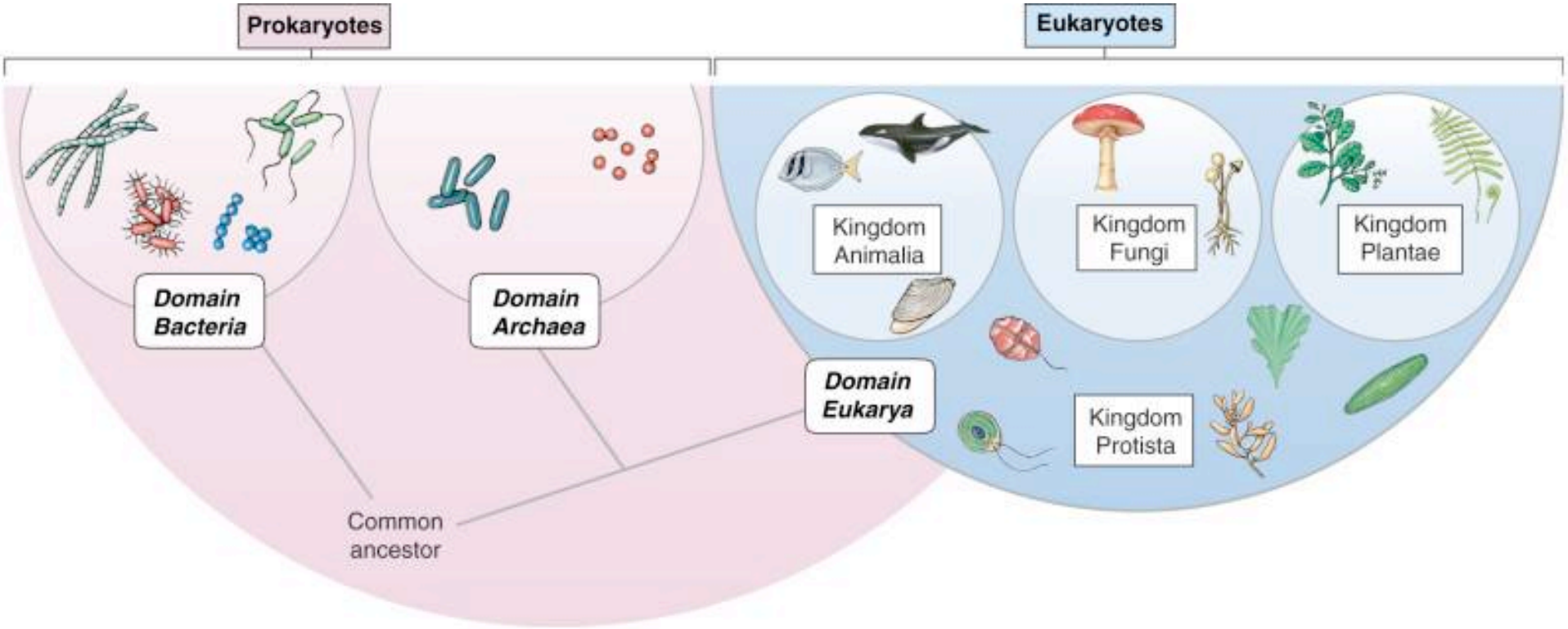
Diversity of Prokaryotic Life

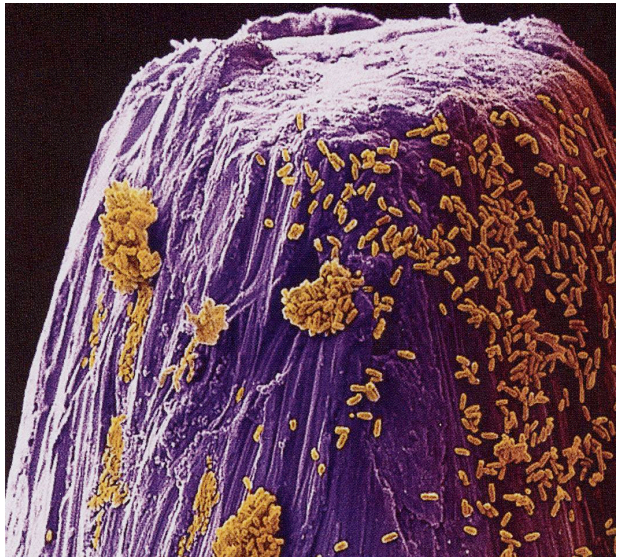
Domains:

Bacteria & Archaea

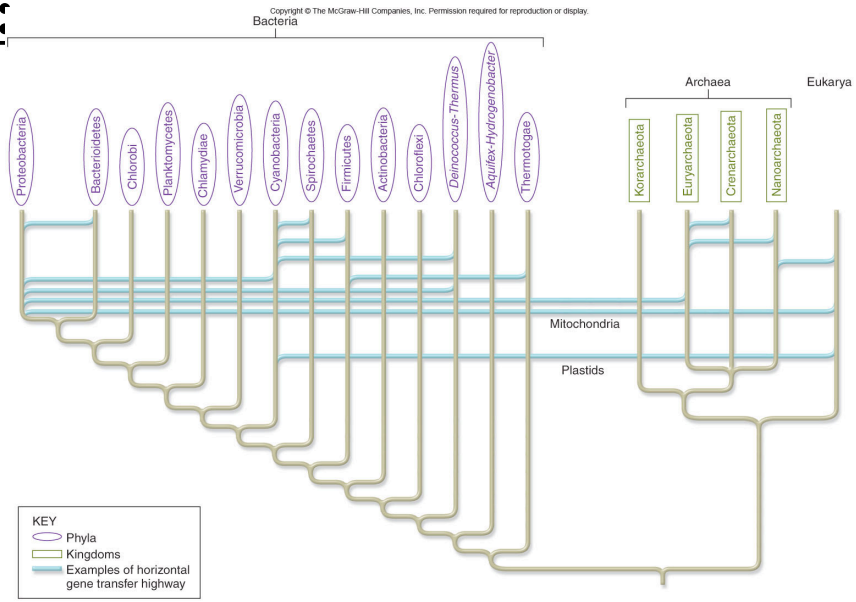


Prokaryotes

- **Commonly refered to as "bacteria"**
- **> 5,000 species**
- **Prokaryotic cells**



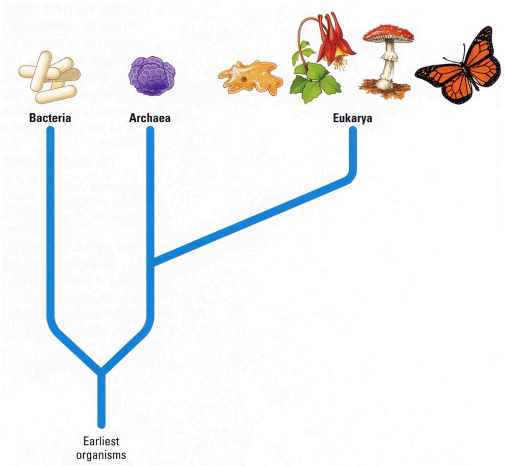
2 Domains: ***Bacteria*** ***Archaea***



Domains of prokaryotes are divided into clades (not kingdoms or phyla)

