Edexcel Biology GCSE

Topic 6: Plant Structures and their Functions

Notes

(Content in bold is for higher tier only)

CONTENTS

6.1, 6.2, 6.3 - Photosynthesis

Plants and algae are the main **producers** of food, which they synthesise from sunlight in a process called **photosynthesis**. They are also therefore the primary producers of **biomass** in all food webs and food chains.

- Photosynthesis occurs in **plants** and **algae**.
- It is an **endothermic reaction**, meaning that it takes in more energy than it releases.
- Light energy from the environment is transferred to **chloroplasts** in leaves.

The equation for photosynthesis is:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

Each compound has its own **chemical symbol**:
Carbon dioxide: CO_2
Water: H_2O
Oxygen: O_2
Glucose: $C_6H_{12}O_6$

The rate of the process is affected by a number of factors.

Factor	Effect
Temperature	With an increase in temperature, the rate of photosynthesis increases. As the reaction is controlled by **enzymes**, this trend continues up to a certain temperature until the enzymes begin to **denature** and the rate of reaction decreases.
Light Intensity	For most plants, the higher the light intensity, **the faster the rate of the reaction.**
Carbon dioxide concentration	Carbon dioxide is also needed to make glucose (see equation). As the concentration of carbon dioxide increases, **the rate of reaction increases**.

Any of the factors above may become a **limiting factor**. This is an environmental condition (such as light intensity) which, in low levels, restricts any increase in the rate of photosynthesis. Despite increases in other factors (such as temperature or carbon dioxide concentration), the rate of photosynthesis will not increase any more. This can be seen on a graph as the curve levelling off.

6.4 - **Higher Only** Interaction of Limiting Factors in Photosynthesis

By carrying out an experiment measuring the **oxygen production** of a plant, you can calculate the rate of photosynthesis.

- Pondweed is placed in a test tube full with water. The top is sealed with a bung. A **capillary tube** also containing water leads into the test tube, and it is attached to a syringe.
- A lamp is placed at a measured distance from the test tube.
- As it photosynthesises, oxygen is produced, forming a gas tube in the capillary tube
- The distance the bubble has moved is measured using a ruler to calculate the volume of oxygen produced.
- Many variables can be changed to observe their effect on photosynthesis: the temperature (using a **water bath**), time the pondweed is left, the light intensity (varied by the distance the lamp is from the plant).
- It is important to control all factors that may affect photosynthesis except your **independent variable** (the one you want to observe), so it is a valid experiment.

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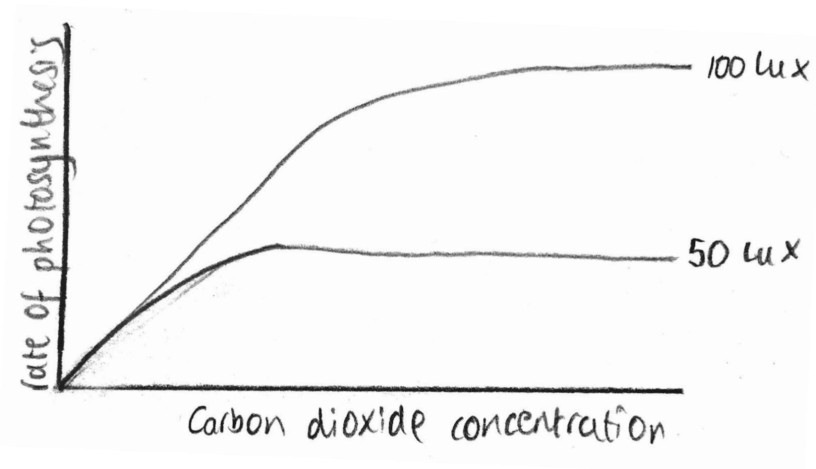
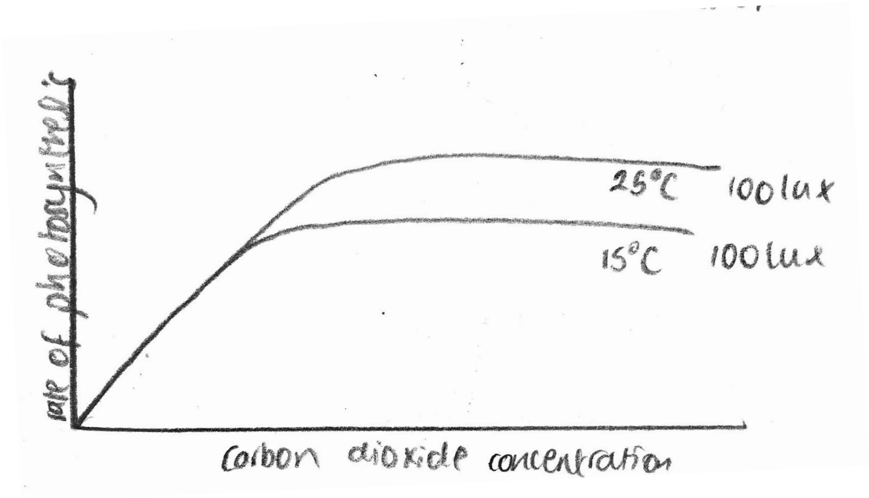
- **A graph involves one limiting factor if it has one line which levels off, with the factor on the horizontal axis and rate of photosynthesis on the vertical axis.**

