CELL PHYSIOLOGY

TOPIC 2.0 MOVEMENT IN AND OUT OF CELLS

Syllabus extract

SPECIFIC OBJECTIVES *The learner should be able to:*	***Content*** ***Movement in and out of cells***
• Describe diffusion, osmosis, active transport, phagocytosis and pinocytosis. • State the factors that affect the processes of diffusion. • Describe the processes of osmosis. • Explain the significance of diffusion and osmosis in organisms. • Explain how solvents and solutes are exchanged in animal and plant tissues or cells across the cell membrane in relation to its structure. • Describe how unicellular organisms obtain water and food. • Explain the relationship between structure and function of a cell membrane.	• Diffusion and osmosis, active transport, phagocytosis and pinocytosis: exocytosis and endocytosis. • **Diffusion:** factors affecting rate of diffusion, • **process of osmosis:** including; turgidity, plasmolysis, water potential, osmotic potential, wall pressure. • Significance of diffusion process and significance of osmosis in organisms. • Exchange of solvents and solutes in plant and animal tissues or cells across the cell membrane in relation to its structure. • How unicellular organisms obtain water and food. • Relationship between structure and function of a cell membrane.
Movement in and out of cells practical • Identify habitats with suitable media for organisms' survival. • Demonstrate use of salt in food preservation, use of visking tubing, glass columns, microscope in diffusion and osmosis experiments. • Demonstrate conditions affecting the rate of diffusion. • Demonstrate effects of osmosis on the cell/ tissues.	• Habitats with suitable media for organism's survival • Use of salt in food preservation, use of visking tubing, glass columns and microscope in diffusion experiments. • Conditions affecting the rate of diffusion. • Effect of osmosis in living tissues.

Introduction

The plasma membrane isolates the inside of the cell protoplasm from its extracellular environment. Materials are exchanged between the protoplasm and the extracellular environment across the plasma membrane. The plasma membrane is selectively permeable and allows transport of materials across it.

The transport of substances is important to;

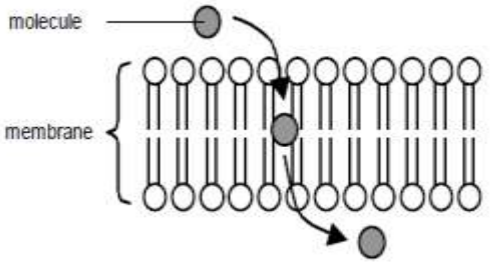
a. Supply cells with oxygen for respiration and raw materials for anabolism (synthesis of biological molecules)
b. Regulate the pH and solute concentration for maintaining a stable internal environment for enzymes to function optimally
c. Excrete toxic waste substances
d. Secrete useful substances for cell activities

Note: the transport of substances across the cell membrane takes place by two major fundamental processes.

Substances move in and out of cells by the following processes:

1. Simple diffusion
2. Facilitated diffusion
3. Osmosis
4. Active transport
5. Endocytosis
   i. Phagocytosis
   ii. Pinocytosis
   iii. Receptor mediated endocytosis
6. Exocytosis

SIMPLE DIFFUSION



Diffusion is the random movement of ions or molecules from a region where they are at higher concentration to a region of their lower concentration. That is, to move **down a concentration gradient** until equilibrium is reached. The phospholipid bilayer is permeable to very small and uncharged molecules like oxygen and carbon dioxide. These molecules diffuse freely in an out of the cell through the phospholipid bilayer.

Hydrophobic substances (lipid-soluble) e.g. steroids, can also diffuse through. These non-polar molecules do not require the aid of membrane proteins (channel or carrier) to move across the cell membrane.
The rate of diffusion depends upon;

a) The concentration gradient

This refers to the difference in the relative concentration on either side of the membrane or between two points. The greater the difference between the points, the faster the rate of diffusion and if the difference is less, the slower the diffusion rate. Therefore a reduced concentration gradient causes a reduced rate of diffusion and vice versa.

b) Distance over which diffusion takes place

This is the distance over which the molecules are to travel i.e. the surface thickness across which the molecules move. The greater the distance the lower the rate of diffusion. This is another factor which limits cell size.

Note: the inverse square law states that the rate of diffusion is proportional to the reciprocal of the distance. Diffusion is therefore only effective over very short distances.

c) Surface area over which diffusion occurs

The larger the surface area over which the molecules are exposed, the faster the rate of diffusion.
Fick's law summarises the three factors. It states that 'the rate at which one substance diffuses through another is directly proportional to $\frac{surface\ area\ X\ difference\ in\ concentration}{thickness\ of\ membrane}$

d) Temperature

When increased, temperature causes an increased rate of diffusion because the particles acquire increased kinetic energy which causes increased speed of movement hence increased rate of diffusion.
At low temperatures, the kinetic energy is very low and the speed of movement by particles is equally very low.

e) Size and nature of diffusing molecules

The smaller the size of the diffusing particles, the faster they diffuse i.e. smaller particles move very fast while the large ones will move slowly.
Fat soluble molecules (non-polar substances) diffuse more rapidly through the cell membrane than water soluble (polar) molecules.

f) Permeability

The more porous a surface is, the greater the number of particles that diffuse through it hence the greater the rate of diffusion. Diffusion rate increases with increase in size of the pores.

Significance of diffusion

1. It's a means by which gaseous exchange occurs in plants and animals e.g. in plants diffusion of gases occur through the stomata and in animals, in gills of fish, , the skin and buccal cavity of amphibians alveoli of reptiles, mammals and birds.
2. Absorption of certain digested food materials e.g. glucose in the ileum.
3. A means of exchange of materials between blood in capillaries and the tissues

4. Movement of chlorides and hydrogen carbonate ions into and out of red blood cells during the chloride shift occurs by facilitated diffusion
5. During formation of the nerve impulse, sodium ions diffuse into the nerve cells facilitating generation of nerve impulses and ensures transmission of nerve impulses from one neurone to another i.e. diffusion facilitates synaptic transmission
6. It ensures excretion of waste products e.g. ammonia in fresh water fishes
7. It's the main means of transportation of materials within the cell's cytoplasm e.g. in unicellular organisms
8. Absorption of mineral salts by plants from the soil is effected by diffusion as one of the mechanisms

Fick's law suggests that structures are adapted to maximise the rate of diffusion by;
(i) Having a steep concentration gradient
(ii) Having a high surface area to volume ratio
(iii) Being thin to minimise the distance over which diffusion occurs

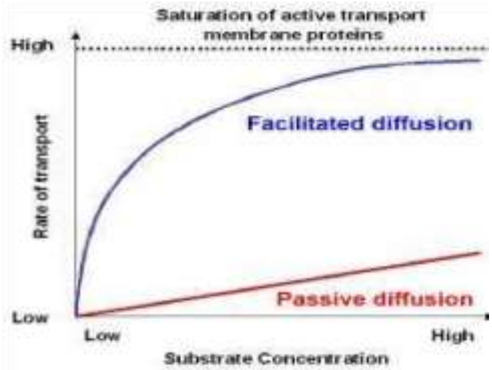
In order maximize the rate of diffusion, tissues where diffusion occurs attained **special adaptations.** These include;

a) The lungs are ventilated by the respiratory tract (trachea, bronchus, bronchioles) which maintain a steep concentration gradient between the lung alveoli and blood in the capillaries.
b) Respiratory surfaces like the lung alveoli and intestine epithelial lining possess a rich supply of blood vessels which transport away the diffusing materials hence maintaining a steep gradient which sustains the fast diffusion
c) Diffusion surfaces e.g. lung alveoli and intestines (ileum) are covered by a thin epithelium lining which reduces the distance over which diffusion takes place.
d) The epithelial lining covering the alveoli and rumen of the ileum is very permeable to allow molecules to travel across them
e) In lungs there are numerous alveoli and in the ileum infoldings known as villi and microvilli which is coupled with a very long ileum also increases the surface area along which particles move into cells hence increase the rate of diffusion.
f) Flattened body e.g. platyhelminthes (flatworms) which increases the surface area for movement of materials by diffusion
g) Some organisms are of small size e.g. unicellular organisms which increases the surface area to volume ratio of the surface that permits increased rate of diffusion

FACILITATED DIFFUSION

This refers to the passive transport of molecules and ions across a membrane by specific transport proteins, carrier and channel proteins, found within the membrane in the direction of lower concentration of the ions or molecules i.e. in favour of the concentration gradient (difference) of ions.

Facilitated diffusion is a faster form of movement than simple diffusion and it involves transport of large polar molecules and ions that cannot be transported by simple diffusion. Even though water is an extremely small, its polar therefore it does not move across the cell membrane by simple diffusion.



A charged molecule or atom and its surrounding shell of water, find the hydrophobic layer (non-polar) of the membrane more difficult to penetrate thus the lipid bilayer partly accounts for the membrane's selective permeability by preventing very large molecules and small polar molecules of ions to move across it.

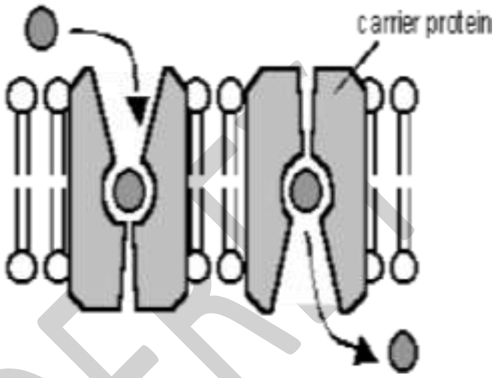
Trans-membrane proteins form channels or act as transport proteins to facilitate and increase the rate of diffusion across the semi permeable membrane. The transport protein molecules involved in facilitated diffusion include channel and carrier proteins.

Facilitated diffusion by carrier proteins

Some small hydrophobic organic molecules e.g. amino acids and glucose pass through the cell membrane by facilitated diffusion using carrier proteins. These proteins are specific for one molecule, so substances can only cross a membrane if it contains the appropriate proteins i.e. they are specific.

The transport of glucose across the plasma membrane of fat cells, skeletal muscle fibres, the microvilli of the ileum mucosa and across proximal convoluted tubule cells of vertebrate kidneys is brought about by a change in the shape of the carrier protein once the glucose molecule bonds to it. The binding state is called the ping state and the releasing state is the pong state.

Carrier proteins alter their conformation/shape when moving the solute across the membrane.



The solute molecule is released on the other side of the membrane, down its concentration gradient. The carrier proteins bind molecules to them at the binding site and then change shape so as to release the molecules on the other side.

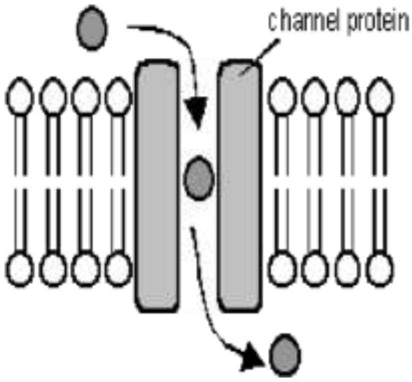
Facilitated diffusion by protein channels:

These trans-membrane proteins form water-filled hydrophilic functional pores in the membrane whose shape is specific for the passage of particular ions or polar molecules.

