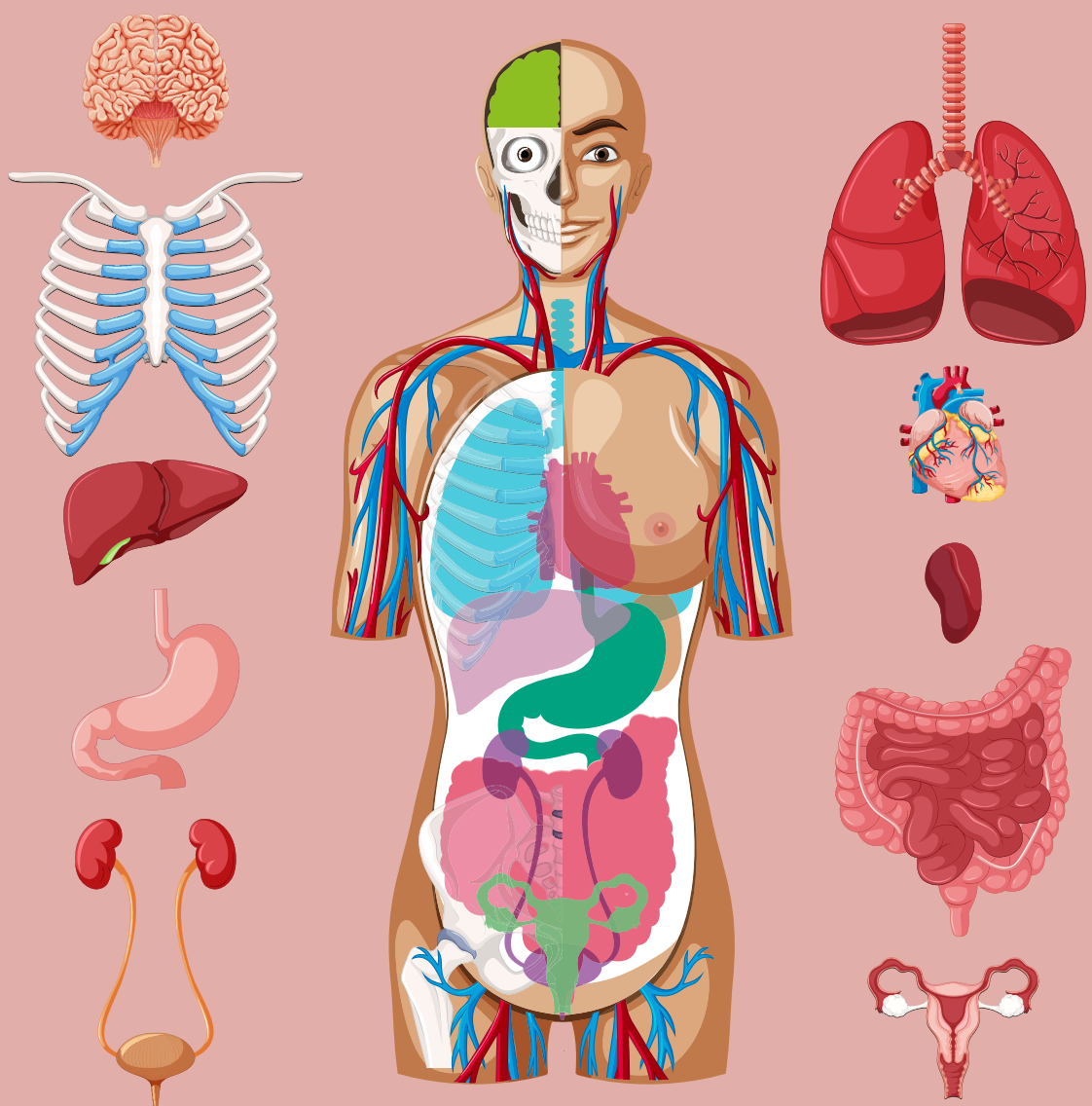
9th Grade Biology and Health Education

Magdalena Milanova
Emil Panayotov
Aneta Maneva



МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА

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оценяване и одобряване на проекти на учебни помагала
за подпомагане на обучението, организирано в чужбина,
на проекти на учебници и на проекти на учебни комплекти“

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Редактор: Емил Тихомиров Панайотов, 2020 г.
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Национално издателство за образование и наука „Аз-буки“
1113 София, бул. „Цариградско шосе“ 125, бл. 5,
тел. 02/4250470; e-mail: azbuki@mon.bg; web: www.azbuki.bg; www.azbuki.eu
Графично оформление корица: Гергана Евгениева Попиванова
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LEVELS OF ORGANISATION OF THE STRUCTURES IN THE HUMAN BODY

Hierarchy

The atom is the smallest particle which builds the base for larger structures. When combined, atoms form molecules, which in turn unite in supramolecular assemblies, organelles and cells. Cells performing similar functions form tissues. Various tissues build organs and organs compose systems that are the main parts of organisms. All living organisms, whether single-celled or multicellular, plants or animals, show the characteristics of movement, respiration, sensitivity, growth, reproduction, excretion and nutrition. Animals are multicellular organisms whose cells have no cell walls or chloroplasts. Most animals ingest solid food and digest it internally. They have a mobile way of living.

Origin

All animals pass through several stages of development: zygote – fertilised egg cell; cleavage – cells increase in number and decrease in size; germ layers formation (endoderm, mesoderm, and ectoderm) – they give rise to tissues; segmentation – further changes; organogenesis – formation of organs.

Cellular Parts

All cells have a cell membrane, which is a thin boundary enclosing the cytoplasm. It stops the cell contents from escaping and controls the substances which are allowed to enter and leave the cell. In general, oxygen, food and water are allowed to enter; waste products are allowed to leave; harmful substances are kept out. Organelles are specialised particles which have particular functions in the cytoplasm. Many chemical reactions take place in the cytoplasm, which keeps the cell alive by providing energy and making substances that it needs. Most cells contain one nucleus (pl. nuclei), which is usually seen as a rounded structure enclosed in a membrane and embedded in the cytoplasm. The function of the nucleus is to control the type and quantity of enzymes produced by the cytoplasm. In this way, it regulates the chemical changes which take place in the cell. As a result, the nucleus determines what the cell will be, for example, a blood cell, a liver cell, a muscle cell or a nerve cell. The nucleus also controls cell division. A cell without a nucleus cannot reproduce.

Specialisation of Cells

When they have finished dividing and growing, most cells become specialised – they do one particular job, develop a distinct shape and special kinds of chemical changes take place in their cytoplasm. The changes in shape and the chemical reactions enable the cell to carry out its special function (e.g. red blood cells).

Tissue

Tissue, such as bone, nerve or muscle in animals, is composed of hundreds or thousands of similar cells grouped together for a particular function. These cells have a common origin, similar structure and a special function; for example, muscles contract to cause movement.

Organs and Systems

Organs consist of several tissues grouped together to make a structure with a special function. For example, the stomach is an organ which contains tissues made from covering epithelial cells, gland cells and muscle cells. These cells are supplied with food and oxygen brought by blood vessels.

The stomach also has a nerve supply. The heart, lungs, intestines, brain and eyes are further examples of organs in animals.

An organ system usually refers to a group of organs whose functions are closely related. For example, the heart and blood vessels make up the circulatory system; the brain, spinal cord and nerves make up the nervous system.

TISSUE LEVEL OF ORGANISATION

Types of Tissue

There are four basic tissue types defined by their morphology and function: epithelial tissue, connective tissue, muscle tissue, and nervous tissue. Epithelial tissue creates protective boundaries and is involved in the diffusion of ions and molecules. Connective tissue underlies and supports other tissue types. Muscle tissue contracts to initiate movement in the body. Nervous tissue transmits and integrates information through the central and peripheral nervous systems.

Epithelial Tissue

Epithelial tissue covers the body and lines its cavities. Certain types of epithelial tissue may have cilia or microvilli. Stratified epithelium has many layers of cells, with only the bottom layer touching the basement membrane. Glandular epithelium secretes a product either into ducts or into the blood. The cells are closely attached, with little or no extracellular matrix.
Features – high cellularity, special sensory receptors, forms a barrier, avascular, innervated
Types – squamous, cuboidal, columnar, simple, stratified, pseudostratified, specialised

Connective Tissue

Connective tissue supports, protects and nourishes all body parts. It consists of cells separated by a matrix that contains ground substance and fibres (e.g., collagen fibres).

There are four types of connective tissue:

- loose fibrous connective tissue, including adipose tissue;
- dense fibrous connective tissue (tendons and ligaments);
- cartilage and bone (the cartilage matrix is solid, yet flexible; the bone matrix is solid and rigid);
- blood (the matrix is a liquid called plasma) and lymph.

Structure – cells (structural, immunological defence, energy reservoir), extracellular matrix (ground substance, protein fibres)

Types of fibres – collagen, reticular, elastic

Classification – proper (dense, loose), embryonic (mesenchyme, mucous), specialised (cartilage, adipose, bone, blood)

MuscTissue

Muscular tissue is of three types: skeletal, smooth, and cardiac. Skeletal and cardiac muscles are striated. Cardiac and smooth muscles are involuntary (not under conscious control). Skeletal muscle is found in muscles attached to bones. Smooth muscle is found in internal organs. Cardiac muscle makes up the heart.

Features – elastic, extensible, contractile

Types – skeletal (striated), cardiac (gap junctions, intercalated discs), smooth (non-striated)

Nervous Tissue

Nervous tissue is composed of neurons (nerve cells) and several types of neuroglia (supporting and nourishing tissue). Each neuron has dendrites, a cell body, and an axon. Axons conduct nerve impulses in places of contact called synapses.

Neurons – soma, dendrites, axons, ganglia (peripheral nervous system), nuclei (central nervous system)

Neuroglia – astrocytes, oligodendrocytes, Schwann cells, microglia – blood-brain barrier

DIGESTIVE SYSTEM. FOOD AND NUTRITION

Food is used as follows: for growth – it provides the substances needed for making new cells and tissues; as a source of energy – energy is required for the chemical reactions that take place in living organisms to keep them alive. When food is broken down during respiration, the energy from the food is used for chemical reactions such as building complex molecules, movement, heartbeat and nerve impulses. Mammals and birds use energy to maintain their body temperature; for replacement of worn and damaged tissues – the substances provided by food are needed to replace the millions of our red blood cells that break down each day; to replace the skin that is worn away and to repair wounds.

Nutrients

A balanced diet must contain enough carbohydrates and fats to meet our energy needs. It must also contain enough protein of the right kind to provide the essential amino acids to make new cells and tissues for growth or repair. The diet must also contain vitamins and mineral salts, plant fibres and water. Proteins, lipids (fats) and carbohydrates form the group of nutritional substances; water, mineral salts and vitamins are functional substances and additives; spices and colouring agents are ballast substances.

People get energy from carbohydrates, fats and proteins. Carbohydrates are usually the most easily available source of energy; the greatest amount of energy is released by decomposing fats; proteins give about the same energy as carbohydrates. The total amount of energy must be sufficient to sustain life (e.g. heart beating, breathing); to maintain our body temperature; to meet the needs of physical activities. The amount of energy that can be obtained from food is measured in calories or joules. One gram of carbohydrate or protein can provide us with 16 or 17 kJ (kilojoules). A gram of fat can give 38.9 kJ. Our energy requirements vary greatly according to our age, occupation and activity. For example, a person who does hard manual work, such as construction work, will use more energy than someone who has an office job. An athlete needs more energy input than someone who does not do much physical exercise.

Females tend to have lower energy requirements than males because, on the one hand, females have, on average, a lower body mass than males, and, on the other, there are different physical demands made on boys and girls. However, an active female may have a higher energy requirement than an inactive male of the same age. As children grow, the energy requirement increases because of the energy demands of the growth process and the extra energy associated with maintaining their body temperature. Once we become adults, metabolism and energy demands begin to slow down with age due to a progressive loss of muscle tissue.

There is relatively less protein in food derived from plants than there is in animal products. Vegetarians and semi-vegetarians, who include dairy products, eggs and possibly fish in their diets, will obtain sufficient protein to meet their needs. However, some vegetarian foods now contain relatively high proportions of protein: Quorn products (made from mycoprotein – derived from fungi) typically contain 14.5 g protein per 100 g, compared with 18.0 g protein per 100 g for beef

sausage, and they do not contain animal fats. Vegans, who eat no animal products, need to ensure that their diets include a good variety of cereals, peas, beans and nuts in order to obtain all the essential amino acids to build their body proteins.

Examples of Special Needs

Pregnancy. A pregnant woman who is already receiving an adequate diet needs no extra food. Her body's metabolism will adapt to the demands of the growing baby although the demand for energy and protein does increase. If, however, her diet is deficient in protein, calcium, iron, vitamin D or folic acid, she will need to increase her intake of these substances to meet the needs of the baby. The baby needs protein for building its tissues, calcium and vitamin D are needed for bone development, and iron is used to make the haemoglobin in its blood.

Growing children. Most children up to the age of about 12 years need less food than adults, but they need more in proportion to their body weight. For example, an adult may need 0.57 g protein per kg body weight, but a 6-11-month-old baby needs 1.85 g per kg and a 10-year-old child needs 1 g per kg for growth. In addition, children need extra calcium for growing bones, iron for their red blood cells, vitamin D to help calcify their bones and vitamin A for disease resistance.

Malnutrition

As a term, malnutrition is often used to mean simply not getting sufficient quantities of food. However, it has a much wider meaning than this, including getting too much of a certain type of food or the wrong kind of food. If the total food intake is not enough to meet the body's need for energy, the body tissues themselves are broken down to provide the energy to stay alive. This leads to weight loss, muscle loss, weakness and, ultimately, starvation.

Obesity

It is unclear why some people are prone to obesity. One reason may be a genetic predisposition, in which the brain centre that responds to food intake does not signal when sufficient food has been ingested; in some cases, it may be the outcome of an infectious disease. Whatever the cause, the solution is to reduce food intake to a level that does not exceed the body's needs.

DIGESTIVE ORGANS. MECHANICAL DIGESTION

There are five main processes associated with digestion that occur in the alimentary canal: ingestion, digestion, absorption, assimilation and egestion. Ingestion is the taking of substances such as food and drink into the body through the mouth. Mechanical digestion is the breakdown of food into smaller pieces without chemical change to the food molecules. Chemical digestion is the breakdown of large insoluble molecules into small soluble molecules. Absorption is the movement of small food molecules and ions through the wall of the intestine into the blood. Assimilation is the movement of digested food molecules into the cells of the body where they are used, becoming part of the cells. Egestion is the passing out of food that has not been digested or absorbed, as faeces, through the anus.

Feeding involves taking food into the mouth, chewing it and swallowing it down into the stomach. This satisfies our hunger, but to be of any use to the whole body, food needs to be digested first. This means that the solid food is dissolved and the molecules are reduced in size. The soluble products then have to be absorbed into the bloodstream and carried by the blood all around the body.

The inside of the alimentary canal is lined with layers of cells forming an epithelium. New cells in the epithelium are being produced all the time to replace the cells worn away by the movement of the food. There are also cells in the lining that produce mucus. Mucus is a slimy liquid that lubricates the lining of the canal and protects it from wear and tear. Mucus may also protect the lining from attack by the digestive enzymes which are released into the alimentary canal. Some of the digestive enzymes are produced by cells in the lining of the alimentary canal, as in the stomach lining. Others are produced by glands that are outside the alimentary canal but pour their enzymes through tubes (called ducts) into the alimentary canal. The salivary glands and the pancreas are examples of such digestive glands. The alimentary canal has many blood vessels in its walls, close to the lining. These bring oxygen needed by the cells and take away the carbon dioxide they produce. They also absorb the digested food from the alimentary canal.

Peristalsis

The alimentary canal has layers of muscle in its walls. The fibres of one layer of muscles run around the canal (circular muscles) and the others run along its length (longitudinal muscles). When the circular muscles in one region contract, they make the alimentary canal narrow in that region. A contraction in one region of the alimentary canal is followed by another contraction just below it so that a wave of contraction passes along the canal, pushing food in front of it. The wave of contraction is called peristalsis.

