Chapter 17

Viruses

Chapter Focus

A virus is an infectious particle consisting of a genome of single-stranded or double-stranded DNA or RNA enclosed in a protein capsid, and sometimes within a membrane envelope derived from the host. Viruses replicate using the metabolic machinery of their bacterial, animal, or plant host. Viral infections may destroy the host cell and cause diseases within the host organism. Viruses may have evolved from plasmids or transposons.

Chapter Review

17.1 A virus consists of a nucleic acid surrounded by a protein coat

A **virus** is an infectious particle consisting of genes inside a protein coat and, in some viruses, a membranous envelope.

Viral Genomes Viral genomes may be single-stranded or double-stranded DNA or RNA. Viral genes are usually contained on a single linear or circular nucleic acid molecule.

Capsids and Envelopes The **capsid**, or protein shell, is built from a large number of often identical protein subunits *(capsomeres)* and may be rod-shaped (*helical viruses*), polyhedral (*icosahedral viruses*), or more complex in shape. **Viral envelopes**, which are derived from membranes of the host cell but also include viral proteins and glycoproteins, may cloak the capsids of viruses that infect animals. Some viruses also contain a few viral enzymes.

Complex capsids are found among **bacteriophages**, or **phages**, viruses that infect bacteria. Of the phages that infect the bacterium *E. coli*, T2, T4, and T6 have similar capsid structures consisting of an icosahedral head and a protein tail piece with tail fibers for attaching to a bacterium.

17.2 Viruses replicate only in host cells

Viruses are obligate intracellular parasites that lack metabolic enzymes and other equipment needed to replicate. Each virus type has a limited **host range** due to proteins on the outside of the virus that recognize only specific receptor molecules on the host cell surface.

General Features of Viral Replicative Cycles Once the viral genome enters the host cell, the cell's enzymes, nucleotides, amino acids, ribosomes, ATP, and other resources are used to replicate the viral genome and produce capsid proteins. Many DNA viruses use host DNA polymerases to copy their genome, whereas RNA viruses use virus-encoded RNA polymerases for replicating their RNA genome.

After replication, viral nucleic acid and capsid proteins spontaneously self-assemble to form new viruses within the host cell. Hundreds or thousands of newly formed virus particles are released, often destroying the host cell in the process.

Replicative Cycles of Phages A **lytic cycle** culminates in lysis of the host cell and release of newly produced phages. **Virulent phages** replicate only by a lytic cycle.

The T4 phage uses its tail fibers to stick to a receptor site on the surface of an *E. coli* cell. The sheath of the tail contracts and thrusts its viral DNA into the cell, leaving the empty capsid behind. The *E. coli* cell begins to transcribe and translate phage genes, one of which codes for an enzyme that chops up host cell DNA. Nucleotides from the degraded bacterial DNA are used to produce viral DNA. Capsid proteins are assembled into phage tails, tail fibers, and heads. The viral components assemble into phage particles. These are released after the manufacture of an enzyme that damages the bacterial cell wall, which causes the cell to swell and burst.

Mutations that change their receptor sites and **restriction enzymes** that chop up viral DNA once it enters the cell help bacteria defend against viral infection.