This allows charged substances, usually ions, and polar molecules to diffuse across the cell membrane. Most channels have fixed shapes and can be gated (opened or closed), allowing the cell to control the entry and exit of the ions, these include the ligand-gated and voltage gated channels. Transport proteins allowing the passage of ions are called ion channels. The proteins form specific water filled hydrophilic channels that permit the diffusion of various ions such as K^+, Na^+, Ca^{2+},Cl^-,HCO_3^-.

There are also specialised channels for water known as aquaporins found in both plant and animal cells. The aquaporins speed up the rate of diffusion of water molecules down its water potential gradient.

Fig 2 & 3 pg 69 Kent OR Fig 5.17 pg 144 Soper OR Fig 4.18 pg 67 Toole Fig 2



Comparison between simple and facilitated diffusion		
Similarities	**Differences**	
Both move molecules from a region of high concentration to a region of low concentration through a partially permeable membrane	**Simple**	**Facilitated**
	Diffusion can occur in either direction	Diffusion occurs in only one direction
	Similar molecules diffuse at the same rate	Specific molecules diffuse faster than others
	Does not require special transport proteins	Occurs via special channels or carrier proteins

ACTIVE TRANSPORT

It is the movement of molecules or ions across a cell membrane against their concentration gradient aided by the protein pump with specific binding sites, involving the expenditure of energy.

Cells which carry out active transport have a high respiratory rate and a large number of mitochondria to generate a high concentration of Adenosine Tri Phosphate (ATP). The energy from ATP can be directly or indirectly used in active transport.

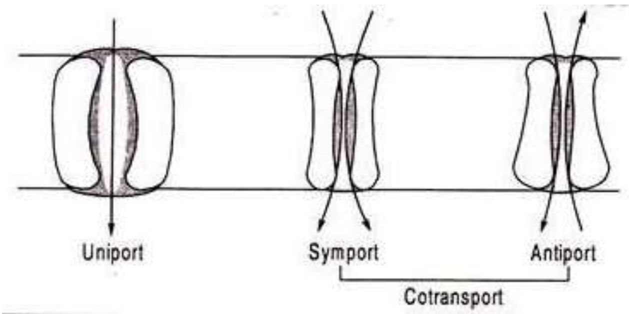
Active transport can be slowed or inhibited by respiratory poisons (inhibitors) e.g. cyanide or lack of oxygen.

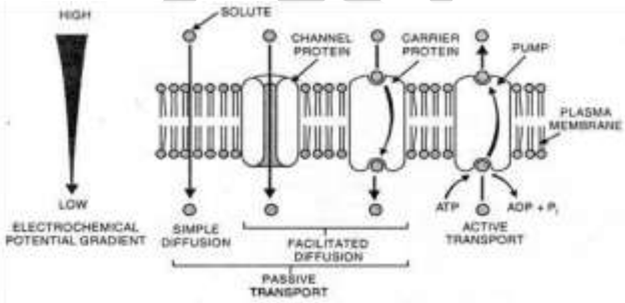
Mechanism of active transport

This can be direct active transport if the energy from ATP is used directly to transport the substances, ions or molecules, or it can be indirect active transport if the energy is not directly used to transport a substance across a membrane.

Types of membrane proteins involved in active transport. Three main types of membrane proteins exist;

a. Uniport carriers. They carry (transport) a single ion or molecule in a single direction.
b. Simport carriers. They carry two substances in the same direction.
c. Antiport carriers. They carry two substances in opposite directions.





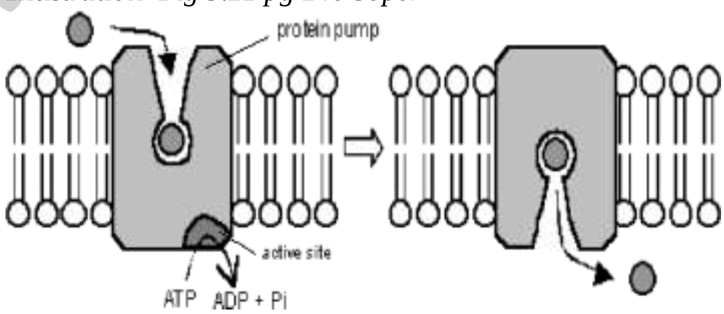
One common example of active transport is the sodium-potassium which actively removes sodium ions from cells, while actively accumulating potassium ions into the cell from their surroundings.

Direct active transport (e.g. Na^+ - K^+ pump)

The sodium potassium pump is a carrier protein which spans the cell membrane from one side to the other. The Na^+ - K^+ pump accepts sodium ions and ATP on the inside, while it accepts potassium ions on the outside.

ATP is hydrolysed to ADP and an inorganic phosphate by enzyme ATPase. The binding of the phosphate and sodium to the inside of the protein pump changes the protein conformation. The protein pump actively transports three sodium ions (3 Na^+) out of the cell for every two potassium ions ($2K^+$) pumped against their concentration gradient into the cell.

Illustration *Fig 5.21 pg 146 Soper*



This generates a difference in ionic charge on the two sides of the membrane i.e. the inside of the cell becomes negative with respect to the outside. This potential difference across the membrane is important for the transmission of nerve impulses. The Na^+ gradient is also used in the coupled uptake of solutes such as glucose into the cells against its concentration gradient.

Importance of the sodium-potassium pump

(i) Maintains electrical activity in nerve and muscle cells
(ii) Drives active transport of other substances such as sugars and amino acids
(iii) Provides the high concentration of potassium ions needs inside cells for protein synthesis, glycolysis and other vital processes

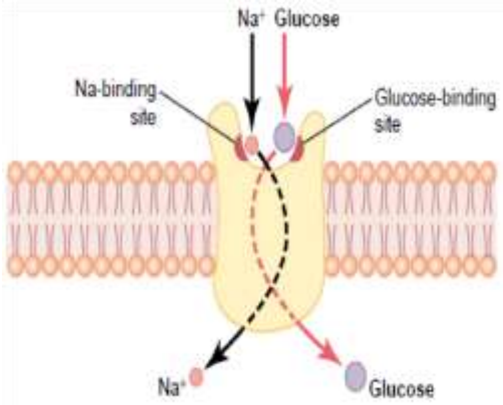
(iv) Controls osmotic balance of animal cells during osmoregulation

Note: if the pump is inhibited the cell swells and bursts, because buildup of sodium ions inside the cells results in excess water entering the cells by osmosis. However, bacteria, fungi and plants which have cell walls do not need the sodium potassium pumps.

Indirect active transport mechanism (secondary active transport)

This is also known as **co-transport** i.e. a form of active transport in which the pumping of one substance indirectly drives the transport of one or more other substances against a concentration gradient e.g. the coupled uptake of glucose into cells lining the ileum in mammals where glucose and Na^+ ions are absorbed into the cells. Sodium ions move down a concentration gradient while the glucose molecules against the concentration gradient. In co-transport of Na^+ and glucose, ATP is used by the protein pump to pump Na^+ out of the cell creating a Na^+ concentration gradient. The Na^+ and glucose molecules then bind to trans-membrane protein (carrier protein), also called co-transport proteins/coupled transport proteins.

Illustration *Fig 2 pg 70 Kent*



They are then moved by the proteins inside the cells i.e. the Na^+ moves down its concentration gradient while the glucose molecules moves down against its concentration gradient.

A similar process transports glucose and amino acids into the cells having the digestive tract in mammals. But here, absorption of nutrients is dependent on the sodium-potassium pump.

The factors required for active transport to take place;

1. Temperature

Increase in temperature increases the rate of transport of substances by active transport, so long as the increase in not above the optimum. The increase in temperature makes respiratory enzymes more active, having their speeds of movement increased (kinetic energy) with that of substrate molecules which results into collisions of molecules at a faster rate thus forming enzyme substrate complexes that form products. In this case, ATP is required to power active transport.

At very high temperatures, above the optimum, respiratory enzymes are denatured in the carrier proteins in the membrane. This reduces the rate of active transport.

At very low temperatures, below the optimum, the respiratory enzymes together with the carrier proteins are inactive and this reduces the rate of active transport.

2. Availability of oxygen

Oxygen is required for aerobic respiration to generate ATP. Increase in oxygen concentration results into increased rates of active transport as more ATP molecules are available for the process. In circumstances of very little or no oxygen, the rate of active transport is reduced since in the case of anaerobic respiration, there's very little or no ATP molecules available for active transport

3. Concentration of respiratory substrates e.g. glucose

If the concentration of respiratory substrate is increased, the rate of active transport also increases and if it is lowered, the rate of active transport lowers. This is because increase in the amount of the substrate increases the rate of ATP generation during respiration. If the amount of substrate is reduced, the rate of ATP generation is also lowered.

Importance of active transport

1. It is a means of absorption of food materials in the mammalian gut
2. It is the means of absorption of mineral salts by plant root hairs and the root epidermal cells of the peliferous layer
3. Selective reabsorption of glucose and sodium ions from the proximal convoluted tubule, and sodium ions from kidney cortex occurs by active transport

4. It facilitates the excretion of waste materials from the cells to the extracellular fluids against a concentration gradient e.g. excretion of urea
5. It is important in muscle contractions and relaxations where there's active pumping in and out of calcium ions inside the cytoplasm (sarcoplasm) of the muscle.
6. It is used in the loading and unloading of materials in the plants phloem tissue which creates pressure differences in the phloem tissue that maintain mass flow of materials.
7. Active transport is vital in transmission of nerve impulses along nerve cells where it creates a membrane action potential using the potassium-sodium pumps.
8. It plays a part in the opening and closure of stomata where differential pumping of potassium ions between the guard cells and neighboring subsidiary cells lead to turgidity changes hence causing stomatal movements (opening/closure).
9. Removal of excess water from amoeba by contractile vacuoles occurs by active transport
10. Fresh water fish carry out the active uptake of mineral ions from the external environment by special cells in the gills

Note: metabolic poisons (inhibitors), inhibit the enzymes and carrier proteins required to bring about active transport by either changing the active sites/binding sites for the enzymes/carrier proteins for the molecules to be transported. The poisons also inhibit ATP synthesis hence cutting off the source of energy needed to effect the active transport.

