Cambridge GCSE Notes
5090 Biology

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Contents

1 Cells

1.1 Cell structure and function

A cell is the smallest unit from which all organisms are made. These structures are so small that microscopes must be used to observe them. Microscopes are equipment that can magnify objects many times, meaning even the tiniest objects will appear large under a microscope. In case of cells and such, methylene blue or iodine solution must be used to stain the cells to increase their visibility under the microscope.

Most animal cells consist of the following: cell membrane, mitochondria, nucleus, cytoplasm, and ribosomes.

Cell membranes are partially permeable in that not all substances will be allowed to pass through the membrane. It is a thin layer consisting of mostly protein and fat. It is what separates the contents of the cell from those in the surroundings.

Mitochondria are organelle which are so small that they can only be clearly seen under an electron microscope. This is the site of aerobic respiration inside the cell. Aerobic respiration is the process by which glucose is broken down to release energy, which is then used for the cell's metabolic reactions[1].

The nucleus of a cell is where the genetic information of the cell is stored. It is stored in the form of chromosomes, which are structures made from deoxyribonucleic acid[2], DNA. Chromosomes are long and thin structures which are so small that they are only clearly visible when a cell is dividing.

The cytoplasm is a clear jelly consisting of mostly water. It has many substances dissolved in it, especially proteins. All metabolic reactions take place in the cytoplasm. Ribosomes are structures only visible under an electron microscope. This is the site of protein synthesis, wherein instructions in the DNA of the chromosomes are used to link together long chains of amino-acids.

Vesicles are temporary membrane bound organelle that contain solutions inside animal cells.

All of the above organelle are also present in plant cells, with the exception of the vesicle and some additional organelle, specifically: chloroplasts, sap vacuole, and, cellulose cell wall.

Chloroplasts are membrane-bound organelle that contain the green pigment called chlorphyll. They often contain starch grains. Chlorophyll is responsible for absorbing the energy from sunlight, which is then used to make food by photosynthesis.

The sap vacuole is another membrane bound organelle filled by a fluid, which is cell sap in plants. The pressure in the vacuole due to it being full presses outward on the cell itself, helping it keep its shape.

The cellulose cell wall is a fully permeable wall surrounding the cell in plants, and is made of cellulose, which is a polysaccharide (see Section 4). These protect

[1] Metabolic reactions are those which occur inside living organisms.

[2] Candidates need not remember this name.

and support the cell, and when excess water has entered the cell, it is stopped from bursting by the cell wall.

Bacteria are prokaryotic cells (see Section 2), and hence have no proper nucleus and only have their genetic material freely suspended in their cell cytoplasm in circular form. They often contain additional rings of DNA as plasmids. Bacterial cells also have ribosomes, yet lack mitochondria. The cell wall in bacterial cells is composed of peptidoglycan, they may have flagella, which are structures that allow mobility to the cells. They may have a further protective capsule shaped layer, called the capsid.

1.2 Specialised cells, tissues and organs

Some cells can become specialised and their structures are related to their specifc functions, examples of such cells will be covered.

A tissue is a group of similar cells that work together to perform a particular function. An organ is a group of tissues that work together to perform a particular function. An organ system is made up of sesveral organs to perform a particular function. Multiple organ systems make up an organism, which is a living thing.

Note that, when looking at magnified images, the following formula applies:

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}}$$

2 Classification

2.1 Concept and use of a classification system

A living thing is defined by its ability perform the following:

- Movement is the ability of an organism to change position or place.
- Respiration is the chemical process through which organisms gain energy (see Section 10).
- Sensitivity is an organisms ability to detect changes in their environment and respond to them.
- Growth is defined as the permanent increase in size and dry mass of an organism
- Reproduction means making more of the same organsism
- Nutrition is done by taking in materials to build cells, provide energy for metabolism, etc.
- Excretion is the removal of waste and excess products from the body.

All organisms can be classified into specific groups by their common features. A species is a group of organism that can reproduce to produce fertile offspring.

The binomial naming system is a system of naming species as an internationally agreed system, in which the scientific name of an organism is made up of two parts, namely the genus and species in the following format:

Genus species

Note that, the *Genus* has a capitalised first letter and *species* is all in lower case.

Dichotomous keys consist of features of organisms corresponding to the organisms features.

2.2 Features of organisms

The largest groups living organisms are classified into are called kingdoms. There are five: animal, plant, fungus, protoctist and prokaryote.

Animals have cells with nuclei, lacking cell walls and chloroplasts. They feed on organic substances[3] made by other living organisms.

Plants have cell walls made of cellulose and often contain chloroplasts. They make their own food by use of photosynthesis, a majority of them have roots, stems and leaves, yet some lack these structures.

Fungi are organisms made up of microscopic thread like structures called hyphae. Hyphae are composed of several cells joined end-to-end. Such cells

[3]Organic substances, in terms of chemistry, are any substances that contain the element carbon, but in biology the term will be used to refer to compounds made by living things

have cell walls but those are not made of cellulose. Such organisms are decomposers, in that they break down waste material from other organisms and dead organisms. They reproduce by means of spreading spores, which are cells with a tough, protective outer covering, which can be spread by an animal, or the wind. Fungi are multicellular, yet some may be unicellular. They lack chlorophyll, and feed by digesting waste material.

Some protoctists have plant like cells while others have animal like cells. Most protoctists are unicellular but some are multicellular.

Prokaryotes are organisms such as bacteria. They are usually unicellular, lacking proper nuclei, have cell walls made not of cellulose, lacking mitochondria, and circularly organised DNA, freely suspended in the cytoplasm. They often have additional rings of DNA called plasmids.

The animal kingdom is further classified into two groups: vertebrates and invertebrates.

Vertebrates are animals with backbones, this group includes fish, amphibians, reptiles, birds and mammals.

Mammals are animals with hairy skin, their young develop in their uterus, where they are attached to their mother through a placenta. Mothers have mammary glands which produce milk on which the young feed. They have different kinds of teeth: incisors, canines, premolars and molars. They have an ear flap on the outside of their bodies. They have sweat glands and a diaphragm, a muscle which assists in breathing (see Section 9).

Birds have feathers, and sometimes scales. They have beaks and their front two limbs are wings, though not all birds can use them to fly. They lay eggs with hard shells to reproduce.

Reptiles are vertebrates with scaly skin which lay eggs with soft shells.

Amphibians are vertebrates which lack scales, their eggs are laid in the water and lack shells. The tadpoles (babies) livie in the water but the adults often live on land. Tadpoles have gills for gas exchange underwater, but adults have lungs.

Fish are vertebrates with scaly skin, with gills that they have throughout their life cycles, with fins to swim and lay eggs lacking shells in the water.

Arthropods are invertebrates with an exoskeleton and several pairs of jointed legs.

Myriapods are made up of several similar segments, each of which has jointed legs and a pair of antennae.

Insects are arthropods with three pairs of jointed legs, and two pairs of wings, of which a pair may be vestigial in that they have evolved to be so small that they are now useless. They breathe through tubes called trachae. Their body can be divided into a head, thorax and abdomen. They have a pair of antennae.

Arachnids have four pairs of jointed legs, lack antennae and have their body consisting of two parts, namely the cephalothorax and abdomen.

Crustaceans are arthropods with more than four pairs of jointed legs with two pairs of antennae.

Ferns are plants with roots, stems and leaves (fronds), which reproduce by means of spores produced on the undersides on their lives. They do not flower.

Flowering plants are those with roots, stems and leaves, whose reproduction consists of flowers and seeds where those seeds are produced in ovaries inside the flower. This group can be further divided into two, dicots and monocots.

Dicots produce seeds with two cotyledons, with a main root with side stemming out of it. Their leaves have a network of veins, and the flowers are arranged in multiples of four or five. They have vascular bundles in their stems, arranged in a ring (see Section 7).

Monocots produce seeds with a single cotyledon, where their roots grow out directly from the stem. The leaves have parallel veins and the flower parts in multiples of three. The vascular bundles in monocots are arranged randomly.

Viruses are not considered to be living organisms as they do not show any living properties until they enter a living cell. They consist of "cells" which are made up of a protein coat and genetic material, composed of ribonucleic acid, RNA.

3 Movement into and out of cells

3.1 Diffusion and osmosois

Water is used as a solvent in many organsisms.

All substances are made up of particles called atoms or molecules. These particles are in a state of constant movement, the intensity of this movement depends on their kinetic energy which can be controlled using the temperature of the particles in question. This movement results in particles spreading out passively, requiring no extra energy, and this energy of particles is the energy by which substances diffuse.

The movement of a substance occurs from one region to another.

Diffusion is the net movement of molecules or ions from a region of their higher concentration that of their lower concentration, i.e., down a concentraion gradient as a result of their random movement. The surface area in contact between the substances being diffused increases diffuse rate with increase in itself, and vice versa. The temperature of the particles corresponds to the particles' kinetic energy, where the more the energy the faster the diffusion and vice versa. The concentration gradient is the difference between the concentration of the substance diffusing between the regions of diffusion. The higher this gradient, the faster the diffusion and vice versa. Lastly, the closer the two regions are, the faster the diffusion and vice versa.

