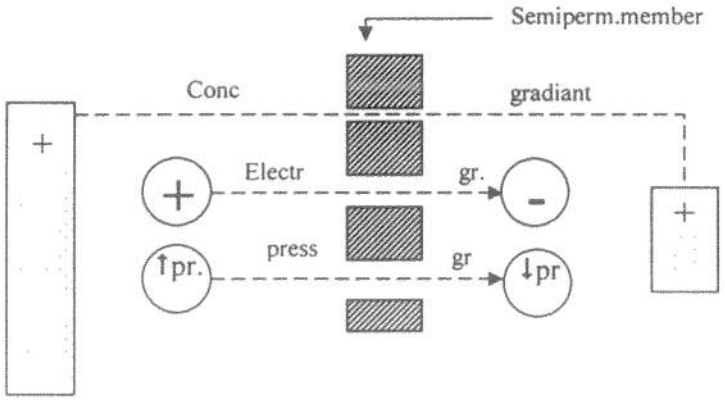
Membrane transport

A. Passive transport (Diffusion)

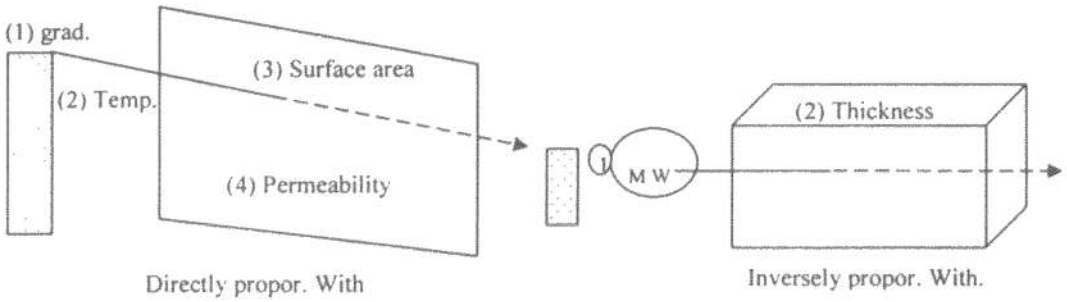
- **Definition**
  - It is transport of a substance across a semipermeable membrane down its electrochemical gradient.
  - Another definition:- It is the process by which a gas or a substance in a solution expands because of the continuous random motion of its particles to fill all of the available volume.
- **Criteria of passive transport**
  1. Occurs down concentration (chemical), electrical or pressure gradient.
  2. Does not need energy.



- **Factors affecting rate of diffusion**

A- Directly proportional with

1- The gradient for diffusion whether chemical, electrical or pressure.
2- Temperature :- increases the random motion of the molecules.
3- Surface area of the membrane available for diffusion.
4- Permeability of the membrane.



B- Inversely proportional with

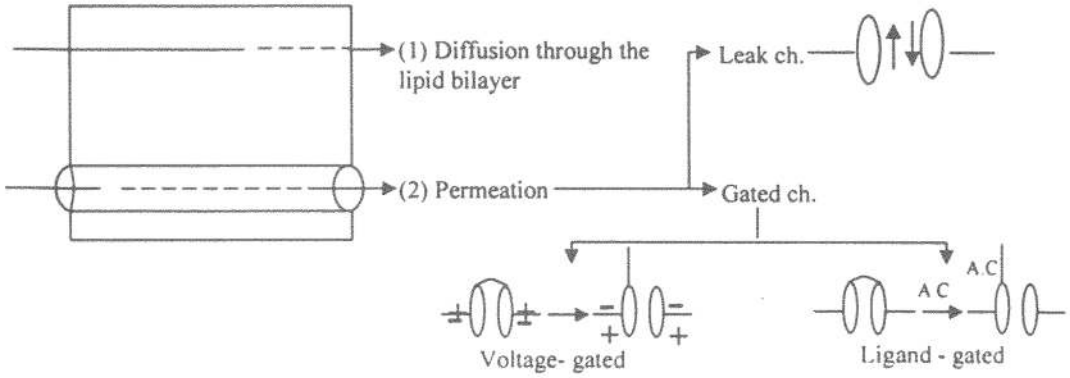
1- Molecular weight (molecular size) of the substance: diffusion rate is inversely proportional with the square root of the molecular size.