Differences between the functioning of carrier proteins in facilitated and those in active transport

Carrier proteins in facilitated diffusion	Carrier proteins in active transport
1. Do not use ATP	1. Use energy in form of ATP
2. Carry substances from a region of their lower concentration	2. Carry substances usually from a region of their lower concentration to a region of their higher concentration
3. Not affected by metabolic rate/ respiratory inhibitors/ oxygen concentration/ concentration of respiratory substance e.g. sugar, glucose	3. Affected by metabolic rate/ respiratory inhibitors/ oxygen concentration/ concentration of respiratory substances e.g. sugars
4. Carry substances slower	4. Carry substances faster
5. Carry substances in both directors across a membrane	5. Carry a particular substance in one direction

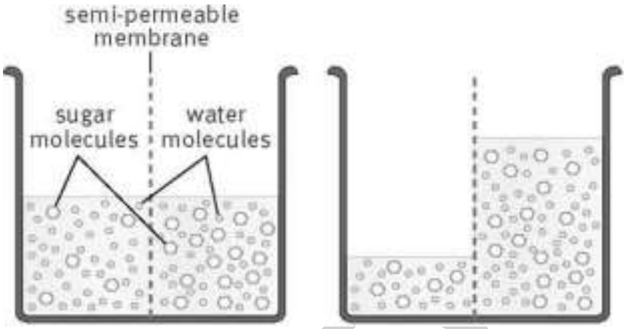
Differences between diffusion and active transport

Diffusion	Active transport
1. Materials move down their concentration gradient	1. Materials move usually against their concentration gradient
2. Does not require energy in form of ATP	2. Energy in form of ATP is used
3. Slower	3. Faster
4. Allows all transmiscible molecules and ions to pass through cell membranes	4. Causes selective uptake of materials
5. Not affected by metabolic rate	5. Affected by metabolic rate
6. Not affected by lack oxygen	6. Affected by lack of oxygen
7. Not affected by metabolic reactions	7. Affected by metabolic reaction

OSMOSIS

This the passive movement of water molecules, across a partially permeable membrane, from a region of lower solute concentration to a region of higher solute concentration. It may also be defined as the passive movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane.

Fig 1c pg 72 Kent

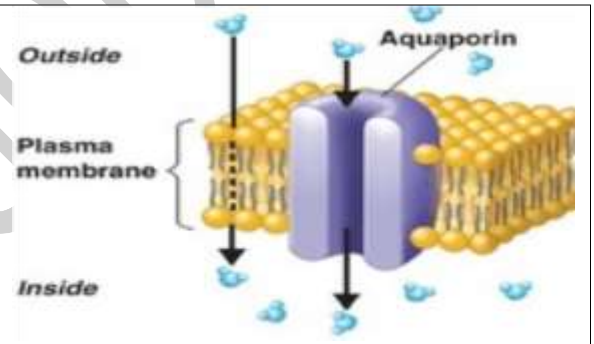


A selectively permeable membrane is one that allows unrestricted passage of water molecules but no passage of solute molecules. Different concentrations of solute molecules lead to different concentrations of free water molecules on either side of the membrane. On the side of the membrane with a high concentration of free water molecules (low solute concentration), more water molecules will strike the pores in the membrane in a given interval of time, water molecules pass through the pores resulting in net diffusion of water molecules from the region of high concentration of free water molecules to the region of low concentration of free water molecules.

A net flow of free water molecules is maintained because in the side with more solute molecules, water forms hydrogen bonds with solutes which are charged or polar forming a hydration shell around them in solution, making water molecules unfree and therefore cannot flow back across the membrane.

Osmosis and aquaporins

In living cells, transport of water across the cell membrane is facilitated by channel proteins called aquaporins which have specialised channels for water.

Water molecules are small but they are polar and therefore cannot interact with hydrophobic phospholipid layers easily and therefore diffusion through the lipid bilayer is extremely rare (such as areas of the fluid mosaic membrane rich in phospholipids with unsaturated carbon tails) or not there at all, and water molecules can quickly enter with ease through aquaporins in the cell membrane.	

Water potential

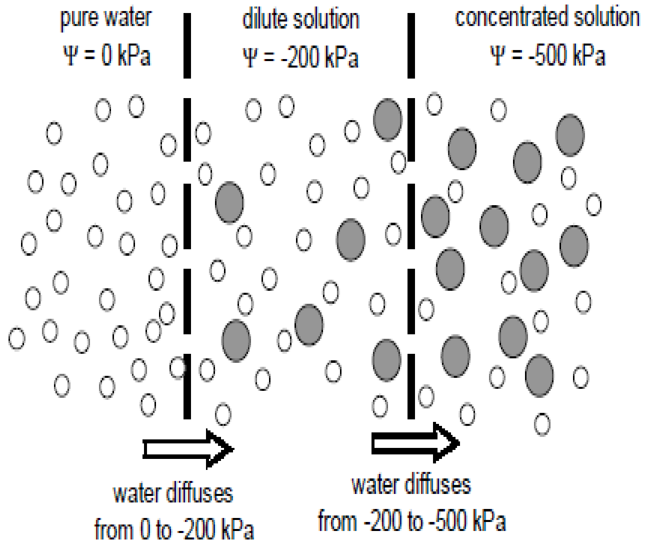
This is the net tendency of any system to donate water to its surroundings OR the term given to tendency of water molecules to enter and leave a solution by osmosis. The symbol for the water potential is Ψ, the Greek letter psi, and is usually measured in kilopascals (Kpa).

The higher the concentration of water molecules in a system, the higher the total kinetic energy of water molecules in that system, and the higher is its water potential. The water potential of pure water is zero pressure units and any addition of solute to pure water reduces its water potential and makes its value negative i.e. pure water has the highest water potential.

In pure water or dilute solution with very few solute molecules, the water molecules have a *high free kinetic energy* and can move very freely. A dilute solution therefore has a higher water potential than a concentrated solution. This is because the movement of the water molecules is restricted by the attraction between solute and water molecules i.e. there are fewer water molecules with a *high kinetic energy* to move across the membrane. This is because water is a polar molecule which attracts the positive part of the solute (cation) to its partially negatively charged oxygen atom, negative part of the solute (the anion) is attracted to the slightly positively charged hydrogen part of the water, forming hydrogen bonds. This reduces the mobility of the water molecules, lowering their kinetic energy, and decreasing the tendency of the system to lose water molecules.

The greater the concentration of solutes, the more negative is the water potential. Water potential of a plant cell , ψ_w, is the algebraic sum of its wall pressure (pressure potential) ψ_p and its osmotic (solute) potential ψ_o. A concentrated solution has a low water potential and water therefore moves down a water potential gradient i.e. water diffuses from a region of high water potential (less negative or zero value) to a region of lower water potential (more negative value). The water potential of pure water Ψ_W at atmospheric pressure is arbitraily given the value of 0 Kpa Ψ_W = 0 Kpa. The water potential of solutions is therefore less than 0 i.e $\Psi_{solution}$ < 0 Kpa.

Fig 44 pg 51 Roberts



Water potential if affected by amount of solutes and external pressure.
When an external pressure is applied to pure water or a solution, its water potential increases. This is because the pressure forces water molecules out of the system.

Solute potential (Ψ_s)

This is the potential or force of attraction towards water molecules caused by dissolved substances (solutes) inside the solution. That is to say, a change in water potential of a system in the presence of solute molecules. The attraction between solute molecules and water molecules reduces the random movement of water molecules. The addition of more solute molecules lowers the water potential of a solution.

- Solute potential/osmotic potential is denoted by (Ψ_S) and its equal to 0 for pure water
- Solute potential is always negative for solutions because the forces of attraction between the solute molecules and water molecules reduces the movement of water molecules.
- For a solution, water potential is equal to solute potential and its always negative

Pressure potential (Ψ_P)

This is the pressure exerted on a fluid by its surrounding. At any one time, the water potential of a plant is the sum of the solute potential and pressure potential. Pressure potential is usually, though not always, positive.

$$\underbrace{\Psi_W}_{\text{Water potential of plant cell}} = \underbrace{\Psi_s}_{\text{Solute / osmotic potential}} + \underbrace{\Psi_p}_{\text{Pressure potential}}$$

When water enters the cell by osmosis, the pressure of the cytosol builds up, pushing out against the cell membrane. This pressure is called hydrostatic pressure. In plant cells, this pressure builds up pushing the cell membrane against the cell wall. Because the cell wall is capable of only very limited extension, a pressure builds up that resists further entry of water. The cell wall begins to resist the swelling caused by the influx of water. The pressure that the cell wall develops is the pressure potential. For plants therefore, pressure potential is the pressure exerted on the cell contents by the cell wall and cell membrane.
Pressure potential is usually positive, but in the xylem of a transpiring plant the water column is under tension and the pressure potential is negative.

Osmotic pressure and cell relationship

Osmotic pressure is the hydrostatic pressure needed to stop osmotic flow. If the membrane is strong enough, the cell reaches an equilibrium, a point at which the osmotic pressure drives water into the cell exactly

counterbalanced by the hydrostatic pressure which tends to drive water back out of the cell. However, the plasma membrane itself cannot withstand the large internal pressures and an isolated cell under such conditions would just burst. In contrast, cells of prokaryotes, fungi, plants and many protists are surrounded by a strong cell wall which can withstand high internal pressure without bursting.
If a cell is surrounded by pure water or a solution whose concentration is lower than that of the cell contents, water will osmotically flow into the cell; such a solution with a lower osmotic pressure than that of the cell's cytoplasm is said to be **hypotonic**. If the cell is surrounded by a solution whose solute concentration exceeds that of the cell cytoplasm, water flows out of the cell. In this case the outer solution is said to be **hypertoni**c to the cell cytoplasm. If the cell concentration of the cell cytoplasm and the surrounding medium are the same and there would be no net flow of water in other directions and the external solution is said to be isotonic.
The osmotic flow of water into the cell is **endosmosis** and the osmotic flow of water out of the cell is **exosmosis**.

