A-Level Biology
Revision notes 2020/2021

Contents

Biological Molecules and Enzymes

Carbohydrates

Contain 3 elements:

1. Carbon (C)
2. Hydrogen (H)
3. Oxygen (O)

Carbohydrates are found in one of three forms:

1. Monosaccharides
2. Disaccharides (both sugars)
3. Polysaccharides

Disaccharides and glycosidic bonds

These are formed when two **monosaccharides** are condensed together. One monosaccharide loses an H atom from carbon atom number 1 and the other loses an OH group from carbon 4 to form the bond.

The reaction, which is called **a condensation reaction**, involves the loss of water (H_2O) and the formation of a 1,4-glycosidic bond.

Examples of Disaccharides

Sucrose: glucose + fructose,

Lactose: glucose + galactose,

Maltose: glucose + glucose.

Functions of carbohydrates

1. Substrate for respiration (glucose is essential for cardiac tissues).
2. Intermediate in respiration (e.g. glyceraldehydes).
3. Energy stores (e.g. starch, glycogen).
4. Structural (e.g. cellulose, chitin in arthropod exoskeletons and fungal walls).
5. Transport (e.g. sucrose is transported in the phloem of a plant).
6. Recognition of molecules outside a cell (e.g. attached to proteins or lipids on cell surface membrane).

Lipids

Lipids are made up of the elements carbon, hydrogen and oxygen but in different proportions to carbohydrates. The most common type of lipid is the **triglyceride**

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Lipids can exist as fats, oils and waxes. Fats and oils are very similar in structure (triglycerides).

Triglycerides

These are made up of 3 fatty acid chains attached to a glycerol molecule.

Functions of lipids

1. **Storage** - lipids are non-polar and so are insoluble in water.
2. **High-energy store** - they have a high proportion of H atoms relative to O atoms and so yield more energy than the same mass of carbohydrate.
3. **Production of metabolic water** - some water is produced as a final result of respiration.
4. **Thermal insulation** - fat conducts heat very slowly so having a layer under the skin keeps metabolic heat in.
5. **Electrical insulation** - the myelin sheath around axons prevents ion leakage.
6. **Waterproofing** - waxy cuticles are useful, for example, to prevent excess evaporation from the surface of a leaf.
7. **Hormone production** - steroid hormones. Oestrogen requires lipids for its formation, as do other substances such as plant growth hormones.
8. **Buoyancy** - as lipids float on water, they can have a role in maintaining buoyancy in organisms

Phospholipids

A phosphate-base group replaces one fatty acid chain. It makes this part of the molecule (the head) soluble in water whilst the fatty acid chains remain insoluble in water.

Due to this arrangement, **phospholipids** form bilayers (the main component of cell and organelle membranes).

Proteins

Different proteins can appear very different and perform diverse functions (e.g. the water-soluble antibodies involved in the immune system and the water-insoluble keratin of hair, hooves and feathers). Despite this, each one is made up of **amino acid subunits.**

There about 20 different amino acids that all have a similar chemical structure but behave in very different ways because they have different side groups. Hence, stringing them together in different combinations produces very different proteins.

When 2 amino acids are joined together **(condensation)** the amino group from one and the acid group from another form a bond, producing one molecule of water. The bond formed is called a **peptide bond**.

Hydrolysis is the opposite of condensation and is the breaking of a peptide bond using a molecule of water.

Fibrous proteins are made of long molecules arranged to form fibres (e.g. in keratin). Several helices may be wound around each other to form very strong fibres.

Globular proteins are made of chains folded into a compact structure. One of the most important classes are the enzymes. Although these folds are less regular than in a helix, they are highly specific and a particular protein will always be folded in the same way. If the structure is disrupted, the protein ceases to function properly and is said to be denatured.

If a protein is made up of several polypeptide chains, the way they are arranged is called the **quaternary structure**. Again, each protein formed has a precise and specific shape (e.g. haemoglobin)

Functions of proteins

1. Virtually all enzymes are proteins.
2. **Structural:** e.g. collagen and elastin in connective tissue, keratin in skin, hair and nails.
3. **Contractile proteins:** actin and myosin in muscles allow contraction and therefore movement.
4. **Hormones:** many hormones have a protein structure (e.g. insulin, glucagon, growth hormone).
5. **Transport:** for example, haemoglobin facilitates the transport of oxygen around the body, a type of albumin in the blood transports fatty acids.
6. **Transport into and out of cells:** carrier and channel proteins in the cell membrane regulate movement across it.
7. **Defence:** immunoglobulins (antibodies) protect the body against foreign invaders; fibrinogen in the blood is vital for the clotting process.

Enzymes

The majority of the reactions that occur in living organisms are **enzyme-controlled.** Enzymes are **proteins** and thus have a specific shape. They are therefore specific in the reactions that they catalyse - one enzyme will react with molecules of one **substrate**.

The site of the reaction occurs in an area on the surface of the protein called the **active site.**

Enzyme Controlled Reactions

Reactions proceed because the products have less energy than the substrates.

However, most substrates require an input of energy to get the reaction going, (the reaction is not spontaneous).

The energy required to initiate the reaction is called the **activation energy.**

When the substrate(s) react, they need to form a complex called the transition state before the reaction actually occurs. This **transition state** has a higher energy level than either the substrates or the product.

Factors Affecting the Rate of Reaction

1. Temperature
2. pH
3. Enzume Concentration
4. Substrate Concentration

Cofactors

Most enzymes require additional help from cofactors, of which there are 2 main types:

1. **Coenzymes** - these are organic compounds, often containing a vitamin molecule as part of their structure.
2. **Metal ions** - most speed up the formation of the enzyme-substrate complex by altering the charge in the active site e.g. amylase requires chloride ions, catalase requires iron.

Inhibitors

Inhibitors slow down the rate of a reaction. Sometimes this is a necessary way of making sure that the reaction does not proceed too fast, at other times, it is undesirable.

Reversible Inhibitors:

Competitive reversible inhibitors

Non-competitive reversible inhibitors

Irreversible Inhibitors:

These molecules bind permanently with the enzyme molecule and so effectively reduce the enzyme concentration, thus limiting the rate of reaction, for example, cyanide irreversibly inhibits the enzyme cytochrome oxidase found in the electron transport chain used in respiration. If this cannot be used, death will occur.

Chromatography

This technique separates out mixtures of chemicals by using their different solubilities in certain solvents.

Cells and Organelles

Cells

The cell is the basic unit of an organism and consists of a jelly-like material surrounded by a cell membrane.

It can be seen with a light microscope (LM) but many of the structures within a cell - **organelles** - can only be seen clearly with an electron microscope (EM). That is partly because an EM has a greater magnifying power (ability to enlarge something).

Prokaryotic and eukaryotic cells

There are 2 basic cell types:

Prokaryotic: bacteria and cyanobacteria (which used to be called blue-green algae).

Eukaryotic: all other cells, such as protoctista, fungi, plant and animal cells.

Organelles

Much of what you will need to know applies to the structure of **eukaryotic cells**. They are characterised by having membrane-bound organelles.

Cytosol and Endoplasmic Reticulum (ER)

Cytoplasm refers to the jelly-like material with organelles in it.

If the organelles were removed, the soluble part that would be left is called the **cytosol**. It consists mainly of water with dissolved substances such as amino acids in it.

Also present in the cytosol are larger proteins and enzymes used in reactions within the cell. Running through the cytosol is **endoplasmic reticulum (ER)**, a system of flattened cavities lined by a thin membrane. It is the site of the synthesis of many substances in the cell and so provides a compartmentalised area in which this takes place. The cavities also function as a transporting system whereby substances can move through them from one part of the cell to another.

There are 2 types of ER:

Rough (RER): looks rough on the surface because it is studded with very small organelles called ribosomes. Ribosomes are made of RNA and protein and are the site of protein synthesis

Smooth (SER): obviously looks as though it has a smooth surface. It is where lipids and steroids are made so you would expect there to be a lot of SER in liver cells where lipid is metabolised.

Golgi apparatus

The **Golgi apparatus** is a series of flattened layers of plate-like membranes.

The proteins that are made by the RER for export from the cell are pinched off at the end of the cavity of the RER, so that a layer of membrane surrounds them. The whole structure is called a **vesicle**. This vesicle will move through the cytosol and fuse with the membrane of the Golgi apparatus.

In the cavity of the Golgi apparatus, the vessel proteins are modified for export - for example, by having a carbohydrate added to the protein. At the end of a Golgi cavity, the secretory product is pinched off so that the vesicle containing the substance can move through the cytosol to the cell surface membrane.

The vesicle will fuse with this membrane and so release the secretory product. If the vesicle contains digestive enzymes, it is called a **lysosome**. Lysosomes may be used inside the cell during endocytosis, or to break-down old, redundant organelles.

Mitochondria

A typical cell may contain 1,000 mitochondria, though some will contain many more. Generally, they are sausage-shaped organelles whose walls consist of 2 membranes.

The inner membrane is folded inwards to form projections called **cristae**. Inside this is the matrix.

Most of the reactions for aerobic respiration take place in the mitochondria so it is an incredibly important organelle.

Cell wall and chloroplasts

These are only found in plant cells. **Chloroplasts** like the mitochondria - have an envelope of two membranes making up the outer "wall".

They have pairs of membranes called **thylakoids** arranged in stacks, each stack being called a **granum**. Connecting different grana together are inter-granal thylakoids. Surrounding the internal membranes, inside the envelope is the**stroma**.

The reactions of photosynthesis take place in the membranes and stroma of the chloroplast.

Nucleus

The **nucleus** is separated from the surrounding cytoplasm by the double membrane around it, the nuclear envelope. This regulates the flow of substances into and out of the nucleus.

Other organelles

Vacuole: fluid-filled space in the cytoplasm surrounded by a membrane called the tonoplast; contain a solution of sugars and salts called the cell sap.

Microtubules: hollow rod-like structures with walls of tubulin protein. Provide the structural support of cells and can aid transport through the cell.

Microfilaments: rod-like structures made of contractile protein. Again, like microtubules, provide support and aid movement.

Centrioles: a pair of short hollow cylinders, usually found near the nucleus of an animal cell. They are involved in the formation of spindle fibres used in mitosis.

Cilia: hollow tubes extending outside some cells. They move fluid, which is outside the cell - for example, ciliated cells lining the respiratory tract move mucus, away from the lungs.

