyphae from two different mating types form gametangia. The gametangia fuse, and zygotes form within a zygospore. The zygospore eventually germinates, and a sporangium emerges.

INTERACTIVITY

Learn about the characteristics of the different groups of fungi.

Reproduction Fungi can reproduce asexually, primarily by releasing spores that travel through air and water. Simply breaking off a hypha or budding off a cell can also serve as asexual reproduction.

Most fungi also can reproduce sexually. **Figure 21-23** shows the life cycle of a type of bread mold, a fungus called *Rhizopus stolonifer*. Sexual reproduction in fungi often involves two different mating types. In *Rhizopus*, as in most fungi, gametes of both mating types are about the same size and are not usually called male and female. Instead, one mating type is called "+" (plus) and the other "–" (minus). The + and – nuclei form pairs that divide in unison as the mycelium grows. Many of the paired nuclei fuse to form diploid zygote nuclei, which go through meiosis to make haploid spores. Each spore has a different combination of parental genes, and each can make a new mycelium.

Diversity of Fungi More than 100,000 species of fungi are known. Of course, they all share the characteristics that define them as fungi but they differ from one another in important ways. Biologists have used these similarities and differences, along with DNA comparisons, to place the fungi into several distinct groups. The major groups of fungi differ from one another in their reproductive structures, as summarized in **Figure 21-24**.

READING CHECK **Describe** What is the structure of a typical fungus?

The Major Phyla of Fungi		
Phylum	Distinguishing Features	Examples
Basidiomycota (club fungi) 	Sexual spores found in club-shaped cell called a basidium	Mushrooms, puffballs, earthstars, shelf fungi, jelly fungi, rusts
Ascomycota (sac fungi) 	Sexual spores found in saclike structure called an ascus	Morels, truffles, *Penicillium* species, baker's yeast
Zygomycota (common molds) 	Tough zygospore produced during sexual reproducing that can stay dormant for long periods	*Rhizopus stalonifer* (black bread mold), molds found on rotting strawberries and other soft fruits, mycorrhizae associated with plant roots
Chytridomycota (chytrids) 	Only fungi with flagellated spores	Many species are decomposers found in lakes and moist soil.

Figure 21-24

The Major Phyla of Fungi

The table summarizes the main differences among the four major phyla of fungi. **Infer** Would you expect to find chytrids in aquatic or terrestrial habitats? Explain your answer.

Fungi in the Environment

Fungi play an essential role in maintaining ecosystem health and equilibrium. But there are also some species that disrupt health by causing disease in plants and animals.

Decomposition

Many fungi feed by releasing digestive enzymes that break down leaves, fruit, and other organic material into simple molecules they can absorb as food. This has the effect of recycling important minerals and nutrients into the soil. ***Fungi help ecosystems maintain homeostasis by breaking down dead organisms and recycling essential elements and nutrients.***

Parasitism

As useful as many fungi are, others can infect plants and animals. ***Parasitic fungi can cause serious diseases in plants and animals by disrupting homeostasis.***

Plant Diseases A number of parasitic fungi cause diseases that threaten food crops. Corn smut, for example, destroys corn kernels, and wheat rust affects one of the most important crops grown in North America. Fungal diseases are responsible for the loss of approximately 15 percent of the crops in temperate regions of the world and even more of the crops grown in tropical areas.

Animal Diseases Fungal diseases also affect insects, frogs, and mammals. Amphibians worldwide have been impacted by one deadly fungus—*Batrachochytrium dendrobatidis* (*Bd*). This fungus typically lives in water or soil. It reproduces asexually and the resulting spores are present in the water. When an amphibian comes into contact with the water that contains the spores, the fungus invades the outer layer of the skin, disrupting the immune system and ultimately causing death. *Bd* has been blamed for the extinction of hundreds of amphibian species and poses a threat to up to one third of the world's amphibian populations.

INTERACTIVITY

Investigate how invasive pathogens impact species recovery programs.

READING TOOL

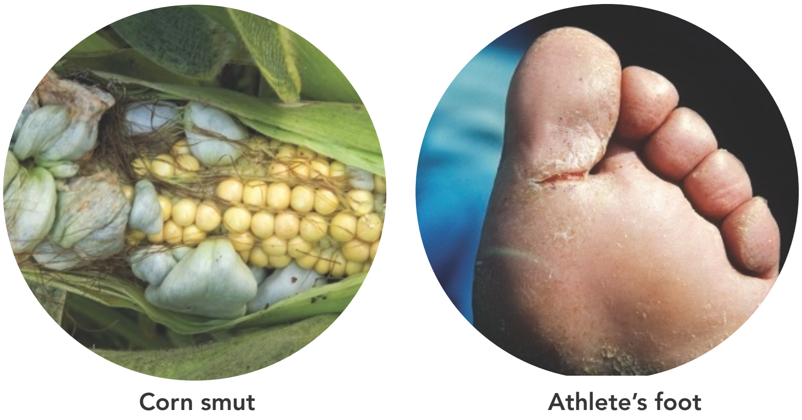
As you read this section, compare the roles of fungi with those of prokaryotes and protists. Think about the benefits and diseases caused by all three groups.

INTERACTIVITY

Figure 21-25

Parasitic Fungi

Corn smut infests the kernels of a corn plant, reducing the farmer's crop yield (left). Athlete's foot is caused by the fungus *Tinea pedis* (right.)



