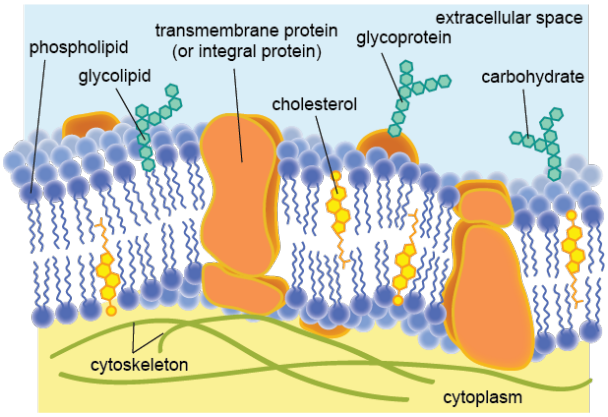
Module 3 – Cells

Phospholipid Bilayer



Permeability of the Bilayer

The cell membrane is *selectively permeable*

- Proteins, nucleotides and other large molecules needed by the cell cannot penetrate the membrane
- Other molecules and many ions can penetrate the membrane to varying degrees

Functions of Membrane Proteins

1. **Receptors** – for attachment of chemical hormones and neurotransmitters

2. **Enzymes** – help w/chemical reactions or breakdown molecules

3. **Ion channels or pores** – allow water-soluble substances, like ions into the cell

4. **Membrane-transport carriers** – transport molecules across the membrane (includes gated channels)

5. **Cell-identity markers** – includes antigens (foreign particles that stimulate the immune system) or glycoproteins

Ways substances can cross the Membrane

1. Endocytosis/exocytosis (pinocytosis for small molecules)
2. Diffusion via the lipid bilayer (fat-soluble molecules)
3. Diffusion via protein channels (water/water-soluble molecules)
4. Facilitated Diffusion
5. Active Transport

Mechanism of Diffusion

Diffusion is the movement of molecules form an area of *high concentration* to an area of low *concentration* (due to molecules' random thermal motion)

Molecules can have both a concentration gradient as well as an electrochemical gradient (if electrically charged molecule). Ions will move towards areas of opposite charge (+ to -, - to +).

Electrochemical equilibrium: when the two gradients of a molecule are equal and opposite to one another (electrical force equal to and in opposite direction to the chemical force)

Diffusion Factors for Protein Channels

1. **Size of protein channels**
   - Approximately 0.8 nm
   - Sugar molecules too large

2. **Charge on the molecule**
   - Positive ion won't go through a positively charged channel

3. **Electrochemical Gradient**
   - The greater the electrochemical gradient of a molecule, the greater its rate of movement through the channels

4. **Number of channels in the membrane**
   - Even if large concentration gradient for an ion, it won't move across the membrane unless there are channels for it

Facilitated Diffusion vs. Simple Diffusion

FD is the passive movement of a substance across a membrane through the aid of a membrane protein carrier. These substances, often water soluble, are too large to pass through protein channels.

FD and SD similar in that they both don't need energy and are powered by the concentration gradient of a molecule. FD is different because:

- Rate of transport limited by #of available proteins
- Rate of transport limited by speed at which the carrier can change shape/config.
- Shows chemical specificity and may be completely inhibited by similarly-shaped molecules

Active transport

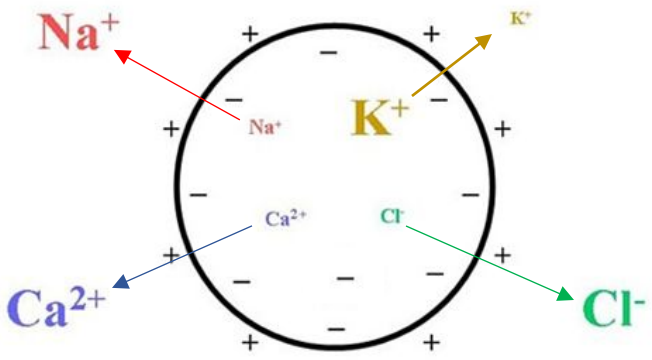
- Requires proteins that span the cell membrane
- Like facilitated diffusion, can be saturated, shows chemical specificity and competitive inhibition
- Involves the use of energy
- Moves molecules against their concentration gradient
- Ex: Na+/K+ pump which gets energy from ATP

Units of Osmosis

- Osmole: Unit used to describe the number of osmotically active particles in a solution
- Osmolality: equal to the number of osmoles per kg of water
- Osmolarity: equal to the number of osmoles per L of solution
- Ex: The osmolality/concentration of 1 molar solution of NaCl is 2 osmoles per kg of water. NaCl dissociates into Na^- and Cl^-

Concentration Gradients and Membrane Permeabilities

- Na^+, Ca^{++}, and Cl^- have higher concentration outside the cell than inside; want to move into the cell.
- K^+ has higher concentration inside the cell than outside; wants to move out of the cell
- Concentration gradient does not ensure that ions will move in that direction
- Most cells not very permeable to larger ions, despite concentration gradient such as Na^+
    - Few channels for them to move into the membrane
- Membrane is more permeable to K^+ and some can leak out of the cell through diffusion

