CHAPTER 15

15 FUNCTIONS OF CELL SURFACE.

15.1 Overview

Cell Surface components;

a) Cell wall / Glycocalyx
b) Cell membrane.

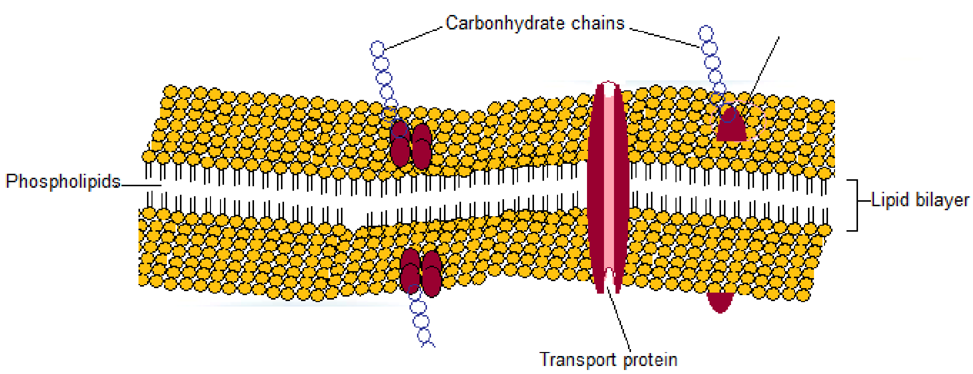
Functions of cell surface are;

a) Boundary that surrounds and protects the cell.
b) Regulation of the flow of materials into and out of the cell to maintain proper state of the intracellular conditions.
c) Cell to cell communication and adhesion.
d) Site of many enzymatic reactions and metabolic pathways.

All cells have cell membrane and therefore it is the only one among the two that has all the functions above.

Functions of cell membrane:

i) Controls what enters and exits the cell to maintain an internal balance called homeostasis
ii) Provides protection and support for the cell
iii) Structure of cell membrane control movement of materials in and out. The make up of Lipid Bilayer -2 layers of phospholipids, Phosphate head which is polar (water loving), Fatty acid tails non-polar (water fearing) and the Proteins embedded in membrane have created cell membranes pores (holes) in it
Which enable selectively permeable. This means that it allows some molecules in and keeps other molecules out.



15.2 Passive Transport Movement of materials across the plasma membrane.

Cell does not use energy.

Types of passive transport

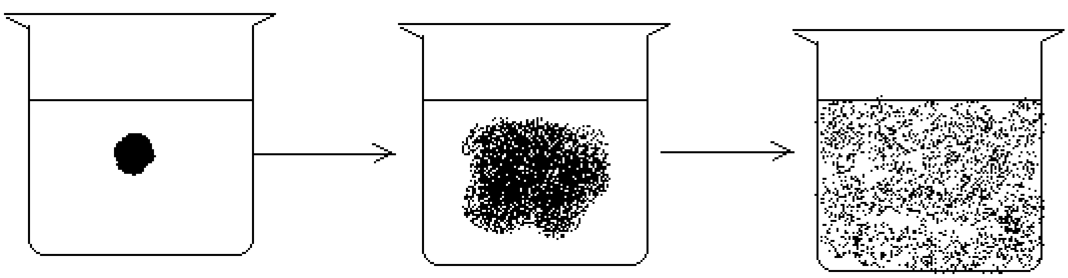
a) Simple diffusion.
b) Osmosis
c) Facilitated diffusion

15.2.1 Simple diffusion

Definition: Diffusion is the net movement of molecules (or ions) from a region of their high concentration to a region of their lower concentration

a) Characteristics of Simple diffusion

- Material or molecules have natural kinetic energy that make them move from one side of membrane to the other.
- Material move passively from region of higher concentration to lower concentration, what is called concentration gradient.
- The movement is random - molecules move **back and forth**.
- Movement of materials continues until the solute on both sides is equalized - a situation called equilibrium.
- After is reached equilibrium, the molecules continue to move from inside of the membrane to the outer, but there is no net movement of solute.
- Molecules involved in diffusion utilize their inherent thermo-energies i.e. kinetic energy.
- Movement from higher solute concentration to lower solute concentration is enabled by free energy.
- Laws of thermodynamics dictate that alls events proceed in the direction of decreasing free energy.



