TRANSPORT IN PLANTS

S.2 TRANSPORT IN PLANTS: SLIDES PREPARED BY TR. EGABILE ALFRED 0786612648

Competency

The learner appreciates how substances enter and exit from cells and knows the transport processes in plants, the structures involved, and their functions.

Learning outcomes

The learner should be able to:

a) understand the importance and key methods of movement of materials into and out of cells.

b) investigate the different ways in which materials move into, though, and out of cells.

c) know how the root hair is adopted for absorption of water and mineral salts.

d) understand the processes of transpiration and translocation.

e) conduct experiments on and understand the factors that affect transpiration.

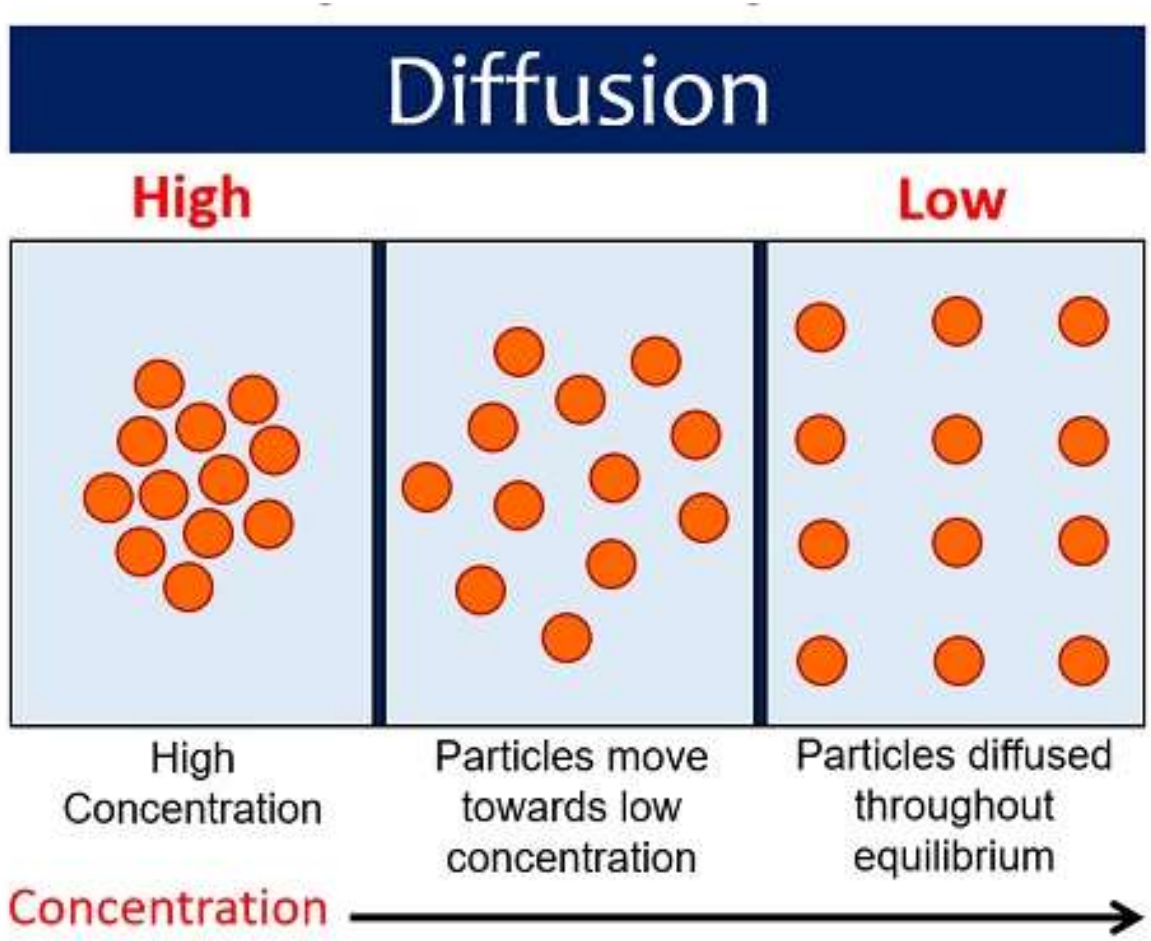
Introduction

- Cells need food materials which they can use for energy or use to build up their cell structures.
- They also need salts and water, which play a part in chemical reactions in the cell.
- Cells also need to get rid of substances such as carbon dioxide, which, if they accumulated in the cell, would upset some of the chemical reactions or even poison the cell.
- Substances may pass through the cell membrane either passively by **diffusion** , **osmosis** or actively by some form of **active transport**.

DIFFUSION

Diffusion

Is the movement of molecules and ions from a region of their higher concentration to a region of their lower concentration down a concentration gradient, as a result of their random movement.



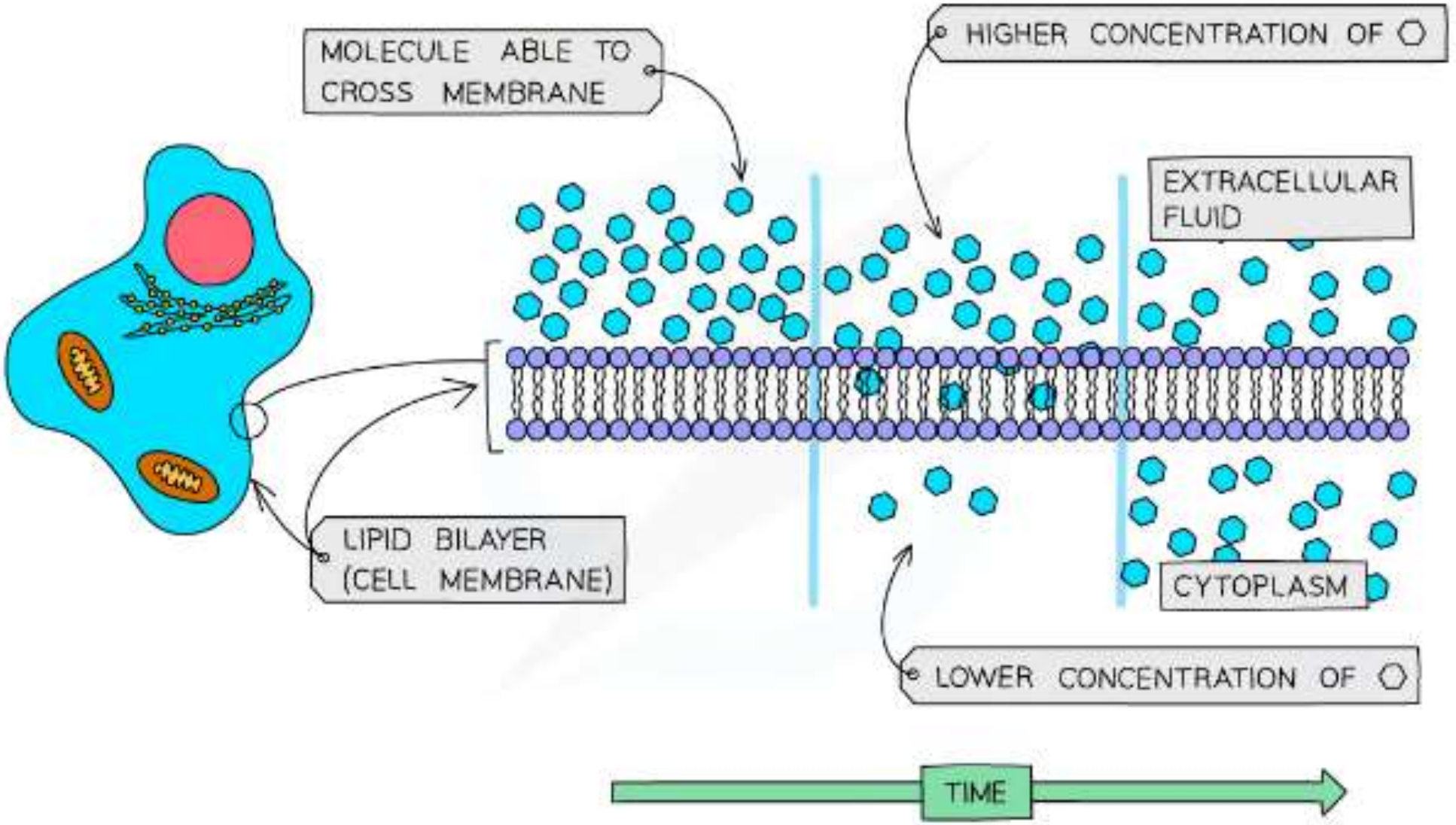
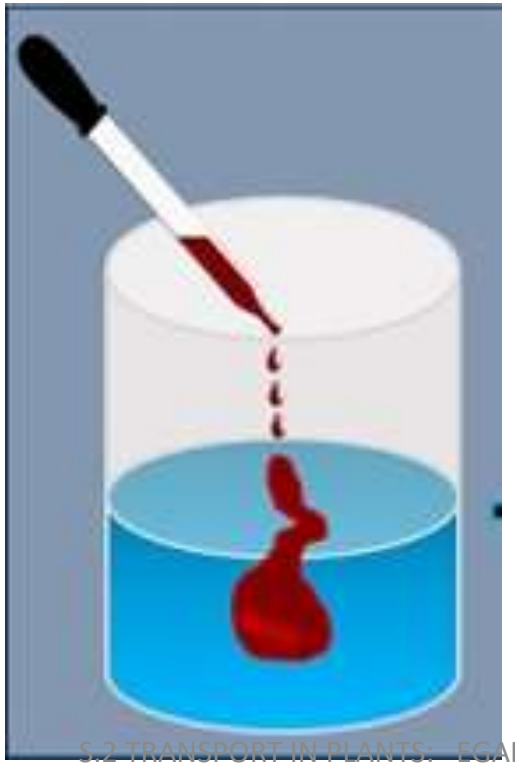

