L.3

Movement Across The cell Membrane

Dr. Yaseen Khashman Hussein

Types of Movement Across The Cell Membrane

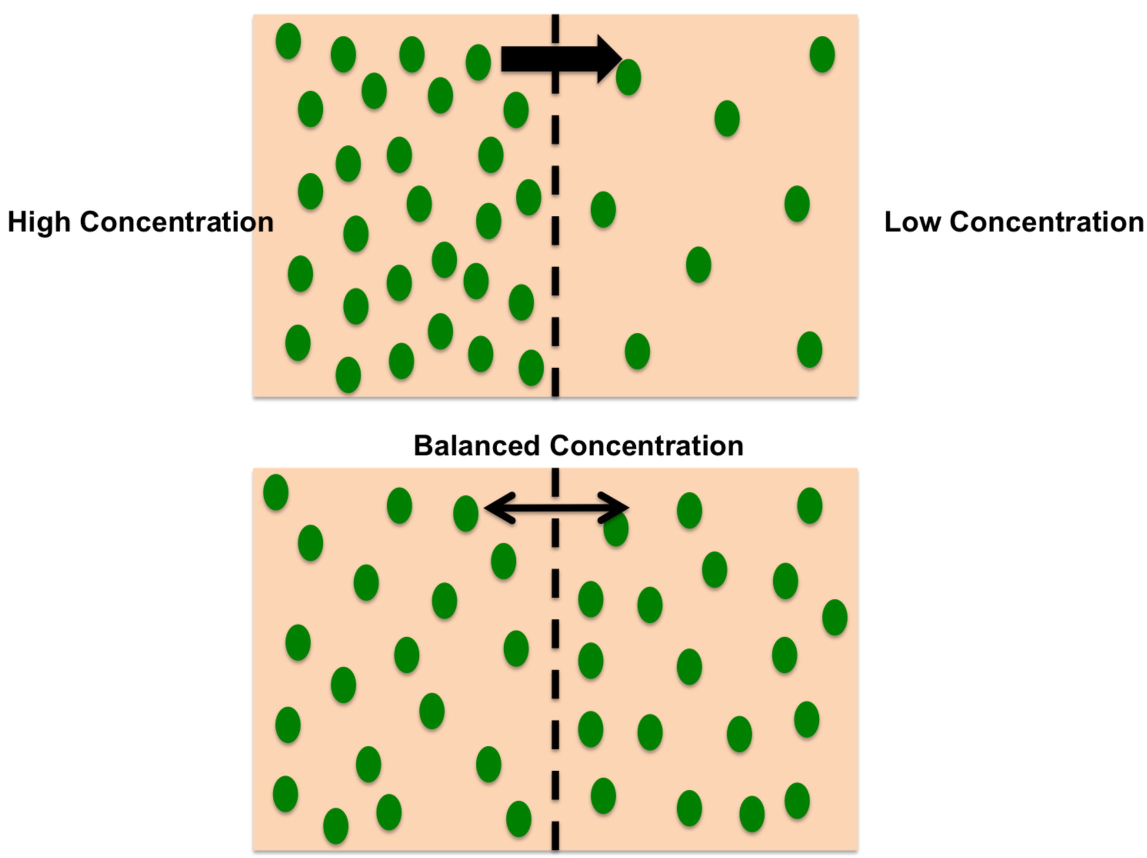
In order for the cell cytoplasm to communicate with the external environment, materials must be able to move through the plasma membrane. This movement occurs through several mechanisms as explained below.

Passive transport

Naturally, molecules move from an area of high concentration to low concentration without the need of energy. This type of movement is **passive transport**. Molecules with strong electrical charges such as ions cannot simply diffuse across the cell membrane. Irrespective of their size, their charge prevents them from moving freely across the cell membrane. It is depend on the permeability of the cell membrane. Other molecules such as proteins, starch and sugar are simply too large to diffuse across the membrane. Sometimes, some of these large molecules are transported across the cell membranes **by carrier proteins**; this does not require energy and as a result is a **form of passive transport**. There are three types of passive transport; **simple diffusion, facilitated diffusion, and osmosis.**

Diffusion

One method of **movement** through the membrane is **diffusion.** Diffusion is a random movement of molecules from a region of higher concentration to one of lower concentration. For example, If you have a bottle of perfume and take the cap off. The perfume molecules will waft out and diffuse into the air where there is a lower concentration of them. **Net diffusion stops when concentration on both sides equal or when there is an uniform distribution of particles**. Diffusion of one compound is independent to diffusion of other compounds

