Edexcel IAL Biology A Level

Topic 5 : Energy Flow, Ecosystems and the Environment

Notes

Photosynthesis

Photosynthesis is a reaction in which **light energy** is used to **split apart the strong bonds in water** molecules, in a process of **photolysis,** in order to combine hydrogen with carbon dioxide to produce a **fuel in the form of glucose**. Oxygen is a **waste product** of this reaction and is released into the atmosphere. The **rate** of photosynthesis is determined by **carbon dioxide concentration, light intensity** as well as **temperature.**

Chloroplasts are the **site of photosynthesis** and this organelle is adapted to photosynthesis in the following ways:

- It contains stacks of **thylakoid membranes called grana** which contain the **photosynthetic pigments,** such as chlorophyll, arranged as photosystems.
- It contains **stroma** which is the fluid surrounding the grana, stroma contains all the **enzymes** required for the **light independent** stage of photosynthesis

Photosynthetic pigments

Photosynthetic pigments are involved in **absorbing light** required for photosynthesis and subsequently convert it to **chemical energy.** The colour of pigments is determined by the **light they reflect.**

Chlorophylls absorb red as well as blue-violet light, they only **reflect green light,** thus giving chlorophyll green colour. The two forms of chlorophyll are **chlorophyll a** with the **highest abundance** which absorbs light at 430 nm and 663 nm, and **chlorophyll b,** which absorbs at 453 nm and 642 nm.

Apart from chlorophyll, **carotenoids** are also involved in photosynthesis and serve to **prevent damage of chlorophyll.** Carotenoids are present in two forms, **beta carotene** which is **orange** in colour and **xanthophyll** which is **yellow** in colour.

An **absorption spectrum** can be used to determine the wavelengths absorbed by particular pigments by illustrating the **percentage of light absorbed** at a particular wavelength. Whereas an **action spectrum** illustrates the relationship between the **rate of photosynthesis** for a given **wavelength.**

Chromatography

Chloroplast photosynthetic pigments can be **separated** in a process called **chromatography**.The process requires building up a concentrated spot of pigments on a **chromatography plate** and immersing the plate in a solvent, which travels up it, separating the different pigments as they have **differing solubilities in the solvent**. The chromatography plate produced will have several spots up the plate, each being a different pigment that can be identified by calculating its **Rf value** and comparing the one you calculated to data book values for each pigment.

Rf value = Distance travelled by spot ÷ Distance travelled by solvent.

The stages of photosynthesis

Photosynthesis occurs in 2 stages, **the light-dependent reaction** and **the light-independent reaction** (also known as the **Calvin cycle**). The **light-dependent reaction** occurs across the **thylakoid membrane**, the ATP and reduced NADP produced then take part in the **light-independent reaction in the stroma.** ATP is required in the second stage of photosynthesis to release energy from its **hydrolysis** to ADP; the breaking of the bond between 2 phosphate molecules in ATP releases a relatively large amount of energy.

Light-dependent reaction

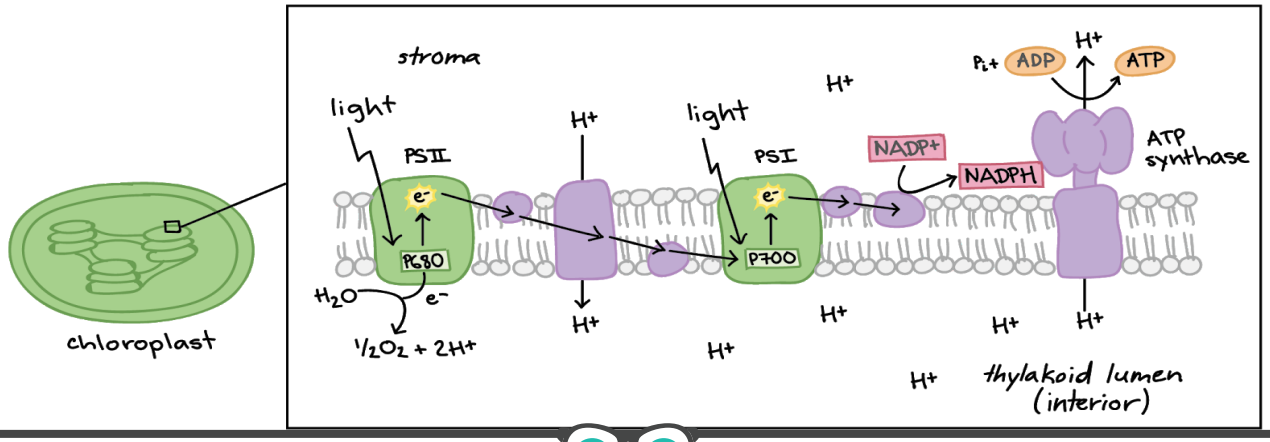
1. Light energy **excites electrons** in chlorophyll in the thylakoid membrane, causing them to leave the chlorophyll and pass to an **electron acceptor** at the start of the **electron transport chain.** This is called **photoionisation.**

2. Electrons pass down the chain from one **electron carrier** to the next in a **series of redox reactions (where one molecule gains an electron lost from another molecule).** This energy released from electrons as they pass down the electron transport chain generates **ATP from ADP and inorganic phosphate** in a process called **photophosphorylation**.

