## Cell Membrane Proteins

-- ***peripheral*** proteins primarily serve to support a membrane's structure (ie. maintain the integrity of the membrane) (see fig. 4.3 p. 70).

-- ***Integral proteins*** fall into five classes:

I) Cell-Recognition Glycoproteins -- serve as 'ID tags' or 'fingerprints', specific to a cell, person, and/or species; recognized by antibodies/white blood cells. If recognized as 'foreign', they might be signaled for destruction or attacked directly.

II) Channel Proteins – tubular proteins (hollow) that allow small, highly polar molecules to pass through the entirety of the membrane (eg. ions and water).

III) Carrier Proteins – proteins that accept a molecule that is to either enter or exit a cell. Once the molecule is accepted, a protein 'morphs' into a different shape that somehow allows for the release of the molecule on the *other side* of the membrane.

-- substances such as glucose, amino acids, glycerol, and ions use carrier proteins to cross a membrane.

-- sometimes, ATP energy is required for carrier protein usage.

NOTE: Protein types II and III are often referred to as ***Transport Proteins***.

IV) Receptor Proteins -- molecular 'triggers' that instigate a sequence of events within the cell upon binding to a certain molecule (hormone, enzyme, neurotransmitter) on the exterior of the cell.

-- these proteins are very specific as to what molecules they are able to bind to (similar to a key and a lock).

V) Enzymatic Proteins -- catalyze a certain reaction at or near the cell membrane.

Structural Anchoring of Proteins in the Cell Membrane

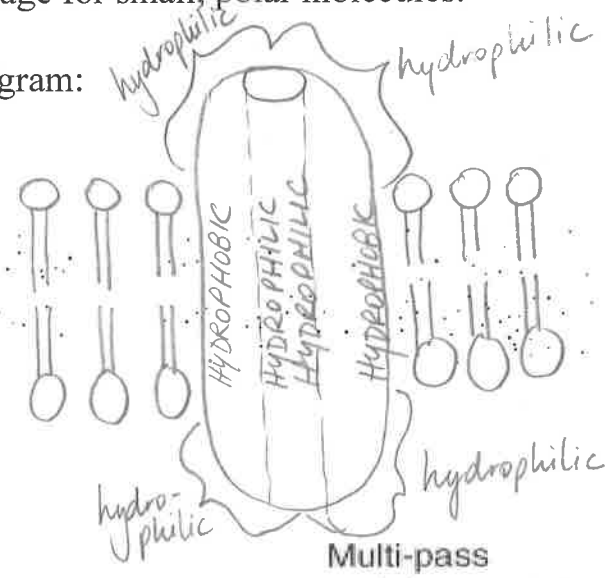
-- the outside edges of the three-dimensional protein (the edges in contact with the hydrophobic core of the phospholipid bilayer) are hydrophobic, meaning that amino acids possessing non-polar R-groups line up on these edges in order to associate (via London Forces) with the hydrophobic core.

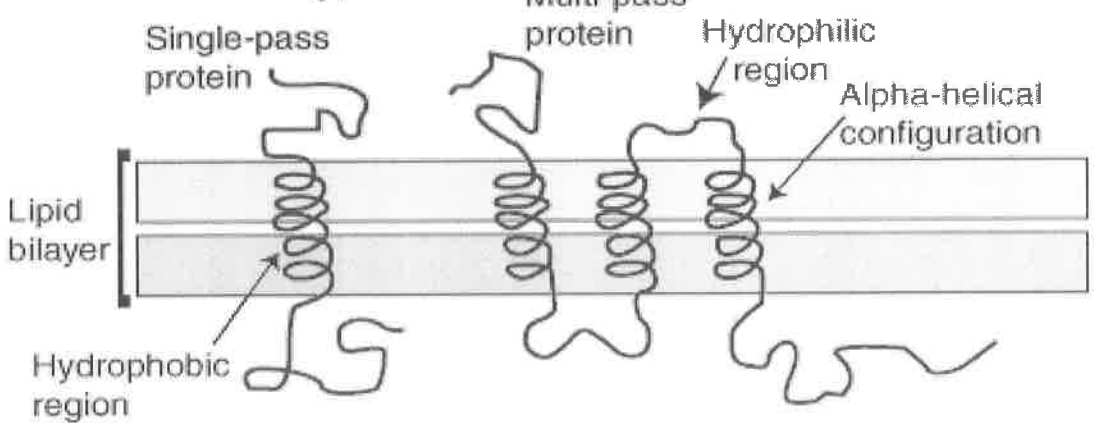
- these hydrophobic regions of Integral Proteins are often coiled into an alpha-helix shape.

