IGCSE BIOLOGY 0610 · CHAPTER 5 NOTES · ~11 MIN READ

Plant nutrition

How plants make their own food: the photosynthesis equation, what glucose is used for, leaf structure, investigating light, chlorophyll and CO_2, limiting factors — and the minerals plants need.

Photosynthesis | Limiting factors | Leaf structure | Mineral ions

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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- **Photosynthesis**: plants make **carbohydrates** (glucose) from **carbon dioxide and water**, using **light energy** absorbed by **chlorophyll** in chloroplasts. Oxygen is released.
- Word equation: carbon dioxide + water → glucose + oxygen. EXT Balanced: **$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$**.
- The **leaf** is adapted: broad and thin, **palisade cells** full of chloroplasts, **stomata** for gas exchange, air spaces, and veins.
- Rate is limited by **light, carbon dioxide or temperature**. Plants need **nitrate** (for protein) and **magnesium** (for chlorophyll).

BY THE END YOU CAN

- Define photosynthesis and write the word equation.
- Write the balanced symbol equation. EXT
- Describe the roles of chlorophyll, and the uses of the carbohydrate made.
- Identify leaf tissues and explain how the leaf is adapted.
- Describe the tests and controls for light, chlorophyll and carbon dioxide.
- Explain the effect of light, CO_2 and temperature on the rate, including limiting factors. EXT
- State the roles of nitrate and magnesium ions.

1 Photosynthesis

What is photosynthesis?

PHOTOSYNTHESIS

carbon dioxide + water —(light energy; needs chlorophyll)→ glucose + oxygen

$6CO_2 + 6H_2O$ —(light, chlorophyll)→ $C_6H_{12}O_6 + 6O_2$

raw materials

CO_2 from the air (through stomata)
water from the soil (through xylem)

products

glucose: stored as starch, used for respiration, made into cellulose...
oxygen: leaves through stomata

Light energy is stored as chemical energy in glucose

Photosynthesis is the reaction that makes glucose from carbon dioxide and water, using light energy.

Photosynthesis — the process by which plants **manufacture carbohydrates** from **raw materials** using **energy from light**.

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

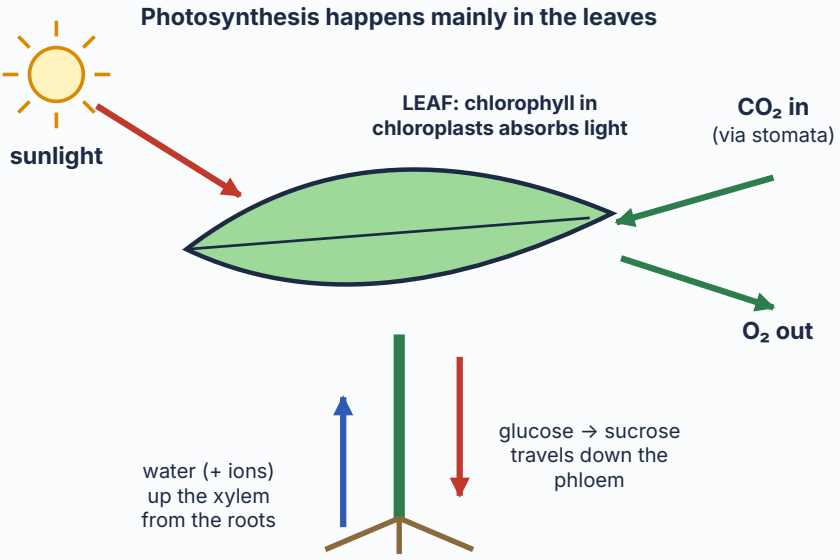
word equation; light energy and chlorophyll are needed

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

EXT balanced symbol equation (check: 6 C, 12 H and 18 O on each side)

Chlorophyll — the **green pigment** in **chloroplasts**. It **absorbs light energy** and transfers it to chemical energy used to make carbohydrates.

- The **raw materials** are **carbon dioxide** (from the air, through the stomata) and **water** (from the soil, through the roots and xylem).
- The **products** are **glucose** and **oxygen**. Light energy is stored as **chemical energy** in the glucose.
- Photosynthesis happens in **chloroplasts**. Most are in the **palisade mesophyll** cells at the top of the leaf.



Where each substance comes from and goes to.