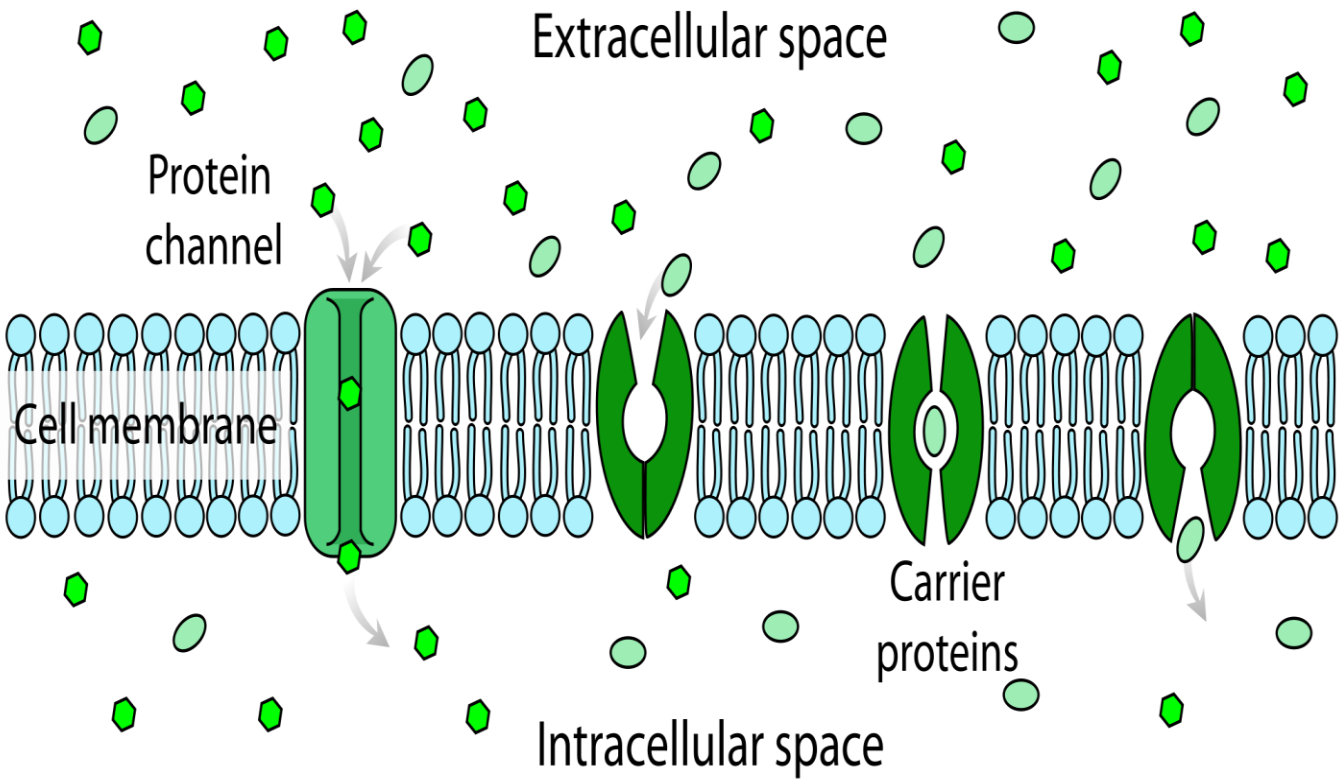


1. Simple diffusion: Movement of a substance from a region of higher concentration to lower concentration and this type of diffusion does not require energy.

2. Facilitated diffusion: This process does not require ATP but does **require** cell membrane **proteins** which are called **carrier proteins** to carry the molecules across the cell membrane .The proteins encourage movement in the direction that diffusion would normally take place, from a region with a higher concentration of molecules to a region of lower concentration.

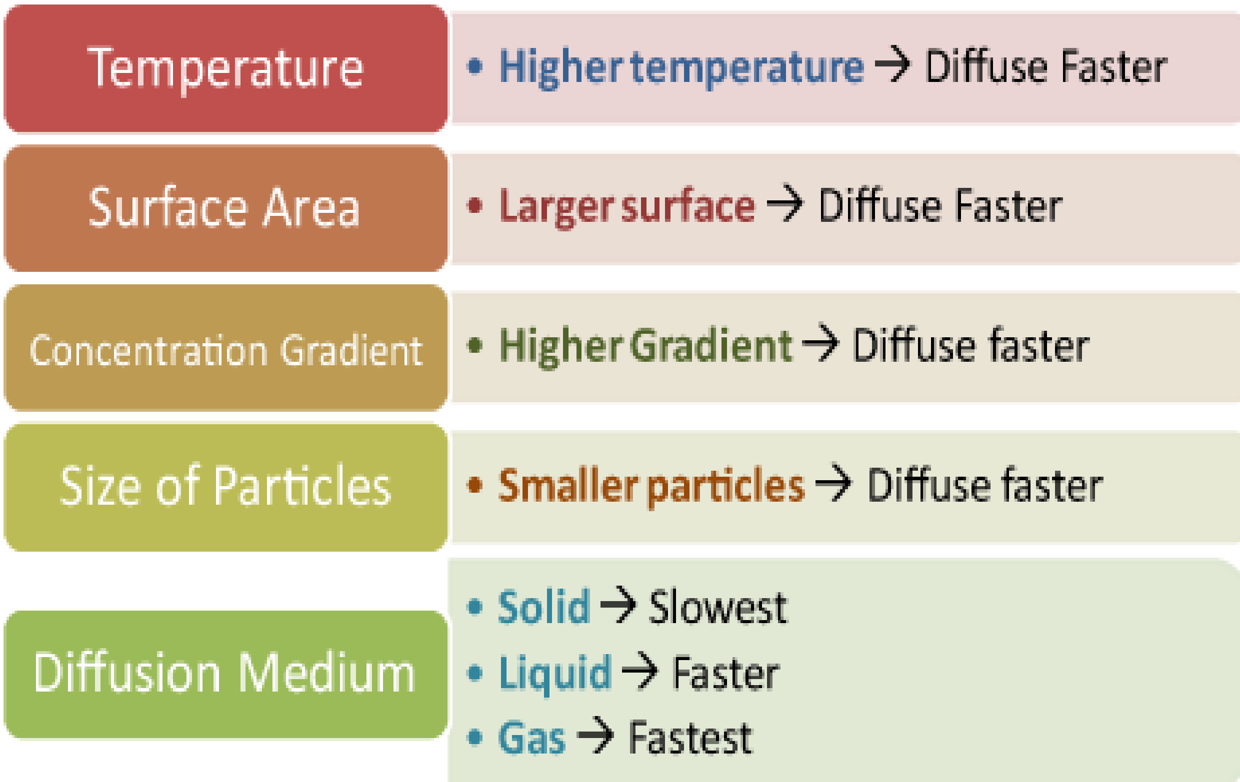
It is highly selective process, thus, this allows diffusion of large compounds such as sugars and amino acids. Ions and polar molecules cannot pass easily across the membrane. In this process **ions** and **hydrophilic** substances travel across the cell membrane with the help of transport proteins. Transport proteins are specific (**like enzymes**) for the substances they transport. They work in one of two ways:

- They provide a hydrophilic **channel** through which the molecules in question can pass.
- They **bind** loosely (**freely**) to the molecules and carry them through the membrane.



