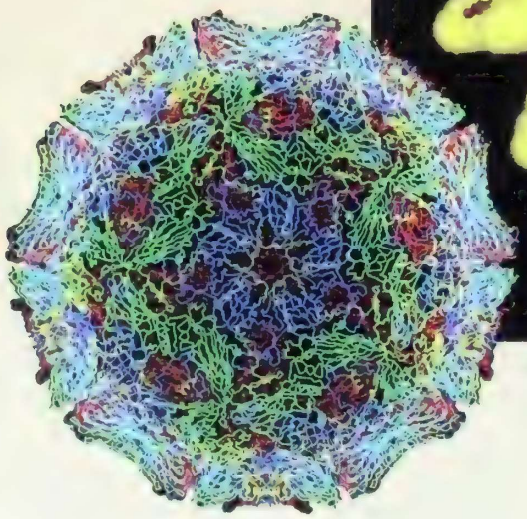
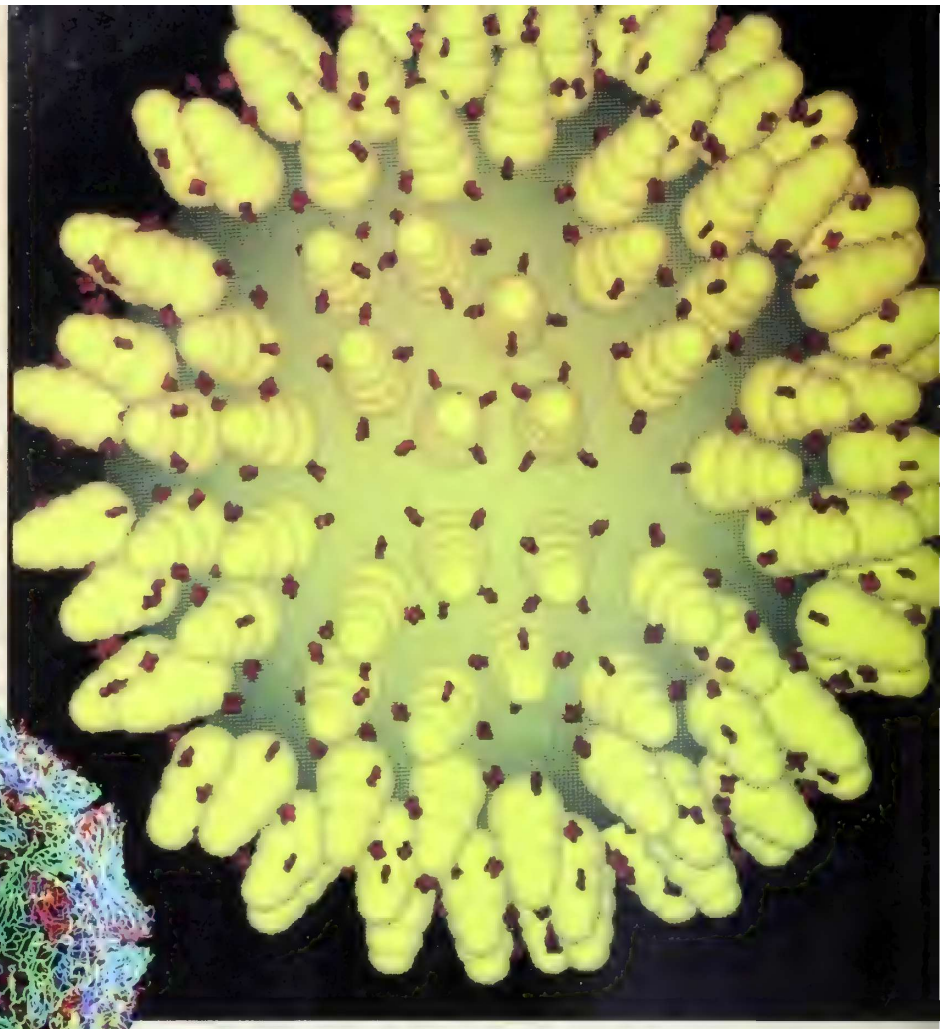
CHAPTER 17

Viruses and Monerans





These photographs show the computer-generated images of the semiliki forest virus (right) and the foot-and-mouth virus (left).

We are accustomed to thinking of ourselves as complex organisms—and that view is correct. By comparison, there must be simpler organisms—and that view too is correct. According to this standard, the simplest organisms should be the single-celled bacteria. Even simpler than bacteria must be viruses, which cannot live outside a living cell.

As useful as this reasoning is, it has two flaws. First, no species should be thought of as simple. Even the tiniest bacterium has a complexity of organization that is almost beyond description. Second, every species has been shaped by millions of years of natural selection. The result is a world filled with spectacular examples of life's ability to adapt to and master challenges. What are viruses and bacteria? How are they classified? How do they adapt to their surroundings? Read on to find out.

CHAPTER OUTLINE

17–1 Viruses
- What Is a Virus?
- Life Cycle of a Lytic Virus
- Lysogenic Infection
- Viruses and Living Cells
- Origin of Viruses

17–2 Monerans—Prokaryotic Cells
- Classification of Monerans
- Identifying Monerans
- How Monerans Obtain Energy
- Bacterial Respiration
- Bacterial Growth and Reproduction
- Importance of Monerans
- Bacteria in the Environment

17–3 Diseases Caused by Viruses and Monerans
- Viruses and Disease
- Bacteria and Disease
- Controlling Bacteria

17–1 Viruses

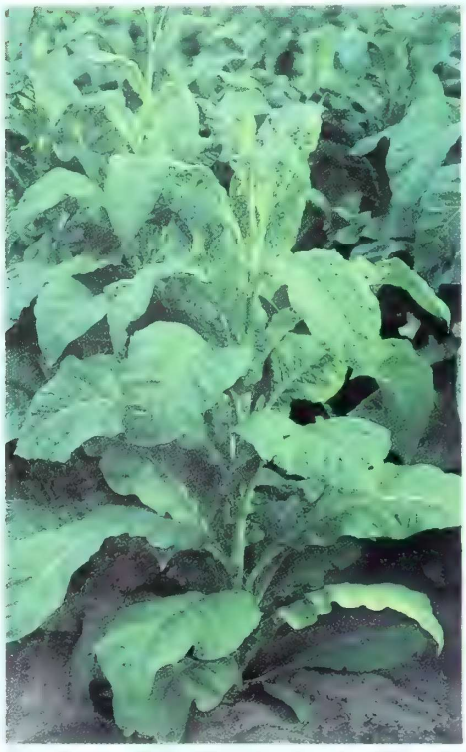
Section Objectives

- Describe the structure of viruses.
- Discuss two methods by which viruses infect living cells.

Imagine for a moment that you have been presented with a great challenge. A disease has begun to destroy certain crops. The leaves of diseased plants are covered with large bleached spots that form a pattern farmers call a mosaic. As the disease progresses, the leaves turn yellow, wither, and fall off, killing the plants.

To determine what is causing the disease, you take some leaves from a diseased plant and crush them until a juice is extracted. Then you place a few drops of the juice on the surfaces of leaves of healthy plants. A few days later, you discover that wherever you have placed the juice on the healthy leaves, a mosaic pattern has appeared. You reason that the cause of the disease must be in the juice of the infected plant.

You then search for a microorganism that might be responsible for the disease, but none can be found in the juice. In fact, even when the juice is passed through a filter with pores so fine that not even cells can pass through, the juice still causes the disease. When you look at a small amount of the filtered juice under the light microscope, you see no evidence of cells. The juice, which is capable of transferring the disease from one plant to another, must contain disease-causing particles so



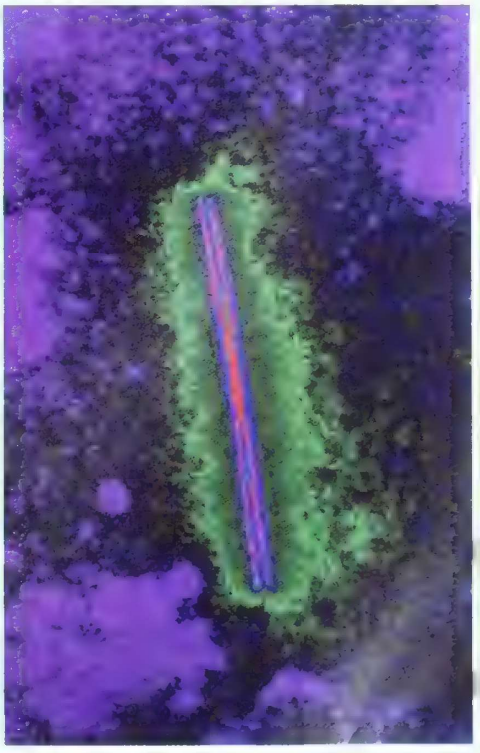
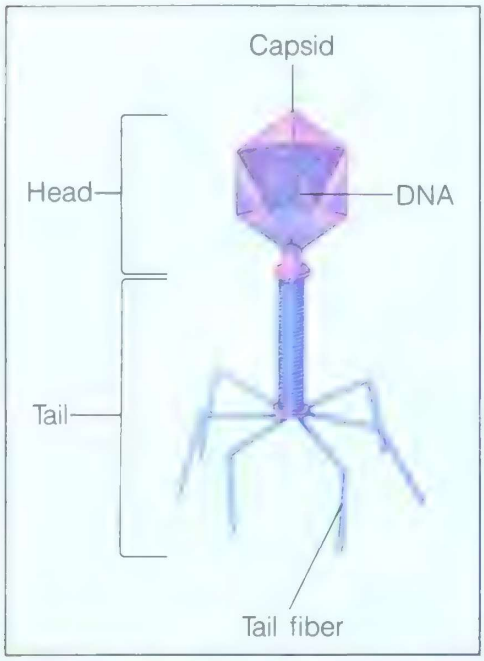


Figure 17–1 *The tobacco mosaic virus causes the leaves of tobacco plants to develop large bleached spots that form a pattern called a mosaic (left). The color-enhanced micrograph shows a tobacco mosaic virus that has been magnified approximately 41,800 times.*

small that they are not visible under the light microscope. Although you cannot see the disease-causing particles, you decide to give them the name viruses, from the Latin word meaning poison.

With a few exceptions, most of these events actually took place. About 100 years ago in what is now the Soviet Union, an epidemic of tobacco mosaic disease occurred that seriously threatened the tobacco crop. The disease-causing nature of the juice from infected leaves was discovered by the Russian biologist Dimitri Iwanowski. A few years later, the Dutch scientist Martinus Beijerinck named these disease-causing particles **viruses**.

Figure 17–2 A bacteriophage is a virus that infects bacteria. Compare the structures shown in the diagram of the bacteriophage to those in an actual bacteriophage.





What Is a Virus?

You have just read how scientists hypothesized the existence of viruses, which they thought were cells even smaller than one-celled bacteria. This idea persisted until 1935 when the nature of a virus was discovered by the American biochemist Wendell Stanley. He had set out to chemically isolate the particle responsible for the tobacco mosaic disease. Stanley identified the particle as the tobacco mosaic virus (TMV).

