

# Bacteria

*What are the two major groups of prokaryotes?*

*How are Gram positive and Gram-negative bacteria different?*

*How can bacteria be grouped by energy source?*

*What are the three ways that bacteria reproduce and adapt?*

## I Prokaryotes-

A) Archaea

B) Bacteria

## II Bacteria Structure- Peptidoglycan-

A) Gram-Positive Bacteria

B) Gram- Negative Bacteria

2. E. coli structure  
cell wall-

flagella

nucleoid

pili

## III Obtaining energy

A) Photoautotrophs-

B) Chemoautotrophs-

C) Heterotrophs

## IV Reproduction and Adaptation

A) Binary Fission

B) Genetic Recombination  
a. Conjugation

b. Transformation

c. Transduction

C) Endospore Formation



# Bacteria

## Key Ideas

- What are the two major groups of prokaryotes?
- How are Gram-positive and Gram-negative bacteria different?
- How can bacteria be grouped by energy source?
- What are three ways that bacteria reproduce and adapt?

## Key Terms

plasmid  
peptidoglycan  
Gram-positive  
Gram-negative  
conjugation  
transformation  
transduction  
endospore

## Why It Matters

Prokaryotes are everywhere, even in boiling hot springs to Antarctic lakes. These small, single-celled organisms can live where nothing else can survive.

Prokaryotes are the oldest living things on Earth. Fossil prokaryotes date back about 3.5 billion years! Over the millennia, prokaryotes have adapted to live in almost every environment.

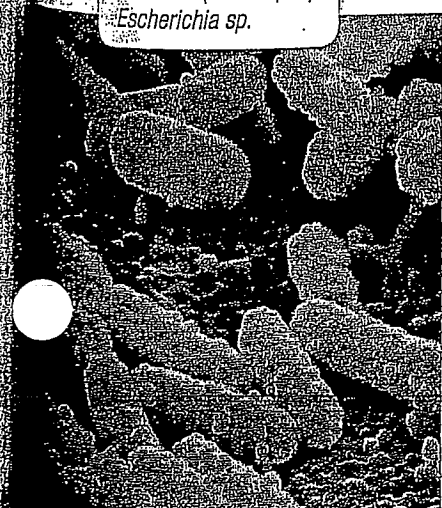
## What Are Prokaryotes?

Prokaryotes are single-celled organisms that do not have membrane-bound organelles. They are generally found in three shapes, as shown in **Figure 1**: a rod shape (*bacillus*), a sphere shape (*coccus*), and a spiral shape (*spirillum*). ➤ Prokaryotes are divided into two major groups: the domain Archaea and the domain Bacteria. Both groups are commonly referred to as *bacteria*.

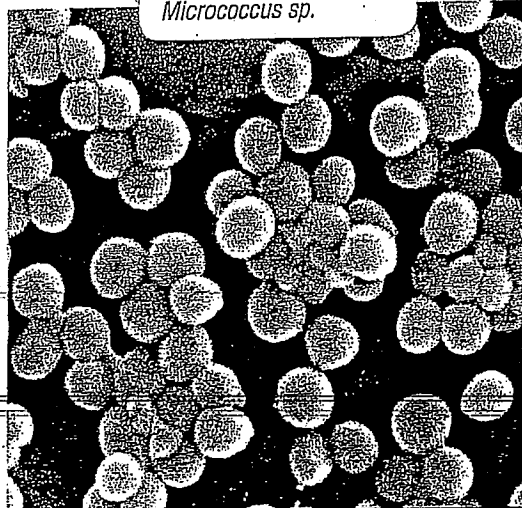
**Archaea** Archaea are found in many places, including extreme environments such as salt lakes and hot springs. Archaea are structurally very different from Bacteria. Some Archaean molecules are more similar to those found in eukaryotes. Others are unique among living organisms.

**Bacteria** Most known prokaryotes are members of the domain Bacteria. Bacteria can be found virtually everywhere. One square inch of skin plays host to an average of 100,000 bacteria!

