INFOGRAPHHUB SERIES · 9 PARTS · AGES 11–16

Photosynthesis

Nine infographics on how plants turn light, water and air into sugar, and why every living thing depends on it.

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Each part is one printable infographic. Work through them in order, or use the part you need. The quiz answers are printed upside down at the foot of the quiz. Sources for every part are listed on its page at infographhub.com.

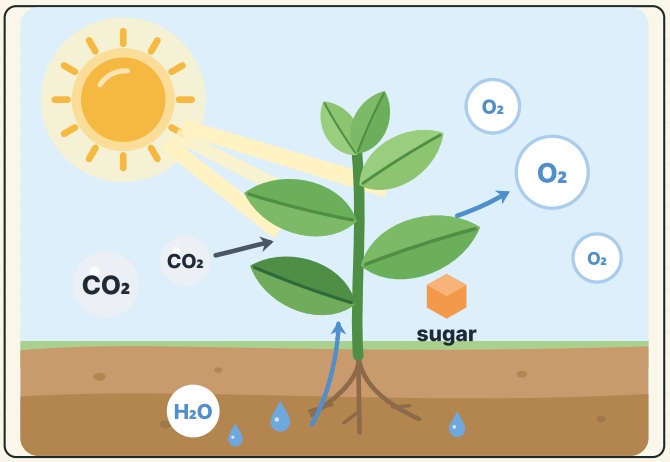
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PHOTOSYNTHESIS PART 1 OF 9 · AGES 11–16

How Photosynthesis Works

Plants turn light, water and carbon dioxide into sugar and release the oxygen we breathe.



1

Light is captured

Chlorophyll in the chloroplasts absorbs mostly red and blue light and reflects green, which is why most leaves look green.

2

Water arrives from the roots

Roots absorb water from the soil. It travels up through the xylem to the cells of the leaf.

3

Carbon dioxide enters

CO_2 from the air diffuses into the leaf through tiny pores called stomata, found mostly on the underside of leaves.

4

Water is split

In the thylakoid membranes, light energy splits water. Oxygen is released and the energy is stored in ATP and NADPH.

5

Sugar is built

In the stroma, the Calvin cycle uses ATP and NADPH to fix CO_2 into sugar. The enzyme RuBisCO does the fixing.

6

Energy is used or stored

Glucose powers growth and respiration, or is stored as starch. Oxygen leaves the leaf through the stomata.

The overall equation

$6CO_2 + 6H_2O$ + light energy → $C_6H_{12}O_6$ (glucose) + $6O_2$

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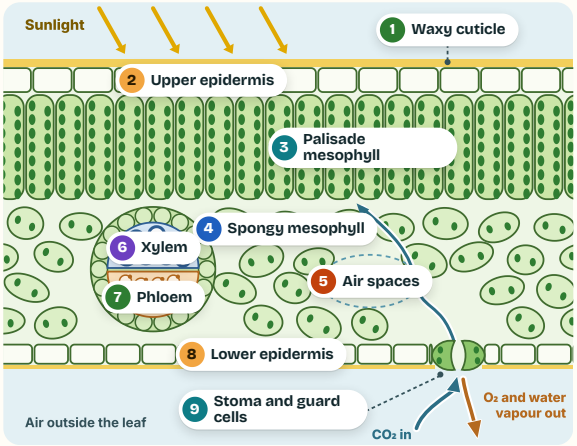
2. Inside a Leaf: Labelled Leaf Cross-Section

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PHOTOSYNTHESIS PART 2 OF 9 · AGES 11–16

Inside a Leaf

A thin slice through a leaf shows layers of cells, each built to catch light, let gases in or carry water and sugar.



1 Waxy cuticle

A thin, waterproof and see-through layer of wax. It cuts water loss but lets light pass. It is usually thickest on the upper surface.

2 Upper epidermis

One layer of clear cells with no chloroplasts, so light shines straight through to the cells below. It protects the inside of the leaf.

3 Palisade mesophyll

Tall, tightly packed cells just under the surface, crammed with chloroplasts. Most photosynthesis happens here, where the light is brightest.

4 Spongy mesophyll

Rounder, loosely packed cells with fewer chloroplasts. The gaps between them let gases spread through the leaf.

