Photosynthesis

BCH 100 – Introductory Biochemistry · Dr. Radi

By the end of this unit, you can…

- Compare photosynthesis with cellular respiration, and locate the light reactions and Calvin cycle within the chloroplast
- Explain how pigments harvest light and how Photosystems II and I drive the Z-scheme of electron flow
- Describe photophosphorylation (cyclic vs non-cyclic) and the ATP + NADPH the light reactions produce
- Walk the Calvin cycle – fixation, reduction, regeneration – and RuBisCO's role and limitation
- Give the Calvin-cycle stoichiometry and the fate of the sugar (sucrose, starch, cellulose)

Today's route

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1. Photosynthesis – The Light Reactions
2. The Calvin Cycle

1 · Photosynthesis – The Light Reactions

"Plants are better than us – they run respiration in reverse, powered by sunlight. Watch light split water and charge up ATP and NADPH."

Plants are better than us

We **burn** glucose for energy; plants **build** it – running the same chemistry **in reverse**, powered by **sunlight**. Photosynthesis takes **CO_2 + water + light** and makes **glucose + O_2**; respiration takes **glucose + O_2** and makes **CO_2 + water + ATP**. They're **exact mirror images** – and that O_2 you're breathing? A plant made it.

PHOTOSYNTHESIS

chloroplast · builds & reduces

$$CO_2 + H_2O + \text{light} \rightarrow \text{glucose} + O_2$$

exact mirror images — the products of one are the reactants of the other

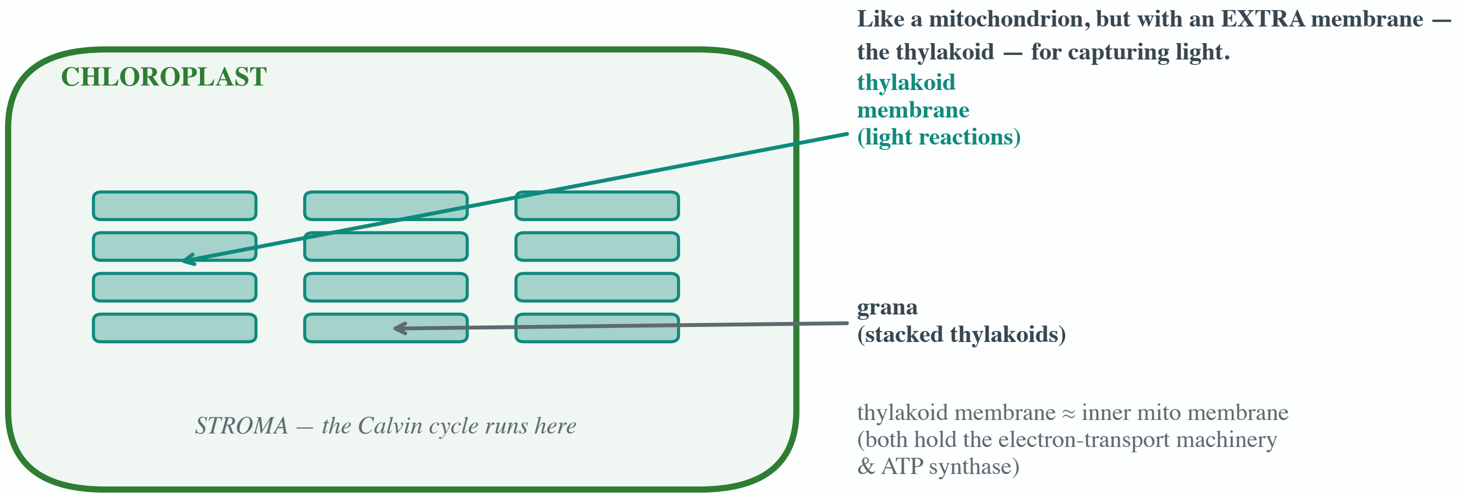
RESPIRATION

mitochondrion · burns & oxidizes

$$\text{glucose} + O_2 \rightarrow CO_2 + H_2O + \text{ATP}$$

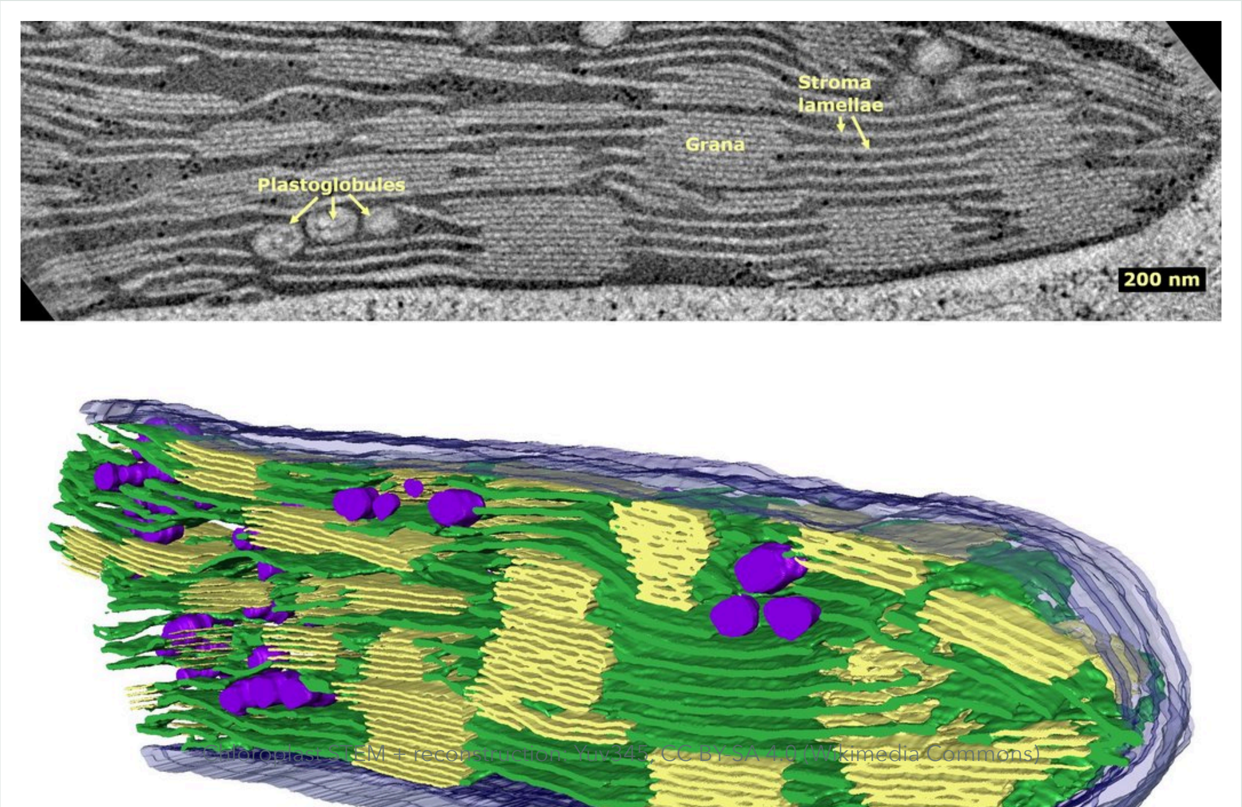
Where it happens: the chloroplast

Photosynthesis runs in the **chloroplast** – think of it as a mitochondrion with an **extra membrane**. Stacked inside are the **thylakoids** (the green disks, piled into **grana**); their membrane holds the **light-reaction** machinery. Surrounding them is the **stroma**, where the **Calvin cycle** builds sugar. Thylakoid ≈ inner mitochondrial membrane.



