6 PLANT NUTRITION

YOUR NOTES

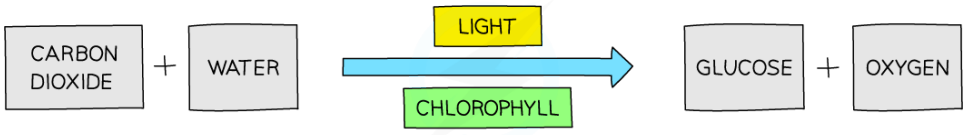
CONTENTS:

VIEW EXAM QUESTIONS

6.1 PHOTOSYNTHESIS

Photosynthesis Theory: Basics

- Green plants make the carbohydrate **glucose** from the raw materials **carbon dioxide** and **water**
- At the same time **oxygen** is made and released as a waste product
- The reaction requires **energy** which is obtained by the pigment **chlorophyll** trapping light from the Sun
- So photosynthesis can be defined as **the process by which plants manufacture carbohydrates from raw materials using energy from light**
- It can be summed up in the following equation:



Photosynthesis word equation

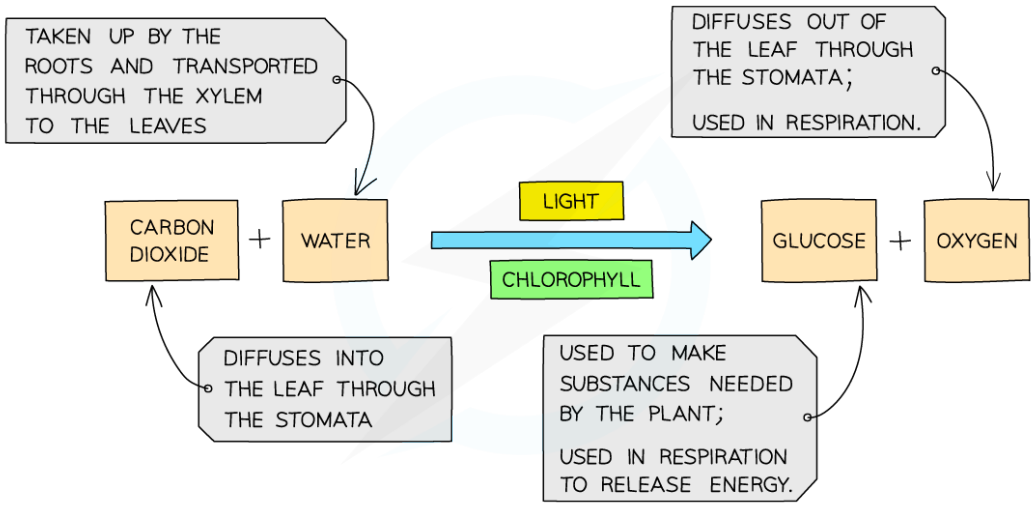
EXAM TIP

If asked for the raw materials required for photosynthesis, the answer is carbon dioxide and water. Although required for the reaction to take place, light energy is not a substance and therefore cannot be a raw material.

6 PLANT NUTRITION

6.1 PHOTOSYNTHESIS cont...

YOUR NOTES

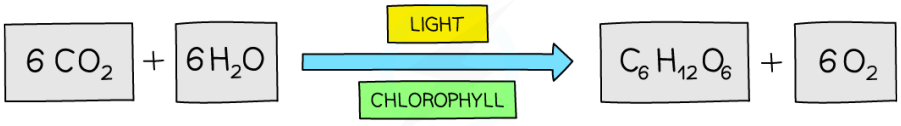


How plants get the materials they need

EXTENDED ONLY

Photosynthesis Theory

- The **balanced chemical equation** for photosynthesis is:



Balanced chemical equation for photosynthesis

- The **light energy** is converted into **chemical energy** in the **bonds** that are holding the atoms in the glucose molecules together

6 PLANT NUTRITION

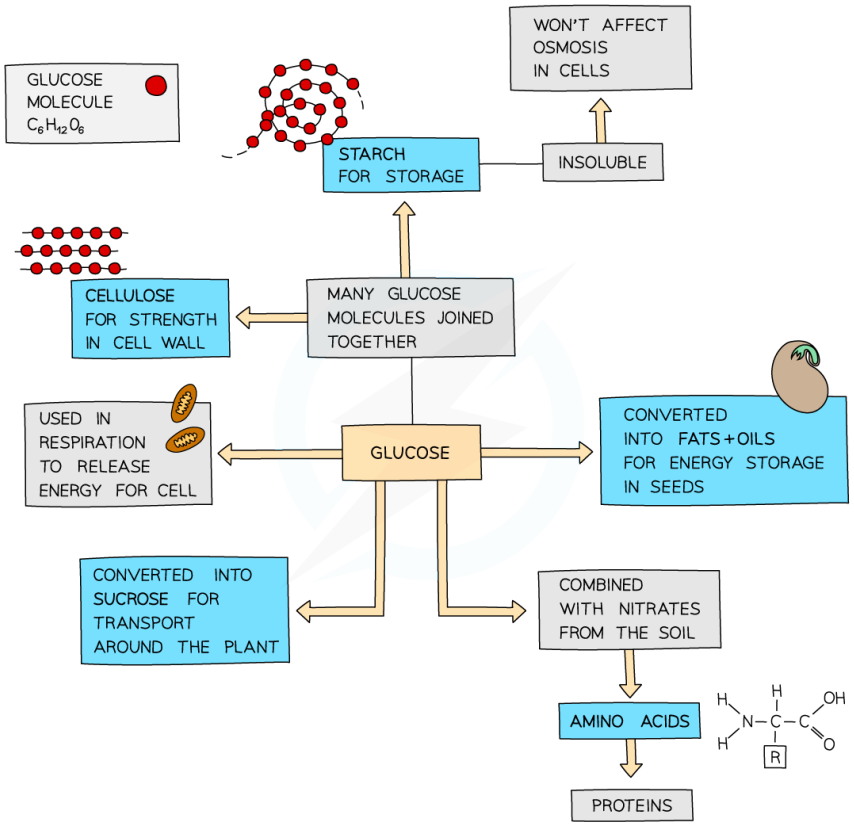
6.1 PHOTOSYNTHESIS cont...

YOUR NOTES

EXTENDED ONLY

The Products of Photosynthesis

- Plants use the glucose they make as a **source of energy** in **respiration**
- They can also convert it into **starch** for storage, into **lipids** for an energy source in seeds, into **cellulose** to make cell walls or into **amino acids** (used to make proteins) when combined with nitrogen and other mineral ions absorbed by roots



The fate of glucose

EXAM TIP

The photosynthesis equation is the exact reverse of the aerobic respiration equation – so if you have learned one you also know the other one!

You will usually get more marks for providing the balanced chemical equation than the word equation.

