CHAPTER 5

Membrane Structure & Function

5.1 Plasma Membrane Structure and Function

- Structure
  - Asymmetrical (2 sides of proteins not identical).
  - **Phospholipid bilayer** w/ embedded proteins (form *mosaic* pattern on membrane).
  - **Phospholipids** have hydrophilic & hydrophobic regions; (hydrophobic) nonpolar tails are directed inwards, (hydrophilic) polar heads directed outwards to face extracellular + intracellular fluid.
  - **Cholesterol…**
    - ✓ Lipid found in animal P.M.
    - ✓ Stiffens + strengthens membrane at higher temp.
    - ✓ Prevent from freezing at lower temp. by not allowing contact b/w certain phospholipid tails.
    - ✓ Helps regulate its *fluidity*.
  - **Proteins…**
    - ✓ **Peripheral:** on inside surface of membrane/ *held in place* by cytoskeletal filaments.
    - ✓ **Integral:** embedded/ *can move laterally* back & forth/ protrude from only 1 surface or from both sides (*trans-membrane* proteins).
    - ✓ **Glycoproteins & glycolipids:** attached carbohydrate chain of sugar that projects externally.

- Function
  - **Plasma mem.** separates internal environment of cell from external environment.
  - **Regulates** entrance & exit of molecules.

Fluid-Mosaic Model

- **Fluidity** of P.M. dependent on lipid components (phospholipids bilayer).
  - Allows cells to be pliable/ phospholipid molecule can move sideways/ tails can wiggle.
  - At body temp. P.M. has consistency of olive oil.
  - The greater the concentration of unsaturated fatty acid residues, the more fluid the membrane.
  - Needed for function of some proteins (e.g. enzymes become inactive when membrane solidifies).
- **Mosaic** – protein content in P.M.

Carbohydrate Chains

- In **animal cells**: glycoproteins are called *glycocalyx* – "sugar coat" of carbohydrate chains.
- Protects cell/ facilitates adhesion b/w cells/ reception of molecules/ cell-to-cell recognition.
- Cells are unique b/c of diverse carbohydrate chains ("fingerprint").

- Responsible for transplant tissue rejection.
- Basis for A, B, and O blood groups in humans.

Protein Function

- Integral proteins determine membrane's specific functions & can be:
  - **Channel proteins:** allow particular molecule to cross membrane freely (e.g. H^+ movement across inner membrane of mitochondria).
  - **Carrier proteins:** selectively combine w/ specific molecule so it can cross P.M (e.g., Na^+-K^+ pump).
  - **Cell recognition proteins:** are glycoproteins that allow immune system to recognize pathogens.
  - **Receptor proteins:** shaped so specific molecule (e.g. hormone) can bind to it.
  - **Enzymatic proteins:** carry out specific metabolic reactions.
  - **Junction proteins:** join animal cells so tissues can function.

Permeability of Plasma Membrane

- Selectively (differentially) permeable: *hydrophobic* – plasma membrane/ *hydrophilic* – proteins.
  - Small non-charged lipid molecules (alcohol, O_2) pass through membrane freely.
  - Small polar molecules (CO_2, H_2O) move down **concentration gradient** (high – low concentration).
  - Ions & charged molecules combine w/ carrier proteins.

- Passive transport: *does not use energy (ATP).*
  - **Diffusion:** does not require carrier protein & **osmosis**.
  - **Facilitated transport:** carrier protein required.
- Active transport: *requires carrier protein & uses energy (ATP).*
- Bulk transport…
  - Endocytosis, exocytosis & pinocytosis.
  - Macromolecules (polypeptides, polysaccharides or polynucleotides) transported by vesicle formation (membrane-assisted transport).
  - Requires energy.

5.2 Passive Transport Across a Membrane

Diffusion

- Movement of molecules from higher to lower concentration (down concentration gradient) until equilibrium is achieved.
- Solution contains **solute (**usually solid) & **solvent** (usually liquid).
- When solute is evenly distributed, random movement continues but with no net change.
- Gases readily diffuse through lipid bilayer; (movement of O_2 from alveoli to blood in lung capillaries).

- **Rate of diffusion:** temperature, pressure, electrical currents & molecular size.