Flagella: similar to cilia, though longer. Used in the movement of the whole cell. The only structure like this in humans is the tails of the sperm.

The Cell Membrane

Much of the membrane is made up of a 'sea' of **phospholipids** with protein molecules 'floating' in between the phospholipids. Some of these proteins span the whole width of the membrane.

Because the membrane is fluid, and because of the mosaic arrangement of the protein molecules, the structure of the membrane is called the **fluid mosaic model.**

The phospholipids are arranged in two layers **(a bilayer)**. The phosphate heads are polar molecules and so are water-soluble. The lipid tails are non-polar and therefore are not water-soluble.

Functions of a membrane it's:

1. Selectively permeable barrier.
2. Structural, keeping the cell contents together
3. Allows communication with other cells
4. Allows recognition of other external substances
5. Allows mobility in some organisms, e.g. amoeba
6. The site of various chemical reactions.

Movement

It is important that the cell is supplied with all the substances it needs (e.g. oxygen) and that waste substances (e.g. carbon dioxide), or substances for export, leave the cell. There are various processes by which this can happen...

Diffusion

This is the process that is used in oxygen entering a cell, and carbon dioxide leaving.

These molecules will move from where they are at a high concentration to where they are at a lower concentration. i.e. they diffuse down a concentration gradient.

Fick's Law

Fick's law is used to measure the rate of diffusion.

Osmosis

This is a special case of diffusion in which we are concerned only with the movement of water.

Water potential

This is a measure of the tendency of water molecules to move from one place to another.

The movement of water molecules from a region of higher water potential to a region of lower water potential through a semi-permeable membrane.

Solute potential and pressure potential

The water potential of a cell is dependent upon the combination of its solute and pressure potentials.

Osmosis in animal and plant cells

If the water potential surrounding an animal cell is higher than that of the cell, it will gain water, swell and burst. If the surrounding solution's water potential is lower than that of the cell, it will lose water and shrivel up. This is why it is so important to maintain constant water potential inside the bodies of animals.

In animal Cells:

Water potential = Solute potential

In Plant Cells:

Water potential = Solute potential + Pressure potential

Facilitated diffusion

If charged particles or large molecules are to move across the membrane, another process needs to be found, as they are less soluble (or even insoluble) in lipid. They move through protein-lined pores.

Channel proteins: These line a water-filled pore in the membrane so water-soluble molecules can easily pass through. Different channels allow different substances to pass through (the channels are selective). Some channels are gated (they will only open when appropriately stimulated).

Carrier proteins: In this case, the substance actually combines with a protein and is carried from one side of the membrane to the other. (The exact details of this process remain unclear.) These proteins are specific for a particular substance.

In both these cases, substances are moving down the concentration gradient so no energy is required.

Active transport

Sometimes substances need to be moved from where they are at a lower concentration to where they are at a higher concentration - against the concentration gradient. This allows cells to take up essential molecules even when they are at a low concentration outside.

Because molecules are moved against the concentration gradient, it requires energy. It is thought that **active transport** uses carrier proteins similar to those involved in facilitated diffusion.

Endocytosis and exocytosis

If very large molecules or groups of molecules need to enter or exit a cell, they do so using **vesicles**.

The material to be transported out of the cell is surrounded by membrane. The vesicle will fuse with the cell surface membrane and the contents leave. This is called **exocytosis**.

Materials entering the cell can do so when the plasma membrane invaginates to surround the material. The membrane seals off to form a vesicle, which can then move into the cell. This is **endocytosis.**

If the material is fluid, minute vesicles are formed. This type of endocytosis is called **pinocytosis.**

If the material is relatively large, and is digested by enzymes after fusion of the vesicle with a lysosome, it is called **phagocytosis**. This occurs in white blood cells that ingest bacteria and other foreign bodies.

Tissues

A **tissue** is defined as a collection of cells, together with any extracellular secretion, that is specialised to perform one or more particular function. Tissues may contain only one type of cell, or several types.

Examples:

Epithelial tissues are animal tissues and form sheets covering surfaces. Two tissues that you need to know about are squamous and **ciliated epithelia**. Both are one cell thick and so are called **simple epithelia**. The cells rest on a basement membrane which is a network of collagen and glycoproteins that is secreted by cells underneath the epithelial tissue.

Squamous epithelia: In this tissue, the cells are of one type and are smooth, flat and very thin. They are packed closely together like tiles on a roof and provide a low friction surface over which fluids can move. It is found lining the cheeks, inside blood vessels, lining the chambers of the heart and forms the alveoli in the lungs.

Ciliated epithelia: This tissue is made up of cells with cilia and so is often found in areas where it is needed to transport something - for example, lining the oviducts and bronchioles of the lungs. Sometimes the cells are shaped like cubes and the tissue is called cuboidal ciliated epithelia. If the cells are tall and narrow, it is referred to as columnar ciliated epithelia.

Xylem and phloem: These two plant tissues differ from the above examples in that they are made up of more than one cell type. Xylem has the dual function of support of the plant and transport of water and dissolved

mineral salts. It is made up of vessel elements, tracheids, fibres and parenchyma cells. Phloem tissue is responsible for translocation which is the transport of soluble organic substances - for example, sugar.

Palisade mesophyll: This tissue is found in the leaf and is made up of one type of cell. The cells are tall and thin and are tightly packed together. Their function is to harness the light energy required for photosynthesis and so each cell is packed with chloroplasts.

Organs: An organ is part of the body which, forms a structurally and functionally separate unit and is made up of more than one type of tissue. Examples of plant organs are leaves, roots and stems. Examples of animal organs are the liver, brain, heart and kidney. Organs may be organised into groups with particular functions and are then called **systems** - for example, the digestive system.

Classification

Kingdoms

All living organisms are classified into different groups.

The 5 kingdoms are called:

1. Monera (also known as 'Prokaryota')
2. Protocista
3. Fungi
4. Plantae
5. Animalia

The way the kingdom is broken down is as follows:

A number of species make up a **genus.**

A number of genera make up a **family.**

A number of families make up an **order.**

A number of orders make up a **class.**

A number of classes make up a **phylum.**

A number of phyla make up a **kingdom.**

Species

The **species** is the lowest level of classification within each Kingdom. All members of a species are capable of interbreeding to produce fertile offspring. They have a particular set of characteristics.

Genus

A **genus** is a group of similar or closely related species.

The Animalia Kingdom

Some examples of classifications within the Animalia Kingdom:

Kingdom e.g.Animalia

Phylum e.g Chordata

Class e.g Mammalia

Order e.g. Primates

Family e.g. Homindae

Genus e.g Homo

Species e.g. Sapiens

Useful tip: Use the following sentence to prompt you for the first letter for each classification below Kingdom:

Please **C**ool **O**ff, **F**or **G**oodness **S**ake!

Body Plans

A **body plan** can be thought of as a cross-section through an animal, showing only the most fundamental arrangement of the tissue layers. It does not show any detail, such as the position of the internal organs.

Three main body plans:

Diploblastic acoelomate

Triploblastic acoelomate

Triploblastic coelomate

Phyla of the Animal Kingdom

For each phylum it is important to know:

General features.

The classification of one member species.

Gas Exchange

General Principles for Efficient Gas Exchange

Different organisms have different mechanisms for obtaining the gases they require.

Diffusion is required to supply all organisms with oxygen.

The efficiency of diffusion is increased if there is:

1. A large surface area over which exchange can take place.
2. A concentration gradient without which nothing will diffuse.
3. A thin surface across which gases diffuse.

Fick's Law

Fick's law is used to measure the rate of diffusion.

The larger the area and difference in concentration and the thinner the surface, the quicker the rate.

Unicellular organisms

Unicellular Organisms do not have specialised gas exchange surfaces. Instead gases diffuse in through the cell membrane.

The smaller something is, the smaller the surface area is but, more importantly, the bigger the surface area is compared to its volume.

Multicellular organisms

Multicellular Organisms are bigger than Unicellular organisms. This makes efficient diffusion of gases more difficult.

However, if they are small, or large but very thin (like the flatworms, Platyhelminths), the outer surface of the body is sufficient as an exchange surface because the surface area to volume ratio is still high.

Gas Exchange in Plants

Plants obtain the gases they need through their leaves. They require **oxygen for respiration** and **carbon dioxide for photosynthesis**.

The gases diffuse into the intercellular spaces of the leaf through pores, which are normally on the underside of the leaf - **stomata**. From these spaces they will diffuse into the cells that require them.

Gas Exchange in Insects

Insects have no transport system so gases need to be transported directly to the respiring tissues.

There are tiny holes called **spiracles** along the side of the insect.

The spiracles are openings of small tubes running into the insect's body, the larger ones being called **tracheae** and the smaller ones being called **tracheoles**.

The ends of these tubes, which are in contact with individual cells, contain a small amount of fluid in which the gases are dissolved. The fluid is drawn into the muscle tissue during exercise. This increases the surface area of air in contact with the cells. Gases diffuse in through the spiracles and down the tracheae and tracheoles.

Ventilation movements of the body during exercise may help this diffusion.

The spiracles can be closed by valves and may be surrounded by tiny hairs. These help keep humidity around the opening, ensure there is a lower concentration gradient of water vapour, and so less is lost from the insect by evaporation.

Gas Exchange in Fish

Fish use **gills** for gas exchange. Gills have numerous folds that give them a very large surface area.

The rows of gill filaments have many protrusions called **gill lamellae**. The folds are kept supported and moist by the water that is continually pumped through the mouth and over the gills.

Gas Exchange in Humans

The gas exchange surface of a mammal is the **alveolus**.

There are numerous **alveoli** - air sacs, supplied with gases via a system of tubes (**trachea**, splitting into two **bronchi** - one for each lung - and numerous **bronchioles**) connected to the outside by the mouth and nose.

These **alveoli** provide a massive surface area through which gases can diffuse. These gases diffuse a very short distance between the alveolus and the blood because the lining of the lung and the capillary are both only one cell thick.

The blood supply is extensive, which means that oxygen is carried away to the cells as soon as it has diffused into the blood. Ventilation movements also maintain the concentration gradients because air is regularly moving in and out of the lungs.

This breathing in **(inspiration)** and breathing out **(expiration)** is controlled via nervous impulses from the respiratory centre in the medulla of the brain.

Both the intercostal muscles (in between the ribs) and the diaphragm receive impulses from the respiratory centre. Stretch receptors in the lungs send impulses to the respiratory centre in the brain giving information about the state of the lungs.

