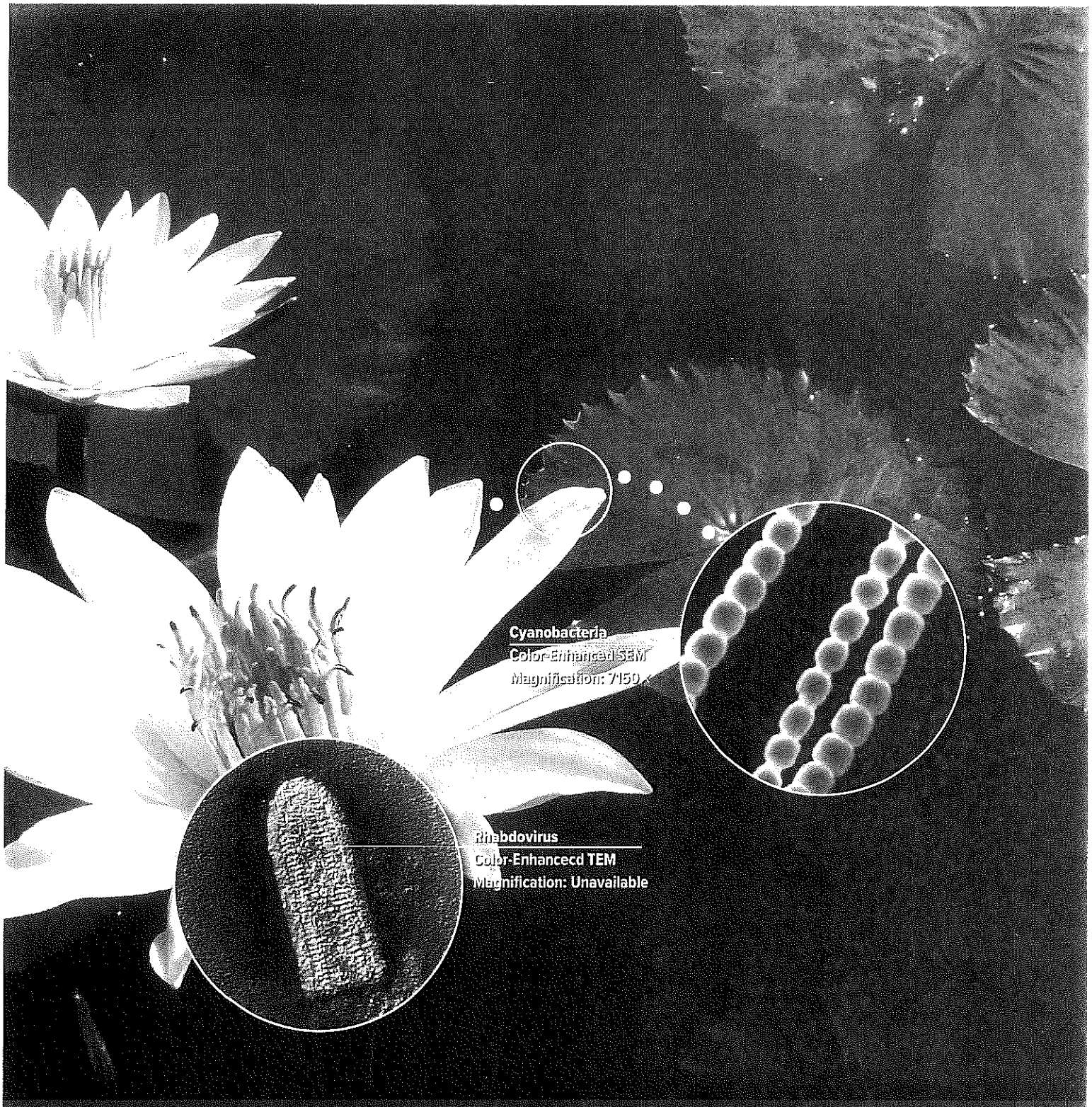


Cyanobacteria
Color-Enhanced SEM
Magnification: 7150 ×

Rhabdovirus
Color-Enhancecd TEM
Magnification: Unavailable

THEME FOCUS **Scale, Proportion, and Quantity**
Prokaryotes are the most abundant organisms on Earth.

BIG Idea **Bacteria are microscopic organisms, and viruses are nonliving microscopic agents that invade cells.**

Reading Preview

Essential Questions

- What are the differences between archaea and bacteria and their subcategories?
- What are the survival methods of bacteria at both the individual and population levels?
- How are bacteria beneficial to humans?

Review Vocabulary

prokaryotic cell: cell that does not contain any membrane-bound organelles

New Vocabulary

bacteria
nucleoid
capsule
pilus
binary fission
conjugation
endospore

Multilingual eGlossary

Video Lab

Bacteria

Key Idea **Prokaryotes are diverse organisms that live in nearly all environments.**

Real-World Reading Link What do yogurt, cheese, and strep throat have in common? You might wonder what food and disease have in common, but they each are the result of microscopic organisms called bacteria.

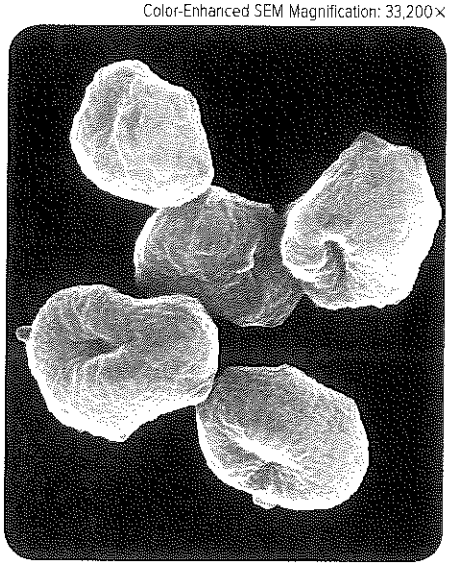
Diversity of Prokaryotes

Many scientists think that the first organisms on Earth were microscopic, unicellular organisms called prokaryotes. Today, prokaryotes are the most numerous organisms on Earth. They are found everywhere from the depths of the oceans to the highest mountaintops. Some prokaryotes are the only organisms able to survive in hostile environments, such as the water in hot sulfur springs or the Great Salt Lake. The word *prokaryote* is a Greek word that means *before a nucleus.*

All prokaryotes were once classified into one group–Kingdom Monera–based on their lack of a nucleus and membrane-bound organelles. However, modern research has shown that great differences exist among prokaryotes. They are now divided into two domains–Domain Bacteria and Domain Archaea. **Bacteria** (sometimes called eubacteria) are prokaryotic organisms that belong to Domain Bacteria. Bacteria live in nearly every environment on Earth and are important in the human body, industry, and food production. Archaea (previously called archaeabacteria) live in extreme environments and are sometimes called extremophiles. Archaea have been found to have some similarities with eukaryotic cells, such as cytoplasm proteins and histones. **Figure 1** shows representatives of these two domains.

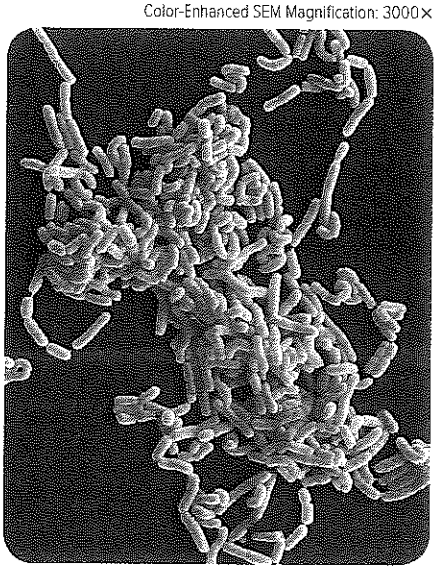
Figure 1 Archaea are similar to the first life-forms on Earth. The middle photo shows cells of bacteria. The right photo shows cyanobacteria.

Color-Enhanced SEM Magnification: 33,200×



Archaea

Color-Enhanced SEM Magnification: 3000×



Bacteria

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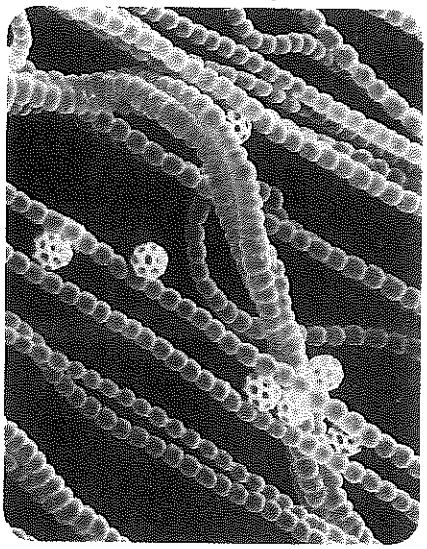
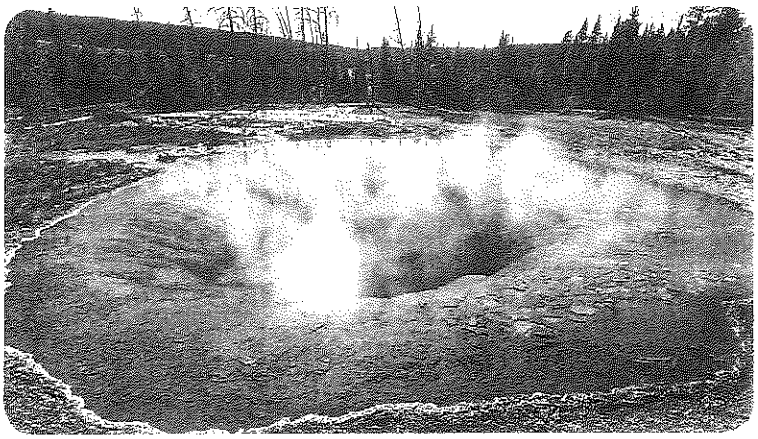
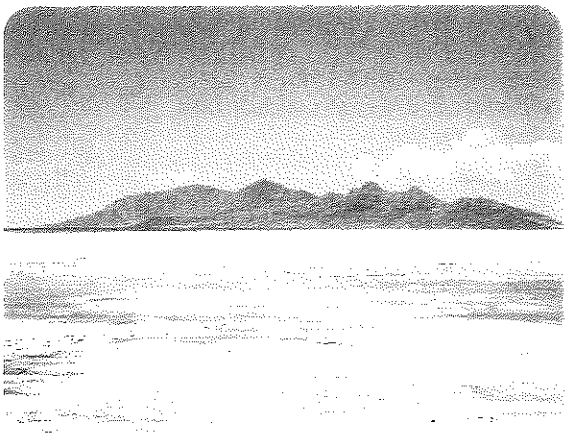


Cyanobacteria

(l)Eye of Science/Photo Researchers; (c)©Steve Gschmeissner/Science Photo Library/Corbis; (r)STEVE GSCHMEISSNER/Getty Images



Hot springs



Great Salt Lake

Figure 2 Some members of Domain Archaea can live in hostile environments, such as the sulfur hot springs in Yellowstone National Park and the Great Salt Lake in Utah.
Identify ***in what other hostile places you might find archaea.***

Bacteria Bacteria are the most-studied organisms and are found almost everywhere except in extreme environments, where mostly archaea are found. Bacteria have strong cell walls that contain peptidoglycan. Some bacteria have a second cell wall, a property that can be used to classify them. Additionally, some bacteria, such as the cyanobacteria in **Figure 1,** are photosynthetic.

