

# Prokaryotes



## Prokaryotes have inhabited the Earth for billions of years

•Fossil evidence shows that prokaryotes were abundant 3.5 bya, and they evolved alone for the following 2 billion years.

•Prokaryotes are ubiquitous, numerous, and small, surviving in environments that are too hot, cold, acidic, salty, or alkaline for any eukaryotes

•Despite being small, prokaryotes influence all other life – as the cause of disease and other problems, as benign inhabitants of all other environments, and, more commonly, in beneficial relationships with all other living things.

•Probably the most essential activities carried out by prokaryotes are the numerous ways they function in the decomposition of dead remains.

## Archaea and bacteria are the two main branches of prokaryotic evolution

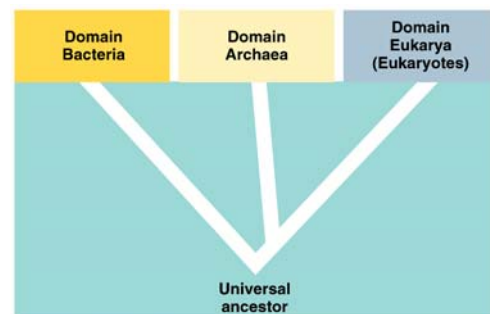
Main Features	Bacteria	Archaea
rRNA sequences	Many unique to bacteria	Many match eukaryotic ones
RNA polymerase	Relatively small and simple	Complex; similar to eukaryotic
Introns	Absent	Present in some genes
Antibiotic sensitivity	Inhibited	Not inhibited
Peptidoglycan in cell wall	Present	Absent
Membrane Lipids	Carbon chains unbranched	Carbon chains branched

•When viewed through a microscope, these two groups look similar.

•Many of these differences concern their nucleic acid.

•In most features archaea are more similar to eukaryotes than to bacteria.

•Currently, it is thought that modern archaea and eukaryotes evolved from a common ancestor.



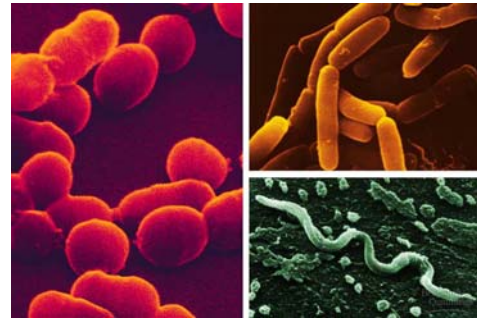
### Prokaryotes come in a variety of shapes

**Cocci** (singular, coccus) are spherical and often occur in defined groups of two or more. Those that occur in clusters are called staphylococci. Those that occur in chains are called streptococci.

**Bacilli** (singular, bacillus) are rod-shaped and usually occur singly. Diplobacilli occur in pairs and streptobacilli occur in chains.

**Vibrios** resemble commas.

**Spirilla** and **spirochetes** are spiral shaped. Spirilla are shorter and less flexible than spirochetes.



### Prokaryotes obtain nourishment in a variety of ways

- Modes of nutrition refer to how organisms obtain energy and carbon.

- **Autotrophs** are “self-feeders” that make carbon compounds from carbon in  $\text{CO}_2$  and the energy in sunlight (photoautotrophs) or inorganic compounds such as hydrogen sulfide (chemoautotrophs).

- Cyanobacteria are photoautotrophic prokaryotes that use  $\text{H}_2\text{O}$  as a source of electrons and release  $\text{O}_2$  as a waste product.

- **Heterotrophs** are “other-feeders” that make carbon compounds from the carbon in existing organic compounds and obtain energy from those same compounds (chemoheterotrophs) or from sunlight (photoheterotrophs).

- *E. coli* is an important chemoheterotroph that lives in the human intestine, that can live on simple sugars alone.

- With generation times as short as several hours or less, prokaryotic populations can multiply exponentially as long as there is a ready supply of nutrients.

### The first cells probably used chemicals for both carbon and energy

- One hypothesis holds that since they evolved in an energy-rich soup and since absorbing nutrients from the environment is chemically simpler than synthesizing them anew, the first organisms are most likely to have been heterotrophs.

- An early form of this chemoheterotroph met its energy needs by absorbing organic molecules, including ATP, from its surroundings. Such an organism would possess enzymes for processing organic compounds and releasing energy from ATP. Through time, enzymes that could use energy released from the breakdown of organic compounds and regenerate ATP from ADP evolved.

- Another, more likely, hypothesis assumes that little by way of organic molecules and ATP was available in the primordial organic soup. In this scenario, the organisms would have used  $\text{CO}_2$  as a carbon source. Energy would have been obtained by chemical reactions involving sulfur and iron compounds. Such an organism would have been a chemoautotroph that generated its ATP through a primitive form of chemiosmosis.

