IB BIOLOGY | C1.3 | SL AND HL

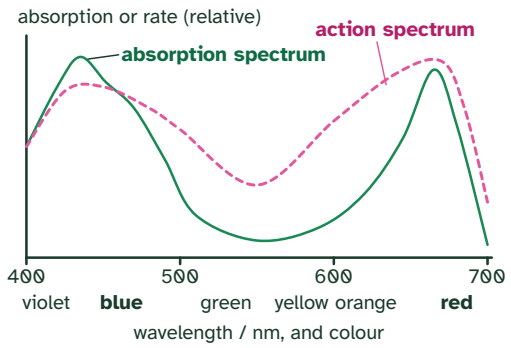
REVISION ON TWO PAGES

Light into *sugar*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

Photosynthesis turns light energy into chemical energy, splitting water for hydrogen to fix carbon dioxide into sugar.



Draw it like this. Wavelengths and colours on the axis, red to violet: *Richard Of York Gave Battle In Vain*

C1.3.5, C1.3.6 START HERE

Absorbed light and *used* light

- A pigment absorbs a wavelength only if the photon's energy **matches a jump an electron can make**. The **excited electron**'s energy becomes chemical energy.
- Chlorophyll absorbs **blue and red** and little green. **Green is reflected**, so leaves look green.
- **Absorption spectrum:** how much of each wavelength the pigments absorb. **Action spectrum:** the **rate of photosynthesis** at each wavelength.
- **Alike:** both peak in blue and red. **Unlike:** the action spectrum's green dip is shallower and its blue peak lower.
- **Skill:** rate = O_2 produced (or CO_2 consumed) ÷ time, for each wavelength. Plot rate against wavelength: that is the action spectrum.

C1.3.1 to 3

Light energy into *carbon compounds*

- Photosynthesis **transforms light energy into chemical energy** in carbon compounds: most of the chemical energy in ecosystems.
- **Carbon dioxide is converted to glucose** using hydrogen from **splitting water**.
- **Oxygen is a by-product** in plants, algae and cyanobacteria. It **comes from the water**, not from CO_2.

Word equation learn it

carbon dioxide + water → **glucose** + oxygen, with light energy and chlorophyll over the arrow.

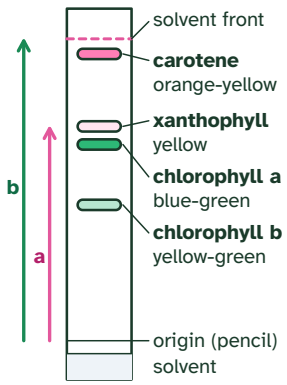
Where the atoms go

Glucose's carbon and oxygen come from CO_2, its hydrogen from water. The O_2 gas comes from water.

C1.3.4 SKILL

Separating pigments by *chromatography*

- Leaf extract is spotted on a pencil origin. The solvent climbs paper or a thin-layer plate and carries each pigment **at its own speed**.
- **R*f* = distance moved by pigment ÷ distance moved by solvent front**, both from the origin; to the middle of the band.
- **Identify by colour and R*f***, against a table made with the same solvent. R*f* is always below 1.



R*f* = **a** ÷ **b**. Values change with the solvent

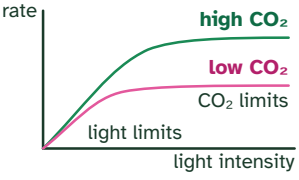
C1.3.7 SKILL

Limiting factors

- The **limiting factor** is the one in shortest supply. Raise it and the rate rises, **until another factor limits**.
- **Vary one:** move a lamp, add sodium hydrogencarbonate, use a water bath. Count oxygen bubbles or time leaf discs to float.
- **Hypotheses** are provisional and need repeated testing. Name the **independent and dependent variables**.

Lazy Cats Toast

L Light splits water	**C** CO_2 carbon to fix	**T** Temp. enzymes



C1.3.8

CO_2 *enrichment* experiments

- Plants in the **CO_2 expected later this century**, beside plants in today's air, **predict future photosynthesis** and growth.

Enclosed greenhouse more control

CO_2 from a cylinder; temperature, light, water and nutrients **controlled**. A controlled variable: temperature.

FACE free-air CO_2 enrichment

Rings of pipes in a field or forest keep **real soil, weather and competition**. A controlled variable: crop variety.

Inside the chloroplast: *thylakoid* and Calvin cycle

C1.3.9, C1.3.10 HIGHER LEVEL

Photosystems: pigments in an *array*

- An **array of chlorophyll and accessory pigments**, **always in a membrane**: in chloroplast thylakoids and in cyanobacteria.
- Pigments pass **energy** to the **reaction centre**, a special chlorophyll that **emits an excited electron**.
- **Why an array:** one pigment alone could do no part of photosynthesis. Many catch more light and wavelengths, and pass energy on before it is lost.