6 PLANT NUTRITION

6.2 INVESTIGATING PHOTOSYNTHESIS

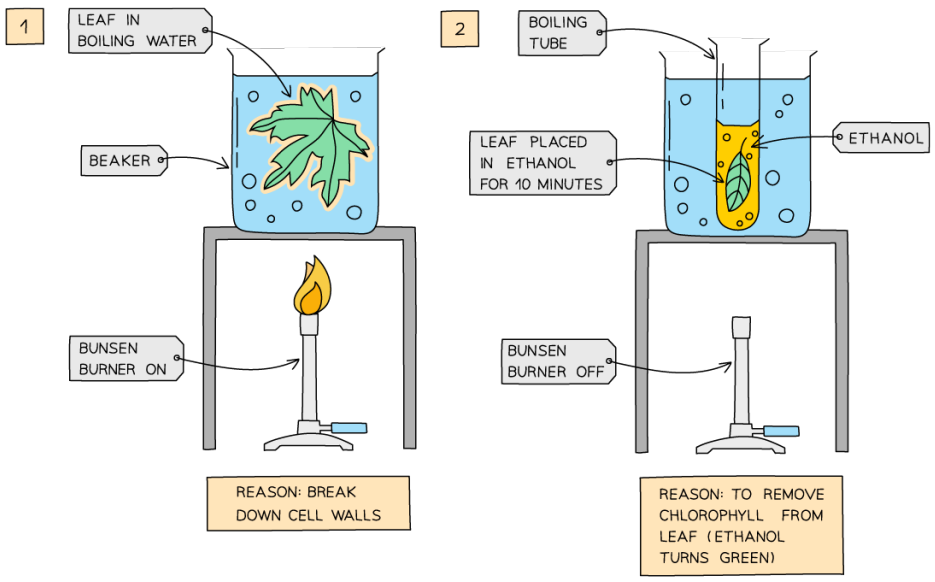
YOUR NOTES

Starch Production & Need for Chlorophyll

- Although plants make glucose in photosynthesis, **leaves cannot be tested for its presence** as the glucose is quickly used, converted into other substances and transported or stored as starch
- Starch is stored in chloroplasts where photosynthesis occurs so **testing a leaf for starch** is a reliable indicator of which parts of the leaf are photosynthesising

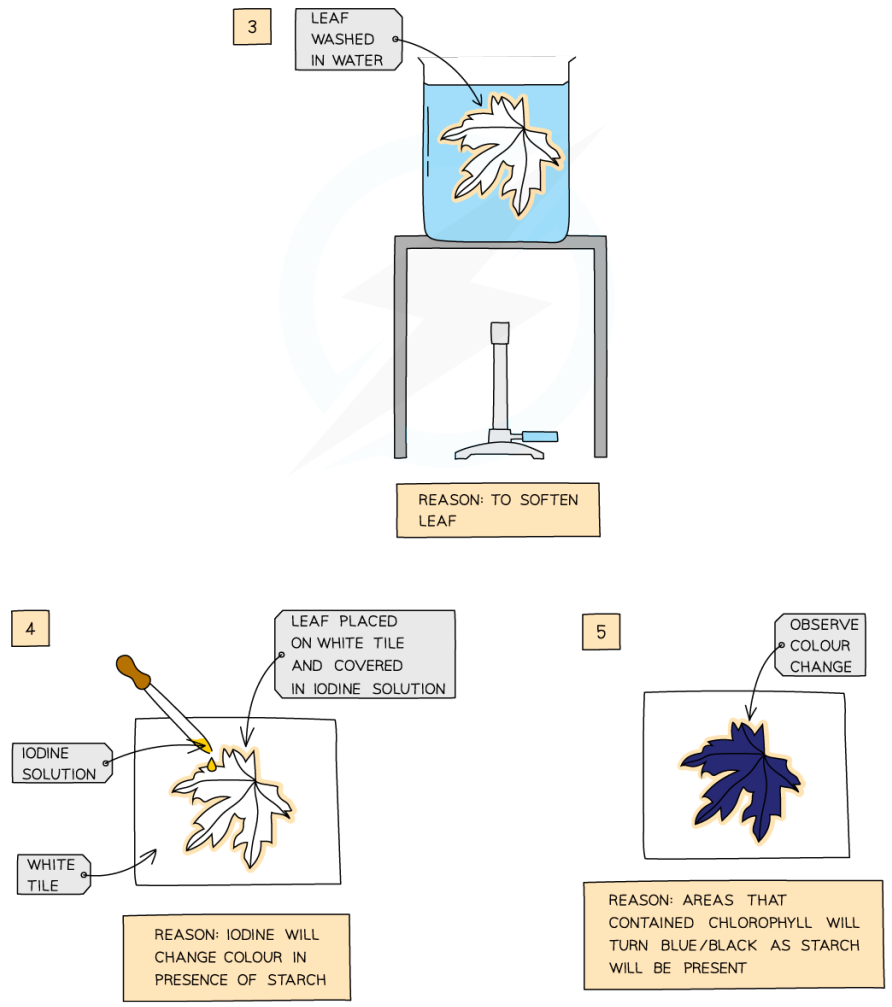
Leaves can be tested for starch using the following procedure:

- A leaf is dropped in **boiling water** to **kill and break down the cell walls**
- The leaf is left for 5-10 minutes in hot **ethanol** in a boiling tube. This **removes the chlorophyll** so colour changes from iodine can be seen more clearly
- The leaf is dipped in boiling water to soften it
- The leaf is spread out on a white tile and covered with **iodine solution**
- In a green leaf, the entire leaf will turn **blue-black** as photosynthesis is occuring in all areas of the leaf
- This method can also be used to test whether chlorophyll is needed for photosynthesis by using a **variegated** leaf (one that is partially green and partially white)
- The white areas of the leaf contain no chlorophyll and when the leaf is tested **only the areas that contain chlorophyll stain blue-black**
- The areas that had no chlorophyll remain orange-brown as **no photosynthesis is occurring here and so no starch is stored**



6.2 INVESTIGATING PHOTOSYNTHESIS cont...

YOUR NOTES



Testing a variegated leaf for starch

- Care must be taken when carrying out this practical as **ethanol is extremely flammable**, so at that stage of the experiment the Bunsen burner should be turned off. The safest way to heat the ethanol is in an electric water bath rather than using a beaker over a Bunsen burner with an open flame

6 PLANT NUTRITION

6.2 INVESTIGATING PHOTOSYNTHESIS cont...

YOUR NOTES

The Need for Light in Photosynthesis

- The same procedure as in the investigation above can be used to investigate if light is needed for photosynthesis
- Before starting the experiment the plant needs to be **destarched** by placing in a dark cupboard for 24 hours
- This ensures that **any starch already present in the leaves will be used up** and will not affect the results of the experiment
- Following destarching, a leaf of the plant can be **partially covered with aluminium foil** and the plant placed in sunlight for a day
- The leaf can then be removed and tested for starch using iodine
- The area of the leaf that was covered with aluminium foil will remain **orange-brown** as it did not receive any sunlight and could not photosynthesise, while the area exposed to sunlight will turn **blue black**
- This proves that light is necessary for photosynthesis and the production of starch

The Need for Carbon Dioxide in Photosynthesis

- Destarch a plant
- Tie a clear bag containing **sodium hydroxide**, which will **absorb carbon dioxide** from the surrounding air, around one leaf
- Tie a clear bag containing **water** (control experiment), which will **not absorb carbon dioxide** from the surrounding air, around another leaf
- Place the plant in bright light for several hours.
- Test both leaves for starch using iodine
- The leaf from the bag containing sodium hydroxide will r**emain orange brown** as it could not photosynthesise due to lack of carbon dioxide
- The leaf from the control bag containing water should turn blue black as it had all necessary requirements for photosynthesis