MOLECULE ABLE TO CROSS MEMBRANE
HIGHER CONCENTRATION OF
EXTRACELLULAR FLUID
LIPID BILAYER (CELL MEMBRANE)
CYTOPLASM
LOWER CONCENTRATION OF
TIME

Illustration of *diffusion* using food coloring Experiment

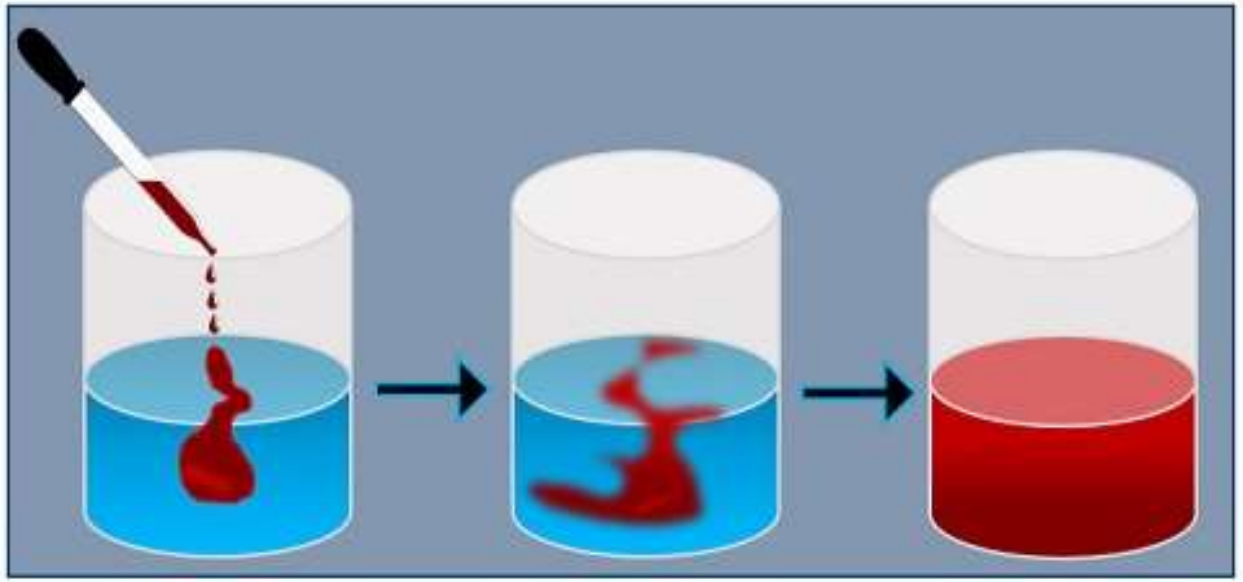
- If drops of food coloring are added into the beaker containing water. What do you thing would happen???



Expected response

- First, the **food coloring** (solute) initially concentrates on the top area.
- The **water** (solvent) in the beaker around it has a low concentration of food coloring.
- After a while, the food coloring spreads from the region of high concentration into the area of low concentration, turning the whole solution **red**.
- Finally, **diffusion stops** because the region with a high concentration of food colouring will be no longer.

Illustration



Illustrating diffusion using tea bags

- If one puts a tea bag into a cup of hot water, the contents of the tea will mix within the water.
- The colour from the tea leaves will diffuse from its higher concentration (tea bag) to the lower concentration (water in the cup).
- When you take out the tea bag, you will see that the water turns black-red due to diffusion.

Factors that affect the rate of diffusion

The rate of diffusion in an organism can be affected by the surface area, diffusion distance, concentration gradient and temperature

Surface area

- The smaller the surface area, the slower the rate of diffusion and the larger the surface area the faster the rate of diffusion. This is because the membrane will have many entry points for particles` to pass.
- some structure are tiny and numerous so as to increase their surface area- e.g. root hair cells in plants (which absorb water and mineral ions) and cells lining the ileum in animals (which absorb the products of digestion)

Diffusion distance

- The smaller the distance molecules have to travel the faster transport will occur.
- This is why blood capillaries and alveoli have walls which are only one cell thick to ensure the rate of diffusion across them is as fast as possible

Concentration gradient

- The greater the difference in concentration on either side of the membrane, the **faster** the movement across it will occur.
- This is because on the side with the higher concentration, more random collisions against the membrane will occur.

Temperature

- The higher the temperature, the faster the rate of diffusion since at high temperature, the particles have higher kinetic (movement) energy and they will move and spread faster.

Examples (importance) of in living organisms

- In the small intestine where by the products of digested food such a glucose and amino acids move from lumen of small intestine to the blood capillaries in the villi.
- In the leaves where carbondioxide moves from the air spaces between mesophyll cells into the chloroplasts in mesophyll or palisade cells for photosynthesis.
- In the leaves where oxygen moves from the air spaces between mesophyll cells into the mitochondria in mesophyll cells for respiration.

- In the lungs where carbondioxide moves from blood in to the lungs for removal out of the body.
- In the lungs where oxygen moves from the lungs into the blood to be used for aerobic respiration in the cells.

2.OSMOSIS

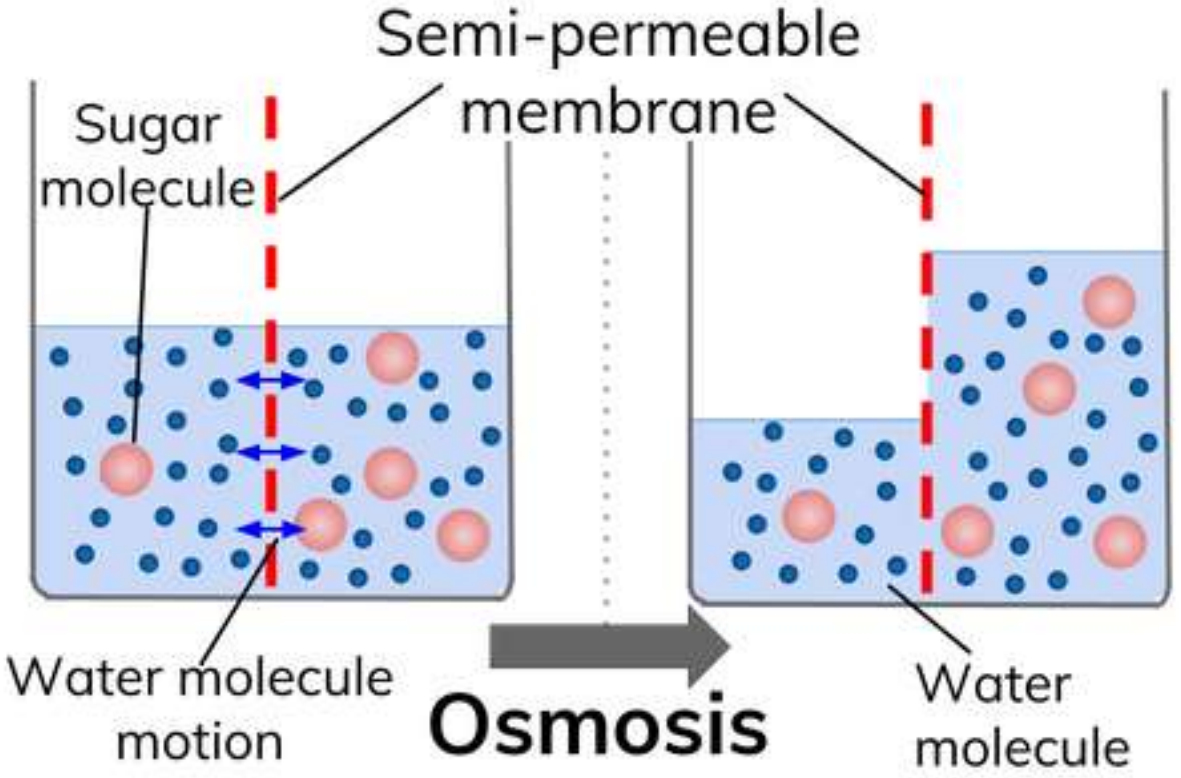
Definition: Osmosis is the process that involves the net movement of water molecules from a region of higher concentration (dilute solution) to a region of lower concentration (concentrated solution)across a semi-permeable membrane.

Or: Osmosis is the diffusion of water across a semi- permeable membrane from a dilute solution (high concentration of water) to a concentrated solution (low concentration of water).

- **A semi-permeable membrane** allows water through, but can not allow larger molecules dissolved in water pass through.

