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

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1. Prokaryotic Nutritional & Metabolic Adaptations

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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 chemautotrophs
- **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\(_2\)

**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 useable forms of nitrogen.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Energy Source</th>
<th>Carbon Source</th>
<th>Type of Organism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phototroph</td>
<td>Light</td>
<td>CO(_2), NO(_3^-)</td>
<td>Phototrophes (photosynthetic bacteria, algae, or flowering plants)</td>
</tr>
<tr>
<td>Chemoautotroph</td>
<td>Chemo</td>
<td>CO(_2), NO(_3^-)</td>
<td>Chemoautotrophes (bacteria, archaebacteria)</td>
</tr>
<tr>
<td>Chemoheterotroph</td>
<td>Organic compounds</td>
<td>Chemo</td>
<td>Chemoheterotrophes (bacteria)</td>
</tr>
</tbody>
</table>

2A. Survey of Prokaryotic Groups

**Domain Bacteria – 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**

- 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 $\rightarrow$ nitrite $\rightarrow$ nitrate)

**Pathogenic genera:**

*Neisseria*

- gonorrhea (*N. gonorrhoeae*)

*Bordetella*

- whooping cough (*B. pertussis*)

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**Gamma proteobacteria**

- largest & most diverse class of Proteobacteria

*Thiomargarita* and other genera

important in the sulfur cycle

*Vibrio*

- cause of cholera (*V. cholerae*)

*Escherichia*

- normal gut flora (*E. coli*)

*Salmonella*

- typhoid fever, foodborne salmonellosis

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**Deltaproteobacteria**

**Myxobacteria**

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

**Delta subgroup**

**Bdellovibrio**

- unusual and interesting bacterial predator
**Epsilon proteobacteria**

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

Pathogenic genera:

- Helicobacter
  - H. pylori – peptic ulcers

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

**Other Gram-negative Groups**

- **Spirochetes**
  - Treponema
    - T. pallidum – cause of syphilis
  - Borrelia
    - B. burgdorferi – Lyme disease

- **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\(_2\) → NH\(_4^+\))

- **Anabaena**
  - carries out nitrogen fixation in non-photosynthetic heterocysts

- **Oscillatoria**
  - another genus of cyanobacteria
2B. Survey of Prokaryotic Groups
Domain Bacteria – Gram-positive groups

Gram-positive groups

Eukarya
Archaea
Bacteria

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Eukaryotes
Korarchaeotes
Euryarchaeotes
Crenarchaeotes
Nanoarchaeotes
Proteobacteria
Chlamydias
Spirochetes
Cyanobacteria
Gram-positive bacteria

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...**

**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-negative)
  - obligate intracellular pathogens

**Actinobacteria**

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

- **Corynebacterium**
  - cause of diphtheria (C. diphtheriae)

- **Mycobacterium**
  - cause of tuberculosis (M. tuberculosis)
  - cause of leprosy (M. leprae)
2C. Survey of Prokaryotic Groups

Domain Archaea

Eukarya
Archaea
Bacteria

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

Archaea have more in common with eukaryotes than bacteria.

The Two Major Groups of Archaea

Crenarchaeota

- includes most of the thermophiles

Euryarchaeota

- includes the methanogens, halophiles, and a few thermophiles

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