Biology 112: Chapter 6: Cell Membranes

Membrane Structure – A phospholipid bilayer separates two aqueous regions

- **Hydrophilic regions**: the phosphorus – containing "head" of the phospholipid is electrically charged and therefore associated with polar water molecules
- **Hydrophobic regions**: the long, nonpolar fatty acid "tails" of the phospholipid associate with other nonpolar materials, but they do not dissolved in water or associated with hydrophilic substances

→ Cholesterol has a rigid ring structure which makes the membrane more solid (counteracts the effect of unsaturated fatty acids) → allows a cell to tune the fluidity of the cell membrane according to the needs of the cell → cholesterol can make up 25% of the lipid content in the membrane of animals

→ Increases in cholesterol and fatty acid saturation make the membrane less fluid; the "kinks" in unsaturated fatty acids make for a less dense, more fluid packing

→ Decrease in temperature results in a less fluid membrane → organisms have the ability to change the lipid composition of their membranes in response to a change in temperature

→ It is energetically favorable for bilayers to seal, that is to form an enclosed space (self assembles into something that resembles a cell; by doing this, there are no more exposed phospholipids anywhere = simple cell)

➔ The entire phospholipid bilayer is called a two-dimensional fluid

Four types of movement:

- Lateral diffusion: lateral movement (most important) → fluidity of a membrane allows for some molecules to move laterally
- Flexion
- Rotation
- Flip-flop: very rare because hydrophilic head has to cross the hydrophobic interior

→ It would do this due to the asymmetric nature of the phospholipid bilayer; phospholipids and glycolipids are asymmetrically distributed; sugar modifications are added in Golgi, therefore on the outer surface; some protein bind to specific cytosolic phospholipids

➔ Fluidity is important for cell shape changes and lateral diffusion of membrane proteins

The fluid mosaic model: a mosaic of proteins embedded in a two-dimensional fluid → how do proteins insert into the membrane = by exposing hydrophobic amino acids in transmembrane areas

→ The proteins are noncovalently embedded in the phospholipid bilayers by their hydrophobic regions, but their hydrophilic regions are exposed to the watery conditions on either side of the bilayer

- Integral proteins are at least partly embedded in the phospholipid bilayer; these proteins have both hydrophilic and hydrophobic regions
    - An integral protein that extends all the way through the phospholipid bilayer and protrudes on both sides = transmembrane proteins:
        - Have hydrophobic regions of amino acids that cross the phospholipid bilayer; they have a specific orientation, showing different "faces" on the two sides of the membrane
- Peripheral membrane proteins lack hydrophobic regions and are not embedded in the bilayer; they are covalently attached to lipids or bind non-covalently to other transmembrane proteins

→ Function: signal transduction, transport of molecules, energy generation, cell adhesion

→ Proteins are asymmetrically distributed on the inner and out surfaces of the membranes; gives the two surfaces of the membrane different properties → differences = great functional significance

Membrane Transport

→ Biological membranes = selectively permeable: allows the membrane to determine what substances enter or leave the cell or organelle ➔ gasses and water can cross; large polar molecules and ions cannot cross the membrane

Two fundamentally different processes by which substances cross biological membranes:

Passive transport: do not require any input of outside energy to drive them (no metabolic energy)

1. Diffusion: The passive mixing of substances resulting in transport along a concentration gradient; random movement toward a state of equilibrium
    - Reason: "random walk" (Brownian motion) of individual molecules due to thermal motions and collisions
    - Diffusion rates are determined by distance, temperature, size of molecule, and **concentration gradient**
    - Rate or diffusion depends on:
        - Diameter of the molecules or ions: smaller molecules diffuse faster
        - Temperature of the solution: higher temperatures lead to faster diffusion because ions or molecules have more energy, and thus move more rapidly, at higher temperatures
        - Concentration gradient in the system – change in solute concentration with distance in a given direction: greater the concentration gradient, the more rapidly a substance diffuses
2. Osmosis: diffusion of water across a selectively permeable membrane; depends on the *number* of particles, not the *kinds* of particles
    - Water moves from regions of low solute concentration to regions of high solute concentration

    Hypertonic: higher solute concentration compared to cell
    Isotonic: equal solute concentrations
    Hypotonic: lower solute concentration compared to cell
    → Water moves from a hypotonic solution across a membrane to a hypertonic solution ➔ net movement
    Turgor pressure: the pressure within the cell → cells with sturdy walls take up limited amount of water, and in doing so they build up internal pressure against the cell wall, which prevents further water from entering
3. Facilitated Diffusion
    - Large polar and charged substances do not diffuse across lipid bilayers → one way for these important raw materials to enter cells is through the process of facilitated diffusion
    - Depends on two types of membrane proteins: channel proteins and carrier proteins
        - **Channel proteins:** integral membrane proteins that form channels across the membrane through which certain substances can pass
            - *Ion channels*: can be open or closed (i.e. they are gated) → **gated channel** opens when a stimulus causes a change in the 3D shape of the channel; stimulus = binding of a chemical signal, or ligand (*ligand-gated channels* vs. *voltage-gated channels*)
            - Ion channels are specific for one type of ion
            - **Aquaporins**: these channels function as a cellular plumbing system for moving water; water molecules move in single file through the channel;, which excludes ions so that the electrical properties of the cell are maintained
        - **Carrier protein**: some substances bind to carrier proteins that speed up their diffusion through the bilayer
            - Rate of movement depends on the concentration gradient across the membrane → does reach a state of saturation (point at which increases in the concentration gradient are not accompanied by an increased rate of diffusion)

        - Transition between these states is random and reversible → when all binding sites are occupied, the carrier is saturated; therefore the rate of diffusion levels off

Active Transport: requires the expenditure of energy (directly or indirectly)

- Substances are moved across the membrane *against* the concentration gradient
- Three types of active transport, each involving its own type of membrane protein:
    - A **uniporter** moves a single substance in one direction
    - A **symporter** moves two substances in the same direction → e.g. cells in the intestine must bind to sodium in addition to an amino acid in order to absorb amino acids from the intestine
    - An **antiporter** moves two substances in opposite directions, one into the cell (or organelle) and the other out of the cell (or organelle) → e.g. sodium-potassium pump
- **Primary active transport**: involves direct hydrolysis of ATP, which provides the energy required for transport
    - *Sodium-potassium pump* in animal cells: pumps out 3Na+, pumps in 2K+, uses the energy of 1 ATP
    - Control of osmolarity (net movement of one ion out)
    - Generation of membrane potential (electrical charge)
    - Sets up a concentration gradient that allows other transport processes to occur
- **Secondary active transport** – does not use ATP directly; its energy is supposed by an ion concentration and electrical gradient established by primary active transport
    - This form of transport uses ATP indirectly. The ATP molecules are consumed to establish the ion gradient
    - The gradient is then used to move a substance, as described for the symport and antiport systems → they often use the concentration gradient of an ion to drive the transport of a substance
    - Both types of coupled transport proteins – symporters and antiporters – are used

Glucose is not transported into the cell using ATP directly because it is more economical to use the sodium mechanism → indirect mechanism creates more flexibility because the sodium potassium pump has to run continuously regardless (**uses secondary transport**)

Facilitated diffusion only works to transport glucose along concentration gradient; secondary active transport allows glucose to be transported against the concentration gradient (both are seen with glucose in gut)

→ In contrast to diffusion, active transport requires the expenditure of energy (directly or indirectly); substances are moved across the membrane **against** the concentration gradient