OCR (B) Biology GCSE

Topic B3: Living together

Notes

(Paragraphs in **bold** are higher tier only)

What happens during photosynthesis

Photosynthesis is the process of **converting light energy to chemical energy**. It is carried out primarily by plants, although some prokaryotes can also photosynthesise. In plants, photosynthesis occurs in the **chloroplasts,** which are a type of organelle found within the cells. There is a high concentration of chloroplasts in the upper leaf cells as this is where most sunlight hits the plant.

Photosynthesis involves a series of **endothermic chemical reactions** which can be described in two stages:

- **Stage one (light-dependent stage)**
  Chloroplasts contain a **pigment** called **chlorophyll** which makes the plant green. When light hits the leaf, it is **absorbed** by the chlorophyll pigment. The light also **splits water molecules** into **hydrogen ions and oxygen**. Oxygen is a waste product and is released from the plant, whereas hydrogen is transferred to the second stage.

  Inputs: light, water
  Outputs: hydrogen, oxygen (waste)

- **Stage two (light-independent stage)**
  Hydrogen ions from the first stage are combined with **carbon dioxide** to make **glucose**. Glucose is a sugar molecule which can be stored in the plant as **starch**. When the plant needs energy, it is broken down and used as fuel for **cellular respiration**. It can then be used for growth and repair, and can help synthesise proteins, lipids, carbohydrates and other molecules within the plant.

  Inputs: hydrogen (from stage one), carbon dioxide
  Outputs: glucose

Equations for photosynthesis

carbon dioxide + water → glucose + oxygen

$$6CO_2 + 6H_20 \xrightarrow[Chlorophyll]{Light} C_6H_{12}0_6 + 60_2$$

Enzymes and photosynthesis
The chemical reactions in photosynthesis are **catalysed** by **enzymes**. Enzymes are **proteins** that help to speed up reactions but are not changed or used up themselves during the reaction, meaning that they can be **used repeatedly**. The molecule that the enzyme binds to during a reaction is referred to as the **substrate**, and the place on the enzyme where the substrate binds is called the **active site**. During a reaction, a substrate molecule binds to an enzyme at the active site and is then broken down into the end products. This is referred to as the **lock and key model** of enzyme action, as each enzyme is **specific** to one type of substrate, similar to how each lock requires a different key.

Different factors can change the rate of an enzyme-catalysed reaction:

- pH - Enzymes have an optimum pH that they work best at. As the pH moves away from this, it causes the shape of the active site to change. This means that the substrate cannot fit in the active site, hence no enzyme-substrate complexes can form. This means that the enzyme has become denatured, and the rate of reaction decreases.

- Temperature - As the temperature increases up to the enzyme's optimum, the rate of reaction increases. This is because the molecules have more kinetic energy, thus move faster. Consequently, more successful collisions occur and more enzyme-substrate complexes can form. At very high temperatures above the optimum, the enzymes become denatured and the active site changes shape. This decreases the rate of reaction as enzyme-substrate complexes cannot form.

- Substrate concentration - As the substrate concentration increases, the rate of reaction increases proportionally. At high substrate concentrations, the rate of reaction plateaus (stops increasing) as all the enzyme active sites are full.

Factors effecting the rate of photosynthesis

The rate of photosynthesis is limited by the limiting factor. This is the factor which is least available to the plant. For example, at night, light intensity is very low hence the rate of photosynthesis is also very low, regardless of the carbon dioxide concentration and temperature.

- Carbon dioxide concentration - As CO2 concentration increases, rate of photosynthesis also increases.

- Temperature - Photosynthesis requires enzymes to carry out the reaction. As these enzymes have an optimum temperature, photosynthesis also has an optimum temperature. This is usually about 25°C. At low temperatures, for example in the winter, plants photosynthesise slowly as the enzymes have little kinetic energy, thus few enzyme-substrate complexes are made. At very high temperatures, these enzymes denature, also slowing the rate of photosynthesis.

- Light intensity - As the light intensity increases, rate of photosynthesis increases. **This obeys the inverse square law, meaning that light intensity is inversely proportional to the square of the distance between the plant and light source: ($I \propto \frac{1}{d^2}$), where *I* is light intensity and *d* is the distance between the plant and the light source.**
  A high light intensity can sometimes lead to the plant heating up above the optimum temperature, however, thus temperature would become the limiting factor and the rate of photosynthesis would not be increased by a further increase in light intensity.