Osmosis is the net movement of water molecules from a region of higher water potential to a region of lower water potential, through a partially permeable membrane.

Plants are supported by the pressure of the water inside the vacuole pressing outwards on the cell wall.

Osmosis is the process by which water moves in and out of animal cells. When an animal cell has a lower water potential than its surroundings, water moves into the cell, eventually as the water moves in the strain becomes large enough to make the cell burst. When the initial conditions are opposite, a significant amount of water moves out of the cell. This causes the cell to shrink.

In case of plant cells, when an excess amount of water has entered the cell, the cell becomes tight and firm, as the cell will not burst due to the cell wall. It is said that the cell has become turgid. The pressure with which the cell is kept turgid is called turgor pressure. However, when excess water moves out of the cell, the cell shrinks, but the cell wall cannot, as a result the cell membrane tears away from the cell wall. This condition of the cell is known as plasmolysis. This damages the cell wall and may result in the cell dying.

3.2 Active transport

Active transport is the movement of molecules or ions into or out of a cell through a cell membrane, from a region of their lower concentration to that of their higher concentration, using energy released during respiration.

This occurs in root hair cells of plants, where mineral ions are higher in concentration outside the root hair cell than inside. As a result, energy from respiration is used to conduct these cells into the plant's cell.

4 Biological molecules

4.1 Biological molecules

Carbohydrates are biological molecules containing carbon hydrogen and oxygen. Lipids are those which consist of the same elements, in different proportions. Proteins are composed of carbon, hydrogen, oxygen and nitrogen. DNA contains phosphorous, carbon, hydrogen and oxygen.

All of the above are large molecules, or polymers, which are made from smaller molecules, or monomers. The monomer for carbohydrates such as starch, cellulose and glycogen is glucose. Proteins are made from amino acids. Lipids are made from fatty acids and glycerol and DNA is made from nucleotides.

Starch is tested for by addition of iodine solution, which will turn blue black from brown in presence of starch. Glucose and maltose are reducing sugars, which, when heated with Benedict's solution, turn green, yellow or orange-red from blue depending on the concentration of the sugar present. Proteins are tested for by addition of biuret reagent, which changes to violet from blue in presence of proteins.

Lipids are tested for by first mixing the sample in ethanol, in which the lipid dissolves. This ethanol is then put into water, where, if tiny droplets are formed giving the solution a milky appearance, fats are present. Such droplets floating in water is called an emulsion, and the test is named accordingly.

5 Enzymes

5.1 Enzyme action

A catalyst is a substance that increases the rate of a chemical reaction, itself remaining unchanged at the end of the reaction.

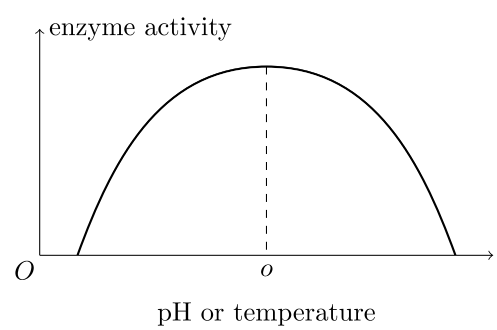
Enzymes are protein structures that function as biological catalysts and are invovled in all metabolic reactions. Enzymes are composed of an active site, into which a substrate binds to form an enzyme-substrate complex, after which products are formed. Each enzyme only catalyses a certain kind of reaction, as each enzyme's active site is shaped differently, only specific substrates can fit in it. They are said to be complementarily shaped. In short, all enzymes catalyse specific reactions, with specific substrates, as they have specifically shaped active sites.

5.2 Effects of temperature and pH

The progress of enzyme catalysed reactions can be followed by measuring concentrations of reactants and products.

With increase in temperature, enzyme activity increases as particles in the mixture have a higher kinetic energy, increasing chances of collision of substrate with enzyme. However, beyond a certain maximum, the enzyme activity will decrease as the protein structure of enzymes will become denatured, and change shape. The result of this will be the active site being unable to fit their complementary substrates. This denaturation of enzymes is permanent and cannot be reversed. The temperature at which the enzyme shows maximum activity is known as the optimum temperature.

At low pH, the enzyme is also denatured, only temporarily. With increase in pH towards the maximum, enzyme activity will increase, beyond which enzyme activity will lower for the same reason. The pH at which enzyme activity is maximum is called the optimum pH of that enzyme.



Above is a graph where enzyme activity is plotted against pH or temperature, where o is the optimum temperature or pH.

6 Plant nutrition

6.1 Photosynthesis

As discussed before, all organisms derive their energy through respiration of glucose, but they must get the glucose from somewhere. Most animals eat plants for their glucose, plants make their own glucose by photosynthesis.

In photosynthesis, using energy from the sun trapped by chlorophyll, carbon dioxide and water are synthesised into glucose and oxygen, a fact that can be shown in the following word and chemical symbol equations:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\Pi} \text{glucose} + \text{oxygen}$$
$$6\,CO_2 + 6\,H_2O \xrightarrow{\Pi} C_6H_{12}O_6 + 6\,O_2$$

where Π represents energy from sunlight trapped by chlorophyll.

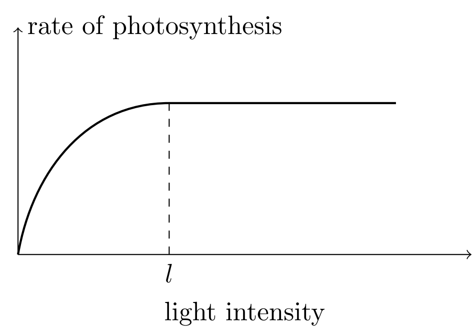
Note that it is chlorophyll that is responsible for turning light energy to chemical energy required for photosynthesis.

This formed glucose can be used directly for respiration in the plant. However, when energy is not immediately needed, it can be converted to starch to be used as an energy store. It may be converted to cellulose to make the plant's cell walls. To be transported through the plant, starch is converted to sucrose before being converted to glucose.

A variegated leaf is that which lacks chlorophyll and hence green colour in some places. When we test for starch using iodine in these places which lack chlorophyll, the result is negative, which shows that chlorophyll is definitely required for photosynthesis.

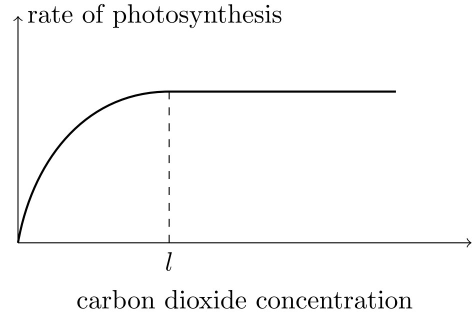
When a leaf is covered with black paper and kept in a place with plenty of light, after starch test it is observed that only the places that were uncovered have starch, meaning the covered part of the leaf did not perform photosynthesis due to lack of light.

Potassium hydroxide solution, KOH, absorbs carbon dioxide. When a leaf is kept in a closed container in presence of this solution, that closed container has all its carbon dioxide absorbed by the potassium hydroxide. The leaf has no carbon dioxide near it. Starch test shows absence of starch. This means carbon dioxide is required for photosynthesis.

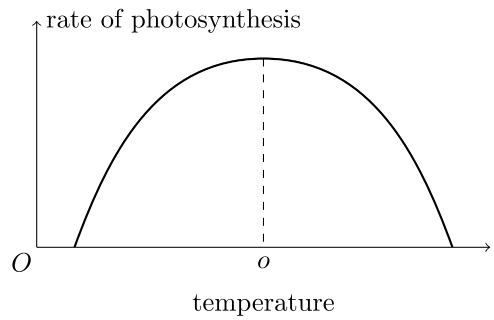


The above graph shows the rate of photosynthesis when plotted against light intensity. At low light, there is no photosynthesis and it increases as light intensity increases. Beyond light intensity l, rate of photosynthesis does not increase further. When light intensity is less than l, the limiting factor is the light intensity, beyond it some other factor is limiting rate of photosynthesis.

The same pattern is seen for carbon dioxide concentration in the atmosphere:



Temperature also affects rate of photosynthesis. This comes down to the fact that some of the reactions involved in photosynthesis are enzyme controlled, and the curve when rate of photosynthesis is plotted against temperature looks very similar to that when enzyme activity is plotted against temperature. It shows that plants have an optimum temperature for maximum photosynthesis, o in the following graph:



Throughout this entire graph, temperature is indeed the limiting factor.

6.2 Leaf structure

Leafs are structures in plants which are the site of photosynthesis, more specifically, chloroplasts in these leaves are the sites of photosynthesis. They are broad, to maximise contact with sunlight to absorb energy. This broadness also maximises surface area to absorb as much carbon dioxide as possible. They are thin so that sunlight can pass right through them and so that carbon dioxide diffuses quickly to all the cells.

The cross section of a leaf consists of many layers. First is the upper epidermis, where tightly packet cells reduce the quantity of water vapour escaping from the leaf. These lack chloroplasts and hence cannot photosynthesise. They produce a waxy, thin, transparent covering called the made of a waxy substance. This layer is called the cuticle.

The subsequent layer is the palisade mesophyll, the first part of the mesophyll layer. These are tall, regularly shaped narrow cells containing high numbers of chloroplasts. They get the maximum exposure to sunlight and hence photosynthesise as the layer above them is transparent.

