Prokaryotes

Chapter 26

Why Three Domains?

✓ Living organisms can be divided into three domains: Bacteria, Archaea, and Eukarya. The prokaryotic Archaea and Bacteria differ from each other more radically than the Archaea from the Eukarya.

Why Three Domains?

✓ Evolutionary relationships of the domains were revealed by rRNA sequences. Their common ancestor lived more than 3 billion years ago, that of the Archaea and Eukarya at least 2 billion years ago. Review Figure 26.2 and Table 26.1

figure 26-02.jpg

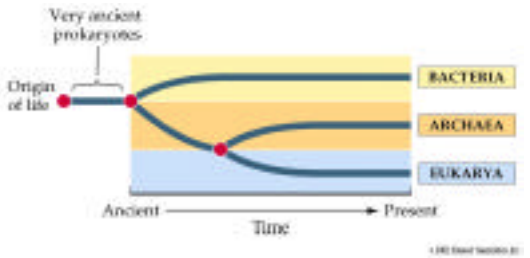
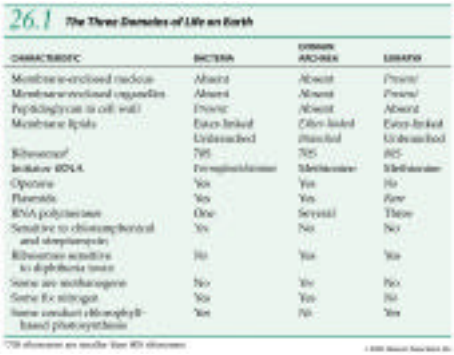


Figure 26.2

table 26-01.jpg



Microbe names

NAME OF MICROORGANISM	MEANING OF NAME
Entamoeba histolytica	Ent = intestinal, amoebae = shape and means of movement, histo = tissue, lytic = lysing, or digesting, tissue
Escherichia coli	Named after Theodor Escherich in 1888; found in the colon
Haemophilus ducreyi	Hemo = blood, phil = love; named after Augusto Ducrey in 1889
Neisseria gonorrhoeae	Named after Albert L. Neisser in 1879; causes the disease gonorrhea

Bacterium vs human taxonomy

TAXONOMIC CATEGORY	HUMAN	BACTERIUM THAT CAUSES SYPHILIS
Kingdom	Animalia	Monera (Prokaryotae)
Division/Phylum	Chordata	Gracilicutes
Subphylum	Vertebrata	
Class	Mammalia	Scotobacteria
Order	Primate	Spirochaetales
Family	Hominidae	Spirochaetaceae
Genus	Homo	Treponema
Specific epithet	sapiens	pallidum

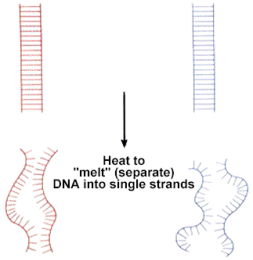
A dichotomous key

1a. Prokaryotic MONERA
1b. Eukaryotic see 2a
2a. Strictly unicellular PROTISTA
2b. Either uni-or multicellular see 3a
3a. Nutrition by photosynthesis PLANTAE
3b. Nutrition by absorption or ingestion see 4a
4a. Reproduce primarily sexually ANIMALIA
4b. Reproduce either sexually or asexually FUNGI

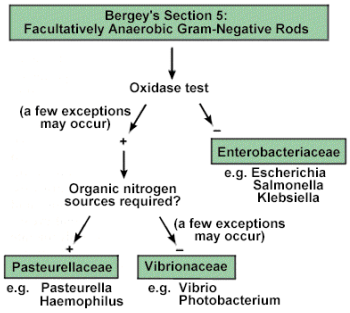
Bacterial Key

1a	Gram-positive	Go to 2
1b	Not gram-positive	Go to 3
2a	Cells spherical in shape	Gram-positive cocci
2b	Cells not spherical in shape	Go to 4
3a	Gram-negative	Go to 5
3b	Not gram-negative (lack cell wall)	Mycoplasma
4a	Cells rod-shaped	Gram-positive bacilli
4b	Cells not rod-shaped	Go to 6
5a	Cells spherical in shape	Gram-negative cocci
5b	Cells not spherical in shape	Go to 7
6a	Cells club-shaped	Corynebacteria
6b	Cells variable in shape	Propionibacteria
7a	Cells rod-shaped	Gram-negative bacilli
7b	Cells not rod-shaped	Go to 8
8a	Cells helical with several turns	Spirochetes
8b	Cells comma-shaped	Vibrioids

DNA hybridization



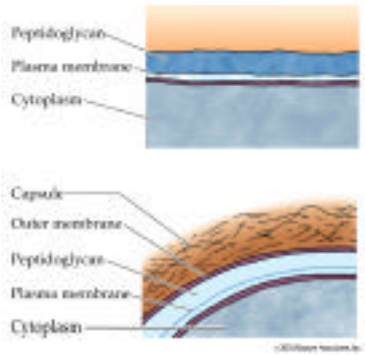
Bergey's manual



The Prokaryotes

- ✓ Most numerous organisms on Earth,occupying an enormous variety of habitats.
- ✓ Most prokaryotes are cocci, bacilli, or spiral forms. Some link together to form associations, but very few are truly multicellular.
- ✓ Prokaryotes lack nuclei, membrane-enclosed organelles, and cytoskeletons. Their chromosomes are circular. They often contain plasmids. Some contain internal membrane systems.
- ✓ Many prokaryotes move by means of flagella, gas vesicles, or gliding mechanisms. Prokaryotic flagella rotate.
- ✓ Prokaryotic cell walls differ from those of eukaryotes. Bacterial cell walls generally contain peptidoglycan. Differences in peptidoglycan content result in different reactions to the Gram stain.