6 PLANT NUTRITION

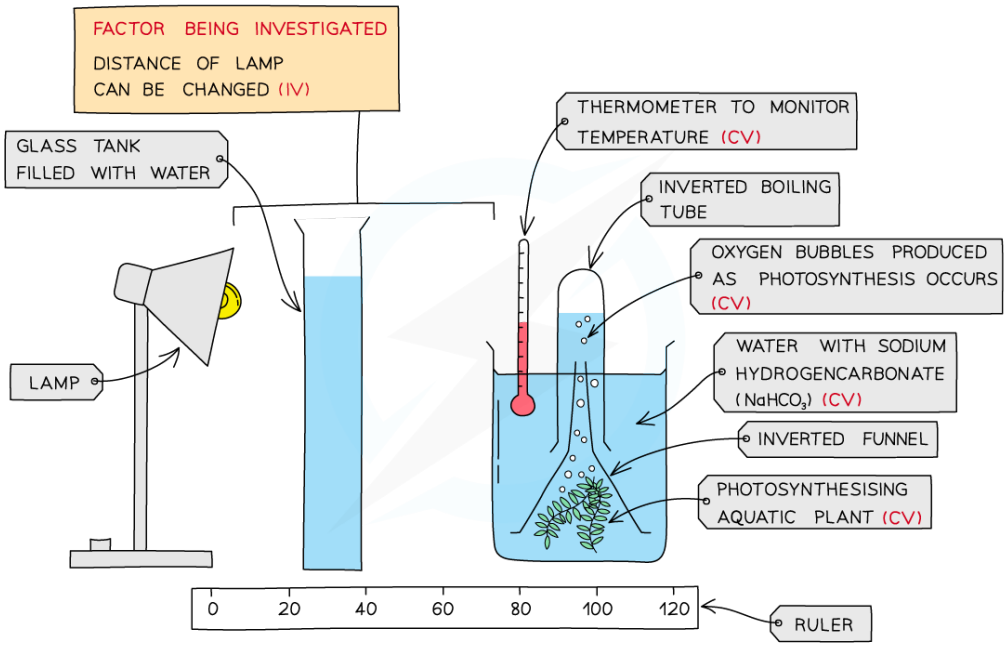
6.2 INVESTIGATING PHOTOSYNTHESIS cont...

YOUR NOTES

The Rate of Photosynthesis Using a Water Plant

- The plants usually used are **Elodea** or **Camboba** – types of pondweed
- As photosynthesis occurs, oxygen gas produced is released
- As the plant is in water, the oxygen released can be seen as **bubbles** leaving the cut end of the pond weed
- The number of **bubbles produced over a minute** can be counted to record the rate
- The more bubbles produced per minute, the faster the rate of photosynthesis
- A more accurate version of this experiment is to collect the oxygen released in a test tube inverted over the top of the pondweed over a longer period of time and then measure the **volume of oxygen** collected
- This practical can be used in the following ways:

Investigating the effect of changing light intensity by moving a lamp different distances away from the beaker containing the pondweed



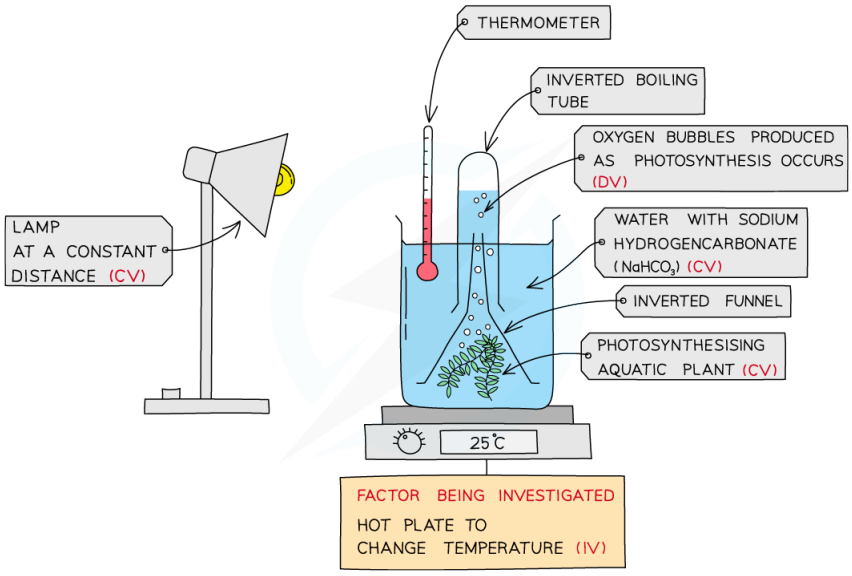
Investigating the effect of changing light intensity on the rate of photosynthesis

6 PLANT NUTRITION

6.2 INVESTIGATING PHOTOSYNTHESIS cont...

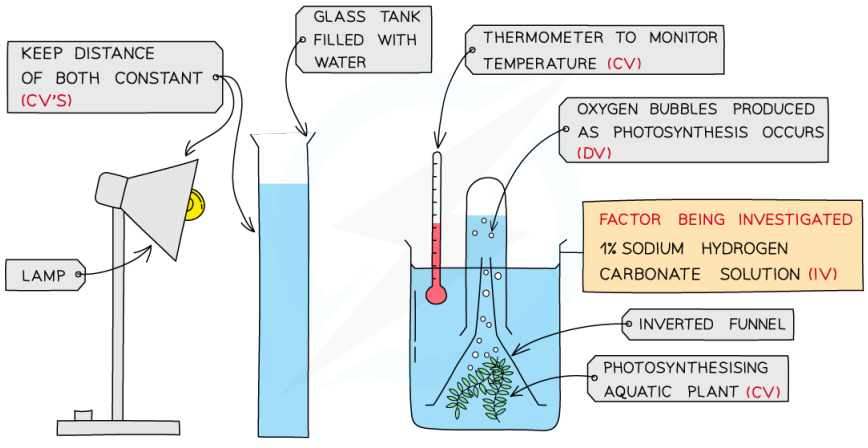
YOUR NOTES

Investigating the effect of changing temperature by changing the temperature of the water in the beaker



Investigating the effect of changing temperature on the rate of photosynthesis

Investigating the effect of changing carbon dioxide concentration by dissolving different amounts of sodium hydrogen carbonate in the water in the beaker



Investigating the effect of changing carbon dioxide concentration on the rate of photosynthesis

- Care must be taken when investigating a condition to **keep all other variables constant** in order to ensure a **fair test** – for example, when investigating changing light intensity, a **glass tank** should be placed in between the lamp and the beaker to **absorb heat** from the lamp and so avoid changing the temperature of the water as well as the light intensity

6 PLANT NUTRITION

6.2 INVESTIGATING PHOTOSYNTHESIS cont...

YOUR NOTES

EXAM TIP

Alternative ways of measuring the gas (oxygen) given off in these experiments would be to measure the volume of gas produced using an inverted measuring cylinder with graduations filled with water that readings can be taken from as the water is displaced by the gas, or by using a syringe attached by a delivery tube to the funnel.

