

Section 19–2

1 FOCUS

Objectives

19.2.1 Describe the structure of a virus.

19.2.2 Explain how viruses cause infection.

Guide for Reading

Vocabulary Preview

Have students preview the Vocabulary words by skimming the section for the highlighted, boldface terms and recording the definition of each.

Reading Strategy

Before students read, have them preview the different viral structures shown in Figure 19–9 and make a list of questions about the structures and functions of viruses. Students should look for answers to their questions as they read the section.

2 INSTRUCT

What Is a Virus?

Use Visuals

Figure 19–8 Before students have read the introduction to the section or the caption to the figure, have them look at the photo of the infected tobacco leaf. Then, describe the puzzle that faced scientists who were trying to determine the cause of tobacco mosaic disease. Review the experiments that led to the discovery of viruses. Have students analyze for themselves the results of each experiment and suggest to them further experiments that could be performed. Then, have students read the text. By looking into the problem for themselves, students will gain a much better understanding of the way viruses were discovered. **L2**

19–2 Viruses

Guide for Reading



Key Concepts

- What is the structure of a virus?
- How do viruses cause infection?

Vocabulary

virus
capsid
bacteriophage
lytic infection
lysogenic infection
prophage
retrovirus

Reading Strategy:

Using Visuals As you read about viral replication in this section, trace each step in **Figure 19–10**. Then, list the steps, and write a few sentences to describe each step.

Imagine that you have been presented with a great puzzle. Farmers have begun to lose a valuable crop to a plant disease. The disease produces large pale spots on the leaves of plants similar to those shown in **Figure 19–8**. The diseased leaves look like mosaics of yellow and green. As the disease progresses, the leaves turn completely yellow, wither, and fall off, killing the plant.

To determine what is causing the disease, you take leaves from a diseased plant and extract a juice. You place a few drops of the juice on the leaves of healthy plants. A few days later, the mosaic pattern appears where you put the drops. Could the source of the disease be in the juice?

You use a light microscope to look for a germ that might cause the disease, but none can be seen. Even when the tiniest of cells are filtered out of the juice, it still causes the disease. You hypothesize that the juice must contain disease-causing agents so small that they are not visible under the microscope. Although you cannot see the disease-causing particles, you're sure they are there. You give them the name *virus*, from the Latin word for "poison."

If you think you could have carried out this investigation, congratulations! You're walking in the footsteps of a 28-year-old Russian biologist, Dmitri Ivanovski. In 1892, Ivanovski identified the cause of tobacco mosaic disease as juice extracted from infected plants. In 1897, Dutch scientist Martinus Beijerinck suggested that tiny particles in the juice caused the disease, and he named these particles viruses.

What Is a Virus?

In 1935, the American biochemist Wendell Stanley obtained crystals of tobacco mosaic virus. Living organisms do not crystallize, so Stanley inferred that viruses were not alive. **Viruses** are particles of nucleic acid, protein, and in some cases, lipids.

Viruses can reproduce only by infecting living cells. Viruses differ widely in terms of size and structure, as you can see in **Figure 19–9**. As different as they are, all viruses have one thing in common: They enter living cells and, once inside, use the machinery of the infected cell to produce more viruses.

Most viruses are so small they can be seen only with the aid of a powerful electron microscope. **A typical virus is composed of a core of DNA or RNA surrounded by a protein coat.** The simplest viruses contain only a few genes, whereas the most complex may have more than a hundred genes.

Figure 19–8 Tobacco mosaic virus causes the leaves of tobacco plants to develop a pattern of spots called a mosaic.



