

Nutrition in flowering plants

Revision notes · How plants make glucose by photosynthesis, what affects its rate, how the leaf is adapted, and the practical work.

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. **Biology only** is not in the Double Award and is only examined on Paper 2.

Nutrition in flowering plants Spec 2.18-2.23

Photosynthesis and its equations Spec 2.18, 2.19

Photosynthesis is the process by which plants and algae make glucose. The energy comes from **light**, which is absorbed by the green pigment **chlorophyll** in the chloroplasts.

Photosynthesis is important because it converts **light energy to chemical energy**. The chemical energy is stored in the glucose that is made. Plants use this glucose for respiration and to build new plant material. Almost all food chains start with this stored energy.

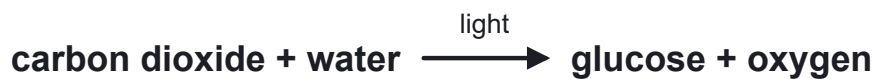
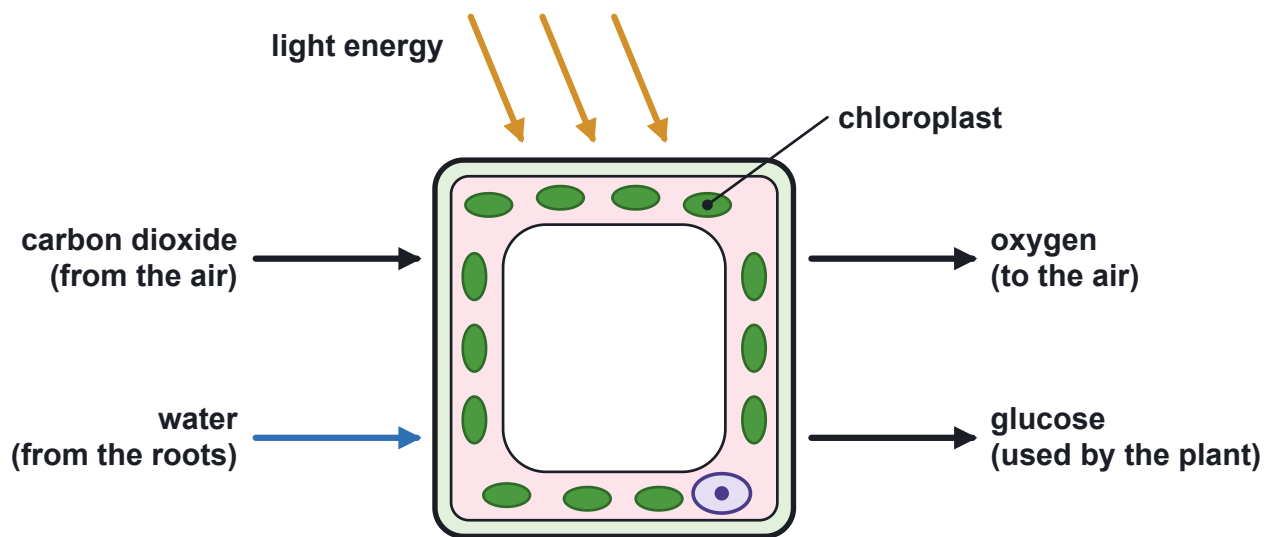
Light energy is used to react **carbon dioxide** and **water** to produce **glucose** and **oxygen**.

carbon dioxide + water → glucose + oxygen (in the presence of light and chlorophyll)

$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ (in the presence of light and chlorophyll)

Where the raw materials come from and where the products go

Substance	Reactant or product	Source or fate
Carbon dioxide	Reactant	Diffuses into the leaf from the air
Water	Reactant	Absorbed from the soil by the roots and carried to the leaf in the xylem
Glucose	Product	Used for respiration, or to build new plant material (biomass)
Oxygen	Product	Diffuses out of the leaf into the air



