Introduction to Prokaryotes

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-source, collaborative, and web-based compilation model, CK-12 pioneers and promotes the creation and distribution of high-quality, adaptive online textbooks that can be mixed, modified and printed (i.e., the FlexBook® textbooks).

Printed: November 12, 2016

flexbook
next generation textbooks

CHAPTER 1 Introduction to Prokaryotes

Lesson Objectives

- Outline the classification and evolution of prokaryotes.
- Describe the structure of prokaryotic cells.
- Identify variation in the metabolism and habitats of prokaryotes.
- Explain how prokaryotes reproduce and increase genetic variation.

Lesson Vocabulary

- Archaea Domain
- Bacteria Domain
- biofilm
- cyanobacteria
- flagellum (flagella, plural)
- genetic transfer
- plasmid

Introduction

No doubt you've had a sore throat before, and you've probably eaten cheese or yogurt. If so, then you've already encountered the amazing world of prokaryotes. Prokaryotes are single-celled organisms that lack a nucleus. They also lack other membrane-bound organelles. Prokaryotes are tiny. They can only be viewed with a microscope (see **Figure** 1.1). But they are the most numerous organisms on Earth. Without them, the world would be a very different place.

Prokaryote Classification and Evolution

Prokaryotes are currently placed in two domains. A domain is the highest taxon in the classification of living things. It's even higher than the kingdom.

Classification of Prokaryotes

The prokaryote domains are the **Bacteria Domain** and **Archaea Domain**, shown in **Figure** 1.2. All other living things are eukaryotes and placed in the domain Eukarya. (Unlike prokaryotes, eukaryotes have a nucleus in their cells.)

Evolution of Prokaryotes

Prokaryotes were the first living things to evolve on Earth, probably around 3.8 billion years ago. They were the only living things until the first eukaryotic cells evolved about 2 billion years ago. Prokaryotes are still the most numerous organisms on Earth.

It's not certain how the three domains of life are related. Archaea were once thought to be offshoots of Bacteria that were adapted to extreme environments. For their part, Bacteria were considered to be ancestors of Eukarya.

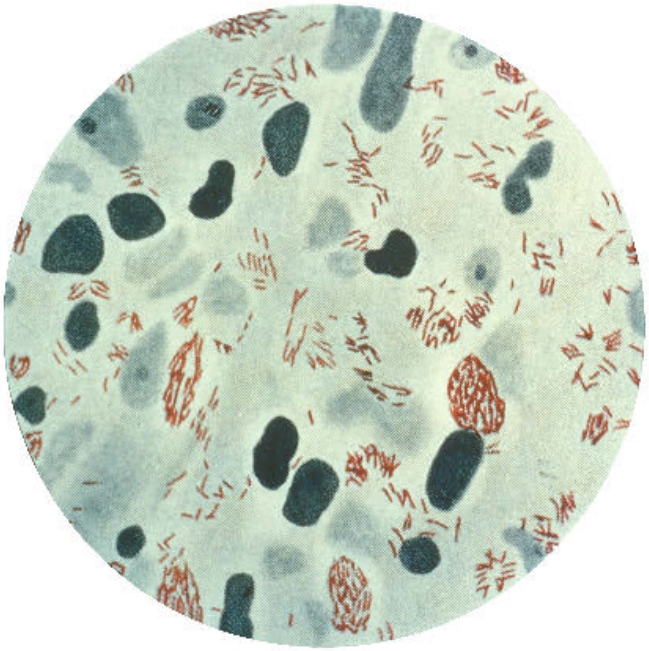


FIGURE 1.1

The tiny red rods in this micrograph are prokaryotes that cause the disease known as leprosy.