SECTION RESOURCES

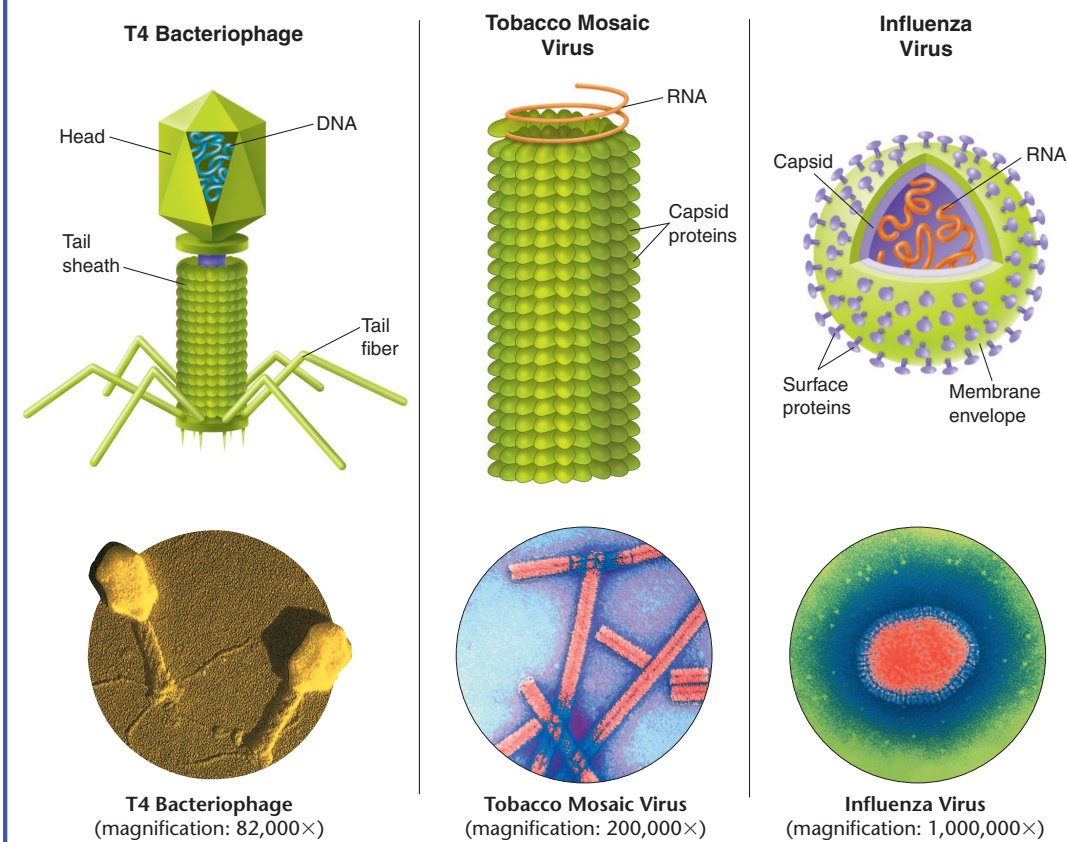
Print:

- **Teaching Resources**, Section Review 19–2
- **Reading and Study Workbook A**, Section 19–2
- **Adapted Reading and Study Workbook B**, Section 19–2
- **Lesson Plans**, Section 19–2

Technology:

- **iText**, Section 19–2
- **BioDetectives Videotapes**, "Influenza: Tracking a Virus"
- **Animated Biological Concepts Videotape Library**, 31 Lytic and Lysogenic Cycles
- **Transparencies Plus**, Section 19–2

FIGURE 19-9 VIRUS STRUCTURES



A virus's protein coat is called its **capsid**. The capsid includes proteins that enable a virus to enter a host cell. The capsid proteins of a typical virus bind to receptors on the surface of a cell and "trick" the cell into allowing it inside. Once inside, the viral genes are expressed. The cell transcribes and translates the viral genetic information into viral capsid proteins. Sometimes that genetic program causes the host cell to make copies of the virus, and in the process the host cell is destroyed.

Because viruses must bind precisely to proteins on the cell surface and then use a host's genetic system, most viruses are highly specific to the cells they infect. Plant viruses infect plant cells; most animal viruses infect only certain related species of animals; and bacterial viruses infect only certain types of bacteria. Viruses that infect bacteria are called **bacteriophages**.

CHECKPOINT What happens when a cell transcribes a viral gene?

