CAIE Biology A-level

Topic 13: Photosynthesis

Notes

Photosynthesis

Photosynthesis is a process in which **light energy** is converted into chemical energy stored in organic molecules such as 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:

- They contain **stacks of thylakoid membranes called grana** which contain the photosynthetic pigments (**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.

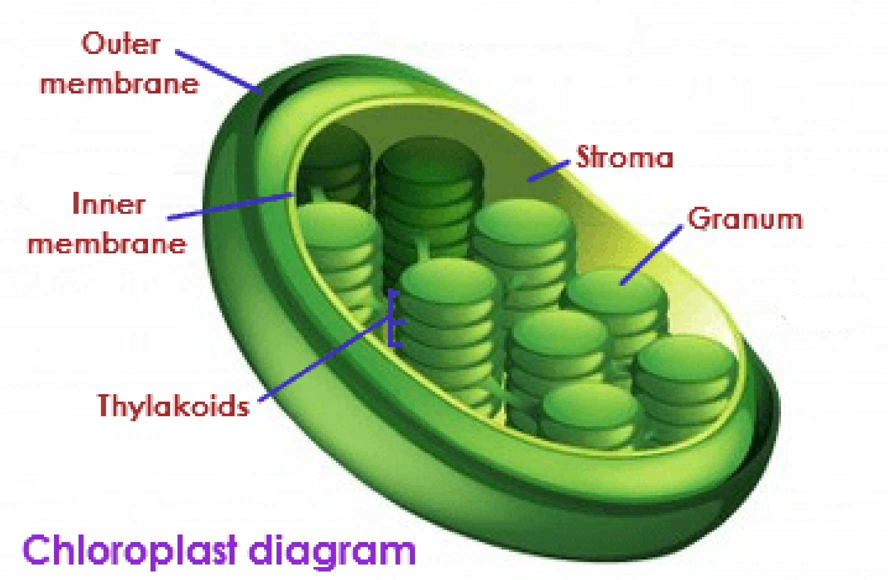


*Figure SEQ Figure * ARABIC 1 Tutorvista*

Photosynthetic pigments

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

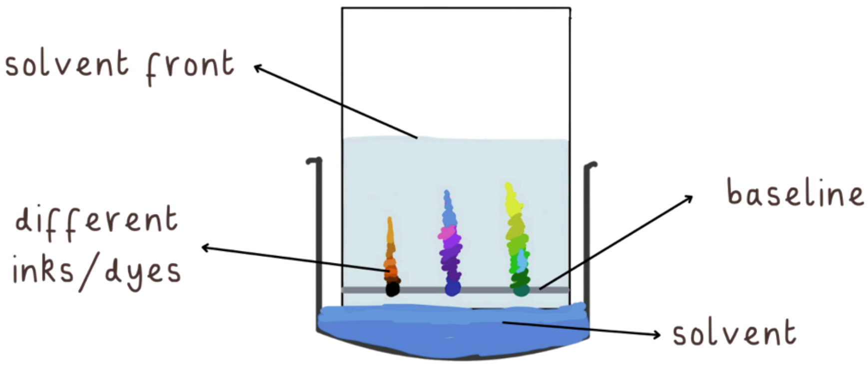
Chlorophylls absorb red and blue-violet light; they only reflect green light, thus giving chlorophylls a green colour. The two forms of chlorophyll are **chlorophyll a**, which is the most abundant and absorbs light at 430 nm and 663 nm, and **chlorophyll b,** which absorbs at 453 nm and 642 nm.

Apart from chlorophyll, **carotenoids** are also involved in photosynthesis and help prevent damage to chlorophyll by absorbing excess energy. 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. In contrast, an **action spectrum** illustrates the relationship between the rate of photosynthesis for a given wavelength.

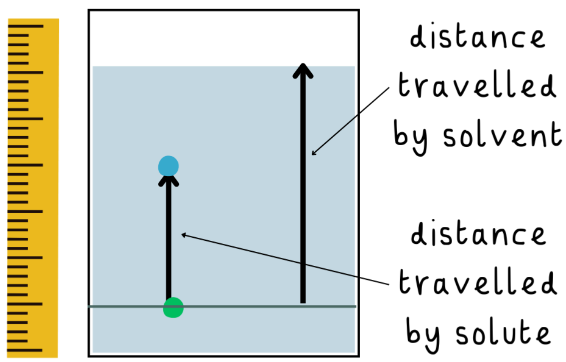
Separating photosynthetic pigments:

Photosynthetic pigments can be separated by extracting the pigments from a leaf and then carrying out chromatography.



- First, draw a line (called the baseline) with a pencil, approximately 1-2 cm above the bottom of the filter paper.
- After extracting the pigments from the leaf, place a dot of the pigment on the baseline.
- The filter paper is suspended in solvent and left until the solvent moves near the top.
- Draw a line to where the solvent has reached at the top (solvent front) and work out the Rf values for each pigment present inside the leaf using the formula:

Rf value = distance travelled by solute / distance travelled 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.