Archaea In extreme environments that are hostile to most other forms of life, archaea predominate. Some archaea called thermoacidophiles (thur muh uh SIH duh filz) live in hot, acidic environments, including sulfur hot springs, shown in **Figure 2,** thermal vents on the ocean floor, and around volcanoes. These archaea thrive in temperatures above 80°C and pH levels of 1-2. Some of these archaea cannot survive temperatures as low as 55°C. Many are strict anaerobes, which means that they die in the presence of oxygen.

Other archaea called halophiles (HA luh filz) live in very salty environments. The salt concentration in your cells is 0.9 percent, oceans average 3.5 percent salt, and the salt concentrations in the Great Salt Lake, shown in **Figure 2,** and the Dead Sea can be greater than 15 percent. Halophiles have several adaptations that allow them to live in salty environments. Halophiles usually are aerobic, and some carry out a unique form of photosynthesis using a protein instead of the pigment chlorophyll.

The methanogens (meh THAHN oh jenz) are the third group of archaea. These organisms are obligate anaerobes, which means they cannot live in the presence of oxygen. They use carbon dioxide during respiration and give off methane as a waste product. Methanogens are found in sewage treatment plants, swamps, bogs, and near volcanic vents. Methanogens even thrive in the gastrointestinal tract of humans and other animals and are responsible for the gases that are released from the lower digestive tract.

Differences between bacteria and archaea Bacteria and archaea have many differences that have led them to be classified in different domains. Recall that there are three domains. Based on their classification, we understand that bacteria and archaea are as different from each other as they are from eukaryotic cells. Some differences include: bacterial cell walls contain peptidoglycan but archaea do not; different lipids in their plasma membranes; and different ribosomal proteins and RNA. The ribosomal proteins in archaea are similar to those of eukaryotic cells.

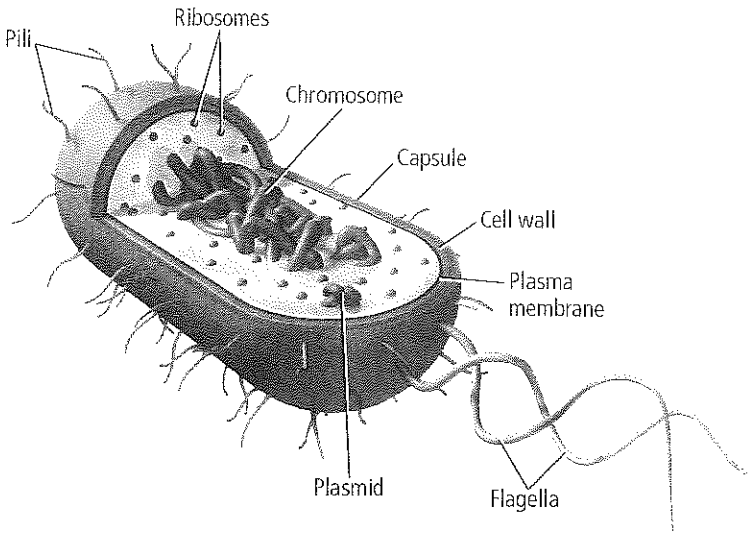
BrainPOP

VOCABULARY

Word origin

Halophile
halo- from the Greek word *hals,* meaning *salt*
-phile from the Greek word *phileo,* meaning *like*

Figure 3 Prokaryotic cells have structures that are necessary for carrying out life processes. **Compare and contrast** *how a bacterial cell differs structurally from a eukaryotic cell.*



Prokaryote Structure

Prokaryotes are microscopic, unicellular organisms. They have some characteristics of all cells, such as DNA and ribosomes, but they lack a nuclear membrane and other membrane-bound organelles, such as mitochondria and chloroplasts. Although a prokaryotic cell is very small and doesn't have membrane-bound organelles, it has all it needs to carry out life functions. Examine **Figure 3** as you read about the structure of prokaryotic cells.

Launch Lab

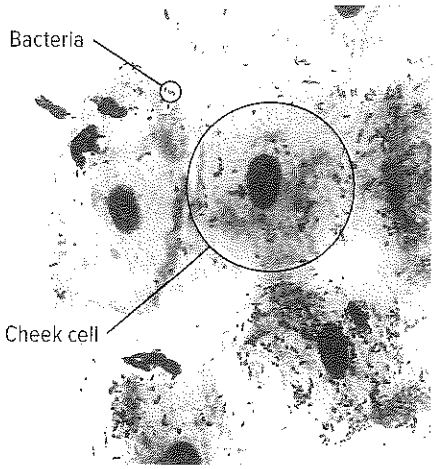
Review **Based on what you've read about bacterial cells, how would you now answer the analysis questions?**

Chromosomes The chromosomes in prokaryotes are arranged differently from the chromosomes found in eukaryotic cells. Their genes are found on a large, circular chromosome in an area of the cell called the **nucleoid.** Many prokaryotes also have at least one smaller piece of DNA, called a *plasmid,* which also has a circular arrangement.

Capsule Some prokaryotes secrete a layer of polysaccharides around the cell wall, forming a **capsule,** illustrated in **Figure 3.** The capsule has several important functions, including preventing the cell from drying out and helping the cell attach to surfaces in its environment. The capsule also helps prevent bacteria from being engulfed by white blood cells and shelters the cells from the effects of antibiotics.

Pili Structures called pili are found on the outer surface of some bacteria. **Pili** (singular, pilus) are submicroscopic, hairlike structures that are made of protein. Pili help bacterial cells attach to surfaces. Pili also can serve as a bridge between cells. Copies of plasmids can be sent across the bridge, thus providing some prokaryotes with new genetic characteristics. This is one way of transferring the resistance to antibiotics.

Figure 4 A size comparison shows how a human cheek cell is much larger than bacteria found in a human mouth.



Stained LM Magnification: 400×

Size Even when using a typical light microscope, prokaryotes are small when magnified 400 times. Prokaryotes are typically only 1 to 10 micrometers long and 0.7 to 1.5 micrometers wide. Study **Figure 4,** which shows a bacterial cell and a human cell. Notice the relative size of bacterial cells found adjacent to a cheek cell.

Recall that small cells have a larger, more favorable surface area-to-volume ratio than large cells. Because prokaryotes are so small, nutrients and other substances the cells need can diffuse to all parts of the cell easily.

Eye of Science/Photo Researchers

Prokaryote Characteristics

As with other types of organisms, prokaryotes now can be identified using molecular techniques. By comparing DNA, evolutionary relationships can be determined. Historically, scientists identified prokaryotes using criteria such as shape, cell wall, and movement.

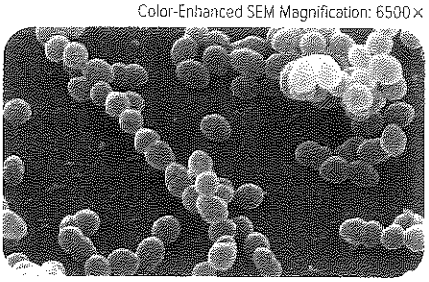
Shape There are three general shapes of prokaryotes, as shown in **Figure 5.** Spherical or round prokaryotes are called cocci (KAHK ki) (singular, coccus), rod-shaped prokaryotes are called bacilli (buh SIH li) (singular, bacillus), and spiral-shaped prokaryotes are called spirilli (spi RIH li) (singular, spirillium).

Cell walls Scientists also classify bacteria according to the composition of their cell walls. All bacterial cells have peptidoglycan in their cell walls. Peptidoglycan is made of disaccharides and peptide fragments. Biologists add dyes to the bacteria to identify the two major types of bacteria–those with and those without an outer layer of lipid–in a technique called Gram's stain.

Bacteria with a large amount of peptidoglycan appear dark purple once they are stained and are called Gram-positive. Bacteria with the lipid layer have less peptidoglycan and appear light pink after staining. These bacteria are called Gram-negative. Because some antibiotics work by attacking the cell wall of bacteria, physicians need to know the type of cell wall that is present in the bacteria that they suspect is causing illness to prescribe the proper antibiotic.

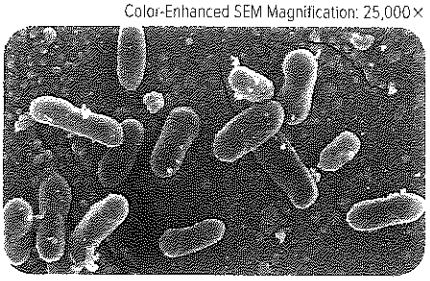
Movement Although some prokaryotes are stationary, others use flagella for movement. Prokaryotic flagella are made of filaments, unlike the flagella of eukaryotes, which are made of microtubules. Flagella help prokaryotes move toward light, higher oxygen concentration, or chemicals such as sugar or amino acids that they need to survive. Other prokaryotes move by gliding over a layer of secreted slime.

Color-Enhanced SEM Magnification: 6500×



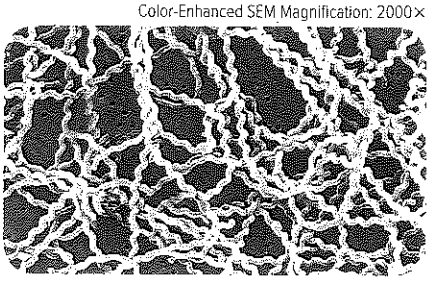
Cocci

Color-Enhanced SEM Magnification: 25,000×



Bacilli

Color-Enhanced SEM Magnification: 2000×



Spirochetes

Figure 5 There are three shapes of prokaryotes: cocci, bacilli, and spirilli.

(t)Eye of Science/Photo Researchers; (c)Dr. Gary Gaugler/Science Source; (b)Science Source/Photo Researchers

MiniLab 1

Classify Bacteria

MiniLab

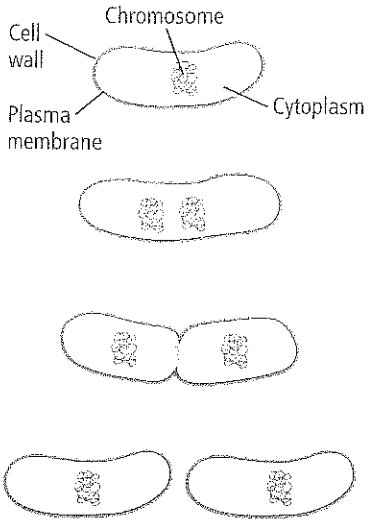
What types of characteristics are used to divide bacteria into groups? Bacteria can be stained to show the differences in peptidoglycan (PG) in their cell walls. Based on this difference in their cell walls, bacteria are divided into two main groups.

Procedure

1. Read and complete the lab safety form.
2. Choose four different **slides of bacteria** that have been stained to show cell wall differences. The slides will be labeled with the names of the bacteria and marked either thick PG layer or thin PG layer.
3. Use the oil immersion lens of your **microscope** to observe the four slides.
4. Record all of your observations, including those about the cell color, in a data table.

