

TOPIC 3: THE CELL MEMBRANE**I. Importance and Objectives**

A. We have an entire topic on cell membranes because membrane structure and function are critical to the way that electrical impulses are conducted. What you learn in this lecture you will explicitly use when learning about nerve, muscle, cardiac and kidney physiology.

B. Objectives

1. Understand membrane structure & function
2. Understand how molecules move by
 - a) Diffusion
 - b) Osmosis
 - c) Active Transport
3. Understand why cell membranes have an electrical charge

II. Membrane Composition and Function**A. Composition (Figs 2.14b and 2.15)**

1. Lipid Bilayer (Note: water is polar; see Review Box on page 35)
 - a) Phospholipids are primary membrane component
 - (1) polar (hydrophilic) heads on outside (electrically charged)
 - (2) non-polar (hydrophobic) tails on inside (electrically neutral)
 - (3) are fluid; they twirl and move
 - b) Cholesterol molecules tucked among phospholipids; increase membrane fluidity
2. Proteins
 - a) Some stud outside, some stud inside
 - b) Some span membrane, with polar regions at ends, and non-polar regions buried within lipid bilayer. Float like icebergs in a sea of phospholipids.
3. Carbohydrates
 - a) Only a small amount
 - b) Glycoproteins (carbo + protein)
 - c) Glycolipids (carbo + lipid)
4. Fluid Mosaic Model of Membrane Structure
 - a) Membrane is fluid, like cooking oil
 - b) Mosaic pattern of proteins embedded within lipid bilayer

B. Most Important Functions

1. Lipid Bilayer
 - a) Primary structure of membrane
 - b) Barrier to diffusion
 - (1) physically hinders molecules from crossing
 - (2) hydrophobic interior barrier to passage of water soluble substances between ICF and ECF.
 - c) Is responsible for fluidity of membrane
2. Membrane Proteins
 - a) channels for small water soluble molecules
 - b) carrier molecules that transfer specific substances
 - c) receptor sites on outer surface that recognize and bind specific molecules in the ECF (e.g., hormones)
3. Membrane protein channel regulation
 - a) Many membrane protein channels are like “gates” that open & close

- b) Opened or closed by
 - (1) binding of chemical messenger
 - (2) change in electrical current
- c) Crucial to how electrical currents are propagated

III. Membrane Adhesions Between Different Cells

- A. Extracellular matrix
 - 1. meshwork of fiber proteins and carbohydrates
 - 2. acts as an extracellular glue to hold cells together within a tissue
- B. Cell junctions
 - 1. tight junctions (Fig 2.26)
 - a) impermeable junctions that join lateral edges of epithelial cells
 - 2. desmosomes (Fig 2.27)
 - a) place where filaments tie cells together
 - 3. gap junctions (Fig 2.27)
 - a) gaps between cells joined by tunnel called connexons
 - b) small molecules can pass through “tunnel” without ever entering the ECF

IV. Membrane Transport

- A. Overview
 - 1. Membrane is selectively permeable; some molecules can pass through and some molecules can't
 - 2. Factors that affect permeability of a molecule
 - a) its solubility in lipid (i.e., ability to dissolve in phospholipid bilayer and hence pass through it)
 - (1) uncharged (= non-polar) molecules (e.g., O₂, CO₂, fatty acids) are lipid soluble and so can pass through lipid bilayer
 - (2) ions (e.g., Na⁺, K⁺) and polar molecules (glucose and proteins) are not lipid soluble and can NOT pass through lipid bilayer
 - b) its size
 - (1) small molecules cross membrane more easily than large molecules
 - 3. Methods of Crossing
 - a) passive (no energy required)
 - b) active (requires energy)
- B. Passive Diffusion (Figs 4.6 & 4.7 & 4.8)
 - 1. Solutes “try” to distribute evenly in a solution
 - a) This happens because all molecules are in continuous random motion when the temperature is greater than absolute zero (-459° F)
 - b) difference in concentration of a material between two adjacent areas is called a **concentration gradient**
 - c) Net movement of solutes is from area of high concentration to low concentration until concentrations are equal (Fig 4.8)
 - 2. Factors that affect *rate of diffusion* of a solute across a membrane
 - a) magnitude of concentration gradient (bigger = faster)
 - b) permeability of membrane to solute (more permeable = faster)
 - c) surface area of membrane (bigger = faster)
 - d) molecular weight of substance (smaller = faster)
 - e) distance over which diffusion occurs (shorter = faster)

