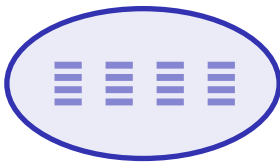


Photosynthesis

A-Level Biology ■ Topic 13

A-Level Biology



What we will cover

- 1 The chloroplast
- 2 The two stages
- 3 Pigments & spectra
- 4 The light-dependent stage
- 5 The Calvin cycle
- 6 Limiting factors



leaves are green with chlorophyll



The chloroplast

Double membrane; stacks of **thylakoids** (grana) in a **stroma** that also holds DNA, ribosomes and starch grains. Light-dependent reactions happen on thylakoid membranes; the Calvin cycle happens in the stroma.

The two stages

- **light-dependent**
(thylakoids) – makes ATP & reduced NADP
- **Calvin cycle** (stroma) –
spends them to fix CO_2 into
sugars

Two stages, two places, two products

Light-dependent stage

On the thylakoid membranes: light drives **non-cyclic photophosphorylation** , making ATP and reduced NADP.

Photolysis

The **oxygen-evolving complex** carries out the **photolysis** of water – splitting it by light – which replaces the electron and releases **oxygen** .

Light-independent stage

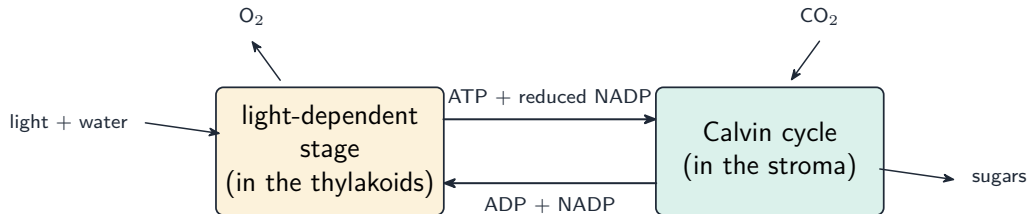
The **light-independent stage** , also called the **Calvin cycle** , happens in the stroma and uses those two products to fix CO₂.

Why “light-independent”

It needs no light of its own – but it stops within seconds in the dark, because ATP and reduced NADP stop arriving.

Name the *place* as well as the stage. Thylakoid membrane and stroma are where half the marks live.

The two stages are linked



The two stages are linked: the first makes the ATP and reduced NADP that the second spends to turn CO₂ into sugars

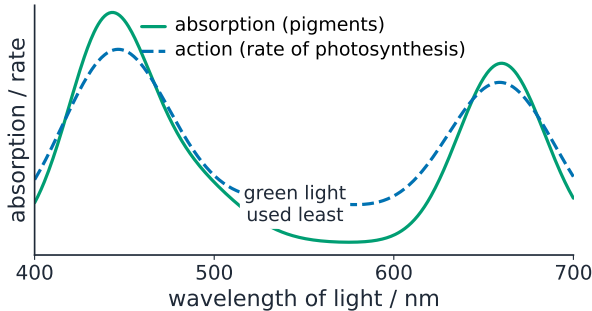
Light-dependent products feed the Calvin cycle

- **Thylakoids:** light splits water $\rightarrow$ ATP, reduced NADP, and O_2
- **Stroma:** $RuBP + CO_2$ (**rubisco**) $\rightarrow$ GP $\rightarrow$ TP

Most TP regenerates RuBP; some makes sugar.



Pigments and spectra

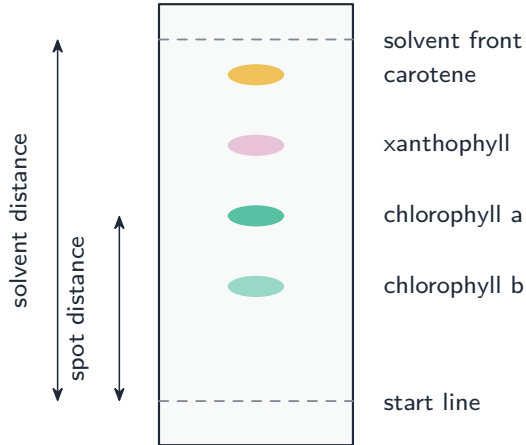


action tracks absorption · green light used least

A **pigment** is a coloured substance that absorbs light. **Chlorophyll** takes mainly red and blue; **carotene** and **xanthophyll** absorb other colours and pass the energy on, so the thylakoid traps as much as it can.