-- the 'ends' (ECF-side and Cytoplasm-side) of the protein are predominantly made up of amino acids possessing polar R-groups, so that they can form hydrogen bonds with the water on both the ECF-side and the cytoplasm-side.

-- the interior of a *Channel* Protein (the walls lining the pore/tunnel) is made up of amino acids with polar R-groups in order to create a hydrophilic-friendly passage for small, polar molecules.

A simple diagram:



## Methods by which Molecules are able to Cross a Membrane

1. SIMPLE DIFFUSION (including OSMOSIS):

   a. *Without* a Channel Protein -- small, non-polar molecules such as oxygen, carbon dioxide, and fatty acids.
      - Water as well, even though it is polar, due to the strength of the bulk flow.

   b. *With* a Channel Protein -- small, polar molecules such as ions and water.

2. TRANSPORT INVOLVING PROTEIN *CARRIERS*:

   -- may or may not involve the expenditure of ATP.

3. ENDOCYTOSIS AND EXOCYTOSIS:

   -- involves vesicle formation along with the expenditure of ATP.

## A More Specific Look at: TYPES OF TRANSPORT

Class A: PASSIVE TRANSPORT (no ATP required)

I). Simple Diffusion

-- the net movement of a substance (molecules) from a region of higher concentration to a region of lower concentration.

-- in other words, the net movement of a substance (molecules) *down* (or *with*) its ***concentration gradient*** until it is distributed evenly.

-- a dynamic equilibrium is achieved whereby the rate of movement in either direction is equal.

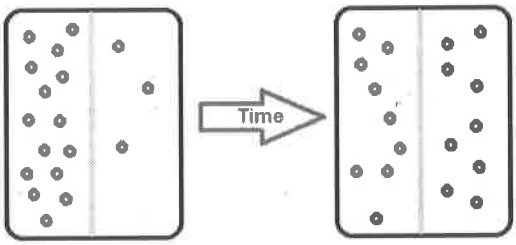
***Gradient*** -- a physical *difference* between two regions of space, promoting the movement of molecules from one region to another.
   -- there exist *concentration* gradients, *pressure* gradients, and *electrical* gradients.

-- diffusion is a **spontaneous** process.

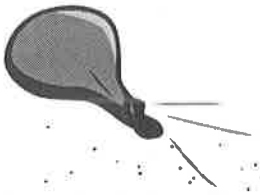
-- diffusion may involve a CHANNEL PROTEIN for small, polar molecules.

-- see fig. 4.5 p. 73 and fig. 4.6 p. 73 ($O_2$ in lungs).

Concentration Gradient

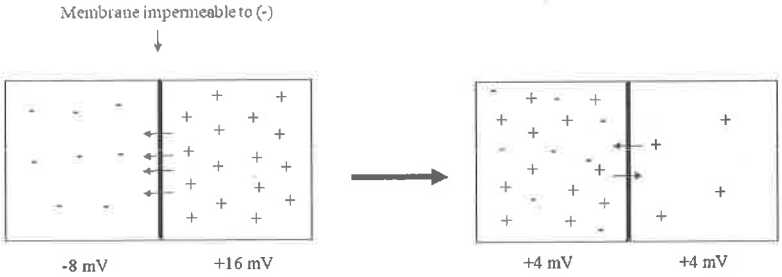



Pressure Gradient



Electrical Gradient

# Diffusion and Ions




NOTE: Electrical equilibrium may require movement against the concentration gradient

## Factors that Affect the Rate of Diffusion

1. Magnitude of Concentration Gradient:

-- first and foremost, it is the actual existence of a concentration gradient that initiates diffusion.