Drop of dye in water

Dye disperses in water

b) Factors which determine the level of free energy

- Energy from ATP is not required for this type of penetration

i) Concentration of ion - free energy

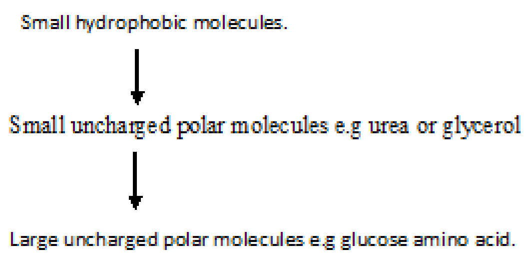
Example : If the concentration of molecules is different in 2 regions diffusion will cause molecules to move from a region of high concentration to one of low concentration

Concentration gradient = (concentration at point 2 - concentration at point 1)

- The higher the concentration gradient the more rapid the net diffusion
- Rate of diffusion = diffusion constant x concentration gradient

- Diffusion tries to even out the concentrations so they are equal everywhere
- Simple diffusion across a membrane is called **permeability**
- Diffusion is most efficient over short distances (about the diameters of cells)

ii) Solubility in oil – the more hydrophobic or non polar it is , the higher the rate of diffusion Hydrophobic substances have a high permeability through bilayer membranes than those that like water (hydrophilic) . The order of solubility is as show in flow diagram below;



- Hydrophobicity is measured by oil/water partition

Application : Many biological chemicals are deliberately made hydrophobic to increase their rate of penetration into cells. Examples include many drugs and pesticides such as DDT.

Charged molecules which are highly hydrated find the lipid bilayer highly impermeable no matter how small they are.
e.g Na^+ and Cl^- though smaller than water molecules ate 10^9 times less permeable to artificial bilayer than water molcules.
Water molecules diffuse rapidly across the bilayer although water is relatively insoluble in oil.
Exeception of water is because water is dipolar and lack net electric charge.
Water molecules too are small.
Water and non polar moleules diffuse rapidly through cell membranes although they diffuse through the lipid bilayer slowly.

iii) Heat
Temperature. Higher temperatures give molecules or ions more kinetic energy. Molecules move around faster, so diffusion is faster

iv) Pressure

v) **Entropy:** This diffusion is movement of molecules from higher free energy to lower free energy.Thermodynamic equilibrium - is the point when there is no net movement of molecules because the free energy is minimum.

vi) **The surface area**. The greater the surface area the faster the diffusion can take place. This is because the more molecules or ions can cross the membrane at any one moment.
vii) The **type of molecule or ion diffusing** : Non-polar molecules diffuse more easily than polar molecules because they are soluble in the non polar phospholipid tails.
viii) Size of molecules. Large molecules need more energy to get them to move so they tend to diffuse more slowly.

Example of diffusion through Biological membrane

i) Oxygen – Non-polar so diffuses very quickly.

ii) Carbon dioxide – Polar but very small so diffuses quickly.

iii) Water – Polar but also very small so diffuses quickly.

15.2.2 Osmosis

Is a type of diffusion whereby molecules / material move from **lower solute concentration to higher solute concentration**. It occurs in a situation whereby there is a semi -permeable barrier separating the two solute concentration.

The red dots refer to solute (the higher the solute concentration the lower the water concentration)

Mechanism .

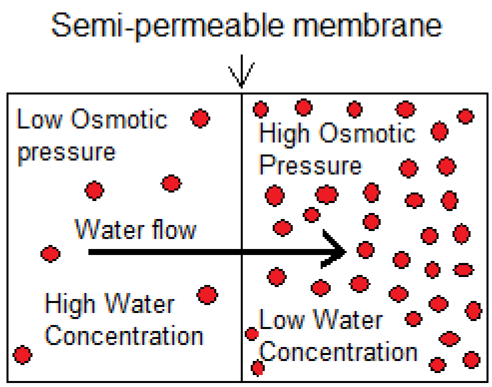
- Osmosis is passive: doesn't require ATP energy
- Diffusion principle occurs to solutes molecules and to water molecules.
- Energy of water molecules decreases as increasing concentrations of other substances are dissolved in the water because the dissolved solute molecules interrupt the ordered three dimensional interactions that normally occur between individual water molecules.

- Water molecules tend to move from the region where the solute concentration is lower (and hence the free energy of water molecules is higher) to areas where the solute concentration is higher (hence the free energy of the water molecules is lower).
- Except for the pumping of the blood, all **water** movements in the body are by osmosis
- Osmotic flow through most biological membranes is not by simple diffusion- it is by bulk flow and is similar to the flow caused by a pressure gradient

  Example of osmosis: The kidney is an osmotic machine and it adjusts body water volume by osmosis

  Medical problems involving osmosis: pulmonary edema, childhood diarrhea, cholera and it is treated using osmotic techniques e.g. rehydration, inflammation of tissues etc.