### Archaea thrive in extreme environments

- Extreme halophiles thrive in salty places such as the great salt lake.



- Some hyperthermophiles thrive in hot springs, even at temperatures above boiling (for example deep ocean vents). Other hyperthermophiles thrive in very low pH environments such as those found in the Yellowstone National Park.

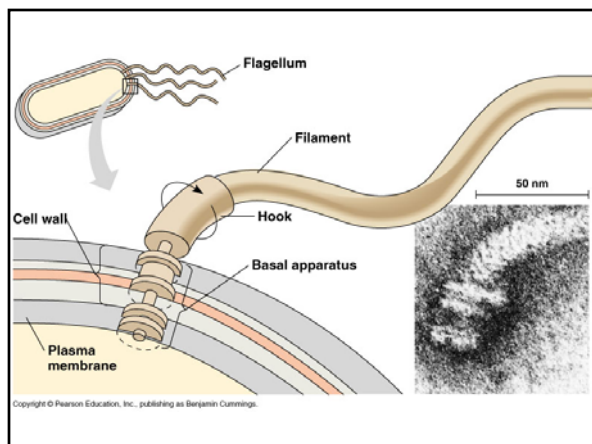


- The methanogens are a group of anaerobic, methane-producing bacteria that thrive in some vertebrates intestines and in the mud of swamps.

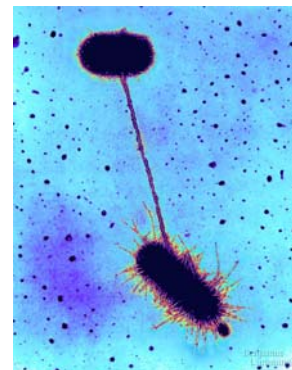
- The methanogens are the organisms responsible for the production of marsh gas and are a major contributor to flatulence in humans. Methanogens also digest cellulose in the gut of animals such as cattle and deer.

### Diverse structural features help prokaryotes thrive almost everywhere

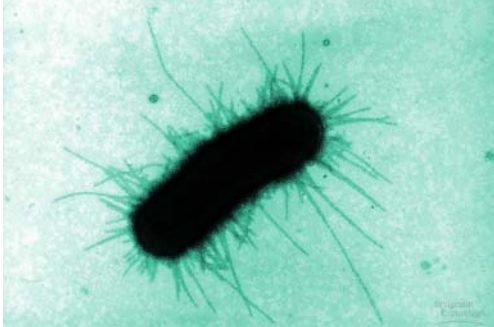
- The size, structure, and function of prokaryotic flagella differ from those aspects of eukaryotic flagella.
- Flagella can be either scattered over a cell or in bunches at one or both ends. They are composed of protein in two parts: external, nonmembrane-bounded filaments and rotating rings embedded in the plasma membrane and cell wall. Motion is produced as they spin on their axes like propellers.



- The role of sex pili is conjugation (transfer of DNA in bacteria).



- Pili are protein filaments thinner than bacterial flagella. Pili help bacteria stick to each other or to surfaces in their environments.



- Some bacteria can survive adverse environmental conditions by producing thick-walled endospores inside the parent cell walls around a replicated copy of DNA. Endospores are extremely resistant to decomposition and disintegration.



- An example of the toughness of endospores is illustrated by those of ***Clostridium botulinum***, a bacteria that grows in anaerobic, low-acid environments, such as poorly canned vegetables. The toxins released by colonies of this bacterium causes botulism when consumed by humans.

- Actinomycetes are constructed from branching filaments of cells. They are chemoheterotrophic soil bacteria that breakdown organic molecules. Some actinomycetes are commercial sources of antibiotics.

*i.e.-* Streptomycin from *Streptomyces* bacteria

#### Cyanobacteria sometimes “bloom” in aquatic environments

- Blooms are population explosions of microorganisms.
- Diseases can be caused by bacterial growth on, and destruction of, tissues, but they are more likely to be caused by the release of exotoxins (exotoxins are made of glycolipids) from growing bacteria or the presence of endotoxins on the surfaces (cell walls) of these bacteria.
- Staphylococcus aureus* is a normal skin bacterium, but when it grows inside a person, the exotoxins it produces can cause serious disease, such as toxic shock syndrome.

- Harmless bacteria can develop pathogenic strains. For example, ***E. coli** 0157:H7*, normally found in cattle, produces an exotoxin that causes bloody diarrhea and may even lead to kidney failure. The best prevention is to avoid uncooked meat.



- Species of *Salmonella* produce endotoxins that cause food poisoning and typhoid fever.
- Sanitation, the use of antibiotics, and education are three of our defenses against bacterial diseases.

•However antibiotic-resistant bacteria have evolved and are now a major health issue.

•The cause of Lyme disease, *Borrelia burgdorferi*, is caused by a tick and elicits a distinctive set of symptoms and potential disorders.



