Edexcel GCSE Biology

Your notes

Photosynthesis

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Photosynthesis

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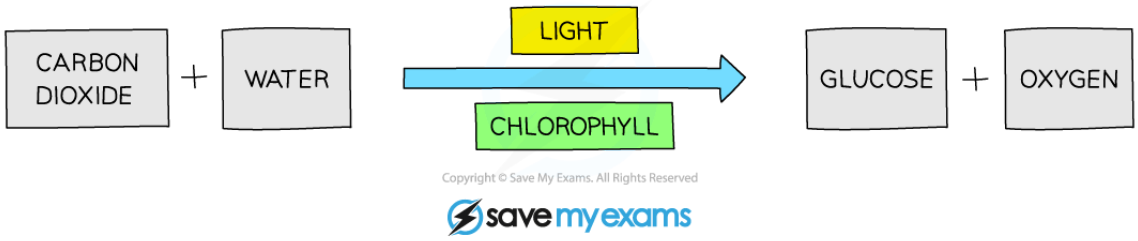
Photosynthesis

- Photosynthesis is an **endothermic** reaction in which energy from sunlight is transferred to the chloroplasts in green plants
  - Green plants use this energy to 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
- Photosynthesis can be defined as **the process by which plants manufacture carbohydrates from raw materials using energy from light**
- Plants are
  - **Autotrophs** – they can make complex molecules (glucose) from simple molecules (carbon dioxide and water)
  - **Producers –** they can make their own food and so are the first organism at the start of all food chains
    - E.g. Plants and algae
- Photosynthesis can be summarised in a word equation as shown below:



Word equation for photosynthesis

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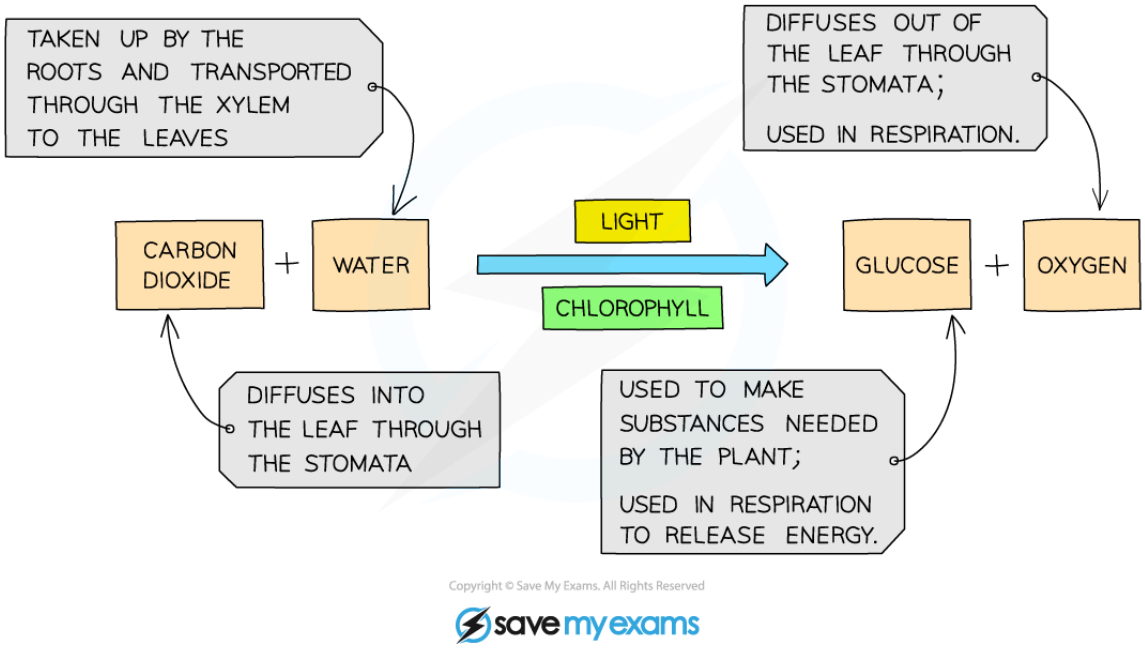
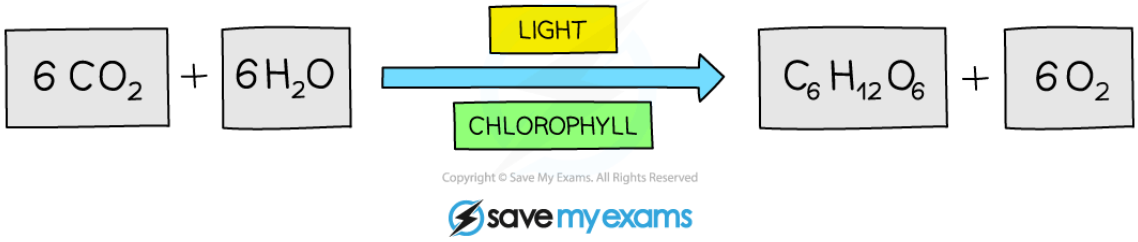