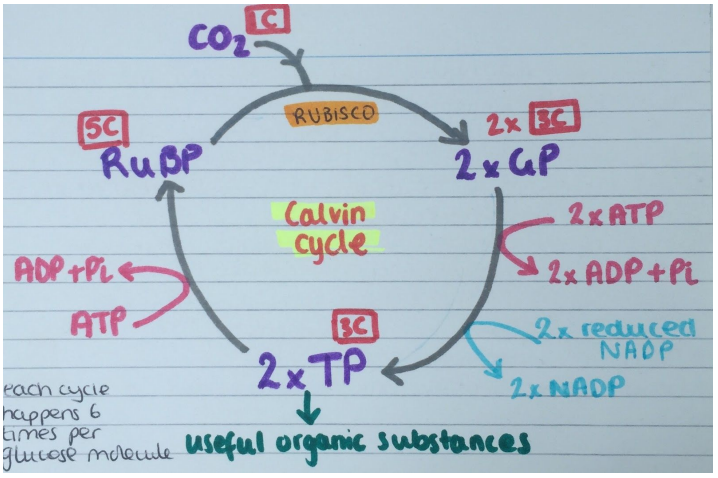
3. Light splits water into **protons (H+ ions), electrons and oxygen** (the waste by-product). This process is called **photolysis of water**. The electrons are used to **replace** the electrons lost from the chlorophyll in step 1. The protons are pumped across the membrane using the ATP created in step 2 in a process called **chemiosmosis**. This creates a **chemical potential gradient.**

4. **Reduced NADP** is generated as the electrons in the electron transport chain are transferred to **NADP** along with a **proton.**

5. Protons pass back through the membrane through an **ATP synthase** enzyme which makes ATP. Approximately **4 protons** make **one ATP molecule.** Both the ATP and reduced NADP made from the light dependent stage are used in the light-independent stage of photosynthesis.



Light independent reaction occurs as following:



1. **RuBP** is combined with **carbon dioxide** in a reaction called **carbon fixation, catalysed by the enzyme RUBISCO.**

2. **RuBP** is converted into **two glycerate 3-phosphate (GP)** molecules

3. Reduced NADP and ATP are used to **reduce each GP molecule glyceraldehyde 3-phosphate (GALP - also called TP).** In this process, the reduced NADP becomes **oxidised.**

4. 1/6 of GALP molecules are used to make simple sugars like **glucose** (every 6 cycles) which is then converted to essential organic compounds such as **polysaccharides, lipids, amino acids and nucleic acids.**

5. The remaining 5/6 molecules are used to **regenerate RuBP** with the **help of ATP**.

Biomass

In any **ecosystem**, plants synthesise organic compounds from either **atmospheric or aquatic carbon dioxide.** Most of the sugars synthesized by plants are used by the plant as **respiratory substrates,** whereas the remaining sugars are used for **synthesis of biological molecules** which form the biomass of plants.

The biomass can be measured in terms of **mass of carbon** or **dry mass of tissue per given area per given time.** The chemical energy stored in **dry biomass** can be estimated using **calorimetry**, a process where you burn a fuel and measure the energy change created in a given mass in water; this can be used to work out the **stored energy.**

Productivity

Net primary productivity (NPP) – the rate at which energy is transferred into the organic molecules that make up new plant biomass, that is **the chemical energy store in plant biomass after respiratory losses** to the environment have been taken into account

Gross primary productivity (GPP) – the rate at which energy is incorporated into organic molecule in the plants in photosynthesis, that is **the chemical energy store in plant biomass, in a given area or volume, in a given time**

Therefore, NPP = GPP – R

The net primary production is available for **plant growth** and **reproduction** as well as to **other trophic levels** in the ecosystem, such as decomposers and herbivores.

The net production of **consumers** (N), such as animals, can be calculated by: N= I – (F+R) where **I** represents the **chemical energy store** in **ingested food, F** represents the **chemical energy lost** to the environment in **faeces and urine** and **R** represents the **respiratory losses** to the environment.