Parasitic fungi can also infect humans, as shown in **Figure 21-25**. The fungus that causes athlete's foot forms a mycelium in the outer layers of the skin, which produces a red, inflamed sore from which the spores can easily spread from person to person. Fungi are also responsible for vaginal yeast infections and for infections of the mouth called thrush. Fungi in these regions of the body are usually kept in check by competition from bacteria and by the body's immune system. This balance can be upset by the use of antibiotics, which kill bacteria, or by damage to the immune system.

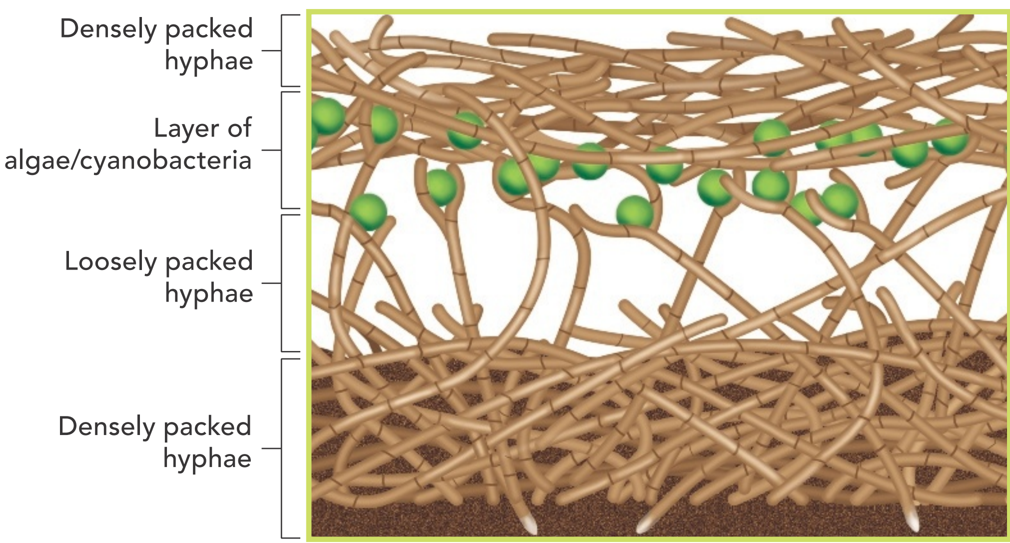
Lichens The close relationships fungi form with members of other species are not always parasitic in nature. Some fungi form mutualistic associations with photosynthetic organisms in which both partners benefit. For example, a **lichen** is a symbiotic association between a multicellular fungus, a yeast, and a photosynthetic organism. The photosynthetic organism is either a green alga or a cyanobacterium, or both. **Figure 21-26** shows the structure of a lichen.

Lichens are often the first organisms to enter barren environments, gradually breaking down the rocks on which they grow. In this way, lichens help in the early stages of soil formation. Lichens are also remarkably sensitive to air pollution: They are among the first organisms to be affected when air quality deteriorates.

Figure 21-26

Inside a Lichen

The protective upper surface of a lichen is made up of densely packed fungal hyphae. Below this are layers of green algae or cyanobacteria and loosely woven hyphae. The bottom layer contains small projections that attach the lichen to a rock or tree. **Infer** How do lichens assist in soil formation?



Mycorrhizae Fungi also form mutualistic relationships with plant roots. Almost half of the tissues of trees are hidden beneath the ground in masses of tangled roots. These roots are woven into a partnership with an even larger web of fungal mycelia. These symbiotic associations of plant roots and fungi are called **mycorrhizae** (my koh RY zee; singular: mycorrhiza).

Researchers now estimate that 80 to 90 percent of all plant species form mycorrhizae with fungi. Mycorrhizae gather water and nutrients from the soil, and are essential for the growth of many plants. The seeds of orchids, for example, cannot germinate in the absence of mycorrhizal fungi. Many trees are unable to survive without fungal symbionts. Interestingly, the partnership between plant and fungus does not end with a single plant. The roots of each plant are plugged into mycorrhizal networks that connect many plants. What's more astounding is that these networks appear to connect plants of different species.

A recent experiment showed that carbon atoms from one tree often end up in another tree nearby. In an experiment using isotopes to trace the movement of carbon, ecologist Suzanne Simard found that mycorrhizal fungi transferred carbon from paper birch trees growing in the sun to Douglas fir trees growing in the shade. As a result, the sun-starved fir trees thrived, basically by being "fed" carbon from the birches. Simard's findings suggest that plants—and their associated fungi—may be evolving as a partnership essential to ecosystem health.

Human Uses of Fungi Humans have used mushrooms and other fungi as food for thousands of years. While some wild mushrooms are poisonous, many other species are not only highly nutritious, but delicious to eat. Fungi also help to make two of the most ancient forms of human food and drink. Bread and wine are both formed by the action of those single-celled fungi known as yeasts.

BUILD VOCABULARY

Prefixes The prefix *myco-* refers to fungi. *Mycology* is the study of fungi.

Figure 21-27

Birch Trees

Studies have shown that mycorrhizal relationships between birch trees and Douglas fir trees might help maintain ecosystem health.

