

Chapter 5

5.1 Plasma Membrane Structure and Function

1. The plasma membrane is a **phospholipid bilayer** with embedded proteins.
2. Phospholipids have both hydrophilic and hydrophobic regions; nonpolar tails (hydrophobic) are directed inward, polar heads (hydrophilic) are directed outward to face both extracellular and intracellular fluid.
3. The proteins form a *mosaic* pattern on the membrane.
4. **Cholesterol** is a lipid found in animal plasma membranes; it stiffens and strengthens the membrane.
5. The plasma membrane is asymmetrical; glycolipids and proteins occur only on outside and cytoskeletal filaments attach to peripheral proteins only on the inside surface.
6. Integral proteins are usually found in the membrane and are held in place by the cytoskeleton and the extracellular matrix (ECM).
7. ECM are only found in animals and their functions include supporting the plasma membrane and communicating between cells.

A. Fluid-Mosaic Model

1. The fluid-mosaic model describes the plasma membrane.
2. The fluid component refers to the phospholipids bilayer of the plasma membrane.
3. Fluidity of the plasma membrane allows cells to be pliable.
4. Fluidity is affected by cholesterol molecules in the plasma membrane.
5. The mosaic component refers to the protein content in the plasma membrane.
6. Proteins bond to the ECM and/or cytoskeleton to prevent movement in the fluid phospholipid bilayer

B. Carbohydrate Chains

1. **Glycolipids** have a structure similar to phospholipids except the hydrophilic head is a variety of sugar; they are protective and assist in various functions.
2. **Glycoproteins** have an attached carbohydrate chain of sugar that projects externally.
3. In animal cells, the *glycocalyx* is a “sugar coat” of carbohydrate chains; it has several functions.
4. Cells are unique in that they have highly varied carbohydrate chains (a “fingerprint”).
5. The immune system recognizes foreign tissues that have inappropriate carbohydrate chains.
6. Carbohydrate chains are the basis for A, B, and O blood groups in humans.

C. The Functions of the Proteins

1. **Channel proteins** allow a particular molecule to cross membrane freely (e.g., Cl^- channels).
2. **Carrier proteins** selectively interact with a specific molecule so it can cross the plasma membrane (e.g., Na^+ - K^+ pump).
3. **Cell recognition proteins** are glycoproteins that allow the body's immune system to distinguish between foreign invaders and body cells.
4. **Receptor proteins** are shaped so a specific molecule (e.g., hormone) can bind to it.

5. **Enzymatic proteins** carry out specific metabolic reactions.
 6. **Junction proteins** join animal cells so tissues can function.
- D. How Do Cells Talk to One Another? (*Science Focus box*)
1. Cell Signaling
 - a. molecules, or chemical messengers, “talk” to other cells and may change cells, tissues, or organs.
 - b. These cells do not respond to all molecules. They require binding to a receptor protein.
 - c. Once the signaling molecule is bound to a receptor, the signal follows through a transduction pathway.
 - d. The cell’s response to the transduction pathway can change the shape or movement of the cell, alter the metabolism or function of the cell, or alter the gene expression and amount of a cell protein.
- E. Permeability of the Plasma Membrane
1. The plasma membrane is **differentially (selectively) permeable**; only certain molecules can pass through.
 - a. Small non-charged lipid molecules (alcohol, oxygen) pass through the membrane freely.
 - b. Small polar molecules (carbon dioxide, water) move “down” a **concentration gradient**, i.e., from high to low concentration.
 - c. Ions and charged molecules cannot readily pass through the hydrophobic component of the bilayer and usually combine with carrier proteins.
 2. Both passive and active mechanisms move molecules across membrane.
 - a. **Passive transport** moves molecules across membrane without expenditure of energy; includes **diffusion** and **facilitated transport**.
 - b. **Active transport** requires a carrier protein and uses energy (ATP) to move molecules across a plasma membrane; includes **active transport**, **exocytosis**, **endocytosis**, and **pinocytosis**.
 3. The presence of a membrane channel protein called an **aquaporin** allows water to cross membranes quickly.
 4. Substances enter or exit a cell through **bulk transport**.