Knowledge of limiting factors is useful for farmers as they can reduce the limitation on the rate of photosynthesis due to these factors. This will mean that the plants have more energy to use for growth, thus the yield is higher and growth time is shorter. Farmers can reduce the effects of these limiting factors by placing plants in a greenhouse. Greenhouses trap heat, thus the plants are always kept at their optimum temperature. In addition, artificial lighting can be used so that the plant can photosynthesise during the night as well, and carbon dioxide can be pumped into the greenhouse.

How do producers get the substances they need?

Photosynthetic organisms take in and release a number of different substances. **Carbon dioxide** and **water** are taken in for photosynthesis, and **mineral ions** are needed for building cell structures. The main waste product for plants is **oxygen**, which is released during photosynthesis. A small amount is used during **respiration,** but most exits the plant.

Gases like oxygen and carbon dioxide move through the plant via **diffusion**. Diffusion is the **passive** process of molecules moving from an **area of high concentration to an area of low concentration**. This **does not require energy**. Gases diffuse through **cell membranes**, and enter and exit the plant via the **stomata**, which are pores usually found on the lower surfaces of the leaves.

Water molecules move via **osmosis**. This is a similar process to diffusion and does also **not require energy**. Water molecules move from an area of high concentration to an area of low concentration **through a partially permeable membrane**. It is partially permeable as it only lets certain molecules pass through it.

Mineral ions from the soil are taken up by **root hair cells.** Due to the low concentration of mineral ions in the soil, they must move **up the concentration gradient** into the root from a low concentration to a high concentration. **This requires energy** and is referred to as **active transport**.

Root hair cells are **highly adapted** to carry out active transport efficiently:

- They have a **large surface area**.
- They have a large concentration of **mitochondria**, which can carry out **respiration** to produce **energy** for active transport. They lack other organelles that they do not need, for example they do not contain chloroplasts as they cannot photosynthesise underground.
- They have a **thin cell membrane** to speed up the rate of diffusion and active transport (as there is a **shorter distance** that molecules have to travel across).

Stomata and guard cells

Stomata are located on the lower side of the leaf and allow diffusion of carbon dioxide into, and water vapour and oxygen out of, the leaf. **Guard cells** surround the stomata and can **control the opening and closing** of it to **limit water loss** from the plant; when there is a limited water supply, the guard cells cause the stomata to close to prevent water loss. This, however, also **reduces the diffusion** of carbon dioxide in through the stomata for use in photosynthesis, so can cause carbon dioxide to become the limiting factor and reduce the rate of photosynthesis. Plants in hot places often have **fewer stomata** to reduce water loss and some, for example cacti, only open their stomata at night.

Xylem and phloem

Plants have a transport system made up of **xylem and phloem vessels**. These are used to transport molecules from the roots of the plant to the stem and leaves, and vice versa. The **xylem** is used to transport **water** through plants from the roots to the leaves, where **transpiration** occurs. The xylem is made from **hollowed-out dead cells** that have the ends removed to make a tube for water to pass through. The **phloem** is made of **living cells** and is used to **transport sugars and food nutrients** in **translocation**.

Transpiration

Transpiration is the loss of water vapour from the mesophyll cell surface due to evaporation. The water vapour then exits the plant via the stomata. Water molecules are drawn up the xylem by transpiration pull (not osmosis). Water molecules are cohesive, meaning they stick together. This means that as the water evaporates at the leaf and diffuses out of the stomata, more water is drawn up the plant from the roots. This water helps to maintain plant structure by keeping cells turgid; if the plant loses too much water which is not replaced, it begins to wilt as water moves out of cells and turgor pressure decreases. To limit water loss, the plant closes the stomata to prevent water vapour diffusing out.

