Cell Membrane Transport

Learning Outcome B9

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- Analyse the structure and function of the cell membrane

Student Achievement Indicators

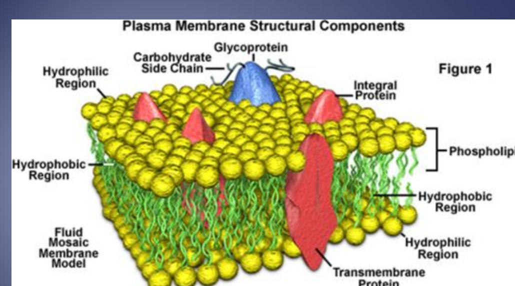
- Apply knowledge of organic molecules including:
  - phospholipid
  - proteins
  - glycoproteins
  - glycolipids,
  - carbohydrates
  - cholesterol
- Explain the structure and function of the fluid-mosaic membrane model.
- Identify the hydrophobic and hydrophilic regions of the phospholipid bilayer.
- Explain why the cell membrane is described as "selectively permeable".
- Describe the passive transport processes including diffusion, osmosis, and facilitated transport.
- Explain factors that affect the rate of diffusion across a cell membrane, such as:
  - temperature
  - size
  - charge of concentration gradient
  - pressure gradient

Student Achievement Indicators

- Predict the effects of hypertonic, isotonic, and hypotonic environments on osmosis in animal cells.
- Describe active transport processes including active transport, endocytosis (phagocytosis and pinocytosis), and exocytosis.
- Compare specific transport processes, including:
  - diffusion
  - osmosis
  - facilitated transport
  - active transport
  - endocytosis
  - exocytosis
- *In terms of concentration gradient, use of channel or carrier proteins, use of energy and types/sizes of molecules being transported*
- Devise an experiment using the scientific method

The Cell Membrane

- Outer living boundary of the cell
- Gives the cell mechanical strength
- Helps to maintain homeostasis by regulating the passage of molecules into and out of the cell

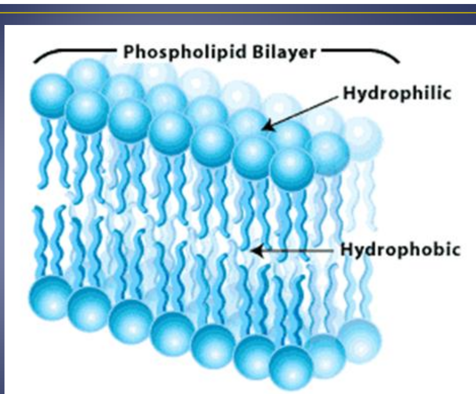


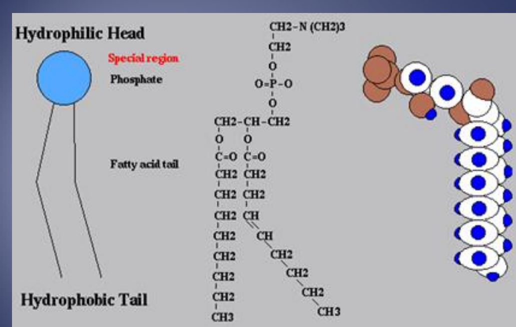
Cell Membrane Structure

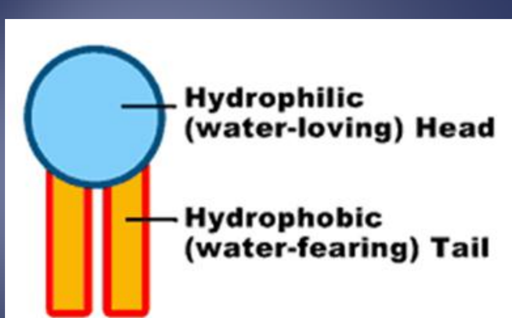
- The cell membrane is a phospholipids bilayer with protein molecules partially or completely embedded into it.
- Phospholipids – fats
- Bilayer – two
- The structure of the cell is described as a fluid-mosaic model because:
  - It has a fluid consistency (like oil)
  - The proteins scattered throughout the membrane form a mosaic pattern.
- Each phospholipid in the membrane has a polar (charged) head and two non-polar tails.
- The phospholipids form a bilayer naturally when surrounded by water

Cell Membrane Structure

- The heads face outwards since they are polar and are attracted to the polar water molecules.
- The heads are called hydrophilic, which means water loving.
- The non-polar tails are not attracted to water, so they face inward, away from the water and are called hydrophobic which means water hating.