The process of mechanical digestion mainly occurs in the mouth by means of the teeth, through a process called mastication (chewing). Humans are omnivores (organisms that eat animal and plant material). We have the same types of teeth as carnivores, but human teeth are not used for catching, holding, killing or tearing up prey, and we cannot cope with bones. Our top incisors pass in front of our bottom incisors and cut pieces off the food, such as when biting into an apple

or taking a bite out of a piece of toast. Our canines are more pointed than the incisors but are not much larger. They function like extra incisors. Our premolars and molars are similar in shape and function. Their specific surfaces, called cusps, meet when the jaws are closed, and crush the food into small pieces to make them easier to digest.

Tooth Structure

The part of a tooth that is visible above the gum line is called the crown. The gum is tissue that overlays the jaws. The rest, embedded in the jawbone, is called the root. The surface of the crown is covered by a very hard layer of enamel. This layer is replaced by cement in the root, which enables the tooth to grip to its bony socket in the jaw. Below the enamel is a layer of dentine. Dentine is softer than enamel. Inside the dentine is a pulp cavity, containing nerves and blood vessels. These enter the tooth through a small hole at the base of the root.

The Mouth

The act of taking food into the mouth is called ingestion. In the mouth, the food is chewed and mixed with saliva. The chewing breaks the food into pieces that can be swallowed and it also increases the surface area for the enzymes to work on later. Saliva is a digestive juice produced by three pairs of glands whose ducts lead into the mouth. It helps to moisten the food and make the small pieces stick together. Saliva contains one enzyme, salivary amylase, which acts on cooked starch and begins to break it down into maltose. Beyond the oral cavity is the ‘throat’ or pharynx.

Swallowing

Food has to pass over the windpipe to enter the gullet (oesophagus). To ensure that food does not enter the windpipe and cause choking during swallowing, a flap of cartilage called the epiglottis guides the food into the gullet. The beginning of the swallowing action is voluntary, but once the food reaches the back of the mouth, swallowing becomes an automatic or reflex action. The food is forced into and down the gullet by peristalsis. This takes about 6 seconds with relatively solid food; the food is then admitted to the stomach. Liquid travels more rapidly down the gullet.

DIGESTIVE ORGANS IN THE ABDOMINAL CAVITY. CHEMICAL DIGESTION AND ABSORPTION

The Stomach

The stomach has elastic walls, which stretch as the food collects in it. The pyloric sphincter is a circular band of muscle at the lower end of the stomach that stops solid pieces of food from passing through. The main function of the stomach is to store the food from a meal, turn it into a liquid and release it in small quantities at a time to the rest of the alimentary canal. The peristaltic action of muscles in the wall of the stomach leads to churning and squeezing the food in the stomach and mixing it with gastric juice, turning the mixture into a creamy liquid called chyme. This action gives the food a greater surface area so that it can be digested more efficiently. Glands in the lining of the stomach produce gastric juice containing the protease enzyme. It helps in the process of breaking down large protein molecules into small peptides. The stomach lining also produces hydrochloric acid, which provides the best degree of acidity for stomach protease to work in and kills many of the bacteria taken in with the food. The regular, peristaltic movements of the stomach, about once every 20 seconds, mix up the food and gastric juice into a creamy liquid. How long food remains in the stomach depends on its nature. Water may pass through in a few minutes; a solid meal of carbohydrate may be held in the stomach for less than an hour. The pyloric sphincter lets the liquid products of digestion pass into the first part of the small intestine called the duodenum.

The Small Intestine

Pancreatic juice and bile from the liver are poured into the duodenum to act on food there. The pancreas is a digestive gland lying below the stomach. It makes a number of enzymes, which act on all classes of food. Protease breaks down proteins into amino acids. Pancreatic amylase attacks starch and converts it to maltose. Lipase digests fats (lipids) to fatty acids and glycerol. Pancreatic juice contains sodium hydrogencarbonate, which partly neutralises the acidic liquid from the stomach. This is necessary because the enzymes of the pancreas do not work well in acid conditions. All the digestible material is thus changed to soluble compounds, which can pass through the lining of the intestine and into the bloodstream.

Bile

Bile is a green, watery fluid made in the liver, stored in the gall bladder and delivered to the duodenum by the bile duct. It contains bile salts, which emulsify the fats by breaking them up into small droplets with a large surface area so that they are more efficiently digested by lipase. Bile has the function of neutralising the acidic mixture of food and gastric juices as it enters the duodenum. This is important because enzymes secreted into the duodenum need alkaline conditions to work at their optimum rate.

Digestion of Protein

Pepsin is an enzyme which is secreted in the stomach. It acts on proteins and breaks them down into soluble compounds called peptides. These are shorter chains of amino acids than proteins. Trypsin is secreted by the pancreas in an inactive form and it has a similar role to pepsin. The small intestine itself does not appear to produce digestive enzymes.

Digestion of Starch

Starch is digested by salivary amylase in the mouth and by pancreatic amylase in the duodenum. Amylase converts large, insoluble starch molecules into smaller, soluble maltose molecules. Maltose is too big to be absorbed through the wall of the intestine and it is broken down to glucose by the enzyme maltase, which is present in the cells of the villi.

Functions of Hydrochloric Acid in Gastric Juice

The hydrochloric acid, secreted by cells in the wall of the stomach, creates a very acid pH of 2 which denatures enzymes in harmful organisms in food, such as bacteria (which may cause food poisoning) and it provides the optimum pH for the protein-digesting enzyme pepsin.

Absorption

The small intestine consists of the duodenum and the ileum. Nearly all the absorption of digested food takes place in the ileum, along with most of the water. Small molecules of the digested food such as glucose and amino acids pass into the bloodstream, while fatty acids and glycerol pass into the lymphatic system.

The Large Intestine (Colon and Rectum)

The material passing into the large intestine consists of water with undigested matter, largely cellulose and vegetable fibres (roughage), mucus and dead cells from the lining of the alimentary canal. The large intestine secretes no enzymes but the bacteria in the colon digest part of the fibre to form fatty acids, which the colon can absorb. Bile salts are absorbed and returned to the liver by the blood circulation. The colon also absorbs much of the water from the undigested residues. The semi-solid waste, the faeces or 'stool', is passed into the rectum by peristalsis and is expelled at intervals through the anus. The residues may spend from 12 to 24 hours in the intestine. The act of expelling the faeces is called egestion or defecation.

The epithelial cells of the villi contain enzymes in their cell membranes that complete the breakdown of sugars and peptides, before they pass through the cells on their way to the bloodstream.

DISEASES OF THE DIGESTIVE SYSTEM

Dental Decay (Dental Caries)

Decay begins when cavities appear in the enamel. They are caused by bacteria on the tooth surface which feed on the sugars deposited on the teeth, respiring them and producing acid, which dissolves the calcium salts in the tooth enamel. The enamel is dissolved away in patches, exposing the dentine to the acids. Dentine is softer than enamel and dissolves more quickly so cavities are formed. The cavities reduce the distance between the outside of the tooth and the nerve endings. The acids produced by the bacteria irritate the nerve endings and cause toothache. If the cavity is not cleaned and filled by a dentist, the bacteria will get into the pulp cavity and cause a painful abscess at the root. Often, the only way to treat this is to have the tooth pulled out. Although some people's teeth are more resistant to decay than others, it seems that it is the presence of refined sugar (sucrose) in the diet that contributes to decay.

Gum Disease (Periodontal Disease)

There is usually a layer of saliva and mucus over the teeth. This layer contains bacteria that live on the food residues in the mouth, building up a coating on the teeth called plaque. If the plaque is not removed, mineral salts of calcium and magnesium are deposited on it, forming a hard layer of 'tartar' or calculus. If the bacterial plaque that forms on teeth is not removed regularly, it spreads down the tooth into the narrow gap between the gum and enamel. Here it causes inflammation, called gingivitis, which leads to redness and bleeding of the gums and to bad breath. It also causes the gums to recede and expose the cement. If gingivitis is not treated, it progresses to periodontitis; the fibres holding the tooth in the jaw are destroyed, so the tooth becomes loose and falls out or has to be pulled out.

Anaemia

Lack of iron in the diet can lead to iron-deficiency anaemia, which is a decrease in the number of red blood cells. Red blood cells, when mature, have no nucleus and this limits their life to about 3 months, after which they are broken down in the liver and replaced. The symptoms of anaemia are weakness, tiredness and irritability.

Rickets and Osteomalacia

Vitamin D helps in the absorption of calcium and phosphorus through the gut wall. Bone is made of the mineral calcium phosphate. A lack of the vitamin results in poor calcium and phosphorus deposition in bones, leading to softening. The weight of the body can deform bones in the legs, causing the condition called rickets in children. Adults deficient in vitamin D can suffer from osteomalacia; they are very vulnerable to fracturing bones if they fall.

Diarrhoea

Diarrhoea is the loss of watery faeces. It is sometimes caused by bacterial or viral infection, for example from food or water. Once infected, the lining of the digestive system is damaged by the

pathogens, resulting in the intestines being unable to absorb fluid from the contents of the colon or too much fluid being secreted into the colon. Undigested food then moves through the large intestine too quickly, resulting in insufficient time to absorb water from it. Unless the condition is treated, dehydration can occur.

Ulcer

Peptic ulcer disease can be caused by Helicobacter pylori infection, nonsteroidal anti-inflammatory drugs usage, gastric acid and pepsin secretion. The lining of the stomach and duodenum is normally protected from damage by mucus, intestinal blood flow and bicarbonate. However, if any of them is missing, the damaging substance like gastric acid (composed of hydrochloric acid, potassium chloride and sodium chloride) will cause damage to the stomach and duodenum wall.

Cirrhosis

Cirrhosis arises as a result of a chronic liver disease. Various conditions that cause liver injury can lead to cirrhosis such as hepatitis, alcoholic liver disease, biliary problems, fatty liver, drugs, and toxins. Liver failure is usually irreversible.

Anorexia Nervosa

Anorexia is an eating disorder, characterized by low weight, food restriction, fear of gaining weight, and a strong desire to be thin. Many people with anorexia see themselves as overweight even though they are, in fact, underweight. They often deny that they have a problem with low weight. They weigh themselves frequently, eat small amounts, and only eat certain foods. Some exercise excessively, force themselves to vomit, or use laxatives to produce weight loss.

Bulimia Nervosa

Bulimia is an eating disorder characterized by binge eating followed by purging. Binge eating refers to eating a large amount of food in a short amount of time. Purging may be done by vomiting or taking laxatives. Other efforts to lose weight may include the use of diuretics, stimulants, water fasting, or excessive exercise. Most people with bulimia are at a normal weight. The forcing of vomiting may result in thickened skin on the knuckles and breakdown of the teeth. Bulimia is frequently associated with other mental disorders such as depression, anxiety, and problems with drugs or alcohol. There is also a higher risk of suicide and self-harm.

RESPIRATORY SYSTEM. MECHANISM OF BREATHING

All vital processes, such as movement, growth and reproduction, require energy. In animals, this energy can be obtained only from the food they eat. All chemicals from the food should be decomposed which happens in the process called 'respiration'. Aerobic respiration needs a supply of oxygen and produces carbon dioxide as a waste product. All cells must be supplied with oxygen and must be able to get rid of carbon dioxide. In humans and other mammals, the oxygen is obtained from the air by means of the lungs where it dissolves in the blood and is transferred to the tissues by the circulatory system. The exchange of oxygen and carbon dioxide across a respiratory surface depends on the diffusion of these two gases. The presence of millions of alveoli in the lungs provides a large surface for gaseous exchange and a two-cell layer separates the air in the alveoli from the blood in the capillaries. One layer is the alveolus wall; the other is the capillary wall which makes the distance for diffusion very short.

The alveoli are surrounded by networks of blood capillaries. The continual removal of oxygen by the blood in the capillaries lining the alveoli keeps its concentration low. The steep diffusion gradient maintained that way favours the rapid diffusion of oxygen from the air passages to the alveolar lining. The continual delivery of carbon dioxide from the blood into the alveoli, and its removal from the air passages by ventilation, similarly maintains a diffusion gradient that promotes the diffusion of carbon dioxide from the alveolar lining into the bronchioles.

Ventilation of the lungs helps to maintain a steep diffusion gradient between the air at the end of the air passages and the alveolar air. The concentration of the oxygen in the air at the end of the air passages is high, because the air is constantly replaced by the breathing actions. The respiratory surfaces of land-dwelling mammals are moist because oxygen has to be dissolved in the thin film of moisture before passing across the epithelium.

Lung Structure

The lungs are enclosed in the thorax (chest). They have a spongy texture and can be expanded and compressed by movements of the thorax so that air is sucked in and blown out. The lungs are joined to the back of the mouth by the windpipe or trachea. The trachea divides into two smaller tubes, called bronchi (sg. bronchus), which enter the lungs and divide into even smaller branches called bronchioles. These fine branches end in a mass of air sacs called alveoli. The epiglottis above the larynx and other structures at the top of the trachea stop food and drinks from entering the air passages when we swallow. Ribs form a cage, which has two main functions: to protect the lungs and heart and to move to ventilate the lungs. The alveoli have thin elastic walls, formed from a single-cell layer or epithelium. Beneath the epithelium is a dense network of capillaries supplied with deoxygenated blood. The 350 million alveoli in humans, with a total absorbing surface of about 90 m2 make it possible to take in oxygen and give out carbon dioxide at a rate to meet the body's needs. The outside of the lungs and the inside of the thorax are lined with a smooth membrane called the pleural membrane. This produces a thin layer of liquid called pleural fluid, which reduces the friction between the lungs and the inside of the thorax.

Gaseous exchange refers to the exchange of oxygen and carbon dioxide, which takes place between the air and the blood vessels in the lungs. The oxygen combines with the haemoglobin in the red blood cells, forming oxyhaemoglobin. The carbon dioxide in the plasma is released when the hydrogencarbonate ions (– HCO3) break down to CO2 and H2O.

Lung Capacity and Breathing Rate

The total volume of the lungs when fully inflated is about 5 litres in an adult. In quiet breathing, when asleep or at rest, you normally exchange only about 500 cm3. At rest, you normally inhale and exhale about 12 times per minute. During exercise, the breathing rate may rise to over 20 breaths per minute and the depth also increases.

The movement of air into and out of the lungs, called ventilation, renews the oxygen supply in the lungs and removes the surplus carbon dioxide. Horseshoe-shaped hoops of cartilage are present in the trachea and bronchi to prevent them collapsing when we breathe in. The lungs contain no muscle fibres and are made to expand and contract by movements of the ribs and diaphragm. The diaphragm is a sheet of tissue that separates the thorax from the abdomen. The ribs are moved by the internal and external intercostal muscles.

Inhaling

1 The diaphragm muscles contract and pull it down.

2 The internal intercostal muscles relax, while the external intercostal muscles contract and pull the ribcage upwards and outward, forcing the lungs to expand. The reduction in air pressure in the lungs results in air being drawn in through the nose and trachea. This movement of air into the lungs is known as ventilation.

Exhaling

1 The diaphragm muscles relax, allowing the diaphragm to return to its domed shape.

2 The external intercostal muscles relax, while the internal intercostal muscles contract, pulling the ribs downwards to bring about a forced expiration. The lungs are elastic and shrink back to their relaxed volume, increasing the air pressure inside them. This results in air being forced out again.

DISEASES OF THE RESPIRATORY SYSTEM AND PREVENTION

Asthma is a condition in which your airways get narrow and swollen and may produce extra mucus. This can make breathing difficult and trigger some discomfort. The common symptoms are: cough, wheeze (a whistling sound when you exhale), shortness of breath.

Allergy is a damaging immune response by the body to a substance, especially a particular food, pollen, fur, or dust, to which it has become hypersensitive.

Bronchitis is inflammation of the bronchi (large and medium-sized airways) in the lungs that causes coughing. Symptoms include coughing up sputum, wheezing, shortness of breath, and chest pain. Bronchitis can be acute or chronic.

Pneumonia is an infection in one or both lungs. Bacteria, viruses, and fungi may cause it and it may lead to inflammation in the air sacs of the lungs (alveoli). The alveoli fill with fluid or pus, making it difficult to breathe. Symptoms: inflammation, shortness of breath.

Rhinitis is inflammation and swelling of the mucous membrane of the nose, characterised by a runny nose and stuffiness and usually caused by the common cold or a seasonal allergy. Colds and allergies are the most common causes of rhinitis. Symptoms of rhinitis include a runny nose, sneezing, and stuffiness.

Pharyngitis is inflammation of the pharynx, which is in the back of the throat. It is most often referred to simply as “sore throat.” Pharyngitis can also cause scratchiness in the throat and difficulty swallowing.

