O.k., Now Starts the Good Stuff…

Prokaryotic Characteristics

- DNA not enclosed in membrane.
- No histone proteins associated with DNA.
- Lack membrane-bound organelles
- Cell wall is, in most cases, composed of peptidoglycan
- Cell division occurs by binary fission

The Prokaryotic Cell

- External Structures
  - Glycocalyx
  - Flagella
  - Axial Filaments
  - Fimbriae and Pili
- The Cell Wall
- Internal Structures
  - Plasma membrane
  - Cytoplasm
  - Nucleoid Region
  - Ribosomes

Glycocalyx

- It is an extracellular polysaccharide (EPS) coat that surrounds the cell. It may include polypeptides, in some cases.
- This coat is very viscous and gelatinous.
- It is found in both capsules and slime layers.
- Capsules protect bacteria from immune cells.
- Slime layers are usually very loosely arranged and enable bacterial attachment and aggregation.

- The capsule is tightly bound to the cell, and is associated with pathogenic bacteria.

- The slime layer is loosely bound to the cell.

- Glycocalyx can help bacteria attach to different surfaces (usually at solid-liquid interfaces).
- It can restrict the amount and types of nutrients that can pass in and out of the cell.
- If it must, the bacterium can also breakdown the EPS and use it for nutrition.
- This coat also serves as a basic way to protect the cell by preventing dehydration.

- The slime layer is associated with the formation of biofilms, which are typically found on teeth.

Flagella

- These are long filamentous structures that serve as a means for locomotion.
- A bacterial flagellum is composed of three basic parts:

  - Filament- helical protein (flagellin) structure around a hollow core.
  - Hook- made of a different protein; filament is attached to it.
  - Basal Body- anchors the flagellum to the cell wall and plasma membrane.

- The basal body is composed of a rod inserted through a series of rings.
- In Gram-negative bacteria, there are two pairs of rings, and in Gram-positive bacteria, there is only one pair.
- Bacterial flagella move differently from eukaryotic flagella.
- They are semi-rigid and move in a clockwise or counterclockwise motion, rotating from the basal body.

- Movement depends on the cell's ability to produce energy continuously.
- The bacterial cell can change its flagellar speed and rotation.
- If the organism moves in one direction for a long period of time, its movement is called a "run".
- Runs are interrupted by "tumbles".
- Tumbles are caused by a reversal in flagellar rotation.

- The use of a flagellum can enable a bacterium to move toward or away from some type of stimulus.
- Positive chemotactic signal (attractant)=_____runs and _____tumbles.
- Negative chemotactic signal (repellant)= _____runs and _____tumbles.
- Serovars (variations among species) can be distinguished by H antigen (flagellar protein)

- THESE FLAGELLA ARE DIFFERENT FROM EUKARYOTIC FLAGELLA!!!!!!!!
- Bacterial cells have four different arrangements of flagella.
  - Monotrichous
  - Amphitrichous
  - Lophotrichous
  - Peritrichous

Axial Filaments

- These are found in spirochetes.
- They are anchored at one end of the spirochete and spirals around the bacterial cell.
- The result is a "soft" corkscrew motion.

Fimbriae and Pili

- These two structures are made from a protein called pilin.
- Fimbriae are used for attachment and are usually found at the ends of or around cells that have them.
- Pili are longer than fimbriae and are used to transfer genetic material from one cell to another.

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

- Pili enable conjugation to occur, which is the transfer of DNA from one bacterial cell to

another.

The Cell Wall

- Semi-rigid structure responsible for keeping the cell's shape.
- Major function- prevents bacterial cell from rupturing when there is a difference of water pressure between the interior and exterior of the cell.
- Also, it serves as an anchor point for the flagellum.
- May contribute to some organisms' pathogenicity and is also the site of action for some antibiotics.