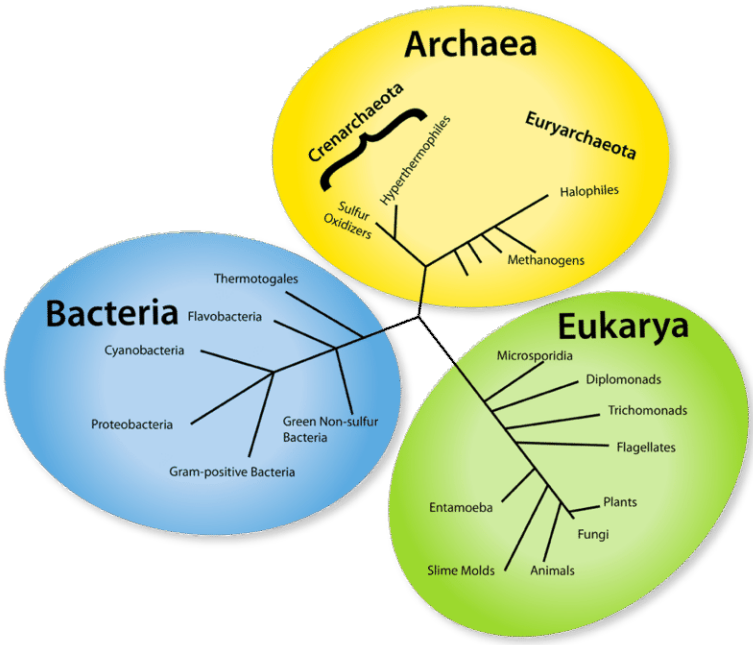


FIGURE 1.2

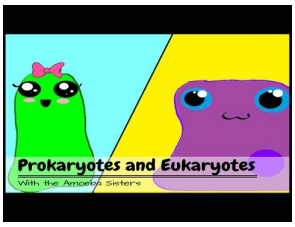
The three domains of life include two prokaryote domains: Bacteria and Archaea.

Scientists now know that Archaea share several traits with Eukarya that Bacteria do not share. How can this be explained? One hypothesis is that the first Eukarya formed when an archaean cell fused with a bacterial cell. By fusing, the two prokaryotic cells became the nucleus and cytoplasm of a new eukaryotic cell. If this hypothesis is

correct, both prokaryotic domains are ancestors of Eukarya.

Prokaryote Structure

All prokaryotes consist of just one cell. They share a number of other traits as well. Watch this entertaining video from the Amoeba Sisters to see how prokaryotes differ in structure from eukaryotes: http://www.youtube.com/watch?v=ruBAHiij4EA .



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/149623

Size and Shape of Prokaryotes

Most prokaryotic cells are much smaller than eukaryotic cells. Prokaryotic cells are typically only 0.2-2.0 micrometer in diameter. Eukaryotic cells are about 50 times as big.

Prokaryotic cells have a variety of different cell shapes. **Figure** 1.3 shows three of the most common shapes: spirals (helices), spheres, and rods. Bacteria may be classified by their shape.

FIGURE 1.3

Prokaryotic cell shapes

Flagella

Most prokaryotes have one or more long, thin "whips" called **flagella (flagellum, plural)**. You can see flagella in **Figure** 1.4. Flagella help prokaryotes move toward food or away from toxins. Each flagellum spins around a fixed base. This causes the cell to roll and tumble.

Outer Layers of a Prokaryote Cell

The cells of prokaryotes have two or three outer layers.

- Like all other living cells, prokaryotes have a cell membrane. It controls what enters and leaves the cell. It's also the site of many metabolic reactions. For example, cellular respiration takes place in the cell membrane.

