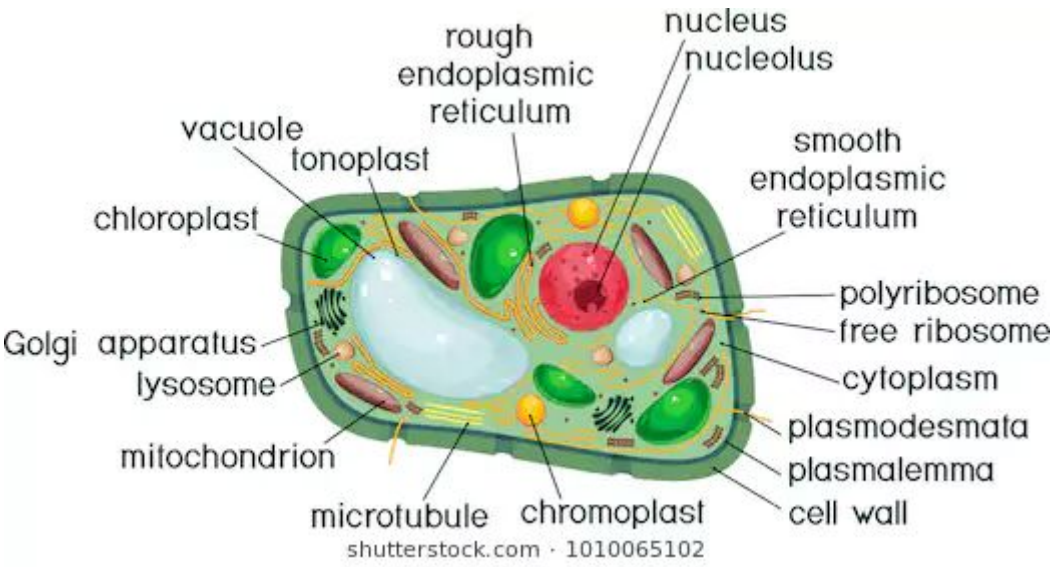
Edexcel IAL Biology A Level

Topic 4: Plant Structure and Function, Biodiversity and Conservation

Notes

Plant cells

Plant cells are **eukaryotic cells**, found in **plants and algae**. Most plant cells have the same organelles as animal cells, plus a few extra. The **ultrastructure** of a plant cell is as follows:



- **Cell wall** - surrounds the cell outside of the cell surface membrane and is made of a **polysaccharide called cellulose.** It **strengthens and supports** the cell and prevents it changing shape. Contains **pores** to allow the movement of substances easily.
- **Chloroplast** - a small, flattened structure that contains a **double membrane**. The inner membrane is stacked into **thylakoid**. Contains **chlorophyll** which is a green pigment that **absorbs light for photosynthesis.**
- **Amyloplast** - an organelle found in some plant cells that **synthesises and stores starch** molecules and **breaks them down to glucose** when the cell requires it.
- **Vacuole** - A **membranous sac** that contains a fluid called **sap,** which contains dissolved sugars and salts for the cell. Its function is to allow the cell to become **turgid** and also to **isolate unwanted chemicals** from the rest of the cell.
- **Tonoplast** - The name of the **membrane surrounding a vacuole.**
- **Plasmodesmata** - Channels of **cytoplasm that pass between adjacent cell walls** of plant cells that allows **fast communication and exchange of substances** between cells.
- **Pits** - Sections of the cell wall which adjacent plant cells can **exchange fluid or communicate through.**
- **Middle lamella** - A layer made of **pectin** that lies between adjacent plant cells, **sticking the cell walls together.**

Plant cell carbohydrates

Starch

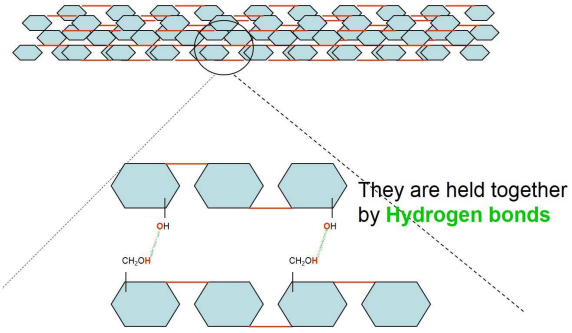
Starch **stores energy** in plants and it is a mixture of **two polysaccharides** called **amylose and amylopectin:**

- **Amylose** – amylose is an **unbranched chain of glucose molecules** joined by **1, 4 glycosidic bonds**, as a result of that amylose is **coiled** and so it is a very **compact** molecule meaning it can **store a lot of energy.**
- **Amylopectin** is **branched** and is made up of glucose molecules joined by **1, 4 and 1, 6 glycosidic bonds**, due to the presence of many side branches it is rapidly digested by enzymes therefore **energy is released quickly.**

The 2 polysaccharides are laid down in **successive rings** that form the starch granules.