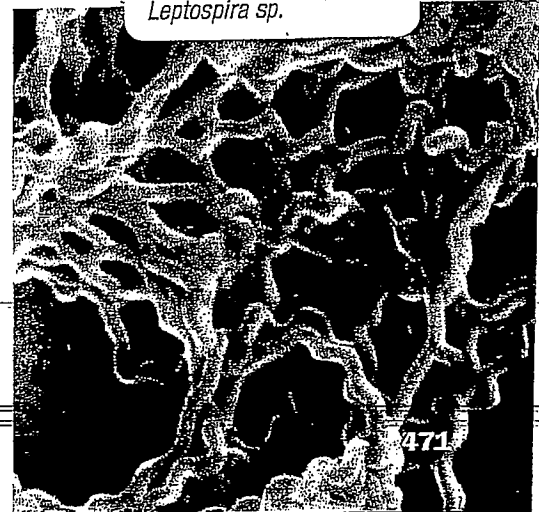
**Bacillus** (rod shaped)  
*Escherichia sp.*



**Coccus** (sphere shaped)  
*Micrococcus sp.*



**Spirillum** (spiral shaped)  
*Leptospira sp.*



**Figure 1** Prokaryotes are generally found in three shapes. The name of a prokaryote can sometimes tell you about its shape. ➤ Which of these prokaryotes have names that reflect their shape?

**plasmid** a circular DNA molecule in bacteria

**peptidoglycan** (pep ti doh GLIE kuhn) a protein-carbohydrate compound that makes the cell walls of bacteria rigid

**Gram-positive** a prokaryote that has a large amount of peptidoglycan in its cell wall and is stained violet during Gram staining

**Gram-negative** a prokaryote that has a small amount of peptidoglycan in its cell wall, has an outer membrane, and is stained pink during Gram staining

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## Bacterial Structure

Although bacteria have no membrane-bound organelles, they do have many internal structures. Bacteria have genetic material in the form of DNA. Bacterial DNA is a single chromosome clustered in a mass called a *nucleoid*. Bacteria often have small extra loops of DNA called **plasmids**. Bacteria have ribosomes and many types of enzymes. Bacteria may also form granules of stored nutrients to be used if nutrients in the environment are in short supply.

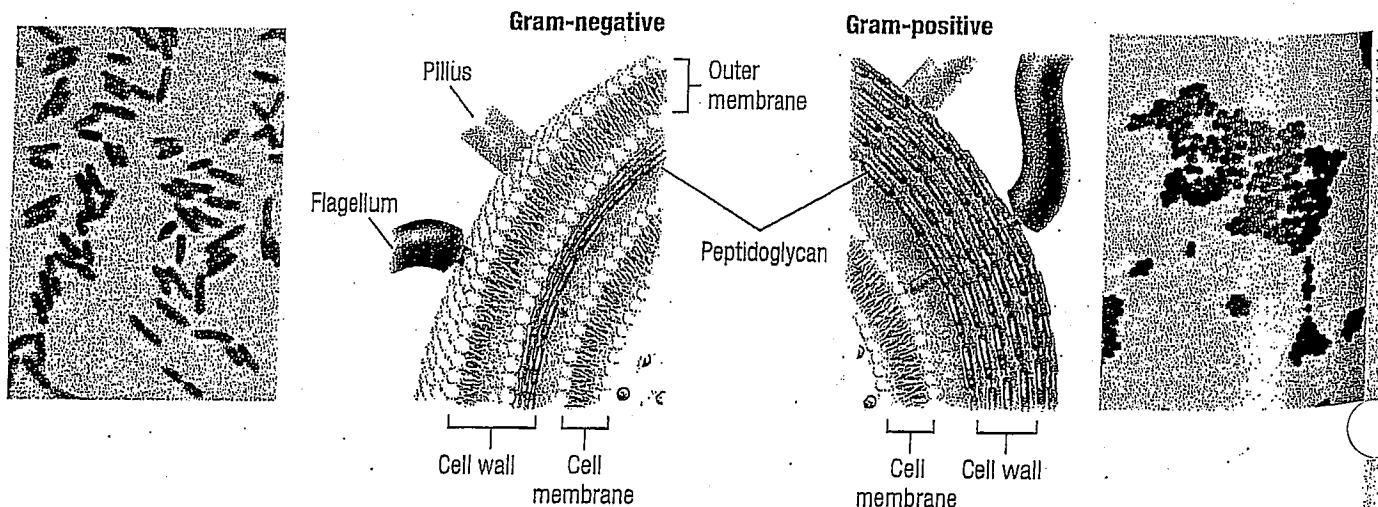
Bacterial cell membranes are lipid bilayers. Outside the cell membrane, bacteria have rigid cell walls that can be one or two layers thick. The bacterial cell wall is made of a protein-carbohydrate compound called **peptidoglycan** and may also include a membrane covering the peptidoglycan layer. The presence of this membrane allows biologists to group bacteria into two categories using a technique called the *Gram stain*. » **Gram-positive** bacteria have a thick layer of peptidoglycan and no outer membrane. **Gram-negative** bacteria have a thin layer of peptidoglycan and have an outer membrane.