Analysis

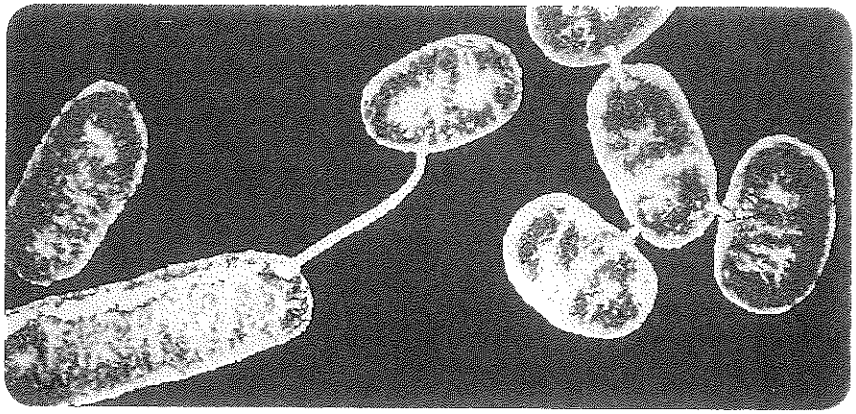
1. **Interpret Data** Based on your observations, make a hypothesis about how to differentiate between the two groups of bacteria.
2. **Describe** two different cell shapes that you observed on the slides.



Binary fission

Figure 6 Binary fission is an asexual form of reproduction used by some prokaryotes. Conjugation is a method of exchanging genetic material used by some prokaryotes.

Analyze ***Which means of reproducing shown here exchanges genetic information?***



Conjugation

Reproduction of Prokaryotes

Most prokaryotes reproduce by an asexual process called binary fission, illustrated in **Figure 6. Binary fission** is the division of a cell into two genetically identical cells. In this process, the prokaryotic chromosome replicates, and the original chromosome and the new copy separate. As this occurs, the cell gets larger by elongating. A new piece of plasma membrane and cell wall forms and separates the cell into two identical cells. Under ideal environmental conditions, this can occur quickly—as often as every 20 minutes. If conditions are just right, one bacterium could become one billion bacteria through binary fission in just ten hours.

Some prokaryotes exhibit a form of reproduction called **conjugation,** in which two prokaryotes attach to each other and exchange genetic information. As shown in **Figure 6,** the pilus is important for the attachment of the two cells so that there can be a transfer of genetic material from one cell to the other. In this way, new gene combinations are created and diversity of prokaryote populations is increased.

Metabolism of Prokaryotes

Anaerobic prokaryotes do not use oxygen for growth or metabolism. Obligate anaerobes cannot live or grow in the presence of oxygen. They obtain energy through fermentation. Facultative anaerobes can grow either in the presence of oxygen or without it. Obligate aerobes require oxygen to grow. Besides being classified by how they use oxygen, prokaryotes can also be classified by how they obtain energy for cellular respiration or fermentation, as shown in **Figure 7.**

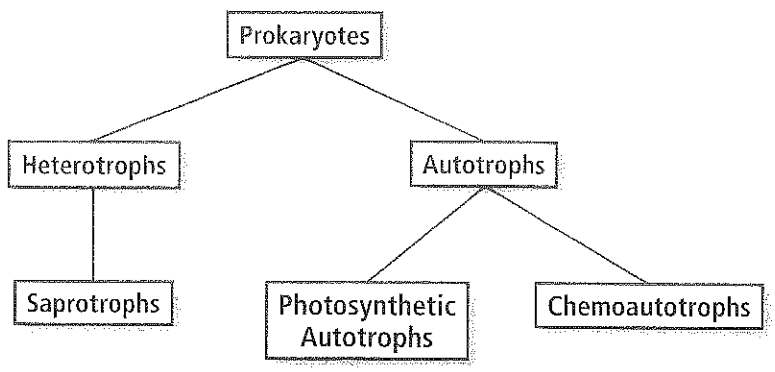


Figure 7 Prokaryotes are grouped according to how they obtain nutrients for energy. Heterotrophic bacteria can also be saprotrophs; autotrophs can be photosynthetic or chemoautotrophic.

Heterotrophs Some prokaryotes are heterotrophs; they cannot synthesize their own food and must take in nutrients. Many heterotrophic bacteria are saprotrophs, or saprobes. They obtain their energy by decomposing organic molecules associated with dead organisms or organic waste.

Photoautotrophs Some bacteria are photosynthetic autotrophs (AW tuh trohfs); they carry out photosynthesis in a manner similar to plants. These bacteria must live in areas where there is light, such as shallow ponds and streams, to synthesize organic molecules to use as food.

Scientists once thought that these organisms were eukaryotes and called them blue-green algae. Later, it was discovered that they were prokaryotes and they were renamed cyanobacteria. These bacteria, like plants, are ecologically important because they are at the base of some food chains and release oxygen into the environment. Cyanobacteria are thought to have been the first group of organisms to release oxygen into Earth's early atmosphere, approximately three billion years ago.

Chemoautotrophs A second type of bacteria are autotrophs that do not require light for energy. These organisms are called chemoautotrophs. They break down and release inorganic compounds that contain nitrogen or sulfur, such as ammonia and hydrogen sulfide, in a process called chemosynthesis. Some chemoautotrophs are important ecologically because they keep nitrogen and other inorganic compounds cycling through ecosystems.

Study Tip

Summarization Write a summary paragraph that addresses the diversity of prokaryotes, how they reproduce, and the importance of prokaryotes.

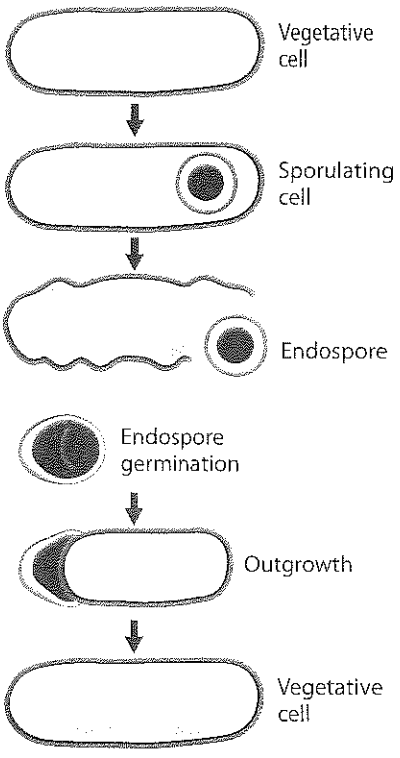
Survival of Bacteria

How can bacteria survive if their environment becomes unfavorable? They have several mechanisms that help them survive such environmental challenges as a lack of water, an extreme temperature change, and a lack of nutrients.

Endospores When environmental conditions are harsh, some types of bacteria produce a structure called an **endospore.** The bacteria that cause anthrax, botulism, and tetanus are examples of endospore producers. An endospore can be thought of as a dormant cell. Endospores are resistant to harsh environments and might be able to survive extreme heat, extreme cold, dehydration, and large amounts of ultraviolet radiation. Any of these conditions would kill a typical bacterial cell.

As illustrated in **Figure 8,** when a bacterium is exposed to harsh environments, a spore coat surrounds a copy of the bacterial cell's chromosome and a small part of the cytoplasm. The bacterium itself might die, but the endospore remains. When environmental conditions become favorable again, the endospore grows, or germinates, into a new bacterial cell. Endospores are able to survive for long periods of time. Because a bacterial cell usually produces only one endospore, this is considered a survival mechanism rather than a type of reproduction.

Figure 8 Endospores can survive extreme environmental conditions.



Mutations If the environment changes and bacteria are not well adapted to the new conditions, extinction of the bacteria is a possibility. Because bacteria reproduce quickly and their population grows rapidly, genetic mutations can help bacteria survive in changing environments. Mutations, which are changes or random errors in a DNA sequence, lead to new forms of genes, new gene combinations, new characteristics, and genetic diversity. If the environment happens to change, some bacteria in a population might have the right combination of genes to allow them to survive and reproduce. From the human point of view, this can lead to problems, such as antibiotic-resistant bacteria, which may cause disease and are hard to treat.

CAREERS IN BIOLOGY

Food Scientist Food scientists help protect the flavor, color, texture, nutritional quality, and safety of our food. They test for amounts of nutrients and the presence of harmful organisms such as bacteria.

Ecology of Bacteria

When many people think of bacteria, they immediately think of germs or disease. Most bacteria do not cause disease, and many are beneficial. In fact, it has been said that humans owe their lives to bacteria because they help fertilize fields, recycle nutrients, protect the body, and produce foods and medicines.

Nutrient cycling and nitrogen fixation Recall that nutrients are cycled in an ecosystem. Some organisms get their energy from the cells and tissues of dead organisms and are called decomposers or detrivores. Saprobes are decomposers, returning vital nutrients to the environment. Without nutrient recycling, all raw materials necessary for life would be used up. Without nitrogen fixation, far more fertilizer would be needed for growing plants.

Connection to Chemistry All forms of life require nitrogen. Nitrogen is a key component of amino acids, the building blocks of proteins. Nitrogen also is needed to make DNA and RNA. Most of Earth's nitrogen is found in the atmosphere in the form of nitrogen gas (N_2). Certain types of bacteria can use nitrogen gas directly. These bacteria have enzymes that can convert nitrogen gas into nitrogen compounds by a process called nitrogen fixation. Some of these bacteria live in soil.

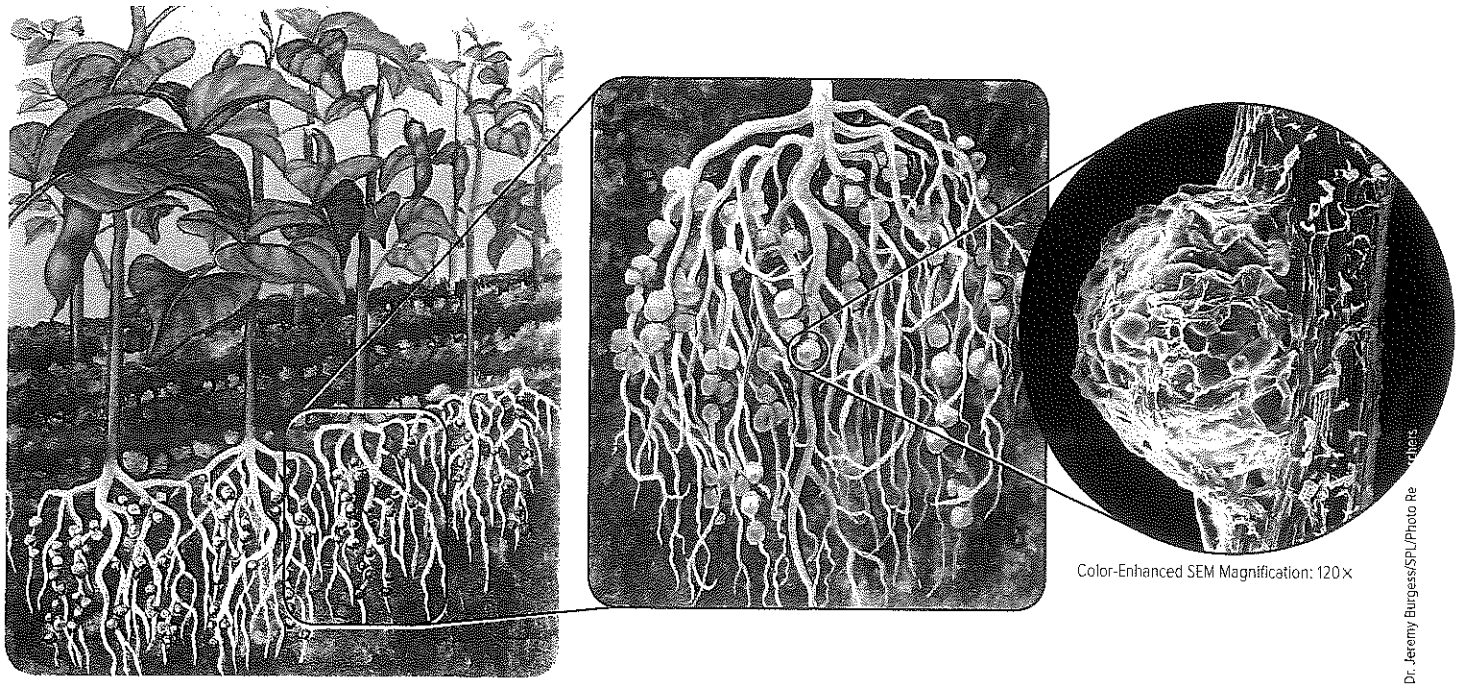


Figure 9 Nitrogen-fixing bacteria on a plant root nodule are able to remove nitrogen from the air and convert it into a form the plant can use.