The figure above explains facilitated diffusion

Factors increase diffusion process through protein channels



3. Osmosis: **Osmosis** is the movement of **water** from a region of higher concentration to one of lower concentration (**to a higher concentration of solutes**). It is another method of movement across the membrane. Osmosis occurs across a membrane that is (**semipermeable**). A semipermeable membrane lets only certain molecules pass through while keeping other molecules out. Osmosis is really a type of **diffusion** involving only water molecules.

- Osmosis = the **diffusion** of water across a semi-permeable membrane
- Plasma membrane permeable to water but not to solute
    - Solute = dissolved particle
    - Solvent = liquid medium in which particles may be dissolved
- Water moves from solution with lower concentration of dissolved particles to solution with higher concentration of dissolved particles (**moves from dilute solution to concentrated solution).**
- The ***osmotic pressure*** is defined to be the pressure required to maintain an equilibrium, with no net movement of solvent.

A cell has one of **three water relationships with the environment** around it.

- **Hypertonic solution**: The cell will lose **water** to its surroundings. The hyper - prefix refers to more solutes in the water around the cell, hence, the movement of water to the higher (hyper-) concentration of solutes. In this case the cell loses water to the environment, **shrinks**, **and may die**.

✓ **In a hypertonic Solution**: Solute concentration higher than cell

  - More dissolved particles outside of cell than inside of cell
  - **Hyper** = more; **Tonic** = dissolved particles
  - Water moves **out** of cell into solution
  - Cell **shrinks**

- **Hypotonic Solution**: Water will enter the cell **faster than it leaves**. The hypo - prefix refers to fewer solutes in the water around the cell, hence, the movement of water into the cell where the solutes are more heavily concentrated. In this case the cell will **expand and may burst**, **unless protected by a cell wall** such as that found in bacteria and plant cells.

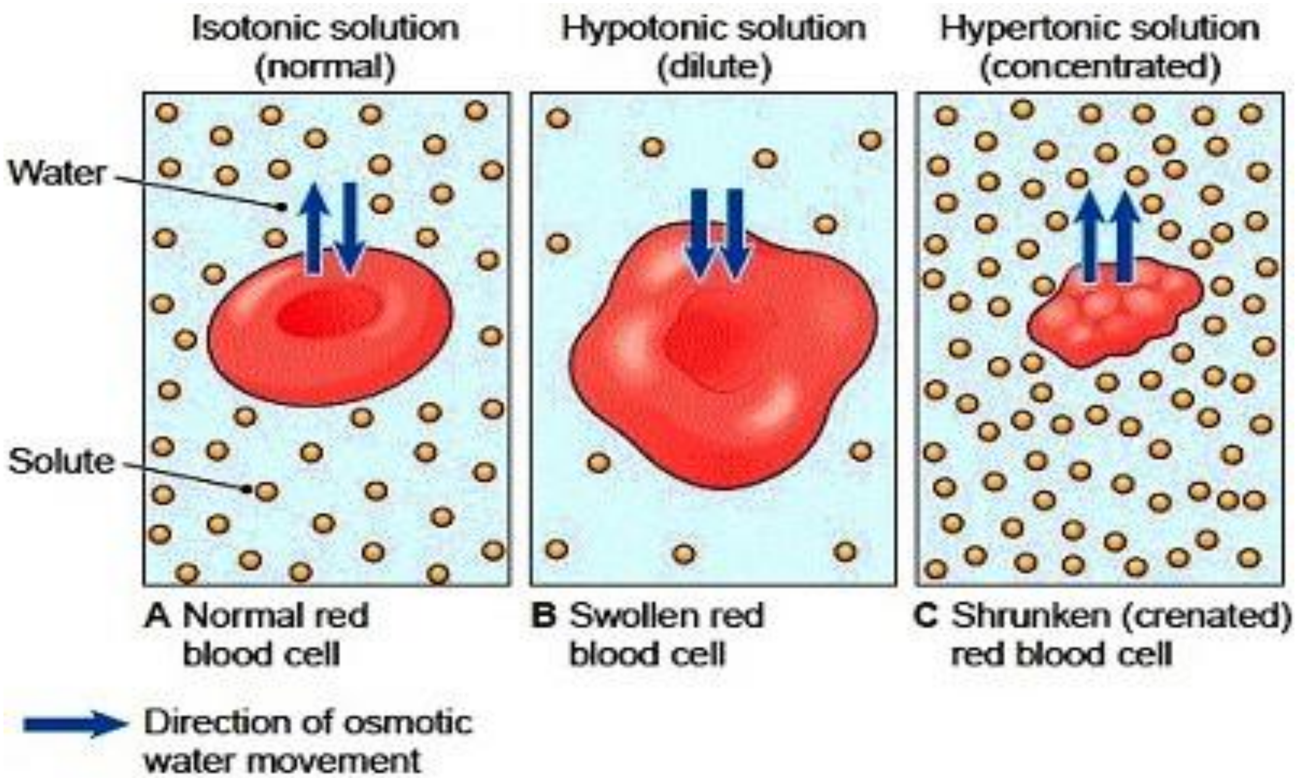
✓ **In a hypotonic Solution**: Solute concentration lower than cell

