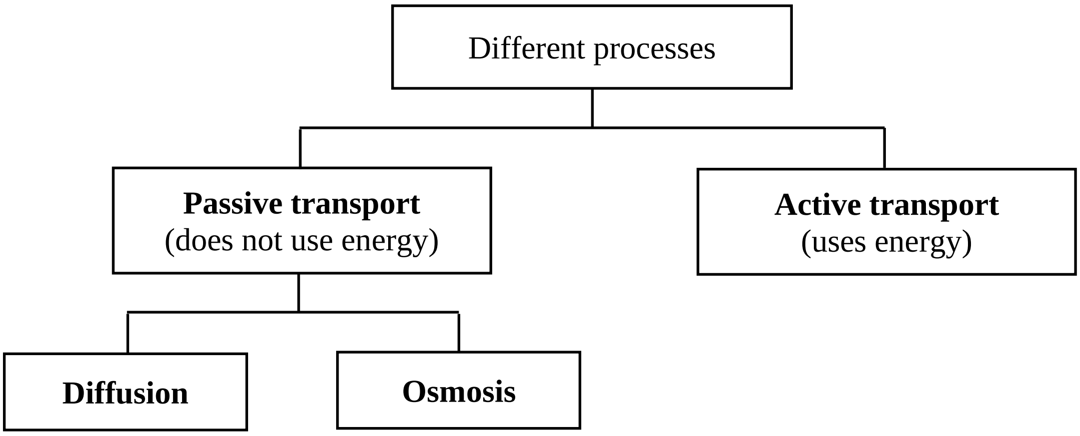
Chapter 3 – Movement of Substances



Definition

Diffusion	Osmosis	Active transport
Movement of substances from region of higher → lower concentration	Movement of water molecules from solution of higher → lower water potential	Movement of particles from region of lower → higher concentration
Does not require membrane	Requires partially permeable membrane	Requires membrane with channel / carrier proteins
• Speed of diffusion decreases as diffusion proceeds • Particles move in all directions but net movement is towards region of lower concentration • Equilibrium is reached when average motions of particles are same in all directions but particles have not stopped moving (dynamic state)	• Continues until ratio of water molecules to solute molecules on both sides of membrane are same • Size of solute particles does not affect osmosis	
• Movement from high → low con. • Energy is not required		• Movement from low → high con. • Energy is required

3.1 Diffusion

Diffusion

net movement of particles (molecules, ions) from region of high → low concentration, down concentration gradient

Concentration gradient

Concentration gradient: difference in concentration between regions

→ the steeper the concentration gradient, the faster the rate of diffusion

Factors affecting rate of diffusion

1. **Temperature**
2. **Concentration gradient**
3. **Ratio of surface area to volume**
4. **Molecular mass** (m_r)
5. **Diffusion distance**

Dynamic equilibrium

- Particles always move about, don't stop even if same number of particles everywhere
- Particles evenly spread, no net change in system

3.2 Osmosis

Osmosis

net movement of water from solution of higher → lower **water potential**, down water potential gradient, through partially permeable membrane

Water potential: measure of tendency of water to move from one place to another

Solution	Concentration	Water potential
Dilute	Low	High
Concentrated	High	Low

Hypotonic, isotonic and hypertonic solutions (osmosis in animal cells)

Type	Two solutions	
	Con.	WP
Hypertonic	High	Low
Isotonic	=	=
Hypotonic	Low	High

Water potential gradient:

- Partially permeable membrane: separates solutions of different water potentials
- Water moves down water potential gradient: high → low

Plant cell

Effect	Water potential of solution	
	higher	lower
Water potential of cell sap	lower	higher
Process	osmosis	
Movement of water (thru ppm)	enter cell sap	leave cell sap
Result	**turgid**	**flaccid / limp**
Vacuole	increase in size	decrease in size
Cytoplasm	pushed against cell wall	shrink away from cell wall
Others	• Cell does not burst – protected by inelastic cell wall • Turgor pressure: pressure exerted by water in vacuole	• Plasmolysis: cytoplasm and cell membrane shrink away from cell wall • Restore plasmolysed cell: place in solution of high water potential