Chemoreceptors

There are also **chemoreceptors** in the medulla and certain blood vessels that are sensitive to changes in carbon dioxide levels in the blood.

Photosynthesis

Photosynthesis

Chlorophyll absorbs light from the visible part of the electromagnetic part of the spectrum, but there are several types of chlorophyll...

chlorophyll a

chlorophyll b

chlorophyll c

bacteriochlorophyll (found in photosynthetic bacteria!)

There are also other families of pigments, such as the carotenoids.

Not all wavelengths of light are equally absorbed and different chlorophylls absorb more strongly in different parts of the visible spectrum.

Photosystems

The pigments are arranged in funnel shaped **photosystems** that sit on the thylakoid membranes in the chloroplasts.

In each photosystem, several hundred pigment molecules, called **accessory pigments**, are clustered around a particular pigment molecule, known as the primary pigment.

The various accessory pigments absorb light of different wavelengths and pass the energy down the photosystem. Eventually the energy reaches the primary pigment that acts as a reaction centre.

There are 2 types of photosystem:

Photosystem One - PS I:

Its primary pigment is a molecule of **chlorophyll a** with an absorption peak at 700nm. It is called **P700**

Photosystem Two - PS II:

Its primary pigment is a molecule of **chlorophyll b** with an absorption peak at 680nm. It is called **P680**

Light Dependant Reactions

The first reactions of photosynthesis require light energy, and are called **light dependant reactions.**

The aim is to produce ATP from ADP and inorganic P and harvest hydrogen so that carbon dioxide can be reduced to form a carbohydrate in the second series of reactions. The production of ATP using light is called **photophosphorylation**.

Light-Independent Reactions

Calvin cycle

These reactions can occur in the light or the dark. They need ATP for energy to drive the reactions, and they need NADPH for reducing power. They occur in the stroma of the chloroplast and are called the **Calvin cycle**.

Nutrition and Digestion

Nutrition

The whole point of **nutrition** is to obtain a source of **energy** and of **carbon**. This allows cell processes to continue and for growth and repair to take place. Obtaining this energy and carbon is done in a variety of ways by different organisms.

Types of nutrition

The following is a selection of the different types of nutrition which living things use:

Autotrophic means self-feeder, i.e. they produce their own food out of raw materials.

Heterotrophic means that they feed on other organisms that have made their own food.

Photoautotrophic:	e.g. plants and algae. Light is the primary source of energy. Carbon dioxide is the primary source of carbon.
Chemoautotrophic:	e.g. some bacteria. A chemical is the primary source of energy and the carbon source may be organic or inorganic.
Chemoheterotrophic:	e.g. animals, fungi, and most protoctista. Their energy and carbon source is often glucose.

Within the chemoheterotrophs there may be:

Saprotrophic nutrition:	e.g. fungi. They feed on the soluble organic matter from dead organisms. Enzymes are secreted onto the dead organism to digest the large molecules so digestion is external. The small molecules are absorbed and then transported within the fungus.
Parasitic nutrition:	e.g. tapeworm. They feed on already digested food (digested by the host of the endoparasite). The parasite therefore produces no enzymes and needs no gut system. Small molecules are absorbed over the body surface.
Holozoic nutrition:	e.g. many animals and carnivorous plants. They feed on solid organic matter from a living or dead organism. They therefore will need to be able to catch or obtain and produce enzymes to digest their food.

Food must be:

Ingested

Masticated

Digested

Absorbed

Egested

Human Digestive System

Tissue layers of the gut wall

The **submucosa** contains nerves, blood and lymph vessels, collagen and elastic fibres.

The nerves regulate:

The gut movements by muscle contractions to force the food along or to mix the food with secretions in a particular region.

The digestive secretions into the lumen of the gut.

Mouth and saliva

Even before food enters the mouth the sight, smell and thought of the food stimulates a conditional reflex that results in the release of **saliva** into the mouth.

When food enters the mouth, the stimulation of the taste buds results in an **unconditional reflex**, whereby impulses are relayed to the brain via sensory neurones and then via motor neurones to the salivary glands. Again, releasing saliva.

1 - 1.5 litres of saliva is released each day.

The saliva contains **mucus**, which lubricates the food, mineral salts to activate enzymes, lysozyme which kills bacteria entering with the food, and amylase, an enzyme that breaks down starch into shorter polysaccharides and then into maltose.

Chewing mechanically breaks up the food so that there is a larger surface over which the amylase can work. The food and saliva mixture is pushed into a ball called a **bolus** and swallowed.

Oesophagus

The **oesophagus** is a muscular tube with a squamous epithelium lining and mucus glands to lubricate the passageway down to the stomach.

Peristalsis moves the food down and when the food reaches the lower portion of the tube, the circular muscle making up the **sphincter** (a muscular ring controlling the passage of food between consecutive sections of the gut) relaxes and opens.

With no food present, the sphincter remains closed so that no acid can enter and burn the oesophagus.

Duodenum

Most chemical digestion by enzymes takes place in the **duodenum**.

The **mucosa**is folded and the millions of microscopic projections created by this folding of the inner surface of the wall are called **villi**. In between the villi are intestinal glands (or crypts of Leiberkuhn) which secrete intestinal juice.

The possession of the villi and the folds in the cell surface membranes of the epithelial cells lining the villi (microvilli) massively increases the surface area.

Transport

Comparison of Transport in Mammals and Plants

If an organism is small and has a large surface area to volume ratio, all the nutrients and respiratory gases can be taken in by **diffusion** across the body surface.

Most multicellular plants and animals have too small a surface area to volume ratio so diffusion would be too slow to provide the necessary molecules. Therefore, they require a system to transport nutrients and waste products around the organism.

The needs of a plant and animal are similar in some aspects and very different in others.

Both need to transport food molecules around the organism but plants, for instance, do not use the transport system to fight disease.

Transport in Plants

Two main types of plant tissue are used in transport - **xylem** and **phloem**. Xylem transports water and minerals. Phloem transports organic molecules such as the products of photosynthesis.

Xylem

There are four types of xylem cells:

Xylem vessels

Tracheids

Parenchyma

Fibres

Phloem

There are four types of phloem cells:

Sieve tube elements

Companion cell

Parenchyma

Fibres

Transport in Mammals

In mammals, the pump is the heart. Substances are carried in a transport medium of the blood. The blood is contained within vessels, with substances being released out of, or into the blood as it flows through certain vessels called **capillaries.**

Blood vessels

Blood is carried within a closed transport system that is made up of three types of vessel:

Arteries carry blood away from the heart.

Capillaries are the site of the exchange of materials between the blood and tissues.

Veins take blood back into the heart.

Blood

Just over half of the blood volume is made up of a pale yellow fluid called **plasma**. The rest of the blood is made up of cells (red blood cells and white blood cells) and platelets.

Blood has several vital functions:

Transport

Defence

Formation of lymph and tissue fluid.

Homeostasis

Red Blood Cells

Also known as **erythrocytes**. These contain a pigment, haemoglobin, which gives them their colour.

Red blood cells are made in the bone marrow (the liver in a foetus) of many bones.

Being like a biconcave disc in shape, the surface area to volume ratio is very large. Oxygen can therefore diffuse very quickly into the cell and because the cell is so small, quickly bind to a haemoglobin molecule.

White Blood Cells

These cells all have a nucleus; most are much larger than red blood cells and are spherical or irregular in shape.

There are two basic types of white blood cells; the **granulocytes** (they have granular cytoplasm and lobed nuclei) and **agranulocytes** (the cytoplasm appears smooth and the nucleus is rounded or horseshoe in shape).

Platelets

These are formed in the **bone marrow** and are fragments of larger cells. They have no nucleus but reactions do take place in the **cytoplasm**.

They have a variety of role such as **blood clotting** and the production of **prostaglandins** that regulate the degree of constriction or dilation in blood vessels.

Blood groups

The most commonly required blood-grouping system is the **ABO system**. It concerns two antigens that can occur on the surface of red blood cells. The antigens are called **agglutinogens** in this case and are: agglutinogen A and agglutinogen B.

Plasma also contains antigens, called **agglutinins** in this case, and they are agglutinin A and agglutinin B.

Blood transfusions

It is important to match blood correctly so that agglutinins in the recipient don't clump the red blood cells of the donor.

In transfusions it is important to remember that the volume of blood donated is relatively small compared to the volume of the recipient's blood. The agglutinins in the plasma from the donor are so diluted that no harm is done. However the aggluinogens on the red blood cells are not so diluted so harm can be done.

Oxygen carriage

Oxygen does dissolve in plasma but the solubility is low and decreases further if the temperature increases. The amount that could be carried by the plasma therefore would be completely insufficient to supply all cells.

The Heart

The structure is closely related to its function.

Mammals have a **double circulation**, which means that the right hand side of the heart pumps deoxygenated blood to the lungs in the pulmonary artery to pick up oxygen and release carbon dioxide. The oxygenated blood then returns to the left hand side of the heart in the **pulmonary vein**.

From there the blood is pumped to the body in the aorta, eventually returning to the right hand side of the heart in the **vena cava** to start the cycle again.

Since the right side pumps to the lungs which are situated close to the heart, the walls are much thinner than the left side which has to pump blood out of the heart to the body.

The heart has 4 chambers:

2 on the left hand side

2 on the right hand side

Atrium: the top chamber on each side

Ventricle: the bottom chamber on each side

The muscle of the heart is called **cardiac muscle** and is made of tightly connecting cells.

The cardiac cycle

One cardiac cycle consists of the atria and then the ventricles contracting so that the blood that has entered the heart is pumped out. This occurs about 70 times every minute and is continuous. The periods of contraction are called **systole**. The periods of relaxation are called **diastole**.

Regulation of the cardiac cycle by the heart itself

The heartbeat is initiated in a specialised area of muscle in the right atrium called the **sinoatrial node (SAN)** or the pacemaker. The SAN starts the waves of depolarisation, which results in contraction.

Nutrition and Digestion

Nutrition

The whole point of **nutrition** is to obtain a source of **energy** and of **carbon**. This allows cell processes to continue and for growth and repair to take place. Obtaining this energy and carbon is done in a variety of ways by different organisms.

Types of nutrition

The following is a selection of the different types of nutrition which living things use:

Autotrophic means self-feeder, i.e. they produce their own food out of raw materials.