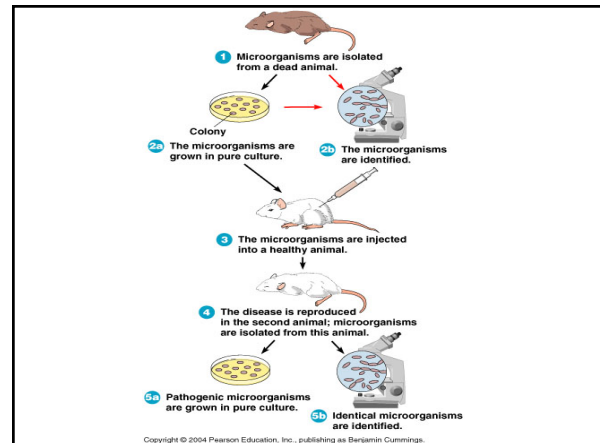
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### Koch's postulates are used to identify disease-causing bacteria

•Discovering the cause of disease is the first step in preventing or curing the disease.

•In 1876, Koch presented diagnostic criteria proving *Bacillus anthracis* to be the cause of anthrax: (a) The same pathogen must be found in each host. (b) The pathogen must be isolated into pure culture. (c) The original disease must be produced in new hosts inoculated with the culture. (d) The same pathogen must be reisolated from the new host.

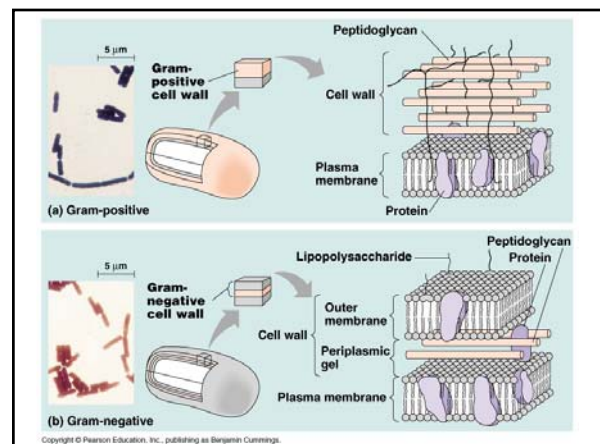
•For some pathogens, Koch's postulates cannot be used because the organism cannot be cultured outside the host. The cause of syphilis, the spirochete *Treponema pallidum*, is such organism, but the first postulate is true, and other evidence leaves no doubt that this bacterium is the cause of the disease.



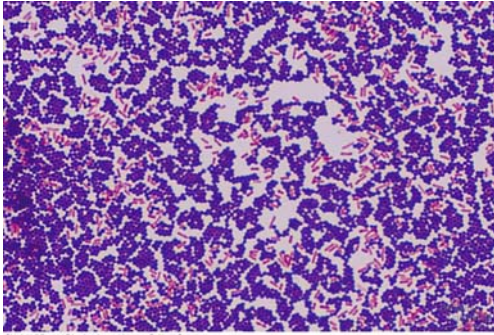
### Gram Stain

**Gram stain**- a staining method that distinguishes between two kinds of bacterial cell walls.

Gram-positive	Gram-negative
simple walls	complex walls
more peptidoglycan	less peptidoglycan
stain violet	stain red
no lipopolysaccharides	lipopolysaccharides (endotoxin)
	generally more threatening
	more resistant to host
	more resistant to antibiotics







#### Chemical cycles in our environment depend on prokaryotes

- Because of the variety of metabolic capabilities, prokaryotes play many beneficial roles in cycling elements among living and nonliving components of environments.
- Only prokaryotes are capable of nitrogen fixation, the conversion of  $N_2$  gas to nitrogen in amino acids. Important nitrogen fixers include many cyanobacteria and many chemoheterotrophs in the soil.
- Many plants depend on prokaryotes for nitrogen.

- The breakdown of organic wastes by decomposers is one of the most common beneficial roles of prokaryotes.

- Prokaryotic decomposers are part of aerobic and anaerobic communities of organisms functioning in sewage-treatment plants.

#### Prokaryotes may help us solve environmental problems

- Natural bacteria are encouraged, or recombinant strains are used to decompose away the remains of oil spills on beaches.
- The species of *Thiobacillus*, autotrophs that obtain energy from oxidizing ions in minerals, can be used to remove toxic metals from old mine and industrial waste sites. However, their use in this role is limited since their metabolism adds sulfuric acid to the water.

#### Prokaryotes are the foundation of life on Earth

- All life depends on prokaryotes, in both the evolutionary and an ecological sense
- Prokaryotes were not only the first producers of  $O_2$ , but were also the first organisms tolerant of increased levels of  $O_2$  in the atmosphere.
- Prokaryotes are extremely important in nutrient cycles of all kinds