Cellulose

Cellulose is a component of cells walls in plants and it's composed of **long, unbranched chains of beta glucose** which are joined by **glycosidic bonds.** Microfibrils are made of **long cellulose chains** linked together by **hydrogen bonds** formed between adjacent chains. These microfibrils form long threads that provide **structural support** in plants cells.



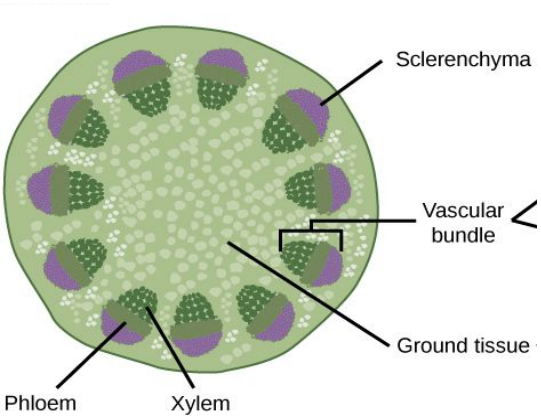
The secondary cell wall

The secondary cell wall is a **second cell wall** formed between the original cell wall (the primary cell wall) and the cell surface membrane. It only begins to grow once the cell has **stopped growing.** Its structure is made of **parallel layers of microfibrils of cellulose**, with other **polysaccharide additions**. The strength and flexibility created by cell walls and their secondary cell walls means plants have useful qualities for human use.

Sclerenchyma fibres, phloem vessels and xylem vessels

Lignin is a polysaccharide that is added to the secondary cell wall of plant cells in the transport **vessel xylem and the sclerenchyma fibres**. The lignin makes the cell walls **less flexible and more rigid**, adding **strength** to the vascular bundle. The primary function of xylem vessels is to **transport water and inorganic ions** around the plant, whereas the main function of sclerenchyma fibres is to **support the plant.**

Both the sclerenchyma fibres and xylem vessels are made from **dead cells,** the xylem vessels form **hollow tubes** of dead cells whereas the cells in sclerenchyma fibres are **tapered at the ends.** Both are found in vascular bundles, although their functions within that are different. Phloem is the other vessel found in the vascular bundle, its function is to **transport organic solutes** via a process known as **translocation.** It is made of living cells lined end to end forming a sieve tube element, with surrounding companion cells. Xylem are found towards the centre of the plant, followed by the phloem vessels, followed by sclerenchyma the furthest out from the centre.



Sustainability

Plant material is **renewable and sustainable** - its level can be maintained at a constant level. This is because we can grow plants at the rate of which they are being used, whereas with substances like crude oil, which is formed over millions of years, it is being used at a rate extremely higher than the rate at which it is made, meaning we will soon run out of it. This is why it is important to turn to plant-based substitutes for the current uses of crude oil and fossil fuels, such as the development of **biodiesel** as a substitute for diesel. Biodiesel is made from ethanol synthesised from the fermentation of plants.

Furthermore, plants have a lot of useful qualities such as **strength** provided by sclerenchyma fibres. In the future we could see plant based products replacing oil-based plastics, not only is this advantageous as oil is running out, but also because plant based products are much more **biodegradable** so would reduce the waste problems created by non-biodegradable plastics.

Plants fibres have other uses to humans, for instance:

- Plant fibres are very strong therefore they can be used to make materials, such as **ropes and fabrics.**
- Production of plant fibre products is **cheaper** than oil-based ones
- Starch can be used to make **bioplastics and bioethanol**
- Substances derived from plants, such as garlic and cinnamon sticks, have **antimicrobial and therapeutic properties**

Water and inorganic ions

The xylem vessel is responsible for transporting both **ions and water** from the roots where they are taken in via root hair cells, and then to the other areas of the plant.

Water is required to keep cells **turgid**. When cells don't have enough water, their cells lose water and the plant **wilts**. This reduces the surface area of leaves exposed to sunlight and can reduce the plant's overall height, so overall reduce the amount they can photosynthesise, as **less sunlight**

is absorbed by chlorophyll. Various reactions, like photosynthesis and hydrolysis reactions, also require water as a reactant. The movement of water through the plant in the transpiration stream is also how the inorganic ions dissolved in water reach the other areas of the plant.