Clade = single common ancestor & all descendents

Phylogeny



3 Domains of Life

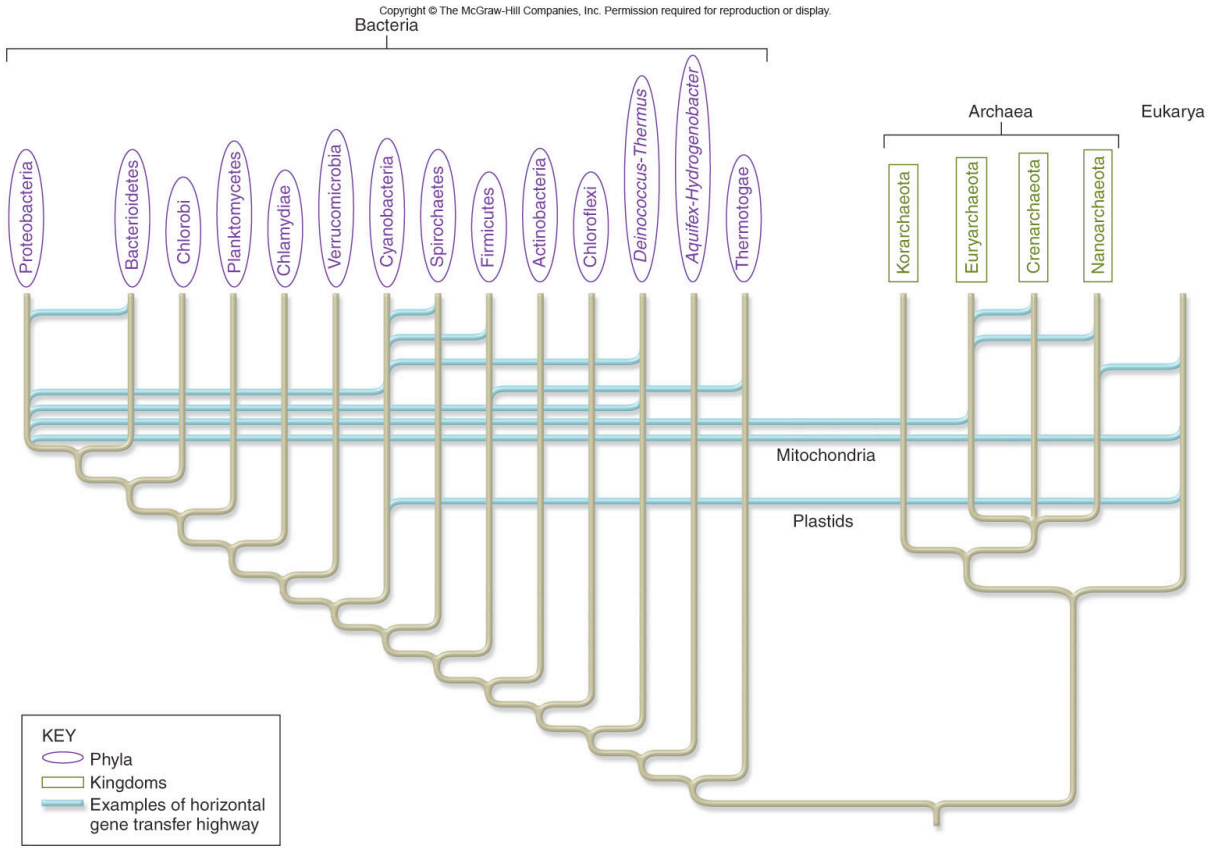
Based on nucleotide sequences of rRNA

- **2 Domains of prokaryotes**
  - *Similarities* -> they share a common ancestor
  - *Differences* -> distinct 2 lineages of prokaryotes

- Eukarya is more closely related to Archaea than it is to Bacteria

- 3 clades (domains) indicate separate evolutionary histories
  = "Vertical evolution" (genetic change over time in lineages)

- Some gene transfer occurred between domains
  = "Horizontal evolution" (new genes from another species)

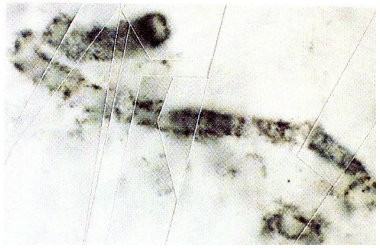


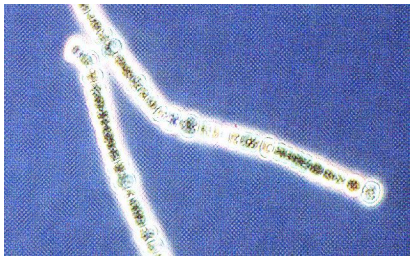
Prokaryotes were the earliest life forms