figure 26-07.jpg



The Prokaryotes

- ✓ Prokaryotes reproduce asexually by fission, but also exchange genetic information.
- ✓ Prokaryotes' metabolic pathways and nutritional modes include obligate and facultative anaerobes, and obligate aerobes. Nutritional types include photoautotrophs, photoheterotrophs, chemoautotrophs, and chemoheterotrophs. Some base energy metabolism on nitrogen- or sulfur-containing ions.

figure 26-08.jpg

Figure 26.8

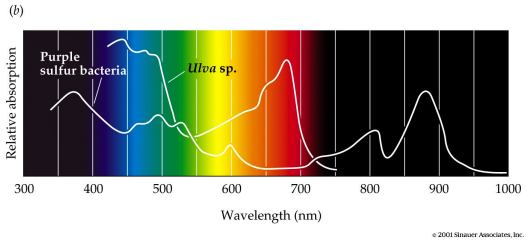


Figure 26.8

table 26-02.jpg

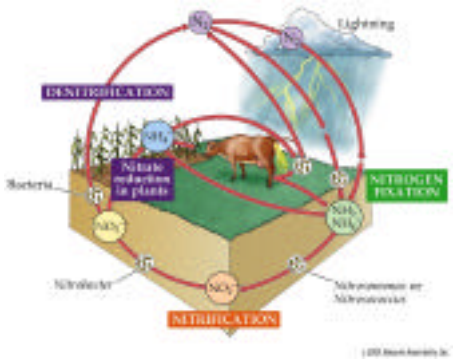
Table 26.2

26.2 How Organisms Obtain Their Energy and Carbon

NUTRITIONAL CATEGORY	ENERGY SOURCE	CARBON SOURCE
Photoautotrophs	Light	Carbon dioxide
Photoheterotrophs	Light	Organic compounds
Chemoautotrophs	Inorganic substances	Carbon dioxide
Chemoheterotrophs	Organic compounds	Organic compounds

figure 26-10.jpg

Figure 26.10



Prokaryotes in Their Environments

- ✓ Some prokaryotes play key roles in global nitrogen and sulfur cycles. Nitrogen fixers, nitrifiers, and denitrifiers do so in the nitrogen cycle.
- ✓ Photosynthesis by cyanobacteria generated the oxygen gas that permitted the evolution of aerobic respiration and the appearance of present-day eukaryotes.
- ✓ Many prokaryotes live in or on other organisms, with neutral, beneficial, or harmful effects.
- ✓ A minority of bacteria are pathogens. Some produce endotoxins, which are rarely fatal; others produce often highly toxic exotoxins.

Prokaryote Phylogeny and Diversity

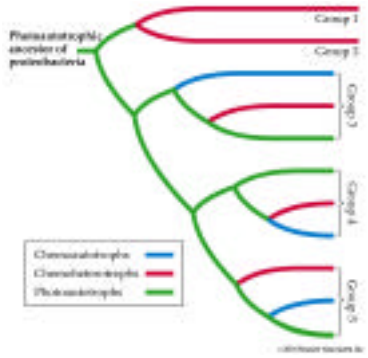
- ✓ Phylogenetic classification of prokaryotes is based on rRNA sequences and other molecular evidence.
- ✓ Lateral gene transfer among prokaryotes makes it difficult to infer prokaryote phylogeny.
- ✓ Evolution can proceed rapidly in prokaryotes because they are haploid and can multiply rapidly.

The Bacteria

- ✓ There are far more known bacteria than archaea. One phylogenetic classification of the domain Bacteria groups them into over a dozen groups.
- ✓ The most ancient bacteria, like the most ancient archaea, may be thermophiles, suggesting that life originated in a hot environment.
- ✓ All four nutritional types occur in the Proteobacteria. Metabolism in different proteobacteria groups has evolved along different lines.

Figure 26.12

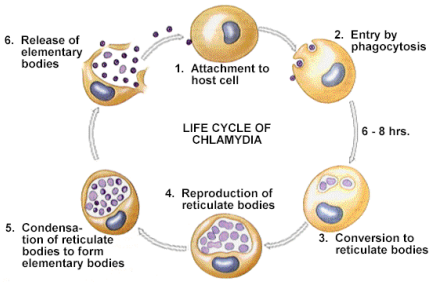
figure 26-12.jpg



The Bacteria

- ✓ Cyanobacteria, unlike other bacteria, photosynthesize using the same pathways plants use. Many fix nitrogen.
- ✓ Spirochetes move by means of axial filaments.
- ✓ Chlamydias are tiny parasites that live within the cells of other organisms.
- ✓ Firmicutes are diverse; some produce endospores, resting structures resistant to harsh conditions. Some actinomycetes produce important antibiotics. Actinomycetes grow as branching filaments.
- ✓ Mycoplasmas, the tiniest living things, lack conventional cell walls and have very small genomes.