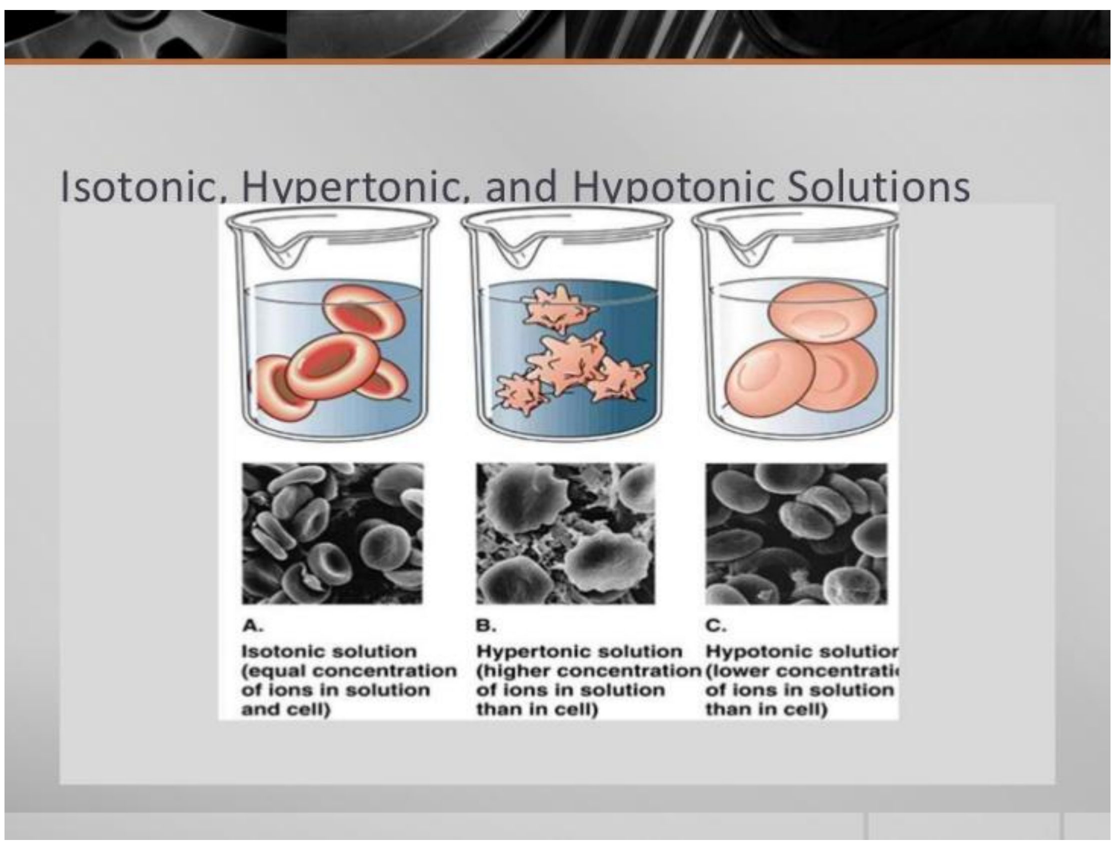
  - Less dissolved particles outside of cell than inside of cell
  - **Hypo** = less, under (think hypodermic, hypothermia); **Tonic** = dissolved particles
  - Water moves **into** cell from solution
  - Cell **expands** (and may **burst**)

- **<u>Isotonic Solution</u>**: There will be no net movement of water across the plasma membrane. Water crosses the membrane, **but at the same rate in both directions**.

✓ **In an isotonic solution**: Solute concentration equal to that of cell

    - **No** net water **movement**


Isotonic solution
(normal)
Hypotonic solution
(dilute)
Hypertonic solution
(concentrated)
Water
Solute
A Normal red blood cell
B Swollen red blood cell
C Shrunken (crenated) red blood cell
Direction of osmotic water movement


Isotonic, Hypertonic, and Hypotonic Solutions
A.
Isotonic solution
(equal concentration
of ions in solution
and cell)
B.
Hypertonic solution
(higher concentration
of ions in solution
than in cell)
C.
Hypotonic solution
(lower concentration
of ions in solution
than in cell)

