The Cell

I. Introduction.

- cell: smallest unit of living matter capable of independent existence; structural and functional unit of all living things.
- other premises of cell theory: activities of an organism are dependent on individual/collective activities of all cells; activities of cells made possible by subcellular structures; continuity of life has a cellular basis.
- protoplasm; colloid of nucleic acids, proteins, CH2O, lipids, water, minerals that are basis of life.
- cell has three major parts: a plasma membrane, cytoplasm, and nucleus.

II. The plasma membrane.

A. General structure.

- a thin membrane that surrounds cells; a bilayer of phospholipid molecules with globular proteins dispersed in it -- the fluid-mosaic model

B. Molecular structure.

1. Phospholipid bilayer naturally results from structure of phospholipid molecule, a hydrophilic head and hydrophobic tail; confers membrane unique permeability properties.

2. Globular proteins are dispersed about the phospholipid bilayer, responsible for many functions of plasma membrane; can be:

a. integral membrane proteins firmly inserted in the lipid bilayer; most span the entire width of the membrane, transmembrane proteins.

b. peripheral membrane proteins not embedded in the lipid bilayer; external and/or internal.

c. functions of the membrane proteins include transport, enzymes, receptors, intercellular junction formation, cell-cell recognition, cytoskeleton attachment.

3. Highly branched sugar groups found attached to external side of some integral proteins and of other external peripheral proteins, glycocalyx.

C. Structural specializations of plasma membranes.

1. Microvilli: fingerlike projections that increase plasma membrane surface area.

2. Specialized membrane junctions (not present in all cells):

a. tight junctions: protein molecules in adjacent plasma membranes fuse together, restricts macromolecule movement between cells.

b. desmosomes: adhesive spots scattered along the sides of abutting cells, prevent separation of cells.
c. gap junctions - hollow channels between cells; allows direct passage of small chemical substances between cells (mostly ions); found in excitable tissues.

D. Functions of plasma membrane: functions of proteins found within membrane.

1. Membrane transport.
- membrane is selectively permeable.
- substances can be transported across either passively or actively.
a. passive transport processes: substances are moved down a concentration gradient.
i. simple diffusion: lipid soluble substances can move across the membrane down a concentration gradient; small non lipid soluble substances will use a channel protein; channels are often molecule specific.
ii. facilitated diffusion: used to move large, lipid insoluble molecules across membrane; involves a transport protein (transmembrane).
iii. filtration: process by which water and solutes are forced through a membrane by hydrostatic pressure.
iv. osmosis: diffusion of solvent across selectively permeable membrane.
b. active transport processes: energy is expended to move substances across a membrane against a concentration gradient.
i. primary active transport: energy to move substance is directly provided directly by ATP hydrolysis -- the sodium/potassium pump.
ii. secondary active transport: driven by passive ion gradients that were set up by primary active transport; some a.a., sugars "piggyback" on sodium ions across the membrane (via a transporter).
c. bulk transport processes: means by which very large molecules and particles are transported across membranes.
i. exocytosis: process that moves substances from cell interior to exterior
ii. endocytosis: process that moves large particles from extracellular space to cell interior; types of endocytosis are phagocytosis, pinocytosis, receptor mediated endocytosis.

2. Generation and maintenance of resting membrane potential.
- sodium/potassium pump sets up a unique distribution of sodium and potassium ions across the membrane; Na+ at greater concentration outside cell, K+ at greater concentration inside cell.

- the plasma membrane is differentially permeable to sodium and potassium (pK+ > pNa+); thus potassium leaks out (down gradient) at a much greater rate than sodium leaks in; this results in a loss of positive ions inside the cell relative to outside; therefore, the inside becomes "negative" relative to the outside of the cell.
- there is a voltage difference across a membrane, the resting membrane potential (-20 - -200 mV depending on cell type).

III. The cytoplasm

- cellular material inside plasma membrane, outside the nucleus; site where most cellular activity is accomplished
- major components of the cytoplasm are cytosol, organelles, inclusions, cytoskeleton.

