AP BIOLOGY | UNIT 3 | TOPIC 3.4

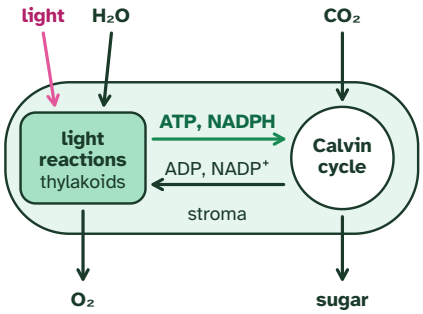
REVISION ON TWO PAGES

Light into *sugar*

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

THE ONE IDEA

Light reactions in the thylakoids make ATP and NADPH. The Calvin cycle in the stroma spends them to build sugar from carbon dioxide.



Draw it like this. Two stages in one chloroplast, each handing the other what it needs.

3.4.A START HERE

Light energy becomes *chemical energy*

- Photosynthesis **transforms light energy into chemical energy** in the bonds of carbon compounds. It does not make energy.
- $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$, with light energy and chlorophyll over the arrow.
- Water is split using light energy: **photolysis**. Its hydrogen is added to carbon dioxide to build glucose, and its **oxygen is given off** as a by-product.
- **Producers** (plants, algae, cyanobacteria) make the carbon compounds every consumer depends on. Energy flows from light to sugar to ATP to work and heat: it is not recycled.

WHERE THE ATOMS OF GLUCOSE COME FROM

C Carbon	**H** Hydrogen	**O** Oxygen
in glucose: from carbon dioxide	in glucose: from water	in glucose: from carbon dioxide

3.4.A ABSORBING LIGHT

Pigments: why a leaf is *green*

- Visible light runs from about 400 nm (violet) to 700 nm (red). The shorter the wavelength, the more energy in each photon.
- A pigment absorbs a photon only if its energy **matches a jump an electron can make**. The electron is then **excited**: that is the energy photosynthesis captures.
- Chlorophyll absorbs **blue and red** strongly and **reflects green**. The carotenoids, accessory pigments, absorb blue and blue-green and widen the range a leaf can use.
- **Chromatography** separates the pigments: the more soluble a pigment is in the solvent, the further it travels.

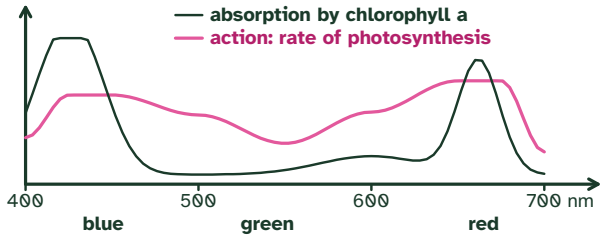
Rf
= pigment distance ÷ solvent front distance, both from the origin

< 1
always, with no units

3.4.A READING THE GRAPHS

Absorption and *action spectra*

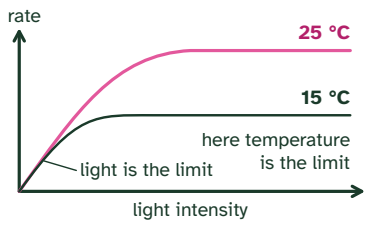
- An **absorption spectrum** shows how much light a pigment takes in at each wavelength.
- An **action spectrum** plots the **rate of photosynthesis** (oxygen produced ÷ time) against wavelength.
- **Similar:** both peak in blue and red and dip in green, because the light a leaf uses is the light its pigments absorb.
- **Different:** the action spectrum's green dip is shallower: chlorophyll b and the carotenoids absorb there and pass the energy on.



3.4.A LAZY CATS TOAST

Limiting factors: whatever runs short sets the pace

- The **limiting factor** is the factor in shortest supply. It sets the rate: raising any other factor does nothing.
- Raise the limiting factor and the rate rises, until another factor takes over and the curve **levels off**. Raise that one and the plateau rises.
- **To test one:** change it alone, then measure the oxygen pondweed gives off or the time leaf disks take to float.
- A hypothesis names the **independent**, the **dependent** and the **controlled** variables.



L
Light intensity
Energy for splitting water.