Hypertonic solution	Hypotonic solution
1. Higher concentration of solute molecules	1. Lower concentration of solute molecules
2. Lower solute potential	2. Higher solute potential
3. Lower concentration of water molecules	3. Higher concentration of water molecules
4. Lower water potential	4. Higher water potential
5. Higher osmotic pressure	5. Lower osmotic pressure
6. More negative water potential	6. Less negative water potential
7. More negative solute potential	7. Less negative solute potential

Osmosis and plant cells

A plant cell will be divided into three main parts

(i) The **cell wall,** which is freely permeable, except when impregnated with lignin
(ii) The **cytoplasm**, which is surrounded internally by the tonoplast and externally by the plasma membrane. Both the tonoplast and plasma membrane are partially permeable.
(iii) The cell vacuole, which contains an aqueous solution of salts, sugars and organic acids.
(iv)

a. Turgidity

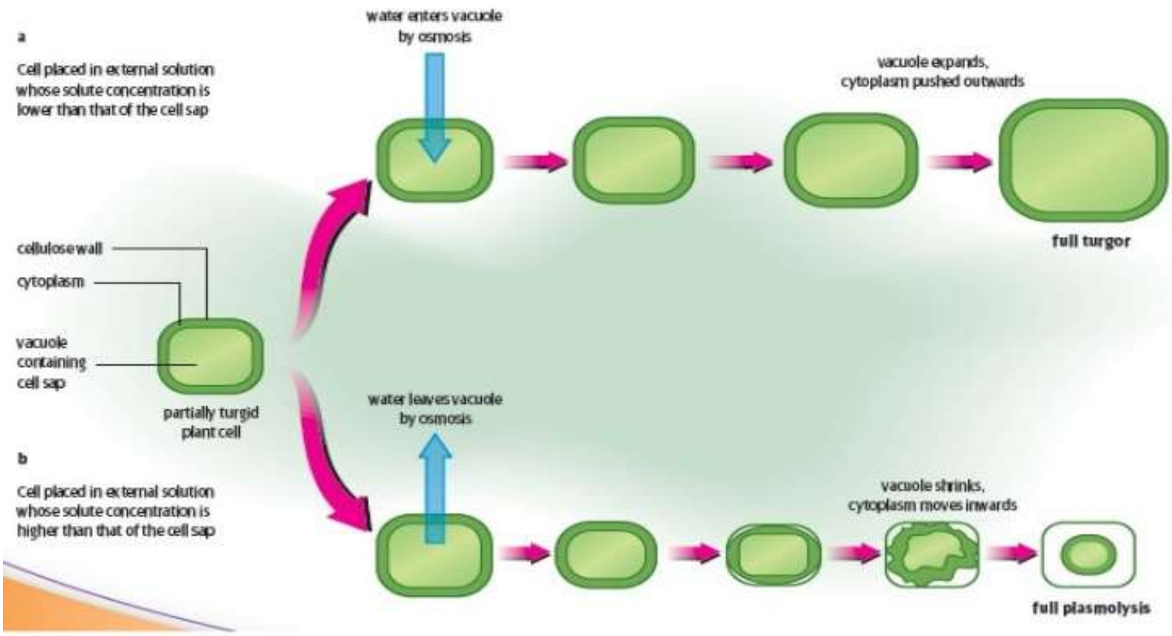
When the external solution is **hypotonic** e.g. distilled water, the cell's cytosol has a lower water potential, causing an influx of water into the cells. The water enters into the cells vacuole, by osmosis, through the partially permeable plasma membrane and tonoplast. The volume of the cell protoplasm increases, the protoplast swells causing an internal hydrostatic pressure developed by the cell hence the cell wall stretches. The pressure potential reaches its maximum when the cell wall is stretched to its maximum. At this point, the cell is described as a **fully turgid** or it has **full turgor** reached and the water potential at this point equals to 0 i.e. Ψ=0 and no more water can enter the cell.
Turgor pressure plays part in supporting plants and maintains their shape and form of herbaceous plants by being filled with fully turgid cells tightly packed together. It is also responsible for holding leaves in flat and horizontal position as well as the opening of the stomata. This is because the cell wall is tough and rigid hence resisting expansion of the protoplast so the cell wall exerts an equal and opposite pressure against the protoplast, and the rapidly increasing hydrostatic pressure inside the cell causing a buildup of the pressure potential. The pressure of the cell wall against the expanding protoplast is called **wall pressure**.

Importance of turgidity in plants

1. Turgor pressure maintains the shape and form of a plant
2. Stems of herbaceous plants and non-woody plants are maintained in an erect position by fully turgid cells tightly packed together to provide support
3. Turgor pressure holds leaves on a flat and horizontal position to receive sunlight.

4. Turgor pressure maintains the floral whorls of flowers open for pollination
5. Turgor pressure causes cell enlargement and stretches stems causing increase in girth
6. The rapid nastic responses of some plants, e.g. thigmonastic collapses of leaves and stems of *Mimosa pudica* are due to changes in turgidity
7. Closing and opening of stomata by guard cells

Fig 4.5 pg 52 Roberts



b. Plasmolysis

When a plant cell is immersed in a hypertonic solution, than its cytosol, the cell decreases in volume as water moves out osmotically from its vacuole through the partially permeable plasma membrane and tonoplast. The protoplast shrinks, pulling away from the cell wall and leaving gaps between the cell wall and plasma membrane. A cell in this condition is said to be **plasmolysed** and the cell becomes **flaccid**.
Plasmolysis is the shrinking of a plant cell’s protoplast away from the cell wall leaving gaps between the cell wall and the plasma membrane.
When a plant cell is placed in hypertonic solution, it loses water by exosmosis. The protoplast shrinks and pulls away from the cell wall. Also on a dry and hot day, the plant cells lose their way **evaporation** and the turgor pressure of the plant cells is reduced with the result that the plant droops. The phenomenon is called **wilting.** This is the drooping of leaves and stems as a result of plant cells losing water exosmotically and becoming flaccid. A plant suffers from **water stress** when it loses more water by **transpiration** than it absorbs by the roots.

Effects of water stress in plants

(i) Excessive water loss causes drooping of shoots and leaves, which produce abscisic acid so as to close the stomata and reduce on the rate of transpiration. This leads to reduction in the rate of photosynthesis due to lack of carbon dioxide
(ii) There’s reduced growth and stunting due to reduced photosynthesis
(iii) Excessive water loss causes dessication and drying up of the plant

Plant-water relations

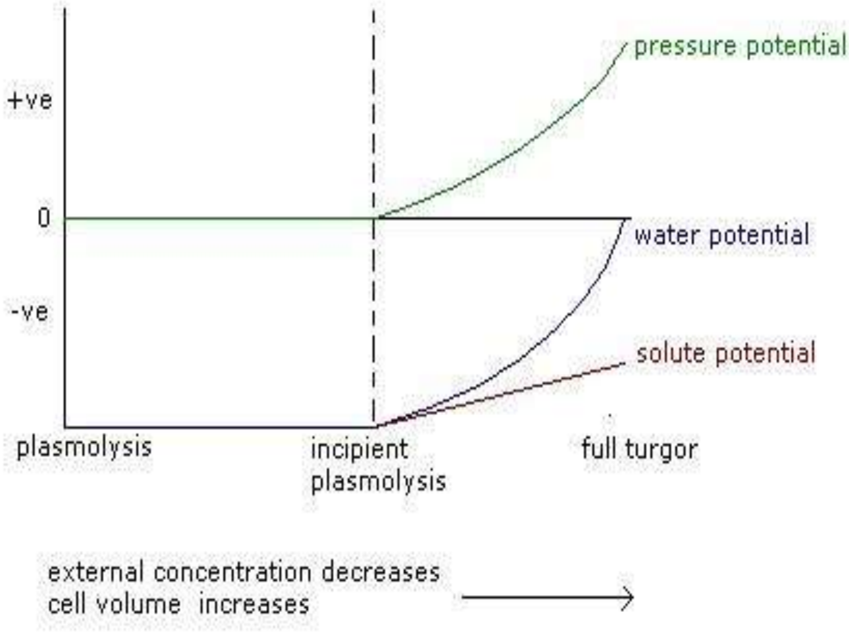
This takes into account of three forces which include;

a. Solute potential Ψs
b. Pressure potential (Ψp).

c. Water potential of the cell sap Ψw

<u>Graphical illustration of a relationship between Ψs (osmotic potential), Ψw (water potential of the cell) and pressure potential (Ψp) of a plant cell at different stages of turgor and plasmolysis is shown below</u>

Fig 4.6 p.g. 54 Roberts



From **full plasmolysis to full turgidity** (full turgor) the **solute potential increases gradually** because the osmotic entry of water into the cell gradullay reduces the concentration of solutes in the cell. The attraction between solute molecules and water molecules reduces which increases the random movement of water molecules hence increasing the solute potential. At full turgidity, the water potential is equal to 0Kpa and solute potential is equal to pressure potential.

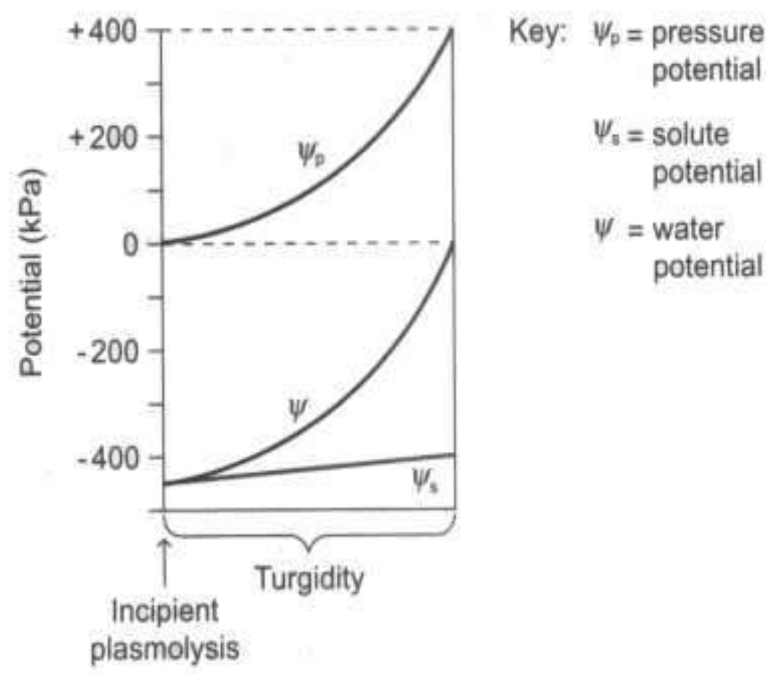
Considering a fully plasmolysed cell, its **pressure potential** is 0Kpa since the protoplast is completely pulled away from the cell wall, so the cell wall does not exert pressure on the protoplast.

From full **plasmolysis to incipient plasmolysis**, the pressure potential **remains constant at 0Kpa**. This is because the protoplast remains pulled away from the cell wall, so the cell wall does not exert any pressure against the protoplast. When immersed in pure water, water enters the sap osmotically and the protoplasm begins to expand. As the osmotic influx of water continues, the protoplast goes on expanding until the cell membrane comes slightly into contact with the cell wall, incipient plasmolysis, but it is not pressed against it, so the protoplast exerts no pressure against the cell wall so the pressure potential remains 0.

From **incipient plasmolysis to full turgidity** (full turgor) the pressure potential **increases rapidly** (becomes positive). As the cell continues to expand, due to the osmotic influx of water, the volume of the protoplasm increases. The osmotic influx of water into the cell is opposed by the inward pressure of the cell wall i.e. pressure potential. The protoplast exerts pressure against the cell wall and the rigid cell wall exerts pressure back against the protoplast causing a rapid increase in the pressure potential of the cell.

At full plasmolysis, the **water potential** of the cell is low (more negative) since the protoplast has a high concentration of solutes and a low concentration of water molecules. From full **plasmolysis to incipient plasmolysis**, the water potential **increases gradually** (becomes less negative) because the osmotic entry of water into the cell gradually increases the concentration of water into the cell.