Environmental factors that limit the rate of water uptake

- Light intensity - when there is a high light intensity, photosynthesis rate is high, meaning that the stomata are open to ensure there is carbon dioxide available. Consequently, transpiration rate is high, meaning that the rate of water uptake must increase to replace the water lost.
- Air movement - Moist air is often trapped around the stomata, which decreases the difference in water vapour concentration inside and outside of the plant. This means that the rate of transpiration, and hence water uptake, is low. Similarly, if there is a humid atmosphere there is a low water uptake. If there is lots of air movement, this moist air is blown away from the leaf, meaning that water uptake increases.
- Temperature - At warm temperatures, the rate of evaporation is high, so the rate of water uptake is high. In addition, the rate of photosynthesis is high, meaning that the stomata will be open, increasing transpiration.

Translocation

Translocation occurs in the phloem vessels and involves the transport of amino acids and sucrose. Areas where amino acids and sucrose are produced are called sources. Regions where they are stored or used for respiration and growth are called sinks. Materials are always transported from source to sink. Sucrose and amino acids are produced in the leaves, before being transported to the roots for storage. They are later transported to regions where they are used in respiration and for growth. Some parts of the plant, such as the leaves, can act as both source and sink within a plant's life as they synthesise molecules and use them in metabolic reactions.

How are organisms in an ecosystem interdependent?

Key terms:

- **Producer** - an organism that converts light energy to chemical energy in order to produce its own nutrients. Photosynthetic organisms are the main producers of food and hence biomass.
- **Consumer** - an organism which gets energy and biomass from feeding on other animals or plants.
- **Herbivore** - organisms which feed on plants.
- **Carnivore** - organisms which feed on animals.
- **Decomposer** - organisms which break down decaying organic material (detritus).
- **Ecosystem** - an ecosystem is made up from all the living organisms and abiotic components (such as soil, rocks and water) in a community. These interact with each other to function as one unit.
- **Population** - A group of organisms of the same species living together in one habitat.
- **Community** - Populations of many different species living together in one ecosystem make up a community.
- **Food chain** - a diagram which shows the order of energy transfer through feeding in an ecosystem.
- **Food web** - a diagram showing how different food chains interact with each other.
- **Biomass** - the total mass of living material.
- **Pyramid of biomass** - shows the total mass of organisms in each trophic level of a food chain.
- **Trophic level** - the trophic level of an organism refers to its position in the food chain, food web or pyramid of biomass.

Producers

Producers are organisms in the first stage of the food chain, such as plants and algae. They take **compounds from the environment** and convert them into **small molecules**, which can then be used to create larger molecules and structures.

Plants take in **nitrogen and carbon** compounds from the environment and combine them with **oxygen, hydrogen and other elements** to make a range of small molecules, including:

- **Sugars** - Contains carbon, hydrogen and oxygen.
- **Fatty acids** - Contains carbon, hydrogen and oxygen.
- **Glycerol** - Contains carbon, hydrogen and oxygen.
- **Amino acids** - Contains carbon, hydrogen, oxygen and nitrogen.

These can be used to create large molecules: **amino acid** chains create **proteins**, **carbohydrates** are made of **sugars**, and **lipids** are made from **glycerol, fatty acids and phosphate**.

Biological molecule tests:
- Test for starch - add iodine to sample, if starch is present it will turn a **blue-black** colour.
- Test for proteins (biuret test) - place sample in test tube and add an equal volume of sodium hydroxide solution. Add a few drops of dilute copper II sulphate solution and mix gently. A **purple** colour indicates the presence of a protein; if there is no protein the solution remains **blue**.
- Test for lipids (emulsion test) - dissolve sample in ethanol. Add an equal volume of distilled water and shake gently, if lipid is present it will turn a cloudy white colour.

When carrying out biological tests, a control test should be done where distilled water is used instead of the sample. This will show what happens when there is a negative result and allows a comparison to be made.

Consumers

Consumers are organisms which feed from plants and animals to obtain biomass. Although some fungi and carnivorous plants are considered consumers, the term typically refers to animals. Animals get their supply of **nitrogen compounds** from plants and other animals through feeding. These compounds are obtained through digestion of plant and animal matter, which **releases small molecules and compounds** so that they can be absorbed and used in the consumer to build bigger molecules.

Food chains and webs

A food chain shows the order of biomass transfer between organisms but does not show the amount of biomass present at each stage. A food web shows all the interconnected food chains in an ecosystem and thus displays how organisms are dependent upon each other. Food chains start with producers, which convert light energy from the Sun to chemical energy. Producers are eaten by herbivores, which gain nutrients and hence biomass from the plant. This consumer is then eaten by another animal which gains the nutrients from the first. Each of these organisms has its own trophic level. Consumers are classed as primary, secondary, tertiary or quaternary, depending on their position in the food chain.