▲ **Figure 19-9** Viruses come in a wide variety of sizes and shapes.

➡ A typical virus is composed of a core of either DNA or RNA, which is surrounded by a protein coat, or capsid.

Use Visuals

Figure 19-9 Ask students: From these three examples, can you describe the typical shape of a virus? (No. The shapes are so different that there is no typical shape.) What parts do all three kinds of viruses have in common? (A capsid and a core of nucleic acid, either DNA or RNA) Point out that each of the three examples in the figure infects different kinds of organisms—bacteria, plants, and animals. Explain that viruses are often classified according to the type of organism they infect. **L2**

Build Science Skills

Using Models Give each student an unshelled sunflower seed. (Other easily shelled seeds will also work well, including peanuts, pumpkin seeds, and pistachio nuts.) Then, ask: In what ways is the structure of a virus like the structure of a sunflower seed? (Students should recognize that both sunflower seeds and viruses consist of a protective outer shell that encases vital contents.)

What does the shell of the sunflower seed represent in a virus? (The capsid) How are the functions of a sunflower seed's shell and a virus's capsid similar? (Both protect the contents.) What does the kernel of the sunflower seed represent? (The virus's core of DNA or RNA) What is the function of the virus's core? (To put the genetic program of the virus into effect) **L2**



SUPPORT FOR ENGLISH LANGUAGE LEARNERS

Vocabulary: Link to Visual

Beginning Use Figure 19-9 to help clarify the meaning of the vocabulary words *virus*, *capsid*, and *bacteriophage*. Write each of these words on the board, and model the pronunciation of each term. While the students have Figure 19-9 in front of them, give a short definition of each term and point to the appropriate part of the figure. Write the definitions on the board. Post these terms on a word wall with other vocabulary terms from the chapter. **L1**

Intermediate To extend the beginning-level activity, pair ESL students with English-proficient students to write three sentences, one using each of the following terms: *virus*, *capsid*, and *bacteriophage*. The student pairs can use the text on pages 478 and 479 and the information in Figure 19-9 to write their sentences. Ask one student in each pair to read the sentences aloud. **L2**

Answer to . . .

✓ **CHECKPOINT** The cell transcribes and translates the viral genetic information into viral capsid proteins. Sometimes that genetic program may simply cause the cell to make copies of the virus, and in the process the host cell is destroyed.



Download a worksheet on the lytic cycle for students to complete, and find additional teacher support from NSTA SciLinks.

Viral Infection

Build Science Skills

Predicting Before students read about viral infection, show them an electron micrograph that shows a virus particle attaching to a cell membrane. Give a simple description of what the image shows, and then ask students what they think will happen to the virus and the cell. Have students consider this question by making a prediction about what events will occur next and how the virus will ultimately affect the cell.

L2

Build Science Skills

Using Analogies Ask a volunteer to read aloud the paragraph that uses the analogy of an outlaw to explain the function of a lytic virus. Then, after students have reread the description of a lysogenic infection, ask: **If a lytic infection is like an outlaw taking over a town in the Old West, what is a lysogenic infection like?** (Responses will vary. Students might suggest that a lysogenic infection is like a relative or family friend who moves into a family's home and stays there for a long time, using everything in the home and borrowing money as well.) L1 L2



Encourage students to view "Influenza: Tracking a Virus" on Videotape Three.



For: Links on the lytic cycle
Visit: www.SciLinks.org
Web Code: cbn-6192



To find out more about the transmission of a virus, view the segment "Influenza: Tracking a Virus," on Videotape Three.

Viral Infection

Once the virus is inside the host cell, two different processes may occur. Some viruses replicate themselves immediately, killing the host cell. Other viruses replicate themselves in a way that doesn't kill the host cell immediately. These two processes are shown in **Figure 19-10**.

