Chapter 4

Functional Anatomy of Prokaryotic and Eukaryotic Cells

Prokaryotic and Eukaryotic Cells

- **Prokaryote** comes from the Greek words for prenucleus.
- **Eukaryote** comes from the Greek words for true nucleus.

**Prokaryote**

- One circular chromosome, not in a membrane
- No histones
- Binary fission
- No organelles except ribosomes
- Peptidoglycan cell walls if Bacteria
- Pseudomurein cell walls if Archaea

**Eukaryote**

- Paired chromosomes, in a nuclear membrane
- Histones
- Mitotic spindle
- Organelles
- Polysaccharide cell walls

**Prokaryotic Cells: Shapes**

- Average size: 0.2 – 1.0 µm × 2 – 8 µm
- Most bacteria are monomorphic
- A few are pleomorphic

  - Bacillus (rod-shaped)
  - Coccus (spherical)
  - Spiral
    - Spirillum
    - Vibrio
    - Spirochete

**Cell Arrangements**

- Pairs: Diplococci, diplobacilli
- Clusters: Staphylococci
- Chains: Streptococci, streptobacilli

**The Structure of a Prokaryotic Cell**

**Glycocalyx**

- Outside cell wall
- Usually sticky
- Capsule: a neatly organized glycocalyx
- Slime layer: unorganized and loose
- Extracellular polysaccharide allows cell to attach
- Capsules prevent phagocytosis

**Flagella**

- Outside cell wall
- Made of chains of flagellin
- Attached to a protein hook
- Anchored to the wall and membrane by the basal body

**Motile Cells**

- Rotate flagella to run or tumble
- Move toward or away from stimuli (taxis)
- Flagella proteins are H antigens (e.g., *E. coli* O157:H7)

**Axial Filaments**

- Also called endoflagella
- In spirochetes
- Anchored at one end of a cell
- Rotation causes cell to move

**Fimbriae and Pili**

- Fimbriae allow attachment
- Pili
  - Facilitate transfer of DNA from one cell to another
  - Gliding motility
  - Twitching motility

**The Cell Wall**

- Prevents osmotic lysis
- Made of peptidoglycan (in bacteria)

**Peptidoglycan**

- Polymer of disaccharide:
  - N-acetylgucosamine (NAG)
  - N-acetylmuramic acid (NAM)
Peptidoglycan in Gram-Positive Bacteria
• Linked by polypeptides

Gram-positive Cell Wall
• Thick peptidoglycan
• Teichoic acids

Gram-negative Cell Wall
• Thin peptidoglycan
• Outer membrane
• Periplasmic space

Gram-positive Cell Wall
• Teichoic acids
  • Lipoteichoic acid links to plasma membrane
  • Wall teichoic acid links to peptidoglycan
• May regulate movement of cations
• Polysaccharides provide antigenic variation

Gram-Negative Outer Membrane
• Lipopolysaccharides, lipoproteins, phospholipids
• Forms the periplasm between the outer membrane and the plasma membrane
• Protection from phagocytes, complement, and antibiotics
• O polysaccharide antigen, e.g., *E. coli* O157:H7
• Lipid A is an endotoxin
• Porins (proteins) form channels through membrane

The Gram Stain Mechanism
• Crystal violet-iodine crystals form in cell
• Gram-positive
  • Alcohol dehydrates peptidoglycan
  • CV-I crystals do not leave
• Gram-negative
  • Alcohol dissolves outer membrane and leaves holes in peptidoglycan

Gram-Positive Cell Wall
• 2-ring basal body
• Disrupted by lysozyme
• Penicillin sensitive

Gram-Negative Cell Wall
• 4-ring basal body
• Endotoxins
• Tetracycline sensitive

Atypical Cell Walls
• Acid-fast cell walls
  • Like gram-positive cell walls
  • Have waxy lipid (*mycolic acid*) bound to peptidoglycan
  • Carbolfuchsin stains through waxy layer & wall
  • *Mycobacterium*
  • *Nocardia*
• Mycoplasmas
  • Lack cell walls
  • Sterols in plasma membrane for protection
• Archaea
  • Wall-less or
  • Walls of pseudomurein (lack NAM and D-amino acids)