The layer below the palisade mesophyll is the spongy mesophyll, the last part of the mesophyll layer. These contain not as many chloroplasts and are not as tightly packed as the palisade mesophyll cells. The air spaces between these relatively irregularly shaped cells allow carbon dioxide and oxygen to diffuse between the air and the cells inside the leaf and also allow water vapour to move from the surface of the cells to outside the leaf.

Vascular bundles are also present in the spongy mesophyll, consisting of tubes called xylem and phloem, which are involved in the transport system of plants (see Section 7).

The last layer is called the lower epidermis, which, on some plants makes a cuticle and some it does not as it is not often exposed to sunlight and hence not much water vapour can be lost from this side. There are openings in this layer called stomata, which are surrounded by a pair of guard cells. These guard cells change their shape, allowing diffusion of oxygen and carbon dioxide in and out from the leaf by opening or closing the stomata. These guard cells also contain chloroplasts so as to make their own glucose for when they need to respire to open and close.

6.3 Mineral nutrition

For plants, absorption of nitrate ions from the soil is important for making amino acids, which is required for the production of proteins. Magnesium ions are required to make chlorophyll, which must also be absorbed from the soil.

7 Transport in flowering plants

7.1 Uptake and transport of water and ions

Plants take in water from the soil, through root hairs. Root hairs are long and thin, and hence have a large surface area, through which uptake of water and mineral ions can be more and faster. These root hairs are on the edge of the root, a little farther, separated by the root cortex lies a xylem vessel.

The xylem vessels are long hollow tubes made from dead cells joined end to end. The walls of xylem are made of cellulose and lignin, the latter of which is very strong, helping keep plants upright. Through these xylem vessels, water arrives in leaves through visible veins on the leaf under which the xylem vessels are. The water reaches specifically the mesophyll of the leaves.

The movement of water through these tubes is seen by placing the root of a plant into coloured water. That coloured water will be absorbed by the root cells and will be brought up through the stem and into the leaves of the plant. When the plant is cut, it will be seen that there are coloured tubes going across it.

7.2 Transpiration and translocation

Transpiration is the loss of water vapour from a plant.

As discussed before, the xylem vessels reach the plant in the spongy mesophyll layer as part of the vascular bundle, from where water diffuses out by osmosis into the cells. As a result, these spongy mesophyll cells tend to have a thin film of moisture over them. Some of this moisture evaporates from the surface of the cells into the air spaces in the spongy mesophyll layer. From these air spaces the water diffuses out into the atmosphere through stomata.

To replace this lost water, water travels from the xylem into the mesophyll cells. The lack of water in the spongy mesophylls of leaves causes a net lower pressure at the top of xylem vessels, where the leaves are. This causes water to flow up the xylem vessels. This movement of water up the leaves due to differences in pressure is called the transpiration stream. The difference in pressure itself is known as the transpiration pull. The transpiration pull pulls up a column of water molecules through the xylem, the water molecules themselves are held together by intermolecular forces of attraction.

When the wind speed in the atmosphere is high, transpiration can occur more as the water in the atmosphere is quickly moved away. This increases the water potential gradient between the inside and outside of the leaf. Water, as a result, diffuses out faster from inside the leaves. This increases rate of transpiration.

Humidity, i.e., the water content in the air, affects rate of transpiration as it does the water potential between the inside and outside of the leaf. The less the humidity, the faster the rate of transpiration and vice versa.

When water is lost from the cells faster than water is absorbed into the plant, wilting occurs as the turgidity of the cells pushing against each other is lost.

Translocation is the transport of sucrose and amino acids in the phloem from parts of plants that produce or release them, called sources, to parts of plants that use or store them, called sinks. Phloem are tubes, similar to xylem only that they are not hollow nor are they made from hollowed cells. They are also part of vascular bundles. Phloem can transport the substance they are transporting up or down the plant whereas xylem can only transport the substances upwards towards the leaves.

8 Human nutrition

8.1 Diet

The diet of a person is the food eaten in a day. A balanced diet is that which contains all required nutrients in suitable proportions, which provides the right amount of energy. There are seven types of nutrients that a human requires in their diet for it to be balanced.

Carbohydrates are needed for energy, examples include starch and sugar. Most countries have a staple food that tends to be carbohydrate rich such as rice, corn, wheat etc.

Lipids are needed for energy and also to make cell membranes. Excess fats and oils[4] is stored under the skin as adipose tissue. In this form, it insulates the body by reducing heat lost to atmosphere. It may form layers around organs, to provide mechanical protection. Cooking oils, meat, eggs, dairy products and oily fish contain such lipids.

Proteins are required to make new cells, i.e., for growth. Haemoglobin, insulin and antibodies are made from insuline. Meat, fish, eggs, dairy products, peas and beans, nuts and seeds contain protein.

Vitamins are organic substances which are required in miniscule amounts. Lack of such vitamins may cause deficiency diseases.

Lack of vitamin C causes scurvy, which causes muscle and joint pain. They cause gums and other places to blead. Vitamin C is found in citrus fruits.

Vitamin D is found in butter, egg yolk and exposure to sunlight is stimulates the skin to make it. Calcium absorption depends on presence of vitamin D. Lack of this vitamin causes rickets, a disease in which bones become soft and deformed.

Minerals are inorganic substances of which we require very little.

Calcium is a mineral found in milk, bread and dairy products. It is needed to make bones, teeth and for blood clotting. Deficiency of calcium causes brittle bones and teeth and poor blood clotting. Lack of calcium may also cause rickets.

Liver, red meat, egg yolk and dark green vegetables contain iron. This mineral is required to make haemoglobin[5], the red pigment in blood which is responsible for carrying oxygen. Lack of iron in the diet causes anaemia, in which there are not enough red blood cells so the tissues do not get enough oxygen delivered to them.

Fibre, also called roughage, is needed to have the alimentary canal working properly. Peristalsis is the rhythmical muscle contractions that move food down the alimentary canal. Harder foods stimulate these muscles more when compared to softer foods. Fibre hence is required to have this system in good working order and helps to prevent constipation. Fibre consists of undigestable matter, such as cellulose from plant cell walls. This is why all plants contain some amount of roughage. Cereal grains, wholemeal bread and brown rice are all sources of roughage.

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[4] A solid lipid is called a fat, a liquid lipid is called an oil

[5] Any word starting with “haem-” tends to have something to do with iron

More than 60% of the human body is water. Cell cytoplasm is mostly water. Metabolic reactions occur in solution with water as the solvent. A large part of blood is plasma, which is also mostly water, in which substances are dissolved before being transported. Enzymes and nutrients are digested in solution. Urine is also mostly waste product. Drinking fluids and fruit give us the water that we need.

8.2 Human digestive system

The digestive system consists of the mouth, salivary glands, oesophagus, stomach, the small intestine (duodenum and ileum), pancreas, liver, gallbladder and large intestine (colon, rectum and anus).

Eaten food consists of large pieces, which are made smaller by means of physical digestion, where no change happens to the chemical content of these large pieces. This is done to increase surface area of food for enzyme action in chemical digestion. These small pieces are broken down further into small molecules, called chemical digestions. These small molecules can then be transported through the blood and later be assimilated into the body.

Digestion begins in the mouth, where teeth break large food pieces into smaller pieces. Teeth are of different types.

Incisors are sharp edged, chisel shaped teeth present at the front of the mouth which are used to bite off food. Canines are more pointed teeth at either side of these incisors which are used to tear off food. Premolars and molars are large flat shaped teeth used for chewing food. There are some teeth that grow around age 18 21. called wisdom teeth, these grow at the back of the jaw and are molars.

Each tooth is embedded into the gum, which is embedded into the jawbone. The exposed part of the tooth is made of enamel, which is the hardest substance the human body produces. However acids can dissolve it. Beneath this enamel layer is that of dentine. Dentine is a bone like structure which has chennels containing living cytoplasm. The centre of the tooth contains nerves and blood vessels, which supply the cytoplasm in the dentine with nutrients and oxygen. The part of the tooth which is in the gum, i.e., is unexposed is surrounded by a layer called cement. It has fibres growing out of it which attach the tooth to the jawbone but allow it to move slightly which biting or chewing.

The alimentary canal is essentially a long, winding tube running from the mouth to the anus. Some parts are kept separated from others, where necessary, by sphincter muscles. Each part of the alimentary canal is kept lubricated with mucus secreted by goblet cells lining the wall of the alimentary canal.

In the mouth, saliva is a fluid secreted by salivary glands. It consists of water, mucus and the salivary amylase enzyme which is responsible for chemical digeston of starch. The mucus in the saliva helps to bind the chewed food into a small ball, called the bolus, which allows it to slide easily down the oesophegus when swallowed. Here, amylase begins to digest starch to maltose. The oesophagus consists of antagonistically arranged longitudinal and circular muscles, whose rhythmic movements help food down the alimentary canal, this rhythmic movement is called peristalsis. The food then reaches the sphincter muscle at the entrance of the stomach. When this muscle relaxes, the bolus enters the stomach. The stomach has a strong muscular walls which contract and relax to mix the food with enzymes and mucus. The walls of the stomach contain goblets cells which secrete mucus, enzymes and hydrochloric acids. The churning of the stomach breaks the bolus down into further smaller pieces. The enzymes secreted are proteases which break proteins in the bolus to poly peptides and then to amino acids.