(biology only) This can be shown in a pyramid of biomass, which displays the amount of biomass present at each stage, starting with producers at the bottom. The process of biomass being passed between organisms is one example of how members of an ecosystem are interdependent. The amount of **biomass decreases between trophic levels** as some biomass is lost as waste:
- **Not all animal and plant material can be digested** to gain biomass from, e.g. fur and bones.
- Biomass is lost through excretion and decay.

As biomass is lost at each stage, there **are fewer animals per species in later trophic levels** since there is not enough biomass gained from prey to sustain a large population. For example, there will be much fewer bears and lions, which come later on in the food chain, than rabbits and deer, which are primary consumers. The size of a population is also restricted by other factors, such as competition from other species, number of available mates and predation.

As organisms at different trophic levels in an ecosystem are interdependent, a drop in the number of animals in a lower trophic level can lead to a drop in later levels due to lack of prey. Similarly, if more animals from a later level were introduced to the ecosystem, there would be more predation on lower levels, meaning that their numbers would decrease. Abiotic factors, such as the **environment and toxic chemicals**, also have an impact on the population of a species. For example, chemicals in water can kill fish and aquatic plants, and pesticides and herbicides can reduce the variation within farmland. For some toxic substances, a small amount will not kill the organism, however as it is passed through the trophic levels it accumulates, meaning that later trophic levels will receive a higher dose and are more likely to be killed. **Disease** can also reduce the population.

The carbon cycle

Carbon is an essential element which makes up the majority of molecules in living organisms. The carbon cycle is used to show how carbon atoms move between the atmosphere and living organisms:

1. Carbon is present in the atmosphere in the form of **carbon dioxide**, which makes up about 0.04% of the air.
2. Carbon dioxide is **taken in by plants** during **photosynthesis**. Here, the carbon is transferred from carbon dioxide to other molecules such as proteins and carbohydrates.
3. These molecules are **passed through the food chain** when **feeding** occurs, hence carbon is also passed between the trophic levels.
4. Carbon is **returned to the atmosphere during respiration**, which releases carbon dioxide, and during **decomposition.**

Carbon can be trapped in dead organisms when decomposition does not occur. These organisms become **fossilised** over thousands of years to form **fossil fuel.** When this fossil fuel is burned, large amounts of carbon dioxide are released back into the atmosphere.

The water cycle

1. Water **evaporates** from bodies of water such as lakes and rivers to form **water vapour (gas).** It also is released from plants during **transpiration**.
2. This water vapour rises upwards and begins to cool. When it cools, **condensation** occurs, turning the vapour back into liquid water which forms clouds.
3. When the cloud becomes too heavy, water falls from the cloud as **precipitation** (rain, snow, hail etc.).
4. This water is then taken up by plants and animals, or returns to a body of water through runoff, so that the cycle can continue.

Decomposition

When organisms die, they are broken down by **decomposers** which return their nutrients to the soil. Dead organic material is known as **detritus**. Decomposers are small organisms in the soil such as bacteria and fungi which use **extracellular digestion** to break down detritus, a process **catalysed by enzymes**. Extracellular digestion is where bacteria and fungi **secrete enzymes from their cells** into the soil to break down organic material, before **reabsorbing the products** back into their cells. It is called “extracellular” as it occurs outside of the cell.

Factors affecting the rate of decomposition (biology only):

- **Temperature** - decomposers rely on enzymes to break down and digest their food. Warm temperatures that are close to the enzyme’s optimum will speed up the rate of decomposition. At low temperatures, the rate of decomposition is low as enzymes are inactive.
- **Presence of oxygen** - with oxygen, decomposers can work aerobically and release carbon dioxide. In oxygen deficient areas of decomposition, for example landfills and marshes, decomposers break down detritus anaerobically. Anaerobic respiration is slower and is worse for the environment as it releases methane, a greenhouse gas which has a much larger effect than carbon dioxide.
- **Presence of water** - in dry soils, decomposition can be slow since decomposers are living organisms that need water to survive. In water logged soils, however, water fills the air spaces which leads to anaerobic decomposition.