Where do the reactants come from and where do the products go?

- This equation can also be shown as a **balanced chemical equation**
  - **Six** carbon dioxide molecules combine with **six** water molecules to make **one** glucose molecule and **six** oxygen molecules



The balanced chemical equation for photosynthesis

The products of photosynthesis

- Plants use the glucose they make as a **source of energy** in **respiration**
- They can also use it to

- Produce **starch** for storage
- Synthesise **lipids** for an energy source in seeds
- To form **cellulose** to make cell walls
- Produce **amino acids** (used to make proteins) when combined with nitrogen and other mineral ions absorbed by roots

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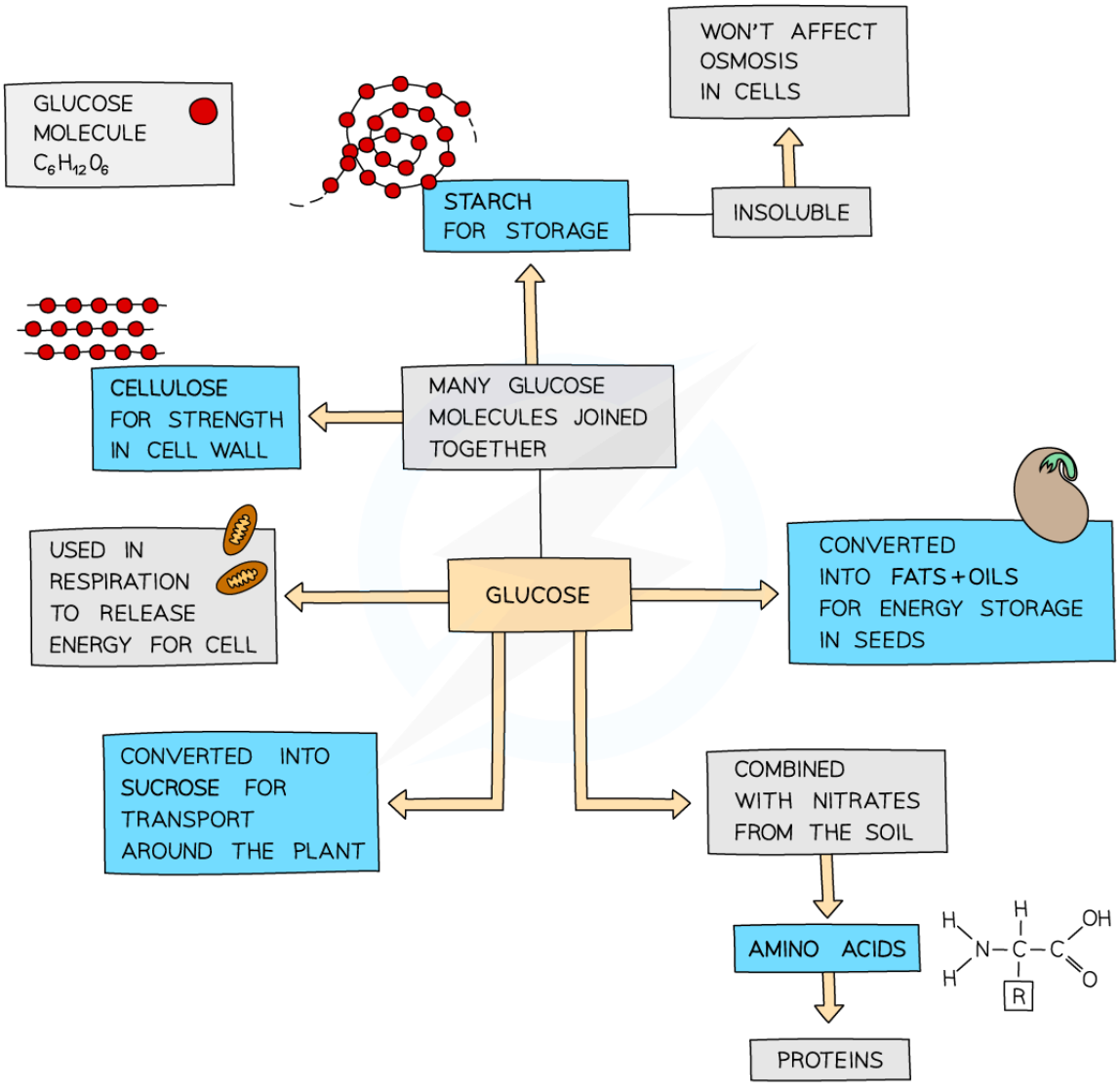

