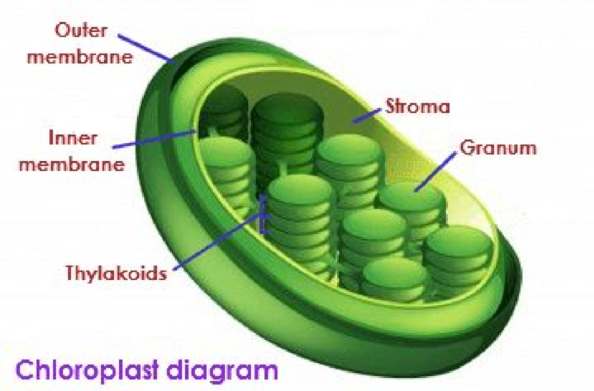
CAIE Biology A-level

Topic 13: Photosynthesis

Notes

Photosynthesis is a reaction in which light energy is converted to chemical energy in the form of glucose. Oxygen is a waste product of this reaction and is released into the atmosphere.

Photosynthesis occurs in the chloroplasts, which are adapted for photosynthesis in the following ways:



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- They contain stacks of thylakoid membranes called grana which contain the photosynthetic pigments such as chlorophyll. These are arranged as photosystems.
- They contain stroma which is the fluid surrounding the grana, stroma contains all the enzymes required for the light independent stage of photosynthesis

The rate of photosynthesis is determined by limiting factors, such as carbon dioxide concentration, light intensity, light wavelength and temperature. The rate of photosynthesis increases as these factors increase, however at high light intensities and temperatures, the leaves can be damaged and enzymes denature, thus the rate is slowed. These factors can be controlled when growing crops to maximise efficiency and yield. This can be done by growing crops in a greenhouse.

Leaves of C4 plants such as maize and sorghum are adapted to work at high temperatures. The enzymes involved in photosynthesis have a higher optimum temperature, so are not damaged by the high temperatures. In addition, they fix carbon dioxide into a four carbon organic acid called malate in mesophyll cells which surround the photosynthetic cells, before transporting that to the photosynthetic cells where it is broken down into carbon dioxide. This ensures that there is a high concentration of carbon dioxide so rubisco fixes carbon dioxide and not oxygen*. This removes carbon dioxide as the limiting factor.

*At temperatures above 25°C (before denaturing), rubisco fixes oxygen and not carbon dioxide. This is a wasteful process.

Photosynthetic pigments

Photosynthetic pigments are involved in absorbing light required for photosynthesis and subsequently convert it to chemical energy. The colour of pigments is determined by the light they reflect.

Chlorophylls absorb red as well as blue-violet light, they only reflect green light, thus giving chlorophyll green colour. The two forms of chlorophyll are chlorophyll a with the highest abundance which absorbs light at 430nm and 663nm, and chlorophyll b, which absorbs at 453nm and 642nm.

Apart from chlorophyll, **carotenoids** are also involved in photosynthesis and serve to prevent damage of chlorophyll. Carotenoids are present in two forms, **beta carotene** which is orange in colour and **xanthophyll** which is yellow in colour.

An **absorption spectrum** can be used to determine the wavelengths absorbed by particular pigments by illustrating the percentage of light absorbed at a particular wavelength. Whereas an **action spectrum** illustrates the relationship between the rate of photosynthesis for a given wavelength.

Photosynthesis

There are two stages of photosynthesis:

- **Light-dependent reaction**
    1. Light energy **excites electrons** in the chlorophyll molecule in the thylakoid membrane, causing them to pass to an **electron acceptor** at the start of the **electron transport chain**. This is called **photoionisation.**
    2. Electrons pass down the chain from one electron carrier to the next in a **series of redox reactions.** This process generates **ATP from ADP and inorganic phosphate** in a process called **photophosphorylation**.
    3. Light splits water into protons (H+ ions), electrons and oxygen (waste). The electrons are used to replace the electrons lost from the chlorophyll in step 1. This process is called **photolysis of water**. The protons are pumped across the membrane using the ATP created in step 2 in a process called **chemiosmosis**. This creates a **chemical potential gradient.**
    4. **Reduced NADP** is generated as the electrons in the electron transport chain are transferred to NADP along with a proton.
    5. Protons pass back through the membrane through an **ATP synthase** enzyme which makes ATP. Approximately 4 protons make one ATP molecule. Both ATP and reduced NADP are used in the light-independent stage of photosynthesis.

- **Light-independent reaction,** also known as the **Calvin cycle,** is the final stage of photosynthesis which uses ATP and reduced NADP from the light dependent stage to produce glucose.

  Light independent reaction occurs as following:

    1) **RuBP** is combined with **carbon dioxide** in a reaction called **carbon fixation, catalysed by the enzyme RUBISCO.**
    2) **RuBP** is converted into **two glycerate 3-phosphate (GP)** molecules
    3) Reduced NADP and ATP are used to **reduce each GP molecule to triose phosphate.** In this process, the reduced NADP becomes oxidised.

4) Some of triose phosphate molecules are used to make **glucose** (every 6 cycles) which is then converted to essential organic compounds such as **polysaccharides, lipids, amino acids and nucleic acids.**
5) Remaining triose phosphate molecules are used to **regenerate RuBP with the help of ATP**.