2- Thickness of the membrane (the distance across which diffusion takes place).

▪ Types of diffusion

1- Simple diffusion

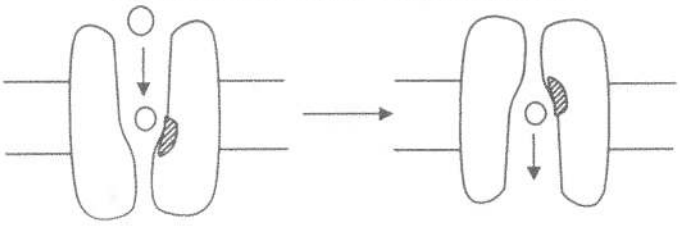
- **Definition:** - Diffusion without a need for carrier.
- **It is concerned with:-** a- Lipid soluble substances.
  b- small water soluble substances, e.g., ions.
- **It occurs through:**
  a. Lipid bilayer
  This is for lipid soluble substances, e.g., O_2, CO_2, fatty acids, glycerol and urea. The diffusion of these substances is directly proportional to their lipid solubility. O_2 is highly lipid soluble so that it enters the cell in large quantities as if the cell membrane did not exist.
  b. Protein channels (permeation)
  This is for small water soluble substance e.g. ions (Na^+, K^+, Cl^- etc).
- **Types of channels in the cell membrane:-**
  1. Leak channels: has no gate (continuously opened), e.g., Na^+-K^+ leak channels.
  2. Gated channels: have gates (open and close) and are of 2 types:
     - Voltage-gated channels: their gates open as a result of change in the electric potential across the cell membrane, e.g., voltage gated Na^+ channel, K^+ channel and Ca^{2+} channel.
     - Ligand-gated channels: their gates open as a result of binding (ligation) of a chemical substance with receptor on the channel protein, e.g., acetylcholine–gated ion channel at motor end plate (neuromuscular junction)

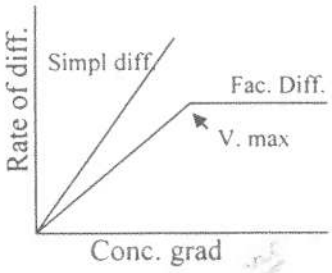


2-Facilitated(carrier mediated) diffusion

- Definition: diffusion that needs carrier protein.

- It is concerned with lipid insoluble large molecules, e.g., glucose and most amino acids.
- Mechanism
  - The carrier protein has a channel large enough to transport the specific molecule, e.g., glucose part way but not all the way through the membrane
  - Binding of the specific molecule, e.g., glucose with a receptor on the carrier protein (a type of integral proteins)→ widening of the inner part of the channel of the carrier protein → facilitation of transport of the molecule across the membrane.





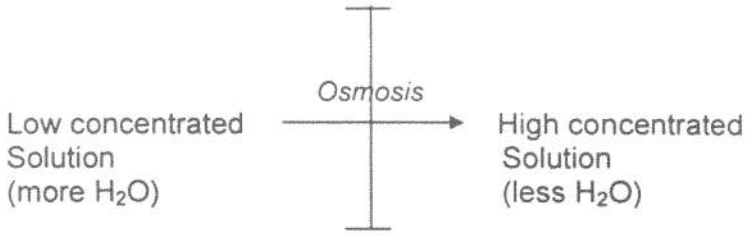
Differences between simple and facilitated diffusion

Simple diffusion	Facilitated diffusion
1. For lipid soluble and small lipid insoluble.	1. For lipid insoluble large molecule.
2. Does not need carrier.	2. Needs carrier.
3. No structural specificity because there is no carrier.	3. High structural specificity:- each carrier is specific for one or very few substances.
4. No competitive inhibition because there is no carrier	4. Competitive inhibition: similar molecules compete with each other for the same carrier and ↓the transport of each other.
5. No saturation, i.e., it ↑ with increasing the concentration gradient without limit (no carrier).	5. Saturation: has a maximum limit (v. max) i.e. it ↑ with increasing the concentration gradient till all the carriers available for this substance become saturated, then it does not increase after that.
6. Less sensitive to temperature changes (no carrier)	6. More sensitive to temperature changes (3 times that of simple diffusion) because binding of the substance with the carrier is through an enzyme.

