Chapter 19: Viruses

Overview

Experimental work with viruses has provided important evidence that genes are made of nucleic acids. Viruses were also important in working out the molecular mechanisms of DNA replication, transcription, and translation. Viruses have been important in the development of techniques of manipulating and transferring genes. As you learn about viruses in this chapter, you will build on the foundation necessary for an understanding of the molecular techniques of biotechnology.

Concept 19.1 A virus consists of a nucleic acid surrounded by a protein coat

1. What was some early evidence of the existence of viruses? Why were they difficult to study?

   In 1883, Adolf Mayer discovered that he could transmit tobacco mosaic disease from plant to plant by rubbing sap extracted from diseased leaves into healthy plants. Viruses were difficult to study because of their size. The tiniest of viruses are only 20 nm in diameter—smaller than a ribosome. Even the largest known virus, which has a diameter of several hundred nanometers, is barely visible under the light microscope.

2. What was Wendell Stanley’s contribution to our knowledge of viruses?

   Wendell Stanley crystallized the infectious particle, now known as the tobacco mosaic virus (TMV), thus confirming earlier hypotheses about the nature of this mysterious agent.

3. What are the four forms of viral genomes?

   1. Double-stranded DNA
   2. Single-stranded DNA
   3. Double-stranded RNA
   4. Single-stranded RNA

4. What is a capsid? What are capsomeres? What different shapes may capsids have?

   The protein shell enclosing the viral genome is called a capsid. Depending on the type of virus, the capsid may be rod-shaped, polyhedral, or more complex in shape. Capsids are built from a large number of protein subunits called capsomeres.

5. As you see, all viruses consist of a nucleic acid enclosed in a protein coat. Some viruses also have a membranous envelope. What are the components of a viral envelope? Which component is derived from the host cell, and which is of viral origin?

<table>
<thead>
<tr>
<th>Viral Component</th>
<th>Derived From</th>
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<tr>
<td>Phospholipids and membrane proteins</td>
<td>Host cell</td>
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6. What is the role of an envelope in animal viruses?
The envelopes help the virus infect their host.

7. For the virus shown in the following figure, label the protein capsid, tail fibers, head, tail sheath, and genome.

See page 383 in your text for the labeled figure.

a. What type of virus is this? Bacteriophage, T4
b. What does its name mean? Bacteria eater
c. What is its host? E. coli
d. Is the genome of this virus DNA or RNA? DNA

Concept 19.2 Viruses replicate only in host cells

8. What property of a virus determines its attachment to a host cell membrane?

Viruses usually identify host cells by a “lock-and-key” fit between viral surface proteins and specific receptor molecules on the outside of cells.

9. Viruses are obligate intracellular parasites. What does this mean?

Viruses can replicate only within a host cell.

10. What is meant by host range? Distinguish between a virus with a broad host range and one with an extremely limited host range, and give an example of each.

Each particular virus can infect cells of only a limited number of host species, called the host range of the virus. Some viruses have broad host ranges, such as West Nile virus, which can infect mosquitoes, birds, horses, and humans. Other viruses have a host range so narrow that they infect only a single species, and are sometimes limited to particular tissue. Possible examples include human cold viruses, and the AIDS virus.

11. Compare the host range for the rabies virus to that of the human cold virus.

The rabies virus has a broad host range, able to infect most species of mammals, while the human cold virus has a narrow host range, only infecting the tissue of the cell lining of the upper respiratory tract in humans.

12. What components of the host cell does a virus use to reproduce itself?

The host cell provides the nucleotides for making viral nucleic acids, as well as enzymes, ribosomes, tRNAs, amino acids, ATP, and other components needed for making the viral proteins.
13. How does a DNA virus reproduce its genome?

Many DNA viruses use the DNA polymerase of the host cell to synthesize new genomes along the templates provided by the viral DNA.

14. How do most RNA viruses replicate their genome?

To replicate their genomes, RNA viruses use virally encoded RNA polymerase that can use RNA as a template.

15. On this figure of a simplified viral reproductive cycle, label arrows to show these processes: transcription, translation, infection, replication, and self-assembly. Annotate your labels to explain the process of viral reproduction.

See page 384 in your text for the labeled figure and explanation.

16. What are bacteriophages? Distinguish between virulent and temperate phages.

A bacteriophage is a virus that infects bacteria; also called a phage. A phage that replicates only by a lytic cycle which destroys the host cell is a virulent phage. Temperate phages can undergo a lysogenic cycle, which allows the phage genome to be replicated without destroying the host.

17. What portion of a phage enters the host cell? How does it do this?

The phage DNA enters the host cell. After the bacteriophage binds to a specific receptor on the outer surface of the host cell, the sheath of the tail contracts, injecting the DNA into the cell and leaving an empty capsid outside.

18. What are restriction enzymes? How do they help prevent viral infection of bacteria?

A restriction enzyme is an endonuclease (type of enzyme) that recognizes and cuts DNA molecules foreign to a bacterium (such as phage genomes). The enzyme cuts at specific nucleotide sequences (restriction sites). Restriction enzymes identify and cut up viral DNA that is detected as foreign.

19. Why don’t restriction enzymes destroy the DNA of the bacterial cells that produce them?

The bacterial cell’s own DNA is methylated in a way that prevents attack by its own restriction enzymes.

20. What are three ways bacteria may win the battle against the phages?

1. Natural selection favors bacterial mutants with receptors that are no longer recognized by a particular kind of phage.

2. When phage DNA successfully enters a bacterium, the DNA is often identified as foreign and cut up by restriction enzymes.
3. Instead of lysing their host cells, many phages coexist with them in a state called lysogeny.

21. What is a *prophage*?

Prophage is a phage genome that has been inserted into a specific site on a bacterial chromosome.