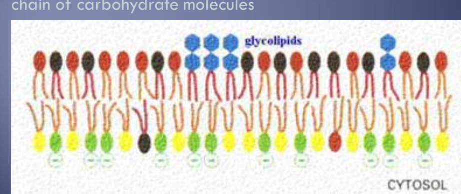


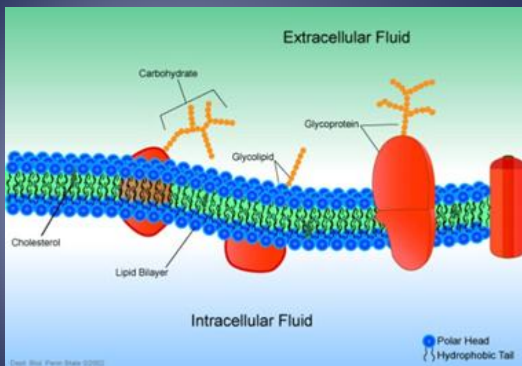




Cell Membrane Structure

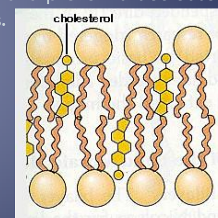
- Certain lipids in the outside portion of the cell membrane are called glycolipids.
- They are similar to phospholipids except the head contains a chain of carbohydrate molecules

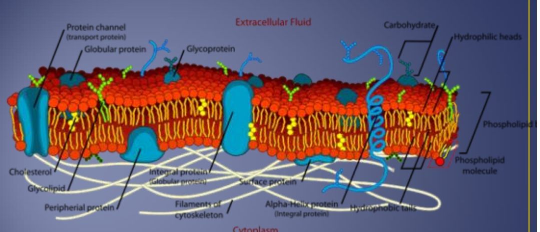




Cell Membrane Structure

- Animal cell membranes also have a substantial number of cholesterol molecules
- They give the bilayer stability and prevent a decrease in fluidity at low temperatures.



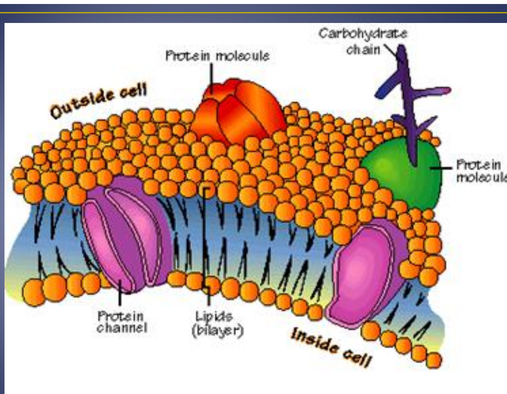


Cell Membrane Proteins

- The various functions of the cell membrane are carried out by the cell membrane proteins.
- Some proteins span the membrane and have carbohydrate chains attached that face outwards.
- Some are located on the internal surface and are anchored to the cytoskeleton filaments.

Potential Functions:

- ✓identify the cell like a fingerprint
- ✓allow ions or molecules to move through them
- ✓act as carriers and channels
- ✓receptors
- ✓enzymatic



Crossing the Cell Membrane

- Small, non-charged molecules especially if they are lipid soluble can cross easily.
- Macromolecules cannot cross freely.
- Charged ions and molecules have difficulty crossing
- Negatively charged ions tend to move through channels from inside the cell to outside the cell.
- Positively charged ions tend to move from outside the cell to inside the cell.

Crossing the Cell Membrane

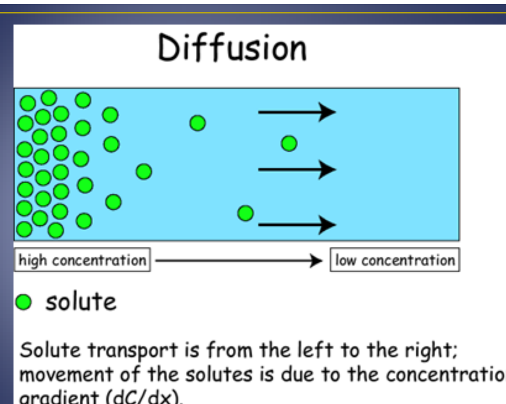
- Since the movement of molecules is restricted, the cell membrane is said to be selectively permeable or differentially permeable.
- Molecules can pass across the cell membrane actively, meaning the process requires ATP
- Some examples of active transport are endocytosis and exocytosis.
- They can also move through the cell membrane passively, which means ATP s not required
- Examples - diffusion and osmosis