Heterotrophic means that they feed on other organisms that have made their own food.

Photoautotrophic:	e.g. plants and algae. Light is the primary source of energy. Carbon dioxide is the primary source of carbon.
Chemoautotrophic:	e.g. some bacteria. A chemical is the primary source of energy and the carbon source may be organic or inorganic.
Chemoheterotrophic:	e.g. animals, fungi, and most protoctista. Their energy and carbon source is often glucose.

Within the chemoheterotrophs there may be:

Saprotrophic nutrition:	e.g. fungi. They feed on the soluble organic matter from dead organisms. Enzymes are secreted onto the dead organism to digest the large molecules so digestion is external. The small molecules are absorbed and then transported within the fungus.
Parasitic nutrition:	e.g. tapeworm. They feed on already digested food (digested by the host of the endoparasite). The parasite therefore produces no enzymes and needs no gut system. Small molecules are absorbed over the body surface.
Holozoic nutrition:	e.g. many animals and carnivorous plants. They feed on solid organic matter from a living or dead organism. They therefore will need to be able to catch or obtain and produce enzymes to digest their food.

Ingested

Masticated

Digested

Absorbed

Egested

Human Digestive System

Tissue layers of the gut wall

The **submucosa** contains nerves, blood and lymph vessels, collagen and elastic fibres.

The nerves regulate:

The gut movements by muscle contractions to force the food along or to mix the food with secretions in a particular region.

The digestive secretions into the lumen of the gut.

Mouth and saliva

Even before food enters the mouth the sight, smell and thought of the food stimulates a conditional reflex that results in the release of **saliva** into the mouth.

When food enters the mouth, the stimulation of the taste buds results in an **unconditional reflex**, whereby impulses are relayed to the brain via sensory neurones and then via motor neurones to the salivary glands. Again, releasing saliva.

1 - 1.5 litres of saliva is released each day.

The saliva contains **mucus**, which lubricates the food, mineral salts to activate enzymes, lysozyme which kills bacteria entering with the food, and amylase, an enzyme that breaks down starch into shorter polysaccharides and then into maltose.

Chewing mechanically breaks up the food so that there is a larger surface over which the amylase can work. The food and saliva mixture is pushed into a ball called a **bolus** and swallowed.

Oesophagus

The **oesophagus** is a muscular tube with a squamous epithelium lining and mucus glands to lubricate the passageway down to the stomach.

Peristalsis moves the food down and when the food reaches the lower portion of the tube, the circular muscle making up the **sphincter** (a muscular ring controlling the passage of food between consecutive sections of the gut) relaxes and opens.

With no food present, the sphincter remains closed so that no acid can enter and burn the oesophagus.

Duodenum

Most chemical digestion by enzymes takes place in the **duodenum**.

The **mucosa**is folded and the millions of microscopic projections created by this folding of the inner surface of the wall are called **villi**. In between the villi are intestinal glands (or crypts of Leiberkuhn) which secrete intestinal juice.

The possession of the villi and the folds in the cell surface membranes of the epithelial cells lining the villi (microvilli) massively increases the surface area.

Transport

Comparison of Transport in Mammals and Plants

If an organism is small and has a large surface area to volume ratio, all the nutrients and respiratory gases can be taken in by **diffusion** across the body surface.

Most multicellular plants and animals have too small a surface area to volume ratio so diffusion would be too slow to provide the necessary molecules. Therefore, they require a system to transport nutrients and waste products around the organism.

The needs of a plant and animal are similar in some aspects and very different in others.

Both need to transport food molecules around the organism but plants, for instance, do not use the transport system to fight disease.

Transport in Plants

Two main types of plant tissue are used in transport - **xylem** and **phloem**. Xylem transports water and minerals. Phloem transports organic molecules such as the products of photosynthesis.

Xylem

There are four types of xylem cells:

Xylem vessels

Tracheids

Parenchyma

Fibres

Phloem

There are four types of phloem cells:

Sieve tube elements

Companion cell

Parenchyma

Fibres

Transport in Mammals

In mammals, the pump is the heart. Substances are carried in a transport medium of the blood. The blood is contained within vessels, with substances being released out of, or into the blood as it flows through certain vessels called **capillaries.**

Blood vessels

Blood is carried within a closed transport system that is made up of three types of vessel:

Arteries carry blood away from the heart.

Capillaries are the site of the exchange of materials between the blood and tissues.

Veins take blood back into the heart.

Blood

Just over half of the blood volume is made up of a pale yellow fluid called **plasma**. The rest of the blood is made up of cells (red blood cells and white blood cells) and platelets.

Blood has several vital functions:

Transport

Defence

Formation of lymph and tissue fluid.

Homeostasis

Red Blood Cells

Also known as **erythrocytes**. These contain a pigment, haemoglobin, which gives them their colour.

Red blood cells are made in the bone marrow (the liver in a foetus) of many bones.

Being like a biconcave disc in shape, the surface area to volume ratio is very large. Oxygen can therefore diffuse very quickly into the cell and because the cell is so small, quickly bind to a haemoglobin molecule.

White Blood Cells

These cells all have a nucleus; most are much larger than red blood cells and are spherical or irregular in shape.

There are two basic types of white blood cells; the **granulocytes** (they have granular cytoplasm and lobed nuclei) and **agranulocytes** (the cytoplasm appears smooth and the nucleus is rounded or horseshoe in shape).

Platelets

These are formed in the **bone marrow** and are fragments of larger cells. They have no nucleus but reactions do take place in the **cytoplasm**.

They have a variety of role such as **blood clotting** and the production of **prostaglandins** that regulate the degree of constriction or dilation in blood vessels.

Blood groups

The most commonly required blood-grouping system is the **ABO system**. It concerns two antigens that can occur on the surface of red blood cells. The antigens are called **agglutinogens** in this case and are: agglutinogen A and agglutinogen B.

Plasma also contains antigens, called **agglutinins** in this case, and they are agglutinin A and agglutinin B.

Blood transfusions

It is important to match blood correctly so that agglutinins in the recipient don't clump the red blood cells of the donor.

In transfusions it is important to remember that the volume of blood donated is relatively small compared to the volume of the recipient's blood. The agglutinins in the plasma from the donor are so diluted that no harm is done. However the aggluinogens on the red blood cells are not so diluted so harm can be done.

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Reproduction

The Cell Cycle

Interphase

DNA replicates as **mitosis**.

Prophase I

Homologous chromosomes condense (**synapsis**) to form bivalents. The chromatids become coiled around each other. As the chromosomes pair up (**homologous**), the twisting produces tension, and sometimes sections of chromatid may break and exchange new partners with corresponding sections of different chromatids. These breakage points result in **"cross-overs"** or **Chiasmata**.

Metaphase I

The bivalents move to the equator of the cell. Which pair of chromosomes orientates to which pole is completely random (called **random assortment**.)

Anaphase I

The pairs of bivalents separate into chromatid pairs, each pair of chromatid is pulled to a pole.

Note: Unlike mitosis, there is no division of the centromeres at this stage.

Telophase I

The pairs of chromatids reach their respective poles, the cell divides.

Prophase II

New spindle is formed and the centrioles have replicated. Nuclear membrane disintegrates.

Metaphase II

The pairs of chromatids line themselves up on the equator as in mitosis, with sister chromatids orientated toward opposite poles.

Anaphase II

The centromeres divide and the chromatids separate, migrating to opposite poles.

Telophase II

The cell divides. Nuclear membranes and nucleoli are reformed. The chromosomes uncoil and go into interphase. The daughter cells have half the number of chromosomes present in the original cell.

Sexual Reproduction in Flowering Plants

Most exam boards only require knowledge about reproduction in **Angiosperms** - the flowering plants.

Flower structure

Sexual reproduction in flowering plants centres on the flower. Within a flower, there are usually structures that produce both male gametes and female gametes.

Development of the ovule and female gamete

Inside the ovary there may develop one or more **ovules**. Each ovule begins life as a small projection into the cavity of the ovary. As it grows and develops it begins to bend but remains attached to the ovary wall by a **placenta**.

At the start, the ovule is a group of similar cells called **the nucellus** . As it develops, the mass of cells differentiates to form an inner and an outer integument, surrounding and protecting the nucellus within, but leaving a small opening called the **micropyle** .

At the centre of the ovule is an embryo sac containing the haploid egg cell (the **female gamete**).

Development of the male gamete

Each anther contains 4 **pollen sacs**. Many pollen grains develop inside each pollen sac. It begins with a mass of large pollen mother cells in each pollen sac. All are **diploid**.

In each pollen grain the wall thickens and forms an inner layer (**the intine**) and an often highly sculptured outer layer (**the exine**). The surface pattern is different on pollen grains from different species. When the pollen grains are mature, the anther dries out and splits open (a process called **dehiscence**) and the pollen is released.

Pollination

Many plants favour **cross-pollination**, so pollen must be transferred to the stigma of another plant if sexual reproduction is to take place. Some flowers rely of the wind to carry pollen grains others rely on insects.

Self-pollination is where the pollen is transferred to the stigmas of the same flower or the stigma of another flower on the same plant. Self-pollination is obviously more reliable, particularly if the nearest plant is not very close.

Fertilisation

If the pollen grain lands on a compatible stigma, a pollen tube will grow so that eventually the egg cell, hidden away in the embryo sac, can be **fertilised**. A tube emerges from the grain, its growth being controlled by the tube nucleus at the tip of the tube. It may grow downwards in response to chemicals made by the ovary (a response known as chemotropism).

Germination

When conditions are right, the seed will take up water through the micropyle by imbibition. This triggers the beginning of the growth of the seed.

The cell swells and the testa splits. With the addition of water, large molecules of carbohydrate, protein and fat can be hydrolysed (broken down) to produce substances for respiration.

Sexual Reproduction in Humans - The First Stages

Like in plants it is the male gamete that needs to be transferred to the female gamete. The female gamete is fertilised and develops inside the mother's body so the reproductive systems of both males and females are highly adapted for this.

Male reproductive system and sperm production

Production of sperm is called **spermatogenesis**. It takes place in the gonads of the male - **the testes**.

Each testis is composed of numerous tiny tubes called **seminiferous tubules**. It is in the walls of these tubules that sperm production actually takes place.

Development begins in the outer side of the wall in a layer of cells called **the germinal epithelium**.

Hormonal control of spermatogenesis

The control centres are the **pituitary gland** and the **hypothalamus** in the brain.

