MOVEMENT OF MATERIALS IN AND OUT OF THE CELL

Substances like nutrients and excretions move in and out of the cell by:

1. Diffusion
2. Osmosis
3. Active transport
4. Phagocytosis
5. Pinocytosis

Movement of substances depends on the permeability of the cell membrane or cell wall.

DIFFUSION

This is the movement of molecules of gases and liquids from a region of high concentration to a region of low concentration. Diffusion occurs because small molecules are in constant random motion. Molecules of gases and liquids by random motion tend to distribute themselves evenly, throughout the available space, unlike in solids where molecules are closely packed together and have no freedom of movement. Diffusion only takes place where there is a difference in concentration i.e. where there is a concentration gradient and continues until there is even distribution of molecules.

EXPERIMENT TO DEMONSTRATE DIFFUSION IN GASES

Apparatus

- Wet red litmus paper,
- cotton wool,
- glass tube,
- ammonium solution,
- glass rod

Method

Some strips of wet red litmus papers are stuck on the walls of a glass tube as indicated below.
The glass tube is corked as one end and a piece of cotton wool is soaked in ammonium solution and is introduced at the other end which is also plugged.

Procedure

Squares of wet red litmus paper were pushed with a glass rod or wire into a wide glass tube so that they stick to the side and are evenly spaced out. The glass tube is corked at one end the other end is closed with a cork carrying a plug of cotton wool, soaked in ammonia

Observation

The alkaline ammonia gas, diffused along the glass tube, turning the litmus papers blue in succession from 1to 5, showing that the ammonia gas was diffusing from one end to the other.

NB: If the experiment is repeated using more dilute solution of ammonia, the rate of diffusion would be seen to be slower.

EXPERIMENT TO DEMOSTRATE DIFFUSION IN LIQUIDS

Materials

- Glass beaker
- Potassium permanganate crystals
- Water
- spatula

Procedure

Fill a glass beaker with about 50cc of water

Place a few crystals of potassium permanganate at the base of the beaker in the water.

Leave the set up for about 30 minutes.

Observation

After 30-40 minutes, the potassium permanganate color will have spread first at the bottom and later upward to color all the water in the beaker.

Conclusion

Diffusion occurs in liquids.

FACTORS AFFECTING THE RATE OF DIFFUSION

1) Concentration gradient

Concentration gradient is the difference in concentration between the 2 regions where diffusion takes place. The higher the concentration gradient between the two regions, the faster is the rate of diffusion.

2) Temperature

The higher the temperature of the substances (molecules), the faster is the rate diffusion, because temperature increases the kinetic energy of molecules.

3) Size/density of molecules

The smaller the molecules, the faster the rate of diffusion. The denser the particle, the lower the rate of diffusion.

4) Distance over which diffusion occurs

The shorter the distance between the two regions of different concentration, the greater is the rate of diffusion like the alveoli of lungs or the epithelial linings of the ileum are thin to provide a short distance for diffusion thus increasing the rate of diffusion.

5) Surface area over which diffusion occurs

The larger the surface over which diffusion is to take place, the faster is the rate of diffusion e.g. diffusion surfaces like the ileum have numerous villi to increase the rate of diffusion.

Types of diffusion

Simple diffusion

This is the type of diffusion where molecules or ions move freely across the cell membrane without being aided.

Facilitated diffusion

This is where molecules or ions move across the cell membrane by being aided by protein carriers using energy.

Significance of diffusion to organisms

i) It helps substances to move in and out of cells.
ii) Plant root hairs take up some salts by diffusion
iii) Unicellular microorganisms like amoeba, take in oxygen and pass out carbon dioxide through the cell membrane by diffusion.
iv) Digested food e.g. simple sugars, amino acids, enter the blood from the gut by diffusion.
v) Once dissolved in blood, the food substances diffuse out of the blood into the cells where they are needed.
vi) Oxygen diffuses into blood and CO_2 out of blood in the lungs of mammals and gills of fish by diffusion.
vii) Waste products of metabolisms e.g. nitrogen containing substances like urea, diffuse out of the animal cells into blood.

OSMOSIS

This is the ***movement of water molecules from a region of their high concentration to a region of their low concentration across a semi permeable membrane.***

Or

It is the ***movement water molecules from a solution of low concentration to a solution of high concentration across a semi permeable membrane.***

A semi/partially/selectively permeable membrane is one which can allow the passage of some materials to occur and prevent other materials from passing across it.

Diagram showing details of osmosis

When 2 solutions are separated by a semi permeable membrane having small pores, water molecules continue to move from a dilute solution to a concentrated solution through it.