-- the greater the gradient (ie. the greater the difference in concentration between two regions) the faster the diffusion.

2. Temperature:

-- an increase in temperature increases the Kinetic Energy (ie. the energy of 'movement') of molecules, whereas a decrease in temperature decreases the KE of molecules, thus:

-- as temperature *increases*, rate of diffusion increases.

-- as temperature *decreases*, rate of diffusion decreases.

3. Ionic/Molecular Size:

-- quite simply, smaller molecules diffuse more rapidly than larger ones.

4. Density/Viscosity of the Medium (solvent):

-- the lower the density/viscosity of the medium, the more quickly molecules diffuse through it (and vice versa).

eg. diffusion within the medium of air is faster than diffusion within the medium of water.

5. Movement of the Medium:

-- currents (eg. air currents or water currents) within the medium tend to facilitate diffusion.

-- in cells, the phenomenon of *cytoplasmic streaming* (a constant movement of cytoplasm) helps with diffusion of materials within the cytoplasm.

6. Solubility/Polarity:

-- non-polar (hydrophobic) molecules will diffuse across the membrane quite readily (fatty acids, oxygen, $CO_2$) relative to polar molecules.

-- polar (hydrophilic) molecules may also diffuse across a membrane but they are limited to utilizing channel proteins as a means to enter/exit the cell, thus slowing down their rates of diffusion.

II). Osmosis (The diffusion of water)

-- Definition - the movement of water molecules from a region of higher water concentration (or lower solute concentration) to a region of lower water concentration (or higher solute concentration) through a *selectively permeable membrane*.

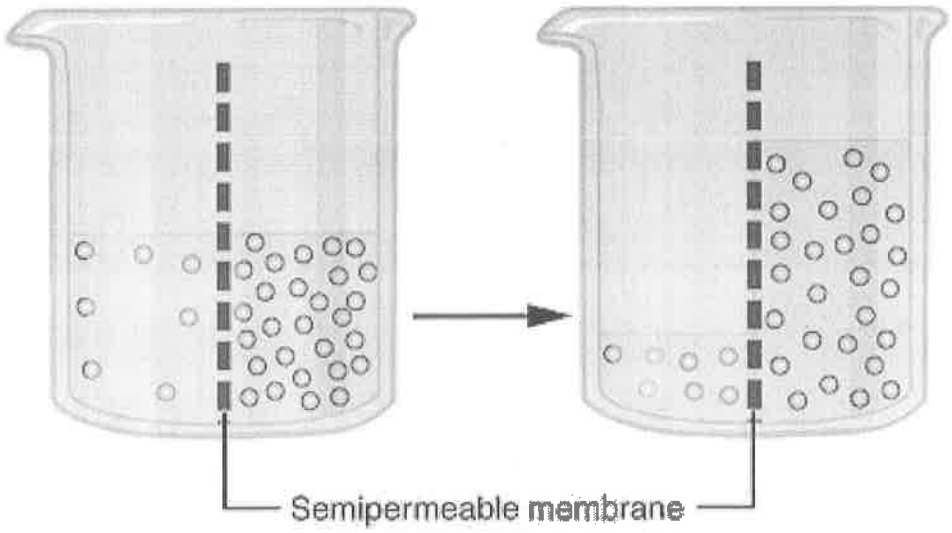
-- water moves passively by osmosis in order to 'even out' solution concentrations.

-- water always moves **UP** a *solute* concentration gradient. ie. Water moves to where the solute concentration is greater.

