You might think this photo shows robots landing on another planet. Actually, this is a picture of viruses attacking a type of unicellular organism called a bacterium (plural, bacteria). Many viruses can attach to the surface of one bacterium.

- Do you think the bacterium is harmful? Are the viruses?
- What do you think happens after the viruses attach to the bacterium?
- What are viruses and bacteria and why are they important?
Get Ready to Read

What do you think?
Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. A bacterium does not have a nucleus.
2. Bacteria cannot move.
3. All bacteria cause diseases.
4. Bacteria are important for making many types of food.
5. Viruses are the smallest living organisms.
6. Viruses can replicate only inside an organism.

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Audio
Review
Inquiry
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Assessment
Concepts in Motion
Multilingual eGlossary
Lesson 1

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- What are bacteria?

Vocabulary

bacterium
flagellum
fission
conjugation
endospore

How clean is this surface?

This photo shows a microscopic view of the point of a needle. The small orange things are bacteria. Bacteria are everywhere, even on surfaces that appear clean. Do you think bacteria are living or nonliving?
Characteristics of Bacteria

Did you know that billions of tiny organisms too small to be seen surround you? These organisms, called bacteria, even live inside your body. Bacteria (singular, bacterium) are microscopic prokaryotes. You might recall that a prokaryote is a unicellular organism that does not have a nucleus or other membrane-bound organelles.

Bacteria live in almost every habitat on Earth, including the air, glaciers, the ocean floor, and in soil. A teaspoon of soil can contain between 100 million and 1 billion bacteria. Bacteria also live in or on almost every organism, both living and dead. Hundreds of species of bacteria live on your skin. In fact, your body contains more bacterial cells than human cells! The bacteria in your body outnumber human cells by 10 to 1.

Key Concept Check  What are bacteria?

Other prokaryotes, called archaea (ar KEE uh; singular, archaean), are similar to bacteria and share many characteristics with them, including the lack of membrane-bound organelles. Archaea can live in places where few other organisms can survive, such as very warm areas or those with little oxygen. Both bacteria and archaea are important to life on Earth.
Structure of Bacteria
A typical bacterium, such as the one shown in Figure 1, consists of cytoplasm and DNA surrounded by a cell membrane and a cell wall. The cytoplasm also contains ribosomes. Most bacteria have DNA that is one coiled, circular chromosome. Many bacteria also have one or more small circular pieces of DNA called plasmids that are separate from its other DNA.

Some bacteria have specialized structures that help them survive. For example, the bacterium that causes pneumonia (noo MOH nyuh), an inflammation of the lungs, has a thick covering, or capsule, around its cell wall. The capsule protects the bacterium from drying out. It also prevents white blood cells from surrounding and antibiotics from entering it. Many bacteria have capsules with hairlike structures called pili (Pl li) that help the bacteria stick to surfaces.

Size and Shapes of Bacteria
Bacteria are much smaller than plant or animal cells. Bacteria are generally only 1–5 micrometers (μm) (1 m = 1 million μm) wide, while an average eukaryotic cell is 10–100 μm wide. Scientists estimate that as many as 100 bacteria could be lined up across the head of a pin. As shown in Figure 2, bacteria generally have one of three basic shapes.

<table>
<thead>
<tr>
<th>Shapes of Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round or Sphere-Shaped</td>
</tr>
<tr>
<td>![Round or Sphere-Shaped]</td>
</tr>
</tbody>
</table>

Figure 2 Bacteria are generally shaped like a sphere, a rod, or a spiral.

Visual Check What are the three basic shapes of bacteria?
Obtaining Food and Energy

Bacteria live in many places. Because these environments are very different, bacteria obtain food in various ways. Some bacteria take in food and break it down and obtain energy. Many of these bacteria feed on dead organisms or organic waste, as shown in Figure 3. Others take in their nutrients from living hosts. For example, bacteria that cause tooth decay live in dental plaque on teeth and feed on sugars in the foods you eat and the beverages you drink.

Some bacteria make their own food. These bacteria use light energy and make food, like most plants do. These bacteria live where there is a lot of light, such as the surface of lakes and streams. Other bacteria use energy from chemical reactions and make their food. These bacteria live in places where there is no sunlight, such as the dark ocean floor.

Key Concept Check How do bacteria obtain food?

Most organisms, including humans, cannot survive without oxygen. However, certain bacteria do not need oxygen to survive. These bacteria are called anaerobic (a nuh ROH bikh) bacteria. Bacteria that need oxygen are called aerobic (er OH bikh) bacteria. Most bacteria in the environment are aerobic.

MiniLab 15 minutes

How does a slime layer work?

Bacteria have a gelatinlike, protective coating called a slime layer on the outside of their cell walls. A slime layer can help a bacterium attach to surfaces or reduce water loss.

1. Read and complete a lab safety form.
2. Cut two 2-cm-wide strips from the long side of a synthetic kitchen sponge.
3. Soak both strips in water. Remove them from the water and squeeze out the excess water. Both strips should be damp.
4. Completely coat one strip with hair-styling gel to simulate a slime layer.
5. Place both strips on a plate and let them sit overnight.