Laryngitis is inflammation of the larynx (voice box). Symptoms often include a hoarse voice and may include fever, cough, pain in the front of the neck, and trouble swallowing. Typically, these last under two weeks.

Flu is a contagious respiratory illness caused by influenza viruses that infect the nose, throat, and sometimes the lungs. It can cause mild to severe illness, and at times can lead to death.

Lung cancer begins in the cells of the lungs - the two spongy organs in your chest that take in oxygen when you inhale and release carbon dioxide when you exhale. Lung cancer is the leading cause of cancer deaths worldwide.

Prevention of Lung Diseases

STOP ACTIVE SMOKING.

Smoking damages your lungs and increases the risk of a number of diseases including lung cancer and chronic obstructive pulmonary disease (COPD). This is due to the inhalation of harmful substances and their passage into your lungs (toxins and carcinogens).

AVOID PASSIVE SMOKING.

Breathing the smoke from cigarettes and pipes boosts the risk for the same diseases that affect people who smoke. Do not allow smoking in your home, in the car, or at school. Stay away from second-hand and third-hand smoke – residual tobacco fumes that adhere to walls and furniture and, along with indoor pollutants, form lung-damaging compounds.

WASH YOUR HANDS.

Wash your hands thoroughly with soap and water several times a day to keep germs away and avoid most of the common infectious diseases that are spread by hand.

COVER THE AIR PASSAGES.

To help stop the spread of germs, cover your mouth and nose with a tissue when you cough or sneeze. Stay away from crowds during peak cold and flu season, get plenty of rest, eat well and keep your stress levels under control.

STAY FIT AND PHYSICALLY ACTIVE.

Do something active for 30 minutes each day to lighten the load on your lungs and increase the efficiency of oxygen transportation and metabolism. Walk around the building, bike around your neighbourhood, or even run in place for a bit.

STAY INFORMED ABOUT THE QUALITY OF AIR.

People with lung diseases such as asthma and COPD need to pay particular attention to the levels of air pollution called particulates (tiny solid or liquid particles) in the environment and limit their outdoor exposure when levels are high.

EXCRETORY SYSTEM. MECHANISM OF URINE FORMATION

Excretion is the removal from organisms of toxic materials and substances in excess: the waste products of its chemical reactions; the excess water and salts taken in with the diet; spent hormones. Excretion also includes the removal of drugs or other foreign substances taken into the alimentary canal and absorbed by the blood. Some products of vital chemical reactions are poisonous and must be removed from the body. For example, the breakdown of glucose during respiration produces carbon dioxide which is further transferred by blood and removed in the lungs. Excess amino acids are deaminated in the liver to form glycogen and urea. The urea is removed from the tissues by the blood and expelled by the kidneys. Urea and similar waste products, like uric acid, from the breakdown of proteins, contain the element nitrogen. That is why they are often called nitrogenous waste products. During feeding, more water and salts are taken in with the food than are needed by the body. These excess substances need to be removed as fast as they accumulate. The hormones produced by the endocrine glands affect the rate at which various body systems work and when they have performed their action, these substances are modified in the liver and excreted by the kidneys. The nitrogenous waste products, excess salts and spent hormones are excreted by the kidneys as a watery solution called urine.

Excretory Organs

The two kidneys are solid, oval structures. They are red-brown, enclosed in a transparent membrane and attached to the back of the abdominal cavity. The renal artery branches off from the aorta and brings oxygenated blood to them. The renal vein takes deoxygenated blood away from the kidneys to the vena cava. A tube, called the ureter, runs from each kidney to the bladder in the lower part of the abdomen.

The renal artery divides up into a great many arterioles and capillaries, mostly in the cortex. Each arteriole leads to a glomerulus. This is a capillary repeatedly divided and coiled, making a knot of vessels. Each glomerulus is almost entirely surrounded by a cup-shaped organ called a renal capsule, which leads to a coiled renal tubule. This tubule, after a series of coils and loops, joins a collecting duct, which passes through the medulla to open into the pelvis. There are thousands of glomeruli in the kidney cortex and the total surface area of their capillaries is very great. A nephron is a single glomerulus with its renal capsule, renal tubule and blood capillaries.

Function of the Kidneys

The red blood cells and the plasma proteins are too big to pass out of the capillary, so the fluid that does filter through is plasma without the protein, i.e. similar to tissue fluid. The fluid thus consists mainly of water with dissolved salts, glucose, urea and uric acid. The process by which the fluid is filtered out of the blood by the glomerulus is called filtration. The filtrate from the glomerulus collects in the renal capsule and trickles down the renal tubule. The capillaries

that surround the tubule absorb back into the blood those substances which are necessary for the organism. First, all the glucose is reabsorbed, with much of the water. Then some of the salts are taken back to keep the correct concentration in the blood. The process of absorbing back the substances needed by the body is called selective reabsorption.

Salts not needed by the body are left to pass on down the kidney tubule together with the urea and uric acid. These nitrogenous waste products, excess salts and water continue down the renal tube into the pelvis of the kidney. From here the fluid, now called urine, passes down the ureter to the bladder. The composition of the urine varies a great deal according to the diet, activity, temperature and intake of liquid. The bladder can expand to hold about 400 cm3 of urine. The urine cannot escape from the bladder because a band of circular muscle, called a sphincter, is contracted, thus shutting off the exit. When this sphincter muscle relaxes, the muscular walls of the bladder expel the urine through the urethra. Adults can control this sphincter muscle and relax it only when they want to urinate. In babies, the sphincter relaxes by a reflex action, set off by pressure in the bladder. By 3 years old, most children can control the sphincter voluntarily.

DISEASES OF THE EXCRETORY SYSTEM AND PREVENTION

Nephritis is a condition in which the nephrons, the functional units of the kidneys, become inflamed. This inflammation, which is also known as glomerulonephritis, can severely affect kidney function.

Pyelonephritis is inflammation of the kidney, typically due to a bacterial infection. Symptoms most often include fever and flank tenderness. Other symptoms may include nausea, burning sensation during urination, and frequent urination. Complications may include pus around the kidney, sepsis, or kidney failure.

Cystitis is an inflammation of the bladder. In most cases, the cause of cystitis is a urinary tract infection (UTI). A UTI happens when bacteria enter the bladder or urethra and begin to multiply.

Kidney stones (also called renal calculi, nephrolithiasis or urolithiasis) are hard deposits made of minerals and salts that form inside your kidneys. Diet, excess body weight, some medical conditions, and certain supplements and medications are among the many causes of kidney stones.

The dialysis machine ('artificial kidney'). Kidney failure may result from an accident involving a drop in blood pressure, or from a disease of the kidneys. In the former case, recovery is usually spontaneous, but if it takes longer than 2 weeks, the patient may die as a result of a potassium imbalance in the blood, which causes heart failure. In the case of kidney disease, the patient can survive with only one kidney, but if both fail, the patient's blood composition has to be regulated by a dialysis machine. Similarly, the accident victim can be kept alive on a dialysis machine until his or her blood pressure is restored. Generally, a dialysis machine consists of a long cellulose tube coiled up in a water bath. The patient's blood is led from a vein in the arm and pumped through the cellulose (dialysis) tubing. The tiny pores in the dialysis tubing allow small molecules, such as those of salts, glucose and urea, to leak out into the water bath. Blood cells and protein molecules are too large to get through the pores. This stage is similar to the filtration process in the glomerulus. To prevent a loss of glucose and essential salts from the blood, the liquid in the water bath consists of a solution of salts and sugar of the correct composition, so that only the substances above this concentration can diffuse out of the blood into the bathing solution. Thus, urea, uric acid and excess salts are removed. The bathing solution is also kept at body temperature and is constantly changed as the unwanted blood solutes accumulate in it. The blood is then returned to the patient's arm vein. A patient with total kidney failure has to spend 2 or 3 nights each week connected to the machine. With this treatment and a carefully controlled diet, the patient can lead a fairly normal life. A kidney transplant, however, is a better solution because the patient is not obliged to return to the dialysis machine. The problem with kidney transplants is to find enough suitable donors of

healthy kidneys and to prevent the transplanted kidney from being rejected. The donor may be a close relative who is prepared to donate one of his or her kidneys (you can survive adequately with one kidney). Alternatively, the donated kidney may be taken from a healthy person who dies, for example, as a result of a road accident. People willing for their kidneys to be used after their death can carry a kidney donor card but the relatives must give their permission for the kidneys to be used. The problem with rejection is that the body reacts to any transplanted cells or tissues as it does to all foreign proteins and produces lymphocytes, which attack and destroy them. This rejection can be overcome by either choosing a donor whose tissues are as similar as possible to those of the patient, e.g. a close relative, or using immunosuppressive drugs, which suppress the production of lymphocytes and their antibodies against the transplanted organ.

What can I do to keep my kidneys healthy?

- Make healthy food choices
- Make physical activity part of your routine
- Aim for a healthy weight
- Get enough sleep
- Stop smoking
- Limit alcohol intake
- Explore stress-reducing activities
- Manage diabetes, high blood pressure, and heart disease

CARDIO-VASCULAR SYSTEM. BLOOD – COMPOSITION AND FUNCTIONS

The blood, pumped by the heart, travels all around the body in blood vessels. It leaves the heart in arteries and returns in veins. Valves, present in the heart and veins, ensure a one-way flow for the blood. As blood enters an organ, the arteries divide into smaller arterioles, which supply capillaries. In these vessels, the blood moves much more slowly, allowing the exchange of materials such as oxygen and glucose, carbon dioxide and other wastes. Blood leaving an organ is collected in venules, which transfer it on to larger veins.

Blood consists of red cells (erythrocytes), white cells (leukocytes) and platelets (thrombocytes) floating in a liquid called plasma. There are between five and six litres of blood in the body of an adult, and each cubic centimetre contains about five billion red cells.

Red Cells

Red cells are tiny, disc-like cells which do not have nuclei. In their cytoplasm, there is the red pigment haemoglobin, a protein combined with iron. In places where there is a high concentration of oxygen, haemoglobin combines with oxygen to form oxyhaemoglobin. Oxyhaemoglobin is an unstable compound; it breaks down and releases its oxygen in places where the oxygen concentration is low. This makes haemoglobin very useful in carrying oxygen from the lungs to the tissues. Blood that contains mainly oxyhaemoglobin is said to be oxygenated. Blood with little oxyhaemoglobin is deoxygenated. Each red cell lives for about 4 months, after which it breaks down. The red haemoglobin changes to a yellow pigment, bilirubin, which is excreted in the bile. The iron from the haemoglobin is stored in the liver. Red cells are made by the red bone marrow of certain bones in the skeleton – in the ribs, vertebrae and breastbone, for example.

White Cells

Most white cells are larger than the red cells and they all have a nucleus. There is one white cell to every 600 red cells and they are made in the same bone marrow that makes red cells. Many of them undergo a process of maturation and development in the thymus gland, lymph nodes or spleen. White blood cells are involved with phagocytosis and antibody production.

The two most numerous types of white cells are phagocytes and lymphocytes. The phagocytes can move about by a flowing action of their cytoplasm and can escape from the blood capillaries into the tissues by squeezing between the cells of the capillary walls. They collect at the site of an infection, engulfing and digesting harmful bacteria and cell debris – a process called phagocytosis. In this way, they prevent the spread of infection through the body. One of the functions of lymphocytes is to produce antibodies.

Platelets

These are pieces of special blood cells produced in the red bone marrow. They help to clot the blood and stop the bleeding in cases of wounds.

Plasma

Plasma is the liquid part of the blood. It is water with a large number of substances dissolved in it, for example, the ions of sodium, potassium, calcium, chloride and hydrogen carbonate. A significant part of the plasma is made up of proteins such as fibrinogen, albumin and globulins. Fibrinogen is needed for clotting, and the globulin proteins include antibodies, which combat bacteria and other foreign matter. The plasma also contains various amounts of food substances such as amino acids, glucose and lipids (fats). There may also be hormones present, depending on the activities taking place in the body. The excretory product, urea, is dissolved in the plasma, along with carbon dioxide. The liver and kidneys keep the composition of the plasma more or less constant, but the amount of digested food, salts and water will vary within narrow limits according to food intake and body activities.

Clotting

When tissues are damaged and blood vessels cut, platelets clump together and block the smaller capillaries. The platelets and damaged cells at the wound also produce a substance that acts, through a series of enzymes, on the soluble plasma protein called fibrinogen. As a result of this action, the fibrinogen is changed into insoluble fibrin, which forms a network of fibres across the wound. Red cells become trapped in this network and so form a blood clot. The clot not only stops further loss of blood, but also prevents the entry of harmful bacteria into the wound.

Blood groups

A blood type (also known as a blood group) is a classification of blood, based on the presence and absence of antibodies (α, β) and inherited antigenic substances (A, B) on the surface of red blood cells (RBCs). These antigens may be proteins, carbohydrates, glycoproteins, or glycolipids, depending on the blood group system. Some of these antigens are also present on the surface of other types of cells of various tissues. Blood types are inherited and represent contributions from both parents. The two most important blood group systems are ABO and Rh; they determine someone's blood type (A, B, AB, and O, with +, − or null denoting RhD status) for suitability in blood transfusion.

HEART AND BLOOD VESSELS. BLOOD CIRCULATION. LYMPH CIRCULATION

Heart

The heart pumps blood through the circulatory system to all the major organs of the body. It has 4 cavities: the upper ones are the atria (sg. atrium) and each of these opens into a chamber, the ventricle, below. Blood enters the atria from large veins. The pulmonary vein brings oxygenated blood from the lungs into the left atrium. The vena cava brings deoxygenated blood from the body tissues into the right atrium. The blood passes from each atrium to its corresponding ventricle, and the ventricle pumps it out into the arteries. The left chambers are separated from the right chambers by a muscle wall called a septum. The artery carrying oxygenated blood to the body from the left ventricle is the aorta. The pulmonary artery carries deoxygenated blood from the right ventricle to the lungs. The walls of the atria contract first and force blood into the two ventricles. Then the ventricles contract and send blood into the arteries. Valves prevent blood flowing backwards during or after heart contractions. The heart muscle is supplied with food and oxygen by the coronary arteries.

Pulse Rate

The ripple of pressure that passes down an artery as a result of the heartbeat can be felt as a 'pulse' when the artery is near the surface of the body. You can feel the pulse in the radial artery on the wrist or in the carotid artery in the neck.

Heart Sounds

Heart sounds can be heard using an instrument called a stethoscope. It amplifies the sounds of the heart valves opening and closing. A healthy heart produces a regular 'lub – dub' sound. Irregular sounds may indicate an irregular heartbeat and this may point to a problem with faulty valves.

Blood and Lymphatic Vessels

Arteries are wide vessels which carry blood from the heart to the limbs and organs of the body. The blood in the arteries, except for the pulmonary arteries, is oxygenated. Arteries have elastic tissue and muscle fibres in their thick walls. The arteries divide into smaller vessels called arterioles. The arterioles divide repeatedly to form a branching network of microscopic vessels passing between the cells of every living tissue. These final branches are called capillaries.

Capillaries are tiny vessels with walls only one cell thick which are permeable so they allow some liquid to pass through. The capillary network is so dense that no living cell is far from a supply of oxygen and food. The capillaries join up into larger vessels, called venules, which then combine to form veins.

Veins return blood to the heart. They are wider and their walls are thinner, less elastic and less muscular than those of the arteries. They also have valves. The blood in most veins is deoxygenated

because respiring cells have used the oxygen and food and produced carbon dioxide. The pulmonary veins, which return blood from the lungs to the heart, are an exception. They contain oxygenated blood and a reduced level of carbon dioxide.

The right side of the heart is supplied by the vena cava (the main vein of the body) and sends blood to the lungs along the pulmonary artery. The left side of the heart receives blood from the lungs in the pulmonary vein and sends it to the body in the aorta (the main artery). There are two pulmonary arteries and two pulmonary veins, because there are two lungs. There are also two vena cavae: one returns blood from the lower body; the other from the upper body.

The blood is stopped from flowing backwards by four sets of valves. Valves that separate each atrium from the ventricle below it are atrioventricular valves. These are the tricuspid (= three flaps) valve (right atrium/right ventricle) and the bicuspid (= two flaps) valve (left atrium/left ventricle). In the pulmonary artery and aorta are the semilunar (= half-moon) valves. If blood tries to flow the other way, the pockets fill up and meet in the middle to stop it.

