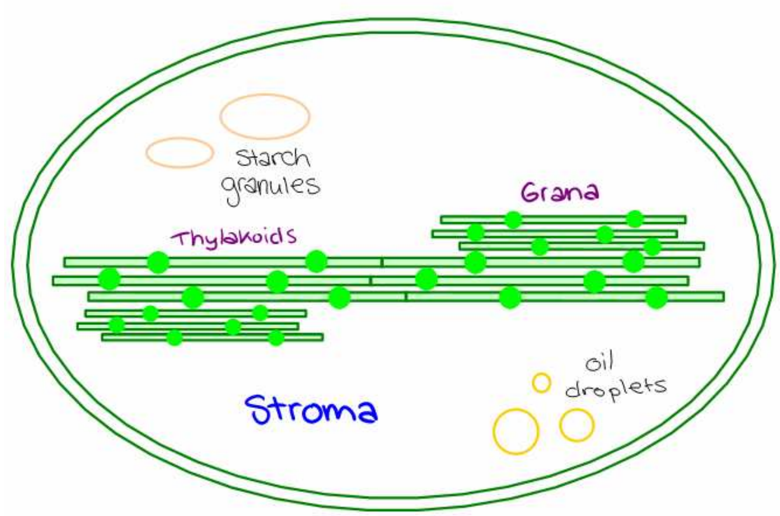
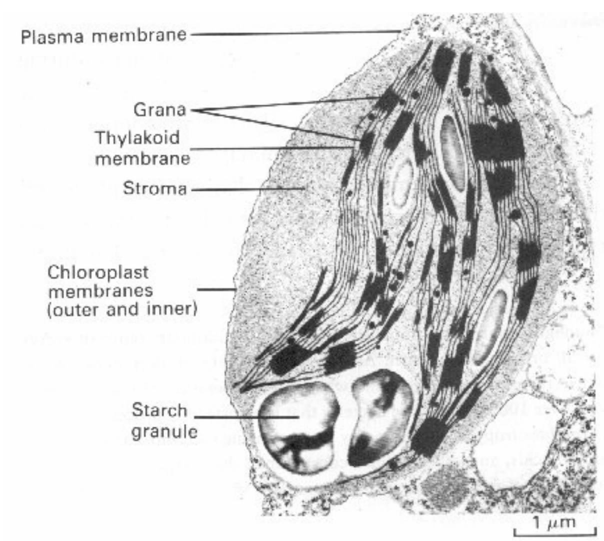
8.2 – Photosynthesis

8.2.1 - Draw and label a diagram showing the structure of a chloroplast as seen in electron micrographs



- cell wall
- double membrane
- starch grain
- grana
- thylakoid
- internal membrane - location of the light dependent reaction
- stroma - surrounds the thylakoids - location of the light independent reaction, including the Calvin cycle. Often contain large starch grains and oil droplets, products of photosynthesis



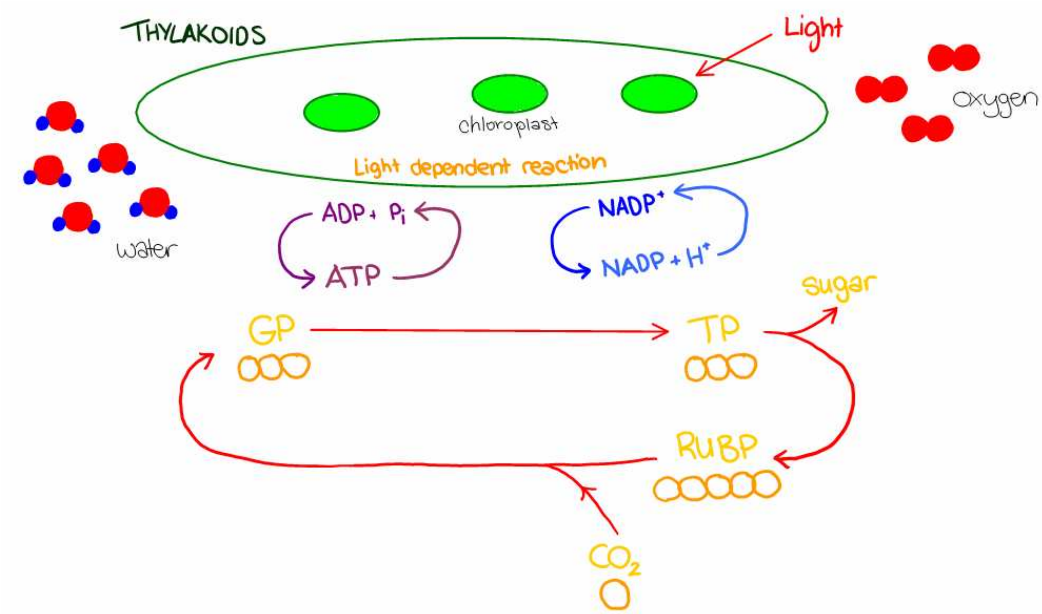
8.2.2 - State that photosynthesis consists of light-dependent and light-independent reactions

