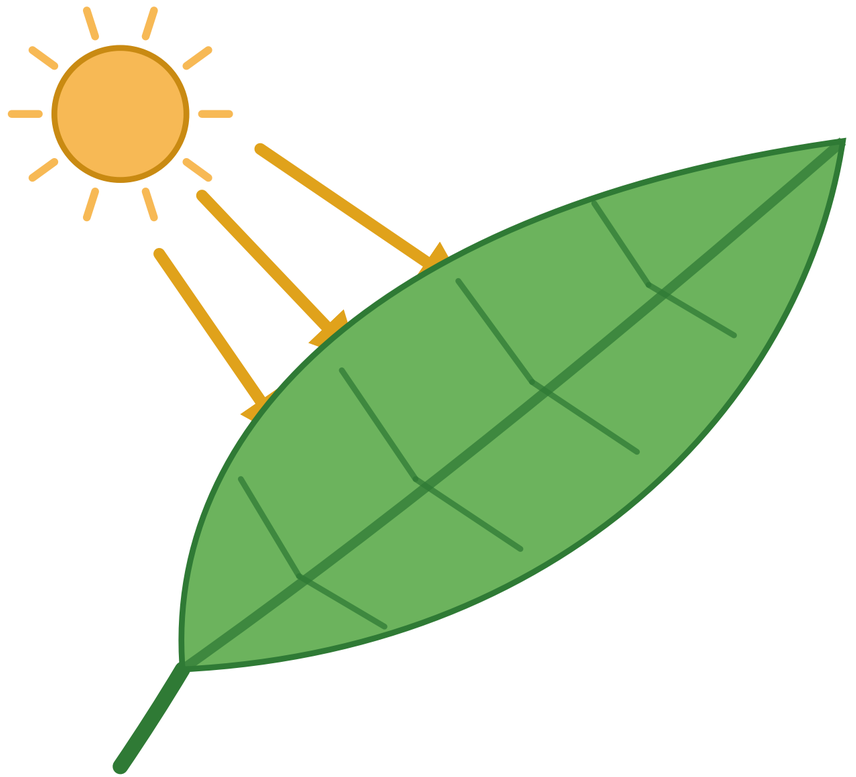
Biology · How plants turn light into food