Blood Pressure

The pumping action of the heart produces a pressure that drives blood around the circulatory system. In the arteries, the pressure fluctuates with the heartbeat, and the pressure wave can be felt as a pulse. The millions of tiny capillaries offer resistance to the blood flow and by the time the blood enters the veins, the surges due to the heartbeat are lost and the blood pressure is greatly reduced.

Lymphatic System

Some of the tissue fluid enters blind-ended, thin-walled vessels called lymphatics which join up to make two large vessels, which empty their contents into the blood system. The fluid in the lymphatic vessels is called lymph and is similar in composition to tissue fluid. Most of the lymph flow results from the vessels being compressed from time to time when the body muscles contract in movements such as walking or breathing. There are valves in the lymphatics, so that the fluid inside is forced in one direction only: towards the heart. At certain points in the lymphatic vessels, there are swellings called lymph nodes. Lymphocytes are stored in the lymph nodes and are released into the lymph where they reach the blood system. There are also phagocytes in the lymph nodes. If bacteria enter a wound and are not ingested by the white cells of the blood or lymph, they will be carried in the lymph to a lymph node and the white cells there will ingest them. That way, the lymph nodes protect the body against infection.

DISEASES OF THE CARDIO-VASCULAR SYSTEM AND PREVENTION

Coronary Heart Disease

In the lining of the large and medium arteries, deposits of a fatty substance are laid down in patches. This happens to everyone and the patches get more numerous and extensive with age, but until one of them actually blocks an important artery the effects are not noticed. It is not known how or why the deposits form. The patches may join up to form a continuous layer, which reduces the internal diameter of the vessel.

The surface of a patch sometimes becomes rough and causes fibrinogen in the plasma to deposit fibrin on it, causing a blood clot (a thrombus) to form. If the blood clot blocks the coronary artery, which supplies the muscles of the ventricles with blood, the muscles suffer from a lack of oxygenated blood and the heart may stop beating. This is a severe heart attack from coronary thrombosis. A thrombus might form anywhere in the arterial system, but its effects in the coronary artery and in parts of the brain (strokes) are the most drastic. In the early stages of coronary heart disease, the patch may partially block the coronary artery and reduce the blood supply to the heart. This can lead to angina, i.e. a pain in the chest that occurs during exercise or exertion. This is a warning to the person that he or she is at risk and should take precautions to avoid a heart attack. Methods of removing or treating atheroma and thrombus formations include the use of angioplasty, a stent and, in the most severe cases, by-pass surgery.

Angioplasty and Stent

Angioplasty involves the insertion of a long, thin tube called a catheter into the blocked or narrowed blood vessel. A wire attached to a deflated balloon is then fed through the catheter to the damaged artery. Once in place, the balloon is inflated to widen the artery wall, effectively freeing the blockage. In some cases, a stent is also applied. This wire-mesh tube can be expanded and left in place. It then acts as scaffolding, keeping the blood vessel open and maintaining the free flow of blood. Some stents are designed to give a slow release of chemicals to prevent further blockage of the artery.

Hypertension

Also known as high blood pressure, hypertension is a long-term medical condition in which the blood pressure in the arteries is persistently elevated. High blood pressure typically does not cause symptoms.

Hypotension

Hypotension is the medical term for low blood pressure (less than 90/60). A blood pressure reading appears as two numbers. The first and higher of the two is a measure of systolic pressure, or the pressure in the arteries when the heart beats and fills them with blood.

Infarction is tissue death (necrosis) due to inadequate blood supply to the affected area. It may be caused by artery blockages, rupture, mechanical compression, or vasoconstriction. A myocardial **infarction** (MI), also known as a heart attack, occurs when blood flow decreases or stops to a part of the heart, causing damage to the heart muscle.

A **stroke** is a medical condition in which poor blood flow to the brain causes cell death. There are two main types of stroke: ischemic, due to lack of blood flow, and haemorrhagic, due to bleeding. Both cause parts of the brain to stop functioning properly. Signs and symptoms of a stroke may include an inability to move or feel on one side of the body, problems understanding or speaking, dizziness, or loss of vision to one side. Signs and symptoms often appear soon after the stroke has occurred. If symptoms last less than one or two hours the condition is also called a mini-stroke. A haemorrhagic stroke may also be associated with a severe headache. The symptoms of a stroke can be permanent. Long-term complications may include pneumonia and loss of bladder control.

The main risk factor for stroke is high blood pressure. Other risk factors include tobacco smoking, obesity, high blood cholesterol, diabetes mellitus, a previous mini-stroke, end-stage kidney disease, and atrial fibrillation. An ischemic stroke is typically caused by blockage of a blood vessel, though there are also less common causes. A haemorrhagic stroke is caused by either bleeding directly into the brain or into the space between the brain's membranes.

Bleeding may occur due to a ruptured brain aneurysm. Diagnosis is typically based on a physical exam and supported by medical imaging such as a CT scan or MRI scan. A CT scan can rule out bleeding, but may not necessarily rule out ischemia, which early on typically does not show up on a CT scan. Other tests such as an electrocardiogram (ECG) and blood tests are done to determine risk factors and rule out other possible causes. Low blood sugar may cause similar symptoms.

Prevention of cardiovascular disease can be achieved by practising regular exercise, by keeping to a balanced healthy diet, by avoiding tobacco smoking and by the maintenance of an optimal blood pressure and normal LDL-cholesterol and glucose levels.

LOCOMOTIVE SYSTEM. BONES

Skeletal System

The skeletal system consists of two types of connective tissue: bone and the cartilage found at joints. In addition, ligaments formed of fibrous connective tissue join the bones.

Functions of the Skeleton

The skeleton supports the body. The bones of the legs support the entire body when we are standing, and bones of the pelvic girdle support the abdominal cavity.

The skeleton protects soft body parts. The bones of the skull protect the brain; the rib cage protects the heart and lungs. The vertebrae protect the spinal cord, which makes nervous connections to all the muscles of the limbs.

The red bone marrow in the skeleton produces blood cells. All bones in the fetus have red bone marrow that produces blood cells. In the adult, only certain bones produce blood cells.

The skeleton stores minerals and fat. All bones have a matrix that contains calcium phosphate, a source of calcium ions and phosphate ions in the blood. Fat is stored in yellow bone marrow.

The skeleton, along with the muscles, permits flexible body movement. While articulations (joints) occur between all the bones, we associate body movement in particular with the bones of limbs.

Anatomy of a Long Bone

The main portion (the shaft) of a long bone is called the diaphysis. The diaphysis has a large cavity whose walls are composed of compact bone. The cavity is lined with a thin, vascular membrane (the endosteum) and is filled with yellow bone marrow that stores fat. The expanded region at the end of a long bone is called an epiphysis (pl. epiphyses). The epiphyses are composed largely of spongy bone that contains red bone marrow, where blood cells are made. The epiphyses are coated with a thin layer of hyaline cartilage, called articular cartilage because it occurs at a joint. Except for the articular cartilage on its ends, a long bone is completely covered by a layer of fibrous connective tissue called the periosteum. This covering contains blood vessels, lymphatic vessels, and nerves. The periosteum is continuous with ligaments and tendons connected to a bone.

Bone

Compact bone is highly organized and composed of tubular units called osteons. In a cross section of an osteon, bone cells called osteocytes lie in tiny chambers arranged in concentric circles around a central canal. Matrix fills the space between the rows of chambers. Tiny canals run through the matrix. These canals connect the chambers with one another and with the central canal. The cells stay in contact by strands of cytoplasm that extend into the canals. Osteocytes nearest the centre of an osteon exchange nutrients and wastes with the blood vessels in the central canal. Compared with compact bone, spongy bone has an unorganised appearance. It contains numerous thin plates separated by unequal spaces. Although this makes spongy bone lighter than compact

bone, spongy bone is still designed for strength. The spaces of spongy bone are often filled with red bone marrow, a specialised tissue that produces all types of blood cells. The osteocytes of spongy bone are irregularly placed within the thin plates. Canals bring them nutrients from the red bone marrow.

Cartilage

Cartilage is not as strong as bone, but it is more flexible. Its matrix is gel-like and contains many collagenous and elastic fibres. The cells, called chondrocytes, lie within small chambers that are irregularly grouped. Cartilage has no nerves, making it well suited for padding joints where the stresses of movement are intense. Cartilage also has no blood vessels and relies on neighbouring tissues for nutrient and waste exchange. This makes it slow to heal. The three types of cartilage differ according to the type and arrangement of fibres in the matrix. Hyaline cartilage is firm and somewhat flexible. The matrix appears uniform and glassy, but actually it contains a generous supply of collagen fibres. Hyaline cartilage is found at the ends of long bones, in the nose, at the ends of the ribs, and in the larynx and trachea. Fibrocartilage is stronger than hyaline cartilage because the matrix contains wide rows of thick, collagen fibres. Fibrocartilage can withstand both tension and pressure and is found where support is of prime importance – in the disks located between the vertebrae and also in the cartilage of the knee. Elastic cartilage is more flexible than hyaline cartilage because the matrix contains mostly elastin fibres. This type of cartilage is found in the ear flaps and the epiglottis.

Fibrous Connective Tissue

Fibrous connective tissue contains rows of cells called fibroblasts separated by bundles of collagenous fibres. This tissue makes up ligaments and tendons. Ligaments connect bone to bone. Tendons connect muscle to bone at a joint (also called an articulation).

SKELETON. AXIAL SKELETON

There are two basic parts of the skeleton – axial and appendicular. The axial skeleton includes the bones of the skull and the chest.

The Skull

The skull is formed by the cranium (braincase) and the facial bones.

The Cranium

The cranium protects the brain and it is composed of eight bones fitted tightly together. Some of the bones of the cranium contain the sinuses, air spaces lined by mucous membrane which reduce the weight of the skull and give a resonant sound to the voice. The names of the major bones correspond to the lobes of the brain: frontal, parietal, occipital, and temporal. There is a large opening through which the spinal cord passes and becomes the brain stem. Each temporal bone has an opening that leads to the middle ear. The sphenoid completes the sides of the skull and contributes to forming the orbits. The ethmoid bone, which lies in front of the sphenoid, also helps form the orbits and the nasal septum.

The Facial Bones

These include the mandible, the maxillae (sg. maxilla), the zygomatic bones, and the nasal bones. The mandible, or lower jaw, is the only movable portion of the skull, and it also forms the chin. Tooth sockets are located on the mandible and on the maxillae. The grinding action of the mandible and maxillae allow us to chew our food. Other bones (e.g., ethmoid and vomer) are a part of the nasal septum, which divides the interior of the nose into two nasal cavities. The lacrimal bone contains the opening for the canal, which drains tears from the eyes to the nose. Certain cranial bones contribute to the face. The temporal bone and the wings of the sphenoid bone account for the flattened areas we call the temples. The cartilages complete the tip of the nose, and fibrous connective tissue forms the flared sides of the nose.

The Hyoid Bone

The hyoid bone is a part of the axial skeleton and the only one that does not articulate with another bone. It is attached to the temporal bones by muscles and ligaments and to the larynx by a membrane. In cases of suspicious death, a fractured hyoid is a sign of manual strangulation.

The Vertebral Column

The vertebral column (backbone or spine), consists of 24 vertebrae and 2 bones (sacrum and coccyx). It has four curvatures that provide more resilience and strength for an upright posture. Scoliosis is an abnormal lateral (sideways) curvature of the spine. Kyphosis is an abnormal posterior curvature that often results in a “hunchback.” An abnormal anterior curvature results in lordosis, or “swayback.” As the individual vertebrae are layered on top of one another, they form

the vertebral column. The vertebral canal is in the centre of the column, and the spinal cord passes through this canal. Spinal nerves function to control skeletal muscle contraction. If a vertebra is compressed, or slips out of position, the spinal cord and/or spinal nerves might be injured. The result can be paralysis or even death.

Types of Vertebrae

The cervical vertebrae are located in the neck. The first one, called the atlas, holds up the head just like Atlas, of Greek mythology, held up the world. Movement of the atlas permits the nodding ("yes") motion of the head and allows it to tilt from side to side. The second cervical vertebra is called the axis because it allows a degree of rotation, as when we shake the head to mean "no." The thoracic vertebrae have long, thin processes and articular facets for the attachment of the ribs. Lumbar vertebrae have a large body and thick processes. The five sacral vertebrae are fused together in the sacrum. The coccyx, or tailbone, is usually composed of four fused vertebrae.

Intervertebral Disks

Intervertebral disks prevent the vertebrae from grinding against one another. The disks also absorb shock caused by movements such as running, jumping, and even walking. These disks become weakened with age and can herniate and rupture. Pain results if a disk presses against the spinal cord and/or spinal nerves. Surgical removal of the disk may relieve the pain.

The Rib Cage

The rib cage is composed of the thoracic vertebrae, the ribs and their cartilages, and the sternum. The rib cage is part of the axial skeleton. The rib cage protects the heart and lungs; yet it swings outward and upward upon inhaling and then downward and inward upon exhaling.

The Ribs

A rib is a flattened bone that originates at the thoracic vertebrae. There are 12 pairs of ribs which connect directly to the thoracic vertebrae in the back. The upper seven pairs of ribs connect directly to the sternum by means of costal cartilages. These are called "true ribs." The "false ribs" are the next three pairs of ribs, which connect to the sternum by means of a common cartilage. The last two pairs are called "floating ribs" because they do not attach to the sternum.

The Sternum

The sternum, or breastbone, lies in the midline of the body. Along with the ribs, it helps protect the heart and lungs. The sternum is a flat bone that has the shape of a knife. This is important because it allows the ribs to be counted in order to determine where the apex of the heart is located – usually between the fifth and sixth ribs.

SKELETON. APPENDICULAR SKELETON

The appendicular skeleton consists of the bones within the pectoral and pelvic girdles and their attached limbs. The pectoral (shoulder) girdle and upper limb provide for flexibility. The pelvic (hip) girdle and lower limbs provide for strength.

The Pectoral Girdle and Upper Limb

There are left and right pectoral girdles in the human body. Each girdle consists of a scapula (shoulder blade) and a clavicle (collarbone). The clavicle extends across the top of the thorax. It joins with the sternum and the scapula, a visible bone in the back. The muscles of the arm and chest attach to the scapula. The cavity of the scapula articulates with the head of the humerus. This allows the arm to move in almost any direction, but reduces stability. This is the joint most apt to dislocate. Ligaments and tendons stabilise this joint. The components of a pectoral girdle freely follow the movements of the upper limb, which consists of the humerus within the arm and the radius and ulna within the forearm. When the upper limb is held so that the palm is turned forward, the radius and ulna are about parallel to each other. When the upper limb is turned so that the palm is turned backward, the radius crosses in front of the ulna, a feature that contributes to the easy twisting motion of the forearm. The hand has many bones, and this increases its flexibility. The wrist has eight carpal bones, which look like small pebbles. From these, five metacarpal bones fan out to form a framework for the palm. The metacarpal bone that leads to the thumb is opposable to the other digits (fingers or toes). An opposable thumb can touch each finger separately or cross the palm to grasp an object. The knuckles are the enlarged distal ends of the metacarpals. Beyond the metacarpals are the phalanges, the bones of the fingers and the thumb. The phalanges of the hand are long, slender, and lightweight.

The Pelvic Girdle and Lower Limb

The pelvic girdle (hip girdle) consists of two heavy, large coxal bones (hip bones). The pelvis is a basin composed of the pelvic girdle, sacrum, and coccyx. The pelvis bears the weight of the body, protects the organs within the pelvic cavity, and serves as the place of attachment for the legs. Each coxal bone has three parts: the ilium, the ischium, and the pubis, which are fused in the adult. The hip socket occurs where these three bones meet. The ilium is the largest part of the coxal bones, and our hips form where it flares out. The pubis, from which the term pubic hair is derived, is the anterior part of a coxal bone. The two pubic bones are joined by a fibrocartilaginous joint, the pubic symphysis. The male and female pelves differ from each other. In the female, the iliac bones are more flared; the pelvic cavity is shallower, but the outlet is wider. These adaptations facilitate the birthing process during vaginal delivery.