The fate of glucose molecules produced in photosynthesis

Examiner Tips and Tricks

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.

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Limiting Factors

- 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 that 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
- The number of **chloroplasts** or the amount of chlorophyll in the chloroplasts can also affect the rate of photosynthesis

Temperature

- The temperature of the environment affects how much **kinetic energy** all particles have – so temperature affects the speed at which carbon dioxide and water move through a plant
- By affecting how much **kinetic energy** particles have, temperature also determines enzyme activity
  - The lower the temperature, the less kinetic energy particles have, resulting in fewer **successful collisions** occurring between reactants and enzymes over a period of time
  - Increasing temperature increases the kinetic energy of particles, increasing the likelihood of **successful collisions** between reactants and enzymes, which leads to increased formation of products
  - At higher temperatures, however, enzymes that control the processes of photosynthesis can be **denatured** (where the active site changes shape and is no longer complementary to its substrate) – this reduces the overall rate of photosynthesis

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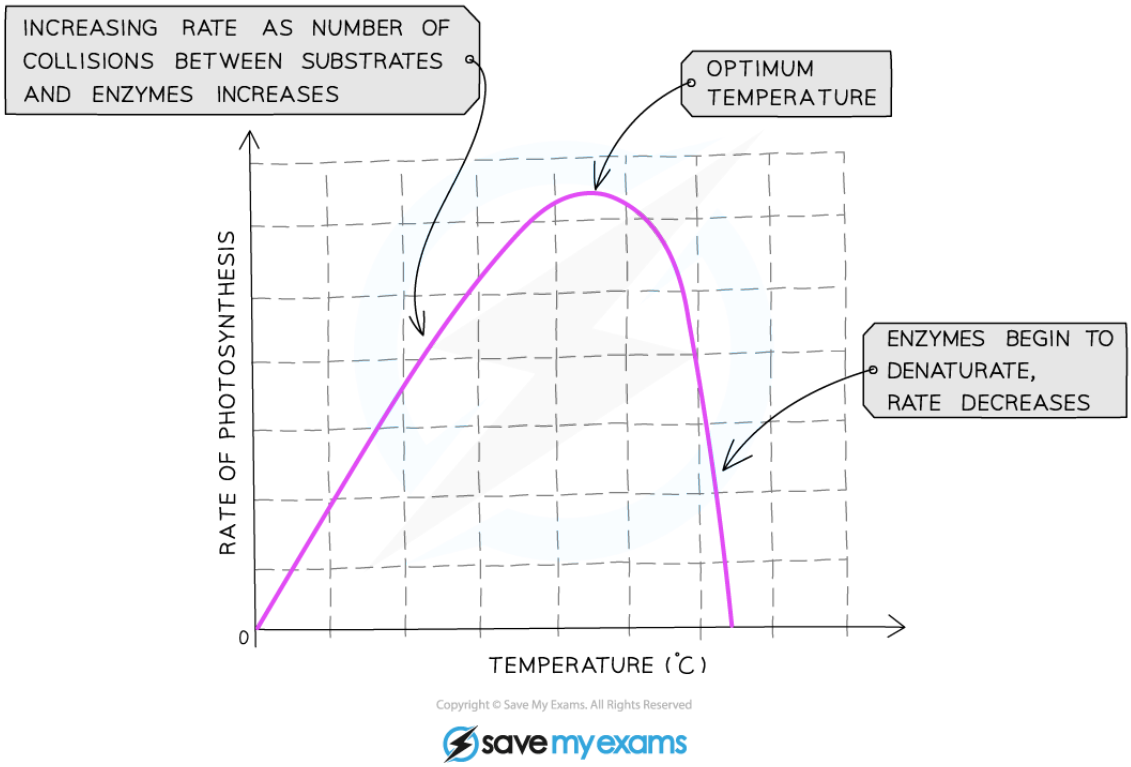
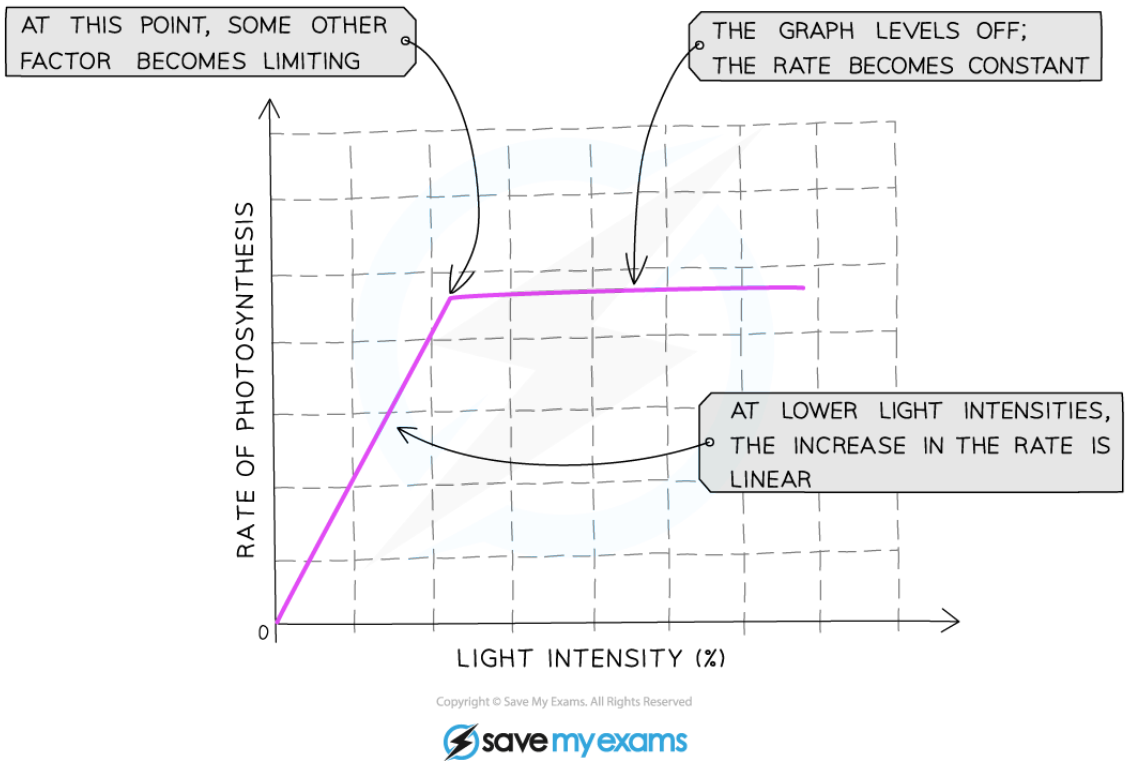