Rickettsiae and Clamydiae present special problems



The Archaea

✓ Archaea cell walls lack peptidoglycan, and their membrane lipids contain branched long-chain hydrocarbons connected to glycerol by ether linkages.

Eubacteria vs Archaeabacteria

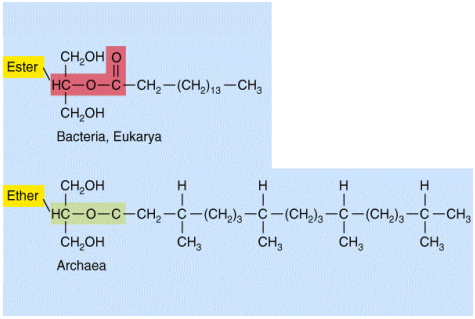
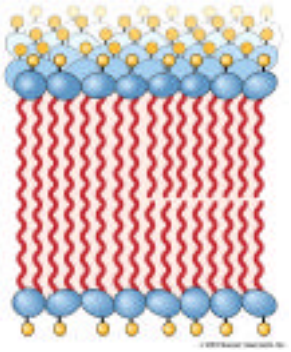
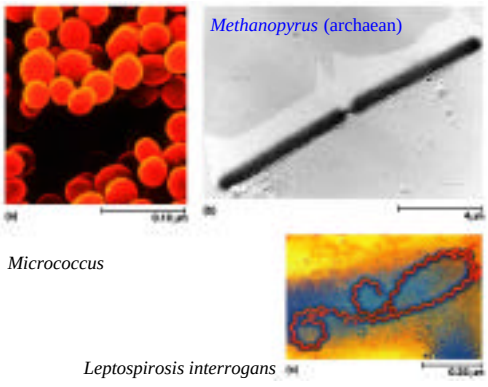


figure 26-22.jpg

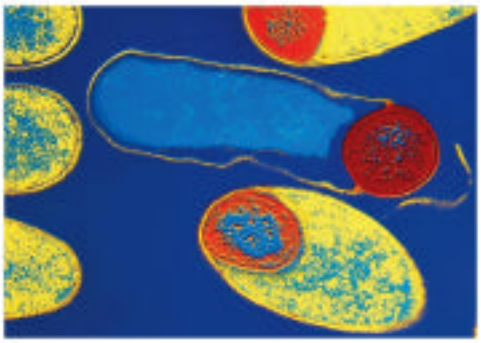


The Archaea

- ✓ The domain Archaea can be divided into two kingdoms: Crenarchaeota and Euryarchaeota.
- ✓ Crenarchaeota are heat-loving and often acid-loving archaea.
- ✓ Methanogens produce methane by reducing carbon dioxide. Some live in the guts of herbivorous animals; some in high-temperature environments on the ocean floor.
- ✓ Extreme halophiles are salt lovers that lend a pinkish color to salty environments; some grow in extremely alkaline environments.
- ✓ Archaea of the genus Thermoplasma lack cell walls, are thermophilic and acidophilic, and have a tiny genome (1,100,000 base pairs).

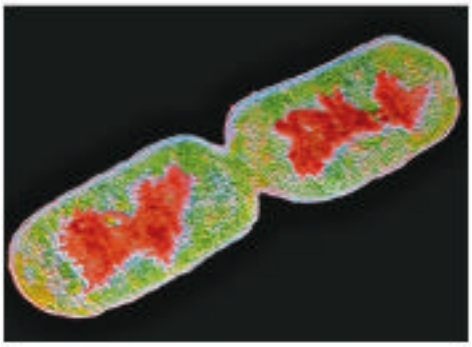


Clostridium endospores

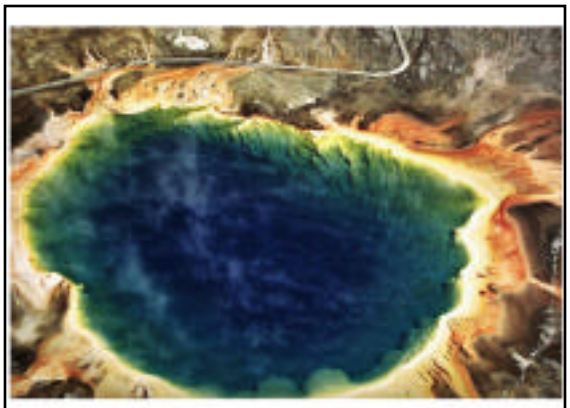


Aqiofex (archaean)

