Characteristics of Prokaryotic Cells

Prokaryotic Form and Function

- Prokaryotes can be distinguished from eukaryotes by:
  - The way their DNA is packaged (lack of nucleus and histones)
  - The makeup of their cell wall (peptidoglycan and other unique chemicals)
  - Their internal structure (lack of membrane-bound organelles)

Prokaryotic Cell

- In all bacteria:
  - Membrane
  - Bacterial chromosome
  - Ribosomes
  - Actin cytoskeleton

- In some bacteria:
  - Fimbriae
  - Cell wall
  - Outer membrane

- In some bacteria (not shown):
  - Pilus
  - Capsule
  - Inclusion
  - Plasmid
  - Plaques

Prokaryotic Cells: Size

- Most are very small (0.5 to 2.0 um in diameter)
- Large surface to volume ratio for nutrients to enter cell quickly

Prokaryotic Cells: Shape

- Most common shapes are coccus (sphere), bacillus (rod) and spiral (spirillum, spirochete, vibrio)

Prokaryotic Cells: Arrangement

- Most common:
  - Diplo- (pairs)
  - Strepto- (strip)
  - Staphylo- (cluster like people at a staff meeting)
Shape & Arrangement are Helpful in Identification and Treatment

- Can you draw the following types of bacteria?
  - *Staphylococcus aureus*
    - Cause of staph infections
  - *Streptococcus pyogenes*
    - Cause of strep throat, Scarlet fever, etc.
  - *Bacillus anthracis*
    - Cause of anthrax

Organization of the Prokaryote

External:
  - Appendages: flagella, pili, fimbriae
  - Glycocalyx: capsule, slime layer

Cell Envelope:
  - Cell wall
  - Membranes

Internal:
  - Cytoplasm
  - Ribosome
  - Inclusions
  - Nucleoid/Chromosome
  - Endospore
  - Plasmid

External Structures: Flagella

- Bacterial locomotion
- Comprised of many proteins
- 360° rotation

Testing for Flagella: Hanging Drop Method

- Bacteria are alive so we can see motility
- Difficult to visualize since microbes are not stained
- Motile bacteria will flit and dart around in the drop
- Non-motile bacteria will wobble back and forth but make no progress away from a stop
External Structures: Pili and Fimbriae

- **Pili**
  - Allows bacteria to attach to surfaces or other bacteria

- **Conjugation pili**
  - Bacteria attach to each other with conjugation pili and transfer plasmids (“mini-chromosomes”) down the pilus.

- **Fimbriae (Attachment pili, think “fingers”)**
  - Facilitates attachment to other bacteria, surfaces, and other types of cells (such as RBCs)
  - Can be involved with the formation of a biofilm

External Structures: Fimbriae

Fimbriae are smaller than flagella and pili, and are important for attachment.

External Structures: Glycocalyces

- Literally means “sugar coat” composed of polysaccharides and protein

- Varies in thickness

- Used to avoid phagocytosis and for adhesion (biofilms)

- Two varieties:
  - **Capsule**
  - **Slime layer**

External Structures: Glycocalyces

- **Slime layer**
  - Unorganized, loose, thin glycocalyx
  - Promote adherence to surfaces (i.e., catheters)
  - Protects cell from drying out, traps nutrients, binds cells together
  - Important in biofilm production

- **Capsule**
  - Organized, tightly packed, thick glycocalyx
  - Prevents phagocytosis of bacteria by white blood cells
  - If Streptococcus pneumoniae lacks a capsule, it is not able to cause pneumonia.

Glycocalyces: Capsule

- Capsid:
  - Bound more tightly to the cell, denser and thicker than a slime layer
  - Encapsulated bacterial cells generally have greater pathogenicity because they can hide from the host’s immune system
Capsid:
- Visible by negative staining
- Produces a sticky (mucoid) character to colonies

Biofilms: Glycocalyces and Fimbriae

External Structures: Biofilm Formation
The slime layer is associated with the formation of biofilms, which are typically found on teeth.

Organization of the Prokaryote
External:
- Appendages: flagella, pili, fimbriae
- Glycocalyx: capsule, slime layer

Cell Envelope:
- Cell wall
- Membranes

Internal:
- Cytoplasm
- Ribosome
- Inclusions
- Nucleoid/Chromosome
- Endospore
- Plasmid

Cell Membrane: Function
- Functions:
  - Forms a boundary between inside and outside of cell
  - Highly selective in its permeability (regulates chemicals that enter and exit the cell, much like a guard at a door)
  - Contains respiratory enzymes which enable the membrane to "capture" or "harness" cellular energy in the form of ATP

Cell Envelope: Cell Membranes
- Structure:
  - Very similar to eukaryotic cells
  - Fluid-mosaic model with phospholipids in a "fluid", dynamic bilayer and proteins arranged in a "mosaic" pattern
- Functions:
  - Form a boundary between inside and outside of cell
Plasma Membrane

Fluid Mosaic Model
- Described as fluid because the molecules are able to move
- Described as mosaic because it is made up of many different kinds of components.