Analyze and Conclude

1. Describe the appearance of the two strips in your Science Journal. How do they differ?
2. Key Concept Explain how a slime layer might be beneficial to a bacterium when moving or finding food.
Movement
Some bacteria are able to move around to find the resources that they need to survive. These bacteria have special structures for movement. *Many bacteria have long whiplike structures called flagella* (fluh JEH luh; singular, flagellum), as shown in Figure 4. Others twist or spiral as they move. Still other bacteria use their pili like grappling hooks or make threadlike structures that enable them to push away from a surface.

Reproduction
You might recall that organisms reproduce asexually or sexually. Bacteria reproduce asexually by fission. **Fission** is *cell division that forms two genetically identical cells*. Fission can occur quickly—as often as every 20 minutes under ideal conditions.

Bacteria produced by fission are identical to the parent cell. However, genetic variation can be increased by a process called conjugation, shown in Figure 5. During **conjugation** (kahn juh GAY shun), two bacteria of the same species attach to each other and combine their genetic material. DNA is transferred between the bacteria. This results in new combinations of genes, increasing genetic diversity. New organisms are not produced during conjugation, so the process is not considered reproduction.

**Reading Check** How does conjugation increase the genetic diversity of bacteria?

---

**Conjugation**

*Figure 5* Conjugation results in genetic diversity by transferring DNA between two bacteria cells.

**Visual Check** What structure does the donor cell use to connect to the recipient cell?

1. The donor cell and recipient cell both have circular chromosomal DNA. The donor cell also has DNA as a plasmid. The donor cell forms a conjugation tube and connects to the recipient cell.

2. The conjugation tube connects both cells. The plasmid splits in two and one plasmid strand moves through the conjugation tube into the recipient cell.

3. The complimentary strands of the plasmids are completed in both bacteria.

4. With the new plasmids complete, the bacteria separate from each other. The recipient cell now contains plasmid DNA from the donor cell as well as its own chromosomal DNA.
Endospores

Sometimes environmental conditions are unfavorable for the survival of bacteria. In these cases, some bacteria can form endospores. An endospore (EN doh spor) forms when a bacterium builds a thick internal wall around its chromosome and part of the cytoplasm, as shown in Figure 6. An endospore can protect a bacterium from intense heat, cold, or drought. It also enables a bacterium to remain dormant for months or even centuries. The ability to form endospores enables bacteria to survive extreme conditions that would normally kill them.

Archaea

Prokaryotes called archaea were once considered bacteria. Like a bacterium, an archaean has a cell wall and no nucleus or membrane-bound organelles. Its chromosome is also circular, like those in bacteria. However, there are some important differences between archaea and bacteria. The ribosomes of archaea more closely resemble the ribosomes of eukaryotes than those of bacteria. Archaea also contain molecules in their plasma membranes that are not found in any other known organisms. Archaea often live in extreme environments, such as hot springs and salt lakes. Some scientists refer to archaea as extremophiles (ik STREE muh filez)—a term that means “those that love extremes.”

Endospore Formation

1. Bacterial cells in favorable conditions form without endospores.
2. As conditions become unfavorable, the cell forms an endospore around some of its DNA.
3. The cell breaks down, leaving the endospore-protected DNA.

Figure 6 An endospore protects a bacterium.

Math Skills

Use a Formula

Each time bacteria undergo fission, the population doubles. Use an equation to calculate how many bacteria there are: \( n = x \times 2^f \) where \( n \) is the final number of bacteria, \( x \) is the starting number of bacteria, and \( f \) is the number of times that fission occurs.

Example: 100 bacteria undergo fission 3 times.
\[ f = 3, \text{ so } 2^f \text{ is } 2 \text{ multiplied by itself } 3 \text{ times.} (2 \times 2 \times 2 = 8) \]
\[ n = 100 \times 8 = 800 \text{ bacteria} \]

Practice

How many bacteria would there be if 1 bacterium underwent fission 10 times?
Visual Summary

Bacteria are unicellular prokaryotes.

Many bacteria feed on dead organic matter.

Bacteria can increase genetic diversity by sharing DNA through conjugation.

Use Vocabulary
1. Use the term bacteria in a sentence.
2. The long whiplike structure that some bacteria use for movement is a(n) _________.
3. Define conjugation in your own words.

Understand Key Concepts
4. Describe a typical bacterium.
5. Which is NOT a common bacteria shape?
   A. rod       C. spiral
   B. sphere    D. square
6. Contrast fission and conjugation.

Interpret Graphics
7. Identify Copy and complete the table below to identify shapes of bacteria.

<table>
<thead>
<tr>
<th>Bacterial Shapes</th>
<th>Illustration</th>
</tr>
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<tbody>
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<td></td>
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Critical Thinking
8. Describe how a bacterium’s small size could be an advantage or a disadvantage for its survival.
9. Explain how bacteria might find food and survive in an environment where few other organisms live.
10. Analyze how bacteria that can form endospores would have an advantage over bacteria that cannot form endospores.

What do you think NOW?

You first read the statements below at the beginning of the chapter.
1. A bacterium does not have a nucleus.
2. Bacteria cannot move.
Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Math Skills
11. How many bacteria would there be if fission occurred 4 times with 1,000 bacteria?
Cooking Bacteria!

How Your Body Is Like Bleach

When it comes to killing germs, few things work as well as household bleach. How does bleach kill bacteria? Believe it or not, killing bacteria with bleach and boiling an egg involve similar processes.

