Chapter 27B:
Bacteria and Archaea

1. Prokaryotic Nutritional & Metabolic Adaptations
2. Survey of Prokaryotic Groups
   A. Domain Bacteria – Gram-negative groups
   B. Domain Bacteria – Gram-positive groups
   C. Domain Archaea

1. Prokaryotic Nutritional & Metabolic Adaptations

Important Metabolic Terms

Oxygen tolerance/usage:

aerobic – requires or can use oxygen (O_2)

anaerobic – does not require or cannot tolerate O_2

Energy usage:

phototroph – uses light as an energy source

- all photosynthetic organisms

chemotroph – acquires energy from organic or inorganic molecules

- organotrophs – get energy from *organic* molecules
- lithotrophs – get energy from *inorganic* molecules

…more Important Terms

Carbon Source:

autotroph – uses CO_2 as a carbon source

- e.g., photoautotrophs or chemoautotrophs

heterotroph – requires organic carbon source

- e.g., chemoheterotroph – gets energy & carbon from organic molecules

Facultative vs Obligate (or Strict):

facultative – "able to, but not requiring"

- e.g., facultative anaerobes can survive with or without O_2

obligate – "absolutely requires"

- e.g., obligate anaerobes cannot survive in O_2

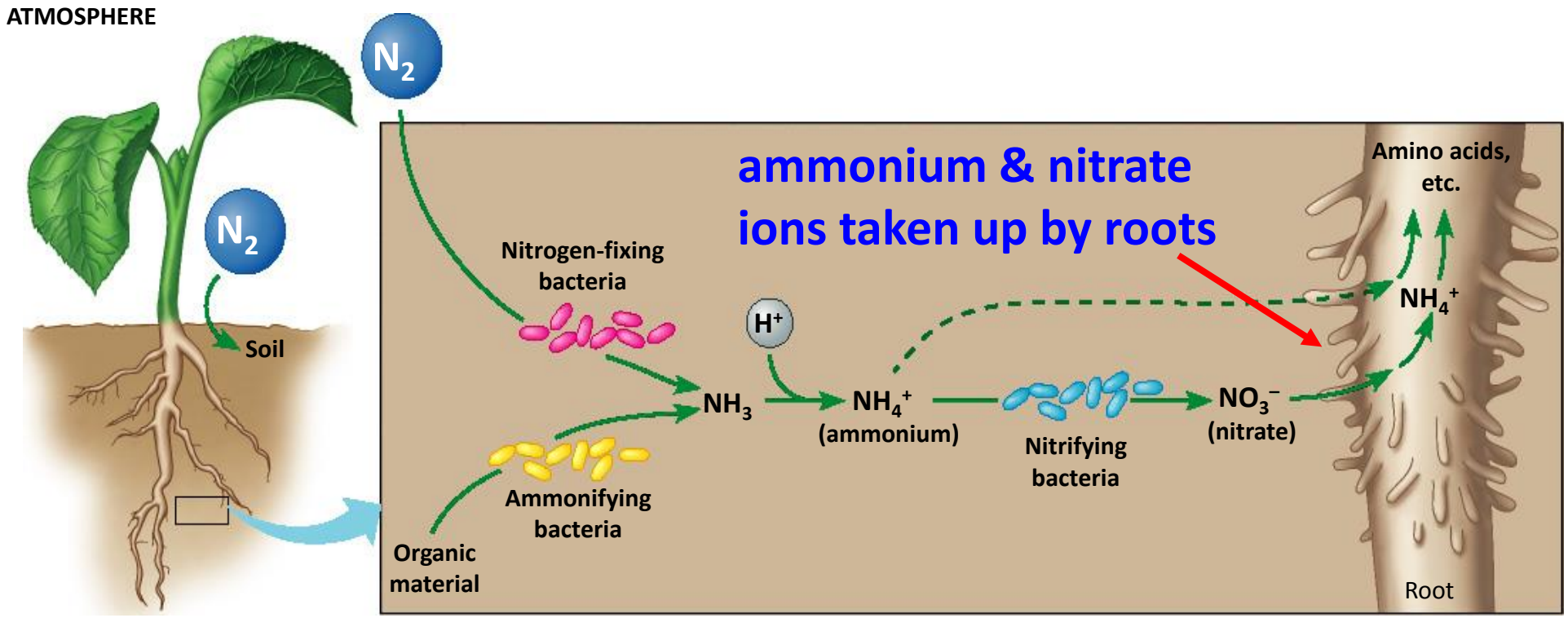
Table 27.1 Major Nutritional Modes

Mode	Energy Source	Carbon Source	Types of Organisms
AUTOTROPH			
Photoautotroph	Light	CO_2, HCO_3^-, or related compound	Photosynthetic prokaryotes (for example, cyanobacteria); plants; certain protists (for example, algae)
Chemoautotroph	Inorganic chemicals (such as H_2S, NH_3, or Fe^{2+})	CO_2, HCO_3^-, or related compound	Unique to certain prokaryotes (for example, *Sulfolobus*)
HETEROTROPH			
Photoheterotroph	Light	Organic compounds	Unique to certain aquatic and salt-loving prokaryotes (for example, *Rhodobacter*, *Chloroflexus*)
Chemoheterotroph	Organic compounds	Organic compounds	Many prokaryotes (for example, *Clostridium*) and protists; fungi; animals; some plants

Nitrogen Fixation

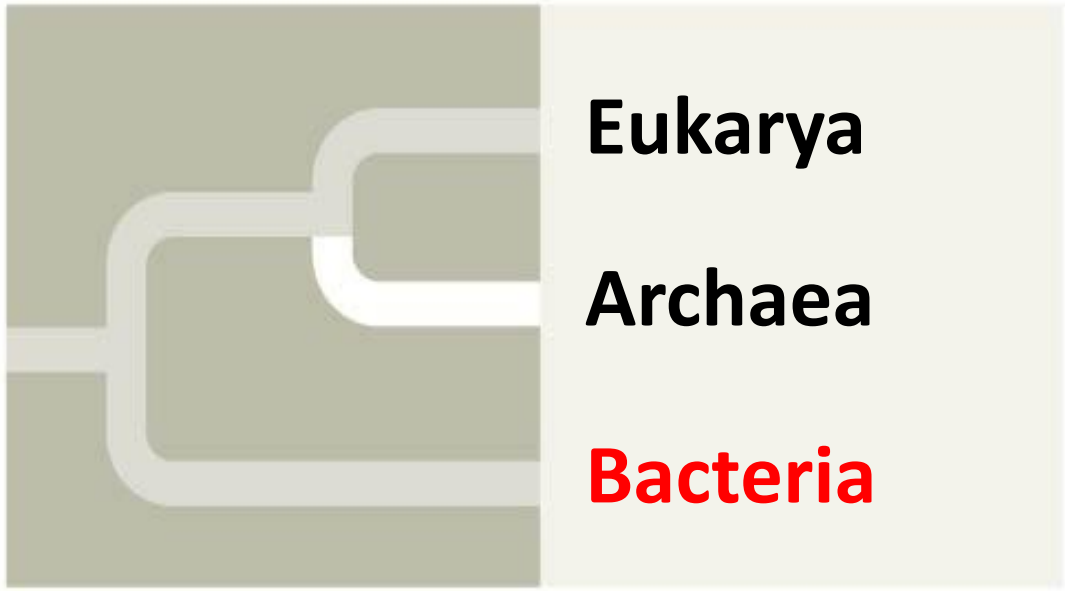
Plants require the element nitrogen in the form of ammonium (NH_4^+) or nitrate (NO_3^-) ions, however they CAN'T "fix" atmospheric nitrogen (N_2) into these forms.

Certain soil bacteria CAN fix nitrogen (i.e., "nitrogen fixers"), thus plants depend on these microbes for <u>useable</u> forms of nitrogen.