When the sphincter muscle at the end of the stomach is relaxed, the bolus, now turned into chyme, enters the duodenum. Here, bile, which is a fluid mixture with a green colour and an alkaline nature, is mixed with the chyme, neutralising the acidity of it which resulted from the stomach acid. The bile enters the duodenum from the bile duct from where it was stored in the gallbladder. Bile is produced by the liver. Bile also emulsifies the lipids in the chyme, increasing their surface area for enzyme action. A tube called the pancreatic duct leads from the pancreas into the duodenum, through which pancreatic juice flows into the duodenum. The pancreatic juice contains enzymes such as amylase, maltase, lipase and protease. Pancreatic amylase breaks down starch to maltose, which maltase breaks to glucose. Lipases act on the emulsified lipids and break them down to fatty acids and glycerol. Proteases act on proteins to break them down to amino acids. Once food has passed the duodenum, it enters the ileum. The initially ingested food now consists of small soluble molecules. These molecules must now pass through the walls of the small intestine to be absorbed into the blood, this process is hence called absorption. The inner wall of the duodenum is covered with tiny projections called villi, of which there are many foldings forming microvilli. On the membranes of these cellular structures enzymes such as maltase acts to breakdown maltose to glucose. These monomer units; glucose, fatty acids, glycerol, amino acids and mineral ions, are absorbed through these microvilli. Most of these substances pass into the blood in the capillaries in the villi. All these capillaries join into the hepatic portal vein through which blood transports all these substances to the liver. Fatty acids and glycerol pass into the lacteal part of villi, which eventually empty into the blood. The villi are shaped with such microvilli to maximise surface area.

Note that protease consists of specifically two proteins, pepsin and trypsin which are both involved in the same task.

Hydrochloric acid in the stomach is present to kill any accidentally ingested bacteria.

The protease in the stomach has an an acidic optimum pH whereas those in the ileum have a neutral to alkaline optimum pH.

8.3 Absorption and assimilation

It is in the small intestine, that all nutrients are absorbed. Absorption is the movement of nutrients from from the intestine to the cells lining the digestive system and into the blood by diffusion, osmosis and active transport.

Assimilation is the uptake and use by cells of nutrients from the blood.

Villus are folded in a way to form many many microvilli to maximise surface area of the small intestine to maximise movement of nutrients and rate of movement of these nutrients from the intestinal lumen into the capillaries of the villi. Most of the water ingested is absorbed in the small intestine, also into the blood, the colon also does the same. The ingested food that remains after action of the small intestine, travels into the colon, where remaining water is absorbed. The final undigested part of food is stored into the rectum until the sphincter muscle to the anus is opened, and the undigested part is egested.

Most molecules and ions travel through the hepatic portal vein to the liver to be absorbed.

9 Human gas exchange

9.1 Human gas exchange

The human gas exchange surface consists of the lungs. They are specialised for exchange of gases by having:

- Large surface area, to maximise diffusion.
- Thin surface distance; the surface is only one cell thick so as to minimise distance for diffusion, maximising diffusion rate.
- They are well supplied with capillaries so as to diffuse as much oxygen into the blood and as much carbon dioxide out of the blood as possible. The lungs take in sufficient air so as to cause maximum diffusion as well.

In the atmosphere, **the proportions of gases** present follow: 21% of oxygen O_2 , 0.04% of carbon dioxide (C_2O). These are the gas proportions that we breathe in, i.e., that we inspire. The air that we breathe out, exhale or expire consists of the following compositing: 16% oxygen, 4% carbon dioxide and very high amount of water vapour, compared to that inhaled.

The respiratory tract consits of the larynx, trachea, bronchus and bronchioles. Once air has entered through our noses, it passes the larynx or the voice box. It then goes through the trachea. The trachea splits into two bronchi (bronchus, singular) which branch out into bronchioles further into grape like structures called alveoli. It is these alveoli through which gaseous exchange in humans occur. These are balloon-like in that they blow up when we inhale, and deflate when we exhale.

Inside these alveoli, gases accumulate when we breathe in, and around these there are capillaries enveloping it. The alveolar wall is only one cell thick, and is moist, so as to minimise the distance oxygen has to travel to diffuse into the blood in the surrounding capillaries. The surface area in contact with the blood vessels is also large so as to maximise diffusion. They are constantly supplied with blood so that blood can be oxygenated. They also have a good supply of oxygen from our constant breathing in and out, also called ventilation.

The ribs are the cage-like bones surrounding our lungs and heart. That which is enveloped by the ribs is called the thorax. In between and around each rib-bone there are intercostal muscles, which are arranged antagonistically[6], namely the external and internal intercostal muscles. Beneath the ribs, there is the diaphragm, which is a muscle separating the thorax, i.e. the chest cavity from the abdominal cavity.

Breathng in occurs when the pressure inside the thorax, i.e. the lungs lowers to below that of atmospheric pressure. Air from outside the body rushes in through the nose and mouth into the alveoli when this happens. To do this, the volume of the thorax must be maximised, which is done by contraction of the diaphragm from its relaxed dome shape. Alongside that, the external intercostal

[6] A pair of muscles where, when one contracts the other relaxes and vice versa.

muscles contract, relaxing the internal intercostal muscles. This results in the ribs moving up and outwards, decreasing internal pressure and causing air to rush into the lungs.

To **breathe out** the exact opposite must occur. The thorax's volume must lower, so as to increase lung pressure to be greater than that of the surrounding atmosphere. To do so, the thorax relaxes into its dome shape and the internal intercostal muscles relax whereas the external intercostal muscles relax, causing the ribs to move down and in. As a result, air rushes out of the lungs into the atmosphere.

Physical activity has effects on the rate and depth of breathing. When performing physical tasks, such as running, our body needs lots of oxygen as fast as possible to respire aerobically, to produce energy for muscle contraction. This is why we breathe faster, at a higher rate, and take deeper breaths, to maximise oxygen in our blood. Often, this oxygen demand is not met, and the body has to compensate by performing anaerobic respiration, which releases less energy in comparison to aerobic respiration. Anaerobic respiration produces lactic acid, which accumulates in the blood and muscles. To break down this lactic acid, we continue breathing in quicker and deeper even after we have completed the physical task, as the breakdown of lactic acid requires oxygen. This is known as **paying off the oxygen debt**, this breakdown occurs in the liver and we can say we borrowed oxygen when we performed anaerobic respiration, and we are paying it off by taking in the oxygen we need. The rate and depth of breathing is controlled by the brain, which, when it senses that the pH of blood has lowered due to lactic acid, stimulates the diaphragm and intercostal muscles to contract and relax harder and more often. Faster and deeper breaths result.

The trachea, bronchi, even the inside of the nose is lined with **goblet cells and cilia**. Goblet cells produce mucus, a chemical which traps any pathogen or particle that enters the respiratory tract. Cilia are hair like structures which continuously beat upward, pushing mucus upward toward the top of the throat to be swallowed. Once they are, the acid in the stomach destroys any possibly harmful pathogen that may have been stuck in that mucus.

10 Respiration

10.1 Respiration

Respiration is the chemical process by which energy is released from glucose in all living cells. This energy is required for many processes, including:

- Muscle contraction
- Protein synthesis
- Cell division
- Active transport
- Growth
- Passage of electrical nerve impulses
- Maintenance of a constant body temperature (homeostasis).

10.2 Aerobic respiration

Aerobic respiration is the breaking of glucose using oxygen to release energy. Given below, are the word and chemical equations denoting the process of respiration:

$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$$

10.3 Anaerobic respiration

Anaerobic respiration is the breaking of glucose without oxygen to release a relatively little amount of energy. In humans, the breakdown occurs as follows:

$$\text{glucose} \rightarrow \text{lactic acid}$$

In yeast, the following happens:

$$\text{glucose} \rightarrow \text{alcohol} + \text{carbon dioxide}$$

The parts concerning Excess Post-exercise Oxygen Consumption (EPOC), otherwise known as paying of the oxygen debt is given in the last part of Section 9.

During exercise, the heart rate is fast so as to supply oxygen to all the parts that need it as quickly as possible. After exercise, the heart rate remains fast for some time to transport lactic acid to the liver where it can be broken down using oxygen.

11 Transport in humans

11.1 Circulatory system

A **circulatory system** consists of a network of blood vessels, a pump or heart to keep the blood flowing and valves which ensure the flow is in one direction only.

A **double circulatory system** is that in which blood passes through the heart twice for a complete circulation. In such a system, blood at low pressure is sent to the lungs, and its pressure is raised once again after it arrives at the heart and is sent off to the body.

11.2 Heart

The **mammalian heart** is essentially a muscle with four chambers. To prevent backflow, valves are present at specific locations around the heart. The thickness of the muscles of each chambers varies depending on the distance they must pump the blood. The atria are significantly less thick than ventricles as they need only pump blood to the ventricles which are right beneath them. The left[7] ventricle is significantly thicker than the right, as the left pumps blood to the whole body whereas the right only pumps to the lungs.