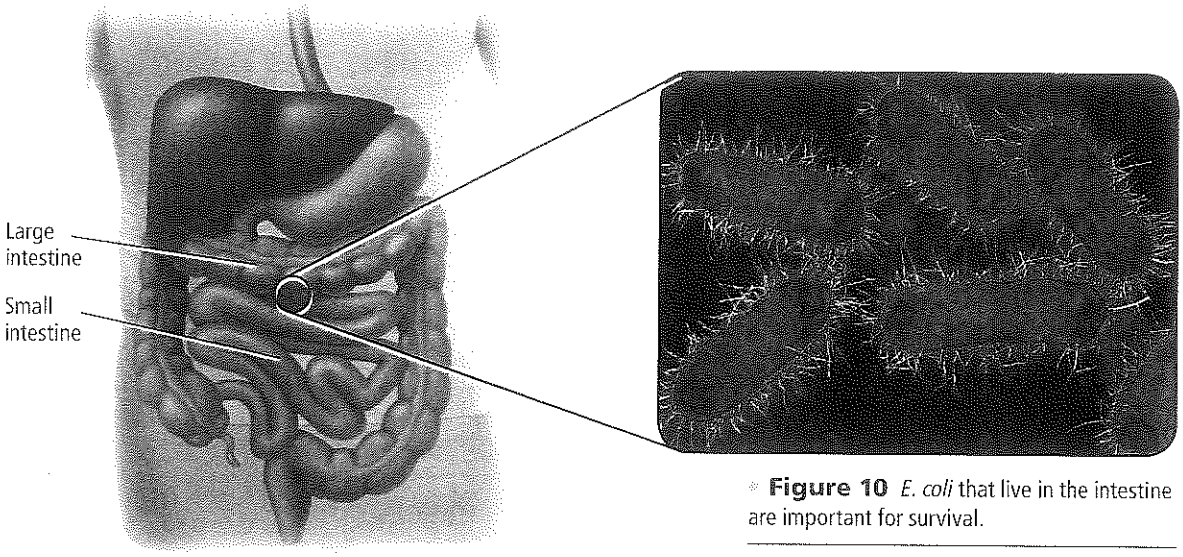


Figure 10 *E. coli* that live in the intestine are important for survival.

Some nitrogen-fixing bacteria live in a symbiotic relationship in the root nodules of plants such as soybeans, clover, and alfalfa. The bacteria use the nitrogen in the atmosphere to produce forms of nitrogen the plant can use. The plants then are able to take up ammonia (NH_3) and other forms of nitrogen from the soil. These plants are at the base of a food chain, and the nitrogen is passed along to organisms that eat them. **Figure 9** shows where nitrogen-fixing bacteria live on root nodules.

Normal flora Your body is covered with bacteria inside and out. Most of the bacteria that live in or on you are harmless. These are called normal flora. Normal flora are of great importance to the body. By living and replicating on the body, they compete with harmful bacteria and prevent them from taking hold and causing disease.

A certain type of bacterium called *Escherichia coli (E. coli)* lives inside your intestines and is illustrated in **Figure 10.** Some *E. coli* strains can cause food poisoning. The type that lives in the digestive tracts of humans and other mammals is harmless and important for survival. The *E. coli* that live in humans make vitamin K, which humans absorb and use in blood clotting. In this symbiotic relationship, *E. coli* are provided with a warm place and food with which to live. In return, the bacteria provide the body with an essential nutrient.

Foods and medicines Think about what you have eaten in the last few days. Have you had pizza? How about a cheeseburger? Cheese, yogurt, buttermilk, and pickles, as well as other foods, are made with the aid of bacteria.

Bacteria are even used in the production of chocolate. Although bacteria are not found in the chocolate products you eat, bacteria are used to break down the covering of cocoa beans during the production of cocoa. Bacteria also are responsible for the commercial production of vitamins, such as vitamin B_{12} and riboflavin.

Bacteria are important in the fields of medicine and research. Although some bacteria cause disease, others are useful in fighting disease. Streptomycin, bacitracin, tetracycline, and vancomycin are commonly prescribed antibiotics that were originally made by bacteria.

Reading Check **Describe** ways that bacteria are beneficial.

Table 1 Human Bacterial Diseases

Interactive Table

Category	Disease
Sexually transmitted diseases	Syphilis, gonorrhea, chlamydia
Respiratory diseases	Strep throat, pneumonia, whooping cough, tuberculosis, anthrax
Skin diseases	Acne, boils, infections of wounds or burns
Digestive tract diseases	Gastroenteritis, many types of food poisoning, cholera
Nervous system diseases	Botulism, tetanus, bacterial meningitis
Other diseases	Lyme disease, typhoid fever

Disease-causing bacteria Only a small percentage of bacteria cause disease. Some of the diseases caused by bacteria are listed in **Table 1.** The small percentage of bacteria that cause disease do so in two ways. Some bacteria multiply quickly at the site of infection before the body's defense systems can destroy them. In cases of serious infections, bacteria then might spread to other parts of the body.

Other bacteria secrete a toxin or other substance that might cause harm. The bacteria that cause botulism secrete a toxin that paralyzes cells in the nervous system. Bacteria that cause cavities in teeth use sugar in the mouth for energy, and in turn secrete acids that erode the teeth.

Bacteria also can cause disease in plants, and most plants can become infected. Such infections can destroy entire crops and have long-ranging consequences on local ecosystems. For example, citrus canker, a bacterial disease that kills orange trees, has severely impacted the Florida citrus crop and prompted eradication programs.

Section 1 Assessment

Section Summary

- Many scientists think that prokaryotes were the first organisms on Earth.
- Prokaryotes belong to two domains.
- Most prokaryotes are beneficial.
- Prokaryotes have a variety of survival mechanisms.
- Some bacteria cause disease.

Understand Main Ideas

1. MAIN Idea **Diagram** a bacterium.
2. **Discuss** possible rationales that taxonomists might have used when deciding to group prokaryotes into two distinct domains instead of in one group.
3. **Explain** survival mechanisms of bacteria at both the individual and population levels.
4. **List** three examples of how bacteria are beneficial to humans.

Think Critically

5. **Analyze** why it is more difficult for biologists to understand the diversity in prokaryotes as compared to plants or animals.

MATH in Biology

6. Imagine that today at 1 P.M., a single *Salmonella* bacterial cell landed on potato salad sitting on your kitchen counter. Assuming your kitchen provides an optimal environment for bacterial growth, how many bacterial cells will be present at 3 P.M. today?

Online Quiz

Reading Preview

Essential Questions

- What is the general structure of a virus?
- What are similarities and differences in the lytic cycle, the lysogenic cycle, and retroviral replication?
- What is the relationship between a prion's structure, replication, and action and its ability to cause disease?

Review Vocabulary

protein: large, complex polymer composed of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur

New Vocabulary

virus
capsid
lytic cycle
lysogenic cycle
retrovirus
prion

Multilingual eGlossary

Viruses and Prions

MAIN Idea **Viruses and prions are smaller and less complex than bacteria; they invade cells and can alter cellular functions.**

Real-World Reading Link "It's Cold and Flu Season," "1918 Spanish Flu Epidemic Kills Millions," "New Cases of SARS Reported," "Number of H1N1 Cases Increases"—headlines tell many stories about diseases that spread worldwide. What do colds, severe acute respiratory syndrome (SARS), and types of flu have in common? They all are caused by viruses.

Viruses

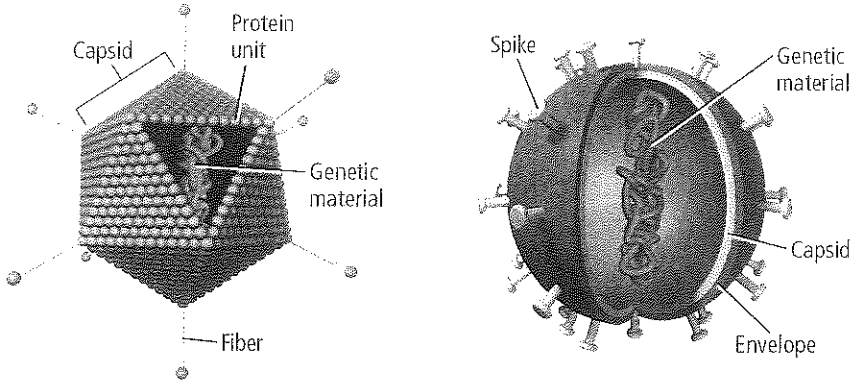
Although some viruses are not harmful, other viruses are known to infect and harm all types of living organisms. A **virus** is a nonliving strand of genetic material within a protein coat. Most biologists don't consider viruses to be living because they do not exhibit all of the characteristics of life. Viruses have no organelles to take in nutrients or use energy, they cannot make proteins, they cannot move, and they cannot replicate on their own. In humans, some diseases, such as those listed in **Table 2,** are caused by viruses. Just as there are some bacteria that cause sexually transmitted disease, some viruses can cause sexually transmitted diseases–such as genital herpes and AIDS. These viruses can be spread through sexual contact. Diseases caused by these viruses have no cure or vaccine to prevent them.

Virus size Viruses are some of the smallest disease-causing structures that are known. They are so small that powerful electron microscopes are needed to study them. Most viruses range in size from 5 to 300 nanometers (a nanometer is one billionth of a meter). It would take about 10,000 cold viruses to span the period at the end of this sentence.

Table 2 **Human Viral Diseases** Interactive Table

Category	Disease
Sexually transmitted diseases	AIDS (HIV), genital herpes
Childhood diseases	Measles, mumps, chicken pox
Respiratory diseases	Common cold, influenza
Skin diseases	Warts, shingles
Digestive tract diseases	Gastroenteritis
Nervous system diseases	Polio, viral meningitis, rabies
Other diseases	Smallpox, hepatitis

Figure 11 Viruses have several different types of arrangements, but all viruses have at least two parts: an outer capsid portion made of proteins, and genetic material.



Adenovirus **Influenza virus**

CAREERS IN BIOLOGY

Virologist Virologists study the natural history of viruses and the diseases they cause. Most virologists spend many hours in the laboratory conducting experiments.

