Transport of Substances Across Cell Membranes

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Diffusion

- Movement of molecules from one location to another by random thermal motion
  - Net flux between two compartments always proceeds from higher to lower concentrations
  - Diffusion equilibrium is reached when the concentration of the diffusing substance in the two compartments become equal

Diffusion

- The magnitude of the net flux (J) across a membrane is directly proportional to the
  - concentration difference across the membrane (Co− Ci)
  - the surface area of the membrane (A)
  - the membrane permeability coefficient (P)

- Fick's first law of diffusion

$$J = PA(C_o - C_i)$$

Diffusion Through the Lipid Bilayer

- Nonpolar molecules diffuse through the hydrophobic portions of membranes much more rapidly than do polar or ionized molecules because nonpolar molecules can dissolve in the fatty acyl tails in the lipid bilayer.

- Nonpolar molecules
  - Oxygen, carbon dioxide, fatty acids, steroid hormones
- Polar or ionized molecules
  - Most of the organic molecules

Diffusion Through the Ion Channels

- Na^+, K^+, Cl^-, Ca^{2+}
- Ions diffuse across membranes by passing through ion channels formed by integral membrane proteins
- Ion channels show selectivity for the type of ion or ions
  - channel diameter
  - the charged and polar surfaces of the polypeptide subunits
  - the number of water molecules associated with the ions

Ion movements and Membrane Potential

- Membrane potential: the electrical potential across the membrane, negative inside, positive outside

- Provides an electrical force that can influence the movement of ions through their channels across a plasma membrane.
  - Attracting positive ions into the cells

Electrochemical Gradient

- The diffusion of ions across a membrane depends on both the concentration gradient and the membrane potential

- K+ ;
  - Concentration gradient favors flux to the outside
  - Membrane potential to the inside

- Channel gating: The process of opening and closing ion channels

- A single ion channel may open and close many times each second, fluctuates between these conformations

- Factors that can alter channel protein conformations
  - Ligands (ligand gated channels)
  - Voltage change (voltage gated channels)
  - Physical deformation (mechanically gated channels)

Mediated Transport

- Involves binding the transported solute to a transporter protein in the membrane

- Changes in the conformation of the transporter move the binding site to the opposite side of the membrane

Mediated Transport

- Ion channels typically move several thousand times more ions per unit time than molecules moved by transporters
  - a transporter must change its shape for each molecule transported across the membrane
  - an open ion channel can support a continuous flow of ions without a change in conformation.

Facilitated Diffusion

- Net flux of molecules from higher concentration to lower concentration

- Energy is not required

- Transport of glucose
  - GLUTs

Active Transport

- Mediated transport process that moves molecules against an electrochemical gradient across a membrane by means of a transporter and an input of energy

- Primary active transport uses the phosphorylation of the transporter by ATP to drive the transport process

Secondary Active Transport

- Uses the binding of ions to the tranporter to drive the secondary transport process

- The downhill flow of an ion is linked to the uphill movement of a second solute either in the same direction (symport) or in the opposite direction (antiport) of the ion

Osmosis

- Water is polar
- Aquaporins: water channels
- Different numbers in different membranes and the numbers can be altered in response to various signals

Osmosis

- Net diffusion of water across a membrane

- Osmolarity: the total solute concentration of a solution

- 1 osmol (osm) = 1 mol of solute particles
  - 1 M glucose = 1 osm
  - 1 M NaCl =2 osm

- Osmolarity ↑ water concentration ↓

Osmotic Pressure

- When a solution containing solutes is separated from pure water by a *semipermeable membrane* (a membrane permeable to water but not to solutes), the pressure that must be applied to the solution to prevent the net flow of water into it is known as the osmotic pressure of the solution.
- Osmolarity ↑ Osmotic pressure ↑
- Represents the amount of pressure that would have to be applied to a solution to prevent the net flow of water into the solution by osmosis

- Osmolarity of the intracellular fluids 300 mOsm
  - Isotonic = 300 mOsm
  - Hypertonic > 300 mOsm
  - Hypotonic < 300 mOsm

- Tonicity: concentration of nonpenetrating solute

Endocytosis

- Regions of the plasma membrane invaginate and pinch off to form vesicles that enclose a small volume of extracellular material
  - Pinocytosis
  - Phagocytosis
  - Receptor mediated endocytosis

Endocytosis

- Pinocytosis (fluid endocytosis)
    - Non-specific
    - Engulfs the extracellular fluid
        - Ions, nutrients, small molecules
- Phagocytosis
    - Immune cells
    - Bacteria or cell debris from damaged tissue
    - pseudopodia fold around the surface of the particle
    - fuse into large vesicles called phagosomes
    - fuse with lysosomes

Endocytosis

- Receptor mediated endocytosis
- Receptors recognizes one ligand with high affinity
- Clathrin is recruited to the plasma membrane
- Clathrin coated pit forms
- Pinch off from membrane
- Clathrin are removed and receptors recycled to the membrane

Exocytosis

- Provides a way to replace portions of the plasma membrane that endocytosis has removed
- Provides a route by which membrane impermeable molecules (such as protein hormones) that the cell synthesizes can be secreted into the extracellular fluid.
- The secretion of substances by exocytosis is triggered in most cells by stimuli that lead to an increase in cytosolic Ca^{2+} concentration in the cell
- Increase in cytosolic Ca^{2+} concentration activates proteins required for the vesicle membrane to fuse with the plasma membrane and release the vesicle contents into the extracellular fluid

Epithelial Transport

- Epithelial cells line hollow organs or tubes and regulate the absorption or secretion of substances across these surfaces
- Apical membrane: One surface of an epithelial cell generally faces a hollow or fluid-filled tube or chamber
- Basolateral membrane: The plasma membrane on the opposite surface, rests upon a basement membrane and is usually adjacent to a network of blood vessels

Intestine

Epithelial Transport

- The two pathways by which a substance can cross a layer of epithelial cells;
  - paracellular pathway: diffusion occurs between the adjacent cells of the epithelium
    - Tight junctions, limited diffusion
    - Small ions and water
  - transcellular pathway: substance moves into the epithelial cell across either the apical or basolateral membrane diffuses through the cytosol, and exits across the opposite membrane

- The transport and permeability characteristics of the apical and basolateral membranes are not the same
- Contain different ion channels and different transporters for mediated transport
- As a result of these differences, substances can undergo a net movement from a low concentration on one side of an epithelium to a higher concentration on the other side