The **absorption spectrum** matches the **action spectrum** – showing the pigments drive photosynthesis.

Chromatography



Chromatography separates the pigments – each travels its own distance up the paper.

$$R_f = \frac{\text{spot distance}}{\text{solvent distance}}$$

Identifying a pigment

Rf value

Each pigment is identified by its **Rf value** : the distance the pigment moved divided by the distance the solvent moved.

Why it is constant

Both distances scale together, so Rf does not depend on how long the run was – only on the solvent and the paper.

Absorption spectrum

Different pigments absorb different **wavelengths** , which is why a leaf needs several of them.

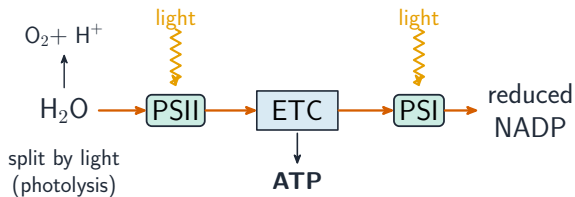
Measuring the rate

A redox **indicator** such as DCPIP loses its colour as illuminated chloroplasts work – so you can test different wavelengths directly.

An action spectrum plots the *rate* against wavelength; an absorption spectrum plots what the pigment *absorbs*. Matching the two is the classic exam link.



The light-dependent stage



Photophosphorylation makes ATP. In the **non-cyclic** form:

- **photoactivation** : light boosts chlorophyll's **electrons** to a higher energy, in both PSI and PSII
- **photolysis** of water releases **oxygen**
- electrons flow $\text{PSII} \rightarrow \text{PSI}$
- ATP *and* reduced NADP are made

The light-dependent stage, step by step

1. photolysis

light splits water: $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + 4\text{e}^- + \text{O}_2$ – the source of the oxygen released

2. excitation

light raises electrons in chlorophyll to a higher energy level

3. the chain

energetic electrons pass along an **electron transport chain**, releasing energy as they go

4. chemiosmosis

that energy pumps protons into the thylakoid space; they flow back through ATP synthase, making ATP

5. reduction

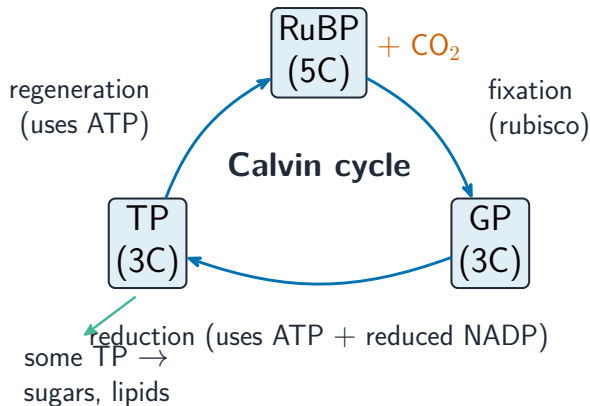
the electrons finally reduce NADP to NADPH

cyclic photophosphorylation

electrons return to photosystem I instead – ATP only, no NADPH and no oxygen

Two products go forward to the Calvin cycle: **ATP** and **reduced NADP**. Everything in this stage exists to make those two.

The Calvin cycle



- **fixation** – **rubisco** joins CO₂ to RuBP → GP

- **reduction** – GP → TP using ATP & reduced NADP

- **regeneration** – TP remakes RuBP

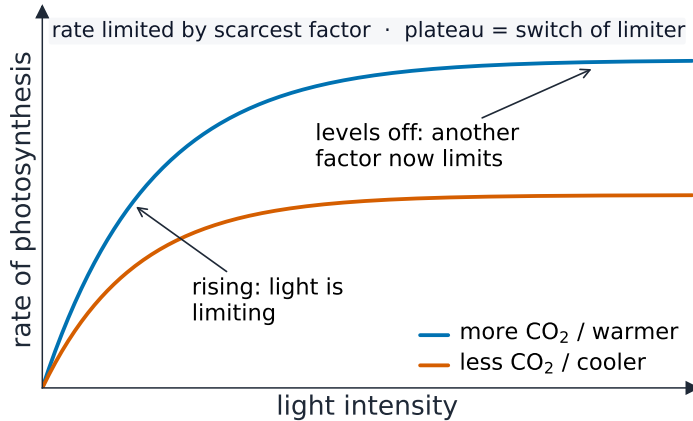
Some TP leaves to make sugars.