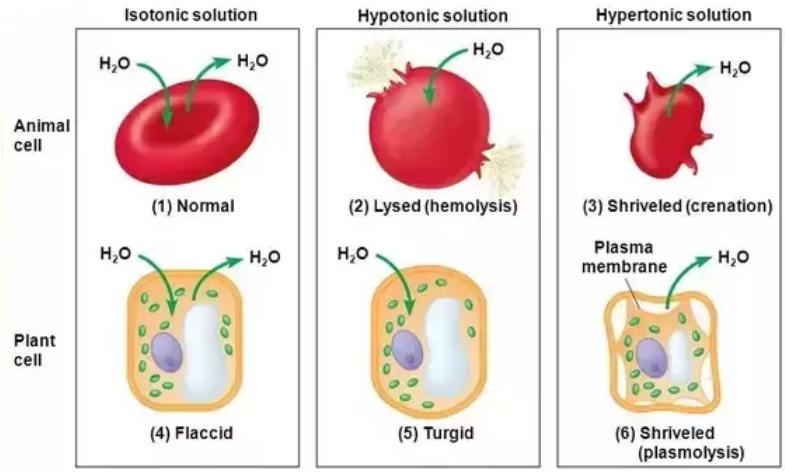


Osmosis

- Movement of water down its concentration gradient
- Requires special pores due to the hydrophobic portion of the lipid membrane
- Water will move to an area with a higher concentration of solute
- Factors affecting osmosis:
    - The membrane's permeability to the solutes in the intracellular and interstitial fluid
    - The concentration gradients of the solutes in the intracellular and interstitial fluids
    - The pressure gradient across the cell membrane

Tonicity

- Used to describe the ability of a solution to cause osmosis across a biological cell membrane
- Typical human cell osmolarity (concentration of fluid) → 300 mOsm/kg of water
- Hypotonic: lower concentration of fluid than cell (more water outside of cell), cause osmosis into the cell (cell would swell)
- Hypertonic: higher concentration of fluid than cell (less water outside of cell), cause osmosis out of the cell (cell would shrink)
- Isotonic: same concentration of fluid inside and outside the cell (300mOsm/kg) so no osmosis occurring



Solution = 300 mOSm | Solution < 300 mOSm | Solution > 300 mOSm

Resting Membrane Potential

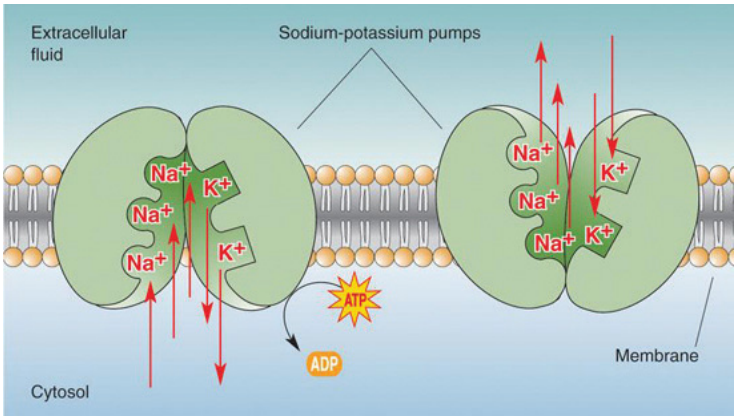
- Electric potential: charge difference across two points
- Ion movement is influenced by electrochemical gradient (electrical and chemical concentration gradient)
- A small amount of accumulated excess negative ions (anions) inside the cell rest along inner membrane
- An equal amount of positive ions (cations) outside of the cell rest along outer membrane
- Creates an electrical potential difference across the membrane (inside more NEG)
- Potential difference is seen even in resting cells (resting membrane potential); all cells have resting membrane potential.
- Equal to -70mV (millivolts) for most cells

Sodium/Potassium Pump

- Is an integral membrane protein
- Maintains the concentration gradient for these two ions since sodium leaks into the cell and potassium leaks out of the cell
- Is an electrogenic pump: contributes to cell being more electronegative on the inside (and therefore maintains the resting membrane potential)
- Pumps 3 Na^+ ions out and 2 K^+ ions in
- Requires ATP for energy because it is pumping both ions against their concentration gradient (active transport)
- most cells would burst and die without the pump
    - pumping out more ions outside of the cell than inside reduces osmolarity in the cell
    - water leaves the cell by osmosis and cell volume is maintained

Equilibrium Potential

- Electrochemical equilibrium: When electrical gradient and chemical concentration gradient are equal in magnitude but in opposite directions; no net movement of ions
- Equilibrium potential: The voltage (electrical potential) that must be applied inside of the cell in order to stop the movement of that ion down its concentration gradient
- The larger the concentration gradient, the larger the equilibrium potential needed to stop the movement of the ion
- Approximate equilibrium potentials for neurons:
    - E(K+) = -90mV (must apply a negative charge)
    - E(Na+) = +60mV (must apply a positive charge)
    - E(Cl-) = -70mV



Review Questions

1. The human cell membrane is made up of
   a. Proteins
   b. Carbohydrates
   c. Lipids
   d. All of the above

2. Which of the following is true about facilitated diffusion?
   a. Molecules are moved against their concentration gradient
   b. The type of molecule that is moved is non-specific
   c. Has unlimited capacity
   d. Can be inhibited by chemically similar molecules

3. Facilitated diffusion and active transport are similar in that they both:
   a. Require energy
   b. Can be competitively inhibited
   c. Move substances down their concentration gradient
   d. Have chemical specificity
   e. A and C
   f. B and D

4. Which of the following solutions will cause a human cell to swell?
   a. 100 mM NaCl
   b. 250 mM KCl
   c. 150 mM NaCl
   d. 100 mM $CaCl_2$

5. Which of the following has a higher concentration inside the cell than outside?
   a. Na^+
   b. Cl^-
   c. K^+
   d. Ca^{++}

6. Which of the following is false regarding the sodium/potassium pump?
   a. It is an integral membrane protein
   b. It pumps 3 K^+ ions out and 2 Na^+ ions in
   c. It requires ATP
   d. It helps maintain the resting membrane potential

Answer Key:
1. D 2. D 3. F 4. A 5. C 6. B