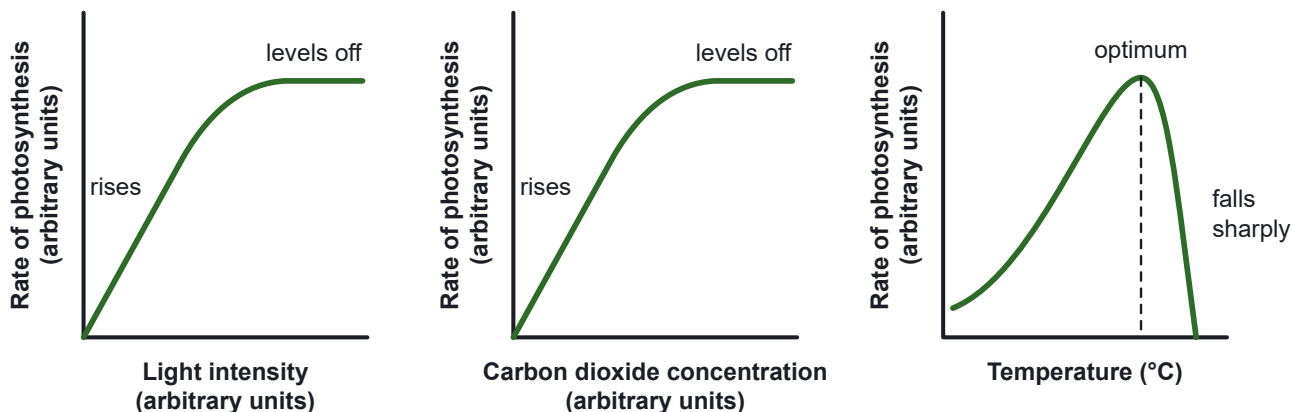
Photosynthesis in a leaf cell: **light energy** is absorbed by chlorophyll in the chloroplasts.

Exam tip: Light is the energy source, not a reactant, so it does not go in the word equation as a substance. Write 'in the presence of light' or put 'light energy' above the arrow. Check that the symbol equation is balanced: 6 carbon atoms, 12 hydrogen atoms and 18 oxygen atoms on each side.

Factors affecting the rate of photosynthesis Spec 2.20

A **limiting factor** is something that is in short supply, so it stops the rate of a process from going any faster. The rate of photosynthesis is affected by **carbon dioxide concentration**, **light intensity** and **temperature**.

How each factor affects the rate of photosynthesis		
Factor	Effect on rate	Why
Light intensity	Rate increases as light intensity increases, then levels off	Light provides the energy for the reaction. At low light, the amount of light limits the rate. At high light, another factor is limiting.
Carbon dioxide concentration	Rate increases as concentration increases, then levels off	Carbon dioxide is a reactant. At low concentration, there is not enough of it. At high concentration, another factor is limiting.
Temperature	Rate increases up to an optimum temperature, then falls sharply	Photosynthesis is controlled by enzymes. A higher temperature gives more collisions between enzymes and substrates. Above the optimum the enzymes are denatured, so the rate falls.



Light intensity and carbon dioxide: the rate rises, then levels off. Temperature: the rate rises to an optimum, then falls sharply.

On a graph, the rate rises while the factor on the x-axis is the limiting factor. Where the line goes flat, that factor is no longer limiting and something else is. Reading a graph this way is a common exam question.