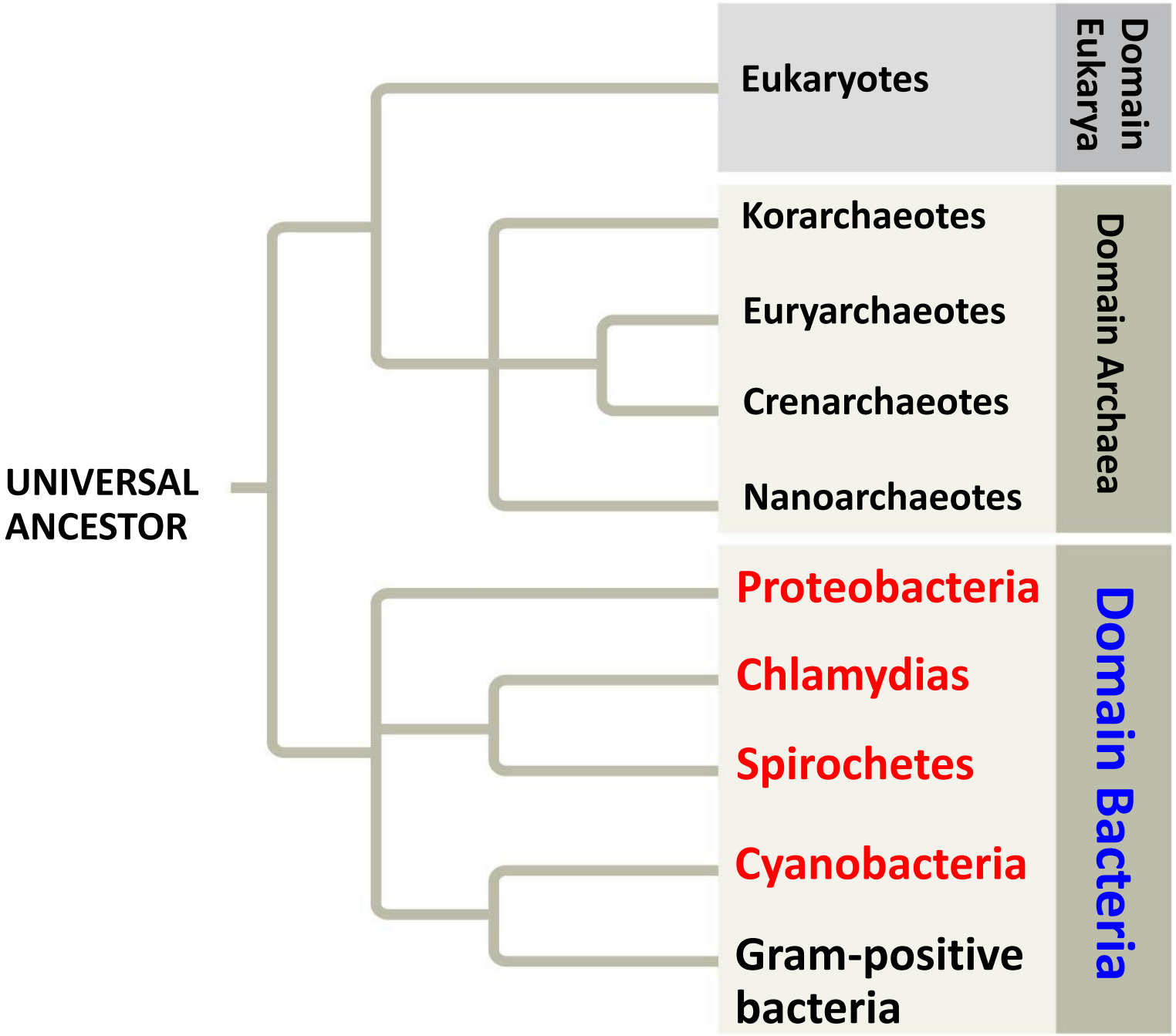


2A. Survey of Prokaryotic Groups

Domain Bacteria – Gram-negative groups



Gram-negative Groups



Proteobacteria

The phylum Proteobacteria contains most of the Gram-negative heterotrophs and is divided into 5 classes:

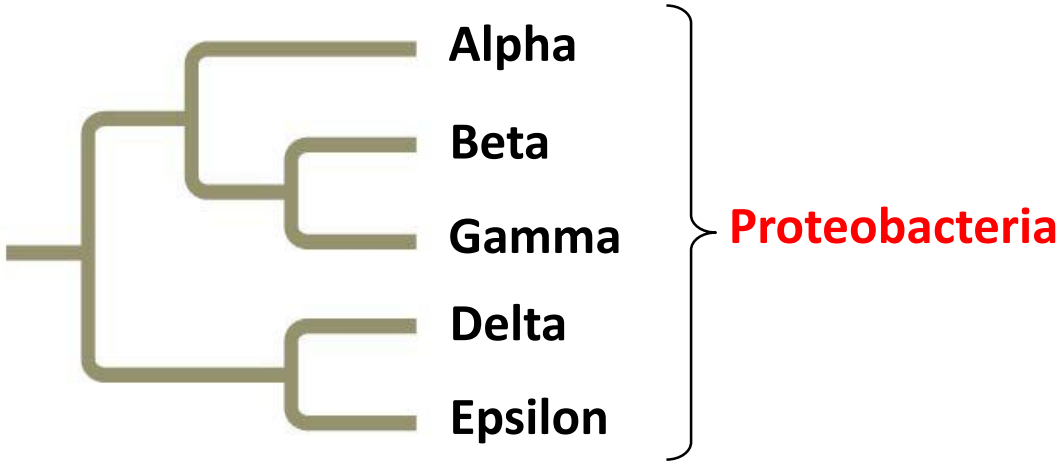
Alphaproteobacteria

Betaproteobacteria

Gammaproteobacteria

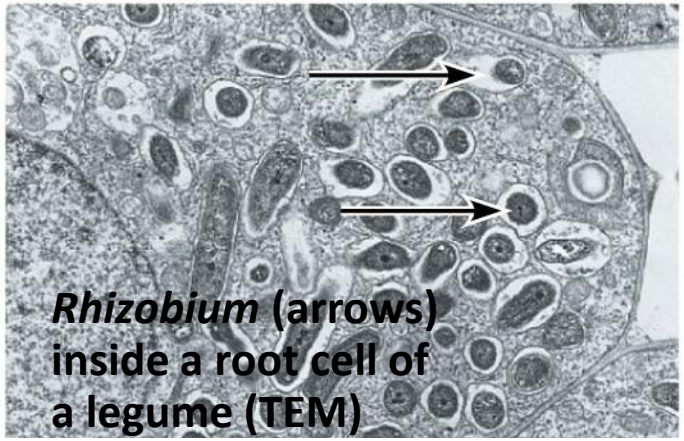
Deltaproteobacteria

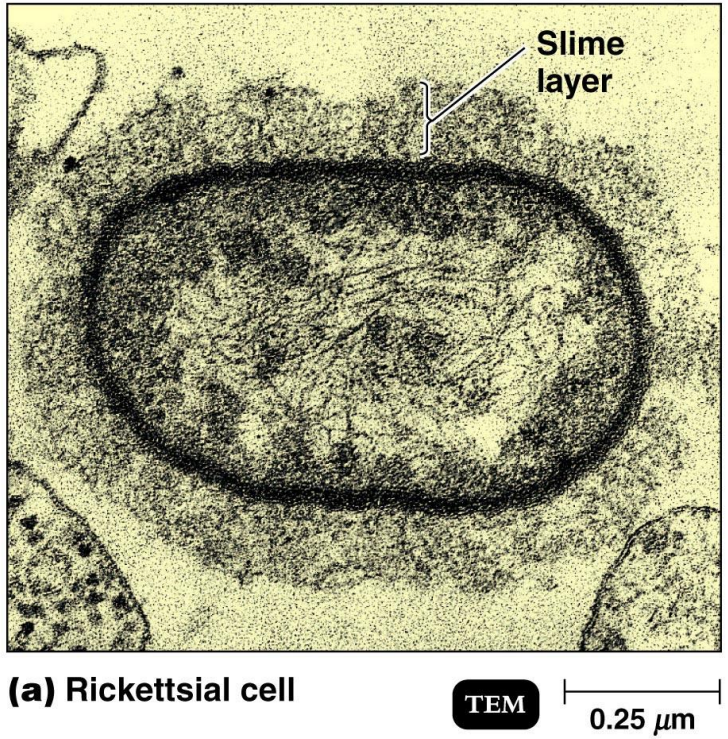
Epsilonproteobacteria



Alphaproteobacteria

Alpha subgroup





- scientists hypothesize that mitochondria evolved from aerobic alpha proteobacteria through endosymbiosis