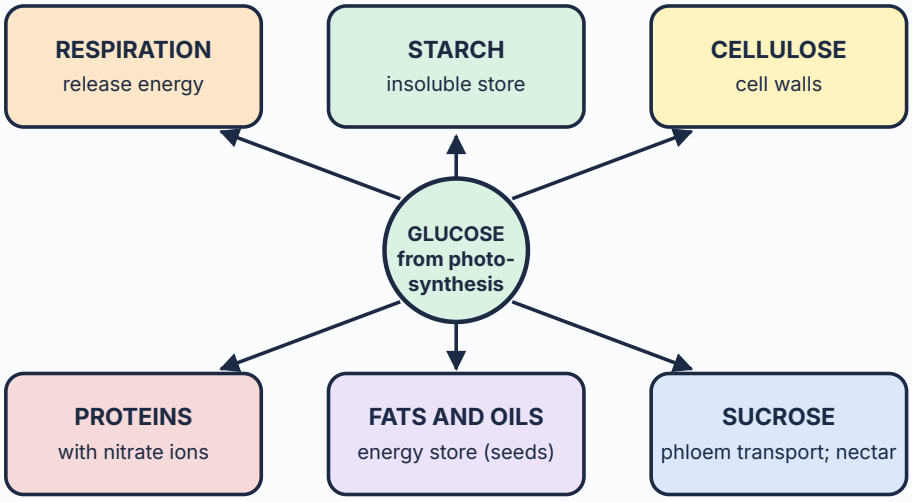
COMMON MISTAKE

"Plants photosynthesise in the day and respire at night." Plants **respire all the time** and photosynthesise only when there is **light**.

COMMON MISTAKE

"Plants take in CO_2 and give out O_2, animals do the opposite, so plants do not respire." Plants respire too (see Gas exchange, respiration & excretion).

What does the plant do with glucose?



Plants cannot move food, so they convert glucose into whatever they need

Glucose is converted into other substances as the plant needs them.

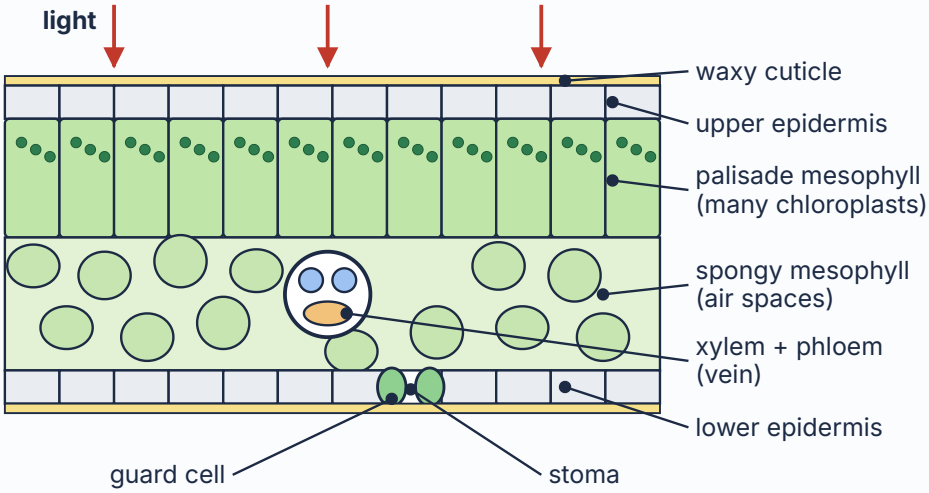
- **Respiration** — to release energy for all the cell's processes.
- **Starch** — an **insoluble** energy store (in leaves, roots, seeds, tubers). Being insoluble, it does not affect the cell's water potential.
- **Cellulose** — to build **cell walls**.
- **Sucrose** — **soluble**, so it can be **transported** in the phloem. It is also found in **nectar**, which attracts insects.
- **Fats and oils** — energy stores (especially in seeds). **Proteins** — made using **nitrate** ions (glucose + nitrate → amino acids).

EXAM TIP

Remember: **starch is stored, sucrose is transported**. Starch is insoluble, sucrose is soluble.

2 The leaf

Structure and function



air spaces let CO_2 diffuse to the cells; stomata control gas exchange

A section through a leaf. The arrangement of the tissues is the key to how a leaf works.

