

## Bacteria

Did you know that bacteria cause the following threats to public health?

- Anthrax (*Bacillus anthracis*)
- Syphilis (*Treponema pallidum*)
- Strep throat (*Streptococcus*)
- Botulism (*Clostridium botulinum*)
- Skin boils (*Staphylococcus*)

## Objectives of This Lesson

After completing this lesson, you will be able to:

- Describe the general characteristics of a basic bacterium
- List four ways of classifying bacteria
- Gain familiarity with the infectious or disease-causing characteristics of bacteria
- Recognize and name the general shapes and forms of bacteria
- Explain the significance of the cell wall structures (such as the peptidoglycan) and the Gram stain
- Describe the three main processes of cellular respiration and their implications on bacterial life
- Describe the two main factors that influence bacterial growth
- State at least one pathogenic disease associated with bacteria

## Bacteria: The Basics

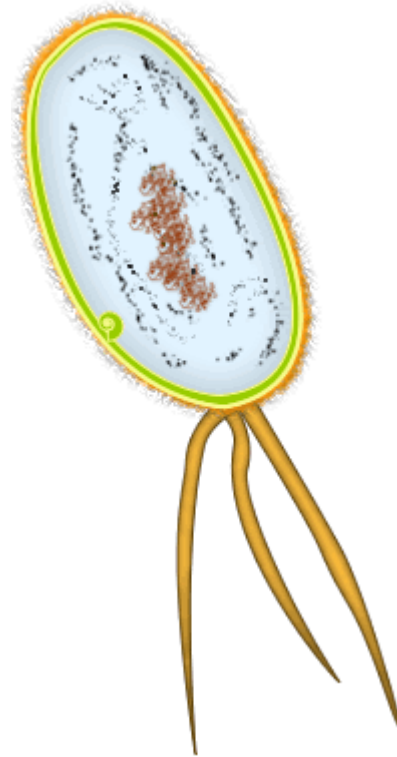
Bacteria are prokaryotic cells, the simplest of microbial cells. In essence, they consist of cell protoplasm contained within a retaining structure or cell envelope.

### Basic Characteristics:

- Prokaryotic
- Simplest of all microbial cells
- Single-celled organisms
- Distinctive cell walls, or unique cell envelopes, which contain a peptidoglycan layer
- Tiny; measured in units called micrometers ( $\mu\text{m}$ )
- Lack a true nucleus; instead, have a region called the 'nucleoid region' (i.e., DNA)
- DNA is free floating
- May have additional DNA which is not associated with this nucleoid region (called a plasmid)

### Other Characteristics:

- Rapid growth and cell division (binary fission) under favorable conditions
- Mutants that arise from bacteria can become extremely resilient organisms because bacteria can:
  - Grow and reproduce cells quickly
  - Adapt quickly to changing environments
- Plasmids impart additional resistant characteristics to bacteria via cell-to-cell transfer of this extra DNA material
- Capable of colonizing in almost any environment
- Extremely diverse and numerous in soils or waters



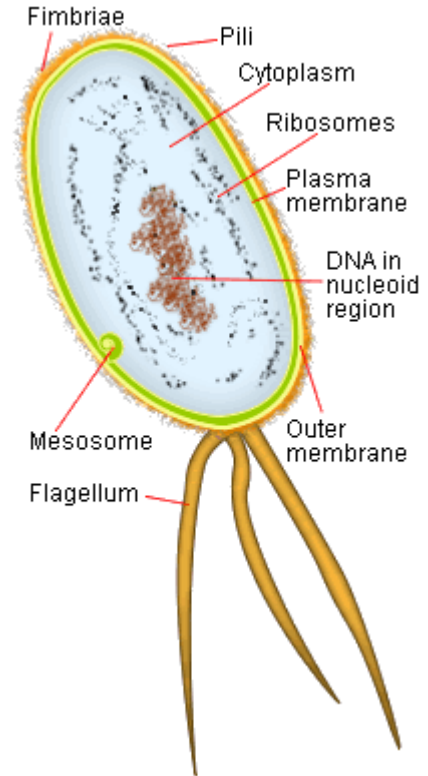
## Basic Bacteria

The overall form of a basic bacterial cell is that of a complex **cell envelope** that encloses **cell protoplasm**. **Cell appendages** from the envelope protrude into the environment surrounding the cell.

