# Prokaryote structure

Overview of prokaryotes (bacteria and archaea).
Structural features of prokaryotic cells.

## Key points:

Prokaryotes are single-celled organisms belonging to the domains Bacteria and Archaea.

Prokaryotic cells are much smaller than eukaryotic cells, have no nucleus, and lack organelles.
All prokaryotic cells are encased by a cell wall.
Many also have a capsule or slime layer made of polysaccharide.

Prokaryotes often have appendages (protrusions) on their surface. Flagella and some pili are used for locomotion, fimbriae help the cell stick to a surface, and sex pili are used for DNA exchange.
Most prokaryotic cells have a single circular chromosome. They may also have smaller pieces of circular DNA called plasmids.

## Introduction

Bacteria often get a bad rap: they’re described as unsafe “bugs” that cause disease. Although some types of bacteria do cause disease (as you know if you've ever been prescribed antibiotics), many other are harmless, or even beneficial.

Bacteria are classified as prokaryotes, along with another group of single-celled organisms, the archaea. Prokaryotes are tiny, but in a very real sense, they dominate the Earth. They live nearly everywhere – on every surface, on land and in water, and even inside of our bodies.

To emphasize that last point: you probably have about the same number of prokaryotic cells in your body as human cells! That may sound gross, but many of our prokaryotic "sidekicks" play important roles in keeping us healthy.

In this article, we'll look at what prokaryotes are and what exactly makes them different from eukaryotes (such as you, a houseplant, or a fungus). Then, we'll take a closer look at the structures these efficient, omnipresent little organisms use to survive.

## What are prokaryotes?

Prokaryotes are microscopic organisms belonging to the domains Bacteria and Archaea, which are two out of the three major domains of life. (Eukarya, the third, contains all eukaryotes, including animals, plants, and fungi.) Bacteria and archaea are single celled, while most eukaryotes are multicellular.

Fossils show that prokaryotes were already here on Earth $3.5$ billion years ago, and scientists think that prokaryotic ancestors gave rise to all of the life forms present on Earth today.

## Prokaryotes vs. eukaryotes

Prokaryotes and eukaryotes are similar in some fundamental ways, reflecting their shared evolutionary ancestry. For instance, both you and the bacteria in your gut decode genes into proteins through transcription and translation. Similarly, you and your prokaryotic inhabitants both pass genetic information on to your offspring in the form of DNA.

In other ways, prokaryotes and eukaryotes are quite different. That may be obvious when we're comparing humans to bacteria. But for me at least, it's less obvious when we're comparing a bacterium to a yeast (which is tiny and unicellular, but eukaryotic). What actually separates these categories of organisms? The most fundamental differences between prokaryotes and eukaryotes relate to how their cells are set up. Specifically:

Eukaryotic cells have a nucleus, a membrane bound chamber where DNA is stored, while prokaryotic cells don't. This is the feature that formally separates the two groups.

Eukaryotes usually have other membrane-bound organelles in addition to the nucleus, while prokaryotes don't.

Cells in general are small, but prokaryotic cells are really small. Typical prokaryotic cells range from 0.2 2 in diameter, while typical eukaryotic cells range from 10 100 in diameter.

Many prokaryotic cells have sphere, rod, or spiral shapes (as shown below). In the following sections, we'll walk through the structure of a prokaryotic cell, starting on the outside and moving towards the inside of the cell.

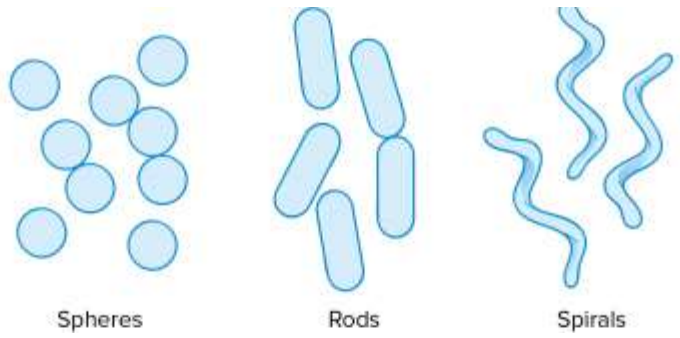



Image modified from "Bacterial morphology diagram," by Mariana Ruiz Villareal (public domain).

## The capsule

Many prokaryotes have a sticky outermost layer called the capsule, which is usually made of polysaccharides (sugar polymers).

The capsule helps prokaryotes cling to each other and to various surfaces in their environment, and also helps prevent the cell from drying out. In the case of disease-causing prokaryotes that have colonized the body of a host organism, the capsule or slime layer may also protect against the host's immune system. Remember Griffith's experiment, which demonstrated the existence of a "transforming principle" (DNA) that could turn rough, harmless bacteria into smooth, pathogenic bacteria? The smooth bacteria were smooth (and capable of causing disease) because they had a capsule!

## The cell wall

All prokaryotic cells have a stiff cell wall, located underneath the capsule (if there is one). This structure maintains the cell's shape, protects the cell interior, and prevents the cell from bursting when it takes up water.

