# Structure of Bacterial Cells

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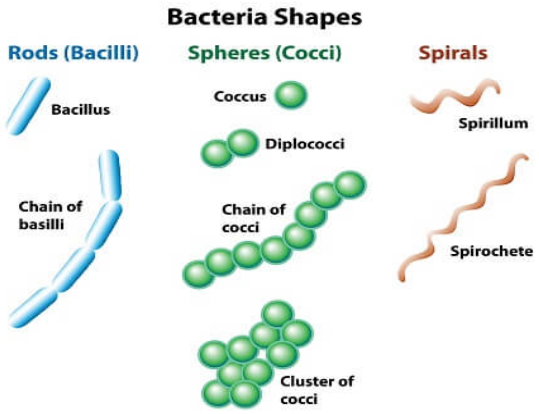
## Shape and size of bacteria

Bacteria are classified by shape into three basic groups: **cocci , bacilli,** and **spirochetes**. The cocci are round, the bacilli are rods, and the spirochetes are spiral-shaped. Some bacteria are variable in shape and are said to be **pleomorphic** (many-shaped).




The shape of a bacterium is determined by its rigid cell wall. The microscopic appearance of a bacterium is one of the most important criteria used in its identification.

In addition to their characteristic shapes, the arrangement of bacteria is important. For example, certain cocci occur in pairs (**diplococci**), some in chains (**streptococci**), and others in grapelike clusters (**staphylococci**).

Bacteria range in size from about 0.2 to 5 μm . The smallest bacteria (*Mycoplasma*) are about the same size as the largest viruses (poxviruses) and are the smallest organisms capable of existing outside a host. The longest bacteria rods are the size of some yeasts and human red blood cells (7 μm).

## Cell Wall

The cell wall is the outermost component common to all bacteria (except *Mycoplasma* species, which are bounded by a cell membrane, not a cell wall). Some bacteria have surface features external to the cell wall, such as a capsule, flagella, and pili.

The cell wall is located external to the cytoplasmic membrane and is composed of **peptidoglycan**. The peptidoglycan provides structural support and maintains the characteristic shape of the cell.

Bacterial cells can be classified according to the components of cell wall to Gram positive and Gram negative bacteria.

### Peptidoglycan

Peptidoglycan is a complex, network that surrounds the entire cell and is composed of a single covalently linked macromolecule. It is found *only* in bacterial cell walls. It provides rigid support for the cell, is important in maintaining the characteristic shape of the cell, and allows the cell to withstand media of low osmotic pressure, such as water.

The term **peptidoglycan** is derived from the peptides and the sugars (glycan) that make up the molecule. Synonyms for peptidoglycan are **murein** and **mucopeptide**.

The carbohydrate backbone, which is composed of alternating *N*-acetylmuramic acid and *N*-acetylglucosamine molecules. Attached to each of the muramic acid molecules is a tetrapeptide consisting of both D- and L amino acids, the precise composition of which differs from one bacterium to another.
Because peptidoglycan is present in bacteria but not in human cells, it is a good target for antibacterial drugs. Several of these drugs, such as penicillins, cephalosporins and vancomycin inhibit the synthesis of peptidoglycan .

**Lipopolysaccharide**

The lipopolysaccharide (LPS) of the outer membrane of the cell wall of gram negative bacteria is **endotoxin**. It is responsible for many of the features of disease, such as fever and shock (especially hypotension), caused by these organisms . It is called endotoxin because it is an integral part of the cell wall, in contrast to exotoxins, which are actively secreted from the bacteria. The constellation of symptoms caused by the endotoxin of one gram-negative bacteria is similar to another, but the severity of the symptoms can differ greatly. In contrast, the symptoms caused by exotoxins of different bacteria are usually quite different.
The LPS is composed of three distinct units:
(1) A phospholipid called lipid A, which is responsible for the toxic effects.
(2) A core polysaccharide of five sugars linked through ketodeoxyoctulonate (KDO) to lipid A.
(3) An outer polysaccharide consisting of up to 25 repeating units of three to five sugars. This outer polymer is the important somatic or O antigen of several gram negative bacteria that is used to identify certain organisms in the clinical laboratory.
Some bacteria, notably members of the genus *Neisseria*, have an outer lipooligosaccharide (LOS) containing very few repeating units of sugars.

