Cell Membrane Transport Processes

Passive Transport

Learning Objectives:

- Describe the term" selective permeability".
- List the purposes of membrane transport.
- Classify cell membrane transport processes.
- Define the terms: Diffusion, osmosis, osmotic pressure, hydrostatic pressure, tonicity, isotonic solution, hypotonic solution, hypertonic solution.
- Describe the similarities and differences between passive unfacilitated and passive facilitated transports. Give examples of substances transported by each type.
- Describe what will happen if you place a cell (e.g. RBC) in each of following solutions: Isotonic, Hypotonic, and Hypertonic.

Cell Membrane Transport Processes:

- Our cells are bathed in an extracellular fluid called ***interstitial fluid that is derived from the blood.*** It is like a rich, nutritious "***soup***" interstitial fluid contains thousands of ingredients, including *amino acids, sugars, fatty acids, vitamins, regulatory substances such as hormones and neurotransmitters, salts, and waste products.*

- To remain healthy, each cell must extract from this mix the exact amounts of the substances it needs at specific times.

- Although there is continuous traffic across the plasma membrane, it is a ***selectively, or differentially, permeable barrier*****:**

  - It allows some substances to pass while excluding others.

  - It allows nutrients to enter the cell, but keeps many undesirable substances out.

  - It keeps valuable cell proteins and other necessary substances in the cell, but allows wastes to exit.

Cell Membrane Transport Processes:

- **Selective permeability is a characteristic of healthy, intact cells.**

- When a cell (or its plasma membrane) is severely damaged, the membrane becomes permeable to virtually everything, and substances flow into and out of the cell freely.

- **This phenomenon is evident when someone has been severely burned. Precious fluids, proteins, and ions "weep" from the damaged cells.**

Cell Membrane Transport Processes:

- Transport of material across cell membrane is central to the life of every cell.

- Cells, and organelles, can all accumulate molecules and ions at concentrations which are strikingly different from the surrounding areas.

- The purpose of membrane transport may be:

  - **Nutrition:** Bring in the biochemical substrates necessary for life.
  - **Respiration:** Exchange of gasses.
  - **Elimination of waste** from the cell.
  - **Setting up an ionic medium** for a particular purpose.
  - **Bringing in signals**, e.g. hormones, or ions (e.g. Ca++) to trigger metabolic changes.
  - **Electrical:**

    - ✓ ***Setting up a "membrane potential"***
    - ✓ ***Firing of impulses ("action potentials")***

  - **Cell may be used as a conduit within an organ**, e.g. intestinal epithelium.

Cell Membrane Transport Processes:

❖ Transport is classified as:

- **Passive transport:** small molecules or ions, flowing down (with) their concentration gradient. No energy input is required. Energy is inherent in the concentration gradient. This is a type of diffusion:
  - ✓ **Unfacilitated:** material moves through cell membrane phospholipids.
  - ✓ **Facilitated:** *requires a transport protein*, bilayer impermeable to material.
- **Active transport:** small molecules/ions move against their concentration gradient. This requires the input of energy from the cell.
- **Exocytosis & Endocytosis:** *macromolecules, whole organisms or debris* are moved across membranes by *invagination or pinching off membranes.*

Cell Membrane Transport Processes – *Passive Transport:*

- The most important type of passive transport is ***diffusion;*** the tendency of molecules or ions to move from an area of higher concentration to an area of lower concentration, that is, down or along their ***concentration gradient.***

- The constant random and high-speed motion of molecules and ions (a result of their ***intrinsic kinetic energy***) results in collisions.

- The greater the difference in concentration of the diffusing molecules and ions between the two areas, the more collisions occur and the faster the net diffusion of the particles.

Cell Membrane Transport Processes – *Passive Transport:*

- Because the driving force for diffusion is the kinetic energy of the molecules themselves, the speed of diffusion is influenced by molecular ***size*** *(the smaller, the faster) and by* ***temperature*** *(the warmer, the faster).*

- However, a molecule or ion *will diffuse through the membrane if the molecule is:* **lipid soluble, small enough to pass through membrane channels, or assisted by a carrier molecule.**

- The unassisted diffusion of lipid-soluble or very small particles is called ***simple diffusion****. Assisted diffusion is known as* ***facilitated diffusion****.*

- *A special name,* ***osmosis****, is given to the diffusion* of a solvent (usually water) through a membrane.

