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:

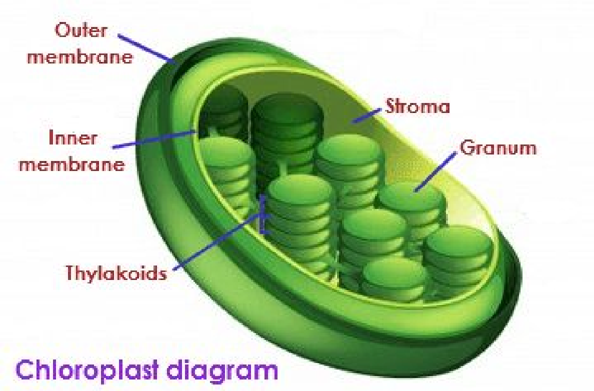

*Figure SEQ Figure * ARABIC 1 Tutorvista*

- 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

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.

Separating photosynthetic pigments:

This can be done by extracting the pigments from a leaf and then carrying out **chromatography**.

- This can be done by drawing a line with pencil approximately 1/2cm above the bottom of the filter paper
- After extracting the pigments from the leaf you then place a dot of the pigment on line
- The filter paper is then suspended in solvent which is then left in there until the solvent moves near to the top
- You then draw a line to where the solvent has reached at the top and work out the **Rf values** for each pigment present inside the leaf

Rf value = distance moved by solute / distance moved by solvent

The **further** the pigment moves up the filter paper, the **larger the Rf value**. The Rf value can then be used to find out which pigments are present in the leaf.

Photosynthesis

There are two stages of photosynthesis:

- **Light-dependent reaction**
    1. Light energy **excites electrons** at the reaction centres of the photosystems (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 are released from photosystem II (PSII) and they pass down the chain from one electron carrier to the next in a **series of redox reactions.** ATP is produced via chemiosmosis. The electrons then leave PSII and enter photosystem I. Again they go down the electron transport chain and ATP is produced again. This process again generates **ATP from ADP and inorganic phosphate**.
    3. Light splits water into protons (H+ ions), electrons and oxygen (waste). The electrons are used to replace the electrons that leave photosystem II. 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 return to the stroma through **ATP synthase** via facilitated diffusion which produces ATP. Approximately 4 protons make one ATP molecule. Both ATP and reduced NADP are used in the light-independent stage of photosynthesis.

Photolysis of water and the flow of electrons from photosystem II to photosystem I whilst generating ATP and reduced NADP is called **non-cyclic photophosphorylation**. This is the 'standard' version of the light-dependent stage of photosynthesis.

Cyclic photophosphorylation can also take place. This type of photophosphorylation only involves PSI. This is when electrons that are leaving photosystem I are **returned back** to photosystem I instead of being used to form reduced NADP. During cyclic photophosphorylation **reduced NADP isn't generated** but ATP is still generated by PSI without using any electrons from PSII.

- **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. These set of reactions take place in the **stroma**.

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**.

Limiting factors

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.

Light intensity

- As light intensity increases**, ATP** and **reduced NADP** are produced at a **higher rate**

Carbon dioxide concentration

- As concentration increases, **more carbon fixation** takes place and an **increased rate of TP production** in the Calvin cycle

Temperature

- The rate of **enzyme-controlled reactions** will also increase however when temperature goes above optimum the enzymes will **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.