Efficiency of biomass and energy transfer

The **efficiency** of energy transfer between trophic levels of a food chain can be calculated using the following equation:

(Energy transferred to the next level ÷ total energy in) X 100

Ecosystems

Some important definitions:

Population - A group of organisms of the **same species** living in the **same place** at the **same time.**

Community - **All the organisms of all species** living in the **same place** at the **same time.**

Habitat - The place where an organism lives characterised by **physical abiotic factors** and the **other organisms living there.**

Abiotic factor - A **non-living physical or chemical factor** that affects an organism, for instance, pH and light intensity.

Biotic factor - A **living factor** that affects an organism, for instance predation and diseases.

Ecosystem - A relatively **self-contained unit** consisting of **all the organisms living in a place** including the **abiotic and biotic factors.**

Niche - An organism's **role** in the ecosystem, including **the abiotic and biotic factors** required for its **survival.**

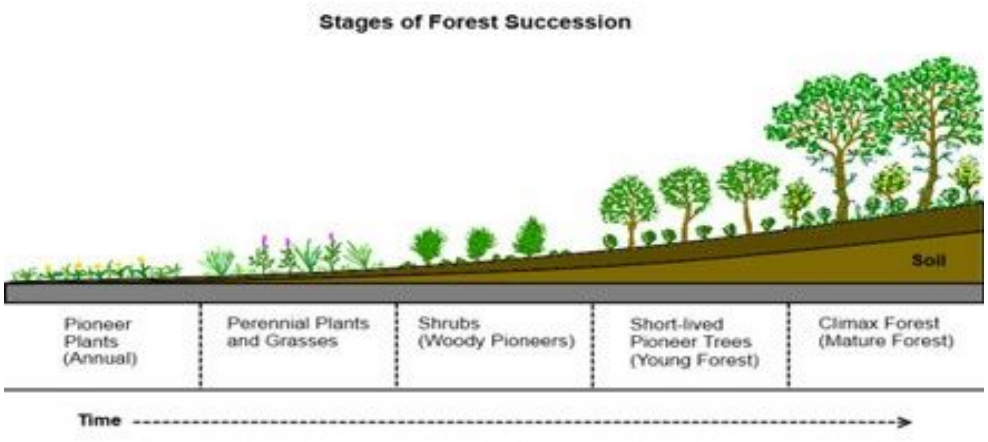
The **distribution** of organisms in a habitat is affected by its **niche and abiotic and biotic factors** as they determine how easy it is for an organism to survive and thrive in a location. For instance habitats with **low levels of competition** and **high availability of nutrients, water and space** will have large populations of organisms.

Succession

Succession is the change of one community of organisms into the other. Primary succession occurs when area **previously devoid of life** is colonised by communities of organisms, for instance after the eruption of a volcano which lead to formation of a rock surface.

The area is first colonised by the **pioneer species,** such as lichens, which are adapted to survive in such harsh conditions. As organisms die, they add and are decomposed by microorganisms, thus **adding humus,** this in turn leads to **formation of soil** which makes the environment **less hostile,** more suitable for more complex organisms. Over time, the soil becomes **richer in minerals,** enabling larger plants such as shrubs to survive. Eventually**, a climax community** is established which is the final stage of succession, **a self-sustaining and stable community of organisms.**

Secondary succession occurs in a **previously colonised area** in which an existing community has been cleared. This type of succession can occur after events such as forest fires. As a soil layer is already present, **succession begins at a later stage.**



Climate Change

Global warming is a term used to describe a **gradual increase in the average temperature** of the Earth's atmosphere and surface. It is believed that global warming will lead to a **permanent change in the Earth's climate.** The evidence for climate change includes:

- **Records of carbon dioxide levels** – increasing levels of carbon dioxide in the atmosphere are believed to contribute towards climate change as carbon dioxide is a greenhouse gas and is involved in the greenhouse effect
- **Temperature records** - this enable analysis of changes in temperature
- **Pollen in peat bogs** – pollen grains are preserved in peat bogs and analysis of samples of pollen can give us an idea of what kind of plants were present at the time when the peat was being formed
- **Dendrochronology** - the study of tree rings as the size of tree rings is affected by temperature

Limitations

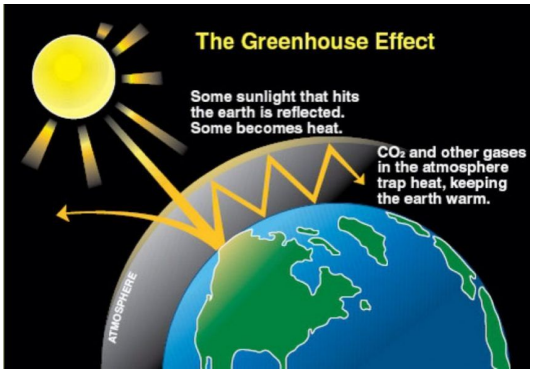
The data can be extrapolated to make predictions which can then be used in models of future climate change. On the other hand, such models have limitations as they do not include factors such as reduction in emission of greenhouse gases.