The effect of temperature on the rate of photosynthesis

Light intensity

- The **intensity** of the light available to the plant affects the rate of photosynthesis
- 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



Graph showing 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.

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

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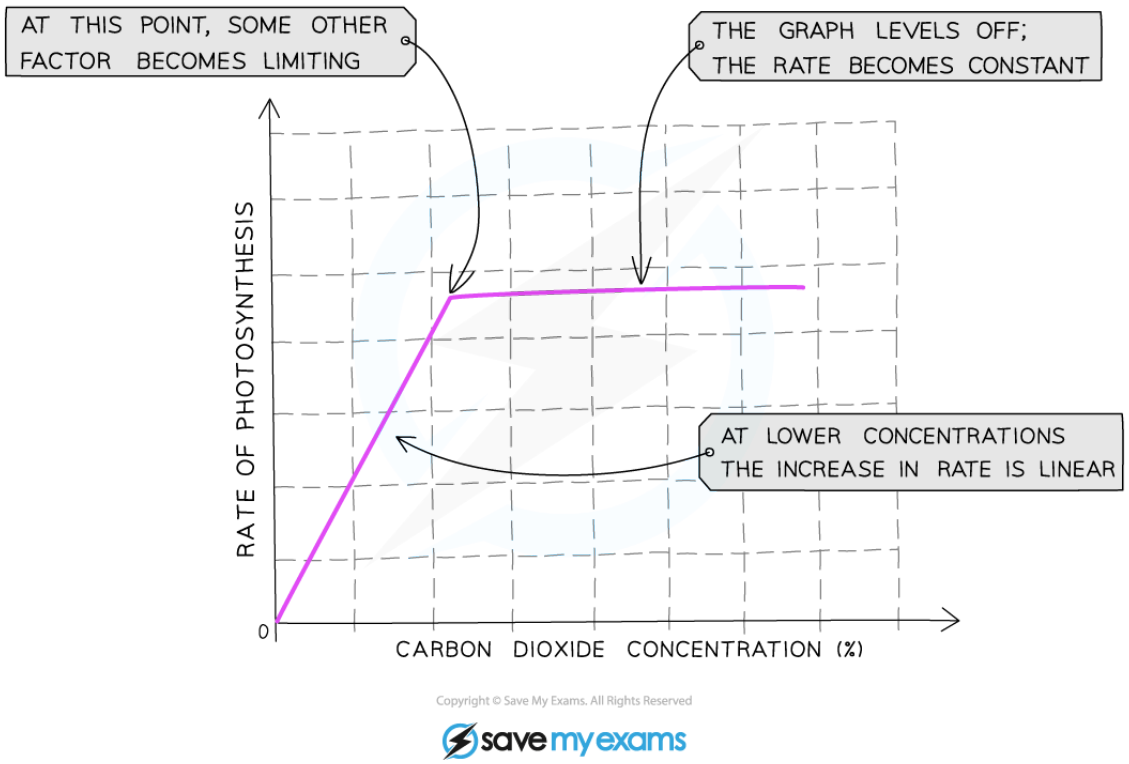

