Smart Pals
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Bionergetics

GCSE AQA BIOLOGY: TOPIC 4

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Photosynthesis

Photosynthesis → chemical process in which light energy is used to convert carbon dioxide and water into glucose and oxygen.

Photosynthesis occurs in chloroplasts as they contain chlorophyll - a green pigment that absorbs light energy. This process is an endothermic reaction - energy is transferred from surroundings and is absorbed.

The word equation for photosynthesis is:

Carbon dioxide + water → glucose + oxygen

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

The glucose produced during photosynthesis is used for:

1. Respiration - glucose is broken down to release energy for process like active transport, growth and making new substances.
2. Making amino acids - glucose is combined with nitrate ions from the soil to make amino acid, which are then built into proteins for growth and repair.
3. Making cellulose - glucose joined together to form cellulose for strong cell walls.
4. Stored as fats/ oils - glucose is converted into lipids, mainly stored in seeds for long-term energy.
5. Stored as starch- insoluble store of energy in roots, stems, and leaves; used when photosynthesis isn't happening.

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Limiting factors of photosynthesis

A limiting factor stops photosynthesis from happening at its maximum possible rate. Even if other conditions are perfect, the limiting factor will hold the process back. The rate of photosynthesis is affected by light intensity, Carbon dioxide concentration, temperature and chlorophyll.

1. Light intensity

- light provides the energy for photosynthesis.
- A low light intensity slows the rate
- as light intensity increases, the rate of photosynthesis increases until another factor becomes limiting.

2. Carbon dioxide concentration

- CO2 is a raw material for photosynthesis.
- low CO2 concentration slows the rate of photosynthesis.
- Increasing CO2 increases the rate until another factor becomes limiting.

3. Temperature

- photosynthesis is controlled by enzymes.
- if it's too cold, the enzymes work slower so the rate also slows down.
- as temperature increases, rate increases until optimum temperature is reached.
- if the temperature goes above optimum, the enzymes denature, causing the rate to fall rapidly.

4. Chlorophyll concentration

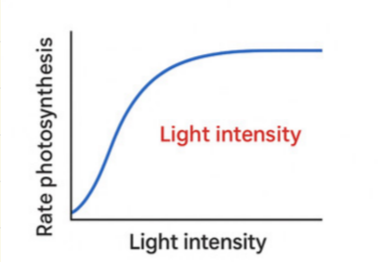
- if there is a small amount of chlorophyll (can be due to disease or lack of nutrients) less light is absorbed, slowing down the rate of photosynthesis.

Rate of photosynthesis

Rate of photosynthesis → how fast plants convert carbon dioxide and water into glucose and oxygen using light energy. There are three main graphs you need to know for the rate of photosynthesis.

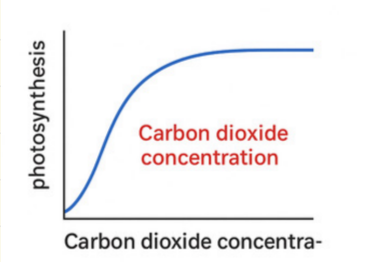
Light intensity:

- At low light, rate of photosynthesis is limited by the energy available
- if light intensity increases, the rate rises
- At a certain point, other factors (CO_2 or temperature) become the limiting factor, so the graph levels off.



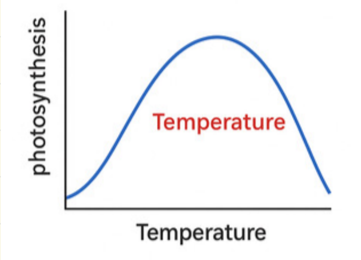
Carbon dioxide concentration:

- Low CO_2 limits the rate of photosynthesis because it is a raw material.
- more CO_2 means a higher rate up to a limit.
- eventually, light and temperature become limiting, so rate levels off.