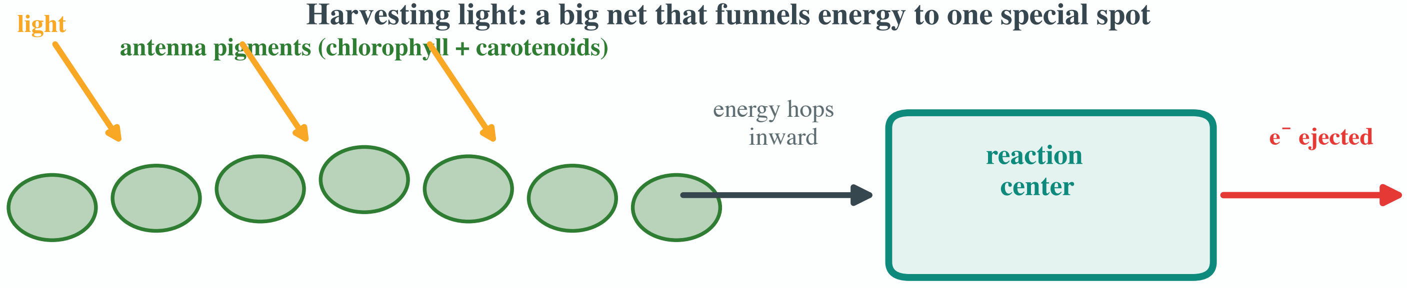
The real thing

Here's an actual chloroplast under the microscope – those green-and-gold stacks are **grana**, hundreds of **thylakoid** disks packed together to catch every photon. Between them stretch the **stroma lamellae**. This dense folding is **why** a single leaf cell can hold enough machinery to feed the whole plant.



Catching the light

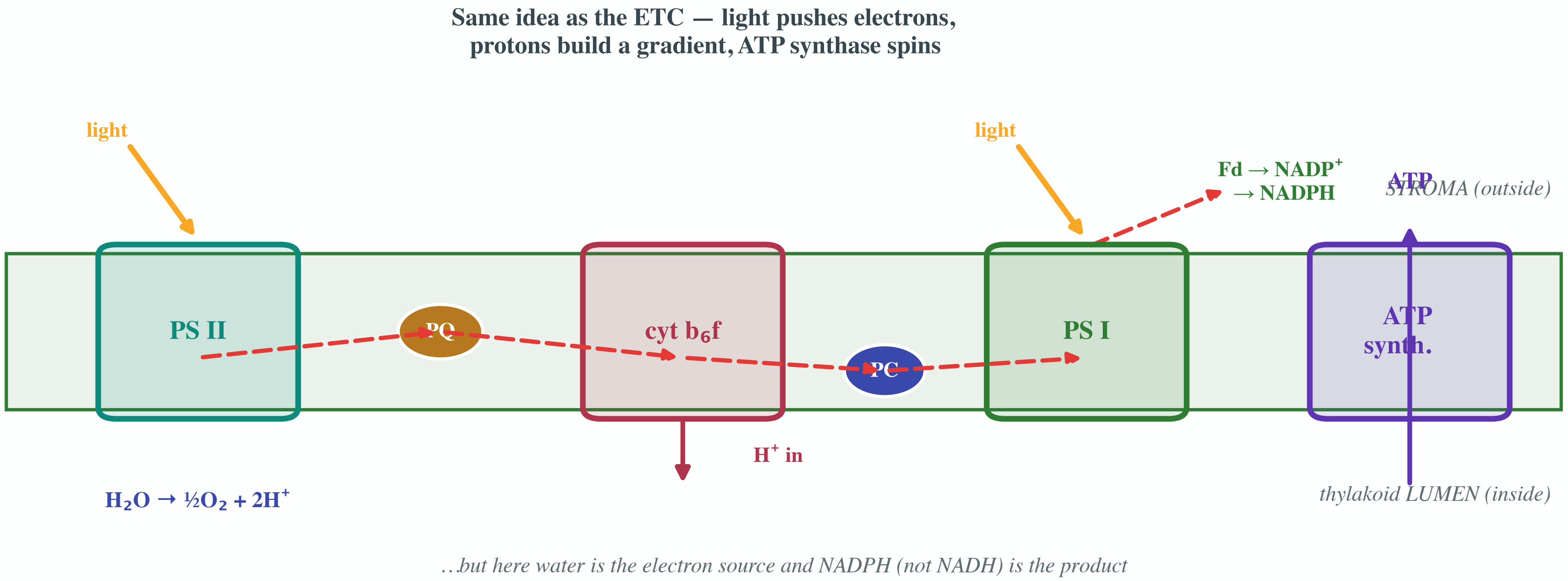
A single chlorophyll can't do much alone – so plants build a **big antenna**: hundreds of **pigments** (chlorophylls plus accessory **carotenoids**) that soak up photons and pass the energy **inward**, molecule to molecule, until it reaches one special **reaction center**. There, the energy finally **ejects an electron** – and the chemistry begins.