Light Dependent Reaction

- sun's energy is trapped by chlorophyll
- light energy is used to split water - photolysis
- hydrogen is retained by the hydrogen acceptor, $NADP^+$
- ATP is generated from ADP and phosphate, using light energy
  - called photophosphorylation
- oxygen is given off as a waste product
- occurs in the grana, in the thylakoid membranes

Light Independent Reaction

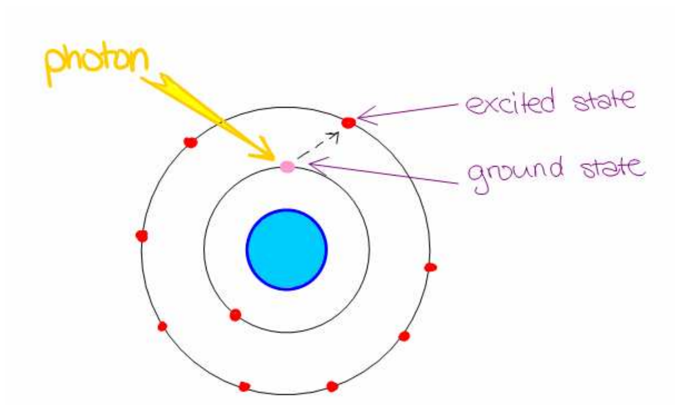
- chemical energy is used - ATP and the reduced hydrogen acceptor $NADPH + H^+$
- sugars are built up using CO_2
- occurs in the stroma
- can occur during dark periods if products of the light dependent reactions are available



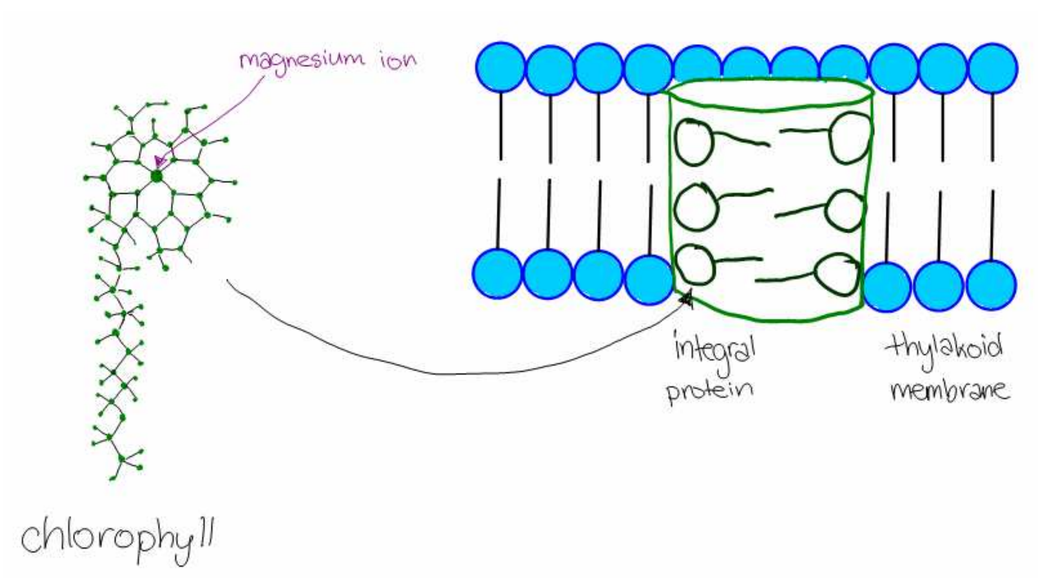
8.2.3 - Explain the light-dependent reactions

In the **light dependent reactions**, light energy from the sun is converted into chemical energy. This is trapped in the chlorophyll, which are grouped into structures called photosystems. The **photosystems** are found on the thylakoid membranes of the grana.