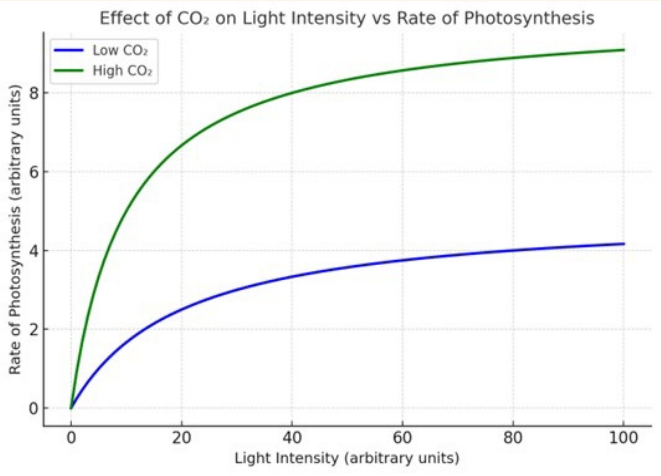


Temperature:

- rate of photosynthesis increases as temperature rises (enzymes work faster)
- peak at optimum temperature.
- after optimum, enzymes denature, causing a rapid drop in the rate.



Sometimes, you can get graphs that show more than one limited factor, for example:



In the graph, we can see that the X axis is the light intensity, and the Y axis is the rate of photosynthesis.

We can also see that we have two lines: the blue line represents low carbon dioxide, and the green line represents high carbon dioxide

At low intensity, both lines start off the same because light is the limiting factor- there's not enough light energy food synthesis to go faster, regardless of carbon dioxide levels.

As light intensity increases:

- in high carbon dioxide conditions (green line), the rate keeps rising for longer as there's plenty of carbon dioxide available, so light remains the main limiting factor until much higher intensities.
- in low carbon dioxide conditions (blue line), the rate levels off sooner because carbon dioxide runs out as limiting factor – increasing light further won't help.

Rate of photosynthesis - practical

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

1. Fill a beaker with water and add a small amount of sodium hydrogencarbonate (provides a constant supply of carbon dioxide)
2. Place the pondweed in the beaker, with the freshly cut end pointing towards the light source
3. Position the lamp at a set distance from the beaker (E.g. 10 cm)
4. Switch on the lamp and start the stopwatch
5. Count the number of bubbles released in one minute
6. Repeat three times at that distance and calculate a mean
7. Move the lamp further away in set increments (e.g. 20 cm, 30 cm, 40 cm) and repeat the steps 4 to 6

Equipment:

- fresh pondweed
- Beaker
- Lamp (light source)
- Ruler
- stopwatch
- Sodium
- Hydrogen carbonate
- Gas syringe (optional)

variables:

- independent – distance between lamp and pondweed (changes light intensity)
- Dependent – rate of photosynthesis by counting bubbles
- Control – temperature of water, concentration of sodium hydrogencarbonate

Analysis:

- plot graph of rate of photosynthesis (Y axis) against light intensity (X axis)
- light intensity can be calculated using the inverse square law:

Light intensity ∝ 1/distance^2

conclusion:

- the closer the light source, the higher the light intensity, and the faster the rate of photosynthesis
- After a certain intensity, the rate plateaus because another factor becomes limiting

Artificially creating ideal conditions for farming

Farmers do this to maximise the rate of photosynthesis, so crops grow faster and yield more food.

Methods used to create ideal condition:

1. Greenhouse - to trap heat from sunlight, keeping temperature warm and steady. This allows farmers to control humidity levels, and protect plants from pests, diseases, and harsh weather.
2. Artificial lighting – extend the amount of time plants can photosynthesise beyond daylight hours. This is useful in winters or cloudy conditions when natural light is limited.
3. CO2 enrichment – pumping extra CO2 into the greenhouse air increases rate of photosynthesis. This is sometimes done by burning small amounts of gas or using CO2 generators.
4. Controlling pests and diseases– using pesticides or biological controls keeps plants healthy so energy isn't wasted fighting infection.