Genera of note:

Rhizobium

- nitrogen fixation in soil

Agrobacterium

- cause tumors in plants, used in genetic engineering

Rickettsia

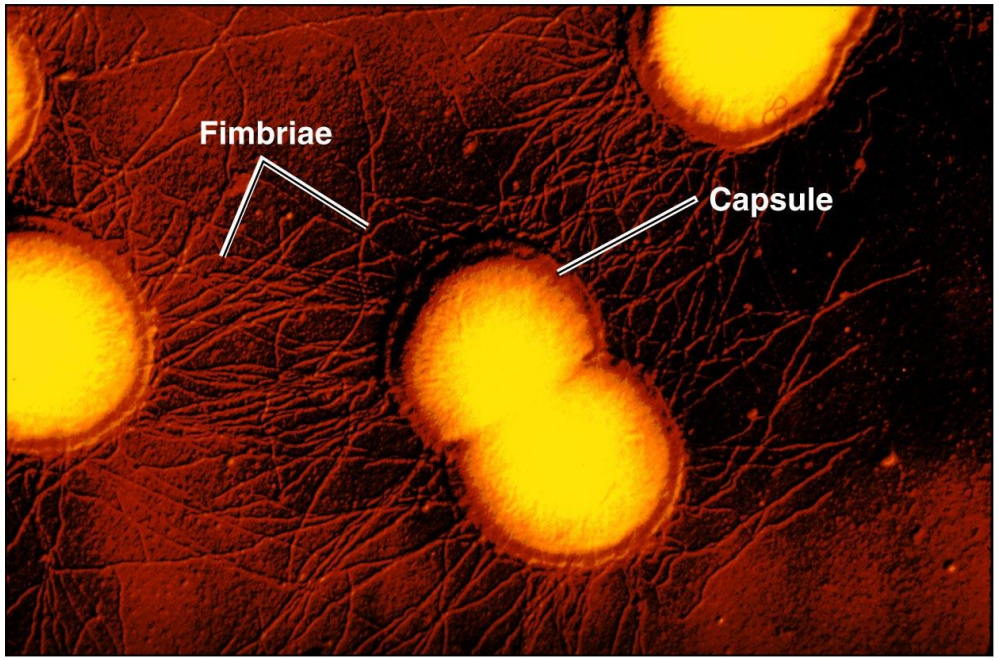
- cause of typhus, “rickets”, Rocky Mountain spotted fever

Betaproteobacteria

Genus of ecological importance:

Nitrosomonas

- enrich soils through nitrification (ammonium – NH_4^+ to nitrite – NO_2^-)



N. gonorrhoeae

Pathogenic genera:

Neisseria

- gonorrhea (*N. gonorrheae*)

Bordetella

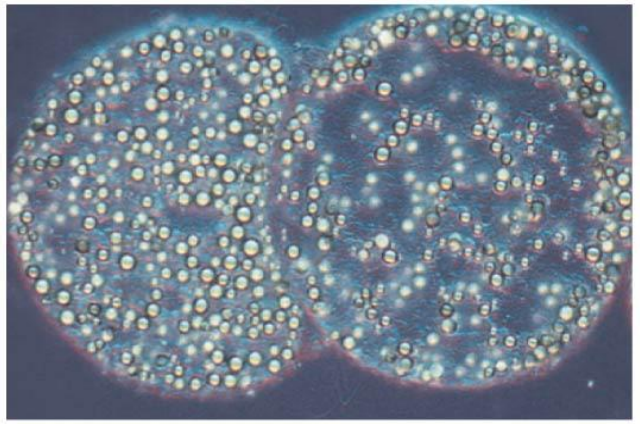
- whooping cough (*B. pertussis*)

Gammaproteobacteria

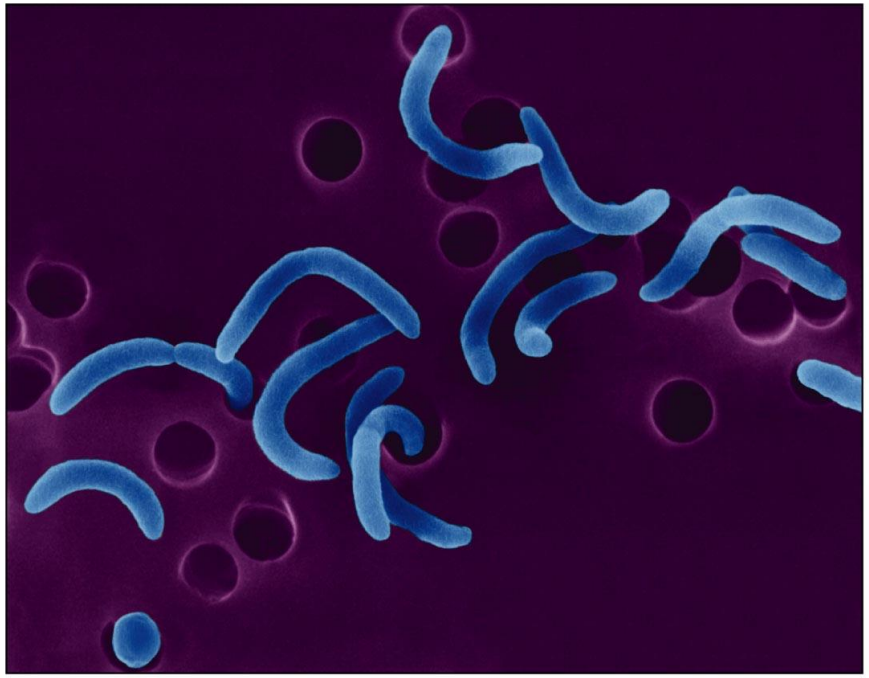
- largest & most diverse class of Proteobacteria

Thiomargarita and other genera important in the sulfur cycle

Gamma subgroup



Thiomargarita namibiensis containing sulfur wastes (LM)



V. cholerae

Vibrio

- cause of cholera (*V. cholerae*)

Escherichia

- normal gut flora (*E. coli*)

Salmonella

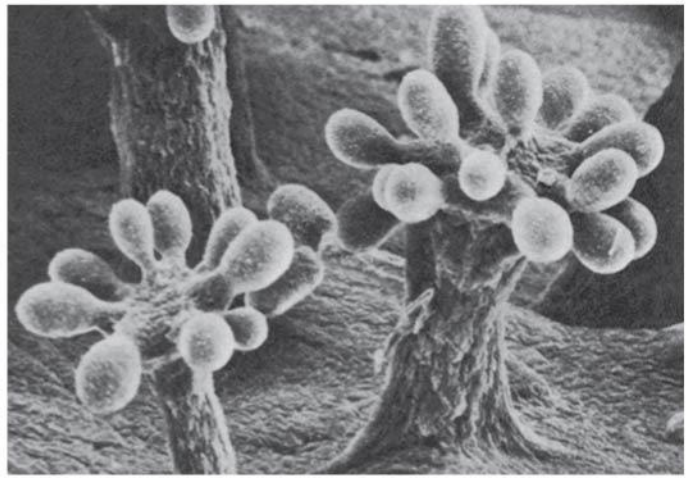
- typhoid fever, foodborne salmonellosis

Deltaproteobacteria

Myxobacteria

- the slime-secreting myxobacteria, which produces drought resistant "myxospores"

