CHAPTER 2: TRANSPORT IN PLANTS

INTRODUCTION

Plants require various substances for their growth and other processes. These substances have to be moved from the roots, where they are absorbed from the soil to various parts of the plant where they are required. Glucose from photosynthesis has to be transported from the leaves where it is made to various parts of the plant. This requires an effective and efficient transport system. This transport system in plants is made up of two specialized tissues; the xylem and phloem. This chapter is aimed to uncover the mechanism of transporting substances in and out of cells and around plant tissues.

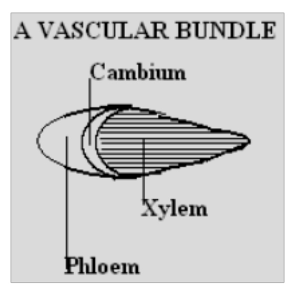
Objectives

By the end of this chapter, you should be able to;

i. *Identify tissues that are used for transport in plants*
ii. *Describe the structural and functional differences between the xylem and phloem*
iii. *Describe the processes of diffusion, osmosis and active transport*
iv. *Explain the factors that affect the rate of diffusion*
v. *Explain how substances are transported in the xylem and phloem*
vi. *Explain the significance of diffusion osmosis and active transport*
vii. *Describe the transpiration stream*
viii. *Explain the importance of transpiration*
ix. *Explain the factors that affect the rate of transpiration*

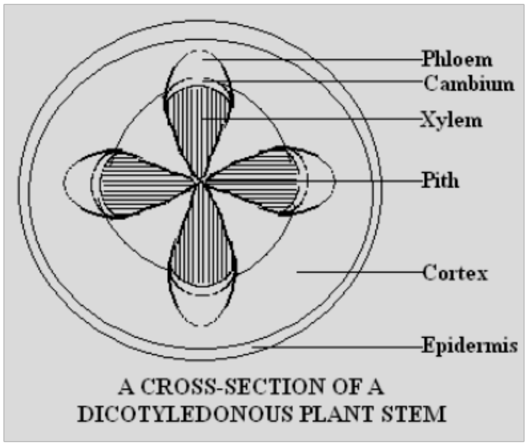
THE VASCULAR BUNDLES

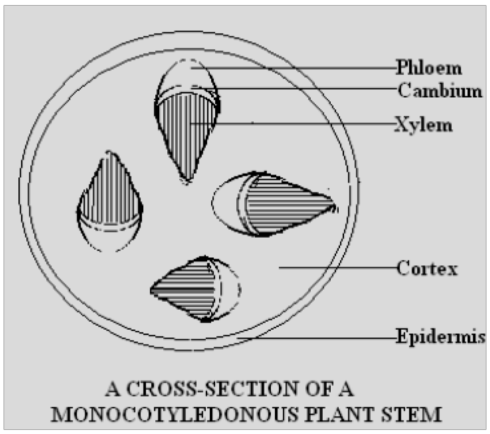
The xylem and phloem are arranged together in compact masses called the vascular bundles. Usually the xylem is situated in part of each bundle near the centre of the stem, with the phloem near the outer surface of the stem.



arranged in a ring, near to the outside edge.