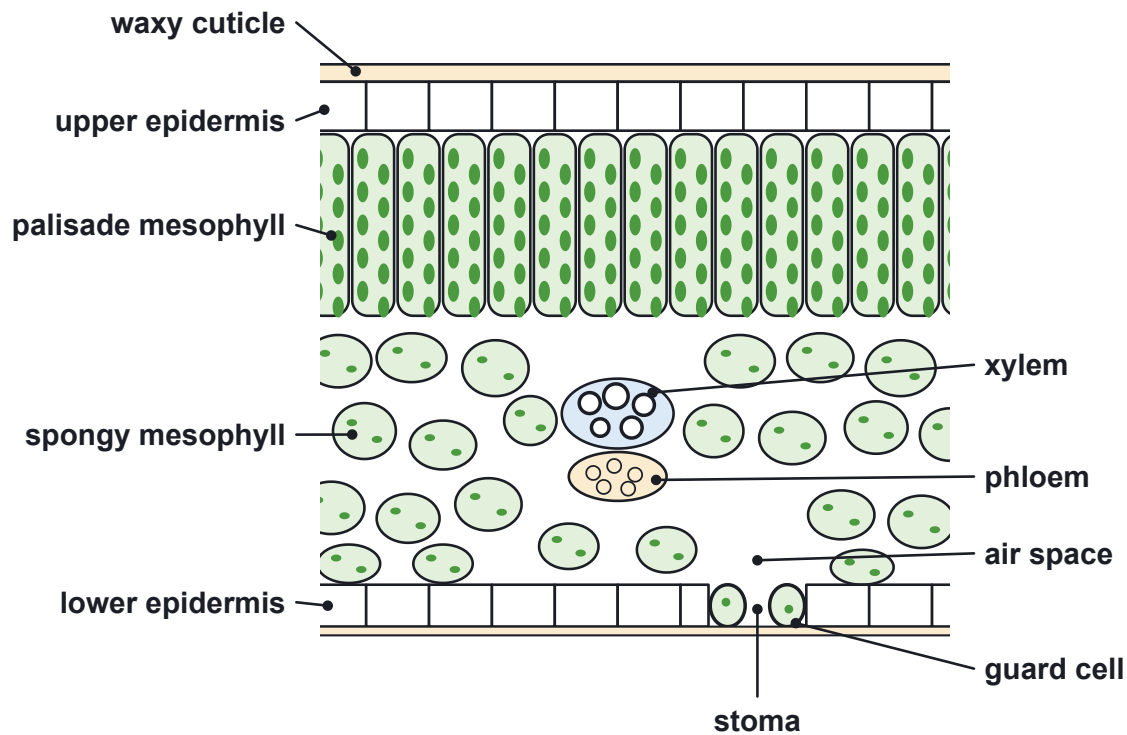
Maths skill: To describe a graph, state the trend, then quote data from it, for example the value where the line levels off. For a table of results, plot the factor you changed on the x-axis and the rate on the y-axis.

Common mistake: Do not write that the enzymes are 'killed' at high temperature. Enzymes are not alive. They are denatured, because their active site changes shape.

Leaf structure and adaptations Spec 2.21, 2.42B

A leaf is adapted to absorb light for photosynthesis and to allow gas exchange of carbon dioxide and oxygen.

Structures in a leaf and how they are adapted		
Structure	Adaptation	How it helps
Whole leaf	Broad, flat and thin	Large surface area to absorb light, and a short distance for gases to diffuse
Waxy cuticle	A waxy, waterproof layer on the surface	Reduces water loss by evaporation
Upper epidermis	A thin layer of transparent cells	Lets light through to the cells underneath
Palisade mesophyll	Tightly packed, tall cells near the top of the leaf, with many chloroplasts	Most photosynthesis takes place here, close to the light
Spongy mesophyll	Loosely arranged cells with air spaces between them	Carbon dioxide can diffuse through the leaf to the cells, and oxygen can diffuse out
Stomata and guard cells	Pores, mostly in the lower epidermis, opened and closed by guard cells	Allow gases to enter and leave, and control water loss
Xylem and phloem (veins)	Vascular bundles running through the leaf	Xylem brings water for photosynthesis. Phloem carries sucrose away.



Leaf cross-section: most photosynthesis happens in the **palisade mesophyll**; gases diffuse through the air spaces and stomata.

Biology only

How the leaf is adapted for gas exchange

Biology only

Carbon dioxide and oxygen move into and out of a leaf by diffusion, down their concentration gradients. The structure of the leaf makes this diffusion fast.

Biology only

- Broad, flat shape: a **large surface area** for gases to diffuse in and out.
- Thin leaf: a short diffusion distance, so gases reach the cells quickly.
- Many stomata, mostly in the lower epidermis: pores that let carbon dioxide diffuse in and oxygen diffuse out. Guard cells open and close them.
- Air spaces in the spongy mesophyll: gases diffuse quickly between the stomata and the cells, and a large surface area of cells is exposed to the air.
- Moist cell surfaces: gases dissolve in the thin film of water on the mesophyll cells, then diffuse into or out of the cells.