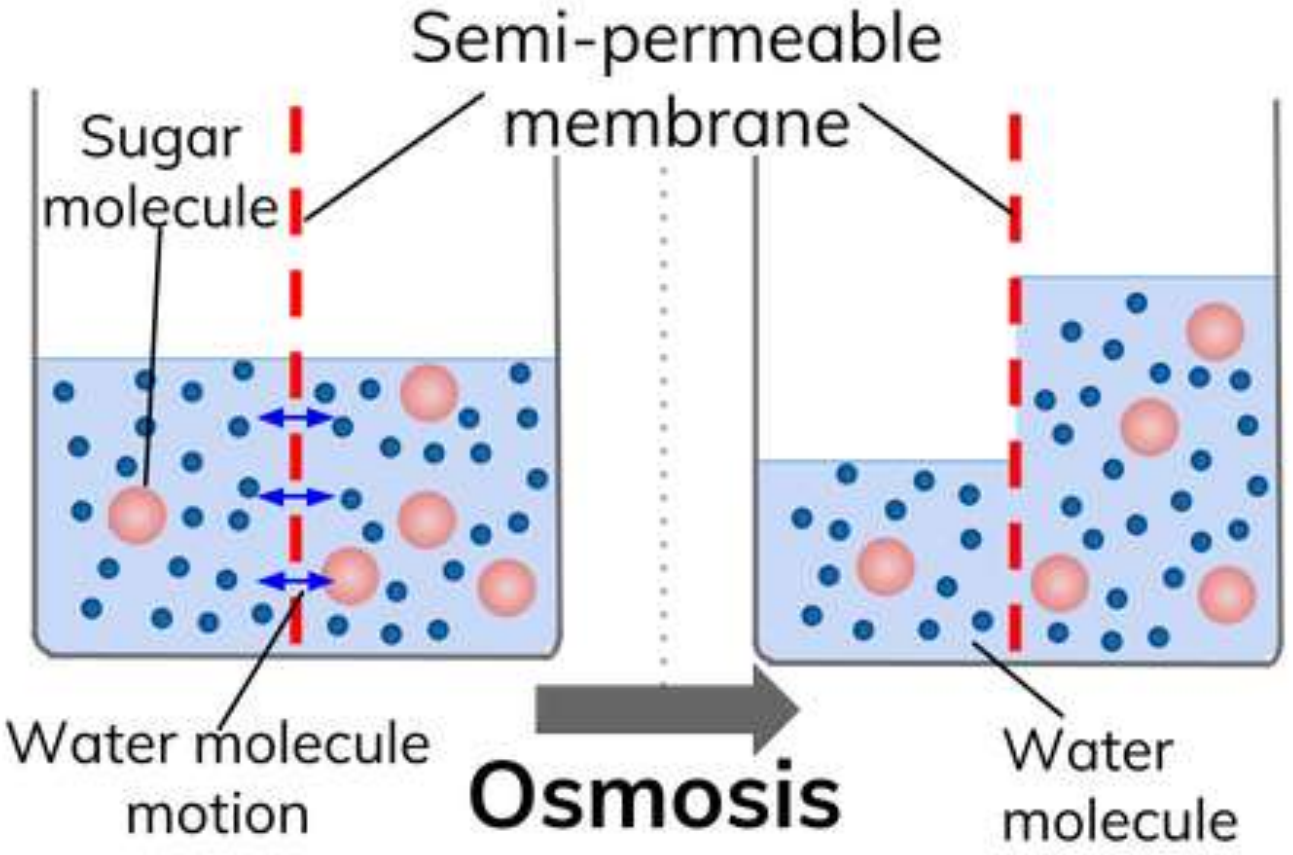
Note: osmosis strictly involves movement of **ONLY** water molecules and **NOT** any other substance.

- In the diagram, the concentration of sugar is initially higher on the right side of the membrane.
- Therefore, water moves by osmosis to the right hand side to equalize. the concentrations.



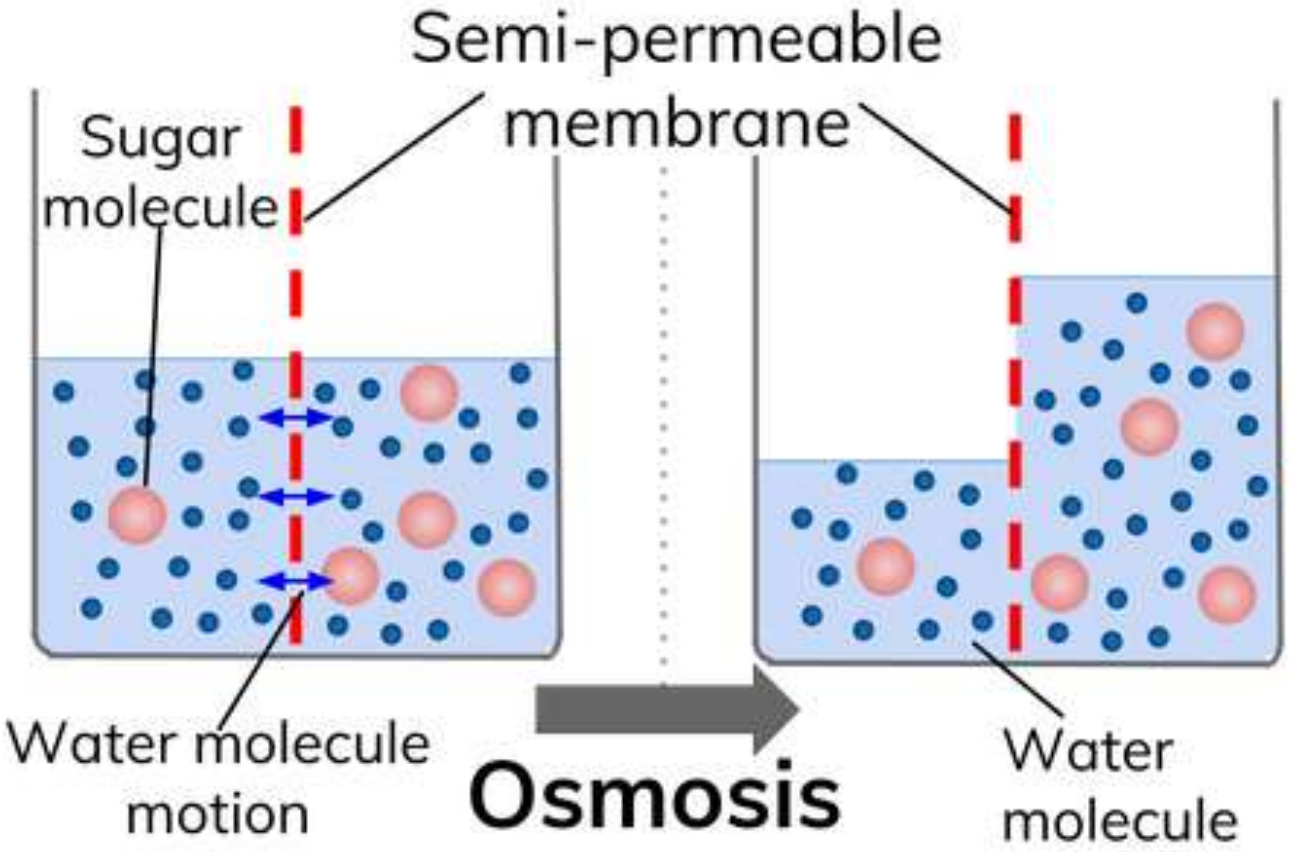
Water movement

- Water will move to make the concentrations the same on both sides of the membrane:
- When there are lots of water molecules (in a dilute solution) on one side of a semi- permeable membrane, but not many on the other side (in a concentrated solution), water will move from the dilute to the concentrated solution.



Net movement of water

- It is important to remember that water molecules will move through the membrane in both directions, but the net (overall) movement of water will be from the dilute solutic to a concentrated solution.



Terms used in osmosis

Hypotonic solution: This is a solution containing less solute and more water molecules compared to another. A hypotonic solution is less concentrated.

Isotonic solution: This is a solution with the same concentration of solutes and water compared to another.

Hypertonic solution: This is a solution with more solutes and less water molecules than the other. A hypertonic solution is more concentrated.

Turgid - cells are described as turgid when they are swollen due to a high-water content.

Turgor pressure - The pressure on the cell wall from the cell membrane pushing upon it. This is a result of the cell becoming turgid as water moves into the cell via osmosis.

Flaccid - Occurs when water moves out of the cell via osmosis. The cell shrinks but the cell membrane does not peel away from the cell wall. If more water leaves the cell, it becomes plasmolyzed.

Plasmolysis - Occurs when there is too little water in cells. In plant cells, the cell membrane peels away from the cell wall.

Water potential. a term that quantifies the tendency of water to move from one area to another due to osmosis.

How osmosis differs from diffusion

osmosis	Diffusion
Involves only the movement of water molecules	Involves the movement of water ions, gases, ions, molecules etc
Requires a semi-permeable membrane	Does not require a semi-permeable membrane

Reaction of the cells in different types of solution

Types of solution	Concentration as compared to cell sap	Movement of water in the cell
Hypotonic	More dilute than cell sap Higher water potential than cell	Water flows into the cell Cell become turgid
Isotonic	Same concentration as cell sap Zero water potential	No net flow of water Cell becomes flaccid
Hypertonic solution	Concentration of solutes is higher outside the cell Lower water potential than cell	Water flows out of the cell Cell becomes Plasmolysed

- When the cell is more concentrated than the surrounding cells, water molecules diffuse into the cell via osmosis, making it turgid.
- When it is less concentrated than the surrounding cells, water molecules will leave the cell, making it flaccid and leading to plasmolysis.
- This effect can be investigated by placing cells in solutions of different concentrations.

Investigating osmosis in chicken's eggs

Aim

To investigate the effect of different concentrations of sodium chloride solution on raw un-shelled egg.

Hypothesis

As the concentration of sodium chloride solution increases, the mass of the raw un-shelled egg will decrease due to the loss of water molecules from the eggs by osmosis.

Variables

Independent variable. Concentration of sodium chloride solution.

Dependent variable. Mass of the raw un-shelled egg

Control variable. Size of the egg

Materials

- Paper towel
- Three 200 cm^3 plastic beakers
- Weighing balance
- Three de-shelled eggs
- Sodium chloride solutions in a range of concentration 0%, 10%, 20%. (150 cm^3 of each concentration)

Procedure

- Ensure the de-shelled eggs are dry by gently drying it with a paper towel.
- Place the eggs on a weighing balance and record the mass in a suitable table.
- Put the eggs in each of the 200 cm^3 plastic beakers labelled **A, B** and **C**.
- Pour in 150 cm^3 of sodium chloride solution to cover the egg in the beakers A, B and C. Record the concentrations of sodium chloride used.
- Leave the eggs in the sodium chloride solution for 24 hours.