Delta subgroup

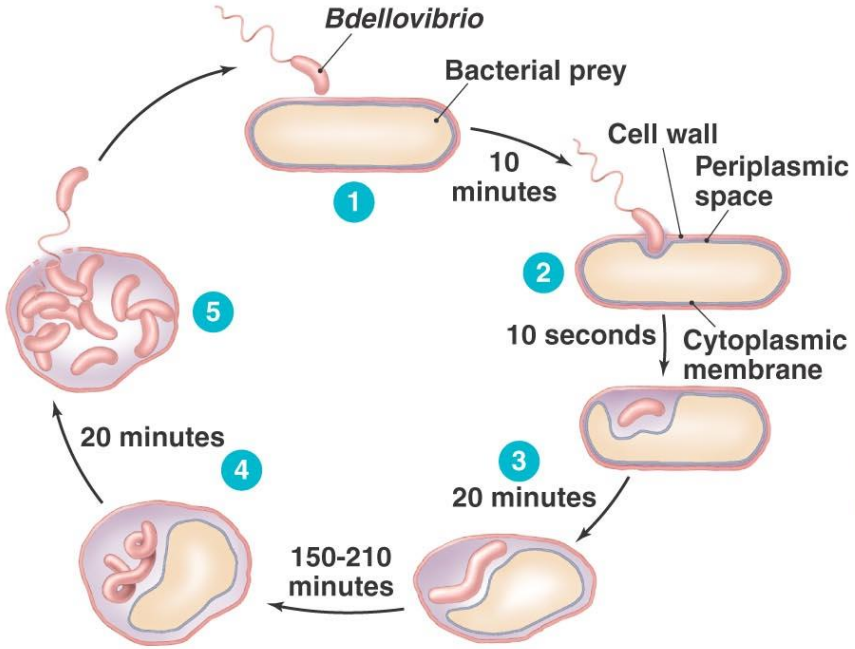


300 µm

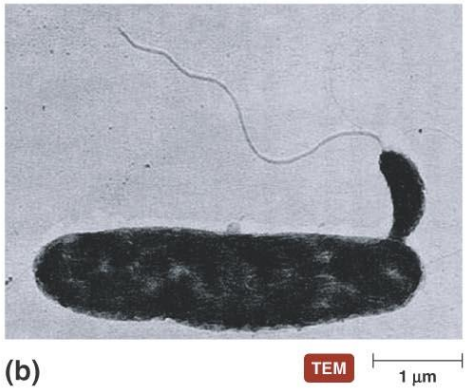
Fruiting bodies of *Chondromyces crocatus*, a myxobacterium (SEM)

Bdellovibrio

- unusual and interesting bacterial predator



(a)



(b)

Epsilonproteobacteria

Most members of this group have are helical or vibrioid morphology.

Pathogenic genera:

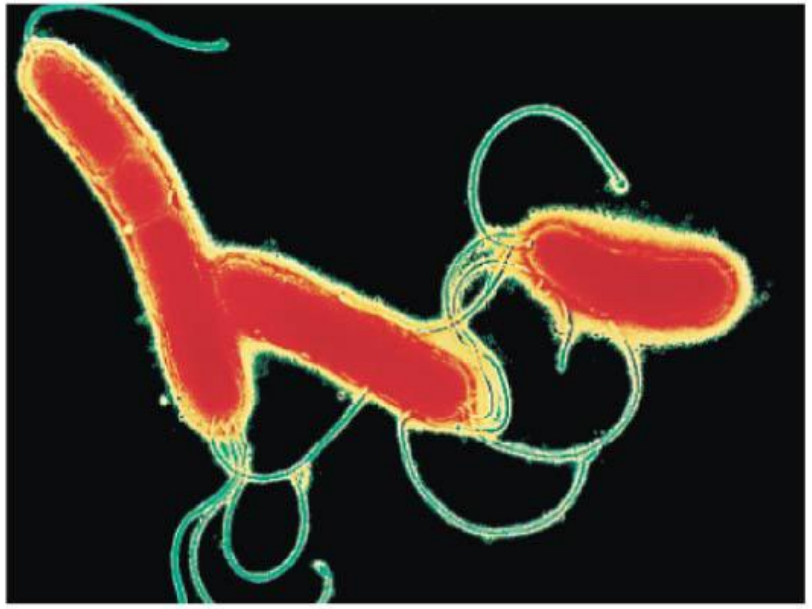
Helicobacter

- ***H. pylori*** **– peptic ulcers**

Campylobacter

- **various species cause blood poisoning, intestinal illness (e.g., *C. jejuni*)**

Epsilon subgroup



Helicobacter pylori **(colorized TEM)**

Other Gram-negative Groups

Spirochetes

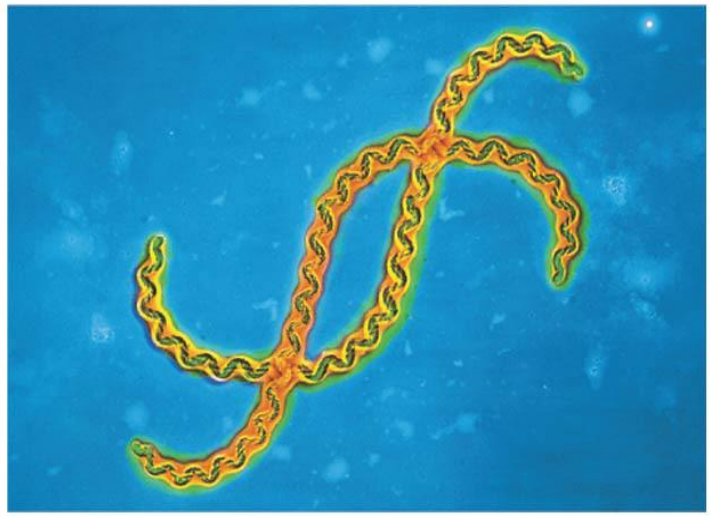
Treponema

- *T. pallidum* – cause of syphilis

Borrelia

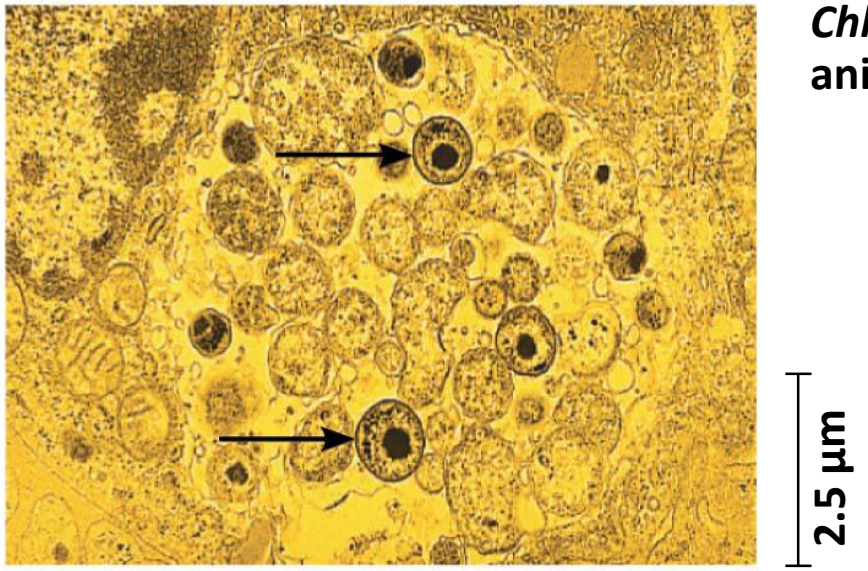
- *B. burgdorferi* – Lyme disease

Spirochetes



Leptospira, **a spirochete (colorized TEM)**

Chlamydias



Chlamydia **(arrows) inside an animal cell (colorized TEM)**

Chlamydiae

- **small intracellular pathogens with cell walls *lacking* peptidoglycan**
  - ***Chlamydia trachomatis*** **– most common STD**