Part	Function
waxy cuticle	waterproof layer: reduces water loss
upper epidermis	transparent single layer: lets light through
palisade mesophyll	tall cells **packed with chloroplasts**: most photosynthesis happens here
spongy mesophyll	loosely packed cells with **air spaces** so CO_2 and O_2 can diffuse
lower epidermis with **stomata** and **guard cells**	stomata let CO_2 in and O_2 and water vapour out; guard cells open and close them
xylem (in the veins)	brings **water and mineral ions** to the leaf
phloem (in the veins)	carries **sucrose** (and amino acids) away

How the leaf is adapted

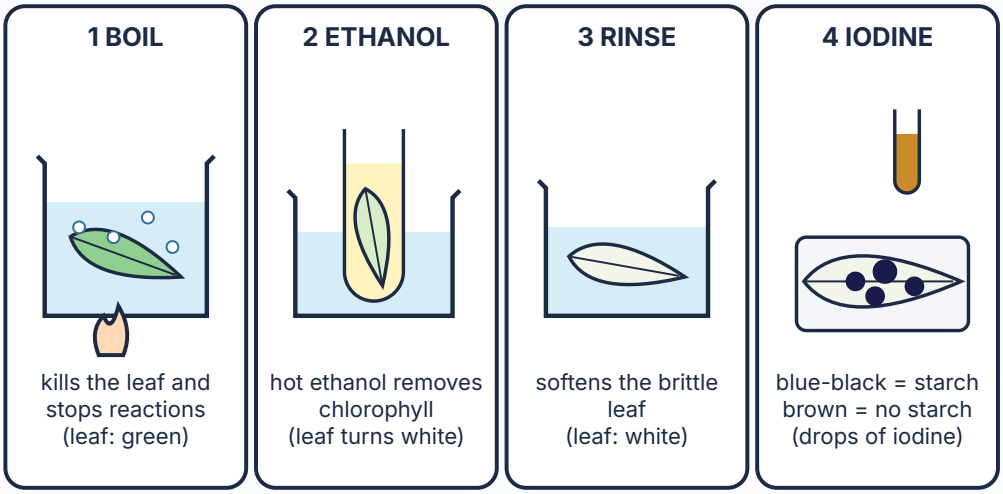
- **Broad and flat** — a large surface area to absorb light.
- **Thin** — a short distance for gases to diffuse and light to reach all cells.
- **Palisade cells at the top** — nearest to the light, packed with chloroplasts.
- **Air spaces** in the spongy layer — carbon dioxide diffuses to the cells quickly.
- **Stomata** — let gases in and out. **Guard cells** open them in the light and close them to save water.
- **Veins** — supply water and carry sugars away. They also **support** the leaf.

EXAM TIP

Exam answers need **feature + advantage**: "thin leaf, so a short diffusion distance for CO_2."

3 Investigating photosynthesis

Testing a leaf for starch

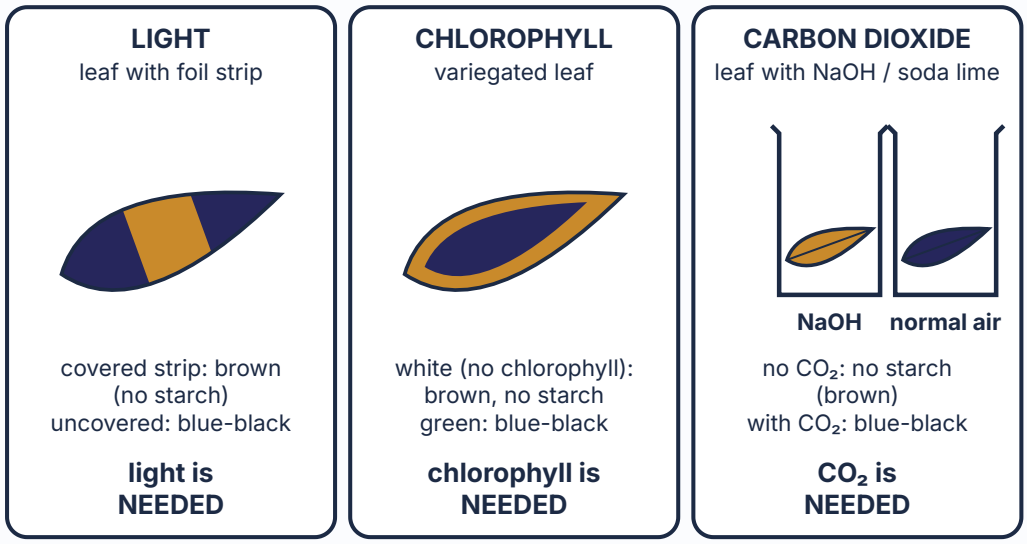


Safety: never heat ethanol with a flame — use a hot water bath

Four steps. Starch is evidence that photosynthesis has been happening.