Animal cell

Effect	Water potential of solution	
	Higher (hypotonic)	Lower (hypertonic)
Water potential of cytoplasm	lower	higher
Process	osmosis	
Movement of water (thru ppm)	enter cell	leave cell
Result	**expand** and **burst**	**shrink** and **crenate**

Change in cell

Cell	Water potential	
	Increase	Decrease
Animal cell	Expand & burst	Shrink & cremate
Plant cell	Turgid	Flaccid / limp & plasmolysed

Importance of turgor in plants

Turgor: turgidity of cell with water

- maintain shape of soft tissues → remain firm & erect
- High rate of evaporation of water from cells
  → lose turgidity, plant wilts
- Movements of certain plant parts ← changes in turgor
  → changes in turgor of guard cell: opening of stomata

Plasmolysis: cell become flaccid

- Cells killed if remain plasmolysed for too long
- × add too much fertiliser around roots
  - Soil solution: very concentrated
    → water move out of roots by osmosis
  - Plant wilt
    1. Roots × absorb water
    2. Continued evaporation of water from leaves
- add sufficient water to dilute the soil solution

Why cutting the strips lengthwise causes them to immediately curl outwards?

This is caused by turgor pressure in the cortex cells.

- These cells are prevented from expanding by an outermost cell layer (epidermis). Epidermal cells are prevented from stretching by a cuticle layer.
- The cuticle protects the epidermal cells against water loss.
- Cutting releases the restraint exerted by the epidermis. The cortex expands and causes the strip to curl outwards.

3.3 Surface Area to Volume Ratio

Cell: move nutrients & waste materials across cell surface membrane fast enough to stay alive

- Rate: determined by surfae area to volume ratio
- The greater the area of cell surface membrane per unit volume,
  the faster the rate of diffusion of a substance (for a given concentration gradient)

Cells cannot grow beyond certain size

Increase in surface area,
decrease in surface area to volume ratio,
decrease in rate of movement of substances across cell

Actively growing cells: usually small

- Example: cells in
  (a) root tips
  (b) shoot tips
- Cells grow in size, metabolism slow down
  → stop growing when reach maximum size

Cells adapt to surface area for absorption

Cells: specifically adapted → absorb materials

Cell	Adaptation	Effect
1. **root hair cells**	1) long narrow protrusions	Increase surface area of cell surface membrane
2. **epithelial cells**	2) folds in membrane	

3.4 Active Transport

Active transport

Movement of particles (solutes, ions) from solution of lower → higher concentration, against concentration gradient, through partially permeable membrane

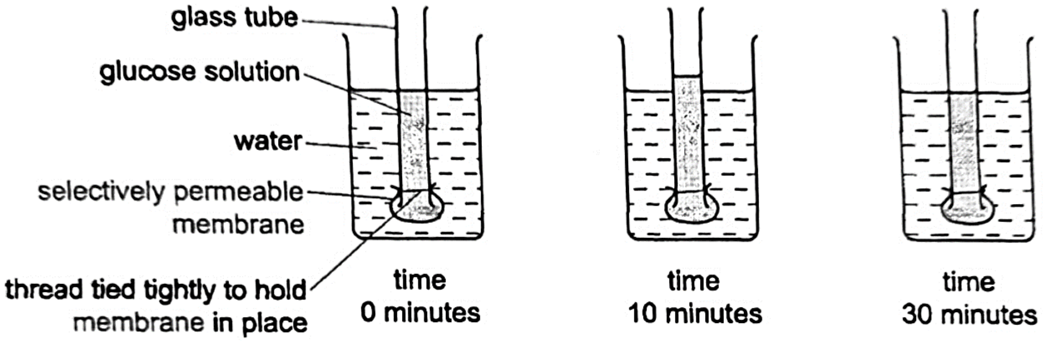
- Occurs only in living cells (living cells respire)
- Respiration: release energy
  → part of the energy: used in active transport
- Example: <u>root hair cell</u>
  - Take in dissolved mineral salts through:
    1. Diffusion
    2. Active transport
  - Mineral salts enter root hair cell – against concentration gradient