**Teichoic Acid**

Teichoic acids are fibers located in the outer layer of the gram-positive cell wall and extend from it. They are composed of polymers of either glycerol phosphate or ribitol phosphate.
The medical importance of teichoic acids lies in their ability to induce septic shock when caused by certain gram-positive bacteria; that is, they activate the same pathways as does endotoxin (LPS) in gram-negative bacteria. Teichoic acids also mediate the attachment of staphylococci to mucosal cells. Gram-negative bacteria do not have teichoic acids.

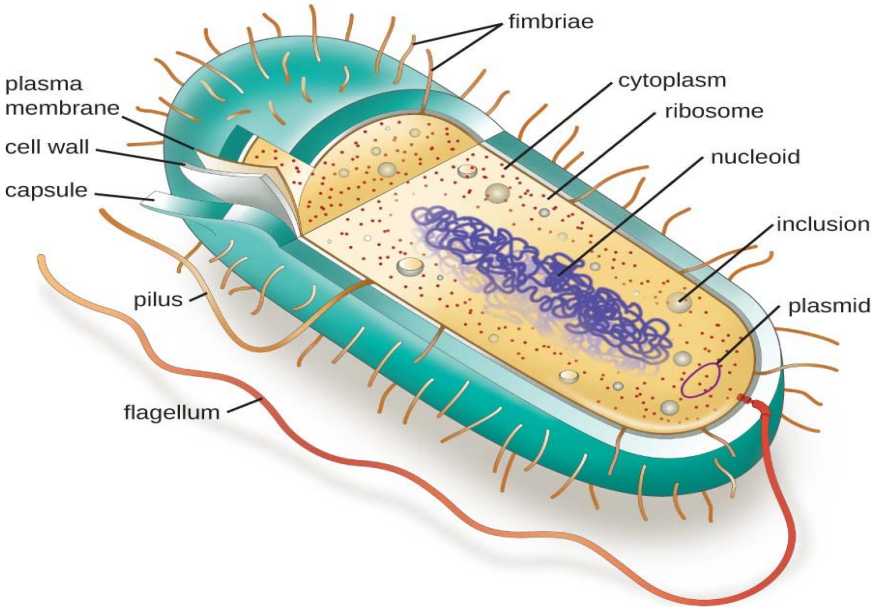
**Cell Walls of Acid-Fast Bacteria**

Mycobacteria (e.g., *Mycobacterium tuberculosis*) have an unusual cell wall, resulting in their inability to be Gram-stained. These bacteria are said to be **acid fast** because they resist decolorization with acid–alcohol after being stained with carbol fuchsin. This property is related to the high concentration of lipids, called **mycolic acids,** in the cell wall of mycobacteria.