### Constituents of bacterial cell components

Cell Appendages	Cell Envelope	Cell Protoplasm (Plasma membrane)
<u>Flagella</u>	<u>Glycocalyx</u>	Ribosomes
<u>Pili</u>	Cell wall	Mesosomes
<u>Fimbriae</u>	Cell membrane	Granules
		Nucleoid

All bacterial cells have a:	Not all bacterial cells have:
<ul style="list-style-type: none"> <li>● Cell envelope</li> <li>● Protoplasm that contains:                             <ul style="list-style-type: none"> <li>○ Cell membrane</li> <li>○ Cytoplasm (cell pool)</li> <li>○ Ribosomes</li> <li>○ Nucleoid</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>● Cell wall (most have them)</li> <li>● Flagella</li> <li>● Pili</li> </ul>



### HINT

Roll your mouse over underlined words. Your browser displays the definition. Click the word to read the same definition in the glossary.

## Construct a Bacterium

Click on the links below that represent parts that make up a bacteria cell. If the part you select is part of a bacteria cell, it will appear at right. If the part you select is not part of a bacteria cell, a message will appear explaining where it belongs.

- [Capsid](#)
- [Cytoplasm](#)
- [DNA](#)
- [Fimbriae \(Cilia\)](#)
- [Flagella](#)
- [Hyphae](#)
- [Icosahedral Coat](#)
- [Membrane](#)
- [Mesosome](#)
- [Peptidoglycan](#)
- [Pili](#)
- [Pseudopod](#)
- [Ribosomes](#)

## Classifying Bacteria

Most microbiologists classify bacteria according to a phylogenetic classification system based on *Bergey's Manual of Systematic Bacteriology (Bergey's Manual)*. The *Bergey's Manual* is a guide to distinguishing bacterial species based on phenotypic differences. For our purpose, and for simplicity's sake, we will use a more basic classification approach. Understanding this simple classification method can lead to a better comprehension of the *Bergey's Manual*.

We can classify bacteria according to:

- Shape
- Cell wall structure and the Gram Stain
- Cellular respiration
- Growth factors: *Energy Source and Nutrient Source*

## Classifying Bacteria by Shape

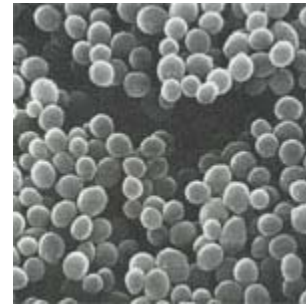
Bacteria cells vary in shape:

- Cocci – spherical
- Bacilli – rods, or cylindrical
- Spirillum – spiral, or helical
- Filamentous – complex forms, like 'jellybeans in a straw'

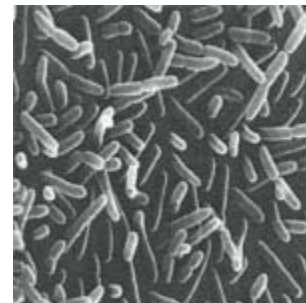
The shape of a cell affects its survival and activity in the environment. For example, cocci have less surface area per volume than bacilli or spirillum, and thus can survive more severe desiccation or dehydration. Bacilli, however, have a greater surface area to volume ratio and can take up nutrients from dilute solutions more efficiently. Shape also affects motility. For instance, spirillum are spiral cells, move with a corkscrew motion, and meet less resistance from surrounding water.