-- the result of osmosis is the *dilution* of the solution that is receiving water and the *strengthening* of the solution that is giving up water. Dynamic equilibrium is achieved when each solution has the SAME concentration.

-- water tends to move more readily than ions and other polar molecules because water does not actually require transport proteins, though it may use channel proteins.

-- see fig. 4.7 p. 74.



Concepts Related to Osmosis:

***OSMOTIC PRESSURE*** (OP) -- the pressure, generated by the amount of *solute* in solution, that serves to *draw* water toward a region.

-- OP increases as solute concentration increases (or as water volume decreases).

-- the greater the OP of a region, the more water is drawn *toward* that region.

*TURGOR PRESSURE* (TP) (aka Hydrostatic Pressure or Blood Pressure) -- the pressure, generated by the amount of *solvent* in solution, that serves to *push* water to another region.

-- TP increases as water volume increases (or as solute concentration decreases).

-- the greater the TP of a region, the more water is pushed *away from* that region.

As a region's OP increases, its TP decreases.

As a region's OP decreases, its TP increases.

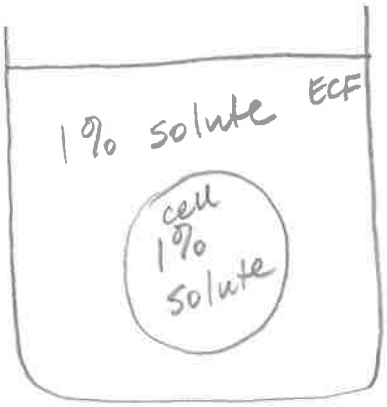
*TONICITY*

-- Tonicity is another term for concentration or strength of solution.

-- a cell may be subjected to three different types of solutions, all with different relative *tonicities*.

** for each of the following scenarios, envision a cell being placed into a beaker of solution. The cell contains cytoplasm, which has a certain tonicity (ie. [solute]), and the beaker will serve as the 'ECF' with a certain tonicity (ie. [solute]).

a. Isotonic Solutions ("***Iso***" = the same as)




-- the tonicity (solution concentration/OP) is equal on both sides of the membrane.

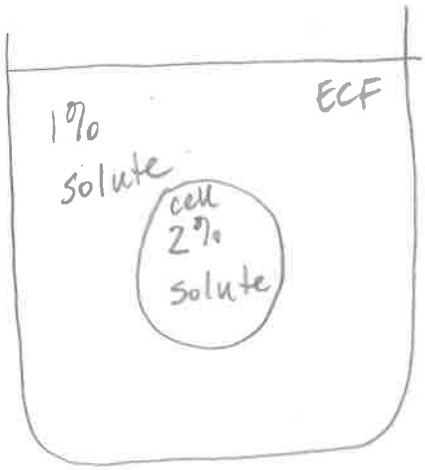
-- thus, there is no NET gain or loss of water by the cell.

-- water does move into the cell but it also moves out of the cell at the same rate (*dynamic equilibrium*).

-- in other words, there are no *macroscopic* changes to the system, but equal and 'nullifying' *microscopic* changes occur.

-- see fig. 4.8 p. 75.

b. Hypotonic Solutions ("***Hypo***" = less than)



-- a solution/region whose tonicity/[solute]/OP is less than that of another solution/region is said to be **hypo**tonic to the other, more concentrated, region.

-- analyzing the situation in the diagram, the cell possesses greater tonicity/[solute]/OP so water will flow (via osmosis) from the ECF into the cell and the cell will *swell*.

-- this, in turn, increases the TP (turgidity) of the cell (more water = more turgidity).

-- likewise, as water enters the cell, the OP within the cell decreases (more water = less OP).

-- water will move back and forth with less and less 'vigor' until a dynamic equilibrium is established.

-- see fig. 4.8 p. 75.