From **incipient plasmolysis to full turgidity** (full turgor) the water potential **increases rapidly** (becomes less negative) due to further osmotic entry of water. The volume of the protoplasm increases, the protoplast swells further and presses against the rigid cell wall. The rigid cell wall presses back against the protoplast, causing a rapid increase in the pressure potential of the cell. The water potential of increases rapidly due to the rapidly increasing pressure potential, until the water potential becomes 0Kpa at full turgidity at which point the cell cannot take in more water.



When full turgor is reached, the cell cannot expand anymore and at this point Ψs (osmotic potential) is exactly outbalanced by the pressure potential (Ψp).

If the solution produces no change within the volume of the cell, it has a solute concentration similar to that of the cell sap or tissue and therefore water potential of the solution equals to the water potential of the cell or tissue.

In general:

- Ψcell = Ψs (always negative) + Ψp (always positive)
- At total plasmolysis; the vacuole almost disappears, minimum hydrostatic pressure, cell membrane completely not attached to the cell wall. Cell generally small and described as flaccid.
- At incipient plasmolysis; cell membrane begins to leave cell wall and water is lost from the cell.
- At full turgidity; the cell vacuole with maximum volume and no more water can enter.

Differences between wilting and plasmolysis

Wilting	Plasmolysis
1. Occurs due high temperature	1. Occurs due to an osmotic gradient
2. The entire cell, including the cell wall, shrink	2. Only the protoplast shrinks away from the cell wall
3. Water loss is serious leading to dessication which causes death	3. Water loss is not serious and can hardly result into death
4. Results in drooping of shoots and leaves of the plant	4. Does not result into drooping of leaves and shoots of the plant

Osmosis and animal cells

If the red blood cells are placed in a **hypotonic solution** i.e. 0.5% sodium chloride, water enters the cells by osmosis. The cell expands (swells) and the thin plasma membrane bursts, releasing the cell contents, this is called **haemolysis**. Haemolysis is due to red blood cells lacking cellulose cell walls which would prevent red blood cells expansion and therefore stops bursting.

If a human red blood cell is placed in an **isotonic solution** i.e. 0.9% sodium chloride solution, the cell neither shrinks nor swells/no change in shape or volume because there's no net movement of water molecules .
If the red blood cells are placed in a **hypertonic solution** i.e. 1.2% sodium chloride, there is a net outflow of water by osmosis. The cell shrinks and the cell membranes appears crinkled and this is called **crenation**.
Note: unicellular protists e.g. *Amoeba* and *Paramecium* have contractile vacuoles to regulate the water content in the cell.

Role of osmosis in living organisms

1. It is the main form by which root hairs and piliferous layer cells on roots absorb water from the soil
2. Movement of water from the root via the root cortex to the xylem
3. In herbaceous plants, osmosis brings about turgidity in plant cells due to presence of cell wall leading to provision of support and shape in a whole plant body.
4. Osmosis causes plant structures (organs) like leaves and flowers to determine their form for example holding the leaf in flat and horizontal position enabling it to trap maximum sunlight.
5. Osmosis bring about opening and closure of petals of flowers and osmosis bring about the opening and closure of stomata in plant leaves when the guard cells become turgid facilitating gaseous exchange in plants
6. Movement of water from the gut into the blood stream
7. Kidney nephrons (tubules) re-absorb water back into the blood stream via the blood capillaries osmotically leading to water conservation in the body hence bringing about osmoregulation

Factors affecting osmosis in physical systems

1. **Temperature**
   Provided pressure is constant, when a partially permeable membrane separates pure water on two sides, the molecules of water will move from a region with a higher temperature to a region with a lower temperature.
2. **Pressure**
   Provided temperature is constant, when pure water in two sides of a partially permeable membrane is subjected to diffusion pressures, water molecules move from the side with a higher pressure to the side with lower pressure.
3. **Solute molecule**
   Water molecules from a dilute solution to a concentrated solution

Differences between diffusion and osmosis

Diffusion	Osmosis
1. Involves movement of solute or gas molecules	1. Involves movement of solvent
2. Involves movement of solute molecules or ions from a region of their higher concentration to a region of their lower concentration	2. Involves movement of solvent molecules from a region of their higher concentration to a region of their lower concentration
3. Occurs where there are no barriers to movement	3. Occurs through a partially permeable membrane

Differences between active transport and osmosis

Active transport	Osmosis
1. Involves movement of solute molecules	1. Involves movement of solvent molecules
2. Solute molecules move against their concentration gradient	2. Solvent molecules move down their concentration gradient
3. Energy is required in form of ATP	3. No energy is required

4. Occur only in living tissues	4. Can occur in non-living tissues
5. Occurs across both partially permeable membrane and freely permeable membranes	5. Occurs across a partially permeable membrane
6. Affected by lack of oxygen/ affected by metabolic poisons/ affected by the metabolic rate	6. Not affected by lack of oxygen/ not affected by metabolic poisons/ not affected by the metabolic rate
7. Concentration equilibrium is not obtained at the end	7. Concentration equilibrium may be obtained at the end
8. Carrier proteins required	8. No carrier proteins required

An experiment to determine the water potential of plant materials such as a potato tuber

Apparatus and materials

- Sucrose
- Distilled water
- Potato tubers
- Cork borer
- Beakers
- Stop clock
- Razor blade
- Ruler

Procedure

1. Prepare a series of sucrose solutions on known concentrations e.g. 0.1M, 0.2M, 0.3M, 0.4M, 0.5M and 0.6M.
2. Place the same volume of each solution in six labelled beakers
3. Set up another beaker containing the same volume of distilled water, which is 0.0M
4. Using a cork borer, make seven cylindrical pieces of the potato tuber
5. Make all the cylindrical pieces 3cm long using a razor blade and a ruler
6. Add a potato cylinder to each of the labelled beakers containing the sucrose solutions, including the 0.0M solution
7. Leave the potato cylinders completely immersed in the sucrose solutions for 1 hour
8. Remove the potato cylinders from the sucrose solutions and measure their lengths accurately to the nearest mm

Treatment of results

1. Calculate the percentage increase or decrease in length of the potato cylinders in each of the solutions
2. Plot a graph of percentage change in length against molarity of sucrose solutions
3. From the graph determine the molarity of sucrose solution at which there is no change in length
4. Record the value, and from a set of tables determine the osmotic potential of this solution

Conclusion

The water potential of the potato tuber is equal to the osmotic potential of the sucrose solution at which there is no change in length of the potato cylinder

Determination of the mean solute potential of the cell sap in a sample of plant cells using the method of incipient plasmolysis

The incipient plasmolysis method involves counting the number of plasmolysed cells in a given field of view under the microscope for different concentrations of sucrose solutions then determining the percentage plasmolysis and plotting a graph of percentage of plasmolysed cells against molarity of sucrose solutions.

By interpretation from the graph, the sucrose concentration which occurs when 50% of the cells to be plasmolysed is read off.

Using the relationship:

(a) Ψcell = Ψs cell + Ψp cell, and
(b) Ψsolution = Ψs solution
When the two are in equilibrium, Ψcell = Ψsolution, when Ψp cell = 0

At incipient solution the protoplasts have shrunk to the point where they begin to pull away from the cell wall and the pressure potential is zero, since no pressure is exerted by the protoplasts against the cell wall, therefore; Ψcell = Ψs cell = Ψ solution, from **(a)** and **(b)** above.

Hence the solution causing incipient plasmolysis has the same solute potential as the cell sap.

So, at 50% plasmolysis the average cell is said to be at incipient plasmolysis, and solute potential of the solution causing this plasmolysis can be obtained to give the mean solute potential of the cell sap, from the tables of the relationships between molarity of sucrose solutions and solute potential of sucrose solutions.

BULK TRANSPORT ACROSS THE CELL MEMBRANE

CYTOSIS

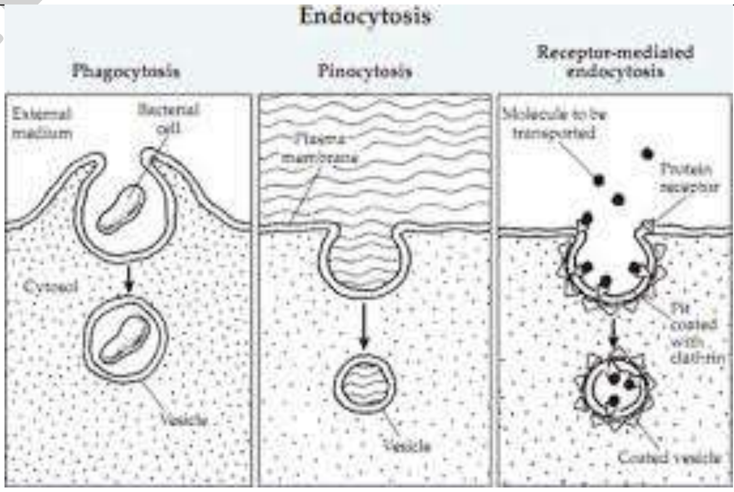
This is a form of active transport involving infoldings and out-folding of sections of the cell surface membrane resulting into the bulk transport of materials into a cell (endocytosis) or out of the cell (exocytosis). The flexibility of the cell membrane is an important factor in the bulk transport of materials into the cell. Cytosis involves the contractile proteins in cellular microfilaments and microtubules pulling a small region of a membrane from the rest of the membrane using energy in the form of ATP. Cytosis results in bulk transport of materials into the cell or outside the cell, thus cytosis is divided into two main types i.e.

a. Endocytosis
b. Exocytosis

Endocytosis

This is bulk transport of materials inside the cell. It involves a small area of plasma membrane folding inwards (invaginating) to surround a material to be taken in and moves deeper inside the cell. There are three types of endocytosis;

a. Phagocytosis
b. Pinocytosis
c. Receptor-mediated endocytosis



Phagocytosis (cellular eating)

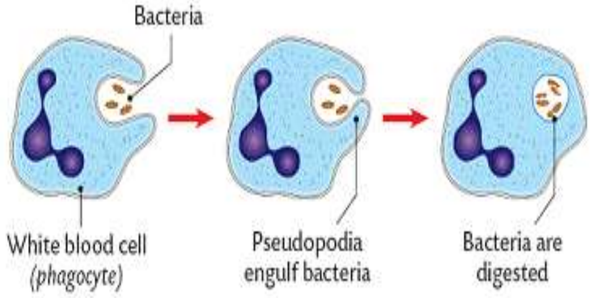
This is called cellular eating and it involves the cell taking in large solid substances. Phagocytosis involves invagination of cell membrane, forming a cup-shaped depression, surrounding the organism or particle forming a phagocytotic vesicle or vacuole which pinches off the cell membrane and moves into the cytoplasm. Lysosomes fuse with vacuoles and release hydrolytic enzymes into the vacuole which break down the substances in the vacuole. The protein substances are absorbed into the surrounding cytoplasm across the

lining of the vacuole. Any undigested material may be got rid of by the vesicles of vacuoles moving into the cell surface membrane and fusing with it.
Cells specialised for phagocytosis are called phagocytes and are said to be phagocytic, as in white blood cells and amoeba.

