2 Diffusion and osmosis

Candidates should be able to:

(a) *define *diffusion* as the movement of molecules from a region of their higher concentration to a region of their lower concentration, down a concentration gradient

(b) *define *osmosis* as the passage of water molecules from a region of their higher concentration to a region of their lower concentration, through a partially permeable membrane

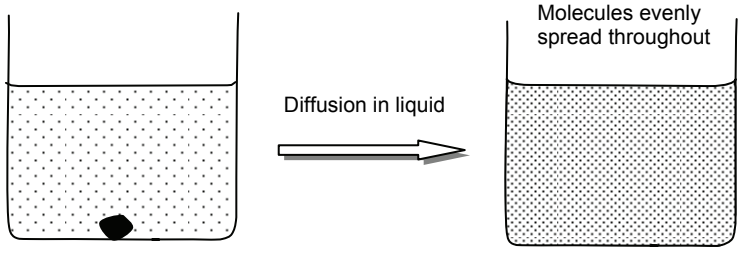
(c) *assess the importance of water potential gradient in the uptake of water by plants and the effects of osmosis on plant and animal tissues

* - *Asterisks placed alongside learning outcomes indicate areas of the syllabus where it is anticipated that teachers might use applications of information technology (IT) as appropriate.*

2.1 Diffusion

Define

Diffusion is the movement of molecules from a region of their higher concentration to a region of their lower concentration, down a concentration gradient.



- *Diffusion* is a passive process (free-energy).
- The rate of flow of the diffusing substance is depended on the following factors:
  - concentration gradient - the greater the concentration gradient, the greater is the rate of diffusion
  - molecule size - small molecule diffuses faster than the big one.
  - state of matter - solids (slowest diffusion) < liquid < gases (fastest diffusion)
  - temperature - high temperature increases the rate of diffusion.

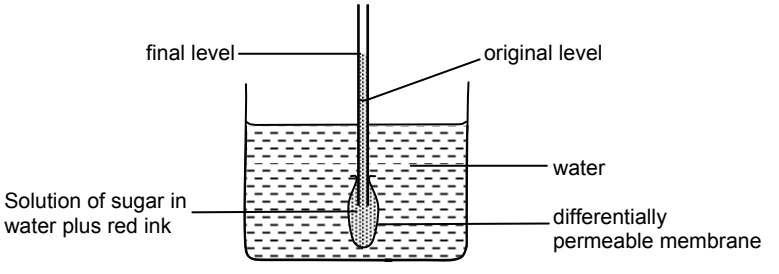
- *Diffusion* eventually will lead to an equal distribution state, all the components are perfectly miscible with each other and mixing ultimately becomes nearly uniform.

- Examples of *diffusion*:
  - During photosynthesis, carbon dioxide is dissolved in water film, then moves into root hair cells and also moves from the water film surrounding the mesophyll cells inside a leaf, to the chloroplasts in the leaf.
  - During respiration, water vapour moves from water film, through the intercellular spaces of the leaf and out through the stomata.
  - Oxygen is dissolved in the moisture lining of air sacs of the lungs, then moves through the walls of the alveoli into the blood. While carbon dioxide, in the solution, moves from the cells, through tissue fluid, into the blood.

Worked Examples

Example 1

An apparatus was set up as below. The original level and the final level (after some hours later) of the solution in the tubing were marked.



(i) Explain the changes after some hours later to the above apparatus.

(ii) Name the process responsible for the changes above.

Solution:

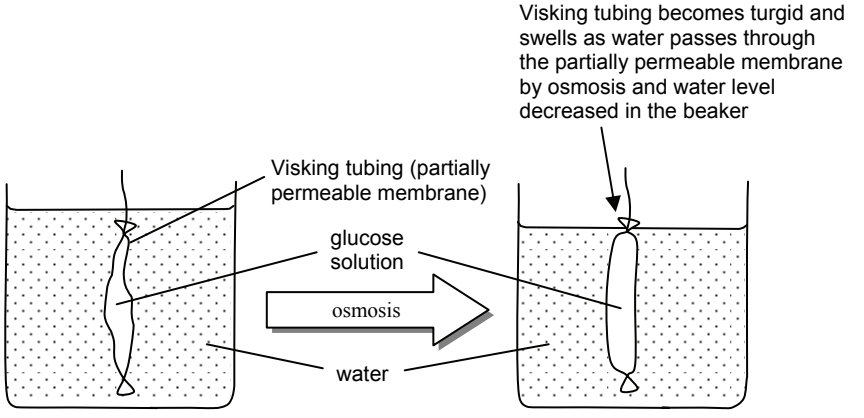
(i) The water in the beaker had turned red. This is due to the molecules movement of red ink from a region of high concentration to a region of low concentration.

(ii) Diffusion.

2.2 Osmosis

Define

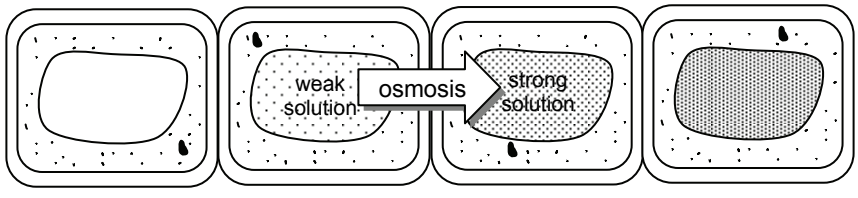
Osmosis is the passage of water molecules from a region of their higher concentration to a region of their lower concentration, through a partially permeable membrane.