Typical questions

Multiple choice questions

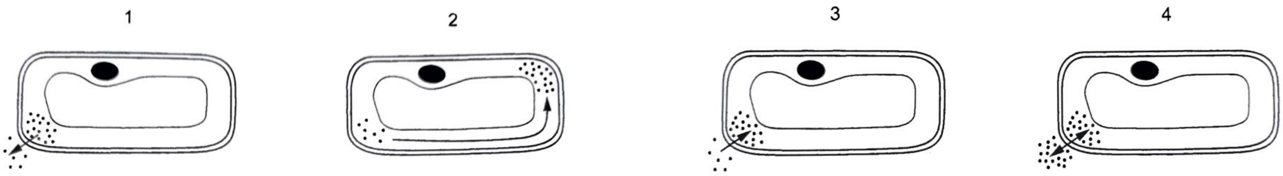
1. What is an example of active transport? (N2011/P1/Q3)
   A movement of ions up the xylem
   B movement of water into root hairs
   C uptake of glucose by cells of villi
   D uptake of oxygen by red blood cells

2. The diagrams show the apparatus used during an investigation. (N2013/P1/Q3)



   What explains the changes in levels?
   A Glucose molecules have diffused against the concentration gradient.
   B The membrane allows only water molecules to diffuse through it.
   C Water molecules diffuse through the membrane more rapidly than glucose molecules.
   D Water molecules have diffused both up and down the concentration gradient.

3. The diagrams show four identical plant cells. (N2016/P1/Q3)
   The dots show the concentration of a chemical. The arrows represent the direction of movement of the chemical.



   Which diagram(s) show a cell where active transport is taking place?
   A 1 and 2
   B 2 and 3
   C 2 and 4
   D 3 only

4. Some processes occurring in organisms are listed. (N2017/P1/Q2)
   ① absorption of glucose by villi
   ② reabsorption of minerals by the kidney
   ③ translocation of sugars in the phloem
   ④ transpiration from the leaves of a plant
   ⑤ uptake of minerals by root hairs
   ⑥ uptake of water by root hairs
   Which processes may involve respiration?
   A 1, 2, 3 and 5
   B 1, 3, 4 and 5
   C 2, 3, 4 and 6
   D 2, 4, 5 and 6

Structured questions

1. (a) Define the terms: [2]

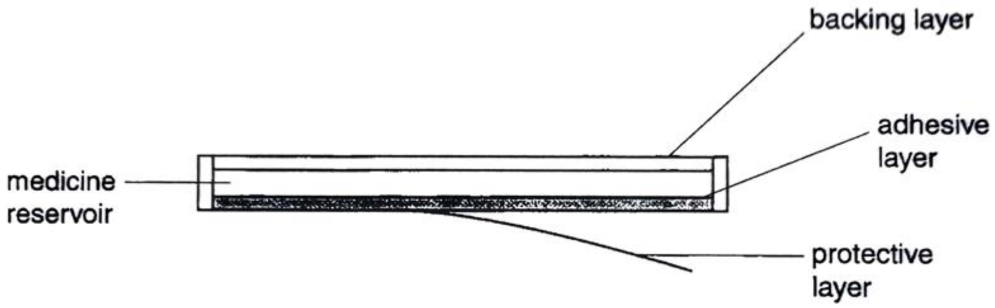
   (i) diffusion

   The movement of substances from a region of higher concentration to a region of lower concentration, down a concentration gradient.

   (ii) osmosis

   The movement of water from a region of higher water potential to a region of lower water potential through a partially permeable membrane.

   (b) Transdermal patches are adhesive patches which are stuck on the skin. The patches contain small amounts of medicines. The inner protective layer is peeled off and the patch is stuck on the skin. The figure below shows a section of transdermal patch with the protective layer being peeled off.



   (i) Suggest how the medicine in the patch reaches the blood stream. [2]

   The medicine in the patch diffuses across the adhesive layer and the skin. It then diffuses across the thin walls of the capillaries and reaches the blood stream.

   (ii) Suggest two advantages of giving medicines using a patch rather than taking medicines through the mouth. [2]

   The patch allows a controlled release of medicine into the blood stream continuously.
   The patch is more convenient than taking medicines through the mouth.