Since Stanley's discovery, many viruses have been identified, largely through the use of the electron microscope, which was invented in the 1930s. We now appreciate the fact that viruses have distinct structures that are complex and fascinating. **A virus is a noncellular particle made up of genetic material and protein that can invade living cells.**

STRUCTURE OF A VIRUS A typical virus is composed of a core of nucleic acid surrounded by a protein coat called a capsid. The capsid protects the nucleic acid core. Depending on the virus, the core is either DNA or RNA but never both. The core may contain several genes to several hundred genes.

A more complex structure occurs in certain viruses known as **bacteriophages**. You may recall from Chapter 7 that bacteriophages are viruses that invade bacteria. A bacteriophage has a head region, composed of a capsid (protein coat), a nucleic acid core, and a tail. Bacteriophages are interesting to study because their hosts (bacteria) multiply quickly. The most commonly studied bacteriophages are those of the T group. They are named T1, T2, T3, T4, and so on.

The bacteriophage known as T4 has a core of DNA contained within a protein coat. A number of other proteins (about 30 in all) form the other parts of the virus, including the tail fibers. The tail fibers are the structures by which the virus attaches itself to a bacterium.

Viruses come in a variety of shapes. Some, such as the tobacco mosaic virus, are rod-shaped. Others, such as the bacteriophages, are tadpole-shaped. Still others are many-sided, helical, or cubelike. Figure 17–3 shows some of these shapes.

Viruses vary in size from approximately 20 to 400 nanometers. A nanometer is one billionth of a meter. The tobacco mosaic virus is about 300 nanometers long, whereas the virus that causes polio is about 20 nanometers in diameter.

SPECIFICITY OF A VIRUS Usually, specific viruses will infect specific organisms. For example, a plant virus cannot infect an animal. There are some viruses that will infect only humans. Others, such as the virus that causes rabies, infect all mammals and some birds. Still others infect only coldblooded animals (animals with body temperatures that change with the surrounding air). There are even some viruses that will infect species of animals that are closely related. For example, viruses that infect mice may infect rats. So you can see that viruses are capable of infecting virtually every kind of organism, including mammals, birds, insects, and plants.

Life Cycle of a Lytic Virus

In order to reproduce, viruses must invade, or infect, a living host cell. However, not all viruses invade living cells in exactly the same way. When T4 bacteriophages invade living cells, they cause the cells to lyse, or burst. Thus T4 viruses are known as lytic (LIHT-ihk) viruses.

INFECTION A virus is activated by chance contact with the right kind of host cell. In the case of T4, molecules on its tail fibers attach to the surface of a bacterium. The virus then injects its DNA into the cell. In most cases, the complete virus particle itself never enters the cell.

GROWTH Soon after entering the host cell, the DNA of the virus goes into action. In most cases, the host cell cannot tell the difference between its own DNA and the DNA of the virus. Consequently, the very same enzyme RNA polymerase that makes messenger RNA from the cell's own DNA begins to make messenger RNA from the genes of the virus. This viral messenger RNA now acts like a molecular wrecking crew, shutting down and taking over the infected host cell. Some of these viral genes turn off the synthesis of molecules that are important to the infected cell. One viral gene actually produces an enzyme that destroys the host cell's own DNA but does not harm the viral DNA!

REPLICATION As the virus takes over, it uses the materials of the host cell to make thousands of copies of its own protein coat and DNA. Soon the host cell becomes filled with hundreds of viral DNA molecules. When *Escherichia coli*, or *E. coli*, the bacterium found in the human intestine, is infected by a T4 bacteriophage, this sequence of infection, growth, and replication can happen in as brief a time as 25 minutes!

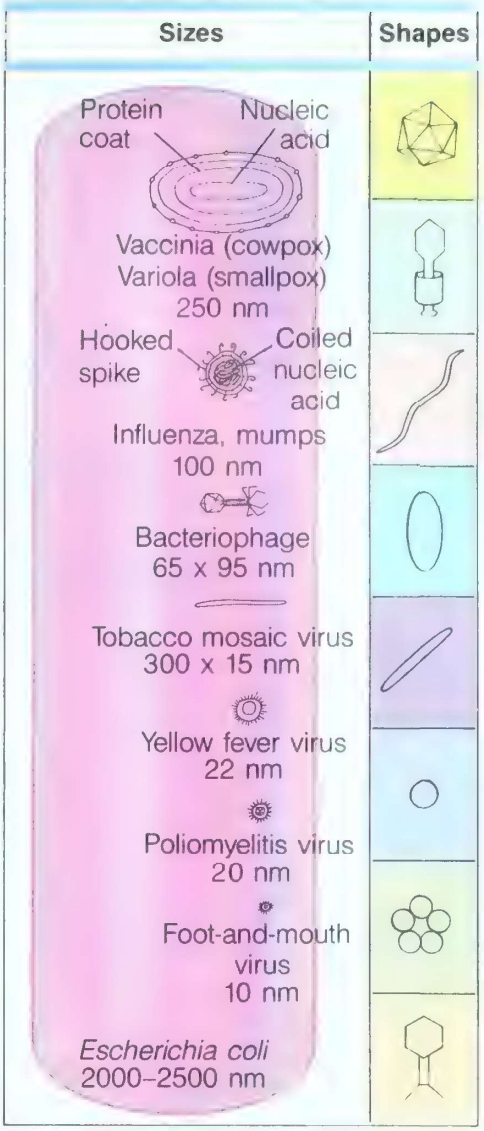


Figure 17–3 *Viruses come in a variety of sizes and shapes. Notice the size of the bacterium* E. coli *as compared to the sizes of the viruses.*

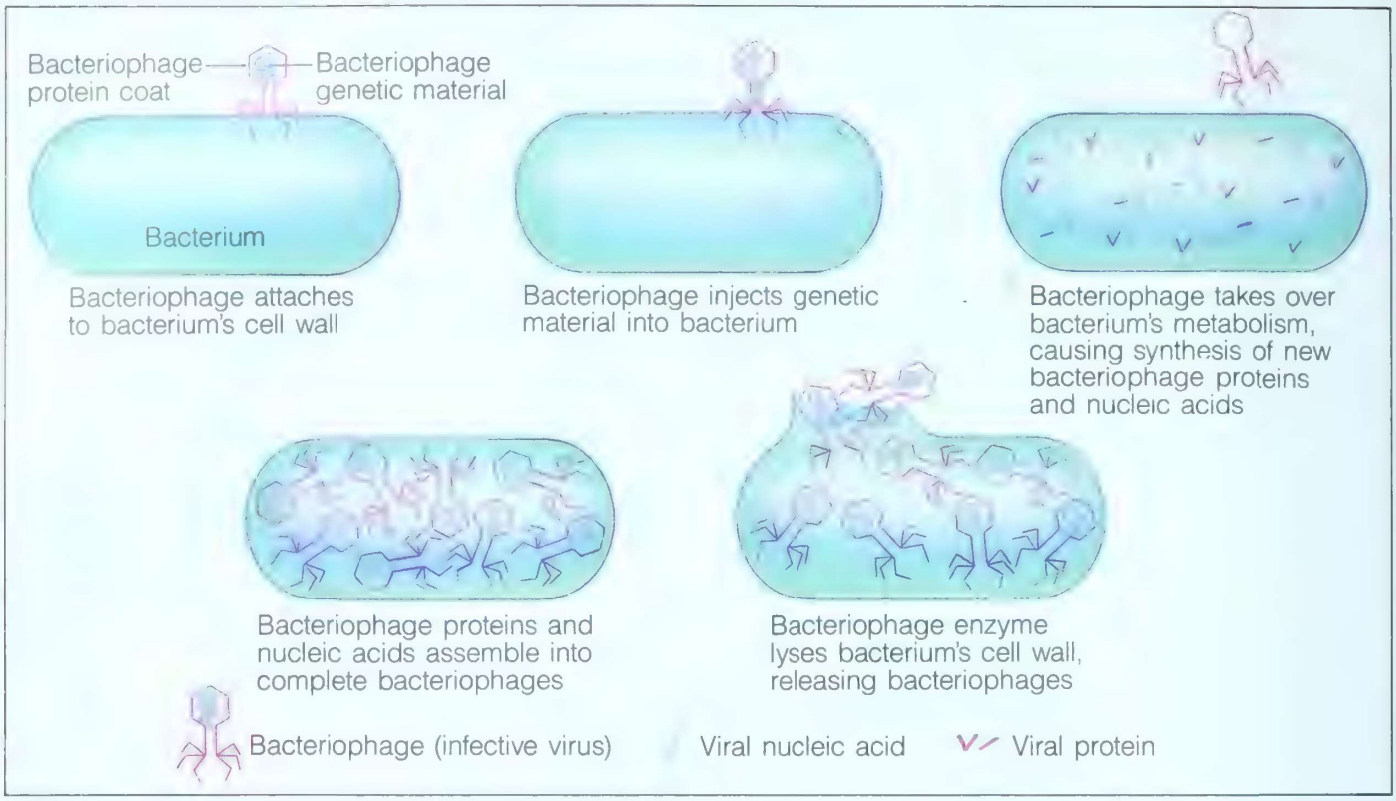


Figure 17–4 *In the life cycle of a lytic virus, the virus invades a bacterium, reproduces, and is scattered when the bacterium lyses, or breaks.*

During the final stage of reproduction, the DNA molecules serve as the starting points around which new virus particles are assembled. Before long, the infected cell lyses (bursts) and releases hundreds of virus particles that may now infect other cells. Because the host cell is lysed and destroyed, this process is called a **lytic infection**. Lytic infections are one way in which viruses can infect host cells.

The life cycle of a lytic virus such as T4 consists of repeated acts of infection, growth, and cell lysis. We may imagine the virus as a desperado moving into a town in the Old West. First, the desperado eliminates the town's existing authority (host cell DNA). Then the desperado demands to be outfitted with new weapons, horses, and riding equipment by terrorizing the local merchants and businesspeople (using the machinery of the host cell to make proteins). Finally, the desperado recruits more outlaws and forms a gang that leaves the town and attacks new communities (the host cell bursts, releasing hundreds of virus particles).

Figure 17–5 *This electron micrograph shows bacteriophages attacking the bacterium* E. coli. *How do viruses attach themselves to the bacterium?*



Lysogenic Infection

Another way in which a virus infects a cell is known as a **lysogenic** (ligh-soh-JEHN-ihk) **infection**. In a lysogenic infection, the virus does not reproduce and lyse its host cell—at least not right away! Instead, the DNA of the virus enters the cell and is inserted into the DNA of the host cell. Once inserted into the host cell's DNA, the viral DNA is known as a **prophage**.

The prophage may remain part of the DNA of the host cell for many generations. An example of a lysogenic virus is the bacteriophage *lambda*, which infects *E. coli*.

