Plant nutrition

IGCSE Biology

Photosynthesis

Green leaves capture sunlight for photosynthesis.

Image: Joselodos, CC0 (commons.wikimedia.org)

Photosynthesis 光合作用 is the process by which plants make **carbohydrates** 碳水化合物 from simple **raw materials** 原料, using **energy** 能量 from light. It is how plants feed themselves.

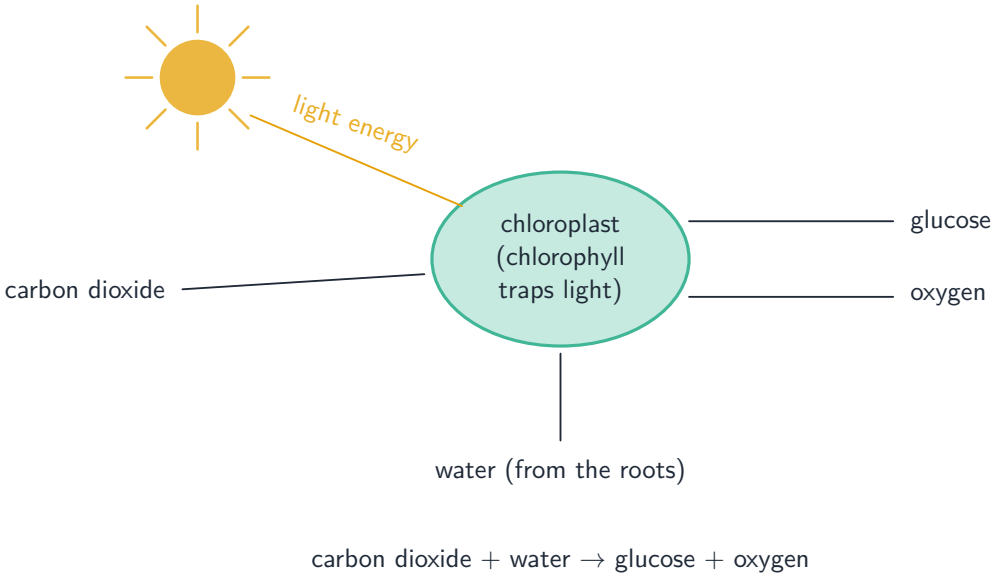
The word equation

$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen}$$

In words: plants take in **carbon dioxide** 二氧化碳 and water, and make **glucose** 葡萄糖 and **oxygen** 氧气. This reaction can only happen in the light, and only where there is **chlorophyll** 叶绿素.

(Supplement) The balanced chemical equation is:

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



carbon dioxide + water → glucose + oxygen

Photosynthesis takes in carbon dioxide and water and makes glucose and oxygen, using light

What chlorophyll does

Chlorophyll is a green **pigment** 色素 found in the **chloroplasts** 叶绿体. It traps light and transfers the energy from light into energy stored in chemicals. That chemical energy is then used to build carbohydrates.

What the plant does with the glucose

Use	What happens
store	changed to **starch** 淀粉, an energy store that does not dissolve
build	made into **cellulose** 纤维素 to build **cell walls** 细胞壁
release energy	broken down in **respiration** 呼吸作用 to release energy
transport	changed to **sucrose** 蔗糖 and moved around the plant in the **phloem** 韧皮部
attract animals	made into **nectar** 花蜜 to attract **insects** 昆虫 for **pollination** 传粉

Minerals from the soil

Plants also take up mineral **ions** 离子 from the soil through their roots:

- **nitrate ions** 硝酸根离子—needed to make **amino acids** 氨基酸 (and so proteins).
- **magnesium ions** 镁离子—needed to make chlorophyll.

A plant short of nitrate grows poorly with weak stems; a plant short of magnesium has yellow leaves (it cannot make enough chlorophyll).