Eggs are made mostly of proteins. Proteins are complex molecules in all plant and animal tissues. Proteins have specific functions that are dependent on the protein’s shape. A protein’s function changes if its shape is changed. When you cook an egg, the thermal energy transferred to the egg causes changes to the shape of the egg’s proteins. Think of the firm texture of a cooked egg. When the egg’s proteins are heated, they become a tangled mass.

Scientists also know now that your body’s immune cells produce hypochlorite. Your body protects itself with the same chemical you can use to clean your kitchen!

Like eggs, bacteria also contain proteins. When bacteria are exposed to high temperatures, their proteins change shape, similar to those in a boiled egg. But what is the connection with bleach? Scientists have discovered that an ingredient in bleach, hypochlorite (hi puh KLOR ite), also causes proteins to change shape. The bacterial proteins that are affected by bleach are needed for the bacteria’s growth. When the shape of those proteins changes, they no longer function properly, and the bacteria die.

It’s Your Turn

RESEARCH AND REPORT A bacterial infection often causes inflammation, or a response to tissue damage that can include swelling and pain. Research and report on what causes inflammation.
Why does this larva glow?

Some bacteria have the ability to glow in the dark. The moth larva shown on this page is filled with many such bacteria. These bacteria produce toxins that can slowly kill the animal. A chemical reaction within each bacterium makes the larva’s body appear to glow.
Beneficial Bacteria

When you hear about bacteria, you probably think about getting sick. However, only a fraction of all bacteria cause diseases. Most bacteria are beneficial. In fact, many organisms, including humans, depend on bacteria to survive. Some types of bacteria help with digestion and other body processes. For example, one type of bacteria in your intestines makes vitamin K, which helps your blood clot properly. Several others help break down food into smaller particles. Another type of bacteria called *Lactobacillus* lives in your intestines and prevents harmful bacteria from growing.

Animals benefit from bacteria as well. Without bacteria, some organisms, such as the cow pictured in Figure 7, wouldn’t be able to digest the plants they eat. Bacteria and other microscopic organisms live in a large section of the cow’s stomach called the rumen. The bacteria help break down a substance in grass called cellulose into smaller molecules that the cow can use.

**How do bacteria affect the environment?**

Bacteria are everywhere in your environment. They are in the water, in the air, and even in some foods.

1. Read and complete a lab safety form.
2. Carefully examine the contents of the two bottles provided by your teacher.
3. Record your observations in your Science Journal.

**Think About This**

1. Compare your observations of bottle A to those of bottle B. Which one appears to have more bacteria in it? Support your answer.

2. **Key Concept** Based on your observations, how could bacteria affect the environment around you?

**Visual Check** What role do bacteria play in a cow’s digestion?
Decomposition

What do you think would happen if organic waste such as food scraps and dead leaves never decayed? Decomposition, the breaking down of dead organisms and organic waste, is an important process in nature. When a tree dies, bacteria and other decomposing organisms feed on the dead organic matter. As decomposers break down the tree, they release molecules such as carbon and phosphorus into the soil that other organisms can then take in and use for life processes.

Nitrogen Fixation

Organisms use nitrogen to make proteins. Although about 78 percent of the atmosphere is nitrogen gas, it is in a form that plants and animals cannot use. Some plants can obtain nitrogen from bacteria. These plants have special structures called nodules, shown in Figure 8, on their roots. Bacteria in the nodules convert nitrogen from the atmosphere into a form usable to plants. Nitrogen fixation is the conversion of atmospheric nitrogen into nitrogen compounds that are usable by living things.

Key Concept Check

What are some ways that bacteria are beneficial to the environment?

Can decomposition happen without oxygen?

You have just read that bacteria play an important role as decomposers in the environment. How do you think decomposition differs in aerobic and anaerobic environments?

1. Read and complete a lab safety form.
2. Obtain two self-sealing plastic bags from your teacher. Use a permanent marker and label one bag Bag A and the other Bag B.
3. Place a slice of apple in bag A. Seal the bag leaving as much air as possible inside of it. Set the bag aside.
4. Place another slice of apple in bag B. Carefully squeeze the bag to remove as much air as possible before sealing it. Place both bags in the location specified by your teacher and leave overnight.
5. The next lab day, observe both bags. Note the appearance of the apples. Record your observations in your Science Journal.
6. Carefully dispose of both bags according to your teacher’s directions.

Analyze and Conclude

1. Determine which apple changed the most. How could you tell? List specific evidence to support your answer.
2. Draw Conclusions Does decomposition occur faster, slower, or not at all in environments without oxygen? Justify your answer.
3. Key Concept Summarize why bacteria are considered important decomposers.
**Bioremediation**

Can you imagine an organism that eats pollution? Some bacteria do just that. The use of organisms, such as bacteria, to clean up environmental pollution is called **bioremediation** (bi oh rih mee dee AY shun). These organisms often break down harmful substances, such as sewage, into less harmful material that can be used as landfill or fertilizers.

Bacteria are commonly used to clean up areas that have been contaminated by oil or harmful plastics. Some kinds of bacteria can even help clean up radioactive waste, such as uranium in the abandoned mine fields shown in **Figure 9**. In many cases, without using bacteria, the substances would take centuries to break down and would contaminate soils and water.