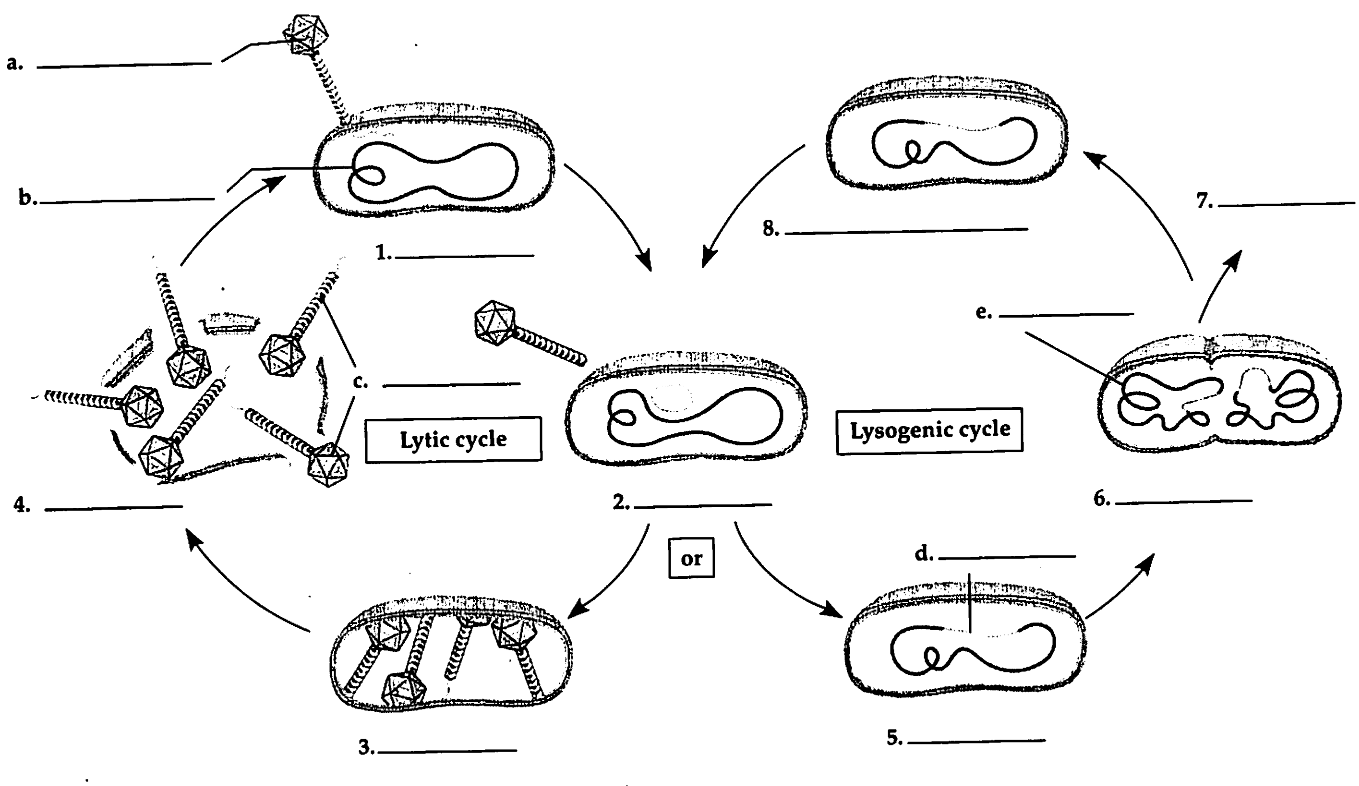
In a **lysogenic cycle**, a virus replicates its genome without killing its host. **Temperate phages** can replicate by lytic and lysogenic cycles.

When the phage lambda (λ) injects its DNA into an *E. coli* cell, it can begin a lytic cycle, or its DNA may be incorporated into the host cell's chromosome and begin a lysogenic cycle as a **prophage.** Most of the genes of the inserted phage genome are repressed by a protein coded for by a prophage gene. Reproduction of the host cell replicates the phage DNA along with the bacterial DNA. The prophage may exit the bacterial chromosome, usually in response to environmental stimuli, and start a lytic cycle.

Several disease-causing bacteria would be harmless except for the expression of prophage genes that code for toxins.

FOCUS QUESTION 17.1

In the following diagram of lytic and lysogenic cycles, describe steps numbered **1–8** and label structures **a–e.**



Replicative Cycles of Animal Viruses The genomes of animal viruses may be double- or single-stranded DNA or RNA. A viral envelope surrounds the capsid of almost all animal viruses that have RNA genomes.

What is the replicative cycle of an enveloped RNA virus? Glycoproteins extending from the viral membrane attach to receptor sites on a host cell plasma membrane. The capsid is transported into the cell. The viral genome replicates and directs the synthesis of proteins. Viral glycoproteins are produced and embedded in the ER membrane, processed by the Golgi apparatus, and then transported to the plasma membrane. New viruses bud off within an envelope that is derived from the host's plasma membrane and bears viral glycoproteins.

Herpesviruses replicate within the host cell nucleus and are temporarily cloaked in host cell nuclear membrane. The herpesvirus's double-stranded DNA can remain latent as a mini-chromosome in the nucleus of certain nerve cells until it initiates herpes infections in times of stress.

The single-stranded RNA of some animal viruses can serve directly as mRNA. The RNA genome of other viruses must first be transcribed into a strand of complementary RNA (using a viral enzyme packaged inside the capsid) that then serves as mRNA and as a template for making genome RNA.