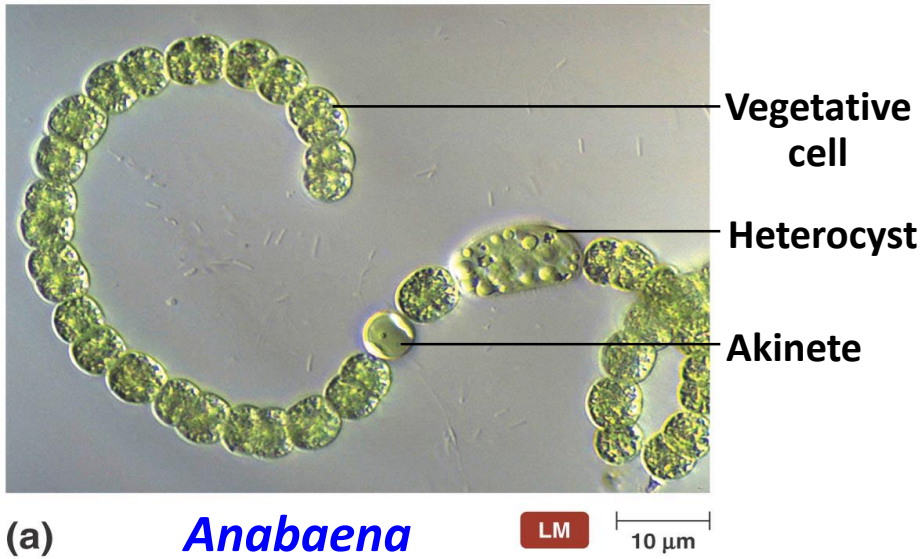
Cyanobacteria

Gram-negative, *oxygenic* photoautotrophs

- produce vast amounts of oxygen gas via photosynthesis
- fix nitrogen ($N_2 \rightarrow NH_4^+$)

