CAIE Biology A-level

Topic 13: Photosynthesis

Flashcards

In which cell organelle does photosynthesis occur?

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In the chloroplasts of plant cells.

Where in the chloroplast does the light-dependent stage of photosynthesis occur?

Where in the chloroplast does the light-dependent stage of photosynthesis occur?

In the thylakoids.

Where in the chloroplast does the light-independent stage of photosynthesis occur?

Where in the chloroplast does the light-independent stage of photosynthesis occur?

In the stroma.

Why are there many different photosynthetic pigments?

Why are there many different photosynthetic pigments?

Each pigment absorbs light most efficiently at specific wavelengths. Having multiple pigments allows the organism to capture more energy from the Sun, compared to having just one pigment.

Which photosynthetic pigment is found in all photosynthetic plants?

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Chlorophyll *a*.

Which colours of light do chlorophyll pigments absorb, and which do they reflect?

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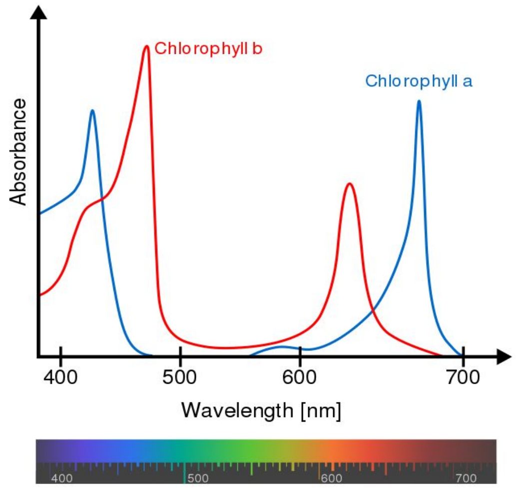
Chlorophyll *a* and *b* absorb red light (wavelength 650-700 nm) and blue light (wavelength 400-450 nm).

The chlorophyll pigments reflect green light (wavelength 500-550 nm). This is why most plants are green.



By Chlorophyll_ab_spectra2.PNG: Daniele Pugliesiderivative work: M0tty - This file was derived from: Chlorophyll ab spectra2.PNG:, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20509583

Plants containing carotenoid pigments (xanthophyll and carotene) tend to be which colours?

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Red, orange and yellow. The carotenoids absorb blue light (wavelength 400-450 nm) and reflect red, orange and yellow (wavelength 550-700 nm). The presence of these pigments gives carrots, pumpkins and tomatoes their colour.

Explain the difference between an absorption spectrum and an action spectrum.

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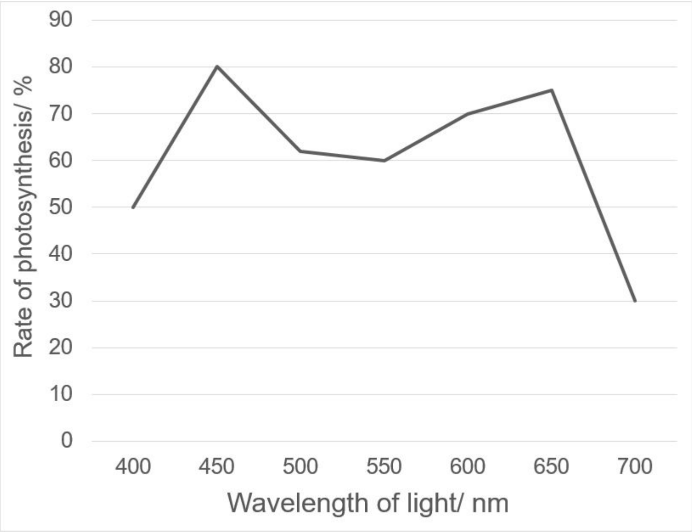
An **absorption spectrum** measures which wavelengths of light are absorbed by the chlorophyll pigments.

An **action spectrum** measures the rate of photosynthesis occurring at particular wavelengths.



An action spectrum

Name the technique used to separate chloroplast pigments.

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Chromatography.

How is the Rf value calculated in chromatography?

How is the Rf value calculated in chromatography?

$$\text{Retention value } (R_f) = \frac{\text{Distance travelled by component}}{\text{Distance travelled by solvent}}$$

Define photoactivation.

Define photoactivation.

The process by which two electrons in the chlorophyll molecule become excited (due to absorption of light energy) which causes them to leave the molecule. This results in the ionisation of the chlorophyll molecule.

What happens to the electrons that leave the chlorophyll molecule during photoactivation?

What happens to the electrons that leave the chlorophyll molecule during photoactivation?

The two electrons are taken up by an electron acceptor. From here, they move down electron carriers within the thylakoid membrane in the electron transfer chain (ETC). The electrons release energy as they move down the ETC.