There are multiple types of chlorophyll found in each photosystem, each of which absorb a different wavelength of light. *Chlorophyll A* is in the centre of the photosystem. When light hits the chlorophyll, electrons are excited and lost in **oxidation**.



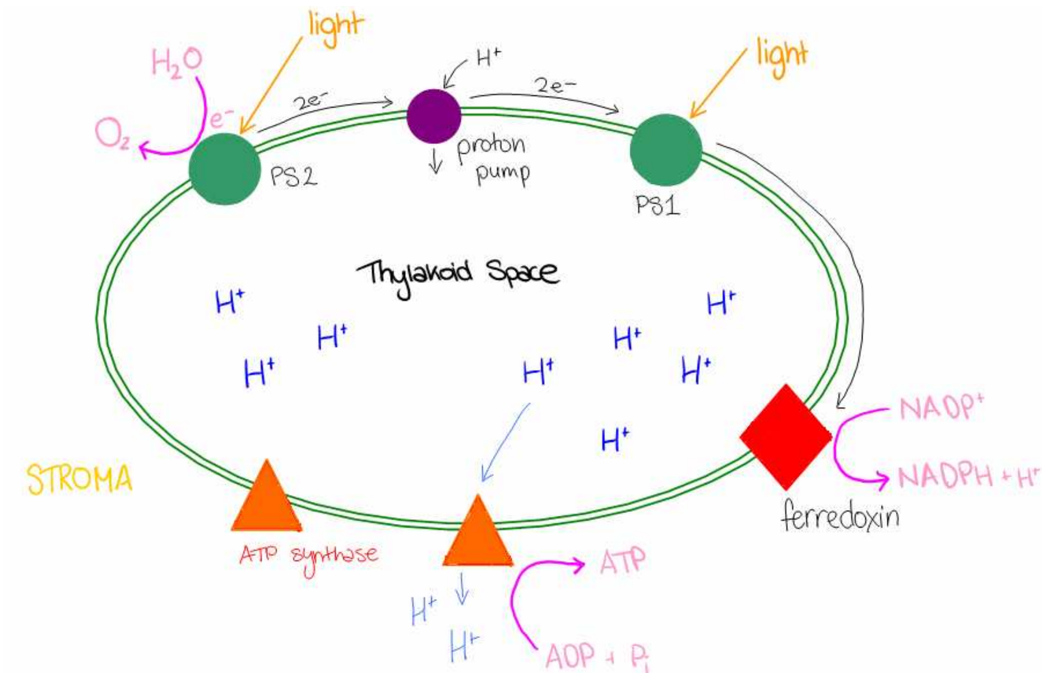
< atom



Cyclic Photophosphorylation

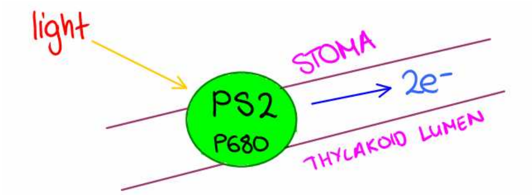
ATP is produced in a cyclic process when the **ratio of NADPH + H^+ : $NADP^+$ is high**. Photosystem 1 does not generate any NADPH + H^+, but acts to send electrons to the proton pump.

Photosystem 1 is oxidised, releasing an excited an electron to reduce the membrane proton pump. Protons, in the forms of H^+ are pumped into the thylakoid space. This creates a concentration gradient necessary for the later production of ATP. The electrons are the cycled back to the first photosystem to reduce it.

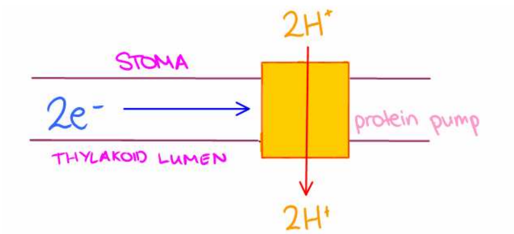


Non-cyclic Photophosphorylation

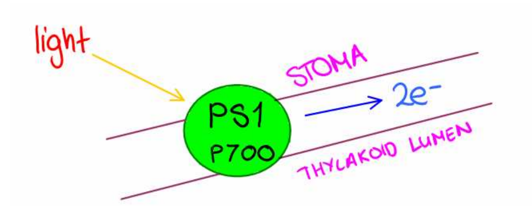
The light energy from the sun is trapped in t he chlorophyll, and ATP is produced. The co-enzyme $NADP^+$ is reduced to form NADPH + H^+. The first photosystem, photosystem two [**PS2**] is able to absorb light of the wavelength 680nm, which is why it is called P680. The second photosystem, photosystem one [**PS1**] is activated by wavelengths of 700nm, and called P700.