The femur (thighbone) is the longest and strongest bone in the body. The head of the femur articulates with the coxal bones, and the short neck better positions the legs for walking. At its distal end, the femur has medial and lateral structures that articulate with the tibia of the leg. This is the region of the knee and the patella, or kneecap. The patella is held in place by the quadriceps

tendon. At the distal end, the medial malleolus of the tibia causes the inner bulge of the ankle. The fibula is the more slender bone in the leg. The fibula has a head that articulates with the tibia and a distal lateral malleolus that forms the outer bulge of the ankle. Each foot has an ankle, an instep, and five toes. The many bones of the foot give it considerable flexibility, especially on rough surfaces. The ankle contains seven tarsal bones, one of which can move freely where it joins the tibia and fibula. The heel bone is also considered part of the ankle. The instep has five elongated metatarsal bones. The distal ends of the metatarsals form the ball of the foot. If the ligaments that bind the metatarsals together become weakened, flat feet are apt to result. The bones of the toes are called phalanges, just like those of the fingers. In the foot, the phalanges are stout and extremely sturdy.

Articulations

Bones are joined at the joints, classified as fibrous, cartilaginous, or synovial. Many fibrous joints, such as the sutures between the cranial bones, are immovable. Cartilaginous joints may be connected by hyaline cartilage, as in the costal cartilages that join the ribs to the sternum. Other cartilaginous joints are formed by fibrocartilage, as in the intervertebral disks. Cartilaginous joints tend to be slightly movable. Synovial joints are freely movable and therefore flexible. The bones of joints are joined by ligaments. The joint capsule is lined with synovial membrane, which gives off synovial fluid as a lubricant. Fluid-filled sacs reduce friction. Menisci (sg. meniscus), formed of cartilage, stabilise a joint, and articular cartilage caps the bones. Ball-and-socket joints form the hip and shoulder. Hinge joints construct the knee and elbow. Like a hinged door, they largely permit movement in one direction only. Intact skeletal muscles are attached to bones by tendons that span joints. When a muscle contracts, one bone moves in relation to another bone.

SKELETAL MUSCLES

All muscles can contract (shorten), so that some part of the body or the entire body moves. Humans have three types of muscle tissue: smooth, cardiac, and skeletal. The cells of these tissues are called muscle fibres.

Smooth muscle fibres are shaped like narrow cylinders, with pointed ends. Each has a single nucleus. The cells are usually arranged in parallel lines, forming sheets. Striations (bands of light and dark) are seen in cardiac and skeletal muscle but not in smooth muscle. Smooth muscle is located in the walls of hollow internal organs and blood vessels, and it causes these walls to contract. Contraction of smooth muscle is involuntary, occurring without conscious control. Smooth muscle can sustain prolonged contractions and does not fatigue easily.

Cardiac muscle forms the heart wall. Its fibres are generally uni-nucleated, striated, and tubular. Contractions spread quickly throughout the heart wall. Cardiac fibres relax completely between contractions, which prevents fatigue. Contraction of cardiac muscle is rhythmic. It occurs without outside nervous stimulation and without conscious control (involuntary).

Skeletal muscle fibres are tubular, multinucleated, and striated. They make up the skeletal muscles attached to the skeleton. Fibres run the length of the muscle and can be quite long. Skeletal muscle is voluntary because we can decide to move a particular part of the body.

Functions of Skeletal Muscles

Skeletal muscles support the body. Their contraction opposes the force of gravity and allows us to remain upright. Skeletal muscles cause movements of bones and other body structures. Their contraction assists movement in cardiovascular and lymphatic vessels. Skeletal muscles help protect internal organs and stabilise joints. Muscles pad the bones, and the muscular wall in the abdominal region protects the internal organs. Muscle tendons help hold bones together at joints. Our skeletal muscles are attached to the skeleton, and their contraction causes the movement of bones at a joint.

Basic Structure of Skeletal Muscles

A whole muscle contains bundles of skeletal muscle fibres called fascicles. Within a fascicle, each fibre is surrounded by connective tissue, and the fascicle is also surrounded by connective tissue. Muscles are covered with fascia, a type of connective tissue that extends beyond the muscle and becomes its tendon. Tendons quite often extend past a joint before anchoring a muscle to a bone. Small, fluid filled sacs can often be found between tendons and bones. They act as “cushions,” allowing ease of movement.

Skeletal muscles work in pairs. Each muscle is concerned with the movement of only one bone. The origin of a muscle is on a stationary bone, and the insertion of a muscle is on a bone that moves. When a muscle contracts, it pulls on the tendons at its insertion, and the bone moves. For example, when the biceps brachii contracts, it raises the forearm.

Skeletal muscles usually function in groups. To make a particular movement, the nervous system stimulates an appropriate group of muscles. One muscle does most of the work and it

is called the prime mover. While it is working, other muscles called synergists function as well. Synergists assist the prime mover and make its action more effective. Muscles work in opposite pairs as well. The muscle that acts opposite to a prime mover is called an antagonist. For example, the biceps brachii and the triceps brachii are antagonists. The biceps flexes the forearm, and the triceps extends the forearm. Smooth body movements depend on an antagonist relaxing when a prime mover is acting.

The names of the skeletal muscles are connected to their characteristics.

1. Size - the *gluteus maximus* is the largest muscle that makes up the buttocks. The *gluteus minimus* is the smallest of the gluteal muscles. Other terms used to indicate size are vastus (huge), *longus* (long), and *brevis* (short).

2. Shape - the *deltoid* is shaped like a triangle. (The Greek letter delta has this appearance: Δ.) The *trapezius* is shaped like a trapezoid. Other terms used to indicate shape are *latissimus* (wide) and *teres* (round).

3. Location - the external oblique muscles are located outside the internal obliques. The *frontalis* muscle overlies the frontal bone. Other terms used to indicate location are pectoralis (chest), *gluteus* (buttock), *brachii* (arm), and *sub* (beneath).

4. Direction of muscle fibres - the *rectus abdominis* is a longitudinal muscle of the abdomen (rectus means straight). The *orbicularis oculi* is a circular muscle around the eye. Other terms used to indicate direction are *transverse* (across) and *oblique* (diagonal).

5. Attachment - the *sternocleidomastoid* is attached to the sternum, clavicle, and mastoid process of the temporal bone of the skull. The *brachioradialis* is attached to the brachium (arm) and the radius (forearm).

6. Number of attachments - the *biceps brachii* has two attachments, or origins, and is located on the arm. The quadriceps *femoris* has four origins and is located on the femur.

7. Action - the extensor *digitorum* extends the fingers or digits. The adductor longus is a large muscle that adducts the thigh. Adduction is the movement of a body part toward the midline. Other terms used to indicate action are *flexor* (to flex or bend), *masseter* (to chew), and *levator* (to lift).

DISEASES OF THE LOCOMOTIVE SYSTEM AND PREVENTION

Osteoporosis is a condition in which the bones are weakened due to a decrease in the bone mass that makes up the skeleton. After the ages 20 to 30 there is an equal rate of formation and breakdown of bone mass until ages 40 to 50. Then, reabsorption begins to exceed formation, and the total bone mass slowly decreases. Over time, men are apt to lose 25% and women to lose 35% of their bone mass. A man's testosterone (male sex hormone) level generally does not begin to decline significantly until after age 65. In contrast, the estrogen (female sex hormone) level in women begins to decline at about age 45. Sex hormones play an important role in maintaining bone strength, so this difference means that women are more likely than men to suffer a higher incidence of fractures, involving especially the hip, vertebrae, long bones, and pelvis. Osteoporosis is essentially a disease that occurs as we age.

Everyone can take measures to avoid having osteoporosis when they get older. Adequate dietary calcium throughout life is an important protection against osteoporosis. A small daily amount of vitamin D is also necessary for the body to use calcium correctly. Exposure to sunlight is required to allow skin to synthesise a precursor to vitamin D.

Spasms are sudden and involuntary muscular contractions most often accompanied by pain. Spasms can occur in smooth and skeletal muscles. Multiple spasms of skeletal muscles are called a seizure, or convulsion. **Cramps** are strong, painful spasms, especially of the leg and foot, usually due to strenuous activity. Cramps can even occur when sleeping after a strenuous workout. **Facial tics**, such as periodic eye blinking, head turning, or grimacing, are spasms that can be controlled voluntarily, but only with great effort. A **strain** is caused by stretching or tearing of a muscle. A **sprain** is a twisting of a joint leading to swelling and injury, not only of muscles but also of ligaments, tendons, blood vessels, and nerves. The ankle and knee are often subject to sprains. When a tendon is inflamed by a sprain, tendinitis results. Tendinitis may irritate the bursa (a fluid-filled sac) underlying the tendon, causing **bursitis**.

Myalgia refers to achy muscles. The most common cause for myalgia is either overuse or overstretching of a muscle or group of muscles. Myalgia without a traumatic history is often due to viral infections. Myalgia may accompany inflammation of the muscles, either in response to viral infection or as an immune system disorder. **Fibromyalgia** is a chronic condition whose symptoms include achy pain, tenderness, and stiffness of muscles. Its precise cause is not known, but it may also be due to an underlying infection that is not obvious at first.

Muscular dystrophy is a broad term applied to a group of disorders characterised by a progressive degeneration and weakening of muscles. As muscle fibres die, fat and connective tissue take their place. **Duchenne muscular dystrophy**, the most common type, is inherited through a flawed gene carried by the mother. It is now known that the lack of a protein called dystrophin causes the condition. When dystrophin is absent, calcium leaks into the cell and activates an enzyme that dissolves muscle fibres. In an attempt to treat the condition, muscles have been injected with immature muscle cells that do produce dystrophin.

Myasthenia gravis is an autoimmune disease characterized by weakness that especially affects the muscles of the eyelids, face, neck, and extremities. Muscle contraction is impaired because the immune

system mistakenly produces antibodies that destroy acetylcholine receptors. In many cases, the first sign of the disease is a drooping of the eyelids and double vision. Treatment includes drugs that inhibit the enzyme that digests acetylcholine so that the latter accumulates in neuromuscular junctions.

Anabolic Steroids

Steroids encompass a large category of substances, both beneficial and harmful. Anabolic steroids are a class of steroids that generally cause tissue growth by promoting protein production. They are naturally occurring hormones created by the body and commonly used to regulate many physiological processes, from growth to sexual function. Most anabolic steroids are closely related to male sex hormones, such as testosterone. These metabolically potent drugs are controlled substances available only by prescription under the close supervision of a physician because of their many side effects and vast potential for abuse. Athletes may take dangerously large amounts of anabolic steroids to enhance athletic performance or to increase strength, often with serious consequences. The most common health consequences include high blood pressure, jaundice (yellowing of the skin), acne, and a greatly increased risk of cancer. In women, anabolic steroid abuse may cause masculinisation, including a deepened voice, excessive facial and body hair, coarsening of the hair, menstrual cycle irregularities. Anabolic steroid abuse is even more dangerous during adolescence. When taken prior to or during the teenage growth spurt, steroids may result in permanently shortened height or early onset of puberty. Ironically, while proper use of anabolic steroids has been helpful in treating many cases of impotence in males, abuse of these drugs may cause impotence and even shrinking of the testicles. Perhaps the most frightening aspect of anabolic steroid abuse are the reports of increased aggressive behaviour and violent mood swings.

MALE REPRODUCTIVE SYSTEM

Reproduction is the process of producing new individuals. In humans, the two sexes, male and female, each produce special types of reproductive cells, called gametes. The male gametes are the sperm (or spermatozoa) and the female gametes are the ova (sg. ovum) or eggs. To produce a new individual, a sperm has to reach an ovum and fuse with it. The sperm nucleus then passes into the ovum and the two nuclei also fuse. This is fertilisation. The cell formed after the fertilisation of an ovum by a sperm is called a zygote. A zygote will grow by cell division to produce first an embryo and then a fully formed organism. In humans, the male produces millions of sperm, while the female produces a smaller number of eggs (usually one a month for about 40 years). Usually only one egg is fertilised at a time; two eggs being fertilised at the same time produces non-identical twins. To bring the sperm close enough to the ova for fertilisation to take place, there is an act of mating or copulation. The sperm swim inside the female's reproductive system and fertilise any eggs that are present. The zygote then grows into an embryo inside the body of the female.

Sperm are produced in the male reproductive organs, called the testes (sg. testis). These lie outside the abdominal cavity in a special sac called the scrotum. In this position, they are kept at a temperature slightly below the rest of the body. This is the best temperature for sperm production. The testes consist of a mass of sperm-producing tubes. These tubes join to form ducts leading to the epididymis, a coiled tube about 6 metres long on the outside of each testis. The epididymis, in turn, leads into a muscular sperm duct. The two sperm ducts, one from each testis, open into the top of the urethra just after it leaves the bladder. A short, coiled tube called the seminal vesicle branches from each sperm duct just before it enters the prostate gland, which surrounds the urethra at this point. The urethra passes through the penis and may conduct either urine or sperm at different times. The penis consists of connective tissue with many blood spaces in it. This is called erectile tissue.

The lining of the sperm-producing tubules in the testis consists of rapidly dividing cells. After a series of cell divisions, the cells grow long tails called flagellae (sg. flagellum) and become sperm, which pass into the epididymis. During copulation, the epididymis and sperm ducts contract and force sperm out through the urethra. The prostate gland and seminal vesicle add fluid to the sperm. This fluid plus the sperm it contains is called semen, and the ejection of sperm through the penis is called ejaculation.

Sexual arousal in the male results in an erection. That is, the penis becomes firm and erect as a result of blood flowing into the erectile tissue. Arousal in the female stimulates the lining of the vagina to produce mucus. This lubricates the vagina and makes it easy for the erect penis to enter. In the act of copulation, the male inserts the penis into the female's vagina. The sensory stimulus (sensation) that this produces causes a reflex in the male, which results in the ejaculation of semen into the top of the vagina. In humans, the sex act has intense psychological and emotional importance.

Puberty

Puberty in boys occurs at about the same age as in girls (10-14 years). The testes start to produce sperm for the first time and also release a hormone, called testosterone, into the bloodstream. The male secondary sexual characteristics, which begin to appear at puberty, are enlargement of the testes and penis, deepening of the voice, growth of hair in the pubic region, armpits, chest and, later on, the face. In both sexes, there is a rapid increase in the rate of growth during puberty. In addition to the physical changes at puberty, there are emotional and psychological changes associated with the transition from being a child to becoming an adult, i.e. the period of adolescence. Most people adjust to these changes smoothly and without problems. Sometimes, a conflict arises between having the status of a child and the sexuality and feelings of an adult.

FEMALE REPRODUCTIVE SYSTEM

The eggs are produced from the female reproductive organs called ovaries. These are two whitish oval bodies, 3-4 cm long. They lie in the lower half of the abdomen, one on each side of the uterus. Close to each ovary is the expanded, funnel-shaped opening of the oviduct, the tube down which the ova pass when released from the ovary. The oviduct is sometimes called the Fallopian tube. The oviducts are narrow tubes that open into a wider tube, the uterus or womb, lower down in the abdomen. When there is no embryo developing in it, the uterus is only about 80 mm long. It leads to the outside through a muscular tube, the vagina. The cervix is a ring of muscle closing the lower end of the uterus where it joins the vagina. The urethra, from the bladder, opens into the vulva just in front of the vagina.

Ovulation

The egg cells (ova) are present in the ovary from the time of birth. No more are formed during the female's lifetime, but between the ages of 10 and 14 some of the egg cells start to mature and are released, one at a time about every 4 weeks from alternate ovaries. As each ovum matures, the cells around it divide rapidly and produce a fluid-filled sac, called a follicle. When mature, it projects from the surface of the ovary like a small blister. Finally, the follicle bursts and releases the ovum with its coating of cells into the funnel of the oviduct. This is called ovulation. Then, the ovum is wafted down the oviduct by the action of cilia in the lining of the tube. If the ovum meets sperm cells in the oviduct, it may be fertilised by one of them. The released ovum is enclosed in a jelly-like coat and is still surrounded by a layer of follicle cells. Before fertilisation can occur, sperm have to get through this layer of cells and the successful sperm has to penetrate it with the aid of enzymes secreted by the head of the sperm. The egg cell is much larger than a sperm cell and only one egg is released each month while the woman is fertile. The egg cell contains a large amount of cytoplasm, which is rich in fats and proteins. The fats act as energy stores. Proteins are available for growth if the egg is fertilised.