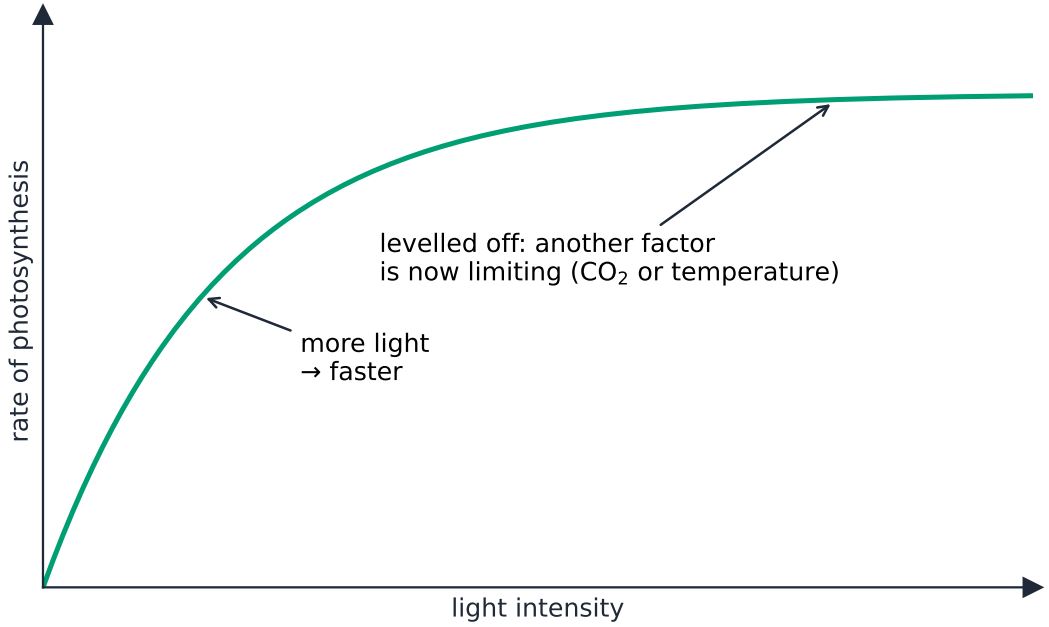
The rate of photosynthesis

The **rate** 速率 of photosynthesis depends on three things:

- **light intensity** 光照强度—more light gives a faster rate, up to a point.

- carbon dioxide **concentration** 浓度—more carbon dioxide gives a faster rate.
- **temperature** 温度—a warmer temperature is faster, until it gets so hot that the enzymes are denatured.

(Supplement) At any moment, the one factor that is in shortest supply holds back the rate. This is called the **limiting factor** 限制因素. For example, on a dull day light intensity is usually the limiting factor; on a bright day carbon dioxide may be.



More light speeds up photosynthesis until another factor becomes limiting

Investigating photosynthesis

To show that a plant needs light, chlorophyll and carbon dioxide, you test a leaf for starch after taking one of them away. A **control** 对照 keeps every other condition the same, so the test is fair. (First leave the plant in the dark to use up its starch.) A leaf with green and white parts shows starch only in the green parts, which have chlorophyll.

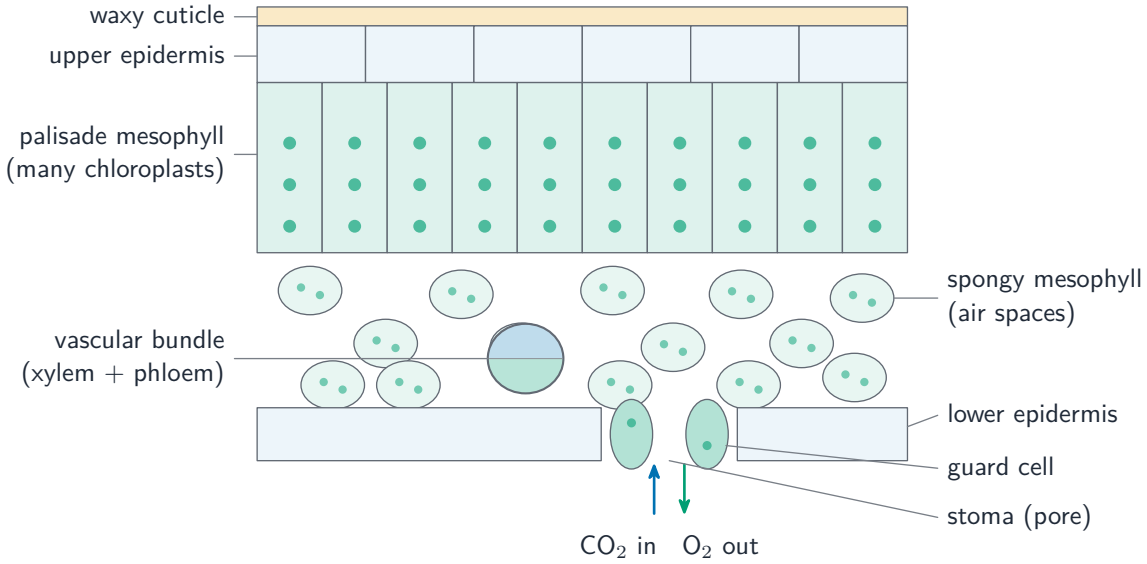
You can also watch **gas exchange** 气体交换 in a water plant using hydrogencarbonate **indicator** 指示剂, which changes colour as the carbon dioxide level changes. In the light the plant takes in carbon dioxide for photosynthesis; in the dark it gives out carbon dioxide from respiration.