- **1 Boil** the leaf in water for about a minute: this kills it and stops reactions.
- **2** Put the leaf in **hot ethanol** in a water bath (flame off) to **remove the chlorophyll**.
- **3 Rinse** in warm water to soften the leaf.
- **4 Add iodine solution**: **blue-black** where there is starch; **orange-brown** where there is none.

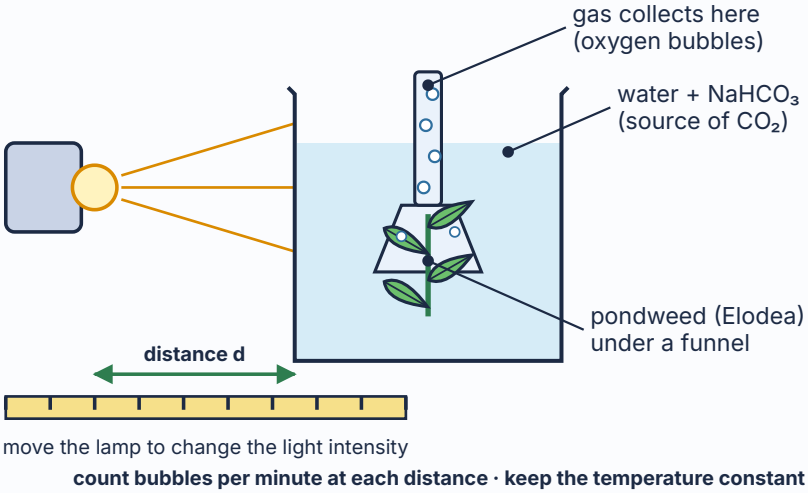
Light, chlorophyll and carbon dioxide



Three experiments. In each, a control shows that only one factor is different.

- **Destarch** the plant first: keep it in the **dark** for 24–48 hours so that any starch present at the end was made during the experiment.
- **Light:** cover part of a leaf with **foil**. Only the uncovered part makes starch.
- **Chlorophyll:** use a **variegated** leaf (green and white). Only the green parts make starch.
- **Carbon dioxide:** put one plant with **soda lime or sodium hydroxide** (absorbs CO_2) and a **control** with normal air. Only the control makes starch.

Measuring the rate of photosynthesis



move the lamp to change the light intensity

count bubbles per minute at each distance · keep the temperature constant

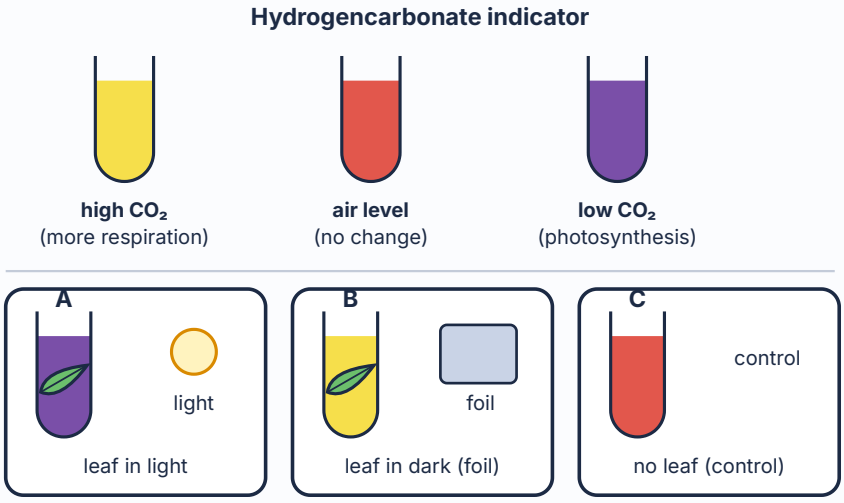
Count the oxygen bubbles released by pondweed at different distances from a lamp.

- The **number of bubbles per minute** is the rate of photosynthesis (oxygen is released).
- **Independent variable:** distance of the lamp (changes the **light intensity**). Other variables to keep the same: temperature, pondweed, and CO_2 (add sodium hydrogencarbonate).
- A **water bath or heat shield** stops the lamp from warming the water.

WORKED EXAMPLE

Bubbles counted in three one-minute periods at one distance: 38, 41 and 39. Calculate the mean rate.