Fertilisation

The sperm swim through the cervix and into the uterus by wriggling movements of their tails. They pass through the uterus and enter the oviduct. If there is an ovum in the oviduct, one of the sperm may bump into it and stick to its surface. The acrosome at the head of the sperm secretes enzymes which digest part of the egg membrane. The sperm then enters the cytoplasm of the ovum and the male nucleus of the sperm fuses with the female nucleus. This is the moment of fertilisation. Although a single ejaculation may contain over three hundred million sperm, only a few hundred will reach the oviduct and only one will fertilise the ovum. The released ovum is thought to survive for about 24 hours; the sperm might be able to fertilise an ovum for about 2 or 3 days. Therefore, there is only a short period of about 4 days each month when fertilisation might occur. If this fertile period can be estimated accurately, it can be used either to achieve or to avoid fertilisation (conception). The fertilised egg is called a zygote.

Puberty

Although the ovaries of a young girl contain all the ova she will ever produce, they do not start to be released until she reaches the age of about 10-14 years (puberty). The ovary also releases female sex hormones into the bloodstream. These hormones are called estrogens and when they circulate around the body, they bring about the development of secondary sexual characteristics: the increased growth of the breasts, a widening of the hips, the growth of hair in the pubic region and in the armpits and an increase in the size of the uterus and vagina. Once all these changes are complete, the girl is capable of having a baby.

The Menstrual Cycle

The ovaries release an ovum about every 4 weeks. In preparation for this, the lining of the uterus wall thickens, so that an embryo can embed itself if the released ovum is fertilised. If no implantation occurs, the uterus lining breaks down. The cells, along with blood are passed out of the vagina. This is called a menstrual period. The appearance of the first menstrual period is one of the signs of puberty in girls. After menstruation, the uterus lining starts to re-form and another ovum starts to mature. At the start of the cycle, the lining of the uterus wall has broken down (menstruation). As each follicle in the ovaries develops, the amount of estrogens produced by the ovary increases. The estrogens act on the uterus and cause its lining to become thicker and develop more blood vessels. These changes help an early embryo to implant. Two hormones produced by the pituitary gland promote ovulation. The hormones are follicle-stimulating hormone (FSH) and luteinising hormone, or lutropin (LH). They act on a ripe follicle and stimulate maturation and release of the ovum. Once the ovum has been released, the follicle that produced it develops into a solid body called the corpus luteum. This produces a hormone called progesterone, which affects the uterus lining in the same way as the estrogens, making it grow thicker and produce more blood vessels. If the ovum is fertilised, the corpus luteum continues to release progesterone and so keeps the uterus in a state suitable for implantation. If the ovum is not fertilised, the corpus luteum stops producing progesterone. As a result, the thickened lining of the uterus breaks down and loses blood, which escapes through the cervix and vagina. Between the ages of 40 and 55, the ovaries cease to release ova or produce hormones, menstrual periods cease, the woman can no longer have children, and sexual desire is gradually reduced.

CONTRACEPTION

Contraception is the term used for the system of methods for prevention of pregnancy (conception). It is not related to prevention of sexually transmitted infections (STIs).

Natural Methods of Contraception

Abstinence - this involves a couple avoiding sexual intercourse. In this way, sperm cannot come into contact with an egg and fertilisation cannot happen.

Monitoring body temperature - intercourse could be avoided for 3-4 days before and 1 day after ovulation. By keeping records of the intervals between menstrual periods, it is possible to calculate a potentially fertile period of about 10 days in mid-cycle. During or soon after ovulation, a woman's temperature rises by about 0.5 °C. It is reasonable to assume that 1 day after the temperature returns to normal, a woman will be infertile.

Cervical mucus - as the time for ovulation approaches, the mucus becomes more fluid. Women can learn to detect these changes and so calculate their fertile period.

By combining the 'calendar', 'temperature' and 'mucus' methods, it is possible to achieve about 80% 'success'. It is a very helpful way of finding the fertile period for couples who do want to conceive.

Artificial Methods of Contraception

Barrier methods

Condom - a thin rubber sheath is placed on the erect penis before sexual intercourse. The sheath traps the sperm and prevents them from reaching the uterus. It also prevents the transmission of sexually transmitted infections (STIs).

Diaphragm - a thin rubber disc, placed in the vagina before intercourse, covers the cervix and stops sperm entering the uterus. Condoms and diaphragms, used with chemicals that immobilise sperm, are about 95% effective. However, a diaphragm does not prevent the risk of transmission of STIs.

Femidom (a female condom) - it is a sheath of polyurethane or rubber, with a flexible ring at each end. The ring at the closed end of the sheath is inserted into the vagina to hold it in place and the ring at the open end is placed outside the vagina. During sexual intercourse, semen is trapped inside the femidom. A femidom reduces the risk of infection by STIs.

Chemical methods

Spermicides - these are chemicals which can kill or immobilise sperm in the form of a cream, gel or foam which are placed in the vagina. Spermicides are not very reliable but, in combination with condoms or diaphragms, they are effective.

Intra-uterine device (IUD) - a small T-shaped plastic and copper device, which is inserted by a doctor or nurse into the wall of the uterus, where it probably prevents implantation of a fertilised ovum. It is about 98% effective but there is a small risk of developing uterine infections, and it does not protect against STIs.

Contraceptive pill - the pill contains chemicals, which have the same effect on the body as the hormones estrogen and progesterone. When mixed in suitable proportions these hormones suppress ovulation and so prevent conception. The pills need to be taken each day for the 21 days between menstrual periods. They are 99% effective, but long-term use of some types may increase the risk of cancer of the breast and cervix. The pill does not protect against STIs.

Morning-after pills - a medication that will prevent pregnancy after unprotected intercourse. The expression "morning-after pill" shows that the medication can begin one to several days after unprotected intercourse.

Contraceptive implant - a small plastic tube about 4 cm long, which is inserted under the skin of the upper arm of a woman by a doctor or nurse. Once in place it slowly releases the hormone progesterone, preventing pregnancy. It lasts for about 3 years. It does not protect against STIs, but has more than a 99% success rate in preventing pregnancy.

Contraceptive injection - this injection, given to women, contains progesterone and stays effective for between 8 and 12 weeks. It works by thickening the mucus in the cervix, stopping sperm reaching an egg. It also thins the lining of the uterus, making it unsuitable for implantation of an embryo. It does not protect against STIs.

Surgical methods

Male sterilisation (vasectomy) - this is a simple and safe surgical operation in which the man's sperm ducts are cut and the ends sealed. This means that the semen contains the secretions of the prostate gland and seminal vesicle but no sperm, so cannot fertilise an ovum. Sexual desire, erection, copulation and ejaculation are unaffected. The testis continues to produce sperm and testosterone. The testosterone ensures that there is no loss of masculinity. The sperm ducts can be rejoined by surgery but this is not always successful.

Female sterilisation (laparotomy) - a woman may be sterilised by an operation in which her oviducts are tied, blocked or cut. The ovaries are unaffected. Sexual desire and menstruation continue as before, but sperm can no longer reach the ova. Ova are released, but break down in the upper part of the oviduct. The operation cannot usually be reversed.

DISEASES OF THE REPRODUCTIVE SYSTEM AND PREVENTION

Sexually transmitted diseases (STDs) are caused by viruses, bacteria, fungi, and parasites.

STDs Caused by Viruses

AIDS – it stands for acquired immune deficiency syndrome. The virus that causes it is the human immunodeficiency virus (HIV). After a person has been infected, years may pass before symptoms develop, but they can still infect other people. HIV is transmitted by direct infection of the blood or sexually. Babies born to HIV carriers may become infected with HIV, either in the uterus or during birth or from the mother's milk. If the mother is given medical therapy during labour and the baby within 3 days, this method of transmission is reduced. There is no evidence that the disease can be passed on by droplets, by saliva or by normal everyday contact. There is a range of medicines that can be given separately or as a 'cocktail', which slow the progress of the disease. Research to find a vaccine and more effective treatment is ongoing.

Genital Warts – these are caused by the human papillomaviruses (HPVs). When present, the warts are seen on the penis and foreskin of men and near the vaginal opening in women. A newborn can become infected while passing through the birth canal. Infected individuals may have those growths removed by surgery, freezing, or burning with lasers or acids. A vaccine has been released for the human papillomaviruses. Genital warts are associated with cancer of the cervix, as well as tumours of the vulva, vagina, anus, and penis.

Genital Herpes – it is caused by herpes simplex virus. Type 1 usually causes cold sores and fever blisters, while type 2 more often causes genital herpes. People usually get infected with herpes simplex virus type 2 when they are adults. Some people exhibit no symptoms. Others may experience a tingling or itching sensation before blisters appear on the genitals. Once the blisters rupture, they leave painful ulcers that may take as long as three weeks or as little as five days to heal. The blisters may be accompanied by fever; pain on urination; swollen lymph nodes in the groin; and in women, a copious discharge. At this time, the individual has an increased risk of acquiring an HIV infection. There are antiviral drugs available that reduce the number and length of outbreaks. However, these drugs are not a cure for genital herpes.

Hepatitis – it infects the liver and can lead to liver failure, liver cancer, and death. There are six known viruses that cause hepatitis, designated A-B-C-D-E-G. Hepatitis A can also be sexually transmitted through oral/anal contact. Hepatitis B is spread through sexual contact and by blood-borne transmission. Simultaneous infection with hepatitis B and HIV is common, because both share the same routes of transmission. A combined vaccine is available for hepatitis A and B. Hepatitis D and G are sexually transmitted.

STDs Caused by Bacteria – only STDs caused by bacteria are curable with antibiotics.

Chlamydia – the tiny bacterium Chlamydia trachomatis causes infections of the lower reproductive tract that are usually mild or asymptomatic, especially in women. After infection,

men may experience a mild burning sensation on urination and a mucoid discharge. Women may have a vaginal discharge along with the symptoms of a urinary tract infection. If a baby comes in contact with chlamydia during birth, inflammation of the eyes or pneumonia can result.

Gonorrhoea – it is caused by the bacterium Neisseria gonorrhoeae. Typical symptoms in males are pain upon urination and a thick, greenish yellow urethral discharge. In males and females, a latent infection leads to pelvic inflammatory disease (PID), which can also cause sterility in males. If a baby is exposed during birth, an eye infection leading to blindness can result.

Syphilis – it is caused by a bacterium called Treponema pallidum. Penicillin is an effective antibiotic. Syphilis has three stages, often separated by latent periods, during which the bacteria are resting before multiplying again. Congenital syphilis is caused by syphilitic bacteria crossing the placenta. The child is born blind and/or with numerous anatomical malformations.

Vaginal Infections – overgrowth of certain bacteria inhabiting the vagina causes vaginosis. A common culprit is the bacterium Gardnerella vaginosis. Symptomless males may pass on the bacterium to women, who do experience symptoms like vaginal discharge with a strong odour, a burning sensation during urination, and/or itching or pain in the vulva. Some women have no signs of the infection.

The yeast *Candida albicans*, and a protozoan, Trichomonas vaginalis, are two other causes of vaginitis. *Candida albicans* infection causes a thick, white, curd-like vaginal discharge and is accompanied by itching of the vulva and/or vagina. Trichomoniasis caused by *Trichomonas vaginalis* affects both males and females. Infected males are often asymptomatic and pass the parasite to their partner during sexual intercourse. Symptoms of trichomoniasis in females are a foul-smelling, yellow-green frothy discharge and itching of the vulva/vagina.

If a person suspects that he or she has caught a sexually transmitted disease, treatment must be sought at once. It is always confidential. The patients must ensure that anyone they have had sexual contact with also gets treatment.

PRENATAL DEVELOPMENT. BIRTH

Pregnancy and Development

The fertilised ovum (zygote) divides into two cells and each of them divides again, so producing four cells. The cells continue to divide to produce a solid ball of cells (morula), which becomes a blastocyst. The cells of the blastocyst arrange themselves so that there is an inner cell mass surrounded by an outer layer of cells. The inner cell mass will become the embryo, and the layer of cells will become the chorion. This early embryo travels down the oviduct to the uterus. Here it sinks into the lining of the uterus, a process called implantation. The embryo continues to grow and produces new cells that form tissues and organs. After 8 weeks, when all the organs are formed, the embryo is called a fetus. One of the first organs to form is the heart, which pumps blood around the body of the embryo. During implantation, the chorion secretes enzymes to digest away some of the tissue and blood vessels of the endometrium of the uterus. The chorion also begins to secrete human chorionic gonadotropin (hCG), the hormone that is the basis for the pregnancy test.

Gastrulation turns the inner cell mass into the embryonic disk. Cells migrate to become tissue layers called the primary germ layers. By the time gastrulation is complete, the embryo has three primary germ layers: ectoderm, mesoderm, and endoderm. As the embryo grows, the uterus enlarges to contain it. Inside the uterus, the embryo becomes enclosed in a fluid-filled sac called the amnion or water sac, which protects it from damage and prevents unequal pressures from acting on it. The fluid is called amniotic fluid. The oxygen and food needed to keep the embryo alive and growing are obtained from the mother's blood by means of the placenta - a disc-like structure which becomes closely attached to the lining of the uterus and it is attached to the embryo by the umbilical cord. The nervous system (brain, spinal cord and sense organs) start to develop very quickly. Oxygen and nutrients such as glucose and amino acids pass across the placenta to the embryo's bloodstream. Carbon dioxide passes from the embryo's blood to that of the mother. Blood entering the placenta from the mother does not mix with the embryo's blood.

Soon limb buds appear and they give rise to the arms and the legs. During the fifth week the head enlarges, and the sense organs become more prominent. It is possible to make out the developing eyes and ears, and even the nose. The nervous system is developed well enough to permit reflex actions, such as a startle response to touch. At the end of this period, the embryo is about 38 mm long and weighs no more than an aspirin tablet, even though all organ systems have been established.

Fetal Development

The placenta is the source of progesterone and estrogen during pregnancy. These hormones have two functions: (1) they prevent any new follicles from maturing, and (2) they maintain the endometrium. Menstruation does not usually occur during pregnancy.

Cartilage begins to be replaced by bone as ossification centres appear in most of the bones. The skull has six large membranous areas called fontanels. These permit a certain amount of flexibility as the head passes through the birth canal and allow rapid growth of the brain during infancy.

Birth

The period from fertilisation to birth takes about 38 weeks in humans (gestation period). A few weeks before the birth, the fetus lies head downwards in the uterus, with its head just above the cervix. When birth starts, the uterus begins to contract rhythmically. These regular rhythmic contractions become stronger and more frequent. The opening of the cervix gradually widens enough to let the baby's head pass through and the contractions of the muscles in the uterus wall are assisted by muscular contractions of the abdomen. The amniotic sac breaks at some stage in labour and the fluid escapes through the vagina. Finally, the muscular contractions of the uterus wall and abdomen push the baby head-first through the widened cervix and vagina. The umbilical cord, which still connects the child to the placenta, is tied and cut. Later, the placenta breaks away from the uterus and is pushed out separately as the 'afterbirth'.

The sudden fall in temperature felt by the newly born baby stimulates it to take its first breath and it usually cries. In a few days, the remains of the umbilical cord attached to the baby's abdomen shrivel and fall away, leaving a scar in the abdominal wall, called the navel.

Within the first 24 hours after birth, the baby starts to feed. During pregnancy, the mammary glands enlarge as a result of an increase in the number of milk-secreting cells. Milk contains the proteins, fats, sugar, vitamins and salts that babies need for their energy requirements and tissue-building. The liquid produced in the first few days is called colostrum. It contains more protein than the milk produced later. It also contains some of the mother's antibodies to diseases from which she has recovered. This provides passive immunity to infection. It also carries white cells that produce antibodies or ingest bacteria thus defending the baby against infection at a time when its own immune responses are not fully developed. Breastfeeding provides milk free from bacteria, whereas bottle feeding carries the risk of introducing bacteria that cause intestinal diseases. Breastfeeding also offers emotional and psychological benefits to both mother and baby.

POSTNATAL DEVELOPMENT

Postnatal development can be broadly divided into the age categories of: Neonatal (birth to 1 month), Infancy (1 month to 2 years), Childhood (2 years to puberty), Puberty (12 years to mid-teens) and Young Adult – a new category (late teens to early twenties).

Neurological development continues postnatally with both growth and reorganization of the central nervous system. The amount of simple physical growth is shown by the skeletal flexibility designed around the brain and spinal cord, which allows continued postnatal growth of these structures.

Development does not cease once birth has occurred, but continues throughout the stages of life: infancy, childhood, adolescence, and adulthood. Infancy, the toddler years, and preschool years are times of remarkable growth. During the birth to 5-year-old stage, humans acquire gross motor and fine motor skills. These include the ability to sit up and then to walk, as well as being able to hold a spoon and manipulate small objects. Language usage begins during this time and will become increasingly sophisticated throughout childhood. As infants and toddlers explore their environment, their senses – vision, taste, hearing, smell, and touch – mature dramatically. Socialisation is very important, as a child forms emotional ties with its caregivers and learns to separate self from others. Babies do not all develop at the same rate, and there is a large variation in what is considered normal.