Cell Wall Composition

- The cell wall is composed of peptidoglycan (a.k.a murein).
- This can be found by itself or in conjunction with other substances.
- Peptidoglycan is made up of a repeating disaccharide attached by polypeptides to form a lattice network that protects the entire cell.
- The disaccharide portion of the peptidoglycan is made up of monosaccharides called N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM).

- Both of these sugars are related to glucose.
- These sugars are alternatively linked in rows of 10 to 65, resulting in a glycan backbone.
- Each row is linked by a polypeptide.
- The structure of the polypeptide link will vary, however, it always includes tetrapeptide side chains. These are four amino acids attached to NAMs.
- Parallel chains may be bonded to each other directly or may be linked by a peptide cross bridge.

Gram-positive Cell Walls

- Consist of many layers of peptidoglycan (murein); thick rigid structure.
- They also contain teichoic acid in their cell walls which are made up of an alcohol and phosphate.
- There are two types of teichoic acid: lipoteichoic acid and wall teichoic acid.
- The lipoteichoic acid spans the peptidoglycan layer and is linked to the plasma membrane.

- The wall teichoic acid is linked to the peptidoglycan layer.
- Because the teichoic acid is negatively charged, positively charged ions (cations) will bind to it and is regulated by it.
- There are some Gram-positive bacteria that have mycolic acid (a waxy lipid) in their cell walls. These are termed acid-fast positive cells.

Gram-negative Cell Walls

- Consists of a thin layer of peptidoglycan and an outer membrane. The thin layer makes it susceptible to mechanical damage.
- The peptidoglycan is bonded to lipoproteins in the outer membrane and is found in the periplasm.

- The periplasm is full of degradative enzymes and transport proteins.
- These walls do not contain teichoic acids.

- The outer membrane
  - is composed of lipopolysaccharides and phospholipids.
  - has a strong negative charge
    - can evade phagocytosis and the complement system.
  - It also provides a barrier to certain antibiotics, like penicillin or detergents, heavy metals, and certain dyes.
- Porins, Lipid A, and O polysaccharides are specifically found in the outer membrane.

- **Lipopolysaccharide:**
  - Polysaccharide chains function as cell markers and receptors
  - **Endotoxin:** stimulates fever and shock reactions
- **Lipoproteins:** anchor the outer membrane to peptidoglycan
- **Porin proteins:**
  - Completely span the outer membrane
  - Only allow relatively small molecules to penetrate
  - Size can be altered to block the entrance of harmful chemicals
  - Act as a defense against certain antibiotics

Atypical Cell Walls

- The genus *Mycoplasma* have no cell walls, but instead have modified cell membranes that contain sterols in them.
- Archaea may lack cell walls or may have walls composed of sugars and proteins, but not peptidoglycan.
  - They do, however, contain a substance similar to peptidoglycan called pseudomurein, which contain N-acetyltalosaminuronic acid instead of NAM.

Gram-positive vs. Gram-negative

- A technique devised by Danish physician Hans Christian Gram in 1884, uses a staining and washing technique to differentiate between the two forms.
- When exposed to a gram stain, gram-positive bacteria retain the purple color of the stain because the structure of their cell walls traps the dye.
- In gram-negative bacteria, the cell wall is thin and releases the dye readily when washed with an alcohol or acetone solution.

Plasma Membrane

- The plasma membrane is the thin outermost component of the cell that maintains its shape.
- It maintains the homeostasis of the cell but does not isolate it.
- The cell membrane is consists mainly of phospholipids.
- Phospholipids have a hydrophilic head and a hydrophobic tail.
- These phospholipids arrange themselves in such a way that it forms a lipid bilayer.

Fluid Mosaic Model

- It is fluid because of the motions of the lipids and how they interact.

- It is called a mosaic because of the mixed components found in the membrane.
- The model depicts the membrane not as one that solely consists of a lipid bilayer, but instead one that consists of lipids and proteins.
- A variety of phospholipids, glycolipids, and sterols are incorporated in the membrane and embedded in the membrane are proteins.