PROPHAGE ACTIVITY The presence of the prophage can block the entry of other viruses into the cell and may even add useful DNA to the host cell's DNA. For example, a lambda virus can insert the DNA necessary for the synthesis of important amino acids into the DNA of *E. coli*. As long as the lambda virus remains in the prophage state, *E. coli* can use the viral genes to make these amino acids.

A virus may not stay in the prophage form indefinitely. Eventually, the DNA of the prophage will become active, remove itself from the DNA of the host cell, and direct the synthesis of new virus particles. A series of genes in the prophage itself maintains the lysogenic state. Factors such as sudden changes in temperature and availability of nutrients can turn on these genes and activate the virus.

RETROVIRUSES One important class of viruses are the **retroviruses**. Retroviruses contain RNA as their genetic information. When retroviruses infect a cell, they produce a DNA copy of their RNA genes. This DNA, much like a prophage, is inserted into the DNA of the host cell. Retroviruses received their name from the fact that their genetic information is copied backward—that is, from RNA to DNA instead of from DNA to RNA. The prefix *retro-* means backward. Retroviruses are responsible for some types of cancer in animals and humans. One type of retrovirus produces a disease called AIDS.

Viruses and Living Cells

As you have just learned, viruses must infect living cells in order to carry out their functions of growth and reproduction. They also depend upon their hosts for respiration, nutrition, and all of the other functions that occur in living things. Thus viruses are **parasites**. A parasite is an organism that depends entirely upon another living organism for its existence in such a way that it harms that organism.

Are viruses alive? If we require that living things be made up of cells and be able to live independently, then viruses are not alive. However, when they are able to infect living cells, viruses can grow, reproduce, regulate gene expression, and even evolve. Viruses have so many of the characteristics of living things that it seems only fair to consider them as part of the system of life on Earth.

Because it is possible to study the genes that viruses bring into cells when they infect them, viruses have been extremely valuable in genetic research. Many of the major breakthroughs in genetics and molecular biology have been made by studying the regulation and expression of viral genes.

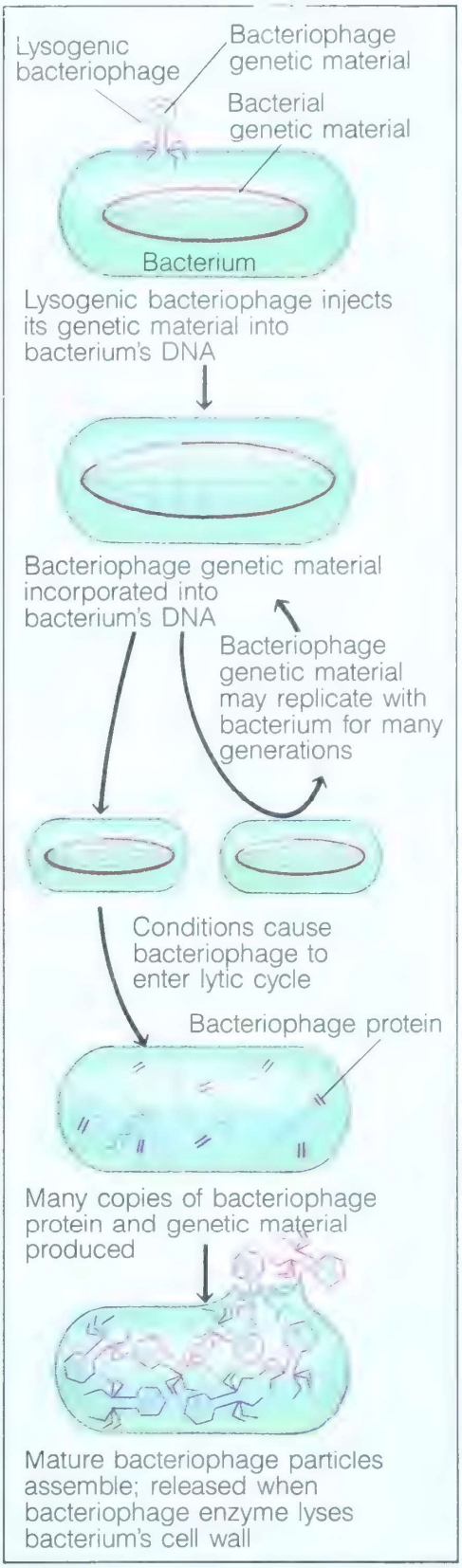


Figure 17–6 *In a lysogenic infection, the DNA of the bacteriophage enters the host cell and is inserted into its DNA.*

Origin of Viruses

Although viruses are smaller and simpler than the smallest cells, they could not have been much like the first living things. Viruses are completely dependent upon living cells for growth and reproduction, and they cannot live outside their host cells. Thus 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 and have continued to evolve, along with the cells they infect, over billions of years.

17–1 SECTION REVIEW

1. What is a virus?
2. List and describe the parts of a bacteriophage.
3. Describe two methods of viral infection.
4. How can a virus be helpful before it is harmful?

Section Objectives

- Describe the four major phyla of monerans.
- Compare autotrophic and heterotrophic monerans.
- Describe growth and reproduction in monerans.
- Identify the role of monerans in the environment.

17–2 Monerans—Prokaryotic Cells

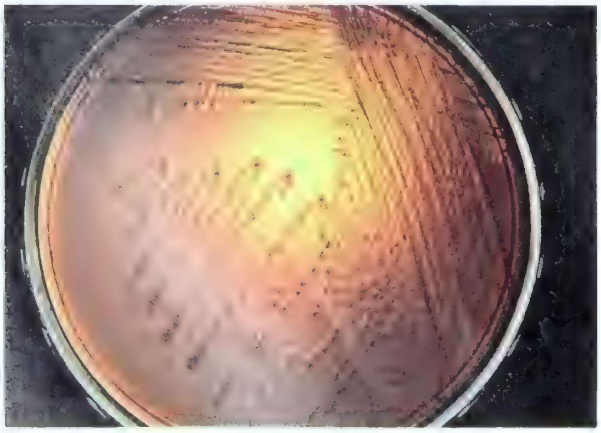
Imagine living all your life as the only family on your street. Then, on a morning like any other, you open the front door and there are houses all around you, cars and bicycles on the street, neighbors tending their gardens, children walking to school. Where did they come from? What if the answer turned out to be that they were always there—you just couldn't see them? In fact, they lived on your street for years and years before your house was even built. How would your view of the world change? What would it be like to go, almost overnight, from being the only family on the block to just one family in a crowded community? A bit of a shock?

Because of Robert Hooke and Anton van Leeuwenhoek, the human species had just such a shock. The invention of the light microscope opened our eyes to what the world around us is really like. And it opened our eyes almost overnight. Suddenly we saw that the block is very crowded!

Microscopic life covers nearly every square centimeter of planet Earth. What form does that microscopic life take? As you learned in Chapter 5, there are cells of every size and shape imaginable, even in a drop of pond water. The smallest and most common of these cells are the **prokaryotes**. Prokaryotes are cells that do not have a nucleus.

Where do we find prokaryotes? Everywhere! Prokaryotes exist in almost every place on Earth. They grow in numbers so great that they form colonies you can see with the unaided eye.

Figure 17–7 *With a nutrient-rich culture medium on which to grow, these bacteria have produced thousands of colonies.*



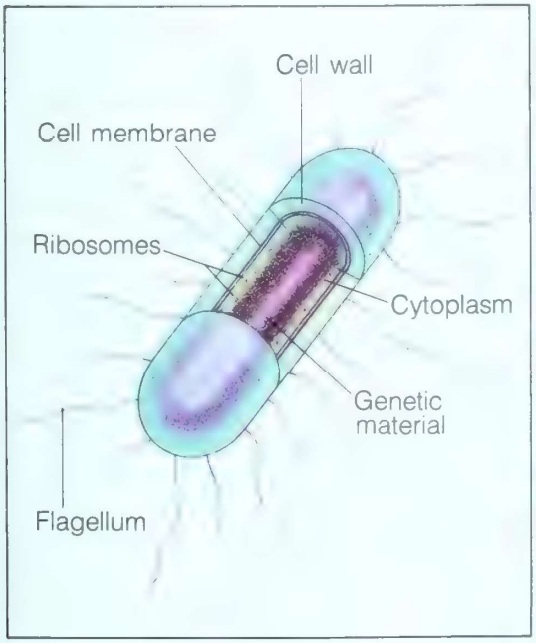
Classification of Monerans

All prokaryotes are placed in the kingdom Monera. The monerans are the first large group of organisms that we shall consider as we examine each of the five kingdoms of living things. In this textbook we have divided the kingdom Monera into four phyla. These phyla are Eubacteria (yoo-bak-TIHR-ee-uh), Cyanobacteria (sigh-uh-noh-bak-TIHR-ee-uh), Archaebacteria (ahr-kee-bak-TIHR-ee-uh), and Prochlorobacteria (proh-klor-oh-bak-TIHR-ee-uh). Although there are important differences among these four groups of organisms, each group shares enough similarities with the others to allow them to be called **bacteria**, or one-celled prokaryotes.

Bacteria range in size from 1 to 10 micrometers (one micrometer is equal to one thousandth of a millimeter). Bacteria are much smaller than eukaryotic cells, or cells with a nucleus, which generally range from 10 to 100 micrometers in diameter. The reason for the difference in size is that bacteria and other monerans do not contain the complex range of membrane-enclosed organelles that are found in most eukaryotic cells.

EUBACTERIA The phylum Eubacteria ("true" bacteria) is the largest of all the moneran phyla. Members of this phylum have always been referred to as bacteria. Eubacteria are generally surrounded by a cell wall composed of complex carbohydrates. The cell wall protects the bacterium from injury. Within the cell wall is a cell membrane that surrounds the cytoplasm. Some eubacteria are surrounded by two cell membranes. In some organisms, long whiplike flagella protrude from the membrane through the cell wall. Flagella are used for movement.