Selective Permeability
- Selective about what crosses based on:
  - Size
  - Electrical charge
  - Other properties

Concentration Gradient
- Difference in concentration of molecules in one area compared to another

Osmosis
- Maintaining a proper water balance is vital for every cell
- Osmosis is a type of passive diffusion that moves water across a selectively permeable membrane from an area of lower solute concentration to an area of higher solute concentration
- Osmosis does not involve the movement of solutes

Tonicity
Cell Envelope: Cell Wall

- Cell wall has 2 important functions:
  - supports shape of cell
  - prevents osmotic lysis
  - Does it regulate transport?
- Cell Wall is external to cell membrane
- 3 Types of Cell Walls
  - Gram-Positive
  - Gram-Negative
  - Acid-Fast

Cell Wall: Peptidoglycan

- Repeating framework of long glycan (sugar) chains cross-linked by short peptide (protein) fragments
- Provides the cell wall strength to resist rupturing due to osmotic pressure
- Gram-Positive bacteria have many layers of Peptidoglycan
- Gram-negative bacteria have few layers of Peptidoglycan
- Very strong structure
- Synthesis inhibited by penicillin (lyses cell)

Cell Wall: Peptidoglycan

- Thick peptidoglycan layer
- One PM
- Teichoic acid (tea-co-ic):
  - Function unclear
  - Binds with crystal violet and iodine to form insoluble complex in Gram stain (positive=purple)
- The envelope of Gram positive bacteria has one cell membrane

Cell Wall: Gram Positive

- This thick peptidoglycan layer is what protects the cell from the high level of salt in MSA.

Gram-Positive Cells: The 4 P’s

1. Positive
   - Gram-positive cells
2. Peptidoglycan
   - Have many layers of peptidoglycan
3. Purple
   - Stain purple in a gram stain
4. Penicillin
   - Susceptible to penicillin since penicillin targets the many peptide crosslinks in peptidoglycan

Cell Wall: Gram Negative

- Thin peptidoglycan layer
- Outer membrane has lipopolysaccharides (LPS)
- Two membranes
  - Cell membrane (same as Gram-positive)
  - Outer membrane
  - Much more resistant to antibiotics and other chemicals than Gram-positive bacteria because of the selective in its permeability of outer membrane
**Gram Negative: Lipopolysaccharides**

- Lipopolysaccharides (LPS) (Lipid A + polysaccharide)
  - These are endotoxins, which will cause shock and fever
  - O-antigen is recognized by the host and initiates the immune response

**The Gram Stain: Procedure**

1. Crystal violet: stains all cells purple
2. Gram’s iodine: stabilizer that causes the dye to form large complexes. The thicker gram-positive cell traps the large complexes.
3. Alcohol: dissolves lipids in the outer membrane and removes the dye from gram-negative cells.
4. Safranin: stains gram-negative bacteria because they are colorless after step three they

**Waxy Cell Walls: Mycobacteria**

- Mycobacteria have cell walls composed of mycolic acid, a waxy lipid
- Use the acid-fast stain to characterize Mycobacteria. Acid-fast stain requires heating the stain to penetrate through the cell wall.
- Difficult to disinfect and treat due to cell wall composition
  - Mycobacteria tuberculosis
  - Mycobacteria leprosae

**Organization of the Prokaryote**

External:
- Appendages: flagella, pili, fimbriae
- Glycocalyx: capsule, slime layer

Cell Envelope:
- Cell wall
- Membranes

Internal:
- Cytoplasm
- Ribosome
- Inclusions
- Nucleoid/Chromosome
- Endospor
- Plasmid

**Internal Structure: Cytoplasm**

- Cytoplasm – Semi-fluid substance in which cellular reactions are carried out

**Internal Structure: Ribosomes**

Ribosomes

- Structure
  - Composed of ribonucleic acid (rRNA) and protein
  - Bacterial ribosomes similar to eukaryotic ribosomes, except bacteria have 70S ribosomes and eukaryotes have 80S ribosomes. Streptomycin and erythromycin work by binding to 70S ribosomes. Does streptomycin bind to our ribosomes?
- Function
  - Protein Synthesis
  - (little protein production factories)
Inclusions