Dominated earth from 3.5-2 billion years ago

Oxygen generating cyanobacteria evolved 2.7 bya

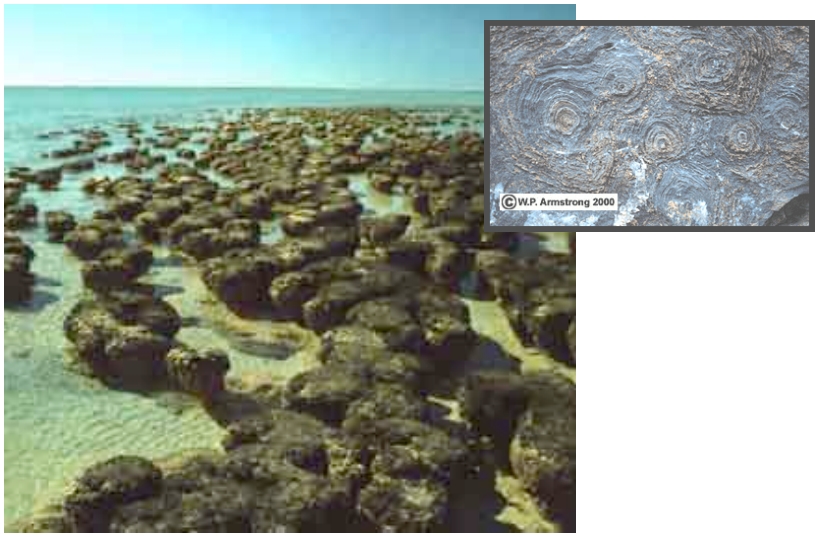
Fossil cyanobacteria

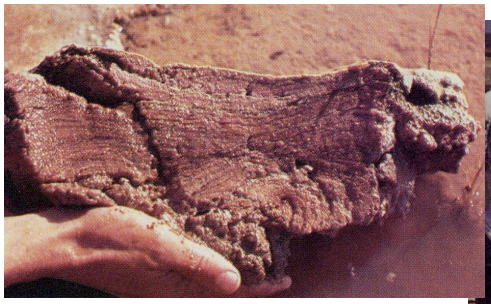


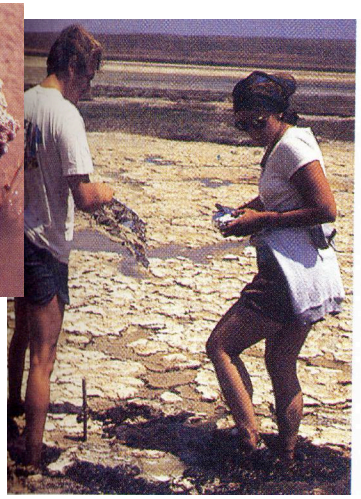


Living cyanobacteria

Oldest fossils: Stromatolites
= "mats"of photosynthetic bacteria



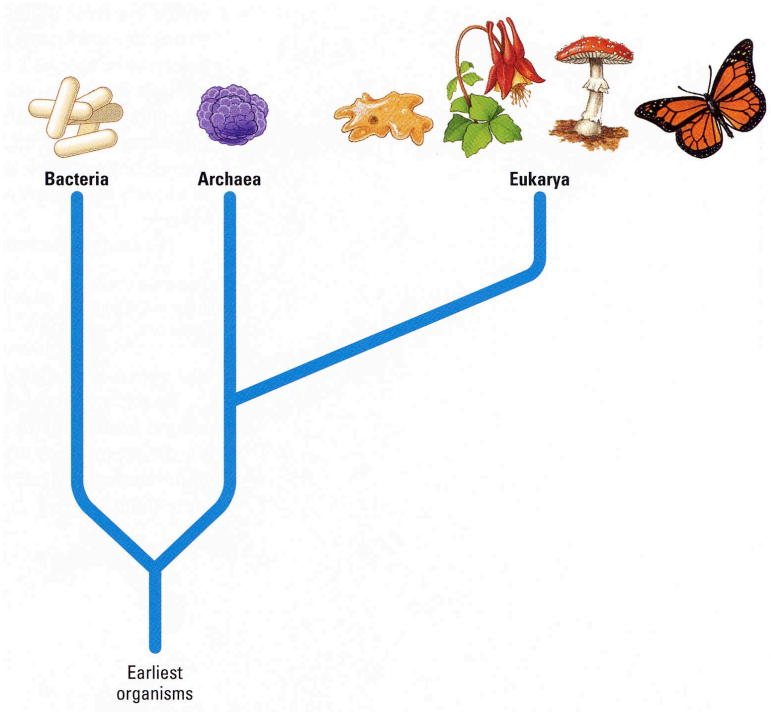




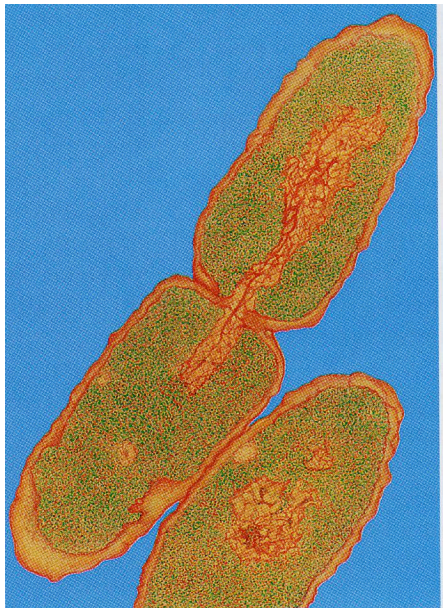
Bacterial mats

Layers of sediments
& sticky prokaryotes

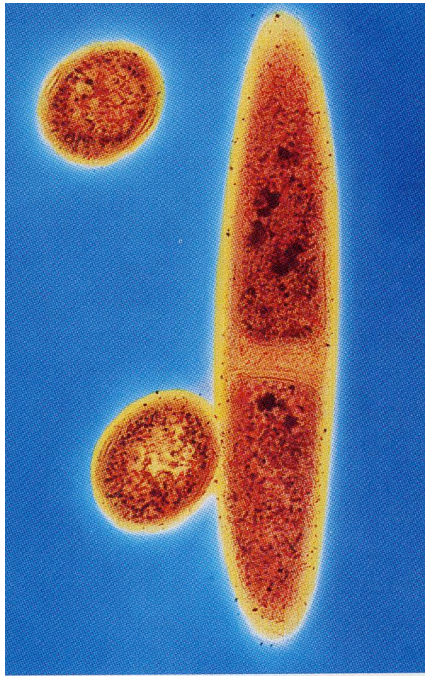
Similarities in cell structure



Unicellular Prokaryotes



Bacteria

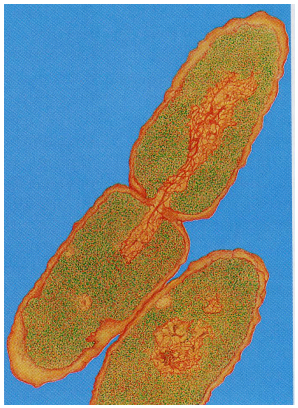


Archaea

Characteristics of Prokaryotic Cells

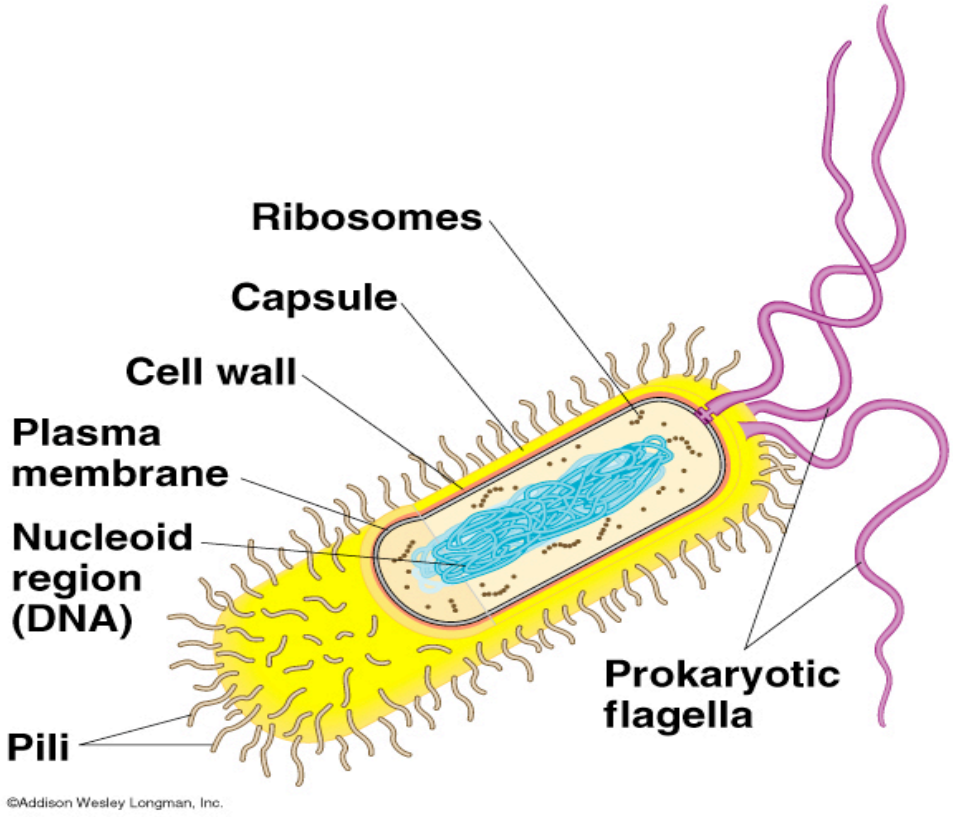
- Cell walls present
- 1-2 plasma membranes
- Circular chromosome
- Ribosomes in cytoplasm
- Plasmids