- *Osmosis* is also a free-energy process.
- A dilute solution contains more water molecules, hence has a higher water potential. Water moves from a region of higher water potential to a region of lower water potential.

Importance of water gradient

- *Osmosis* is the way in which plants take in water:
  - The cell membrane acts as a partially permeable membrane
  - The cell sap inside the vacuole is a strong solution
  - Water passes into the cell by *osmosis*
  - The concentration of the sap is now weaker
  - Water passes from the weak solution into the strong solution in the next cell by *osmosis*

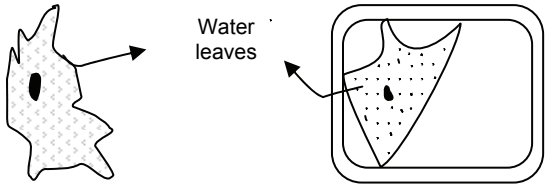


Effects of osmosis

In a strong solution (hypertonic)

- When an animal cell is immersed in a strong solution (such as glucose solution), it <u>shrinks</u> as water moves out of the cell because the strong solution is more concentrated relative to the cytoplasm.

- The protoplasm of plant cells also shrinks away from its cell wall. This process is called **plasmolysis**



In a equally concentrated solution (isotonic)

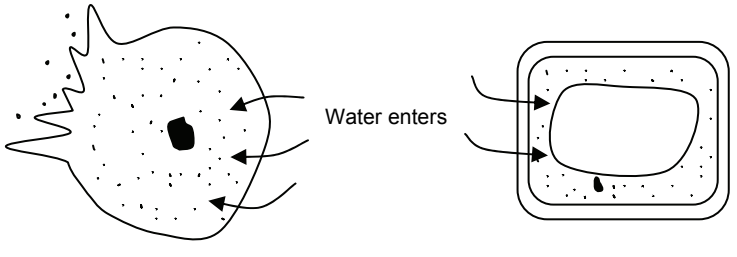
- Since the water potential on both sides of the membrane is equal, there is no concentration gradient and hence no net movement of water.

In a weak solution (hypotonic)

- When an animal cell is immersed in a weak solution (such as water), it swells and bursts as water enters it through *osmosis*. Plant cell does not swell because the plant cell wall structure (strong and relatively inelastic) prevents the cell from over-expansion.

- The plant cell becomes turgid and firm in a weak solution. As water moves into the plant cells, the vacuole increases in volume. It presses the cytoplasm against the cell wall. This pressure is call <u>turgor pressure</u>.

- Turgor pressure helps the plant:
  - To keep stems upright
  - To keep leaves flat (better to absorb sunlight)
  - To control the opening and closing of the stomata.



Cell becomes turgid and bursts

Cell becomes turgid but cell wall prevents bursting

Worked Examples

Example 1

Figure 1A shows a segment of potato tuber immersed in concentrated glucose solution.

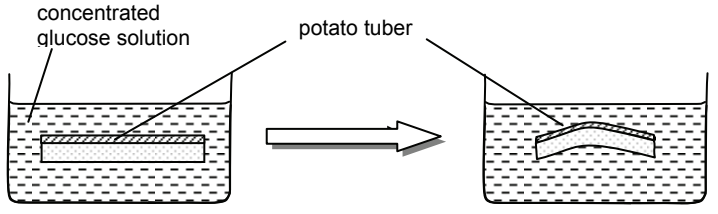


Fig. 1A Fig. 1B

(i) Explain what has happened in Figure 1B.

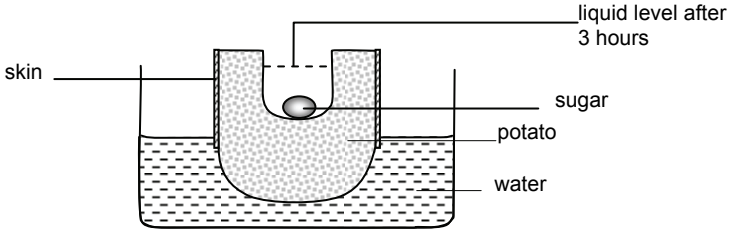
(ii) Name the process responsible for the changes above.

Solution:

(i) The length of the potato tuber decreased as water leaves segment. The cell membrane is partially permeable. This is due to the lower water potential in the concentrated solution than in the cell sap.

(ii) Osmosis.

Example 2



A potato was cut as the diagram above and was placed in a dish of water. A small amount of sugar was then placed in the hollow. Three hours later it was observed that the sugar had dissolved and the hollow contained liquid up to the level shown on the diagram. The water around the potato in dish A was then replaced by a concentrated sugar solution while dish B was left unchanged.

(a) What changes would you expect to see after few hours, in

(i) dish A;

(ii) dish B

(b) Name the process responsible for the changes describe above.

(c) Explain these changes with reference to the cells of the potato tissue.

Solution:

(a) (i) The liquid in the hollow of the potato in dish A would have disappeared.

(ii) The liquid in the hollow of the potato in dish B would have increased in volume.

(b) Osmosis.

(c) In dish A, the solution surrounding the potato is hypertonic to the cell sap of nearby cells, hence water would leave the cells. The water potential of the cell sap in these cells would become lower than the adjoining cells, hence water would move into those cells. The net result is the movement of water from the hollow through the cells, to the surrounding liquid. In dish B, the cell sap is hypotonic to the solution in the hollow. Water would leave the cells and moves into the liquid in the hollow, resulting in the increase in volume.