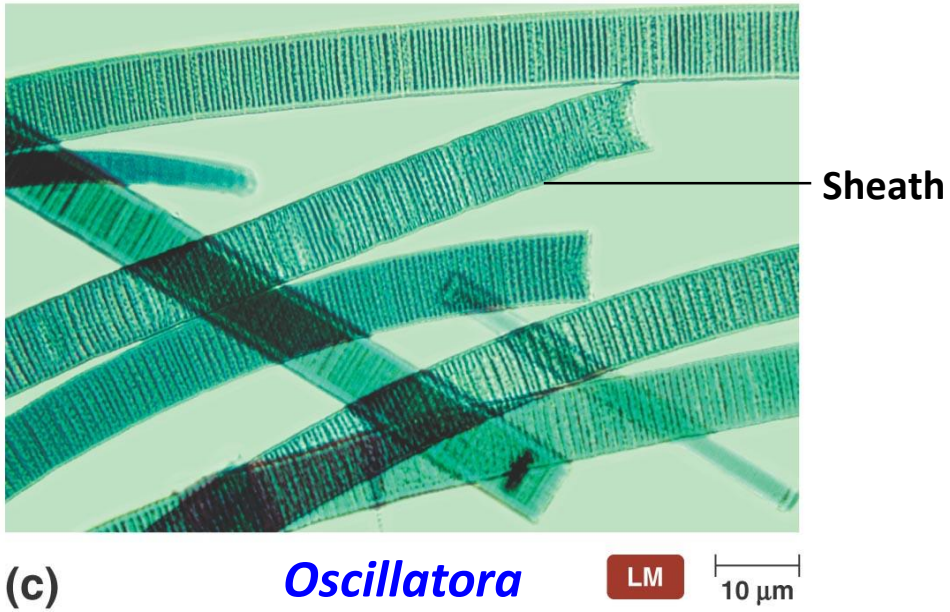
Anabaena

- carries out nitrogen fixation in non-photosynthetic heterocysts



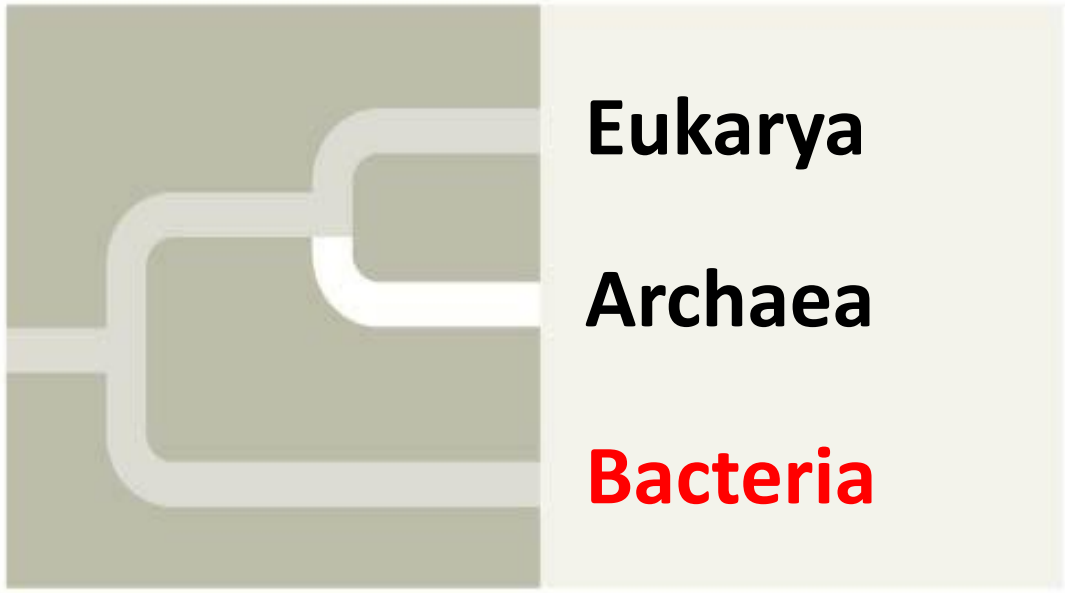
Oscillatora

- another genus of cyanobacteria

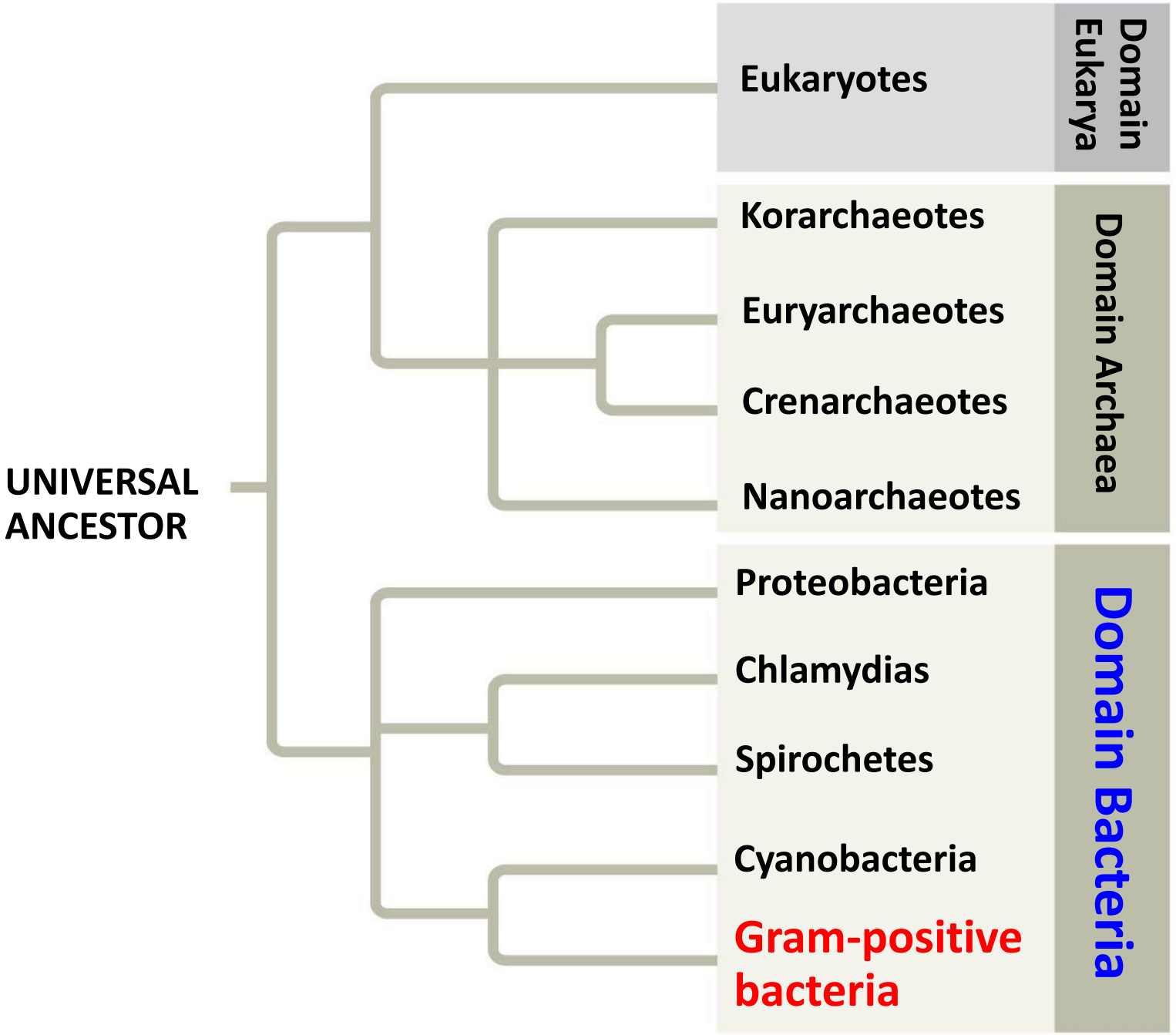


2B. Survey of Prokaryotic Groups

Domain Bacteria – Gram-positive groups



Gram-positive Groups



Gram-Positive Phyla

Most *known* Gram-positive bacteria are found in 2 main phyla:

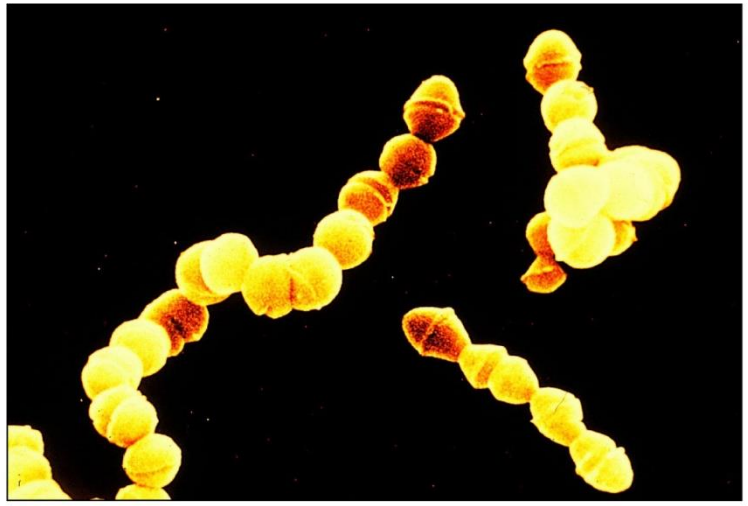
Firmicutes

- low G + C content (less than 50%)
- many common pathogens

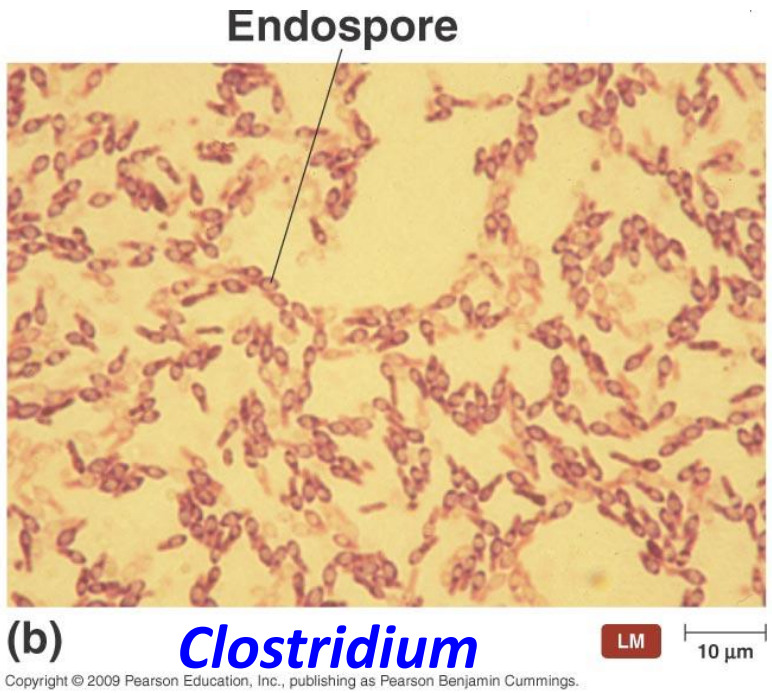
Actinobacteria

- high G + C content (greater than 50%)
- characterized by branching filaments

Firmicutes…



Streptococcus



Clostridium

Pathogenic genera:

Streptococcus

- cause of strep throat (*S. pyogenes*)

Staphylococcus

- includes Methicillin-resistant *Staphylococcus aureus* (MRSA)

**Bacillus*

- cause of anthrax (*B. anthracis*)

**Clostridium*

- cause of tetanus (*C. tetani*)
- cause of botulism (*C. botulinum*)

**produce endospores*

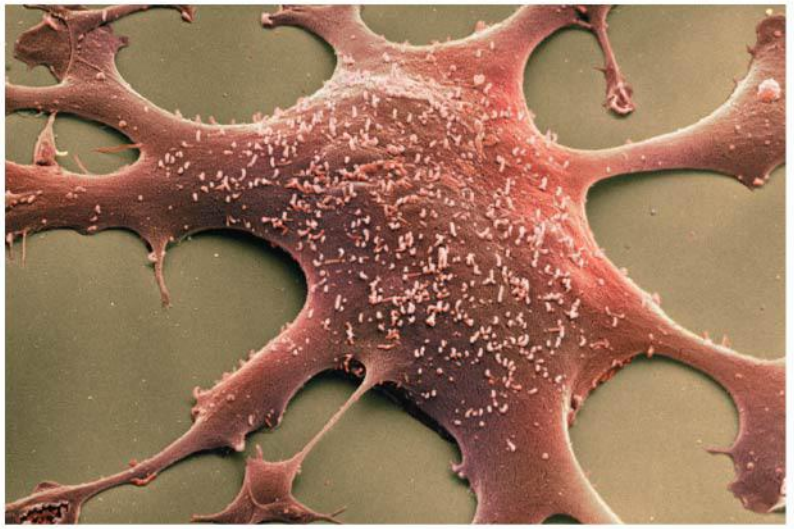
…other Firmicutes

Lactobacillus

- species used in fermented food products (e.g., yogurt, buttermilk, pickles)
- part of normal, *healthy* microbiota in human mouth, digestive tract, vagina

Mycoplasma

- *very* small (less than 1 μm)
- no cell wall (are Gram-neg.)
- obligate *intracellular* pathogens

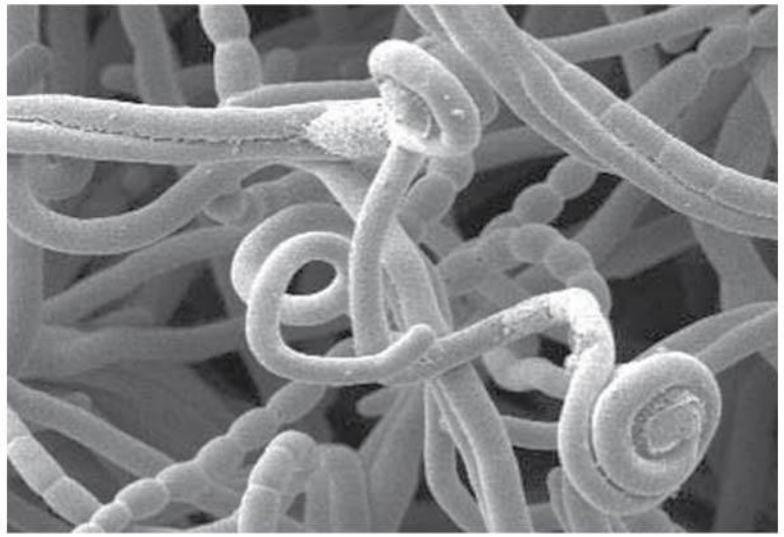


Hundreds of mycoplasmas covering a human fibroblast cell (colorized SEM)