Photosynthesis

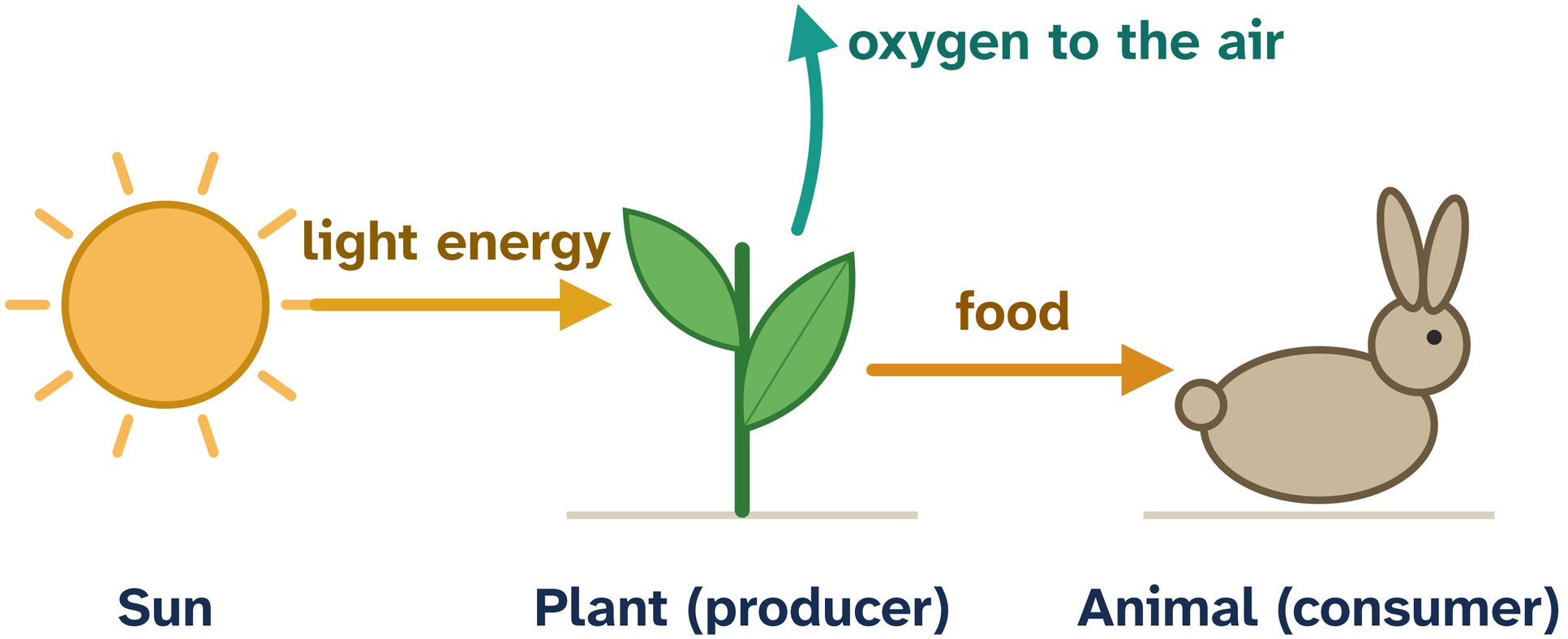


Goals

By the end of this lesson you can

- Write the word and balanced equations
- Explain where the energy in glucose comes from
- Describe how a leaf is built for photosynthesis
- Explain what limits the rate of photosynthesis
- Describe what plants do with glucose

Why photosynthesis matters



- Plants, algae and cyanobacteria make their own food
- They use light energy to build sugar from simple substances
- Animals, fungi and most bacteria rely on that food
- Oxygen is released as a by-product

The engine of life on Earth

99%

of Earth's ecosystems are powered by photosynthesis

- The rare exceptions include deep-sea vents, powered by chemical energy

The word equation



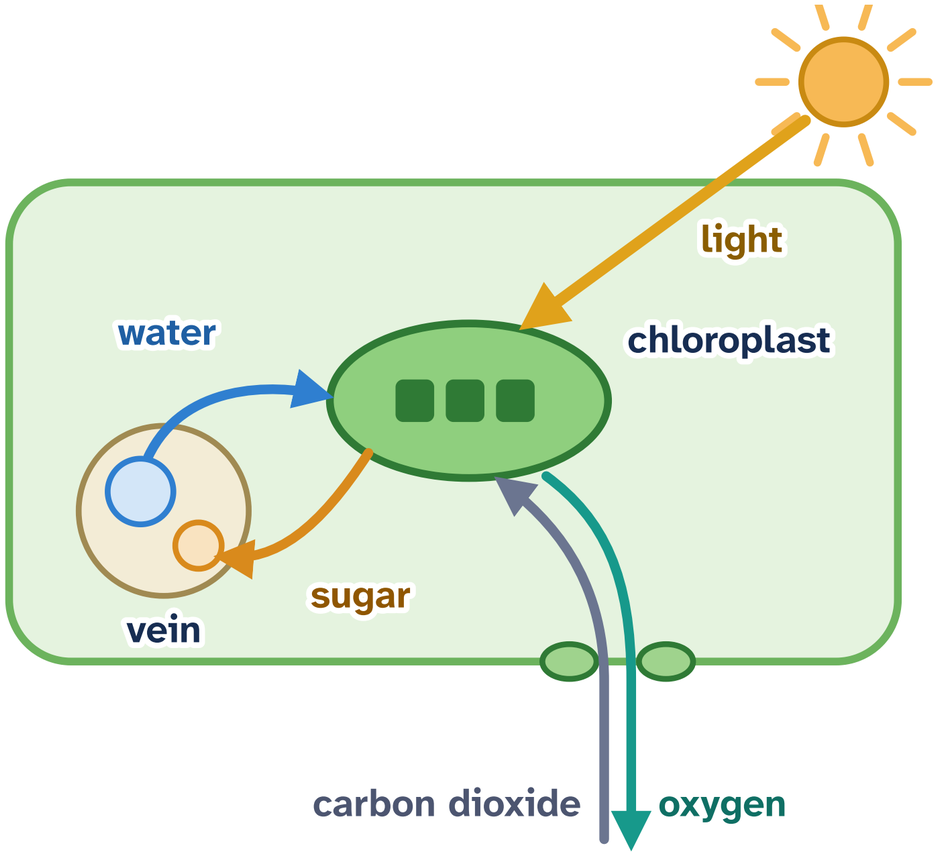
- Carbon dioxide + water → glucose + oxygen
- Products: glucose, a sugar, and oxygen gas
- Reactants: carbon dioxide from the air, water from the soil
- Needs light energy, absorbed by green chlorophyll