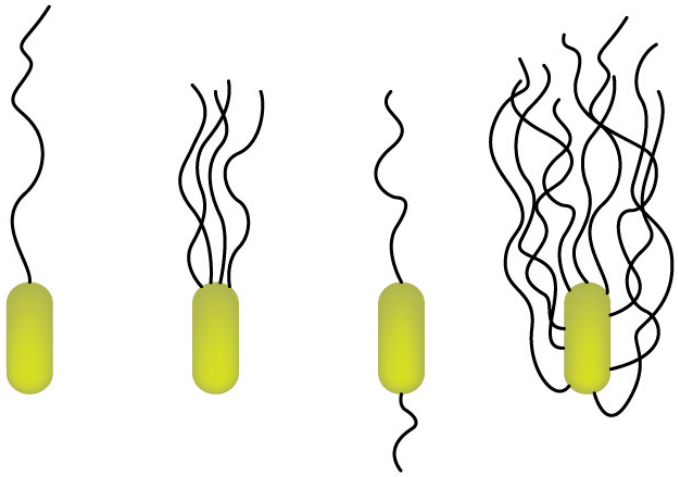


FIGURE 1.4
Prokaryote flagella

- Most prokaryotes also have a cell wall. It lies just outside the cell membrane. It makes the cell stronger and more rigid.
- Many prokaryotes have another layer, called a capsule, outside the cell wall. The capsule protects the cell from chemicals and drying out. It also allows the cell to stick to surfaces and to other cells.

You can see a model of a prokaryotic cell in **Figure** 1.5. Find the cell membrane, cell wall, and capsule in the figure.

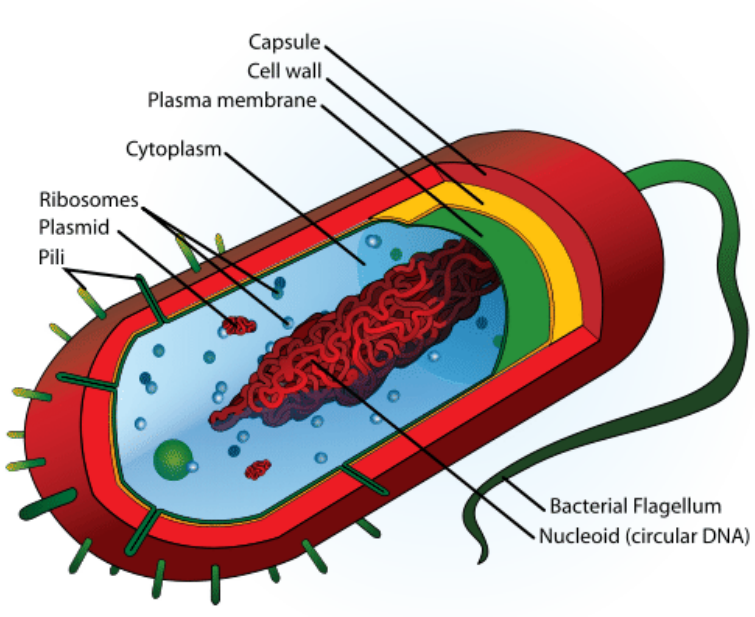


FIGURE 1.5
Model of a prokaryotic cell

Cell Structures

Several other prokaryotic cell structures are also shown in **Figure** 1.5. They include:

- cytoplasm. Like all other cells, prokaryotic cells are filled with cytoplasm. It includes watery cytosol and other structures.
- ribosomes. This is the site where proteins are made.
- cytoskeleton. This is a network of fibers and tubules that crisscrosses the cytoplasm. The cytoskeleton helps the cell keep its shape.
- pili. These are hair-like projections from the surface of the cell. They help the cell hold on to surfaces or do other jobs for the cell.

Prokaryotic DNA

All prokaryotic cells contain DNA, as you can see in **Figure** 1.6. Most of the DNA is in the form of a single large loop. This DNA coils up in the cytoplasm to form a structure called a **nucleoid**. There is no membrane surrounding it.

Most prokaryotes also have one or more small loops of DNA. They are called **plasmids**.