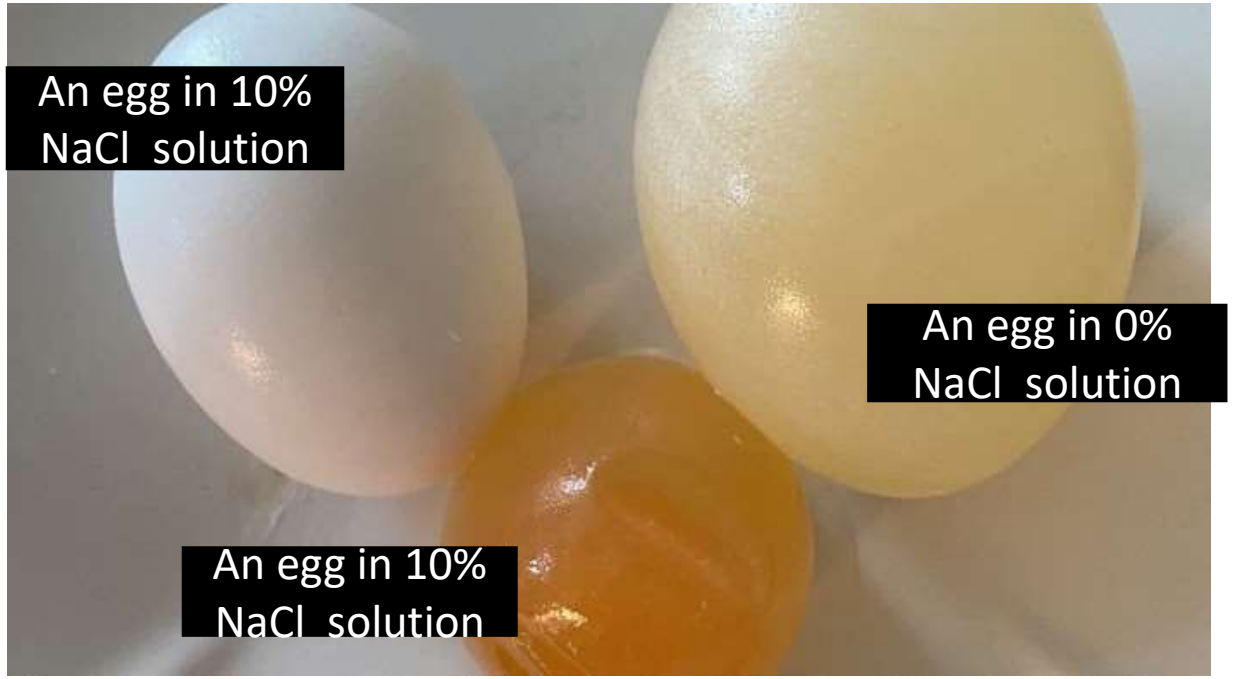
- Pour the sodium chloride solutions in each of the beakers off the egg.
- Dry the egg carefully using a paper towel.
- Place the egg on the balance and record the mass in the table.
- Calculate change in mass and percentage change in mass.
- Compare the results for the different concentrations of sodium chloride

Result *(carryout the experiment in your laboratory and fill your results in the table below)*

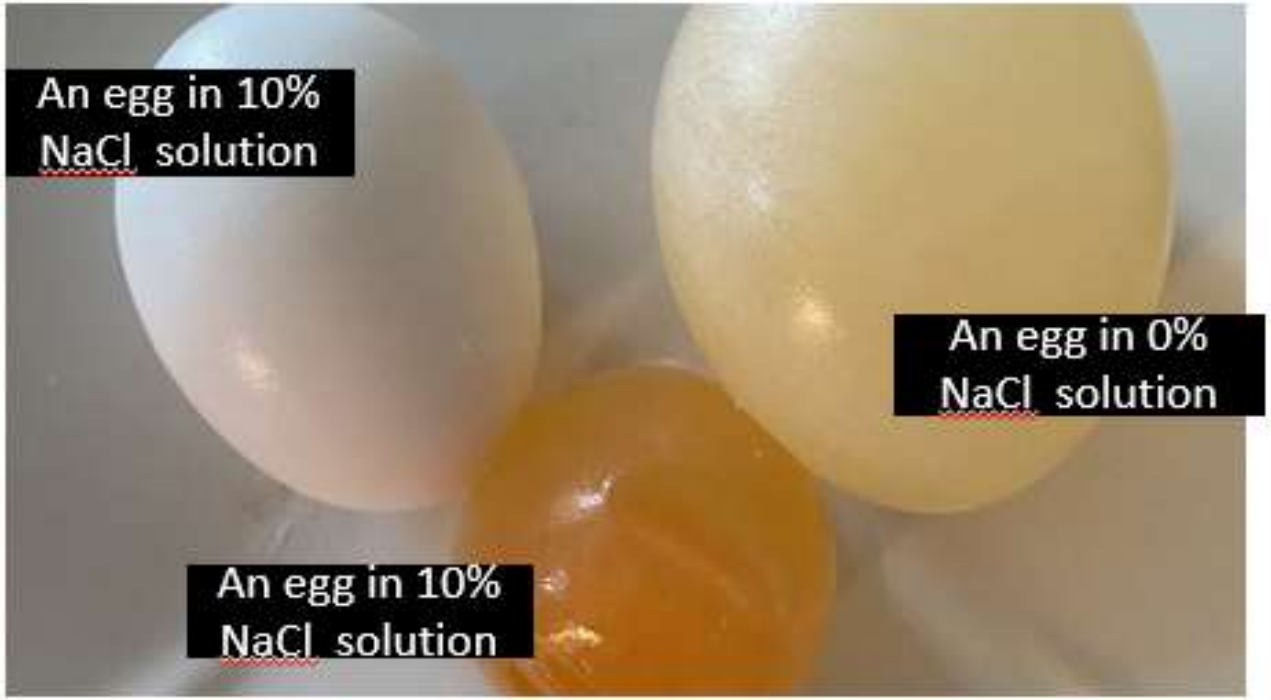
Beaker	Concentration of Sodium chloride solution (%)	Initial mass of the egg (g)	Final mass of the egg (g)	Change in mass of the egg (g)	Percentage change in mass of the egg
A	0				
B	10				
C	20				

Observation and explanation

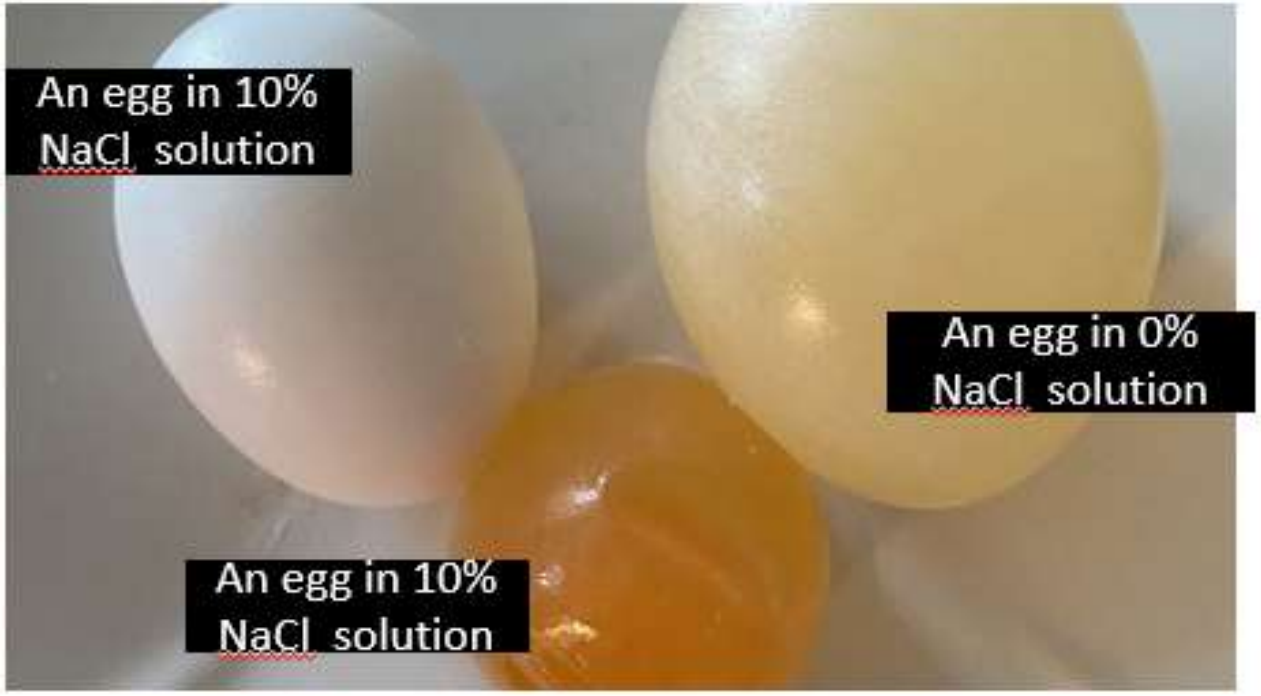
- The egg in 20% sodium chloride has lost mass.
- This is because the concentration of solutes inside the egg membrane is less than 20% sodium chloride, so water has diffused out through the semi- permeable egg membrane by osmosis.
- Therefore, the 20% sodium chloride is a hypertonic solution



- The egg in 0% sodium chloride has gained mass.
- This is because the concentration of solutes inside the egg membrane is more than that of 0% sodium chloride, so water has diffused in through the semi- permeable egg membrane by osmosis.
- Therefore, the 0% sodium chloride is a hypotonic solution



- The egg in 10% sodium chloride has not gained a significant mass.
- This is because the concentration of solutes inside the egg membrane is equal to that of 10% sodium chloride, so was no net movement of water through the semi- permeable egg membrane by osmosis.
- Therefore, the 10% sodium chloride is a isotonic solution.