Experiment to demonstrate osmosis in an artificial cell

Materials

- ✓ Cellophane /visking tube,
- ✓ Capillary tube,
- ✓ Beaker,
- ✓ Syrup or sugar solution,
- ✓ Thread or elastic band,
- ✓ Clamp

Procedure

a) Tie one end of the visking tubing using a rubber bung.
b) Make a sugar solution and pour it into the tubing
c) Tie the open end of the tubing to the capillary tube using a rubber bung or thread.
d) Pour some water in the beaker half way full
e) Insert the capillary tube with the visking tubing into water.
f) Note the level of the solution in the capillary tube and that of water in the beaker.
g) Clamp the capillary tube on a retort stand and leave the set up for 30 minutes.

Observation

In a few minutes, the level of the solution is seen to rise up the capillary tube

Interpretation

Water molecules are passed through the cellophane tubing into the sugar solution by osmosis, thus increasing its volume and forcing it up the capillary tube.

Water acts as a dilute solution

Sugar solution acts as a concentrated solution

Membrane of the visking tubing acts as the semi permeable membrane.

EXPERIMENT TO DEMONSTRATE OSMOSIS IN A LIVING TISSUE

Apparatus

- ✓ Fresh Irish potatoes,
- ✓ knife,
- ✓ Petri dishes,
- ✓ sugar or salt
- ✓ water

Procedure

a) 3 fresh Irish potatoes are peeled and their ends sliced flat. The interiors are scooped out to form a cup with walls of uniform thickness.
b) In A, some grains of sugar are placed in the cup, while the other potato B is left empty as a control.
c) The third potato is boiled to kill or destroy the tissues and also some sugar grains are put in the cup.
d) All the potato cups are placed in water in Petri dishes. The experiment is let to run for 2-6 hours.

End of experiment (2-6 hours)

The liquid in the cup potato A had risen to form a sugar solution and in the Petri dish, the level had fallen.

In potato B and in the boiled potato, the cups were still empty and the water level in the Petri dishes remained the same.

Conclusion

Osmosis takes place in living tissues and does not take place in boiled tissues. This is because, by boiling, the tissues are destroyed and loose semi permeability

Explanation

Living tissues have cell membrane or cell walls acting as semi permeable membrane and allow water to move through by osmosis while boiling a living tissue makes it impermeable.

Terms used in osmosis

Osmotic potential

This is the ability of a solution to exert osmotic pressure. This describes the concentration of the solution of the solution in terms of the ability of water molecules to move hence a solution with high osmotic potential has more water molecules able to move.

Osmotic pressure

This describes the concentration of the solution in terms of the ability of water molecules to move hence a solution with high osmotic potential has more water molecules able to move. This is the pressure exerted by a hypertonic solution to draw water in to its self.

Water potential

This is the concentration of water in a solution. Therefore a solution has a high osmotic pressure if it is highly concentrated and vice versa. This is the ability of a hypotonic solution to loose water to a more concentrated solution.

Hypotonic solutions

This is used to describe a solution containing less solute and more water molecules compared to another e.g. hypotonic solution has a lower osmotic pressure and is generally termed as less concentrated.

Isotonic solutions

These are solutions with the same concentration of salts and water i.e. Solutions with the same isotonic pressure

Hypertonic solutions

This is used to describe a solution with more solutes and less water molecules than the other. A hypertonic solution has a higher osmotic pressure and is generally termed as more concentrated solution.