22. Since cells that have incorporated phage DNA into their genome may continue to divide and propagate the viral genome, this might be considered somewhat like the Trojan horse. What might trigger the switchover from *lysogenic* to *lytic* mode?

An environmental signal, such as a certain chemical or high-energy radiation, can trigger the switchover from the lysogenic to the lytic mode.

23. Label the following elements of the figure below: *lysogenic phage, lysogenic cycle, lytic cycle, prophage, phage DNA, bacterial chromosome,* and *self assembly*.

See page 386 of your text for the labeled figure.

24. Describe the *lytic* and *lysogenic* modes of bacteriophage reproduction.

The lytic mode of bacteriophage reproduction results in the release of new phages by lysis (and death) of the host cell. In the lysogenic mode of bacteriophage reproduction, the viral genome becomes incorporated into the bacterial host chromosome as a prophage, is replicated along with the chromosome, and does not kill the host.

25. There are some general differences between bacteriophages and animal viruses. What are two elements that nearly all animal viruses have?

Nearly all animal viruses have an RNA genome and an envelope.

26. What is a *retrovirus*? How do retroviruses, such as HIV, replicate their genome?

A retrovirus is an RNA virus that replicates by transcribing its RNA into DNA and then inserting the DNA into a cellular chromosome; an important class of cancer-causing viruses.

27. Here is a sketch of HIV. Label these parts: *envelope, reverse transcriptase, RNA,* and *capsid*.

See page 389 of your text for the labeled figure.

28. Compare and contrast a *prophage* and a *provirus*. Which one are you likely to carry?

A prophage is a phage genome that has been inserted into a specific site on a bacterial chromosome.

A provirus is a viral genome that is permanently inserted into a host genome. Animal cells are most likely to carry a provirus.
29. This sketch shows the infection of a cell by HIV. Extend label lines to give a complete explanation of the process. Refer to Figure 19.8 in your text for details.

See page 389 of your text for the labeled figure and explanation.

30. The final section in Concept 19.2 is titled “Evolution of Viruses.” From this part, describe the two possible sources of viral genomes. You will see each of these important mobile genetic elements again.

<table>
<thead>
<tr>
<th>Description of the Mobile Genetic Element</th>
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<tbody>
<tr>
<td>Plasmids</td>
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<td>Transposons</td>
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**Concept 19.3 Viruses, viroids, and prions are formidable pathogens in animals and plants**

31. What are three ways that viruses make us ill? Why do we recover completely from a cold but not from polio?

1. Viruses may damage or kill cells by causing the release of hydrolytic enzymes from lysosomes.
2. Some viruses cause infected cells to produce toxins that lead to disease symptoms.
3. Some viruses have molecular components that are toxic, such as envelope proteins.

We can recover completely from infection by a cold virus because the infected respiratory epithelial cells regenerate, but polio infects mature nerve cells that are not able to regenerate.

32. What tools are in the medical arsenal against human viral diseases?

Vaccines: Vaccines are a harmless variant or derivative of a pathogen that stimulates the immune system to mount defenses against the harmful pathogen.

Antiviral drugs: Most antiviral drugs resemble nucleosides and as a result interfere with viral nucleic acid synthesis.

33. **Emerging viruses** such as HIV, Ebola, and SARS seem to burst upon the human scene. What are three processes that contribute to this sudden emergence?

1. The mutations change existing viruses into new genetic varieties (strains) that can cause disease, even in individuals who are immune to the ancestral virus.
2. The dissemination of a viral disease from a small, isolated human population made possible by global travel and other social factors.
3. The spread of existing viruses from other animals.

34. The 2009 flu pandemic is H1N1. What is a pandemic? What does the name of the flu mean?

A pandemic is a global epidemic. The name H1N1 identifies which forms of the two viral surface proteins are present: hemagglutinin (H) and neuraminidase (N).
35. Distinguish between horizontal transmission and vertical transmission in plants.

In horizontal transmission, the plant is infected from an external route.

In vertical transmission, the plant inherits a viral infection from a parent.

36. How do viruses spread throughout plant bodies?

Once a virus enters a plant cell and begins replicating, viral genomes and associated proteins can spread throughout the plant by means of plasmodesmata, the cytoplasmic connections that penetrate the walls between adjacent plant cells.

37. What is a viroid? What important lesson do they teach? Name one viroid disease.

A viroid is a circular RNA molecule that infects plants. An important lesson from viroids is that a single molecule can be an infectious agent that spreads a disease. One example of a viroid disease is cadang-cadang, which is killing millions of coconut palms.

38. Prions strike fear into carnivores everywhere. What are they? How are they transmitted? What do they do?

Prions are infectious proteins which appear to cause a number of degenerative brain diseases in various animal species. Prions are most likely transmitted in food. They cause misfolding of proteins, particularly in the brain. The infection results in slow damage, but ultimately leads to death.

39. Name four diseases caused by prions.

Scrapie in sheep, mad cow disease, Creutzfeld-Jakob disease, and kuru

40. What are two alarming characteristics of prions?

1. Prions act very slowly, with an incubation period of at least ten years before symptoms develop.

2. Prions are virtually indestructible; they are not destroyed or deactivated by heating to normal cooking temperature.

When the prion gets into a cell containing the normal form of the protein, the prion somehow converts normal protein molecules to the misfolded prion versions.

41. Two Nobel Prizes have been awarded for the study of prions. One went to Carlton Gajdusek, who worked with the Fore people of Papua, New Guinea in the 1960s to determine the cause of a kuru epidemic. Who got the second Nobel Prize in this area, and when?

Stanley Prusiner, 1997
Test Your Understanding Answers

Now you should be ready to test your knowledge. Place your answers here:

1. c    2. d    3. c    4. d    5. b