Active transport

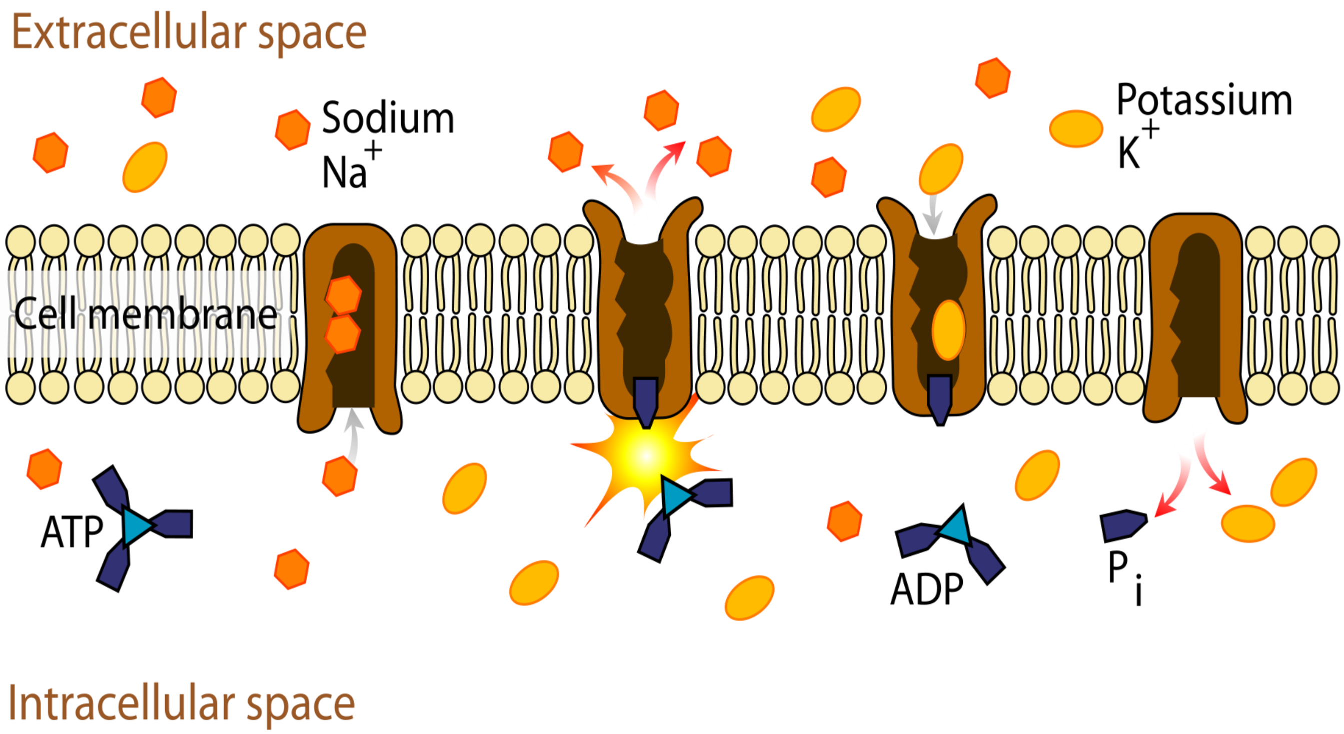
Another method for movement across the membrane is **active transport**. It is the transport of molecules **against** their concentration gradient from a region of low concentration to a region of high concentration. This type of transport **requires** a **carrier protein** and **energy** supplied by the cell.

When active transport is taking place, a **protein** moves a certain material across the membrane from a region of lower concentration to a region of higher concentration. Because this movement is happening against the concentration gradient, the cell must expend (use) **energy** that is usually derived from a substance called adenosine triphosphate, or ATP.

A common example of active transport is the sodium-potassium pump. This transmembrane protein pumps sodium out of the cell (**a region of high concentration of sodium**) and potassium into the cell (**a region of high concentration of potassium**). The sodium-potassium pump is necessary for proper nerve transmission and is a major energy consumer in the body. The inside of the cell is **negatively** charged compared with outside of the cell. The difference in electric charge across a membrane is expressed in voltage and termed the membrane potential. Because the inside of the cell in negatively charged, a positively charged ion on the outside, like sodium, is attracted to the negative charges inside the cell. Thus, two forces drive the diffusion of ions across a membrane:

- A **chemical force**, which is the ion's concentration gradient, and
- A **voltage gradient** across the membrane, which attracts positively charged ions and repels negatively charged ions

This combination of forces acting on an ion form an **electrochemical gradient**. (This transport of sodium and potassium set up the nerve cell for the impulse that will occur within it later).



Active transport is **divided into two types according to source of energy** used to effect the transport

In both the instances, transport depends on **carrier proteins** that penetrate membrane.

1. PRIMARY ACTIVE TRANSPORT
2. SECONDARY ACTIVE TRANSPORT

✓ PRIMARY ACTIVE TRANSPORT

In this transport the energy is derived directly from breakdown of **ATP** or **some high energy phosphate compound.**

In primary Active Transport: H^+, Na^+, Ca^{+2} all utilize ATP to force these things across the membrane. There is one major distinction between **active transport** and **facilitated diffusion** other than one **needing energy** and the other not. Active transport always causes a molecule to be *forced to move from a lower concentration to higher,* which it does not want to naturally do. The most important of all transport pumps are the one that uses ATP to simultaneously force K^+ (potassium ions) into the cell and Na^+ (sodium ions) out of the cell. This is famously called the **Sodium-Potassium protein pump**. **Active transport processes account for about 40% of the energy used in the body.**

EXAMPLE:

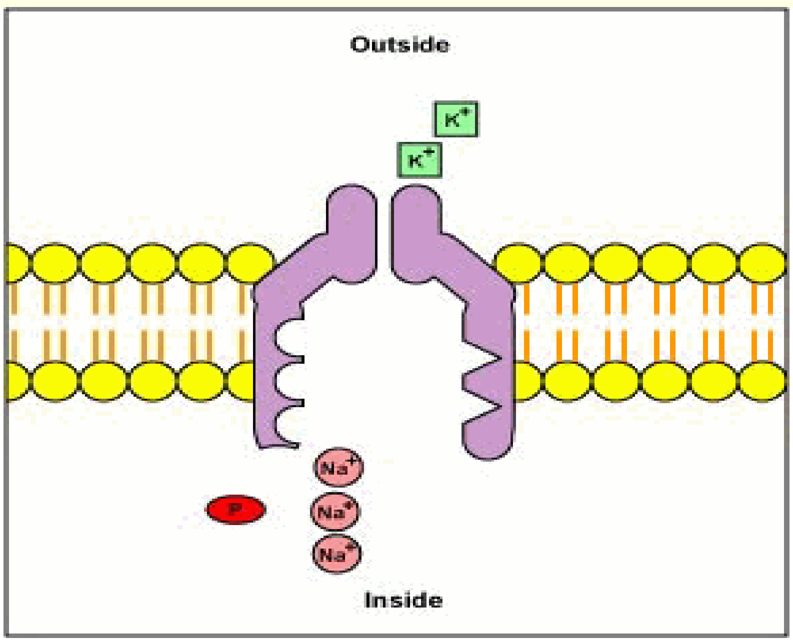
1.NA+,K+-ATPase PUMP (or NA+_K+ PUMP)

O Present in all the cells of the body, maintains low intracellular [NA+]and high intracellar [K+]

O By transporting **3 NA**+ from intracellular to extra cellular fluid

O And **2 K**+ from extra cellular to intracellular fluid

O Both NA+ and K+ are transported against their electrochemicalgradients.