A graph showing the effect of the concentration of carbon dioxide on the rate of photosynthesis

Chlorophyll

- The **number of chloroplasts** (as they contain the pigment chlorophyll which absorbs light energy for photosynthesis) will affect the rate of photosynthesis
- The more chloroplasts a plant has, the faster the rate of photosynthesis
- The number of chloroplasts (or amount of chlorophyll they contain) can be affected by:
  - Diseases (such as tobacco mosaic virus)
  - Lack of nutrients (such as magnesium)
  - Loss of leaves (fewer leaves means fewer chloroplasts)

Examiner Tips and Tricks

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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.

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Light & the Rate of Photosynthesis

Higher tier only

- The **intensity** of the light available to a plant determines the amount of energy that it has to carry out photosynthesis
  - This means that **more light** a plant receives, the **faster** the rate of photosynthesis
  - In other words, the rate of photosynthesis is **directly**

    proportional to light intensity
- However, the **intensity** of the light available to a plant depends on **how far** the light source is from the plant
  - The **further away** a plant is from a **light source**, the **lower** the rate of photosynthesis
  - In other words, the rate of photosynthesis is **inversely**

    proportional to the **distance** from the light source

Light intensity & distance

- A light meter can be used to measure light intensity
- Light intensity outside (natural light) changes gradually throughout the day as the **sun rises and sets**
- Artificial light sources (e.g. bulbs) can also vary in light intensity when they are at **different distances** from a plant
- As a light source gets **further away** from a plant (i.e. as the distance from a light source **increases**), the light intensity **decreases**
  - Also, therefore, as the distance decreases, the light intensity increases
- This means that **light intensity is inversely proportional to the distance** between the plant and the light source
- Light intensity actually decreases in proportion to the **square** of the distance - this is known as the **inverse square law**
  - Therefore, the inverse square law is as follows:

$$\text{light intensity} \propto 1 \div \text{distance}^2$$

- For example, if the distance between a plant and a light source was doubled, the light intensity would be four times smaller

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Examiner Tips and Tricks

Here are a couple of tips to help you understand the inverse square law:

- The symbol '$\propto$' means "is proportional to"
- If 'x' is **inversely proportional** to 'y', it is also true to say that 'x' is **proportional** to '1 ÷ y'

Practical: Investigating Light & Photosynthesis

- Investigations to determine the effects of light intensity, carbon dioxide concentration and temperature on the **rate of photosynthesis** can be carried out using **aquatic plants**, such as *Elodea* or *Cabomba* (types of **pondweed**)
- The effect of these limiting factors on the rate of photosynthesis can be investigated in the following ways:
  - **Light intensity** – change the distance (*d*) of a light source from the plant (light intensity is proportional to $1/d^2$)
  - **Carbon dioxide concentration** – add different quantities of sodium hydrogencarbonate ($NaHCO_3$) to the water surrounding the plant, this dissolves to produce CO_2
  - **Temperature (of the solution surrounding the plant)** – place the boiling tube containing the submerged plant in water baths of different temperatures
- Whilst changing one of these factors during the investigation (as described below), **ensure the other two remain constant**
  - For example, when investigating the effect of light intensity on the rate of photosynthesis, a glass tank should be placed in between the lamp and the boiling tube containing the pondweed to absorb heat from the lamp – this prevents the solution surrounding the plant from changing temperature

Apparatus

- Beaker
- Scalpel
- Pondweed
- Boiling tube
- Boiling tube bung
- Solution of water and sodium hydrogencarbonate
- Water bath
- Light source
- Ruler