Exam tip: Always give an adaptation and the reason it helps. For example, 'the air spaces in the spongy mesophyll allow carbon dioxide to diffuse to the photosynthesising cells'.

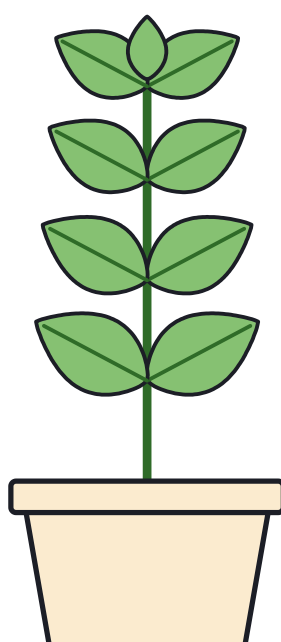
Mineral ions: magnesium and nitrate Spec 2.22

Plants need more than carbon dioxide, water and light. They also need **mineral ions** for healthy growth. The roots absorb these ions from the soil. You need to know two of them.

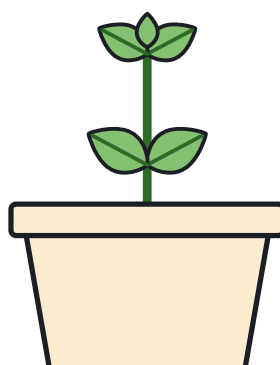
Two mineral ions that plants need

Mineral ion	Why the plant needs it	Effect of a shortage
Magnesium ions	Needed to make chlorophyll	Leaves turn yellow, because there is less chlorophyll
Nitrate ions	Needed to make amino acids , which are joined to make proteins for growth	Stunted (poor) growth

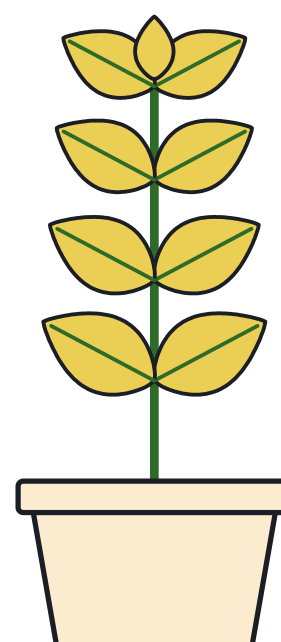
Without enough chlorophyll, a plant absorbs less light, so it photosynthesises more slowly and makes less glucose. Without enough amino acids, the plant cannot make the proteins it needs for new cells, so it grows slowly.



Healthy



**Lacks nitrate:
stunted growth**



**Lacks magnesium:
yellow leaves (chlorosis)**

Lack of **nitrate** causes **stunted growth**; lack of **magnesium** causes **yellow leaves**.