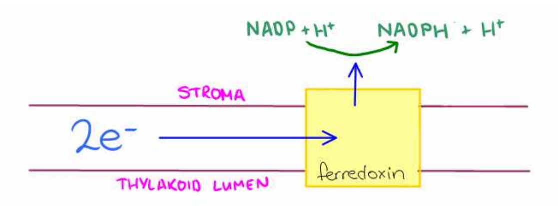
Light is first absorbed by the **chlorophyll A** in **PS2**. This energy is then converted into chemical energy by releasing electrons in oxidation .



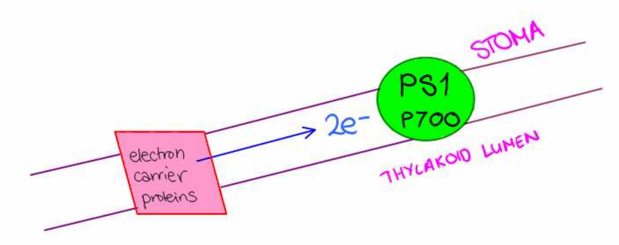
The electrons from PS2 then pass along the thylakoi d membrane in a series of redox reactions. The protein pumps are reduced to pump **H^+ ions** into the thylakoid space.



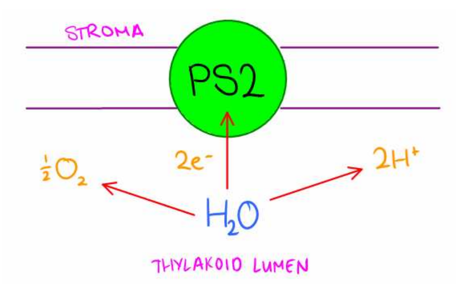
In PS1, a different light frequency is absorbed. The photosystem is oxidised to release electrons.



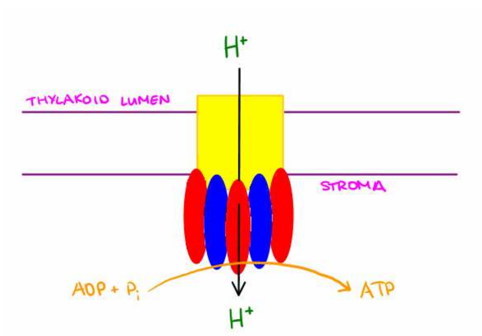
The electrons pass from PS1 to ferrod oxins, which reduce $NADP^+$ to NADPH + H^+. The NADPH stays in the stroma to be used in the light independent reactions.



Photosystem 1 is reduced by the electrons from PS2.