6.3 LIMITING FACTORS

EXTENDED ONLY

What is a Limiting Factor?

- If a plant is given unlimited sunlight, carbon dioxide and water and is at a warm temperature, the limit on the rate (speed) at which it can photosynthesise is its own ability to absorb these materials and make them react
- However, most often plants do not have unlimited supplies of their raw materials so their rate of photosynthesis is **limited** by **whatever factor is the lowest at that time**
- So a **limiting factor** can be defined as **something present in the environment in such short supply that it restricts life processes**
- There are **three** main factors which limit the rate of photosynthesis:
  - **Temperature**
  - **Light intensity**
  - **Carbon dioxide concentration**
- Although water is necessary for photosynthesis, it is **not considered a limiting factor** as the amount needed is relatively small compared to the amount of water transpired from a plant so there is hardly ever a situation where there is not enough water for photosynthesis

6 PLANT NUTRITION

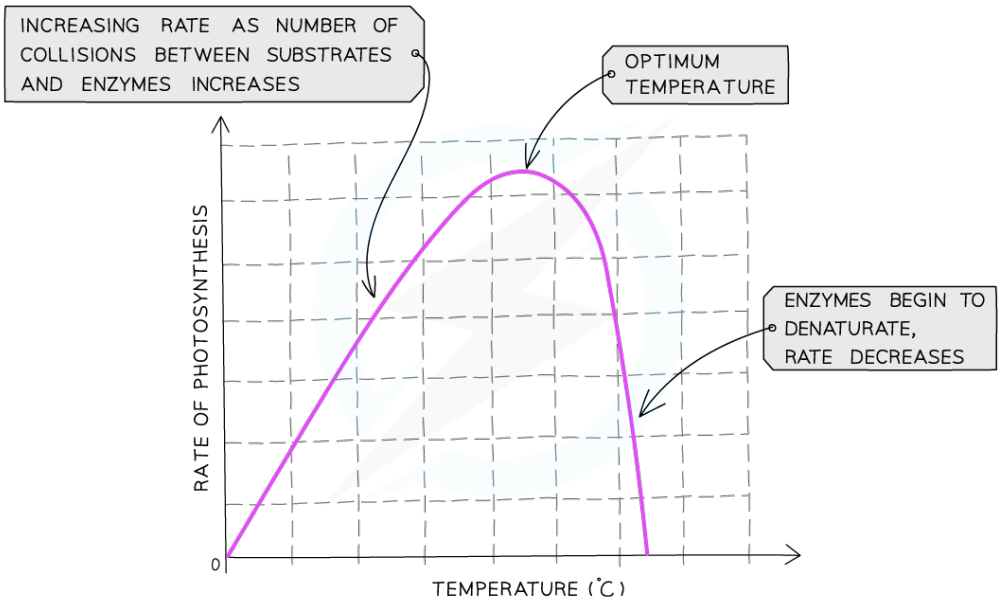
6.3 LIMITING FACTORS cont...

YOUR NOTES

EXTENDED ONLY cont...

Temperature

- As temperature increases the rate of photosynthesis increases as the reaction is **controlled by enzymes**
- However, as the reaction is controlled by enzymes, this trend only continues up to a certain temperature beyond which the enzymes begin to **denature** and the rate of reaction **decreases**



The effect of temperature on the rate of photosynthesis

6 PLANT NUTRITION

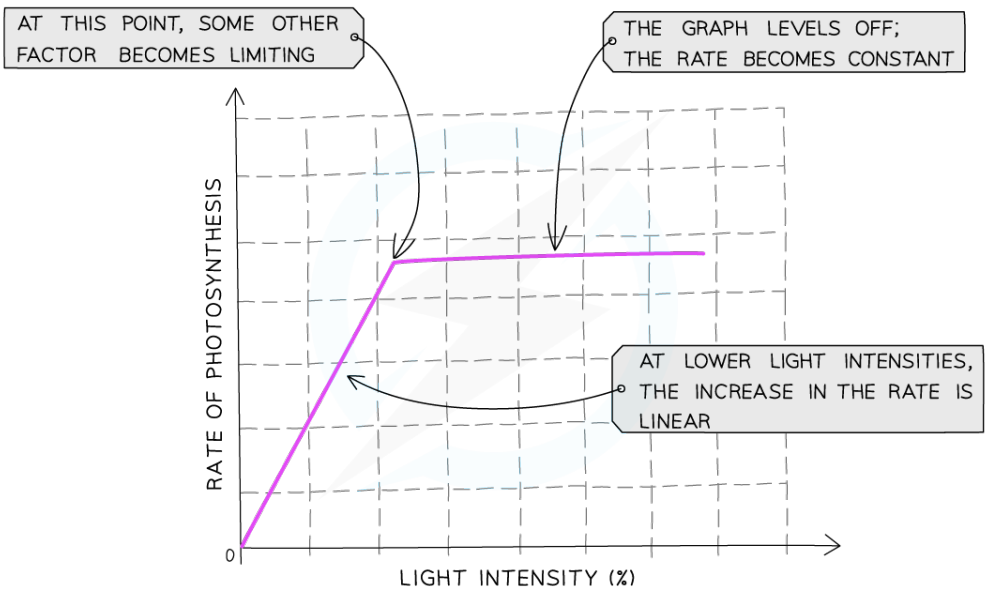
6.3 LIMITING FACTORS cont...

YOUR NOTES

EXTENDED ONLY cont...

Light Intensity

- The **more light** a plant receives, the **faster the rate** of photosynthesis
- This trend will continue until some other factor required for photosynthesis prevents the rate from increasing further because it is now in short supply



The effect of light intensity on the rate of photosynthesis

At low light intensities, increasing the intensity will initially increase the rate of photosynthesis. At a certain point, increasing the light intensity stops increasing the rate.The rate becomes constant regardless of how much light intensity increases as something else is limiting the rate.

- The factors which could be limiting the rate when the line on the graph is horizontal include **temperature not being high enough** or **not enough carbon dioxide**

6 PLANT NUTRITION

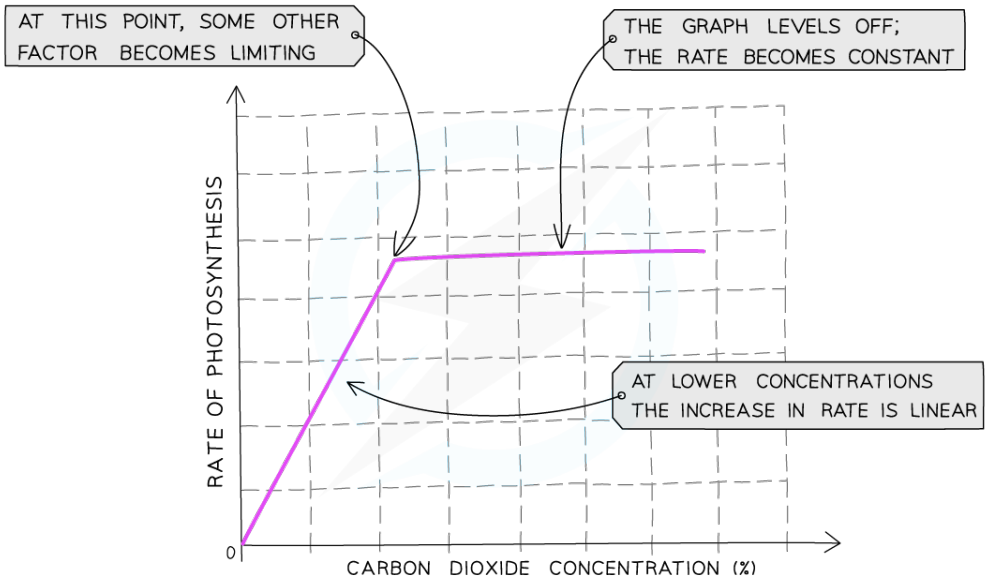
6.3 LIMITING FACTORS cont...