The balanced symbol equation

$$6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

Element	Left side	Right side
Carbon	6 × 1 = 6	6
Hydrogen	6 × 2 = 12	12
Oxygen	6 × 2 + 6 × 1 = 18	6 + 6 × 2 = 18

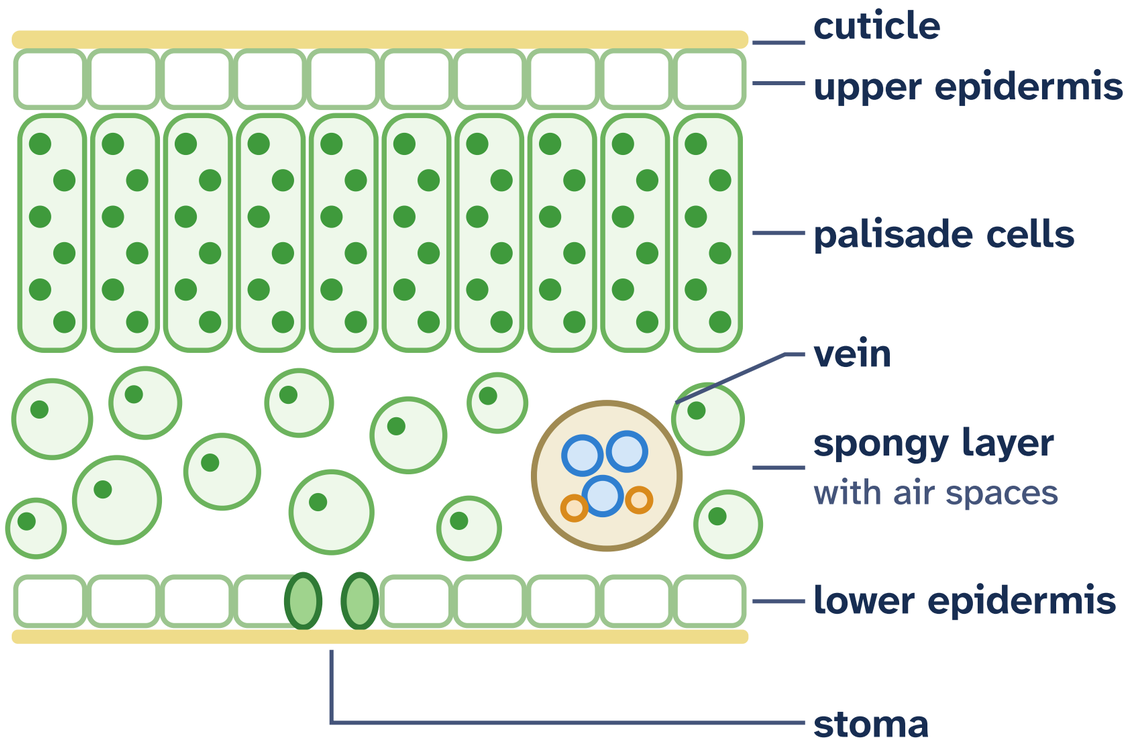
- $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
- Six carbon dioxide and six water molecules in
- One glucose and six oxygen molecules out
- Count the atoms: 6 C, 12 H and 18 O on each side



1. Light is absorbed by chlorophyll in the chloroplasts
2. Water arrives from the roots through the xylem
3. Carbon dioxide diffuses in through a stoma
4. Sugar is made and carried away in the phloem
5. Oxygen diffuses out through the stoma