- **Special types of Passive Transport**

A) Osmosis

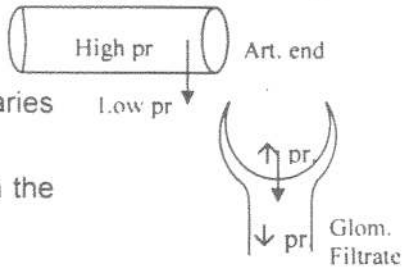
- It is the diffusion of water (the solvent) from area of less concentrated solution (more solvent) to the area of more concentrated solution (less solvent).
- Osmotic pressure is the pressure needed to stop osmosis. Osmotic pressure depends on number rather than the size of particles in a solution



- Diffusion of water (osmosis) takes place through both lipid bilayer and protein channels. This is because water molecules have very small size and high kinetic energy; so that the molecules penetrate the lipid bilayer like bullets before hydrophobic characters of lipid layer stop them.

B) Filtration (Bulk flow):

- Means diffusion of fluid through a membrane that is caused by difference in hydrostatic pressure.
- Examples:
  a. Filtration at arterial end of systemic capillaries to form interstitial fluid.
  b. Filtration through glomerular capillaries in the kidney to form glomerular filtrate.



C) Solvent drag

- Means diffusion of a solute following diffusion of its solvent through the membrane, i.e., the solvent drags the solute after it.
- Example:- Reabsorption of urea after H_2O reabsorption in renal tubules

B- Active transport

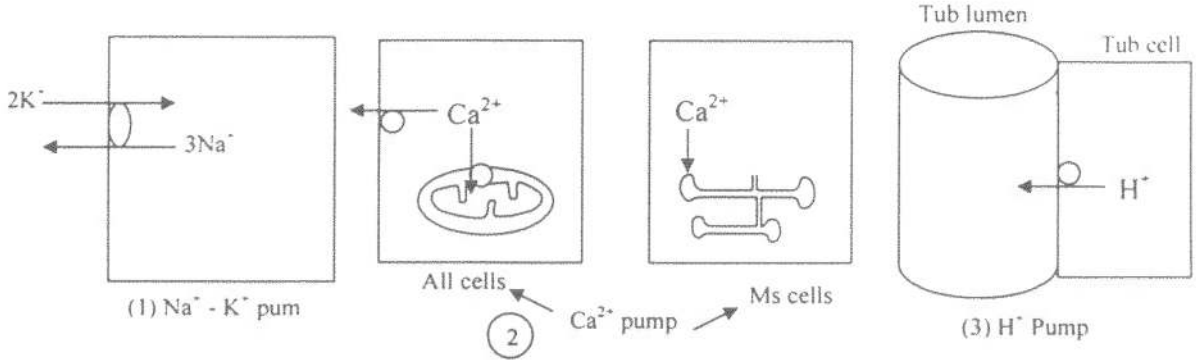
- **Definition:-** Transport of a substance against its electro-chemical gradient.
- **Criteria of active transport:-** two
  1- Occurs against concentration (chemical), electrical or pressure gradient i.e. up hill.
  2- Needs energy.