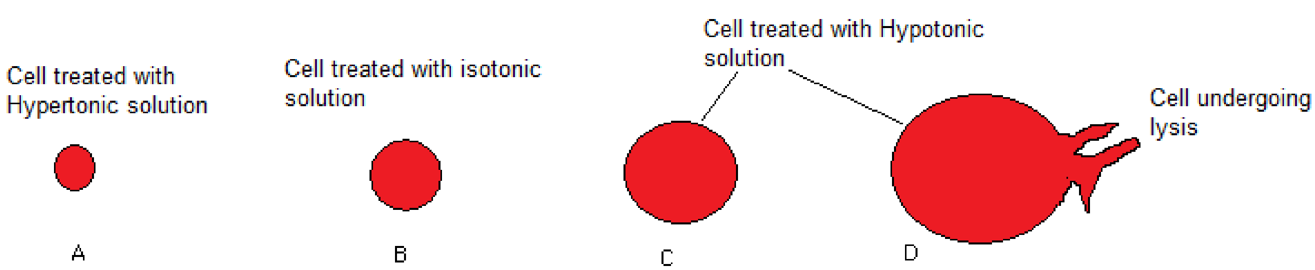
Diagram



Thermodynamics principle can be used to explain:

Plasmolysis - occurs when mammalian cells are placed in sucrose solution exceeding **0.25m** in concentration. Cell loose water and shrink. If cells are put in sucrose solution of less than 0.55 then they absorb water and swell up. This can be explained by the phenomenon that cells are impermeable to sucrose particles.
Isotonic solutions - are solutions which have the same concentration with the solute hence no charge in cell volume.
Hypertonic solutions - solutions whose solute concentration is higher than that of the cell , therefore water diffuses out of the cell.
Hypotonic solutions- are solution whose solute concentration is lower than that of the cell thus water molecules diffuse from the solution into the cell.

Cells Swell in Hypotonic Solutions swell and if not controlled the lyses.



Cells are surrounded by a selectively permeable membrane through which solution diffuse through. It should be noted that some solutions diffuse faster than others.

Rate of passages of solute through the cell membrane is determined by:-

i) **Solute solubility in oil** - solutes more soluble in oil are more permeable than those less soluble in oil.
ii) **Size of the solute molecule** - small molecules like water and methanol tend to move through the membrane of the cell quickly.

iii) **Electric charge of soluble** - highly charged molecule pass through the membrane less readily than weakly charged.

Charged molecules (ions) tend to be insoluble in oil. In water ions attract a shell of water molecules around them. Thereby increasing their effective size.

15.2.3 FACILITATED DIFFUSION (FD)

Used to speed up diffusion into the cell to meet the needs of the cell i.e. supplement simple diffusion. This is so especially for sugar and osmosis acids which are relatively insoluble in lipids and so diffuse poorly through membranes. These hydrophilic substances are essential for many cellular activities. FD resemble simple diffusion in that net movement of solute occurs from regions of higher to lower concentration until equilibrium is reached.

Features of facilitated diffusion.

They distinguish facilitated diffusion from simple diffusion.

- Facilitated diffusion (FD) - rate of solute movement is usually several orders of magnitude greater than in simple diffusion.
- At equilibrium, the net movement of solute in simple diffusion is the same as that of FD.
- It resembles enzymatic catalysis in the following ways:
  - Time required for equilibrium to be attained is reduced but the final equilibrium conditions remain unchanged.
  - Exhibit saturation kinetics. Explain
  - The rate of solute movement in FD approaches maximum as the solute concentration increased. But in simple diffusion rate of solute movement is directly propotional to solute concentration.

This hyperbolic shape of curve is similar to the movement obtained when one plots the rate of an enzyme – catalyzed reaction as a function of substrate concentration.

- In FD moved is facilitated by transport proteins Fig 15. 5A and it is highly selective in the molecules penetrating through the membrane (simple diffusion is not Fig 15. 5B).