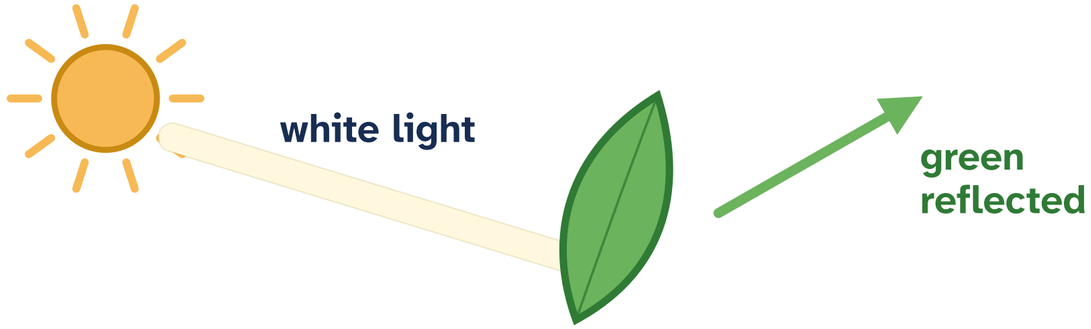
Photosynthesis step by step

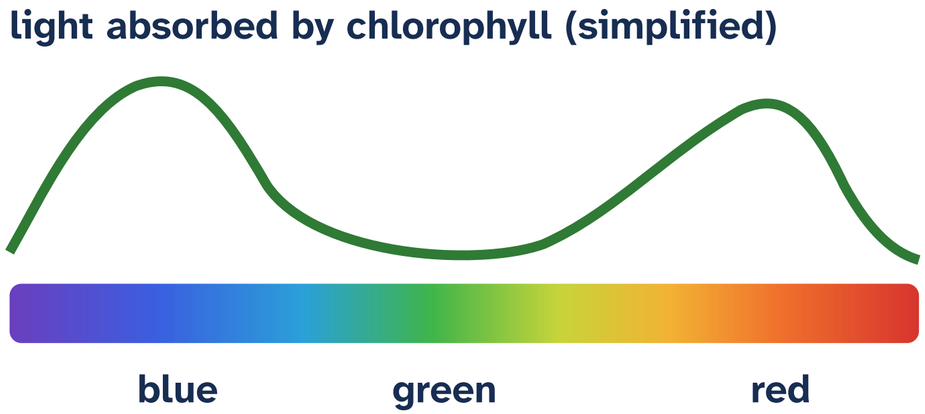
- Light captured, water and carbon dioxide delivered
- Water split, sugar built, oxygen released



Inside a leaf

- Waxy cuticle cuts water loss from the surface
- Palisade cells, packed with chloroplasts, sit near the top
- Spongy layer has air spaces for gases to move
- Stomata, opened and closed by guard cells, let gases in and out
- Veins bring water in xylem and carry sugar away in phloem