Virus origin Although the origin of viruses is not known, scientists have several theories about how viruses evolved. One theory, now considered to be most likely, is that viruses came from parts of cells. Scientists have found that the genetic material of viruses is similar to cellular genes. These genes somehow developed the ability to exist outside of the cell.

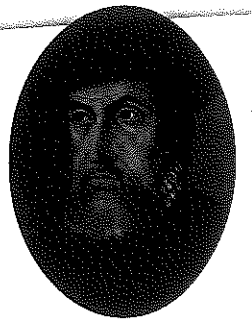
Virus structure **Figure 11** shows the structures of adenovirus, influenza virus, bacteriophage, and tobacco mosaic virus. Adenovirus infection causes the common cold, and influenza virus is responsible for causing the flu. A virus that infects bacteria is called a bacteriophage (bak TIHR ee uh fayj). Tobacco mosaic virus causes disease in tobacco leaves. The outer layer of all viruses is made of proteins and is called a **capsid.** Inside the capsid is the genetic material, which could be DNA or RNA, but never both. Viruses generally are classified by the type of nucleic acid they contain.

Reading Check **Sketch** the general structure of a virus.

Figure 12

The History of Smallpox

Though it has been eradicated, smallpox has been an important and deadly disease throughout history.



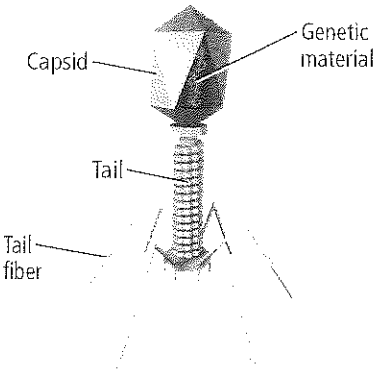
1157 B.C. Smallpox kills Egyptian Pharaoh Ramses V. Two centuries earlier, Egyptian prisoners caused the first known smallpox epidemic when they were captured by the Hittites in Syria.

243 B.C. A terrible epidemic ravages China. Invading Huns bring smallpox to China, where the disease is called "Hun-pox."

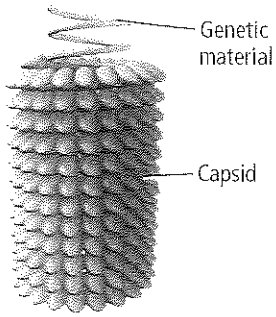
1017 A hermit in China introduces mild cases of smallpox into humans to build immunity (variolation).

1519 Hernando Cortes and his crew spread smallpox to Mexico, which decimates the Aztec population.

0 1000 1500



Bacteriophage



Tobacco mosaic virus

Connection to History The virus that causes smallpox is a DNA virus. Outbreaks of smallpox have occurred in the human population for thousands of years. A successful program of worldwide vaccination eliminated the disease, and routine vaccination was stopped. For a closer look at the history of the discovery of the virus that causes smallpox and smallpox vaccination, examine **Figure 12.**

Viral Infection

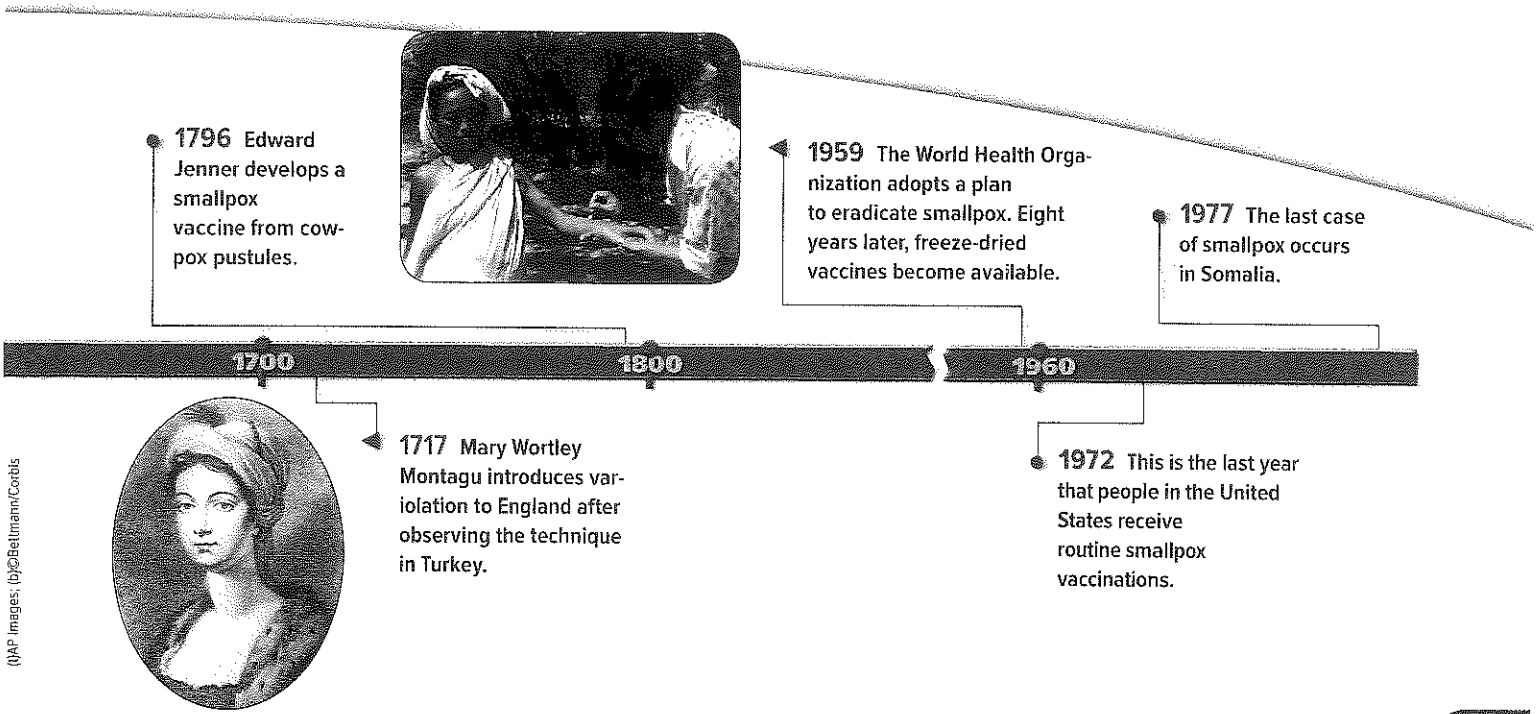
To replicate, a virus must enter a host cell. The virus attaches to the host cell using specific receptors on the plasma membrane of the host. Different types of organisms have receptors for different types of viruses, which explains why many viruses cannot be transmitted between different species.

Once the virus successfully attaches to a host cell, the genetic material of the virus enters the cytoplasm of the host. In some cases, the entire virus enters the cell and the capsid is broken down quickly, exposing the genetic material. The virus then uses the host cell to replicate by either the lytic cycle or the lysogenic cycle.

VOCABULARY

ACADEMIC VOCABULARY

Widespread
widely diffused or prevalent
Finding a cure for HIV is of widespread interest in the world.



(l)AP Images; (b)©Bettmann/Corbis

Lytic cycle In the **lytic cycle**, illustrated in **Figure 13**, the host cell makes many copies of the viral RNA or DNA. The viral genes instruct the host cell to make more viral protein capsids and enzymes needed for viral replication. The protein coat forms around the nucleic acid of new viruses. These new viruses leave the cell by exocytosis or by causing the cell to burst, or lyse, releasing new viruses that are free to infect other cells. Viruses that replicate by the lytic cycle often produce active infections. Active infections usually are immediate, meaning that symptoms of the illness caused by the virus start to appear one to four days after exposure. The common cold and influenza are two examples of widespread viral diseases that are active infections.

FOLDABLES
Incorporate information from this section into your Foldable.

Lysogenic cycle In some cases, the viral DNA might enter the nucleus of the host cell. In the **lysogenic cycle**, also illustrated in **Figure 13**, the viral DNA inserts, or integrates, into a chromosome in a host cell. Once integrated, the infected cell will have the viral genes permanently. The viral genes might remain dormant for months or years. Then, at some future time, the viral genes might be activated by many different factors. Activation results in the lytic cycle. The viral genes instruct the host cell to manufacture more viruses. The new viruses will leave the cell by exocytosis or by causing the cell to lyse.

Many disease-causing viruses have lysogenic cycles. Herpes simplex I is an example of a virus that causes a latent infection. This virus is transmitted orally, and a symptom of this infection is cold sores. When the viral DNA enters the nucleus, it is inactive. It is thought that during times of stress, whether physical, emotional, or environmental, the herpes genes become activated and the production of viruses occurs.

DATA ANALYSIS LAB 1

Based on Real Data*

Model Viral Infection

Is protein or DNA the genetic material?
In 1952, Alfred Hershey and Martha Chase designed experiments to find out whether protein or DNA provides genetic information. Hershey and Chase labeled the DNA of bacteriophages—viruses that infect bacteria—with a phosphorus isotope and the protein in the capsid with a sulfur isotope. The bacteriophages were allowed to infect the bacteria *E. coli*.

Data and Observations

- At least 80 percent of the sulfur-containing proteins stayed on the surface of the host cell.
- Most of the viral DNA entered the host cell upon infection.
- After replication inside the host cell, 30 percent or more of the copies of the virus contained radioactive phosphorus.

Think Critically

1. **Analyze and Conclude** Do the results of these experiments support the idea that proteins are the genetic material or DNA is the genetic material? Explain.

2. **Infer** If proteins and DNA had entered the cell, would these data be useful to answer Hershey and Chase's question?