**Reading Check** Why might using bacteria to clean up environmental spills be a good option?

**Bacteria and Food**

Would you like a side of bacteria with that sandwich? If you have eaten a pickle lately, you might have had some. Some pickles are made when the sugar in cucumbers is converted into an acid by a specific type of bacteria. Pickles are just one of the many food products made with the help of bacteria. Bacteria are used to make foods such as yogurt, cheese, buttermilk, vinegar, and soy sauce. Bacteria are even used in the production of chocolate. They help break down the covering of the cocoa bean during the process of making chocolate. Bacteria are responsible for giving chocolate some of its flavor.

**Figure 9** These bacteria clean the environment by removing harmful uranium from the water.
Harmful Bacteria

Of the 5,000 known species of bacteria, relatively few are considered pathogens—agents that cause disease. Some pathogens normally live in your body, but cause illness only when your immune system is weakened. For example, the bacterium Streptococcus pneumoniae lives in the throats of most healthy people. However, it can cause pneumonia if a person’s immune system is weakened. Other bacterial pathogens can enter your body through a cut, the air you breathe, or the food you eat. Once inside your body, they can reproduce and cause disease.

Key Concept Check Describe one way that bacteria can be harmful to health.

Bacterial Diseases

Bacteria can harm your body and cause disease in one of two ways. Some bacteria make you sick by damaging tissue. For example, the disease tuberculosis, shown in Figure 10, is caused by a bacterium that invades lung tissue and breaks it down for food. Other bacteria cause illness by releasing toxins. For example, the bacterium Clostridium botulinum can grow in improperly canned foods and produce toxins. If the contaminated food is eaten, the toxins can cause food poisoning, resulting in paralyzed limbs or even death.

Treating Bacterial Diseases Most bacterial diseases in humans can be treated with antibiotics. Antibiotics are medicines that stop the growth and reproduction of bacteria. Many antibiotics work by preventing bacteria from building cell walls. Others affect ribosomes in bacteria, interrupting the production of proteins.

Many types of bacteria have become resistant to antibiotics over time. Some diseases, such as tuberculosis, pneumonia, and meningitis, are now more difficult to treat.

**Figure 10** In an X-ray, the lungs of a person with tuberculosis may show pockets or scars where bacterial infection has begun.

**Visual Check** How do you think the bacteria that made this person sick entered his or her body?

**Science Use v. Common Use**

- **resistance**
  - *Science Use* the capacity of an organism to defend itself against a disease
  - *Common Use* the act of opposing something
Bacterial Resistance  How do you think bacteria become resistant to antibiotics? This process, shown in Figure 11, can happen over a long or short period of time depending on how quickly the bacteria reproduce. Random mutations occur to a bacterium’s DNA that enable it to survive or “resist” a specific antibiotic. If that antibiotic is used as a treatment, only the bacteria with the mutation will survive.

Over time, the resistant bacteria will reproduce and become more common. The antibiotic is no longer effective against that bacterium, and a different antibiotic must be used to fight the disease. Scientists are always working to develop more effective antibiotics to which bacteria have not developed resistances.

Reading Check  How do bacteria develop resistance to antibiotics?

Food Poisoning

All food, unless it has been treated or processed, contains bacteria. Over time these bacteria reproduce and begin breaking down the food, causing it to spoil. As you read on the previous page, eating food contaminated by some bacteria can cause food poisoning. By properly treating or processing food and killing bacteria before the food is stored or eaten, it is easier to avoid food poisoning and other illnesses.

Pasteurization  (pas chuh ruh ZAY shun) is a process of heating food to a temperature that kills most harmful bacteria. Products such as milk, ice cream, yogurt, and fruit juice are usually pasteurized in factories before they are transported to grocery stores and sold to you. After pasteurization, foods are much safer to eat. Foods do not spoil as quickly once they have been pasteurized. Because of pasteurization, food poisoning is much less common today than it was in the past.

Key Concept Check  How does pasteurization affect human health?
Lesson 2 Review

Use Vocabulary
1. **Distinguish** between an antibiotic and a pathogen.
2. **Define** *bioremediation* using your own words.
3. **Use the term** *pasteurization* in a sentence.

Understand Key Concepts
4. Which of the following is NOT a beneficial use of bacteria?
   A. bioremediation
   B. decomposition
   C. food poisoning
   D. nitrogen fixation
5. **Compare** the benefits of nitrogen fixation and decomposition.
6. **Analyze** the importance of bacteria in food production.

Interpret Graphics
7. **Examine** the figure below and describe what would happen if bacteria were not present.

Critical Thinking
8. **Identify** Copy and complete the graphic organizer below to identify ways that bacteria can be beneficial.
9. **Evaluate** the effect of all bacteria becoming resistant to antibiotics.

Visual Summary
- Bacteria can help some organisms, including humans and cows, digest food.
- Bacteria can be used to remove harmful substances such as uranium.
- Some bacteria are pathogens, and cause diseases in humans and other organisms.

What do you think NOW?
You first read the statements below at the beginning of the chapter.
3. All bacteria cause diseases.
4. Bacteria are important for making many types of food.
Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.
How do lab techniques affect an investigation?

Pathogens such as bacteria cover almost every surface. When you touch a surface, you transfer particles from that surface to your skin and then to other objects you touch. Your teacher has spread a substance that simulates bacteria on some surfaces in this lab. You will be divided into two groups. Each group will perform the same lab activity but will use slightly different laboratory techniques.