- **A graph with two lines represents two limiting factors in two experiments. The investigation involves increasing the factor on the horizontal axis, and is carried out at two different other environmental conditions, such as two different temperatures.**



Light intensity is measured in lux and in this graph we can see that the limiting factor is light intensity. This is because the 50 lux levels limits the rate of photosynthesis compared to the 100 lux experiment, showing that at 50 lux light intensity was the limiting factor - it had the potential to increase the rate of photosynthesis further if it were increased.

- **A graph involves three limiting factors is similar to the one above, but another factor is stated on each line, which is the same in each**



The limiting factor is temperature as light intensity is the same in each and carbon dioxide is increasing.

Farmers can use the knowledge of limiting factors to enhance the conditions in the greenhouse for a greater rate of photosynthesis. This will increase growth leading to increased profits.

6.5 - Core Practical: Light Intensity and Rate of Photosynthesis

We can set up a simple experiment to measure the rate of photosynthesis in a plant:

We will need a **sealed 100ml flask** filled with **water at room temperature**, a **gas syringe**, a small amount of **pondweed**, a small **lamp** and a **1m ruler**.

1. Use the ruler to place the flask and pondweed 15cm from the lamp.
2. Leave the apparatus for around 10 minutes to allow the pondweed to adjust.
3. Connect the gas syringe to the flask and record the change in volume on the syringe after 5 minutes.
4. Move the lamp 10cm further away and measure the volume change again. Repeat.

Plot your results on a **graph of distance from lamp on the x-axis**, and **change in gas volume on the y-axis**.

6.6 - **Higher Only** Inverse Square Law: Rate of Photosynthesis

As mentioned above, light intensity is directly proportional to the rate of photosynthesis. This is because the greater the intensity of light, the more photons (light energy) hit the chloroplasts in the leaf, and the more photosynthesis can occur at once.

It makes sense, then, that the opposite pattern can be seen between the rate of photosynthesis and the distance from the light source: inverse proportion describes a relationship between two factors which involves one increasing whilst one decreasing. As the distance between the light source and the plant increases, the light intensity decreases. The light intensity is inversely proportional to the square of the distance- called the inverse square law.

Light intensity $\propto$ 1/distance^2

This means that if a lamp is 2 metres away from a plant, then then light intensity of the lamp is a ¼ of its original value.

$1/2^2 = ¼$

6.7 and 6.8 - Structure Adaptations

Several cells in plants are adapted to perform specific functions:

Root hair cells: **specialised to take up water by osmosis and mineral ions by active transport from the soil as they are found in the tips of roots**

- Have a large surface area due to root hairs, meaning more water can move in
- The large permanent vacuole affects the speed of movement of water from the soil to the cell
- Mitochondria to provide energy from respiration for the active transport of mineral ions into the root hair cell

Xylem cells: **specialised to transport water and mineral ions up the plant from the roots to the shoots**