In a stem of a dicotyledonous plant, e.g. bean plant, the vascular bundles are

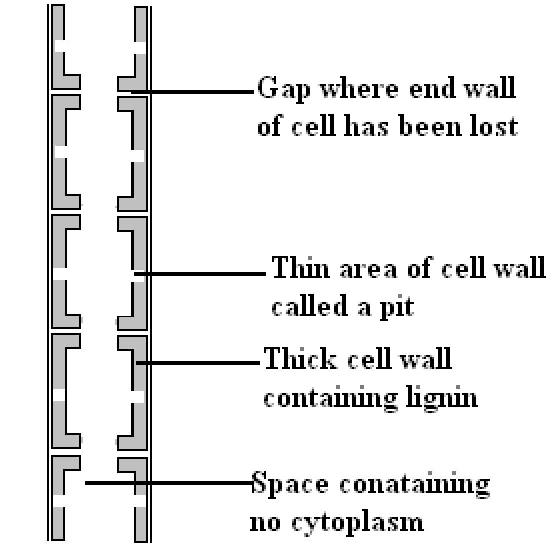




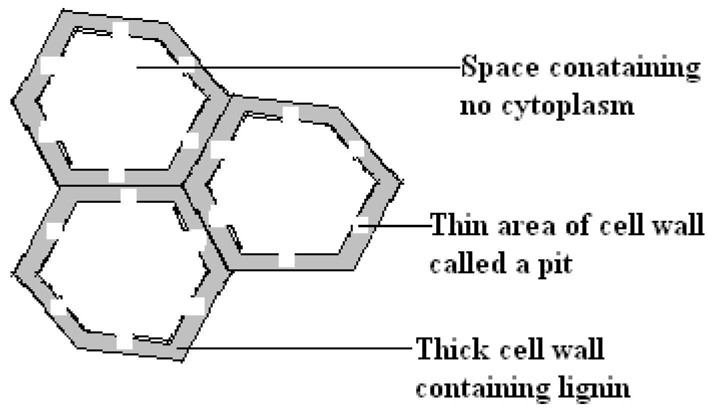
In a monocotyledonous plant, e.g. maize and sugarcane, the vascular bundles are scattered in no pattern at all.

STRUCTURE AND FUNCTION OF XYLEM VESSELS

Xylem cells do not contain cytoplasm and nucleus. Their walls of xylem vessels are made up of cellulose and lignin. Lignin is very tough and strong, so xylem vessels help to keep plants firm and upright. A xylem vessel is like a long drain pipe made up of many hollow, dead cells, joined together end to end. The end walls of the cells disappear thereby forming a long open tube or vessel. Xylem vessels run from the roots of plants up through the stem, branching into each and every leaf. Xylem vessels therefore carry water and minerals from roots to photosynthesizing cells in leaves.



LONGITUDINAL SECTION
OF A XYLEM VESSEL



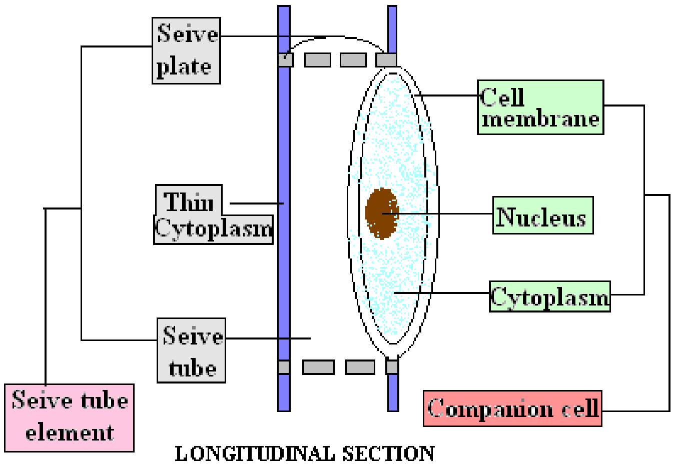
TRANSVERSE SECTION
OF A XYLEM VESSEL

MOVEMENT OF SUBSTANCES IN THE XYLEM VESSELS

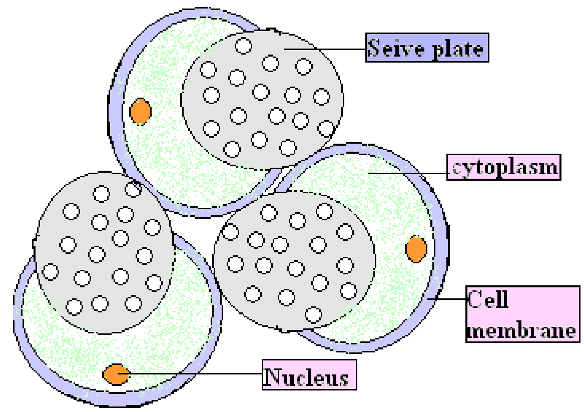
The movement of water and mineral salts dissolved in water in the xylem depends on ***transpiration***. Transpiration is the loss of water from the surface of plants, mainly from leaves. The loss of water from the leaves has an effect of pulling water up through the xylem. This pulling force is called ***suction pump***. As a result, there is a flow of water up through the plant from the roots. This flow of water caused by the pulling effect of transpiration is known as ***transpiration stream***. During transpiration, the pressure at the top of the xylem vessel is lowered while the pressure at the bottom stays high. Water therefore, flows up the xylem vessel to the leaves. A constant flow of water is maintained due to continuous loss of water from the leaf surfaces and absorption of water from the soil by roots.