Ions required for plant growth and development include:

- Nitrate ions – they are required to make nucleotide bases in DNA and amino acids
- Calcium ions – they are needed to form calcium pectate for the middle lamellae
- Phosphate ions - required to make ADP and ATP
- Magnesium ions - needed to produce chlorophyll

Bacterial growth

In optimum conditions a bacterial population can grow exponentially fast, each bacteria can divide once every 20 minutes. The optimal conditions for different bacteria varies greatly, explaining why bacteria are present everywhere on earth, even in places like in acidic lakes where no other organisms can survive. Generally speaking, ideal conditions for growth are:

- Warmth - to maximise the rate of enzyme-controlled reactions.
- Moisture - bacteria need water to dissolve nutrients in and for many chemical reactions.
- Nutrients - bacteria need various ions for survival (such as phosphate ions for ATP) and glucose for respiration, all of which they obtain from their external environment.
- Optimum pH - to maximise the rate of enzyme-controlled reactions.
- Oxygen - Required for species of bacteria that respire aerobically.

Drug testing

Overtime the testing of drugs before people can use them has become more and more vigorous; particularly after the case of thalidomide, where thousands of babies were born with birth defects after the sleeping pill was not tested on pregnant women, so its effects on them and their babies not known.

William Withering's digitalis soup

Through trial and error, the scientist William Withering developed a remedy for the condition dropsy - swelling of tissue due to the accumulation of excess water, now called oedema - by using foxglove and an active ingredient within it known as digitalis. By chance he discovered that one of his patient's dropsy was treated when using an older remedy that contained foxglove and from there made different versions of the remedy containing different concentrations of foxglove, this was his 'digitalis soup'.

Too much digitalis resulted in him poisoning his patients, but too little had no effect on the dropsy, it was through this trial and error that Withering found the optimum dosage, something

that is found today by starting with very small doses that slowly increase and monitoring of the effects it has.

The stages of drug testing

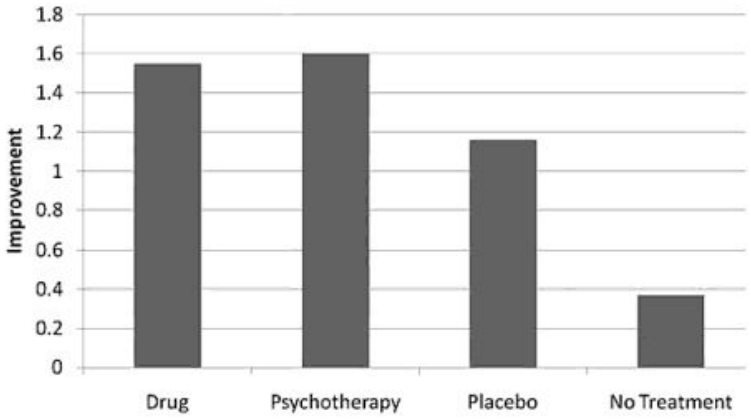
1. The drugs are tested on **human tissues and cells** grown in a lab and **computer models** predict the effect of them.

2. The drugs are then tested on **animals**. UK law states each drug must be tested on at least **2 different species**; it is done to view the side effects of the drugs.

3. The final main stage is **clinical trials** which involve testing the drugs on human volunteers and is made of 3 main phases:7
    - **Phase 1** - Testing on a small group of **healthy volunteers** - this again checks for **side effects** and is monitored to see the areas of the body it effects and how long it remains in the body for.
    - **Phase 2** - Testing the drug on a **small group of volunteers with the illness.** This is done to start determining **effectiveness** in both treating and preventing the disease and also to find the optimum **dosage**.
    - **Phase 3** - Once a drug has passed phase 2 it is tested on **a large number of participants,** often reaching thousands of volunteers. This final stage is done to confirm **effectiveness, dosage, side effects, longer-term effects, whether the drug should not be used on anyone** and also so the results can be compared to **existing treatments.**

The pharmaceutical industry is a big one and also one that scientists and companies can **profit** from, this is why it's important for drug testing to have common features to help **avoid bias and false results,** requirements such as:

- **A placebo group** - a **placebo** is a substance with **no active ingredients**, in other words, it does not contain the drug being tested and is normally just a sugar pill. When patients are taking medication there is what is known as **'the placebo effect'** where the patient's condition improves because **psychologically** they believe the drug will make them better, so they do make some improvement. Drug testing need to compare to the placebo group of patients to observe whether the drug is **more effective than the psychological effects.**



- **Double-blind trials** - A **blind** trial is where the patient does not know whether they have the active drug or the placebo drug; this is so the placebo effect can be observed. A **double-blind** trial is where **neither the patient nor the doctor** knows which drug they have; this is to stop any **subconscious bias** the doctor may have when assessing the patient and their improvement.