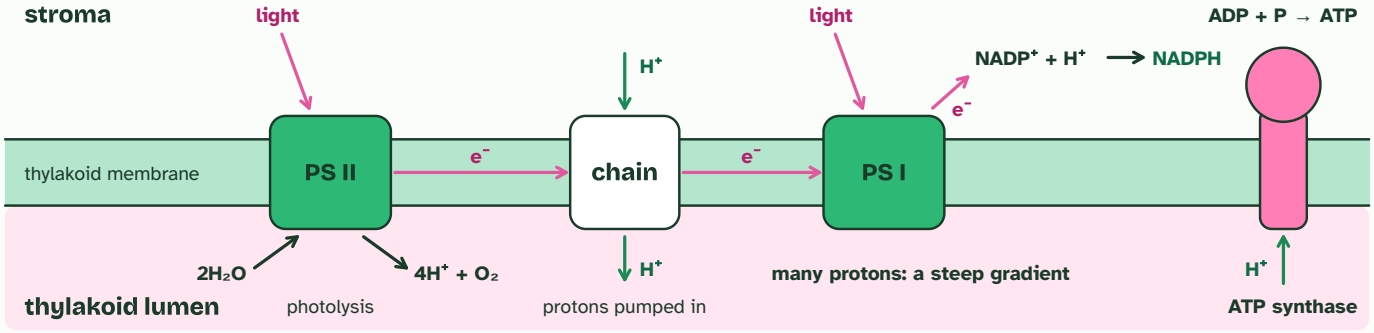
C
Carbon dioxide
The carbon to fix.

T
Temperature
Enzymes: an optimum, then denaturing.

The light reactions and the *Calvin cycle*

3.4.B IN THE THYLAKOID MEMBRANE

The *light-dependent reactions* make ATP and NADPH



1
Photosystem II
An array of pigments passes light energy to its reaction center, which emits an excited electron.

2
Photolysis
Photosystem II takes electrons from water: $2H_2O$ give 4 electrons, 4 protons and one O_2.

3
Electron transport
Electrons give up energy along the chain. It pumps protons from the stroma into the lumen.

4
Photosystem I
Light excites the electrons again. $NADP^+$ takes two, and a proton, and is reduced to NADPH.

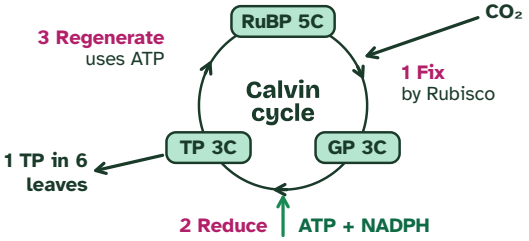
5
ATP synthase
Protons flow back down their gradient and drive ADP + phosphate to ATP: chemiosmosis.

Prokaryotes came first. Cyanobacteria were the first to split water, and chloroplasts descend from them. Their oxygen built up in the air about 2.4 billion years ago and made aerobic respiration possible.

3.4.B LIGHT-INDEPENDENT, BUT NOT IN THE DARK

The *Calvin cycle* builds sugar in the stroma

- **Carbon fixation**: the enzyme **Rubisco** joins carbon dioxide to a 5-carbon acceptor (RuBP), which splits into two 3-carbon molecules.
- **Reduction:** NADPH gives the hydrogen and ATP the energy to turn them into a 3-carbon sugar. ADP and $NADP^+$ go back to the thylakoid.
- **Regeneration:** five of every six sugars remake the acceptor, using more ATP. One turn fixes one carbon dioxide, so **six turns make one glucose**.
- Rubisco is slow, and poor at low carbon dioxide, so the stroma holds a great deal of it. Each half needs the other:



NO LIGHT
The cycle stops
No ATP or NADPH is made, so the Calvin cycle stops a few seconds later. "Light-independent" does not mean it runs in the dark.

NO CARBON DIOXIDE
The chain backs up
NADPH is not used, so no $NADP^+$ returns. Photosystem I has nowhere to pass its electrons, the chain fills and photolysis stops.

WATCH OUT

Five mistakes that *cost points*

- ✕ **The oxygen gas comes from water**, not from carbon dioxide. Photosystem II splits the water.
- ✕ **Pigments pass on energy, not electrons.** Only the reaction center emits an electron.
- ✕ **Protons build up in the thylakoid lumen**, not an intermembrane space. ATP is made in the stroma.
- ✕ **Electrons go through photosystem II first.** $NADP^+$ is reduced at photosystem I.
- ✕ **Green is the light a leaf did not absorb.** Chlorophyll does not make green light.

COVER THE SHEET

Can you *answer these?*

1. Identify the source of each atom in glucose.
2. Explain why chlorophyll absorbs little green light.
3. Calculate Rf: pigment 5.7 cm, solvent front 8.0 cm.
4. Describe how an action spectrum differs from an absorption spectrum.
5. Predict the rate if a plant on a light plateau is warmed.
6. Explain how the proton gradient makes ATP.
7. Describe what the Calvin cycle uses and makes.
8. Predict what happens to photolysis with no carbon dioxide. Justify it.

IN THE EXAM

Say where: lumen or stroma, photosystem II or I. Then follow the electrons in order: water, photosystem II, the chain, photosystem I, $NADP^+$.

GO FURTHER

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