Lytic Infection Bacteriophage T4 is an example of a bacteriophage that causes a lytic infection. **In a lytic infection, a virus enters a cell, makes copies of itself, and causes the cell to burst.** Bacteriophage T4 has a DNA core inside an intricate protein capsid that is activated by contact with a host cell. It then injects its DNA directly into the cell. The host cell cannot tell the difference between its own DNA and the DNA of the virus. Consequently, the cell begins to make messenger RNA from the genes of the virus. This viral mRNA is translated into viral proteins that act like a molecular wrecking crew, chopping up the cell DNA, a process that shuts down the infected host cell.

The virus then uses the materials of the host cell to make thousands of copies of its own DNA molecule. The viral DNA gets assembled into new virus particles. Before long, the infected cell lyses, or bursts, and releases hundreds of virus particles that may go on to infect other cells. Because the host cell is lysed and destroyed, this process is called a **lytic infection**.

In its own way, a lytic virus is similar to an outlaw in the American Old West. First, the outlaw eliminates the town's existing authority (host cell DNA). Then, the outlaw demands to be outfitted with new weapons, horses, and riding equipment by terrorizing the local people (using the host cell to make viral proteins and viral DNA). Finally, the outlaw forms a gang that leaves the town to attack new communities (the host cell bursts, releasing hundreds of virus particles).

Lysogenic Infection Other viruses, including the bacteriophage lambda, cause **lysogenic infections** in which a host cell makes copies of the virus indefinitely. **In a lysogenic infection, a virus integrates its DNA into the DNA of the host cell, and the viral genetic information replicates along with the host cell's DNA.** Unlike lytic viruses, lysogenic viruses do not lyse the host cell right away. Instead, a lysogenic virus remains inactive for a period of time.

The viral DNA that is embedded in the host's DNA is called a **prophage**. The prophage may remain part of the DNA of the host cell for many generations before becoming active. A virus may not stay in the prophage form indefinitely. Eventually, any one of a number of factors may activate the DNA of a prophage, which will then remove itself from the host cell DNA and direct the synthesis of new virus particles.

The steps of lytic and lysogenic infections may be different from those of other viruses when they attack eukaryotic cells. Most animal viruses, however, show patterns of infection similar to either the lytic or lysogenic patterns of infection of bacteria.



