Chapter 11 – PROKARYOTES: Survey of the Bacteria & Archaea

1. The Bacteria

2. The Archaea

Important Metabolic Terms

Oxygen tolerance/usage:
aerobic – requires or can use oxygen (O₂)
anaerobic – does not require or cannot tolerate O₂

Energy usage:
autotroph – uses CO₂ as a carbon source
  • photoautotroph – uses light as an energy source
  • chemoautotroph – gets energy from inorganic mol.
heterotroph – requires an organic carbon source
  • chemoheterotroph – gets energy & carbon from organic molecules

…more Important Terms

Facultative vs Obligate:
facultative – “able to, but not requiring”
e.g.
  • facultative anaerobes – can survive w/o O₂

obligate – “absolutely requires”
e.g.
  • obligate anaerobes – cannot tolerate O₂
  • obligate intracellular parasite – can only survive within a host cell
The 2 Prokaryotic Domains

Overview of the Bacterial Domain
We will look at examples from several bacterial phyla grouped largely based on rRNA (ribotyping):

- **Gram+ bacteria**
  - Firmicutes (low G+C), Actinobacteria (high G+C)
- **Proteobacteria** (Gram- heterotrophs mainly)
- **Gram- nonproteobacteria** (photoautotrophs)
- **Chlamydiae** (no peptidoglycan in cell walls)
- **Spirochaetes** (coiled due to axial filaments)
- **Bacteroides** (mostly anaerobic)

1. **The Gram+ Bacteria**
Gram+ Bacteria
The Gram+ bacteria are found in 2 different phyla:

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

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

Firmicutes
Characteristics associated with this phylum:
- low G+C Gram+ bacteria
- some produce endospores
- many are pathogenic

Genera of note:
- *Clostridium*
  - cause tetanus, botulism
  - obligate anaerobes
- *Bacillus*
  - B. anthracis – anthrax
- *Lactobacillus*
  - food production (yogurt)
- *Mycoplasma*
  - very small, no cell wall
  - produce endospores

Clostridium Botulinum – Botulism
Botulinum toxin, inhibits neuromuscular junctions causing paralysis & frequently death:
- notorious in home canned goods
- symptoms include: dry mouth, slurred speech, blurred vision, vomiting, diarrhea, respiratory failure
- illness is NOT due to bacterial infection but due to intoxication with botulinum toxin
- can be treated with antitoxins (antibodies to the toxin) if caught early enough
**Clostridium tetani – Tetanus**

Tetanus toxin impairs inhibitory nerve signals necessary for the relaxation of muscles:

- transmitted via endospores in fecal matter that contaminate soil (typically via puncture wounds)
  - causes muscle rigidity such as “lockjaw”
  - spasms of respiratory muscles can be lethal

...more Firmicutes

**Streptococcus**
- most notorious bacterial pathogen
  - *Streptococcus pyogenes* (“strep throat”, scarlet fever)
  - *Streptococcus mutans* (tooth decay/dental caries)

**Staphylococcus**
- *Staphylococcus aureus* (food poisoning, MRSA, etc…)

**Streptococcus Mutans & Tooth Decay** *(pp. 747-9)*

Dental caries (tooth decay) is caused by the normal microbiota of the mouth that form a biofilm (containing *S.mutans*) we call plaque on the tooth enamel surface:

- due mainly to metabolism of the disaccharide sucrose (not glucose or fructose) which yields corrosive lactic acid
- avoidance of sucrose and mechanical removal of biofilm (brushing & flossing) minimizes tooth decay
Actinobacteria
Characteristics associated with this phylum:
• high G+C Gram+ bacteria
• filamentous appearance, superficially resemble molds
• includes many important soil bacteria, some pathogens

Genera of note:
Mycobacterium
• responsible for leprosy, tuberculosis
• have unusual cell walls w/mycolic acids (acid fast!)