- **Osmosis:** ***water molecules*** pass ***from*** a solution of a ***lesser consternation of solute***, ***to*** a solution of ***greater concentration of solute***, via a semi-permeable membrane. ***This evens out the concentration gradient in a situation where the solute is unable to move.***

Passive, Unfacilitated Transport:

- *Rate and direction* of transport *depends of on the size and direction of concentration gradient*. No outside energy is required *(it uses kinetic energy)*, so it is called ***exergonic.***

- Nonpolar and lipid soluble substances diffuse directly through the lipid bilayer. Such substances include **O_2, CO_2**, and **fat-soluble vitamins**. Because oxygen concentration is always higher in the blood than in tissue cells, O_2 continuously diffuses from the blood into the cells. CO_2, on the other hand, is in higher concentration within the cells, so it diffuses from tissue cells into the blood.

- Availability of this transport is determined by *the small size of the molecule and lack of polarity:*

  - **Small non polar molecules**; e.g. O_2 & CO_2 **move easily**.
  - **Large non polar molecules,** e.g steroids **cross more slowly**.
  - **Small polar molecules**, e.g. water **cross more slowly** (water crosses 10,000 times slower than it would move that distance without a membrane).
  - **Ions**, however small, **can hardly cross at all** by this mean, because they get *caught up on the charged heads of the phospholipids*.

Passive, Facilitated Transport:

- *Certain molecules, notably glucose and other sugars, some amino acids, and ions are transported passively even though they are unable to pass through the lipid bilayer.* Instead they move through this type of transport.

- The transported substance either:

  - ***binds to protein carriers in the membrane and is ferried across***

    or

  - ***moves through water filled protein channels.***

- It shares some features of the unfacilitated transport (e.g. concentration gradient, the use of kinetic energy, being exergonic).

Passive, Facilitated Transport:

❖ This type of transport ***differs from the unfacilitated transport by:***

- **A protein carrier molecule** (transport protein) provides a channel across the cell membrane. It provides a channel to facilitate diffusion of a material across an otherwise impermeable membrane.

- Each carrier molecule is highly specific for one material, for a group of closely related materials. It is ***stereo-specific***, i.e. **dependent upon molecule shape.**

- **Carrier proteins are multipass transmembrane proteins** with several helical transmembrane domains which allow the passage of the material.

- This method provides the means for **hydrophilic & polar molecules,** and also **ions,** to enter the cell down their concentration gradients.

- **Rate of transport is only dependent on the concentration gradient up to a point** when ***all the carrier proteins have been saturated , a maximum velocity is reached.***

Passive, Facilitated Transport:

❖ Example of Passive Facilitated Transport:

- **Glucose transport**, used for cellular nutrition when blood sugar is high enough to set up the necessary concentration gradient:

  - ✓ *The glucose binds to an extracellular domain of the glucose transport protein.*

  - ✓ *This causes a conformational change within the protein.*

  - ✓ *This in turn allows polar amino acids in the transmembrane domain to hydrogen-bond with glucose so that it can cross the membrane.*

Osmosis:

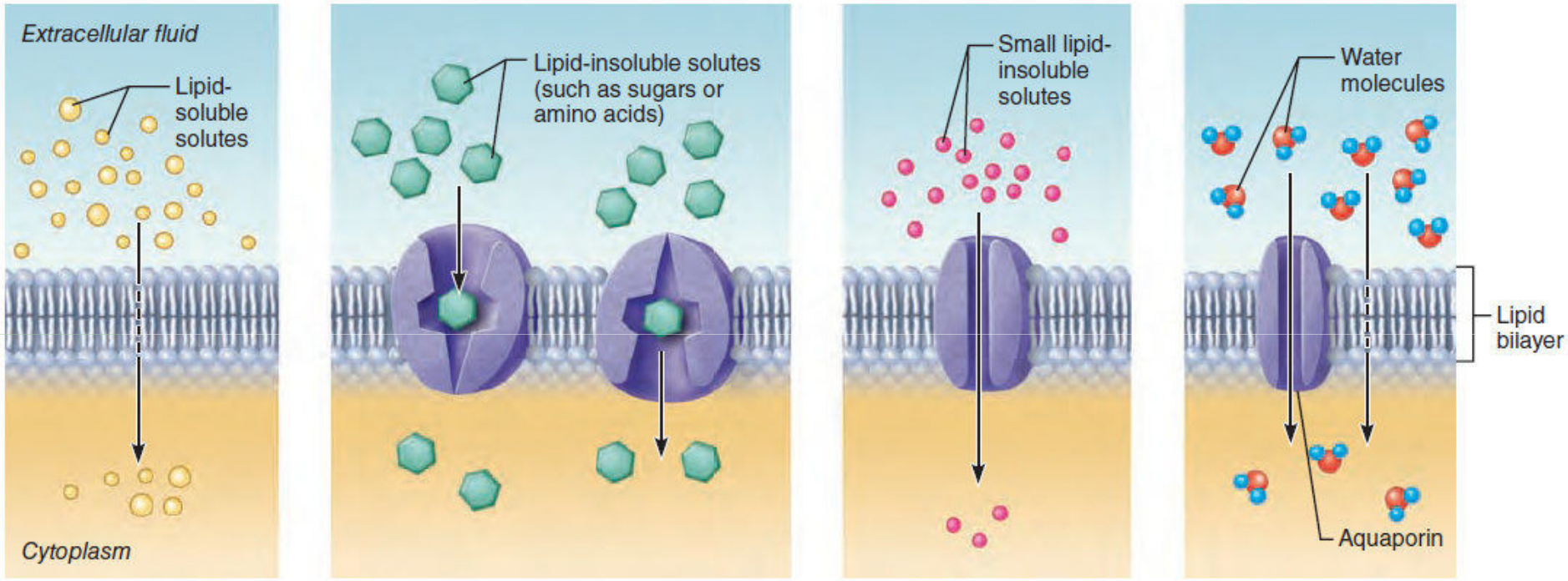
- **Osmosis:** ***The diffusion of a solvent, such as water, through a*** selectively permeable membrane.

- Even though ***water is highly polar***, it passes via osmosis through the lipid bilayer. This is surprising because you'd expect water to be repelled by the hydrophobic lipid tails.

- One hypothesis is that *random movements of the membrane lipids open small gaps between their wiggling tails, allowing water to slip and slide its way through the membrane by moving from gap to gap*.

- **Hydrostatic pressure** is *the back pressure exerted by water against the membrane within the cell* **is equal** to its **osmotic pressure** *(the tendency of water to move into the cell by osmosis).*

Passive Transport:



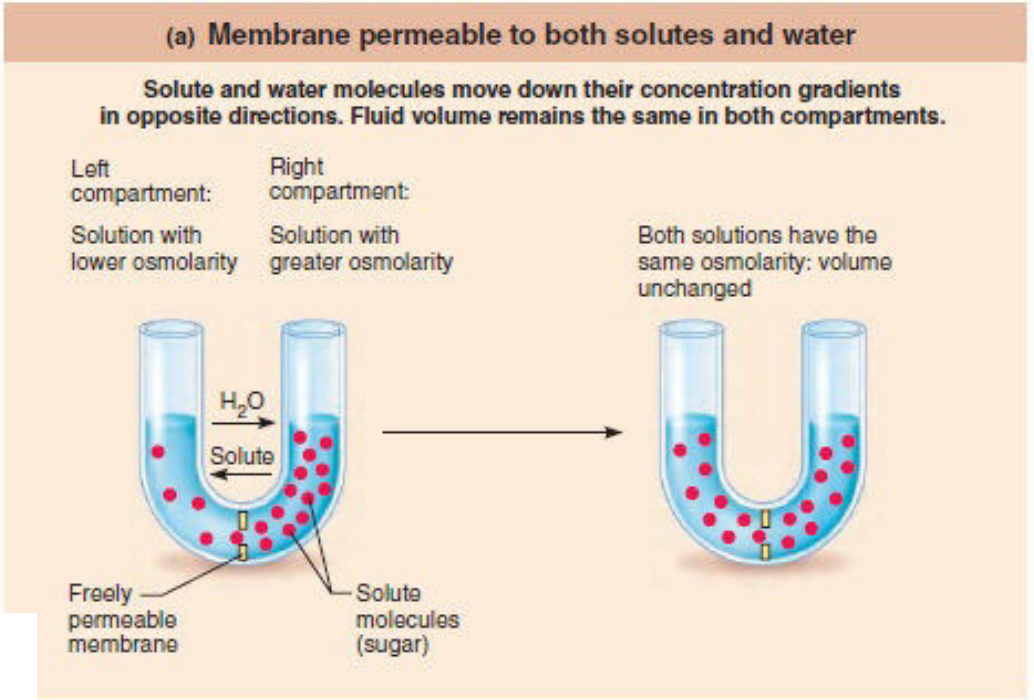
(a) **Simple diffusion** of fat-soluble molecules directly through the phospholipid bilayer