Within the phylum Eubacteria is a wide variety of organisms that have many different lifestyles. Some species live in



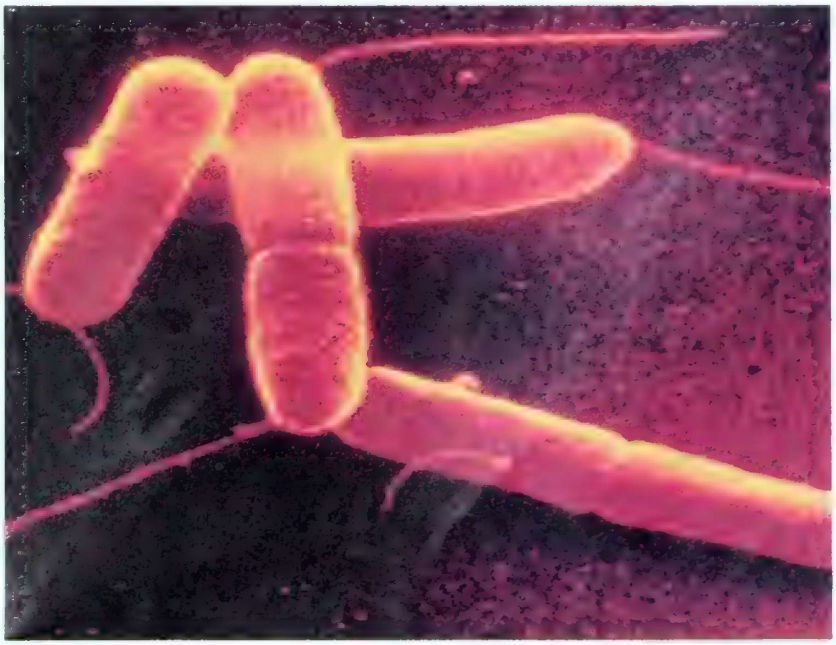


Figure 17–8 *A bacterium such as* E. coli *(right) has the basic structure typical of most bacteria: cell wall, cell membrane, region of genetic material, and cytoplasm. Note the flagella projecting from the cell surface.*



Figure 17–9 *Bacteria can survive in many environments that support no other forms of life, such as in a near-boiling hot spring called Morning Glory Pool in Yellowstone National Park, Wyoming.*

the soil. Others infect larger organisms and produce disease. Still others are photosynthetic. Photosynthetic bacteria are those bacteria capable of making their own food by using light energy. Later in this chapter we will examine some of the important roles that eubacteria play in the natural environment and some of the ways in which they affect us.

CYANOBACTERIA The bacteria that belong to the phylum Cyanobacteria are photosynthetic. Cyanobacteria are also known as blue-green bacteria. At one time, cyanobacteria were called blue-green algae, but today we use the word algae only for eukaryotes. In fact, only a few of the blue-green bacteria are a blue-green color. Those monerans that are blue-green in color contain a blue pigment called phycocyanin. They also contain chlorophyll *a*, which you will recall from Chapter 6 is green. The presence of these two pigments gives the name blue-green to the entire group of cyanobacteria. The presence of other pigments, however, may change the color of these monerans to yellow, brown, or even red.

Cyanobacteria contain membranes that carry out the light reactions of photosynthesis. These membranes contain the photosynthetic pigments and are quite different from and simpler than the chloroplasts (organelles that trap light energy and convert it to chemical energy) in plant cells.

Cyanobacteria are found throughout the world—in fresh and salt water and on land. A few species can survive in extremely hot water, such as that in hot springs. Others can survive in the Arctic, where they can even grow on snow. In fact, cyanobacteria are often the very first species to recolonize the site of a natural disaster, such as a volcanic eruption.

ARCHAEBACTERIA AND PROCHLOROBACTERIA Recent studies of monerans have led to the establishment of two new phyla that include organisms that differ from eubacteria and cyanobacteria. One phylum, Archaebacteria, includes organisms that live in extremely harsh environments. For example, one group of archaebacteria lives in oxygen-free environments such as thick mud and the digestive tracts of animals. These archaebacteria are called **methanogens** because they produce methane gas. Other archaebacteria live in extremely salty environments, such as the Great Salt Lake in Utah, or in extremely hot environments, such as hot springs where temperatures approach the boiling point of water.

The prochlorobacteria are a newly discovered group of photosynthetic organisms that contain chlorophyll *a* and *b* as their principal pigments. The presence of these pigments makes prochlorobacteria more similar to chloroplasts of green plants than to cyanobacteria. For this reason, prochlorobacteria are sometimes called Prochlorophyta (*-phyta* means plants) to emphasize this similarity. To date, only two species of prochlorobacteria have been discovered.

Identifying Monerans

Identifying living organisms can be a simple task. If we were given an unknown plant or animal, we would search through the photographs and diagrams in a reference book until we found one that resembled our unknown specimen. Such a method works for organisms that we can identify by appearance. But what about bacteria? How can they be identified?

CELL SHAPE One way in which bacteria can be identified is by their shape. **Bacteria have three basic shapes: rod, sphere, and spiral.** Rod-shaped bacteria are called **bacilli**

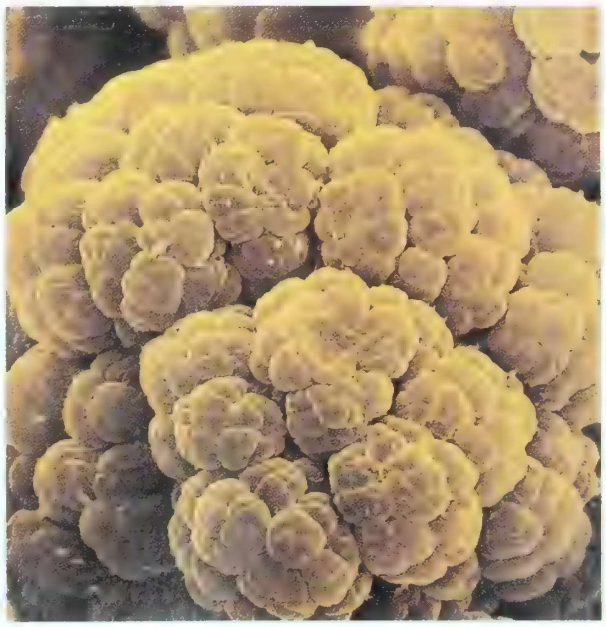
SCIENCE, TECHNOLOGY, AND SOCIETY ISSUE

A Separate Kingdom?

One of the more unusual groups of organisms in the kingdom Monera are the methanogens, which are methane-producing bacteria. Methanogens obtain their energy by producing methane gas (CH_4) from carbon dioxide gas (CO_2) and hydrogen gas (H_2). These monerans live in places where there is little available oxygen, such as beneath the surfaces of muddy marshes, in sewage, and even in human intestines.

Recently, a rather startling suggestion was made by Carl Woese of the University of Illinois. After carefully comparing hundreds of organisms, Woese proposed that the methanogens be placed in a new kingdom called Archaebacteria. The ribosomes and ribosomal RNA of Archaebacteria are so different from other living things, Woese argued, that they must be placed in a separate living kingdom.

Is Woese right? He may well be. But one thing is certain: His findings and suggestions have touched off a debate among biologists as to how living things should be classified. This debate has prompted dozens of scientists from all over the world to test Woese's ideas and to devise new experiments and new ways of comparing living organisms. This flurry of activity can lead to a better understanding of living organisms.



The methanogen Methanosarcina mazei

Getting back to the issue at hand: Are methanogens deserving of their own kingdom? We will have to wait and see. Who knows, in a few years we may find ourselves with a new addition to the present scheme of classification.



Figure 17–10 *Bacteria have three basic shapes. Rod-shaped bacteria are called bacilli (left), spherical bacteria are called cocci (center), and spiral-shaped bacteria are called spirilla (right).*

(buh-SIHL-igh; singular: bacillus). Spherical bacteria are called **cocci** (KAHK-sigh; singular: coccus). And spiral-shaped bacteria are called **spirilla** (spigh-RIHL-uh; singular: spirillum). See Figure 17–10.

Individual bacterial cells can also arrange themselves in a number of different ways. For example, cocci cells sometimes grow in colonies containing two cells. These two-celled colonies are called diplococci. Other cocci cells grow into long chains called streptococci. Still other cocci cells form large clumps and clusters called staphylococci. Using this information, we can now identify some bacterial cells by looking at them under the microscope.

Unfortunately, many bacteria look the same under the microscope. So we need to find another characteristic by which to distinguish one type from another. Fortunately, there are three other characteristics of bacteria that improve our ability to identify them: their cell walls, the kind of movement they are capable of, and how they obtain energy.

Figure 17–11 *When spherical bacteria grow into long chains, they are called streptococci.*



CELL WALL The chemical nature of bacterial cell walls can be studied by means of a method called Gram staining—which is named after its inventor, the Danish physician Hans Christian Gram. Gram's stain consists of two dyes—crystal violet (purple) and safranine (red).

When Gram added his stain to bacteria, he noticed that the bacteria took up either the purple dye or the red dye. The bacterial cells with only one thick layer of carbohydrate and protein molecules outside the cell membrane took up the crystal violet. They appeared purple under the light microscope. These bacteria are called Gram-positive bacteria. The bacterial cells with a second, outer layer of lipid and carbohydrate molecules took up the safranine. They appeared red under the microscope. These bacteria are called Gram-negative bacteria.

BACTERIAL MOVEMENT We can also identify bacteria by studying how they move. Some bacteria are propelled by means of one or more flagella. Others lash, snake, or spiral forward. Still others glide slowly along a layer of slimelike material that they secrete themselves. And there are some bacteria that do not move at all.

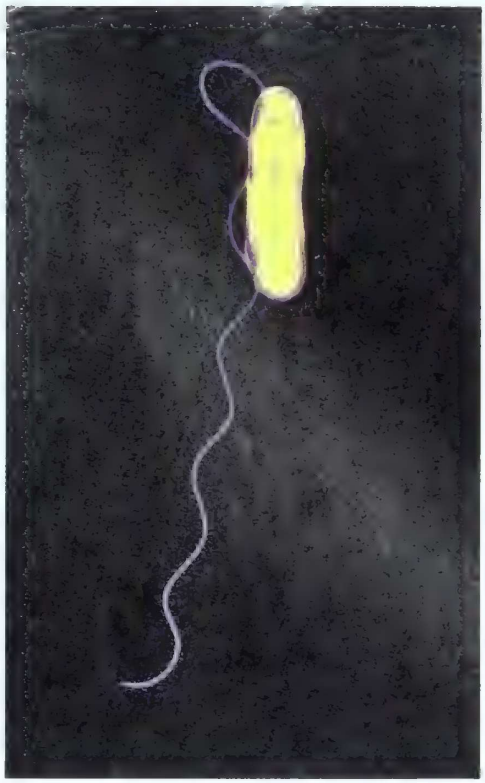


Figure 17–12 *Many types of bacteria, such as the bacterium that causes Legionnaires' disease, move by means of a whiplike flagellum.*

How Monerans Obtain Energy

Although the structure of monerans is rather simple, their lifestyles are remarkably complex. No characteristic of monerans illustrates this point better than the ways in which they obtain energy.

AUTOTROPHS Monerans that trap the energy of sunlight in a manner similar to green plants are called **phototrophic autotrophs.** Examples of phototrophic autotrophs include the cyanobacteria and some photosynthetic eubacteria.

Monerans that live in harsh environments and obtain energy from inorganic molecules are called **chemotrophic autotrophs.** The inorganic molecules that are used by chemotrophic autotrophs include hydrogen sulfide, nitrites, sulfur, and iron. *Nitrosomonas* is an example of a chemotrophic autotroph that uses ammonia and oxygen to produce energy.

HETEROTROPHS Many bacteria obtain energy by taking in organic molecules and then breaking them down and absorbing them. These bacteria are called **chemotrophic heterotrophs**. Most bacteria, as well as most animals, are chemotrophic heterotrophs.