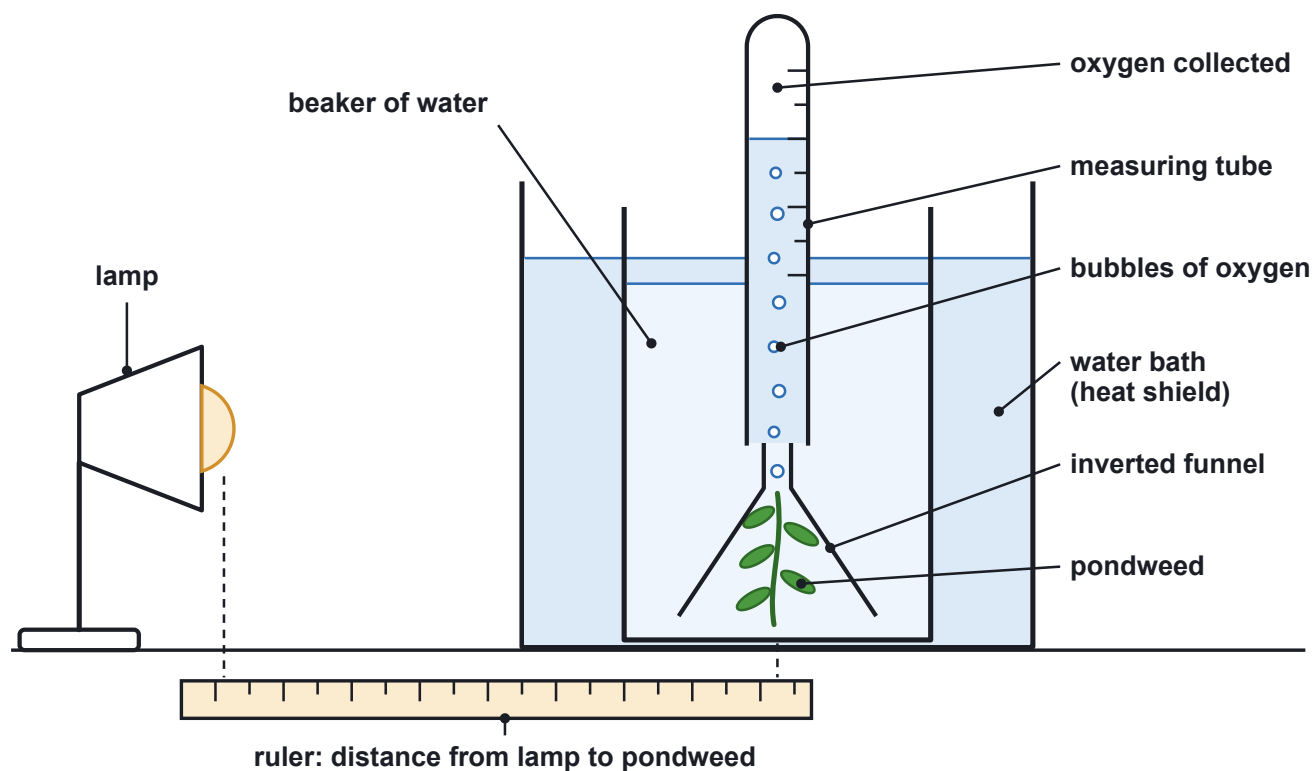
Common mistake: Link each ion to its job: magnesium goes with chlorophyll (yellow leaves), nitrate goes with amino acids and proteins (stunted growth). Do not say that plants use nitrate to make chlorophyll or glucose.

Practical: oxygen from a water plant Spec 2.23

A water plant such as pondweed (*Elodea* or *Cabomba*) gives off bubbles of **oxygen** when it photosynthesises. Counting the bubbles, or measuring the volume of gas, gives a measure of the **rate of photosynthesis**. You can change the light intensity by moving a lamp to different distances from the plant.

1. Set up a beaker of water with a little sodium hydrogencarbonate, which supplies carbon dioxide. Place a piece of pondweed, cut end upwards, under an inverted funnel with a test tube or measuring tube over the end.
2. Place a clear container of water between the lamp and the beaker as a heat shield, or use an LED lamp, so the temperature stays constant.

- Place the lamp a measured distance from the pondweed, for example 10 cm. Switch off other light sources.
- Leave the plant for a few minutes to adjust to the new light level.
- Count the bubbles released from the cut end of the stem in one minute. Alternatively, collect the gas and measure its volume over a set time.
- Repeat at different distances, for example 20, 30, 40 and 50 cm. Repeat each distance at least three times and calculate a mean.



Investigating light intensity: change the **distance** of the lamp and measure the **oxygen** produced.