More Definitions:

*Deplasmolysis* -- the ***gain*** of water by a cell due to it being exposed to a hypotonic environment.

*Turgidity* -- the pressure that water exerts from the cytoplasm toward the outside of the cell against the cell membrane. Increases as water volume (TP) increases.

*Lysis* -- the rupturing or bursting of a cell due to extreme deplasmolysis.

****Hemolysis*** -- the bursting of a *Red Blood* Cell.

b. Hypertonic Solutions (“***Hyper***” = greater than)


-- a solution/region whose tonicity/[solute]/OP is greater than that of another solution/region is said to be **hyper**tonic to the other, less concentrated, region.

-- analyzing the situation in the diagram, the cell possesses a lesser tonicity/[solute]/OP so water will flow (via osmosis) from the cell into the surrounding ECF and the cell will begin to *shrivel*.

-- this, in turn, decreases the TP (turgidity) of the cell (less water = less turgidity).

-- likewise, as water leaves the cell, the OP within the cell increases (less water = greater OP).

-- water will move back and forth with less and less ‘vigor’ until a dynamic equilibrium is established.

-- see fig. 4.8 p. 75.

More Definitions:

*Plasmolysis* – the ***loss*** of water by a cell due to it being exposed to a hypertonic environment.

*Crenation* -- the shriveling of a cell due to extreme water loss; leads to cell death.

III). Facilitated Transport

-- see fig. 4.9 p. 76.

-- adheres to the law of diffusion, therefore is passive in nature (no ATP energy required).

-- however, a CARRIER PROTEIN is required.

-- glucose, fructose, amino acids, and glycerol are too large to enter the cell via channel proteins, and they are too polar to simply move through the highly non-polar core of the phospholipid bilayer, so they enter the cell with aid (*facilitation*) from carrier proteins.

-- ions may also utilize carrier proteins in this manner.

-- carrier proteins are very specific for the molecule they can carry.

-- some hormones (eg. insulin) have the ability to 'create', or make available, more glucose carriers. (ie. insulin signals for the production of more glucose carriers so that liver and skeletal muscle cells can take up more glucose).

Class B: ENERGY-REQUIRING TRANSPORT

I). Active Transport

-- see fig. 4.10 p. 76.

-- active transport occurs when molecules or ions need to move across a cell membrane UP/AGAINST their concentration gradient (ie. from a lower concentration to a higher concentration).

-- requires ATP energy and a CARRIER PROTEIN.

-- cells that perform a lot of active transport (eg. nerve cells) have a large number of mitochondria near the cell membrane.

-- carrier proteins that are involved with active transport are commonly called PUMPS.

eg. the sodium/potassium ion pump in nerve cells (see fig. 4.11 p. 77).

-- any molecule can be moved by active transport if it needs to be, except for macromolecules such as carbohydrates, proteins, and fats, which are too large.

-- protein pumps have two binding sites:

i. to bind the molecule/ion to be transported.

ii. to bind ATP.

II). Endocytosis/Exocytosis

-- see fig. 4.12 p. 78.

-- some molecules are too large to be transported by protein carriers, thus they are transported into/out of the cell through VESICLE formation.

-- ATP is required.

a. Endocytosis (ENTERING by vesicle):

-- the process by which a vesicle is formed at a cell membrane in order to bring substances into the cell.

-- molecules may move UP or DOWN their concentration gradients during endocytosis, but energy is ALWAYS required in order for vesicles to form.

-- Three types of endocytosis:

i. *Phagocytosis* ('cell-eating'):

-- very large material is engulfed by the cell (eg: bacteria and dead cells).

-- white blood cells (aka Phagocytes) perform phagocytosis to engulf bacteria and to recycle the usable parts of 'worn-out' red blood cells.

-- can be observed with a compound light microscope.

ii. *Pinocytosis* ('cell-drinking'):

-- engulfing of large molecules such as proteins, carbohydrates, fats, and nucleic acids (macromolecules).