Osmosis and cells

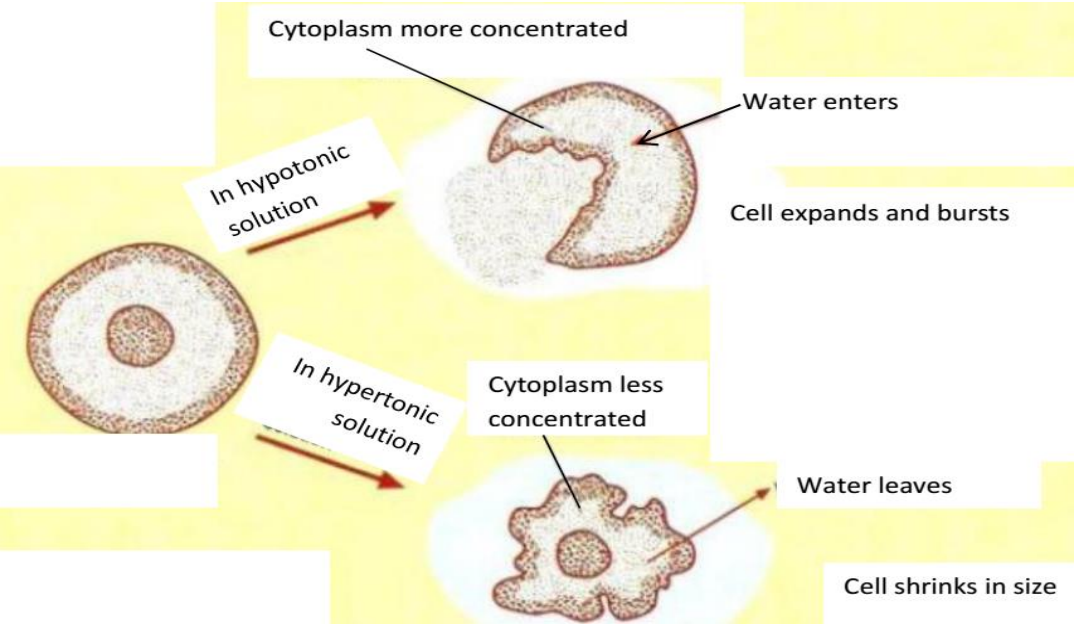
Animal cells

Unlike the plant cells, animal cells lack a cell wall and only have a cell membrane which is weak and non-resistant to high internal pressure.

Osmosis and red blood cells

When red blood cells are placed in a dilute solution (hypotonic solution) i.e. distilled water, the cells swell up and eventually burst (haemolyse). This is because water moves from the surrounding solution (distilled water) via the semi permeable cell membrane into cells.

Haemolysis in red blood cells



When the red blood cells are placed in a more concentrated solution (hypotonic solution) e.g. a strong sugar solution, water moves out of the cells to the surrounding solution by osmosis. As a result, the cells shrink the process called crenation or laking.
However, when red blood cells are placed in isotonic solution they neither gain nor lose water.

Turgor
This is the attainment of enough water in the cell to make it expand to its maximum volume.
Turgor pressure
This is the force exerted on the cell wall of the plant cell due to pushing of the cytoplasm as a result of water entering the cell vacuole and expanding.
Turgidity
Is a destination of a cell which has attained enough water and expanded to maximum size.
When a plant cell is placed in a dilute solution (water) than the cell sap, water enters by osmosis through the semi permeable cell wall and cell membrane into the cell sap. The volume of cell sap increases and it makes the sap vacuole expand. This causes the cytoplasm move towards the cell wall and gaining turgidity.
Time comes when all the cytoplasm is pressing against the cell wall and no more water can be absorbed. At this state, the cell is said to have gained full turgidity and the force on the cell wall is called turgor pressure.

Diagram showing a cell gaining turgidity

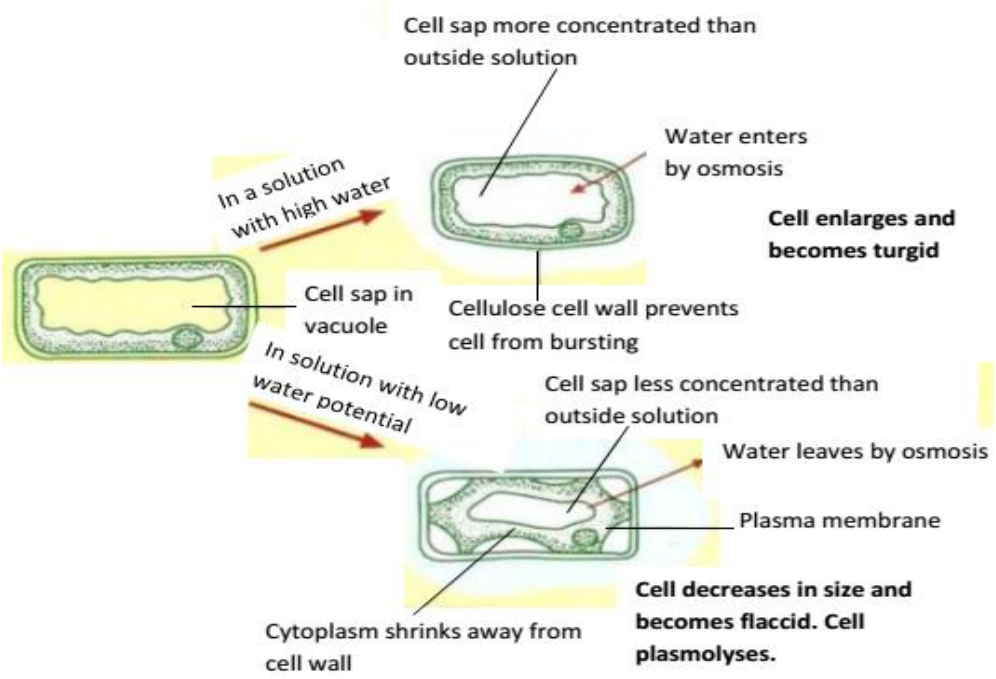
Plasmolysis

This is the loss of water from the cell to the surrounding causing the vacuole to shrink and cause the cytoplasm to lose contact with the cell wall.