Mechanism of phagocytotic killing by white blood cells
The engulfing cells detect chemo-active molecules (usually small peptide molecules) released by the target matter, and respond by moving towards it. White blood cells form cytoplasmic extensions to form pseudopodia which surround and engulf micro-organisms. The microorganisms attach onto the white blood cell by some 'lock and key' mechanism involving receptor proteins on the cell surface membrane.

Micro-organisms are completely surrounded by pseudopodia due to the activation of the contractile processes of the cell's cytoskeleton. These proteins react with ATP to form phagocytotic vesicles or phagosomes which pinch off the cell membrane into the cytoplasm. The phagosome fuses with the lysosome to form a phagolysosome. Inside the phagolysosome are microbes which are broken down by hydrolytic enzymes

[Clegg and Mackean Pg 240 fg 11.23]



Pinocytosis (cellular drinking)
Pinocytosis is the process by which the cells takes in bulk liquid material. It is also called cellular drinking, it is similar to phagocytosis only that the infoldings forming the vesicles are much smaller.

Liquid and large macro molecules such as proteins are taken in via small pinocytotic vesicles. Smaller pinocytotic vesicles may be formed, in which case the process is called micro-pinocytosis. The process is highly specific involving the binding of the molecules with corresponding receptor molecules in the plasma membrane.

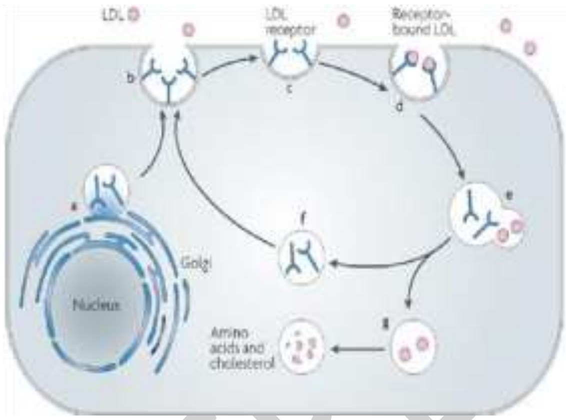
BS page 147

A summary of the role of the plasma membrane in endocytosis and exocytosis
UNEB 2012

Receptor mediated endocytosis
This involves receptor molecules on a cell membrane which binds with specific substance from extracellular fluid i.e. it is selective.

The receptor proteins are usually already clustered in regions of the membrane called **coated pits**. Extracellular substances (**ligands**) bind to these receptors (a ligand is a molecule that binds specifically to a receptor site of another molecule). As the receptor sites are filled, the surface folds inwards until the coated vesicles finally separates from the cell surface membrane forming a coated vesicle containing ligand molecules. After ingested material is liberated from the vesicle, the receptors are recycled to the plasma membrane by the same vesicle.

Illustration (M. Kent pg 71)

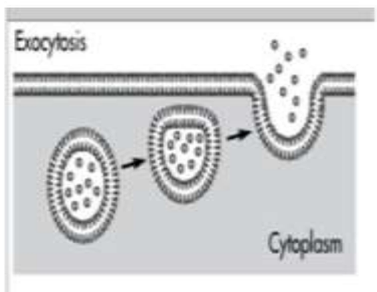


One common example is the binding of cholesterol molecules to specific receptor proteins on the plasma membrane triggers the inward folding of the cell membrane. A vesicle is formed that carries the cholesterol molecule into the cell.

Exocytosis
This involves the vesicles or vacuoles moving to the cell membrane fusing with the releasing their contents to the outside of the cell.

Exocytosis provides a means by which enzymes, hydrochloric acid in the gastric glands, hormones in the various ductless glands, antibodies, sweat-secreting cells of sweat glands of human skin, and cell wall precursors are released from the cell.

The vesicles are often derived from the Golgi apparatus or endoplasmic reticulum, which move along microtubules of the cytoskeleton of the plasma membrane. When the vesicles get into contact with the plasma membrane, the lipid molecules of the two bilayers rearrange and diffuse. The content of the vesicles spill to the outside of the cell and the vesicle membrane becomes part of the plasma membrane



Note: Vesicle and food vacuole formation are active processes, which require energy from respiration.

Importance of cytosis
1. Many secretory cells use exocytosis to release their excretory products outside themselves e.g. pancreatic cells manufacture insulin and secrete it into blood by exocytosis and many other hormones are secreted in this form by the gland cells
2. Exocytosis facilitates synaptic transmission during which neuro-transmitter substances like acetylcholine in synaptic vesicles of synaptic knobs fuse with the pre-synaptic membrane to release neuro transmitter substances into the synaptic cleft of the synapse.
3. Exocytosis delivers cell wall materials to the outside of the cell from the Golgi apparatus/body through vesicles which contain proteins and certain carbohydrates
4. Exocytosis leads to replenishment of the plasma membrane as the vesicle membrane become part of the plasma membrane become part of the plasma membrane after spilling/discharging their contents to the outside.

Summary			
Features	**Simple diffusion**	**Facilitated diffusion**	**Active transport**

Concentration gradient	Down the concentration gradient from high to low	Down the concentration gradient from high to low	Against a concentration gradient from low to high
Energy expenditure	None	None	Energy expenditure is in the form of ATP
Carrier protein/ transporter	Not required	Required	Required
Speed	Slowest mode	Fast	Fastest

SAMPLE QUESTIONS

1. The table below shows results of an experiment to determine the solute potential of onion epidermal cells using incipient plasmolysis method. In each case, the total number of cells observed in one field of view was eighty (80).

Concentration of sucrose solution (mol /dm^3)	Number of cells plasmolysed	Percentage plasmolysis
0.1	0	
0.2	0	
0.3	2	
0.4	3	
0.45	10	
0.50	60	
0.55	80	
0.60	80	

(a) Copy and complete the table by working out the percentage of cells which are plasmolysed. (04 marks)

(b) What is meant by the terms?
(i) Solute potential. (03 marks)
(ii) Incipient plasmolysis. (03 marks)

(c) (i) Plot a graph to show the relationship between percentage of plasmolysed cells and sucrose concentration. (08 marks)
(ii) From the graph, determine the concentration of the onion epidermal cells to be used to determine their solute potential. (02 marks)
(iii) Briefly explain how you arrived at your answer in (c) (ii) above. (08 marks)

(d) Explain the ecological significance of osmosis to plants. (06 marks)

2. (a) (i) Define the term active transport. (02 marks)
(ii) Describe the sodium-potassium pump as an example of active transport. (07 marks)

(b) Define the terms uniport carrier, symport carrier and antiport carrier. (06 marks)

(c) With an example, explain the process of cotransport. (05 marks)

3. An experiment was carried out with cells of the carrot tissue which was first thoroughly washed in pure water. The slices of carrot tissue were immersed in aerated potassium chloride solution of known concentration at varying temperatures. At the fourth hour, the carrot tissue at 25^0C was treated with potassium cyanide. The results are shown in the table below.

Time in minutes	Potassium ion uptake in mg g-1	
	At 2^0C	At 25^0C
0	0	0

60	90	170
120	105	360
240	130	480
300	130	500
360	130	50

(a). Represent the above data graphically. [6marks]

(b). Describe the changes in the rate of potassium ions absorption within the first four hours at 25^0C. [3marks]

(c). During the first hour, some potassium ions enter the carrot cells passively. Suggest any two possible means of their movement and any two conditions needed for one of them to occur. [4marks]

(d). (i). Calculate using minutes, the mean rate of absorption of potassium ions at 25^0C between the 2^{nd} and 6^{th} hour [3marks]

(ii). Compare the rates of absorption of potassium ions at 2^0C and 25^0C during the experiment. [4marks]

(iii). Suggest an explanation for the differences of potassium at the two temperatures. [6marks]

(e). Explain the effects of treating the carrot with potassium cyanide on the rate of their absorption of potassium ions. [4marks]

(f). Suggest

(i). the aim of the experiment. [1mark]

(ii). why the carrot tissue was first washed in pure water [2marks]

(iii). why the potassium chloride solution was aerated. [2marks]

(g). Briefly explain the significance of the existence of the casparian strip within endodermal cells of the root. [5marks]

4. **Figure 1** shows changes in the different potentials of a fully plasmolysed plant cell placed in a hypotonic solution.
Figure 2 shows the rate of movement of two different substances across a phospholipid membrane; glucose by facilitated diffusion and water by simple diffusion, at varying extracellular concentration.

Figure 1

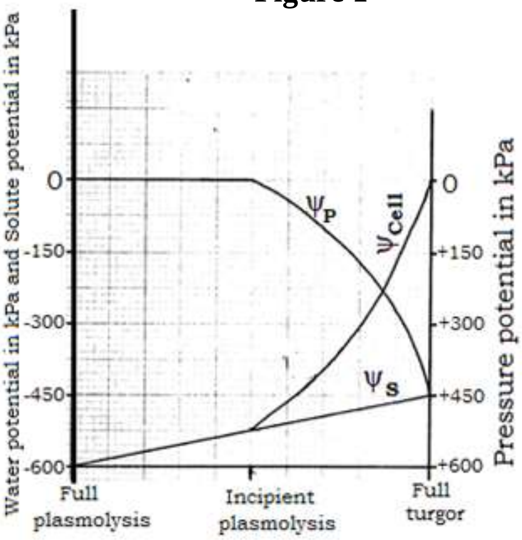
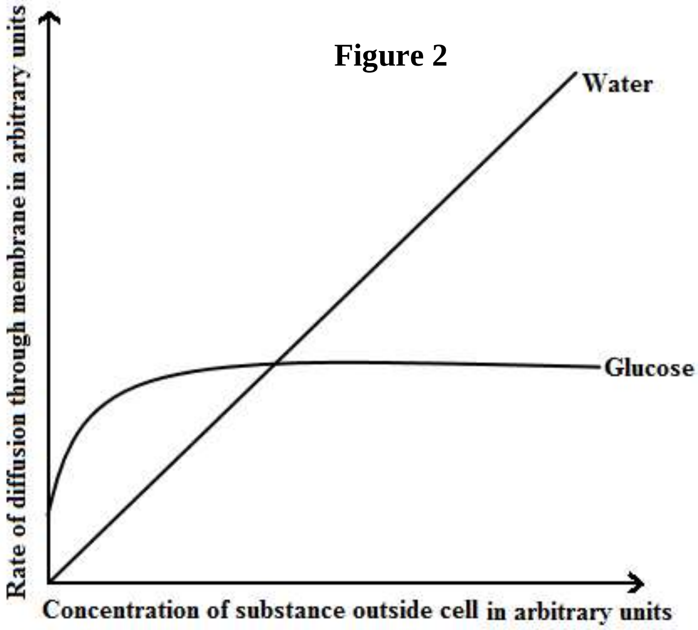