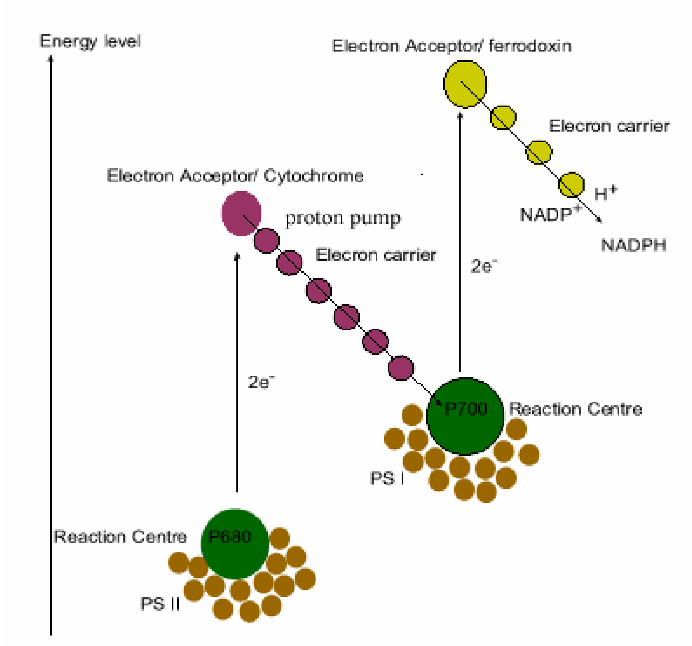


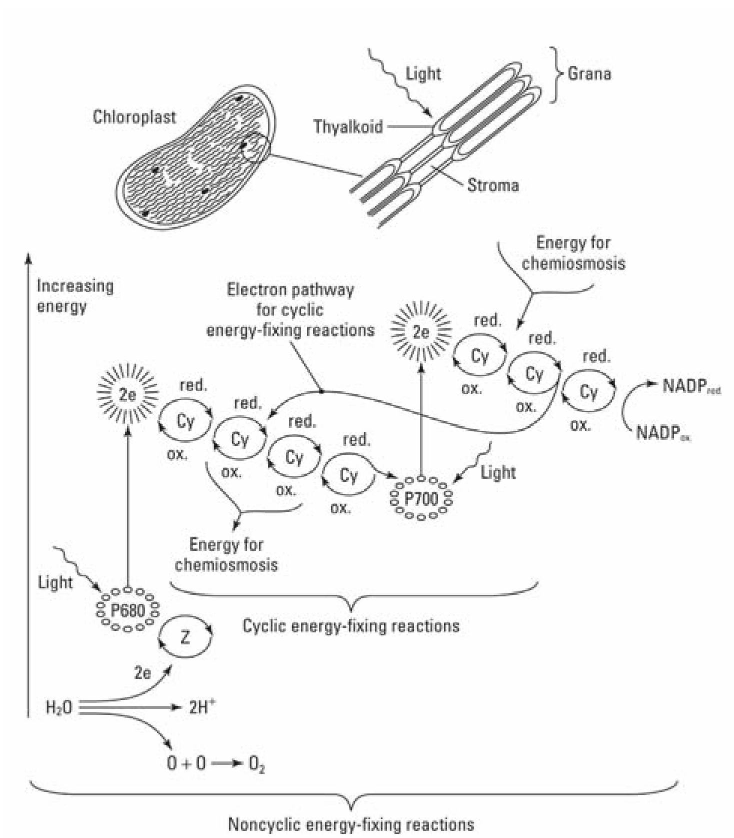
Photosystem 2 is then reduced so that it can absorb more light. When water i s split through photolysis, electrons are given to the photosystem . This is the source of H^+ ions and the waste O_2.



Since there is a high concentration of H^+ ions in the thylakoid lumen, they can diffuse back into the stroma through the pore in ATP synth ase. This process drives the phosphorylation of ADP to ATP.

During these redox reactions in the light dependent reactions, the energy levels of the electrons change. This is summarised below.





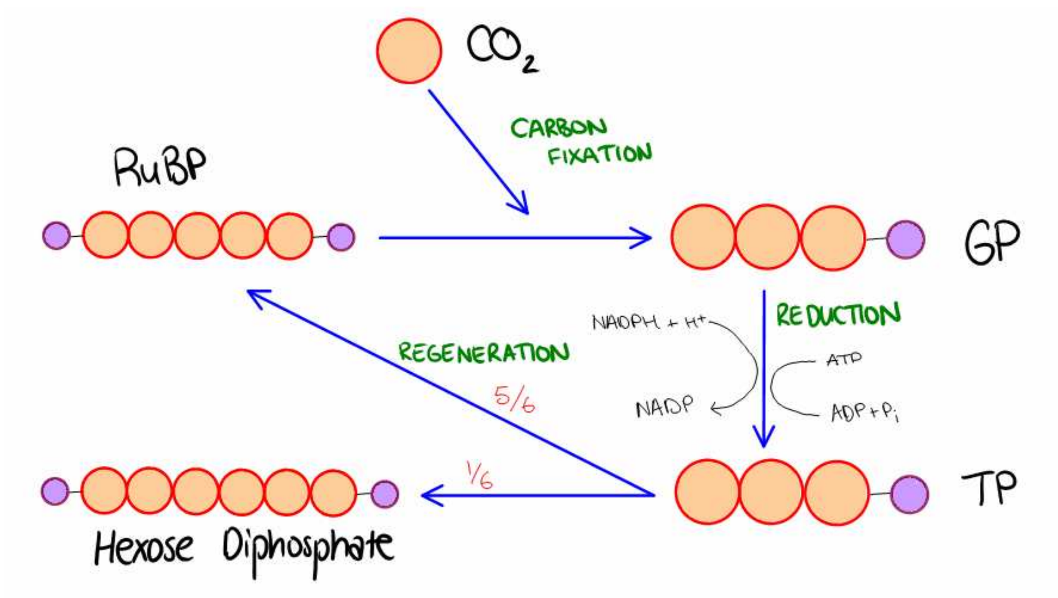
8.2.4 - Explain photophosphorylation in terms of chemiosmosis