- There are different types of proteins found in the plasma membrane.
- Transport proteins allow water-soluble proteins to go in and out of the cell.
- Receptor proteins can bind hormones and other substances that can trigger changes in the cell's activities.
- There are also recognition proteins on the cell surface that act like a "signature", identifying the cell as being a specific type.

Cytoplasm

- The cytoplasm, or protoplasm, of bacterial cells is where the functions for cell growth, metabolism, and replication are carried out.
- It is a gel-like matrix composed of water, enzymes, nutrients, wastes, and gases and contains cell structures such as ribosomes, a chromosome, and plasmids.
- All of the cellular components are scattered throughout the cytoplasm.

Nucleoid region

- DNA in the bacterial cell is generally confined to a central region.
- Even though it is not membrane-bound, it is visibly distinct (using TE) from the cell interior.
- The bacterial nucleoid does not divide by mitosis.
- During DNA replication, each strand of the replicating bacterial DNA attaches to proteins at what will become the cell division plane.
- As the bacterium grows, the newly replicated chromosomes become separated.

- Some bacteria will have circular DNA strands called plasmids in their cytoplasm.
- Plasmids are (typically) circular double-stranded DNA molecules that are separate from the chromosomal (nucleoid) DNA.
- Each cell may have anywhere from one to hundreds of the same plasmid present.

Ribosomes

- Ribosomes give the cytoplasm of bacteria a granular appearance in electron micrographs.
- They translate the genetic code from the molecular language of nucleic acid to that of amino acids - the building blocks of proteins.
- Proteins are the molecules that perform all the functions of cells and living organisms.

- Bacterial ribosomes are similar to those of eukaryotes, but are smaller and have a slightly different composition and molecular structure.
- Bacterial ribosomes are never bound to other organelles as they sometimes are (bound to the endoplasmic reticulum) in eukaryotes, but are free-standing structures distributed throughout the cytoplasm.

- There are sufficient differences between bacterial ribosomes and eukaryotic ribosomes that some antibiotics will inhibit the functioning of bacterial ribosomes, but not a eukaryote's, thus killing bacteria but not the eukaryotic organisms they are infecting.
- Ribosomes are composed of two subunits, each one consists of a protein and ribosomal RNA.
- The prokaryotic ribosome consists of a 30s subunit and a 50s subunit. Together, they make a 70s subunit.
- The "s" refers to Svedberg units, which indicate the relative rate of sedimentation during ultra-high-speed centrifugation.

- Inclusion bodies enable a cell to store nutrients, and to survive nutrient depleted environments.

- During nutrient depleted conditions, some bacteria (vegetative cell) form into an endospore in order to survive.

Bacterial Size and Shape

- Bacterial size ranges are from 0.2 to 2.0 μm long.
- There are basic shapes that bacteria come in.
  - coccus (sphere-shaped)
  - bacillus (rod-shaped)
  - spirillum (spiral-shaped)
- There are other shapes, however.

- Relative size of a bacterial cell compared to other cells including viruses.

- Comma-shaped (curved) rods are known as vibrio.
- Spirochetes are helical and flexible.
- Spirilla are corkscrew shaped and rigid.
- There are other differences between spirilla and spirochetes.
- There are also star-shaped cells, rectangular, flat cells, and triangular cells.
- These, however, are not commonly seen shapes of bacteria.

Bacterial Arrangement

- Coccus
  - Diplococci
  - Streptococci
  - Staphylococci
  - Tetrad
  - Sarcina
- Bacillus
  - Diplobacilli
  - Streptobacilli

Once a Sphere, Always a Sphere?

- Bacterial shape is genetically determined.

- Genetically, bacteria are monomorphic, meaning that they are a single shape.
- However, there are some bacteria that are pleomorphic, meaning that they can change their shape.
- The environment can also play a role in the organism's morphology.

Unique groups of bacteria

- Intracellular parasites
- Photosynthetic bacteria
- Green and purple sulfur bacteria
- Gliding and fruiting bacteria