*Conclusio*n

- As the concentration of sodium chloride increased, the mass of the egg decreased, indicating the movement of water through the semi-permeable membrane of the egg due to osmosis

Examples (importance) of osmosis in living organisms

In plants

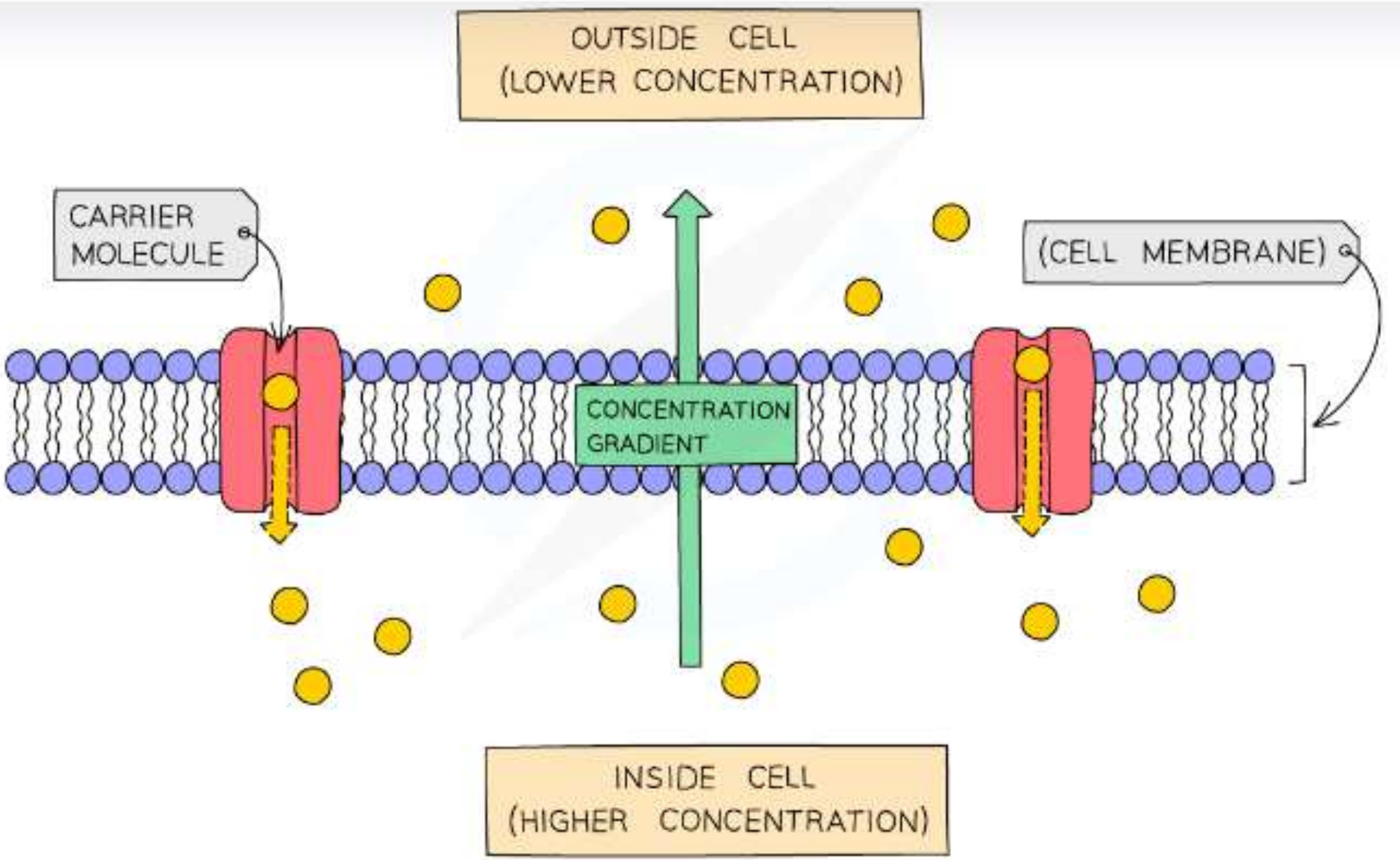
- Absorption of water by root hairs from soil.
- It enhances movement of water from root hairs via the cortex to the xylem.
- In germination, the initial absorption of water is by osmosis
- It brings about support in non- woody plants as their cells take up water and become turgid.
- It facilitates opening and closing of stomata due to changes in turgidity.

In animals

- It enables movement of water to capillaries in villi.
- Movement of water from tissue fluid into the cell.
- It enables reabsorption of water into the blood stream in the kidney tubules.

Active transport

- Active transport is the movement of particles through a cell membrane from a region of **lower concentration** to a region of **higher concentration** using **energy from respiration.**
- Energy is needed because particles are being moved **against a concentration gradient**, in the opposite direction from which they would naturally move (by diffusion)
- Active transport is a vital process for the movement of molecules or ions across membranes


OUTSIDE CELL
(LOWER CONCENTRATION)
CARRIER
MOLECULE
(CELL MEMBRANE)
CONCENTRATION
GRADIENT
INSIDE CELL
(HIGHER CONCENTRATION)

Importance of active transport

- Active transport is a vital process for the movement of molecules or ions across membranes which include the following.

➢ **Uptake of glucose** by epithelial cells in the villi of the small intestine.

➢ **Selective reabsorption** of mineral ions by kidney tubules in the nephron

➢ **Uptake of mineral ions** from soil water by root hair cells in plants

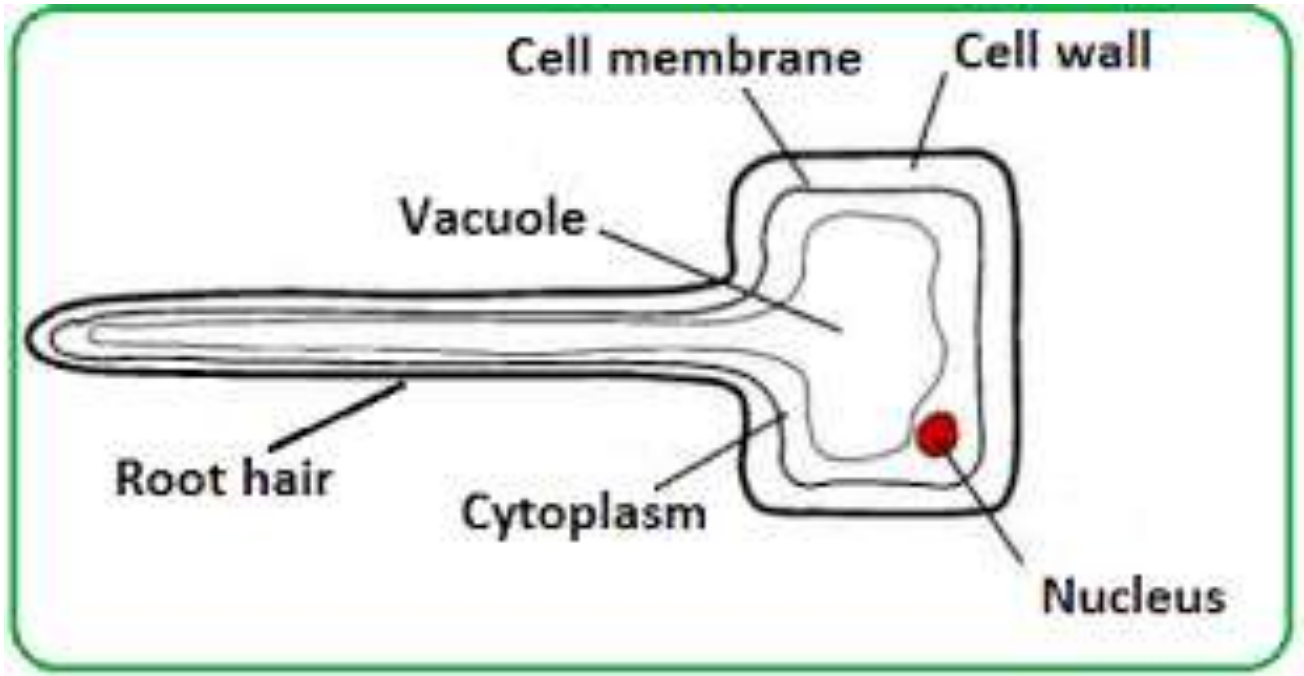
Absorption of water and mineral salts in plant

- Water and mineral salts are absorbed from the soil into the plant by roots.
- The region of the root responsible for water absorption is the root hair.