Streptomyces
• important soil bacteria

Mycobacterium leprae – Leprosy
• now usually referred to as “Hansen’s disease”
  • chronic, non-lethal destruction, deformation of more peripheral body tissues
  • grows best at 30o C. (body extremities)
  • can infect and destroy myelin sheath of peripheral nerves compromising nerve function
• can be effectively treated with antibiotics

2. Gram− Bacteria
Proteobacteria
The proteobacteria contain most of the Gram-heterotrophs and are divided into 5 classes:

- Alphaproteobacteria
- Betaproteobacteria
- Gammaproteobacteria
- Deltaproteobacteria
- Epsilonproteobacteria

Alphaproteobacteria
Characteristics associated with this class:
• broad range of (sometimes unusual) morphology
• capable of growth at very low nutrient levels
• many important nitrogen fixers

Genera of note:
- *Rickettsia*
  • intracellular pathogens causing numerous infectious diseases
  • usu. transmitted by insect vectors
- *Azospirillum*
  • important nitrogen fixing soil bacteria

Betaproteobacteria
Characteristics associated with this class:
• metabolize by-products of anaerobic decomposition
• a number of pathogenic genera
• genera that contribute to the sulfur cycle

Genera of note:
- *Nisseria*
  • cause of gonorrhoea, bacterial meningitis
- *Thiobacillus*
  • chemoautotrophs that convert H₂S to sulfates
**Gammaproteobacteria**

Characteristics associated with this class:
- largest class of proteobacteria
- tremendous variety

Genera of note:
- *Pseudomonas* • troublesome in hospitals
- *Salmonella* • common food pathogen
- *Escherichia* • normal gut bacteria
- *Vibrio* • responsible for cholera

**Vibrio cholerae – Cholera**

*Vibrio cholerae* (pp. 755-8):
- curved rod that causes cholera
- transmitted via contaminated water or food
- massive fluid loss via diarrhea due to cholera toxin:
  - inhibits regulation of salt ion balance in gut epithelium leading to fluid loss via diffusion into gut lumen

**Deltaproteobacteria**

Characteristics associated with this class:
- bacteria that prey on other bacteria
- many sulfur reducing genera (produce H₂S from SO)

Genera of note:
- *Bdellovibrio* • bacterial predator
- *Desulfovibrio* • H₂S producing anaerobe
Epsilonproteobacteria

- helical or vibrioid

Genera of note:

*Helicobacter*

- most common cause of ulcers

Ulcer formation due to *H. pylori*

**Gram- Nonproteobacteria**

This group includes the photosynthetic bacteria:

**Cyanobacteria**

- oxygenic (produce O₂) photoautotrophs
- can fix nitrogen (N₂ → NH₃)

**Purple & Green Bacteria**

- anaerobic photoautotrophs
- anoxygenic (e.g., produce sulfur)
Other Bacterial Phyla

- **Spirochaetes**
  - axial filaments; responsible for syphilis, Lyme disease

- **Chlamydiae**
  - Gram-negative cocci with cell walls that lack peptidoglycan

- **Bacteroides**
  - anaerobes, significant portion of fecal bacteria

**Chlamydia trachomatis**

- Gram-negative pathogen with outer membrane and **no** peptidoglycan layer.
  - obligate *intracellular* parasite
  - cause of most common STD in the U.S.
    - can lead to pelvic inflammatory disease (PID) & infertility in women
  - also causes *trachoma*, a type of chronic conjunctivitis
    - leading cause of preventable blindness in world
    - frequently transmitted to infants during birth
  - **effectively treated with antibiotics**

3. The Archaea
**The Domain Archaea**

Highly diverse group of prokaryotes with unique physiologies, habitats & rRNA that:

- have "non-peptidoglycan" cell walls
- have unusual membrane lipids

Classified into 2 phyla:

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crenarchaeota</td>
<td>• most of the thermophiles</td>
</tr>
<tr>
<td>Euryarchaeota</td>
<td>• methanogens and halophiles</td>
</tr>
<tr>
<td></td>
<td>• some thermophiles</td>
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</tbody>
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**Key Terms for Chapter 11**

- aerobic, anaerobic
- autotroph, heterotroph
- facultative, obligate
- proteobacteria
- firmicutes, actinobacteria
- chlamydiae, spirochaetes, bacteriodes
- methanogens, halophiles

**Relevant Chapter Questions**

MC: 1-8, 10

**NO known archaea cause disease in humans or animals!**