Learn It

In a laboratory it is important to be very careful to keep surfaces as free from contamination as possible. Scientists follow specific lab techniques very carefully to prevent contamination that could affect results.

Try It

1. Read and complete a lab safety form.
2. Put on a pair of gloves. Select a Petri dish from the stack. Open the Petri dish and follow the directions on the slip of paper.
3. Go to the station with the jar. Open the jar and use forceps to remove an item. Place the item in your Petri dish. Close the jar. Follow the directions again.
4. Take your Petri dish to the dissecting microscope and examine your object. Sketch the object in your Science Journal.
5. Observe the surfaces in your work area as your teacher shines a black light over them.

Apply It

6. What surfaces light up the most under the black light?
7. What do you see when you use the black light?
8. **Key Concept** What difference do you see in the lab areas used by the two groups? Based on your observations, how do you think this difference affects which techniques are used in labs and hospitals?
What are viruses?

The streaking patterns on the petals of these tulips are not painted on but are caused by a virus. Tulips with these patterns are prized for their beautiful appearance. How do you think a virus could cause this flower’s pattern? Do you think all viruses are harmful?
**Characteristics of Viruses**

Do chicken pox, mumps, measles, and polio sound familiar? You might have received shots to protect you from these diseases. You might have also received a shot to protect you from influenza, commonly known as the flu. What do these diseases have in common? They are caused by different viruses. A **virus** is a strand of DNA or RNA surrounded by a layer of protein that can infect and replicate in a host cell. If you have had a cold, you have been infected by a virus.

A virus does not have a cell wall, a nucleus, or any other organelles present in cells. The smallest viruses are between 20 and 100 times smaller than most bacteria. Recall that about 100 bacteria would fit across the head of a pin. Viruses can have different shapes, such as the crystal, cylinder, sphere, and bacteriophage (bak TIHR ee uh fayj) shapes shown in **Figure 12**.

**Launch Lab**

**How quickly do viruses replicate?**

One characteristic that viruses share is the ability to produce many new viruses from just one virus. In this lab you can use grains of rice to model virus replication. Each grain of rice represents one virus.

<table>
<thead>
<tr>
<th>Generation</th>
<th>First</th>
<th>Second</th>
<th>Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of “viruses”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Read and complete a lab safety form.
2. Copy the table above into your Science Journal.
3. Estimate the number of **grains of rice** in the **fishbowl** and record this number for the first generation.
4. One student will add the contents of his or her **cup** to the fishbowl. Estimate how many viruses are now in the fishbowl and record your estimate for the second generation.
5. The rest of the class will add the contents of their cups to the fishbowl. Estimate the number of viruses and record that number of viruses for the third generation.

**Think About This**

1. Recall that bacteria double every generation. How does the number of viruses produced in each generation compare with the number of bacteria produced in each generation?

2. **Key Concept** How could the rate at which viruses are produced affect human health?

**Figure 12** Viruses have a variety of shapes.
Dead or Alive?

Do you think that viruses are living things? Scientists do not consider viruses to be alive because they do not have all the characteristics of a living organism. Recall that living things are organized, respond to stimuli, use energy, grow, and reproduce. Viruses cannot do any of these things. A virus can make copies of itself in a process called replication, but it must rely on a living organism to do so.

Key Concept Check Are viruses alive? Explain why or why not.

Viruses and Organisms

Viruses must use organisms to carry on the processes that we usually associate with a living cell. Viruses have no organelles so they are not able to take in nutrients or use energy. They also cannot replicate without using the cellular parts of an organism. Viruses must be inside a cell to replicate. The living cell that a virus infects is called a host cell.

When a virus enters a cell, as shown in Figure 13, it can either be active or latent. Latent viruses go through an inactive stage. Their genetic material becomes part of the host cell’s genetic material. For a period of time, the virus does not take over the cell to produce more viruses. In some cases, viruses have been known to be inactive for years and years. However, once it becomes active, a virus takes control of the host cell and replicates.

**Figure 13** A virus infects a cell by inserting its DNA or RNA into the host cell. It then directs the host cell to make new viruses.

**Visual Check** What occurs when a virus becomes latent?
Replication

As you read earlier, a virus can make copies of itself in a process called replication, shown in Figure 13. A virus cannot infect every cell. A virus can only attach to a host cell with specific molecules on its cell wall or cell membrane. These molecules enable the virus to attach to the host cell. This is similar to the way that only certain electrical plugs can fit into an outlet on a wall. After a virus attaches to the host cell, its DNA or RNA enters the host cell. Once inside, the virus either starts to replicate or becomes latent, also shown in Figure 13. After a virus becomes active and replicates in a host cell, it destroys the host cell. Copies of the virus are then released into the host organism, where they can infect other cells.

Mutations

As viruses replicate, their DNA or RNA frequently mutates, or changes. These mutations enable viruses to adjust to changes in their host cells. For example, the molecules on the outside of host cells change over time to prevent viruses from attaching to the cell. As viruses mutate, they are able to produce new ways to attach to host cells. These changes happen so rapidly that it can be difficult to cure or prevent viral diseases before they mutate again.