### Examples of Bacteria Classified by Shape:

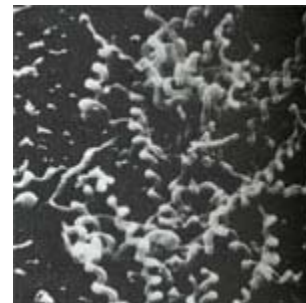
- **Cocci:**
  - *Streptococcus*
  - *Staphylococcus*
- **Bacilli:**
  - *Bacillus anthracis*
  - *Clostridium*
- **Spirillum:**
  - *Treponema pallidum*
- **Filamentous:**
  - *Leptothrix*, *Crenothrix*



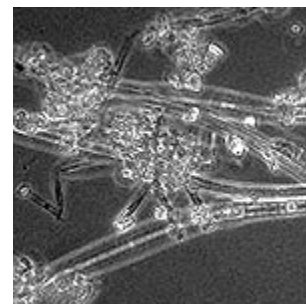
Coccus



Bacilli (rods)



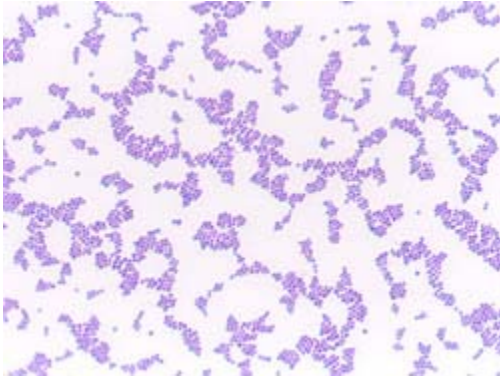
Spirillum



Filamentous

## Classifying Bacteria by Cell Wall Structure: The Gram Stain

Another way to classify bacteria is based on differences in the composition of cell walls. The difference becomes clear by means of a technique called the **Gram stain**, which identifies bacteria as either **Gram positive** or **Gram negative**. After staining, Gram positive bacteria hold the dye and appear purple, while Gram negative bacteria release the first dye used and appear red from the second (counter) dye. Gram positive bacteria have thicker cell walls than Gram negative bacteria. Knowing whether a disease-causing bacterium is Gram positive or Gram negative helps a physician to prescribe the appropriate antibiotic. The stain is named for H. C. J. Gram, a Danish physician who invented it in 1884.



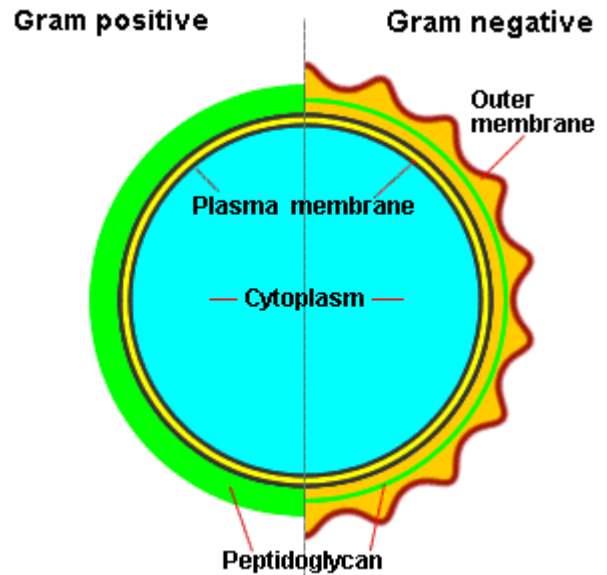
Gram stain of Gram positive Staphylococcus cell



Gram stain of Gram negative E. coli cell

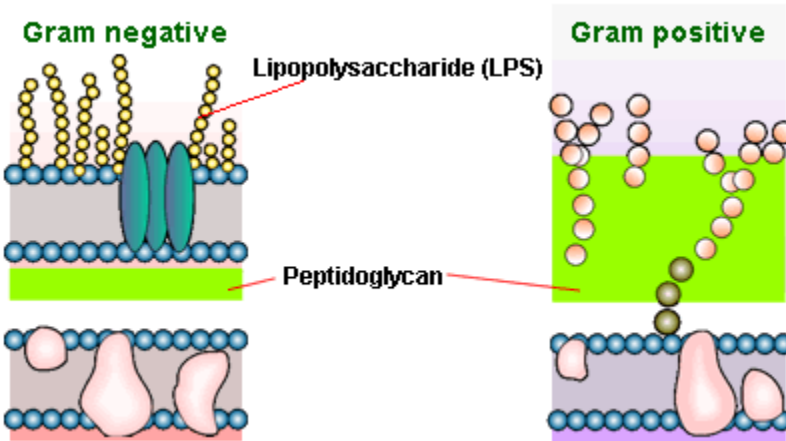
## Distinctive Cell Walls: Peptidoglycan