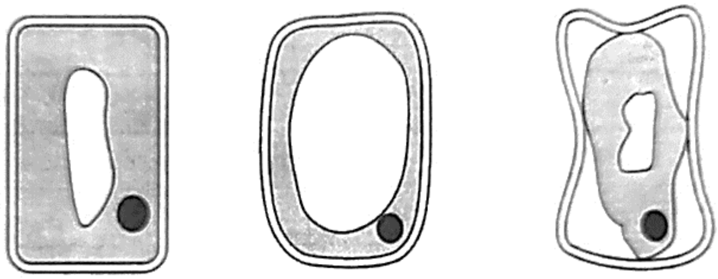
   (iii) Suggest one disadvantage of giving medicines using a patch. [1]

   The patch may cause skin irritation to a patient.

2. (a) There are three ways in which substances move into and out of cells in living organisms.
   Compare these three types of movement of substances. [3]

   In both diffusion and osmosis, substances are moved from a region of higher concentration to a region of lower concentration, down a concentration gradient. However, in active transport, substance are moved from a region of lower concentration to a region of higher concentration, against a concentration gradient.
   Osmosis refers to the movement of water only while diffusion and active transport refer to the movement of other substances.
   Osmosis and active transport require a partially permeable membrane while diffusion does not require a partially permeable membrane.
   Diffusion and osmosis do not require energy to take place while active transport requires energy to take place.
   Active transport only occurs in the presence of oxygen while diffusion and osmosis occur in both the presence and absence of oxygen.

(b) The figure below shows three plant cells A, B and C.
Cells B and C were placed in sugar solutions of different concentrations for 30 minutes.
Cell A shows the appearance of the cells before they were placed in sugar solutions.



(i) Explain the changes that have occurred in cells B and C in the above figure. [2]

Cell B:
Cell B was placed in a sugar solution of lower concentration. Water moved from the sugar solution down the water potential gradient.

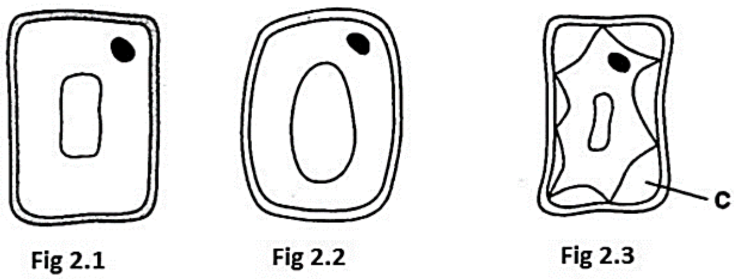
(ii) State which one of the three cells A, B and C is turgid. [2]

Cell B

(iii) Root hair cells have a high ion concentration.
Explain how this is maintained and its importance. [2]

Root hair cells absorb water and mineral salts from the surrounding soil solution for the plant. They contain many mitochondria, which carry out aerobic respiration for the active transport of ions into the cells. Thus, the cell sap in their vacuoles has a high ion concentration.
The cell membrane of the root hair cells prevents the cell ap from moving out.
The root hair cells constantly maintain a low water potential relative to the surrounding soil solution, so that water can constantly move into them through osmosis.

3. Fig. 2.1 shows a typical plant cell. Fig. 2.2 shows the same cell after it had been placed in solution A for ten minutes. The cell was then transferred to solution B and Fig. 2.3 shows how it appeared after a further ten minutes. (N2003/2A/1)



(a) Explain what caused the cell to appear as it does in Fig. 2.2. [3]

Solution (A) has a higher water potential than the cell sap of the cell [1]
Water molecules entered the cell by osmosis across a partially permeable membrane. [1]
Vacuole increases in size and pushes cytoplasm against the inelastic cell wall. The plant cell appears turgid [1]

(b) When a small eraser was placed on the cell shown in Fig 2.2, the cell did not collapse but remained firm to support the eraser. Explain why. [1]

<u>The cell sap in the expanding vacuole exerts a pressure (turgor pressure) or pushes cytoplasm against the inelastic cell wall. [1] This supports the eraser and prevents the cell from collapsing.</u>

