Cell Membrane
(CH. 8)

Phospholipid Bilayer
Selectively permeable:
allows some substances to cross more easily than others
Historical Perspective

- 1895: Charles Overton
  - Postulated that membranes are made of lipids
  - Lipid soluble substances entered membranes more easily
- 1917: Irving Langmuir
  - Made artificial membranes
  - Added phospholipids in benzene to water and obtained a film
- 1925: E. Gorter and F. Grendel
  - Reasoned that the membrane has to be a bilayer
  - Measured that there were just enough phospholipids in red blood cells to cover them as a bilayer
- 1935: Hugh Davson and James Danielli
  - Sandwich model: phospholipid bilayer between proteins
  - 1950: electron microscopy suggested they were right
  - Problems: 1) not all membranes have the same composition
  - 2) membrane proteins are amphipathic
- 1972: S. J. Singer and G. Nicolson
  - Proposed the fluid mosaic model (proteins are inserted in membranes)
  - Freeze-fracture method of EM supports this model

<u>Fluid</u> Mosaic Model

- Phospholipids (PL) held by hyrdophobic interactions
  - They drift randomly (at 2μm/sec) in plane of membrane
  - They rarely even flip from one side of bilayer to the other
  - Proteins move slower along cytoskeleton or do not move
- Fluidity is determined by hydrocarbon tails of PL
  - Saturated tails of PL make membranes less fluid
  - Unsaturated tails of PL make membranes more fluid
  - Some cells can vary the PL type content depending on temp
- Cholesterol enhances homeostasis of fluidity
  - Prevents memb. from being too fluid by reducing PL mobility at ↑ T
  - Prevents memb. from solidifying by hindering close packing of PL at ↓ T
- **Proof:** combining different cells results in intermingling of most memb components

Fluid <u>Mosaic</u> Model

- Protein content varies depending on memb function (50 types in RBC)
- Integral proteins
  - Transmembrane proteins that span entire memb
  - Non-polar aa form a-helices within memb
  - Hydrophilic aa make up protein portions located outside of memb
- Peripheral proteins
  - No within memb
  - Attached loosely inside or out (some to other proteins)
- Membranes have different inside and outside faces
  - Carbohydrates: only outside (~15 sugar molecules long)
    - Allows cell-cell recognition and act as markers for cell ID (A, B, AB, O)
    - Glycolipids: attached to lipids; glycoproteins: attached to proteins
  - Cytoskeleton: inside

Functions of Membrane Proteins

- Transport
  - Passive
  - Active (requires energy)
- Enzymatic activity
- Signal transduction
- Intercellular joining
- Cell-cell recognition
- Attachment to cytockeleton and ECM

Selectively Permeable

- Allows passage of some molecules while excluding others
- Molecules pass at different rates
- Examples
  - Nutrients: sugars, amino acids, etc.
  - O_2 (in); CO_2 (out)
  - Inorganic ions: Na^+, K^+, Ca^{2+}, and Cl^-
- Hydrophobic layer
  - Allows to pass
    - Hydrophobic molecules (O_2 and CO_2)
    - Very small polar, uncharged molecules (H_2O, ethanol)
  - Does not allow to pass
    - Larger polar molecules (glucose)
    - Most ions (H^+ and Na^+)

Transport Proteins (Transmembrane)

- Hydrophilic channel/tunnel
- Physical binding and movement

Passive Transport

- Diffusion (solutes, ex. O_2)
  - Tendency of molecules to spread into available space
  - Dynamic equilibrium is reached when no NET movement occurs (motion in and out is same)
  - A substance will move down its Concentration Gradient (from where there is more to where there is less)
  - No energy required (increases entropy=decreases free energy=spontaneous)
  - SPECIFIC TO EACH SOLUTE (independent of others)
- Osmosis (water through membrane)
  - RELATIVE TERMS (two solutions)
    - Hypotonic (less concentrated)
    - Hypertonic (more concentrated)
    - Isotonic (same concentrations)
  - IRRELEVANT WHAT TYPES OF SOLUTES (concentration is sum of all)