- **Types of active transport:-**

1-Primary active transport

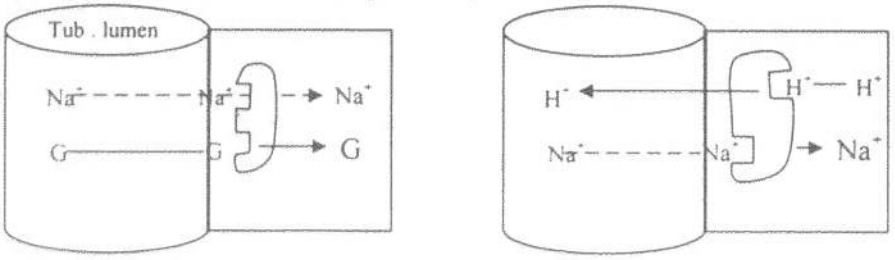
- **Definition:-**Transport of a substance against its electrochemical gradient by a specific carrier and this carrier has ATPpase activity, i.e., hydrolyze ATP and produces energy .
- **Examples:-**
  b. Na^+-K^+ pump: a pump present in all cells of the body that pumps 3 Na^+ to outside the cell coupled with pumping 2 K^+ to the inside of the cell.
  c. Calcium pump:-
    - In all cells, 2 pumps are present
      1. In the cell membrane and pumps Ca^{2+} to outside the cell.
      2. In the mitochondria and pumps Ca^{2+} to the inside of mitochondria.
    - In muscle fibers:- in addition to the previous pumps another pump is present in the sarcoplasmic reticulum that pumps Ca^{2+} to the inside of the sarcoplasmic reticulum.

  Through these pumps, Ca^{2+} is maintained at very low level intracellularly, about 10,000 times less than extracellularly.
  d. H^+ pump:- In the renal tubules (second half of distal tubules and collecting ducts) and pumps H^+ from the cell to the tubular lumen.



2- Secondary active transport

- **Definition:-** Transport of a substance actively (against its electro-chemical gradient) secondary to passive transport of another substance (down its electro chemical gradient).



- **Types:-** two types

a. Co-transport (symport):-

- In which the two substances are transported in the same direction.
- Example:- sodium-glucose and sodium-amino acids co-transport that occurs in epithelial cells of the intestine and renal tubules. In this mechanism, glucose and Na^+ bind to a common carrier and glucose is carried into the cell (against its electrochemical gradient) as Na^+ moves to the inside of the cell (down its electrochemical gradient).

b. Counter transport (Antiport):-

- In which the two substance are transported in opposite directions.
- Example:- sodium-hydrogen counter transport in the renal tubular epithelium. In this mechanism, there is a common carrier for Na^+ and H^+, Na^+ binds to a receptor on the outer surface of the carrier and H^+ binds to a receptor site on the inner surface of the carrier. H^+ is carried outside the cell (against its electrochemical gradient) as Na^+ moves passively to the inside of the cell (down its electrochemical gradient).

3- Endocytosis (cell ingestion)

- **Definition:-** is an active process by which macromolecules, e.g., protein and large particles, e.g., bacteria are transported to the inside of the cell.
- **Types:-** 2 types

a. Pinocytosis (cell drinking)

- Definition:- It is the process by which macromolecules, e.g., proteins are transported to the inside of the cell. It is transported in a vesicle containing ECF, thus the name cell drinking.
- It occurs in most body cells.
- Mechanism:
  1. Attachment of the substance to a specific receptor on the cell membrane. The receptors are concentrated in small pits called coated pits.
  2. The entire pit invaginates inwards by action of contractile elements.
  3. The borders of the invaginated pit close over the attached substance with some ECF and form a vesicle (pinocytic vesicle).
  4. The vesicle separate from the cell membrane and pass to the cytoplasm.

(1) attachment (2) Invagination (3) vesicle formation (4) Separation

b. **Phagocytosis (cell eating)**

- Definition:- It is the process by which large particles e.g. bacteria are transported to the inside of the cell.
- It occurs only in some specific cells of the body (phagocytic cell) e.g.,
  1. Some white blood cells:- mainly neutrophils (microphages) and monocytes (macrophages)
  2. Tissue macrophages.
- Mechanism:- Essentially the same as pinocytosis, but differs in two aspects:-
  1. The phagocytic vesicle contains only particle without ECF and hence the name cell eating.
  2. If the ingested substance is digestable, there will be an additional step in which lysosomes come in contact with the phagocytic vesicles and release its digestive enzymes into the vesicle to digest the ingested substance.

4-Exocytosis (cell excretion)

- Definition:- Is a process by which macromolecules and large particles are transported to the outside of the cell.
- Mechanism:- Reverse to endocytosis.