YOUR NOTES

EXTENDED ONLY cont...

Carbon Dioxide Concentration

- Carbon dioxide is one of the raw materials required for photosynthesis
- This means the **more carbon dioxide** that is present, **the faster the reaction** can occur
- This trend will continue until some other factor required for photosynthesis prevents the rate from increasing further because it is now in short supply



The effect of carbon dioxide concentration on the rate of photosynthesis

- The factors which could be limiting the rate when the line on the graph is horizontal include **temperature not being high enough** or **not enough light**

6 PLANT NUTRITION

6.3 LIMITING FACTORS cont...

YOUR NOTES

EXTENDED ONLY

Changing Glasshouse Conditions

- The knowledge about limiting factors and how they affect the rate of photosynthesis can be used to help **control factors in glass houses** to ensure **maximum crop yields** for farmers
- Growing crops outside does not allow farmers to control any of these factors to increase growth of plants
- In a glass house, several conditions can be manipulated to increase the rate of photosynthesis, including:
  - **artificial heating** (enzymes controlling photosynthesis can work faster at slightly higher temperatures – only used in temperate countries such as the UK)
  - **artificial lighting** (plants can photosynthesise for longer)
  - **increasing carbon dioxide content** of the air inside (plants can photosynthesise quicker)
  - **regular watering**
- When considering the use of glasshouses and manipulating conditions like this, farmers need to balance the **extra cost** of providing heating, lighting and carbon dioxide against the **increased income**
- In **tropical countries** where temperatures are much hotter, glasshouses may still be used to control other conditions however they may need to be **ventilated** to release hot air and **avoid temperatures rising too high**, which could cause the denaturation of the enzymes controlling the photosynthesis reaction

EXAM TIP

Interpreting graphs of limiting factors can be confusing for many students, but it's quite simple.

In the section of the graph where the rate is increasing (the line is going up), the limiting factor is **whatever the label on the x axis (the bottom axis) of the graph is**.

In the section of the graph where the rate is not increasing (the line is horizontal), the limiting factor will be **something other than what is on the x axis** – choose from **temperature**, **light intensity** or **carbon dioxide concentration**.

6 PLANT NUTRITION

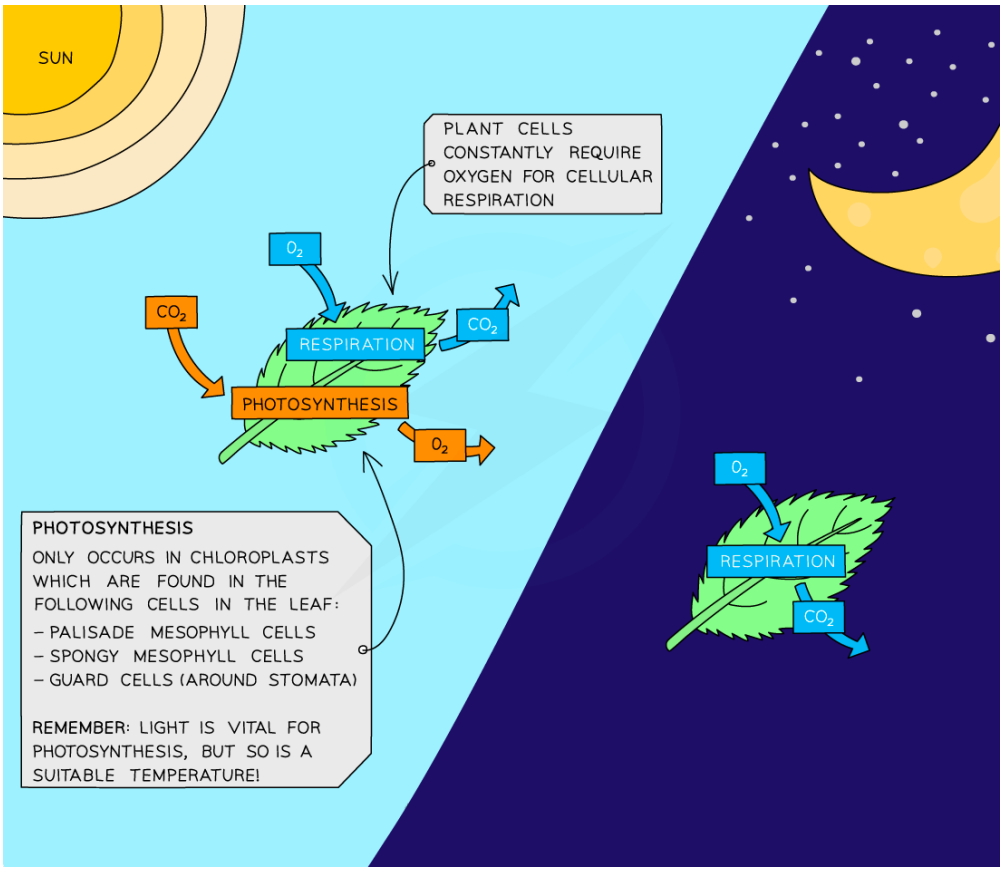
6.4 INVESTIGATING GAS EXCHANGE

YOUR NOTES

EXTENDED ONLY

Effect of Light on Net Gas Exchange

- Plants are **respiring all the time** and so plant cells are **taking in oxygen and releasing carbon dioxide** as a result of aerobic respiration
- Plants also **photosynthesise during daylight** hours, for which they need to **take in carbon dioxide and release the oxygen** made in photosynthesis
- At night, plants do not photosynthesise but they continue to respire, meaning **they take in oxygen and give out carbon dioxide**



Photosynthesis and respiration in plants

6 PLANT NUTRITION

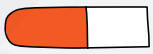
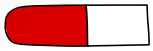
6.4 INVESTIGATING GAS EXCHANGE cont...

YOUR NOTES

EXTENDED ONLY cont...