The hypothalamus secretes **GnRH (gonadotrophin releasing hormone)**. This is released into the blood and stimulates the anterior lobe of the pituitary gland.

The anterior lobe of the pituitary gland secretes **ICSH (interstitial cell stimulating hormone)**.

ICSH: this stimulates the leydig cells that produce testosterone.

FSH: this stimulates the seminiferous tubules, including the Sertoli cells. They produce sperm in response.

Note: Testosterone also acts on the seminiferous tubules and stimulates sperm production.

Female reproductive system and egg production

The production of eggs is called **oogenesis**. It takes place in the ovaries and begins before birth.

The outer layer of the ovary (the **germinal epithelium**) produces primary oocytes. It also produces follicle cells that congregate around the oocytes, forming a structure called the **primary follicle**.

Nervous and Hormonal Control

Nervous and Hormonal Control

Hormones

Hormones are just one of the tools used to send messages to the various parts of the body. They are usually small molecules made by a gland. They are secreted following a suitable stimulus and transported in the blood.

Blood carries hormones to a target organ or group of cells which will recognise the hormone (this triggers a specific chemical response when the correct receptor is activated). The behaviour of the target will then change, bringing about the right response.

Hormones need to combine with specific receptor molecules on, or in, a **target cell** to have an effect.

There are two structural types of hormone: protein and steroid

Protein hormones

Examples: insulin, glucagon, and adrenaline (try and remember these).

Protein hormone molecules bind with receptors on the surface of a cell membrane. This starts off a chain reaction inside the cell.

Steroid hormones

Examples: testosterone, oestrogen.

Steroid hormones are different to protein hormones in that they cross the cell surface membrane and bind to receptors in the cytoplasm. These hormone- receptor complexes then enter the nucleus.

The 'neurone'

The **nervous system** carries messages around the body using specialised cells called **neurones**. Neurones convey their 'messages' using electrical impulses.

The central nervous system and the peripheral nervous system

The nervous system (NS) is made up of two parts:

Central nervous system comprising the brain and spinal cord.

Peripheral nervous system.

The somatic (voluntary) and autonomic (involuntary) nervous system

Different areas of the nervous system are used for different types of nervous reaction:

Conscious control

Non-conscious control

Sensory neurones and motor neurones

Receptors are cells that detect stimuli - for example, heat, pressure, light.

Sensory neurones bring impulses from receptors to the central nervous system (CNS).

From there, the impulse may pass on to a **motor neurone** to be taken to a muscle or gland (the effector).

Sometimes there is an intermediate **neurone** (also known as a 'relay' neurone) within the CNS linking the sensory neurone with the motor neurone.

Formation and Transmission of Impulses

Resting potential

In the surface membrane of a cell there are **protein carriers.**

These actively pump Na^+ (Sodium) ions out of the cytoplasm to the outside of the cell. At the same time, K^+(Potassium) ions are pumped from the outside in.

Action potential

When a receptor is stimulated, it will create a **positive environment** inside the cell.

This is caused by a change in the concentrations of Na^+ and K^+ ions in the cell and happens in a number of steps.

Saltatory conduction

Generally cells are covered in a fatty myelin sheath and therefore the Na^+ and K^+ cannot flow through this. This means that the ions can only flow through unprotected cell-surface membrane.

In the case of a myelinated neurone, the ions can only move in and out of the cytoplasm at the nodes of Ranvier.

Because of this, the action potential will 'jump' from one node to the next; a process called **saltatory conduction**, and so will travel much faster than in an unmyelinated neurone.

Synapses

When an action potential reaches the end of one neurone there must be a way to start an action potential in the next neurone.

The two neurones will not be in direct contact and action potentials cannot jump across the gap, called a **synapse** (or synaptic cleft), so another method is employed...

Release of neurotransmitters

As you can see above, the electrical impulse cannot cross the **synaptic cleft**, so a chemical called a **neurotransmitter** is released at the end of the first neurone out of the presynaptic membrane. It diffuses across the synapse, binds with the second neurone on the postsynaptic membrane and generates an action potential.

Two examples of neurotransmitters are **acetylcholine (ACL)** and **noradrenaline**. They are synthesised in vesicles, which requires energy, so the synaptic knobs have many ATP-producing **mitochondria** in them.

Immunity

Self and non-self

On the surface of all cells are chemical markers (for example, proteins) called **antigens**.

Your body recognises the antigens on your cells as your own (self); anything with different antigens to you (non-self) stimulates an **immune response**.

In an immune response, your body will recognise the antigen as **foreign** (and therefore bad) and will attack it.

Infection and disease

Your immune system is made up of cells that work with the body's physical and chemical barriers. It helps prevent any **pathogen** (disease-causing organism) entering your body, and your body therefore becoming infected.

Note: Harmful bacteria are an example of a pathogen.

If the worst comes to the worst and any pathogens do get into your body, the immune system tries to stop them from causing harm.

Physical and chemical barriers

The first line of defence is made up of **physical** and **chemical barriers.**

These types of barriers are **non-specific** (i.e. if any organism is not recognised, it is assumed to be a pathogen, and will be treated the same way).

These barriers occur at the skin or any other openings to the outside world.

Here is a list of some physical and chemical barriers you should know to quote in your exams:

Physical Barriers

Skin: it is a hard outer layer that generally prevents the entry of any undesirables.

Nose, throat and digestive tract: the membrane lining these secretes sticky mucus to trap microbes. Fine hairs called cilia waft the mucus away.

Chemical Barriers

Eyes: tears have lysozyme enzyme in them. This kills some bacteria.

Ear: your wax has antimicrobial properties.

Stomach: hydrochloric acid in your stomach kills bacteria.

Large intestine, urethra and vagina: resident harmless bacteria use the nutrients that any harmful microbes would need to survive (i.e. harmless bacteria out-compete the harmful bacteria).

Sweat: is an acidic liquid that contains enzymes which kills some bacteria.

The Second Line of Defence

The second line of defence is also a non-specific response (i.e. the response is the same for any pathogen).

It is a 3-pronged attack on any microbes that have survived the first line of defence...

Attack no 1: Inflammation

Inflammation happens because cells damaged by invading pathogens and particular white blood cells release 'alarm' chemicals which makes blood vessels enlarge (vasodilate) and the capillaries more 'leaky'.

Attack no 2: Phagocytes and lymphocytes

Inflammation attracts white blood cells to the area.

The three types of white blood cell you need to know for your exam are **neutrophils, macrophages** (these are both phagocytes, which are engulfing cells), and **lymphocytes**.

The **phagocytes** (for example a neutrophil), having squeezed through the capillary wall and into the infected tissue, engulf and digest offending bacteria as shown in the following diagram...

Attack no 3: Macrophages and Interferon

Other than direct 'hand-to-hand' combat, some killing is done at a distance.

Macrophages make proteins that act in two ways:

1. They can punch holes in the bacteria and parasites so that they die.
2. Or the proteins can stick to the outside of the bacteria to make them more appealing for the phagocytes to eat!

If a virus or an intracellular parasite (one that lives inside a cell) has invaded a cell, the cell will make a chemical called interferon. Interferon ultimately prevents that cell from making molecules that the pathogen would need to survive.

Lymphocytes

The third line of defence depends on **lymphocytes**. There are two basic types of lymphocyte and both are made in bone marrow.

T Cells: mature after having first migrated from the bone marrow to the thymus gland. Involved in the cell-mediated response

B Cells: migrate to and then mature in either the bone marrow or in the foetal liver or spleen. Involved in the humoral response.

Cell-mediated response (T cells)

If an antigen is presented to a **T cell** with a **complementary shaped receptor**, the T cell is stimulated, increases in size and starts to divide.

A **clone** of identical T cells is formed, all with the correct shaped receptor. These T cells then differentiate to form 4 groups of specialised T cells. **These are:**

Killer T cells

Helper T cells

Suppressor T cells

Memory cells

Humoral response (B cells)

As with T cells, a B cell will form a clone if it comes into contact with a **complementary shaped antigen**. The clone contains mostly plasma cells for immediate use and some memory cells for use in the future.

Antibodies

The plasma cells are highly developed and are able to make several thousand **antibody molecules** every second.

Memory

Immunological memory

Plasma cells and most of T cells die after only a few days. However, the memory B cells and a few memory T cells survive.

Each plasma cell and T cell will only be programmed to only respond to the one antigen that they have already encountered. So they wait in the lymph nodes in case re-infection occurs, in which case they are ready to attack.

This way, although the first infection was dealt with in a few days to a few weeks by the primary response, the secondary response to re-infection is much quicker and much more powerful.

Artificial immunity - vaccines

Vaccine is small quantities of the antigen attached to the offending organism.

Natural Immunity

If the activation of the immune system occurs naturally during an infection, this is termed **natural immunity**. Because in response to the antigens, Band T cells have gone into action and a memory has been produced, it is also termed active immunity. **Vaccination would also be termed a form of active immunity**.

Antibiotics

These are drugs used to treat or cure infections and to be effective they must **kill** or **disable** the pathogen, leaving host cells unharmed. Most antibiotics are used to **treat bacterial** and **fungal infections**, there are very few that are effective against viruses. A few antibiotics are synthetic but most are derived from **living organisms**. They work by either interfering with the growth or metabolism of the bacteria or fungi. They may inhibit the synthesis of the cell wall, translation or transcription of proteins; interfere with membrane function or enzyme action.

Penicillins are well known antibiotics, which work by preventing the synthesis of peptidoglycan polymer cross links in the cell walls of bacteria. They are only effective when the organism is making new cell walls, i.e. growing.

Allergies

These are a result of an **overreaction of the immune system** to a harmless antigen, as in asthma, hay fever and eczema.

They are caused by **allergens** - for example, pollen, dust, particles of animal skin, dust mites and their faeces.

Homeostasis

Homeostasis

Homeostasis is the way the body maintains a stable internal environment. It is important for the body to have a stable environment for cells to function correctly.

There are several things that need to be regulated:

Body temperature

Amount of water within the body

The amount of glucose in the body

The amount of nitrogenous waste in the body

Temperature Control

The vast majority of organisms function between 10-35°C. There are basically two ways to regulate body temperature and we use these to categorise organisms:

1. **Homoiotherms:** These are organisms that that regulate their own body temperature internally. Their internal body temperature is independent of the external temperature. (Don't use the term 'warm-blooded').
2. **Poikilotherms:** These are organisms that cannot regulate their own body temperature internally. Their internal temperature fluctuates with the external temperature. (Don't use the term 'cold-blooded').