- Pili
- Capsule
- Some have flagella
- Some have internal membranes



Small cells (1-10 um)

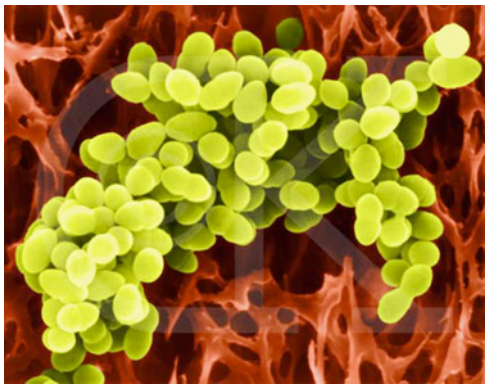
- No nuclear membrane
- No organelles



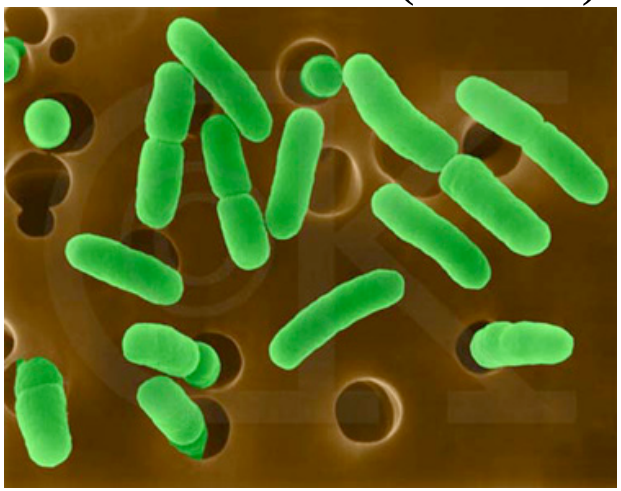
Morphology of Prokaryotes

4 cell shapes

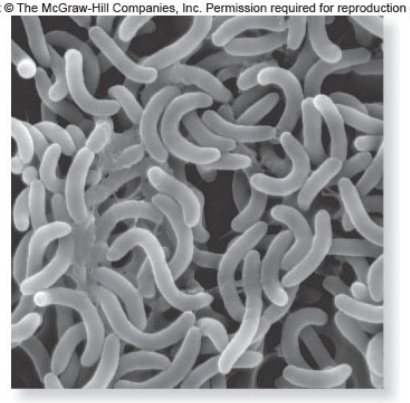
Spherical: coccus (cocci)



Rods: bacillus (bacilli)

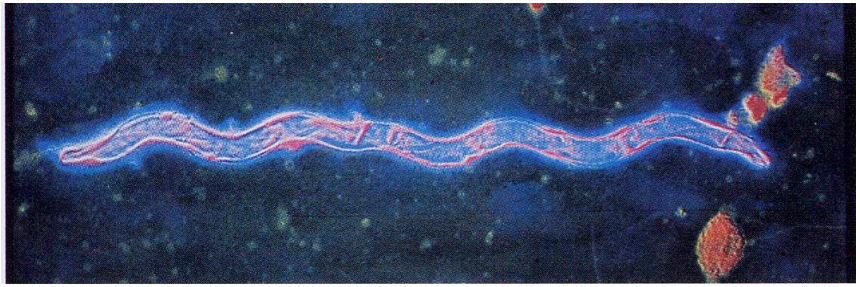


Comma: Vibrios

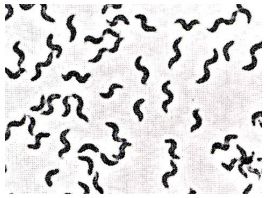


Dennis Kunkel Microscopy, Inc.