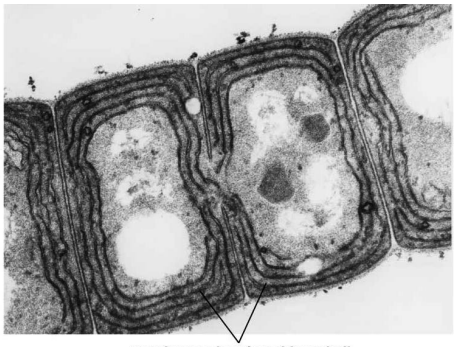
Binary fission



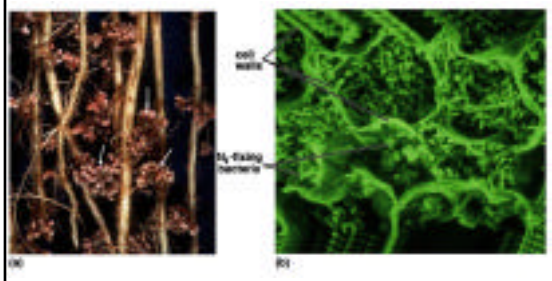
Conjugation



Oscillatoria (chlorophyll in membranes)



Nitrogen fixing bacteria



Halobacteria

Thermophilic

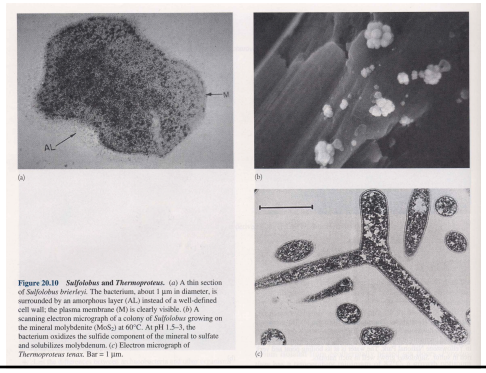
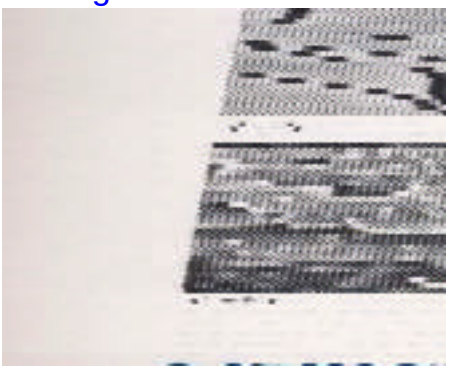
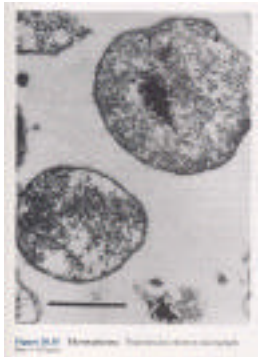


Figure 20.10 *Sulfolobus* and *Thermoproteus*. (a) A thin section of *Sulfolobus brierleyi*. The bacterium, about 1 µm in diameter, is surrounded by an amorphous layer (AL) instead of a well-defined cell wall; the plasma membrane (M) is clearly visible. (b) A scanning electron micrograph of a colony of *Sulfolobus* growing on the mineral molybdenite (MoS_2) at 60°C. At pH 1.5–3, the bacterium oxidizes the sulfide component of the mineral to sulfate and solubilizes molybdenum. (c) Electron micrograph of *Thermoproteus tenax*. Bar = 1 µm.

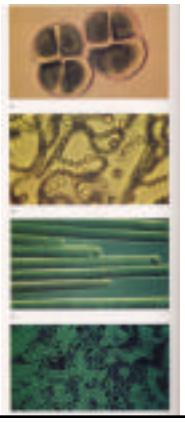
Methanogenic



Thermoplasma



Cyanobacteria



Infection

- ✓ Multiplication of any parasitic organism within the host's body.
- ✓ Infestation is often used with macroscopic organisms.

How do bacteria make us ill

- ✓ Pathogens
  - ✒ Invade
  - ✒ Attach and multiply
  - ✒ Produce toxins
    - ☞ Endotoxins
    - ☞ Exotoxins
  - ✒ Resist host defenses.
  - ✒ Damage the host.

Pathogenicity

- ✓ The capability of an organism to cause a disease or to establish an infection.
  - ✒ Characteristics of the organism.
  - ✒ Ability of host to resist infection.
- ✓ Primary pathogens infect healthy individuals.

Virulence

- ✓ The degree of the ability of a pathogen to cause a disease.
- ✓ Virulence factors are properties of the organism that enhance its pathogenicity.

Virulence factors

- ✓ Help the pathogen cause the disease or aid in the infection process.
  - ✒ Toxins
  - ✒ Extracellular enzymes
  - ✒ Cellular factors

Toxins

- ✓ Toxins have a damaging effect on cells and tissues of the host.
  - ✒ Exotoxins are secreted into environment surrounding the pathogen.
  - ✒ Endotoxins are part of the cell.

Exotoxins

- ✓Proteins.
- ✓Produced by either Gram positive or Gram negative bacteria.
- ✓Highly specific effect on host.
- ✓Can be destroyed by heat or chemically.
- ✓Form toxoids.
- ✓Stimualte the production of antitoxins.

Endotoxins

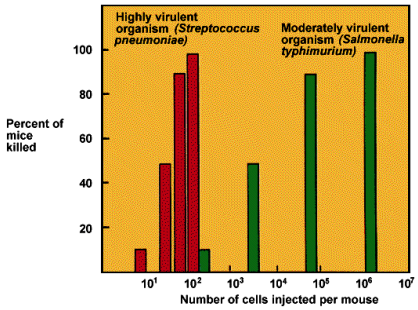
- ✓Usually endotoxins are components of the outer membrane.
- ✓Gram negative bacteria only.
- ✓Polysaccharides.
- ✓Very heat-stable
- ✓Do not produce toxoids.
- ✓Often associated with fever and shock.