- **Peer review** - This is where studies such as drug testing are **reviewed** by other professionals to be sure they're **accurate, well carried out and significant.** This **avoids public scares** such as the one created over the MMR vaccine and autism, which are based on poorly conducted studies that aren't representative of the drug or medicine in question.

Taxonomy and classification

Classification - A means of organising the variety of life based on relationships between organisms using differences and similarities in phenotypes and in genotypes.

Classification can be **artificial**, such as organising groups of organisms by **visible similarities** like the ability to fly; or classification can be based on **evolutionary origins** - this is known as **phylogenetic classification.** A species is defined as a **group of organisms** that can **successfully breed to produce fertile offspring and who share similar characteristics**; this is important to classifying organisms and also telling apart different species.

Originally, classification was more artificial and based around **human judgement,** but as technology and biochemistry have developed the classification of organisms has been refined to **molecular observations** of the cells they contain and **comparison of DNA,** allowing classification to develop and focus more on phylogeny. Comparison of DNA base sequence, mRNA or polypeptides can be used to observe how closely organisms are related and how recently they shared a **recent common ancestor** from which both species developed.

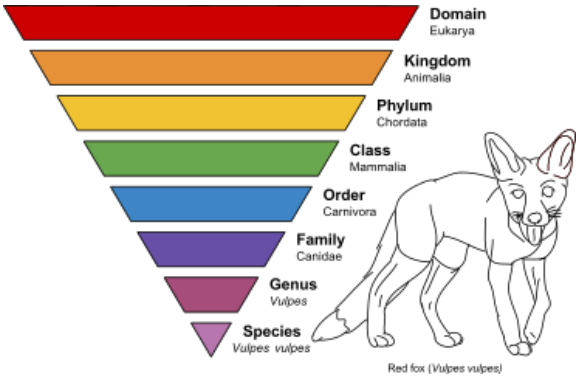
The scientific community evaluates data, such as data that may influence the classification of organisms, in the following ways:

- The findings are published in **scientific journals** and presented in **scientific conferences.**
- Scientists then study the evidence in a process called **peer review**
- Scientists start collecting evidence to either **support or reject the suggestion**

The current classification system first groups organisms into **3 domains -**

- **Archaea** (primitive bacteria often found in extreme environments)
- **Bacteria**
- **Eukaryotes** (plants, animals, fungal cells and protists)

From there, each domain is classified into **smaller, non-overlapping groups called taxons**. The order of taxons in the phylogenetic classification system is **domain, kingdom, phylum, class, order, family, genus and species**. All organisms are universally named using the **binomial naming system** which consists of the genus and the species, for instance humans are universally named the '*Homo sapiens*'.



Biodiversity

Key terms:

Biodiversity - **The variety of life within a given area** - can be local (a specific habitat) or global.

Endemism - **Species that are found in one place on earth and nowhere else.**

Over time the variety of life on earth has become extensive, yet **human activities are threatening the existence of a lot of species.** Some such activities include:

- **Deforestation** - this causes the **loss of habitat and food sources** for a number of species.
- **Over-exploitation** - this is where humans are using organisms and land **unsustainably**. Fishing for instance, is causing the deaths of some groups of fish faster than their population can be increased again by births.
- **Climate change** - the burning of fossil fuels has lead to increased emissions of greenhouse gases causing **global warming** and **climate change.** This has caused mass **habitat destruction** in the arctic causing populations of arctic animals to plummet. It has also caused the climate to change faster than animals can adapt, so **decreased their populations and changed their distribution** across the world.
- **Pollution** - pollution of chemicals, plastics and other materials across land, lakes and the seas has caused the deaths of many individuals, leading to **endangerment and extinction** of many species.