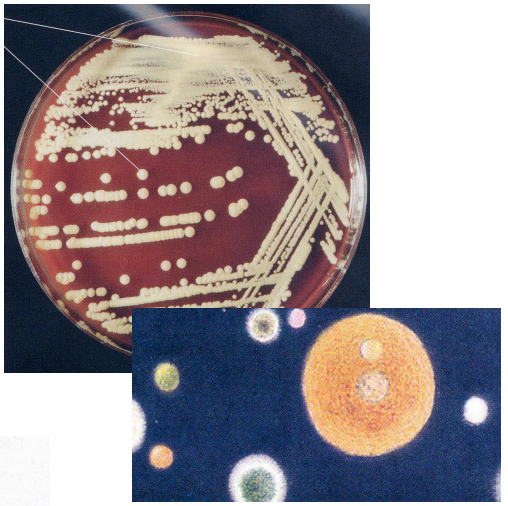
Spiral: Spirochaetes



Bacteria may live singly



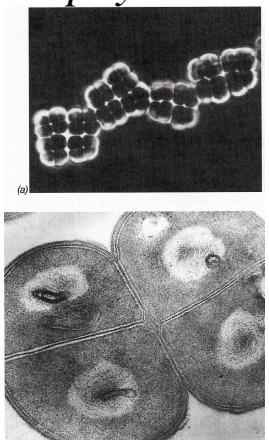
Bacteria colonies



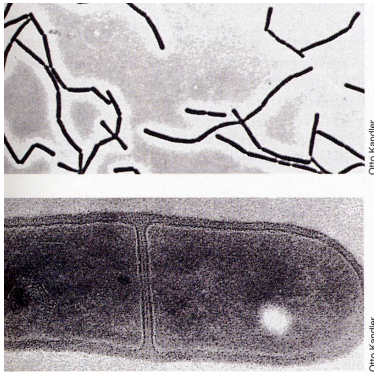
Some bacteria live in groups

Independent cells weakly held together

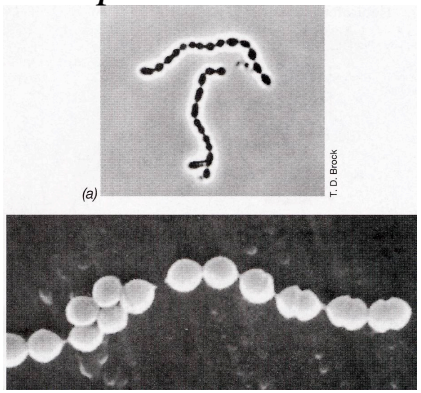
Staphylococcus

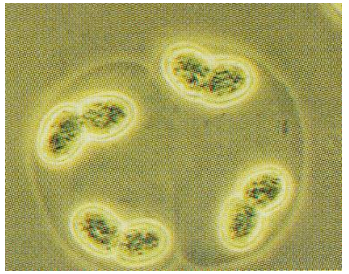


Lactobacillus



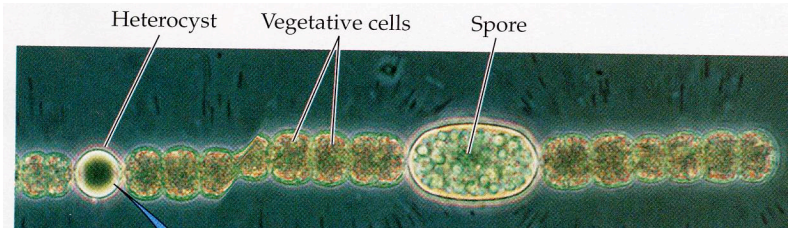
Streptococcus





Cyanobacteria filaments

- Long chains of cells
- Division of labor in some cells



Reproduction in prokaryotes

No sexual reproduction

- **no meiosis, gametes or gamete fusion**

Binary fission - Asexual reproduction

Produces 2 clone cells

1 cell divides:
2 identical cells

- **Mutation is main source of genetic variation**
- **Short generation time**
- **Rapid population growth**
- **Rapid evolution & adaptation**

Lateral (horizontal) gene transfer

Genes received from phages, other cells & environment

Oxygen & prokaryotes

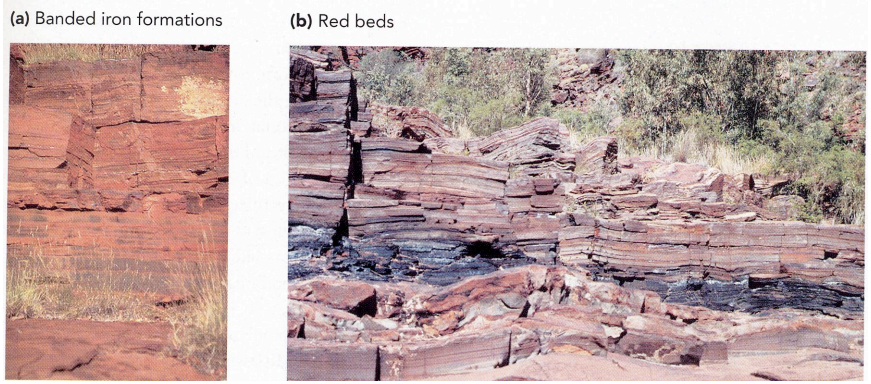
- **Obligate aerobes** - need O_2
- **Obligate anaerobes** - need environments without O_2
  - sulfur bacteria in mud
- **Facultative anaerobes** - can live in either habitat
  - Ex: *E. coli*

Early bacteria were anaerobic - why?

Cyanobacteria & the Oxygen Revolution (2 bya)

Iron oxides in sediments: evidence of free oxygen

- **Oceans: Iron formations**
- **Land: Red beds**



Basic metabolic requirements

All organisms need a constant supply of energy & nutrients

Energy source (to make ATP molecules)

Phototrophs - energy from sunlight

Chemotrophs - energy from molecules in environment

Nutrients (Carbon source)

Carbon is needed to make organic molecules

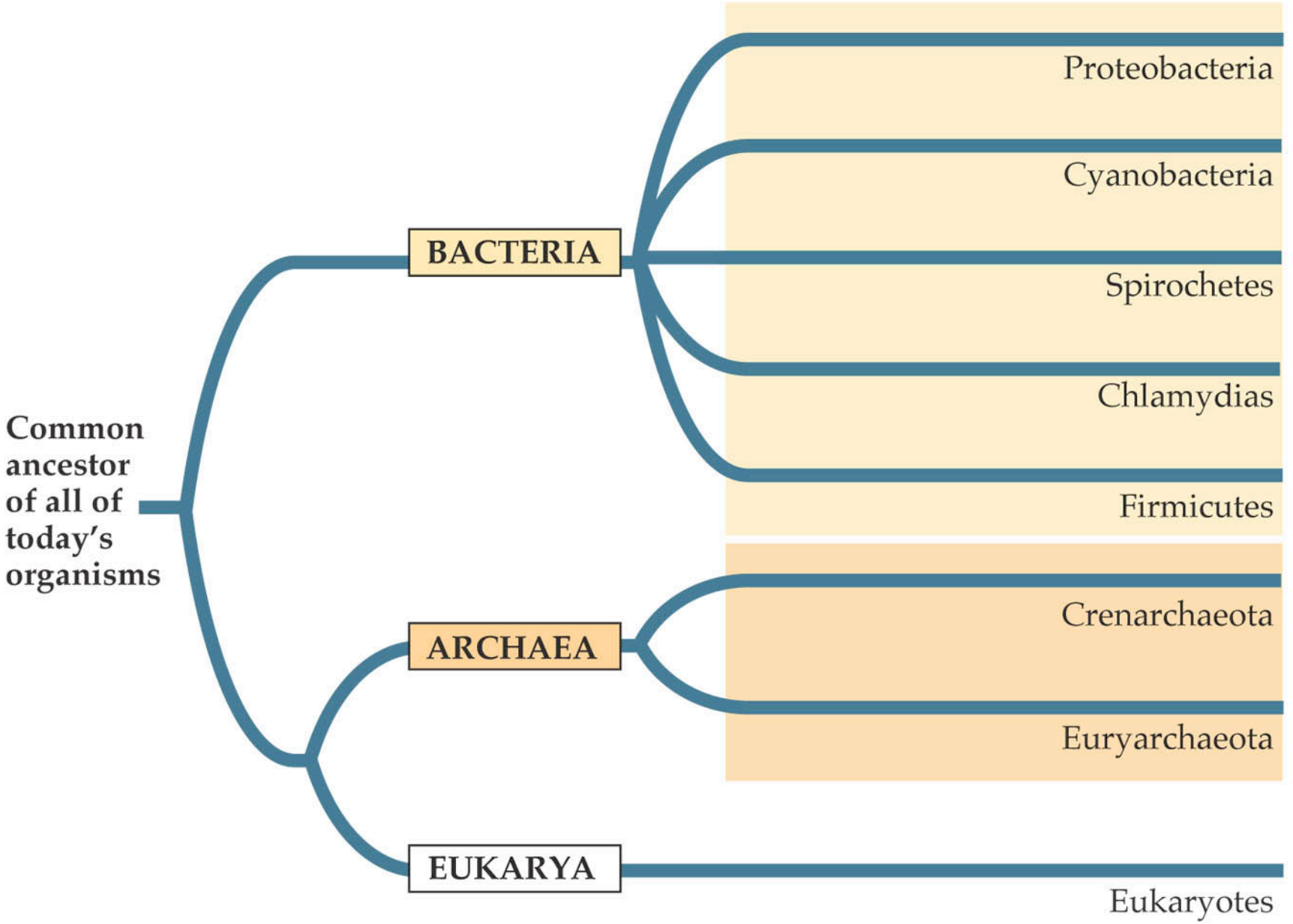
* **Autotrophs use CO_2 (inorganic molecule)**
* **Heterotrophs use organic molecules (glucose: $C_6H_{12}O_6$)**