- During the day, especially when the sun is bright, **plants are photosynthesising at a faster rate than they are respiring**, so there is a **net intake of carbon dioxide and a net output of oxygen**
- We can investigate the effect of light on the **net gas exchange** in an aquatic plant using a **pH indicator** such as **hydrogencarbonate indicator**
- This is possible because carbon dioxide is an **acidic gas** when dissolved in water
- Hydrogencarbonate indicator shows the **carbon dioxide concentration in solution**

The table shows the colour that the hydrogencarbonate indicator turns at different levels of carbon dioxide concentration:

CONCENTRATION OF CARABON DIOXIDE	COLOUR OF HYDROGEN CARBON INDICATOR		CONDITIONS IN PLANT
HIGHEST	YELLOW		MORE RESPIRATION > PHOTOSYNTHESIS – LOWER pH (MORE ACID)
HIGHER	ORANGE		
ATMOSPHERIC LEVEL	RED		PHOTOSYNTHESIS = RESPIRATION
LOWER	MAGENTA		MORE PHOTOSYNTHESIS > RESPIRATION – HIGHER pH (MORE ALKALINE)
LOWEST	PURPLE		

6 PLANT NUTRITION

6.4 INVESTIGATING GAS EXCHANGE cont...

YOUR NOTES

EXTENDED ONLY cont...

- Several leaves from the same plant are placed in stoppered boiling tubes containing some **hydrogen carbonate indicator**
- The effect of light can then be investigated over a period of a few hours

Results from a typical gas exchange experiment are shown in the table below:

TUBE	CONTENTS	CONDITIONS	INDICATOR TURNS	CONCLUSION
A	LEAF	LIGHT	PURPLE	THERE IS A NET INTAKE OF OXYGEN BY A LEAF IN LIGHT
B	LEAF	DARK	YELLOW	THERE IS A NET INTAKE OF CARBON DIOXIDE BY A LEAF IN THE DARK
C	NO LEAF	LIGHT	RED	THIS IS THE CONTROL – THE TWO OTHER TUBES CAN BE COMPARED WITH IT

6 PLANT NUTRITION

6.5 LEAF STRUCTURE

YOUR NOTES

Structure of the Leaf

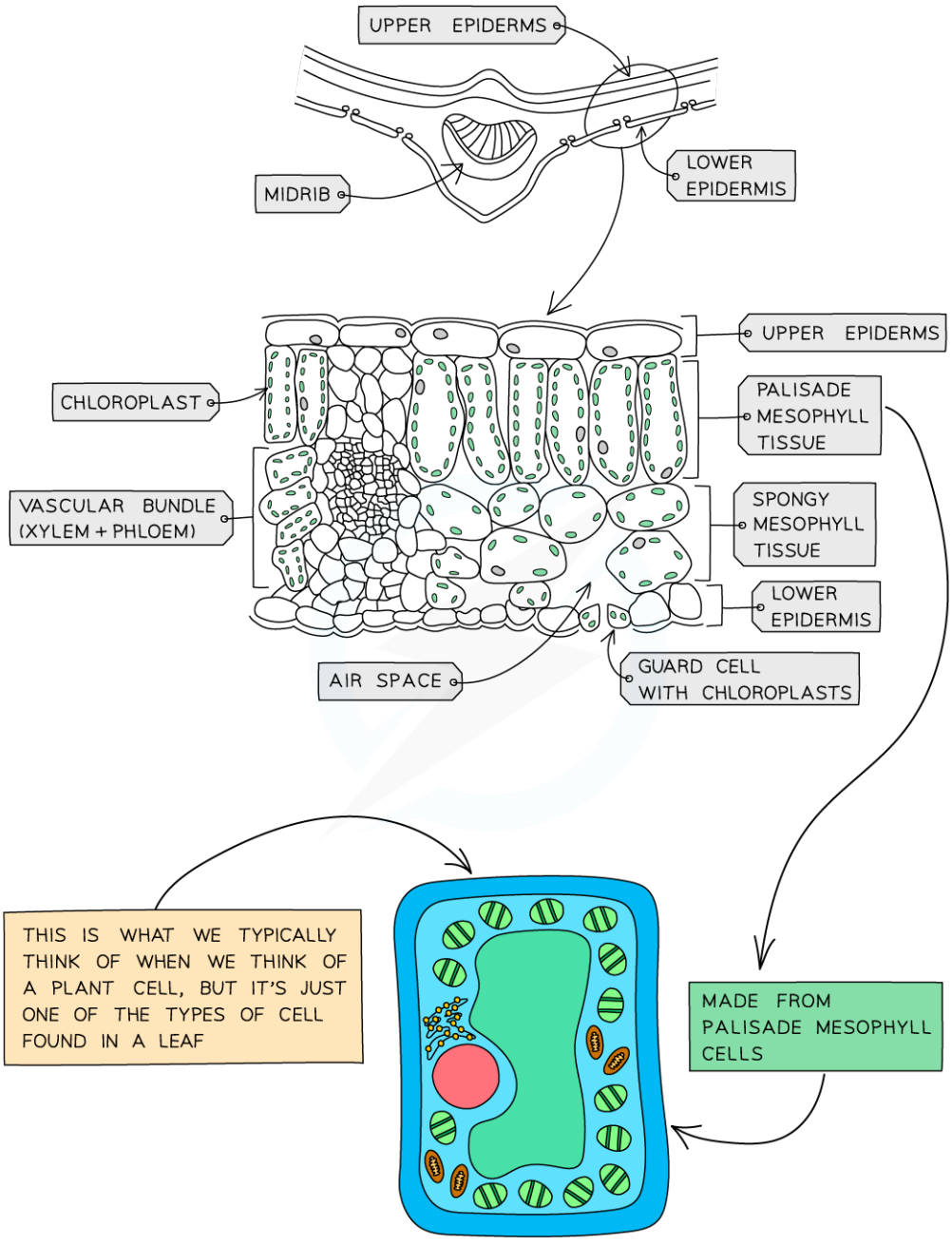
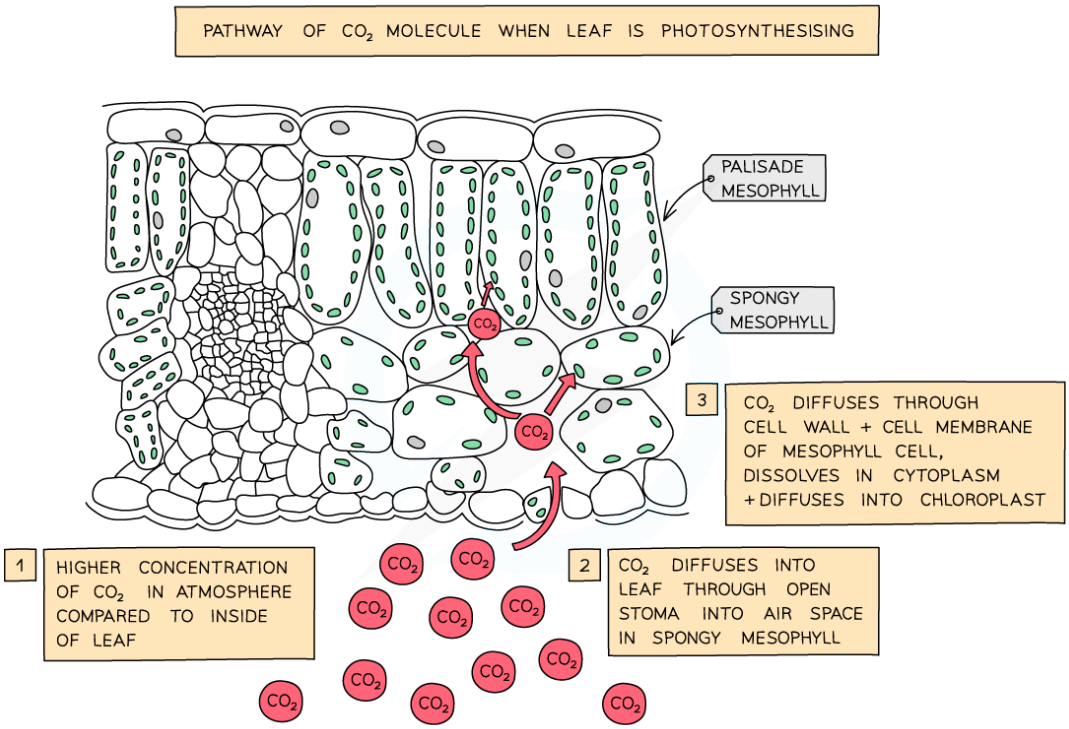