A high concentration of H^+ ions accumulates in the thylakoid space due to **proton pumping**. This results in a proton gradient, causing protons to be pumped across the membrane through the **ATPase** molecules. This drives the motor mechanism of the structure, reducing ADP into ATP. This is like the process used in respiration.

The excited electrons the move to fill the vacancies in the reaction centre of PS2, then in PS1. They are used to reduce $NADP^+$, in non-cyclic photophosphorylation, in which the reaction pathway is linear.

8.2.5 - Explain the light-independent reactions

The CO_2 in the air is fixed to form carbohydrates. This is done using the energy trapped from sunlight in the light dependent reactions in the form of ATP and NADPH. These reactions take place in the **stroma**.

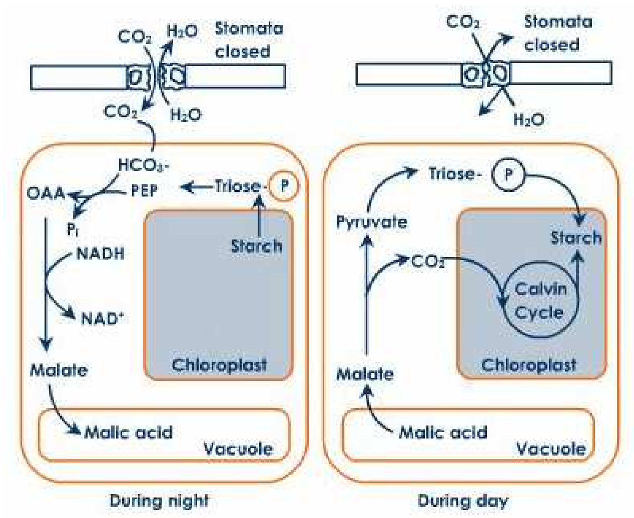


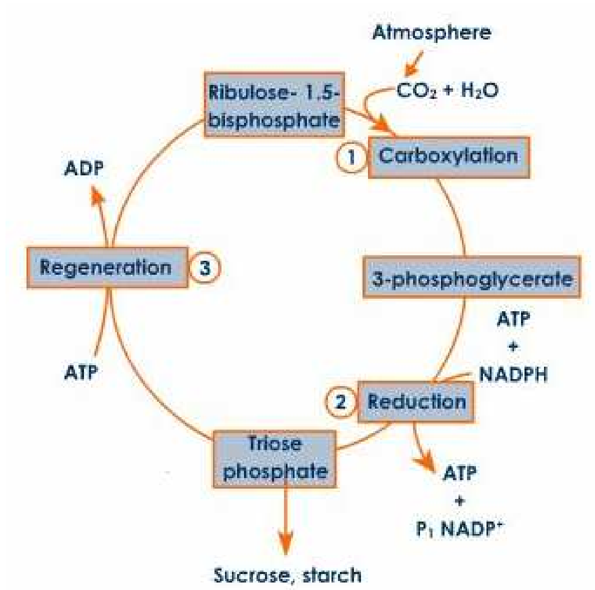
During **fixation** of CO_2, the carbon dioxide is trapped by **RuBP** to form two molecules of glycerate-3-phosphate.

The **GP** is then reduced to **TP** in the **reduction step**, using **ATP and NADPH + H^+** to provide the energy.