Metabolic Diversity

Allows prokaryotes to occur in all habitats in the biosphere

Nutritional Type	Energy Source	Carbon Source
Photoautotroph **Cyanobacteria**	Sunlight	CO_2
Chemoautotroph **Sulfur bacteria** (deep sea vents)	Inorganic molecules: Hydrogen sulfide (H_2S) Ammonia (NH_3)	CO_2
Photoheterotroph **Purple non-sulfur bacteria**	Sunlight	Organic molecules
Chemoheterotroph **Most bacteria**	Organic molecules	Organic molecules

- **Saprobes** = decomposers that absorb nutrients from dead organic matter
- **Parasites** = absorb nutrients from living hosts
- **Pathogens** = parasites that cause disease in host



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 27.8 Two Domains: A Brief Overview

Domain: Archaea

Ancient Bacteria

"Extremophiles"

Extreme habitats

High temperatures

High salinity

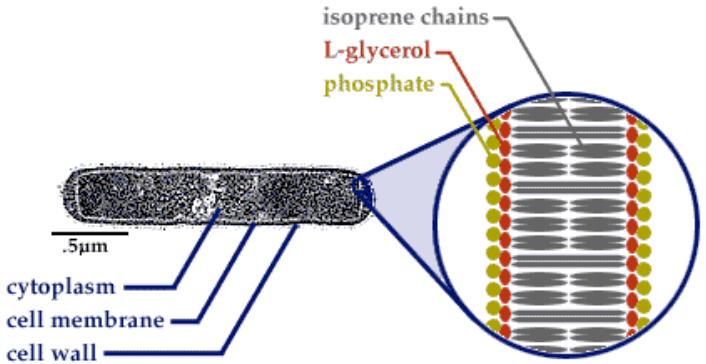
Deep ocean

Others live in soils & ocean water

Archaea are anerobic and use inorganic molecules

Cellular differences in Bacteria & Archaea

Archaea	Bacteria
No peptidoglycan in cell walls	Peptidoglycan cell walls
Unique membrane lipids	"Regular" phospholipids
Histone proteins on DNA	Histones absent



Crenarchaeota "clade"

Thermoacidophilic Archaea

Thermophilic = Heat loving

Extreme heat (up to 80°C)

Acidophilic = Acid loving

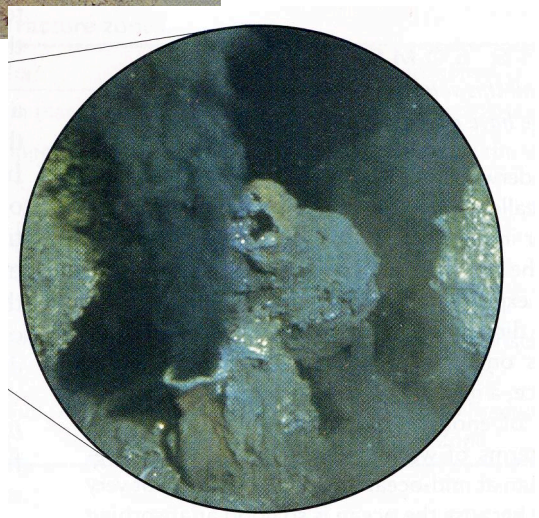
pH: 0 - 3

Habitats:

- **Hot, acidic water of thermal sulfur springs**

- **Deep sea sulfide hydrothermal vents ("black smokers")**

Base of food chain for vent community



Euryarchaeota "clade"

Methanogens

- **Methane producers**

$$4H_2 + CO_2 = CH_4 + 2H_2O$$

- **Use hydrogen sulfide as an energy source**

- **Habitats:** **Anaerobic aquatic sediments**
  Sewage treatment facilities

- **Lifestyles:** **Free-living**
  Symbiotic mutualists in animal guts
  - breakdown food for host & provide nutrients
  - breakdown cellulose
  - bacteria get source of energy (H_2S)

Euryarchaeota "clade"

Halophiles: Salt loving archaea

- **Habitats: Saturated brine**
  (10x salt conc. of ocean)
  Great Salt Lake
  Desert salt pan crusts

- **Carotenoid pigments give cells a pink color**

- **Thrive in 15-20% salinity**

- **Some live in alkaline lakes with a high pH** (pH = 11)

Salt evaporation ponds
in
San Francisco Bay

Domain: Bacteria

- **Far more species than Archaea**
- **The most ancient bacteria groups are thermophiles**
  - **evidence that life evolved**
  - **in hot environments**
- **Over a dozen clades**
- **Identified by shape, staining & metabolism**

Escherichia coli

Ecological Importance of Bacteria

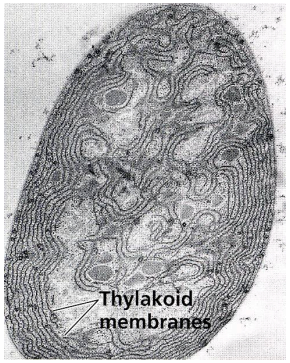
- **Cyanobacteria produce oxygen**
- **Nutrient cycling**
  - **Role as decomposers**
  - **Nitrogen fixation: N_2 -> NH_3**
    - Only bacteria can fix nitrogen
    - Contributes to soil & water fertility
    - Autotrophs can't use nitrogen gas