Both Gram positive and Gram negative organisms have more than one layer protecting their cytoplasm and nucleus from the outer environment. This is different from animal cells, which have only a single cytoplasmic membrane, made of a phospholipid bilayer. The layer just outside the bacterial cytoplasmic or plasma membrane is called the **peptidoglycan layer**. The peptidoglycan is what gives both cell wall types their rigid and protective qualities.



## Gram Positives and Gram Negatives: Key Differences

Gram positive bacteria have simpler, but thicker walls, with a relatively large amount of peptidoglycan. The walls of Gram negative bacteria are thinner and have less peptidoglycan but are more complex in structure. An outer membrane on the Gram negative cell wall contains **lipopolysaccharides (LPS)**. These are toxic substances responsible for making Gram negative organisms more threatening than Gram positives. Even the LPS of dead organisms are a potential threat.



## Gram Positives

The Gram positive cell envelope has two layers:

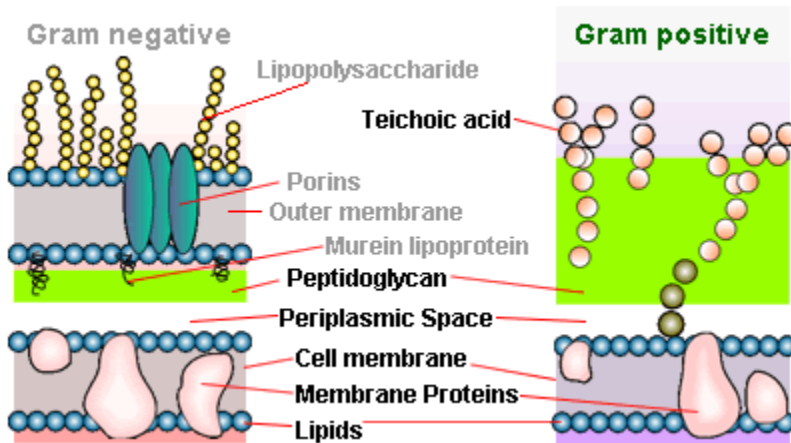
- An outer cell wall – thick peptidoglycan layer, composed of complex cross-linked peptidoglycan, teichoic acid, polysaccharides and other proteins
- Cytoplasmic membrane - contains proteins that span the lipid bilayer

### Special Components of Gram Positive Bacteria

The special components of Gram positives are:

- Teichoic Acids
- Polysaccharides

The teichoic acids anchor the outer cell wall to the cytoplasmic membrane by attaching to glycolipids. Teichoic acids also act as antigenic determinants, so they are important for the serologic identification of many Gram positive organisms.



### Examples of Gram positive Bacteria:

- *Streptococcus pyogenes* - causes strep throat
- *Staphylococcus aureus* - causes skin infections and may be responsible for boils

## Gram Negatives

The Gram negative cell envelope has 3 layers (not including the periplasmic space):

