Chapter 4

Acellular and Prokaryotic Microbes
Part 1: Microbial Diversity

Learning Objectives

Chapter 4 introduces acellular microbes (viruses, viroids, and prions) and prokaryotic microbes (bacteria and archaea). Photosynthetic bacteria and unique bacteria (e.g., rickettsias, chlamydias, mycoplasmas, and especially large and especially small bacteria) are discussed in this chapter. The information in Chapter 4 is considered essential in an introductory microbiology course.

Terms Introduced in This Chapter

After reading Chapter 4, you should be familiar with the following terms. These terms are defined in Chapter 4 and in the Glossary.

Acid-fast stain
Aerotolerant anaerobe
Anaerobe
Anoxygenic photosynthesis
Bacteriophage
Capnophile
Capsid
Capsomeres
Coccobacillus
Differential staining procedures
Diplobacilli
Diplococci
Facultative anaerobe
Gram stain
Inclusion bodies
Lytic cycle
Methanogens
Microaerophiles
Mimivirus
Nitrogen fixation
Obligate aerobe
Obligate anaerobe
Octad
Oncogenic

Oncogenic viruses
Oxygenic photosynthesis
Pleomorphism
Prions
Simple stain
Staphylococci
Streptobacilli
Streptococci
Structural staining procedures
Temperate bacteriophage
Tetrad
Transmissible spongiform encephalopathies
Vectors
Virion
Viroids
Virulent bacteriophage

Review of Key Points

- Microbes can be divided into those that are cellular (bacteria, algae, protozoa, and fungi) and those that are acellular (viruses, viroids, and prions). The cellular microorganisms can be divided into those that are prokaryotic and those that are eukaryotic. Acellular microbes are sometimes referred to as infectious particles.
- Complete virus particles are called virions. They are so small that they can be seen only by using electron microscopes.
- Viruses are not living organisms. They lack the enzymes necessary for the production of energy, proteins, and nucleic acid. To replicate, viruses must invade living host cells.
- Except in extremely rare cases, viruses possess *either* DNA or RNA—not both.
- The simplest of human viruses consists of nothing more than nucleic acid surrounded by a protein coat, known as a capsid, The capsid plus the enclosed nucleic acid are referred to as the nucleocapsid.
- Viruses can be classified by their type of nucleic acid, shape of the capsid, size of the capsid, number of capsomeres, presence or absence of an envelope, type of host(s) and host cell(s) they infect, type of disease they cause, and antigenic properties.
- Bacteriophages are viruses that infect bacteria. There are two categories of bacteriophages: virulent bacteriophages, which cause destruction (lysis) of the host cell, and temperate bacteriophages, which change the host cell genetically.
- Once it enters a host cell, a virulent bacteriophage always initiates the lytic cycle, which results in the destruction of the cell.
- The five steps in the lytic cycle are attachment, penetration, biosynthesis, assembly, and release.
- Bacteriophages can only attach to bacteria that possess surface molecules (receptors) that can be recognized by molecules on the phage surface.

- Unlike virulent bacteriophages, temperate bacteriophages do not immediately initiate the lytic cycle. Their DNA can remain integrated into the host cell's chromosome for generation after generation.
- Like bacteriophages, animal viruses can only attach to and invade cells bearing appropriate surface receptors.
- There are six steps in the multiplication of animal viruses: attachment, penetration, uncoating, biosynthesis, assembly, and release.
- Animal viruses escape from their host cells either by lysis of the cell or by budding. Viruses that escape by budding become enveloped viruses.
- Drugs used to treat viral infections are called antiviral agents. Antibiotics are not effective against viral infections.
- Viruses that cause cancer are known as oncogenic viruses or oncoviruses.
- Acquired immunodeficiency syndrome (AIDS) is caused by an enveloped, single-stranded RNA virus known as human immunodeficiency virus (HIV).
- Viroids are infectious RNA molecules that cause a variety of plant diseases.
- Prions are infectious protein molecules that cause a variety of animal and human diseases. The highly publicized "mad cow disease" is an example of a prion-caused disease.
- Bacteria reproduce by binary fission. The time it takes for one bacterial cell to split into two cells is referred to as that organism's generation time.
- A bacterium's Gram reaction, basic cell shape, and morphologic arrangement are very important clues to its identification.
- The three general shapes of bacteria are cocci, bacilli, and curved or spiral-shaped.
- A bacterial species having cells of different shapes is said to be pleomorphic.
- Cocci occur singly or in pairs (diplococci), chains (streptococci), clusters (staphylococci), or packets of four (tetrads) or eight (octads).
- Bacilli occur singly, in pairs (diplobacilli), or in chains (streptobacilli), or they may be branched or filamentous. Very short bacilli are called coccobacilli.
- Curved bacteria may occur singly, or in pairs or chains. Spiral-shaped bacteria usually occur singly.
- A pile or mound of bacteria on the surface of a solid culture medium is referred to as a colony; it contains millions of bacterial cells. Bacterial colony morphology includes size, color, overall shape, elevation, consistency, and the appearance of the margin of the colony.
- Bacterial smears must be fixed before staining. The two most common types of fixation are heat fixation and methanol fixation; the latter technique is preferred. The fixation process serves to kill the organisms, preserve their morphology, and anchor the smear to the slide.
- If a bacterium is blue to purple at the end of the Gram staining procedure, it is said to be Gram positive. If, on the other hand, it ends up being pink to red, it is said to be Gram negative.
- The acid-fast stain is of value in the diagnosis of tuberculosis. Acid-fast bacteria are red