In the complicated replicative cycle of **retroviruses**, the viral RNA genome is transcribed into double-stranded DNA by a viral enzyme, **reverse transcriptase**. This viral DNA is then integrated into a chromosome, where it is transcribed by the host cell into viral RNA, which acts both as new viral genome and as mRNA for viral proteins.

HIV (human immunodeficiency virus) is a retrovirus that causes **AIDS (acquired immunodeficiency syndrome)**. The integrated viral DNA remains as a **provirus** within the host cell DNA. New viruses, assembled with two copies of the RNA genome and two molecules of reverse transcriptase within a capsid, bud off covered in host cell plasma membrane studded with viral glycoproteins.

FOCUS QUESTION 17.2

Summarize the flow of genetic information during replication of a retrovirus. Indicate the enzymes that catalyze this flow.

________ → ________ → ________

Enzymes:

Evolution of Viruses Viruses may have evolved from fragments of cellular nucleic acids that moved from one cell to another and eventually evolved special packaging. Sources of viral genomes may have been *plasmids*, self-replicating circles of DNA found in bacteria and yeast, and *transposons*, segments of DNA that can change locations within a cell's genome. Thus, viruses, plasmids, and transposons are all *mobile genetic elements*.

17.3 Viruses are formidable pathogens in animals and plants

Viral Diseases in Animals The symptoms of a viral infection may be caused by viral-programmed toxins produced by infected cells, cells killed or damaged by the virus, or the body's defense mechanisms fighting the infection.

Vaccines are harmless variants or derivatives of pathogens that induce the immune system to react against the actual disease agent. Vaccinations have greatly reduced the incidence of many viral diseases.

Unlike bacteria, viruses use the host's cellular machinery to replicate, and few drugs have been found to treat or cure viral infections. Some antiviral drugs resemble nucleosides and interfere with viral nucleic acid synthesis.

Emerging Viruses Examples of *emerging viruses* include HIV, Ebola virus, and West Nile virus. A general outbreak of a disease is called an **epidemic**. The flu epidemic of 2009 spread rapidly, becoming a global epidemic or **pandemic**.

The sudden emergence of viral diseases may be linked to the mutation of an existing virus (more common in RNA viruses, which have higher mutation rates), to the dissemination of an existing virus to a more widespread population (as in HIV), or to the spread from one host species to another (as in the 2009 flu pandemic, which likely passed to humans from pigs). Many new human diseases are thought to originate by the third mechanism.

Influenza types B and C infect only humans; type A infects other animals as well as humans. If different strains of influenza A undergo genetic recombination within an animal's cells and accumulate mutations that allow the virus to infect human cells, the recombinant virus may be highly pathogenic. The H1N1 virus (named for the form of the viral surface proteins hemagglutinin and neuraminidase) caused both the 1918 and 2009 flu pandemics. The H5N1 virus is carried by wild and domestic birds. The human mortality rate for avian flu infections is greater than 50%, but thus far the virus is not easily transmitted from person to person.

Viral Diseases in Plants Most plant viruses are RNA viruses. Plant viral diseases may spread through *vertical transmission* from a parent plant via infected seeds or cutting, or through *horizontal transmission* from an external source. Plant injuries increase susceptibility to viral infections, and insects can act as carriers of viruses.

FOCUS QUESTION 17.3

How does a virus spread throughout a plant? Are there cures for viral plant diseases?

Word Roots

capsa- = a box (*capsid:* the protein shell that encloses a viral genome)

lyto- = loosen (*lytic cycle:* a type of phage replicative cycle resulting in the release of new phages by lysis (and death) of the host cell)

-phage = to eat (*bacteriophage:* a virus that infects bacteria)