5 Air spaces

Carbon dioxide diffuses through these gaps to every mesophyll cell, while oxygen and water vapour diffuse out towards the stomata.

6 Xylem

Hollow tubes strengthened with lignin that bring water and mineral ions from the roots. In a leaf vein, the xylem lies on the upper side.

7 Phloem

Living cells that carry dissolved sugars from the leaf to the rest of the plant (translocation). In a vein, the phloem lies below the xylem.

8 Lower epidermis

The bottom layer of clear cells, covered by a thinner cuticle. In most plants it holds far more stomata than the upper surface.

9 Stoma and guard cells

A tiny pore between two guard cells. They open it to let carbon dioxide in and oxygen out, and close it to save water.

Thin, flat and full of holes

A leaf's broad, flat shape gives a large surface to catch light. Because it is thin, light reaches the inner cells and gases only travel a short way.

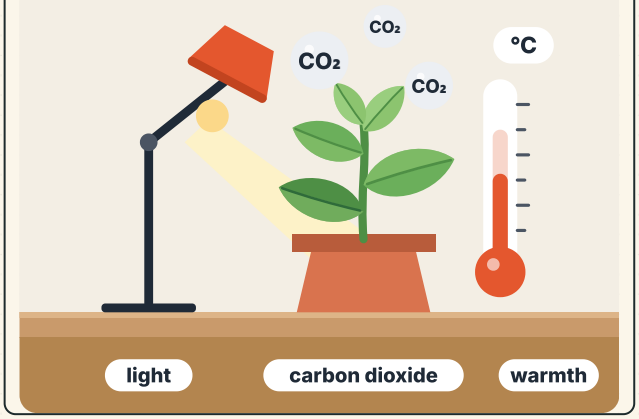
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3. What Limits Photosynthesis? The Limiting Factors

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PHOTOSYNTHESIS PART 3 OF 9 · AGES 11–16

What Limits Photosynthesis

A plant can only photosynthesise as fast as its scarcest ingredient allows. These are the factors that set the speed.



Light intensity

More light gives a faster rate, until the graph levels off because something else runs short. In the dark, photosynthesis stops.

Carbon dioxide concentration

Air is only about 0.04% carbon dioxide, so CO_2 often limits the rate on bright, warm days. More CO_2 speeds it up until the rate levels off.

Temperature

Warmth speeds up the enzymes, so the rate rises to an optimum. Too hot, and the enzymes are denatured and the rate falls quickly.

Amount of chlorophyll

Less green pigment catches less light. Chlorophyll contains magnesium, so plants short of it turn yellow and photosynthesise less.

Water supply

Water is a reactant, but a thirsty plant slows first because it closes its stomata to save water, which also shuts out carbon dioxide.

The slowest factor wins

At any moment, the factor in shortest supply sets the rate. Raising the others makes no difference until that one increases.

Distance from the light

Light intensity $\propto 1 /$ distance^2. Move a lamp twice as far from a plant and the light reaching it falls to a quarter.

Reading the graph

Where a rate graph rises, the factor on the x-axis is limiting. Where it levels off, something else has become the limiting factor.

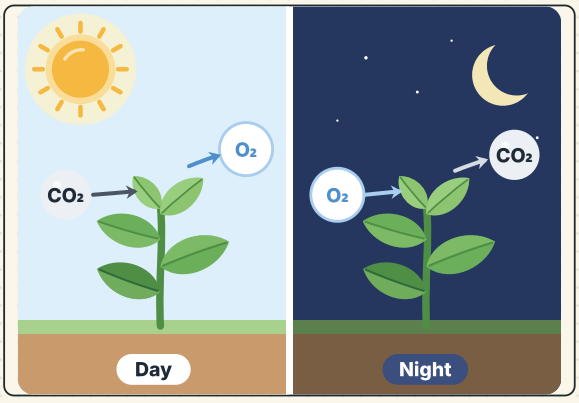
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4. Photosynthesis vs Respiration: Key Differences

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Photosynthesis vs Respiration

One stores energy in sugar, the other releases it. Plants do both, and the products of one are the ingredients of the other.