at the end of the acid-fast staining procedure.

- Most motile bacteria possess whiplike structures called flagella. The terms monotrichous, amphitrichous, lophotrichous, and peritrichous are used to describe the number and location of flagella on the bacterial cell.
- On the basis of its oxygen requirements, a bacterial isolate can be classified as an obligate aerobe, a microaerophile, a facultative anaerobe, an aerotolerant anaerobe, or an obligate anaerobe.
- Obligate aerobes and microaerophiles require oxygen. Obligate aerobes require an atmosphere containing about 20% to 21% oxygen. Microaerophiles require reduced oxygen concentrations (usually around 5% oxygen).
- Obligate anaerobes, aerotolerant anaerobes, and facultative anaerobes can thrive in atmospheres devoid of oxygen.
- Bacteria requiring increased concentrations of carbon dioxide are called capnophiles. For optimum growth in the laboratory, capnophiles require an atmosphere containing 5% to 10% carbon dioxide.
- All bacteria need some form of the elements carbon, hydrogen, oxygen, sulfur, phosphorus, and nitrogen for growth. In addition, certain bacteria require potassium, calcium, iron, manganese, magnesium, cobalt, copper, zinc, and uranium. Fastidious (nutritionally demanding) microbes may require additional vitamins, amino acids, and other organic compounds.
- Pathogenic bacteria may produce pili, capsules, endotoxin, exotoxins, and exoenzymes that enable them to cause disease.
- Rickettsias, chlamydias, and mycoplasmas are rudimentary Gram-negative bacteria. Mycoplasmas differ from other bacteria in that they have no cell walls. Rickettsias and chlamydias are unique because they are obligate intracellular pathogens.
- Certain bacteria, including a group of bacteria referred to as cyanobacteria, are photosynthetic. Some photosynthetic bacteria, including cyanobacteria, produce oxygen as a by-product of photosynthesis; this type of photosynthesis is known as oxygenic photosynthesis.
- Genetically, archaea are more closely related to eukaryotic organisms than to bacteria, although both archaea and bacteria are prokaryotic. Archaea differ from bacteria in several ways: they possess a different type of rRNA; their cell walls contain no peptidoglycan; many of them live in extreme environments; and some (called methanogens) produce methane.

A Closer Look at Life in the Absence of Oxygen

Someday, you may overhear someone erroneously state that "[l]ife is impossible there (perhaps referring to one of the planets) because there isn't any oxygen." But you'll know differently! You'll be able to point out that life is indeed possible in the absence of oxygen. Furthermore, you'll be able to explain that organisms capable of life in the absence of oxygen are called

anaerobes.

But, who discovered anaerobes? The credit for discovering anaerobes can be given to three scientists: a 17th-century scientist, an 18th-century scientist, and a 19th-century scientist. Each of them made scientific observations that contributed to our present knowledge and understanding of anaerobes.

In 1680, **Anton van Leeuwenhoek** performed an experiment using pepper and sealed glass tubes. In a letter to the Royal Society of London, he wrote that "animalcules developed although the contained air must have been in minimal quantity." (Leeuwenhoek used the term "animalcules" to refer to the tiny organisms that he observed, using the simple, single lens microscopes, which he made.)

Lazzaro Spallanzani, an Italian scientist, performed similar experiments in the latter half of the 18th century. He drew the air from microbe-containing glass tubes, fully expecting the microbes to die—but some did not. He wrote in a letter to a friend, "The nature of some of these animalcules is astonishing! They are able to exercise in a vacuum the functions they use in free air. … How wonderful this is! For we have always believed there is no living being that can live without the advantages air offers it."

It was **Louis Pasteur** who actually introduced the terms "aerobe" and "anaerobe." In an 1861 paper, he wrote "these infusorial animals are able to live and multiply indefinitely in the complete absence of air or free oxygen. … These infusoria can not only live in the absence of air, but air actually kills them. … I believe this is…the first example of an animal living in the absence of free oxygen." (The term "infusoria" was used by early microbiologists to refer to microorganisms. Infusoria was later used to specifically refer to ciliated protozoa, but the term is now obsolete.)