STRUCTURE AND FUNCTION OF PHLOEM TUBES

Phloem tubes are made of many cells joined to end to end. The end walls of the phloem cells have not been completely broken down. They have small holes in them, forming ***sieve plates***. The cells containing sieve plates are called ***sieve tube elements*** which contain cytoplasm but no nucleus. Sieve tube elements do not have lignin in their cell walls. Each sieve tube element has a ***companion cell*** which has a nucleus and many other organelles. Companion cells carry out life processes to support the sieve tube elements. Phloem tubes support glucose from the leaves to all parts of the plant where it is required for various processes or for storage.



LONGITUDINAL SECTION OF PHLOEM TUBES



A TRANSVERSE SECTION OF A PHLOEM TUBE

MOVEMENT OF SUBSTANCES IN THE PHLOEM TUBES

Plants make carbohydrates in the form of glucose through the process of photosynthesis. Some of the glucose is used to make amino acids, proteins, oils and other organic substances. Some of this sugar made in plant leaves is transported in the phloem tubes as sucrose. Sugar is transported from leaves to all parts of the plant through a process known as ***translocation.*** The sap in the phloem tube cells contains a lot of sugar as compared to the cells in the leaves. Energy is therefore required to move sucrose through the phloem tube cells. This is active transport. The mechanism of active transport will be dealt with in detail ahead in this very same chapter. Specialized ***parenchyma cells*** known as transfer cells are involved in transporting the sucrose through the sieve tubes. Photosynthesizing cells in leaves are known as ***sources*** and the different parts of plants where sugars are used are called ***sinks***.

FUNCTIONAL DIFFERENCES BETWEEN XYLEM VESSELS AND PHLOEM TUBES

1. Xylem vessels transport water and mineral salts from the roots to photosynthesizing cells, while phloem tubes transport already made food in the form of sucrose to all parts of the plant where it is used for various activities.
2. Xylem vessels, being lignified are strong and help to support plants to stand firm and upright, while phloem tubes do not have lignin, are not that strong and therefore do not provide support to plants.

STRUCTURAL DIFFERENCES BETWEEN XYLEM VESSELS AND PHLOEM TUBES

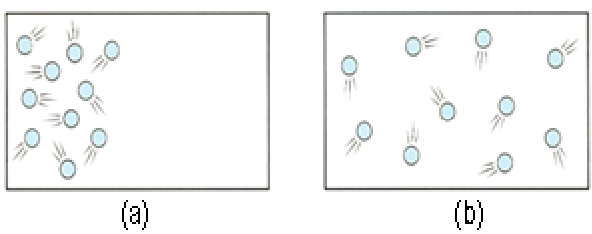
1. Xylem vessels do not contain cytoplasm while phloem tubes have strands of cytoplasm.
2. Cell walls of xylem vessels are made of cellulose and lignin while cell walls of phloem tubes are made of cellulose only but not lignified.
3. Xylem vessels consist of dead cells while phloem tubes are made of living cells called sieve tube elements.

4. The end walls of xylem vessels have disappeared completely, thereby forming long, open tubes while the end walls of phloem tubes are perforated, i.e. not completely broken, thereby forming sieve plates which have small holes in them.
5. Both xylems and phloem cells do not have nucleus but phloem cells have companion cells next to them, containing nucleus and many other organelles that support them.

DIFFUSION

All substances are made up of sub-microscopic particles called molecules. In gases (*like air*) the molecules can move freely. In liquids (*like water*) the molecules can also move. In solids the molecules are more or less stationary. In solutions (e.g. sugar dissolved in water) the molecules of the dissolved substance can move.

Representation of molecules in a gas



As a result of their random movements the molecules become evenly distributed

As a result of this random movement, the molecules of a gas become evenly dispersed. This movement is called ***diffusion***. The scent of a hyacinth diffuses throughout a room. The scent molecules diffuse from a region where they are concentrated (*the flower*) to regions where they are absent or in low concentration. In an area as large as a room, there will be air currents and convection currents which will play a greater part than diffusion.

One of the ways substances enter and leave cells is by diffusion. If a substance is more concentrated outside a cell than inside, the molecules will tend to diffuse into the cell. If a substance is more concentrated inside the cell than outside, the molecules will tend to diffuse out of the cell.

Diffusion therefore, is the movement of molecules of a liquid or gas from an area where they are highly concentrated to an area where they are absent or in low concentration.

DIFFUSION GRADIENT

The molecules are more densely packed on the left and so they tend to diffuse into the space on the right. This is a diffusion gradient

Molecules diffuse down the concentration gradient and the steeper the gradient, the faster diffusion occurs. This occurs because of random motion of molecules. The end result of diffusion is a uniform concentration of molecules known as ***equilibrium***. The bigger the difference in concentration, the greater will be the diffusion gradient.

INVESTIGATION: TO SHOW DIFFUSION IN A SOLUTION

MATERIALS: Gas jar, water, potassium permanganate crystals.

PROCEDURE:

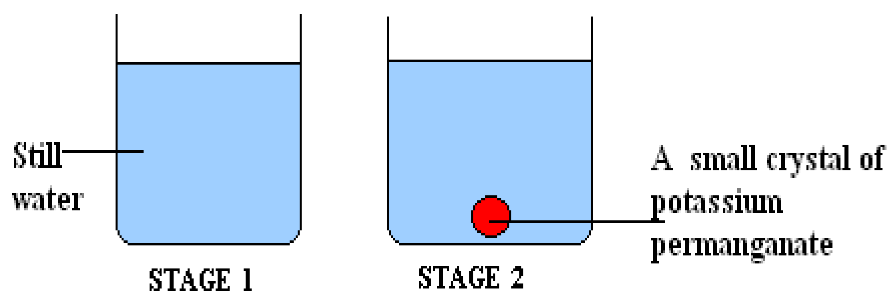
i. Fill a gas jar with water and leave it for several hours to become completely still or stable.

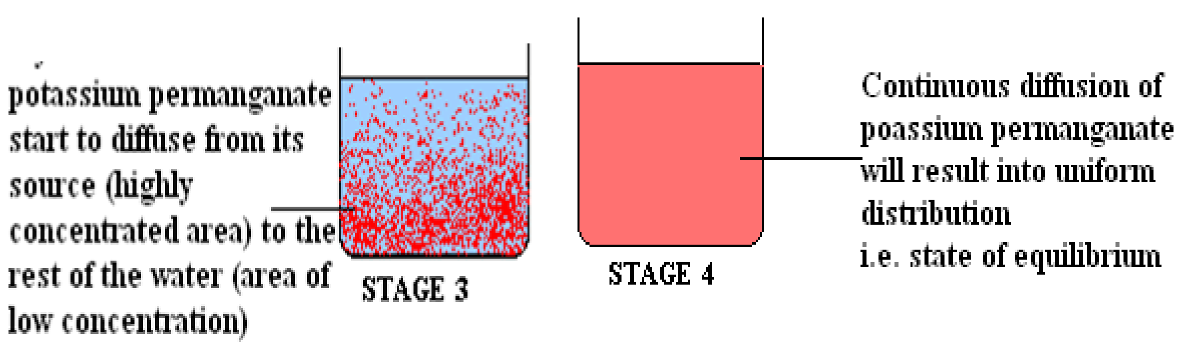
ii. Drop a small crystal of potassium permanganate into the water.

iii. Observe and record what happens.

iv. Leave the apparatus to stand undisturbed for some few hours.

v. Observe and record what happens after some few hours.





FACTORS THAT AFFECT THE RATE OF DIFFUSION

A number of factors affect the rate at which diffusion takes place.

a) TEMPERATURE OF THE SUBSTANCES

Temperature facilitates random motion of molecules. When temperature is high, molecules move more quickly and that results into rapid diffusion. When the temperature is low, diffusion slows down.

b) SIZE OF PARTICLES

Smaller particles diffuse faster than bigger particles. There is a limit to the size of particles that can pass through the membranes. Very large particles can not pass through.

c) CONCENTRATION OF SUBSTANCES

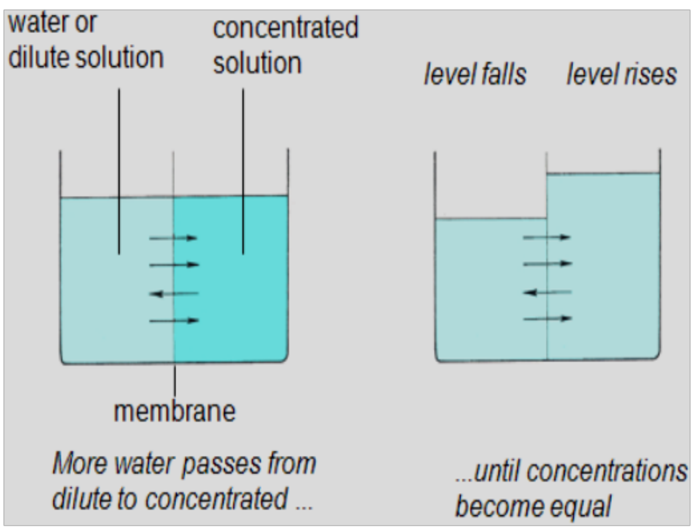
The difference in concentration between any two regions which results in diffusion is called diffusion gradient. The bigger the difference in concentration between the two sides of the membrane, the faster diffusion occurs. Diffusion occurs from the region of high concentration to the region of low concentration, i.e. along the concentration gradient.

IMPORTANCE OF DIFFUSION

Diffusion is important in gas exchange for respiration of plants and animals. Some of the products of digestion are absorbed from the ileum of mammals by diffusion. Diffusion occurs where there is no barrier to the free movement of molecules or ions.

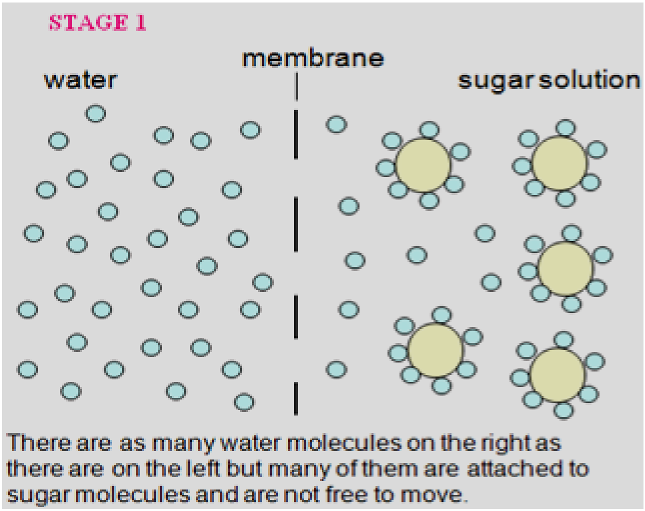
OSMOSIS

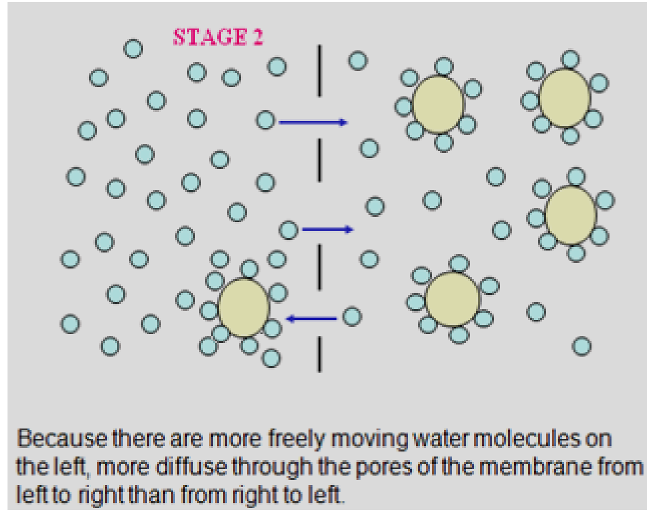
Osmosis is a special case of diffusion. Osmosis involves the diffusion of water through a membrane. The membrane may be artificial and non-living e.g. Cellophane. In biology, the important membrane is the cell membrane. The membrane must allow water molecules to diffuse through. It is ***permeable*** to water. If a concentrated solution is separated from a dilute solution by a suitable membrane, water will pass from the dilute to the concentrated solution. In fact, water passes both ways but faster from the dilute to the concentrated solution.

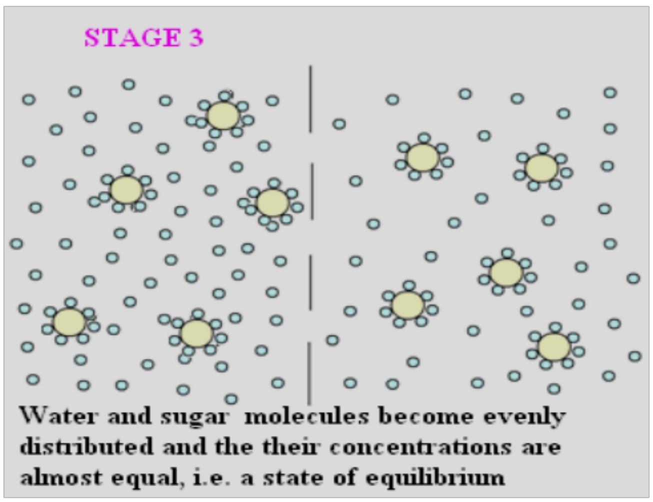


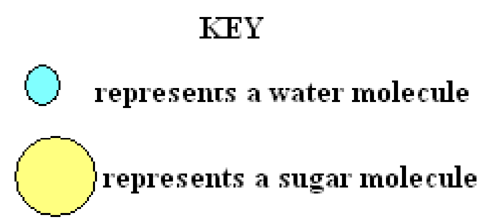
Osmosis is therefore a net movement of water molecules from a region of higher water concentration or low solute concentration to a region of lower water concentration or higher solute concentration. This movement takes place across a partially or selectively permeable membrane. Plant cells have a cell membrane which allows some molecules to pass through it and others not. The cell membrane is therefore semi-permeable or selectively permeable because it selects what substances to pass through it or not.

There are microscopic pores in the membrane. Molecules below a certain size can diffuse through the pores. Water molecules can easily diffuse through the pores.









Sugar molecules can pass through the membrane but, being surrounded by a cloud of water molecules, they move more slowly.

INVESTIGATION: TO SHOW OSMOSIS IN PLANT CELLS

MATERIALS: 3 beakers, water, salt/sugar, irish potatoes, razor/knife, ruler and a balance.

PROCEDURE:

i. Cut three equal strips of irish potato, each of mass 4 g and length 8 cm.
ii. Take three beakers and label them A, B and C.
iii. Pour 30 cm^3 of 30% salt/sugar solution in beaker B and 30 cm^3 of distilled water in beaker C.
iv. Leave beaker A without putting in anything, i.e. air filled.
v. Test the flexibility of each strip of potato and record your findings in your table.
vi. Put the potato strips in the beakers A, B and C and leave the set up for 20 minutes.
vii. After 20 minutes, test the flexibility of of the strips by bending them and record your findings.
viii. Measure the length and mass of the three potato strips and record the results in a table like

the one shown below.

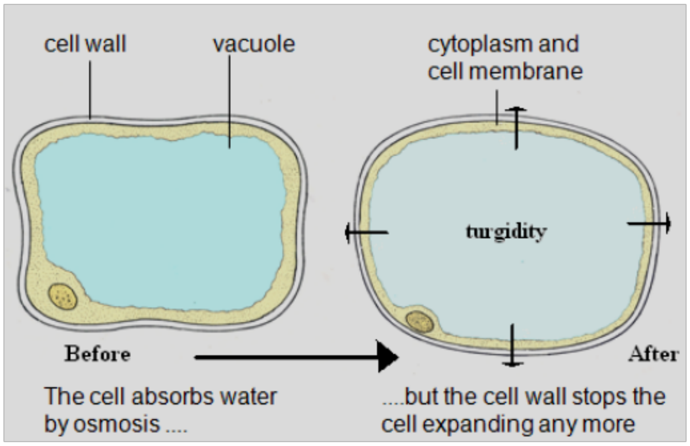
Table of results

	Potato strips at the beginning of the experiment	Potato strips in beaker A- air filled, after 20 min.	Potato strips in beaker B- 30% salt/sugar soln after 20 min	Potato strips in beaker C- distilled water, after 20 min.
Flexibility				
Length (cm)				
Mass (g)				

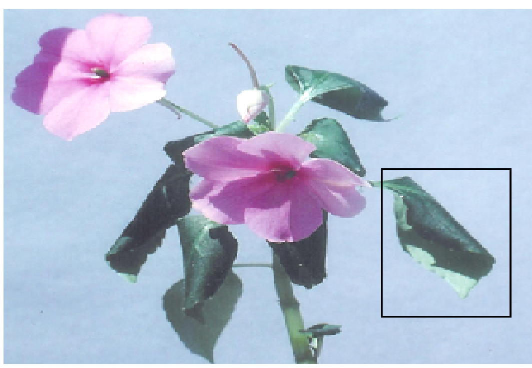
RESULTS

When a plant cell is placed in water, the concentration of water around the cell is much higher than in the cytoplasm or vacuole of the cell. As a result, a lot of water moves into the cytoplasm and vacuole across the cell membrane by osmosis.

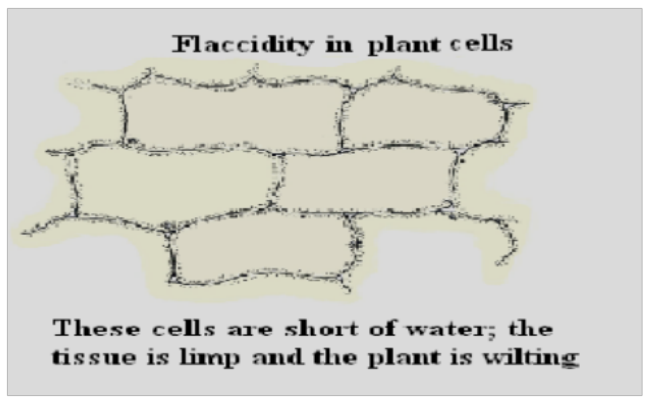
As more and more water enters the cytoplasm and the vacuole, they swell and exert an outward pressure but the cell wall prevents the cell from bursting since it is strong and presses back on the cytoplasm. The outward pressure exerted by the vacuole and the cytoplasm on to the cell wall of a plant cell is called ***turgor pressure.*** The cell is therefore said to be ***turgid***. This makes the cell to be tight and firm, a condition known as ***turgidity***. If all the cells in the plant are turgid, the plant willbe firm and upright and the leaves would be expanded.



When a plant cell is put in a concentrated solution, the concentration of water in the cytoplasm and vacuole of the cell is higher than the concentrated solution around the cell. As a result, water moves from the cytoplasm into the solution around the cell, across the cell membrane by osmosis. The cytoplasm shrinks, unable to exert the turgor pressure on the cell wall and it becomes floppy. The cell is sais to be ***flaccid*** and this condition of the cell is known as ***flaccidity.*** This result into the plant loosing its firmness and begins to wilt.



In this picture the plant is wilting from lack of water.



If the solution around the cell is very concentrated, a lot of water diffuse out of the cell cytoplasm, making it to shrink further to the centre of the cell. The cell membrane tears away from the cell wall. This condition is known as ***plasmolysis***. The plant cell in this state is said to be ***plasmolysed***. This usually kills a plant cell because the cell membrane is damaged.

ACTIVE TRANSPORT

Sometimes a cell needs to absorb a substance that is in a very low concentration in its surroundings. On their own, such substances would diffuse down the concentration gradient, i.e. out of the cell to the outside environment. A plant however, can make these substances move in the opposite direction, up the concentration gradient. There are special protein molecules called ***transport proteins*** embedded in the cell membrane. When substances bump into these transport proteins, they push them through the membrane and into the cell. This process requires energy which the cell provides through respiration. This process is known as ***active transport***. Active transport can be defined as the movement of substances or ions in or out of the cell through the cell membrane, from a region of their lower concentration to a region of their higher concentration, thus against a concentration gradient, using energy released by respiration.