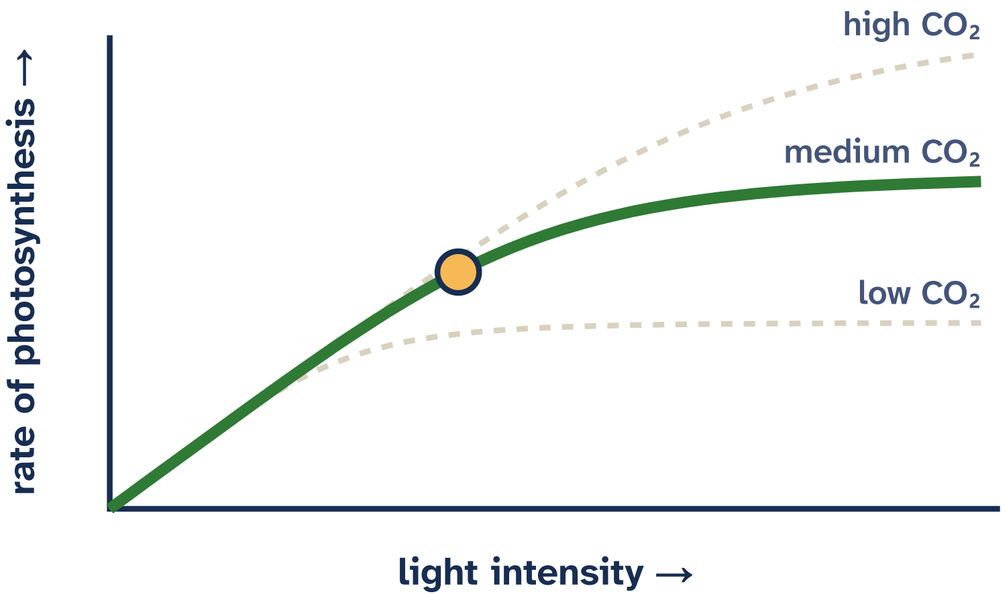




Why leaves are green

- Chlorophyll absorbs mostly red and blue light
- Green light is mostly reflected, so leaves look green
- Chlorophyll sits inside the chloroplasts
- Absorbed light energy drives the reactions

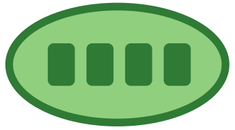
What limits the rate?



Simplified model: it shows the shapes of the graphs, not measured values. The best temperature differs from plant to plant.

- Light intensity: more light, faster rate, until it levels off
- Carbon dioxide: more carbon dioxide, faster rate, until it levels off
- Temperature: enzymes speed up when warmer, but too hot damages them
- Water: short of water, stomata close and carbon dioxide is cut off

Photosynthesis vs respiration

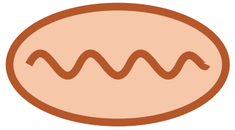


Photosynthesis

carbon dioxide + water → glucose + oxygen

- Happens in chloroplasts
- Only in light
- Takes in carbon dioxide and water
- Stores energy in glucose

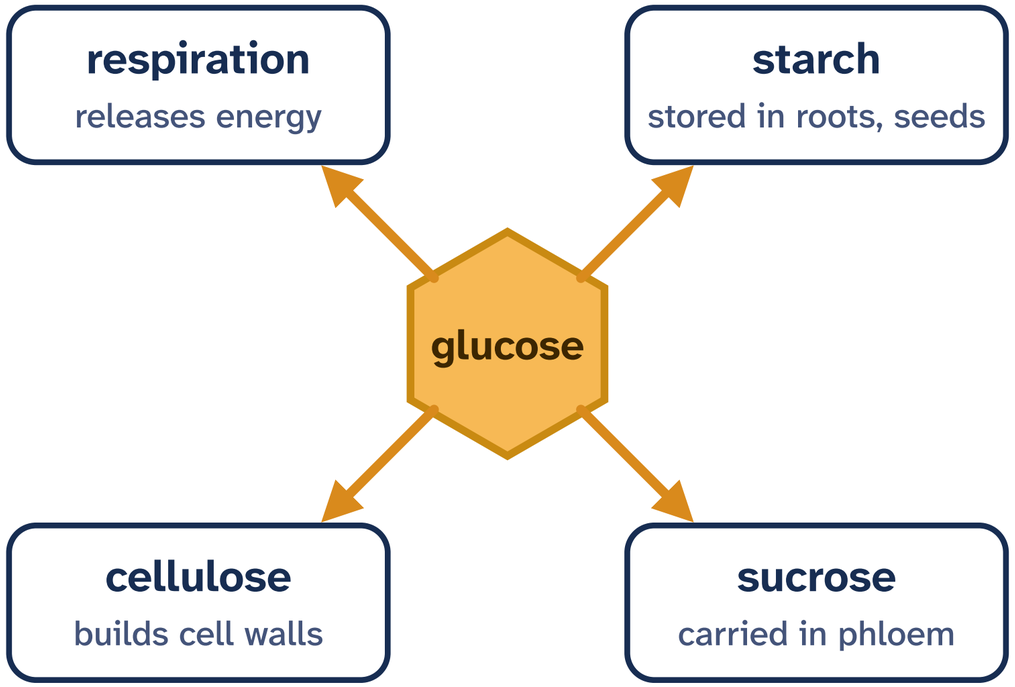




Respiration

glucose + oxygen → carbon dioxide + water

- Happens in mitochondria
- Day and night, in every living cell
- Takes in glucose and oxygen
- Releases energy from glucose

