

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: $0.2 - 1.0 \mu\text{m} \times 2 - 8 \mu\text{m}$
- 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

glycocalyx

- 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
 - **Twisting** motility

The Cell Wall

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

Peptidoglycan

- Polymer of disaccharide:
 - N-acetylglucosamine (NAG)
 - N-acetylmuramic acid (NAM)

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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

- CV-I washes out

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
 - Carbol-fuchsin 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

- **Cytoplasmic streaming:** Movement of cytoplasm throughout cells

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