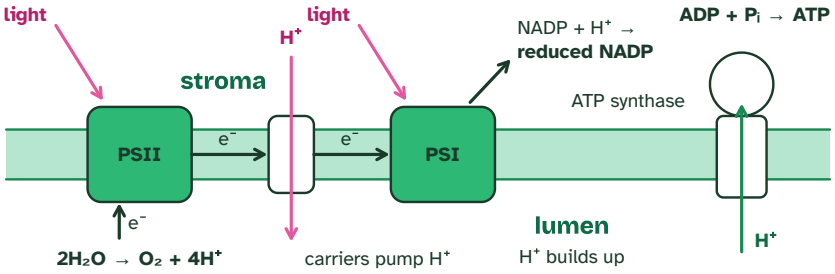
C1.3.19 HIGHER LEVEL

The two halves *need each other*

- The thylakoids make **ATP and reduced NADP**; the Calvin cycle spends them and hands back ADP, phosphate and NADP.
- **No light:** no ATP or reduced NADP is made, so **the Calvin cycle stops** seconds later.
- **No CO_2:** NADP is not handed back, so PSI fills, the chain backs up and **photosystem II stops**.

C1.3.11 to 14 HIGHER LEVEL

The thylakoid: a system for the *light-dependent* reactions



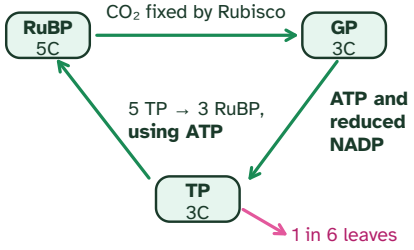
Photolysis: *Please Eat Oranges*. **P**rotons to the lumen, **E**lectrons to PSII, **O**xygen out.

- **Photolysis:** **photosystem II** refills with electrons from water. **Oxygen is waste**; from about 2.4 billion years ago it built up in the air, with immense effects on life and rocks.
- **Chemiosmosis:** the chain of carriers **pumps protons** into the lumen; they flow back through **ATP synthase**, making ATP.
- **NADP** takes **two electrons from photosystem I** and a proton from the stroma: reduced NADP.
- **Non-cyclic:** electrons from PSII to PSI to NADP. **Cyclic:** from PSI round the chain again, ATP only.

C1.3.15 to 18 HIGHER LEVEL

The Calvin cycle: *fix*, reduce, regenerate

- **Fix:** **Rubisco** joins CO_2 to **RuBP**, giving two **glycerate 3-phosphate (GP)**. It is slow and poor at low CO_2, so the stroma holds a lot: the **most abundant enzyme on Earth**.
- **Reduce:** **reduced NADP and ATP** turn GP into **triose phosphate (TP)**.
- **Regenerate:** **five TP make three RuBP**, using ATP. For glucose, five-sixths of all TP is recycled.
- **Products:** **all carbon** in the organism was fixed here. Sugars, lipids, amino acids and nucleotides come by pathways **traced back to the cycle**, adding nitrate and phosphate.



Fresh Rolls Rise: **F**ix, **R**educe, **R**egenerate.

WATCH OUT

Five mistakes that *cost marks*

- ✕ **The oxygen comes from water, not CO_2.** CO_2's oxygen ends up in glucose and water.
- ✕ **A limiting factor does not stop photosynthesis.** It is the one in shortest supply.
- ✕ **An action spectrum is a rate, not absorption.** It shows what the plant does with each colour.
- ✕ **Photosystem II splits water; photosystem I reduces NADP.** Electrons pass through II first.
- ✕ **"Light-independent" is not "in the dark".** The Calvin cycle needs ATP and reduced NADP.

COVER THE SHEET

Can you *answer these?*

1. State the word equation for photosynthesis.
2. Outline how to find a pigment's R*f*.
3. Compare absorption and action spectra.
4. Describe how to vary light intensity in an experiment.
5. Distinguish greenhouse and FACE experiments.
6. Explain the advantage of a pigment array. HL
7. Explain how a thylakoid makes ATP. HL
8. Outline the three stages of the Calvin cycle. HL
9. State where all of a plant's carbon was fixed. HL
10. Explain why lack of CO_2 stops photosystem II. HL

IN THE EXAM

Pair the terms consistently: "NADP and reduced NADP" or "$NADP^+$ and NADPH", never mixed. And **say where**: thylakoid membrane, lumen or stroma.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.