A. Cytosol: viscous matrix where everything else in the cell is suspended.

B. Organelles: membrane bound structures, specialized cellular components each performing a particular function.

- delineating membrane allows organelles to maintain internal environments different from surrounding cytosol -- important to perform specific functions that require a very specific environment very different from that of cytosol.
- compartmentalization--an organization to biochemical activity?

1. Mitochondria: powerplants of the cell, ATP production.
   - composed of two membranes, inner and outer mitochondrial membranes.
   - contain their own DNA and RNA, can self-replicate.

2. Ribosomes: composed of two globular proteins and rRNA; site of protein synthesis.
   - free in cytoplasm or attached to membranous system of RER.

3. Endoplasmic reticulum (ER): system of interconnected parallel membranes and tubes enclosing a fluid-filled cavity (cisterna); continuous with nuclear membranes; two types or ER rough (RER) and smooth (SER).
   a. RER: flattened membrane sacs studded with ribosomes, important in synthesis of proteins secreted from the cell or for incorporation in cellular membranes.
      - cell's membrane synthesis center.
      - protein synthesis overview.
   b. SER: structural continuation of RER, not functional continuation.
      - more tubular, no ribosomes and no role in protein synthesis.

- role in lipid metabolism: synthesis of cholesterol, lipoproteins, steroid hormones, absorption of fats, drug detox.

4. Golgi apparatus: flattened membranous sacs stacked upon one another, associated with groups of tiny membranous vesicles.
- transport vesicles from the RER fuse with receiving side of GA; as contents passed along to shipping face of GA, proteins are modified, packaged, and sorted for delivery to a specific site.
- three types of vesicles arise from GA shipping face: secretory vesicles, vesicles containing membrane proteins, lysosomes.

5. Lysosomes: spherical membranous units, contain digestive enzymes.
- used in digestion of foreign materials, breakdown of stored fuels, degradation of non-usable tissue or organelles (autolysis).

6. Perixosomes: membranous sacs containing powerful oxidase enzymes that use oxygen to detoxify many harmful substances (alcohol, formaldehyde); disarm free radicals, convert them to H2O2.

C. Inclusions.
- inert substances accumulated in the cytoplasm such as glycogen and pigments - not membrane-bound.

D. Cytoskeleton.
- structural framework of a cell; maintains shape, stabilizes attachments, plays a vital role in cell movement, organelle movement.
- includes various filamentous structures such as microtubules, microfilaments, and intermediate filaments.

1. Microtubules: cytoskeletal element with the largest diameter.
- hollow tubes made up of spiral arrangements of molecules of the globular protein tubulin.
- all originate/radiate from a particular area in the cytoplasm called centrosome.
- radiating arrangement determines cell shape, distribution of organelles (motor proteins associated with MTs), critical cellular movements in cell division.

2. Microfilament: thin strands made of polymers of G-actin molecules (a contractile protein).
- different cells have different arrangements of MFs - dense peripheral bundles, stress fibers.
- muscle has a very specific arrangement of actin filaments that interact with the myosin to generate contractile forces.

3. Intermediate filaments: intermediate in size between MTs/MFs.
    - controversial functions: form highly elaborate networks throughout the cell to help maintain cell shape; role in junction formation, nuclear support, cell signaling?

4. Centrosome: microtubular organization center, contain centrioles.
    - centrioles: nine triplets of microtubules; arranged cylindrically to form a hollow tube; organization of mitotic spindle in cell division.

5. Cilia: whiplike, motile cellular extensions that occur in exposed surfaces of certain cells; move substances in one direction across the cell surface.
    - cilium - nine doublet microtubules around a central pair.
    - flagella: similar in structure to cilia; occur singly, involved in cell motility.

IV. The nucleus.

- control center of the cell; contains genetic information of a cell; codes for all proteins; largest cell organelle; a few cells are multinucleate.
- nuclear envelope: double membrane, each membrane is a phospholipid bilayer.
- nucleoli: most prominent structure in the nucleus; not membrane bound; involved in RNA synthesis
- chromatin: a complex, highly coiled structure composed of DNA/protein (histones); visible as chromosomes during cell division.

V. Extracellular Material (ECM).

- ECM is a jellylike substance composed of proteins, polysaccharides, water.
- molecules secreted by the cell that hold the cell together.