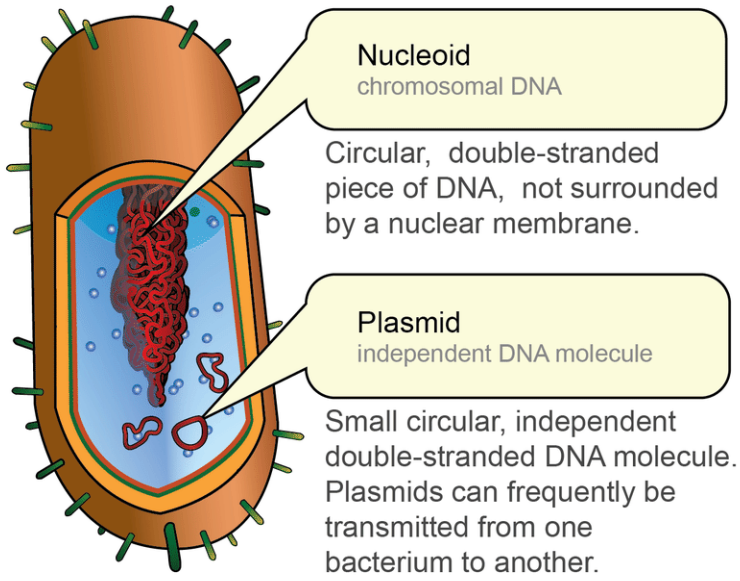


FIGURE 1.6
DNA in a prokaryotic cell

Biofilms

Some prokaryotes form structures consisting of many individual cells, like the cells in **Figure** 1.7. This is called a biofilm. A **biofilm** is a colony of prokaryotes that is stuck to a surface. The surface might be a rock or a host's tissues. The sticky plaque that collects on your teeth between brushings is a biofilm. It consists of millions of prokaryotic cells.

Prokaryote Metabolism and Habitats

Like all living things, prokaryotes need energy and carbon. They meet these needs in a variety of ways and in a range of habitats.

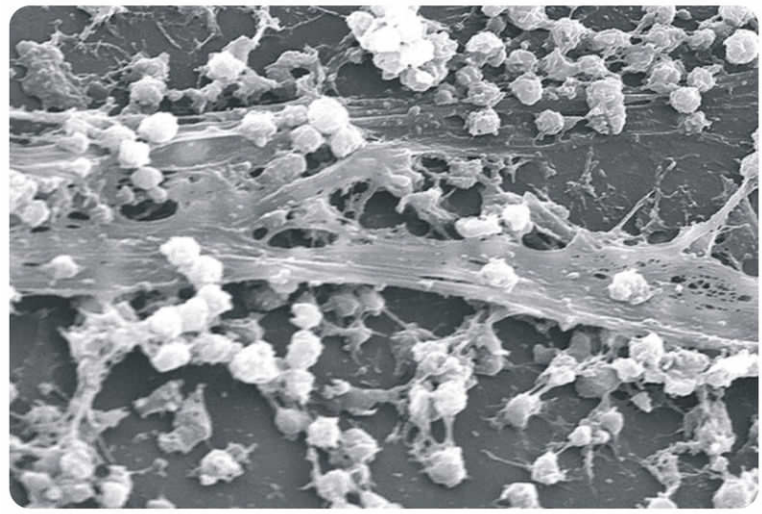


FIGURE 1.7

Microscopic view of a bacterial biofilm

Metabolism in Prokaryotes

Prokaryotes may have just about any type of metabolism. They may get energy from light or from chemical compounds. They may get carbon from carbon dioxide or from other living things.

- Most prokaryotes get both energy and carbon from other living things. Many of them are decomposers. They break down wastes and remains of dead organisms. In this way, they help to recycle carbon and nitrogen through ecosystems.
- Some prokaryotes use energy in sunlight to make food from carbon dioxide. They do this by the process of photosynthesis. They are important producers in aquatic ecosystems. Look at the green streaks on the lake in **Figure** 1.8. They consist of billions of photosynthetic bacteria called **cyanobacteria**.

FIGURE 1.8

Green cyanobacteria on a lake make food by photosynthesis.

Habitats of Prokaryotes

Prokaryotes live in a wide range of habitats. For example, they may live in habitats with or without oxygen.

- Prokaryotes that need oxygen are described as aerobic. They use oxygen for cellular respiration. Examples include the prokaryotes that live on your skin.
- Prokaryotes that don't need oxygen or are poisoned by it are described as anaerobic. They use fermentation or other anaerobic processes rather than cellular respiration. Examples include many of the prokaryotes that live inside your body.