**Gram-Positive Bacteria** The Gram stain involves two colors of dye. The first dye is dark purple. Gram-positive bacteria trap the dark purple dye because their peptidoglycan layer is very thick. The second, pink dye is also absorbed, but it cannot be seen because the purple dye is much darker. As a result, Gram-positive bacteria appear purple after staining, as **Figure 2** shows.

**Gram-Negative Bacteria** The thin peptidoglycan layer of Gram-negative bacteria does not trap the purple dye. When the pink dye is added, it is absorbed by the cell. Because the pink dye is the only dye present in Gram-negative bacteria, they appear pink after staining, as **Figure 2** shows. The outer membrane of Gram-negative bacteria makes them more resistant to host defenses and to medicines.

» **Reading Check** Is *E. coli* (right) a Gram-positive or Gram-negative bacterium? (See the Appendix for answers to Reading Checks.)

**Figure 2** After Gram staining, the Gram-negative bacteria on the left appear pink. The Gram-positive cells on the right appear violet after staining.

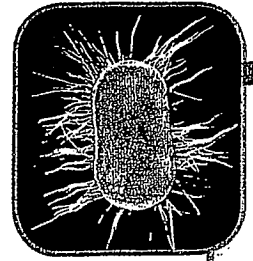


# Up Close Bacteria

*Escherichia* (ESH uh RIK ee uh) *coli* is a Gram-negative bacterium. There are many strains of *E. coli*. Most are harmless residents of healthy human and animal intestines. One strain, *E. coli* O157:H7, produces a powerful toxin and can cause severe illness. About 73,000 people become ill and about 60 people die every year in the United States from *E. coli* O157:H7 poisoning.

## *E. coli*

Scientific name: *Escherichia coli*  
 Size: up to 1  $\mu\text{m}$   
 Habitat: inhabits the intestines of many mammals  
 Mode of nutrition: heterotrophic  
 Diet: organic matter from living organisms or from the environment



**Cell structure** *E. coli* has a rigid cell wall composed of peptidoglycan. Outside the cell wall is an outer membrane composed of lipids and polysaccharides.

**Genetic material** Like all bacteria, *E. coli* has a single DNA molecule in the form of a loop. *E. coli* has approximately 5,000 genes.

**Locomotion** *E. coli* propels itself through its environment by rotating its whiplike flagella.

Ribosome

Cell wall

Outer membrane

Cell membrane

Peptidoglycan

**Reproduction** Most bacteria reproduce by dividing into two identical new cells. *E. coli* can divide as often as every 20 minutes.

**Adherence** *E. coli* has short, thin, protein tubes called pili. Pili adhere to surfaces, such as the intestinal lining, and join bacterial cells before bacteria exchange genetic information.

## Quick Lab

## Model Bacterial Growth

You can estimate how many bacteria are present in a population if you know the growth rate of bacteria and how much time has passed.

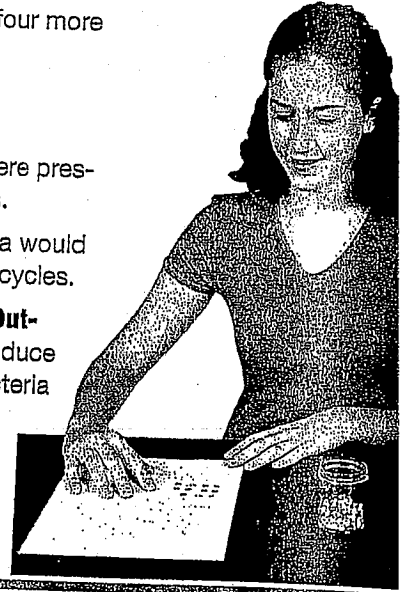
## Procedure

- 1 Obtain a cupful of paper circles from a hole punch.
- 2 Begin with a single circle, which represents a single bacterium.
- 3 Add a second circle to indicate one cycle of bacterial cell division.
- 4 Model another cycle of division by adding another circle for each of the bacteria in your population.

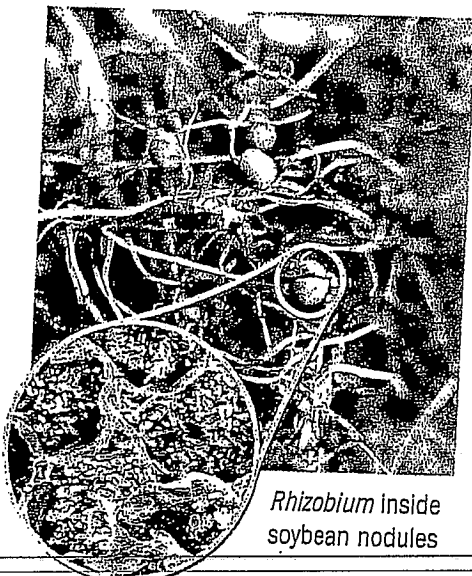
- 5 Repeat the procedure for four more cycles.