The cell wall of most bacteria contains peptidoglycan, a polymer of linked sugars and polypeptides. Peptidoglycan is unusual in that it contains not only Lamino acids, the type normally used to make proteins, but also D-amino acids ("mirror images" of the L-amino acids). Archaeal cell walls don't contain peptidoglycan, but some include a similar molecule called pseudo peptidoglycan, while others are composed of proteins or other types of polymers.

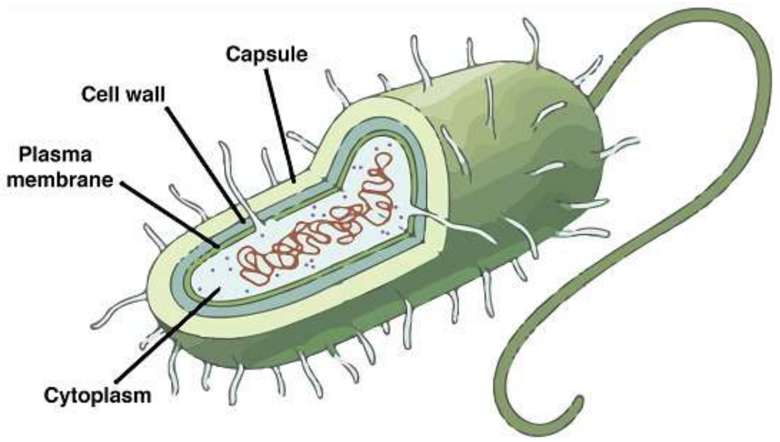



Image modified from "Structure of Prokaryotes: Figure 2," by OpenStax College, Biology (CC BY 3.0).

Some of the antibiotics used to treat bacterial infections in humans and other animals act by targeting the bacterial cell wall. For instance, some antibiotics contain D-amino acids similar to those used in peptidoglycan synthesis, "faking out" the enzymes that build the bacterial cell wall (but not affecting human cells, which don't have a cell wall or utilize Damino acids to make polypeptides).

## The plasma membrane

Underneath the cell wall lies the plasma membrane. The basic building block of the plasma membrane is the phospholipid, a lipid composed of a glycerol molecule attached a hydrophilic (water-attracting) phosphate head and to two hydrophobic (water repelling) fatty acid tails. The phospholipids of a eukaryotic or bacterial membrane are organized into two layers, forming a structure called a phospholipid bilayer.

The plasma membranes of archaea have some unique properties, different from those of both bacteria and eukaryotes. For instance, in some species, the opposing phospholipid tails are joined into a single tail, forming a monolayer instead of a bilayer (as shown below). This modification may stabilize the membrane at high temperatures, allowing the archaea live happily in boiling hot springs.

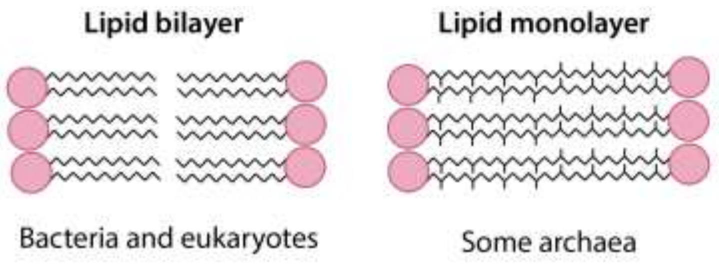



Image modified from "Archaea membrane," by Fransciscosp2 (public domain).

## Appendages

Prokaryotic cells often have appendages (protrusions from the cell surface) that allow the cell to stick to surfaces, move around, or transfer DNA to other cells. Thin filaments called fimbriae (singular: fimbria), like those shown in the picture below, are used for adhesion—that is, they help cells stick to objects and surfaces in their environment.