Passive Diffusion (Oxygen)

Osmosis

Water moves from:

↑ water/solute potential to ↓ water/solute potential

↑ water concentration (↓ osmotic pressure) to ↓ water concentration (↑ osmotic pressure)

↓ solute concentration (hypotonic) to ↑ solute concentration (hypertonic)

Osmosis

Plants vs. Animals

	Hypertonic	Isotonic	Hypotonic
Plants	Plasmolysis (cell membrane pulls away from wall-lethal)	Flaccid (limp)	Turgid (firm) (strong pressure against wall-good)
Animals	Shrivel (do not survive)	Normal (survive)	Lysis (burst) (do not survive)

Water Leaves cell Same in / out Enters cell

Plant or Animal?

Hypotonic or Hypertonic?

Osmoregulation

- Control how much water enters/leaves a cell
- Ex. Paramecium

(live in pond-hypotonic-water)

  - Cell membrane less permeable to water
  - Contractile vacuole fills with water and expels it
- Brine Shrimp

(live in salty-hypertonic-water)

  - Drink to replace lost water
  - Pump Chlorine and Sodium ions out

Transport of Molecules across Membrane

- Passive transport

(moves solutes DOWN their concentration gradient)

  - Diffusion (through membrane)
  - Facilitated Diffusion (with help of proteins)
    - Bind specific substrates
    - Can become saturated
    - Can be inhibited by molecules resembling substrate
    - Do not catalyze chemical reactions; facilitate physical movement
    - Types: transloctors, corridors, gated channels (open/close with stimulus)
- Active Transport

(moves solutes against their concentration gradient)

  - Requires work/energy (ATP; can transfer a Pi to protein and change its shape)
  - ↑ K; ↓ Na in animal cells

Passive Transport

(Examples)

Active Transport

(Examples)

- **Antiporter:** simultaneously transports two substances across membrane in opposite directions (one with and one against concentration gradient)
- **Symporter:** simultaneously transport two substances across membrane in same direction (one with and one against concentration gradient)

Active Transport

(Example: Na/K Pump)

- 3 Na ions from inside bind
- Pi transferred from ATP—shape of protein changes and Na ions are released outside
- 2 K ions from outside bind
- Pi is removed—protein assumes original shape and releases K ions

Voltage across Membranes

- Voltage:
  - electrical potential energy
  - Separation of opposite charges
- Membrane potential
  - Voltage across membrane: -50 to –200mV
  - Spontaneous passage of cations (+) in and anions (-) out
- Diffusion of ions is due to electrochemical gradient:
  - Chemical force (conc. gradient)
  - Electrical force (memb. potential)

- Electrogenic pump
  - Animals: sodium-potassium creates a more negative cytosol (3 + charges-Na out and 2 + charges-K in)
  - Plants: proton pump (actively transports H+ ions out

Nerve Impulse

Cotransport

- Two substances transported across a membrane together
  - First one "downhill" (with conc. gradient; actively pumped before
  - Second one "uphill" (against conc. gradient)
  - Plants "load" sucrose into cells that transport it to non-photosynthetic cells (roots)

Exocytosis

- When a cell secretes macromolecules by fusing vesicles with plasma membrane

Endocytosis (Phagocytosis)

- A cell engulfs a particle by wrapping pseudopodia around it and forms a vesicle/vacuole (cellular eating)

Endocytosis
(Pinocytosis)

- A cell engulfs droplets of extracellular fluid which may contain non-specific solute molecules

Receptor-Mediated Endocytosis

Ingestion of <u>ligands</u> (substances that bind) by specific <u>receptor proteins</u> on extracellular membrane surface and containing special proteins on cellular face (coated pits)

Uptake of low-density lipoprotein (LDL) particles that transport cholesterol in the blood