## Analysis

1. **State** how many bacteria were present at the end of four cycles.
2. **Calculate** how many bacteria would be present at the end of six cycles.
3. **CRITICAL THINKING: Predicting Outcomes** If your bacteria reproduce every 20 min, how many bacteria would you have at the end of 4 h, assuming that you begin with one bacterium?



**Figure 3** Bacteria of the genus *Rhizobium* live within these soybean root nodules. The bacteria fix nitrogen from the air into a form that both the bacteria and the plants can use.



*Rhizobium* inside soybean nodules

## Obtaining Energy and Nutrients

Bacteria differ in how they obtain energy and nutrients. Grouping prokaryotes based on their energy source separates them into photoautotrophs, chemoautotrophs, and heterotrophs.

**Photoautotrophs** Organisms that get their energy from sunlight through photosynthesis are called *photoautotrophs*. These bacteria include purple sulfur and nonsulfur bacteria, green sulfur bacteria, and cyanobacteria. Green and purple sulfur bacteria can grow only in oxygen-free environments. Cyanobacteria are abundant today and are a major component of the plankton that floats in the oceans. They produce a great deal of our oxygen and probably formed Earth's oxygen atmosphere.

**Chemoautotrophs** Prokaryotes called *chemoautotrophs* (KEE moh AWT oh TRAHFS) are the only organisms that can get their energy from inorganic sources. They use molecules that contain sulfur or nitrogen and simple organic molecules to obtain energy. In the presence of hydrogen-rich chemicals, chemoautotrophic bacteria can form all of their own amino acids and proteins.

**Heterotrophs** Most prokaryotes are *heterotrophs* and get both their energy and their nutrients from other organisms. Most absorb nutrients from dead organisms, but some are parasites or pathogens. Many heterotrophic bacteria live in the presence of oxygen, but can live without it. *Rhizobium*, shown in **Figure 3**, is an important heterotrophic bacterium that converts nitrogen in the air into molecules that can be used by other organisms.

These dividing bacteria stick together because of a coating that surrounds the cells and their offspring.

A pilus from one bacterium attaches to a second bacterium. The cells then join and exchange genetic material.

Inside these bacteria, endospores have formed. When conditions improve, the spores will produce new bacteria.

## Reproduction and Adaptation

Prokaryotes reproduce by binary fission; exchange genetic material through conjugation, transformation, and transduction; and survive harsh conditions by forming endospores.

**Binary Fission** Prokaryotes usually reproduce asexually by binary fission. In this process, a single cell divides into two identical new cells, as **Figure 4** shows. Mutations do occur during prokaryotic reproduction, and new forms emerge frequently.

**Genetic Recombination** There are three ways that prokaryotes can form new genetic combinations. **Conjugation** occurs when two bacteria exchange genetic material. **Transformation** occurs when bacteria take up DNA fragments from their environment. **Transduction** occurs when genetic material, such as a plasmid, is transferred by a virus. Plasmids often convey antibiotic resistance.

**Endospore Formation** Some bacteria survive harsh conditions by forming thick-walled structures called **endospores**. Endospores form inside the bacteria. They surround the DNA and a small bit of cytoplasm. Endospores can survive boiling, radiation, and acid. They show no signs of life and can be revived after hundreds of years.

**Figure 4** Bacteria can reproduce by binary fission, exchange DNA through conjugation, and survive harsh environments by spore formation.

**conjugation** a type of sexual reproduction in which two cells join to exchange DNA

**transformation** the transfer of genetic material in the form of DNA fragments

**transduction** the transfer of DNA from one bacterium to another through a virus

**endospore** a thick-walled structure that forms inside bacteria and resists harsh conditions

### Section

## 1

## Review

### KEY IDEAS

1. Identify the two major groups of prokaryotes.
2. Explain the difference between Gram-positive and Gram-negative bacteria.
3. Describe three ways that bacteria can obtain energy.

4. Describe how bacteria reproduce, exchange genetic information, and survive harsh conditions.

### CRITICAL THINKING

5. **Predicting Outcomes** If Earth suddenly lost its light source but stayed at the same temperature, which organisms might survive?
6. **Applying Information** How do the products of binary fission, conjugation, and endospore germination differ from each other?

## ALTERNATIVE ASSESSMENT

7. **Bacterial Meal** Research foods that are made by using prokaryotes. Prepare a menu, including recipes, for a meal made entirely of these foods. If possible, prepare the meal and share with your classmates. Or prepare the ingredients in small groups outside class, and bring the finished products to class to share.