Because we are chemotrophic heterotrophs ourselves, many bacteria compete with us for food sources. For example, *Salmonella* is a bacteria that grows in foods such as raw meat, poultry, and eggs. If these foods are not properly cooked, *Salmonella* will get to your dinner table before you do! Once there, these bacteria will not only "eat" some of the food ahead of time, but they will release poisons into the food. Food poisoning can result. The symptoms of food poisoning range from an upset stomach to serious illness.

There is another group of heterotrophic bacteria that has a most unusual means of obtaining energy. These bacteria are photosynthetic—they are able to use sunlight for energy. But they also need organic compounds for nutrition. These bacteria are called **phototrophic heterotrophs**. There is nothing quite like these organisms in the rest of the living world.

Bacterial Respiration

Like all organisms, bacteria need a constant supply of energy to perform all their life activities. This energy is supplied by the processes of respiration and fermentation. Respiration

PROBLEM SOLVING IN BIOLOGY

FOOD POISONING

Every year, thousands of cases of bacterial food poisoning are reported. In each case, a medical detective is assigned to find out how the person got food poisoning. Once the cause of the food poisoning has been determined, the medical detective can move to correct the conditions that led to the food poisoning.

Two types of bacteria that cause food poisoning are salmonella and staphylococci. A medical detective knows that these bacteria produce very different symptoms. So in order to determine which bacteria is the culprit, the detective will ask a series of important questions. The first thing the detective will want to know is exactly what the patient ate in the 24 hours prior to becoming ill and where the food was eaten. Other important information that the detective will gather includes how long after eating the patient became ill and whether the patient developed a fever. The detective will also want to know if the patient developed chills. Armed with answers to these questions, the detective can determine what caused the food poisoning and which meal contained the tainted food. But how?

The medical detective knows many details about these two types of bacterial food poisoning. For example, staphylococci produce a toxin, or poison, that is secreted into the food source as the bacteria multiply. Once a person eats the tainted food, the toxin will be carried throughout his or her body by the bloodstream. Within a few hours after the food has been ingested, the toxin will usually cause symptoms that include diarrhea, vomiting, nausea, and abdominal cramps. Fortunately, recovery is usually complete 24 to 48 hours after the onset of the symptoms.

Like staphylococci, salmonella produce a toxin. This toxin, however, is contained in the bacteria's cell walls and is released only when the bacteria lyse, or burst. Because of this difference, the symptoms produced by salmonella are somewhat unlike those produced by staphylococci. For example, it takes longer for a person to feel the effects of salmonella, often 12 hours or more. Salmonella infections almost always cause diarrhea. And they also generally result in a fever, chills, frequent vomiting, and abdominal pain. It may also take a patient quite a bit longer to recover from a case of salmonella food poisoning.

Now it's time for you to play medical detective.



Salmonella bacterium magnified 12,600 times

Case Study 1 A patient with food poisoning reports that he ate his last meal at about 6 P.M. Although he felt fine the next morning, the patient became very sick at work. Due to severe abdominal pain and vomiting, the patient returned home. The patient also had a fever, chills, and severe diarrhea. He still felt sick the next day and did not fully recover for several days.

Case Study 2 You interview a patient who is suffering from food poisoning. However, this patient shows signs of recovery and feels well enough to go back to work. You discover that the last time the patient ate was about 6 P.M. the night before. While watching television later that evening, the patient became ill and had extremely severe abdominal cramps. The patient had a mild case of diarrhea that has subsided. There was no fever.

Analysis Analyze each case study to determine whether the food poisoning was caused by salmonella or staphylococci. Support your diagnoses based on the data provided.

is the process that involves oxygen and breaks down food molecules to release energy. Fermentation, on the other hand, enables cells to carry out energy production without oxygen.

Organisms that require a constant supply of oxygen in order to live are called **obligate aerobes**. We, and many species of bacteria, are obligate aerobes. Some bacteria, however, do not require oxygen, and in fact may be poisoned by it! These bacteria are called **obligate anaerobes**. Obligate anaerobes must live in the absence of oxygen.

An example of an obligate anaerobe is the bacterium *Clostridium botulinum*, which is often found in soil. Because *Clostridium* is unable to grow in the presence of oxygen, it normally causes very few problems. However, if these bacteria find their way into a place that is free of air (air contains oxygen) and filled with food material, they will grow very quickly. As they grow, the bacteria produce **toxins**, or poisons, that cause botulism. Botulism is a rare form of food poisoning that interferes with nerve activity and can cause paralysis and, if the breathing muscles are paralyzed, death. A perfect place for these bacteria to grow is in the space inside a can of food. Most commercially prepared canned foods are safe because the bacteria and their toxins have been destroyed by heating the foods for a long time before the cans are sealed. However, botulism is always a danger when food is canned at home. Thus experienced canners thoroughly heat food before sealing it in jars.

A third group of bacteria are those that can survive with or without oxygen. They are known as **facultative anaerobes**. Facultative anaerobes do not require oxygen, but neither are they poisoned by its presence. What does such diversity imply? It means that bacteria can live in virtually every place on the surface of planet Earth. And indeed they do! Bacteria are found in freshwater lakes and ponds, at the bottom of the ocean, at the tops of the highest mountains, in the most sterile hospital rooms, and even in our own digestive systems!

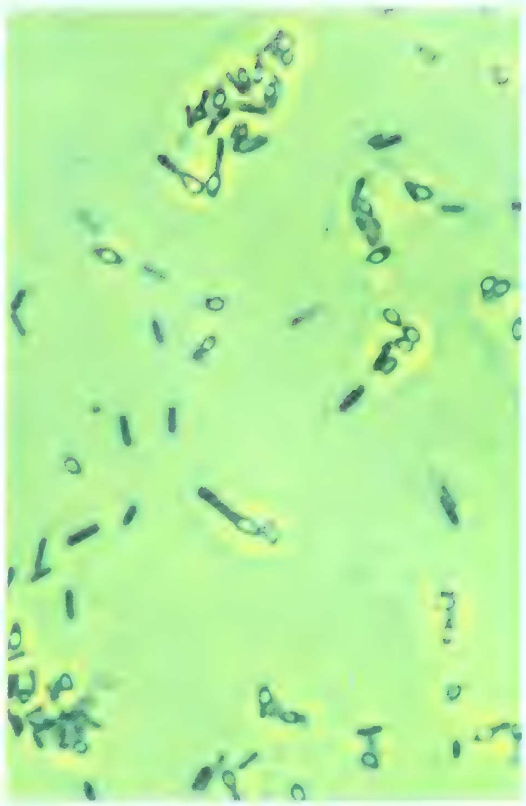


Figure 17–13 *Botulism, a kind of food poisoning, is caused by the bacterium* Clostridium botulinum. *The small round structures on some of the bacteria are endospores.*

Bacterial Growth and Reproduction

When conditions are favorable, bacteria can grow and reproduce at astonishing rates. Some types of bacteria can reproduce as often as every 20 minutes! If unlimited space and food were available to a single bacterium and if all of its offspring divided every 20 minutes, then in just 48 hours (2 days) they would reach a mass approximately 4000 times the mass of the Earth! Fortunately for us, this does not happen. In nature, the growth of bacteria is held in check by the availability of food and the production of waste products. However, bacteria do reproduce, and they do so in a number of ways.

BINARY FISSION When a bacterium has grown so that it has nearly doubled in size, it replicates its DNA and divides in half, producing two identical daughter cells. This type of



Figure 17–14 *Most bacteria reproduce by binary fission, producing two identical cells (right). However, some bacteria reproduce by conjugation, or the transfer of parts of their genetic information from one cell to another through a protein bridge (left).*

reproduction is known as **binary fission**. Because binary fission does not involve the exchange or recombination of genetic information, it is an asexual form of reproduction. The bacterium *E. coli* undergoes binary fission. See Figure 17–14.

CONJUGATION Although many bacteria reproduce only through asexual binary fission, others take part in some form of sexual reproduction. Sexual reproduction involves the exchange of genetic information. One form of sexual reproduction that occurs in some bacteria is known as **conjugation**. See Figure 17–14.

During conjugation, a long bridge of protein forms between and connects two bacterial cells. Part of the genetic information from one cell, called the donor, is transferred to the other cell, called the recipient, through this bridge. When the process of conjugation is complete, the recipient cell has a different set of genes from those it had before conjugation occurred. The new combinations of genes that result from conjugation increase the genetic diversity in that population of bacteria. Genetic diversity helps to ensure that even if the environment changes, a few bacteria may have the right combinations of genes to survive.

SPORE FORMATION When growth conditions become unfavorable, many bacteria form structures called spores. One type of spore, called an **endospore**, is formed when a bacterium produces a thick internal wall that encloses its DNA and a portion of its cytoplasm.

The endospore can remain dormant for months or even years, waiting for more favorable growth conditions. When conditions improve, the endospore will open and the bacterium will begin to grow again. Strictly speaking, spore formation in bacteria is not a form of reproduction because it does not

result in the formation of new bacterial cells. However, the ability to form spores makes it possible for some bacteria to survive harsh conditions that would otherwise kill them.

Importance of Monerans

Many of the remarkable properties of monerans provide us with products upon which we depend every day. For example, bacteria are used in the production of a wide variety of foods and beverages, such as cheese, yogurt, buttermilk, and sour cream. Some bacteria are used to make pickles and sauerkraut, and some make vinegar from wine.

Bacteria are also used in industry. One type of bacteria can digest petroleum, which makes them helpful in cleaning up small oil spills. Some bacteria remove waste products and poisons from water. Others can even help to mine minerals from the ground. Still others have been useful in synthesizing drugs and chemicals through techniques of genetic engineering.

Many kinds of bacteria develop a close relationship with other organisms in which the bacteria or the other organism or both benefit. Such a relationship is called **symbiosis** (sihm-bigh-OH-sihs). The symbiotic relationships that bacteria develop with other organisms are particularly important. Monerans form symbiotic relationships with organisms from all of the other four kingdoms.

Our intestines are inhabited by large numbers of bacteria, including *E. coli.* Indeed, the species name *coli* was derived from the fact that these bacteria were discovered in the human colon, or large intestine. In the intestines, the bacteria are provided with a warm safe home, plenty of food, and free transportation. We, in turn, get help in digesting our food. These bacteria also make a number of vitamins that we cannot produce on our own. So both we and the bacteria benefit from this symbiotic relationship.