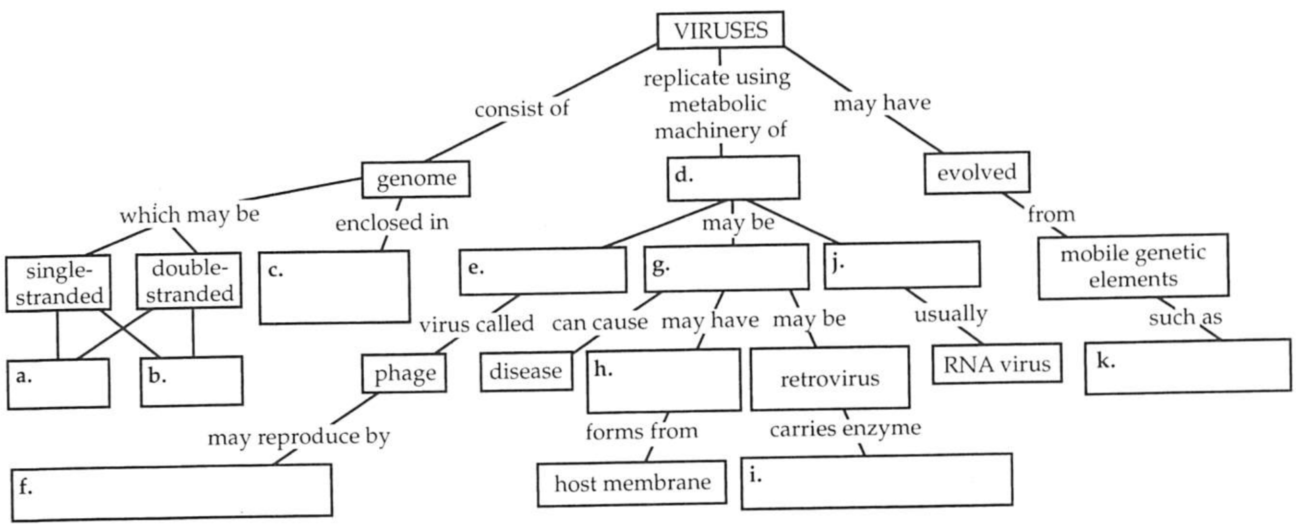
pro- = before (*provirus:* a viral genome that is permanently inserted into a host genome)

retro- = backward (*retrovirus:* an RNA virus that replicates by transcribing its RNA into DNA and then inserting the DNA into a cellular chromosome)

virul- = poisonous (*virulent phage:* a phage that replicates only by a lytic cycle)

Structure Your Knowledge

1. Create a concept map that describes the lytic and lysogenic cycles of a phage.
2. Complete the following concept map to help organize your understanding of viruses.



Test Your Knowledge

MULTIPLE CHOICE: *Choose the one best answer.*

1. The study of viruses has provided information on all of the following topics *except*
   a. the molecular biology of all organisms.
   b. the sexual replicative cycles of viruses.
   c. new techniques for manipulating genes.
   d. the causes of diseases.
   e. the role of mutation in the relationship between host and virus.

2. Viral genomes may be any of the following *except*
   a. single-stranded DNA.
   b. double-stranded RNA.
   c. misfolded infectious proteins.
   d. a linear single-stranded RNA molecule.
   e. a circular double-stranded DNA molecule.

3. The reverse transcriptase carried by retroviruses
   a. uses viral RNA as a template for making complementary RNA strands.
   b. protects viral DNA from degradation by restriction enzymes.
   c. destroys the host cell DNA.
   d. translates RNA into proteins.
   e. uses viral RNA as a template for DNA synthesis.

4. Virus particles are formed from capsid proteins and nucleic acid molecules
   a. by spontaneous self-assembly.
   b. at the direction of viral enzymes.
   c. using host cell enzymes.
   d. using ATP stored in the tail piece.
   e. by both **b** and **d.**

5. A virus has a base ratio of (A + G)/(U + C) = 1. What type of virus is this?
   a. a single-stranded DNA virus
   b. a single-stranded RNA virus
   c. a double-stranded DNA virus
   d. a double-stranded RNA virus
   e. a retrovirus

6. Vertical transmission of a plant virus involves
   a. movement of viral particles through plasmodesmata.
   b. inheritance of an infection from a parent.
   c. a bacteriophage transmitting viral particles.
   d. insects carrying viral particles between plants.
   e. entry through damaged cells.

7. Bacteria defend against viral infection
   a. with antibiotics they produce.
   b. with restriction enzymes that chop up foreign DNA.
   c. through the transfer of R plasmids.
   d. with reverse transcriptase.
   e. through the incorporation of viral DNA into the bacterial chromosome.

8. Drugs that are effective in treating viral infections
   a. induce the body to produce antibodies.
   b. inhibit the action of viral ribosomes.
   c. interfere with the synthesis of viral nucleic acid.
   d. change the cell-recognition sites on the host cell.
   e. are vaccines that stimulate the immune system to create immunity.

9. An RNA viral genome may be replicated by
   a. DNA polymerase from the host.
   b. RNA polymerase coded by viral genes and carried in the viral capsid.
   c. reverse transcriptase that synthesizes RNA.
   d. RNA polymerase from the host.
   e. restriction enzymes from the host.