The preadolescent years, from 6 to 12 years of age, are a time of continued rapid growth and learning. Preadolescents form identities apart from parents, and peer approval becomes very important. Adolescence begins with the onset of puberty, as the young person achieves sexual maturity. For girls, puberty begins between 10 and 14 years of age, whereas for boys it generally occurs between ages 12 and 16. During this time, the sex-specific hormones cause the secondary sexual characteristics to appear. Profound social and psychological changes are also associated with the transition from childhood to adulthood.

Aging encompasses the progressive changes from infancy until eventual death. Today, gerontology, the study of aging, is of great interest because there are now far more elderly individuals in our society than ever before, and the number is expected to rise dramatically. It is estimated that in the next half-century, the number of people over the age of 65 will increase by 147%. Human lifespan is judged to be a maximum of 120-125 years. The present goal of gerontology is not necessarily to increase the lifespan, but to increase the health span, the number of years that an individual enjoys the full functions of all body parts and processes.

NERVOUS SYSTEM

Co-ordination is the way all the organs and systems of the body are made to work efficiently together. Co-ordination by chemicals is brought about by the endocrine system. The nervous system works by sending electrical impulses along nerves. The endocrine system depends on the release of chemicals, called hormones, from endocrine glands. Hormones are carried by the bloodstream.

The brain and spinal cord together form the central nervous system. Nerves carry electrical impulses from the central nervous system to all parts of the body, making muscles contract or glands produce enzymes or hormones. Electrical impulses are electrical signals that pass along nerve cells (neurons). Glands and muscles are called effectors because they go into action when they receive nerve impulses or hormones. The nerves also carry impulses back to the central nervous system from receptors in the sense organs of the body. Nerve impulses from the sense organs to the central nervous system are called sensory impulses; those from the central nervous system to the effectors, resulting in action, are called motor impulses. The nerves that connect the body to the central nervous system make up the peripheral nervous system.

Nerve Cells (Neurons)

The central nervous system and the peripheral nerves are made up of nerve cells, called neurons. There are three types of neurons. Motor neurons carry impulses from the central nervous system to muscles and glands. Sensory neurons carry impulses from the sense organs to the central nervous system. Relay neurons (also called multi-polar or connector neurons) are neither sensory nor motor but make connections to other neurons inside the central nervous system.

Each neuron has a cell body consisting of a nucleus surrounded by a little cytoplasm. Branching fibres, called dendrites, from the cell body make contact with other neurons. A long filament of cytoplasm, surrounded by an insulating sheath, runs from the cell body of the neuron. This filament is called an axon. The cell bodies of the neurons are mostly located in the brain or in the spinal cord and it is the nerve fibres that run in the nerves. A nerve is easily visible, white, tough and stringy and consists of hundreds of microscopic nerve fibres bundled together. Most nerves will contain a mixture of sensory and motor fibres. So, a nerve can carry many different impulses. These impulses will travel in one direction in sensory fibres and in the opposite direction in motor fibres. Some of the nerve fibres are very long. A single nerve cell may have a fibre 1 m long.

The Nerve Impulse

Sensations are felt only when a nerve impulse reaches the brain. The impulse itself is a series of electrical pulses that travel down the fibre. Each pulse lasts about 0.001 s and travels at speeds of up to 100 m /s−1. All nerve impulses are similar. We are able to tell where the sensory impulses have come from and what caused them only because the impulses are sent to different parts of the brain. The nerves from the eye go to the part of the brain concerned with sight. So when impulses are received in this area, the brain recognises that they have come from the eyes and we ‘see’ something.

The Reflex Arc

One of the simplest situations where impulses cross synapses to produce action is in the reflex arc. A reflex action is an automatic response to a stimulus. (A stimulus is a change in the external or internal environment of an organism.) It provides a means of rapidly integrating and co-ordinating a stimulus with the response of an effector (a muscle or a gland) without the need for thought or a decision. When a bright light shines in the eye, the pupil contracts. You cannot stop this reflex and you are not even aware that it is happening. The nervous pathway for such reflexes is called a reflex arc.

The Peripheral Nervous System

The PNS contains only nerves and ganglia. Cranial nerves take impulses to and from the brain. Spinal nerves take impulses to and from the spinal cord. The PNS is divided into the somatic system and the autonomic system. The somatic system serves the skin, skeletal muscles, and tendons. Some actions are due to reflexes, which are automatic and involuntary. Other actions are voluntary and originate in cerebral cortex.

Autonomic System

Two divisions in this system are the sympathetic division and the parasympathetic division.

Sympathetic Division – responses that occur during times of stress.

Parasympathetic Division – responses that occur during times of relaxation.

Actions in these divisions are involuntary and automatic. These divisions innervate internal organs. Two neurons and one ganglion are used for each impulse.

BRAIN

The spinal cord and the brain make up the central nervous system (CNS), where sensory information is received and motor control is initiated. Both the spinal cord and the brain are protected by bone. The spinal cord is surrounded by vertebrae, and the brain is enclosed by the skull. Both the spinal cord and the brain are wrapped in protective membranes known as meninges (sg. meninx). The spaces between the meninges are filled with cerebrospinal fluid, which cushions and protects the CNS. Cerebrospinal fluid is also contained within the four ventricles of the brain and in the central canal of the spinal cord. The nervous tissue in the CNS is composed of grey matter and white matter. Grey matter contains cell bodies and short, non-myelinated fibres. White matter contains myelinated axons that run together in bundles called tracts.

The cerebrum (telencephalon) is the largest portion of the brain in humans. It communicates with and coordinates the activities of the other parts of the brain. The cerebrum has two halves called the left and right cerebral hemispheres divided by a longitudinal fissure. They communicate via the corpus callosum, an extensive bridge of nerve tracts. Shallow grooves called sulci (sg. sulcus) divide each hemisphere into lobes – frontal, parietal, occipital and temporal. Each lobe is associated with particular functions.

The cerebral cortex is a thin, highly convoluted outer layer of grey matter that covers the cerebral hemispheres. The cerebral cortex accounts for sensation, voluntary movement, and all the thought processes we associate with consciousness. The cerebral cortex contains motor areas and sensory areas, as well as association areas. The primary motor area in the frontal lobe sends out motor commands to lower brain centres, which pass them on to motor neurons. The primary somatosensory area in the parietal lobe receives sensory information from lower brain centres in communication with sensory neurons. Association areas are places where integration occurs and where memories are stored. Processing centres of the cortex receive information from the other association areas and perform higher-level analytical functions. There are masses of grey matter deep within the white matter. These basal nuclei integrate motor commands to ensure that the proper muscle groups are stimulated or inhibited. Integration ensures that movements are coordinated and smooth.

The hypothalamus and the thalamus are in the diencephalon. The hypothalamus is an integrating centre that helps maintain homeostasis. It regulates hunger, sleep, thirst, body temperature, and water balance. The hypothalamus controls the pituitary gland and serves as a link between the nervous and endocrine systems. The thalamus integrates sensory information and sends it on to the appropriate portions of the cerebrum. The thalamus is involved in arousal of the cerebrum, and it also participates in higher mental functions such as memory and emotions. The pineal gland, which secretes the hormone melatonin, is located in the diencephalon. It is believed to help alleviate jet lag or insomnia.

The cerebellum lies under the occipital lobe of the cerebrum. It has two portions. Each portion is primarily composed of white matter. Overlying the white matter is a thin layer of grey matter that forms a series of complex folds. The cerebellum receives sensory input from the eyes, ears,

joints, and muscles about the present position of body parts. It also receives motor output from the cerebral cortex about where these parts should be located. After integrating this information, the cerebellum sends motor signals by way of the brain stem to the skeletal muscles. In this way, the cerebellum maintains posture and balance. It also ensures that all of the muscles work together to produce smooth, coordinated, voluntary movements. The cerebellum assists the learning of new motor skills such as playing the piano or hitting a baseball.

The brainstem contains the midbrain, the pons, and the medulla oblongata. The midbrain acts as a relay station for tracts passing between the cerebrum and the spinal cord or cerebellum. It also has reflex centres for visual, auditory, and tactile responses. The pons functions with the medulla oblongata to regulate breathing rate. Reflex centres in the pons coordinate head movements in response to visual and auditory stimuli.

The medulla oblongata contains a number of reflex centres for regulating heartbeat, breathing, and blood pressure. It also contains the reflex centres for vomiting, coughing, sneezing, hiccupping, and swallowing.

The reticular formation is a complex network of nuclei that receives sensory signals and sends them to higher centres. Motor signals received by the system are sent to the spinal cord.

The limbic system is an evolutionary ancient group of functionally linked structures deep within the cerebrum. The limbic system blends primitive emotions and higher mental functions into a united whole. That is why activities like sexual behaviour and eating seem pleasurable while unpleasant sensations or emotions (pain, frustration, hatred and despair) are translated by the limbic system into a stress response.

Memory is the ability to hold a thought in mind or to recall events from the past. Learning takes place when we retain and use past memories. Language depends on semantic memory. Some of the same areas in the brain are involved in both memory and language. Any disruption of these pathways could lead to an inability to comprehend our environment and use speech correctly.

SPINAL CORD

Structure

The spinal cord extends from the base of the brain through a large opening in the skull called the foramen magnum. From there, the spinal cord proceeds in the vertebral canal.

A cross section of the spinal cord shows a central canal, grey matter, and white matter. The spinal nerves project from the cord through intervertebral openings. 31 pairs of spinal nerves extend from the spinal cord. Fibrocartilage intervertebral disks separate the vertebrae. Should the disk rupture or herniate, the vertebra will compress a spinal nerve. Pain and loss of mobility result. The central canal of the spinal cord contains cerebrospinal fluid, as do the meninges that protect the spinal cord. The grey matter is centrally located and shaped like the letter H. Portions of sensory neurons and motor neurons are found in grey matter, as are interneurons that communicate with these two types of neurons. The dorsal root of a spinal nerve contains sensory fibres entering the grey matter. The ventral root of a spinal nerve contains motor fibres exiting the grey matter. The dorsal and ventral roots join before the spinal nerve leaves the vertebral canal, forming a mixed nerve. Spinal nerves are a part of the PNS. The white matter of the spinal cord occurs in areas around the grey matter. The white matter contains ascending tracts taking information to the brain (primarily located posteriorly) and descending tracts taking information from the brain (primarily located anteriorly). Many tracts cross just after they enter and exit the brain, so the left side of the brain controls the right side of the body. Likewise, the right side of the brain controls the left side of the body.

Functions

The spinal cord provides a means of communication between the brain and the peripheral nerves that leave the cord. When someone touches your hand, sensory receptors generate nerve signals that pass through sensory fibres to the spinal cord and up ascending tracts to the brain. The gate control theory of pain proposes that the tracts in the spinal cord have "gates," and that these "gates" control the flow of pain messages from the peripheral nerves to the brain. Depending on how the gates process a pain signal, the pain message can be allowed to pass directly to the brain or can be prevented from reaching the brain. Endorphins can temporarily block pain messages and so can other messages, such as those received from touch receptors. To touch the person back, the brain initiates voluntary control over our limbs. Motor signals originating in the brain pass down descending tracts to the spinal cord and out to our muscles by way of motor fibres. Therefore, if the spinal cord is severed, we suffer a loss of sensation and a loss of voluntary control – paralysis. If the cut occurs in the thoracic region, the lower body and legs are paralyzed, a condition known as paraplegia. If the injury is in the neck region, all four limbs are usually affected, a condition called quadriplegia.

Reflex Actions

The spinal cord is the centre for thousands of reflex arcs. A stimulus causes sensory receptors to generate signals that travel in sensory axons to the spinal cord. Interneurons integrate the incoming

data and relay signals to motor neurons. A response to the stimulus occurs when motor axons cause skeletal muscles to contract. Motor neurons in a reflex arc may also affect smooth muscle, organs, or glands. Each interneuron in the spinal cord has synapses with many other neurons. Therefore, interneurons send signals to other interneurons and motor neurons. Similarly, the spinal cord creates reflex arcs for the internal organs. For example, when blood pressure falls, internal receptors in the carotid arteries and aorta generate nerve signals that pass through sensory fibres to the cord and then up an ascending tract to a cardiovascular centre in the brain. Then nerve signals pass down a descending tract to the spinal cord. Motor signals then cause blood vessels to constrict so that the blood pressure rises.

DISEASES OF THE NERVOUS SYSTEM AND PREVENTION

Functional Disorders

Neurosis is a class of functional mental disorders involving chronic distress, but it should not be mistaken for psychosis, which refers to a loss of touch with reality. There are many different neuroses, including: obsessive-compulsive disorder, obsessive-compulsive personality disorder, impulse control disorder, anxiety disorder, hysteria, and many phobias.

A concussion is a mild traumatic brain injury. It can occur after an impact to your head or after a whiplash-type injury that causes your head and brain to shake quickly back and forth. A concussion results in an altered mental state that may include becoming unconscious.

Paralysis is the loss of muscle function in part of your body. It happens when something goes wrong with the way messages pass between your brain and muscles. Paralysis can be complete or partial. It can occur on one or both sides of your body. It can also occur in just one area, or it can be widespread.

Meningitis is an acute inflammation of the protective membranes covering the brain and spinal cord, known collectively as the meninges. The most common symptoms are fever, headache, and neck stiffness. Causes can be bacterial, viral or other.

Poliomyelitis is an acute infection caused by a poliovirus (an enterovirus). Symptoms include a nonspecific minor illness, sometimes without paralysis, and, less often, flaccid weakness of various muscle groups.

As adults, chemicals and pollutants can accelerate the rate at which adult nerve and brain cells degrade and die by increasing oxidative stress in the body. This is thought to increase the risk of Parkinson's and Alzheimer's diseases, bipolar disorders and chronic fatigue syndrome.

Neurotoxins

Neurotoxins are toxins that are destructive to nerve tissue. Common examples of neurotoxins include lead, ethanol (drinking alcohol), glutamate, nitric oxide, botulinum toxin (e.g. Botox), tetanus toxin, and tetrodotoxin. Some substances such as nitric oxide and glutamate are in fact essential for proper function of the body and only exert neurotoxic effects at excessive concentrations.

Neurotoxins inhibit neuron control over ion concentrations across the cell membrane, or communication between neurons across a synapse. Manifestations of neurotoxin exposure can include widespread central nervous system damage such as intellectual disability, persistent memory impairments, epilepsy, and dementia. Support has been shown for a number of treatments aimed at attenuating neurotoxin-mediated injury, such as antioxidant and antitoxin administration.

The Effect of Drugs on the Nervous System

A psycho-active drug must find its way to the bloodstream to have an effect on the brain. Once the drug reaches the brain, it can bind to specific receptor sites on the neurons which are sensitive to particular types of drugs. Each drug affects specific neurons in a number of parts of the brain.

Many drugs seem to imitate neurotransmitters, the natural chemicals that facilitate or inhibit the transfer of electrical impulses between neurons. For example, opiate drugs such as heroin are thought to exert their drug action by mimicking endorphins which are naturally occurring proteins that reduce pain.

Like neurotransmitters, drugs can speed up (CNS stimulants) or slow down (CNS depressants) the transfer of electro-chemical messages between neurons in the brain. Messages between neurons can also be distorted when hallucinogenic drugs are taken.

In addition to affecting the transfer of messages between neurons, drugs appear to act directly on 'pleasure centres' in the brain, which may explain the euphoria experienced by users of many different types of drugs. It is believed that the effect on the pleasure centre is highly rewarding for many young people and is crucial to the development of drug dependence.

Alzheimer's disease is a progressive disorder that causes brain cells to degenerate and die. Alzheimer's disease is the most common cause of dementia – a continuous decline in thinking, behavioural and social skills that disrupts a person's ability to function independently.

Parkinson's disease is a brain disorder that leads to shaking, stiffness, and difficulty with walking, balance, and coordination. Parkinson's symptoms usually begin gradually and get worse over time. As the disease progresses, people may have difficulty walking and talking.

Tips on Keeping the Nervous System Healthy

1. Keep track of your eating patterns and make sure to eat regularly so as to not deplete the glucose your neurons use for energy.