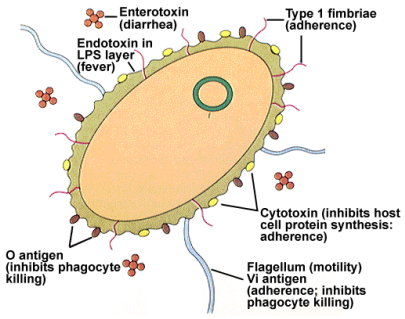
Extracellular enzymes

- ✓Role in the infection process, particularly *invasiveness*.
  - ✒Penetration with hyaluridonase.
  - ✒Lecithinase lyses tissue cells.
  - ✒Coagulase transforms fibrinogen into fibrin.
  - ✒Hemolysins lyse red blood cells.

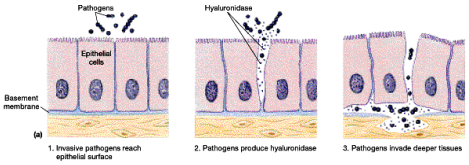
Cellular factors

- ✓Capsules prevent phagocytosis by white blood cells.
- ✓Pili aid in adherence to host cell surfaces.

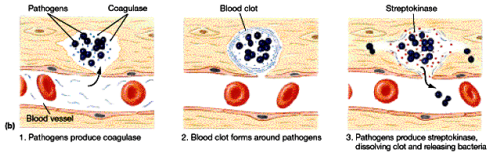




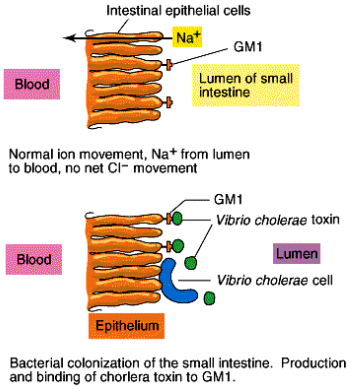
Hyaluronidase

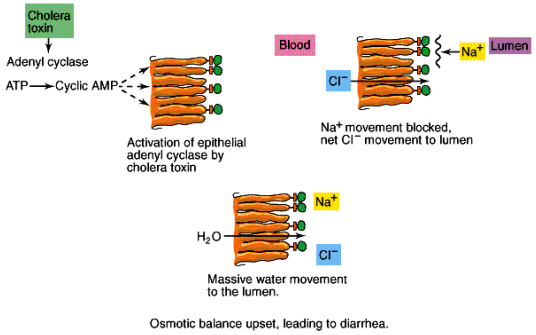


Coagulase



Chorlera toxin

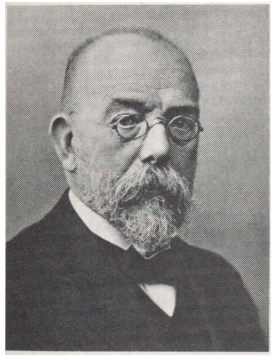




1876 - Robert Koch

✓ First to isolate and identify *B. anthracis* as the cause of anthrax

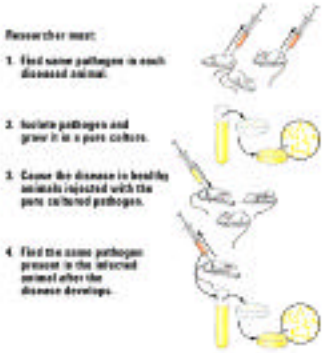
- ✒German Doctor
- ✒Country practice
- ✒Worked in his home
- ✒Transmitted the disease through 20 mice



Koch's postulates

1. A specific microorganism must be found in ever case of the disease.
2. The microorganism must be isolated and grown in pure culture (laboratory).
3. If introduced into a susceptible host the host will develop the disease.
4. The infectious microorganism must be recovered from the host and grown in the laboratory.

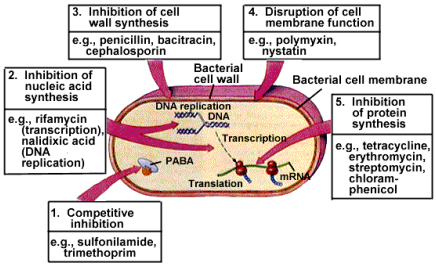
Koch's Postulates



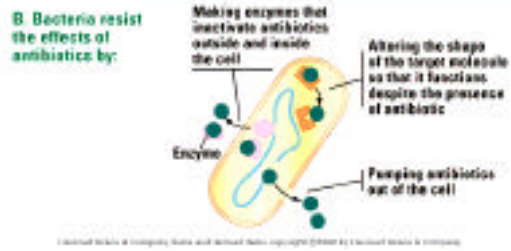
Modes of Action

- ✓Inhibition of cell wall synthesis
- ✓Disruption of cell membrane
- ✓Inhibition of protein synthesis
- ✓Inhibition of nucleic acid synthesis
- ✓Action of antimetabolites