FACTS AND FIGURES

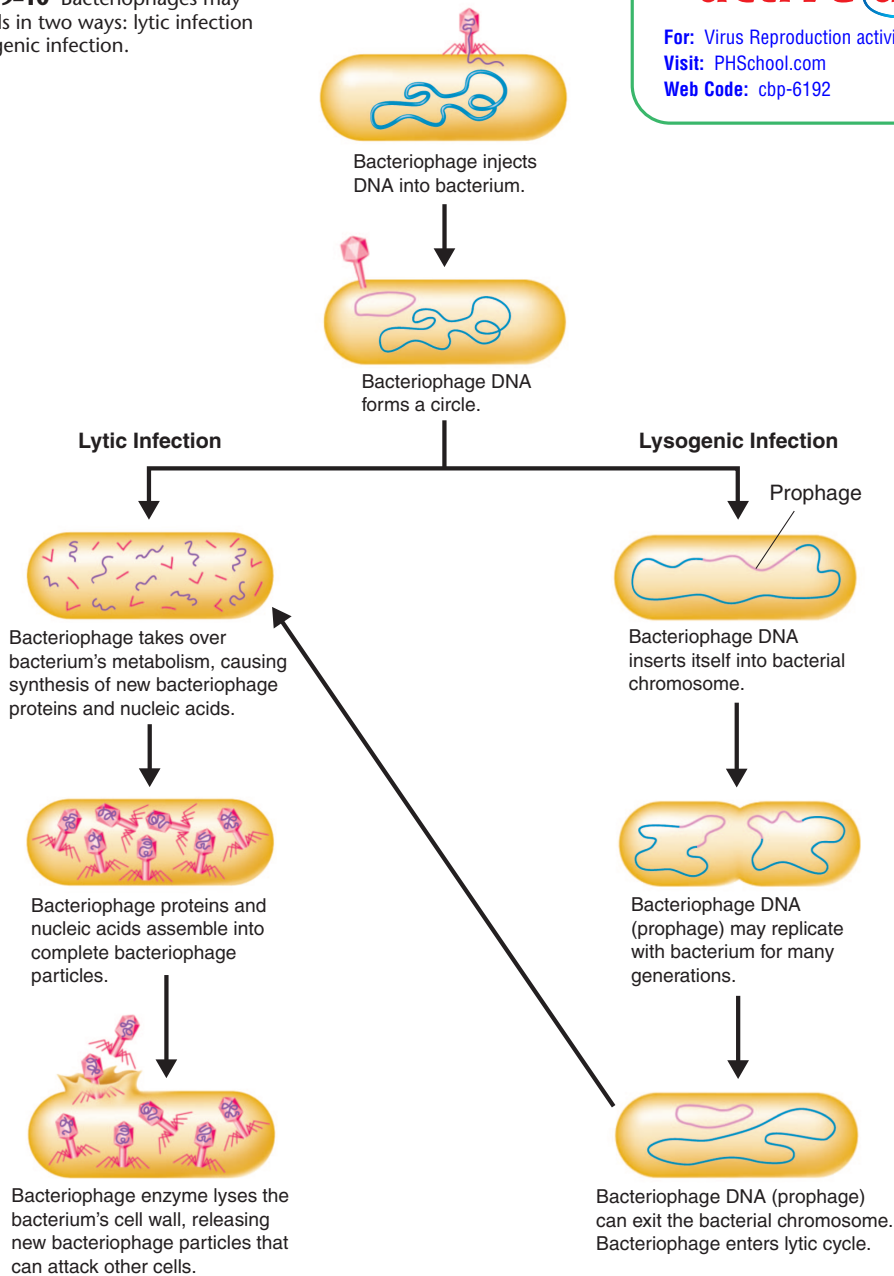
Viruses get in

Although bacteriophages typically inject their DNA into the host cell, not all viruses invade a host cell in this manner. Many animal viruses, such as the semliki virus, enter the host through endocytosis—the binding of the virus to the cell membrane, inducing the cell to take in the virus.

Once inside the host cell, the virus sheds its protein coat and either undergoes replication or becomes part of the host's DNA. Interestingly, a few animal viruses, such as those responsible for rabies, AIDS, and influenza, leave the host cell through budding, which can be thought of as the opposite of endocytosis.

LYTIC AND LYSOGENIC INFECTIONS

Figure 19–10 Bacteriophages may infect cells in two ways: lytic infection and lysogenic infection.



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active art

For: Virus Reproduction activity
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Web Code: cbp-6192

Use Visuals

Figure 19–10 Ask students: In the lysogenic cycle, what happens to the virus DNA? (It inserts itself into the bacterial chromosome.) What is the viral DNA called while it is embedded in the bacterial DNA? (A prophage)

Explain that the bacterium can replicate for many generations with the prophage embedded in its DNA, giving rise to many host cells that contain a prophage. When conditions change, the virus can switch from the lysogenic cycle to the lytic cycle. Explain that it is usually some kind of environmental change that causes the switch, such as a chemical change or radiation. As you describe this process to students, have them trace the path with a finger. Move the finger through the lysogenic cycle to the bottom, where a switch in cycles can occur. Make sure that students understand that a switch in cycles may not occur. The virus can move through the lysogenic cycle for many generations of the bacteria. **L2**

Address Misconceptions

Point out to students that in the description of each type of infection (both lytic and lysogenic), the virus is described as making copies of itself. In a lytic infection, though, the virus uses the materials of the host cell to make copies of itself. In a lysogenic infection, the virus uses the DNA of the host cell to make copies of itself. Explain that, for this reason, biologists often talk about viral "replication" or "multiplication" rather than "reproduction."

L1 L2

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Students explore the two methods viruses use to multiply.

19–2 (continued)

Retroviruses

Quick Lab

Objective Students will make models of two different viruses and conclude that viruses differ in structure.