Figure 17–15 *The round circle at the bottom of this electron micrograph of a bacterium is an endospore. Endospores enable bacteria to survive unfavorable conditions, such as high temperature.*

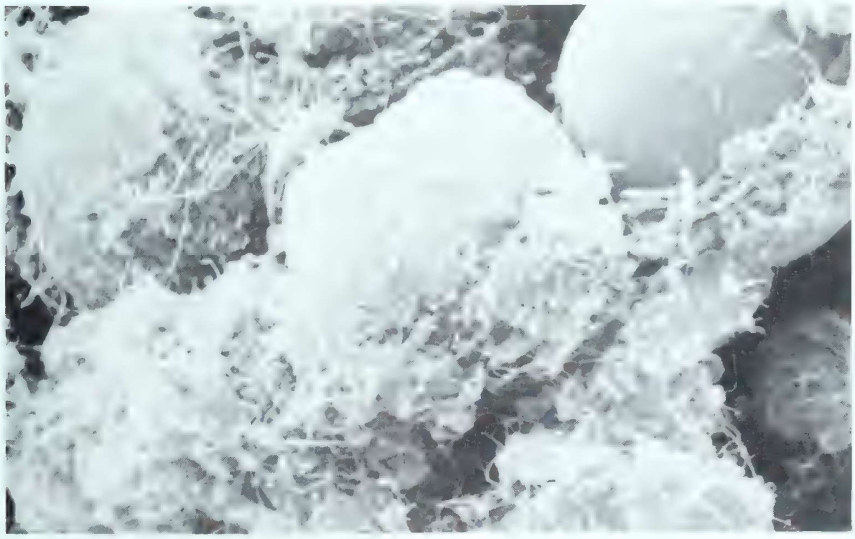


Figure 17–16 *The large round structures in this electron micrograph are cells that form the intestinal wall of the human large intestine, or colon. The smaller rod-shaped cells are the bacteria* E. coli, *which inhabit the large intestine.*

Animals such as cattle are also dependent upon the symbiotic relationship they have with the bacteria in their intestines. You see, no vertebrate (animal with a backbone) can produce the enzymes necessary to break down cellulose, the principal carbohydrate in grass and hay. Bacteria living in the digestive systems of such animals can make these enzymes, thus allowing the animals to digest their food properly.

Bacteria in the Environment

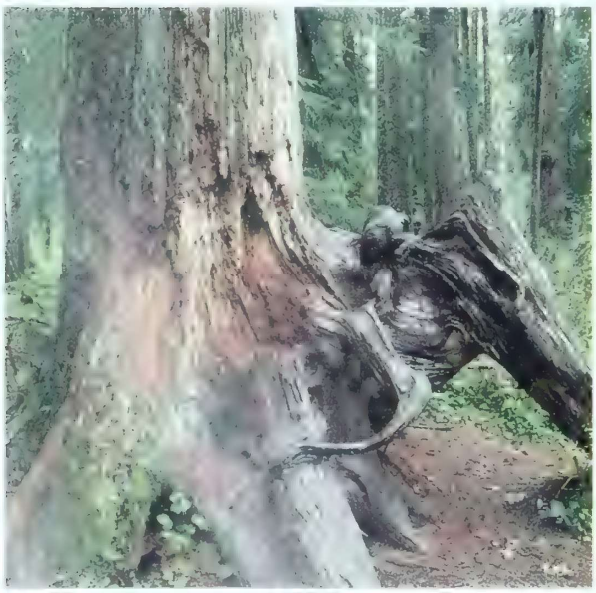
Sometimes we are bold enough to consider ourselves the principal actors on the stage of life. We tend to place other organisms in supporting roles, like the minor actors in a play. But no drama can begin without the dozens of workers who are never seen on stage. The bacteria are like these unseen stagehands. We seldom think about them, but they are absolutely vital to maintaining the kind of living world we see about us.

NUTRIENT FLOW Every living thing depends on a supply of raw materials for growth. If these materials were lost forever when an organism died, then life could not continue. Before long, plants would drain the soil of the minerals they need, plant growth would stop, and the animals that depend on plants for food would starve.

Bacteria recycle and decompose, or break down, dead material. When a tree dies and falls to the forest floor, it begins to undergo many changes. Over the course of a few summers, the bark peels off and the wood begins to weaken because it becomes infested with insects. Then the tree crumbles into the soil. Over time, the whole substance of the tree disappears. What happens to all of the material that made up the tree?

From the moment the tree dies, armies of bacteria attack and digest the dead wood, breaking it down into simpler substances. These bacteria are called **saprophytes** (SAP-ruh-fights). Saprophytes are organisms that use the complex molecules of a once-living organism as their source of energy and nutrition. Gradually, the material of the tree is recycled, enriching the soil in which it grew. Although bacteria play a major role in this process, some eukaryotic organisms, such as insects and fungi, have a supporting role.

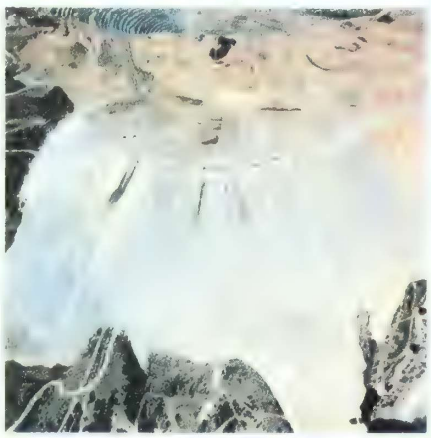
Figure 17–17 Most bacteria are heterotrophs, or organisms that obtain food from the organic compounds of other organisms. Many of these heterotrophs live as saprophytes, decomposing dead organisms such as this tree.



SEWAGE DECOMPOSITION Humans take advantage of the ability of bacteria to decompose material in the treatment of sewage. One of the critical steps in sewage treatment is carried out by a diverse mixture of bacteria that is added directly to the waste water. Waste water contains human waste, discarded food, organic garbage, and even chemical waste. Bacteria grow rapidly in this mixture. As they grow, they break down the complex compounds in the sewage into simpler compounds. This process produces purified water, nitrogen gas and carbon dioxide gas, and leftover products that can be used as crop fertilizers.

The Littlest Miners

Copper is one of the most important minerals in the Earth—our modern civilization needs large amounts of it. Most, however, is low-grade copper ore, which means that the ore has a low percentage of copper in it. This is especially true of the copper ore deposits located in the United States. A way must be found to get the small amount of copper out of the ore in a pure enough form to make it worth mining. Does such a job require big, strong, burly miners? Not at all! The best miners for the job are bacteria, and the process is called bioleaching.



A copper leaching dump in Bingham Canyon, Utah, where low-grade ore is extracted using the bacterium Thiobacillus ferrooxidans

The process of bioleaching begins by stacking large piles of low-grade copper ore out in the open. Then water that has been made acidic is sprayed on the surfaces of the piles. The acidified water helps a bacterium called *Thiobacillus ferrooxidans* to grow. *Thiobacillus*, which occurs naturally in the copper ore, helps to break down sulfate-containing minerals, releasing sulfuric acid and ferric iron. The sulfuric acid and ferric iron react with copper-containing minerals in the ore to produce copper sulfate, which is water soluble. The copper sulfate dissolves in the water, forming copper ions. The dissolved copper sulfate is washed out of the pile and leaks through the bottom of the heap, where it is collected in basins. The copper ions are then separated from the copper sulfate solution to produce metallic copper.

Thiobacillus does what human miners cannot—it extracts copper from low-grade copper ore. Presently, about 10 percent of the copper produced in the United States is mined by using bacteria. A few mining companies have begun to apply the same biotechnological process to extract gold from sulfur-containing gold ore, giving the term gold bug a whole new meaning!

NITROGEN FIXATION All organisms on our planet are totally dependent on monerans for nitrogen. All green plants need nitrogen to make amino acids, which are the building blocks of proteins. And because animals eat plants, plant proteins are ultimately the source of proteins for animals

Although our atmosphere is made up of approximately 80 percent nitrogen gas (N_2), plants are not able to use the nitrogen gas. Neither can most other organisms. Living organisms generally require that nitrogen be "fixed" chemically in the form of ammonia (NH_3) and related nitrogen compounds. Chemists can make synthetic nitrogen-containing fertilizers by mixing nitrogen gas and hydrogen gas, heating the mixture to 500°C, and then squeezing it to 300 times the normal atmospheric pressure. The process is expensive, time-consuming, and sometimes dangerous.



Figure 17–18 *The knoblike structures growing on the roots of this soybean plant are called nodules (top). Within these nodules are the nitrogen-fixing bacteria* Rhizobium, *which have a characteristic rod-shaped appearance (bottom).*

In contrast to this difficult process, many cyanobacteria and other bacteria can take nitrogen from the air and convert it to a form that plants can use. This conversion process is known as **nitrogen fixation**. Monerans are the only organisms capable of performing nitrogen fixation.

Many plants have symbiotic relationships with nitrogen-fixing bacteria. The soybean, which hosts the bacterium *Rhizobium*, is among the best known. *Rhizobium* grows in nodules, or knobs, that form on the roots of the soybean plant. The soybean plant provides a home and a source of nutrients for the nitrogen-fixing *Rhizobium*; the bacterium fixes nitrogen directly from the air into ammonia for the plant. All plants benefit from the nitrogen-fixing ability of monerans, but soybeans are a step ahead. With a little help from their "friends," soybeans have their own fertilizer factories built right into their roots.

As you have learned, eukaryotes are dependent upon monerans to fix nitrogen and release it into the environment. And it is because of the nitrogen-fixing ability of these organisms that more than 170 million metric tons of nitrogen are released into the environment every year.

17–2 SECTION REVIEW

1. Describe the four major phyla of the kingdom Monera.
2. Compare the three basic shapes of bacteria.
3. Distinguish between autotrophic and heterotrophic monerans. Between obligate aerobes, obligate anaerobes, and facultative anaerobes.
4. Describe binary fission and conjugation.
5. List some ways in which bacteria are important.
6. Suppose monerans lost the ability to fix nitrogen. How would this affect other organisms?

Section Objectives

- List some diseases caused by viruses and bacteria.
- Describe two methods of controlling the growth of bacteria.

17–3 Diseases Caused by Viruses and Monerans

Contrary to popular belief, only a small number of viruses and monerans are capable of producing disease in humans. Despite their small numbers, these **pathogens**, or disease-producing agents, are responsible for much human suffering.

From the point of view of a microorganism, however, disease is nothing more than a conflict of lifestyles. All viruses infect living cells, and disease results when the infection causes harm to the host. All bacteria require nutrients and energy, and disease results only when bacteria interfere with the host in obtaining them.