Hundreds of pigments feed one reaction center — so it stays busy even in dim light.

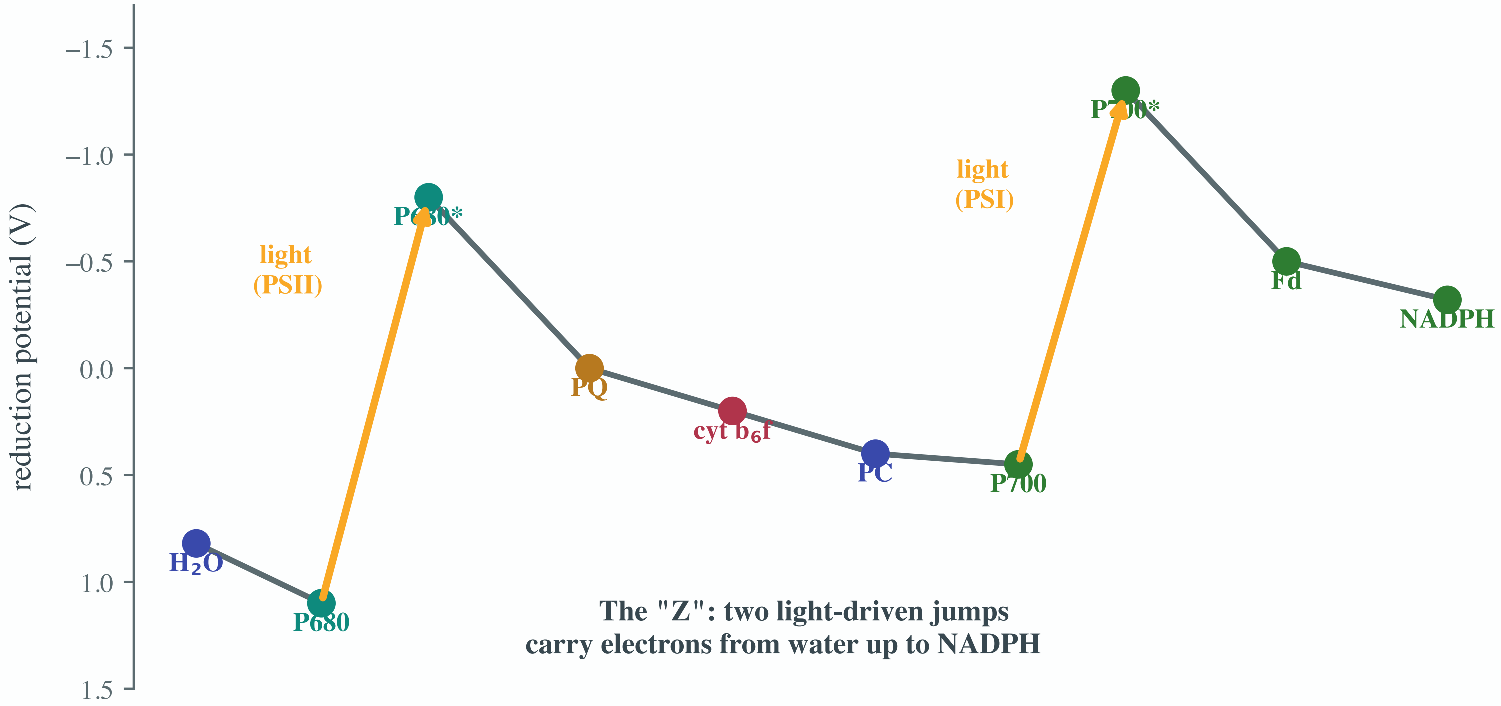
Two photosystems in the membrane

The light reactions look a lot like the **ETC** – a chain of complexes in a membrane, pumping protons. Light hits **Photosystem II**, which **splits water** (that's where the O_2 comes from!) and sends electrons – ferried by **plastoquinone** and **plastocyanin** – through **cytochrome b_6f** to **Photosystem I**. A second hit of light at PSI boosts them again, all the way to **NADPH**. Protons pile up in the lumen and spin **ATP synthase**.



Why it's called the "Z-scheme"

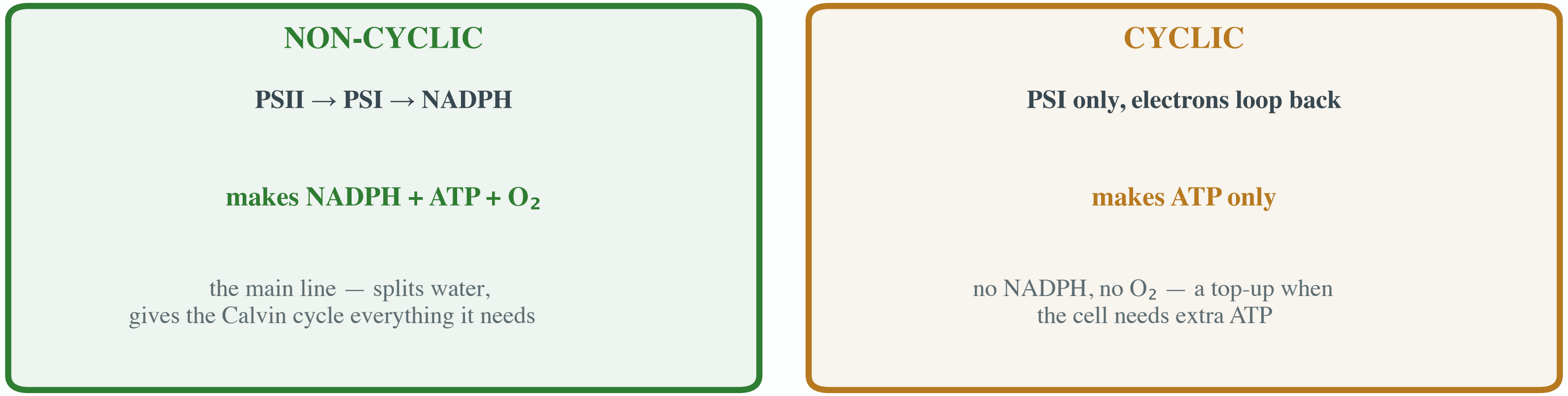
Plot the electrons' energy and you see why: they start low (in **water**), get **boosted uphill** by light at PSII, drift back down the chain, then get **boosted again** at PSI – up to **NADPH**. Two light-driven jumps, one downhill drift between them: it draws a **"Z"** on its side. Sunlight is doing the lifting.



Two ways to make ATP with light

Making ATP with light energy is **photophosphorylation**, and there are two modes. **Non-cyclic** is the main line – PSII to PSI, splitting water and producing **NADPH + ATP + O_2**. **Cyclic** uses **PSI alone**, looping electrons back to make **extra ATP only** (no NADPH, no O_2) – a top-up for when the Calvin cycle needs more ATP than NADPH.