THE SIGNIFICANCE OF ACTIVE TRANSPORT

I. Roots help in the absorption of water and mineral salts by active transport.
II. Active transport also help in the translocation of sucrose through the phloem tubes.

TRANSPIRATION

Transpiration is the loss of water from the surfaces of parts of plants especially leaves. Latent heat from the sun is the source of energy for the vapourisation of water on the surface of the leaf and when this energy has been used up, it leaves the area cooled down. The loss of water exerts a pulling force of water in the xylem vessels which is called ***suction pump***. It is this force which keeps water flowing in the xylems from the roots where they are absorbed to the leaves. This continuous flow of water is known as ***transpiration stream.***

SIGNIFICANCE OF TRANSPIRATION

i. Transpiration has a pulling effect, i.e. suction, which results in the uptake of water.
ii. Transpiration is important in the transportation of mineral salts which are in solution form.
iii. Transpiration has a cooling effect. When latent heat from the sun is used up in the process of vaporization, it leaves the surface cooled down.

FACTORS THAT AFFECT THE RATE OF TRANSPIRATION

1. TEMPERATURE

On a hot day, water will evaporate quickly from the leaves of a plant. Transpiration increases as temperature increases. On a cold day evaporation slows down and this reduces the rate of transpiration.

2. LIGHT INTENSITY

In bright sunlight, a plant may open its stomata to supply plenty of carbon dioxide for photosynthesis. More water can therefore evaporate from leaves as the stoma is open. On a cloudy day, most of the stoma remains closed, thereby reducing water loss as well as the transpiration rate.

3. HUMIDITY

Humidity is the amount of water vapour in the air. The higher the humidity, the less water will evaporate from the leaves. Transpiration decreases as humidity increases. On a less humid day, plants tend to lose a lot of water, hence increased transpiration.

4. MOVEMENT OF AIR OR WIND SPEED

On a windy day, water evaporates more quickly than on a calm day. Transpiration increases as wind speed increases. Perhaps that is why clothes go dry much faster when it is windy irrespective of the heat from the sun. On a calm day, it takes time for the moisture on the leaf surface to be removed thus lower rate of transpiration.

INVESTIGATION: TO FIND OUT THE EFFECT OF SEVERAL FACTORS ON THE RATE OF

TRANSPIRATION

MATERIALS: four well watered potted plants. Polythene bag, fan, refrigerator, card board box and top- pan balance.

PROCEDURE:

I. Take four well watered potted plants and wrap each pot with its soil in a polythene bag.
II. Put each potted plant onto a top pan balance, measure and record their mass.
III. Take the four potted plants and expose each to different conditions;
i.e. potted plant A- in normal cnditions in sunlight.
Potted plant B- blowing it with a fan in sunlight.
Potted plant C- putting it in a card board box.
Potted plant D- putting it in a refrigerator with lights on.
IV. Leave the set up for about 20 minutes.
V. After 20 minutes, record the mass of each potted plant.
VI. Find out which potted plant has lost a lot of water and one that has lost less water.
VII. Find out under which conditions did the plants transpire quickly and slowly.
VIII. Discuss the results.
IX. Draw up necessary conclusions from the results of the investigations.

INVESTIGATION: TO FIND OUT THE RATE OF TRANSPIRATION IN A PLANT

MATERIALS: 1 aquatic plant, potometer, vaseline, water and a ruler.

PROCEDURE:

i. Set up a potometer where a stem of a plant must fit exactly into the rubber tubing with no air gaps.
ii. Apply vaseline to help make an air tight seal.
iii. Fill the aparatus with water by opening the screw clip.
iv. Close the clip again and leave the aparatus in a light airy space. As the plant transpires, the water it loses is replaced by the water taken up by the stem of the plant, making air to be drawn at the end of the capillary tube.
v. When the air/water meniscus reaches the scale on the potometer, begin to record the position of the meniscus every two minutes.
vi. When the meniscus reaches the end of the scale on the potometer, refill the aparatus with water from the reservior as before.
vii. Record your observation.
viii. Draw a graph using the length of part of the capillary tube filled with air ant time taken for water to move along the capillary tube.
ix. Discuss the results.
x. Draw appropriate conclusions from the investigation.