How is the energy from the ETC used in the light-dependent stage?

How is the energy from the ETC used in the light-dependent stage?

The energy lost from the electrons is used to pump two H^+ ions from the stroma into the thylakoid space. This creates a H^+ gradient across the thylakoid membrane.

How is the H^+ gradient used to make ATP?

How is the H^+ gradient used to make ATP?

The H^+ ions in the thylakoid space exit via an ATP synthase enzyme in the thylakoid membrane. This enzyme catalyses the formation of ATP, using the energy in the H^+ ion gradient.

Once in the stroma, NADP accepts the H^+ ions becoming reduced NADP.

What happens to water during the light-dependent stage of photosynthesis?

What happens to water during the light-dependent stage of photosynthesis?

Water is split using light energy (**photolysis**).

$$2H_2O \rightarrow 4H^+ + 4e^- + O_2$$

State what happens to the products of the photolysis of water.

State what happens to the products of the photolysis of water.

- H^+ ions taken up by a hydrogen acceptor, NADP
- Electrons replace those lost from the chlorophyll molecules during photoactivation
- O_2 given off as a waste product

Outline cyclic phosphorylation.

Outline cyclic photophosphorylation.

- Excited electrons from **photosystem I** enter the ETC
- Energy from electrons used to produce ATP. The electrons return to photosystem I (hence the process is **cyclic**)
- There is no reduction of NADP, and no need to photolysis of water to replace the electrons
- Cyclic photophosphorylation is performed to produce extra ATP for immediate energy

Outline non-cyclic photophosphorylation.

Outline non-cyclic photophosphorylation.

- Electrons from **photosystem II** are excited and enter the ETC
- The electrons then move to **photosystem I**, so photolysis of water is required to replace the lost electrons from photosystem II (hence the term **non-cyclic**)
- Non-cyclic photophosphorylation produces ATP and reduced NADP, which are important for the light-independent stage

What are the two important products of the light-dependent stage that are used in the light-independent stage?

What are the two important products of the light-dependent stage that are used in the light-independent stage?

ATP and **reduced NADP** - these compounds transfer energy from the light-dependent stage which is used later.

Name the three stages of the Calvin cycle in the light-independent stage.

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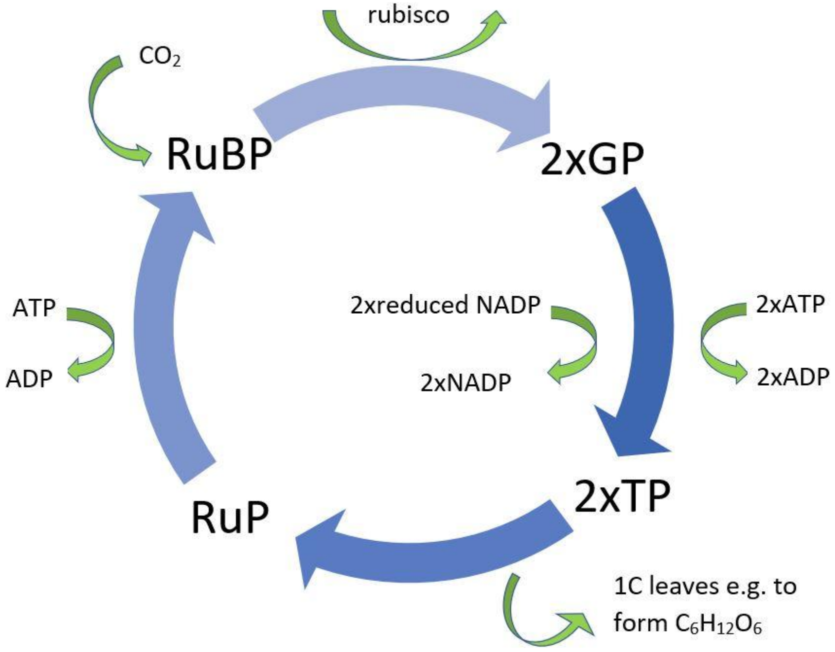
1. Fixation of carbon dioxide
2. Reduction
3. Regeneration



During fixation, which molecule does CO_2 combine with?

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Ribulose bisphosphate (RuBP), a 5-carbon sugar.

Name the enzyme that catalyses the fixation of CO_2.

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Rubisco (in the stroma).

What is the product of the fixation of CO_2?

What is the product of the fixation of CO_2?

Two molecules of glycerate 3-phosphate (GP), a 3-carbon compound.

Describe the reduction step of the light-independent stage.

Describe the reduction step of the light-independent stage.

- Two molecules of GP are reduced to two molecules of triose phosphate (TP). ATP and reduced NADP are required for this step.
- ATP is hydrolysed to provide energy for the conversion. Reduced NADP is used to reduce GP.
- This results in two ADP molecules and two NADP molecules. NADP returns to the light-dependent stage to be reduced again.