Homoiotherms (for example, you)

In your brain is there is an area called the **hypothalamus**. The hypothalamus has a thermo-regulatory centre and this detects the temperature of your blood. You also have thermo-receptors in your skin and these detect the temperature outside.

Water Levels and the Kidney

Controlling the level of water is linked to getting rid of nitrogenous waste so we'll deal with them both together. As mentioned before, nitrogenous waste would be toxic if it accumulated so it must be removed from the body.

This is done in number of steps:

1. Excess proteins (i.e, nitrogenous waste) are broken down into amino acids.
2. These then have the nitrogenous part removed as ammonia (see equation 1 below).
3. Within the liver, the ammonia is converted into urea (see equation 2 below). This process is called deamination.
4. The urea is then transported in the blood to the kidney (where it is extracted and excreted via the bladder).

Ultrafiltration

Urea, along with salt, water and glucose, etc., is extracted from the blood in the kidney by a process called **ultrafiltration**. Blood passing the top of the nephron is under high pressure, so fluid is forced through the sieve-like capillaries and into the capsule. This fluid is called the **filtrate**. It does not contain any blood cells or larger proteins, as they are too big to pass out of the capillaries and into the capsule.

Much of what has been filtered out needs to be returned to the blood - they are too precious to lose - so the next process is called **selective reabsorption**.

Control of ADH

The concentration of the blood (water potential) is monitored by osmoreceptors in the **hypothalamus**. The higher the concentration of the blood the less water there is in the blood.

If the concentration is too high impulses are sent to the **pituitary gland** which then releases more ADH. The water levels will be brought back to normal and the impulses stop.

Glucose Levels

Glucose is needed for respiration so if the level falls below this, the normal body activities may not be able to continue. If the level rises too much the normal behaviour of cells is affected and serious problems can arise. The ideal level of blood glucose is about $1mg/cm^3$.

Insulin reduces the level of glucose in the blood plasma

Glucagon increases the level of Glucose in the blood plasma

Glucagon promotes the conversion of fatty acids. into glucose. This process is called **Gluconeogenisis** (remember, neogenesis means new formation).

The Liver

As well as being involved in the control of blood glucose levels, the liver has other extremely important functions. To be able to fully understand these, the structure of the liver must first be understood.

The **liver** is made up of numerous lobules which are packed with virtually identical cells called **hepatocytes**. The liver is supplied with blood flowing in from the hepatic artery (bringing oxygen) and the hepatic portal vein (bringing blood from the gut).

The blood in this vein carries lots of products from digestion for example; glucose, amino acids, lipids, cholesterol, plasma proteins, urea, carbon dioxide.

Liver Functions:

1. **Carbohydrate metabolism:** gluconeogenesis, glycolysis and glycogenesis all occur in the hepatocytes.
2. **Deamination:** when excess proteins have the NH2 group removed to make ammonia. This is then converted into urea and released into the blood to be taken to the kidney for excretion.

Other functions include:

Fat metabolism

Making cholesterol

Bile production

Detoxification

Storage of Vitamins

Breakdown of haemoglobin (Hb)

Synthesis of plasma proteins

Movement and Support in Animals

Bones

Locomotion is generally brought about by a system of muscles in conjugation with a skeleton. The skeleton may be an endoskeleton, an exoskeleton or a hydrostatic skeleton. The support system will be adapted to methods of locomotion for a particular animal (e.g, flying, swimming, climbing, and walking).

The skeleton

It consists of bone, cartilage, tendons and ligaments.

Its functions are:

Support.

Protection of soft tissue.

Movement - a point of attachment for muscles.

Production of red blood cells and some white blood cells.

A source (sink) for calcium and phosphate.

Cartilage structure

Cartilage is firm but elastic. Cartilage cells are called **chondrocytes**. They secrete a hard, rubbery matrix around themselves.

They also secrete collagen fibres that become embedded in the matrix to strengthen it. The cells themselves live in small cavities in the matrix called **lacunae**.

Muscles and Movement

Movement is made more flexible with joints. Here, **ligaments** hold bones together. They limit the movement thus preventing dislocation. The joints move due to the force of muscles acting on them.

Muscles are attached to bones by **tendons** that are made of collagen fibres. When a muscle contracts, the tendon and its attached bone are pulled towards the contracting muscle.

Each muscle is called a **fibre**. Each fibre made up of a bundle of **myofibrils**.

Each myofibril is made of **myofilaments** - **actin** and **myosin**.

The myofilaments are arranged so that each myosin is surrounded by 6 **actins**.

Actin: consists of 2 threads wrapped around each other. At each twist there is a binding site for myosin. In a relaxed state, a molecule called **tropomyosin** covers these sites.

Myosin: the filament consists of many myosin molecules. Each molecule has a tail and a double globular head.

Contraction

Contraction occurs when an impulses from a motor neurone reaches the synapse at the junction with the muscle. If it is stronger than a **threshold stimulus contraction** will occur.

Ecological Concepts

The Concept of the Ecosystem

An **ecosystem** includes all the living organisms that interact with one another and also with the physical and non-physical factors present.

The boundaries of the ecosystem studied are dictated by the individual carrying out the study. It may be as large as the biosphere or as small as an enclosed bacterial colony.

Understanding ecological terms

The following are important terms which are frequently used in ecology...

Habitat: The place where an organism lives.

Population: A group of organisms, all of the same species, and all of whom live together in a particular habitat.

Community: The total of all populations living together in a particular habitat.

Niche: The position occupied by an organism in a particular ecosystem, dependent upon the resources it uses. The more resources that are taken into account then the more carefully defined the organism's niche will be, the organism will become more specialised.

Ecosystem: The biotic community together with the abiotic environment.

Biotic and abiotic factors

In order to study an ecosystem it is essential that the way in which organisms interact with each other within the ecosystem is considered. These relationships are the **biotic factors** of the ecosystem.

It is also essential that the effects of the physical or non-living factors are considered. These are the **abiotic factors**.

Biotic factors: the biotic factors affecting an ecosystem are mainly concerned with competition either within a single population or between the members of different populations.

Abiotic factors: these are the physical factors that affect an ecosystem. **They include the following:**

Light

Temperature

Water Availability

Oxygen Availability

Edaphic factors

Succession

Succession is the process by which communities colonise an ecosystem and are then replaced over time by other communities.

Pioneer species to climax communities

Pioneer species: These are the first species to occupy a new habitat, starting new communities. They have rapid reproductive strategies, enabling them to quickly occupy an uninhabited area. Many have an asexual stage to their reproduction.

Seres: These are the various stages that follow on from the pioneer species.

Climax community: This is the stable community that is reached, beyond which, no further succession occurs.

Types of Succession

Primary Succession

This occurs when the starting point is a bare ecosystem, (e.g, following a volcanic eruption or a landslide). The pioneer species are usually lichen, moss or algae. They are able to penetrate the bare surface, trap organic material and begin to form humus.

Over several generations soil begins to form. The soil can be used by a more diverse range of plants with deeper root systems. Gradually larger and larger plants occupy the ecosystem along with a diversity of animals.

Finally a climax community is reached and the species present do not change unless the environment changes in some way.

Secondary succession

This occurs when the starting point is bare, existing soil, (e.g, following a fire, flood or human intervention). This type of succession proceeds in the same way as primary succession except that the pioneer species tend to be grasses and fast growing plants.

Populations

The factors affecting **population growth** and how populations increase in numbers are important concepts in ecology as they are necessary in order to successfully study how ecosystems work.

Changes in populations over time

The number of individuals per unit area of chosen habitat is known as the **population density**.

The population density can be affected by a number of factors:

1. **Birth:** The number of new individuals born to a population
2. **Immigration:** The number of new individuals joining a population.
3. **Death:** The number of individuals within a population that die.
4. **Emigration:** The number of individuals leaving a population

Population size can also be affected by the following:

Density dependent factors: These are any factors, dependent on the density of the population in question. Some examples of these are predation, disease and competition.

Density independent factors: These are any factors, not dependent upon the density of the population in question. Some examples of these are climate and catastrophe.

Competition

Competition is often considered to be the most important biotic factor controlling population density.

Competition between organisms may be for a number of different factors, including food, light, territory or reproductive partners.

Competition Types:

Intraspecific competition

Scramble competition

Contest competition

Interspecific competition

Trophic levels

This describes a specific level in a food chain. The term trophic refers to nutrition.

There are four important levels in most food chains:

Producers: Organisms which convert some of the energy from the sun into stored chemical energy (usually plants).

Primary consumers: Organisms that obtain energy by consuming producers. They are herbivores.

Secondary consumers: Organisms which obtain energy by consuming primary consumers. They are carnivores.

Decomposers: These organisms form the end point of every food chain. They are bacteria or fungi that obtain their energy by breaking down dead organisms from the other trophic levels.

Each description of a trophic level will describe an organism's role in the ecosystem. Organisms may occupy more than one trophic level, (e.g, when acting as omnivores).

Transfer of energy between trophic levels

Transfer of energy between trophic levels is relatively inefficient. Energy is transferred from one trophic level to another as organisms are consumed.

Pyramids in ecology

Ecological pyramids are used as a tool to illustrate the feeding relationships of the organisms, which together make up a community.

Pyramid types:

Pyramid of Numbers

Pyramid of Biomass

Pyramid of Energy

Nutrient cycles in the environment

These consider how inorganic **nutrients cycle** through the various trophic levels and remain constantly available.

Nutrient cycle types:

The carbon cycle

The nitrogen cycle

Nitrifying bacteria will produce nitrates from these organic nitrogen compounds.

Denitrifying bacteria are able to return nitrogen to its abiotic source by converting nitrates to nitrogen gas.

Deforestation

Deforestation is the rapid destruction of woodland. Although it can occur due to natural catastrophe it is most commonly caused by human intervention.

Evolution

Types of variation

For each characteristic, the population may show either **continuous** or **discontinuous variation.**

The gene pool and allele frequencies

In any population, the total variety of genes and alleles present is called the **gene pool.**

This gene pool can change in content (new alleles arriving, existing alleles being lost) or the ratio of alleles altering due to the following:

1. mutation,
2. natural selection,
3. emigration,
4. immigration,
5. mate selection.

