Plant Nutrition

Photosynthesis, its equation, uses of the carbohydrates made and the factors that limit its rate, the structure of a leaf, and the mineral ions that plants need.

6.1 Photosynthesis

> **Photosynthesis is the process by which plants make carbohydrates from raw materials (carbon dioxide and water), using energy from light.**

Chlorophyll is a **green pigment** found in **chloroplasts**. It **absorbs light energy** and transfers it into **chemical energy** for the formation of glucose and other carbohydrates.

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{glucose} + \text{oxygen}$$

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

Carbon dioxide enters the leaf through the stomata, water comes up from the roots in the xylem, and oxygen leaves through the stomata.

What happens to the glucose

Use	Detail
respiration	glucose is broken down to release energy
stored as starch	an insoluble energy store (in leaves, roots and seeds)
cellulose	built into cell walls
sucrose	transported through the phloem to other parts of the plant
other substances	with nitrate ions, used to make amino acids and then proteins; also fats and oils

Investigating photosynthesis

To show that **starch** has been made, first **destroy the leaf's enzymes and remove its colour**: dip the leaf in boiling water (to kill the cells), then in hot ethanol (to remove the chlorophyll), rinse it in water, and add **iodine solution**. A leaf that photosynthesised turns **blue-black**.

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To show that this is needed	Experiment	Control
chlorophyll	a variegated leaf (green and white parts): only the **green** parts turn blue-black	the green part, compared with the white part
light	cover part of a leaf with black paper or foil: the **covered** part stays brown	the uncovered part of the same leaf
carbon dioxide	put a plant in a sealed jar with **soda lime** or potassium hydroxide to absorb the carbon dioxide: the leaf stays brown	a plant in a jar without soda lime

Plants must first be **destarched** (kept in the dark for 24 to 48 hours) so that any starch found has been made during the experiment.

The rate of photosynthesis: limiting factors

The rate of photosynthesis depends on **light intensity**, **carbon dioxide concentration** and **temperature**.

Factor	Effect
light intensity	the rate rises as light intensity increases, then levels off when another factor becomes limiting
carbon dioxide concentration	the rate rises with carbon dioxide concentration until it levels off
temperature	the rate rises with temperature (enzymes work faster) up to an optimum of about $30–40\,^{\circ}\mathrm{C}$, then falls as the enzymes are denatured

A limiting factor is the factor in short supply that stops the rate of photosynthesis from going any faster. On a graph, the rate rises while one factor is limiting, and becomes flat (a plateau) when it is no longer limiting and something else is.

Using a limiting factor. In a greenhouse, growers add extra light, heating and carbon dioxide, and the one that is limiting is the one that should be increased.

Investigating the rate with a submerged aquatic plant such as *Elodea* (pondweed): count the **bubbles of oxygen** given off in a given time, or collect the gas. Vary the **light intensity** by changing the distance of a lamp (a lamp closer means higher light intensity), the carbon dioxide concentration by adding sodium hydrogencarbonate to the water, and the temperature using a water bath.

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Hydrogencarbonate indicator can also be used. It changes colour as the level of carbon dioxide changes: it is **red** at normal carbon dioxide levels, turns **yellow** when carbon dioxide is high (as in respiration) and **purple** when carbon dioxide is low (when the plant photosynthesises).

> TRY IT
>
> On a graph of photosynthesis rate against light intensity, the line is flat above a certain point. What can limit the rate there?

Light is no longer limiting, so the rate is limited by another factor: **carbon dioxide concentration** or **temperature**.

6.2 Leaf structure

Leaves are adapted for photosynthesis: they have a **large surface area** to absorb light and are **thin**, so that carbon dioxide only has a short distance to diffuse and light can reach all the cells.

Structure	Adaptation and function
cuticle (waxy layer)	waterproof, reduces water loss by evaporation from the surface
upper epidermis	a thin, transparent layer that lets light through to the cells beneath
palisade mesophyll	tall cells packed with **chloroplasts**, near the top of the leaf where most light falls; the main site of photosynthesis
spongy mesophyll	rounded cells with some chloroplasts and **air spaces** between them, so that gases can diffuse through the leaf
air spaces	allow carbon dioxide to diffuse to the cells and oxygen out; water vapour leaves through them
stomata and guard cells	pores (stomata) in the lower epidermis for gas exchange; each is opened or closed by a pair of **guard cells**
vascular bundle (xylem and phloem)	**xylem** brings water to the leaf; **phloem** carries away sucrose and amino acids
lower epidermis	contains most of the stomata

Most chloroplasts are in the palisade layer, because it is nearest to the light. The stomata are on the underside, which is cooler and out of direct sunlight, so less water is lost.

6.1 Mineral nutrition

Plants take up mineral ions from the soil through their roots. Two important ones:

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- **Nitrate ions** are needed to make **amino acids**, which are joined together to make **proteins**. Without nitrate, a plant has **stunted growth** and its older **leaves turn yellow**.
- **Magnesium ions** are needed to make **chlorophyll**. Without magnesium, the leaves turn **yellow** (chlorosis) because the plant cannot make enough chlorophyll to photosynthesise.

NOTE

A deficiency symptom in an exam question can usually be explained like this: the missing ion is needed to make a specific substance (nitrate for protein, magnesium for chlorophyll), so without it the plant cannot grow or photosynthesise properly.

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