A **high** level of biodiversity is seen as **desirable**, as it **boosts ecosystem productivity** and means a high number and type of species is present, and helps to **increase sustainability of species** and their **survival.** Biodiversity can be measured in 2 ways, or calculated:

- **Species richness** - The **number** of different species in a given area.
- **Index of diversity** - The **number and type** of different species in a given area. This can be calculated numerically using:

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

Where N is the total number of organisms of **all species.**
And n is the total number of organisms of **each particular species.**

The values generated in different habitats can be **compared** to compare their **biodiversities.**

Genetic diversity **within a species** can also be calculated using the following calculation:

$$\text{heterozygosity index} = \frac{\text{number of heterozygotes}}{\text{number of individuals in the population}}$$

Ecosystems

An ecosystem includes all the organisms living in a particular area, known as the community, as well as all the **nonliving elements** of that particular environment. The **distribution and abundance** of organisms in a habitat is controlled by both **biotic** (living) factors e.g. predators, disease and **abiotic** (non-living factors) such as light levels and temperature. Each species has a particular role in its habitat, called its **niche,** which consists of its **biotic and abiotic interactions with the environment.**

Organisms are adapted to their own **niche** so that they may **thrive** in an ecosystem, largely without competition; since if 2 species occupy the same niche, one will be better adapted and eventually outcompete the other species. Adaptations can be:

- **Anatomical** - **structural features** of an organism that increase its chances of survival. For instance, wales swim in very cold water so have a thick layer of insulating blubber to keep them warm.
- **Behavioural** - **the way an organism acts** to increase its chances of survival. For instance, animals like possums that play dead to avoid predators.
- **Psychological** - **processes inside an organism's body** that increase its chances of survival. For instance, bears hibernate through winter and lower their metabolic rate to conserve energy so they don't need to hunt or gather food.

Hardy-weinberg

The Hardy-Weinberg Equation can be used to estimate the **frequency of alleles** in a population and to see whether a change in allele frequency is occurring in a population over time.

p = the frequency of the **dominant** allele (represented by A)

q = the frequency of the **recessive** allele (represented by a)

For a population in **genetic equilibrium**:
p + q = 1.0 (The sum of the frequencies of both alleles is **100**%.)
$(p + q)^2 = 1$ so $p^2 + 2pq + q^2 = 1$

The three terms of this binomial expansion indicate the frequencies of the three genotypes:

p^2 = frequency of **AA** (homozygous dominant)
2pq = frequency of **Aa** (heterozygous)
q^2 = frequency of **aa** (homozygous recessive)

The above equation can be calculated at regular time intervals to observe if allele frequencies are **changing over time in a population**; if they do change, it could suggest some alleles are more **advantageous** than others.

Allele frequencies can change due to 2 main reasons:

- **Mutation** - mutations in genes can result in a **new allele,** resulting in a change in allele proportions.
- **Natural selection** - Natural selection is the process in which fitter individuals, who are **better adapted** to the environment, **survive and pass on the advantageous genes to future generations**. Evolution is the process by which the **frequency of alleles in a gene pool changes over time as a result of natural selection.**

Evolution via natural selection:

1. There's a **variety** of phenotypes and genotypes within a population.
2. **An environmental change** occurs and as a result of that the **selection pressure changes.** Selection pressures are factors that affect an organism's chances of survival.
3. Some individuals possess **advantageous alleles** which give them a **selective advantage** and allow them to **survive and reproduce.**
4. The advantageous alleles are passed on to their **offspring**.
5. Over time, the frequency of alleles in a population **changes** and this leads to evolution.

Reproductive isolation

If two populations become reproductively isolated, new species will be formed due to **accumulation of different genetic information in populations over time,** due to different environments and selection pressures. 3 main changes can result in reproductive isolation:

1. **Seasonal** - when individuals of the same species have **different mating seasons.**

2. **Mechanical** - changes in genitalia that **physically prevent** some members of a population breeding with the others.

3. **Behavioural** - a group of individuals within a population could develop **courtship rituals** that aren't attractive to the main population.

Conservation

Zoos use various methods to **conserve endangered species** and their **genetic diversity,** some of the methods used include:

- **Scientific research** such as studying the behaviour of animals, working on improving breeding success to increase the population size and controlling and eradicating diseases that have the potential to be lethal to animals
- **Captive breeding programmes** in which endangered species are **carefully bred** to increase genetic diversity and population size
- **Reintroduction programmes** which aim to release animals bred in captivity into their **natural habitat** as well as to restore lost habitats
- **Education programmes** which aim to educate people about **the importance of maintaining biodiversity, captive breeding programmes,** as well as **illegal trade of animal products.**

Seed Banks store a large number of seeds in order to conserve genetic diversity and **prevent plant species from going extinct.** Storing seeds, instead of plants, means that a large variety of species can be conserved, it's also **cheaper** than storing whole plants as it takes up **less space.** The seeds are stored in **cool, dry conditions** as this maximises the amount of time they can be stored for and they are periodically tested for **viability**.