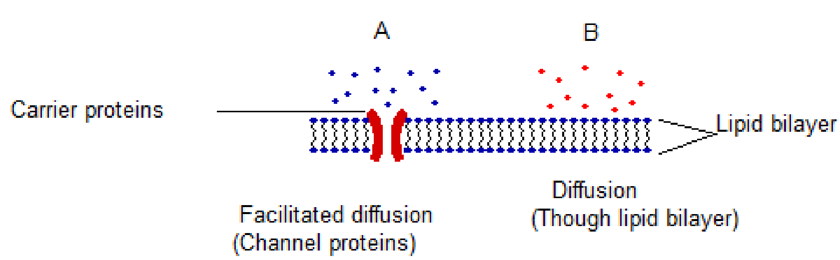
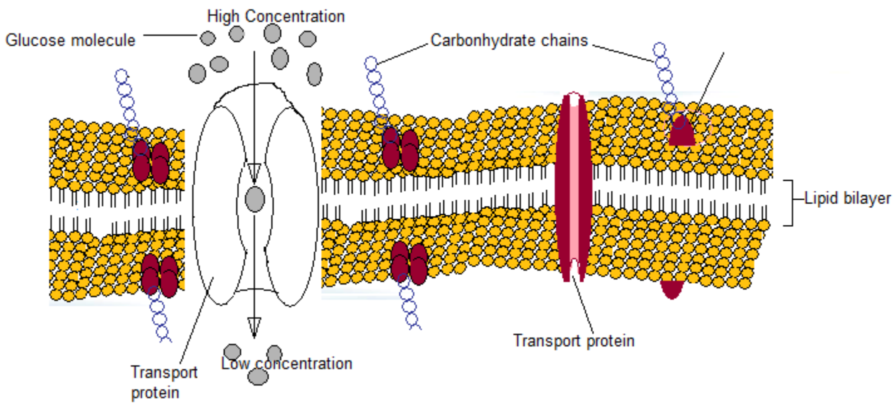


Fig 15. 4

Example of FD

- Diffusion of glucose through the membrane but not to smaller (particles of - carbon) of hexoses e.g fructose. This is similar to the substrate specificity of enzymatic catalysis.
- FD is inhibited by competitive and non competitive inhibitors - simple diffusion is not .
- Molecules closely resembling solute in structure inhibit FD but not SD
- Kinetics of this inhibition resemble competitive inhibition in enzymatic activity.



Reasons for inhibition.

Competition for solute binding sites on membrane transported by both solute and inhibitors. FD is also inhibited by agents known to denature enzymes. Example

Movement of metabolites (materials) across the cell membrane are assisted byTransport of proteins Allow solute to move across the membranes by the process of passive transport.

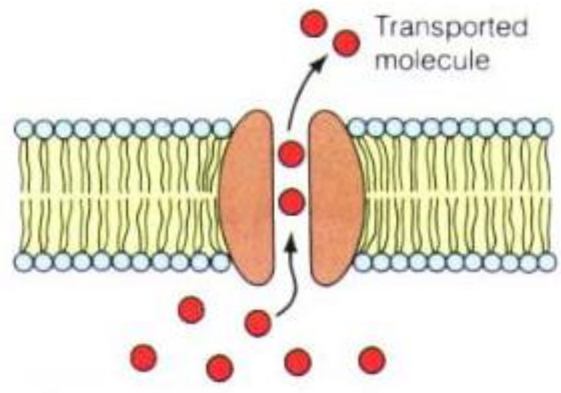
15.3.1 Types of transport proteins.

a) Channel and carried proteins

i) Channel proteins - form channel that transverse the membrane and permit solute of appropriate size and charge to move across the bilayer by simple free diffusion.

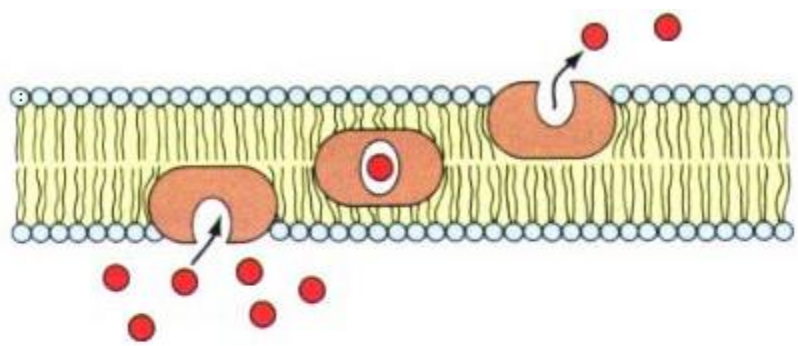
Do not interact directly with small charged solutes.