Reading Check How does mutation enable viruses to continue causing disease?
You might know that viruses cause many human diseases, such as chicken pox, influenza, some forms of pneumonia, and the common cold. But viruses also infect animals, causing diseases such as rabies and parvo. They can infect plants as well—in some cases causing millions of dollars of damage to crops. The tulips shown at the beginning of this lesson were infected with a virus that caused a streaked appearance on the petals. Most viruses attack and destroy specific cells. This destruction of cells causes the symptoms of the disease.

Some viruses cause symptoms soon after infection. Influenza viruses that cause the flu infect the cells lining your respiratory system, as shown in Figure 14. The viruses begin to replicate immediately. Flu symptoms, such as a runny nose and a scratchy throat, usually appear within 2–3 days.

Other viruses might not cause symptoms right away. These viruses are sometimes called latent viruses. Latent viruses continue replicating without damaging the host cell. HIV (human immunodeficiency virus) is one example of a latent virus that might not cause immediate symptoms.

HIV infects white blood cells, which are part of the immune system. Initially, infected cells can function normally, so an HIV-infected person might not appear sick. However, the virus can become active and destroy cells in the body's immune system, making it hard to fight other infections. It can often take a long time for symptoms to appear after infection. People infected with latent viruses might not know for many years that they have been infected.

Reading Check Why is HIV considered a latent virus?

The Flu

1 Flu virus particles in the air enter the body through the nose or mouth when a person inhales.

2 Viruses travel to the lungs, where they begin infecting cells. The viruses enter lung cells and begin replicating.

3 The new viruses enter the bloodstream and travel to other parts of the body. They continue to infect cells all over the body. The infected person experiences flu symptoms and begins to feel sick.

Figure 14 Viruses that infect the respiratory system usually enter through the nose or mouth.

Visual Check Where do flu viruses replicate?
Treating and Preventing Viral Diseases

Since viruses are constantly changing, viral diseases can be difficult to treat. Antibiotics work only against bacteria, not viruses. Antiviral medicines can be used to treat certain viral diseases or prevent infection. These medicines prevent the virus from entering a cell or stop the virus from replicating. Antiviral medicines are specific to each virus. Like bacteria, viruses can rapidly change and become resistant to medicines.

Health officials use many methods to prevent the spread of viral diseases. One of the best ways to prevent a viral infection is to limit contact with an infected human or animal. The most important way to prevent infections is to practice good hygiene, such as washing your hands.

Immunity

Has anyone you know ever had chicken pox? Did they get it more than once? Most people who became infected with chicken pox develop an immunity to the disease. This is an example of acquired immunity. When a virus infects a person, his or her body begins to make special proteins called antibodies. An antibody is a protein that can attach to a pathogen and make it useless. Antibodies bind to viruses and other pathogens and prevent them from attaching to a host cell, as shown in Figure 15. The antibodies also target viruses and signal the body to destroy them. These antibodies can multiply quickly if the same pathogen enters the body again, making it easier for the body to fight infection. Another type of immunity, called natural immunity, develops when a mother passes antibodies on to her unborn baby.

Antibodies

Figure 15  Antibodies bind to pathogens and prevent them from attaching to cells.

Visual Check  How does the antibody prevent the virus from attaching to the host cell?
Vaccines

One way to prevent viral diseases is through vaccination. A **vaccine** is a mixture containing material from one or more deactivated pathogens, such as viruses. When an organism is given a vaccine for a viral disease, the vaccine triggers the production of antibodies. This is similar to what would happen if the organism became infected with the virus normally. However, because the vaccine contains deactivated pathogens, the organism suffers only mild symptoms or none at all. After being vaccinated against a particular pathogen, the organism will not get as sick if exposed to the pathogen again.

Vaccines can prevent diseases in animals as well as humans. For example, pet owners and farmers get annual rabies vaccinations for their animals. This protects the animals from the disease. Humans are then protected from rabies.

Research with Viruses

Scientists are researching new ways to treat and prevent viral diseases in humans, animals, and plants. Scientists are also studying the link between viruses and cancer. Viruses can cause changes in a host’s DNA or RNA, resulting in the formation of tumors or abnormal growth. Because viruses can change very quickly, scientists must always be working on new ways to treat and prevent viral diseases.

You might think that all viruses are harmful. However, scientists have also found beneficial uses for viruses. Viruses may be used to treat genetic disorders and cancer using gene transfer. Scientists use viruses to insert normal genetic information into a specific cell. Scientists hope that gene transfer will eventually be able to treat genetic disorders that are caused by one gene, such as cystic fibrosis or hemophilia.

**MiniLab**

**How do antibodies work?**

When a virus infects a cell it binds to part of that cell called a receptor. The virus and the receptor fit together like puzzle pieces.

1. Read and complete a lab safety form.
2. Cut out two **virus shapes** and two **cell shapes**.
3. Using one virus shape and one cell shape, note how the virus fits against the receptor on the cell. **Tape** the virus and the cell together.
4. Cut out one **antibody shape**. Note how the virus shapes and the antibody shapes attach and tape them together.
5. Try to attach the virus shapes and the antibody shapes you just joined to the cell receptor.

**Analyze and Conclude**

1. **Observe** whether the virus or the joined virus and antibody were better able to attach to the cell.
2. **Key Concept** Explain how producing more antibodies would be beneficial during a viral infection.
Lesson 3 Review

Visual Summary

A virus is a strand of DNA or RNA surrounded by a layer of protein.