- Prongs
- Gas syringe
- Thermometer

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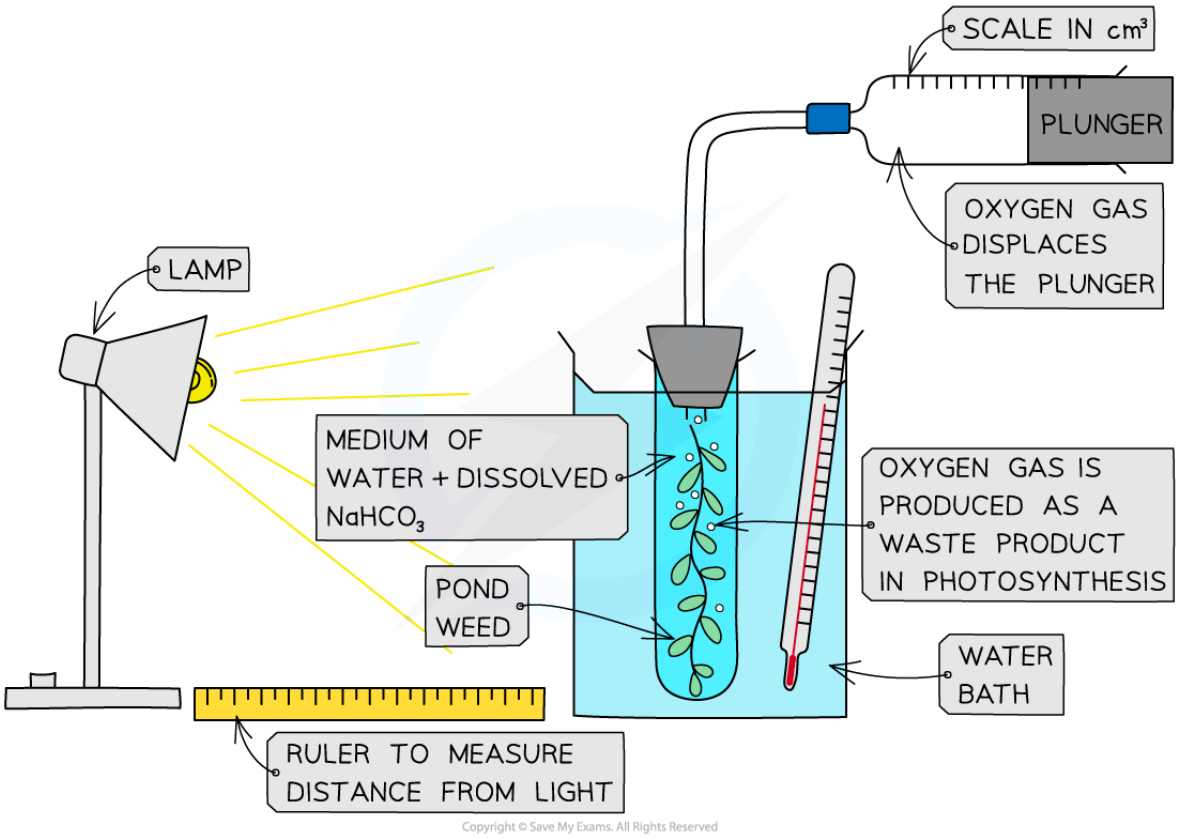

The set up of the experiment to measure the rate of photosynthesis of an aquatic plant (pondweed) by measuring the rate of oxygen gas produced. All three limiting factors can be assessed this way

Method

- **Step 1:** Ensure the water is **well aerated** before use by **bubbling air through it**
  - This will ensure oxygen gas given off by the plant during the investigation form **bubbles** and **do not dissolve in the water**
- **Step 2:** Ensure the plant has been **well illuminated** before use
  - This will ensure that the plant contains all the enzymes required for photosynthesis and that any changes of rate are due to the independent variable
- **Step 3:** Set up the apparatus in a **darkened room**