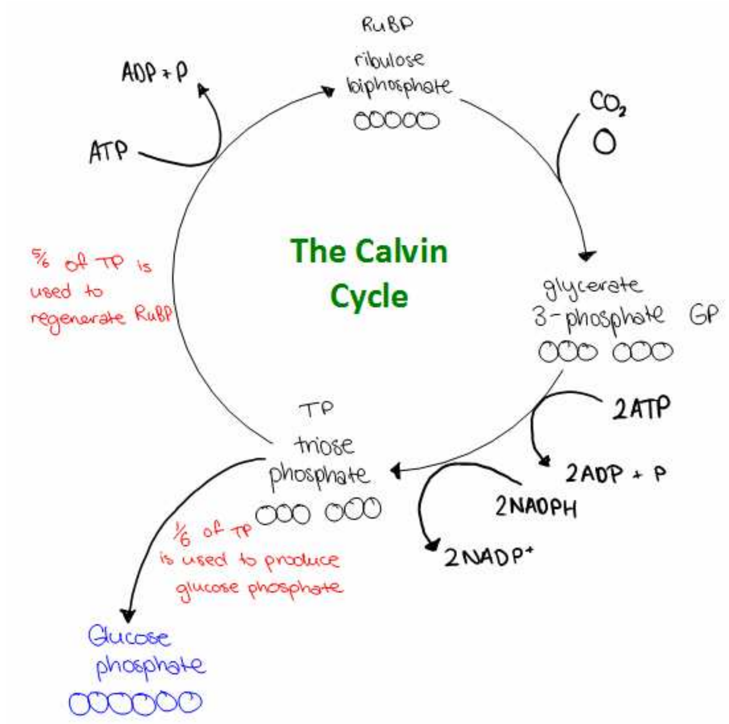
In the **product synthesis step**, **TP** is used to make organic molecules such as glucose phosphate, sugar, starch, lipids, amino acids, etc.

This is followed by the **regeneration** of the acceptor step, where some **TP** turns back into **RuBP**. This allows for more CO_2 to be fixed from the atmosphere.





Ribulose biphosphate is a 5-carbon acceptor. The fixation of carbon itself is catalysed by the enzyme **RuBisCo** [ribulose biphosphate carboxylase], and is the most common protein in the leaves of green plants.

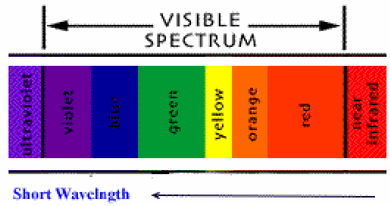


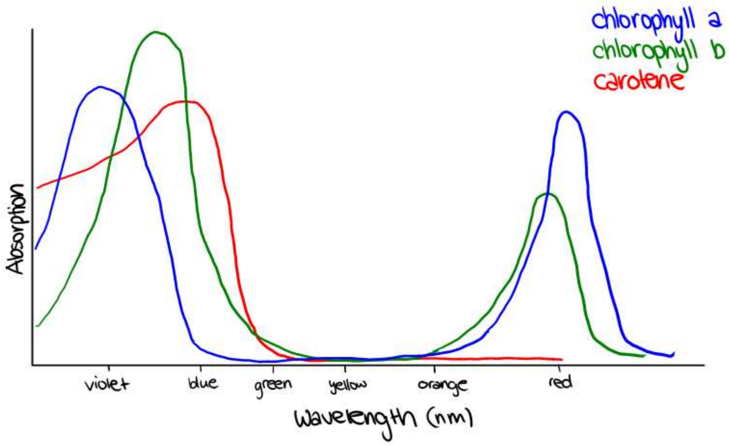
8.2.6 - Explain the relationship between the structure of the chloroplast and its function

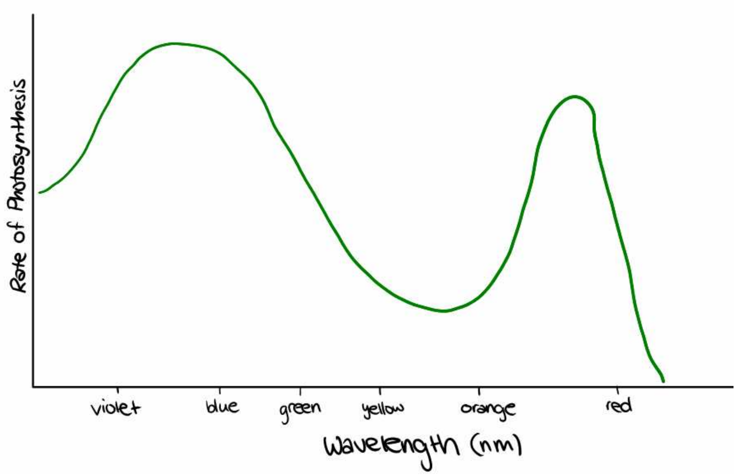
Structure of the Chloroplast	Function or Role
double membrane around the chloroplast	contains the grana and stroma. permeable to CO_2, O_2, ATP, sugar and other products of photosynthesis
photosystems with chlorophyll pigments arranged on thylakoid membranes of grana	provide larger surface area for maximum light absorption
thylakoid spaces within grana	restricted regions for the accumulation of protons and establishment of the proton gradient
fluid stroma with loosely arranged thylakoid membranes	the site of all the enzymes for fixation, reduction and regeneration of acceptor steps of light independent reactions, and many enzymes of the product synthesis steps