The factors favouring stability of the gene pool are:

1. No mutation,
2. No natural selection,
3. The population being large,
4. No gene flow (due to individuals emigrating or immigrating),
5. Random mating,

If these factors favouring stability are fulfilled, the ratio of the alleles for a gene can be established using the **Hardy-Weinberg Equilibrium.**

Hardy-Weinberg Equilibrium

Using the **Hardy-Weinberg Equilibrium,** it is possible to establish the ratio of dominant to recessive alleles.

Natural Selection

For a species to survive, it must reproduce. However, the population is limited by environmental factors and so remains more or less constant over time.

The change in adaptation that occurs is called **evolution.**

There are three types of selection that occur in nature:

Stabilizing selection.

Directional selection.

Disruptive selection.

Evidence for Evolution

There is much evidence for the process of evolution and that natural selection is the mechanism by which it occurs.

Palaeontology

The study of fossils.

Comparative anatomy

Divergent evolution

Also called **adaptive radiation.**

When a group of organisms all possess a structure that appears to have come from a common ancestor and which has the same microscopic structure and body position, as well as other features, they are said to have homologous structures.

Convergent evolution

This is the opposite of adaptive radiation; it is where structures that on first appearance are similar but are actually found to be unrelated.

Examples include:

Insect wing and bird wing.

The eye of a mollusc (e.g, squid) and the eye of a vertebrate.

These structures are said to be analogous. In these cases, selection pressures from the environment in which each species lives have caused particular structures to be advantageous.

Comparative Biochemistry

Various chemicals have been studied in order to find evidence of evolution, DNA and proteins such as cytochrome c in the electron transport chain of respiration are often used.

Looking at the order of bases in the lengths of DNA and the order of amino acids in a protein, it is possible to determine how similar they are in different species.

Species that are closely related have the most similar DNA and proteins; those that are distantly related share far fewer similarities. A comparison of DNA sequences show that it is 99.9% certain that chimpanzees are humans' closest relatives.

Evolution in Action

Evolution occurs when there is a change in the environment or when there is mutation because the allele frequencies will change as a result. This change in allele frequency is called **microevolution.**

Usually mutations are harmful, occasionally they are neutral and infrequently they are beneficial. In this latter case, the mutation can increase an individual's chances of survival (fitness), reproduction and thus the frequency of that genotype.

Antibiotic resistance

Antibiotics are chemicals usually produced by fungi.

They can kill bacteria by preventing cell wall formation and so are given to patients who have a bacterial infection. There may be however, one or more bacteria in the population that are able to inactivate the chemical making them resistant to the antibiotic.

Sickle Cell Anaemia

Haemoglobin is the pigment in red blood cells that carries oxygen around the body.

Definition of a species

A group of organisms with similar morphological, physiological and behavioural features, which can interbreed to produce fertile offspring, and are reproductively isolated from other species.

Health and Disease

Health and Disease

Health can be defined as a person's physical, mental and social condition.

Disease is a disorder or malfunction of the mind or body, which destroys good health.

Categories of disease

There are nine main categories of disease but some diseases are more difficult to classify and fit into more than one of them.

Physical Disease

Infectious disease

Non-infectious diseases

Deficiency diseases

Inherited diseases

Degenerative diseases

Mental disorders

Social diseases

Self-inflicted diseases

Terms used to describe diseases

An infectious disease, which is always present in a population, is called **endemic**.

An epidemic occurs when a disease suddenly spreads rapidly and affects many people. If a disease spreads over a continent or even the world it will be termed **pandemic**.

Health Statistics

Epidemiology is the study of patterns of diseases and the factors affecting its spread. Incidence, prevalence and mortality for a disease may be determined. Collecting information on the distribution of disease helps to identify the underlying causes and if it turns out to be infectious, may point to how it is transmitted.

Smoking and Disease

Tobacco companies do not declare the ingredients in cigarettes, but upon analysis, they contain over 4000 different chemicals, many of which are toxic.

There are three main ingredients, which damage the gaseous exchange system or the cardiovascular system.

Chemicals found in cigarettes

Tar

This is a mixture of aromatic substances, which settles on the airway linings and stimulates changes that may lead to obstructive lung disease and lung cancer.

Carbon monoxide

This gas diffuses across the alveoli into the blood and onto the red blood cells, combining with haemoglobin to form carboxyhaemoglobin. This stops the haemoglobin from becoming fully saturated and so it carries 5-10% less oxygen.

Nicotine

This drug is absorbed readily into the blood and stimulates the nervous system to reduce the diameter of arterioles and the adrenal glands to release adrenaline. This increases heart rate and blood pressure and decreases the blood supply to the extremities - for example, the hands and feet.

Diseases

Lung disease

After heart disease and strokes, this is the most common cause of illness and death in the UK.

Chronic bronchitis

Tar stimulates goblet cells and mucus glands to enlarge, producing more mucus. It destroys the cilia inhibiting the cleaning of the airways and mucus (containing dirt, bacteria and viruses) builds up blocking the smallest bronchioles.

Emphysema

Due to constant infection, **phagocytes** are attracted to the lungs where they release **elastase** - an enzyme that breaks down the elastin in the alveoli walls, to enable them to reach the surface where the bacteria are. Without adequate elastin, the **alveoli** cannot stretch, so they recoil and many burst.

Large air spaces appear, reducing the surface area for gas exchange and making sufferers **breath more rapidly**. As it progresses, patients become breathless and wheezy - they may need a constant supply of oxygen to stay alive.

Chronic obstructive pulmonary disease

This very disabling disease is the result of **chronic bronchitis** and **emphysema** occurring together. Troublesome breathlessness often only occurs once half of the lung tissue has been destroyed, which can only rarely be reversed. Britain has the highest death rate from this disease in the world.

Lung cancer

Tar contains **carcinogens**, which react with the DNA in epithelial cells and cause **mutations**, which can lead to tumours.

Links between smoking and lung disease

These can be put into two groups:

Epidemiological evidence looks for patterns in the diseases, which smokers suffer from. It only shows an association and not a causal link.

Experimental evidence attempts to prove a causal link.

The cardiovascular system

Cardiovascular diseases are degenerative diseases of the heart and circulatory system. They are responsible for 50% of deaths in developed countries and are multifactorial - smoking being one risk factor.

Atherosclerosis

This is caused by a build-up of **fatty material** in artery walls, which reduces the flow of blood and therefore oxygen to the tissues. An **atheroma** is a build-up of cholesterol, fibres, dead muscle cells and platelets and is more likely to develop upon damage to the artery wall by high blood pressure, carbon monoxide or nicotine.

Blood clots (**thrombosis**) become more likely and if one develops in the coronary artery a heart attack may be the result, while if it occurs in an artery supplying the brain, a stroke may result.

Coronary heart disease

This is a disease of the **coronary arteries**, which branch from the aorta to supply the heart muscle. If **atherosclerosis** of these vessels occurs, then the heart has to work harder and blood pressure rises. This makes it difficult for the heart to receive the extra nutrients and oxygen it requires during exercise.

Three forms exist:

Angina

Heart Attacks

Heart Failure

Stroke

These occur if an **artery in the brain bursts** and blood leaks into the brain tissue or when an artery supplying the brain becomes blocked. The brain tissue becomes starved of oxygen and dies. **Strokes** can be fatal or very mild and may affect speech, memory and control of the body.

Links between smoking and cardiovascular disease

Smoking increases the concentration of blood cholesterol, which is a risk factor, so smokers increase the risk of having heart disease or a stroke. The risks of developing the disease increases with age and men are more at risk than women.

Being overweight increases the risk as does eating a diet high in saturated fat and salt. Diets with more antioxidants (vitamins) and soluble fibre decrease the risk as does taking regular exercise. Having diabetes raises the risks and high alcohol intake is another contributory factor.

Genetics

Monohybrid crosses - single gene inheritance

When studying genetics, the following conventions are used:

P is used as shorthand for the parent generation.

F_1 is used for their offspring.

F_2 is used if the offspring (F_1) are crossed.

Capital letters are used to denote a dominant allele.

Lower case letters are used to denote a recessive allele.

Incomplete dominance

This is when neither allele is dominant.

Both alleles are expressed and contribute equally to the phenotype.

A heterozygote has an intermediate phenotype as there is partial influence from both alleles.

Codominance

In this case, both alleles are dominant.

They are independent, so there is no 'blending' as in the snapdragons; instead the phenotype is a result of the full expression of both alleles.

Pleiotropy

This is where one gene affects several characteristics. For example, a disease caused by one pair of alleles may have several or many symptoms.

Polygeny

This is where one characteristic is affected by two or more genes (e.g, skin colour).

Epistasis

This is where one gene interferes with the expression of another gene.

DNA and the Genetic Code

Evidence for the structure of DNA

Many observations contributed to the evidence from which the structure of DNA was eventually deduced by Watson and Crick:

1. Chemical Analysis
2. Chargaff's work on base equivalence
3. Franklin and Wilkins' work on X-ray crystallography

The structure of RNA

Ribonucleic acid (RNA) is also a polynucleotide. The chain of nucleotides is formed in exactly the same way as in DNA, but the molecule has some very important differences:

1. It is a single stranded molecule.
2. The pyrimidine Thymine never occurs but is always replaced by Uracil, another pyrimidine. (Think "No cup of T for U!")
3. It is much smaller than DNA.
4. It comes in three different forms, ribosomal, transfer and messenger.

The Structure of DNA

DNA is a polymer of **nucleotides**.

Nucleotides are made up of:

a phosphate.

a sugar - deoxyribose.

a base - either adenine, guanine, thymine or cytosine.

DNA is a macromolecule polymer made of subunits called nucleotides. The nucleotides are arranged in two chains which are coiled into a spiral shape called a **double helix**.

DNA Replication

Since DNA forms the genetic code and that it is known that genes may be inherited, it follows that DNA must be copied exactly before being incorporated into gametes at meiosis.

It also follows that all new cells in an organism must gain a copy of the genes at mitosis, because they are able to continue the characteristic biochemical behaviour of that organism.

DNA and Protein Synthesis

DNA is the molecule which controls the synthesis of proteins. **Proteins** are used for growth and repair and also as enzymes, in which form they catalyse all other cellular activities.

Thus DNA is able to exert a controlling influence over the whole cell and ultimately, the whole organism. The segments of DNA which hold the key to this control are the **genes**.

Protein Synthesis

Protein synthesis relies on the effective communication of the coded information held in the genes to the sites of protein manufacture, the ribosomes in the cytoplasm.