- Ensure the pondweed is submerged in **sodium hydrogencarbonate solution (1%)** – this ensures the pondweed has a controlled **supply of carbon dioxide** (a reactant in photosynthesis)
- **Step 4:** Cut the stem of the pondweed **cleanly** just before placing into the boiling tube
- **Step 5:** Measure the volume of gas collected in the gas-syringe in a **set period of time** (eg. 5 minutes)
- **Step 6: Change the independent variable** - move the light source closer and repeat step 5
- **Step 7:** Record the results in a table and plot a graph of volume of oxygen produced per minute against the distance from the lamp

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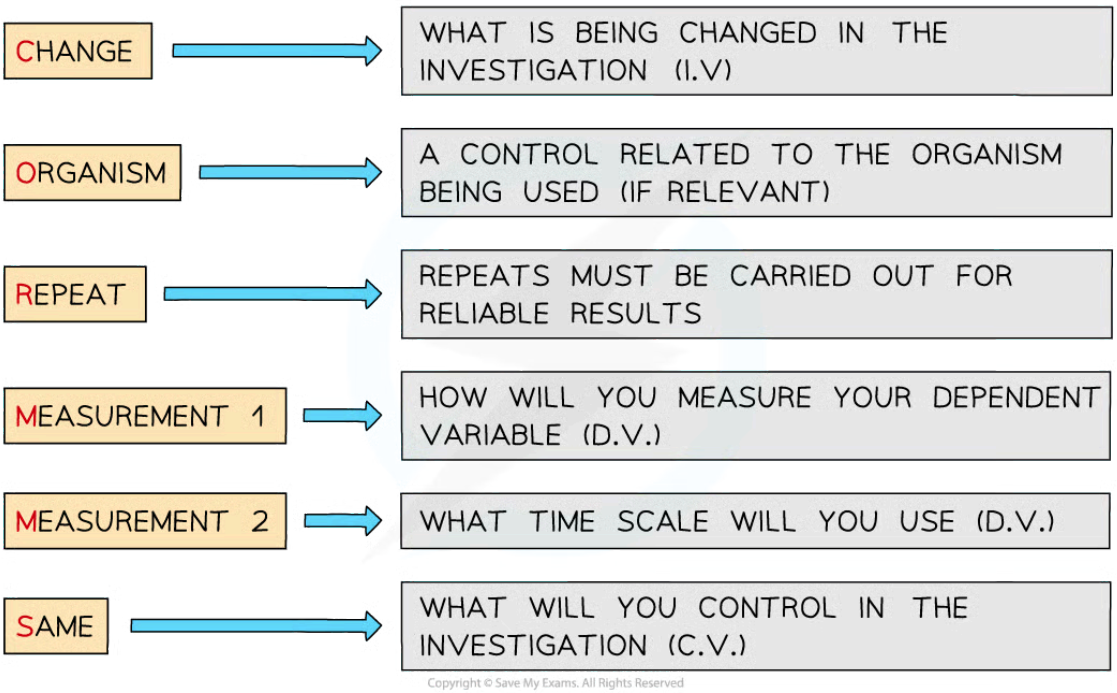
Results and analysis

- Initially, as the distance from the light source decreases, the volume of oxygen produced increases
  - This is because **as the light intensity increases, the rate of photosynthesis increases**
- At a certain point, light is no longer the limiting factor and so an increase in light intensity (decrease in the distance) will not result in an increase in photosynthesis
  - Another factor is limiting the rate of photosynthesis e.g. carbon dioxide concentration
- In this experiment, care needs to be taken to ensure that the temperature is not affected as the light source moves closer

Applying CORMS evaluation to practical work

- When working with practical investigations, remember to consider your CORMS evaluation



CORMS evaluation

- In this investigation, your evaluation should look something like this:
  - **C** - We are changing the distance of the light source from the pondweed
  - **O** - The same plant or same species, age/size of plant is used
  - **R** - We will repeat the investigation several times to ensure our results are reliable
  - **M1** - We will observe the volume of oxygen produced
  - **M2** - ...after a given time
  - **S** - We will control the temperature of the room and carbon dioxide concentration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