The heart is composed of two sides, the left and the right, separated by the septum. On the top of each side is an atrium and on the bottom, a ventricle. Seperating the two are atrio-ventricular valves. **The functioning of the heart** consists of the following steps:

1. Deoxygenated blood from the body flows into the right atrium, simultaneously oxygenated blood from the lungs flow into the left atrium. At this moment, the atrio-ventricular valves on both sides are closed.

2. The atria contract, pressuring blood through the atrio-ventricular valves into their respective ventricles. The valves ensure blood does not flow back into the atria.

3. The ventricles contract, the atrio-ventricular valves stay closed, the semilunar valves that are at the entrance of the aorta and pulmonary artery of the left and right heart respectively open to allow blood to flow through those blood vessels[8]

Note that, the atrio-ventricular valve of the left side of the heart is called the bicuspid valve and that on the right is called the tricuspid valve.

The above events occur multiple times every minute, and the number of times it occurs is called the **heart rate**. It can be measured in the following ways:

[7]Note that the left and right sides of the heart is reversed, as we consider the right to be the right side of whose heart we are observing.

[8]Note that, blood is pumped away from the heart in blood vessels called arteries and toward the heart in those called veins.

- The heart makes a lub-dub sound when it beats, caused by the opening and closing of the valves. Counting the number of times lub-dub is heard per unit time can give heart rate.
- Pulse rate can be measured by placing one's hand on any artery, and counting the number of times it pulses per unit time.
- An echocardiograph (ECG) can be used to measure and record electrical activity in the heart using electrodes stuck into the person's body.

Coronary heart disease (CHD) occurs when the arteries that supply the heart itself with blood, called the coronary arteries, become blocked in some way. It can occur due to the following factors:

- Diet: Eating high amounts of saturated fats results in high cholesterol concentration.
- Sedentary lifestyle: Those with lethargic lifestyles tend to run a higher risk to develop CHD.
- Stress: Leading a high stress lifestyle may also result in CHD.
- Smoking: Smoking greatly increases risk of CHD.
- Genetic predisposition: Many carry hereditary genes which make them susceptible to CHD, such an individual must lead a healthy lifestyle so as to avoid suffering from the disease.
- Age and gender: Older people run a greater risk of contracting CHD, and men are more prone to CHD than women.

Regular exercise and having a healthy diet is the key to combat CHD. Regular exercise keeps the mind and body fit, keeps the blood pressure at a good value, reduces chance of excessive weight gain. They make one feel fit. Other than that, avoiding fatty, greasy, animal-based foods is the key to preventing CHD as such foods contain saturated fats which increase cholesterol levels in the body leading to CHD.

11.3 Blood vessels

It is through the aorta that oxygenated blood flows out of the heart and to the rest of the body parts. Through the inferior and superior vena cava, deoxygenated blood enters the right side of the heart. The hepatic vein and artery carry blood to and from the heart and liver, respectively. The hepatic portal vein is a blood vessel going from the small intestine to the liver, carrying nutrients to be assimilated in the liver. The renal artery and vein carry blood to and from the heart and the kidneys, respectively.

Arteries carry blood away from the heart. They mostly contain oxygenated blood, except the pulmonary artery. They have thick, muscular walls with elastic tissue, that bounce back with the flow of blood to allow the blood to flow smoothly. The lumen of an artery is relatively small, but not as small as capillaries.

Veins carry blood to the heart. They mostly contain deoxygenated blood, except the pulmonary vein. They have thin walls, also composed of muscles and elastic fibres. They have a relatively large lumen and have valves to prevent backflow of blood. Veins do not carry particularly high pressure blood, so, such as to not slow down speed of blood flow they have a large lumen. They need not thick walls as they carry not high pressure blood.

Capillaries are very thin blood vessels which surround cells, they are the middle ground between an artery and a vein. They have very small lumens and walls only one cell thick. It is through capillaries nutrients, oxygen, etc. diffuse in and out of the blood and cells. They are small so as to penetrate every part of the body and supply it with blood as it requires.

11.4 Blood

Blood is a mixture consisting of plasma, red and white blood cells, and platelets. Red blood cells are biconcave and lack all cell organelle. White blood cells are of two types, lymphocytes and phagocytes. Phagocytes have lobed nuclei, whereas lymphocytes have nuclei that take up almost the whole cell. Platelets are tiny structures, smaller than both the blood cells.

Red blood cells contain haemoglobin, which is a substance to which oxygen binds to form oxyhaemoglobin. It is in this form that oxygen is transported around the body. Red blood cells lack any cell organelle to maximise space for oxyhaemoglobin. They are biconcave in shape to maximise surface area for diffusion of oxygen.

White blood cells are involved in immunity of the body. Lymphocytes are cells that produce antibodies to kill any and all pathogens and phagocytes engulf those pathogens to kill them.

Platelets are involved in blood clotting. When a blood vessel is broken, the platelets release a substance to convert soluble fibrinogen present in blood to fibrin, an insoluble protein that forms a mesh-like structure around the wound. Blood cells get trapped in this mesh, preventing excessive blood loss.

Plasma is a substance consisting of mostly water, in which many substances are dissolved for transport. Such as: glucose, amino acids, mineral ions, hormones, carbon dioxide, urea, vitamins and plasma proteins.

Oxygenated blood flows in from arteries into capillaries. Here, oxygen diffuses out from inside red blood cells, into cells and carbon dioxide diffuses into the plasma. Such exchanges occur before the branched capillaries congregate into veins carrying deoxygenated blood. Plasma leaks out from capillaries during this exchange. This leaked plasma is called tissue fluid and it helps in diffusion of substances.

12 Disease and immunity

12.1 Disease

A pathogen is any microorganism that causes disease. A disease that can pass from one host to another is called a transmissible disease. This transmission can occur in two modes: directly or indirectly.

Direct transmission occurs when an infected person comes in direct contact with an uninfected person. This may be in the form of sexual or salivary exchange, or even blood transfusion with an infected person.

Indirect transmission occurs when pathogens come in indirect contact with uninfected people. This may be in the form of pathogen containing droplets in the air, touching a surface touched by an infected person, consuming contaminated substances or animals carrying the disease.

There are **physical barriers** in the body to prevent infection. The skin blocks any pathogen's entry into the body. Hairs in the nose trap any such pathogen. **Chemical barriers** include mucus secreted by the lining of the respiratory tract in which pathogens become trapped. Stomach acid kills any pathogen that has been ingested.

Mosquitoes can carry disease. They carry pathogens in themselves which pass into us when they bite us to suck our blood. They are called vectors[9], as a result.

The **malaria** pathogen is a parasite[10] . When a person infected with malaria is bitten by a mosquito, it passes into the mosquito's body, where it stays. When that mosquito, carrying the malarial pathogen bites another uninfected individual, the malaria parasite passes into that person and they become infected. An infected person suffers high fever, diarrhoea, sweating and convulsions. The malaria parasite first enters the bloodstream at the site of the mosquito bite. By the blood they are transported to the liver, where they mature. Once they have done so, they enter the bloodstream and infect red blood cells, causing them to burst after a certain period of time.

Control of malaria spread can be done by controlling the vectors of the disease, i.e., mosquitoes. Use of insecticides, and covering mosquito breeding grounds so that they cannot reproduce. Draining unnecessary bodies of water and populating those necessary with mosquito larva eating fish can also be done.

The **human immunodeficiency virus** (HIV) causes **auto-immune deficiency syndrome** (AIDS). HIV is a viral pathogen and its structure consists of the following:

- RNA (genetic material)
- Protein coat
- Lipid envelope

[9] Vectors are any organisms that can carry disease
[10] A pathogen is that which depends on another organism to live

HIV **spreads** through direct contact. It can only pass by means of direct blood transfusion and sexual intercourse amongst infected and uninfected individuals. It may pass from mother to faetus as the virus is small enough to pass through the placenta. Through breast milk, HIV can also be transmitted.

Controlling HIV comes down to careful screening of blood for the virus before transfusion. Other than that, limiting sex to one partner and avoiding unprotected sex prevents HIV. Condoms or femidoms should be used during intercourse. Re-using syringe needles amongst multiple individuals should be avoided.

Cholera is a disease caused by a bacterium, which is indirectly transmitted through water that has come in contact with the faeces of an infected individual and is drunk by an uninfected individual. To **prevent** its spread, the sewage system of a country should be well handled and the waste should be removed carefully. Maintaining good hygiene, i.e. washing regularly with soap, covering when sneezing and washing hands regularly can lower chances of cholera transmission.

The action of cholera consists of the bacterium manifesting in the small intestine. It then secretes a toxin which causes the walls of the intestine to release chloride ions. As a result, the water potential of the lumen of the small intestine decreases to below that of the intestine walls (epithelium). Water, as a result, passes from the walls of the intestine into the lumen, causing the faeces to be watery otherwise known as diarrhoea. Water is lost from the body in this way, causing the infected individual to be dehydrated. Many ions are also lost in dissolved form through this water.

The treatment of cholera can be done by rehydrating the infected individual by means of oral rehydration solution (ORS).