CARRIER PROTEINS OF NA+_K+ PUMP-- **has two globular** proteins, smaller one has unknown function, Larger one has following **3 functions**

1. 3 receptors for NA+ ions on inside

2 .2 receptors for K+ ions outside

3. Inside portion has ATP-ase activity

> When 2 K+ ions binds on outside the carrier proteins and 3 NA+ ions on inside,the ATPase becomes activated and liberating energy from ATP

> This **energy** causes conformational **change in pump**

> Expelling 3 NA+ to outside and 2 K+ to inside

IT IS KNOW AS ELECTROGENIC PUMP -- since this pump , pumps 3 NA+ outside and 2 K+ inside, it **causes negativity inside** the cell membrane.

✓ SECONDARY ACTIVE TRANSPORT

In secondary active transport, the **energy** is derived secondarily from **the energy that has been stored in the form of ionic concentration differences of secondary molecular** or **ionic substances** b/w the two sides of the cell membrane, created originally by primary active transport.

As the energy is not provided directly, but indirectly from NA+ **gradient, thus inhibition of** NA+_K+ATPase **pump will decrease transport of** NA+ **out of cell, decrease the transmembrane** NA+ **gradient, and eventually inhibit the active transport.**

Secondary active transport: These is when one chemical is being forced in or out of the cell and another chemical just sort-of follows through. The two terms used for this is **<u>SYMPORT</u>** and **<u>ANTI-PORT</u>**. **Sym- means together** and two chemicals are going together in the same direction. **Anti-port** is when one chemical is forced in one direction and another is passively going in the other direction.

<u>Analogy:</u> Picture those large **turnstile/revolving** doors. Imagine you're pushing the door to get in and another person kind of follows along behind you without doing any work. **That is symport**. Again, using the turnstile example, imagine you're pushing the door to get in and another person sneaks out without doing any work to push themselves out. **That is anti-port.**

EXAMPLE:

1. CO-TRANSPORT OF GLUCOSE AND AMINO ACIDS ALONG WITH SODIUM IONS:

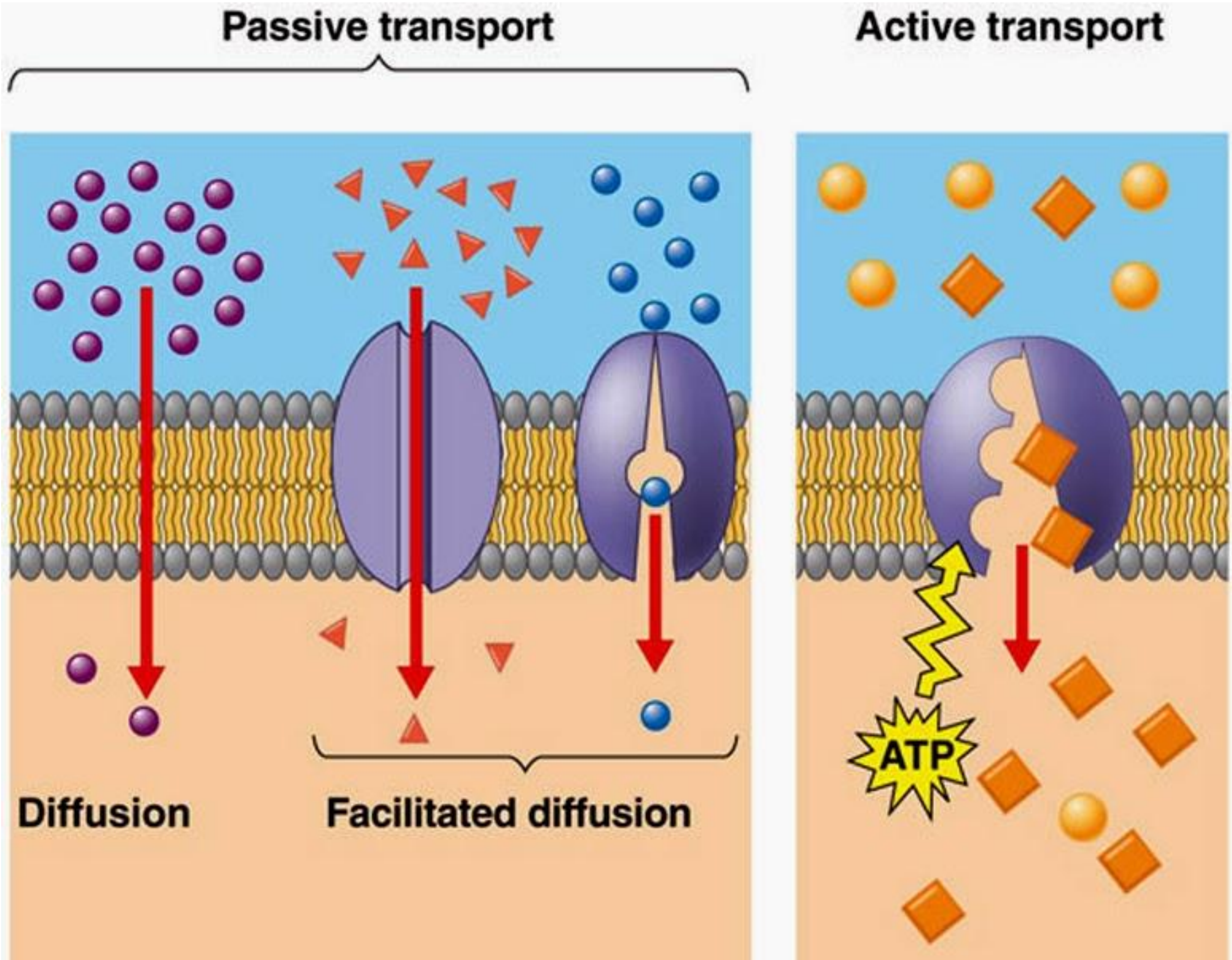
•For NA+ to be pull another substance along with it, a coupling mechanism is required