	Photosynthesis	Respiration
WHERE	In chloroplasts, so only in green cells of plants and algae	Mainly in mitochondria, in every living cell of plants and animals
WHEN	Only when there is light	All the time, day and night
TAKES IN	Carbon dioxide and water, plus light energy	Glucose and oxygen
GIVES OUT	Glucose and oxygen	Carbon dioxide and water, plus energy for the cell
ENERGY	Endothermic: stores light energy as chemical energy in glucose	Exothermic: releases the energy stored in glucose
EQUATION	$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

The compensation point

In dim light, a plant photosynthesises exactly as fast as it respires, so there is no overall exchange of carbon dioxide or oxygen.

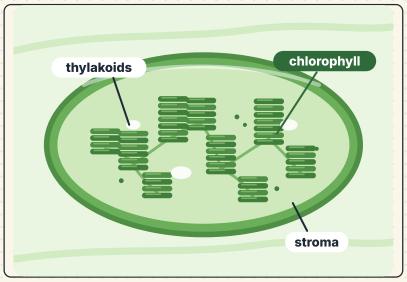
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5. Photosynthesis Key Terms and Equations

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Photosynthesis Key Terms

The equations and words you need to explain photosynthesis precisely, each with a one-line meaning.



Σ The equations

carbon dioxide + water → glucose + oxygen	**Word equation** Light energy, absorbed by chlorophyll, drives the reaction. Write 'light' above the arrow.
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	**Balanced symbol equation** Six carbon dioxide and six water molecules make one glucose and six oxygen. Both sides have 6 C, 12 H and 18 O atoms.
Endothermic reaction	A reaction that takes in energy. Photosynthesis transfers light energy from the surroundings into chemical energy stored in glucose.

Where it happens

Chloroplast	The small structure (organelle) in a plant or algal cell where photosynthesis happens. Palisade cells contain many of them.
Chlorophyll	The green pigment inside chloroplasts that absorbs light energy, mainly red and blue light. Each molecule has a magnesium atom at its centre.
$C_6H_{12}O_6$	**Glucose** The simple sugar made by photosynthesis. It stores chemical energy and is the starting point for everything else the plant builds.
Producer	An organism that makes its own food by photosynthesis, such as a plant or an alga. Producers start almost every food chain.

How fast it goes

Rate of photosynthesis	How fast it happens, measured as oxygen made or carbon dioxide used in a set time, such as bubbles per minute from pondweed.
Limiting factor	Whatever is in shortest supply (light, carbon dioxide, a suitable temperature or chlorophyll) and so holds the rate back.
light intensity ∝ 1 / distance²	**Inverse square law** Double the distance between a lamp and a plant and the light intensity falls to a quarter.

What glucose is used for

Respiration	Glucose is broken down with oxygen to release energy for the plant's cells, day and night.
Starch	Many glucose units joined into an insoluble energy store, kept in leaves, seeds and tubers. Iodine turns blue-black with starch.
Fats and oils	Compact energy stores made from glucose, found especially in seeds.
Cellulose	Long fibres built from glucose that strengthen plant cell walls.
Amino acids and proteins	Glucose combined with nitrate ions taken from the soil makes amino acids, which are joined to build proteins.

Count the atoms

To check the symbol equation, count each element on both sides: 6 carbon, 12 hydrogen and 18 oxygen atoms. And oxygen gas is always O_2, never O.

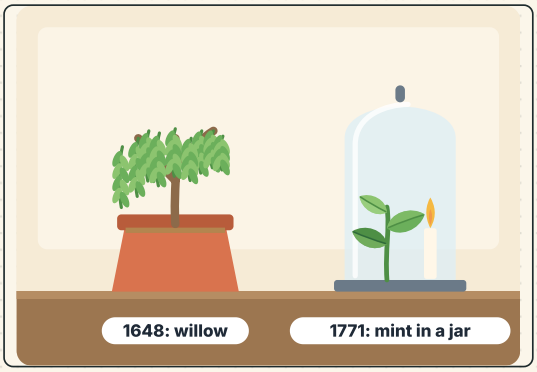
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6. How We Discovered Photosynthesis: A Timeline

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How We Discovered Photosynthesis

Three centuries of experiments, from a willow in a pot to radioactive carbon, that revealed how plants make sugar.



1648 — Van Helmont's willow tree
A willow grew by about 74 kg in five years while its soil lost only about 57 g. He concluded, wrongly, that the new mass came from water alone.