Excessive **alcohol consumption** results in reduced self-control and damages the liver as it is in the liver that the consumed alcohol is broken down. It is drunk as a depressant to obtain a pleasant numb feeling. Alcohol reduces the reaction times of the drinker, as it slows down nerve impulse transmission. It is also looked down upon by society.

Smokers, along with tobacco smoke, ingest three other substances: tar, carbon monoxide and nicotine.

Tar causes bronchitis, in which the goblet cells that line the respiratory tract produce excessive amounts of mucus. It also increases risk of emphysema, a condition in which alveolar walls become less elastic, causing them to burst and fuse together. This reduces the surface area of the gas exchange surface. It is also a carcinogen, meaning it increases risk of cancer.

Nicotine causes the blood vessels to narrow. This may result in coronary heart disease when the coronary arteries become narrowed.

Carbon monoxide binds to the haemoglobin in red blood cells, rendering them useless and reducing the body's oxygen carrying capacity.

It has also been seen that mothers who smoke tend to give birth to babies whose weights are much less than normal. Mothers are advised not to smoke during pregnancy as doing so increases risks of miscarriage and oxygen availability for faetus. Babies may be born with withdrawal syndrome from cigarette smoke and the toxins of the smoke may effect the babies growth as well.

12.2 Antibiotics

A **drug** is any substance taken into the body which alters the body's internal chemical reactions.

Antibiotics are drugs which kill bacteria in the body. They are hence used to treat bacterial infections. They have no effect on viruses.

Antibiotic-resistance can arise in a population of bacteria in the following situation:

1. Person infected with bacteria, takes antibiotics.

2. Most bacteria are killed, but some mutate a gene which helps them be resistant to that specific antibiotic.

3. These mutated bacteria are said to be antibiotic resistant.

MRSA is an example of such an antibiotic resistant bacteria. The evolution of antibiotic resistant bacteria can be reduced by completing antibiotic courses and prescribing them only when necessary.

12.3 Immunity

Active immunity is the defense of the body against pathogens by production of antibodies by lymphocytes in the body itself.

Each type of pathogen has a specifically shaped antigen. The antibody for an antigen is a complementarily shaped protein, produced by specific lymphocytes[11]. These antibodies bind to the antigens on the surfaces of pathogens and either destroy them directly, or join them together so that phagocytosis can be done more easily.

Active immunity arises once an individual has already been infected by a certain pathogen once, or by vaccination.

In vaccination, an individual is injected with weakened pathogens, against which the immune system defends once the antigens of that pathogen has been detected. When lymphocytes produce antibodies, they themselves also multiply. Some of these resulting daughter cells are memory cells, and they remain in the blood for a long time. When the actual pathogen infects the individual, these memory cells detect that pathogen's antigens and produce that specific antibody complementary to that pathogen.

When a population is vaccinated, pathogens have very few places to live, and as a result it becomes extinct. This is called herd immunity, where even if not everyone is vaccinated the pathogen disappears for lack of places to live.

Passive immunity arises when antibodies are taken into the body from another individual. This is by means of passage of antibodies across the placenta and via breast milk from mother to child. The body is not being infected by

[11] A specific lymphocyte can only produce a specific antibody.

any form of pathogen in this situation, and hence no memory cells are formed. As a result, passive immunity does not last very long at all. They only last so long as the antibodies are not broken down in the blood.

In an infant, the immune system is not well developed. That is why antibodies from the mother's breast milk must be given to the infant, to protect it against infection.

HIV destroys lymphocytes, reducing their number in the blood. Lack of lymphocytes reduces the body's antibody producing capability, resulting in a weak immune system.

13 Excretion

13.1 Excretion

Excretion is the removal of toxic materials and the waste products of metabolism from organisms. In mammals, carbon dioxide and urea are waste products of respiration and deamination, excreted through lungs and urine respectively.

13.2 Urinary system

The urinary system consists of the kidneys, ureters, bladders and urethra.

The kidneys remove urea, excess salts and water from the blood and form urine from these toxic substances. The urine then flows to the ureters into the bladder. It is in the bladder the urine is stored until the sphincter muscle to the urethra is opened and the urine is excreted through it.

Note that, urea is only exreted due to the toxicity of it.

The cross section of the kidney is made up of two parts, pyramid shaped medulla and the cortex. The ureter joins the kidney at the medulla. The kidneys are made up of tubules called nephrons.

Nephrons begin in the cortex, loop into the medulla and back out and again into the medulla to join up with the ureter.

Blood flows into the kidney through the renal artery, which devides to form many capillaries called glomeruli. As the blood flows through the glomerulus in the Bowman's capsule, which is the first part of the nephron, small molecules are filtered out of it, including water, glucose, urea and other ions. Not all of these filtered substances need to be lost, so the glomerulus continues along the nephron as the nephron drops down into the cortex as the loop of Henle. Glucose, water and some ions are reabsorbed into the blood from the loop of Henle into the blood vessels that surround it, known as reabsorption. The liquid remaining in the nephrons is urine, consisting of urea, excess water and excess ions and can hence be excreted.

Urea is produced in the liver. Amino acids go to the liver after they have been digested through the hepatic portal vein, here they are assimilated by the liver. Proteins cannot be stored and those that are not needed immediately are broken down. This breakdown consists of removal of the nitrogen-containing part of the amino acid, forming urea. The process through which urea is formed, i.e., the breakdown of amino acid in the described way is called deamination.

14 Coordination and control

14.1 Mammalian nervous system

The nervous system, consisting of the brain, spinal cord and nerves coordinate and control the body's functions. The nervous system is in two parts, the peripheral (PNS) and central nervous systems (CNS).

The CNS consists of the brain and the spinal cord whereas the PNS consists of all the nerves that branch out from the CNS.

Each nerve consists of thousands of neurones. Neurones are of three types: sensory, relay and motor. All neurones have three parts, dendrites from which they recieve nerve impulses, the cell body and the axon through which they transmit nerve impulses. Nerve impulses are electrical in nature.

Sensory neurones have lon dendrites and a long axon, the motor neurone has shorter dendrites and long axons and the relay neurone has short dendrites and axon.

Reflex actions are rapid and automatic response to potentially dangerous stimuli, such as touching a hot surface. We do not think about such actions as the impulses do not reach the brain in such an action. The following happens in a reflex arc:

1. Sensory cells sense something dangerous.
2. Impulses are created and passed onto sensory neurone.
3. Sensory neurone pass it onto relay neurones.
4. Relay neurones pass it onto motor neurones.
5. Motor neurones stimulate effector cells.
6. Danger averted.

Reflex actions are effective as no time is wasted in thinking about what to do, which may the difference between survival and death in some cases

A synapse is the junction between two neurones. There is a gap between each pair of neurones, the gap, along with the ending and starting of those neurones is the synapse. The end of the first neurone has vesicles with neurotransmitter molecules. When an electrical impulse travels down this neurone, the vesicles are stimulated to move to the end of the neurone and empty their contents. These neurotransmitter molecules diffuse over to and bind to the receptor proteins on the dendrites of the second neurone and an electrical impulse is hence generated in that neurone too.

Synapses ensure that neurotransmitters travel in one direction only as only one side of the synapse has receptor proteins and the other has neurotransmitters.

14.2 Mammalian sense organs

Sense organs are groups of receptors cells that respond to specific stimuli such as light, sound, touch, temperature and chemicals. The eye is a sense organ consisting of the following parts:

- Cornea: Refracts entering light.
- Iris: Controls the amount of light entering the eye.
- Lens: Focuses light onto the retina.
- Ciliary muscles and suspensory ligaments: Control the shape of the lens.
- Fovea: Contains the greatest density of light receptors.
- Optic nerve: Carries impulses to the brain.

Circular and radial muscles are antagonistic. They control the size of the opening of the pupil. When we are in a bright atmosphere, not much light need enter the eye, so the pupil must be made smaller. To do so circular muscles contract as radial muscles relax. When light is scarce, the opposite occurs.

The light entering the eye is refracted mostly by the cornea, but fine-tuning is done by the lens. Light coming from far away need not be reflected much, hence the lens must be thin. To do so, suspensory ligaments and ciliary muscles are used. The ciliary muscles relax, the suspensory ligaments become taught and the pull the lens thin. The opposite happens for objects close.

14.3 Mammalian hormones

A hormone is a chemical substance, produced by a gland and carried by the blood which alters bodily functions, that of some specific organs. A few glands and their hormones are:

- Adrenal glands: Adrenaline
- Pancreas: Glucagon and insulin
- Pituitary gland: FSH, LH, (see Section 16)
- Testes: Testosterone
- Ovaries: Oestrogen and progesterone.

Adrenaline is produced in life threatening situations, it stimulates the release of glucagon which results in glycogen stored in the liver to be released into the blood as glucose so that energy can be used. It increases heart rate to provide muscles with oxygen and glucose as much as they require. Breathing rate increases too, to absorb as much oxygen as possible.

Nervous and hormonal control differ in that nervous control is faster yet last longer but hormonal control is slower yet lasts as long as the hormones are not broken down.

14.4 Homeostasis

Homeostasis is the maintenance of a constant internal environment. There are set points of conditions in the body, when the body goes beyond or below which, negative feedback occurs and the body is stimulate to undo this change.