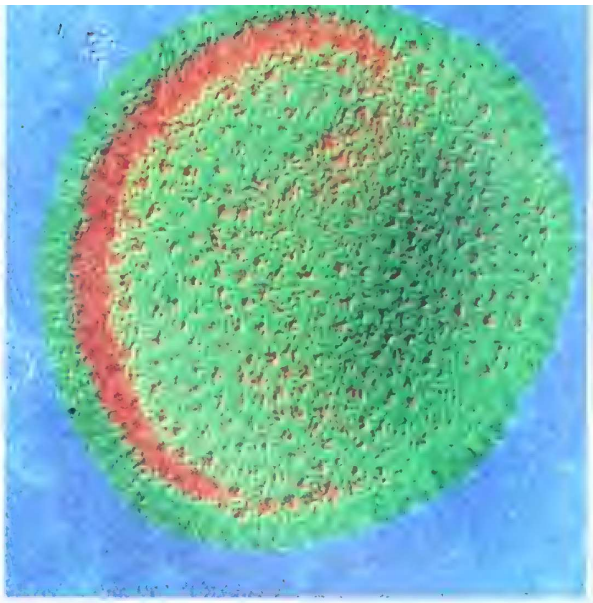


Figure 17–19 *Viruses are the cause of many human diseases. Here you see the virus responsible for influenza (right) and the one that causes rabies (left).*

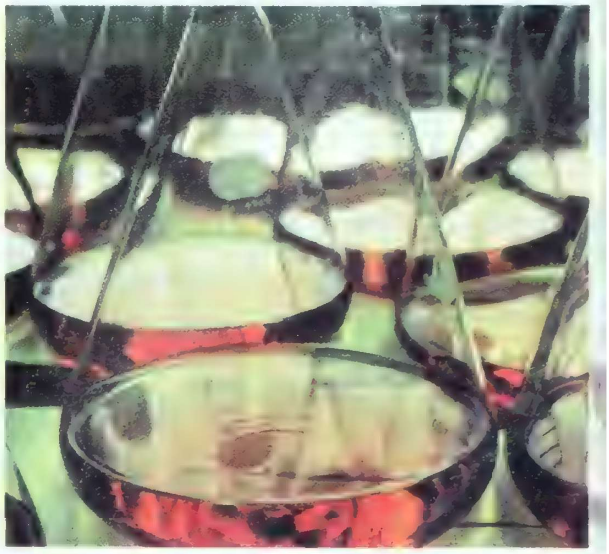
Viruses and Disease

Viruses are the cause of such human diseases as smallpox, polio, measles, AIDS, mumps, influenza, yellow fever, rabies, and the common cold. In most viral infections, viruses attack cells of the body in the same way that the T4 bacteriophage attacks *E. coli.* As the virus reproduces, it destroys the cells that it infects, causing the symptoms of the disease.

Although we tend to think that some viral diseases are curable, the only successful protection against most of them lies in preventing their infection. In order to do this, the body's own immune system must be stimulated to prevent the infection. A vaccine is a substance that contains the weakened or killed disease-causing virus. When injected into the body, the vaccine provides an immunity to the disease. Diseases such as smallpox and polio have all but been eliminated because vaccines were developed to stop their spread. As powerful as they are, however, vaccines can only provide protection if they are used before an infection begins. Once a viral infection starts, there is often little that medical science can do to stop the progress of the disease. However, sometimes the symptoms of the infection can be treated.

INTERFERONS One possible approach in the treatment of viral diseases is the use of substances called interferons. Interferons are small proteins that are produced by the body's cells when the cells are infected by viruses. When interferons are released from virus-infected cells, they seem to make it more difficult for the viruses to infect other cells. The word interferon is derived from the fact that these proteins interfere with the growth of the virus. The specific way in which these proteins work is not yet entirely understood. Until recently, interferons cost millions of dollars a milliliter to isolate and purify. But new techniques using genetically engineered bacteria have made the production of interferons less expensive and more plentiful.

Figure 17–20 *These flasks contain interferons, which were produced by genetically engineered bacteria. Interferons, proteins made by virus-infected cells, inhibit the growth of viruses.*



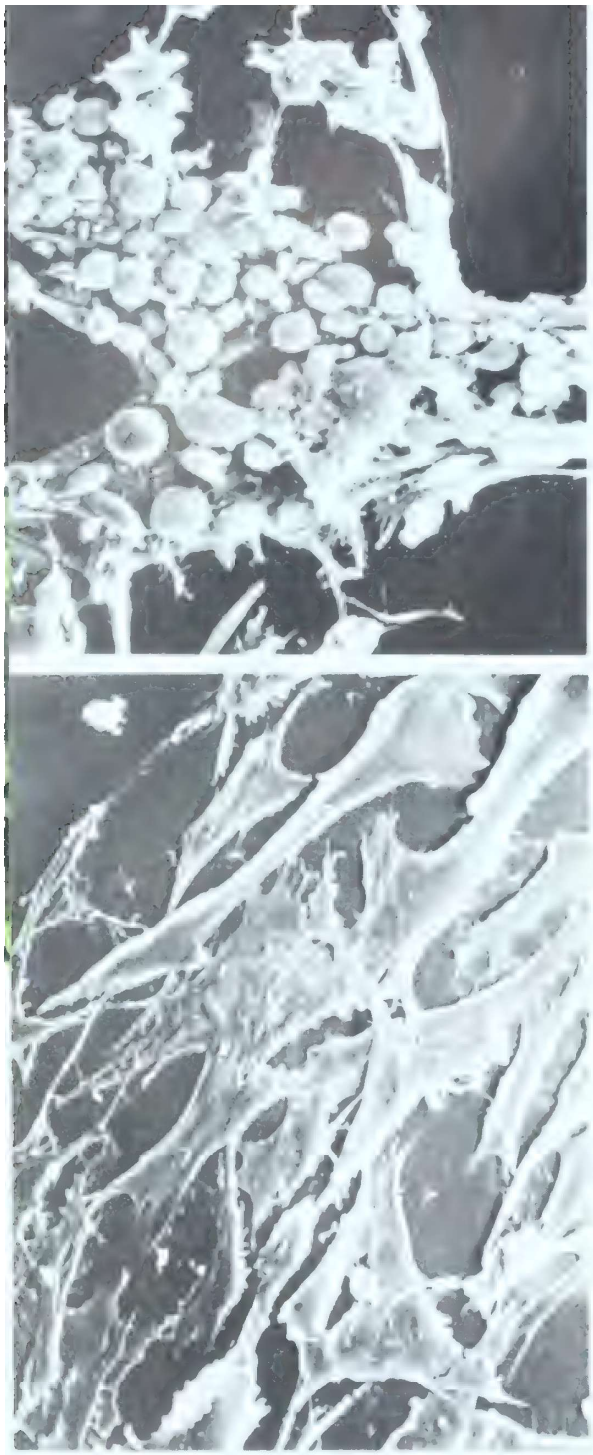


Figure 17–21 These cells of chicken connective tissue clearly show the effects of invasion by a virus. Notice that the normal cells are flat (bottom), whereas those infected with Rous sarcoma virus are round (top).

CANCER Certain viruses cause cancer in animals. These cancer-causing viruses are known as oncogenic (*onco-genic* means tumor-making) viruses. One example is the Rous sarcoma virus (RSV), discovered by the American physician Peyton Rous. RSV causes cancer in chickens and other domestic fowl. As we shall see in Chapter 44, this virus adds certain genes to the infected cell that seem to turn it into a cancer cell. Although it is clear that not all cancers are caused by viruses (cancer is generally not spread by a person-to-person infective process), a few cancers are. This has caused scientists to study cancer-causing viruses closely.

Bacteria and Disease

Of all the bacteria in the world, there are only a few that produce disease. The lifestyles of these few disease-causing organisms have, unfortunately, made us think of disease whenever we think of the word bacteria.

The French chemist Louis Pasteur was the first person to show convincingly that bacteria cause disease. Pasteur established 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.

Some of the diseases caused by pathogenic bacteria include diphtheria, tuberculosis, typhoid fever, tetanus, Hansen disease, syphilis, cholera, and bubonic plague. Bacteria cause these diseases in one of two general ways. They may damage the cells and tissues of the infected organism directly by breaking down its living cells to use for food. Or they may release toxins (poisons) that travel throughout the body, interfering with the normal activity of the host.

Many bacteria can be grown in a culture dish without depending on a host organism. One class of bacteria known as Rickettsiae (rih-KEHT-see-ee) are a curious exception to this rule. In order for Rickettsiae to grow, they must be inside a living cell. In this respect, Rickettsiae are similar to viruses. Rickettsiae seem to possess "leaky" cell walls and membranes that allow them to live directly inside a living cell and absorb nutrients from the cell's cytoplasm. Rickettsiae cause Rocky Mountain spotted fever, typhus, and Legionnaires' disease.

Although we shall discuss the medical measures that are used to fight disease in Chapter 45, it is worth pointing out that many of these diseases can be prevented by stimulating the body's immune system through the use of vaccines. If an infection does occur, however, there are many more effective measures to fight the infection if it is bacterial than if it is viral. These measures include a number of drugs and natural compounds, known as **antibiotics**, that can attack and destroy bacteria. One of the major reasons for the dramatic increase in life expectancy in the last two centuries is an increased understanding of how to prevent and cure bacterial infections.

Controlling Bacteria

Although most bacteria are harmless and many are beneficial, the risks of bacterial infection are great enough to warrant efforts to control bacterial growth.

STERILIZATION The growth of potentially dangerous bacteria can be controlled by sterilization. This process destroys living bacteria by subjecting them either to great heat or to chemical action. Heating is the simplest way to control bacterial growth. Bacteria cannot survive high temperatures for a long time, so most can be killed in boiling water.

An entire hospital, of course, cannot be dropped into boiling water. But it can be sterilized, one room at a time, by using disinfectants. A disinfectant is a chemical solution that kills bacteria. Disinfectants are also used in the home to clean bathrooms, kitchens, and other rooms where bacteria may grow and spoil food or cause disease.

FOOD PROCESSING As you have learned, bacteria are everywhere, including in our food. If we are not careful, the bacteria will begin to "eat" our food before we do. In doing so, the bacteria will cause the food to spoil. One method to stop food from spoiling is to refrigerate those foods in which bacteria might grow. Bacteria, like most organisms, grow slowly at low temperatures. For this reason, food that is stored at a lower temperature will keep longer because the bacteria will take much longer to grow and cause damage. In addition, many kinds of food are sterilized by boiling, frying, or steaming them. Each of these cooking techniques raises the temperature of the food to a point where all the bacteria are killed.

If the food is to be preserved for a long time by canning, the sterilized food must be immediately placed into sterile glass jars or metal cans and sealed. Food that has been properly canned will last almost indefinitely. Finally, a number of chemical treatments will inhibit the growth of bacteria in food. These include treating food with everyday chemicals such as salt, vinegar, or sugar. Salted meat, pickled vegetables, and jam are examples of chemically preserved foods.