HS-LS1-1, HS-LS1-2, HS-LS4-1

LESSON 21.4 Review

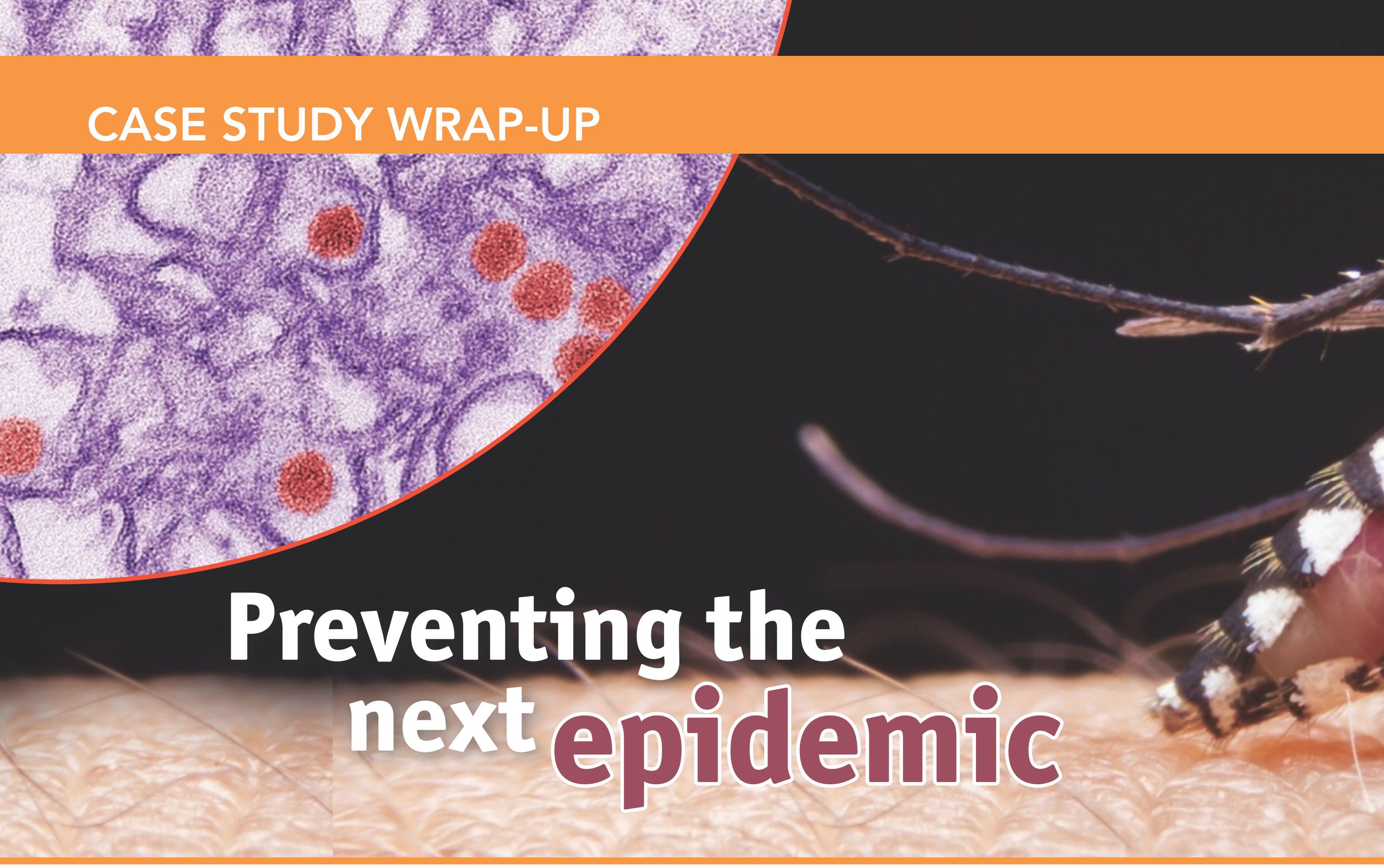
KEY QUESTIONS

1. Identify the characteristics that all fungi have in common.
2. Summarize the role of fungi in maintaining homeostasis in a forest ecosystem.

CRITICAL THINKING

3. **Identify** Both bacteria and fungi are decomposers. What characteristics do these two groups share that allow them to function in this ecological role?
4. **Construct an Explanation** You notice several mushrooms growing in a ring in a grassy yard. Are you likely observing many organisms or a single organism? Explain.

CASE STUDY WRAP-UP



Preventing the next epidemic

Throughout history, humans have suffered from a wide variety of infectious diseases. New and emerging diseases continue to be a threat. What can be done to help combat disease outbreaks?

HS-ETS1-1, HS-ETS1-3, CCSS.ELA-LITERACY.RST.9-10.1, CCSS.ELA-LITERACY.RST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.1, CCSS.ELA-LITERACY.WHST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.7, CCSS.ELA-LITERACY.WHST.9-10.8, CCSS.ELA-LITERACY.WHST.9-10.9

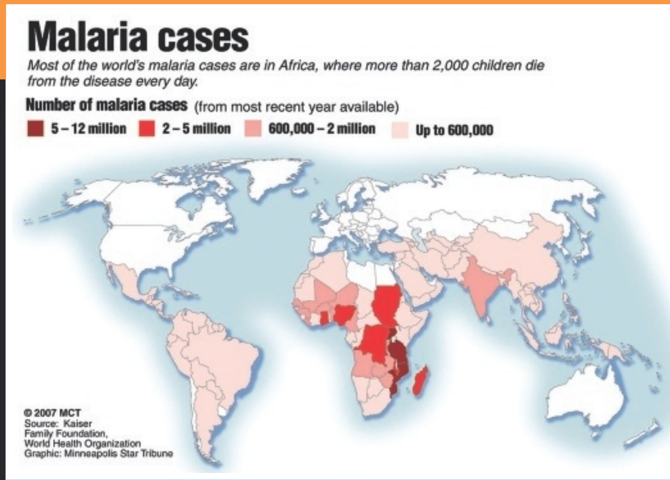
Make Your Case

The human population is more connected than ever before. Vehicles carry people and cargo from place to place, and all over the world. All of these vehicles carry unintended microscopic passengers, some of which may cause disease.