Damage to the Cell Wall
• Lysozyme digests disaccharide in peptidoglycan
• Penicillin inhibits peptide bridges in peptidoglycan
• Protoplast is a wall-less cell
• Spheroplast is a wall-less gram-positive cell
  • Protoplasts and spheroplasts are susceptible to osmotic lysis
• L forms are wall-less cells that swell into irregular shapes

The Plasma Membrane
• Phospholipid bilayer
• Peripheral proteins
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- Integral proteins
- Transmembrane proteins

Fluid Mosaic Model
- Membrane is as viscous as olive oil
- Proteins move to function
- Phospholipids rotate and move laterally

The Plasma Membrane
- Selective permeability allows passage of some molecules
- Enzymes for ATP production
- Photosynthetic pigments on foldings called chromatophores or thylakoids

Chromatophores
- In-foldings of the plasma membrane

The Plasma Membrane
- Damage to the membrane by alcohols, quaternary ammonium (detergents), and polymyxin antibiotics causes leakage of cell contents

Movement of Materials across Membranes
- Simple diffusion: Movement of a solute from an area of high concentration to an area of low concentration
- Facilitated diffusion: Solute combines with a transporter protein in the membrane
- Osmosis: The movement of water across a selectively permeable membrane from an area of high water to an area of lower water concentration
- Osmotic pressure: The pressure needed to stop the movement of water across the membrane

Movement of Materials across Membranes
- Through lipid layer

- Aquaporins (water channels)

The Principle of Osmosis
- Understand this concept!

Movement of Materials across Membranes
- Active transport: Requires a transporter protein and ATP
- Group translocation: Requires a transporter protein and PEP

Cytoplasm
- The substance inside the plasma membrane

The Nucleoid
- Bacterial chromosome

The Prokaryotic Ribosome
- Protein synthesis
- 70S
  - 50S + 30S subunits

Inclusions
- Metachromatic granules (volutin)
  - Phosphate reserves
- Polysaccharide granules - Energy reserves
- Lipid inclusions - Energy reserves
- Sulfur granules - Energy reserves
- Carboxysomes - Ribulose 1,5-diphosphate carboxylase for CO₂ fixation
- Gas vacuoles - Protein-covered cylinders
- Magnetosomes - Iron oxide (destroys H₂O₂)

Endospores
- Resting cells
- Resistant to desiccation, heat, chemicals
- Bacillus, Clostridium
- Sporulation: Endospore formation
- Germination: Return to veg. state
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The Eukaryotic Cell

Flagella and Cilia
• Microtubules
• Tubulin
• 9 pairs + 2 array

The Cell Wall and Glycocalyx
• Cell wall
  • Plants, algae, fungi
  • Carbohydrates
• Cellulose, chitin, glucan, mannan
• Glycocalyx
  • Carbohydrates extending from animal plasma membrane
  • Bonded to proteins and lipids in membrane

The Plasma Membrane
• Phospholipid bilayer
• Peripheral proteins
• Integral proteins
• Transmembrane proteins
• Sterols
• Glycocalyx carbohydrates

The Plasma Membrane
• Selective permeability allows passage of some molecules
• Simple diffusion
• Facilitative diffusion
• Osmosis
• Active transport
• Endocytosis
  • Phagocytosis: Pseudopods extend and engulf particles
  • Pinocytosis: Membrane folds inward, bringing in fluid and dissolved substances

Cytoplasm
• Cytoplasm membrane: Substance inside plasma and outside nucleus
• Cytosol: Fluid portion of cytoplasm
• Cytoskeleton: Microfilaments, intermediate filaments, microtubules

Ribosomes
• Protein synthesis
• 80S
  • Membrane-bound: Attached to ER
  • Free: In cytoplasm
• 70S
  • In chloroplasts and mitochondria

Organelles
• Nucleus: Contains chromosomes
• ER: Transport network
• Golgi complex: Membrane formation and secretion
• Lysosome: Digestive enzymes
• Vacuole: Brings food into cells and provides support
• Mitochondrion: Cellular respiration
• Chloroplast: Photosynthesis
• Peroxisome: Oxidation of fatty acids; destroys H₂O₂
• Centrosome: Consists of protein fibers and centrioles

Endosymbiotic Theory
• Know this concept in general terms