- **Pathogens: + / -**
- **Commensals: + / 0**
- **Mutualists: + / +**

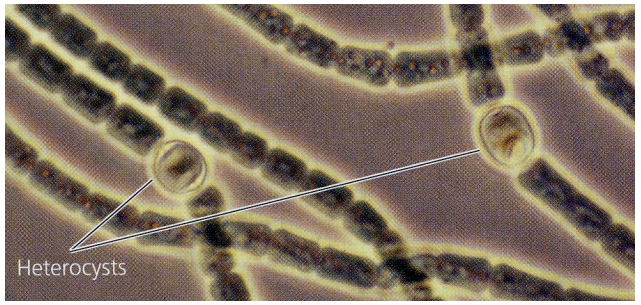
Cyanobacteria

formerly called "blue-green algae"

- **Photoautotrophs**
  - only prokaryotes with oxygen generating photosynthesis
  - thylakoid membranes have chlorophyll a



- **Lifestyles**
  - **Free-living: Solitary & Colonial**
  - **Aquatic habitats: marine & freshwater**
  - **Moist soil surfaces**
  - **Symbiotic mutualist**
    - With some plants, animals & fungi
- **Some fix nitrogen**
  - Heterocysts: specialized cells for N_2 fixation



Importance of Cyanobacteria

- **Oxygen production**
- **Nitrogen fixation - contributes to water & soil fertility**
- **Food in aquatic ecosystems**
  - **For protists & animals**
  - **For humans*: Spirulina* is 70% protein**
- **Blooms (large populations)**
  - **odor & poor water quality for drinking**

Identifying heterotrophic bacteria by the Gram stain

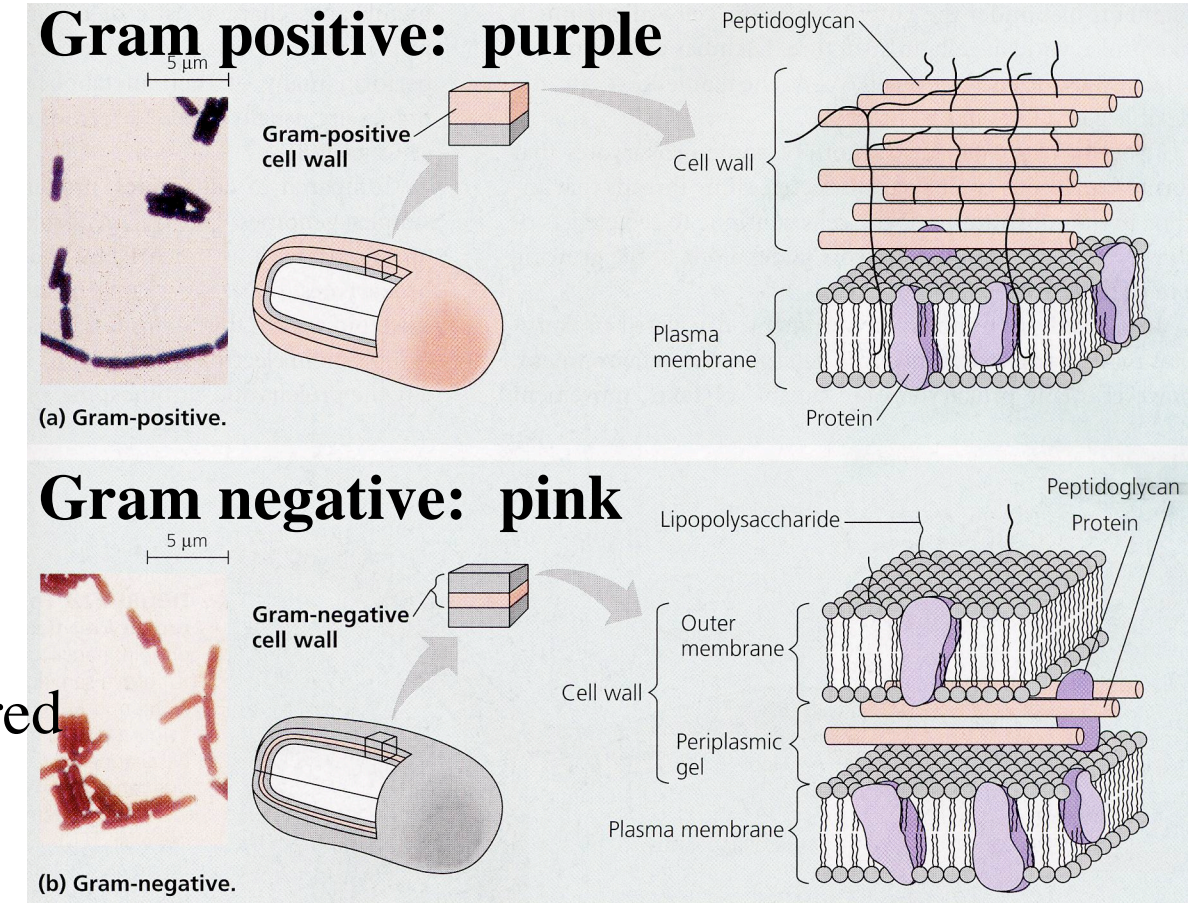
Detects differences in cell wall composition

Gram (+) bacteria

- 1 membrane
- *Thick peptidoglycans* external to cell membrane

Gram (-) bacteria

- 2 membranes
- Cell wall has a *thin peptidoglycan layer* covered by an outer membrane

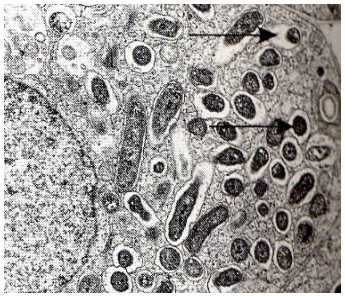


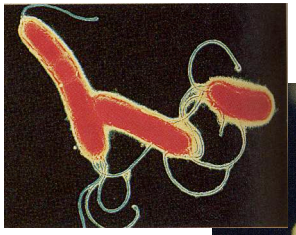
Gram (-) pathogenic bacteria are more harmful than Gram (+) ones & more resistant to antibiotics; outer membrane molecules can also be toxic

Proteobacteria

"Purple" bacteria

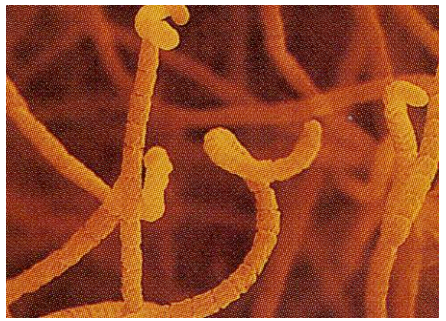
- **Largest & most diverse group (gram negative)**
- **All modes of nutrition** **(but no oxygen production)**
- **Lifestyles**
  - **– Free-living**
  - **– Commensals**
  - **– Symbiotic mutualist**
    - *Rhizobium*: Nitrogen fixing in plants (also free living)
    - *E. coli*: Gut symbiont in animals
  - **–Parasites**
    - *Helicobacter pylori:* causes ulcers
    - *Agrobacterium tumefaciens*: causes crown gall tumor in plants