Choose one of the infectious diseases that has recently been in the news, such as Ebola or Zika. Do some library or Internet research to find out what pathogen causes the disease, where it first was discovered, and what is being done to control the outbreak.

Communicate Information

1. **Construct an Explanation** What was the response to the disease you researched? Was the disease controlled or contained?
2. **Evaluate a Solution** Based on your research, how effective was the solution that was implemented? Is there another solution or recommendation you would suggest based on your research? Cite evidence to support your ideas.



Technology on the Case

The Internet to the Rescue

Many people use the Internet to self-diagnose an injury or illness. Depending on the site you use, you might get good advice or maybe not-so-good advice. However, in this age of technology, the Internet is often your first choice in obtaining a lot of information quickly.

Millions of people turn to the Internet when they are feeling sick—and so do healthcare professionals. John Brownstein works at Boston Children's Hospital and is a professor at Harvard Medical School. He and his colleagues developed a system for tracking infectious diseases online. The system automatically scans a wide variety of Web sites and social media for reports of diseases and overall health. Then it plots the reports on a global map. Outbreaks are shown almost exactly at the same time as they occur. In comparison, traditional methods of tracking diseases involve analyzing reports from doctors and hospitals. Traditional reports identify outbreaks about two weeks after they start.

Epidemiologists are also looking at another unlikely source of health data: mobile phones. People often leave an area when a health crisis strikes—and they take their mobile phones with them. By tracking changes in the location of mobile phones, officials can determine where a health crisis is striking and where to invest resources.

Careers on the Case

Work Toward a Solution

Physicians and nurses are trained to diagnose and treat diseases in individuals. Some medical specialists, however, work to protect the entire human population from diseases.

Epidemiologist

You can think of an epidemiologist as a disease detective. Epidemiologists analyze the cause of disease outbreaks and take action to prevent them. They are employed by hospitals, universities, and government agencies, and work closely with hospitals and other community groups who interact directly with the public.

VIDEO

Watch this video to learn about other careers in biology.

hhmi | BioInteractive

Lesson Review

Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

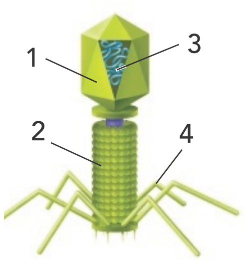
21.1 Viruses

A typical virus is composed of a core of DNA or RNA surrounded by a protein coat.

Viruses can reproduce only by infecting living cells. In a lytic infection, a virus enters a cell, makes copies of itself, and causes the cell to burst. In a lysogenic infection, a virus integrates its DNA into the DNA of the host cell, and the viral genetic information replicates along with the host cell's DNA.

Viruses cause disease by directly destroying living cells or by affecting cellular processes in ways that upset homeostasis. Despite the fact that they are not alive, viruses have many of the characteristics of living things.

- virus
- capsid
- lytic infection
- bacteriophage
- lysogenic infection
- prophage
- retrovirus



Use Visuals Label the parts of this typical bacteriophage.

21.2 Prokaryotes

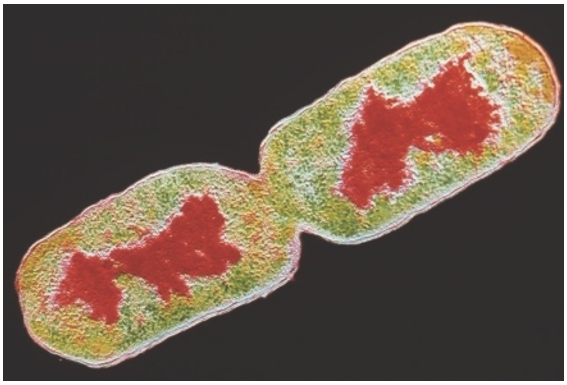
Prokaryotes are classified as Bacteria or Archaea—two of the three domains of life. Bacteria have cell walls made of peptidoglycan. Archaea do not contain peptidoglycan.

Prokaryotes vary in their size and shape, in the way they move, and in the way they obtain and release energy.

Prokaryotes are essential in maintaining every aspect of the ecological balance of the living world. Some prokaryotes are producers that capture energy by photosynthesis. Others break down the nutrients in dead matter and the atmosphere. Some species of prokaryotes have specific uses in human industry. Other bacteria disrupt health and cause disease by destroying living cells or by releasing chemicals that upset homeostasis.

An emerging disease is either a previously unknown disease that appears in a population for the first time or a well-known disease that suddenly becomes harder to control.

- prokaryote
- binary fission
- endospore
- conjugation
- pathogen
- vaccine
- antibiotic



Interpret Photos What process is being shown in this photograph?

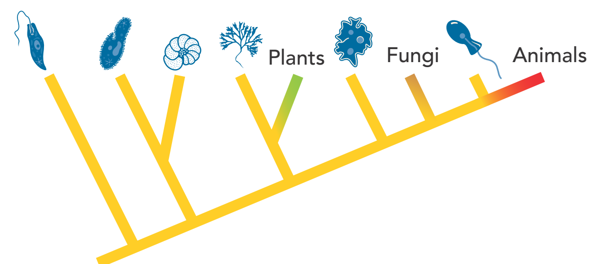
21.3 Protists

Protists are eukaryotes that are not members of the plant, animal, or fungi kingdoms.