- Upon formation, a chemical called lignin is deposited which causes the cells to die. We say that these dead cells have become **lignified**. They become hollow and are joined end-to-end to form a continuous tube so water and mineral ions can move through.
- Lignin is deposited in spirals which helps the cells withstand the pressure from the movement of water

Phloem cells: **specialised to carry the products of photosynthesis (food) to all parts of the plants**

- Cell walls of each cell form structures called sieve plates when they break down, allowing the movement of substances from cell to cell
- Unlike xylem, these cells within phloem are **alive**
- Despite losing many sub-cellular structures, the energy these cells need to be alive is supplied by the mitochondria of the companion cells.
- These cells use this **energy** to transport **sucrose** (the sugar that plants use) around the plant

6.9 - Transpiration and the Stomata

Transpiration is the loss of water of water vapour from the leaves and stems of the plant. It is a consequence of **gaseous exchange**, as the stomata are open so that this can occur.

- Water also evaporates at the open **stomata** (pores) on the leaf surfaces
- As water molecules are attracted to each other, when some molecules leave the plant the rest are pulled up through the xylem
- This results in more water being taken up from the soil resulting in a continuous **transpiration stream** through the plant

Guard cells close and open stomata.

- They are kidney shaped
- They have thin outer walls and thick inner walls
- When lots of water is available to the plant, the cells fill and change shape, opening stomata (they are also light sensitive)
- This allows gases to be exchanged and more water to leave the plant via evaporation
- More stomata are found on the bottom of the leaf, allowing gases to be exchanged whilst minimising water loss by evaporation as the lower surface is shaded and cooler.

6.10 - Translocation

Translocation is the movement of food substances (such as sucrose) made in the leaves up or down the phloem, for use immediately or storage.

- Translocation **only** occurs in the phloem, not the xylem or any other tissues in the plant.
- Translocation of sucrose occurs from the **sources** (the places where it is made) to the **sinks** (the places where it used or stored)
- The location of the sources and sinks can **depend on the season**. For example, in spring the **source could be located in the root**, and the **sink in the leaf** - and in summer this could be the other way around.

6.11B - Adaptations of the Leaf

Leaves have several adaptations to allow them to perform specific functions:

Stomata: See above. They are able to close to minimise water loss and open to increase evaporation and transpiration. Stomata also allow gas exchange to occur when they are open.
Chlorophyll: Chlorophyll is green, which is the most efficient colour for absorbing light. This means that the most light possible is absorbed.
Thinness: Leaves are very thin, meaning that carbon dioxide only has a short distance to travel to enter the leaf (and work in photosynthesis) and oxygen only has a short distance to diffuse out.
Large surface area: Having a large surface area means that the leaf can absorb more light at once, maximising the rate of photosynthesis

6.12 - Environmental Factors and Rate of Water Uptake

The factors that affect the rate of water uptake and transpiration are very similar to those that affect the rate of evaporation:

Factor	Effect
Increase in temperature	The molecules move faster, resulting in **evaporation** happening at a faster rate and therefore the rate of transpiration increases. The rate of photosynthesis increases, meaning more stomata are open for gaseous exchange, so more water evaporates and the rate of transpiration increases.
Increase in relative humidity (the measure of the concentration of water vapour in the air in comparison to the total concentration of water that air can hold)	If the **relative humidity** is high, then there will be a reduced **concentration gradient** between the concentrations of water vapour inside and outside the leaf, resulting in a slower rate of diffusion. This will decrease the rate of transpiration.
Increased air movement (wind)	If more air is moving away from the leaf due to it being blown away, then the concentration of water vapour surrounding the leaf will be lower. This will mean there will be a steeper concentration gradient resulting in diffusion happening faster. This will increase the rate of transpiration.
Increase in light intensity	This leads to an increased rate of photosynthesis, so more stomata open to allow gaseous exchange to occur. This means more water can evaporate, leading to an increased

	rate of transpiration.

6.13 - Rate Calculations for Transpiration

Measuring the uptake of water by the plant gives an indication to the rate of transpiration, because water is only taken up if water leaves the plant. This is observed by using a **potometer**, which involves placing a plant in a capillary tube in water, and measuring the distance travelled by a bubble.