Skills Focus **Using Models, Drawing Conclusions, Calculating**

Materials metric ruler, scissors, tape, craft materials

Time 20 minutes

Strategy Make sure that students accurately follow steps 3 and 4.

Expected Outcomes Students will learn that viruses differ in structure.

Analyze and Conclude

1. A capsid and a core of either DNA or RNA
2. A model of a T4 bacteriophage should include a head, a tail sheath, and a tail fiber. A model of an influenza virus should include surface proteins and a membrane envelope.
3. Students should measure the image of the virus they modeled in Figure 19–9 and divide this length by the magnification, to determine the actual size of the virus. For example, the image of the T4 bacteriophage is 3 cm long; $3\text{ cm} = 3 \times 10^{-2}\text{ m}$;
 $3 \times 10^{-2}\text{ m} / 82,000 = 0.37 \times 10^{-6}\text{ m} = 370\text{ nm}$.
4. Students' questions may vary. Typical questions might include: How does a virus particle get into a cell? How does a virus inject its core of viral genetic material into the cell's DNA?
5. Students' models should directly relate to one of the questions they listed in question 4.

Build Science Skills

Using Analogies Point out that retroviruses, such as the virus that causes AIDS, can remain dormant for various lengths of time. Explain that this is like a plant seed that can remain dormant until conditions are right for growth. Some seeds, for example, have thick coats that don't allow the embryo inside the seed to grow. This seed coat might be broken by abrasion, fire, or the action of soil microorganisms. **L2**

Quick Lab

How do viruses differ in structure?

Materials craft materials, metric ruler, scissors, tape

Procedure

1. Make models of two of the viruses shown in Figure 19–9 on page 479.
2. Label the parts of each of your virus models.
3. Measure and record the length of each of your virus models in centimeters. Convert the length of each model into nanometers:
 $1\text{ cm} = 10\text{ million nm}$.
4. Calculate the length of each virus you modeled. Divide the length of each model by the length of the actual virus to determine how many times larger each model is than the virus it represents.

Analyze and Conclude

1. **Using Models** What parts of your models are found in all viruses?
2. **Drawing Conclusions** What parts do one or both of your models include that are found in only some viruses?



3. **Calculating** How many times larger are your models than the viruses they represent?
4. **Asking Questions** Write two or more questions about the relationship between viruses and single-celled organisms.
5. **Using Models** Suggest ways you can use models to investigate one of your questions in question 4. Suggest an alternative for the virus model you made in this activity.

Retroviruses

Some viruses contain RNA as their genetic information and are called **retroviruses**. When retroviruses infect a cell, they produce a DNA copy of their RNA. This DNA, much like a prophage, is inserted into the DNA of the host cell. There the retroviruses may remain dormant for varying lengths of time before becoming active, directing the production of new viruses, and causing the death of the host cell.

Retroviruses get 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, including humans. The virus that causes acquired immune deficiency syndrome (AIDS) is a retrovirus.

Viruses and Living Cells

Viruses must infect a living cell in order to grow and reproduce. They also take advantage of the host's respiration, nutrition, and all the other functions that occur in living things. Therefore, viruses can be considered to be parasites. A parasite depends entirely upon another living organism for its existence, harming that organism in the process.



FACTS AND FIGURES

Classifying viruses

Because viruses are unique, they are not part of any kingdom, and they are not identified as species. Classification of viruses depends on the chemical and physical properties of the virus. The major division focuses on their genetic material; thus, there are DNA viruses and RNA viruses. Viruses are then further divided by the shapes of their protein coats and their sizes. This scheme

results in a major group called the picornaviruses, which are small RNA viruses with a polyhedral shape. Both poliovirus and the rhinoviruses (which cause the common cold) are subgroups of the picornaviruses. Another way of grouping viruses is by the type of host a virus infects. Thus, animal viruses infect animals, plant viruses infect plants, and bacterial viruses—or bacteriophages—infect bacteria.