Root hair

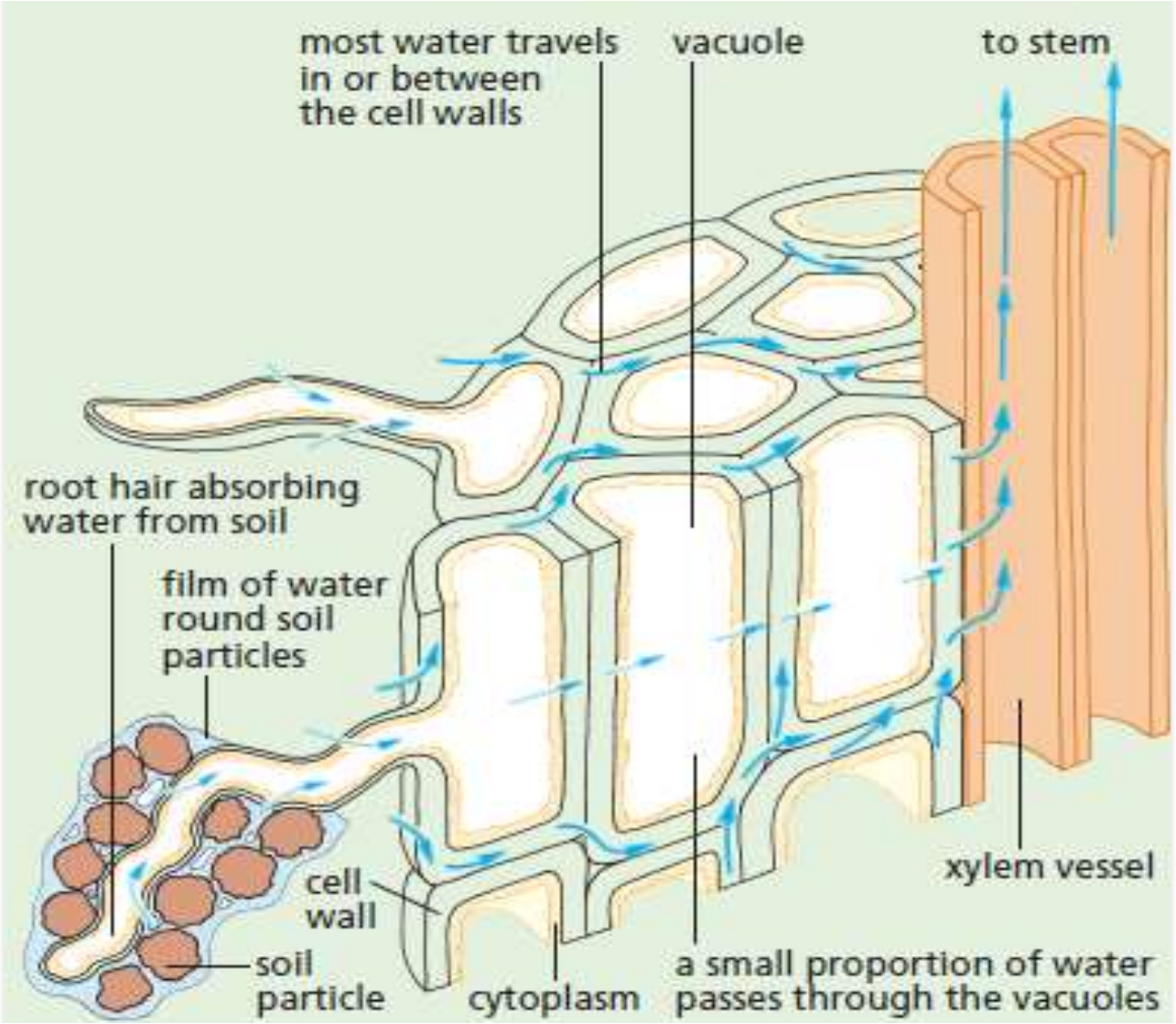
Internal structure of the root hair

- The root hair is made up of slender and flexible cells surrounded by a thin permeable membrane. The membrane surrounds a concentrated cell sap containing a lot of mitochondria.



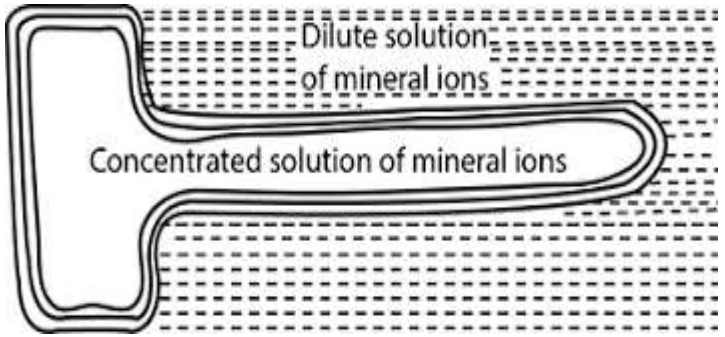
How plants absorb water

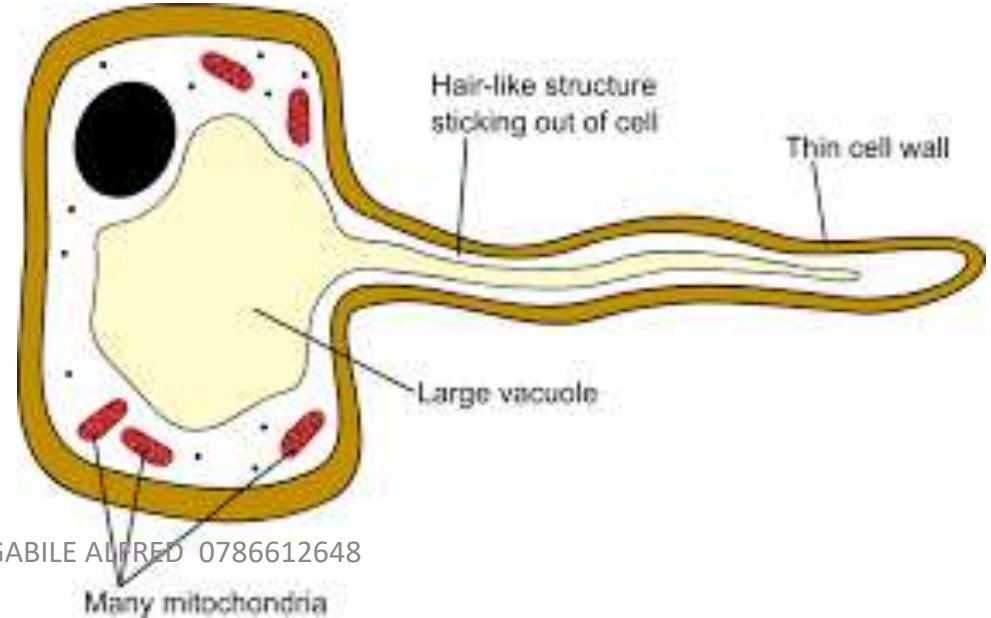
- Water enters the root hairs by osmosis.
- Water passes across the cortex cells of a root to the xylem by osmosis.
- Water is drawn up in the xylem to the stem by root pressure and transpiration pull.



Adaptations of root hairs to their functions

- They have a thin membrane to reduce on the **diffusion** distance of water into the root hairs
- They are very many to offer maximum surface area for absorption of water
- The roots have a concentrated cell sap to maintain a high **osmotic** gradient
- They are very slender and flexible to penetrate any area in the soil so as to obtain water
- They have many mitochondria in their cytoplasm which release energy in form of ATP for **active transport** of materials





TRANSPIRATION

Transpiration is the loss of water vapor from the aerial parts of a plant, mainly through the stomata on the leaves.

- Water helps maintain plant structure by keeping cells turgid.
- If the plant loses too much water which is not replaced, it begins to wilt as water moves out of cells and turgor pressure decreases
- Transpiration can mainly occurs through the stomata on the leaves , however, plants can also lose water transpire through lenticels in the stem and cuticles.

How the process of transpiration occurs

- Water loss occurs at the plant's leaf surface.
- Root hairs absorb water from the soil, and the water moves through the cortex of the root by osmosis until it reaches the xylem vessels in the stem.
- Water moves upward through xylem vessels by processes such as transpiration pull and root pressure.
- Formation of water channels in xylem occurs due to adhesion and cohesion forces.
- Water reaches leaves through xylem, where pores on the leaves called stomata are present.
- Water diffuses out of the stomata of the leaves in form of water vapor

Note

Any process that affects the stems and leaves e.g., destruction by animals, fire, harvesting for medicinal purposes reduce the rate of transpiration due to destruction of the xylem vessels in the roots and stomata on the leaves.