Like most other living things, prokaryotes have a temperature range that they "like" best.

- Thermophiles are prokaryotes that prefer a temperature above 45 °C (113 °F). They might be found in a compost pile.
- Mesophiles are prokaryotes that prefer a temperature of about 37 °C (98 °C). They might be found inside the body of an animal such as you.
- Psychrophiles are prokaryotes that prefer a temperature below 20 °C (68 °F). They might be found deep in the ocean.

Prokaryote Reproduction

Prokaryotes reproduce asexually. This can happen by binary fission or budding.

- In binary fission, a cell splits in two. First, the large circular chromosome is copied. Then the cell divides to form two new daughter cells. Each has a copy of the parent cell's chromosome.
- In budding, a new cell grows from a bud on the parent cell. It only breaks off to form a new cell when it is fully formed.

Genetic Transfer

For natural selection to take place, organisms must vary in their traits. Asexual reproduction results in offspring that are all the same. They are also identical to the parent cell. So how can prokaryotes increase genetic variation? They can exchange plasmids. This is called **genetic transfer**. It may happen by direct contact between cells. Or a "bridge" may form between cells. Genetic transfer mixes the genes of different cells. It creates new combinations of alleles.

Lesson Summary

- Prokaryotes are single-celled organisms that lack a nucleus. They are placed in two domains: the Bacteria Domain and the Archaea Domain. They were the first organisms to evolve. It's not certain how they are related to each other or to eukaryotes.
- Prokaryotic cells are extremely small and have a variety of shapes. Most have flagella and a cell wall. They have several other cell structures as well. Their DNA exists as large and small loops. Some prokaryotes form biofilms, which are colonies of cells stuck to a surface.
- Prokaryotes can have just about any type of metabolism. They may get energy from light or from chemical compounds. They may get carbon from carbon dioxide or from other living things. They also live in a wide range of habitats. For example, some are aerobic and others are anaerobic.
- All prokaryotes reproduce by asexual means. This may occur by binary fission or budding. They can increase their genetic variation by genetic transfer. In this process, cells exchange plasmids.

Lesson Review Questions

Recall

1. How are prokaryotes classified?
2. Identify traits of prokaryotes.
3. What is a biofilm? Give an example.

Apply Concepts

4. A certain prokaryote lives inside the gut of an animal that has a body temperature of about 37 °C. Classify the prokaryote in terms of its need for oxygen and its temperature preference.

Think Critically

5. Compare and contrast aerobic and anaerobic prokaryotes.
6. Explain how and why ideas about the relationships of the Bacteria, Archaea, and Eukarya Domains have changed.
7. Why is genetic transfer important for the evolution of prokaryotes?

Points to Consider

Prokaryotes in the Bacteria Domain cause many diseases in humans.

1. What are some bacterial diseases?
2. How can they be treated?

References

1. CDC. Prokaryotes are very small objects, even under a microscope . public domain
2. Zachary Wilson. Domains of Life . CC BY-NC 3.0
3. Helix: Janice Carr/Centers for Disease Control and Prevention; Sphere: Janice Carr/Centers for Disease Control and Prevention; Rod: Volker Brinkmann, Max Planck Institute for Infection Biology, Berlin, Germany. Helix: http://en.wikipedia.org/wiki/File:Leptospira_interrogans_strain_RGA_01.png; Sphere: http://en.wikipedia.org/wiki/File:Staphylococcus_aureus_01.jpg; Rod: http://commons.wikimedia.org/wiki/File:Salmonella_typhimurium.png . Helix and Sphere: Public Domain; Rod CC BY 2.5
4. Zachary Wilson. Prokaryotic flagella . CC BY-NC 3.0
5. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Model of a prokaryotic cell . Public Domain
6. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. CK-12 Foundation . CC BY-NC 3.0
7. . Bacterial biofilm under microsocope . Public Domain
8. Courtesy of Jesse Allen/NASA. Cyanobacteria are photosynthetic prokaryotes . Public Domain