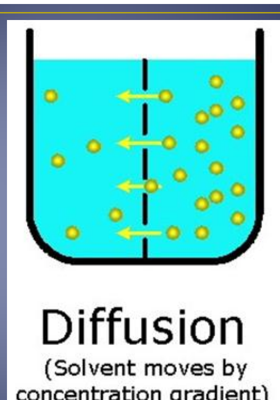
Diffusion

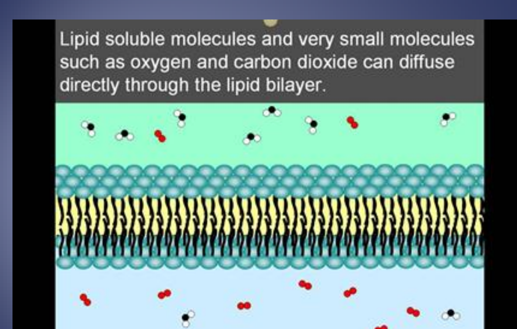
- Is the net movement of a substance from a region of higher concentrations to a region of lower concentration
- Molecules move down their concentrations gradient from an area of high concentration to an area of lower concentration until they are distributed equally.
- Example – dye crystal in water
  - ✓Once the dye molecules and water molecules are evenly distributed, they continue to move about, but there is no net movement of either in any direction.

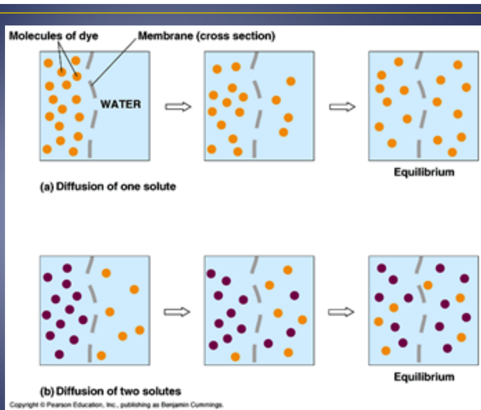
Diffusion

- Only a few types of molecules can enter and exit the cell via diffusion
  - ✓Lipid soluble molecules like alcohol
  - ✓Gases, such and oxygen and carbon dioxide
- Example – the movement of oxygen from air sacs of the lung into bloodstream
  - ✓When you inhale, the O_2 in air sacs is more than the O_2 in blood; therefore the O_2 moves from eh air sacs into the blood by diffusion



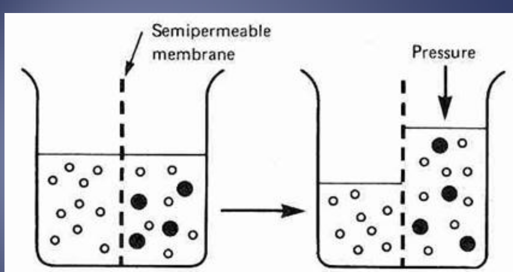


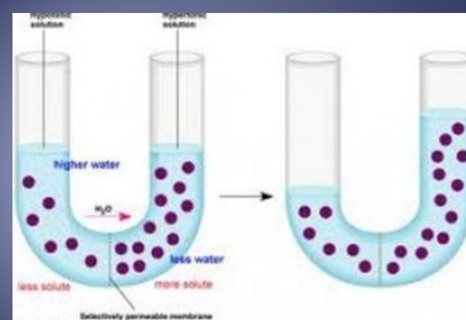


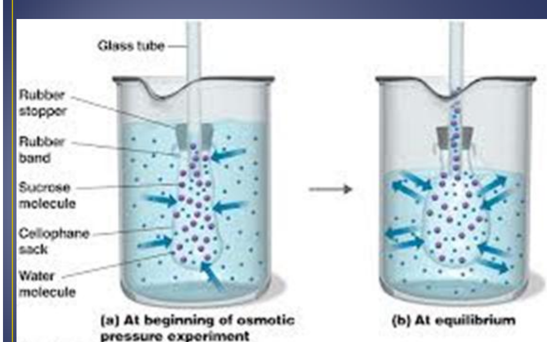


Osmosis

- When water moves across a selectively permeable membrane
- The movement of water from an area of higher concentration to an area of lower concentration across a selectively permeable membrane







Osmosis

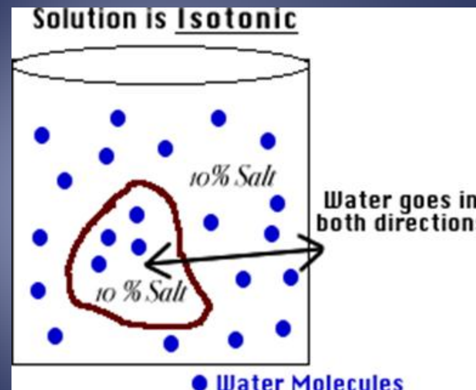
- Osmotic pressure will cause the amount of H_20 to increase on the side with the greater solute concentration.
- Osmosis is constantly occurring in cells; it is very important and can affect health greatly.