Modes of action

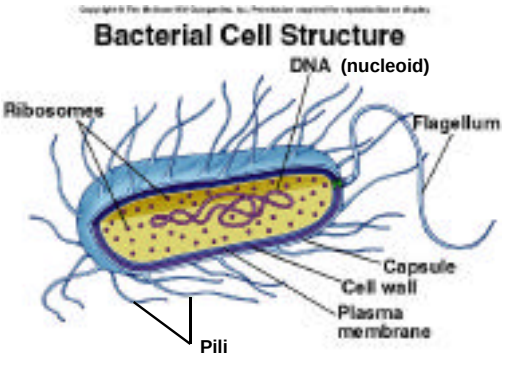


Bacterial resistance

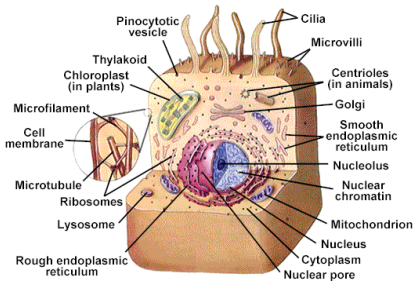


Prokaryote vs. eukaryote

- ✓Prokaryotic cells lack both a membrane-bound nucleus and membrane-bound organelles.
  - ✒Bacteria and cyanobacteria
- ✓Eukaryotic cells are much more complex, containing a membrane-bound nucleus and membrane-bound organelles.
  - ✒Animals, plants, protists, fungi

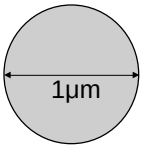


Eukaryotic cell

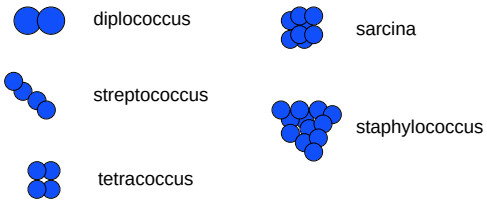


Cocci

One coccus, many cocci.

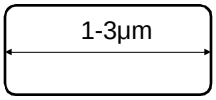


Arrangements of cocci

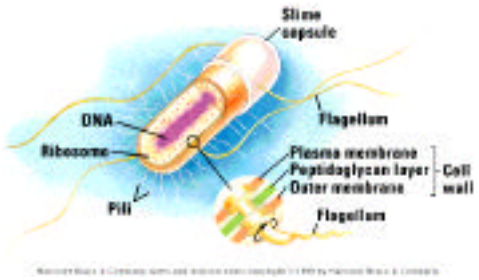


Bacilli

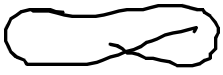
One bacillus, many bacilli.



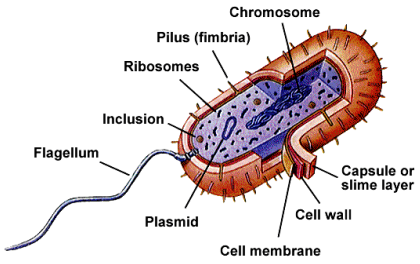
Familiar shape of the bacillus



Spirals

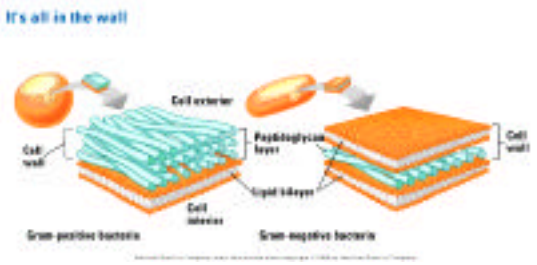


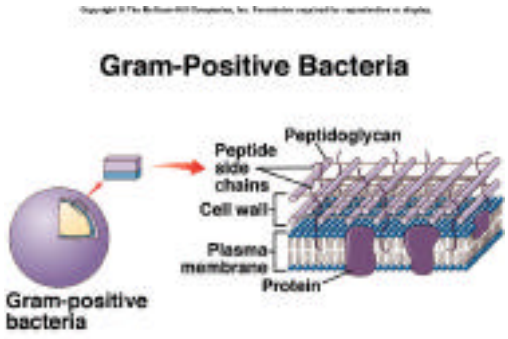
Prokaryotic cell

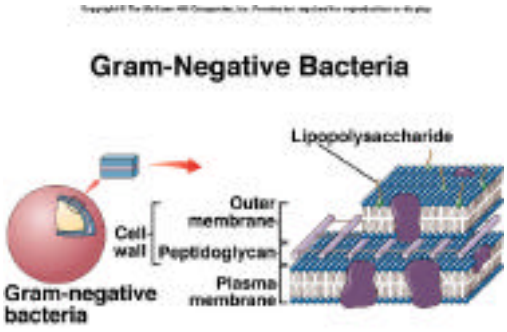


Key structural differences exist between Gram positive and Gram negative bacteria.