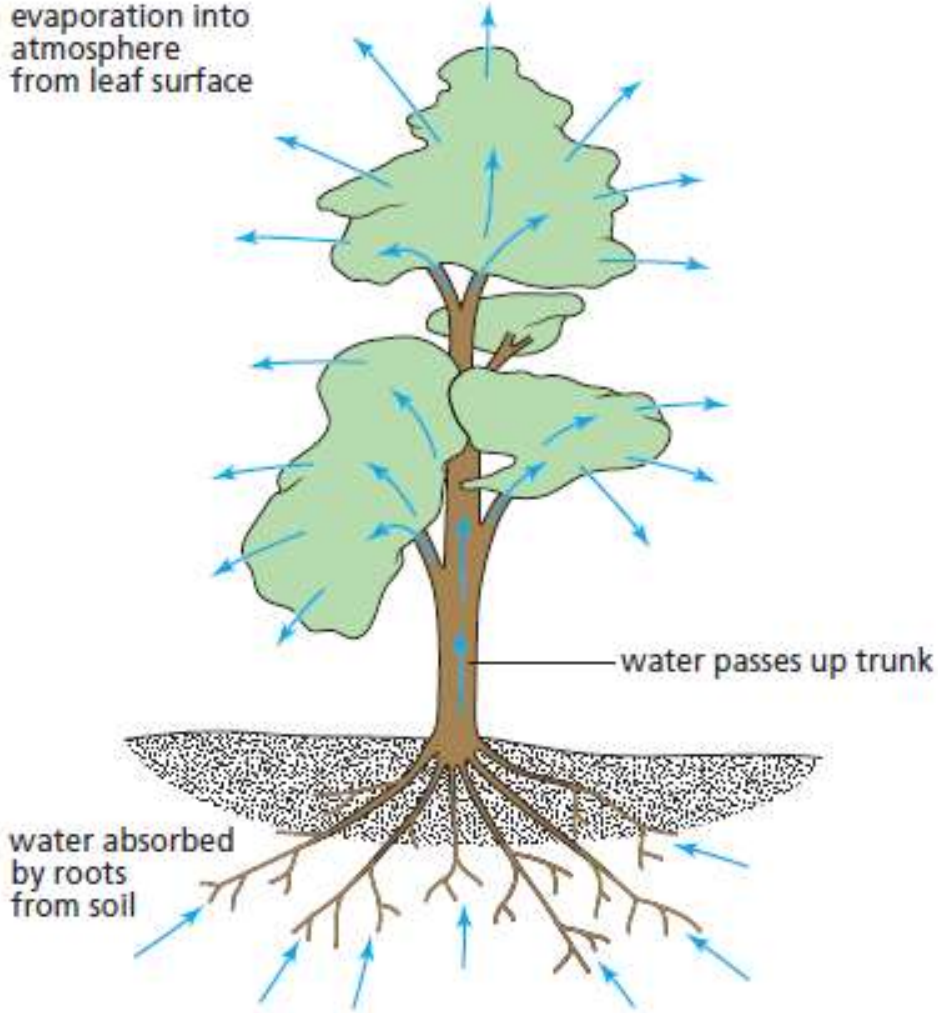


Figure 8.13 The transpiration stream

Experiments on the factors that affect the rate of transpiration

- The effect of environmental factors on the rate of transpiration in plants can be measured using a piece of equipment called a potometer.
- Bubble potometers are commonly used and they measure the movement of an air bubble along a water-filled tube connected to a plant shoot as water is drawn up by the shoot.
- The position of the air bubble is recorded at the start of an experiment, and then one can either measure how far the bubble moves in a set amount of time, or time how long it takes for the bubble to move a certain distance.

- The effects of **various environmental factors** on transpiration can be measured by placing the potometer in different conditions e.g.
  - Wind
  - Light intensity
  - Temperature

Investigating the effect of light intensity on the rate of transpiration

Aim : *to Investigate the effect of light intensity on the rate of transpiration*

Hypothesis: *As the light intensity increases, the rate of transpiration in the plant will also increase*.

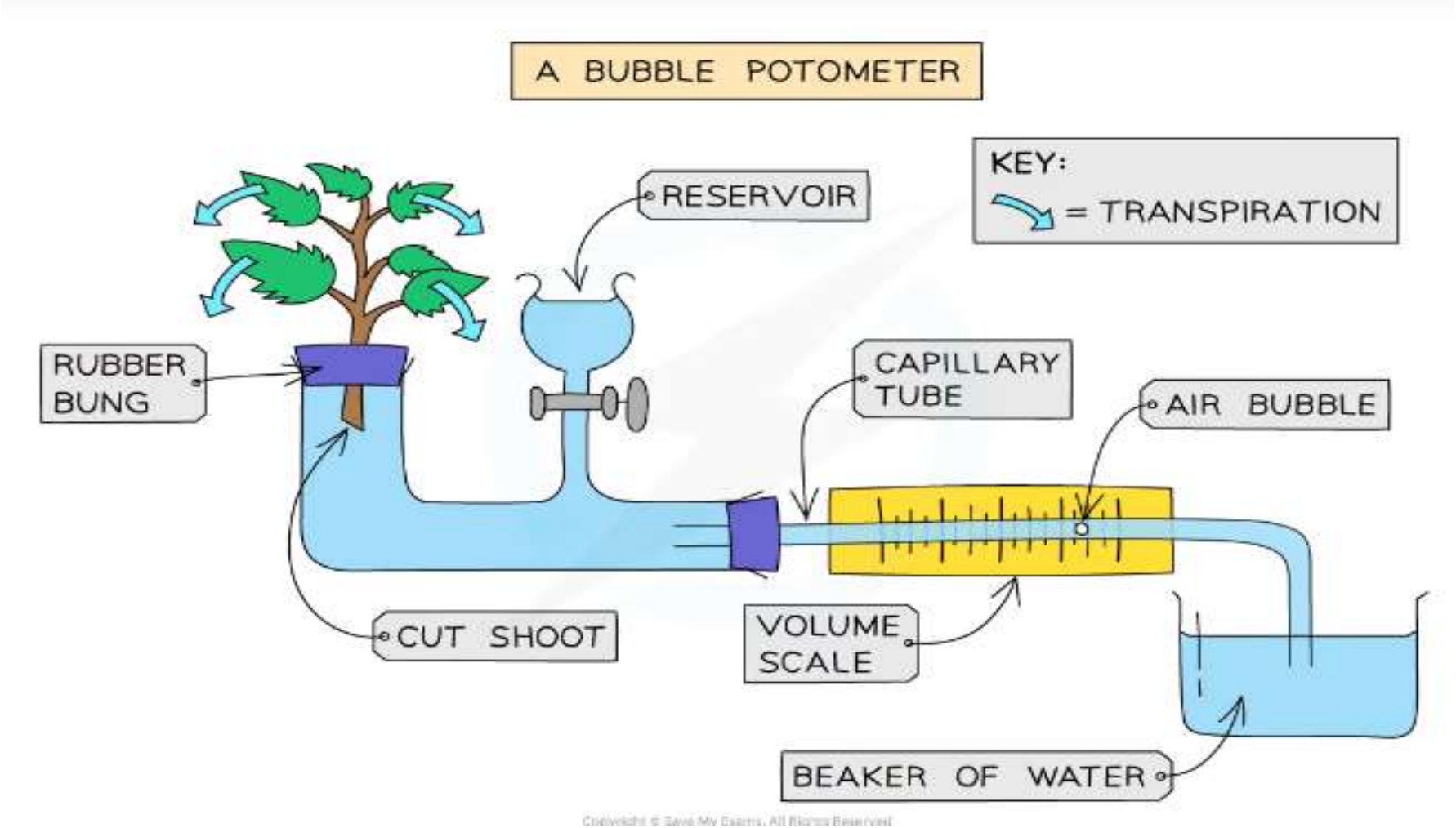
Variables:

- Dependent Variable: rate of transpiration.
- Independent Variable: light intensity.
- Control Variable**:** temperature, type of plant, size of leaf etc.

Materials

- Leafy plant shoot
- Scissors/ knife
- Paper towels/ tissue paper
- Potometer
- Volume scale
- Beaker
- Capillary tube
- Stopwatch
- Vaseline

Set up


A BUBBLE POTOMETER
KEY:
= TRANSPIRATION
RESERVOIR
RUBBER BUNG
CAPILLARY TUBE
AIR BUBBLE
CUT SHOOT
VOLUME SCALE
BEAKER OF WATER

Procedure

- Cut a Leafy plant shoot **underwater using knife**. This is done to **prevent air from entering the xylem**; this could block the movement of water through the plant.
- Set up the apparatus as shown in the diagram below, ensuring that it is **airtight**, and using vaseline to seal any possible gaps.
- **Dry the leaves** of the shoot using tissue paper. Any water present on the leaves might affect the rate of transpiration as it **could block the stomata**
- Lift the capillary tube from the beaker of water to **allow a single air bubble to form** and then place the tube back into the water

- Set up a light source from which the light intensity can be varied. This could be achieved by varying the light bulbs used or by varying the distance between the light source and the plant shoot
- Allow the plant to adapt to the new environment for 5 minutes
- Record the starting location of the air bubble, leave for a set period of 10 minutes), and then record the end location of the air bubble
- Change the light intensity by moving the lamp 10cm further away from the plant shoot.
- Reset the bubble by opening the tap below the reservoir

• Repeat the experiment at the new light intensity, and again at a range of different intensities eg 20cm, 30cm, 40cm etc

Observation

- The bubble travelled a long distance when the potometer was placed near the light bulb (in high light intensity) and travelled small distance when place under low light intensity.

Explanation

- Higher light intensities will increase the rate of transpiration. Stomata close in the dark and their closure greatly reduces the rate of transpiration.
- Stomata open wider as light intensity increases to enable gas exchange for photosynthesis; this increases the rate of transpiration. In deem light or darkness, stomata are closed or partially closed and the rate of transpiration decreases

Conclusion

- Higher light intensities will increase the rate of transpiration and low light intensity decreases the rate of transpiration.

Note

Other environmental factors can be investigated by setting the potometer in the same way as in investigating the effect of light intensity on the rate of transpiration, however, the factors can be varied in the following ways

wind

- A fan on different settings could be used to vary the flow of air around the plant shoot

Temperature

- A heater or air conditioner can be used to give a measurable variation in temperature

Implications of the factors that affect the rate of transpiration to farmers and growers

Light intensity

Higher light intensity can lead to increased transpiration rates due to the stimulation of photosynthesis, which opens stomata for gas exchange.

Implication to farmers/growers.

- Farmers in greenhouses may need to regulate light exposure to control transpiration rates and optimize water usage.
- Select crops based on their light requirements and adaptability to different light conditions (full sun, partial shade, etc.).

Wind.

Increased wind speed can lead to higher transpiration rates as it removes water vapor from the leaf surface more quickly.

Implication to farmers/growers

Growers in windy regions may need to provide windbreaks or shelter for plants to reduce excessive water loss through transpiration.

Use windbreaks to minimize the negative effects of strong winds on transpiration of crops.

Temperature

Higher temperatures generally increase transpiration rates as water evaporates more rapidly from leaves.

Implication to farmers/growers

Farmers may need to adjust irrigation schedules during hot weather to compensate for increased water loss through transpiration.

- Select crop varieties that are well-adapted to the prevailing temperature range.
- Adjust planting schedules to coincide with optimal temperature conditions to prevent excessive loss of water.
- Implement greenhouse or shade structures to regulate temperature and extend the growing season.
- Employ temperature-controlled environments in indoor or hydroponic systems to provide optimal conditions for crops without losing excessive water.