1771 — Priestley's mint and mouse
A sprig of mint 'restored' air in a sealed jar where a candle had burned out, so a candle could burn and a mouse could live in it again.

1779 — Ingenhousz: light is needed
Plants restored the air only in light, and only their green parts did it. In the dark they did not.

1782 — Senebier: carbon dioxide goes in
Plants take in 'fixed air', now called carbon dioxide, and give out oxygen in the light.

1804 — De Saussure: water is used too
Careful measurements showed that water is also a reactant: a plant's gain in mass comes from carbon dioxide and water together.

1882 — Engelmann's bacteria
Oxygen-loving bacteria crowded beside the parts of an alga lit by red and blue light, showing which colours chlorophyll uses.

1905 — Blackman's limiting factors
Experiments on pondweed under different light, temperatures and CO_2 levels showed that the factor in shortest supply limits the rate.

1941 — The oxygen comes from water
Ruben, Kamen and colleagues gave algae water with a heavy oxygen isotope. It turned up in the oxygen released, not from carbon dioxide.

1948–1954 — Mapping the Calvin cycle
Calvin, Benson and Bassham traced radioactive carbon-14 to map how CO_2 is built into sugar. Calvin won the 1961 Nobel Prize in Chemistry.

Wrong answers still help
Van Helmont's conclusion was wrong, but his careful weighing proved the soil was not the source and set up the question others answered.

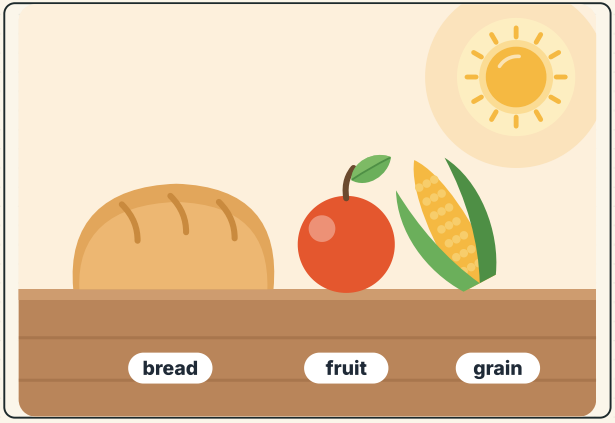
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7. Photosynthesis in Everyday Life: 8 Places You Meet It

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Photosynthesis in Everyday Life

From your breakfast to the air in your lungs, you meet the results of photosynthesis all day long.



Every meal

Grains, fruit and vegetables come from plants; meat, milk and eggs come from animals that ate plants. Almost all food energy began as sunlight.

The air you breathe

Photosynthesis keeps the air supplied with oxygen. About half of Earth's oxygen comes from the ocean, made by tiny drifting phytoplankton.

Wood, paper and cotton

Timber, paper and cotton are mostly cellulose, a fibre plants build from the glucose they make by photosynthesis.

Coal, oil and gas

Fossil fuels formed from ancient plants and plankton. Burning them releases energy that photosynthesis captured millions of years ago.

Greenhouse crops

Growers add warmth, light and extra carbon dioxide to speed up photosynthesis. In Iceland, tomatoes grow under glass all year round.

Stadium grass

Stands shade parts of a pitch, so some clubs use rigs of grow lights to keep the grass photosynthesising and growing.

Autumn colours

As chlorophyll breaks down in autumn, yellow and orange pigments that were hidden underneath show through. Some trees also make new red ones.

The planet's yearly breath

Carbon dioxide in the air falls each northern spring and summer as plants grow, then rises in winter as growth stops and leaves decay.

Not just plants

Algae and cyanobacteria photosynthesise too. One tiny ocean bacterium, Prochlorococcus, makes up to 20% of the oxygen in the biosphere (NOAA).

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8. Photosynthesis Myths: What Plants Really Do

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PHOTOSYNTHESIS PART 8 OF 9 · AGES 11–16

Photosynthesis Myths

Eight things many people believe about plants, and what the evidence actually shows.



MYTH **Plants get their food from the soil.** 1

FACT Plants make their own food, glucose, by photosynthesis. Soil supplies water and mineral ions such as nitrate; 'plant food' fertiliser is minerals, not food.