Protists vary in their structure and function. Some protists move by changing their cell shape, and some move by means of specialized organelles. Other protists do not move actively but are carried by wind, water, or other organisms. Some protists reproduce asexually by mitosis. Others have life cycles that combine asexual and sexual forms of reproduction.

Protists can help maintain homeostasis in an environment, but they also can disrupt homeostasis. Photosynthetic protists make much of the diversity of aquatic life possible. In addition, many protists are involved in mutualistic symbioses, in which they and their hosts both benefit. However, parasitic protists are responsible for some of the world's most deadly diseases, including several kinds of debilitating intestinal diseases, African sleeping sickness, and malaria.

- cilium
- flagellum
- alternation of generations



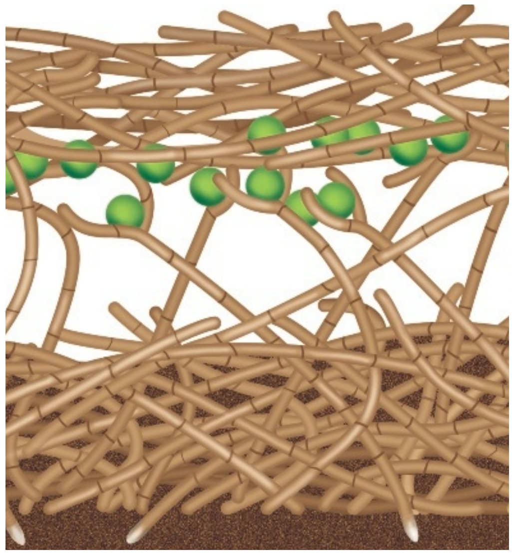
Interpret Diagrams What does this cladogram tell you about the classification of protists?

21.4 Fungi

Fungi are heterotrophic eukaryotes with cell walls that contain chitin.

Fungi help ecosystems maintain homeostasis by breaking down dead organisms and recycling essential elements and nutrients. Parasitic fungi can cause serious diseases in plants and animals by disrupting homeostasis.

- chitin
- hyphae
- fruiting body
- mycelium
- lichen
- mycorrhiza



Interpret Visuals Describe the relationship that forms the lichen.

Organize Information

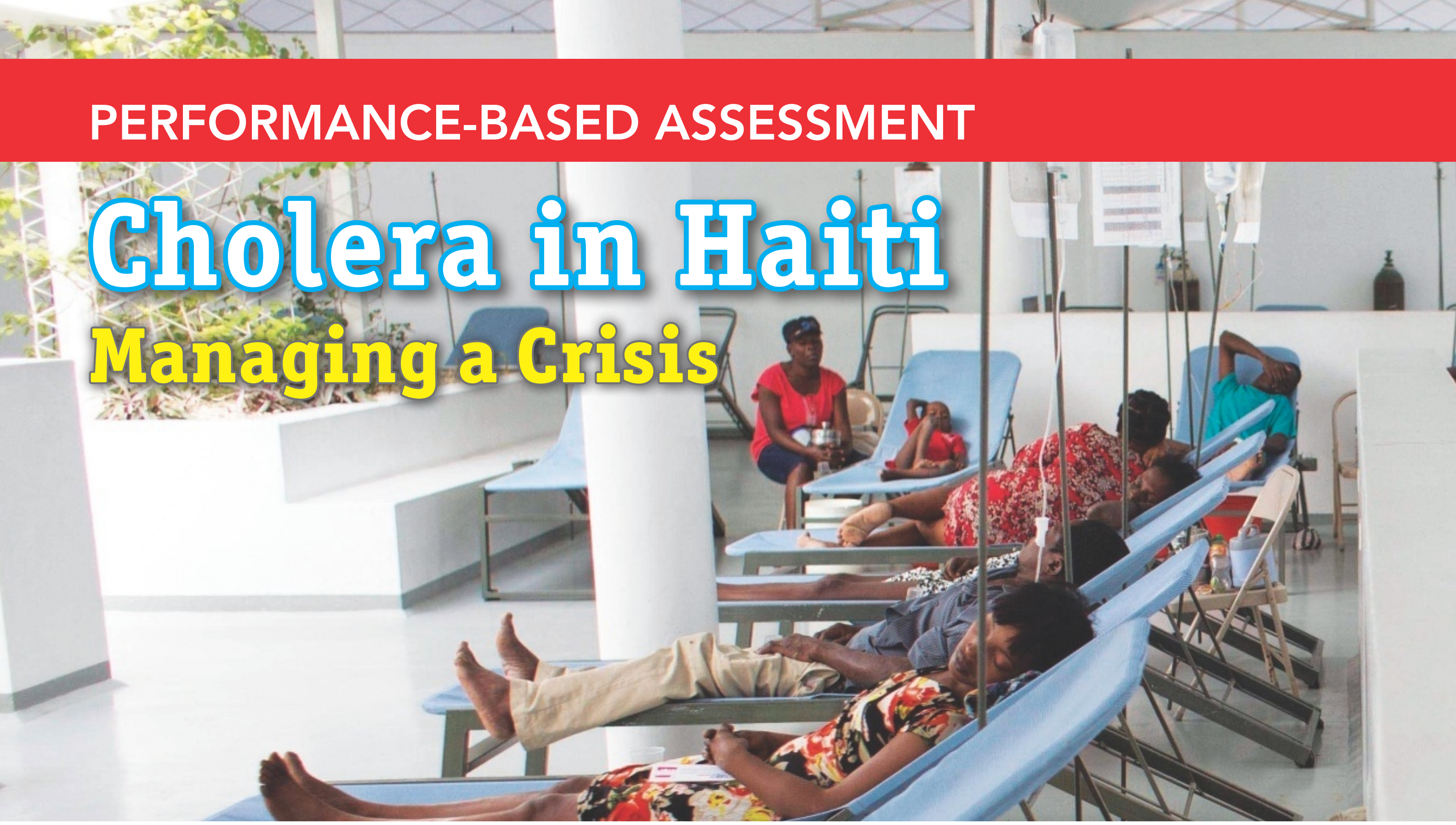
Complete the table that lists the characteristics of both protists and fungi.