Molecules move freely through the aqueous passageway formed by charged hydrophilic regions of the membrane protein in the lipid bilayer.



ii) Carrier proteins. bind to a specific molecule and transfer it across the bilayer by the process of facilitated diffusion. Carrier proteins are highly specific. A particular carrier will transport only one type of chemical compound. E.g ions or sugars

They specifically bind a sollute molecule and transfer it across the lipid bilayer .
Solute bind to a specific binding site on the carrier.
Transformation can be reduced by :
Competitive inhibitors that compete for the same site s the solute.
Non – competitive inhibitors - they bind elsewhere on the carrier protein but after binding they change the configuration of conformation of the transport protein.
NB carrier proteins act in similar way to enzymes but they are not enzymes.

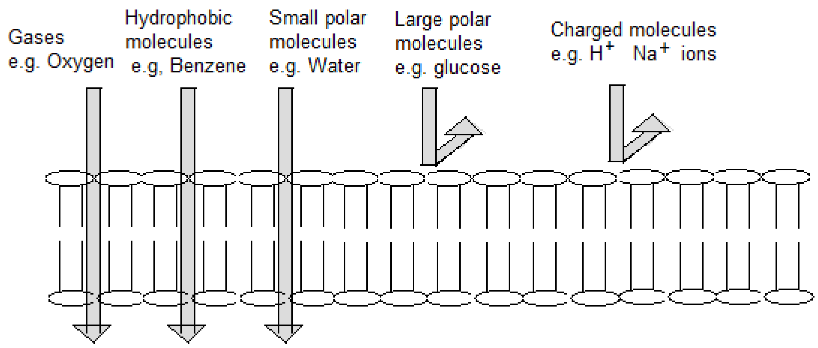


b) Factors affecting movement

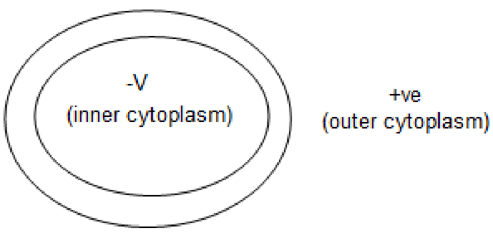
i) **Uncharged solute molecules**
Movement is from higher to lower concentration along cncentration gadient.
Concentration gradient determines the direction of transport.

ii) **Charged solutes**.
Passive transport is involved in movement.
Movement is from higher to lower concentration along electro-chemical gradient.
Movement / grdient is determined by
Concentration gradient of the solute .

iii) Size of molecule : small molecules e.g. water move faster and bigger molecules e.g. glucose



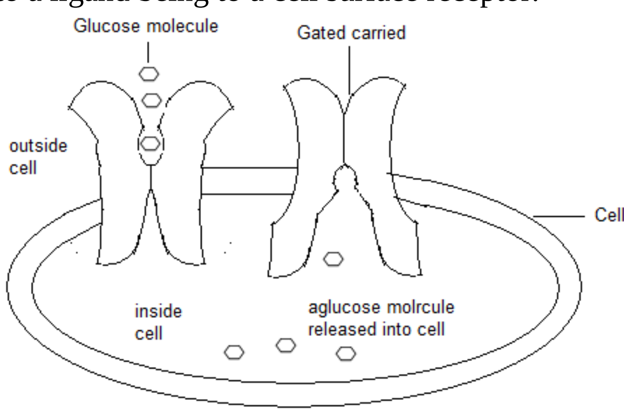
c) Total electrical gradient across the membrane. Example in a cell there is ve+ and ve – charges.



Cellular ion composition / structure will impede of like in figure 15.7 will deter movement of negatively charged particles into the cell.

Type of channels / carriers

a) **Gated pores.**
   i) In response to a particular stimulus (otherwise the pathway is closed)
   ii) In response to a ligand being to a cell surface receptor.



iv) In response to changes in the extracellular or intracellular concentration of specific ions
v) In response to changes in the membrane potential.
vi) Other stimuli.

vii) Through confirmation change cell is able to open and close the gate

Speed in which gated pores open is important because they :

Determine the speed of passage of solute through the membrane.

Determine the ability of solutes passing through one gate to stimulate the openning / closing of another.

Normally the gates close very quickly within miliseconds of having opened

b) **Ionophores may meditate transport of ions down their electro chemical gradients**.

Ionophores are small hydrophobic molecules that dissolve in lipids.

They increase the permeability of a membrane to ions by covering the charge of the transported ion so that it can move through the hydrophobic interior of lipid bilayer.