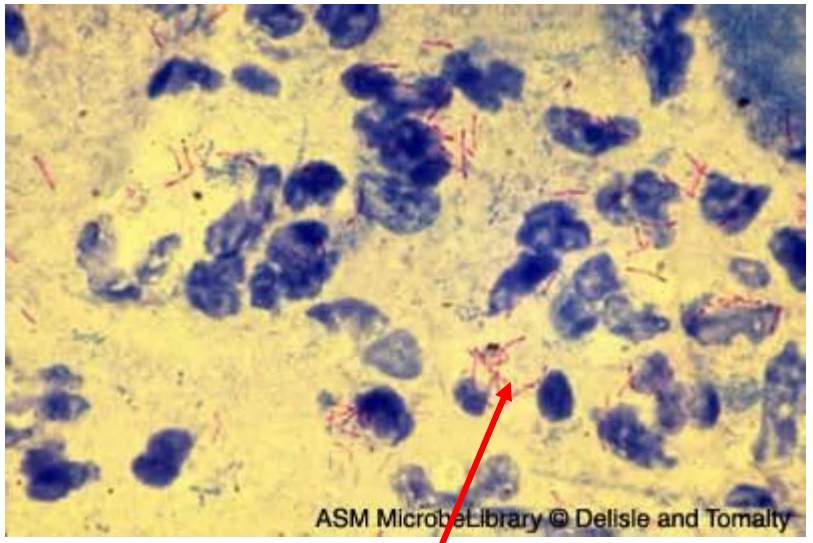
Actinobacteria

Streptomyces

- important soil bacteria, recycle nutrients
- source of many antibiotics (e.g., erythromycin, tetracycline)



Streptomyces, the source of many antibiotics (SEM)



Pathogenic genera:

Corynebacterium

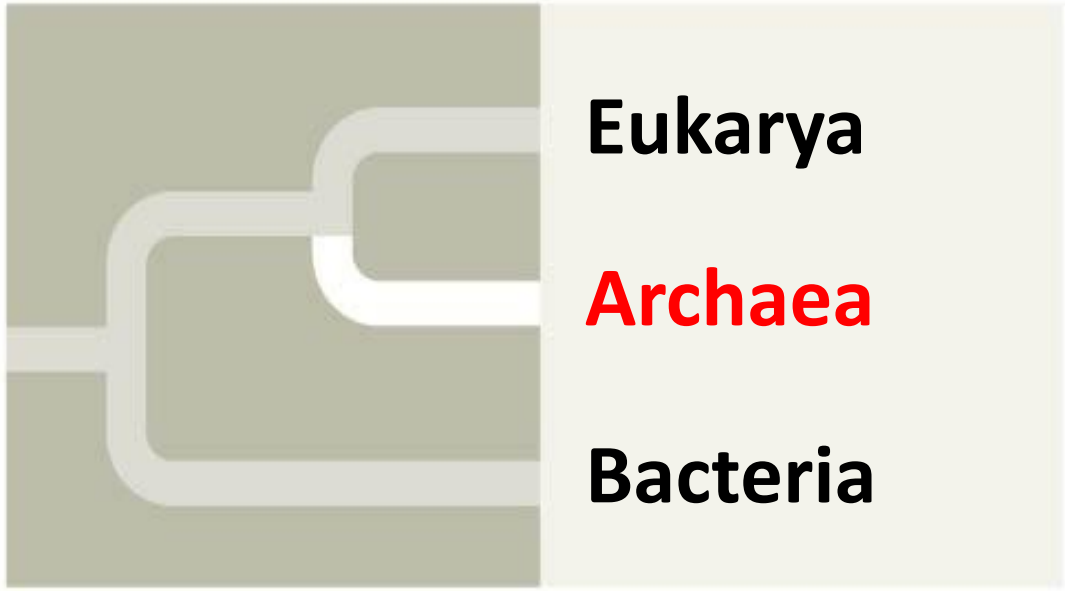
- cause of diphtheria (*C. diphtheriae*)

Mycobacterium

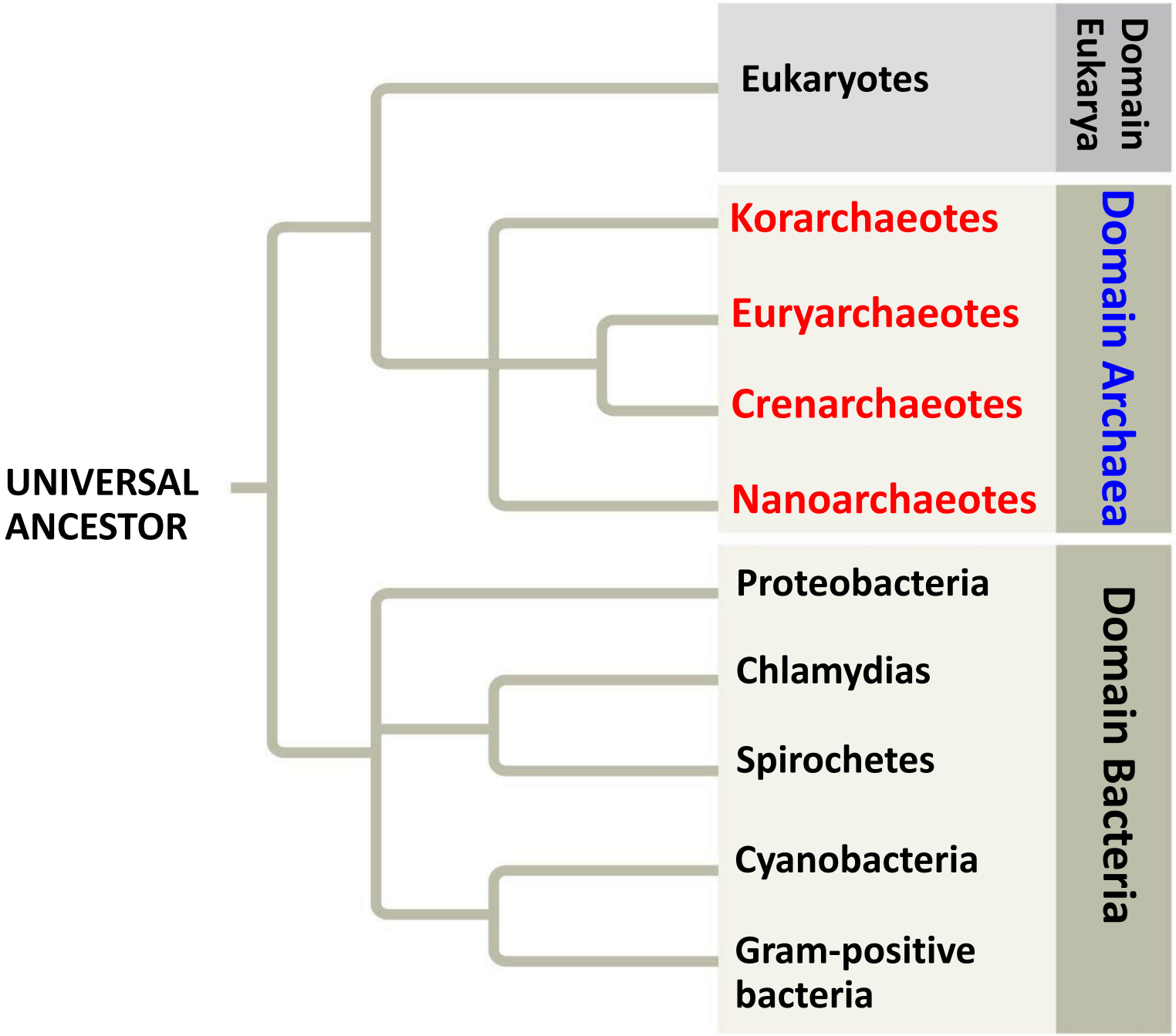
- cause of tuberculosis (*M. tuberculosis*)
- cause of leprosy (*M. leprae*)