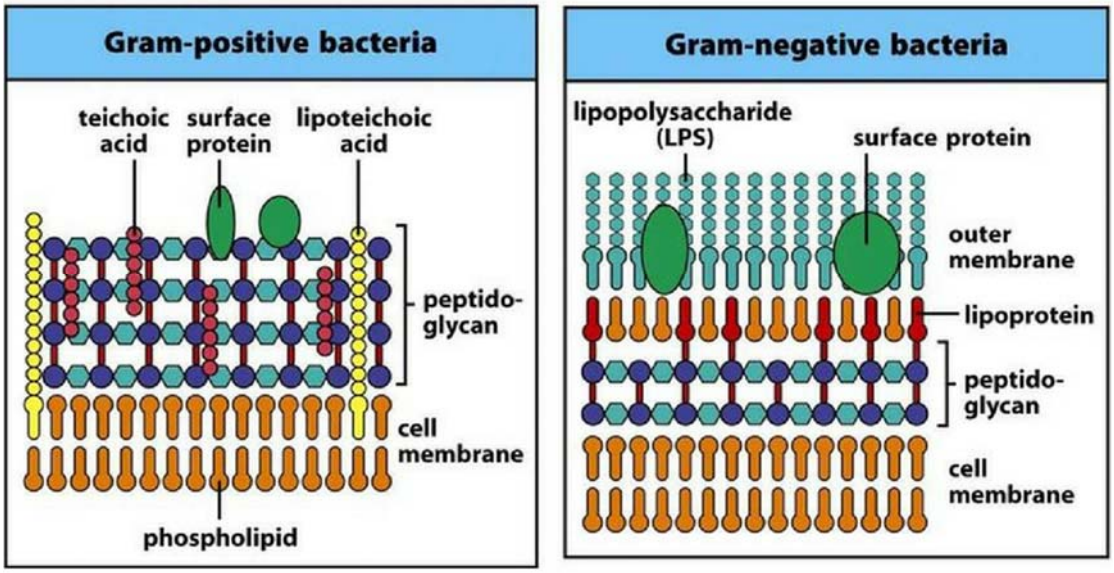
**Cytoplasmic Membrane**

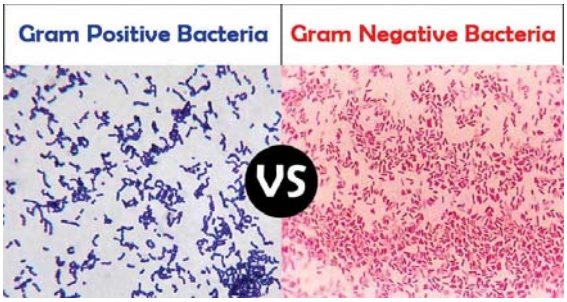
Just inside the peptidoglycan layer of the cell wall lies the cytoplasmic membrane, which is composed of a phospholipid bilayer similar in microscopic appearance to that in eukaryotic cells. They are chemically similar, but eukaryotic membranes contain sterols, whereas prokaryotes generally do not. The only prokaryotes that have sterols in their membranes are members of the genus *Mycoplasma*. The membrane has four important functions: (1) active transport of molecules into the cell, (2) energy generation by oxidative phosphorylation, (3) synthesis of precursors of the cell wall, and (4) secretion of enzymes and toxins.

In view of their importance, three components of the cell wall (i.e.,peptidoglycan, lipopolysaccharide and teichoic acid).




**Gram positive bacteria V/S Gram negative baceteria**






**Cytoplasm**

The bacterial cytoplasm contains the following components:

**Ribosomes**

Bacterial ribosomes are the site of protein synthesis as in eukaryotic cells, but they differ from eukaryotic ribosomes in size and chemical composition. **Bacterial ribosomes** are **70S in size**, with **50S** and **30S** subunits, whereas **eukaryotic ribosomes** are **80S in size**, with **60S** and **40S** subunits. The differences in both the ribosomal RNAs and proteins constitute the basis of the selective action of several antibiotics that inhibit bacterial, but not human, protein synthesis .

**Granules**

The cytoplasm contains several different types of granules that serve as storage areas for nutrients and stain characteristically with certain dyes.

**DNA chromosome**

The DNA chromosome of bacteria is a single, double-stranded and circular molecule. There is no nucleus and no nuclear membrane.

**Plasmids**

Plasmids are extra chromosomal, double-stranded, circular DNA molecules that are capable of replicating independently of the bacterial chromosome. Although plasmids are usually extra chromosomal, they can be integrated into the bacterial chromosome. Plasmids occur in both gram-positive and gram-negative bacteria Plasmids carry the genes for antibiotic resistance , toxin production and bacteriocins which are toxic proteins produced by certain bacteria that are lethal for other bacteria.

**Transposons** "jumping genes."

Transposons are pieces of DNA that move readily from one site to another either within or between the DNAs of bacteria and plasmids.

Transposons can code for drug-resistant enzymes and toxins.

**Structures -Outside the Cell Wall**

**Capsule**

The capsule is a gelatinous layer covering the entire bacterium. It is composed of polysaccharide, except in the anthrax bacillus, which has a capsule of polymerized D-glutamic acid.