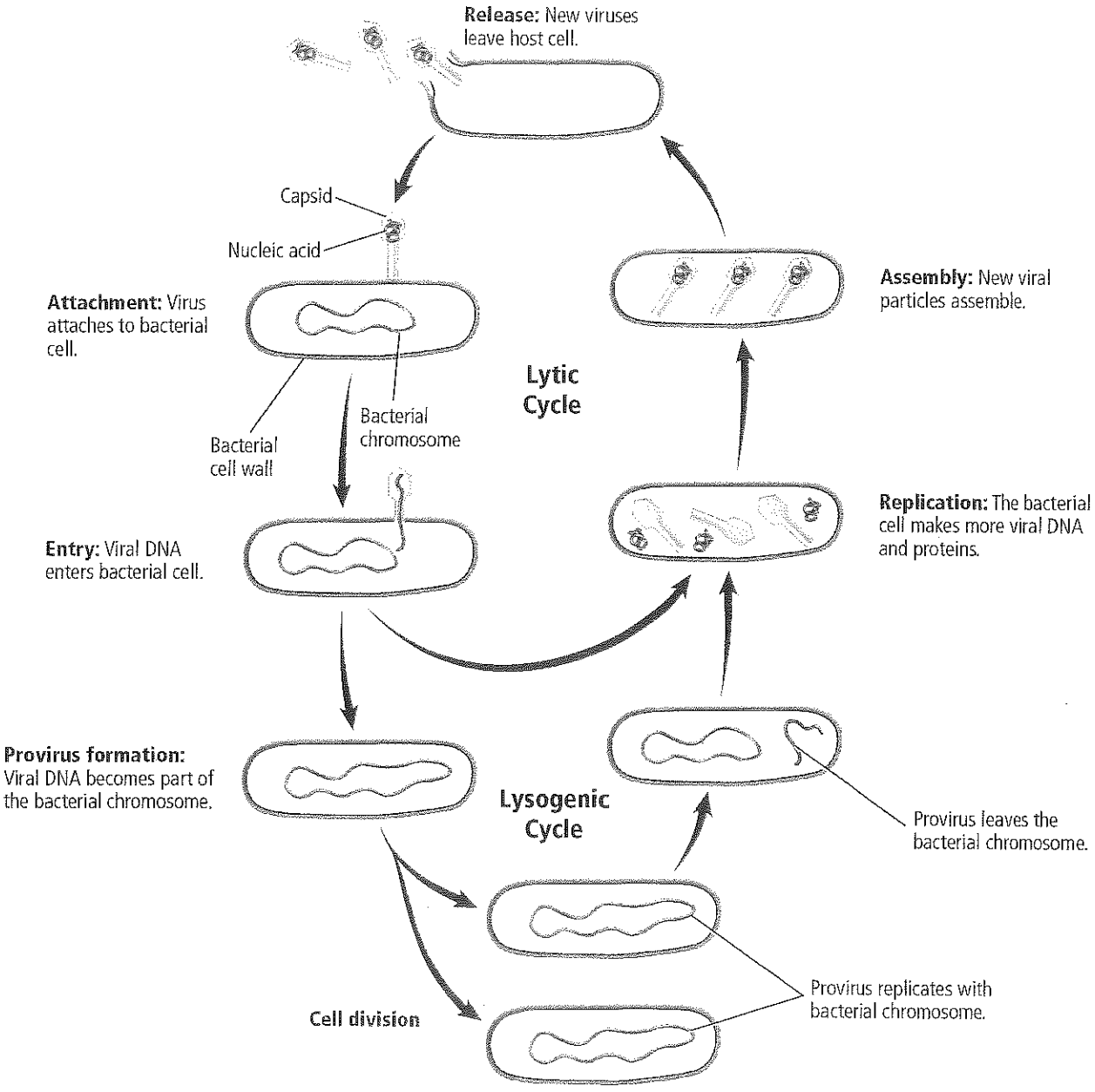
*Data obtained from: Hershey, A.D. and Chase, M. 1952. Independent functions of viral protein and nucleic acid in growth of bacteriophage. *Journal of General Physiology* 36: 39–56.

Visualizing Viral Replication

Figure 13

In the lytic cycle, the entire replication process occurs in the cytoplasm. The viruses' genetic material enters the cell, and the cell replicates the viral RNA or DNA. The viral genes instruct the host cell to manufacture capsids and assemble new viral particles. The new viruses then leave the cells.

In the lysogenic cycle, the viral DNA inserts into a chromosome of the host cell. Many times, the genes are not activated until later. Then the viral DNA instructs the host cell to make more viruses.



Animation

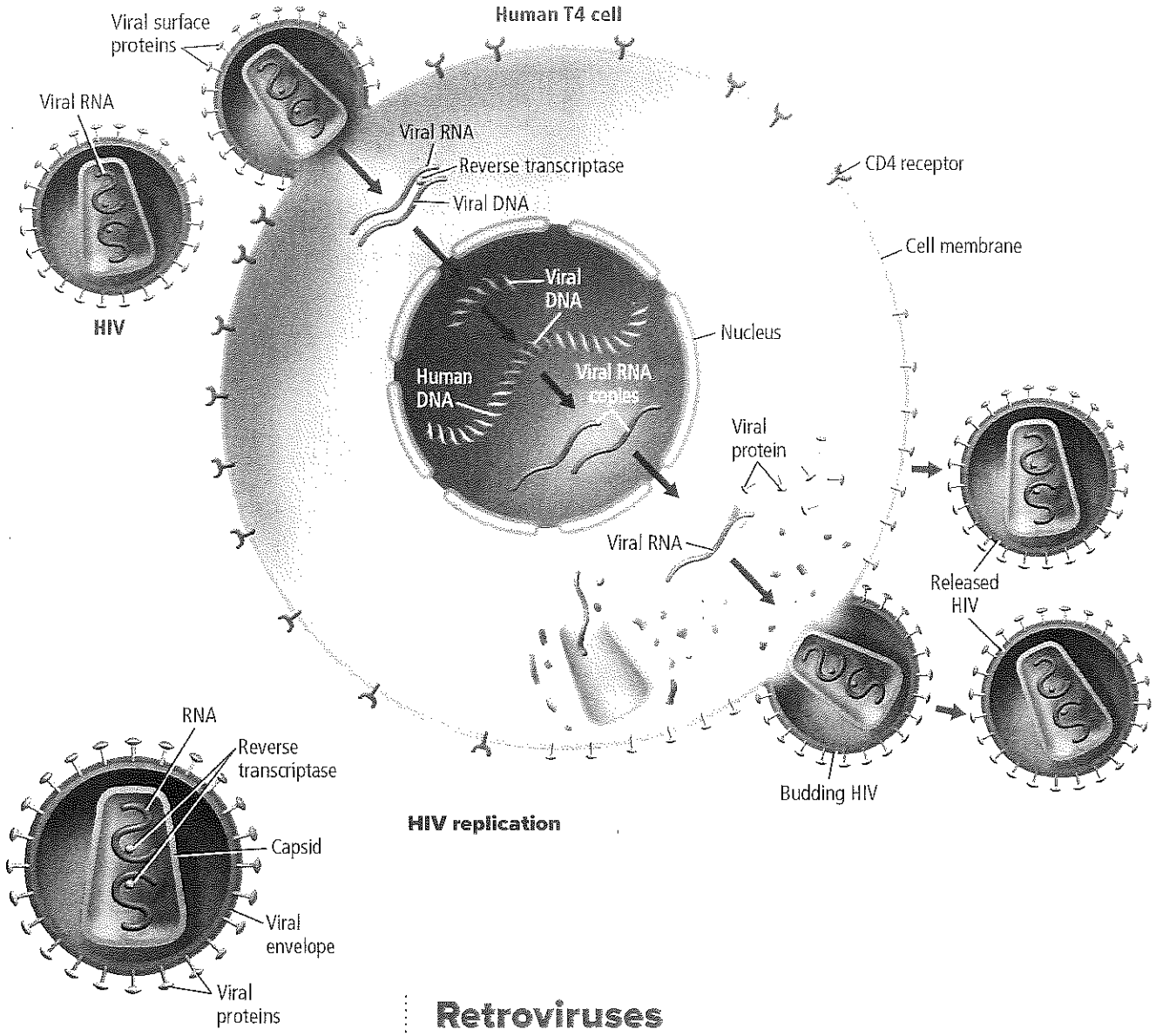


Figure 14 The genetic material and replication cycle of a retrovirus, such as HIV, is different from that of DNA viruses.
Infer *what is unique about the function of reverse transcriptase.*

Animation

What's BIOLOGY Got To Do With It?

Retroviruses

Some viruses have RNA instead of DNA for their genetic material. This type of virus is called a **retrovirus** and has a complex replication cycle. The best-known retrovirus is the human immunodeficiency virus (HIV). Some cancer-causing viruses also belong to this group.

Figure 14 shows the structure of HIV. Like all viruses, retroviruses have a protein capsid. Surrounding the capsid is a lipid envelope, which was obtained from the plasma membrane of a host cell. RNA and an enzyme called reverse transcriptase are in the core of the virus. Reverse transcriptase is the enzyme that transcribes DNA from the viral RNA.

Refer to **Figure 14** as you learn about the replication cycle of HIV. When HIV attaches to a cell, the virus moves into the cytoplasm of the host cell and the viral RNA is released. Reverse transcriptase synthesizes DNA using the viral RNA as a template. Then, the DNA moves into the nucleus of the host cell and integrates into a chromosome. The viral DNA might lie inactive for a period of years before it is activated. Once it is activated, RNA is transcribed from the viral DNA, and the host cell manufactures and assembles new HIV particles.

Prions

A protein that can cause infection or disease is called a proteinaceous (pro te NAY shuhs) infectious particle, or a **prion** (PREE ahn). Although diseases now believed to be caused by prions have been studied for decades, they were not well understood until 1982, when Stanley B. Prusiner first identified that the infectious particle was a protein.

Prions normally exist in cells, although their function is not well understood. Normal prions are shaped like a coil. Mutations in the genes that code for these proteins occur, causing the proteins to be misfolded. Mutated prions are shaped like a piece of paper folded many times. Mutated prions are associated with diseases known as transmissible spongiform encephalopathies (SPUN gee form • in SEH fuh la pah thees) (TSE). Examples of diseases caused by prions include mad cow disease in cattle, Creutzfeldt-Jakob disease (CJD) in humans, scrapie (SKRAY pee) in sheep, and chronic wasting disease in deer and elk.

Prion infection **Figure 15** shows a normal brain compared with a brain infected with prions. What scientists find fascinating about these misfolded proteins is that these prions can cause normal proteins to mutate. These prions infect nerve cells in the brain, causing them to burst. This results in spaces in the brain, hence the description of spongiform (spongelike) encephalopathy (brain disease).

In the mid-1980s, a new variant of CJD, or nvCJD, was discovered in England. Scientists do not fully agree on the origin of nvCJD, but a leading hypothesis is that the prions are transmitted from cattle. Abnormal prions can be found in the brains and spinal cords of cattle. The hypothesis is that if the spinal cord is cut in the butchering process, the prions might contaminate the beef and then be transmitted to humans that eat the beef. Although this mode of transmission is not agreed upon, the United States government has strict regulations concerning the importation of cattle and beef from other countries.

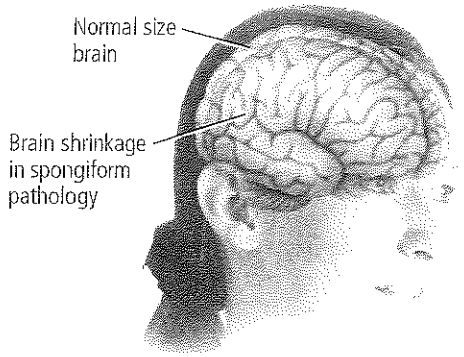


Figure 15 A normal brain compared with the brain of a patient with Creutzfeldt-Jakob disease is pictured here.

Section 2 Assessment

Section Summary

- Viruses have a nucleic acid core and a protein-containing coat.
- Viruses are classified by their genetic material.
- Viruses have three different patterns of replication.
- Many viruses cause disease.
- Proteins called prions also might cause disease.

Understand Main Ideas

1. THINK Idea **Describe** how viruses and prions can alter cell functions.
2. **Compare and contrast** similarities and differences in the replication of a herpes simplex virus with a human immunodeficiency virus.
3. **Draw** a diagram of a virus and label the parts.
4. **Sequence** the steps in the process of how prions might be transmitted from cattle to humans.

Think Critically

5. **Propose** ideas for the development of drugs that could stop viral replication cycles.

WRITING in Biology

6. Write a paragraph explaining why it is difficult to make drugs or vaccines that effectively fight against HIV, given the fact that each time reverse transcriptase works, it makes a slight miscopy.