Viruses cause human diseases such as chicken pox and influenza.

A person’s body produces proteins called antibodies that prevent an infection by viruses.

Use Vocabulary

1. List the different shapes a virus can have.
2. Describe in your own words how a vaccine works.
3. Use the term antibodies in a sentence.

Understand Key Concepts

4. Describe the structure of a virus.
5. Which is made by the body to fight viruses?
   A. antibody  C. bacteriophage
   B. bacteria  D. proteins
6. Classify a virus as a living or nonliving thing. Explain your answer.
7. Compare a vaccine and an antibody.

Interpret Graphics

8. Draw a graphic organizer like the one below including the steps that occur when a virus infects a cell.

9. Describe what happens during this step of viral replication.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

5. Viruses are the smallest living organisms.
6. Viruses can replicate only inside an organism.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Critical Thinking

11. Evaluate the importance of vaccines in keeping people healthy.
Recall that pathogens such as bacteria and viruses are all around you. When studying pathogens, scientists often use agar plates to grow bacteria and other colonies. An agar plate is a Petri dish containing agar, a gel made from seaweed, and nutrients needed for bacteria to grow. When bacteria are transferred to an agar plate, they reproduce. After a few days, you can see colonies of bacteria. Disinfectants are chemicals that deactivate or kill pathogens such as bacteria. In this lab you will test how hand sanitizer, a common disinfectant, affects the growth of bacteria on agar plates.

**Ask a Question**
What effect does hand sanitizer have on bacterial growth?

**Make Observations**

1. Read and complete a lab safety form.
2. Set two agar plates on your desk or work area. Turn your agar plates upside down without opening them. With a permanent marker, label one plate *No Treatment* and the other *Disinfected*. Also write your name and the date on the plate. Turn the agar plates right side up.
3. Rub the end of a cotton swab across the top of your desk or work area. Open the lid of the agar plate labeled *No Treatment* only enough to stick the swab in. Quickly make several S-shaped streaks on the agar. Close your plate and tape it shut.
4. Carefully clean the top of your desk or work area with hand sanitizer. Repeat step 3 using the agar plate labeled *Disinfected*.
5. Move your plates to an incubation area as directed by your teacher.
**Form a Hypothesis**

Using what you know about bacteria and disinfectants, write a hypothesis about how disinfectants affect the growth of bacteria. Make a prediction about how much bacterial growth you expect to see on your two agar plates.

**Test Your Hypothesis**

Check your agar plates after about three days. Record your observations in your Science Journal.

Compare the growth of bacteria on your two agar plates. Do your results support your hypothesis?

**Analyze and Conclude**

Describe the differences in the amount of bacteria that grew on the two agar plates. Which plate had more?

What can you do to decrease the spread of bacteria in school and at home?

Infer Why didn’t your experiment show any evidence of viral replication? How would you study the effect of disinfectants on viruses?

**The Big Idea**

Why do doctors wash their hands or use hand sanitizer between appointments with different patients?

**Communicate Your Results**

Make a short video presentation about the results of your lab. Describe the question you investigated, the steps you took to answer your question, and the results that support your conclusions. Show your video to the class.

**Lab Tips**

- When streaking bacteria on your plates, use a steady, but light, pressure.
- After you disinfect your object, wait for the disinfectant to dry before testing the area.

**Inquiry Extension**

Think about other situations in which cleanliness is important for preventing disease. Write a procedure in which you could test for bacteria as a comparison. Conduct your experiment and present your results to the class.

Remember to use scientific methods.
**Lesson 1: What are bacteria?**
- Bacteria and archaebacteria are unicellular organisms without nuclei. They have structures for movement, obtaining food, and reproduction.
- Bacteria exchange genetic information in a process called **conjugation**. They reproduce asexually by **fission**.

**Lesson 2: Bacteria in Nature**
- Bacteria decompose materials, play a role in the nitrogen cycle, clean the environment, and are used in food.
- Some bacteria cause disease, while others are used to treat it.

**Lesson 3: What are viruses?**
- A **virus** is made up of DNA or RNA surrounded by a protein coat.
- Viruses can cause disease, can be made into **vaccines**, and are used in research.

### Key Concepts Summary

<table>
<thead>
<tr>
<th>Lesson 1: What are bacteria?</th>
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<td>bacterium, flagella, fission, conjugation, endospore</td>
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<td>decomposition, nitrogen fixation, bioremediation, pathogen, antibiotic, pasteurization</td>
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<td>virus, antibody, vaccine</td>
</tr>
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</table>
**Use Vocabulary**

1. Some bacteria have whiplike structures called ________ that are used for movement.
2. Your body produces proteins called ________ in response to infection by a virus.
3. Organisms that cause diseases are known as ________.
4. The process of killing bacteria in a food product by heating it is called ________.
5. Bacteria can form a(n) ________ to survive when environmental conditions are severe.
6. A(n) ________ is made by using pieces of deactivated viruses or dead pathogens.