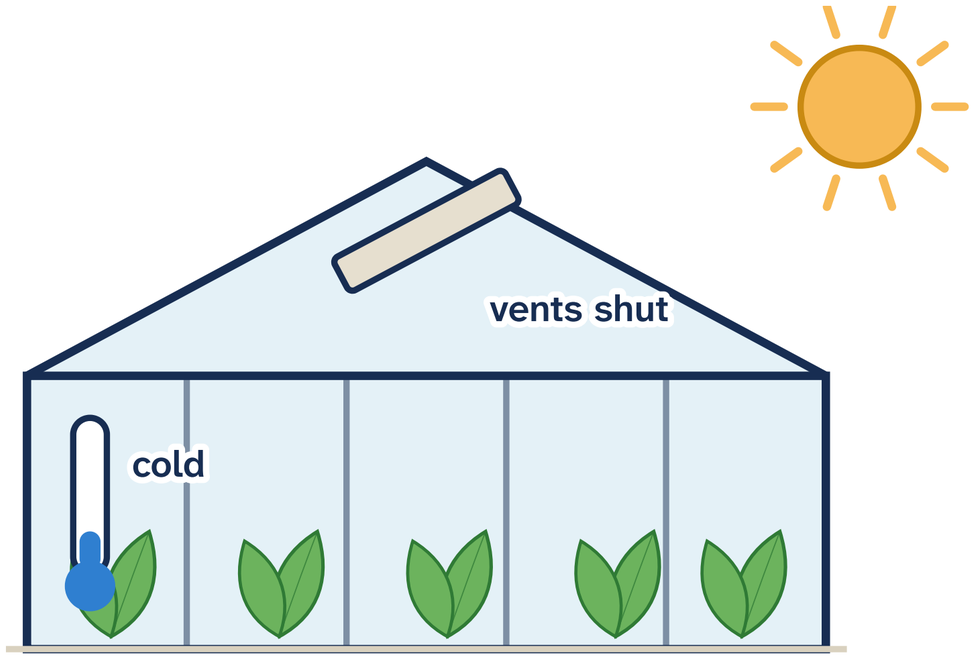


What plants do with glucose

- Release energy from it by respiration
- Store it as starch, for example in roots and seeds
- Build cellulose for new cell walls
- Turn it into sucrose to carry round the plant in phloem