Diagram showing the cross section of a leaf

6 PLANT NUTRITION

6.5 LEAF STRUCTURE cont...

YOUR NOTES



How photosynthesising cells obtain carbon dioxide

Pathway of carbon dioxide from atmosphere to chloroplasts by diffusion:

ATMOSPHERE

↓

AIR SPACES AROUND SPONGY MESOPHYLL TISSUE

↓

LEAF MESOPHYLL CELLS

↓

CHLOROPLAST

6 PLANT NUTRITION

6.5 LEAF STRUCTURE cont...

YOUR NOTES

STRUCTURE	DESCRIPTION
WAX CUTICLE	PROTECTIVE LAYER ON TOP OF THE LEAF, PREVENTS WATER FROM EVAPORATING
UPPER EPIDERMIS	THIN AND TRANSPARENT TO ALLOW LIGHT TO ENTER PALISADE MESOPHYLL LAYER UNDERNEATH IT
PALISADE MESOPHYLL	COLUMN SHAPED CELLS TIGHTLY PACKED WITH CHLOROPLASTS TO ABSORB MORE LIGHT, MAXIMISING PHOTOSYNTHESIS
SPONGY MESOPHYLL	CONTAINS INTERNAL AIR SPACES THAT INCREASES THE SURFACE AREA TO VOLUME RATIO FOR THE DIFFUSION OF GASES (MAINLY CARBON DIOXIDE)
LOWER EPIDERMIS	CONTAINS GUARD CELLS AND STOMATA
GUARD CELL	ABSORBS AND LOSES WATER TO OPEN AND CLOSE THE STOMATA TO ALLOW CARBON DIOXIDE TO DIFFUSE IN, OXYGEN TO DIFFUSE OUT
STOMATA	WHERE GAS EXCHANGE TAKES PLACE; OPENS DURING THE DAY, CLOSES DURING THE NIGHT. EVAPORATION OF WATER ALSO TAKES PLACE FROM HERE. IN MOST PLANTS, FOUND IN MUCH GREATER CONCENTRATION ON THE UNDERSIDE OF THE LEAF TO REDUCE WATER LOSS
VASCULAR BUNDLE	CONTAINS XYLEM AND PHLOEM TO TRANSPORT SUBSTANCES TO AND FROM THE LEAF
XYLEM	TRANSPORTS WATER INTO THE LEAF FOR MESOPHYLL CELLS TO USE IN PHOTOSYNTHESIS AND FOR TRANSPIRATION FROM STOMATA
PHLOEM	TRANSPORTS SUCROSE AND AMINO ACIDS AROUND THE PLANT

6 PLANT NUTRITION

6.5 LEAF STRUCTURE cont...

YOUR NOTES

EXTENDED ONLY

Adaptations of Leaf for Photosynthesis

FEATURE	ADAPTATION
LARGE SURFACE AREA (LEAF)	INCREASES SURFACE AREA FOR THE DIFFUSION OF CARBON DIOXIDE AND ABSORPTION OF LIGHT FOR PHOTOSYNTHESIS
THIN	ALLOWS CARBON DIOXIDE TO DIFFUSE TO PALISADE MESOPHYLL CELLS QUICKLY
CHLOROPHYLL	ABSORBS LIGHT ENERGY SO THAT PHOTOSYNTHESIS CAN TAKE PLACE
NETWORK OF VEINS	ALLOWS THE TRANSPORT OF WATER TO THE CELLS OF THE LEAF AND CARBOHYDRATES FROM THE LEAF FOR PHOTOSYNTHESIS (WATER FOR PHOTOSYNTHESIS, CARBOHYDRATES AS A PRODUCT OF PHOTOSYNTHESIS)
STOMATA	ALLOWS CARBON DIOXIDE TO DIFFUSE INTO THE LEAF AND OXYGEN TO DIFFUSE OUT
EPIDERMIS IS THIN AND TRANSPARENT	ALLOWS MORE LIGHT TO REACH THE PALISADE CELLS
THIN CUTICLE MADE OF WAX	TO PROTECT THE LEAF WITHOUT BLOCKING SUNLIGHT
PALISADE CELL LAYER AT TOP OF LEAF	MAXIMISES THE ABSORPTION OF LIGHT AS IT WILL HIT CHLOROPLASTS IN THE CELLS DIRECTLY
SPONGY LAYER	AIR SPACES ALLOW CARBON DIOXIDE TO DIFFUSE THROUGH THE LEAF, INCREASING THE SURFACE AREA
VASCULAR BUNDLES	THICK CELL WALLS OF THE TISSUE IN THE BUNDLES HELP TO SUPPORT THE STEM AND LEAF

6 PLANT NUTRITION

6.6 MINERAL REQUIREMENTS

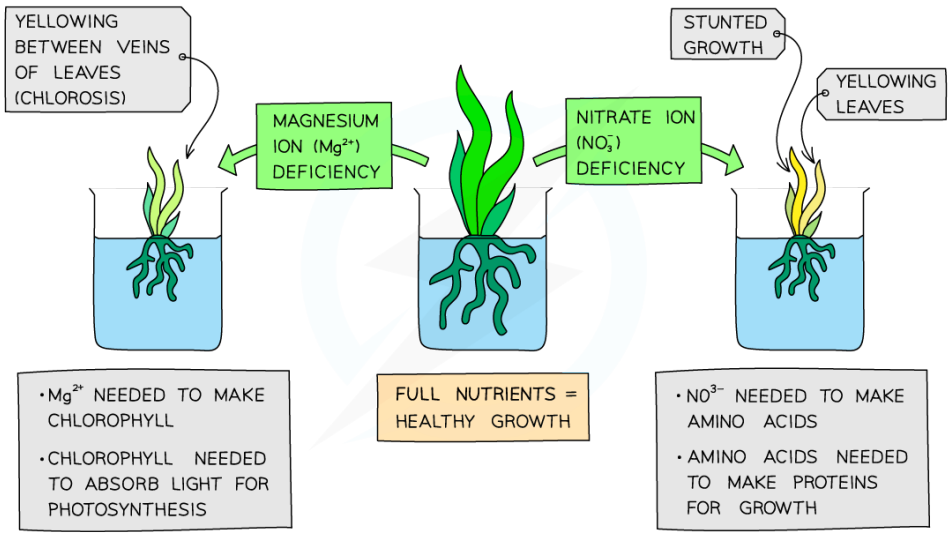
YOUR NOTES

The Need for Mineral Ions

- Photosynthesis produces carbohydrates, but plants contain many other types of biological molecule; such as proteins, lipids and nucleic acid (DNA).
- As plants do not eat, they need to **make these substances themselves**
- Carbohydrates contain the elements carbon, hydrogen and oxygen but proteins, for example, contain **nitrogen** as well (and certain amino acids contain other elements too)
- Other chemicals in plants contain different elements as well, for example chlorophyll contains **magnesium** and **nitrogen**
- This means that without a source of these elements, plants cannot photosynthesise or grow properly
- Plants obtain these elements in the form of **mineral ions actively absorbed from the soil by root hair cells**
- 'Mineral' is a term used to describe any naturally occurring inorganic substance.