•It is achieved by a Carrier Protein, having two binding sites on outside, one for NA+ and other for Glucose or Amino acid

•Once they both are attached, **conc. gradient of NA+** causes conformational change in **Carrier protein**

•And hence Glucose or Amino acid CO-transported with NA+ to inside

• FOUND IN: epithelium of GIT and Renal Tubule



Passive transport
Active transport
Diffusion
Facilitated diffusion
ATP

MOVEMENT OF LARGE PARTICLES

It is possible for large molecules to enter and leave the cell by a certain processes as will be explained.

Endocytosis and exocytosis

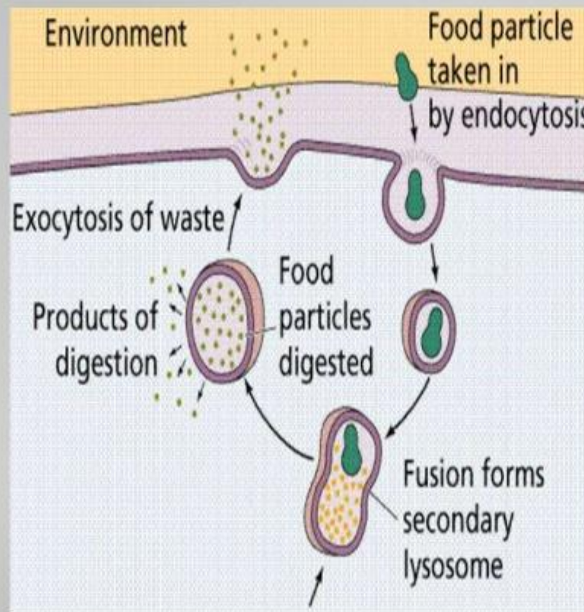
The final mechanism for movement across the plasma membrane into the cell is **endocytosis,** a process in which a small patch (**piece**) of plasma membrane encloses particles or tiny volumes of fluid that are at or near the cell surface. The membrane enclosure then sinks into the cytoplasm and pinches off from the membrane, forming a vesicle that moves into the cytoplasm. When the vesicle contains solid and larger particulate matter, the process is called **phagocytosis.** When the vesicle contains droplets of fluid, the process is called **pinocytosis.** Along with the other mechanisms for transport across the plasma membrane, **[**endocytosis **ensures** that the internal cellular environment will be able to exchange materials with the external environment and that **the cell** will continue to **thrive and function]**. **Exocytosis** is the reverse of endocytosis, where internally produced substances are enclosed in vesicles and fuse with the cell membrane, releasing the contents to the exterior of the cell.

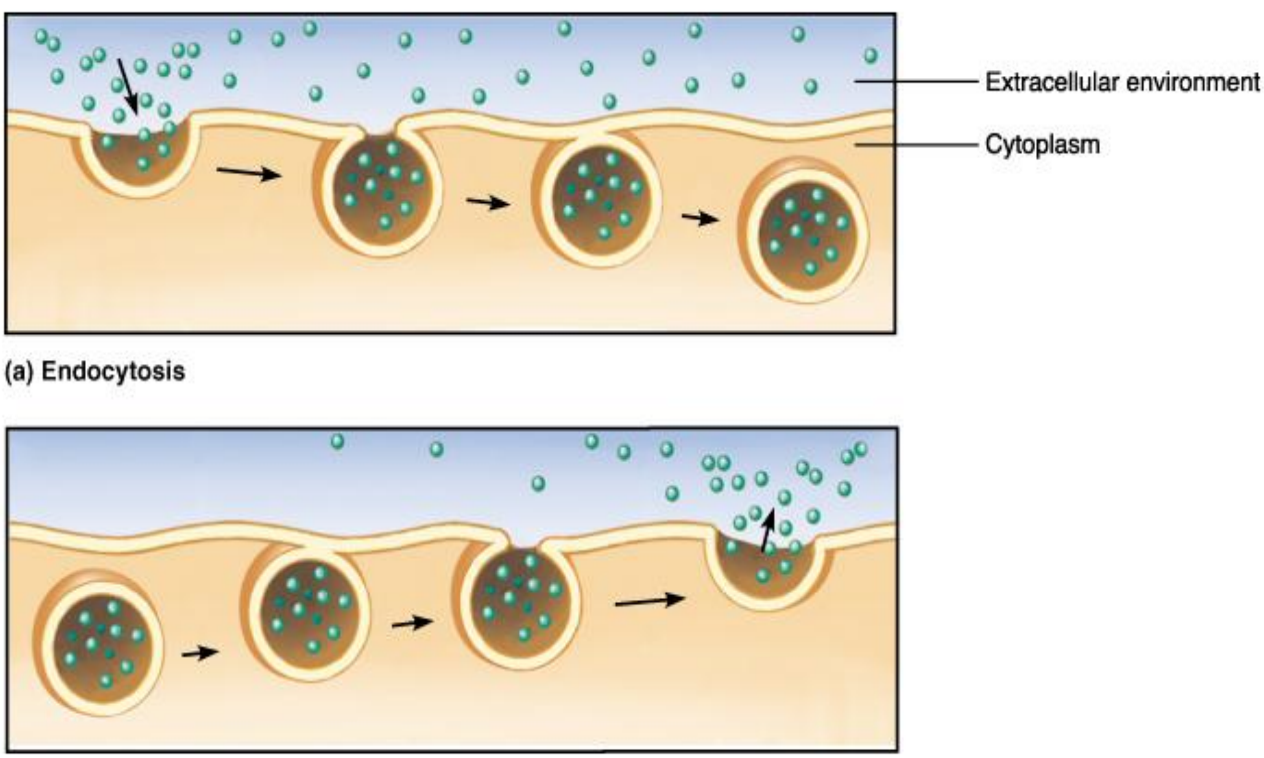
Moving other Materials and Substances into and out of the cell