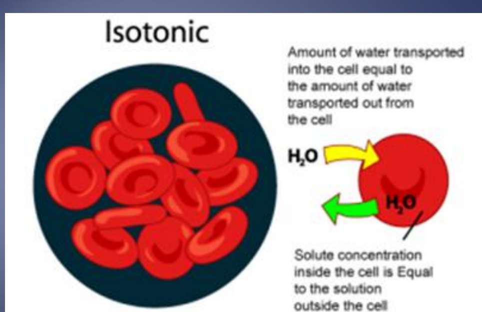
Tonicity

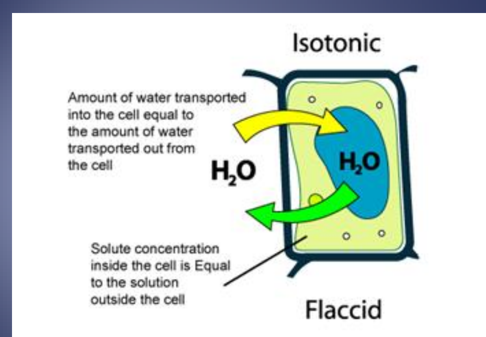
- Refers to the strength of a solution in relationship to osmosis
- There are three types of solutions:
  - ✓isotonic
  - ✓hypotonic
  - ✓hypertonic

Isotonic Solution

- Is a solution with the same percent of solute as the cell
- The solute concentration is the same on both sides of the cell membrane; therefore there is NO net gain or loss of water.

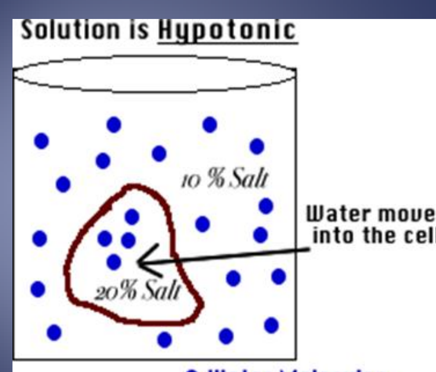


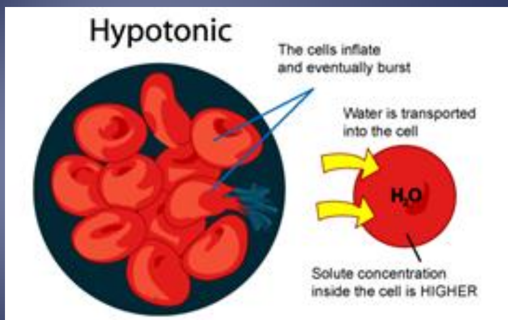


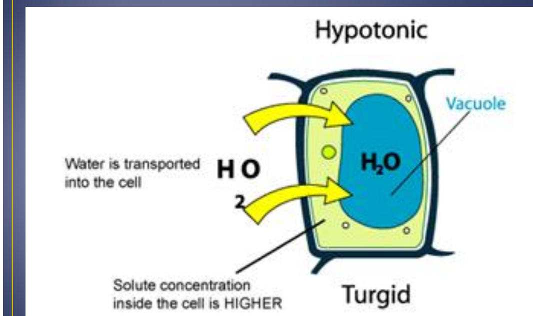


Hypotonic Solution

- Is a solution that has a lower percentage of solute than the cell or an increased percentage of water
- When cells are in this type of solution, water enters the cell.
- The net movement of water is from the outside to the inside of the cell
- Any concentration of salt solution lower than 0.9% is hypotonic to red blood cells
- Red blood cells placed in a solution that is hypotonic will swell with water and they may bust due to build-up of pressure
- Cell bursting is known as lysis