Firmicutes

- **All gram (+) bacteria & a few gram (-) ones**
- **Heterotrophs**
- **Lifestyles: Free-living in soil**
  Parasites (pathogens)

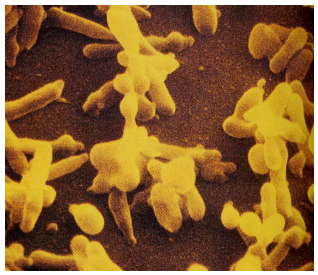


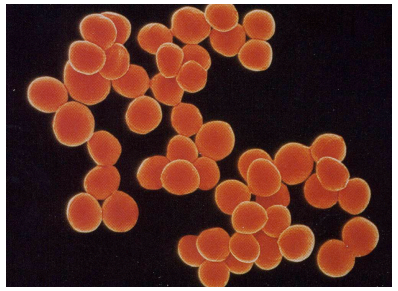
Selected types:

1. Actinomycetes: colonies of branched chains of cells

- many produce antibiotics
- cause tuberculosis & leprosy

2. Mycoplasmas: smallest cells
No cell walls; small genomes





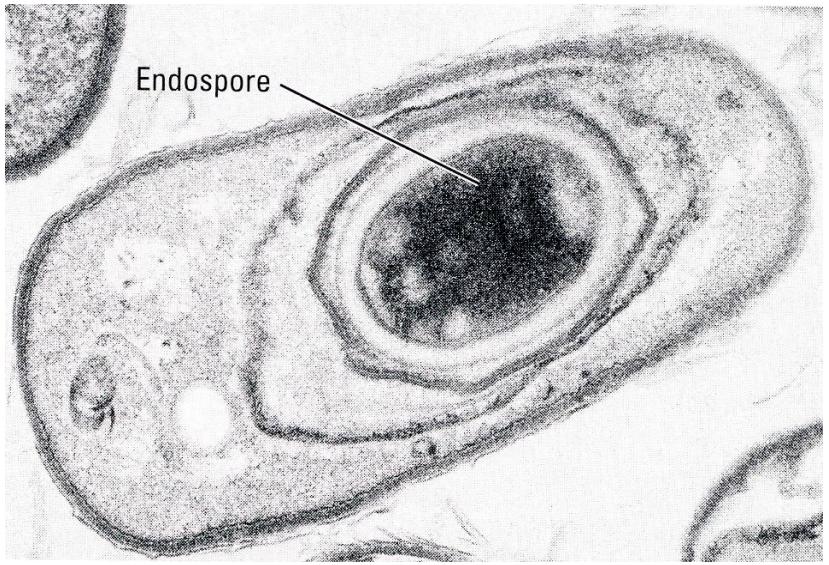
3. Various genera: *Bacillus*, *Streptococcus*, *Staphylococcus*

Firmicutes

Endospores: an adaptation for dormancy

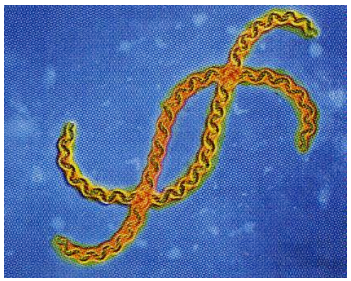
- **Thick protective coat surrounds cell contents**
  - **inside of existing cell**
- **Able to survive extremely harsh conditions**
- **Lethal temp: 250^{o}F**
  - **Autoclave use for sterilization**
  - **High heat needed to can foods**

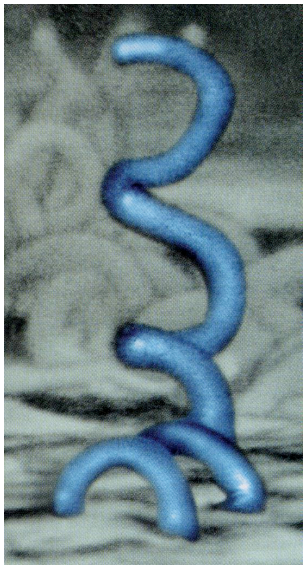
Bacillus anthracis



Spirochetes

- **Gram negative**
- **Chemoheterotrophs**
- **Motile**
  - –- Axial filaments along length of cell
  - – Allows a rolling motion
- **Lifestyles**
  - **– Free-living in mud or water**
  - **– Parasites:** Syphilis & Lyme disease





Spirochete that causes syphilis

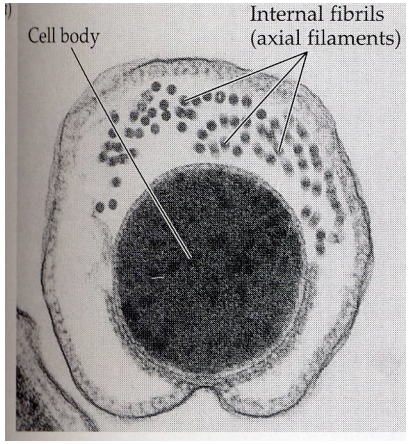
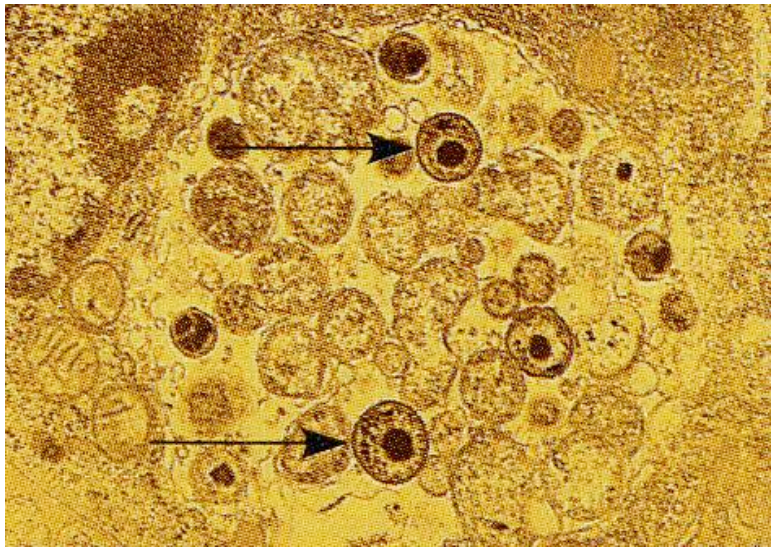


Figure 14.14 Lyme disease, a bacterial disease transmitted by ticks.

Lyme disease spirochete is carried by ticks
Leads to severe arthritis, heart disease & neurological disorders

Chlamydias

- **Gram negative cocci**
- **Extremely small**
- **Chemoheterotrophs**
- **All parasites**
  - **–live inside of animal cells**



- ***Chlamydia trachomatis*** **the most common cause of blindness in the world (trachoma) & also is the most common STD in the US**