Viruses and Living Cells

Use Visuals

Figure 19–11 Point out that the characteristics listed in the table are similar to the list of characteristics of living things students studied in Section 1–3. Help students recall that the first characteristic from that list is “Living things are made up of units called cells.” Ask: **How do the column heads of this table answer the question of whether a virus fulfills that characteristic?** (Since a distinction is made between *Virus* and *Cell* in the column heads, viruses obviously aren’t made up of units called cells.)

L1 L2

3 ASSESS

Evaluate Understanding

Have students make two flowcharts to show two examples of the way viruses infect cells.

Reteach

Have students compare the illustrations of virus structures in Figure 19–9 with the illustration of bacterium structure in Figure 19–2. Place emphasis on what viruses don’t have.

Connecting Concepts

Students’ tables might be similar to the one in Figure 19–11, though the column head for the first column might be Structure. Students might list a variety of cell structures in that first column, including cell membrane, cytoplasm, nucleus, and the several cell organelles. In completing this table, students might write a *no* in the virus column and a *yes* in the cell column for all of the structures, except in a row for genetic material.

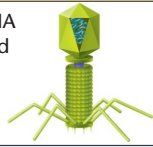



If your class subscribes to the iText, use it to review the Key Concepts in Section 19–2.

Answer to . . .

Figure 19–11 Most students will state that viruses are nonliving. However, accept all responses that are adequately supported.

Viruses and Cells

Characteristic	Virus	Cell
Structure	DNA or RNA core, capsid 	Cell membrane, cytoplasm; eukaryotes also contain nucleus and organelles 
Reproduction	only within a host cell	independent cell division either asexually or sexually
Genetic Code	DNA or RNA	DNA
Growth and Development	no	yes; in multicellular organisms, cells increase in number and differentiate
Obtain and Use Energy	no	yes
Response to Environment	no	yes
Change Over Time	yes	yes

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. Yet, viruses have many of the characteristics of living things. After infecting living cells, viruses can reproduce, regulate gene expression, and even evolve. Some of the main differences between cells and viruses are summarized in **Figure 19–11**. Viruses are at the borderline of living and non-living things.

Although viruses are smaller and simpler than the smallest cells, it is not likely that they could have been the first living things. Because viruses are completely dependent upon living things, 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. Once established, however, viruses have continued to evolve, along with the cells they infect, over billions of years.

▲ **Figure 19–11** The differences between viruses and cells are listed in this chart. **Applying Concepts** Based on this information, would you classify viruses as living or nonliving? Explain.

19–2 Section Assessment

- Key Concept** What are the parts of a virus?
- Key Concept** Describe the two ways that viruses cause infection.
- What is the difference between a bacteriophage and a prophage?
- What is a retrovirus?
- Critical Thinking Making Judgments** Do you think viruses should be considered a form of life? Describe the reasons for your opinion.
- Critical Thinking Evaluating** What are the strengths and weaknesses of the tobacco mosaic virus hypothesis?

Connecting Concepts

Structure and Function

Viruses and cells are similar yet different. Compare the structure of a virus to the structure of a eukaryotic cell. Organize your information in a table. You may wish to refer to Chapter 7, which discusses the structures of cells in detail.

19–2 Section Assessment

- A typical virus is composed of a core of either DNA or RNA surrounded by a protein coat, which is called a capsid.
- In a lytic infection, a virus enters a cell, makes copies of itself, and causes the cell to burst. In a lysogenic infection, a virus embeds its DNA into the DNA of the host cell and replicates.
- A bacteriophage is a virus that infects bacteria. A prophage is the lysogenic viral DNA that is embedded in the host’s DNA.
- A retrovirus is a virus that contains RNA.
- Most students will assert that viruses should not be considered a form of life because they do not exhibit all the characteristics of life.
- The strength of the hypothesis is that it explains the observations. One weakness is that the viruses could not be seen, so there’s no direct evidence that they exist.