Leaf structure

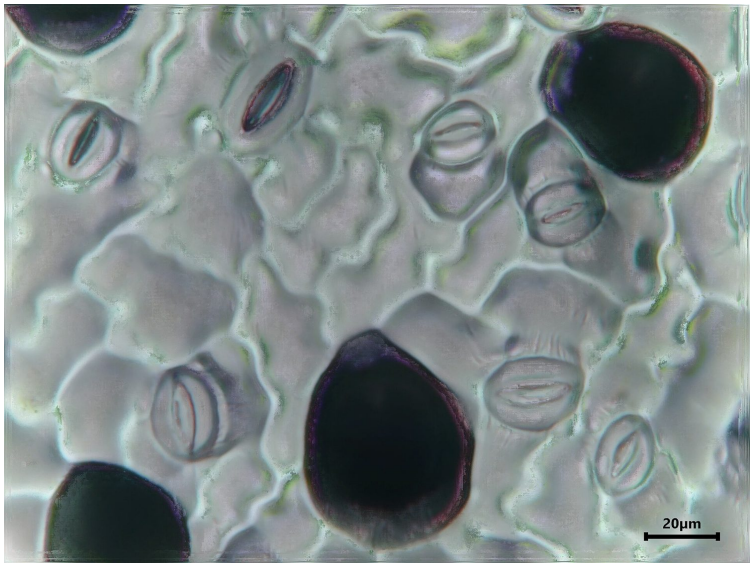
A leaf is well **adapted** 适应 for photosynthesis. Most leaves are broad, with a large **surface area** 表面积 to catch plenty of light, and thin, so that gases and light quickly reach all the cells.

The middle of the leaf, the **mesophyll** 叶肉, is where most photosynthesis happens. These are the main parts of a leaf:

Structure	Job / how it helps photosynthesis
cuticle 角质层	a clear waxy layer on top; it reduces water loss but still lets light through
upper **epidermis** 表皮	a clear layer of cells with no chloroplasts; it lets light pass to the cells below
palisade mesophyll 栅栏叶肉	tall, column-shaped cells packed with chloroplasts, near the top; they do most of the photosynthesis
spongy mesophyll 海绵叶肉	rounded cells with **air spaces** 气腔 between them, so gases can move easily
stomata 气孔	tiny holes, mostly on the lower surface, that let carbon dioxide in and oxygen out
guard cells 保卫细胞	a pair of cells around each stoma; they open and close it
lower epidermis	a thin layer that holds the stomata
vascular bundles 维管束	contain **xylem** 木质部 (brings water to the leaf) and phloem (carries sugars away)



A leaf in cross-section: each tissue is adapted for photosynthesis and gas exchange



Real stomata in the lower surface of a leaf —each pore has two guard cells (scale bar 20 m)

Exam tips

- Learn the word equation exactly: carbon dioxide + water → glucose + oxygen (in light, with chlorophyll).
- Chlorophyll is in the chloroplasts; it does not get used up —it transfers light energy.
- Link each factor to the rate: more light, more carbon dioxide, warmer (but not too hot) → faster, until a **limiting factor** stops further increase.
- For leaf structure, always link the part to its job: broad and thin to catch light; palisade cells full of chloroplasts; stomata and air spaces for gas exchange.
- Nitrate ions → amino acids; magnesium ions → chlorophyll.