Variables		
Type	Variable	How it is controlled or measured
Independent	Light intensity	Changed by changing the distance between the lamp and the plant
Dependent	Rate of photosynthesis	Number of bubbles per minute, or volume of gas collected per minute
Control	Temperature	Heat shield or water bath, and a lamp that gives out little heat
Control	Carbon dioxide concentration	Same amount of sodium hydrogencarbonate in the water each time
Control	The plant	Same piece of pondweed, with the same length of stem, for every distance

Typical results: the further the lamp is from the plant, the lower the light intensity, so fewer bubbles are released per minute. The rate rises as the lamp is moved closer, then levels off when another factor becomes limiting. To show that the gas is oxygen, collect enough of it in a test tube and test it with a glowing splint, which relights.

Counting bubbles is not very accurate because bubbles can be different sizes. Collecting the gas and measuring its volume gives better data.

Practical: Safety: keep the mains lamp and its cable away from the water, and do not touch a hot lamp. Controlling temperature matters because a lamp placed close to the plant also warms the water, which would change the rate.

Exam tip: 'Light intensity' is the independent variable, not 'the distance'. Say that the distance is how you change the light intensity.

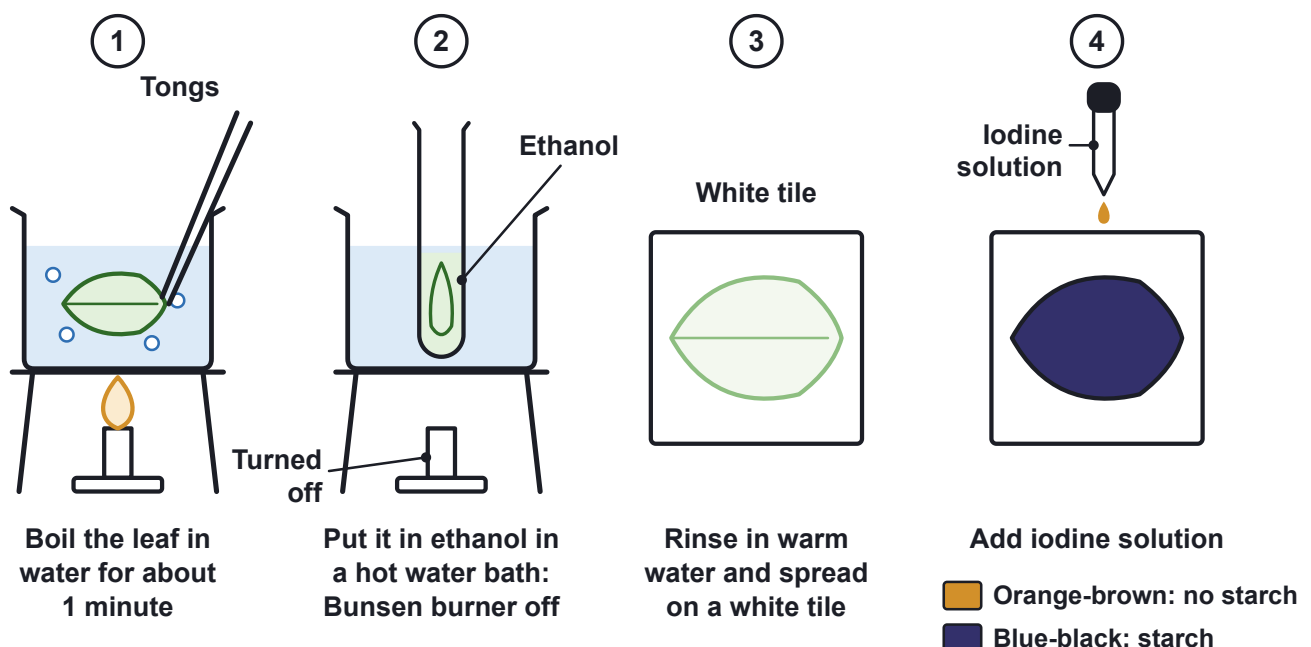
Practical: starch, light, carbon dioxide and chlorophyll Spec 2.23

Plants store the glucose they make as **starch**. A leaf that has been photosynthesising contains starch, so testing a leaf for starch shows that photosynthesis has happened. By changing one condition at a time, you can show that photosynthesis needs **light**, **carbon dioxide** and **chlorophyll**.