1. total = 38 + 41 + 39 = 118
2. mean = 118 ÷ 3 = 39.3
3. **about 39 bubbles per minute**



Hydrogencarbonate indicator changes colour with the carbon dioxide concentration.

- **Yellow** = **more** CO_2 (more respiration). **Red/orange** = air level. **Purple** = **less** CO_2 (photosynthesis using it up).
- A leaf in **light** takes in CO_2 (purple). A leaf in the **dark** only respires, giving out CO_2 (yellow). The tube **without a leaf** is the **control**.

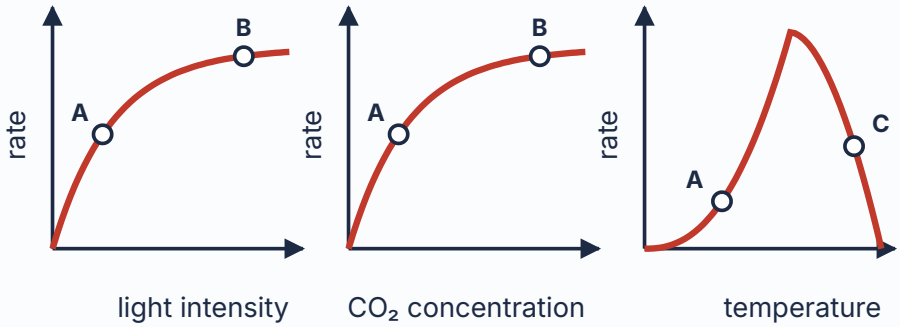
WORKED EXAMPLE

A leaf in a tube of hydrogencarbonate indicator is kept in the dark. The indicator turns yellow. Explain why.

1. there is no light, so no photosynthesis
2. the leaf still respires and releases CO_2
3. **the CO_2 makes the solution more acidic, so the indicator turns yellow**

Limiting factors

Rate of photosynthesis and its limiting factors



A: more light = faster (light is limiting)
B: flat — CO_2 or temperature limits

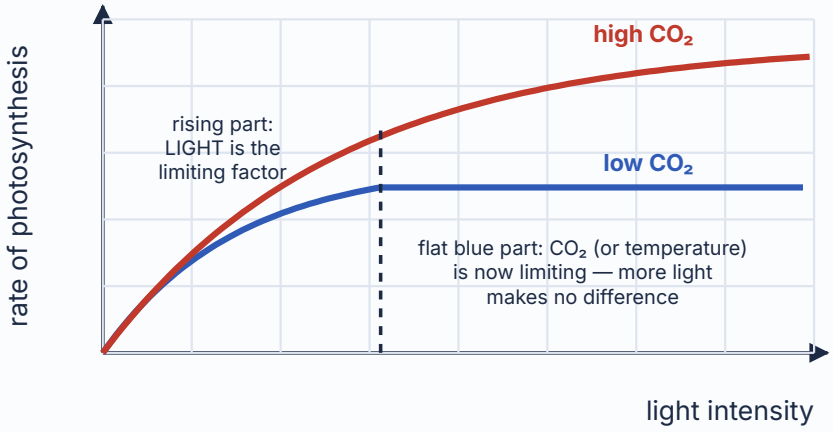
A: more CO_2 = faster (CO_2 is limiting)
B: flat — light or temperature limits

A: warmer = faster
C: too hot — enzymes denature, so rate falls

Rate against light intensity, CO_2 concentration and temperature.

Limiting factor — the factor in **shortest supply** that **sets the maximum rate** of the process.

- **Light intensity:** rate increases with light until another factor limits it, then levels off.
- **Carbon dioxide concentration:** same pattern. CO_2 is only about 0.04% of the air, so it is often limiting.
- **Temperature:** rate increases up to about 30–40 °C. Above that the **enzymes are denatured** and the rate falls.
- The **flat part** of a graph means **some other factor** is limiting, not the one on the x-axis.



Add more CO_2 and the rate can rise again — until something else limits it

EXT With more CO_2 the rate rises again until another factor limits it.

- **At night:** light is limiting. **On a cold, bright day:** temperature is limiting. **On a bright, warm day:** CO_2 may be limiting.
- Growers in **greenhouses** add light, heat and CO_2 (for example paraffin heaters) to get more growth.

WORKED EXAMPLE

A greenhouse is bright and warm, but the tomato plants grow slowly. Suggest a likely limiting factor and a solution.