Ionophores **dissipate ion gradients** which are essential for cellular function, and thus are **poisons**.

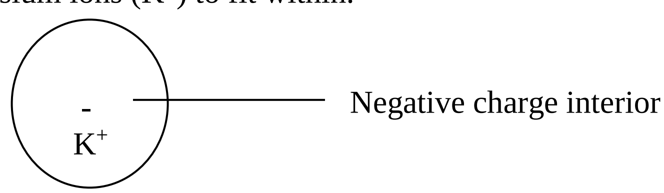
Ionophores that are specific for infectious microorganisms can serve as **antibiotics** (e.g., gramicidin and valinomycin).

- C) **Protein transporters**
  - similar to enzymes in several respects:
    - **specifity --** ***bind*** "substrate" (solute) with multiple noncovalent interactions
    - **increase rate of approach to equilibrium** (condition where $\mathbf{C_1 = C_2}$) but don't change position of equilibrium

Types of ionophores:

I. Mobile ion carriers

- Mobile carrier bind to the ion can carries it from one side of the membrane to the other.
- Example of mobile ion carriers is Valinomycin. It is a ring shaped polymer.
- Exterior of the ring is hydrophobic and interior is negatively charged.
- This allow potassium ions (K^+) to fit within.



Example : 1 Valinomycin picks up K^+ on one side of the membrane and diffuses across the lipid bilayer down the K+ electrochemical gradient. K+ is released on the other side of the membrane.

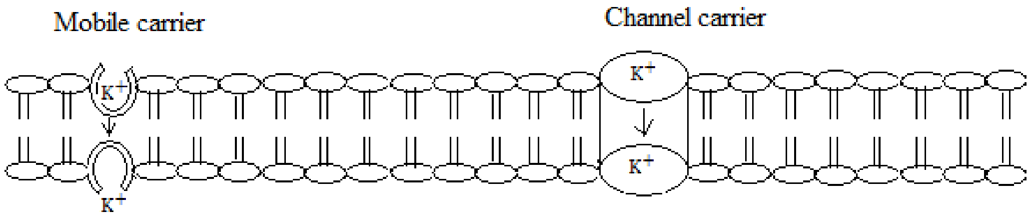


Fig. 15.7

Channel forming carriers

Form *pores* (channels) in the membrane through which ions can diffuse in or out of the cell

Example Gramicidin is antibiotic.

- **It is** a linear polypepetide composed of 15 amino acids all of which are hydrophobic side chains.
- Two such molecules are believed to associate side by side in a bilayer and thus creating trans membrane channel that guides monovalent cations down their electro-chemical gradient.
- Gramicidin ionophore is unstable dimer.
- Remain open for one second.
- Can transport a thousand times more cations than mobile ion carrier in the same time.
- Channel continue transporting ion even in temperatures below freezing point while below freezing point , moble ion carriers stop.

C)

15.3 ACTIVE TRANSPORT ACROSS MEMBRANES

In active transport cell uses energy
Molecules move selectively through membranes in the living cell.
Substance cross the membrane barrier by three general routes.

a) Passive transport
b) Active transport.
c) Endocytosis / exocytosis.

This is the movement of ions and metabolites against their electro – chemical gradients.
This requires expenditure of energy.
Metabolic energy drives active transport whereas passive transport can occur spontaneously as molecules move in a thermodynamically favourable downhill direction along their gradients.

Diagram.

Components of active and passive transport
They need transport proteins that specifically bind to ions or metabolites and help to transport there substances across the lipid barriers of the membrane.
Types of active transport
Na+_ K+ pump.

Mechanism.
ATP – is hydrolysed by membrane bond enzymes ATPare catalyse the release of free energy as ATP is dephosphorylated to ADP.
The enzyme pump acts as ion pump.
Na+_ K+ ATPare is found bound in plasma membrane or virtually all animal cells.
Na+ are pumped trans inside the cell where it is in low level to outside th cell where it is in high concentration.
K+ are pumped outside the cell where it is in low concentration to inside the cell where it is in high concentration.
Na+_ K+ pump generates and maintains the membrane potential or voltage gradient across the membrane .
Membrane is then responsible for driving the active transport of sugars and amino acids into the cell.
NB – pump is electrogemic.
Example where Na+_ K+ is found red blood cells ghost cells.

Diagram

Active transport driven by the stored in ion gradients
NB – all therefore ATP hydrolysis energy e.g Na+_ K+ ATP function by active transport – some moving in the same direction and sometimes opposite direction.