Online Quiz

BioDiscoveries

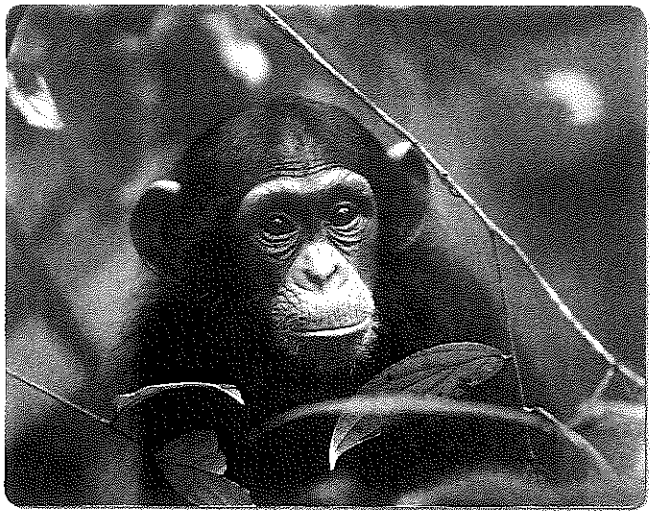
Exploring Inter-species Virus Transmission

While you were sniffling through yet another winter cold, did you ever wonder where the virus originated? Some viruses circulate only among humans, but other viruses can jump from animals to humans. Sometimes, both animals and humans can be infected with the same type of virus, while other viruses must change genetically in order to move from animals to humans.

H1N1 In the spring of 2009, a virus that was initially dubbed "swine flu" began to sweep across the globe. Since then, scientists have discovered that the virus, now called novel influenza A H1N1, passed from pigs to humans early that year. The new virus is what scientists call a quadruple reassortant virus because it contains two swine flu genes, an avian (bird) flu gene, and a human flu gene.

HIV Probably the most notorious virus to make the animal-to-human jump is HIV (human immunodeficiency virus), the virus that leads to AIDS (acquired immunodeficiency syndrome). HIV attacks the human immune system by destroying white blood cells. Scientists have discovered that in the late 1800s, the main strain of the virus, HIV-1 group M, jumped from a subspecies of chimpanzees to humans in Cameroon, a country in West Central Africa. Scientists hypothesize that the virus first infected people who were killing chimpanzees to sell for meat. The blood from the slaughtered primates got into scratches and bites on the human hunters, effectively transmitting HIV-1.

Ebola virus The often fatal disease called Ebola hemorrhagic fever (Ebola HF) is caused by the Ebola virus. Humans, as well as chimpanzees, gorillas, and monkeys, can be infected by subtypes of the virus.



Scientists have traced HIV and Ebola back to chimpanzees.

Scientists are not yet sure of the origins of the Ebola virus, but they think it is carried by a species of animal native to Africa and the Philippines and is spread to humans when they come into contact with infected animals.

Monitoring public health In response to the spread of H1N1, scientists and public health specialists have called for greater monitoring of the health of swine populations around the world. In the future, viruses that pass from animals to humans might spur the same kinds of actions in order to lessen the possibility of epidemics.

CAREERS IN BIOLOGY

Interview an epidemiologist Write down several questions that you have about these types of viruses. Also, write down several questions about what is involved in a career in epidemiology. If possible, ask a scientist your questions.

Michael Nichols/Getty Images

WebQuest

BIOLAB

Design Your Own

HOW CAN THE MOST EFFECTIVE ANTIBIOTICS BE DETERMINED?

Background: **A patient is suffering from a serious bacterial infection. As the doctor, you must choose from several new antibiotics to treat the infection.**

Question: *How can the effectiveness of antibiotics be tested?*

Materials

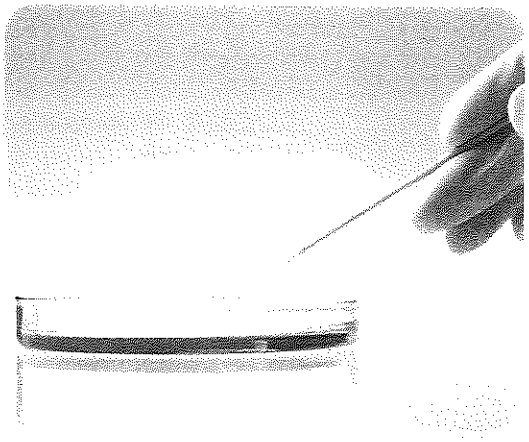
bacteria cultures
sterile nutrient agar
petri dishes
antibiotic disks
control disks
forceps
Bunsen burner
marking pen
long-handled cotton swabs
70% ethanol
thermometer
container
disinfectant
autoclave disposal bag

Safety Precautions

WARNING: ***Clean your work area with disinfectant after you finish.***

Plan and Perform the Experiment

1. Read and complete the lab safety form.
2. Design an experiment to test the effectiveness of different antibiotics. Identify the controls and variables in your experiment.
3. Create a data table for recording your observations and measurements.
4. Make sure your teacher approves your plan before you proceed.
5. Conduct your experiment.
6. **Cleanup and Disposal** Dispose of all materials according to your teacher's instructions. Disinfect your area.



Analyze and Conclude

1. **Compare and contrast** What are the effects of the different antibiotics for the bacteria species that you tested?
2. **Hypothesize** Why would a doctor instruct you to take all of your prescribed antibiotics for a bacterial infection even if you start feeling better before the pills run out?
3. **Explain** What were the limitations of your experimental design?
4. **Error Analysis** Compare and contrast the observations and measurements collected by your group with the data from the experiments designed by other groups. Identify possible sources of error in your experimental data.

COMMUNITY INVOLVEMENT

Create a Poster Misuse of antibiotic prescriptions and use of antibacterial household items are contributing to antibiotic-resistant bacteria. Research the causes of bacterial resistance to drugs and the steps that people in your community can take to help solve this problem. Create a poster display to educate the people in your community about this issue.

Chapter 18 Study Guide

THEME FOCUS Scale, Proportion, and Quantity Prokaryotes are the most abundant organisms on Earth, and cover nearly every surface.

BIG Idea Bacteria are microscopic organisms, and viruses are nonliving microscopic agents that invade cells.

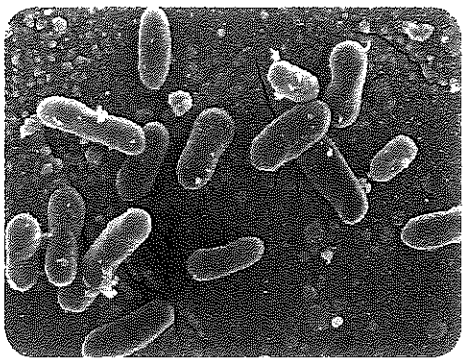
Section 1 Bacteria

bacteria (p. 516)
nucleoid (p. 518)
capsule (p. 518)
pilus (p. 518)
binary fission (p. 520)
conjugation (p. 520)
endospore (p. 521)

KEY Idea Prokaryotes are diverse organisms that live in nearly all environments.

- Many scientists think that prokaryotes were the first organisms on Earth.
- Prokaryotes belong to two domains.
- Most prokaryotes are beneficial.
- Prokaryotes have a variety of survival mechanisms.
- Some bacteria cause disease.

Color-Enhanced SEM Magnification: 25,000×

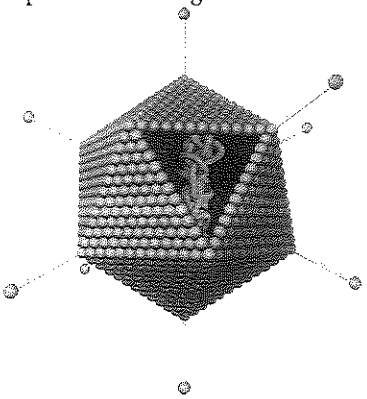


Section 2 Viruses and Prions

virus (p. 525)
capsid (p. 526)
lytic cycle (p. 528)
lysogenic cycle (p. 528)
retrovirus (p. 530)
prion (p. 531)

KEY Idea Viruses and prions are smaller and less complex than bacteria; they invade cells and can alter cellular functions.

- Viruses have a nucleic acid core and a protein-containing coat.
- Viruses are classified by their genetic material.
- Viruses have three different patterns of replication.
- Many viruses cause disease.
- Proteins called prions also might cause disease.



Dr. Gary Gaugler/Science Source

Vocabulary eGames

Chapter 18 Assessment

Section 1

Vocabulary Review

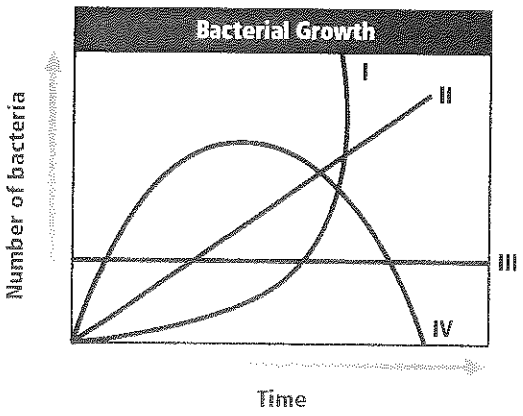
For each set of terms below, choose the one that does not belong and explain why it does not belong.

1. capsule, pilus, endospore
2. binary fission, nitrogen fixation, conjugation
3. endospore, nucleoid, nitrogen fixation

Understand Main Ideas

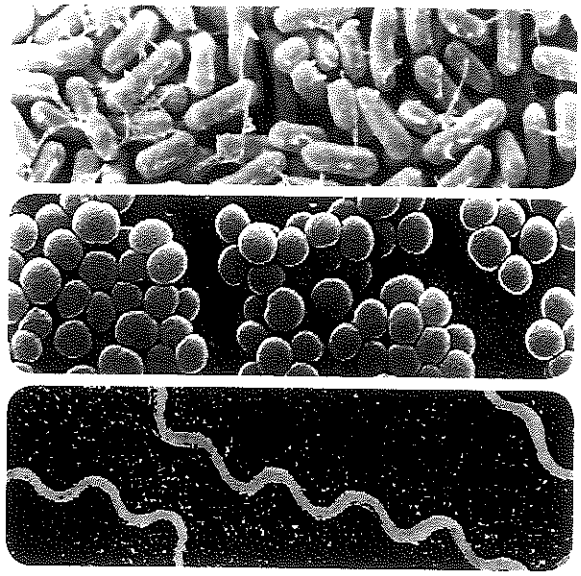
4. Which organism is not included in Domain Archaea?
   - A. cyanobacteria
   - B. methanogens
   - C. halophiles
   - D. thermoacidophiles
5. Why is an electron microscope useful when studying bacteria?
   - A. Electrons can penetrate through the capsules surrounding bacteria.
   - B. Bacteria are tiny.
   - C. Bacteria move quickly; the electrons stun the bacteria.
   - D. Bacteria organelles are small and tightly packed together.

Use the figure below to answer questions 6 and 7.



6. Which line on the graph best indicates the growth rate of a population of bacteria living in ideal conditions?
   - A. line I
   - B. line II
   - C. line III
   - D. line IV
7. Which line on the graph best indicates the growth rate of a population of bacteria exposed to an effective antibiotic?
   - A. line I
   - B. line II
   - C. line III
   - D. line IV
8. You have just been named a contestant on a reality show. Your first challenge is to swallow microbes. Which would be the most dangerous to swallow?
   - A. thermoacidophiles
   - B. halophiles
   - C. *Escherichia coli*
   - D. a bacteriophage

Use the photos below to answer question 9.