	Movement	Reproduction	Method of Obtaining Food	Beneficial Roles	Harmful Roles
Protists	1.	Some reproduce asexually by mitosis. Some reproduce sexually and alternate between diploid and haploid phases.	2.	3.	4.
Fungi	5.	6.	Heterotrophic; absorb nutrients through cell wall or hyphae	7.	8.

PERFORMANCE-BASED ASSESSMENT

Cholera in Haiti

Managing a Crisis



Obtaining, Evaluating, and Communicating Information

HS-ETS1-1, HS-ETS1-3, CCSS.ELA-LITERACY.RST.9-10.1, CCSS.ELA-LITERACY.RST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.1, CCSS.ELA-LITERACY.WHST.9-10.2, CCSS.ELA-LITERACY.WHST.9-10.6, CCSS.ELA-LITERACY.WHST.9-10.7, CCSS.ELA-LITERACY.WHST.9-10.8

STEM The country of Haiti has suffered many problems over the years, but cholera had not been one of them. Then, in 2010, a strong earthquake struck the island. Rescue workers arrived to help victims recover. Unfortunately, the workers likely brought with them the bacteria that cause cholera. Haiti soon was suffering its first cholera epidemic—and others would follow. By 2016, cholera had killed about 10,000 Haitians. Whole communities were wiped out.

Cholera is a bacterial infection of the digestive tract that causes watery diarrhea. Without treatment, victims can die quickly from dehydration. The bacteria, named *Vibrio cholerae*, spread through contaminated drinking water. For this reason, cholera outbreaks can be common in places, such as Haiti, where sanitation is poor and people live close together. How should cholera be managed in Haiti today? Public health officials are struggling to find the best combination of separate strategies. Some possible strategies include vaccination, education, and improved sanitation.

- **Vaccine** In 2016, health officials in Haiti launched a campaign to administer the vaccine against cholera in high-risk areas. Their goal was to vaccinate 800,000 people, which is about 8 percent of the population.
- **Education** Haitians are learning how to prevent cholera by treating drinking water with chlorine and washing hands before they eat.
- **Improved Sanitation** Installing and maintaining modern sewage systems is perhaps the most effective way to prevent cholera and similar diseases. However, these systems are expensive.

1. **Define the Problem** Why does cholera remain a problem in Haiti?

2. **Conduct Research** Find out how public health officials are preventing and treating cholera in Haiti today. Work in a small group to research the variety of strategies used in Haiti, including vaccination programs, quarantines to contain cholera outbreaks, treatment methods for cholera victims, and efforts to provide clean drinking water and improved sanitation throughout the country. Record your findings. Be sure to evaluate your sources for accuracy.

3. **Connect to Society** A great cholera epidemic ravaged the city of London in 1854. The epidemic was ended by the work of a physician named Dr. John Snow. Consult historical resources to learn how Dr. Snow discovered the source of the epidemic and also how he helped public health authorities to end it. Does the history of the London epidemic suggest any lessons for the best way to combat cholera in Haiti?

4. **Evaluate** Review the results of your research. How do you evaluate the different strategies and methods for fighting cholera in Haiti? In your evaluation, consider the importance of containing a cholera epidemic if it occurs, as well as preventing future epidemics.

5. **Construct an Argument** Based on your research, what actions or policies for fighting cholera would you recommend to the government, public health officials, and people of Haiti? Describe both the costs and benefits of your recommendations, as well as the potential consequences if no new actions were taken. Try to include scientific evidence, logical reasoning, and an economic analysis to support your argument.

6. **Communicate** Organize your research findings and your argument for a solution in an essay or computer presentation. Share your report with classmates.

CHAPTER 21

ASSESSMENT

KEY QUESTIONS AND TERMS

21.1 Viruses

HS-LS4-2

1. Particles made up of proteins, nucleic acids, and sometimes lipids that can reproduce only by infecting living cells are called
   a. bacteria.
   b. capsids.
   c. prophages.
   d. viruses.
2. One group of viruses that contain RNA as their genetic information is the
   a. bacteriophages.
   b. retroviruses.
   c. capsids.
   d. prophages.
3. What characteristics do all viruses have in common?
4. How are capsid proteins important to the way a virus functions?
5. Describe the sequence of events that occurs during a lytic infection.
6. What is a prophage?
7. What is the best way for people to protect themselves against most viral diseases?