Figure 2



(a) From **figure 1,** compare the changes in pressure potential and water potential from full plasmolysis to full turgor. (05 marks)

(b) As indicated in **figure 1**, explain the change in water potential from full plasmolysis to full turgor. (15 marks)

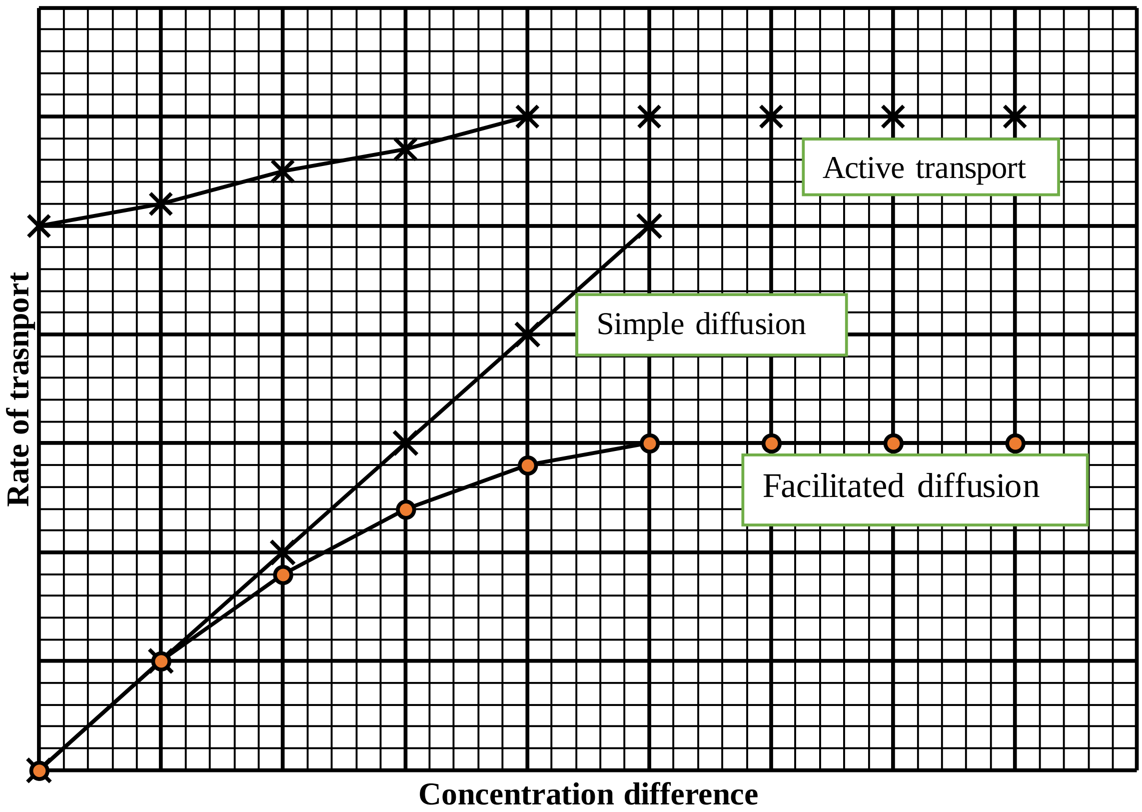
(c) From **figure 2,** describe the effect of increasing extracellular concentration:

(i) on glucose uptake. (07 marks)

(ii) on water uptake (05 marks)

(d) Explain the observed rates of uptake of glucose and water, from figure 2 above. (08 marks)

5. The graph below shows the effect of concentration difference on three transport processes of molecules or ions across a cell surface membrane. Study the information and answer the questions that follow.



a) From the graph;

   (i) state **one** similarity between the three transport processes (02 marks)

   (ii) compare the rate of transport by facilitated diffusion and active transport (05)

   (iii) explain the rates of transport observed when the concentration difference is zero (04 marks)

   (iv) explain the changes in the rate of transport by facilitated diffusion (10 marks)

   (v) what is the basis of the difference in the graphs for simple diffusion and facilitated diffusion (02 marks)

b) (i) Which **one** of the processes would stop if a respiratory inhibitor was added? (01)

   (ii) Explain your answer in b (i) above (03 marks)

c) Outline the differences between the functioning of carrier proteins in facilitated diffusion and those in active transport (04 marks)

d) Describe the sodium potassium pump as an example of active transport (09 marks)

6. Two investigations concerning movement of substances in and out of cells were carried out in 2 different organisms and results were summarized in tables 1 and 2 as indicated below.
The first investigation had 2 experiments. In the first experiment the marine ciliate *corthurnia* was placed in a series of dilutions of sea water and the output of its contractile vacuole was measured. In another experiment, the change in volume of the organism in different dilution of sea water was recorded.

Added fresh water/%	0	10	20	30	40	50	60	70	80	90
Contractile vacuole out put/dm^{3}s^{-1}	0.7	0.6	1.1	1.0	1.5	2.4	6.3	18.2	35.1	9.5
Relative body volume	1.0	1.1	1.2	1.3	1.4	1.6	1.8	2.0	2.1	2.0

In the second investigation, the relative rate of uptake of glucose and xylose (a pentose) from living intestine and from intestine which had been poisoned with cyanide, was determined and results recorded in table 2

Sugar	Without cyanide	With cyanide
Glucose	100	28
xylose	18	18

a) Represent graphically the results in table 1 using a single set of axes (06 marks)

bi) Explain the effects of dilutions on the activity of the contractile vacuole(04 arks)

ii) what do changes in relative body volume indicate about the effect of the contractile vacuole activity?

c) Some species of marine protozoa form contractile vacuoles only the protozoan begins to feed . Suggest an explanation for this observation. (03 marks)

d) How is active transport:

i) similar to facilitated diffusion (02 marks)

ii) different from facilitated diffusion (03 marks)

e) Explain the relative uptake of the sugars by the intestines (05 marks)

f) How do the following factors affect the rate of diffusion across a membrane

i) concentration difference, (02 marks)

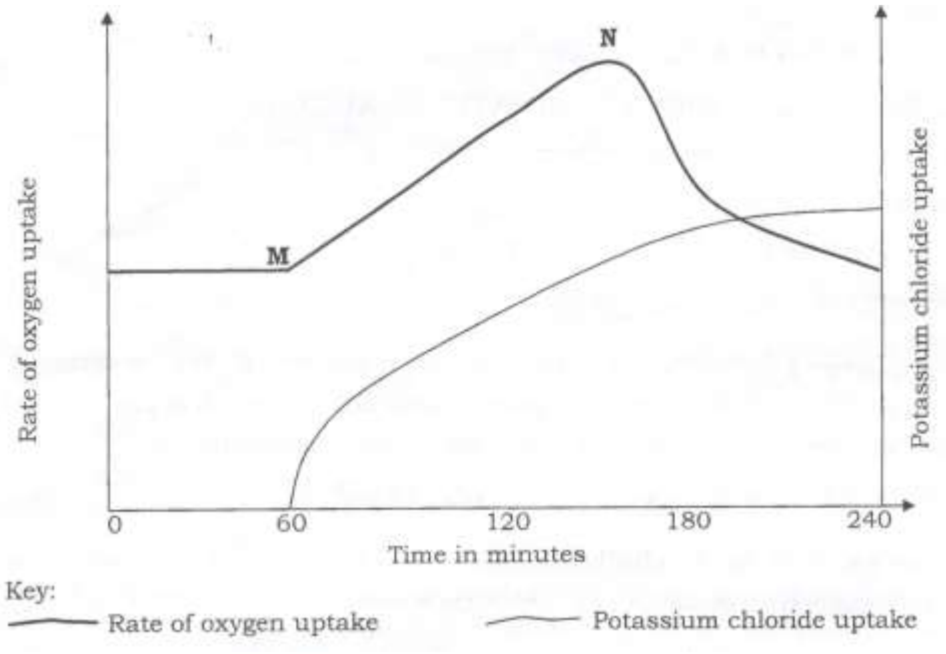
ii) the size of the molecules(02 marks)

iii) temperature (02 marks)

iv) polarity of the molecules(02 marks)

h) state the composition and major function of the animal's cell surface.(03 marks)

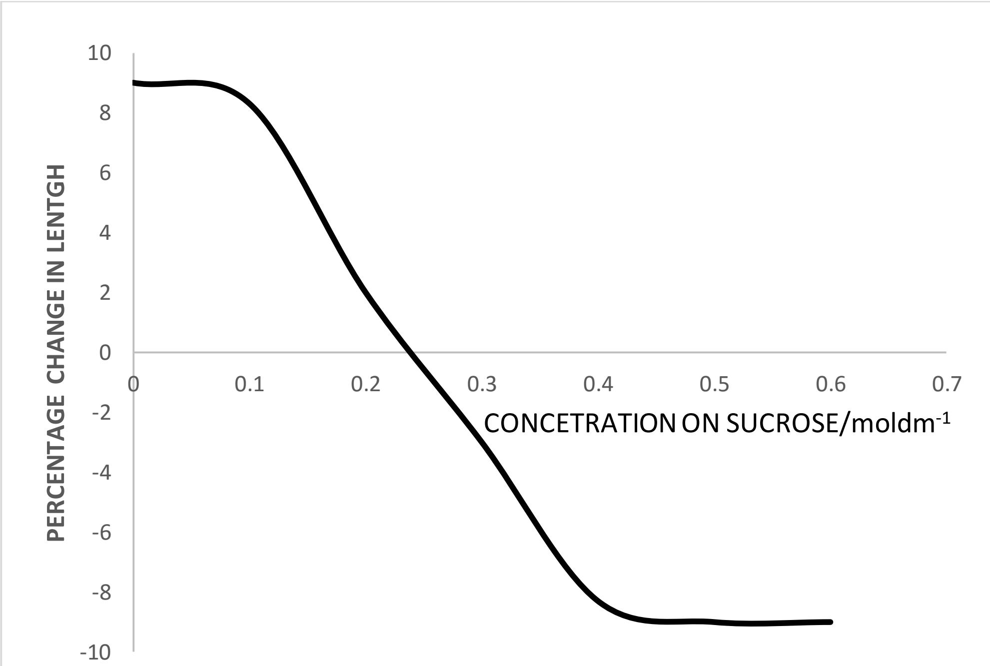
7. In an experiment a set of young cereal roots were washed thoroughly in pure water and transferred into culture solutions containing potassium chloride solution under varying oxygen concentrations (at point **M** on the graph below). After 160 minutes solution of unknown substance was introduced (at point **N** on the graph below). The rate of oxygen uptake and potassium chloride uptake were measured and recorded graphically as shown in the figure below.



a) Compare the rate of oxygen uptake with the rate of chloride uptake between 60 and 240 minutes. (04 marks)

b) Explain the rate of oxygen and potassium chloride uptake as shown in the graph above? (06 marks)

8. The graph below shows the percentage change in length of cylinders of potato which had been placed in sucrose solutions of different concentrations for 12 hours.



a) What is meant by the term **water potential**? (02 marks)

b) In terms of water potential, explain the change in length which occurred when the cylinder of potato was placed in a sucrose solution of concentration of 0.3mol dm^{-1}

c) With a reason, state the concentration of sucrose in the potato tubers used in the experiment above (03 marks)

Potato tubers store starch. As they start to grow or sprout, some of this starch is converted to sugars. Sketch a graph on the one plotted above to represent the changes in length you would expect if the investigation had been carried out with sprouting potatoes

9. Define the term **facilitated diffusion**

c) State **three** ways how facilitated diffusion differs from simple diffusion

d) Describe **one** way how facilitated diffusion occurs across membranes

e) State **two** ways how the action of carrier proteins is similar to that of enzymes

10. State the parameters listed in **Fick's law** of diffusion (03 marks)

b)Explain how each parameter in **Fick's law** of diffusion is reflected in the structure of the mammalian lung

c) Explain the changes in oxygen delivery to the tissues that occur as a person proceeds from a resting state to intense exercise (04 marks)

11. The table below shows the results of an experiment on the rate of absorption of sugars by a mammalian intestine. Study it carefully and answer the questions that follow.