Gram + vs. Gram -







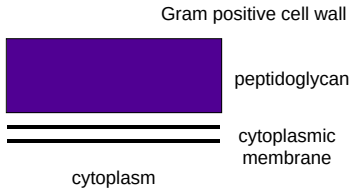
Gram stain

✓1. Crystal violet
✓2. Iodine
✓3. Alcohol rinse
✓4. Safranin

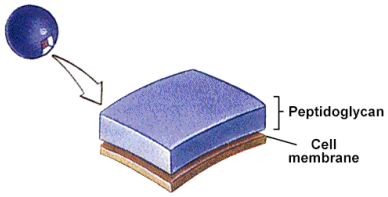
Gram reaction

✓ Step	Positive	Negative
✓ Crystal violet		
✓ Iodine		
✓ Alcohol		
✓ Safranin		

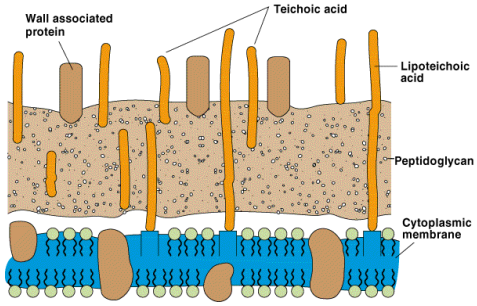
Gram positive



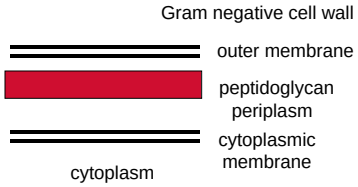
Gram (+)



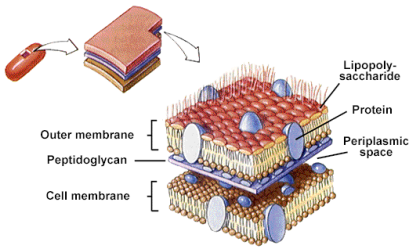
Gram (+) cell wall



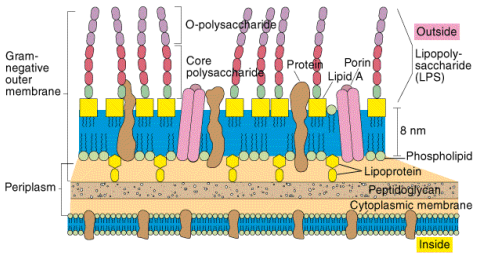
Gram negative



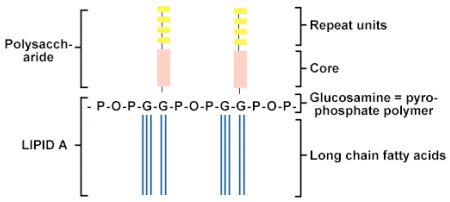
Gram (-)



Gram (-) cell wall

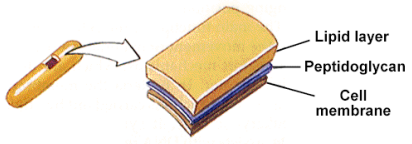


Lipopolysaccharide (endotoxin)



Acid fast bacteria

Carbolfuchsin gets into the cytoplasm and resists decoloration by the acid alcohol



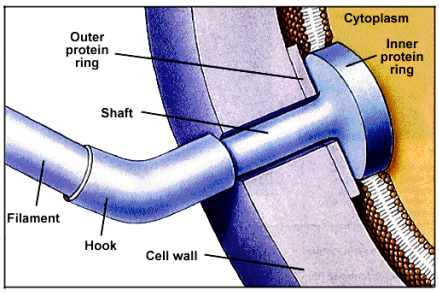
Bacterial internal structures

- ✓Nucleoid (nuclear region)
  - ✒Circular dsDNA
  - ✒Plasmids
    - ☞Small extrachromosomal circular DNA
- ✓Ribosomes
    - ☞70s ribosome verses 80s for eukaryotes
- ✓Cytoplasm
- ✓Endospores

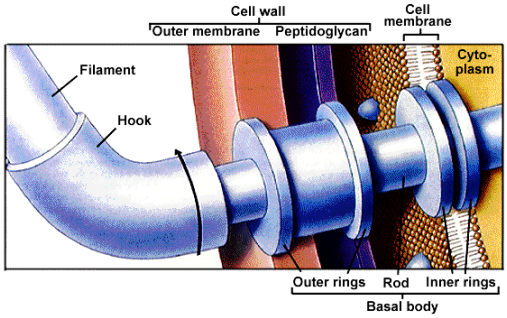
External structures

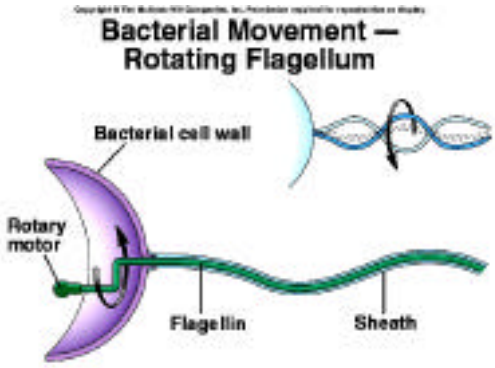
- ✓Flagella (motility)
  - ✒Polar -- on the end
    - ☞Monotrichous -- one on the end
    - ☞Amphitrichous -- one on each end
    - ☞Lophotrichous -- more than one on one or both ends
  - ✒Peritrichous -- all over the surface of the cell
  - ✒Atrichous -- no flagella
- ✓Capsule/slime layer -
    - ☞Prevent phagocytosis, dehydration,
    - ☞Teeth- dental plaque