EXTENDED ONLY

Effects of Mineral Ion Deficiencies



Mineral deficiencies in plants

6 PLANT NUTRITION

6.6 MINERAL REQUIREMENTS cont...

YOUR NOTES

EXTENDED ONLY cont...

MINERAL ION	FUNCTION	DEFICIENCY
MAGNESIUM	MAGNESIUM IS NEEDED TO MAKE **CHLOROPHYLL**	CAUSES YELLOWING BETWEEN THE VEINS OF LEAVES (**CHLOROSIS**)
NITRATE	NITRATES ARE A SOURCE OF NITROGEN NEEDED TO MAKE **AMINO ACIDS** (TO BUILD PROTEINS)	CAUSES **STUNTED GROWTH** AND **YELLOWING OF LEAVES**

> NOW TRY SOME EXAM QUESTIONS

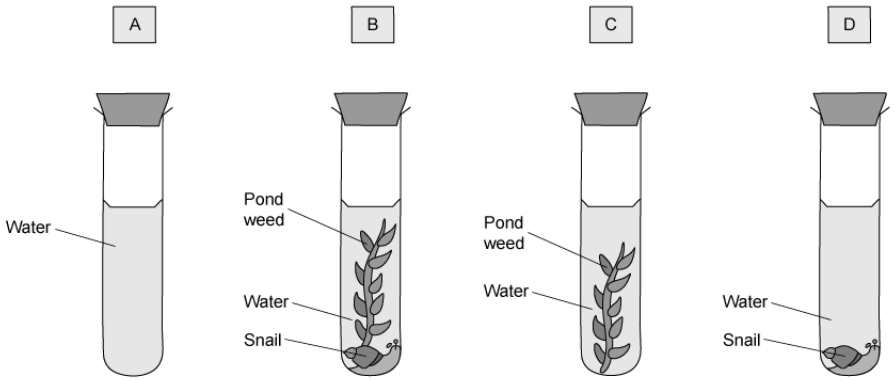
6 PLANT NUTRITION

YOUR NOTES

EXAM QUESTIONS

QUESTION 1

An experiment is set up with four test tubes as shown in the diagram below.



All four test tubes are left in sunlight for 6 hours.

Which test tube would contain the least amount of dissolved carbon dioxide after 6 hours?

QUESTION 2

Which row of the table below shows the correct effects of deficiencies of essential minerals for plant growth?

	effect of magnesium ion deficiency	effect of nitrate ion deficiency
A	yellow leaves	stunted growth
B	stunted growth	long roots
C	small leaves	yellow leaves
D	stunted growth	yellow leaves

6 PLANT NUTRITION

EXAM QUESTIONS cont...

YOUR NOTES

QUESTION 3

Which of the following options is the best explanation for the role of chlorophyll in photosynthesis:

Chlorophyll…

A transfers light energy from the sun because it has magnesium ions.

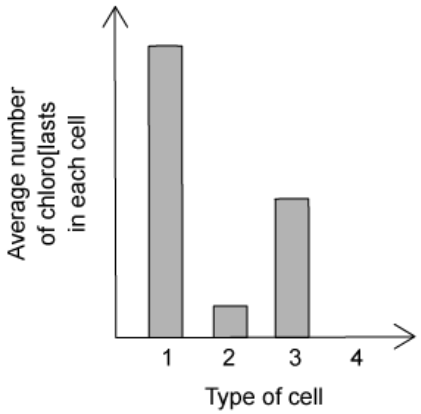
B transfers chemical potential energy from sunlight into organic molecules which can be used to synthesise carbohydrates such as glucose.

C transfers light energy from the sun into chemical energy in inorganic molecules which can be used for growth.

D transfers light energy into chemical potential energy into glucose molecules which are used in the synthesis of other carbohydrates.

QUESTION 4

The average number of chloroplasts found in four different types of cell from the leaf of a plant are shown in the bar chart below.



What are the names of the four types of cell?

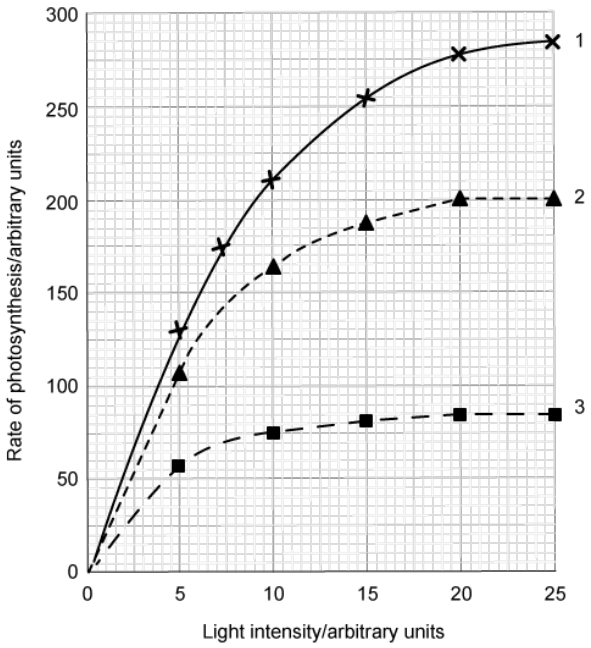
	1	2	3	4
A	spongy mesophyll cell	epidermal cell	palisade mesophyll cell	guard cell
B	palisade mesophyll cell	guard cell	spongy mesophyll cell	epidermal cell
C	epidermal cell	spongy mesophyll cell	palisade mesophyll cell	guard cell
D	palisade mesophyll cell	spongy mesophyll cell	guard cell	epidermal cell

YOUR NOTES

EXAM QUESTIONS cont...

QUESTION 5

The diagram below shows how the rate of photosynthesis is affected by different conditions.



Key

	Temp /°C	CO_2 /%
1	30	0.13
2	20	0.13
3	30	0.03

What of the following correctly identifies the limiting factor for photosynthesis at the three points on the graph?

	1	2	3
A	light intensity	light intensity	carbon dioxide concentration
B	temperature	temperature	light intensity
C	light intensity	temperature	carbon dioxide concentration
D	light intensity	carbon dioxide concentration	temperature

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