Since DNA is part of larger structures (chromosomes), which are unable to move from the nucleus, intermediate messenger molecules are needed. These are messenger RNA molecules.

Making Use of the Genetic Code

Introns and Exons

The Eukaryotic Genome

The term **genome** refers to all of the alleles possessed by an organism. While the amount of DNA for a diploid cell is constant within a species, the differences can be great between species.

Introns and exons

Most, but not all structural eukaryote genes contain introns. Although transcribed, these introns are excised (cut out) before translation.

The number of introns varies with the particular gene, even occurring in tRNAs, rRNAs and viral genes!

Useful and "junk" DNA

Some of the base sequences in the introns and intergenic portions of the genome contain sites that regulate gene expression.

The importance of these sites is that they allow genes to produce various forms of the protein for in different tissues or at different times in the development of the organisms.

Regulation of Protein Synthesis

Evidence from E.coli

The single chromosome of the common intestinal bacterium E.coli is circular and contains some 4.7 million base pairs.

The chromosome replicates in a bi-directional method, producing a figure resembling the Greek letter theta.

The promoter is the part of the DNA to which the RNA polymerase binds before opening the segment of the DNA to be transcribed.

The Operon model

In the late 1950's, François Jacob and Jacques Monod proposed the operon model of prokaryotic gene regulation.

The structure and operation of an operon

Operons can either be inducible (promoters) or repressible according to the control mechanism.

In the 250 structural genes of E.coli, seventy-five different operons have been identified.

When a repressor molecule is present, this blocks the process of RNA polymerase, so preventing any transcription at this site.

Gene regulation in Eukaryotic organisms

One piece of evidence suggests that the influence of the regulator genes may be thousands of base pairs away from the promoter gene, unlike the close sequences found in E.coli.

Eukaryotes have a number of gene control mechanisms not found in prokaryotes. One of these is called **DNA methylation**.

Human Genome Project

The structure of DNA was found by Watson and Crick in 1953, and only in 1956 was it first known that humans had 23 pairs of chromosomes. The subsequent interval of time has been very active in the file of Genetics.

In 1977, Fred Sanger invented the first **DNA sequencing** process. He opened up the possibility of working-out the entire sequence of the bases in the human DNA, a total of some three thousand million (three billion or 3 x 10^9).

Sequencing the Human genome

To sequence a gene, the first difficult part is to obtain the gene. Once obtained, there are laborious manual methods, or those using machines do the process.

The manual methods involves electrophoresis; a process that separates fragments of DNA by using an electrical current.

The future. "This is the end of the beginning"

One of the main project goals is to address the ethical, legal and social issues (ELSI) that may arise from the project. 3-5% of the HGP budget has been set-aside for this purpose.

Knowledge about the effects of DNA variations amongst individuals can lead to diagnosis and possibly treatment of the thousands of disorders that afflict humans all over the world.

Learning about the DNA of other organisms can lead to a better understanding of their natural capabilities in solving challenges in health care, energy sources, agriculture and environmental conservation.

Genetic Engineering

Obtaining the Gene

Genetic engineering aims to remove a desired gene and transfer it to another organism where it can be expressed. This means that the required protein can be synthesised within the new organism.

Obtaining the desired gene

There are various methods that are used...

1. If the amino acid sequence of the desired protein is known, the DNA code can be worked out and the DNA made in the lab by stringing together the correct order of nucleotides.

    Note: Many proteins are extremely large; therefore this would be a tedious process.

2. Isolate the messenger RNA (mRNA) for the desired gene and make a single copy of the complementary DNA using the enzyme reverse transcriptase and another copy is made by adding DNA polymerase so that a doubled stranded length of DNA is made. (The original reverse transcription enzymes were first discovered in retro viruses.)
3. Isolate the gene from the entire genome. To do this the DNA must first be cut into fragments and the one containing the desired gene must be identified. The enzymes used to cut the DNA are called **restriction enzymes** or **restriction endonucleases**.

Inserting the gene into a host cell

The fragments need to be put into an organism that will express the protein.

There are several ways of getting DNA fragments into host cells:

1. **Microinjection.**
2. **Electroporation** - temporary holes are made in the membrane using electrical pulses.
3. **Microprojectiles** - tiny beads of tungsten or gold coated with DNA fired by a gun into the cell.
4. **Using viruses as vectors.**
5. **DNA in liposomes** - fuse with the cell membrane.

Note: These methods only introduce DNA into the cell; they do not incorporate it into the host DNA.

What type of organism would make a good host?

The main requirement of the organism is that large quantities of a protein can be produced as cheaply and easily as possible, it needs to be an organism that:

1. Grows fast.
2. Is easily manipulated.
3. Has a simple chromosome (prokaryotic cells do not have a nuclear envelope).

4. Contains naturally occurring vectors (see later).

A good option therefore is to use yeasts or bacteria.

Transferring the Gene

How to get the fragment into bacteria

A **vector** is a carrier DNA molecule into which the desired gene can be inserted.

Most commonly, this vector is a **plasmid**. This is a small, extra-chromosomal, circular piece of DNA often found in bacteria in addition to their functional DNA.

Vectors and PCR

Agrobacterium tumefaciens (Crown gall disease)

Viruses and bacteria as vectors:

Viruses and some **bacteria** are known to transfer some of their DNA or RNA into the cells of a host. This genetic material integrates into the host genome, causing the production of disease or deformity such as **Galls**.

Galls are large tumour-like growths in plants, usually produced as a response by the plant to some invasion by microbe or insects.

PCR: Polymerase chain reaction

The purpose of this **PCR** is to produce huge numbers of copies of a gene. The enzyme DNA polymerase is added to the sample and when suitably treated, will catalyse many millions of copies of the small sample.

PCR is used as the starting point, or template, for **sequencing**.

Genetic markers

When **gene transfer** is attempted, there must be a way of detecting which microbe has taken up the new gene arrangements. Those that have been unsuccessful have to be eliminated.

Other Ways of Manipulating Genes

Genetic engineering in agriculture

Viruses and some bacteria are known to transfer some of their DNA or RNA into the cells of a host and this genetic material integrates into the host genome, causing the production of disease or deformity such as **Galls**.

Galls are large tumour-like growths in plants, usually produced as a response by the plant to some invasion by microbe or insects.

The Ti plasmid of a particular bacterium called Agrobacterium tumefaciens has been used to insert DNA into plant genomes.

Genes coding for the tolerance to herbicides, resistance to insect pests, viral disease and other factors have been introduced to various plant species.

Cells can be taken from the meristem of a plant of the species in question and kept in a sterile nutrient medium so that the cells divide and form a tissue. This can be split several times and each group of cells can go on to form an individual plant (**meristem tissue culture or micropropagation**).

Genetic manipulation in humans

Gene therapy

Treating a genetic disease by altering an individual's natural genotype by:

1. Germ cell therapy of sperm, egg or early embryo.
2. Somatic cell therapy.

Number 1 is technically possible but ethically unacceptable.

There are 3 ways in which gene therapy can work:

1. Repair of the defective gene.
2. Replacement of the faulty gene with a normal one.
3. Addition of a normal gene, leaving the defective one in position.

Genetic fingerprinting

Much of your DNA is non - coding (i.e. it doesn't code for a protein), but rather it contains regions of highly repetitive sequences of bases (**Variable Number Tandem Repeats - VNTRs**)

The number of repeats, and hence the size of the VNTRs, varies markedly between individuals. Some will come from one parent; the rest will come from the other.

Only identical twins have the same number of VNTRs. Genetic fingerprinting reveals the differences in the size of the VNTRs in different individuals.

Applications of Genetic Engineering

Insulin and Factor VIII

Insulin

Human insulin is a protein, normally produced by the b cells of the islets of Langerhans in the pancreas.

Insulin is involved in the regulation of blood sugar levels, but in **Diabetes** (diabetes mellitus) there is a deficiency in the production of this essential hormone.

Factor VIII

Haemophiliacs suffer from a defective gene that fails to produce Factor VIII, an important agent involved in blood clotting.

Gene Therapy

Gene therapy is the deliberate 'repair' or replacement of damaged genes. Success has been limited to somatic (body) cells rather than sex cells (gametes). This means that any changes are not passed on to subsequent generations (inherited). The modification of germ line cells (germ line therapy) is likely to be discouraged on moral grounds.

How gene therapy works - more recent developments

In an example, called **severe combined immunodeficiency disease (SCID)** the gene for making an enzyme (adenosine deaminase, ADA) is defective and this prevents the immune system from defending the body against infections.

The missing ADA gene is extracted from healthy bone marrow tissue. The gene is then inserted into a virus, which is then rendered harmless (non-invasive) by removing its reproductive genes.

Chymosin

Rennet (rennin or rennilase) and cheese making:

Back in the 1960's, the world faced a severe shortage of calf rennet.

Rennet is a protease enzyme added to milk, along with certain bacteria, which coagulate milk proteins, producing the curds. This then separates from the liquid, whey. The semi-solid curds are then treated by adding salt and then matured in containers to make the cheddar-style cheeses.

(Rennet is an enzyme found in the stomachs of young mammals, like calves, and is important in the digestion of milk proteins.)

Social, Ethical and Economic Implications of Genetic Engineering

Public debate of aspects of GE has resulted in arousing great concern for health and the environment. GE is a new technology, and as such is met with scepticism on one hand and enthusiasm on the other. To fully appreciate the advantages and disadvantages, a good understanding of the facts is essential.

Genetic engineering and traditional breeding

Traditional breeding

Traditional crop and animal breeding has been practiced for thousands of years.

Traditional breeding involves selecting animals or plants with particular characteristics and producing individuals that clearly demonstrate the desired trait or characteristic. Crossing takes place, usually between individuals of the same or closely related species.

The gene pool for such improvements, therefore, is limited to those genes found naturally in the breeding individuals.

Genetic engineering methods

These include terms such as **genetic manipulation, recombinant DNA technology and gene therapy (in humans).**

Transplant surgery

Transplanting foreign tissue carried great risk of rejection by the body's immune system. The patient faces the rest of their life with a cocktail of anti-suppressant drugs.

There is a great shortage in organs suitable for transplantation, resulting in patients suffering or even dying before they get a chance to have the transplant operation.

Xenotransplantation

Organs from other animals can be used in human transplantation, but they pose a potentially greater risk of rejection.

Terms and conditions