The skin consists of hairs, muscles to erect those hairs, sweat glands and ducts, receptors, sensory neurones, blood vessels and fatty tissue.

Insulation through adipose tissues under the skin prevent the loss of heat from the body and entrance of heat from outside the body.

Hypothalamus

Insulation through adipose tissues under the skin prevent the loss of heat from the body and entrance of heat from outside the body.

The hypothalamus has receptors which can sense temperature of blood passing through it. When the temperature of blood is above or below the set point of body temperature the hypothalamus stimulates actions to bring it back to set point.

Sweating happens when we are too hot. When sweat evaporates from our body, the body gets cooler.

Shivering happens when we are too cold, the movement of muscles along with the respiration required to cause it warms us up.

When we are cold our hairs stand up so as to trap warm air.

Vasodilation occurs when we are too hot and heat must be lost to the atmosphere from the blood vasoconstriction is the opposite and occurs when we are too cold and heat must be conserved in the blood. Vasodilation is the dilation of arterioles near the skin surface and vasoconstriction is the constriction of those arterioles.

14.5 Blood glucose control

Cells need steady amount of glucose supply to respire and carry out their processes. Too much glucose can be mad as they can mess with water potentials causing water to move out of the cells.

Insulin is the hormone that when secreted, stimulates liver to convert more and more glucose to glycogen. Glucagon does the opposite in that it stimulates the liver to convert more glycogen to glucose.

Type 1 diabetes is a condition where the body cannot produce its own insulin resulting in high blood glucose concentrations and high urine glucose concentrations. Such persons must eat controlled amounts of carbohydrates as eating too much may make them feel unwell and eating too little will result in them being lethargic as they have no stored glycogen. Their treatment consists of injecting insulin directly into their blood stream.

15 Coordination and response in plants

15.1 Coordination and response in plants

Gravitropism is a response in which parts of a plant grow towards or away from gravity (positive and negative gravitropism, respectively). Phototropism is the same only with light.

Auxin is a hormone that is produced in the shoot tip of a plant and diffuses downward through the plant. The production of auxin is stimulated when light hits the shoot tip.

It stimulates cell elongation and is unequally distributed in response to light and gravity. Specifically, it diffuses away from light and towards gravity. Hence the plant roots elongate downward into the soil and bend toward light.

Shoots are positively phototrophic and negatively gravitrophic, the opposite applies for roots.

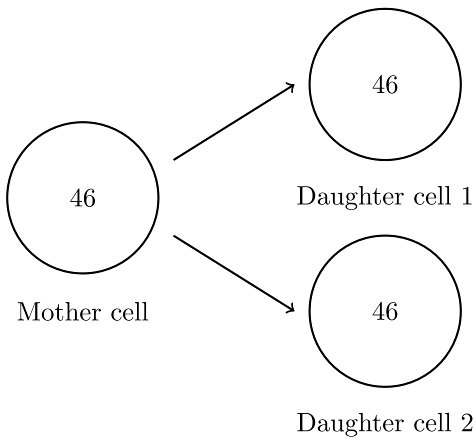
16 Development of organisms and continuity of life

16.1 Nuclear division

Chromosomes, present in the nucleus and that on which genetic information is stored, are structures made of DNA.

A haploid nucleus is that which contains a single set of chromosomes, a diploid one contains two sets. For humans, a diploid nucleus contains 46 chromosomes and a haploid nucleus contains 23.

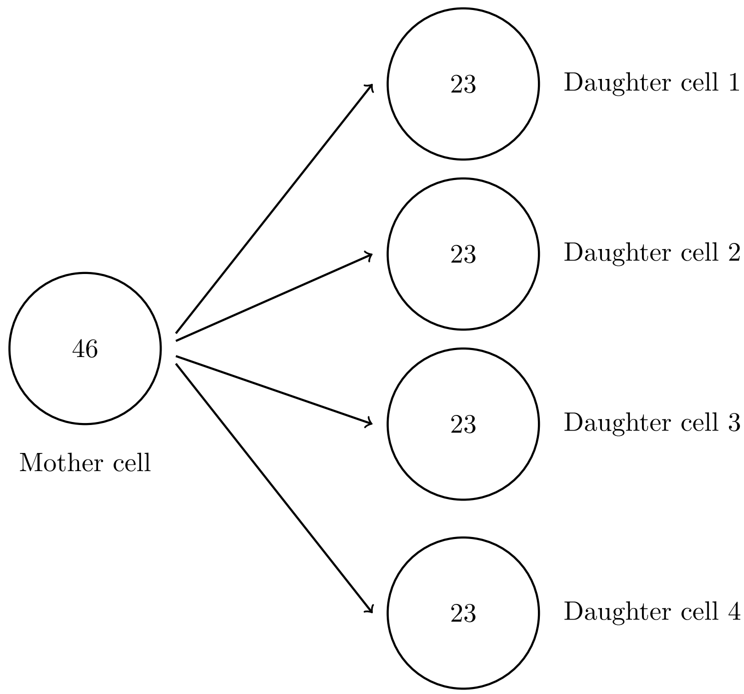
Mitosis is a form of nuclear division which gives rise to genetically identical cells in which the chromosome number of daughter cells is maintained and equal to mother cell and sibling cells.



The above diagram shows a mother cell dividing, by mitosis, into two daughter cells with the same number of chromosomes. The cells produced are genetically identical. An organism grows or repairs parts of its body by mitosis. In other words, mitosis plays the role of growing the body and replacing deprecated cells. Mitosis is also used in asexual reproduction, for example, when potatoes grow new plants from tubers, the new plants form by mitosis, meaning they are all genetically identical.

Stem cells are unspecialised cells that divide by mitosis to produce daughter cells that can become specialised for specific functions. In the bone marrow, there are stem cells from whose mitosis divisions blood cells form. Stem cells in the brain divide to form new neurones.

Meiosis is the type of cell division involved in the production of gametes. Meiosis division is a reduction division in which chromosome number is halved from diploid to haploid, resulting in genetically different cells.



As shown above, meiosis gives rise to four genetically different daughter cells. Which daughter cell gets which combination of the haploid chromosomes is random, and hence the genetic characteristics of the daughter cells of this division is random.

Cancers are a result of defective cells dividing uncontrollably.

16.2 Asexual and sexual reproduction

Asexual reproduction is a procuss by which genetically identical offspring are produced by a single parent. Unicellular organisms usually undergo this form of reproduction, alongside some species of plants under certain situations. The process is faster as mates need not be found and the genetic characteristics of the offspring are perfectly predictable. However, asexual reproductions may reduce the biological diversity of a habitat and genetic disorders may arise in offspring. Asexual reproduction is advantageous for a species newly colonising a new environment, to which it is well suited. It can then reproduce quickly by mitosis and reap the benefits of the area.

Sexual reproduction is a proces involving the fusion of haploid nuclei, a process known as fertilisation, to form a diploid zygote and the production of genetically different offspring. These haploid nuclei, or rather, the cells containing these haploid nuclei are called gametes. The zygote that results from their fusion is haploid. Sexual reproduction gives rise to genetic disparity amongst parent and child, giving rise to biodiversity. Yet it is slow for the same reasons meiosis is fast. There is also less chance of genetic diseases arising. Sexual reproduction allows an organism to adapt to its surroundings, and is useful when new areas are being colonised.

16.3 Sexual reproduction in plants

A flowering plant produces structures called flowers. They consist of the sepals, which are leaf like structures that surround the flower by formning a ring around the flower petals. The petals of a flower are coloured structures that attract insects or birds to it. The stamens of a flower are the male parts of the flower, which consist of a filament and anther, the stalk part and the pollen producing and containing part of the flower respectively. Pollen grains are strructures of a flower containing the male gametes of the flower. The carpel is the female part of the flower, consisting of the ovary which holds the ovules, which are small structures containing the female gametes. The style is the part of the carpel connecting the stigma to the ovary. The stigma is the part of the flower that recieves the pollen.

Pollination is the process by which pollen is carried from the anther of a flower to the stigma of a flower of the same species. It is done by two means, by insects or by wind, and plants utilising these strategies are adapted accordingly.

In plants which are pollinated by insects, the filament is relatively short resulting in the anthers being inside the flower. They have large, attractive petals to attract insects and to act as landing pads for them. Such flowers may have nectar to attract the insects into the flower. Pollen brushes onto the insects body from the anthers as it tries to get the nectar. When the insect flies to another flower looking for nectar, it carries the pollen to that flower, where the flower becomes pollinated. The pollen grains in such plants tend to be rough so as to stick to the pollinating insects. Such plants may be strongly scented. Insect pollinated flowers produce less quantities of pollen than wind pollinated flowers as it is a more surefire method of pollination.

In plants pollinated by the wind, pollen have smooth shapes with large surface area to be carried easily by the wind. The filaments are long and the anthers hang out of the flower in such plants, to maximise the chance of wind carrying the pollen to another flower of the same species. The stigma of such flowers tend to also be stuck out of the flower, to maximise chance of catching the floating pollen. They tend to have shapes that maximise their surface area for the same reason. Such flowers lack particularly attractive petals and nectar as there is no need to attract any insect. Wild pollinated flowers lack any scent at all. Such flowers produce huge quantities of pollen to maximise chance of pollination as most will not reach a stigma. Pollen from such plants tend to be quite lightweight to be carried easily by the wind.