21.2 Prokaryotes

HS-LS4-2

8. Prokaryotes are unlike all other organisms in that their cells
   a. lack nuclei.
   b. have organelles.
   c. have cell walls.
   d. lack nucleic acids.
9. Prokaryotes reproduce asexually by
   a. binary fission.
   b. endospores.
   c. conjugation.
   d. mutation.
10. What are the two distinguishing characteristics of prokaryotes?
11. Describe the three main cell shapes of prokaryotes.
12. Describe two methods by which prokaryotes move.
13. What is meant by the term *emerging disease*? Give three examples of emerging diseases.

21.3 Protists

HS-LS4-2

14. The fossil record shows that the first eukaryotes may have appeared on Earth
    a. more than 4 billion years ago.
    b. more than 1 billion years ago.
    c. about 500 million years ago.
    d. about 100 million years ago.
15. Which of the following statements is most accurate?
    a. Protists are more closely related to one another than to other organisms in other kingdoms.
    b. Protists are the direct descendants of bacteria.
    c. The classification of protists is a work in progress.
    d. Scientists are debating between two classification schemes for protists.
16. Alternation of generations is the process of alternating between
    a. mitosis and meiosis.
    b. asexual and sexual reproduction.
    c. male and female reproductive structures.
    d. diploid and haploid phases.
17. What is the problem with the traditional classification of protists into plantlike, animal-like, and funguslike groups?
18. Why do scientists think that all modern plants, animals, and fungi can be traced to protist ancestors?
19. What function do the cilia and flagella in protists carry out? How do they differ in structure?
20. Summarize the process of conjugation. Is conjugation a form of reproduction? Explain.

21.4 Fungi

HS-LS4-2

21. Which of the following statements about fungi is false?
    a. All fungi are unicellular.
    b. All fungi have cell walls.
    c. All fungi are eukaryotic.
    d. All fungi are heterotrophs.
22. A symbiotic relationship between a fungus and a green alga or a cyanobacterium is a
    a. mycorrhiza.
    b. fruiting body.
    c. lichen.
    d. mushroom.
23. Distinguish between the terms *hypha* and *mycelium*.
24. What is the evolutionary significance of mycorrhizae?

CRITICAL THINKING

HS-LS4-2

25. **Compare and Contrast** In terms of their mechanism of infection, how does a cold virus differ from the HIV virus?
26. **Construct Explanations** Explain how a virus can spread in a bacterial population during the lysogenic phase of infection.
27. **Construct Explanations** Bacteria that live on teeth produce an acid that causes decay. Why do people who do not brush their teeth regularly have more cavities than those who do?
28. **Compare and Contrast** Explain how the outcome of binary fission differs from that of both endospore formation and conjugation.
29. **Apply Concepts** What advantages does the physical removal of infectious microbes by hand washing have over the use of disinfectants? Explain.
30. **Use Analogies** You might have a drawer in your kitchen that is a "junk drawer": a drawer filled with keys, rubber bands, pens, string, rulers, and other items that aren't easy to categorize. How is the protist kingdom like a "junk drawer," and why do you think scientists would like to change that situation?
31. **Predict** Holes in Earth's ozone layer may increase the amount of radiation that reaches the surface of the ocean. If this radiation affects the growth of phytoplankton, what do you think the long-term consequences would be for Earth's atmosphere? Explain your answer.
32. **Construct Explanations** The antibiotic penicillin is a natural secretion of a certain kind of fungus—a green mold called *Penicillium*. Penicillin kills bacteria. Why do you think a mold species has evolved a way to kill bacteria?

A scientist is investigating the effect of three hygiene treatments on bacterial growth. In an experiment, a person's treated hand is swabbed with a sterile cotton ball. Then the cotton is rubbed across a petri dish containing a growth medium. The table shows the results of two trials of the experiment.

Use the data table to answer questions 33 and 34.

Hand Treatment	Trial 1: Number of Colonies	Trial 2: Number of Colonies
Unwashed	247	210
Rinsed in warm water	190	220
Washed with soap and warm water	21	15
Rinsed in alcohol and air-dried	3	0

33. **Calculate** Determine the average number of bacteria colonies for each treatment.
34. **Analyze Data** Compare the effectiveness of the three treatments.

CROSSCUTTING CONCEPTS

35. Cause and Effect Explain how a mutation in a bacterial cell could help it become resistant to infection by a bacteriophage.

36. Cause and Effect Suppose certain bacteria lost the ability to fix nitrogen. How would this affect other organisms in their ecosystem?

37. Patterns A newly discovered organism is unicellular, has a cell wall containing peptidoglycan, has a circular DNA molecule, and lacks a nucleus. Based on those characteristics, to which domain does it belong?