Respiration

Respiration → the process of releasing energy from glucose. Happens in every living cell.

Respiration is exothermic (transfers energy to the environment)

Energy is released in a way that cells can use for:

- movement - muscles contracts, for example, animals running, swimming. Heart muscles contracting to pump blood.
- maintaining body temperature - mammals and birds keep their body temperature constant, this also maintains metabolism
- building larger molecules- producing larger molecules from the smaller ones.

Two types of respiration: aerobic respiration and anaerobic respiration

Aerobic respiration

- Release of a large amount of energy from glucose using oxygen. Happens mainly in mitochondria.
- Releases more energy per glucose than anaerobic respiration.
- Produces waste products: carbon dioxide (exhaled) and water.

Equation:

Glucose + oxygen → carbon dioxide + water + energy

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

Anaerobic respiration

- The release of a small amount of energy from glucose without oxygen.
- Happens when oxygen cannot meet demand (not enough oxygen gets supplied to the muscles), e.g. During intense exercises. Less efficient as it does not completely break down of glucose.

Equation (in animas):

Glucose → lactic acid (+energy)

- used during short bursts of high intensity activity (eg sprinting)
- lactic acid build up causes: muscle fatigue, cramps, drop in pH
- must be removed →requires oxygen debt to oxidise lactic acid into CO_2 and H_2O in the liver.

Equation (in plants and yeast):

Glucose → ethanol+ carbon dioxide (+energy)

- Plants and yeast cells respire anaerobically when oxygen is low, produces ethanol + carbon dioxide (instead of lactic acid, like in animals)
- In yeast, anaerobic respiration takes place through the process called fermentation.
- yeast is used in bread making, carbon dioxide makes dough rise.
- yeast is used to make alcoholic drinks, ethanol remains in the drink.

Reflect on questions:

Why anaerobic respiration is less efficient? - glucose isn't fully oxidised
Why oxygen debt happens? - to remove lactic acid by oxidation in the liver

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Exercise

Exercise affects respiration:

- during exercise, muscles contract more often, meaning they will require more energy.
- respiration rate increases to supply this energy
- initially, aerobic respiration meets demand, but during intense exercise, anaerobic respiration may occur.
- increased breathing and heart rate - you're breathing rate and depth rise to bring more oxygen into the lungs. The heart pumps blood faster deliver this oxygen to muscle cells and remove carbon dioxide more quickly.

Anaerobic respiration and recovery:

- Oxygen debt - the extra oxygen needed after exercise to break down lactic acid into harmless substances like Carbon dioxide and water.
- paying it back: even after you stop, breathing and heart rates stay high to help remove lactic acid from the muscles.
- lactic acid can be transported in the blood to the liver, where it's converted back into glucose.

Measuring exercise impact:

You can measure:

- breathing rate - count of breaths per minute
- heart rate - measure your pulse

Investigation steps:

- record your pulse after resting for 5 minutes
- record again after gentle walking
- repeat after slow jogging
- repeat after 5 minutes of running
- present results in the data chart.

Notes:

Harder exercises pulse rate as your body needs more oxygen and to remove more carbon dioxide

Metabolism

Metabolism → the sum of all chemical reactions in a cell organism.

Includes both: anabolic reactions (building larger molecules from smaller ones), catabolic reaction (breaking larger molecules from smaller ones)

Why metabolism need energy:

Almost all metabolic reactions revue energy from respiration to:

- Building complex molecules
- break down molecules in a controlled way
- maintain body function like growth, repair, and temperature regulations

Examples of metabolic processes:

Conversion of small molecules into large molecules anabolic

- small glucose molecules are joined together in reaction to form glycogen (storage molecule in animals), cellulose and starch (in plants).
- Glucose combined with nitrate ions to make amino acids, which are then made into proteins
- three fatty acids and one molecule of glycerol make lipids

Conversion of larger molecules into smaller molecules (catabolic):

- breakdown of excess proteins to produce urea, which is then excreted in urine
- Glucose is broken down in respiration