Pollination can occur between the male and female parts of the same flower, or the different flowers of the same plant. This is known as self pollination. This results in loss of biodiversity as produced zygotes form a similar genetic makeup. Minimal genetic variation will result from such pollination. Genetic diseases may arise.

Pollination occuring between male and female parts of different plants altogether is called cross pollination. This gives rise to genetic variation, allowing the plant to adapt to changes in environment and increases biodiversity. There is no chance of genetic diseases arising in such a form of pollination.

After pollination, enzymes in the pollen digest through the stigma of the flower to make a path for the male nucleus (gamete) to merge with the female gamete, which is in the ovule, in the ovary. The pollen tube grows into the ovule through a small tube called the micropyle, after which the male gamete travels down the pollen tube and into the ovule where it fuses with the female gamete. This is fertilisation.

Subsequent to fertilisation, most of the flower is redundant. Petals, sepals and stamens all dry, shrink and wither before falling off. The zygote containing ovule divides by mitosis to form an embryo plant, now called a seed. The ovary develops into a fruit.

The thick, hard, outermost layer of the seed is called the seed coat or testa. It prevents entry of water into the seed. The seed itself is kept dehydrated to slow down metabolic reactions in it significantly to keep it dormant. The embryo in the seed is attached to two leave like structures called cotyledons, which are swollen with stored food. Plants that contain two of such leaves are called dicotyledonous and those with one of them are called monocotyledonous. Cotyledons contain stored food, mostly in the form of starch. The plumule is the part of the seed that will develop into the shoot and the radicle is that which will develop into the root.

Dispersal of seeds by animals is a means of colonising new areas and reducing competition around the home area. Such seeds tend to have sweet fruits so as to be ingested by animals, and as the seed emerges unscathed through the animals alimentary canal, it will be left in a condition to be germinated, the process through which the seed changes to a plant. Seeds may also be wind dispersed, in which case they are light and have a large surface area so as to be able to be carried effectively by the wind to a region suitable to germinate.

When the seed is in a situation with the following: water, oxygen and a suitable temperature, it may germinate. Enzymes in the seed work to digest the storeed food into soluble forms in the seed, which is then carried to the growing regions of the embryo. However, germinated seeds may not mature, as some seedlings compete for light due to overcrowding, unsuitable temperature also causes death of sedlings and lack of ions or minerals may stunt growth. Starch is broken down to glucose to be used in respiration during germination, amino acids are used to build up proteins using this energy to make the cytoplasm and cell membranes of the new cells. Lipids are synthesised for the same purpose.

16.4 Sexual reproduction in humans

The male reproductive system in humans consists of the testes, glands which produce sperm; the scrotum, a sack like structure holding these testes; sperm ducts are tubes which carry sperm from the testes to the penis; where the sperm duct connects to the penis, a gland called the prostate gland produces semen and mixes it with the sperm.

In females, the reproductive system consists of the ovaries, where the egg cells are made; leading out of the ovaries are oviducts which lead eggs into the womb or uterus, a structure consisting of very thick, extremely stretchy walls which do so when as this is where the foetus is when the woman is pregnant. The narrow opening to the uteris is called the cervix, after which lies the vagina which leads to outside the body.

A sperm cell is the male human gamete. It consists of a flagellum, a tail like structure which enables the cell to be mobile. The middle piece of the cell contains mitochondria to release energy for swimming. The head of the sperm cell consists of an acrosome, which is a vesicle containing enzymes to digest through the jelly coat of an egg cell. The head also contains the male haploid nucleus, alongside more mitochondria to release energy for the cell's swimming movement. Sperm cells are produced in the testes and they are produced and released millions at a time.

An egg cell is significantly larger than a sperm cell, yet a sperm cell is longer than an egg cell due to its flagellum; it consists of a jelly coat surround the cell surface membrane. Inside the cell the cytoplasm contains "yolk", which is an energy store. The nucleus of the egg cell is haploid. The jelly coat of an egg cell changes when a sperm has fertilised the egg cell, so as to not allow any other sperm to fertilise that egg cell. Egg cells are not produced in high numbers, and a female has a limited store of them, around middle age, a female will no longer have any egg cells.

Testosterone is the male sexual hormone. During their early teenage years, boys' testes start producing this hormone causing them to develop secondary sexual characteristics such as body and facial hair and to start producing sperm. Oestrogen is that in girls, for whom secondary sexual characteristics consist of breasts, monthly menstruation cycles and also body hair.

In women, the menstrual cycle is a monthly hormonal cycle consisting of the release of an egg cell and changing of the uterine lining. This cycle is regulated by four hormones: the follicle stimulating hormone (FSH), luteinising hormone (LH), oestrogen and progesterone, namely. The latter two are released by the ovaries whereas the remaining are released by the pituitary gland in the brain.

At the beginning of the cycle (usually the start of a month), FSH levels are high, stimulating the development of an egg cell in an egg follicle. This developing follicle secretes oestrogen in increasing amounts, which stimulates repair of the uterus lining, makin git thicker and better supplied with blood. When the follicle is fully developed, a surge in LH causes ovulation, in which the egg cell breaks free from the follicle, the remaining follicle is called the corpus luteum. This corpus luteum secretes progesterone which maintains the state of the uterine lining. Progesterone inhibits production of FSH and LH, so no new follicles are stimulated and no more eggs are ovulated. If the egg is not fertilised, the uterine lining breaks down as a result of progesterone secretion stopping. FSH and LH start increasing and the cycle repeats.

The egg cell is fertilised by a sperm cell in the oviduct. After fertilisation, the zygote moves down the oviduct while dividing, it has now become an embryo after having turned into a ball of cells. The uterus has a thick, spongy lining, into which the embryo sinks, called implantation.

As the embryo grows, a placenta also grows which connects the embryo to the wall of the uterus. It is a soft, dark red structure with projections similar to the villi in the small intestine. Here nutrients and waste substances are exchanged between the mother's blood and the foetus's blood. These two blood mixtures never mix, only flow very close to each other. As the foetus grows, an umbilical cord also forms through blood vessels in which foetal blood goes to and from the placenta.

Some pathogens, such as HIV can pass the placenta. Carbon monoxide and alcohol are toxins which can also cross the placenta. This will negatively affect the foetus's growth.

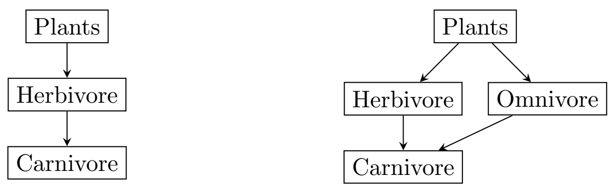
17 Relationships of organisms with one another and with the environment

17.1 Energy flow

Sun is the principal source of energy input to most biological systems.

The energy from the sun is captured into glucose by photosynthesis, that energy is then passed onto other organisms and so every animal on earth is dependent on photosynthesis.

Food Chain Food Web



Using the two diagramatic structures above, energy flow from one organism to another can be represented. A food chain is a diagram showing the flow of energy from one organism to another. food web shows that but in multiple interconnected food chains. Both diagrams begin at producers. Each stage in a food wave or food chain is called a trophic level.

Producers are organisms that make their own organic nutrients, generally using energy from sunlight, through photosynthesis. Consumers are organisms that eat these producers to get their nutrients.

Herbivores are animals that feed on plants, carnivores are animals that feed on animals.

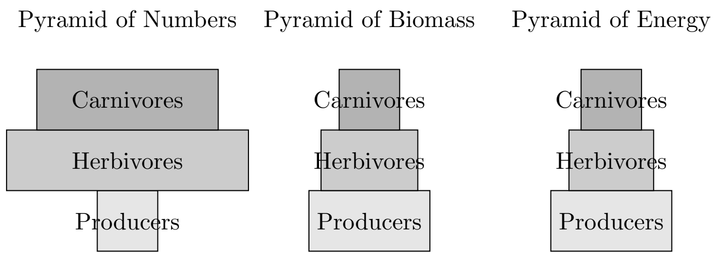
A decomposer is an organism that gets its energy from dead or waste organic material.

The transfer of energy from one trophic level to another is inefficient for the following reasons:

- The organism being eaten has itself respired some of the energy.
- Not all of the organism is eaten
- Not all of the eaten part of the organism is digested

Those that eat consumers are called primary consumers, they are also herbivores. Those that eat primary consumers are secondary and so on tertiary and quaternary. There are rarely more than five trophic levels.

In terms of just energy, it is more efficient for humans to eat crops than to eat animals raised on crops, as energy is lost in two stages when we eat animals, that during photosynthesis from the sun and that during eating by the animals. Crops provide energy directly captured from the sun and hence eating crops is more efficient.



Above are diagrams for the pyramids of numbers, biomass and energy. The pyramid of numbers is uneven because there may be one huge producer, such as a tree upon which many herbivores depend.

The pyramids of biomass represent the mass of each trophic level and are hence evenly shaped because no matter the number of the organisms, the mass will be directly proportional to the energy at that trophic level.

The pyramid of energy represents the energy at each trophic level.