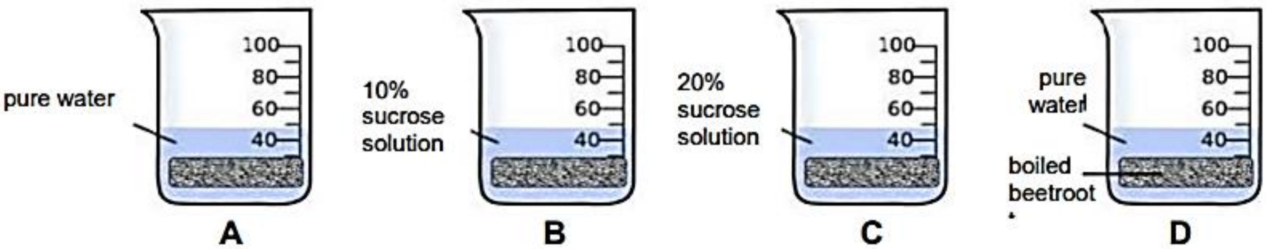
(c) Compare the water potential of solution A and B with the water potential of the cell sap of the cell. [2]

solution A: <u>has a higher water potential than the cell sap of the cell [1]</u>
solution B: <u>has a lower water potential than the cell sap of the cell [1]</u>

(d) At the end of the experiment, state what will be found in region C in Fig. 2.3. Explain your answer. [2]

<u>Solution B. [1]</u>
<u>The cell wall is fully permeable and this allows movement of both the water molecules and solute molecules in solution B into region C. [1]</u>

4. Three identical strips of washed beetroot were weighed and placed in three containers containing water or solutions of different sucrose concentrations.
A fourth strip was boiled and placed in pure water.
The figure below shows the apparatus used in the investigation.



After 12 hours, the strips were removed, carefully blotted dry and reweighed.

(a) (i) State, in which beaker, the strip of beetroot would have gained the most mass. [1]

Beaker A

(a) (ii) Explain why. [2]

<u>Steepest water potential gradient between cell sap of beetroot cells and surrounding solution in beaker A. [1]</u>
<u>Highest rate of osmosis + water molecules enter beetroot cell [1]</u>

(b) (i) The cells of the beetroot contain a purple pigment. Describe what happened to the cells of the beetroot after boiling. [1]

<u>Heat from boiling destroyed the cell membrane of beetroot cells. [1]</u>

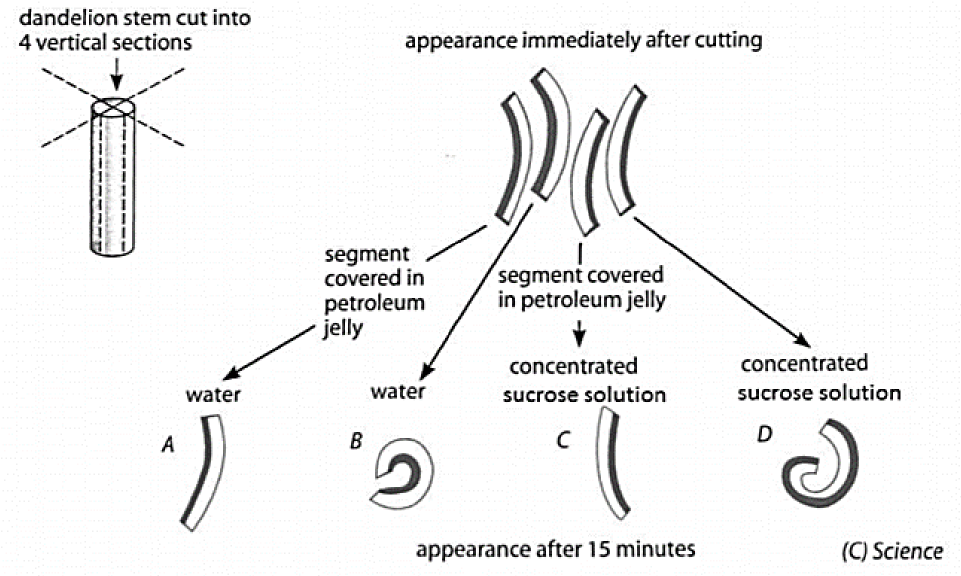
(b) (ii) Explain why the water in beaker D became purple after some time. [1]

<u>Purple pigment in beetroot cell diffuses into the water. [1]</u>

(c) After 12 hours, the mass of the strip of beetroot in beaker B remained unchanged. Explain why. [2]

<u>Cell sap of beetroot cell has the same water potential as the 10% sucrose solution. [1]</u>
<u>No osmosis / no net movement of water molecules. [1]</u>

5. The figure below shows an experiment using a freshly picked dandelion stem. The heavy black lines on the segment represent the outer epidermal layer that are inelastic, while the white regions refer to the stalk's thin-walled cortical layer.