Before starting, the plant is **destarched**: it is left in a dark cupboard for 24 to 48 hours. With no light it cannot photosynthesise, and it uses up its stored starch.

The starch test on a leaf

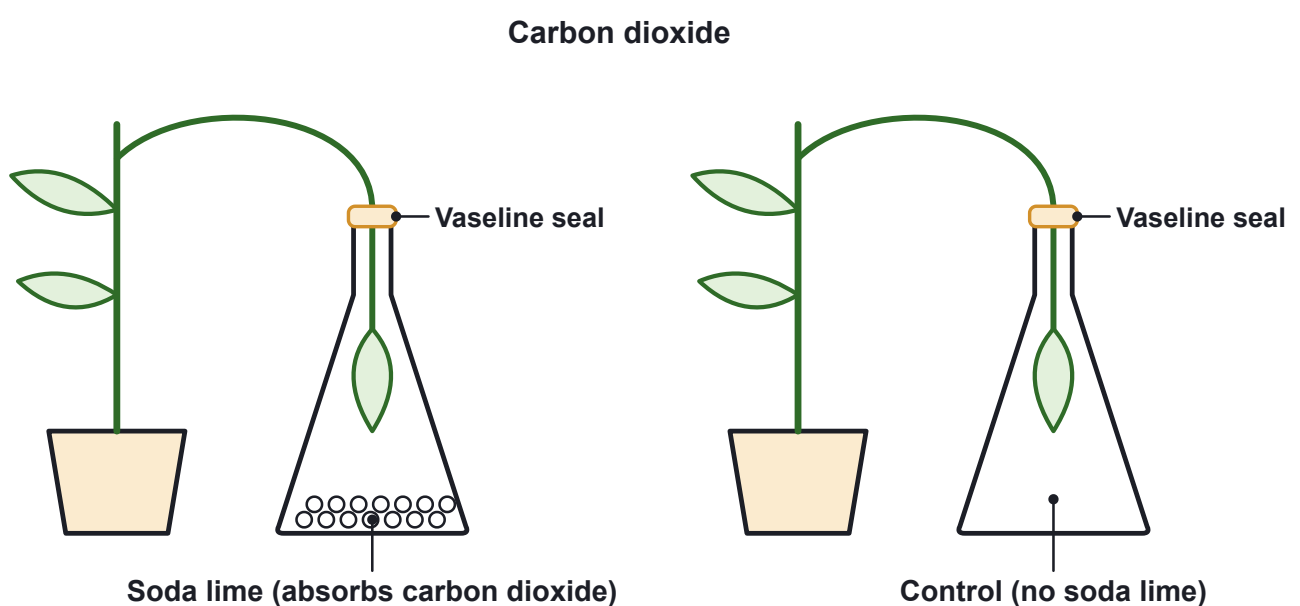
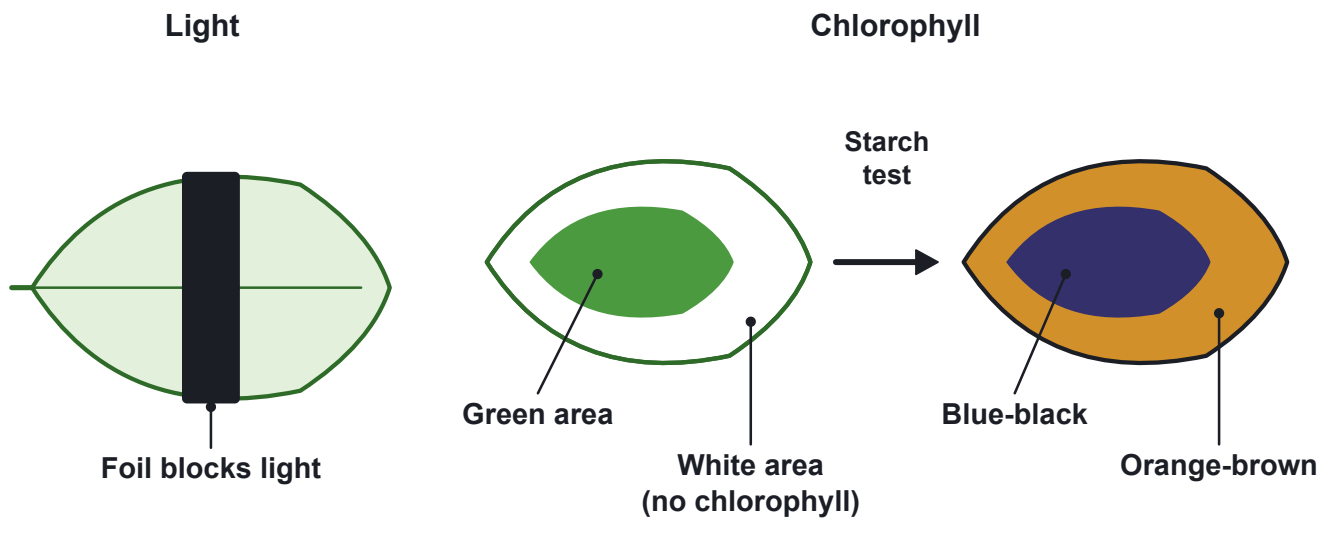
1. Dip the leaf in boiling water for about one minute. This kills the cells and stops chemical reactions, and it softens the leaf so the iodine can get in.
2. Turn off the Bunsen burner. Put the leaf in a boiling tube of ethanol and stand the tube in the hot water. The ethanol removes the chlorophyll, so the leaf turns pale. Ethanol is flammable, so there must be no naked flame.
3. Rinse the leaf in warm water to soften it, then spread it on a white tile.
4. Add drops of iodine solution. A **blue-black** colour shows that starch is present. If there is no starch, the iodine stays **orange-brown**.