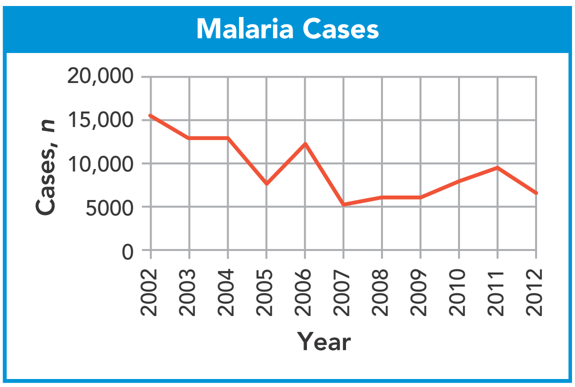
MATH CONNECTIONS

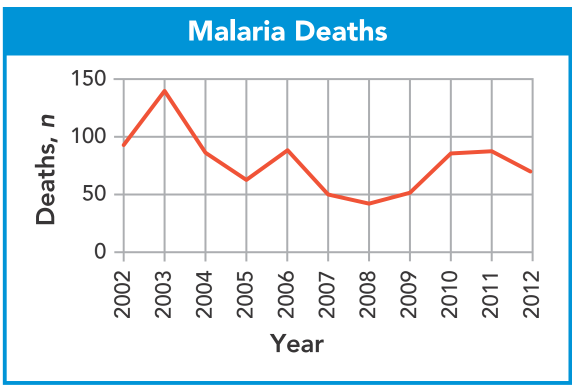
Analyze and Interpret Data

CCSS.MATH.CONTENT.MP2, CCSS.MATH.CONTENT.MP4

South Africa is a country located at the southern tip of Africa. Beginning in 2000, the South African government enacted several policies for controlling malaria. The policies included improved mosquito control.

The graphs show the cases of malaria and deaths from malaria in South Africa from 2000 to 2012. Use the graphs to answer questions 38–40.





Source: Malaria Research Unit, Medical Research Council

38. Identify Patterns Describe the pattern in malaria cases and deaths shown in the graph.

39. Reason Quantitatively For the year 2006 in South Africa, what percentage of malaria cases were fatal?

40. Evaluate a Claim A scientist claims that improved mosquito control caused the decrease in malaria in South Africa. Use the data shown in the graph and your knowledge of malaria to evaluate this claim.

LANGUAGE ARTS CONNECTIONS

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2

41. Write Procedures A middle-school student is using a microscope to observe several single-celled organisms. The student wants to classify each organism as either a prokaryote or a protist. Write a procedure for the student to follow to complete this task.

42. Write Informative Texts Write a paragraph that describes a symbiotic relationship formed by bacteria, protists, or fungi.

Read About Science

CCSS.ELA-LITERACY.RST.9-10.2, CCSS.ELA-LITERACY.RST.9-10.4, CCSS.ELA-LITERACY.RST.9-10.6

43. Summarize Text Describe the main properties of viruses, prokaryotes, protists, and fungi.

44. Determine Meaning Explain the meanings of the terms *pathogen*, *emerging disease*, *epidemic*, and *vaccine*. Why are diseases an important topic for this chapter?

45. Author's Purpose Near the end of the lesson on fungi, the text discusses an experiment that showed how trees can share carbon atoms. What do you think was the author's purpose in discussing this experiment?

END-OF-COURSE TEST PRACTICE

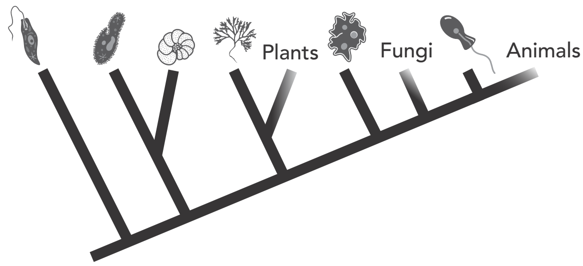
1. What is one of the main ways that evolution occurs in prokaryotes?
   A. Crossing over during DNA replication
   B. Exposure to pathogens that change DNA
   C. Mutations that occur during binary fission
   D. Exchanging DNA during alternation of generations
   E. Decomposing dead organisms

2. Every year in the U.S. millions of people are sickened by the flu. What is one way a person can try to prevent the flu?
   A. Get a flu vaccine every year.
   B. Take antibiotics every year.
   C. Apply sunscreen when exposed to the sun.
   D. Apply mosquito repellent when outdoors.
   E. Store foods at temperatures lower than room temperature.

3. Organisms can be classified into one of three domains: Bacteria, Archaea, or Eukarya. What characteristics distinguish Bacteria from Archaea?
   A. Organisms in the domain Archaea have cell walls, and those in the domain Bacteria do not.
   B. Organisms in the domain Bacteria have nuclei, and those in the domain Archaea do not.
   C. Organisms in the domain Bacteria are prokaryotes, and those in the domain Archaea are eukaryotes.
   D. The DNA sequences of Archaea genes are more similar to eukaryotes than to bacteria.
   E. Organisms in the domain Archaea are more likely than those in the domain Bacteria to be disease-causing pathogens.

4. Scientists once classified fungi as types of plants. Today, fungi are classified in their own kingdom. Which of these traits distinguishes fungi from plants?
   A. Fungi are prokaryotes.
   B. Fungi are autotrophs.
   C. Fungi grow in the ground and are photosynthetic.
   D. Fungi reproduce by asexual reproduction.
   E. Fungi have cell walls made of chitin, a polymer that's also found in insects.

5. Protists have been evolving for over a billion years. The major groups of protists are shown in the cladogram below.



   How does this cladogram represent the present-day classification of protists?
   A. Protists used to be in the animal kingdom, and now they are in the plant kingdom.
   B. Protists used to be classified with eukaryotes and are now classified with prokaryotes.
   C. Protists used to be classified with Eukarya and are now classified with Archaea.
   D. Protists used to be classified separately from plants, fungi, and animals and are now classified as plants, fungi, or animals.
   E. Protists used to be classified as similar to plants, fungi, or animals, and now some are classified into other groups.

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With...					
Question	1	2	3	4	5
See Lesson	21.2	21.1	21.2	21.4	21.3
Performance Expectation	HS-LS4-2				