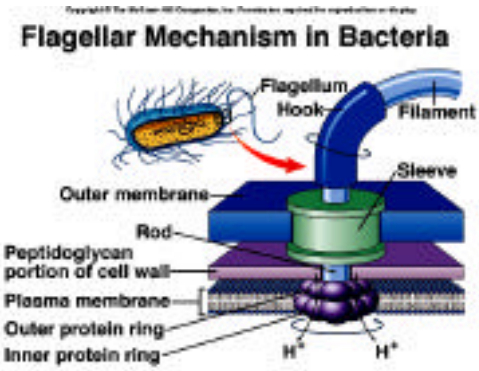
Flagellum in Gram (+)



Flagellum in Gram (-)

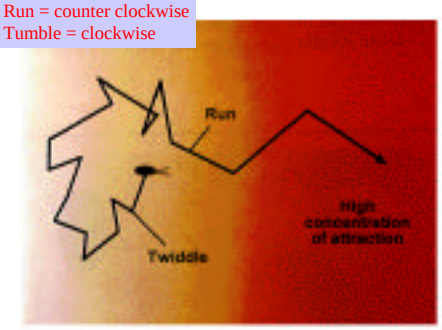


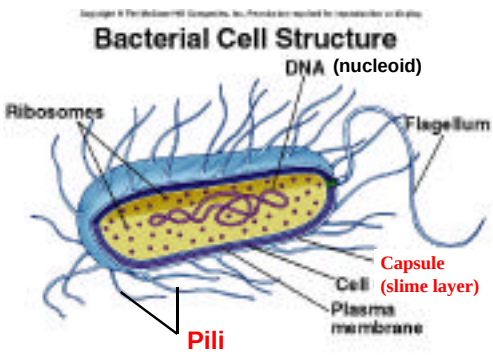




Chemotaxis

Run = counter clockwise
Tumble = clockwise





Bacterial growth

✓ *E. coli* can divide every 20 minutes

✓ Logarithmic growth

- 10 hours
- 30 divisions
- 2^{30} = 1.1 x 10^9 cells

Carbon source

- ✓Autotrophs
  - ✒Use inorganic C, mainly CO_2, as a C source.
- ✓Heterotrophs
  - ✒Use organic C as a C source

Energy source

- ✓Phototrophs
  - ✒Use light as an energy source.
- ✓Chemotrophs
  - ✒Use organic or inorganic compounds as energy sources.

Carbon and Energy Sources

	carbon source	energy source
chemoautotrophs	CO_2	inorganic molecules
chemoheterotrophs	organic molecules	organic molecules
photoautotrophs	CO_2	light
photoheterotrophs	organic molecules	light

Oxygen use

- ✓Obligate aerobes
  - ✒Require oxygen
- ✓Facultative aerobes
  - ✒Grow with or without oxygen
- ✓Obligate anaerobes
  - ✒No oxygen - oxygen is deadly

Aerobic heterotrophs

- ✓Nitrogen-fixing bacteria
  - ☞Fix nitrogen into usable compounds
- ✓Pseudomonads
  - ☞Diverse group - soil, plants, hot tubs, ponds
- ✓Omnibacteria
  - ☞*E. coli* - can use NO_3^- as an electron acceptor instead of oxygen
- ✓Actinobacteria
  - ☞Filamentous bacteria
- ✓Myxobacteria
  - ☞Gliding or fruiting bacteria

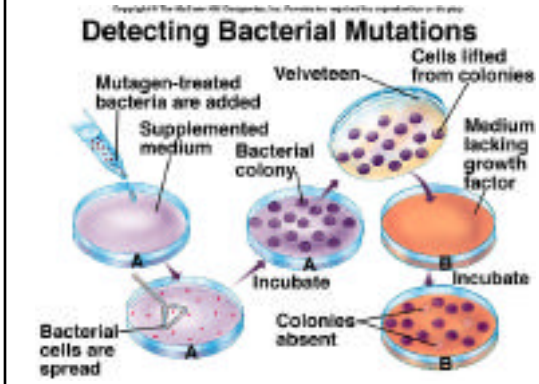
Anaerobic hetrotrophs

- ✓Fermenting bacteria
- ✓Spirochetes

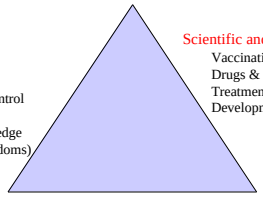
The autotrophs

✓Chemoautotrophs
- ✒Photosynthesis without oxygen

✓Photoautotrophs
- ✒Anaerobic photosynthetic bacteria
- ✒Cyanobacteria
- ✒Chloroxybacteria



The Disease Control Triangle



Public Sanitation
- Water purification
- Sewage treatment
- Quarantine
- Mosquito/rodent control
- Garbage disposal
- Disseminate knowledge (sterile needles/condoms)

Scientific and Medical Research
- Vaccinations
- Drugs & antibiotics
- Treatment protocols
- Development knowledge

Personal Hygiene and Behavior
- become informed, and act accordingly to avoid disease, and if infected take advantage of available resources