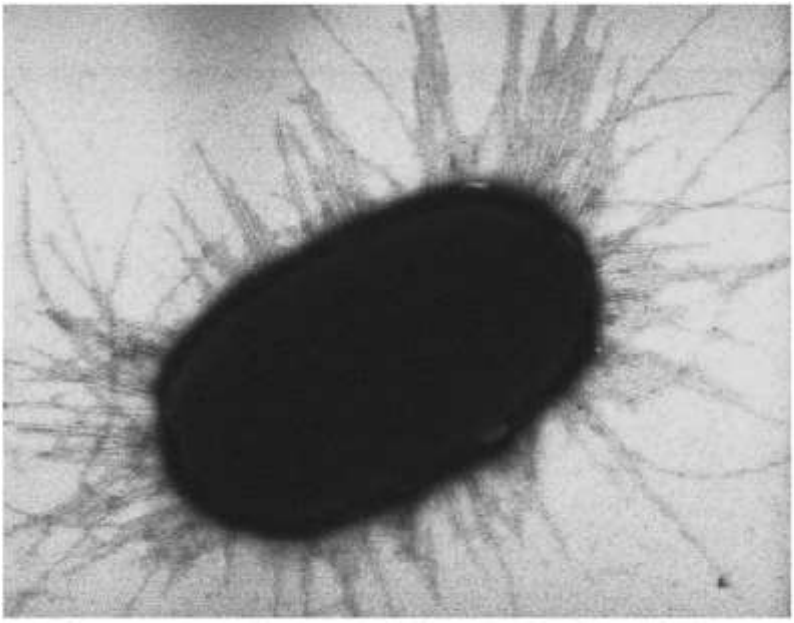
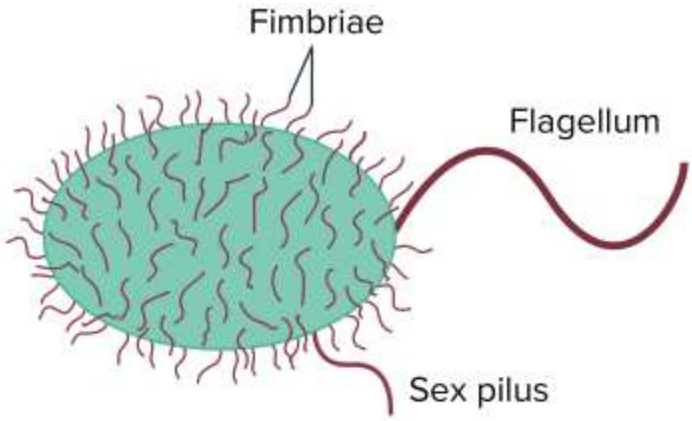


Image modified from "E. coli fimbriae.png," by Manu Forero (CC BY 2.5).

Longer appendages, called pili (singular: pilus), come in several types that have different roles. For instance, a sex pilus holds two bacterial cells together and allows DNA to be transferred between them in a process called conjugation. Another class of bacterial pili, called type IV pili, help the bacterium move around its environment.

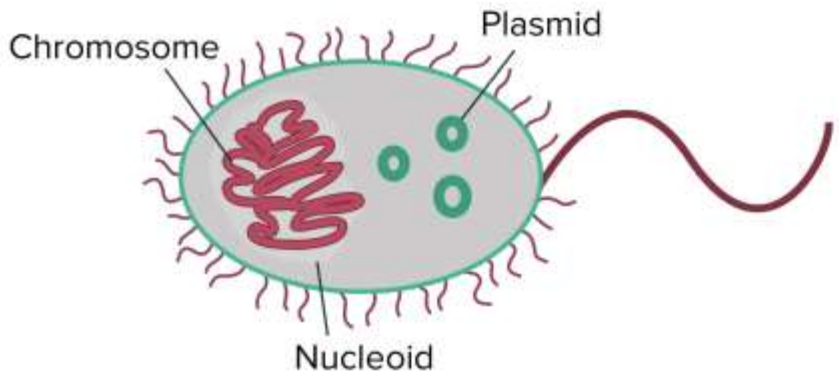
The most common appendages used for getting around, however, are flagella (singular: flagellum). These tail-like structures whip around like propellers to move cells through watery environments.




## Chromosome and plasmids

Most prokaryotes have a single circular chromosome, and thus a single copy of their genetic material. Eukaryotes like humans, in contrast, tend to have multiple rod-shaped chromosomes and two copies of their genetic material (on homologous chromosomes). Also, prokaryotic genomes are generally much smaller than eukaryotic genomes. For instance, the E. coli genome is less than half the size of the genome of yeast (a simple, single-celled eukaryote), and almost 700 times smaller than the human genome!

By definition, prokaryotes lack a membrane-bound nucleus to hold their chromosomes. Instead, the chromosome of a prokaryote is found in a part of the cytoplasm called a nucleoid.




In addition to the chromosome, many prokaryotes have plasmids, which are small rings of double stranded extra-chromosomal ("outside the chromosome") DNA. Plasmids carry a small number of non-essential genes and are copied independently of the chromosome inside the cell. They can be transferred to other prokaryotes in a population, sometimes spreading genes that are beneficial to survival.

For instance, some plasmids carry genes that make bacteria resistant to antibiotics. (These genes are called R genes.) When the plasmids carrying R genes are exchanged in a population, they can quickly make the population resistant to antibiotic drugs. While beneficial to the bacteria, this process can make it difficult for doctors to treat harmful bacterial infections.

## Internal compartments

Prokaryotes aren't "supposed" to have internal compartments like the organelles of eukaryotes, and for the most part, they don't. However, prokaryotic cells sometimes need to increase membrane surface area for reactions or concentrate a substrate around its enzyme, just like eukaryotic cells. Because of this, some prokaryotes have membrane folds or compartments functionally similar to those of eukaryotes.

For example, photosynthetic bacteria often have extensive membrane folds to increase surface area for the light-dependent reactions, similar to the thylakoid membranes of a plant cell. These bacteria may also have carboxysomes, protein-enclosed cellular compartments where carbon dioxide is concentrated for fixation in the Calvin cycle.