-- unlike phagocytosis, this process cannot be seen with a light microscope.

-- once vesicles enter the cell, the contents may be digested (by a lysosome), stored (in a vacuole), or used for whatever functional purpose it possesses.

iii. *Receptor-mediated Endocytosis*:

-- a form of pinocytosis that is more specific in that it utilizes receptor proteins shaped for only specific molecules (vitamins, hormones, lipoproteins, etc.)

-- receptors tend to accumulate in 'coated pits', which are regions of the cell membrane pre-determined for the admittance of specific substances.

-- see fig. 4.13 p. 79.

b. Exocytosis (LEAVING by vesicle):

-- the reverse of endocytosis.

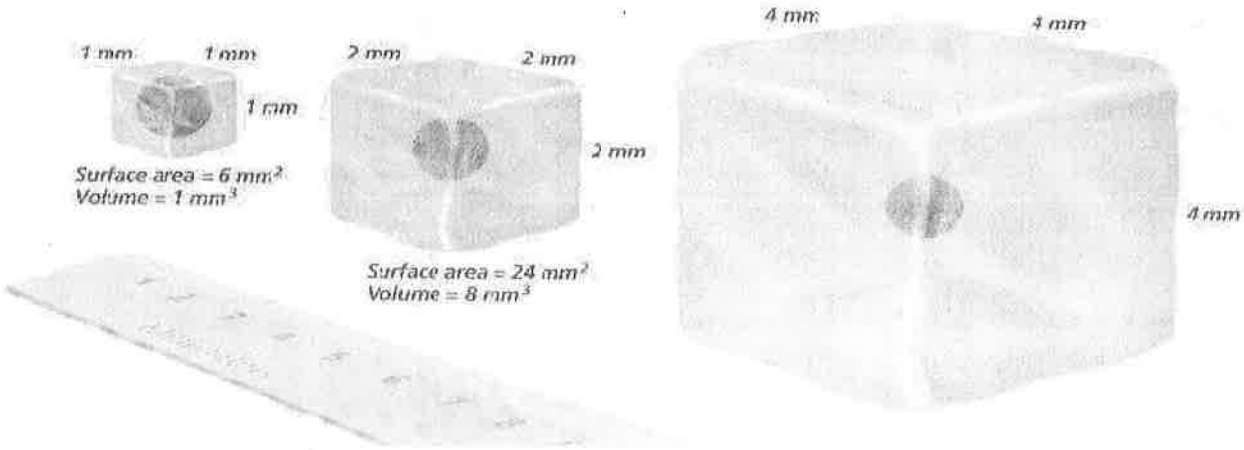
-- required for the secretion/release of molecules from a cell.

-- a vesicle containing materials fuses with the cell membrane and releases the materials into the ECF.

eg. secretory vesicles from the Golgi.

**Cell Size (again)**

- As cells mature (post-mitosis), they grow.
- However, for an *organism* to grow, its cells must **divide**.
- Metabolic restrictions impose limits on the max. **size** of a cell.
- As a cell grows, its **volume** and its **surface area** increase, but they do so at different **rates**. In fact, V grows ***faster*** than SA.
- This is because V is a **cubic** function (V(sphere) = $4/3\pi r^3$), whereas SA is a **quadratic** function (SA(sphere) = $4\pi r^2$).
- therefore, as a cell grows, its **surface area-to-volume ratio (SA:V) decreases**.



- The **SA** of a cell governs its ability to import/export materials.

- The **V** of a cell (the part of the cell housing the organelles) imposes the ***demands*** upon the cell's SA.

- Thus, if the demands are increasing faster than the import/export abilities, the cell may eventually reach a point where it cannot sustain living; it will either have to **divide** or **die**.

- furthermore, a cell's **nucleus** has a limit as to what size of a volume that it can service.

- Once a cell **divides**, its SA:V increases to a level that is conducive to 'healthy living'.