Worked example

Example: a greenhouse on a cold, bright morning



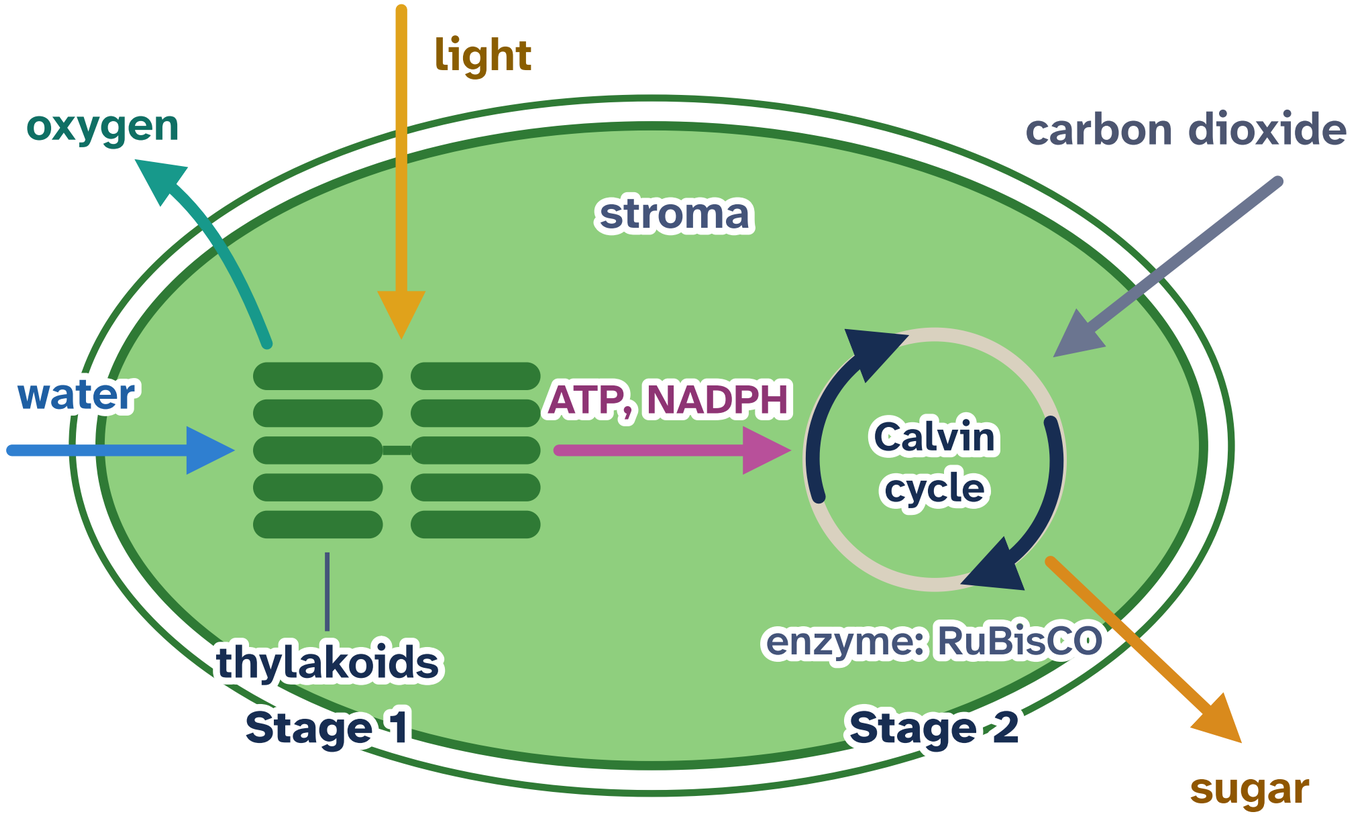
Light	strong sunshine
Temperature	cold
Carbon dioxide	falling, vents shut

Most likely limiting: temperature. Light is strong, so warming the air would raise the rate the most.

Later in the day: with the vents shut, the plants use up carbon dioxide, so it can become limiting. Heating costs fuel, so growers pay to raise only the factor that is actually limiting.

- Sun is shining strongly through the glass
- Air inside is cold and the vents are shut
- Which factor is most likely limiting the rate?
- What could the grower change, and what would it cost?

Going further: two stages



- Stage 1, in the thylakoid membranes, needs light
- Light splits water, releasing oxygen and capturing energy
- Stage 2, the Calvin cycle in the stroma, fixes carbon dioxide
- The enzyme RuBisCO helps build carbon dioxide into sugar

Common mix-ups

Often said

Plants only respire at night.

What the evidence shows

Plants respire all the time. In bright light they photosynthesise faster than they respire, so overall they take in carbon dioxide.

Often said

Plants get their food from the soil.

What the evidence shows

The carbon in a plant's sugar comes from carbon dioxide in the air. Soil supplies water and minerals, not food.

Often said

The oxygen plants release comes from carbon dioxide.

What the evidence shows

It comes from water molecules, split using light energy in the chloroplasts.

Often said

Light is one of the reactants.

What the evidence shows

Light is the energy source, not a substance. That is why it is written above the arrow.

Quick check

A plant has plenty of light and water, but the rate of photosynthesis has stopped rising. What could be the limiting factor?

A The amount of oxygen

B The carbon dioxide concentration

C The amount of glucose stored

D The colour of the pot

Summary

Key takeaways

1. Carbon dioxide + water → glucose + oxygen, using light energy
2. It happens in chloroplasts, mainly in leaf palisade cells
3. Leaves are broad and flat, with air spaces and stomata
4. Light, carbon dioxide and temperature can limit the rate
5. Glucose is used for respiration, starch, cellulose and sucrose