When the cell is in this condition, it is said to be flaccid or plasmolysed. Therefore a flaccid cell is one whose cytoplasm has lost contact with the cell wall due to loss of water from the cell sap of the vacuole.

When the cell is in a more concentrated solution than the cell sap, water moves from the cell sap through a cytoplasm than the cell wall to the surrounding solution. This causes the vacuole to shrink and the cytoplasm to lose contact with the cell wall and the cell is said to be flaccid or plasmolysed.

Diagram showing a plasmolysed cell



Experiment to demonstrate turgor and plasmolysis

Materials

- ✓ Cock borer
- ✓ Four beakers
- ✓ Water
- ✓ Irish potato
- ✓ Razor blade
- ✓ Sugar crystal

Procedure

i) Get four beakers and pour ¾ of water in 3 of them and leave one empty.
ii) Mix the sugar in one beaker to make 5% solution
iii) Mix sugar in another beaker to make 50% solution
iv) Leave one with pure water
v) Use a cock borer to make 4 potato cylinders the same length e.g. 3 cm.
vi) Name this initial length
vii) Deep the potato in each cylinder
viii) Leave the setup for one hour and observe.

Setup

Remove the cylinder from each beaker and measure each length. Also feel the texture. Tabulate your results in the table below.

Initial length/cm	Final length/cm	Change in length/cm	% change in length	Texture(soft/tough)
4.0	4.3	+0.3	+7.5	Tough
4.0	4.0	0	0	Tough
4.0	3.8	-0.2	-5	Soft/flaccid
4.0	3.9	-0.1	-4	Soft

Observation

The cylinder in water had increased in length and became tougher.

The cylinder in 5% sucrose solution didn't have any change in length and the texture remained the same

The cylinder in 50% sucrose solution had decreased in length and become soft, flaccid and curved.

The potato in the empty beaker decreased in length.

Conclusion

Turgor and plasmolysis occur in plant cells.

Explanation

The cylinder in water increased in length because water molecules moved into it from the surrounding water by osmosis because the cell sap had a higher concentration than the surrounding water.

There was no change in length for the cylinder in 5% sucrose solution because the solution had the same concentration as the cell sap of a potato cylinder hence no net osmosis.

There was a decrease in length for the cylinder in 50% sucrose solution because water molecules moved out of the cylinder which had a lower concentration by osmosis.

There was a decrease in length for the cylinder in the empty beaker because water was lost to the surrounding through evaporation.

Significance of osmosis in plants

i) Absorption of water by root hairs from soil
ii) It enhances movement of water from root hairs via the cortex to the xylem.
iii) For support in non- woody plants
iv) It facilitates opening and closing of stomata
v) In germination, the initial absorption of water is by osmosis

Significance of osmosis in animals

i) It enables movement of water to capillaries in villi
ii) Movement of water in to unicellular animals
iii) Movement of water from tissue fluid to the cell
iv) It enables reabsorption of water into the blood stream via the kidney tubules.

Note: many semi- permeable membranes allow the passage of solute and solvents though not to the same extent. All that is required for osmosis to occur is that the solvent molecules move more rapidly than the solute molecules.

ACTIVE TRANSPORT

This is the movement of molecules from the region of low concentration to the region of higher concentration i.e. movement against concentration gradient using energy.

Energy for this process is derived from respiration. Anything that affects the rate of respiration, also affects the active transport e.g. cyanides prevent ATP synthesis.

Active transport takes place by means of carrier molecules in the cell membranes which are protein. The carrier, on reaching the inner part of the membrane releases the molecules and is set free for further transportation.

Examples of active transport

1) Up take of mineral salts from soil by plant roots
2) Absorption of some food molecules e.g. glucose
3) Selective re absorption of molecules e.g. glucose

Importance of active transport

1) Used by plant roots or root hairs to absorb minerals from the soil.
2) Used in the absorption of food materials from the ileum into the blood stream
3) Used in the reabsorption of minerals in the kidney during urine formation
4) Used in the secretion and active uptake of ions in the fish gills from fresh water

PINOCYTOSIS

This is the process by which animal cells take in liquid materials into their bodies. Thus it is said to be cell-drinking.

PHAGOCYTOSIS

This is the process by which animal cells take in solid materials. The cell engulfs/invaginates or takes in solid materials and form a food vacuole where the food is digested. The food is absorbed into the cytoplasm and undigested particles are released. It requires energy.

Importance of phagocytosis

1) Used by amoeba during feeding

2) White blood cells destroy pathogens by phagocytosis
3) Unicellular animals egest undigested material by phagocytosis.