- ENDOCYTOSIS-Endo (within) cytosis (cell)) is a process in which a substance (e.g. proteins) gains entry into a cell without passing through the cell membrane.

- EXOCYTOSIS-Exo (exit) cytosis (cell)) is a process in which a substance is exited from the cell without passing through the cell membrane.

- Examples of things that migth be exited include secretion of proteins like
  enzymes, hormones and antibodies.

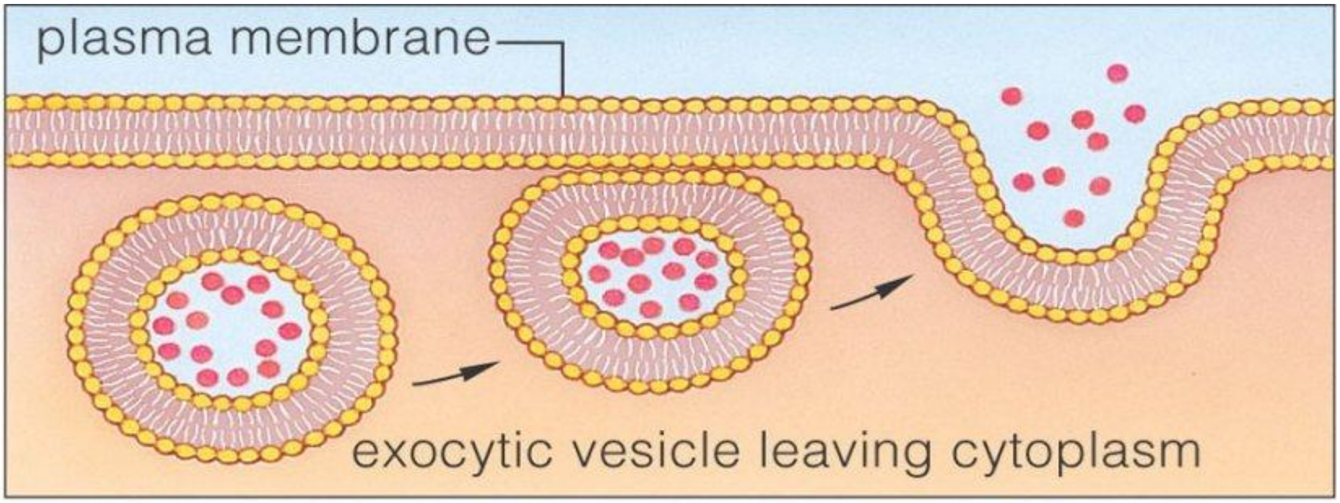




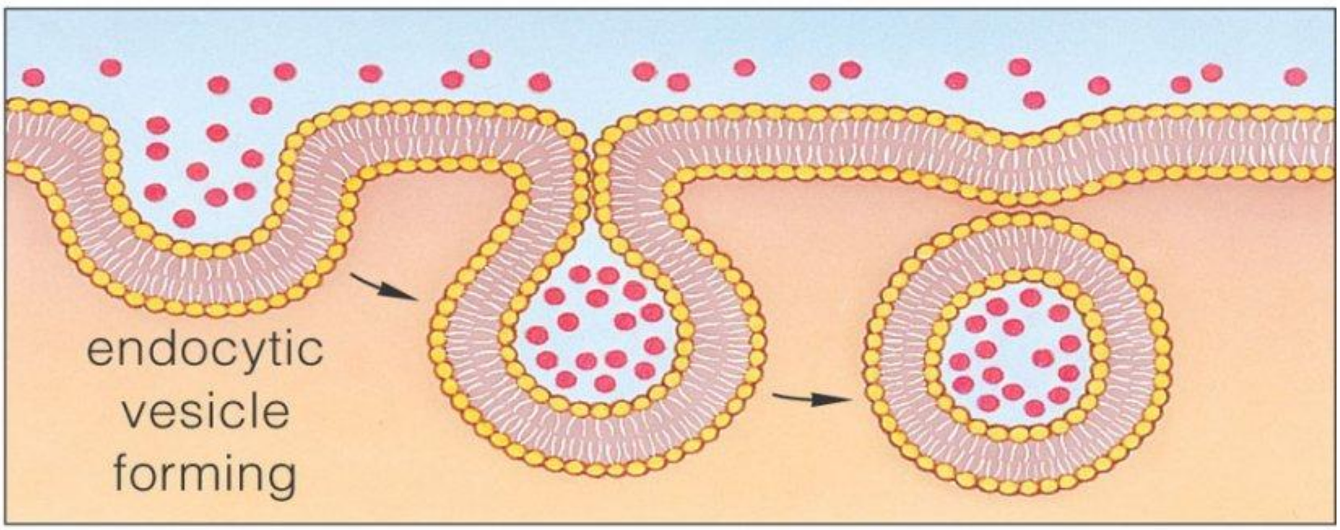
(a) Endocytosis

(b) Exocytosis

a


plasma membrane
exocytic vesicle leaving cytoplasm

b


endocytic
vesicle
forming