Limiting factors

A **limiting factor** is the one in shortest supply.

While the rate rises, **light** limits it; where it levels off, CO_2 or temperature limits it. (Too hot $\rightarrow$ enzymes denature.)

Limiting factors, in detail



A **limiting factor** is the one in shortest supply.

The Calvin cycle, and what limits the whole process

1. fixation

CO₂ joins RuBP (5C), catalysed by **rubisco**, giving two molecules of GP (3C)

2. reduction

GP is reduced to **TP**, using the ATP and reduced NADP from the light stage

3. regeneration

most TP is used to **regenerate RuBP**; the rest leaves to build **carbohydrates**, lipids and **amino acids**

light intensity

raises the rate until another factor takes over

CO₂ concentration

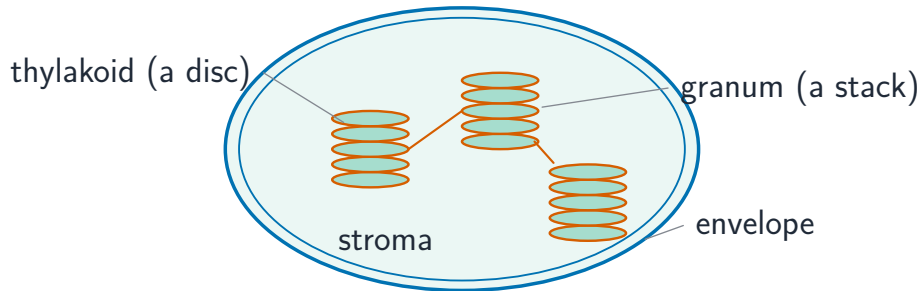
often the limiting factor in the field on a bright day

temperature

speeds it up **only to an optimum** – too high and the enzymes denature

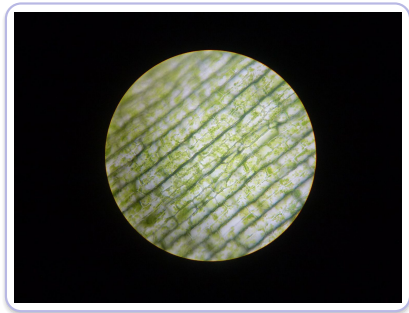
Measure the light-dependent rate with a redox **indicator** such as DCPIP, or measure oxygen bubbles from an **aquatic plant**.

The chloroplast, continued



Thylakoids stack into grana (the first stage happens here); the stroma around them is where the second stage happens

The chloroplast, continued (2)



Chloroplasts (the small green discs) inside the cells of an Elodea (pondweed) leaf, seen under a microscope

Exam tips

- Separate the two stages: **light-dependent** (thylakoid – photolysis, ATP, reduced NADP, O₂) and the **Calvin cycle** (stroma – CO₂ fixed by rubisco, GP → TP).
- Read **limiting-factor** graphs: the plateau is where a different factor (light, CO₂ or temperature) limits the rate.
- Interpret **chromatography** with the R_f value to identify pigments.
- Link chloroplast structure to function (thylakoid stacks for the light reactions; stroma for the Calvin cycle).



Worked example – the Calvin cycle disturbed

A plant photosynthesising steadily is suddenly given no CO_2 . What happens to GP and RuBP?

- CO_2 joins RuBP (via rubisco) to make GP; no $\text{CO}_2 \Rightarrow$ that step stops.
- GP is still being **used up**, reduced to triose phosphate $\Rightarrow$ **GP falls**.
- RuBP is still being **regenerated** from triose phosphate but no longer consumed $\Rightarrow$ **RuBP rises**.
- Remove the **light** instead: the opposite – GP rises, RuBP falls.

Track **what is made** and **what is used** for each molecule. Cutting CO_2 and cutting light give **opposite** answers – read which one the question removed.

Topic 13 – key takeaways

1

Chloroplast

grana for stage 1; stroma for stage 2

2

Light stage

photolysis releases O_2 ; makes ATP & NADPH

3

Calvin cycle

fixation, reduction, regeneration

4

Limiting factors

light, CO_2 , temperature

Check yourself

- 1 Where does the Calvin cycle happen?
- 2 What gas is released by photolysis of water?
- 3 Which enzyme fixes carbon dioxide?
- 4 Name a limiting factor of photosynthesis.



Answers 1. the stroma 2. oxygen 3. rubisco 4. light / CO₂ / temperature