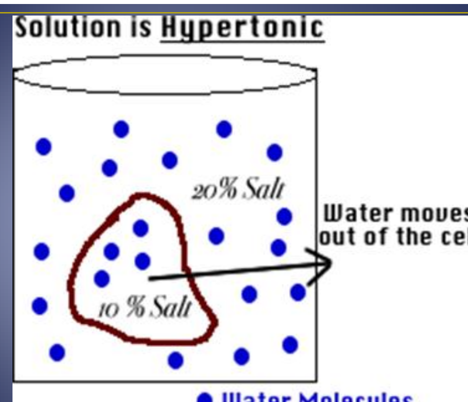


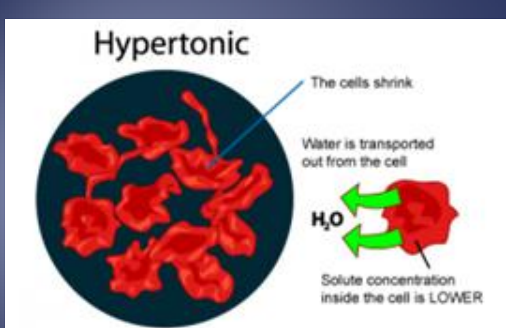


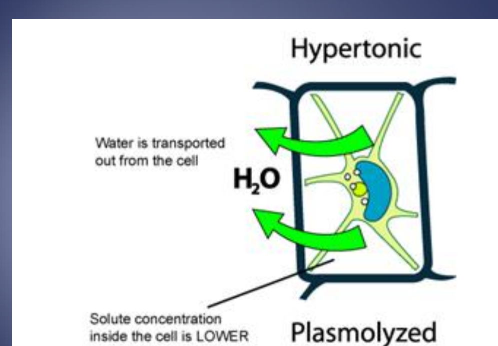


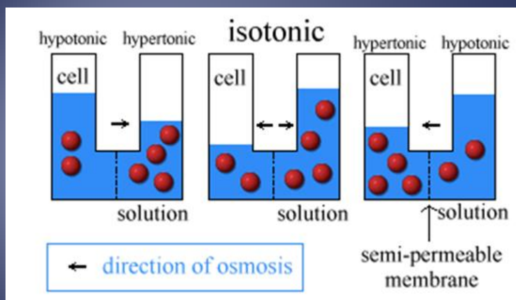
Hypertonic Solution

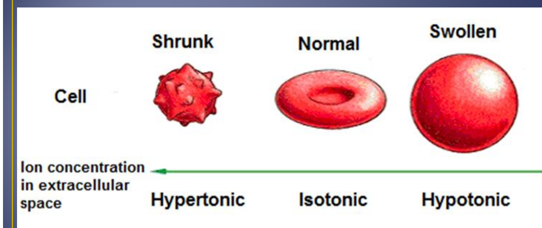
- Is a solution that has a higher percentage of solute than the cell or an increased percentage of water
- When cells are in this type of solution, water leaves the cell.
- The net movement of water is from the inside to the outside of the cell.
- This causes the cell to shrink
- In plant cells a hypertonic solution causes the cytoplasm to shrink, and is known as plasmolysis.
- If a plant cell is placed in a hypertonic solution, the large central vacuole loses water which causes the cytoplasm to shrink and pull away from the cell wall.

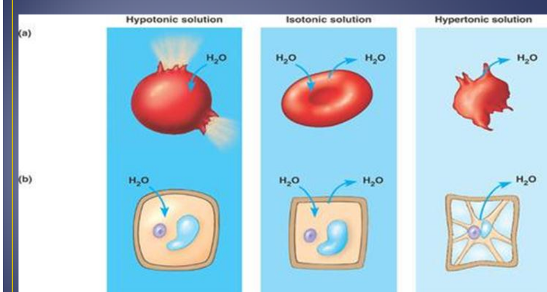












Summary

Tonicity	Solution A	Solution B
Isotonic	1% sugar	1% sugar
A is hypotonic to B	0.5% sugar	1% sugar
A is hypertonic to B	1% sugar	0.5% sugar

When a cell is placed in a:

- Isotonic Solution → doesn't gain or lose water (no net change)
- Hypotonic Solution → the cell gains water (potential lysis
- Hypertonic Solution → the cell loses water and the cytoplasm shrinks (crenation)

Movement across the Cell Membrane

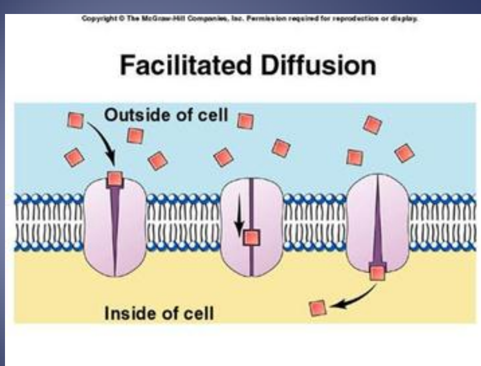
- Biologically useful molecules are able to enter and exit the cell quickly because there are carrier proteins in the cell membrane.
- Barrier proteins are specific, each can only combine with a certain type of molecule to transport it through the membrane.
- These proteins are required by facilitated diffusion (no energy required) or active transport (energy is required)

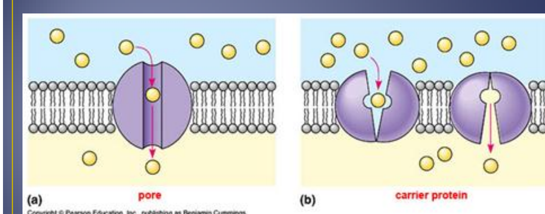
Facilitated Diffusion (aka Facilitated Transport

- Moves glucose and amino acids across the cell membrane even though they are not lipid soluble
- They reversibly combine with carrier proteins which somehow transport them through the cell membrane.
- Carrier proteins are specific
- Example – glucose crosses the cell membrane 100x faster than other sugars of the same size.