1. light and temperature are not limiting
2. carbon dioxide is only about 0.04% of the air, so it may be limiting
3. **add carbon dioxide (for example a paraffin heater or a CO_2 generator) to raise the rate**

COMMON MISTAKE

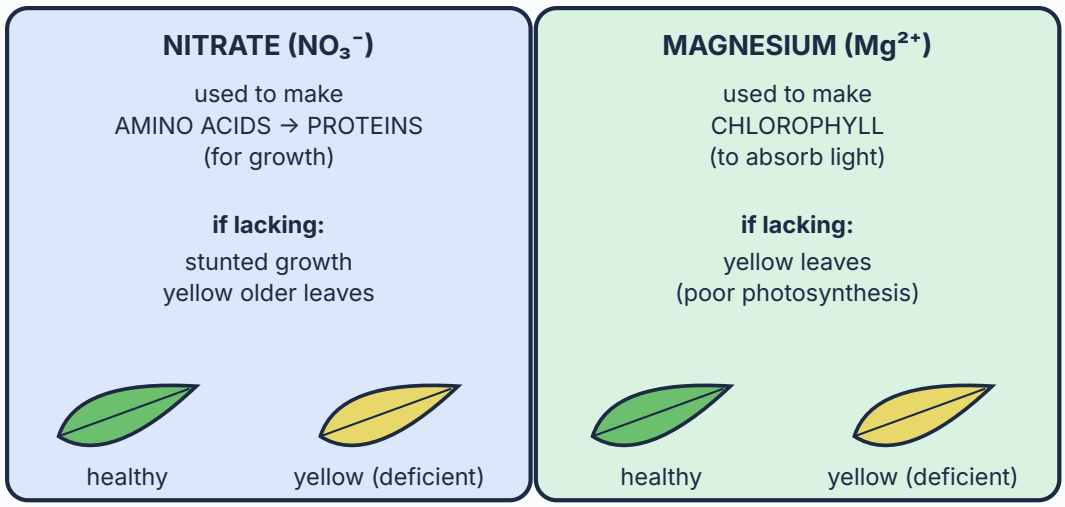
"A flat line means the factor on the x-axis has stopped working." The plant is **limited by another factor** that is in short supply.

EXAM TIP

Graph question? Say which factor is limiting: **rising part** → the x-axis factor. **Flat part** → a different factor.

4 Mineral ions

Nitrate and magnesium



both are absorbed from the soil as ions, by active transport in root hairs

Two mineral ions, their jobs and what goes wrong without them.

- **Nitrate (NO_3^-)** — needed to make **amino acids** and then **proteins**. A lack gives **stunted growth** and **yellow older leaves**.
- **Magnesium (Mg^{2+})** — needed to make **chlorophyll**. A lack gives **yellow leaves** (**chlorosis**), so less photosynthesis.
- Roots take up mineral ions from the soil by **active transport**. Farmers add **fertilisers** to replace them.

COMMON MISTAKE

"Plants get their food from the soil." Plants make **food by photosynthesis**. Soil provides **water and mineral ions**.

5 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. Name the reactants in photosynthesis.
2. Name the green pigment and where it is found.
3. Which leaf cells contain most chloroplasts?
4. Why is it important that a plant is destarched before a starch test experiment?
5. What do guard cells do?
6. Name two uses of the glucose made in photosynthesis.
7. What does a plant need nitrate ions for?
8. EXT Write the balanced symbol equation for photosynthesis.

EXAM-STYLE

9. Explain how a leaf is adapted for photosynthesis. [4]
10. A leaf is kept in the dark for 48 hours, then half of it is covered with foil and the plant is put in light for a day. Describe and explain the result of the starch test. [3]
11. EXT At low light intensity, increasing the CO_2 concentration does not increase the rate of photosynthesis. Explain why. [2]
12. Describe the symptoms of magnesium deficiency and explain them. [2]

Show answers

1. carbon dioxide and water
2. chlorophyll in chloroplasts
3. palisade mesophyll cells
4. so that any starch found must have been made during the experiment
5. open and close the stomata
6. respiration, starch store, cellulose, sucrose (any two)
7. to make amino acids/proteins
8. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
9. thin and broad: large surface area and short diffusion path
   palisade cells packed with chloroplasts at the top
   stomata and air spaces let CO_2 in
   veins bring water
10. the covered half is orange-brown, the uncovered half is blue-black
    light is needed for photosynthesis
    no light, so no starch is made in the covered part
11. light is the limiting factor
    so CO_2 is not in short supply
12. yellow leaves
    magnesium is needed to make chlorophyll

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