Photophosphorylation: making ATP with light

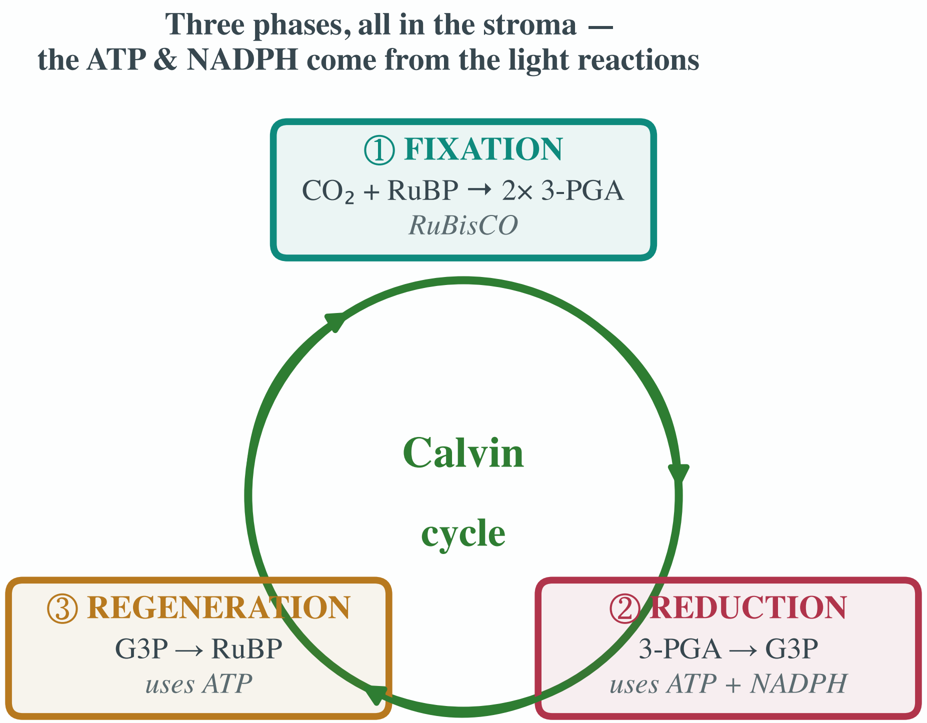


2 · The Calvin Cycle

"Now spend that ATP and NADPH – turn thin air (CO_2) into sugar, one carbon at a time, with the planet's busiest enzyme."