Facilitated Transport (aka Facilitated Diffusion)

- Once the carrier protein moves one molecule to the other side of the membrane it can move more molecules
- Neither simple diffusion nor facilitated diffusion requires any energy because the molecules are moving down their concentration gradients in the same direction they tend to move anyways.





Active Transport

- Molecules or ions move through the cell membrane and accumulate either inside or outside the cell.
- Example – glucose is completely absorbed by the cells that line the digestive tract
- The molecules are moving to the region of higher concentration (opposite direction of diffusion).
- Requires both barrier proteins and ATP energy
- The ATP is required for the carrier to combine with the substance being transported.

Active Transport

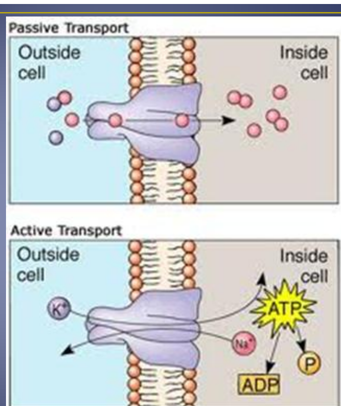
- Cells that are involved mostly in active transport have many mitochondria near the membrane where active transport is occurring.
- Proteins in active transport are usually called pumps since they use energy to move substances against their concentration gradients.
- One very important pump is the sodium-potassium pump
- It is found in all cells but is very active in nerve and muscle cells.
- It move sodium ions to the outside of the cell and potassium ions to the inside of the cell

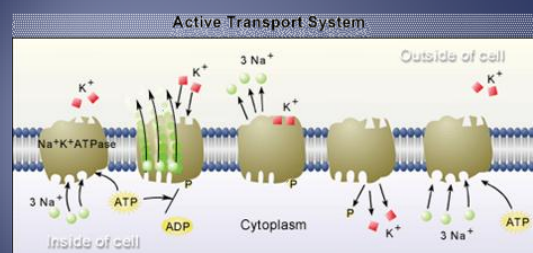
Active Transport

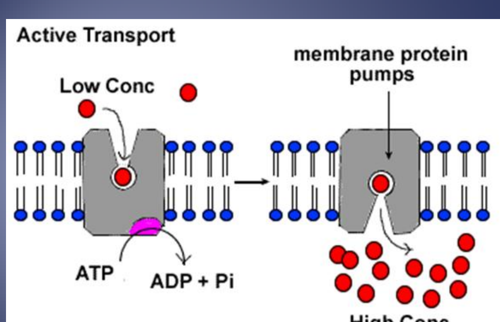
- The carrier protein is able to transport NA^+ and K^+ because of the attachment and detachment of a phosphate groups which comes from a molecule of ATP
- This phosphate group changes the shape of the carrier protein so it can transport NA^+ and K^+.
- The carrier protein acts as an enzyme and breaks down ATP to get a phosphate group so that it can modify its shape

Active Transport

- The passage of Na^+Cl^- (salt) across a cell membrane is very important to cells.
- First Na^+ ions are pumped across a membrane and then Cl^- ions diffuse through the carrier protein following the Na^+
- Some molecules are too big to be transported by carrier proteins and are transported in or out of the cell by vesicle formation.







Endocytosis

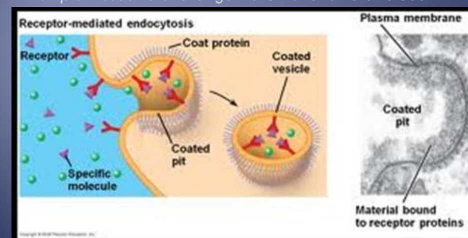
- The process by which a vesicle is formed at the cell membrane to bring macromolecules or larger substances into the cell
- This requires ATP, even when substances are moving with their concentration gradients.
- If the molecule taken in by endocytosis is quite large we call it phagocytosis (cell eating).
- These large molecules are usually debris, such as macrophages (type of WBC), bacteria old RBC.
- Pinocytosis (cell-drinking) is that taking in of fluid along with dissolved solutes by engulfing
- It is also a form of endocytosis.