Scientific conclusions about controversial issues, such as what actions should be taken to reduce climate change, or the degree to which humans are affecting climate change, can sometimes depend on who is reaching the conclusion. While the vast majority of scientists agree on the human impact on climate change, it is the governments and politicians that have the power to change things, often leading to less action being taken than scientists themselves would. Governing bodies are also sometimes skeptical about claims about climate change and will often use any disagreements within the scientific community to delay taking action.

However, steps such as reforestation and the use of sustainable resources are being taken to manage the conflict between human needs and conservation of the environment.

The greenhouse effect

Anthropogenic climate change is climate change caused by human activity - such as burning fossil fuels leading to the release of greenhouse gases. A further human cause is the destruction of forests for land to be used for things like building and agriculture. The greenhouse effect is the process in which infrared radiation from the Sun is trapped by gases, such as carbon dioxide and methane, thus leading to an increase in the temperature of the Earth's surface and atmosphere.



Effects of climate change

The effects of climate change include changing rainfall patterns and changes in seasonal cycles which in turn would lead to:

- Changes in distribution of species – species would move to cooler areas i.e. northwards. This could potentially lead to extinction of some species due to competition.

- **Changes to development** – sex of many reptiles is determined by temperature therefore an increase in temperature would have an effect on **the sex ratio** of certain species, thus potentially leading to **extinction**
- **Disrupted life cycles**

An increase in temperature will also affect **enzyme activity**, initially as temperature increases, the rate of reaction increases because the rate of formation of **enzyme-substrate complexes** increases, as the kinetic energy of molecules increases, thus leading to more frequent collisions. However, the rate of reaction decreases above the optimum temperature as enzymes become **denatured**. Denaturing of enzymes can stop many important biological reactions occurring, so lead to the deaths of animals, plants and microorganisms. **Single-celled organisms** without systems in place for controlling internal temperature would be most affected by temperature increases caused by global warming.

Q_{10}

Q_{10} is a **temperature coefficient** which is a measure of **the rate of change of a biological system that occurs when the temperature changes by 10°C.** The coefficient can be calculated and then used to predict the effects of climate change on different biological systems, such as whole organisms and muscle systems.

Knowledge of the **carbon cycle** can be used to find ways to reduce global warming by the reduction of carbon dioxide levels in the atmosphere. This can be done through:

- **Growing plants** used as **biofuels** which are **carbon neutral** – carbon dioxide released by burning the fuel is removed from the atmosphere by the plants it is made from.
- **Reforestation** to increase the rate at which **carbon dioxide is removed** via photosynthesis.
- **Reduced burning of fossil fuels** as these contain large carbon stores

Speciation and evolution

Evolution

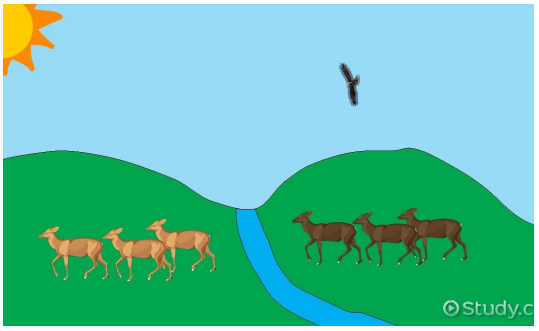
Evolution is **change in the heritable traits of biological populations over successive generations.** It occurs as a result of **change in allele frequency** which in turn is affected by changing **selection pressures.**

- New alleles arise as a result of **gene mutations** which give rise to **variation** within species.
- A change in environment leads to a **change in selection pressures** which in turn makes some alleles more desirable than others.
- Therefore, possessing some alleles enables organisms to survive and reproduce and consequently, the frequency of such alleles increases as they are **passed onto the offspring.**

Speciation

Speciation is the process by which **new species arise** after a population becomes **reproductively or geographically isolated** and cannot interbreed. Speciation can be **allopatric, or sympatric.**

- **Allopatric speciation** is caused by a **physical barrier** - for instance flooding causes an area of land to be separated into 2 new ones, separating the original population. As the two groups become separated and reproductively isolated as a result, **the gene flow between the groups is stopped**. Each group experiences **different selection pressures** as the environment they live in is different. Over time, the frequency of alleles changes through natural selection and the two parts of the population **can no longer interbreed and become separate species.**



- **Sympatric speciation** is where new species evolve from a single ancestral species when inhabiting **the same geographic region**, so reproductive isolation occurs without the population being physically separated. This reproductive isolation can occur due to **seasonal changes** (when the organisms mate), **behavioural changes** (such as changes to courtship rituals) and **mechanical changes** to genitalia that physically prevent mating.