We can place a leaf shoot in one end of the potometer, and use a ruler to measure how far the bubble travels up the capillary tube in a set time (e.g 1 minute). The further the bubble moves in this time, the greater the rate of transpiration and thus the greater the rate of water uptake.

6.14B - Extreme Adaptations

Many plants are adapted to survive in extreme environments. To do so, they need to have specific adaptations which maximise their ability to take in sunlight and carbon dioxide:

Leaf shape and size - many desert plants do not have leaves, or have very small leaves. This reduces the amount of water lost as a result of transpiration.

Presence of a waxy cuticle - many leaves have a waxy **cuticle** on top, preventing evaporation of water in environments where water is scarce.

Stomata - stomata are **small pores on the surface of a leaf**. They can be **closed** to prevent **evaporation** of water in extreme environments, and **opened** when carbon dioxide is needed for photosynthesis. This is useful, as it means that the plant can **adapt** when water is scarce.

6.15B - Plant Hormones and Growth

Plants need hormones to coordinate and control growth. They are needed for tropisms. Examples of these include **phototropism**, the response to light, and **gravitropism** or **geotropism**, the response to gravity. Hormones move from the place they are made to where they are needed in order to produce the appropriate response.

Auxins

Most plants show **positive phototropism** because they grow towards the light source.

- The plant is exposed to light on one side.
- **Auxin**, a growth hormone, moves to the shaded side of the shoot.

- Auxin stimulates cells to grow more here.
- This means the shoot bends towards the light.
- The plant receives more light, meaning photosynthesis can occur at a faster rate.

Most shoots show **negative gravitropism** as they grow away from gravity. If a shoot is horizontal:

- Auxin moves to the lower side.
- The cells of the shoot grow more on the side with most auxin, so it stimulates cells to grow more here.
- This makes the shoot bend and grow away from the ground.
- This is beneficial as light levels are likely to be higher further away from the ground.

Most roots show **positive gravitropism** as they grow towards gravity. If a root is horizontal:

- Auxin moves to the lower side.
- The cells of the root grow more on the side with less auxin, so it stimulates cells to grow on the upper side.
- This makes the root bend and grow downwards.
- This is beneficial as there are more likely to be increased levels of water and nutrients lower down, and it provides stability for the plant.

When the auxin distribution becomes equal on both sides it grows straight in that directions.

You can investigate the effect of light or gravity on **newly germinated** seedlings by varying conditions.

- Placing in cardboard box and shining light from one side
- Attaching a **petri dish** containing the seedlings to a wall (effects of gravity)

6.16B - **Higher Only** Commercial Uses of Plant Hormones

Humans can use plant hormones to alter plant growth. They are used in areas such as agriculture and horticulture for many reasons: to increase yield, obtain desirable features and to lower costs.

Auxin

1. **As weed killers**
   - **Many weeds are broad-leaved**
   - **Weedkillers, containing auxin, have been synthesised so they only affect broad-leaved plants**
   - **The increased amount of auxin causes the cells to grow too rapidly**
   - **This results in the weed dying**
2. **As rooting powders**
   - **Plants with desirable features are cloned to make more plants with the same feature**
   - **One way to clone a plant is to take a cutting from the original plant**

- **Rooting powder containing auxin is applied to it and it is placed in the ground**
- **Roots grow and the new plant begins to grow very quickly**

3. **To promote growth in tissue culture**
    - **Another way to clone a plant is to use tissue culture**
    - **Cells from the plant are taken are placed in a growth medium containing lots of nutrients**
    - **Hormones such as auxins are added**
    - **The cells begin to form roots and shoots**

Gibberellins are used in germination, for fruit and flower:

- **Gibberellins allow seed germination to occur by breaking seed dormancy (the period before germination)**
- **They allow fruits to grow heavier and larger, increasing yields.**
- **They encourage flowering plants to flower at a faster rate.**

As ethene controls ripening, it is used in the food industry.

- **Fruit is picked when it is not ripe**
- **It is firm which means that during transport it gets less bruised and damaged**
- **When it is needed to be sold, it is exposed to ethene and warmer temperatures**
- **Ethene is involved in controlling cell division and stimulates enzymes that result in fruit ripening.**
- **This reduces wastage as more fruit is suitable to be sold and it does not ripen too early**