- Sucrose and amino acids are transported to every tissue of the plant, each cell use it in a different way.
- Root cells convert sucrose into glucose for respiration and store it. Growing cells make cellulose for cell walls from sucrose and use the amino acids to make proteins for growth. And fruits use the sucrose to make the attractive scent and tasty nectar to attract insects.
- The areas of the plant where sucrose is made, are called sources, and where they are delivered to and made use of are called sinks.

Significance/ importance/advantages of Transpiration in Plants

- ✓ Transpiration helps in the conduction of water and minerals to different parts of the plants.
- ✓ Due to the continuous elimination of water from the plant body, there is a balance of water maintained within the plant.
- ✓ It maintains osmosis and keeps the cells rigid hence provides support in non woody plants.
- ✓ A suction force is created by transpiration that helps in the upward movement of water in the plants.
- ✓ The cooling effect of a tree is due to the evaporation of water from its leaves.

Drawbacks/ disadvantages of transpiration in plants

In addition to the significance, transpiration has a few drawbacks/ disadvantages

- ❖ Transpiration slows down if the transpired water is not compensated by absorption from the soil.
- ❖ A lot of energy is released during transpiration which the plant needs to compensate.
- ❖ Plenty of unnecessary water is absorbed by the plants during the process.

TRANSLOCATION

TRANSLOCATION

- This is the transport of organic food such as sucrose and amino acids in the plant through the phloem vessels in the stem.
- Glucose, the product of photosynthesis is the most important food of the plant. Because from it, it makes most of its other nutrients. Glucose is converted into an other more complex sugar called sucrose. Sucrose in the leaves enter the phloem vessels.
- The phloem transports it to every other part of the plant where it is made use of. Amino acids are also transported in the phloem.

Translocation:

- This is the transport of photosynthetic foods such as sucrose and amino acids in the plant through the phloem vessels in the stem.

The process of translocation in plants

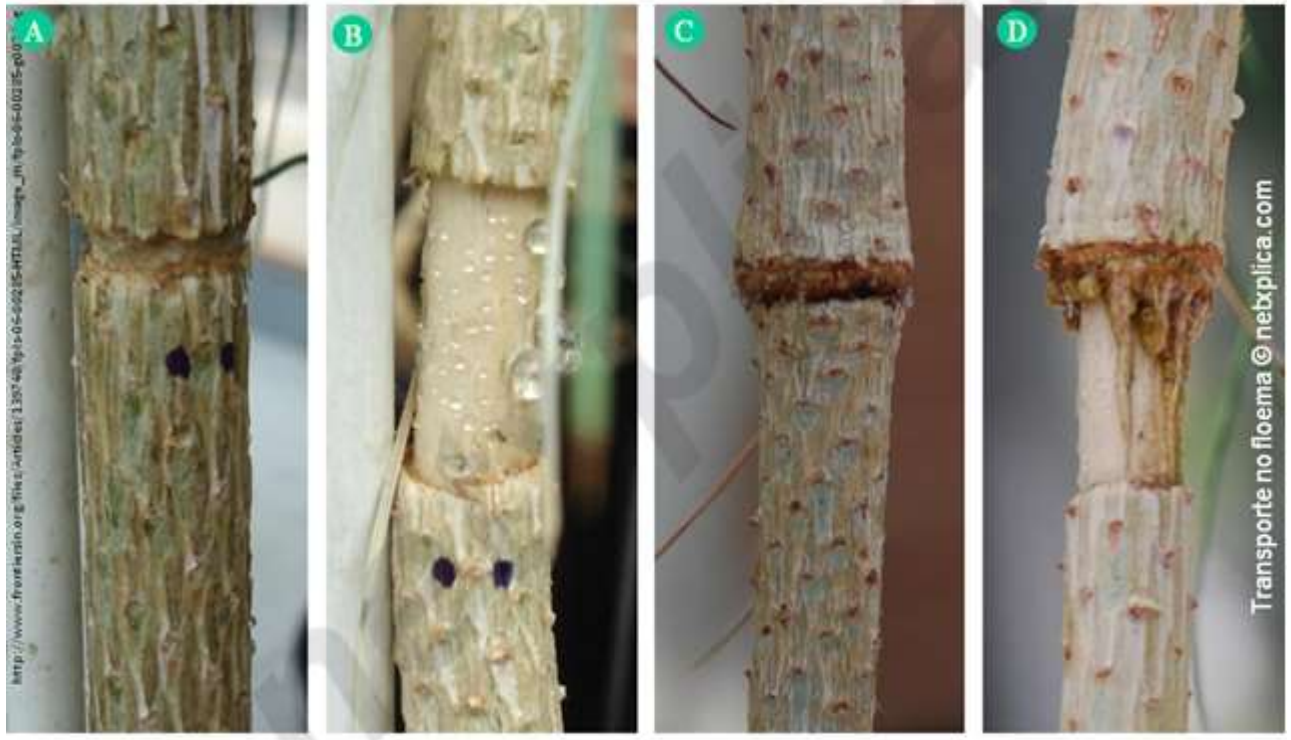
- Glucose, the product of photosynthesis is the most important food of the plant.
- Because from it, it makes most of its other nutrients. Glucose is converted into an other more complex sugar called sucrose.
- Sucrose in the leaves enter the phloem vessels .
- The phloem transports it to every other part of the plant where it is made use of.
- Amino acids are also transported in the phloem.

- Root cells convert sucrose into glucose for respiration and store it.
- Growing cells make cellulose for cell walls from sucrose and use the amino acids to make proteins for growth.
- And fruits use the sucrose to make the attractive scent and tasty nectar to attract insects.
- The areas of the plant where sucrose is made, are called sources, and where they are delivered to and made use of are called sinks.

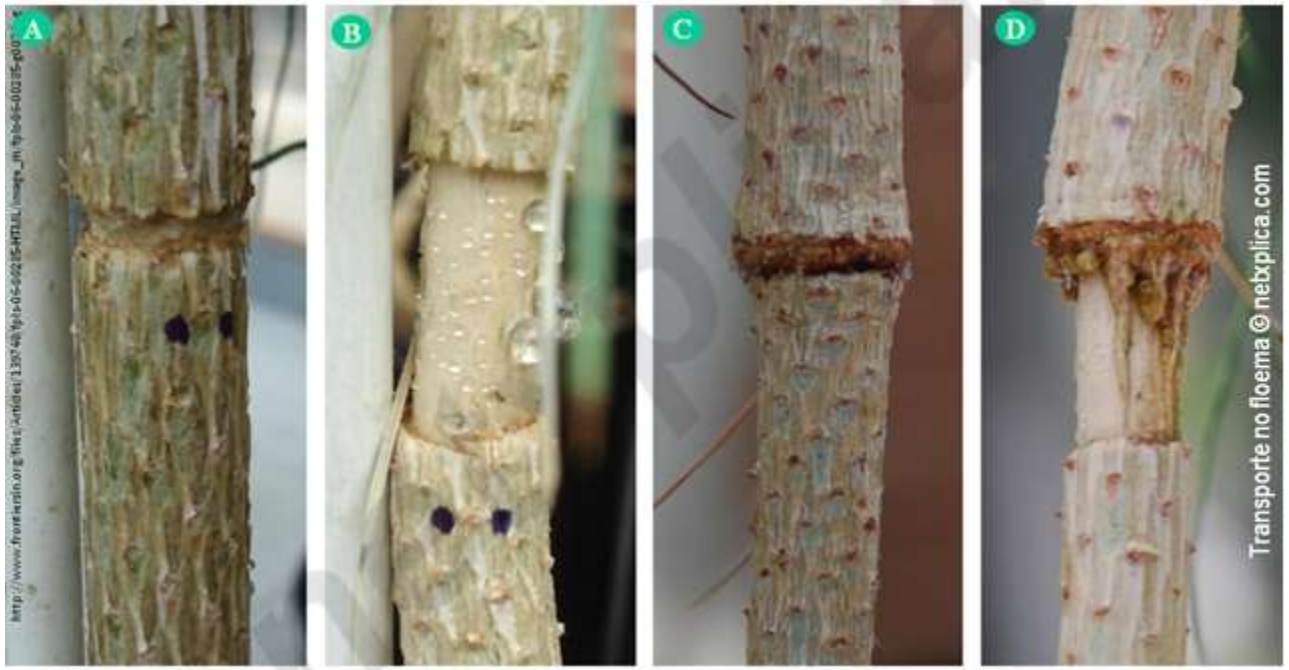
Evidence to show that translocation occurs through phloem

Phloem Girdling (tree ring)

- Girdling is a process where a ring of bark is removed from around the stem of a plant, effectively severing the phloem while leaving the xylem intact.
- When phloem girdling is performed, the movement of sugars and other organic compounds beyond the girdle is blocked.



- As a result, the tissues located below the girdle, which would normally receive sugars from the leaves, show signs of sugar starvation, while the tissues above the girdle swells as a result of accumulation of photosynthetic products.
- This demonstrates the importance of the phloem in sugar transport within the plant.



Summary

- In plants, various mechanisms ensure the efficient transport of water, nutrients, and organic compounds throughout the organism.
- Diffusion allows gases like carbon dioxide and oxygen to move in and out of leaves and roots.
- Active transport, requiring energy, is vital for the uptake of mineral ions by root cells against their concentration gradient.
- Osmosis plays a key role in maintaining turgor pressure within plant cells by regulating water movement.
- Transpiration, the loss of water vapor from leaves, aids in the upward transport of water and minerals through the xylem.
- Translocation involves the movement of products of photosynthesis through the phloem from sources to sinks
- These processes collectively ensure the proper distribution of essential substances in plants for growth and metabolism.

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