9. Which is the correct identification for the bacteria shown above?
   - A. I–cocci, II–bacilli, III–spirilli
   - B. I–bacilli, II–cocci, III–spirilli
   - C. I–spirilli, II–cocci, III–bacilli
   - D. I–bacilli, II–spirilli, III–cocci
10. What is the likely cause of tooth decay?
    - A. a lysogenic virus infecting the living cells of the tooth
    - B. bacteria feeding on the sugar in the mouth and producing acid
    - C. an excess of vitamin K production by bacteria in the mouth
    - D. nitrogen-fixing bacteria releasing ammonia that is eroding the tooth enamel

Online Test Practice

Chapter 18 Assessment

Constructed Response

11. **Open Ended** Make an argument for or against the following statement: Living organisms on Earth owe their lives to bacteria.

12. **THEME FOCUS Scale, Proportion, and Quantity** Describe characteristics of bacteria (both at the individual and population level) that make them tough to destroy.

13. **Open Ended** What types of arguments do you think biologists use when they say that prokaryotes were the first organisms on Earth?

Think Critically

14. **Speculate** what life on Earth might be like if cyanobacteria had never evolved.

15. **Predict** any ecological consequences that would result if all types of nitrogen-fixing bacteria suddenly became extinct.

16. **RANK IDEA** Describe some of the diverse characteristics of prokaryotes.

Section 2

Vocabulary Review

Use what you know about the vocabulary terms on the Study Guide page to describe what the terms in each pair below have in common.

17. lytic cycle, lysogenic cycle

18. prion, virus

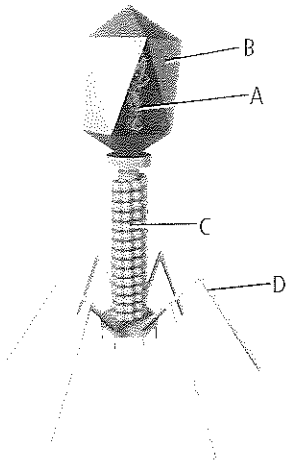
19. capsid, prion

20. virus, retrovirus

Understand Main Ideas

21. Viruses contain which substances?
    - **A.** genetic material and a capsid
    - **B.** a nucleus, genetic material, and a capsid
    - **C.** a nucleus, genetic material, a capsid, and ribosomes
    - **D.** a nucleus, genetic material, a capsid, ribosomes, and a plasma membrane

Use the figure below to answer questions 22 and 23.



22. Which labeled structure represents the genetic material of a virus?
    - **A.** A
    - **B.** B
    - **C.** C
    - **D.** D

23. Which structure represents the capsid of a virus?
    - **A.** A
    - **B.** B
    - **C.** C
    - **D.** D

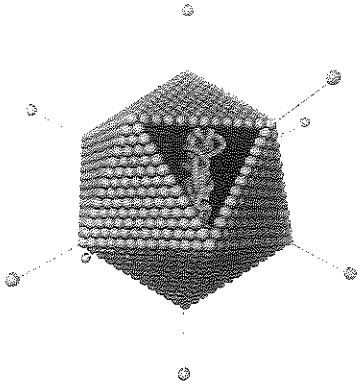
24. HIV is a retrovirus. What does this mean?
    - **A.** Viral RNA is used to make DNA.
    - **B.** Viral DNA is used to make RNA.
    - **C.** Protein is made directly from viral RNA.
    - **D.** Protein is made directly from viral DNA.

25. Which statement about prions is true?
    - **A.** Prions are renegade pieces of RNA that infect cells.
    - **B.** Prions are infectious proteins.
    - **C.** Prion-based diseases affect only cows.
    - **D.** Prions are a newly discovered type of genetic material.

26. Imagine that a patient in a hospital has died mysteriously. A doctor suspects that the cause of death is Creutzfeldt-Jacob disease. How could this diagnosis be confirmed?
    - **A.** by examining the blood to see if there is a high viral count
    - **B.** by asking the patient's family and friends if the patient consumed a lot of meat
    - **C.** by examining the brain to see if there are a lot of spaces in the tissue
    - **D.** by examining nerve cells to see if they have been affected by a bacterial neurotoxin

Online Test Practice

Use the figure below to answer question 27.



27. Which organisms does this virus infect?
   A. humans
   B. bacteria
   C. plants
   D. fungi

Constructed Response

28. **Open Ended** Make an argument for or against the following statement: Viruses are living organisms.

29. **Open Ended** Should people with highly contagious, potentially deadly viruses be quarantined? Defend your response.

30. THINK Idea Make an argument for or against the following statement: Prions are just viruses that lack a capsid.

Think Critically

31. **Infer** why it is more difficult to make an antiviral drug that fights a virus that replicates through the lysogenic cycle than it is to make one that fights a virus that replicates through the lytic cycle.

32. **Evaluate** why it is easier to make drugs that fight bacteria than drugs that fight viruses, even though viruses are structurally less complex than bacteria.

33. **Hypothesize** and develop a technique to slow down or stop a viral replication cycle.

34. **Develop** a list of careers that are associated with bacteria, viruses, and prions.

Summative Assessment

35. BIG Idea You have learned that bacteria are microscopic organisms, and viruses are nonliving agents that invade cells. Compare and contrast bacteria and viruses beyond the previous statement.

36. WRITING in Biology Prepare a newspaper article that clearly explains the differences between treatment and prevention for bacterial infections versus viral infections.

37. WRITING in Biology Compose a sentence that explains each step in the sequence of events in the replication of HIV.

Document-Based Questions

U.S. Data: Centers for Disease Control http://www.cdc.gov/flu/avian/pdf/avianflufacts.pdf.
Global Data: Scotland Government http://www.scotland.gov.uk/library5/health/pfle-00.asp

There were three worldwide influenza epidemics during the twentieth century. The number of deaths is presented in the table below.

	Spanish Flu	Asian Flu	Hong Kong Flu
Years	1918–1919	1957–1958	1968–1969
U.S. deaths	500,000	70,000	34,000
Global deaths	20–40 million	1 million	1–4 million

38. Which epidemic was the most deadly?

39. Why were deaths from the Hong Kong flu not as high in the United States compared to the Asian flu but were higher worldwide?

40. Hypothesize why a flu epidemic eventually stops instead of eliminating all human life.

41. Research statistics about a current strain of the flu. Copy the table and add a column about the flu that you researched. Is the current strain considered an "epidemic"? Site data to support your answer.

Online Test Practice

Standardized Test Practice

Cumulative

Multiple Choice

1. Which primate is an Asian ape?
   A. baboon
   B. gorilla
   C. lemur
   D. orangutan

Use the chart below to answer questions 2 and 3.

Common Name	Scientific Name
Grey wolf	*Canis lupus*
Red wolf	*Canis rufus*
African hunting dog	*Lycaon pictus*
Pampas fox	*Pseudalopex gymnocercus*

2. Which animal is related most closely to the Sechura fox *Pseudalopex sechurae*?
   A. African hunting dog
   B. grey wolf
   C. pampas fox
   D. red wolf

3. Which kind of difference is a valid reason to classify the red wolf and pampas fox in separate genera?
   A. different prey
   B. differences in key DNA sequences
   C. different structures of skulls
   D. different ages of evolutionary origin

4. Which describes the role of an endospore in bacteria?
   A. a dormant state of bacteria that can survive in unfavorable conditions
   B. a form of sexual reproduction in bacteria during which genetic information is exchanged
   C. a protective covering that bacteria secrete to protect themselves against harsh environments
   D. a tiny hairlike structure made of proteins that attaches the bacteria to a surface

5. Which information constitutes a scientific hypothesis?
   A. defined data
   B. proven explanation
   C. published conclusion
   D. reasonable guess

Use the table below to answer questions 6 and 7.

Identifying Bacteria			
Bacterial Strain	Gram Staining	Morphology	Related Disease
Bacillus cereus	Gram-positive	Rods; arranged in chains	Meningitis
Escherichia coli	Gram-negative	Cocci	Traveler's diarrhea
Pseudomonas aeruginosa	Gram-negative	Rodlike; occur in pairs or short chains	Pneumonia
Serratia mercescens	Gram-negative	Rodlike	Pneumonia

6. Which kind of bacteria stains gram-negative and appears rodlike in short chains?
   A. *Bacillus cereus*
   B. *Escherichia coli*
   C. *Pseudomonas aeruginosa*
   D. *Serratia marcescens*

7. Which related disease would be associated with a bacterium that is gram-negative and in paired rods?
   A. meningitis
   B. pneumonia
   C. cystic fibrosis
   D. traveler's diarrhea

8. Which taxon gives you the most general information about an organism?
   A. class
   B. domain
   C. family
   D. phylum

9. A population of rodents on an island makes up a distinct species that is similar to a species found on the mainland. Which process caused this speciation?
   A. behavioral isolation
   B. geographic isolation
   C. reproductive isolation
   D. temporal isolation

Short Answer

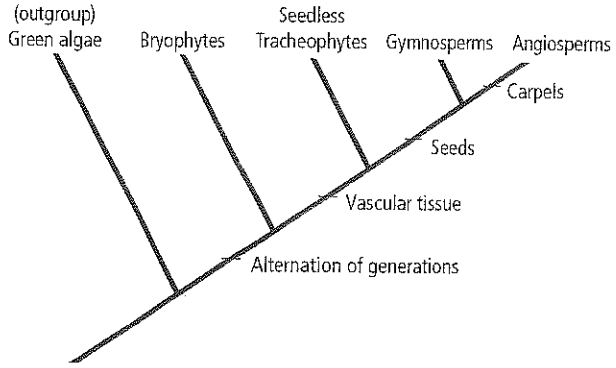
10. Suppose that two mosquitoes are classified as different species using the typological species concept. What data could scientists use, under the biological species concept, to show that they are the same species?

11. Compare the basic shapes of bacteria.

12. Contrast the typological species concept and the phylogenetic species concept.

13. Hypothesize how the evolution of bipedalism made it possible for hominoids to survive better in the drier African environment of the Miocene epoch.

Use the illustration below to answer questions 14 and 15.



14. According to the plant cladogram, what characteristic separates plants from earlier organisms?

15. Specify an example of an ancestral character and a derived character among angiosperms.

Extended Response

16. Certain bacteria fix nitrogen in the root nodules of a bean plant. Assess how the location of those bacteria in nodules is beneficial to the bacteria and the plants.

17. Give one justification for why a farmer might plant beans in the fields when not growing other crops.

18. Compare and contrast Domain Bacteria and Domain Archaea.

19. Justify why a doctor would not prescribe an antibiotic to treat the flu.

Essay Question

Although scientists have made many discoveries to piece together the steps in human and primate evolution, there are still areas of disagreement and gaps in the evidence. For instance, not all scientists agree about the naming of different species in the genus *Homo*, or about the ways to depict the human evolutionary tree.

Using the information in the paragraph above, answer the following question in essay format.

20. Write an essay that describes an area of debate in human evolution that interests you. What are some aspects of the debate or disagreement that you would want to find out more about? What kind of research would you be able to do if you were going to investigate this debate further?

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Review Section . . .	16.1	17.1	17.1	18.1	1.2	18.1	18.1	17.1	15.3	17.2	18.1	17.1	16.2	17.2	17.2	18.1	18.1	17.3	18.2	16.2, 16.3