2C. Survey of Prokaryotic Groups

Domain Archaea



The Domain Archaea



The Domain Archaea

Highly diverse group of prokaryotes first classified in 1977 by Carl Woese and George Fox:

- **have metabolic processes, rRNA sequences and other features more closely resembling eukaryotes**
  - **e.g., initiate translation with *methionine* (as do eukaryotes) rather than *N-formyl methionine* as do the Bacteria**
- **cell walls made of material *other than* peptidoglycan**
- **have unusual membrane lipids**
- **many species inhabit extreme environments**

Comparison of the 3 Domains

Table 27.2 A Comparison of the Three Domains of Life

CHARACTERISTIC	DOMAIN		
	Bacteria	**Archaea**	**Eukarya**
Nuclear envelope	Absent	Absent	Present
Membrane-enclosed organelles	Absent	Absent	Present
Peptidoglycan in cell wall	Present	Absent	Absent
Membrane lipids	Unbranched hydrocarbons	Some branched hydrocarbons	Unbranched hydrocarbons
RNA polymerase	One kind	Several kinds	Several kinds
Initiator amino acid for protein synthesis	Formyl-methionine	Methionine	Methionine

Table 27.2 A Comparison of the Three Domains of Life

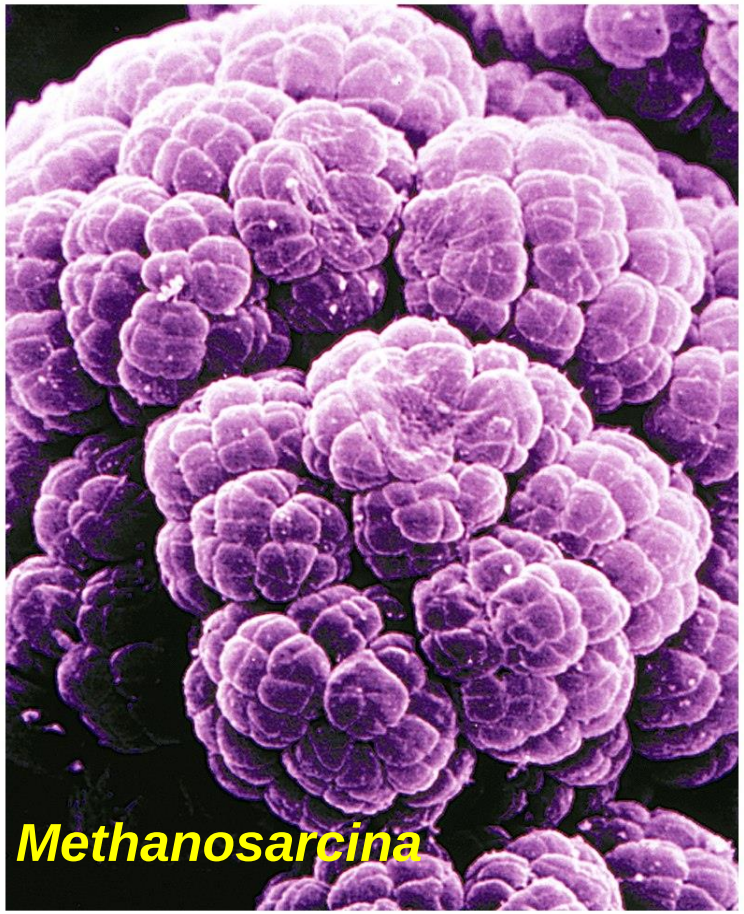
CHARACTERISTIC	DOMAIN		
	Bacteria	**Archaea**	**Eukarya**
Introns in genes	Very rare	Present in some genes	Present in many genes
Response to the antibiotics streptomycin and chloramphenicol	Growth usually inhibited	Growth not inhibited	Growth not inhibited
Histones associated with DNA	Absent	Present in some species	Present
Circular chromosome	Present	Present	Absent
Growth at temperatures > 100°C	No	Some species	No

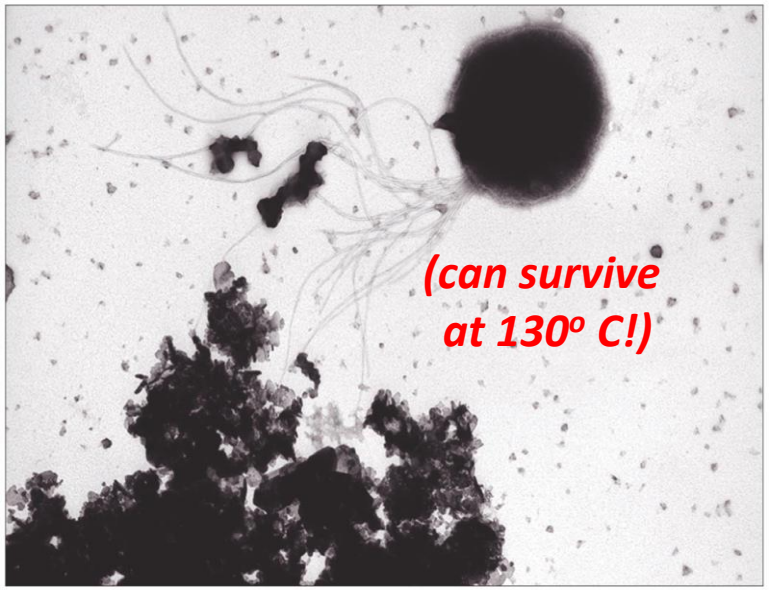
Archaea have more in common with eukaryotes than bacteria.

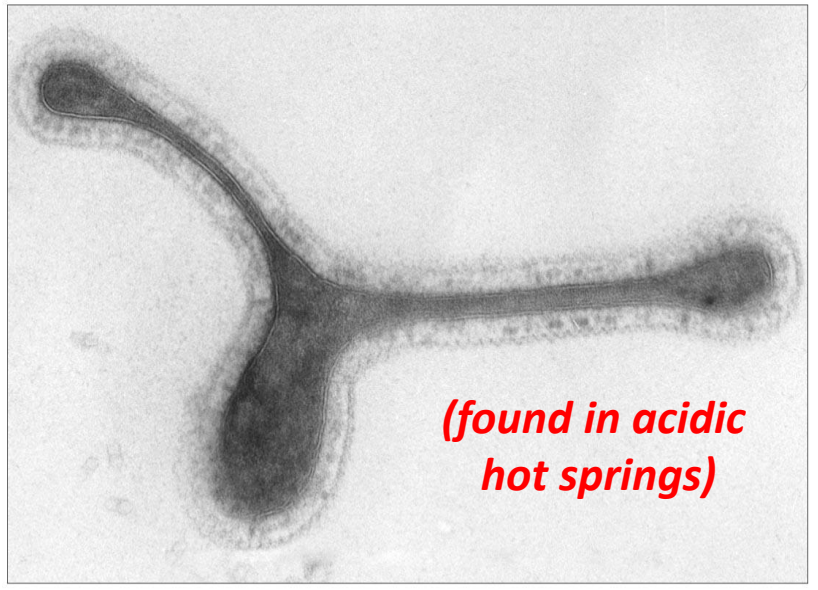
The Two Major Groups of Archaea

Crenarchaeota

- includes most of the thermophiles







Euryarchaeotes

- includes the methanogens, halophiles, and a few thermophiles

****NO known archaeon causes disease in humans or animals!****