The issue of whether to require smallpox vaccinations for military personnel and civilians in the United States became quite important following the terrorist attacks of September 11, 2001. In late 2002, President Bush ordered smallpox vaccinations for military personnel. Before students read this feature, find out or have student volunteers find out what today's government policies about vaccinations for smallpox and other diseases are. After students read the feature, encourage them to use library and Internet resources to learn more about this issue. Also, encourage students to contact local health officials about the risks and benefits of various vaccinations. After students have answered the Research and Decide questions, organize role-playing with students who have opinions on both sides of the issue.

Research and Decide

1. The risks of nationwide vaccination include deaths and illnesses. Students should find out how great the risk is for certain vaccinations. The benefits include prevention of a devastating epidemic as well as possible cost savings.
2. Answers may vary. A typical response might discuss the risks involved in vaccination, the risks involved in not having the population vaccinated, and the costs involved to administer vaccines or to store the amount of vaccine that might be needed in the case of a terrorist attack that uses a pathogen as a weapon.
3. Whichever position a student takes, the opinion should be supported by logical arguments.

Should Mass Vaccinations Be Required?

Smallpox is a deadly disease that produces pustules like those shown in the photograph. Smallpox had been brought under control by a worldwide vaccination program. It appeared that vaccination had eradicated every trace of smallpox in nature. As a result, the routine vaccination of children against smallpox was ended in the United States in 1971. No new smallpox cases have been reported anywhere since 1978. Only two laboratories, one in Atlanta, Georgia, and the other in Russia, are known to have samples of the virus.

Today there is concern that certain infectious diseases, such as smallpox, will be used as a biological weapon. This has led authorities in the United States and other countries to order the production of new stocks of certain vaccines. Preparing millions of doses of a vaccine as a precaution against attack certainly seems like a good idea. But it also raises an important social and scientific question—should a nation require its citizens to be vaccinated against a particular disease, or should we wait until there is evidence of an outbreak of a disease in a given area?

The Viewpoints

Require Vaccinations

Human history shows just how deadly certain infectious diseases can be. Therefore, it makes sense to preempt an outbreak by requiring vaccinations as soon as enough doses of the vaccine are available. The benefits of immunity would outweigh any possible adverse reactions to the vaccine. In addition, it is cheaper to vaccinate everyone, rather than to treat infectious diseases on an individual basis.

Hold the Vaccine in Reserve

As serious as the threat from certain infectious diseases may be, we should keep in mind the rule of medicine that is taught to all doctors: First, do no harm. We already know, unfortunately, that administering vaccines to an entire population will indeed do harm. For example, U. S. health statistics



show that for every 1 million infants vaccinated for smallpox, as many as 5 may have died from reactions to the vaccine. The exact number of deaths that will result from a nationwide vaccination program is not certain, but any number of deaths is too many when the risk of infection is only hypothetical.

Research and Decide

1. **Analyzing the Viewpoints** To make an informed decision, learn more about this issue by consulting library or Internet resources. Then, list both the risks and benefits of nationwide vaccination.
2. **Forming Your Opinion** How do you balance the risks and benefits of vaccination now against the risks and benefits of stockpiling the vaccine? What factors should you consider?
3. **Role-Playing** You are a researcher for the Centers for Disease Control in Atlanta. You have been offered the chance to be inoculated with a vaccine such as smallpox. Would you get the vaccination? Explain your answer and support it with facts from your research.

Students can research vaccinations on the site developed by authors Ken Miller and Joe Levine.



HISTORY OF SCIENCE

An end to smallpox

In 1980, the World Health Organization announced that the smallpox virus had been eradicated. This virus was the cause of many terrible epidemics throughout human history, and as recently as 1967 it caused 2 million deaths worldwide. The introduction of the virus into the Americas by Europeans caused epidemics among Native Americans because they had no immunity. In Europe and Asia, people had long recognized

that someone who had contracted the less severe form of smallpox was forever immunized to the more severe form. In the late 1700s, English physician Edward Jenner noticed that milkmaids who contracted cowpox also gained immunity from smallpox. From that observation and subsequent experimentation, Jenner developed the first vaccine, a term he named from the Latin word for cow, *vacca*, because it was made from the cowpox virus.

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