Testing a leaf for starch: boil, remove chlorophyll in ethanol (no flame), rinse, then add iodine. **Blue-black** means starch is present.

Showing what photosynthesis needs

Investigating the requirements for photosynthesis		
Requirement	Method	Result (after the starch test)
Light	Cover part of a leaf on a destarched plant with foil or black paper, or a stencil, and leave the plant in bright light for several hours.	Uncovered area turns blue-black. Covered area stays orange-brown, so light is needed.
Carbon dioxide	Enclose one leaf of a destarched plant, still attached to the plant, in a sealed flask containing soda lime (or sodium hydroxide solution), which absorbs carbon dioxide. Set up a control leaf in the same way in a flask without soda lime. Leave the plant in bright light for several hours.	Control leaf turns blue-black. Leaf without carbon dioxide stays orange-brown, so carbon dioxide is needed.
Chlorophyll	Destarch a plant with variegated leaves, which have green areas (with chlorophyll) and white areas (without). Leave it in bright light for several hours.	Green areas turn blue-black. White areas stay orange-brown, so chlorophyll is needed.



Showing that photosynthesis needs **light**, **chlorophyll** and **carbon dioxide**: only the part of the leaf with all three turns blue-black.

Practical: Safety: wear eye protection. Ethanol is flammable, so turn off the Bunsen burner before heating it in a water bath. Soda lime and sodium hydroxide are corrosive, and iodine solution stains skin and clothes.

Exam tip: If asked why the plant is destarched, say it makes sure any starch found afterwards was made during the investigation. If asked why the leaf is boiled in ethanol, say it removes chlorophyll so the colour change can be seen.

Quick check

1. Give the word equation for photosynthesis.
2. Which form of energy is photosynthesis converting light into?
3. Name three factors that can affect the rate of photosynthesis.
4. Why do plants need magnesium ions and nitrate ions?
5. What colour does iodine solution turn when starch is present?

Quick check answers

Nutrition in flowering plants

1. Carbon dioxide + water → glucose + oxygen (in the presence of light and chlorophyll).
2. Chemical energy, stored in glucose.
3. Carbon dioxide concentration, light intensity and temperature.
4. Magnesium ions are needed to make chlorophyll. Nitrate ions are needed to make amino acids.
5. Blue-black.