5.2 Passive Transport Across a Membrane

1. **Diffusion** is the movement of molecules from higher to lower concentration (i.e., “down” the concentration gradient).
 - a. A solution contains a **solute**, usually a solid, and a **solvent**, usually a liquid.
 - b. In the case of a dye diffusing in water, the dye is a solute and water is the solvent.
 - c. Once a solute is evenly distributed, random movement continues but with no net change.
 - d. Membrane chemical and physical properties allow only a few types of molecules to cross by diffusion.
 - e. Gases readily diffuse through the lipid bilayer; e.g., the movement of oxygen from air sacs (alveoli) to the blood in lung capillaries depends on the concentration of oxygen in alveoli.

- f. Temperature, pressure, electrical currents, and molecular size influence the rate of diffusion.

A. Osmosis

1. **Osmosis** is the diffusion of water across a differentially (selectively) permeable membrane.
 - a. Osmosis is illustrated by the thistle tube example:
 - 1) A differentially permeable membrane separates two solutions.
 - 2) The beaker has more water (lower percentage of solute) and the thistle tube has less water (higher percentage of solute).
 - 3) The membrane does not permit passage of the solute; water enters but the solute does not exit.
 - 4) The membrane permits passage of water with a net movement of water from the beaker to the inside of the thistle tube.
 - b. **Osmotic pressure** is the pressure that develops in such a system due to osmosis.
 - c. Osmotic pressure results in water being absorbed by the kidneys and water being taken up from tissue fluid.
2. **Tonicity** is strength of a solution with respect to osmotic pressure.
 - a. **Isotonic solutions** occur where the relative solute concentrations of two solutions are **equal**; a 0.9% salt solution is used in injections because it is isotonic to red blood cells (RBCs).
 - b. A **hypotonic solution** has a solute concentration that is *less* than another solution; when a cell is placed in a hypotonic solution, water enters the cell and it may undergo **cytolysis** (“cell bursting”).
 - c. Swelling of a plant cell in a hypotonic solution creates **turgor pressure**; this is how plants maintain an erect position.
 - d. A **hypertonic** solution has a solute concentration that is *higher* than another solution; when a cell is placed in a hypertonic solution, it shrivels (a condition called **crenation**).
 - e. **Plasmolysis** is shrinking of the cytoplasm due to osmosis in a hypertonic solution; as the central vacuole loses water, the plasma membrane pulls away from the cell wall.
3. Facilitated Transport
 - a. **Facilitated transport** is the transport of a specific solute “down” or “with” its concentration gradient (from high to low), facilitated by a carrier protein; glucose and amino acids move across the membrane in this way.

5.3 Active Transport Across a Membrane

- A. **Active transport** is transport of a specific solute across plasma membranes “up” or “against” (from low to high) its concentration gradient through use of cellular energy (ATP).
 1. Iodine is concentrated in cells of thyroid gland, glucose is completely absorbed into lining of digestive tract, and sodium is mostly reabsorbed by kidney tubule lining.
 2. Active transport requires both carrier proteins and ATP; therefore cells must have high number of mitochondria near membranes where active transport occurs.

3. Proteins involved in active transport are often called “pumps”; the sodium-potassium pump is an important carrier system in nerve and muscle cells.
4. Salt (NaCl) crosses a plasma membrane because sodium ions are pumped across, and the chloride ion is attracted to the sodium ion and simply diffuses across specific channels in the membrane.