The capsule may play a role in the adherence of bacteria to human tissues, which is an important initial step in causing infection.

**Flagella**

Flagella are long, whiplike appendages that move the bacteria toward nutrients and other attractants, a process called **chemotaxis**.

Flagellated bacteria have a characteristic number and location of flagella: some bacteria have one, and others have many; in some, the flagella are located at one end, and in others, they are all over the outer surface. Only certain bacteria have flagella. Many rods do, but most cocci do not and are therefore nonmotile.

Flagella may play a role in pathogenesis by propelling the bacteria up the urethra into the bladder.

**Pili (Fimbriae)**

Pili are hairlike filaments that extend from the cell surface. They are shorter and straighter than flagella and are composed of subunits of pilin.

Pili have two important roles:

(1) They mediate the **attachment** of bacteria to specific receptors on the human cell surface, which is a necessary step in the initiation of infection for some organisms.

(2) A specialized kind of pilus, the sex pilus, forms the attachment between the male (donor) and the female (recipient) bacteria during conjugation .

**Glycocalyx (Slime Layer)**

The glycocalyx is a polysaccharide coating that is secreted by many bacteria. It covers surfaces like a film and allows the bacteria to **adhere firmly** to various structures (e.g., skin, heart valves, prosthetic joints, and catheters).

**The medical importance of the** glycocalyx also mediates adherence of certain bacteria, such as *Streptococcus mutans*, to the surface of teeth. This plays an important role in the formation of plaque, the precursor of dental caries.

**Bacterial Spores**

Two genera of medically important gram-positive rods: the genus *Bacillus*, which includes the agent of anthrax, and the genus *Clostridium*, which includes the agents of tetanus and botulism. Spore formation (sporulation) occurs when nutrients, such as sources of carbon and nitrogen, are depleted . The spore forms keratinlike coat that is responsible for the remarkable resistance of the spore to heat, dehydration, radiation , and chemicals.

The spore has no metabolic activity and can remain dormant for many years. After exposure to water specific enzymes degrade the coat, water and nutrients enter, and germination into a pathogenic bacterial cell.

The medical importance of spores lies in their **extraordinary resistance to heat** and chemicals. Steam heating under pressure (autoclaving) at 121°C, usually for 30 minutes, is required to ensure the sterility of products for medical use. Spores are often not seen in clinical specimens recovered from patients infected by spore forming organisms because the supply of nutrients is adequate.

| Gram-Positive bacteria | Gram-Negative bacteria |
|---|---|
| **Cell Wall** | |
| A single-layered, smooth cell wall | A double-layered, wavy cell-wall |
| **Cell Wall thickness** | |
| The thickness of the cell wall is 20 to 80 nanometres | The thickness of the cell wall is 8 to 10 nanometres |
| **Peptidoglycan Layer** | |
| It is a thick layer/ also can be multilayered | It is a thin layer/ often single-layered. |
| **Teichoic acids** | |
| Presence of teichoic acids | Absence of teichoic acids |
| **Outer membrane** | |
| The outer membrane is absent | The outer membrane is present (mostly) |
| **Porins** | |
| Absent | Occurs in Outer Membrane |
| **Mesosome** | |
| It is more prominent. | It is less prominent. |
| **Morphology** | |
| Cocci or spore-forming rods | Non-spore forming rods. |
| | |
| | |
| **Lipid content** | |
| Very low | 20 to 30% |
| **Lipopolysaccharide** | |
| Absent | Present |
| **Toxin Produced** | |
| Exotoxins | Endotoxins or Exotoxins |
| **Examples** | |

| *Staphylococcus*, *Streptococcus*, etc. | *Escherichia*, *Salmonella*, etc. |
|---|---|
| **Gram Staining** | |
| These bacteria retain the crystal violet color even after they are washed with acetone or alcohol and appear as purple-colored when examined under the microscope after gram staining. | These bacteria do not retain the stain color even after they are washed with acetone or alcohol and appear as pink-colored when examined under the microscope after gram staining |