Sugar	Relative rates of absorption taking normal glucose uptake as 100	
	By living intestine	By intestine poisoned with cyanide

Hexose sugars	Glucose	100	30
	Galactose	106	35
Pentose sugars	Xylose	32	32
	Arabinose	30	31

(a) Suggest a reason for the difference between the rates of absorption of hexose and pentose sugars in the living intestines (03 marks)

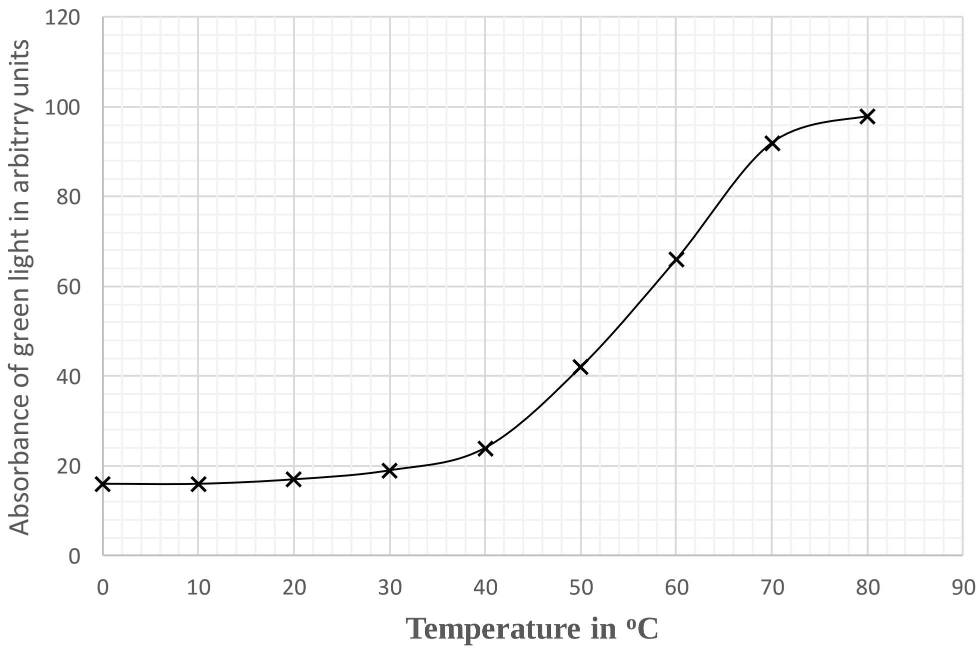
(b) Mention the mechanism by which hexose sugars are absorbed by living intestines ($0\frac{1}{2}$ mark)

(c) What is the advantage to the individual of having hexose sugars absorbed in the way mentioned above?

(d) What could be the effect of cyanide on the mechanism of hexose absorption? (02 marks)

(e) In an intact mammal, absorption of fatty acids is drastically curtailed by any clinical condition which leads to a reduction in bile salt excretion or release. Explain why this is so.

12. Beet root cells contain a pigment that cannot normally escape from the cells through the cell surface membrane. The graph below shows the results of an investigation into the effect of temperature on the permeability of the cell surface membrane of beet root cells. The permeability was measured by using a calorimeter to measure the absorbance of green light by the solution in which samples of beet root had been immersed. The greater the absorbance, the more red pigment had leaved out of the beet root cells.



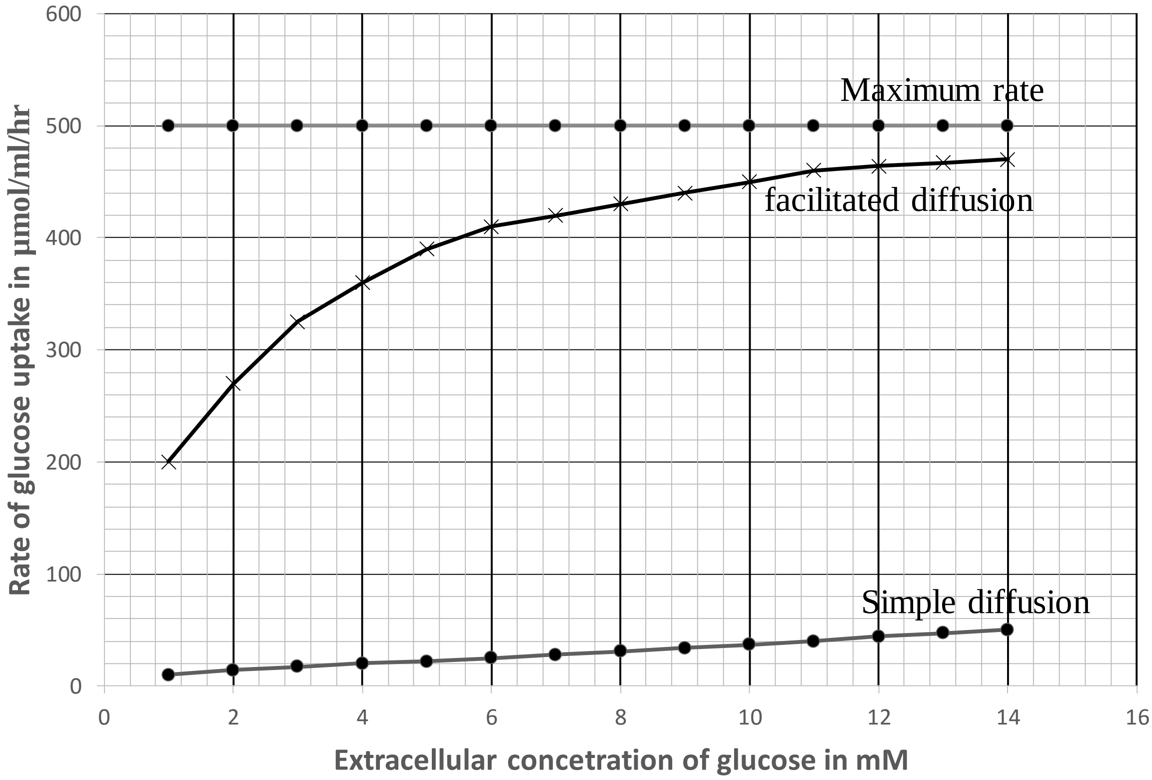
(a) Describe the changes in the absorbance of green light with temperature. (4 marks)

(b) What is the general effect of temperature on the absorbance of light? (1 mark)

(c) With reference to the structure of cell membranes, explain the effect of temperature on absorbance. (4 m

(d) State one other way in which membrane permeability could be altered. (1 mark)

13. In an experiment, the rate of uptake of glucose by the blood using simple and facilitated diffusion at varying extracellular concentration of glucose, was measured. The results are shown in the table below. Study the information and answer the questions that follow.



a) Describe the rate of glucose uptake with increasing extracellular concentration when diffusion is facilitated. (*09 marks*)

b) Compare the rate of glucose uptake when diffusion is facilitated and when it is not. (*08 marks*)

c) Explain the effect of increasing extracellular concentration of glucose on the uptake of glucose, when diffusion is facilitated. (*09 marks)*

d) Suggest what would happen to the rate of glucose if a respiratory poison was introduced into the cell membrane. Give an explanation for your answer. (*03 marks*)

e) Explain why:
   i. Facilitated diffusion occurs (06 marks)
   ii. The cell membrane is able to carry out facilitated diffusion (12 marks)

14. In a physiological investigation, screened red blood cells were placed in different concentrations of aqueous sodium chloride solution. In each case an average total of five thousand (5000) cells were viewed and the total number of haemolysed cells recorded. The results of this investigation are shown in the table below.

Sodium chloride concentration (g /100ml)	0.33	0.36	0.38	0.39	0.42	0.44	0.48
Number of cells haemolysed	4900	4500	4000	3400	1500	800	100
Percentage cells haemolysed/ %							

(a) (¡) calculate the percentage cells haemolysed at each sodium chloride Concentration using the formula below and fill in the table. ($3^1/_2$ marks

Percentage cells haemolysed = $\frac{Number\ of\ cells\ haymolysed}{average\ total\ cells\ viewed\ (5000)}$ X 1000

(b) Plot a graph to show variation of percentage cells haemolysed with sodium chloride Concentration.

(c) Describe the changes in the percentage cells haemolysed. (04 marks)

(d) Explain the shape of the graph. (06 marks)

(e) From the graph, determine the sodium chloride concentration:

(¡) At which 100% haemolysis occurs.

(¡¡) Isotonic to the red blood cells and explain your answer. (04 marks)

(f) Suggest what would happen if the red blood cells were placed in sodium chloride Concentration of

(¡) 0.6g/100ml

(¡¡) 0.1g/100ml (04 marks)

(g) Give reasons why the red blood cells haemolyse over a wide range of salt concentration. (03 marks)

(h) Briefly describe five ways by which green plants obtain Nitrogen. (08 marks)

REFERENCES

1. D.T.Taylor, N.P.O. Green, G.W. Stout and **R. Soper**. Biological Science, 3rd edition, Cambridge University Press
2. M.B.V.**Roberts**, Biology a Functional approach, 4th edition, Nelson
3. C.J.Clegg with D.G.Mackean, ADVANCED BIOLOGY PRICIPLES AND APPLICATIONS, 2nd EDITION, HODDER EDUCATION
4. Glenn and Susan **Toole**, NEW UNDERSTANDING BIOLOGY for advanced level, 2nd edition, Nelson thornes
5. Michael **Kent**, Advanced BIOLOGY, OXFORD UNIVERSITY PRESS
6. Michael Roberts, Michael Reiss and Grace **Monger**, ADVANCED BIOLOGY
7. J.SIMPKINS & J.I.WILLIAMS. ADVANCED BIOLOGY

END