What happens during the regeneration step of the light-independent stage?

What happens during the regeneration step of the light-independent stage?

TP is converted into RuBP, to be used again for fixation of CO_2. This process requires ATP.

What other molecules (aside from RuBP) can TP be converted into?

What other molecules (aside from RuBP) can TP be converted into?

- Sugars e.g. glucose, starch, cellulose
- Amino acids and proteins
- Lipids

Explain the term ‘limiting factor’.

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A limiting factor is one which limits the rate of a reaction (e.g. photosynthesis), often because it is in short supply, regardless of the levels of other factors.

Name the potential limiting factors of photosynthesis.

Name the potential limiting factors of photosynthesis.

- Light intensity
- CO_2 concentration
- Temperature

Explain how changing light intensity affects the rate of photosynthesis.

Explain how changing light intensity affects the rate of photosynthesis.

- At low light intensities, the rate of the light-dependent stage is low. Little ATP and reduced NADP is produced, so the rate of the light-independent stage is low.

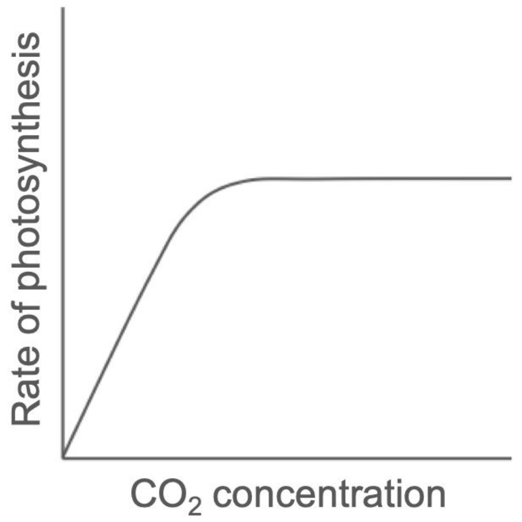
- As light intensity increases, the rate increases. Eventually the volume of O_2 produced and CO_2 absorbed will equal the CO_2 released and O_2 absorbed, i.e. photosynthesis and respiration rates are equal. This is the **compensation point**.

- Past this point, increases in light intensity cause a proportional increase in photosynthesis. This continues until factor becomes limiting.

Explain how changing CO_2 concentration affects the rate of photosynthesis.

Explain how changing CO_2 concentration affects the rate of photosynthesis.

CO_2 is required to combine with RuBP in the light-independent stage of photosynthesis. Increasing the CO_2 concentration will increase the rate of photosynthesis until another factor becomes limiting.



How can the knowledge of limiting factors be used to optimise crop yields in greenhouses?

How can the knowledge of limiting factors be used to optimise crop yields in greenhouses?

- Light intensity is increased by installing lamps and using wavelengths of light chloroplasts can absorb
- The temperature is controlled
- CO_2 concentration may be increased

What is DCPIP?

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DCPIP is a redox indicator. When DCPIP is reduced (by H^+ ions from the photolysis of water), it turns from blue to colourless.

Describe how the structure of a chloroplast is adapted to its function.

Describe how the structure of a chloroplast is adapted to its function.

- The thylakoid membranes, arranged in a stack, provide a large surface area for the absorption of light by photopigments
- The double membrane is permeable to gases and products of photosynthesis
- The thylakoid space accommodates the H^+ ions; the thylakoid membrane maintains the gradient
- The enzymes for the light-independent stage are all found in fluid stroma

In what kind of environment are C4 plants likely to be found?

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Hot, tropical environments with high light intensities and relatively low rainfall.

How does the Calvin cycle in a C3 plant differ from a C4 plant?

How does a C3 plant differ from a C4 plant?

C3 plants use the standard Calvin cycle, producing a 3-carbon compound (GP), in the mesophyll cells.

C4 plants separate the Calvin cycle (which occurs in bundle sheath cells) from an additional CO_2 fixation step (which happens in mesophyll cells).

This separation reduces photorespiration in C4 plants.

PMT
•resources•tuition•courses

What happens to CO_2 in the mesophyll cells of C4 plants?

What happens to the CO_2 in the mesophyll cells of C4 plants?

CO_2 is fixed into malate. The malate moves into the bundle sheath cells and releases CO_2 into the Calvin cycle.

How are C4 plants adapted for fixation of CO_2 at high temperatures?

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How are C4 plants adapted for fixation of CO_2 at high temperatures?

The C4 pathway ensures there is a high concentration of CO_2 for the rubisco enzyme. This prevents oxygen acting as a competitive inhibitor and reducing the rate of photosynthesis.

The enzymes involved in the C4 pathway have a high optimum temperature.