**Link Vocabulary and Key Concepts**

Copy this concept map, and then use vocabulary terms from the previous page and other terms from the chapter to complete the concept map.
Understand Key Concepts

1. Which structure is NOT found in a bacterium?
   A. chromosome
   B. cytoplasm
   C. nucleus
   D. ribosome

2. Which structure helps a bacterium move?
   A. capsule
   B. endospore
   C. flagellum
   D. plasmid

3. What process is occurring in the illustration below?
   A. budding
   B. conjugation
   C. fission
   D. replication

4. Which term describes how bacteria can be used to clean up environmental waste?
   A. bioremediation
   B. decomposition
   C. pasteurization
   D. nitrogen fixation

5. Which statement correctly describes pathogens?
   A. They are always bacteria.
   B. They are in your body only when you are sick.
   C. They break down dead organisms.
   D. They cause disease.

6. Which statement correctly describes antibiotics?
   A. They can kill any kind of bacterium.
   B. They help bacteria grow.
   C. They stop the growth and reproduction of bacteria.
   D. They treat all diseases.

7. What is shown below?
   A. bacteria
   B. bacteriophage
   C. endospore
   D. virus

8. Which is NOT caused by a virus?
   A. chicken pox
   B. influenza
   C. rabies
   D. tuberculosis

9. What do vaccines stimulate the production of?
   A. antibodies
   B. DNA or RNA
   C. protein
   D. ribosomes

10. Scientists hope to be able to use viruses for gene therapy because viruses can
    A. become latent for long periods of time.
    B. inject genetic material into host cells.
    C. make proteins to attack cells.
    D. transport themselves throughout the body.

11. Which statement correctly describes viruses?
    A. All viruses are latent.
    B. All viruses contain DNA.
    C. Viruses are considered living things.
    D. Viruses do not have organelles.
**Chapter Review**

**Critical Thinking**

12. **Compare and contrast** bacteria and archaea.

13. **Evaluate** the importance of bacterial conjugation.

14. **Model** the life of a bacterium that performs nitrogen fixation in the soil.

15. **Contrast** asexual reproduction in bacteria and replication in viruses. What are some advantages and disadvantages of each?

16. **Organize** the effects of bacteria on health by copying and completing the table below.

<table>
<thead>
<tr>
<th>Harmful Effects</th>
<th>Beneficial Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</table>

17. **Analyze** the importance of vaccines in preventing large outbreaks of influenza.

18. **Draw** and label a typical bacterium. Are the features you labeled beneficial for moving, for finding food, or for another purpose? Explain your answer.

19. **Explain** what happens during the process shown below. How does this process eventually create new strains of bacteria that are resistant to antibiotics?

20. **Summarize** an argument that you could use to encourage all the families in your neighborhood to make sure their pets are vaccinated against rabies.

21. What are bacteria and viruses and why are they important? Include examples of how they are both beneficial and harmful to humans.

22. Describe what is happening in the photo below. Explain what is happening to both the bacterium and the virus.

**Math Skills**

23. How many bacteria would there be if 100 bacteria underwent fission 8 times?

24. If each fission cycle takes 20 minutes, how many cycles would it take for 100 bacteria to divide into 100,000?

25. A strain of bacteria takes 30 minutes to undergo fission. Starting with 500 bacteria, how many would there be after 4 hours?
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

**Multiple Choice**

1. Which is NOT a characteristic of bacteria?
   - A They are microscopic.
   - B They are unicellular.
   - C They can live in many environments.
   - D They have a membrane-bound nucleus.

2. Which process increases genetic diversity in bacteria?
   - A attachment to a host organism
   - B division into two organisms
   - C formation of an endospore
   - D transfer of plasmid strands

3. The diagram above illustrates a bacterium. What is the function of the structure labeled A?
   - A attaching to surfaces
   - B sensing surroundings
   - C stinging prey
   - D taking in nutrients

4. The structure labeled B helps a bacterium
   - A move.
   - B protect itself.
   - C reproduce.
   - D transfer DNA.

5. What beneficial vitamin do some human intestinal bacteria produce?
   - A vitamin A
   - B vitamin C
   - C vitamin D
   - D vitamin K

6. Which statement BEST explains why living organisms in an ecosystem depend on bacteria?
   - A Bacteria help reduce the number of predators.
   - B Bacteria kill weaker members of a species so only the stronger ones survive.
   - C Bacteria protect organisms from harmful solar rays.
   - D Bacteria release molecules into soil that are used by other organisms.

7. What role do bacteria play in the process shown above?
   - A They break down cellulose.
   - B They convert nitrogen in grass.
   - C They prevent viruses from growing.
   - D They remove harmful pollutants.
8. In which process do bacteria and other organisms clean up environmental pollution?
   A. bioremediation  
   B. decomposition  
   C. fixation  
   D. pasteurization

   Use the diagram below to answer question 9.

9. What is pictured in the diagram above?
   A. an antibody  
   B. a bacteriophage  
   C. a bacterium  
   D. a plasmid

10. Which BEST explains how mutation benefits a virus?
     A. It enables the virus to adjust to changes in its host cell.  
     B. It enables the virus to reproduce more quickly.  
     C. It enables the virus to resist antibiotic therapy.  
     D. It enables the virus to travel from host to host.

   Constructed Response
   Use the diagrams below to answer questions 11 and 12.

11. Describe how the virus attaches to the host cell in the figure at the top of the diagram.

12. What are the Y-shaped structures on the virus in the figure at the bottom of the diagram? Explain their interaction with the virus.

13. Why can viral infections be more difficult to treat than bacterial infections?

14. What are two methods you can use to prevent a viral infection?

15. What happens to the host cell when a latent virus goes through an inactive stage?