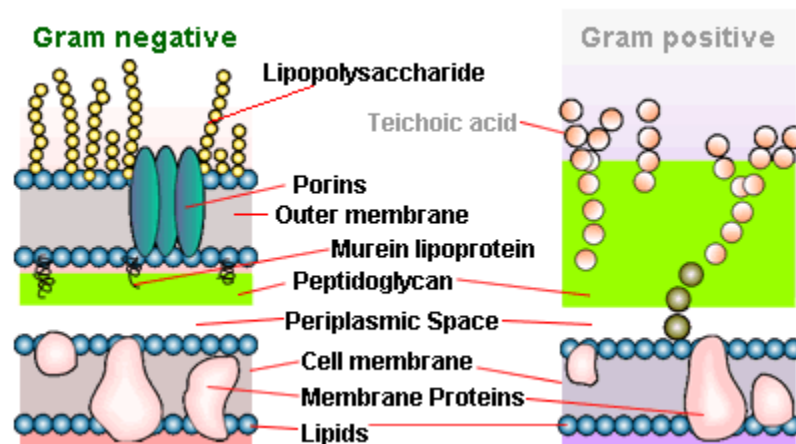
- A unique outer membrane
- A thin peptidoglycan layer
- Cytoplasmic membrane

### Special Components of Gram negative Bacteria

The special components of Gram negatives are:

- Outer membrane
- Murein lipoprotein
- Lipopolysaccharide (LPS) – has toxic properties

Unlike Gram positives, Gram negative cell envelopes have **a complex outer membrane**, which likely explains the resulting difference in the gram-stain process. Unlike Gram positives, the thin peptidoglycan layer does not contain a teichoic acid, but it does have a small, helical lipoprotein called **murein lipoprotein**. This lipoprotein is important because it starts in the peptidoglycan layer and extends outward to bind the unique third outer membrane. Another factor that adds to the complexity of the outer membrane is the presence of **lipopolysaccharides (LPS)**. Lipopolysaccharides are the major toxins of pathogenic Gram negative bacteria. When the cell dies, LPS are released and can cause problems with organs or tissues.



### Examples of Gram Negative Bacteria:

- *Treponema pallidum* - causes syphilis
- *Escherichia coli* - may cause severe gastrointestinal problems

## Classifying Bacteria by Cellular Respiration

We can also classify bacteria according to whether or not they need oxygen to survive.

- **Aerobic bacteria**, or **strict aerobes** - require oxygen
- **Anaerobic bacteria**, or **strict anaerobes** - cannot tolerate oxygen
- **Facultative anaerobics** – are generally aerobes, but have the capacity to grow in the absence of oxygen

### Examples of Bacteria Classified by Cellular Respiration:

- **Aerobic:**
  - *Bacillus cereus*
- **Anaerobic:**
  - *Clostridium* spp. ( botulism, tetanus)
- **Facultative anaerobes:**
  - *Staphylococcus* spp.

## Classifying Bacteria by Growth Factors

Bacteria can further be classified according to how they grow and metabolize. Under this scheme, they are generally classified according to:

- Energy source
- Nutrient source

### Energy Source

- **Chemotroph** – chemical compounds as an energy source (most pathogenic bacteria are chemotrophs.)
- **Phototroph** - light as energy source

### Nutrient Source

- **Heterotroph** – derive carbon from preformed organic nutrients such as sugar (most pathogenic bacteria are heterotrophs.)
- **Autotroph** – derive carbon from inorganic sources such as carbon dioxide

## Question 1 of 7

**Bacteria are among the most complex life forms.**

- A. True
- B. False

Submit Answer

## Question 2 of 7

**Energy processes in bacteria, fungi and higher eukaryotes may be similar.**

- A. True
- B. False

Submit Answer

### Question 3 of 7

**No bacteria can survive in the absence of oxygen.**

- A. True
- B. False

Submit Answer

## Question 4 of 7

**Bacteria are either aerobic or anaerobic.**

- A. True
- B. False

Submit Answer

## Question 5 of 7

**Teichoic acids are components of Gram Positive bacteria.**

- A. True
- B. False

Submit Answer

## Question 6 of 7

**Bacterial lipopolysaccharide (LPS) may be toxic to humans.**

- A. True
- B. False

Submit Answer

## Question 7 of 7

**Bacteria may contain the following:.**

- A. ribosomes
- B. mitochondria
- C. plasmids
- D. nuclei
- E. A & C
- F. A, B, & D

Submit Answer