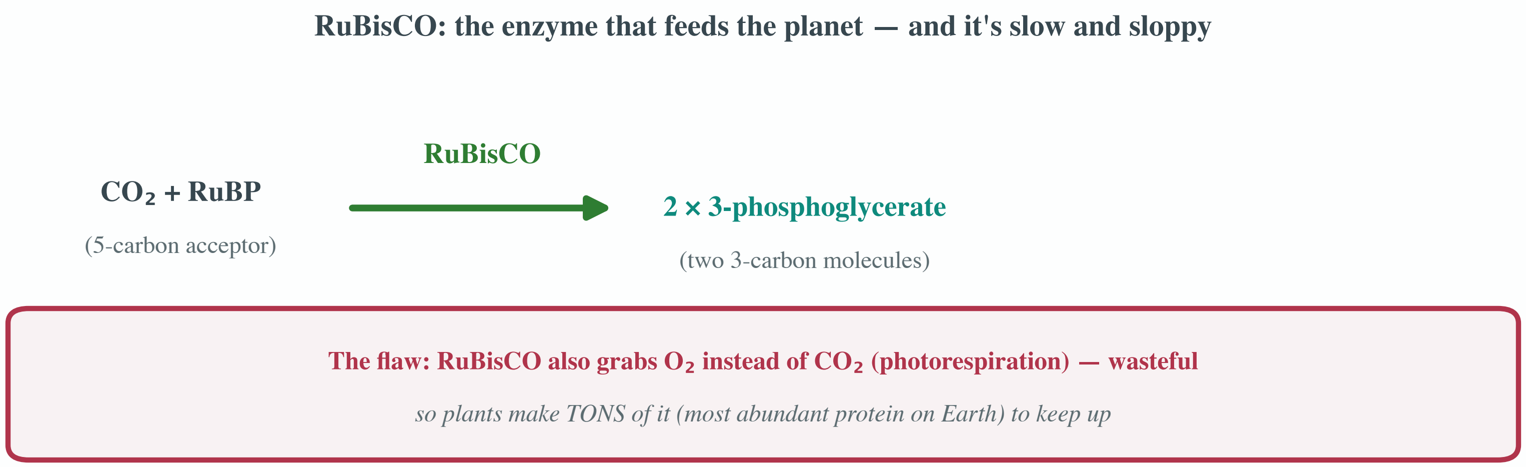
Building sugar from thin air

The light reactions charged up **ATP and NADPH** – now the **Calvin cycle** spends them to turn **CO_2** into sugar. It runs in **three phases**: **fixation** (grab a CO_2), **reduction** (spend ATP + NADPH to make a sugar), and **regeneration** (rebuild the CO_2-catcher). And don't call these the "dark reactions" – they run in daylight and are **completely dependent** on the light reactions' ATP and NADPH!



RuBisCO: the enzyme that feeds the planet

Fixation is the job of **RuBisCO**, which sticks a **CO_2** onto the 5-carbon acceptor **RuBP**, splitting the product into **two 3-carbon** molecules. Nearly every carbon atom in your body passed through this enzyme. Its catch? It's **slow**, and it clumsily grabs **O_2** instead of CO_2 (**photorespiration**) – so plants make **tons** of it, making it the **most abundant protein on Earth**.



The price of a sugar

Carbon comes in **one at a time**, so it takes a lot of turns. **Three** turns fix **three CO_2** and net **one G3P** – at a cost of **9 ATP + 6 NADPH**. To build a full **glucose** (two G3P) takes **six** turns: **18 ATP + 12 NADPH**. Every bit of that energy bill was paid by the **light reactions**.

The price of one sugar

3 CO_2 fixed	**→ 1 net G3P**	**9 ATP + 6 NADPH**
6 turns (6 CO_2)	**→ 1 glucose**	**18 ATP + 12 NADPH**

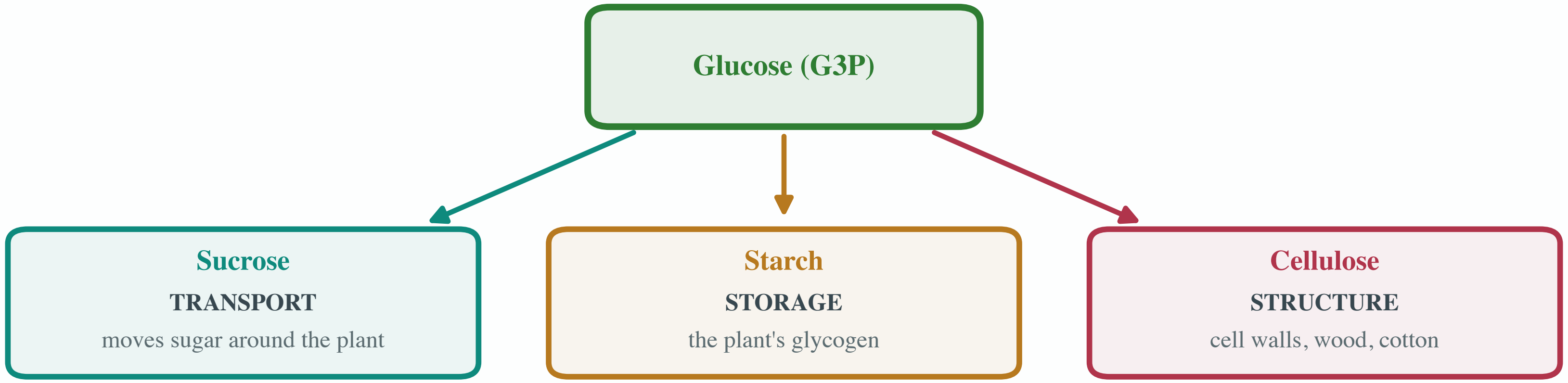
It takes MANY turns — 3 CO_2 per G3P, and 2 G3P per glucose