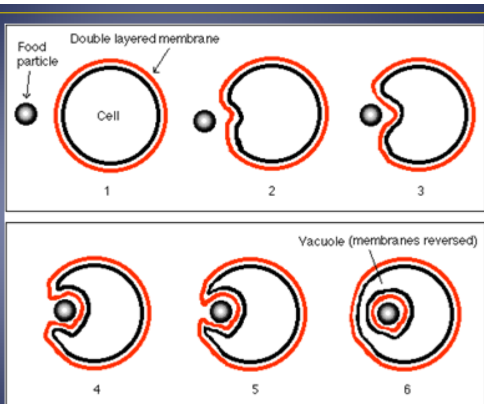
Endocytosis

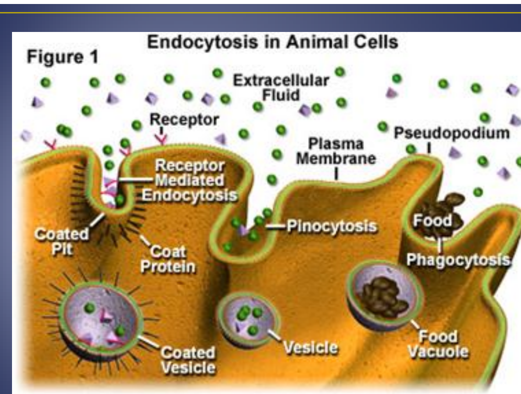
- After endocytosis the vacuoles or vesicles formed contain a substance surrounded by membrane.
- They may fuse with a lysosome to allow for the digestion of substances so it can be incorporated into the cytoplasm.
- There is specialized type of pinocytosis called receptor-mediated endocytosis that specifically shaped receptor proteins.
- These proteins fit specific molecules such as Vitamin A, peptide hormones or lipoproteins.
- The receptor for these substances is found at only location in the cell membrane.
- This location is called a coated pit because there is a layer of protein on the cytoplasmic side of the pit.
- Once formed, the vesicle is uncoated and may fuse with a lysosome.

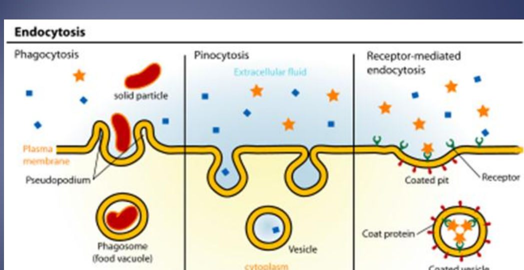
Endocytosis

- This type of pinocytosis is specific and more efficient that ordinary pinocytosis.
- *Example* – used to exchange maternal and fetal blood



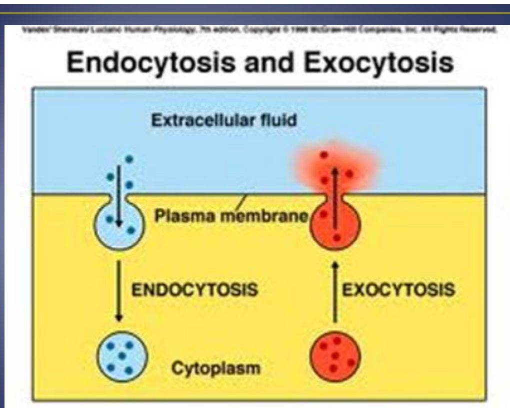


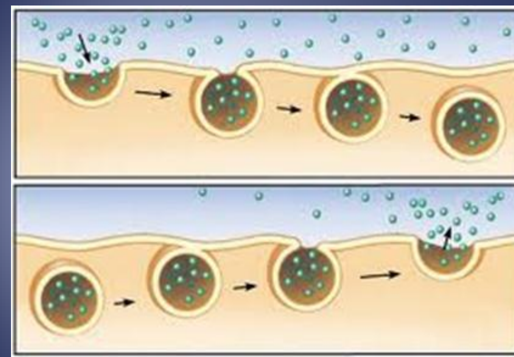




Exocytosis

- Opposite of endocytosis
- A vesicle fuses with the membrane and releases its contents
- It is required for secretion (the acts of releasing a cell product from the cell)





Factors Affecting Diffusion Rates

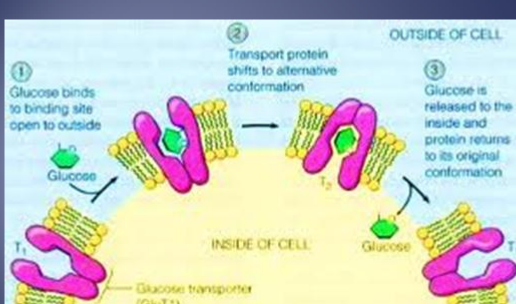
1. Size

- Small molecules can slip by the polar heads of the phospholipid and through the membrane to the other side of the cell membrane.
- Examples – carbon dioxide, water and oxygen
- Very large molecules cannot diffuse across the cell membrane at all.