2. Follow a balanced, low-fat diet with ample sources of vitamins B6, B12, and folate. Make sure that your diet contains lots of fresh fruits, vegetables, and whole grains. Drink plenty of water and other fluids. This helps prevent dehydration, which can cause confusion and memory problems.

3. Avoid smoking and excessive drinking of alcohol.

ENDOCRINE GLANDS

The endocrine system depends on chemicals (hormones), which are released from special glands, called endocrine glands, into the bloodstream. The hormones circulate around the body in the blood and reach certain organs, called target organs. Hormones speed up, slow down or alter the activity of those organs. After being secreted, they are changed by the liver into inactive compounds and excreted by the kidneys.

Responses of the body to hormones are much slower than responses to nerve impulses. They depend on the speed of the circulatory system and on the time it takes for the cells to change their chemical activities. Many hormones affect long-term changes such as growth rate, puberty and pregnancy. Nerve impulses often cause a response in a very limited area of the body. Hormones often affect many organ systems at once. Serious deficiencies or excesses of hormone production give rise to illnesses. Small differences in hormone activity between individuals probably contribute to differences of personality and temperament. Negative feedback provides a means of control: if levels of substances in the body change, the change is monitored and a response to adjust levels to normal is brought about.

Thyroid Gland – it is situated in the front part of the neck and lies in front of the windpipe and produces a hormone called thyroxine. This hormone has a stimulatory effect on the metabolic rate of nearly all the body cells. It controls our level of activity, promotes skeletal growth and is essential for the normal development of the brain.

Parathyroid Glands – parathyroid hormone (PTH) produced by the parathyroid glands, causes blood Ca2+ level to increase. A low blood Ca2+ level stimulates the release of PTH. PTH promotes the activity of osteoclasts and the release of calcium from the bones. PTH also activates vitamin D in the kidneys. Activated vitamin D, a hormone sometimes called calcitriol, then promotes calcium reabsorption by the kidneys. The absorption of Ca2+ from the intestine is also stimulated by calcitriol. These effects bring the blood Ca2+ level back to the normal range, and PTH secretion stops.

Hypothalamus and Pituitary Gland – the hypothalamus regulates the internal environment through the autonomic system (e.g. body temperature and water balance). The hypothalamus also controls the glandular secretions of the pituitary gland. The pituitary is a small gland connected to the hypothalamus by a stalk-like structure. The pituitary has two portions: the posterior and the anterior pituitary.

Neurons in the hypothalamus called neurosecretory cells produce the hormones antidiuretic hormone (ADH) and oxytocin. Inability to produce ADH causes diabetes insipidus. A person with this type of diabetes produces copious amounts of urine which results in severe dehydration and loss of important ions from the blood. The condition can be corrected by the administration of ADH. Oxytocin, the other hormone made in the hypothalamus, causes uterine contraction during childbirth and breast milk release when a baby is feeding.

Three of the six hormones produced by the anterior pituitary have an effect on other glands: thyroid-stimulating hormone (TSH) stimulates the thyroid, adrenocorticotropic hormone (ACTH)

stimulates the adrenal cortex to produce cortisol, gonadotropic hormones stimulate the gonads (the testes in males and the ovaries in females) to produce gametes and sex hormones. The other three hormones produced by the anterior pituitary do not affect other endocrine glands. Prolactin (PRL) causes the mammary glands in the breasts to develop and produce milk. It also plays a role in carbohydrate and fat metabolism. Melanocyte-stimulating hormone (MSH) causes skin-colour changes. Growth hormone (GH), or somatotropic hormone, promotes skeletal and muscular growth.

Adrenal Glands – they are attached to the back of the abdominal cavity, one above each kidney. The adrenal medulla receives nerves from the brain and produces the hormone adrenaline in response to a stressful situation. Its presence causes breathing to become faster and deeper. The heart beats faster, resulting in an increase in pulse rate. The pupils of our eyes dilate, making them look much blacker. These effects all make us capable of reacting quickly and vigorously in dangerous situations ('fight or flight situations') that might require us to run away or put up a struggle. However, in many stressful situations, such as taking examinations or giving a public performance, vigorous activity is not called for. So the extra adrenaline in our bodies just makes us feel tense and anxious.

The Pancreas – it is a digestive gland that secretes enzymes into the duodenum through the pancreatic duct. It is also an endocrine gland. The hormone-producing cells secrete their hormones directly into the bloodstream. One of the hormones is called insulin. Insulin controls the levels of glucose in the blood by instructing the liver to remove the sugars and store them. This happens when levels get too high, such as after a meal rich in carbohydrate. Glucose concentration in the blood is controlled using insulin and glucagon.

Reproductive Organs – the ovaries and testes produce hormones and gametes (sperms and ova). One of the hormones from the ovary, estrogen, prepares the uterus for the implantation of the embryo, by making its lining thicker and increasing its blood supply. The hormones testosterone (from the testes) and estrogen (from the ovaries) play a part in the development of the secondary sexual characteristics.

DISEASES OF THE ENDOCRINE SYSTEM

Inability to produce antidiuretic hormone (ADH) causes diabetes insipidus – a person produces large amounts of urine which results in severe dehydration and loss of important ions from the blood. The condition can be corrected by the administration of ADH.

The growth hormone (GH) is produced by the anterior pituitary. If too little GH is produced during childhood, the individual has pituitary dwarfism, characterised by perfect proportions but small stature. If too much GH is secreted, a person can become a giant. Giants usually have poor health. Sometimes there is overproduction of GH in the adult which results to a condition called acromegaly – only the feet, hands, and face can respond, and these portions of the body become overly large.

If the thyroid fails to develop properly, a condition called congenital hypothyroidism results. Individuals are short and stocky. Thyroid hormone therapy can initiate growth, but unless treatment is begun within the first two months of life, mental retardation results (cretinism). The occurrence of hypothyroidism in adults produces the condition known as myxedema – symptoms include lethargy, weight gain, loss of hair, slower pulse rate, lowered body temperature, and thickness and puffiness of the skin. The administration of adequate doses of thyroid hormones restores normal function and appearance. In the case of hyperthyroidism, the thyroid gland is overactive, and an exophthalmic goitre forms. The eyes protrude because of oedema in eye socket tissues and swelling of the muscles that move the eyes. The patient usually becomes hyperactive, nervous and irritable, and suffers from insomnia. Hyperthyroidism can also be caused by a thyroid tumour.

Hypoparathyroidism causes a dramatic drop in blood calcium, followed by excessive nerve excitability. Nerve signals happen spontaneously and without rest, causing a phenomenon called tetany (the body shakes from continuous muscle contraction). Without treatment, it causes seizures, heart failure, and death. Untreated hyperparathyroidism can result in osteoporosis because of continuous calcium release from the bones. Hyperparathyroidism may also cause formation of calcium kidney stones.

Very high levels of glucocorticoids, produced by the adrenal glands, in the blood can suppress the body's defence system. Cortisone and other glucocorticoids can relieve swelling and pain from inflammation. However, by suppressing pain and immunity, they can also make a person highly susceptible to injury and infection.

When the blood level of glucocorticoids is low due to hyposecretion, a person develops Addison disease. It causes a bronzing of the skin because ACTH can lead to a build-up of melanin. Glucose cannot be replenished when a stressful situation arises. Even a mild infection can lead to death. Left untreated, Addison disease can be fatal. When the level of glucocorticoids is high due to hypersecretion, a person develops Cushing syndrome. There is a tendency toward diabetes mellitus, as muscle protein is metabolised and subcutaneous fat is deposited in the midsection. The result is a swollen "moon" face and an obese trunk, with arms and legs of normal size. Children will show obesity and poor growth in height. Depending on the cause

and duration of the Cushing syndrome, some people may have more dramatic changes. These include masculinisation with increased blood pressure and weight gain.

Diabetes mellitus is characterised by the inability of the body's cells to take up glucose. This causes blood glucose to be higher than normal, and cells rely on other "fuels" like fatty acids for energy. A common symptom of diabetes mellitus is glucose in the urine. As blood glucose increases, more glucose and water are excreted in the urine. This results in frequent urination and complaints of great thirst by affected people. Other symptoms include fatigue, unusual hunger, and weight changes. If untreated, diabetics develop serious and often fatal complications – blurred vision and then vision loss; sores that don't heal result in severe infections. Blood vessel changes cause kidney failure, nerve destruction, heart attack, or stroke.

There are two types of diabetes mellitus. In diabetes type 1, the pancreas is not producing insulin. This condition may be caused by exposure to an agent, most likely a virus, whose presence causes T cells to destroy the pancreatic islets. The body turns to the metabolism of fat, which leads to the build-up of ketones in the blood and, in turn, to acid blood, which can lead to coma and death. The individual must have daily insulin injections which control the diabetic symptoms but can still cause inconveniences because the blood sugar level may swing between hypoglycaemia and hyperglycaemia. Without testing the blood glucose level, it is difficult to be certain which of these is present because the symptoms are similar – perspiration, pale skin, shallow breathing, and anxiety. Immediate attention is required to bring the blood glucose level to its proper level. If the problem is hypoglycaemia, the treatment is two glucose tablets or two doses of glucose gel. Hard candy or orange juice would work too. If the problem is hyperglycaemia, the treatment is insulin.

Long-term complications of both types of diabetes are blindness; kidney disease; and cardiovascular disorders, including atherosclerosis, heart disease, stroke, and reduced circulation. The latter can lead to gangrene in the arms and legs. Pregnancy carries an increased risk of diabetic coma, and the child of a diabetic is somewhat more likely to be stillborn or to die shortly after birth. These complications are not expected to appear if the mother's blood glucose level is regulated and kept within normal limits.

SENSORY SYSTEMS. VISUAL SYSTEM

Sense organs are groups of sensory cells responding to specific stimuli, such as light, sound, touch, temperature and chemicals. Our senses help us perceive changes in our surroundings and in our own bodies. We have sense cells that respond to stimuli (sg. stimulus) by means of structures called receptors. They are either scattered through the skin, or concentrated into special sense organs such as the eye and the ear.

The special property of sensory cells and sense organs is their ability to convert one form of energy to another. The eyes can convert light energy into the electrical energy of a nerve impulse. The ears convert the energy in sound vibrations into nerve impulses. The forms of energy may be very different, e.g. mechanical, chemical, light, but they are all transformed into pulses of electrical energy in the nerves. When a receptor responds to a stimulus, it sends a nerve impulse to the corresponding sensory area in the brain.

The Eye

The sclera is the tough, white outer coating. The front part of the sclera (the cornea) is clear and allows light to enter the eye. The conjunctiva is a thin epithelium, which lines the inside of the eyelids and the front of the sclera and is continuous with the epithelium of the cornea.

The eye contains a clear liquid. The liquid behind the lens is jelly-like and called vitreous humour. The lens is a transparent structure, held in place by a ring of fibres. The eye lens is flexible and can change its shape. In front of the lens is a pigmented disc of tissue called the iris. It controls how much light enters the pupil, which is a hole in the centre of the iris that lets in light to the rest of the eye. The choroid layer, which contains many blood vessels, lies between the retina and the sclera. The internal lining at the back of the eye is the retina and it consists of cells that respond to light. When light falls on them, they send off nervous impulses, which travel in nerve fibres, through the optic nerve, to the brain and so give rise to the sensation of sight. The part of the retina lying directly in front of the optic nerve contains no light-sensitive cells (the blind spot). Tear glands under the top eyelid produce tear fluid. This is a dilute solution of sodium chloride and sodium hydrogencarbonate. The fluid is spread over the eye surface by the blinking of the eyelids, keeping the surface moist and washing away any dust particles or foreign bodies. Tear fluid also contains an enzyme, lysozyme, which attacks bacteria.

Vision

Light from an object produces a focused image on the retina. The curved surfaces of the cornea and lens both refract the light rays that enter the eye, in such a way that each ‘point of light’ from the object forms a ‘point of light’ on the retina. These points of light will form an image, upside-down and smaller than the object. The lens makes the final adjustments to the focus. The pattern of sensory cells stimulated by the image will produce a pattern of nerve impulses sent to the brain. The brain interprets this pattern, using past experience and learning, and forms an impression of the size, distance and upright nature of the object. At the point where the optic nerve leaves the

retina, there are no sensory cells and so no information reaches the brain about that part of the image which falls on this blind spot.

The light-sensitive cells in the retina are of two kinds, the rods and the cones. The cones enable us to distinguish colours, but the rods are more sensitive to low intensities of light and therefore play an important part in night vision when the light intensity is not sufficient to stimulate the cone cells. Images formed at night appear as shades of grey, with no bright colours detected. The cone cells are concentrated in a central part of the retina, called the fovea. The eye can produce a focused image of either a near object or a distant object (accommodation). To do this the lens changes its shape, becoming thinner for distant objects and fatter for near objects.

Abnormalities of the Eye

Colour blindness and misshapen eyeballs are two common abnormalities of the eyes. Complete colour blindness is extremely rare and is caused by a genetic mutation. In most instances, only one type of cone is defective or deficient in number. The most common mutation is the inability to see the colours red and green. This abnormality affects 5-8% of the male population.

Distance Vision

Near-sighted people can see close objects better than they can see objects at a distance. They have an elongated eyeball, and when they attempt to look at a distant object, the image is brought to focus in front of the retina because their lens can compensate for the long eyeball. To see distant objects, these people can wear concave lenses, which spread the light rays so that the image focuses on the retina. Persons who can cannot see close objects well are farsighted. They have a shortened eyeball, and when they try to see close objects, the image is focused behind the retina. When the object is distant, the lens can compensate for the short eyeball. When the object is close, these persons can wear convex lenses to increase the bending of light rays so that the image can be focused on the retina. When the cornea or lens is uneven, the image is fuzzy. The light rays cannot be evenly focused on the retina. This condition, called astigmatism, can be corrected by an unevenly ground lens.

AUDITORY AND EQUILIBRIUM SYSTEM

The ear has two sensory functions: hearing and balance (equilibrium). The sensory receptors for both of these are mechanoreceptors located in the inner ear. Each consists of hair cells with stereocilia (long microvilli) sensitive to mechanical stimulation.

Anatomy and Physiology of the Ear

The ear has three divisions: outer, middle, and inner. The outer ear consists of the pinna and the auditory canal. The opening of the auditory canal is lined with fine hairs and sweat glands. Modified sweat glands are located in the upper wall of the canal. They secrete earwax, a substance that helps guard the ear against the entrance of foreign materials, such as air pollutants. The middle ear begins at the tympanic membrane and ends at a bony wall containing two small openings covered by membranes (the oval window and the round window). Three small bones are found between the tympanic membrane and the oval window called ossicles (hammer, anvil, and stirrup). An auditory tube (Eustachian tube), which extends from the middle ear to the nasopharynx, permits equalisation of air pressure. Chewing gum, yawning, and swallowing in elevators and airplanes help move air through the auditory tubes upon ascent and descent. The inner ear is filled with fluid and it has three areas: the semi-circular canals and the vestibule are concerned with equilibrium, the cochlea is concerned with hearing.

The process of hearing begins when sound waves enter the auditory canal. When a large number of waves strike the tympanic membrane, it vibrates. The auditory ossicles attach to one another. Thus, vibrations of the tympanic membrane will cause vibration of the malleus and in turn, the incus and stapes. The magnitude of the original pressure wave increases significantly as the vibrations move along the auditory ossicles. Finally, the stapes strikes the membrane of the oval window, causing it to vibrate. In this way, the pressure is passed to the fluid within the cochlea.

The sense organ for hearing, called organ of Corti, is located in the cochlear canal. It consists of little hair cells and a gelatinous material called the tectorial membrane. The hair cells sit on the basilar membrane, and their stereocilia are embedded in the tectorial membrane. When the stapes strikes the membrane of the oval window, pressure waves move from the vestibular canal to the tympanic canal across the basilar membrane. The basilar membrane moves up and down, and the stereocilia of the hair cells embedded in the tectorial membrane bend. Then, nerve signals begin in the cochlear nerve and travel to the brain. When they reach the auditory cortex in the temporal lobe, they are interpreted as a sound. Each part of the spiral organ is sensitive to different wave frequencies, or pitch. Near the tip, the spiral organ responds to low pitches. Near the base, it responds to higher pitches. The nerve fibres from each region along the length of the spiral organ lead to slightly different areas in the auditory cortex. The pitch sensation we experience depends upon which region of the basilar membrane vibrates and which area of the auditory cortex is stimulated. Volume is a function of the amplitude (strength) of sound waves. