CAIE Biology IGCSE

6: Plant Nutrition

Notes

(Content in **bold** is for Extended students only)

Photosynthesis

Photosynthesis is a metabolic reaction occurring in plants in which **light energy** converts raw materials into **carbohydrates** such as glucose.

Photosynthesis occurs in the **chloroplasts** of plant cells. Chloroplasts contain **chlorophyll**, which is a green pigment which transfers light energy into chemical energy to make carbohydrates.

Carbohydrates which are made in photosynthesis can be stored in plants and can be used for:

- starch as an energy store
- cellulose to build cell walls
- glucose used in respiration to provide energy
- sucrose for transport in the phloem
- nectar to attract insects for pollination

Word equations for photosynthesis:

carbon dioxide + water → glucose + oxygen

(in the presence of light and chlorophyll)

Chemical equations for photosynthesis:

$$6CO_2 + 6H_2O \xrightarrow[Chlorophyll]{Light} C_6H_{12}O_6 + 6O_2$$

Factors affecting rate of photosynthesis:

The rate of photosynthesis is limited by the limiting factor. This is the factor which is least available to the plant. For example, at night, light intensity is very low hence the rate of photosynthesis is also very low, regardless of the carbon dioxide concentration and temperature.

- **Carbon dioxide concentration** - as carbon dioxide concentration increases, rate of photosynthesis also increases.

- **Temperature** - photosynthesis requires enzymes to carry out the reaction. As these enzymes have an optimum temperature, photosynthesis also has an optimum temperature. This is usually about 25°C. **At low temperatures, for example in the winter, plants photosynthesize slowly as the enzymes have little kinetic energy, thus few enzyme-substrate complexes are made. At very high temperatures, these enzymes denature, also slowing the rate of photosynthesis.**

- **Light intensity** - As the light intensity increases, the rate of photosynthesis increases. **A high light intensity can sometimes lead to the plant heating up above the optimum temperature. This means that temperature would become the limiting factor and the rate of photosynthesis would not be increased by a further increase in light intensity.**

Minerals in plants:
Minerals are taken up actively by root hair cells and have a variety of important roles in the plant.

- **Nitrate ions** - nitrate ions are used in the plant to build **amino acids**, and thus proteins and enzymes. Without nitrate ions, the plant would not be able to grow or repair itself.

- **Magnesium ions** - magnesium ions are used to make **chlorophyll**; thus, a lack of magnesium ions will lead to a lack of chlorophyll, meaning that photosynthesis cannot occur. This means that sugars cannot be formed through photosynthesis, therefore the plant will not have a sufficient enough energy source to grow and repair itself.

The lack of either of these ions leads to **yellow leaves and poor growth**, eventually leading to the plant's death.

Testing the need for chlorophyll in photosynthesis:

To test for the need of **chlorophyll in photosynthesis**, we have to test for the presence of **starch**. Starch presence indicates that photosynthesis has occurred. Although **glucose** is directly produced by photosynthesis, we cannot test for glucose directly because it is quickly converted to substances like starch.

A **variegated** leaf plant should be used. A variegated leaf plant contains leaves with both green and white patches. The plant should be kept in darkness for 48 hours to deplete the starch. The starch is broken down into glucose, which is used for respiration. The plant should then be placed in sunlight so new starch can be produced. The leaves should then be covered with **iodine**. Iodine is used to test for starch. The green patches will turn blue-black, indicating starch production, while the white patches remain orange-brown. Starch is only produced in the green areas, which shows photosynthesis only occurs in the green areas. Therefore photosynthesis only occurs where **chlorophyll** is present.

Testing the need for light in photosynthesis:

To test for the need of **light** in photosynthesis, a plant should be depleted of starch by keeping it in darkness for 48 hours. Clip a piece of **aluminum foil** onto one leaf, then place the plant in sunlight to allow new starch to be produced. The leaves should then be covered with **iodine**. The leaf clipped with **aluminum foil** will turn orange-brown and the areas of the plant exposed with sunlight will turn blue-black. This shows starch is only produced in the areas which were exposed to sunlight, which shows that photosynthesis only occurs in these areas. Therefore light is needed for photosynthesis.

Testing the need for carbon dioxide in photosynthesis:

To test for the need of **carbon dioxide** in photosynthesis, two plants should be depleted of starch by keeping them in darkness. Both plants should be covered by transparent bags: a petri dish of **sodium hydrogencarbonate** and a petri dish of **soda lime** in the other bag. Sodium hydrogencarbonate is used to produce carbon dioxide whereas soda lime absorbs carbon dioxide. The plants should then be placed in sunlight and the leaves should be covered in **iodine**. The leaves from the plant with soda lime turn orange brown as no starch is produced in this plant. The leaves from the plant with sodium hydrogencarbonate turn blue black as starch is produced in this plant.

The effect of light and dark conditions on gas exchange in aquatic plants:

- Four test tubes should be set up with an equal volume of **hydrogencarbonate indicator solution**(an orange indicator solution).
- The test tubes should be set up the following way:
    - **Test tube 1:** a control tube (no leaf present)
    - **Test tube 2**: contains a leaf
    - **Test tube 3:** contains a leaf and test tube covered with aluminum foil
    - **Test tube 4:** contains a leaf and test tube covered with gauze
- Place a bung into the top of each test tube
- The test tubes should be exposed to sunlight for 24 hours

Results:

- **Test tube 1** will show no colour change(will remain orange).

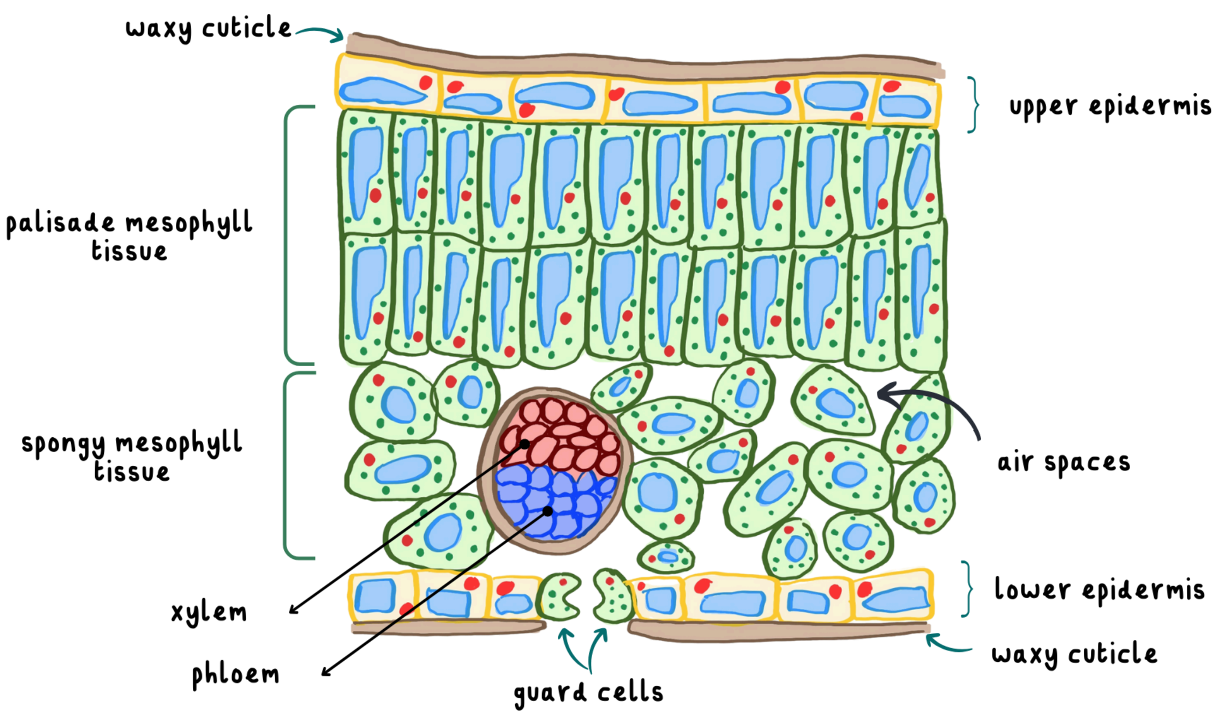
- **Test tube 2** turns colour from orange to purple. This is because when exposed to sunlight, the **rate of photosynthesis** is greater than the **rate of respiration**. This means more CO_2 is removed from the test tube. Thus the colour of the test tube turns purple.

- **Test tube 3** turns colour from orange to yellow. Aluminum foil prevents the entry of light into the test tube. Therefore the **rate of respiration** is greater than the **rate of photosynthesis**, causing more CO_2 to be released into the test tube. This causes the colour of the test tube to turn yellow.

- **Test tube 4** remains orange. Gauze partially allows light to pass through. This means the **rate of photosynthesis** is equal to the **rate of respiration**. As there is no change in CO_2 in the test tube, the indicator solution remains orange.

Leaf structure

Most plant leaves have a large surface area and are thin. These features are important **adaptations** to allow photosynthesis to occur. This means limiting water loss, absorbing as much light energy as possible and allowing for efficient gas exchange.



- **Chloroplasts** - This is where photosynthesis occurs. Chloroplasts contain chlorophyll which allows light energy to be absorbed and converted to chemical energy.

- **Cuticle** - The cuticle is a clear waxy layer that surrounds the leaf. This provides waterproofing and reduces water loss from the leaf without reducing light absorption.

- **Guard cells and stomata** - Stomata are located on the lower side of the leaf and allow carbon dioxide in by diffusion, and water vapour and oxygen out of the leaf by diffusion. Guard cells surround the stomata and can control the opening and closing of the stomata to limit water loss from the plant; when there is a limited water supply, the guard cells cause the stomata to close to prevent water loss. This, however, also reduces the diffusion of carbon dioxide through the stomata for use in photosynthesis, so can cause carbon dioxide to become the limiting factor and reduce the rate of photosynthesis. Plants in hot places often have fewer stomata to reduce water loss. Some plants, for example cacti, only open their stomata at night.

- **Upper and lower epidermis** - the epidermis acts as a protective barrier around the leaf to prevent pathogens entering and causing harm to the organism. Epidermis cells are transparent to let light pass through and do not contain chloroplasts.

- **Palisade mesophyll** - these cells are positioned near the top of the leaf where most sunlight hits, thus palisade cells are adapted to absorb light energy efficiently. The palisade layer cells contain many chloroplasts to carry out photosynthesis. There are also gaps between the cells to allow for efficient gas exchange and osmosis to occur. CO2 and water move into the cells to be used in the photosynthesis reaction.

- **Spongy mesophyll** - This is the lower layer of the leaf. The spongy mesophyll has **air spaces** which increase the surface area and allow the rapid diffusion of CO_2, water and oxygen into the leaf when the stomata are open.

- **Vascular bundles** - vascular bundles form the plant's transport system. They consist of the xylem and the phloem, as well as other cells around them which provide support.

- **Xylem** - the xylem is used to transport water through plants from the roots in transpiration. The xylem is made from hollowed-out dead cells that have the ends removed to make a tube for water to pass through. They have a thick cell wall to provide structural strength and are thin to allow capillary action.

- **Phloem** - the phloem is made of living cells and is used to transport sugars and food nutrients in translocation. The cells of the phloem are adapted by having no nucleus.