Osmosis

- Diffusion of H_2O across selectively permeable membrane due to concentration differences.
- Presence of membrane channel protein **(aquaporin)** allows H_2O to cross membranes quickly.
- **Osmotic pressure:** pressure that develops in a system due to osmosis.
  - Results in H_2O being absorbed by kidneys & H_2O being taken up from tissue fluid.
  - *Greater osmotic pressure = greater osmosis.*

Tonicity

- Strength of solution with respect to osmotic pressure.
- Isotonic solutions…
  - Relative solute concentrations of 2 solutions are **equal.**
  - No net gain or loss of H_2O.
- Hypotonic solution…
  - Solute concentration is *less* than another solution *("cytolysis", cell bursts due to H_2O gain).*
  - Vacuole of plant cell takes in H_2O (creates **turgor pressure**) ∴ plants maintain erect position.
- Hypertonic solution…
  - Solute concentration is *higher* than another solution *("crenation", cell shrinks due to H_2O loss).*
  - **Plasmolysis:** shrinking of cytoplasm; as central vacuole loses H_2O, P.M. pulls away from cell wall.

Facilitated Transport

- Transport of specific solute down concentration gradient (from high to low).
  - Facilitated by carrier protein/ glucose & a.a.

5.3 Active Transport Across a Membrane

- **Transport** of specific solute across plasma membranes "against (from low to high) concentration gradient through use of cellular energy (ATP).
  - Molecules (ISA: ions, sugars & a.a).
  - **Accumulation** of iodine in cells of thyroid gland.
  - **Absorption** of glucose from gut by digestive tract lining.
  - **Re-absorption** of Na from urine by kidney tubule lining.
- **Requires** both carrier proteins & ATP ∴ cells must have high n^o of mitochondria near membranes where active transport occurs.
- **Sodium–potassium pump** in nerve and muscle cells (moves Na^+ outside of cell, K^+ in).
  1. Phosphate group attaches to carrier protein ∴ carrier changes shape.

2. Moves 3 Na^+ outside of cell; takes 2 K^+ from outside.
3. Phosphate group detaches ∴ carrier changes shape.
4. K^+ moves inside (conc. & electrical gradient).

- Salt (NaCl) crosses P.M. b/c Na^+ pumped across, Cl^- attracted to Na^+ & simply diffuses across specific channels in membrane.

Bulk Transport

- Exocytosis…
  - Vesicle formed by *Golgi apparatus* fuses with P.M. as secretion occurs. Vesicle becomes part of P.M. (cell enlarged, normal part of cell growth).
  - **In humans:** digestive enzymes (from pancreatic cells) & hormones (insulin from pancreas).

- Endocytosis…
  - Cells *take in* substances by vesicle formation as portion of P.M. pinches off by **phagocytosis**, **pinocytosis**, or **receptor-mediated endocytosis**.
  - **Phagocytosis:** cells engulf large particles (e.g. bacteria) forming endocytic vesicle.
    - ✓ Common in *unicellular organisms* (amoebas & macrophages).
    - ✓ When **endocytic vesicle** fuses with *lysosome*, digestion of internalized substance occurs.
  - **Pinocytosis:** vesicles form around a liquid or very small particles (e.g. macromolecule)
    - ✓ Used by blood cells, cells lining kidney tubules, cells lining intestinal wall, root cells in plants.
  - **Receptor-mediated endocytosis:** form of pinocytosis; selective, *more efficient.*
    - ✓ **Receptor proteins** shaped to fit w/ specific molecule (vitamin, hormone & lipoprotein).
    - ✓ Located in **coated pit** with layer of fibrous protein on cytoplasmic side; once vesicle is formed, it is uncoated & may fuse w/ lysosome.
    - ✓ **Pits** are associated w/ exchange of substances b/w cells (e.g., maternal and fetal blood).
    - ✓ **Cholesterol** (transported by low-density lipoprotein, LDL) enters cell from bloodstream via receptors in coated pits.
      - In *familial hypocholesterolemia:* LDL receptor cannot bind to coated pit.
      - Excess cholesterol accumulates in circulatory system.
      - ∴ High blood pressure, blocked arteries & heart attack.