B. Bulk Transport

1. In **exocytosis**, a vesicle formed by the Golgi apparatus fuses with the plasma membrane as secretion occurs; insulin leaves insulin-secreting cells by this method.
2. During **endocytosis**, cells take in substances by vesicle formation as plasma membrane pinches off by either phagocytosis, pinocytosis, or receptor-mediated endocytosis.
3. In **phagocytosis**, cells engulf large particles (e.g., bacteria), forming an endocytic vesicle.
 - a. Phagocytosis is commonly performed by ameboid-type cells (e.g., amoebas and macrophages).
 - b. When the endocytic vesicle fuses with a lysosome, digestion of the internalized substance occurs.
4. **Pinocytosis** occurs when vesicles form around a liquid or very small particles; this is only visible with electron microscopy.
5. **Receptor-mediated endocytosis**, a form of pinocytosis, occurs when specific macromolecules bind to plasma membrane receptors.
 - a. The receptor proteins are shaped to fit with specific substances (vitamin, hormone, lipoprotein molecule, etc.), and are found at one location in the plasma membrane.
 - b. This location is a coated pit with a layer of fibrous protein on the cytoplasmic side; when the vesicle is uncoated, it may fuse with a lysosome.
 - c. Pits are associated with exchange of substances between cells (e.g., maternal and fetal blood).
 - d. This system is selective and more efficient than pinocytosis; it is important in moving substances from maternal to fetal blood.
 - e. Cholesterol (transported in a molecule called a low-density lipoprotein, LDL) enters a cell from the bloodstream via receptors in coated pits; in familial hypocholesterolemia, the LDL receptor cannot bind to the coated pit and the excess cholesterol accumulates in the circulatory system.

5.4 Modification of Cell Surfaces

A. Cell Surfaces in Animals

1. The **extracellular matrix** is a meshwork of polysaccharides and proteins produced by animal cells.
 - a. **Collagen** gives the matrix strength and **elastin** gives it resilience.
 - b. **Fibronectins** and **laminins** bind to membrane receptors and permit communication between matrix and cytoplasm; these proteins also form “highways” that direct the migration of cells during development.

- c. **Proteoglycans** are glycoproteins that provide a packing gel that joins the various proteins in matrix and most likely regulate signaling proteins that bind to receptors in the plasma protein.

2. **Junctions Between Cells** are points of contact between cells that allow them to behave in a coordinated manner.

- a. **Anchoring junctions** mechanically attach adjacent cells.
- b. In **adhesion junctions**, internal cytoplasmic plaques, firmly attached to cytoskeleton within each cell are joined by intercellular filaments; they hold cells together where tissues stretch (e.g., in heart, stomach, bladder).
- c. In **desmosomes**, a single point of attachment between adjacent cells connects the cytoskeletons of adjacent cells.
- d. In **tight junctions**, plasma membrane proteins attach in zipper-like fastenings; they hold cells together so tightly that the tissues are barriers (e.g., epithelial lining of stomach, kidney tubules, blood-brain barrier).
- e. A **gap junction** allows cells to communicate; formed when two identical plasma membrane channels join.
 - 1) They provide strength to the cells involved and allow the movement of small molecules and ions from the cytoplasm of one cell to the cytoplasm of the other cell.
 - 2) Gap junctions permit flow of ions for heart muscle and smooth muscle cells to contract.

B. Plant Cell Walls

- 1. Plant cells are surrounded by a porous cell wall; it varies in thickness, depending on the function of the cell.
- 2. Plant cells have a primary cell wall composed of cellulose polymers united into threadlike microfibrils that form fibrils.
- 3. Cellulose fibrils form a framework whose spaces are filled by non-cellulose molecules.
- 4. **Pectins** allow the cell wall to stretch and are abundant in the middle lamella that holds cells together.
- 5. **Non-cellulose** polysaccharides harden the wall of mature cells.
- 6. **Lignin** adds strength and is a common ingredient of secondary cell walls in woody plants.
- 7. **Plasmodesmata** are narrow membrane-lined channels that pass through cell walls of neighboring cells and connect their cytoplasm, allowing direct exchange of molecules and ions between neighboring plant cells.