Study the figure and answer the following questions.

(a) Explain why the pieces of stem all curved immediately after cutting. [2]

There is a release of tension in the cortical layer upon cutting + expansion of cortical layer. [1]
The epidermal layer, which is next to the inelastic cuticle is restricted from expanding as much as the cortical layer, [1]
leading to the cortical layer bending over the epidermal layer upon cutting.

(b) Describe and explain the appearance of the pieces in water or concentrated sucrose solution after 15 minutes. [3]

WATER:
As water has a higher water potential than the cell sap of both the cortical and epidermal cells, water molecules move into the cells by osmosis, through a partially permeable membrane. [1]
Describe: Cortical layer bends over the epidermal layer. [1]
Explain: - Cortical cells expand more than the epidermal cells as inelastic cuticle on epidermal layer causes reduced expansion of the epidermal cells. [1]

SUCROSE SOLUTION:
As the concentrated sucrose solution has a lower water potential than the cell sap of the cells, water molecules move from the cells into the surrounding solution by osmosis, through a partially permeable membrane. [1]
Describe: Epidermal layer bends over the cortical layer. [1]
Explain: - The inelastic cuticle reduces shrinking of the epidermal cells than cortical cells. [1]

6. An experiment was carried out to determine the changes in a plant cell when it was placed in solution X and then transferred to solution Y. The two solutions had different water potentials. Diagram A shows the cell in its original state, diagram B shows the cell eight minutes after it was placed in solution X, and diagram X shows the cell after it had been in solution Y for eight minutes.

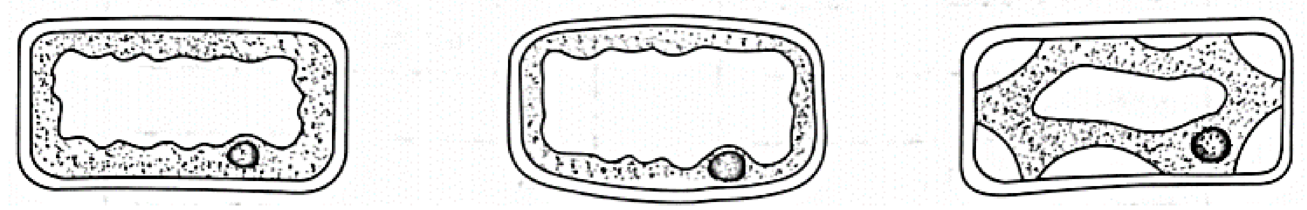


Diagram A   Diagram B   Diagram C

(a) Name the state of the cell in diagrams B and C. [2]

Diagram B: cell is turgid
Diagram C: cell is plasmolysed

(b) Name the process that caused the states observed in (a). Explain how the following process caused these states. [4]

Osmosis.
When the cell is placed into solution X of higher water potential, water molecules pass through the partially permeable cell surface membrane, entering the cell sap through osmosis. The cell expands and becomes turgid.
When the cell is placed into solution Y of lower water potential, water molecules pass through the partially permeable cell surface membrane, leaving the cell sap through osmosis. The cell becomes flaccid and eventually plasmolysed.

(c) How does the cell wall keep the cell intact? [2]

The cellulose from the cell wall is rigid and inelastic.
When the plant cell becomes turgid, the cell wall prevents over-expansion of the cell by exerting an opposing pressure as water enters the cell. This prevents the entry of more water, which might burst the cell.

(d) Describe what will happen to an animal cell if it is placed in solutions Y and then X. [2]

The cell shrinks and cremates, then expands and eventually bursts.