• Enable a cell to store nutrients, and to survive nutrient depleted environments

Internal Structure: Nuclear Region

Nuclear Region

• Nucleoid
  - Mostly deoxyribonucleic acid (DNA)
  - One circular chromosome (we have 46 linear chromosomes)

• Plasmid
  - “mini-chromosome” that contains non-essential, “luxury” DNA

Endospores

• Not a cell structure but a cell state
  - Some bacteria (i.e., Clostridium genus) have the ability to produce endospores, resting stages.
  - Structure
    - DNA + spore coat (extremely tough) + small amount of cytoplasm
  - Function
    - Endospores allow bacteria to survive adverse conditions such as heat, lack of water, disinfectants for thousands of years
    - Difficult to sterilize and they present a big problem in hospitals

  - Life Cycle
    

Unique Groups of Bacteria

Archaebacteria

• “the ancients”
• No examples of pathogenic archaebacteria
• In every habitat on Earth, growing in soil, acidic hot springs, radioactive waste, water, and deep in the Earth's crust, as well as in organic matter and the live bodies of plants and animals

Kingdom Archae bacteria

Thermophilic bacteria - heat loving

Halophilic bacteria - salt loving

Rickettsia sp. - Gram-negative, typhus, Rocky Mountain spotted fever
Kingdom Archae bacteria

For energy these bacteria use sulfur oxidation rather than oxidation from sugars made through photosynthesis!! SO cool!!!!!
• Astrobiologists think that if life is found on other planets it will be bacteria-like
• Record held by a type of thermophile known as a hyperthermophile: 235° F.

Astrobiologists think that if life is found on other planets it will be bacteria-like

For energy these bacteria use sulfur oxidation rather than oxidation from sugars made through photosynthesis!! SO cool!!!!!
• Record held by a type of thermophile known as a hyperthermophile: 235° F.

• Phenotypic methods
  • Microscopic phenotypes (ex. Staphylococcus)
  • Cultural phenotypes (yellow, round, convex, mucoid colonies)
  • Biochemical tests

• Molecular methods
  • DNA sequence, RNA sequence, protein sequence

Species and Subspecies in Prokaryotes

• Theoretically, a collection of bacterial cells, all of which share an overall similar pattern of traits and 70%–80% of their genes
• Members of given species can show variations
  - subspecies, strain, or type are terms used to designate bacteria of the same species that have differing characteristics
  - serotype refers to representatives of a species that stimulate a distinct pattern of antibody (serum) responses in their hosts

Basic Cell Types

<table>
<thead>
<tr>
<th>Prokaryotic cells</th>
<th>Eukaryotic cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>“before nucleus” cells (no nuclear membrane)</td>
<td>“true nucleus” cells (can visualize a dark staining nucleus)</td>
</tr>
<tr>
<td>Simple</td>
<td>More complicated</td>
</tr>
<tr>
<td>Single celled</td>
<td>Single and multi celled</td>
</tr>
<tr>
<td>Single, circular chromosome</td>
<td>Usually paired linear chromosomes</td>
</tr>
<tr>
<td>Divide via binary fission</td>
<td>Divide via mitosis</td>
</tr>
<tr>
<td>No membrane-enclosed structures (no nucleus, no ER...)</td>
<td>Contain membrane-enclosed structures (ER, Golgi, mitochondria, nucleus)</td>
</tr>
<tr>
<td>bacteria</td>
<td>Plants, animals, fungi, protists</td>
</tr>
</tbody>
</table>

Similarities and Differences Between Prokaryotic and Eukaryotic Cells

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Both surrounded by plasma membrane</td>
<td>• Eukaryotes surround DNA with a nuclear membrane</td>
</tr>
<tr>
<td>• Both contain DNA as their genetic information</td>
<td>• Eukaryotes more complicated and may be more than one cell</td>
</tr>
<tr>
<td>• Both contain cytoplasm</td>
<td>• Eukaryotes contain organelles like the ER, Golgi, mitochondria</td>
</tr>
<tr>
<td>• Both have ribosomes and translate proteins</td>
<td>• Eukaryotes have mitochondria for energy production whereas prokaryotes make energy using their plasma membrane</td>
</tr>
<tr>
<td>• Both reproduce</td>
<td>• Prokaryotes typically have a cell wall composed of peptidoglycan</td>
</tr>
<tr>
<td></td>
<td>• Eukaryotes divide via mitosis and prokaryotes via binary fission</td>
</tr>
</tbody>
</table>