Factors Affecting Diffusion Rates

2. Shape

- Certain ions and molecules can enter the cell membrane due to their specific shape.
- Example – glucose is able to get into cells much faster than other sugars due to its specific shape.
- A carrier protein specific for glucose and not other sugars; combines with the glucose molecule on the outer surface of the cell membrane.
- This carrier protein closes around the glucose molecule and then opens to the inside of the cell where the glucose is released.
- The carrier protein then returns to its original shape and is ready to transport other glucose molecules.
- These carriers can move up to 100 glucose molecules per second across the cell membrane.



Factors Affecting Diffusion Rates

3. Concentration

The greater the concentration gradient between the outside and inside of the membrane the greater the rate of diffusion

If the concentration of oxygen outside the cell increases then it will diffuse more quickly into the cell.

The opposite is also true.

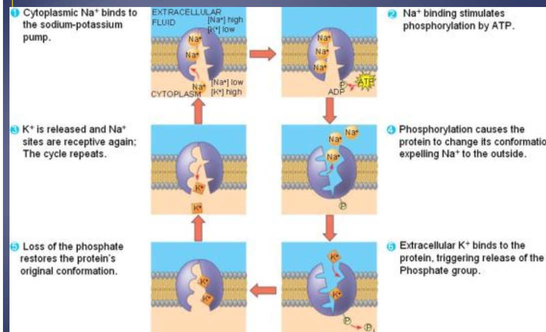
Example – if a muscle cell is working hard and using up large quantities of oxygen in cellular respiration producing ATP, then the low levels inside the cell walls will increase the concentration gradient compared to outside and the rate of diffusion of oxygen into the cell will increase.

The same conditions in the muscle cell would create high concentrations of carbon dioxide inside the cell and increase the rate of diffusion from inside to outside.

Factors Affecting Diffusion Rates

4. Charge

- Ions or molecules with a charge cannot pass through the lipid bilayer by diffusion
- Other mechanisms involving protein carriers and ATP energy are required.
- The Na^{+}/K^{+} pump is an example of this type of transport



Factors Affecting Diffusion Rates

5. Lipid Solubility

- Lipids soluble molecules can move through the lipid bilayer
- Generally these molecules are other lipids
- *Examples* - steroid hormones like testosterone and estrogen
- This easy access to cells explain the powerful and wide range effects of hormones

Factors Affecting Reaction Rates

6. Temperature

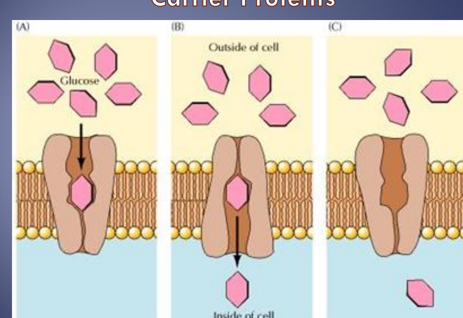
- In general, increase in temperatures cause all molecules to move faster.
- Diffusion is a passive movement of molecules so quicker movement translates into quicker diffusion.

Proteins in the Cell Membrane

1. Carrier Proteins

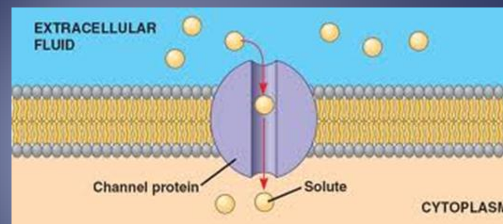
- Selectively interacts with specific molecules.
- Combines with substances and moves it across the plasma membrane

Carrier Proteins



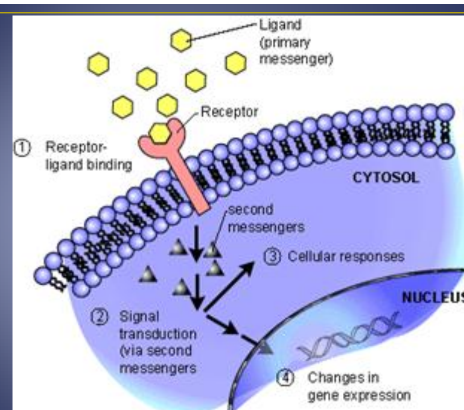
Proteins in the Cell Membrane

2. Channel Proteins
- Allow particular ions/molecules to pass through the plasma membrane.
- *Example* – Cystic Fibrosis is caused by a faulty Cl^- channel



Proteins in the Cell Membrane

2. Receptor Proteins
- Allows certain molecules to bind, because they have the correct specific shape
- Binding of molecule causes a change in shape and brings about a cellular response.
- Involved in cell function but not necessarily directly in the passage of substances into and out of the cell.



Proteins in the Cell Membrane

4. Enzymatic Proteins
- Catalyze specific metabolic reactions such as the break-down and build-up of macromolecules and monomers