We know now that anaerobes are quite common and that they live in specific ecologic niches. They can be found in soil, in freshwater and saltwater sediments (mud), and in the bodies of animals and humans. The indigenous microbiota of humans contains many species of anaerobes, some of which are opportunistic pathogens. Anaerobes cause a wide variety of human diseases, including botulism, tetanus, gas gangrene, pulmonary infections, brain abscesses, and oral diseases. It was Louis Pasteur who, in 1877, discovered the first pathogenic anaerobe—the bacterium that today is known as *Clostridium septicum.*

Increase Your Knowledge

1. To learn more about bacteriophages and bacteriophage research, visit the following Web sites:
   www.cellsalive.com/phage.htm
   www.YouTube.com (search for "bacteriophages")

2. Watch the following YouTube video/animation on viral reproduction (the virus lytic cycle): www.youtube.com/watch?v=wVkCyU5aeeU. (Many other virus videos can be found by searching YouTube for "viruses.")

3. An article entitled "How Mad Cow Disease Works" can be found at https://animals.howstuffworks.com/animal-facts/mad-cow-disease.htm

4. YouTube has many bacteria videos, which can be accessed by searching https://www.youtube.com/ for "bacteria."

5. View the following video on the Gram stain at: http://www.sbs.utexas.edu/psaxena/BIO126L/video/3-GramStain.wmv (This is an excellent video produced by the University of Texas that explains the theory and technique for the Gram staining of bacteria. It is a Windows Media file.)

6. Additional microbiology-related sites:
biology.about.com/od/virology/a/aa11108a.htm
www.phages.org
www.slideshare.net/doctorrao/bacteriophages

7. The American Society for Microbiology has several podcasts available on various topics in microbiology at https://www.asm.org/podcasts

Critical Thinking

1. State the key differences between bacteriophage multiplication and animal virus multiplication.

2. Summarize the key differences between viruses and bacteria.

3. State the key differences between Gram-positive and Gram-negative cell walls.

4. Why are rickettsias, chlamydias, and mycoplasmas described as unique bacteria?

5. What are the key differences between bacteria and archaea?

Additional Chapter 4 Self-Assessment Exercises

(Note: Do not peek at the answers before you attempt to solve these self-assessment exercises.)

Matching Questions

A. Diplococci
B. Diplobacilli
C. Staphylococci
D. Streptobacilli
E. Streptococci

_____ 1. Spherical bacteria arranged in pairs are called _____.

_____ 2. Rod-shaped bacteria arranged in chains are called _____.

_____ 3. Spherical bacteria arranged in clusters are called _____.

_____ 4. Rod-shaped bacteria arranged in pairs are called _____.

_____ 5. Spherical bacteria arranged in chains are called _____.

A. Chlamydias
B. Cyanobacteria
C. Mycoplasmas
D. Rickettsias
E. Spirochetes

_____ 1. The bacteria that cause syphilis and Lyme disease are _____.

_____ 2. _____ are obligate intracellular pathogens that cause diseases such as trachoma, inclusion conjunctivitis, and urethritis.

_____ 3. _____ are photosynthetic.

_____ 4. _____ have no cell walls.

_____ 5. _____ are obligate intracellular pathogens that cause diseases such as typhus and Rocky Mountain spotted fever.

True/False Questions

_____ 1. All diseases caused by *Rickettsia* spp. are arthropod-borne.

_____ 2. Most viruses contain both DNA and RNA.

_____ 3. The cell walls of archaea contain a thicker layer of peptidoglycan than bacterial cell walls.

_____ 4. On entering a bacterial cell, all bacteriophages immediately initiate the lytic cycle.

_____ 5. Mycoplasmas cannot grow on artificial media.

_____ 6. Viruses are the smallest infectious agents.

_____ 7. *Rickettsia* spp. and *Chlamydia* spp. cannot be grown on artificial media.

_____ 8. Prions are infectious RNA molecules.

_____ 9. HIV is an enveloped, single-stranded RNA virus.

_____ 10. Organisms in the genus *Vibrio* are curved bacilli.

Answers to the Additional Chapter 4 Self-Assessment Exercises

Matching Questions

1. A
2. D
3. C
4. B
5. E

1. E
2. A
3. B
4. C
5. D

True/False Questions

1. True
2. False (They contain either DNA or RNA.)
3. False (Archaean cell walls do not contain peptidoglycan.)
4. False (Temperate bacteriophages cause lysogeny.)
5. False (Yes, they can.)
6. False (Viroids and prions are infectious agents that are smaller than viruses.)
7. True
8. False (Prions are infectious proteins; viroids are infectious RNA molecules.)
9. True
10. True