MYTH **Most of a plant's mass comes from the soil.** 2

FACT Van Helmont's willow gained about 74 kg while its soil lost about 57 g. Most new mass is built from carbon dioxide taken from the air, plus water.

MYTH **The oxygen plants give out comes from carbon dioxide.** 3

FACT It comes from water. Tracer experiments in 1941 showed the oxygen released is split from water; the oxygen atoms in CO_2 end up in the sugar.

MYTH **Plants photosynthesise and animals respire.** 4

FACT Plants respire too, in every living cell, day and night. In bright light they photosynthesise faster than they respire, which hides it.

MYTH **Plants breathe in carbon dioxide and breathe out oxygen.** 5

FACT Plants do not breathe. Gases diffuse in and out through the stomata; photosynthesis uses carbon dioxide while respiration uses oxygen.

MYTH **Leaves are green because chlorophyll absorbs green light.** 6

FACT The reverse: chlorophyll absorbs mostly red and blue light and reflects much of the green, which is the light that reaches your eyes.

MYTH **Only leaves can photosynthesise.** 7

FACT Any green part with chloroplasts can, including young stems. Algae and cyanobacteria with no leaves at all make about half of Earth's oxygen, in the ocean.

MYTH **The Amazon rainforest makes 20% of the world's oxygen.** 8

FACT Estimates are nearer 6–9%, and the forest's plants and decomposers use almost all of it again, so its net effect on the air is close to zero.

Follow the atoms

To test a claim about plants, ask where each atom comes from and goes to, and what happens at night. Most myths fail one of these checks.

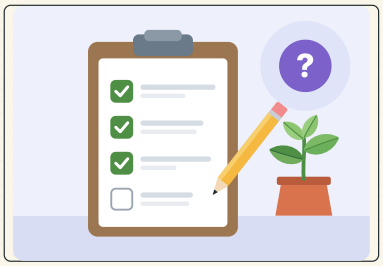
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9. Photosynthesis Quiz: 10 Questions with Answers

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PHOTOSYNTHESIS · PART 9 OF 9 · AGES 11–16

Photosynthesis Quiz

Ten questions on the whole series. Answer them all, then turn the page round to check.



1 Which gas do plants take in from the air for photosynthesis?

- A Oxygen
- B Nitrogen
- C Carbon dioxide
- D Hydrogen

2 Which is the balanced symbol equation for photosynthesis?

- A $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
- B $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- C $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$
- D $6CO_2 + 6O_2 \rightarrow C_6H_{12}O_6 + 6H_2O$

3 In which layer of a leaf does most photosynthesis happen?

- A Upper epidermis
- B Palisade mesophyll
- C Spongy mesophyll
- D Phloem

4 What do guard cells do?

- A Carry water up the plant
- B Open and close the stomata
- C Store starch
- D Make chlorophyll

5 Where does the oxygen released by photosynthesis come from?

- A Carbon dioxide
- B Glucose
- C Water
- D The soil

6 Pondweed makes bubbles faster as a lamp gets brighter, then the rate levels off. Why?

- A Light is still limiting
- B Another factor is now limiting
- C The plant stops respiring
- D The chlorophyll is used up

7 A lamp is moved from 10 cm to 20 cm away from a plant. What happens to the light intensity?

- A It halves
- B It falls to a quarter
- C It doubles
- D It stays the same

8 When do plants respire?

- A Only at night
- B Only in the light
- C All the time
- D Never: only animals respire

9 Which product made from glucose strengthens plant cell walls?

- A Starch
- B Cellulose
- C Oil
- D Amino acids

10 Who showed in 1779 that plants need light to 'restore' air?

- A Joseph Priestley
- B Jan Baptist van Helmont
- C Jan Ingenhousz
- D Melvin Calvin

ANSWERS

1. C: Carbon dioxide
2. A: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ (B is aerobic respiration)
3. B: Palisade mesophyll
4. B: Open and close the stomata
5. C: Water (shown with an oxygen isotope trace in 1941)
6. B: Another factor such as CO_2 or temperature, is now limiting
7. B: It falls to a quarter ($1 \div 2^2 = ¼$)
8. C: All the time, day and night
9. B: Cellulose
10. C: Jan Ingenhousz

SERIES COMPLETE

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