Stages of photosynthesis

There are two stages of photosynthesis:

- **Light-dependent reaction** (This stage takes place in the **grana**).
    1. A chlorophyll molecule in the thylakoid membrane absorbs light energy, which **excites electrons** at the reaction centres of the photosystems, causing them to pass to an **electron acceptor** at the start of the **electron transport chain**. This is called **photoactivation.**
    2. Electrons from photosystem II (PSII) pass down an electron transport chain, releasing energy used to generate ATP by **chemiosmosis**. The electrons then enter photosystem I, where they are re-excited and used to **reduce NADP**.
    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**. Energy released as electrons pass along the electron transport chain is used to pump protons into the thylakoid space, creating a proton gradient.
    4. **Reduced NADP** is generated as the electrons in the electron transport chain are transferred to NADP along with a proton.
    5. The movement of protons back into the stroma through **ATP synthase** drives ATP synthesis by **chemiosmosis**. Both ATP and reduced NADP are used in the light-independent stage of photosynthesis.

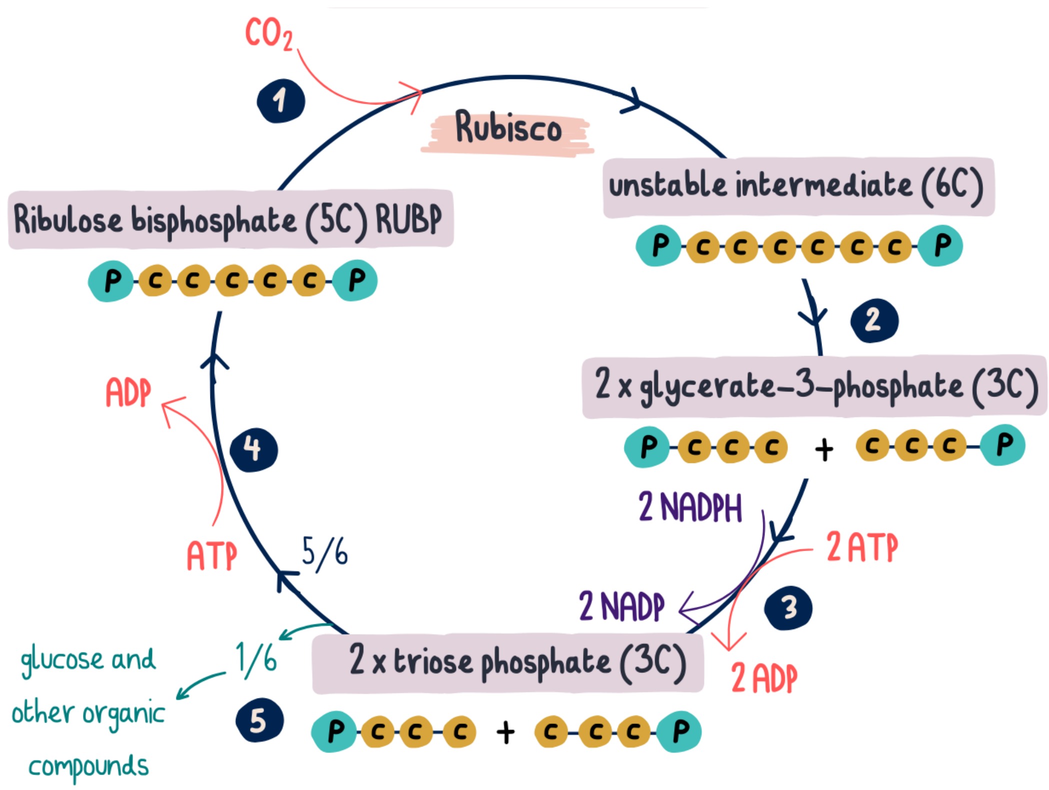
Non-cyclic photophosphorylation involves photolysis of water which is catalysed by the **oxygen-evolving complex**. It also involves electron flow from photosystem II to photosystem I, and the production of both **ATP and reduced NADP**. This is the ‘standard' version of the light-dependent stage of 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 synthesised using photosystem I, without involvement of photosystem II.

Type of phosphorylation	**Non-cyclic photophosphorylation**	**Cyclic photophosphorylation**
Photosystem involved	Photosystem I (PSI) and photosystem II (PSII) are both involved	Only photosystem I (PSI) is involved
Product formed	ATP and reduced NADP are synthesised	ATP is synthesised

- **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 and other organic molecules. This takes place in the **stroma**.

  1. **RuBP** is combined with **carbon dioxide** in a reaction called **carbon fixation, catalysed by the enzyme Rubisco.**
  2. **RuBP** is converted into an unstable 6C intermediate which then splits 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. Remaining triose phosphate molecules which are not used to make glucose are used to **regenerate RuBP with the help of ATP**.
  5. Some of the triose phosphate molecules are used to make **glucose** (every six cycles) which is then converted to essential organic compounds such as **polysaccharides, lipids, amino acids and nucleic acids.**
  6. GP is used to produce some amino acids, and TP is used to produce carbohydrates, lipids, and amino acids.



Limiting factors

The rate of photosynthesis is determined by **limiting factors**, such as carbon dioxide concentration, light intensity and temperature. **The rate of photosynthesis increases as these factors increase**, however at very high light intensities and temperatures, enzymes may denature and photosynthetic tissues can be damaged, reducing the rate of photosynthesis.

Limiting factors	How they affect rate of photosynthesis
Light intensity	As light intensity increases, **ATP** and **reduced NADP** are produced at a **higher rate.** This would lead to an increased rate of photosynthesis.
Carbon dioxide concentration	As the concentration increases, **more carbon fixation** takes place causing an **increased rate of TP production** in the Calvin cycle. This would lead to an increased rate of photosynthesis.
Temperature	The rate of **enzyme-controlled reactions** increases when temperature increases, however when temperature goes above the optimum, the enzymes will **denature**, thus the rate of photosynthesis 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.