all the ATP & NADPH billed to the light reactions

What the sugar becomes

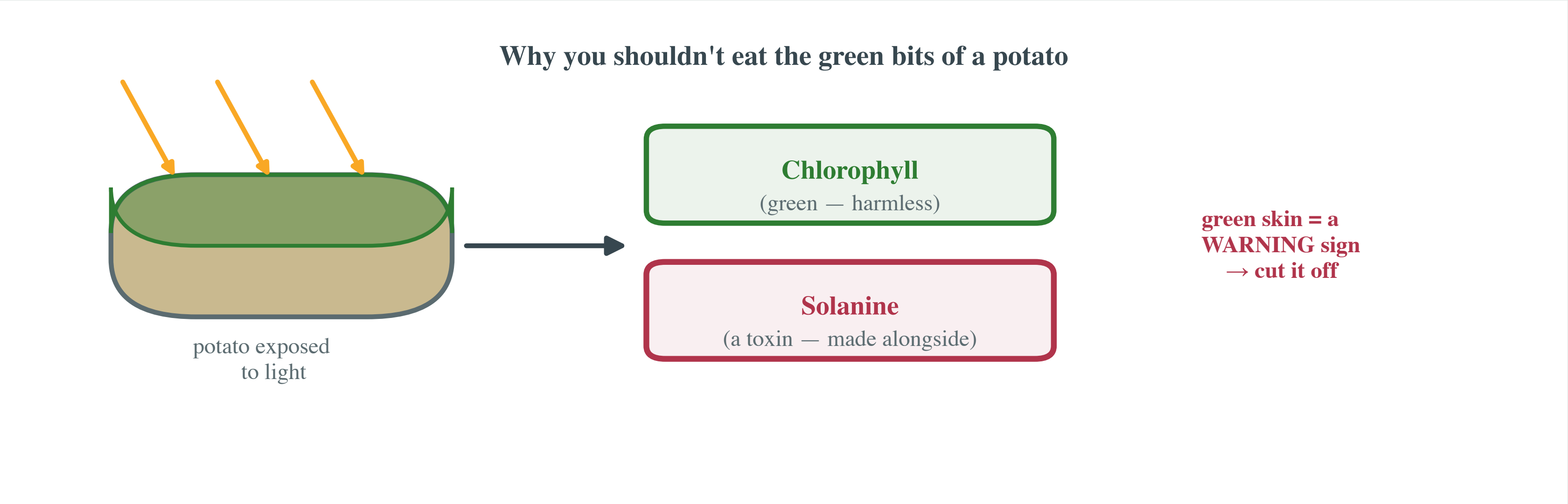
That G3P is the plant's raw material for everything. Some the plant **burns** for its own energy (yes – plants run **glycolysis** too!). Some becomes **sucrose**, the sugar it **ships** around itself (and your maple syrup!). Some is stored as **starch** – the plant's **glycogen**. And a huge amount is spun into **cellulose** – the **cell walls**, wood, and cotton that are most of Earth's biomass.

What the plant does with its sugar



Why green potatoes are bad news

Leave a potato in the light and it turns **green** – it's making **chlorophyll**. Harmless on its own… but the plant makes a bitter toxin, **solanine**, **right alongside** it. So the **green tinge is a warning label**: where there's chlorophyll, there's solanine. Cut the green bits off – or, if it's very green, toss it.



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If any box stays empty, the practice site has a drill for it.
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