- C. Osmosis (= passive diffusion of water)
 1. Simply the net diffusion of water down its concentration gradient
 2. Figures 4.17 and 4.18
- D. Carrier Mediated Transport
 1. Carrier proteins span membrane
 2. Factors that influence kind & amount of substance transported
 - a) Specificity for substance
 - b) Saturation: limit to amount of substance that can be transported per unit time
 - c) Competition between different substances for use of same carrier
 3. Two types
 - a) facilitated diffusion
 - b) active transport
- E. Facilitated diffusion
 1. No energy required for transport
 2. Carrier assists movement of substance down its concentration gradient
 - a) Glucose is important example (Fig 4.11)
 - (1) Higher in ECF (i.e., plasma) than in ICF
 - (2) But can't cross membrane because glucose is polar
 - (3) Glucose carrier molecule allows glucose to passively flow down its concentration gradient from ECF into cell
 3. Small channels can allow movement of ions across membrane (Fig 4.13)
- F. Active Transport
 1. Pump protein requires energy (ATP) to move substance across membrane
 2. Can move molecules *against* their concentration gradient
 3. Example (4.14)
 - a) $\text{Na}^+ \text{K}^+$ ATPase pump keeps Na^+ high in the ECF and K^+ high in the ICF
- G. Vesicular transport
 1. Transport in or out of cell in membrane bound vesicle
- V. Electrochemical gradients
 - A. Molecules with charges affected by
 1. concentration gradients, as described above
 2. electrical gradients
 - a) Opposite charges attract
 - b) ions will "try" to distribute themselves so that negative and positive charges are distributed equally (Fig 4.3)
 - c) difference in charge between two adjacent area is electrical gradient (Fig 4.2)
 3. Simultaneous existence of concentration gradient and electrical gradient is called electrochemical gradient (Fig 4.5)
- VI. Membrane Potential
 - A. Overview
 1. Definition: a separation of electrical charge across a membrane
 2. Because work is required to separate opposite charges already together, separated charges have the potential to do work
 3. Unit of measure is mV (1/1000 of a volt)
 - B. All living cells have a membrane potential
 1. Slight excess of positive charges on outside of cell

2. Slight excess of negative charges inside the cell
 3. Ions responsible: Na^+ , K^+ , A^-
 - a) None of these can diffuse through membrane because each has electrical charge
 - b) Na^+ and K^+ are small enough to cross membrane through protein channels
 - c) A^- is too big to fit into protein channel and so can NOT cross membrane
 4. Cells can have resting potentials between -5mV and -100 mV
- C. Causes of Membrane Potential in Living Cells
1. Effect of K^+ and A^- (Fig 7.6)
 - a) Concentration gradient of K^+ from ICF to ECF
 - b) So K^+ diffuses out of cell through channels and A^- stays in cell
 - c) Results in increase of electrical gradient as positive charges pile up outside and negative charges stuck inside
 - d) Continues until electrical gradient balances concentration gradient at -94 mV
 2. Effect of Na^+ and Cl^- (Fig 7.7)
 - a) Concentration gradient of Na^+ from ECF to ICF
 - b) So Na^+ diffuses into cell through protein channels and Cl^- stays outside
 - c) Results in increase of electrical gradient as positive charges pile up inside and negative charges stuck outside
 - d) Continues until electrical gradient balances concentration gradient at +60 mV
 3. Effect of Na^+ - K^+ -ATPase pump only
 - a) Pumps 3 Na^+ out of cell for every two K^+ pumped into cell
 - b) Creates a small membrane potential because more positive charges leaving the cell than entering it
 4. All together now (Fig 7.8) Resting Membrane Potential in a Nerve Cell
 - a) Membrane is 50 to 75 times more permeable to K^+ than Na^+
 - b) K^+ wants to move out down its concentration gradient but against the electrical gradient.
 - c) Na^+ wants to move in down its concentration gradient and with electrical gradient
 - d) Membrane is more permeable to K^+ so more K^+ moves out than Na^+ moving in
 - e) However enough Na^+ moves in to reduce membrane potential from -94 mV to -70 mV, the resting membrane potential
 - f) **THIS IS NOT AT EQUILIBRIUM!!!!**
 - g) Na^+ - K^+ -ATPase pump counterbalances passive diffusion of K^+ out of cell and Na^+ into cell to maintain the -70 mV resting membrane potential.
 - h) **ALL PASSIVE FORCES BALANCED BY ACTIVE FORCES; NO NET DIFFUSION OCCURS WHEN MEMBRANE IS AT REST!!!!**
 5. Cl^- play very little role
 - a) Because no active transport of Cl^-
 - (1) Does NOT influence membrane potential
 - (2) IS influenced by membrane potential
 - b) So Cl^- diffuses passively across membrane until its concentration gradient is balanced by overall electrical gradient established by membrane potential