PLANT NUTRITION

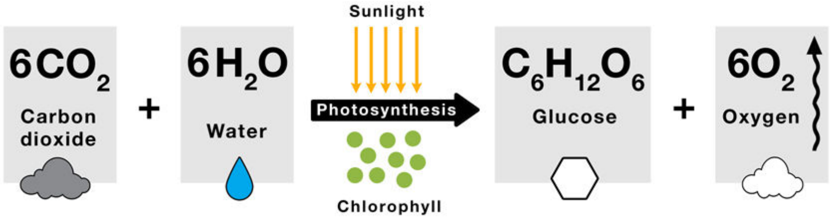
ABDUR REHMAN
BIOLOGY

6.1 Photosynthesis

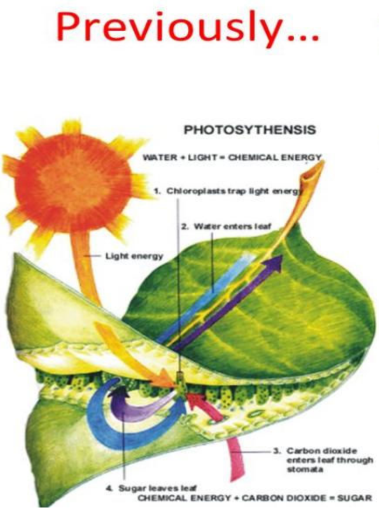
Understand that photosynthesis is the process by which plants make carbohydrates from raw materials using energy from light.

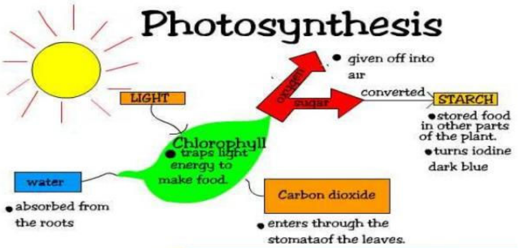
Definition

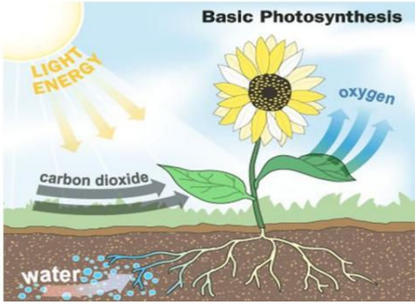
Photosynthesis is the process by which plants, algae, and some bacteria convert light energy from the sun into chemical energy in the form of carbohydrates such as glucose from raw materials like carbon dioxide and water.



- ➢ This process takes place mainly in the cells of leaves.
- ➢ In land plants, water is absorbed from the soil by the roots.
- ➢ Carbon dioxide is absorbed from the air through the stomata.
- ➢ In leaves cells the carbon dioxide and water are joined to make glucose. The energy from this reaction comes from sunlight which is absorbed by the green pigment chlorophyll in the chloroplast of the leaves cell.
- ➢ Chlorophyll absorbs energy from light and uses it to split water molecules into hydrogen and oxygen.
- ➢ The oxygen escapes from the leaf as a waste product of photosynthesis and the hydrogen molecules join with carbon dioxide molecules to make glucose.





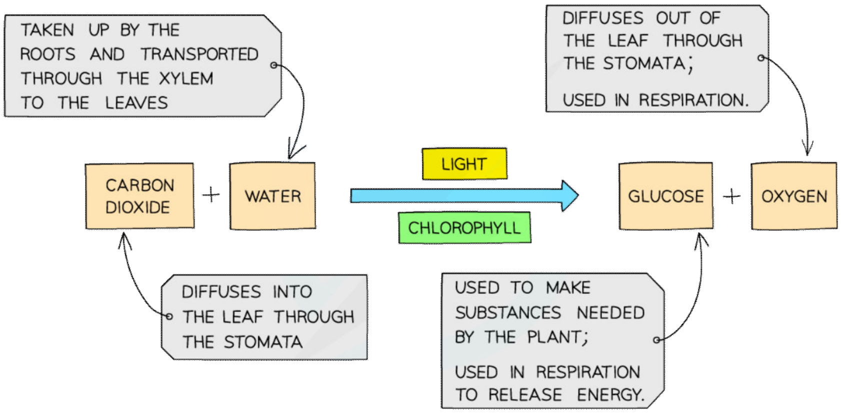


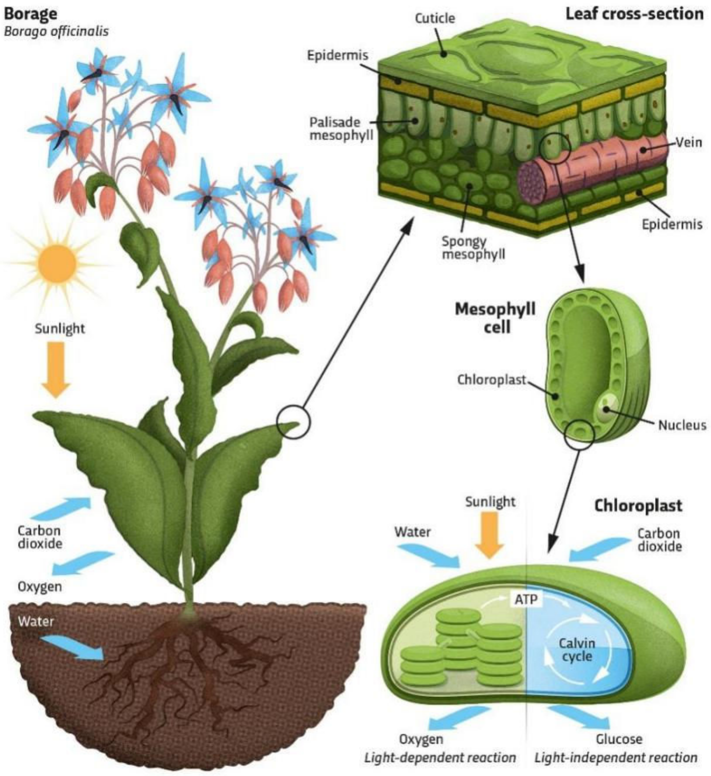
State that chlorophyll is a green pigment that is found in chloroplast.

State that chlorophyll transfers light energy into chemical energy for the formation of glucose and other carbohydrates.

- Chlorophyll is a green pigment that plays a fundamental role in the process of photosynthesis. It is found in the chloroplasts of plant cells.
- It is the pigment which gives the plant leaves it's characteristic Green color.
- Chlorophyll transfers light energy from sunlight into chemical energy in the form of carbohydrates. The light energy is used to split water molecule into hydrogen and oxygen.

Chlorophyll plays a vital role in the process of photosynthesis by transferring light energy into chemical energy, which is then used to form glucose and other carbohydrates.





Outline the subsequent use and storage of the carbohydrates made in photosynthesis, limited to: (a) starch as an energy store (b) cellulose to build cell walls (c) glucose used in respiration to provide energy (d) sucrose for transport through the plant.

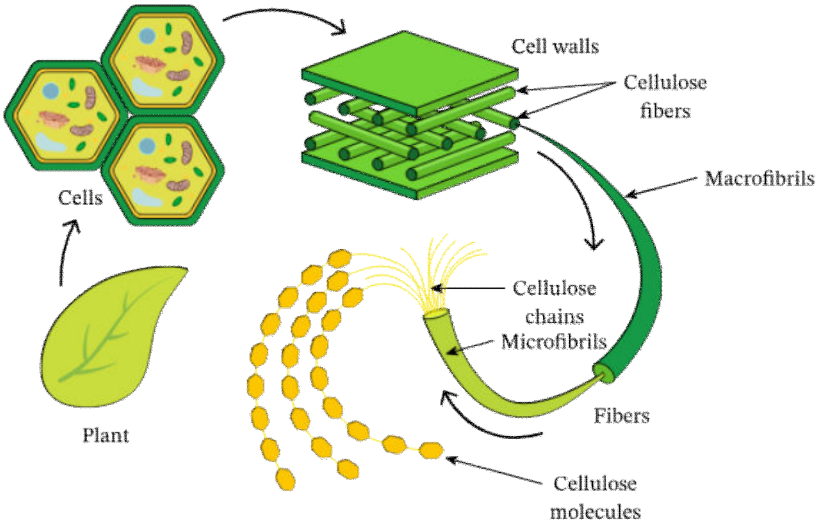
The carbohydrates produced by plants during photosynthesis can be used in the following ways.

(a) starch as an energy store.

Starch is a polysaccharide, consisting of many glucose molecules linked together. It is insoluble in water. After respiration, the excess glucose is turned into starch and stored. It maintains the osmotic balance of cell. Starch serves as a long-term energy reserve for the plant. During times when photosynthesis is not actively occurring, starch is broken down into glucose units, which are then used to produce ATP through respiration.

(b) cellulose to build cell walls.

Cellulose is another polysaccharide composed of glucose molecules. Plant cell walls are made of cellulose. Cell wall is freely permeable and tough. It keeps the plant cell turgid.



(c) glucose used in respiration to provide energy.

Glucose produced during photosynthesis is transported from the leaves to other parts of the plant, such as stems, roots, and fruits, where it is needed for energy production. In respiration glucose is broken down to release energy in the form of ATP. This reaction uses oxygen and as a result carbon dioxide and water are produced. The reaction takes place in mitochondria.

(d) sucrose for transport through the plant.

Sucrose is a disaccharide formed from glucose and fructose molecules. Starch is broken down to sucrose which is soluble. The sucrose is transported out of the cell into the phloem from where it is transported to sink. In the sink tissues, sucrose can be broken down into glucose and fructose, or it may be used directly as a source of energy or as a precursor for other metabolic pathways.

State the word equation and balanced chemical equation for photosynthesis.

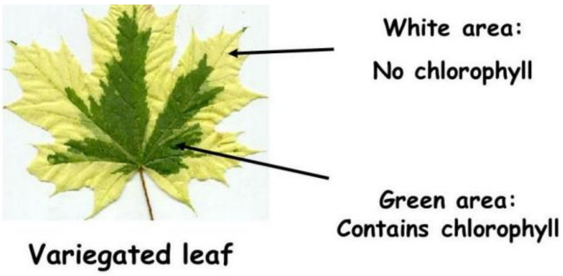
Investigate the need for chlorophyll, light and carbon dioxide for photosynthesis, using appropriate controls.

$$\underbrace{\text{Water + Carbon Dioxide}}_{\text{Reactants}} \xrightarrow{\text{Sunlight}} \underbrace{\text{Oxygen + Glucose}}_{\text{Products}}$$

$$\underset{\text{Carbon Dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

Chlorophyll

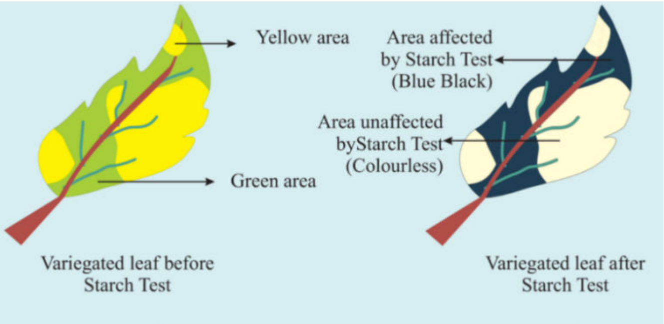
It is not possible to remove chlorophyll from a leaf without killing it and so variegated leaf is used. Variegated leaf is the one which has only patches of chlorophyll.



Variegated leaf

Experiment

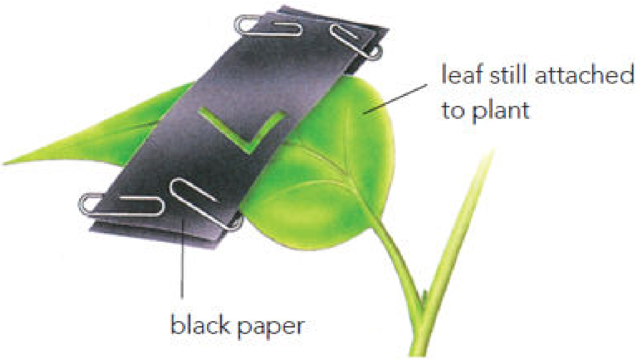
- ➢ Starch is stored in chloroplast where photosynthesis occurs so testing a leaf for starch is a reliable indicator of which parts of the leaf are photosynthesizing.
- ➢ Drop a variegated leaf in boiling water to break down the cell membranes and kill the cell.
- ➢ Boil the leaf for 5 to 10 minutes in ethanol solution this will remove the chlorophyll so color changes from iodine will be visible. Dip the leaf in boiling water to soften it.
- ➢ Spread out the leaf on a white tile and cover it with iodine solution.
- ➢ In a green leaf the entire leaf will turn blue black as photosynthesis is occurring in all areas of the leaf, but as in our case only some parts of the leaf (which were green containing chlorophyll) turns blue black indicating the presence of starch.
- ➢ This indicates that the areas which had chlorophyll photosynthesized hence suggesting that chlorophyll is needed for photosynthesis.



EXPERIMENT TO SHOW CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

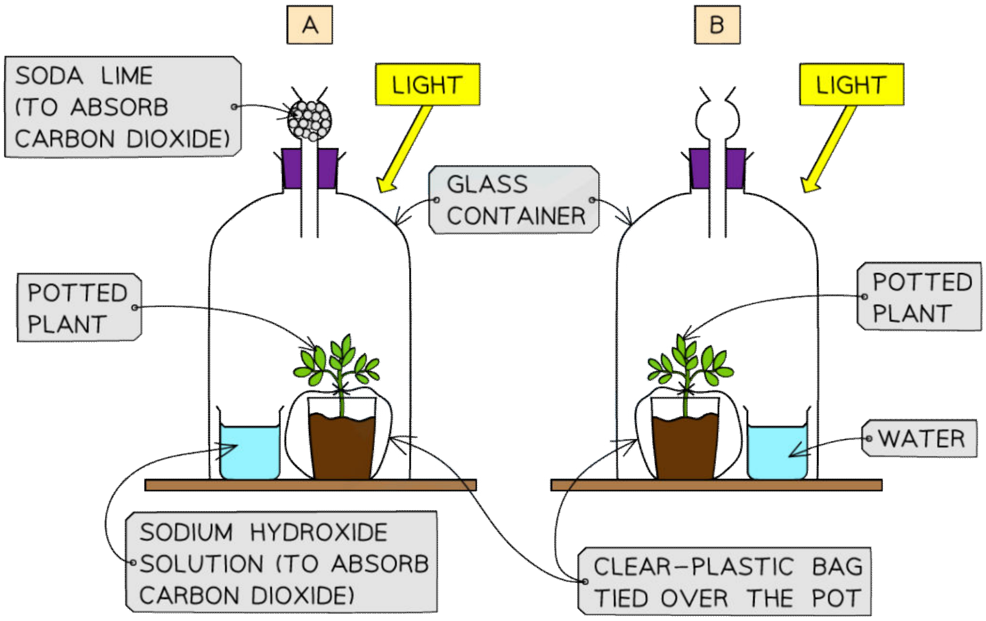
Light

- Obtain another set of healthy plant samples and provide them with adequate water and carbon dioxide.
- Cut a simple shape from a piece of black paper to make a stem cell and fix it to a destarched leaf for a whole day.
- Plant can be destarched by placing it in a dark cupboard for 24 hours (this is done to use all the starch that is already present in the leaf)
- The area of the leaf that was covered with black paper will remain orange brown as it did not receive any sunlight and could not photosynthesize. While the area exposed to sunlight will turn blue black while reacting with iodine.
- This prove that light is necessary for photosynthesis.



Carbon Dioxide

- Destarch two plants by placing in the dark for a prolonged period of time
- Place one plant in a bell jar which contains a beaker of sodium hydroxide (which will absorb carbon dioxide from the surrounding air)
- Place the other plant in a bell jar which contains a beaker of water (control experiment), which will not absorb carbon dioxide from the surrounding air
- Place both plants in bright light for several hours Test both plants for starch using iodine
- The leaf from the plant placed near sodium hydroxide will remain orange-brown as it could not photosynthesise due to lack of carbon dioxide
- The leaf from the plant placed near water should turn blue-black as it had all necessary requirements for photosynthesis



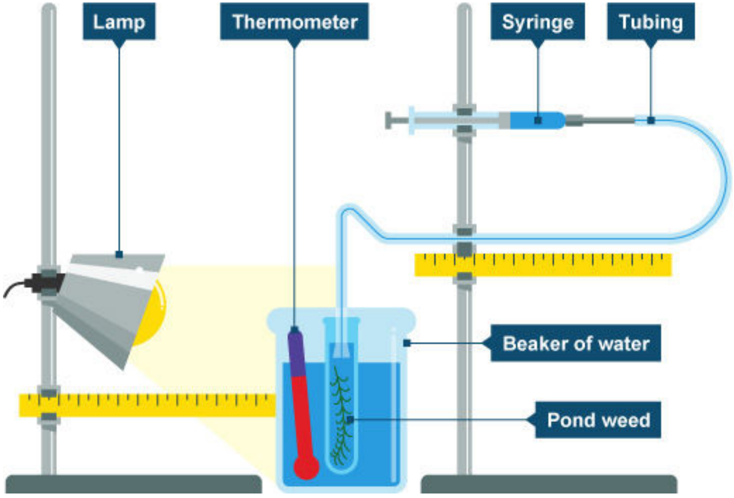
Describe and explain the effect of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis.

Effect of varying light on photosynthesis.

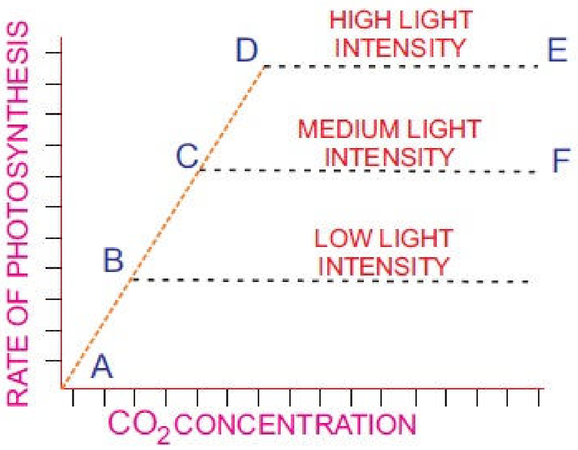
- In this investigation the amount of oxygen produced by a plant is used to calculate the rate of photosynthesis.
- Prepare a beaker of water or boiling tube into which sodium hydrogen carbonate is added.
- Sodium hydrogen carbonate dissolves and produces CO_2 so it is not a limiting factor.

$$\underset{\substack{\text{Sodium Hydrogen-}\\\text{Carbonate}\\\text{(Baking soda)}}}{2NaHCO_3} \xrightarrow{\text{Heat}} \underset{\substack{\text{Sodium}\\\text{Carbonate}}}{Na_2CO_3} + \underset{\substack{\text{Carbon}\\\text{dioxide}}}{CO_2} + \underset{\text{Water}}{H_2O}$$

- Collect a fresh piece of pond weed and cut one of the stem using a scalpel blade.
- Put the stem in test tube and place it in a beaker of water.
- This water bath will keep the temperature of the apparatus at a constant.
- Connect a syringe with the test tube using a tubing in such a way that all the air or oxygen is trapped in it. Set up a light source 10 cm away from the beaker and switch on the lamp.

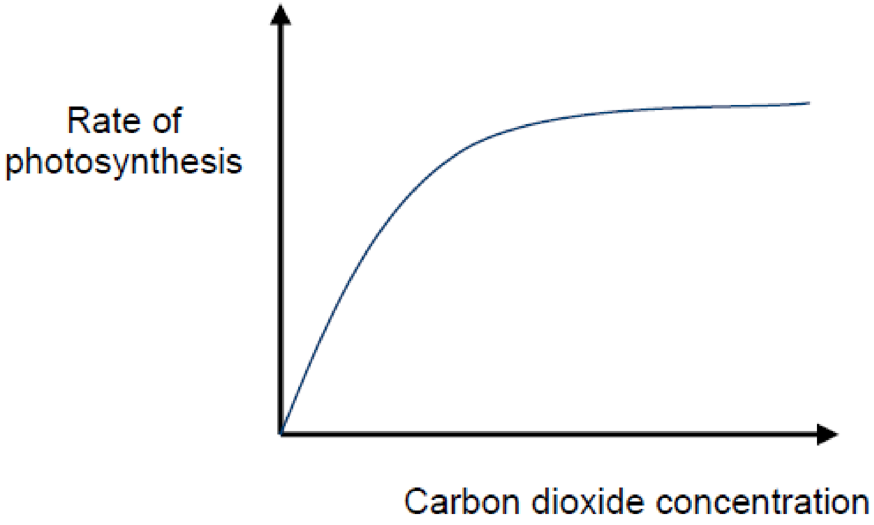


- The plant will start photosynthesis and oxygen will be produced.
- Observe the amount of oxygen produced during a specific period of time i.e.5 minutes.
- Now move the light source so that it is 20cm away from the beaker switch on the lamp and leave it for the same time observe the amount of oxygen produced.
- Repeat the procedure with changing distances and observe the amount of oxygen produced in each case. Observe the results and plot a graph.



Effect of varying Carbon dioxide concentration on photosynthesis.

- Set the whole apparatus as discussed in the previous experiment.
- Keep the distance of lamp at a constant distance of 15cm.
- Vary the concentration of sodium hydrogen carbonate solution as 0.01, 0.02, 0.03, 0.04mol\dm^3
- Record the volume of oxygen collected at each carbon dioxide concentration.
- Plot a graph for your results.

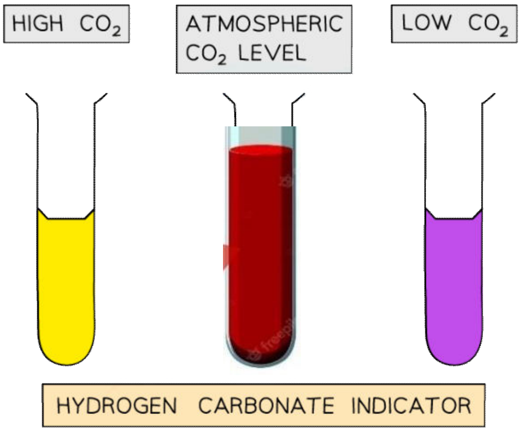


Effect of varying temperature on photosynthesis.

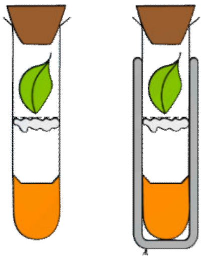
- Set the whole apparatus as discussed in the previous experiment.
- Keep the distance of lamp at a constant distance of 15cm.
- Keep the amount of sodium hydrogen carbonate solution constant at 0.2 mol/dm^3
- Vary the temperature of the water in the beaker at 10^0, 20^0, 30^{0}C.
- Record the volume of oxygen collected at each carbon dioxide concentration.
- Plot a graph for your results.

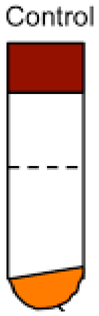
Investigate the effect of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis using submerged aquatic plants and hydrogencarbonate indicator solution.

Hydrogencarbonate indicator can detect increase and decrease in carbon dioxide concentration. It is red when carbon dioxide levels are at normal air levels. However, an increase in carbon dioxide changes the indicator to yellow and a decrease in carbon dioxide changes it to purple.



- Take 3 test tubes filled with hydrogen carbonate indicator.
- Put aquatic plants into test tubes and place one in the dark box and other in light and observe colour change after 1 hour.
- Test tube 3 was placed in light without putting pond weed into it for one hour. This test tube acts as the control group.





- Observe the results in three test tube.

Test Tube	Condition	Color	Explanation
1	Placed in light.	Purple	Pond weed photosynthesized and removed carbon dioxide from hydrogen carbonate solution.
2	Placed in dark.	Yellow	Pond weed did not photosynthesize but respired and added carbon dioxide into hydrogen carbonate solution.
3	No pond weed added.	Red	Control Group

Identify and explain the limiting factors of photosynthesis in different environmental conditions.

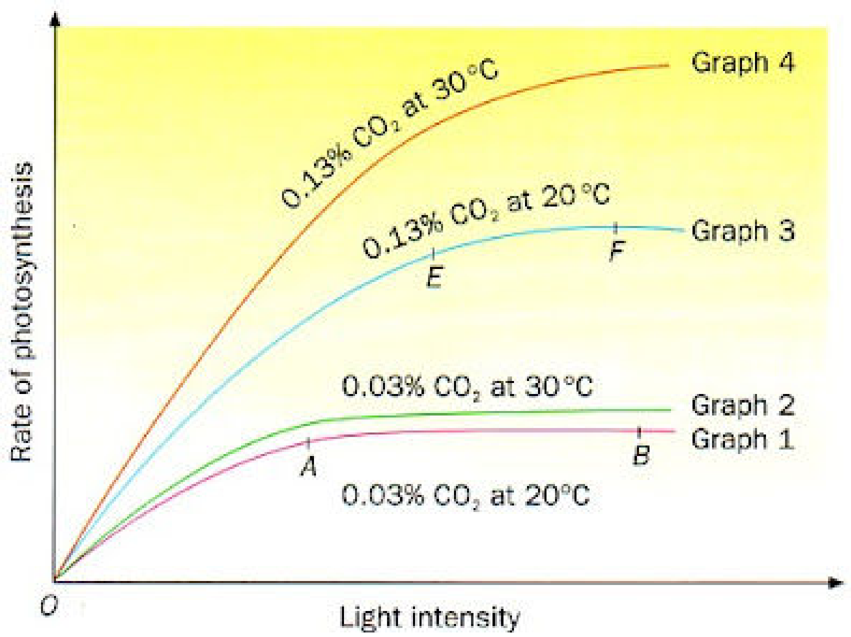
Limiting Factor.

A limiting factor is something present in the environment in such short supply so that it limits life processes.

There are three main factors which limit the rate of photosynthesis:

- Temperature
- Light intensity
- Carbon dioxide concentration

Although water is necessary for photosynthesis, it is not considered a limiting factor as the amount needed is relatively small compared to the amount of water transpired from a plant so there is hardly ever a situation where there is not enough water for photosynthesis.



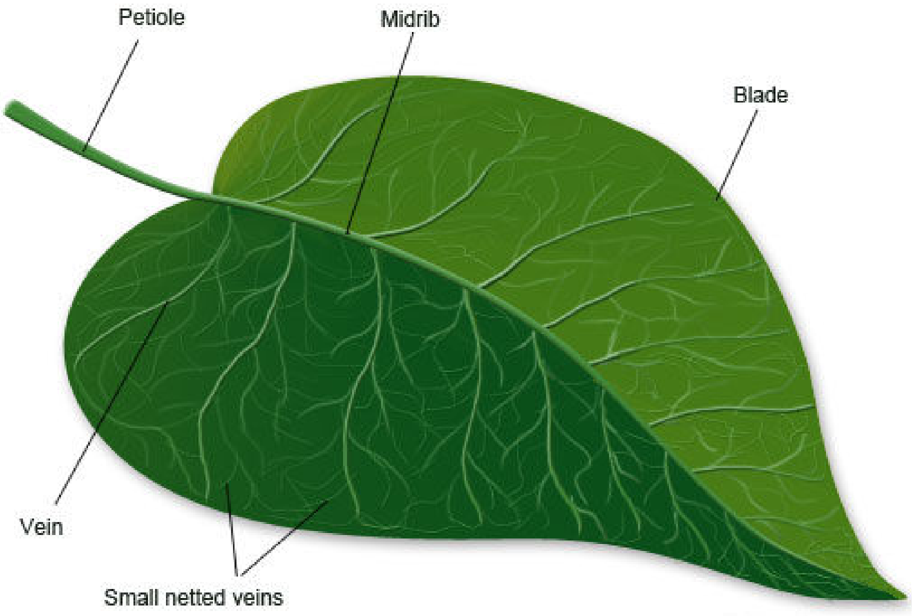
- In graph 1 at A light intensity is the limiting factor.
- In graph 1 at B temperature is the limiting factor.
- In graph 2 carbon dioxide is the limiting factor.
- In graph 3 temperature is the limiting factor.

6.2 Leaf structure

State that most leaves have a large surface area and are thin, and explain how these features are adaptations for photosynthesis.

The structure of the leaf is adapted to carry out both photosynthesis and gaseous exchange. It is specifically adapted to maximize the gaseous exchange of the three primary gases carbon dioxide, Oxygen and water vapours. The adaptations for this are explained below.

- Leaves have a broad, flat structure that provides them with a large surface area exposed to sunlight. This increased surface area allows the leaf to capture more sunlight, which is the primary source of energy for photosynthesis.
- The thinness of leaves reduces the distance that light and gases (carbon dioxide and oxygen) must travel to reach the photosynthetic cells within the leaf. The thin structure ensures that light can penetrate deeper into the leaf, reaching more photosynthetic cells and maximizing the utilization of available light energy.
- The last spaces between cells inside the leaf provide an easy passage through which carbon dioxide can diffuse.
- The branching network of veins provides a good water supply to the photosynthesizing cell. These veins bring water and mineral ions to the leaf cells and carry away the food made by them. As well as carrying food and water the network of vein makes a kind of skeleton that supports the software tissue of the leaf blade.



Identify and label the cuticle, cellular and tissue structures of a dicotyledonous leaf, as seen in diagrams or photomicrographs, and explain how these structures are adaptations for photosynthesis and gas exchange, limited to:

(a) stomata and guard cells

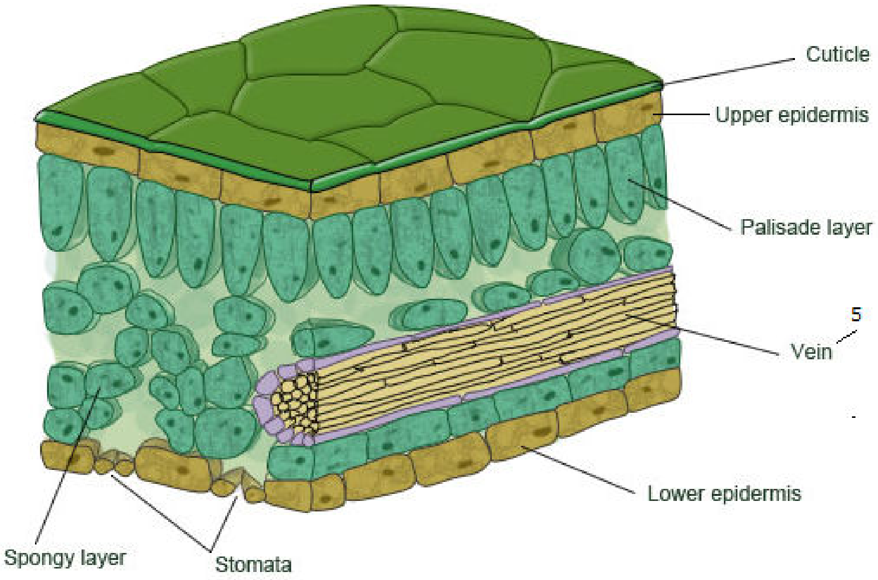
(b) spongy and palisade mesophyll cells

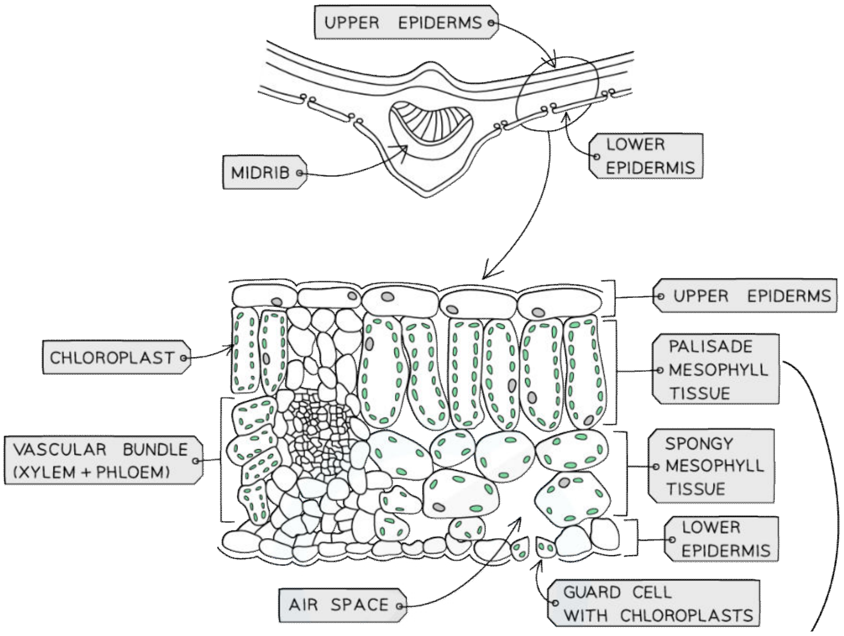
(c) air spaces

(d) vascular bundles (xylem and phloem)

(e) distribution of chloroplasts

(f) upper and lower epidermis





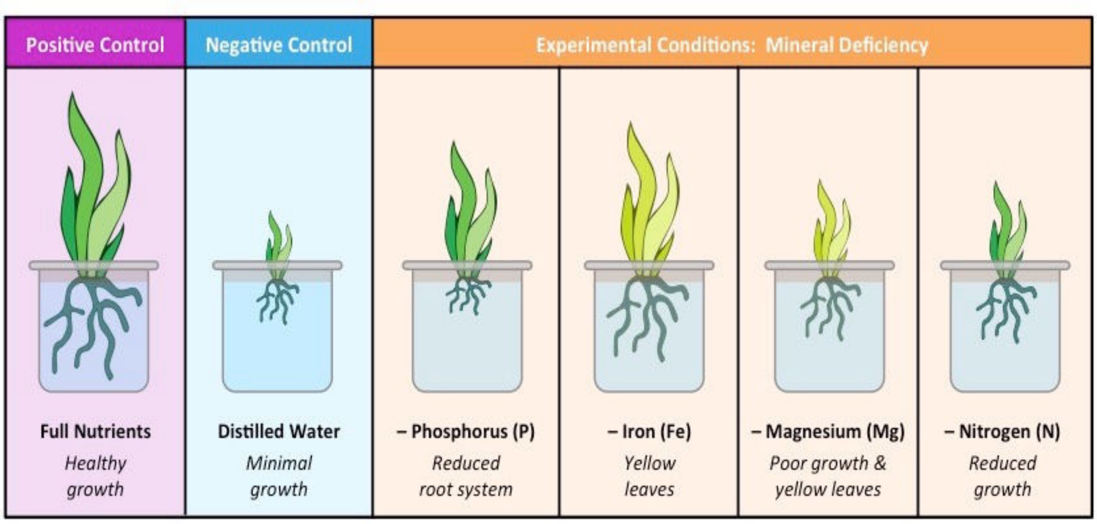
Explain the importance of nitrate ions for making amino acids, required for the production of proteins.

Explain the importance of magnesium ions for making chlorophyll.

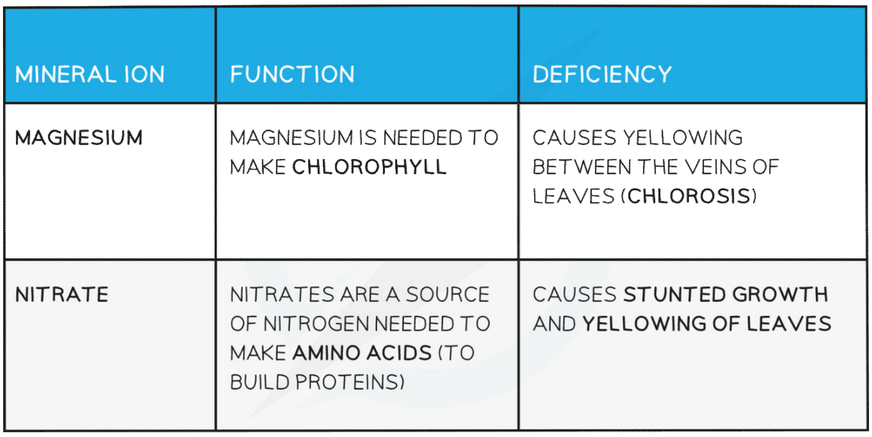
Plants need a supply of nitrate ions for making amino acids. Amino acids are important because they are joined to make proteins. They are needed to make the enzyme and cytoplasm of the cell. If the soil does not contain nitrate ions the plant can show deficiency symptoms. The symptoms will vary depending on the species of the plant if the plant has a shortage of nitrate ions

- ➢ It shows stunted growth.
- ➢ The stem becomes weak.
- ➢ The lower leaves become yellow.
- ➢ The upper leaves become a pale green.

The following picture elaborates some experimental variations with the minerals and their effect on the plant growth.



Plants also need magnesium ions to make chlorophyll the photosynthetic pigment in chloroplast. Plants get its magnesium in mineral ions from the soil. If a plant has a shortage of magnesium, it will not be able to make chlorophyll. The leaves turn yellow from the bottom of the stem upwards Farmers and gardeners can recognize the symptoms and make sure the missing minerals are replaced by adding the correct fertilizer to the soil.



MINERAL ION	FUNCTION	DEFICIENCY
MAGNESIUM	MAGNESIUM IS NEEDED TO MAKE **CHLOROPHYLL**	CAUSES YELLOWING BETWEEN THE VEINS OF LEAVES (**CHLOROSIS**)
NITRATE	NITRATES ARE A SOURCE OF NITROGEN NEEDED TO MAKE **AMINO ACIDS** (TO BUILD PROTEINS)	CAUSES **STUNTED GROWTH** AND **YELLOWING OF LEAVES**

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