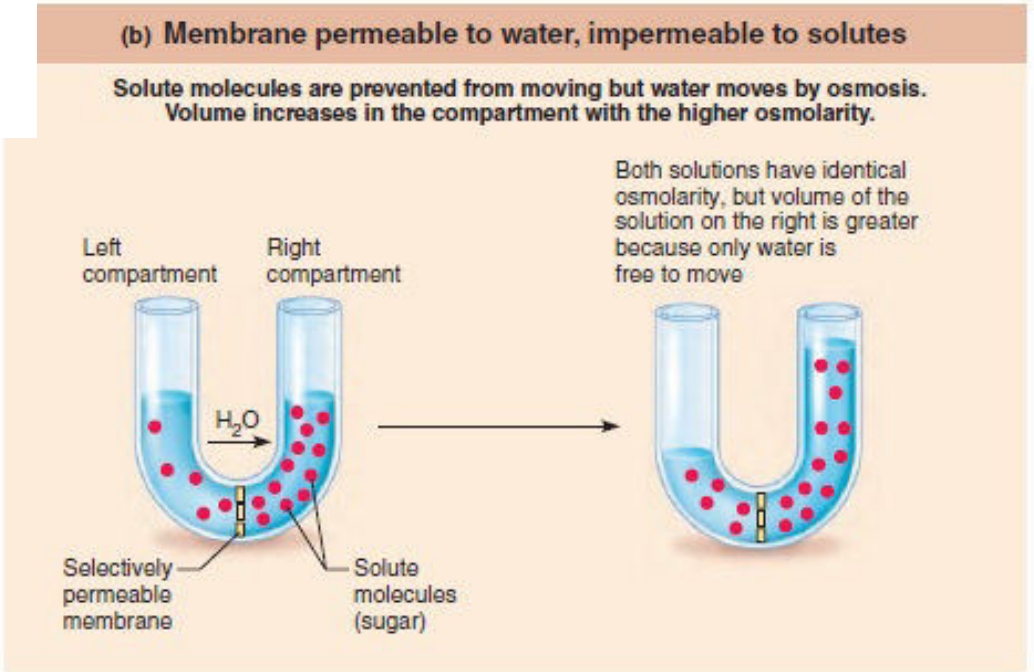
(b) **Carrier-mediated facilitated diffusion** via protein carrier specific for one chemical; binding of substrate causes transport protein to change shape

(c) **Channel-mediated facilitated diffusion** through a channel protein; mostly ions selected on basis of size and charge

(d) **Osmosis**, diffusion of a solvent such as water through a specific channel protein (aquaporin) or through the lipid bilayer

Influence of membrane permeability on diffusion and osmosis





Osmosis:

- **Tonicity** refers to the ability of a solution to change the shape or tone of cells by altering the cells' internal water volume (*tono* = tension).

- **Isotonic** ("the same tonicity") solutions have the same concentrations of nonpenetrating solutes as those found in cells (***0.9% saline or 5% glucose***). Cells exposed to isotonic solutions ***retain their normal shape***, and exhibit no net loss or gain of water.

- **Hypertonic** solutions have a higher concentration of nonpenetrating solutes than seen in the cell (for example, ***a strong saline solution***). Cells immersed in hypertonic solutions lose water and ***shrink,*** or *crenate.*

- **Hypotonic** solutions are more dilute (contain a lower concentration of nonpenetrating solutes) than cells. Cells placed in a hypotonic solution ***plump up rapidly*** as water rushes into them ; ***distilled water*** represents the most extreme example of hypotonicity. Because it contains *no solutes.*

The effect of solutions of varying tonicities on living red blood cells