8.2.7 - Explain the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in green plants

Chlorophyll best absorbs red and blue light. Green light, on the other hand, is reflected, causing plants to appear green.







The rate of photosynthesis is highest and blue and red, and lowest at yellow and green because of the optimum wavelength for chlorophyll .

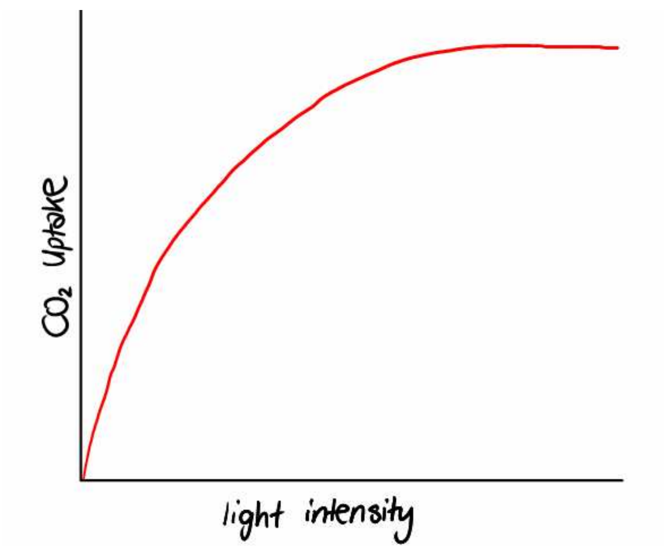
8.2.8 - Explain the concept of limiting factors in photosynthesis, with reference to light intensity, temperature and concentration of carbon dioxide

At any given time, only one of these factors will be the one limiting the rate of photosynthesis.

Light Intensity

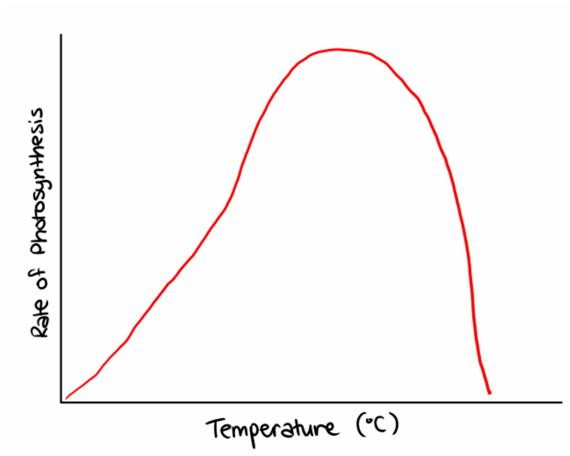
Light is essential for photosynthesis , however it reaches a **compensation point** when the amount of oxygen being produced is the same as that being consumed in respiration. As a result, the relationship reaches a **plateau** at high intensities.

Light energy aids in the production of H^+ ions from water and ATP. On the other hand, when there is no light, the plant can only respire. Too much light can damage the chlorophyll.



Temperature

As the surrounding temperature increases, the rate of photosynthesis increases, with each plant reaching an **optimum temperature** where the rate falls off steeply. The enzymes in the reactions a temperature -sensitive.



Carbon Dioxide Concentration

As the concentration of CO_2 increases, the rate of photosynthesis increases, before it **plateaus**. Each plant has a different **optimum concentration**.

When the CO_2 is the limiting factor, the NADPH simply accumulates in the stroma, stopping the photosystems from operating. ATP is formed through **cyclic photophosphorylation**.