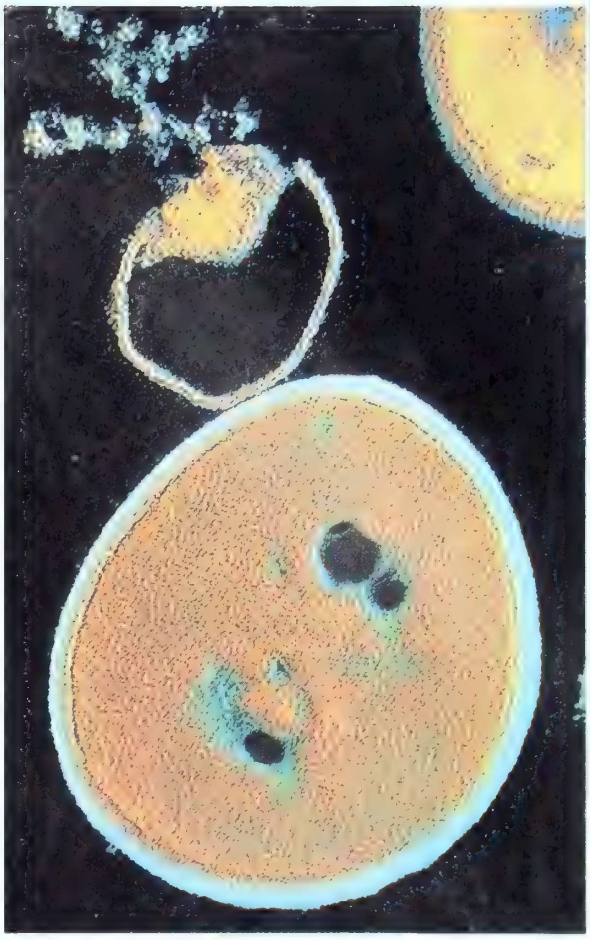


Figure 17–22 *The addition of an antibiotic, or a substance that destroys bacteria, has caused the bacterium* Staphylococcus aureus *to burst.*

17–3 SECTION REVIEW

1. What are some diseases caused by viruses? By bacteria?
2. How can viral and bacterial diseases be prevented? How can they be treated?
3. Describe several methods of controlling bacterial growth.
4. Why is it important to cook food thoroughly before canning?

LABORATORY INVESTIGATION

EXAMINING BACTERIA

PROBLEM

What are some of the characteristics of bacteria?

MATERIALS *(per group)*

100-mL beaker
10 lima beans
2 medicine droppers
2 glass slides
2 coverslips
microscope
methylene blue
flat toothpick

PROCEDURE

1. Fill the beaker halfway with water. Put the lima beans in the beaker and then put the beaker and its contents in a warm place where they will remain undisturbed overnight.
2. After 24 hours, examine the beaker to make sure that the beans are covered with water. If necessary, add more water to cover the beans. Again put the beaker of beans in a warm place overnight.
3. After 48 hours, the water in the beaker should appear cloudy because of the presence of a large number of bacteria. Using a medicine dropper, remove a drop of water from the beaker and place it in the center of a clean glass slide.
4. Cover the drop of water with a coverslip. Examine the drop of water under the low-power objective of the microscope.
5. Examine the drop of water under the high-power objective. **CAUTION:** *When switching to the high-power objective, you should always look at the objective from the side of your microscope so that the objective does not hit or damage the slide.* Notice the shapes and methods of movement of the bacteria.
6. With the second medicine dropper, place a drop of methylene blue in the center of a clean glass slide.
7. Using the broad end of a flat toothpick, gently scrape the inside of your cheek. The scraping should contain some of your cheek cells. Using the same end of the toothpick, mix the scraping from your cheek with the drop of methylene blue.
8. Add a drop of water from the beaker containing the beans to the mixture of cheek scraping and methylene blue. Cover this mixture with a clean coverslip.
9. Locate a cheek cell under the low-power objective of the microscope. Then switch to the high-power objective and use the fine adjustment to locate some bacteria near a cheek cell.
10. Observe the sizes of the bacteria, the cheek cell, and the nucleus of the cheek cell.

OBSERVATIONS

1. Describe the colors and shapes of the bacteria.
2. Are the bacteria arranged singly, in pairs, in chains, or in clusters?
3. Are the bacteria capable of movement? If so, describe the ways in which they move.
4. Compare the size of the bacteria to the sizes of the cheek cell and the nucleus of the cheek cell.

ANALYSIS AND CONCLUSIONS

1. What was the source of the bacteria? How were they able to grow in the beaker containing water and lima beans?
2. Explain why methylene blue was added to the scraping from the cheek.
3. Bacteria are prokaryotic cells, whereas cheek cells are eukaryotic cells. Explain this statement.

STUDENT STUDY GUIDE

SUMMARIZING THE CONCEPTS

The key concepts in each section of this chapter are listed below to help you review the chapter content. Make sure you understand each concept and its relationship to other concepts and to the theme of this chapter.

17–1 Viruses

- A virus is a noncellular particle made up of genetic material and protein.
- Viruses cannot carry out any life processes unless they are within a living host cell.
- Infection and destruction of the host cell by a virus is called a lytic infection.
- In a lysogenic infection, the virus does not reproduce at once and lyse the host cell.

17–2 Monerans—Prokaryotic Cells

- Bacteria are prokaryotes, or cells that do not have a nucleus.
- Rod-shaped bacteria are called bacilli; spherical bacteria are called cocci; and spiral-shaped bacteria are called spirilla.
- Obligate aerobes need oxygen to live. Obligate anaerobes must live in the absence of oxygen. Facultative anaerobes can survive with or without oxygen.
- Some bacteria reproduce by binary fission or conjugation.
- Many bacteria form a symbiotic relationship with other organisms. Some are saprophytes.
- Many bacteria can take nitrogen from the air and convert it into a form that plants can use to make proteins.

17–3 Diseases Caused by Viruses and Monerans

- Although vaccines are the only successful protection against some viral diseases, interferons are being considered as another possible treatment. Antibiotics are substances that can attack and destroy bacteria.

REVIEWING KEY TERMS

Vocabulary terms are important to your understanding of biology. The key terms listed below are those you should be especially familiar with. Review these terms and their meanings. Then use each term in a complete sentence. If you are not sure of a term's meaning, return to the appropriate section and review its definition.

17–1 Viruses

virus
bacteriophage
lytic infection
lysogenic infection
prophage
retrovirus
parasite

17–2 Monerans—Prokaryotic Cells

prokaryote
bacterium
methanogen
bacillus
coccus
spirillum
phototrophic autotroph
chemotrophic autotroph
chemotrophic heterotroph
phototrophic heterotroph
obligate aerobe
obligate anaerobe
toxin
facultative anaerobe
binary fission
conjugation
endospore
symbiosis
saprophyte
nitrogen fixation

17–3 Diseases Caused by Viruses and Monerans

pathogen
antibiotic

CHAPTER REVIEW

CONTENT REVIEW

Multiple Choice

Choose the letter of the answer that best completes each statement.

1. Viruses contain
   a. cell walls.
   b. cell membranes.
   c. nuclei.
   d. protein coats.
2. Viruses that invade cells and cause them to burst are said to be
   a. parasitic.
   b. lysogenic.
   c. saprophytic.
   d. lytic.
3. Methanogens are members of the phylum
   a. Cyanobacteria.
   b. Archaebacteria.
   c. Prochlorobacteria.
   d. Eubacteria.
4. A rod-shaped bacterium is known as a
   a. spirillum.
   b. bacillus.
   c. coccus.
   d. virus.
5. Organisms that need a constant supply of oxygen in order to live are called
   a. obligate anaerobes.
   b. facultative anaerobes.
   c. chemotrophic autotrophs.
   d. obligate aerobes.
6. A structure that forms when a bacterium produces a thick internal wall that encloses its DNA and part of its cytoplasm is called a (an)
   a. endospore.
   b. capsid.
   c. prophage.
   d. spirillum.
7. Organisms that use the complex molecules of once-living organisms for energy and nutrition are called
   a. parasites.
   b. viruses.
   c. saprophytes.
   d. eukaryotes.
8. An example of a disease caused by a bacterium is
   a. influenza.
   b. measles.
   c. AIDS.
   d. syphilis.

True or False

Determine whether each statement is true or false. If it is true, write "true." If it is false, change the underlined word or words to make the statement true.

1. In a <u>lysogenic</u> infection, the virus does not reproduce and lyse its host cell immediately.
2. A virus is composed of a <u>nucleus</u> surrounded by a protein coat.
3. Bacteria are <u>eukaryotes</u>.
4. <u>Spirilla</u> are spherical bacteria.
5. Bacteria that can live with or without oxygen are known as <u>obligate</u> anaerobes.
6. Monerans that trap the energy of sunlight in a manner similar to green plants are called <u>chemotrophic</u> autotrophs.
7. In bacteria, <u>spore formation</u> involves the transferring of genetic material from one cell to another cell.
8. <u>Methanogens</u> are disease-causing agents.

Word Relationships

A. *In each of the following sets of terms, three of the terms are related. One term does not belong. Determine the characteristic common to three of the terms and then identify the term that does not belong.*

1. obligate anaerobe, facultative anaerobe, phototrophic autotroph, obligate aerobe
2. *E. coli*, T4, *Rhizobium*, *Salmonella*
3. prophage, bacillus, spirillum, coccus
4. measles, polio, rabies, tetanus

B. *An analogy is a relationship between two pairs of words or phrases generally written in the following manner: a:b::c:d. The symbol : is read "is to," and the symbol :: is read "as." For example, cat:animal::rose:plant is read "cat is to animal as rose is to plant."*

In the analogies that follow, a word or phrase is missing. Complete each analogy by providing the missing word or phrase.

5. eukaryote:human::prokaryote:_____
6. rod-shaped:bacillus::spherical:_____
7. oxygen:obligate aerobe::no oxygen:_____
8. eubacteria:true bacteria::cyanobacteria:_____

CONCEPT MASTERY

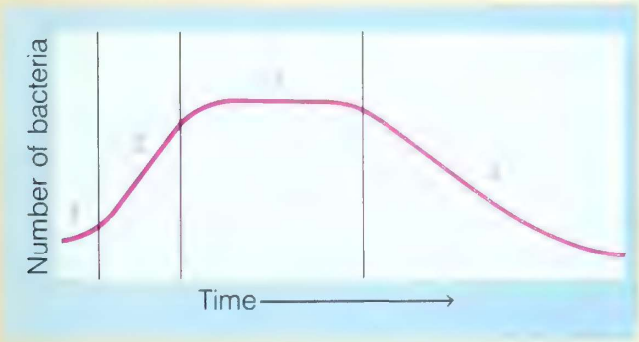
Use your understanding of the concepts developed in the chapter to answer each of the following in a brief paragraph.

1. Why are viruses considered parasites?
2. What is the relationship between cell wall structure and whether a bacterium is Gram positive or Gram negative?
3. What is the difference between bacterial autotrophs and heterotrophs?
4. Describe a symbiotic relationship between bacteria and another organism.
5. What are some ways in which bacteria are important to the environment?
6. Compare the different methods of bacterial reproduction.

CRITICAL AND CREATIVE THINKING

Discuss each of the following in a brief paragraph.

1. **Interpreting graphs** Describe the growth of the bacteria shown in the graph. Explain why growth levels off in stage 3.



2. **Relating concepts** Bacteria can be grown in the laboratory on synthetic media. Can viruses be grown in this way? Can viruses be grown on cultures of bacteria?
3. **Using the writing process** As you know, many diseases are caused by microorganisms. Imagine that you have the ability to develop a chemical capable of wiping out all viruses and monerans on Earth. Write an advertising campaign for your new chemical in which you describe its benefits and dangers.
4. **Using the writing process** In *The War of the Worlds*, a wonderful book written by H. G. Wells, Earth is invaded by aliens. No weapons can kill the invaders, and the Earth seems doomed. The Earth is saved, however, when the invaders die from diseases they contract here. Using a similar premise, write a story about people from Earth voyaging to another planet some time in the future.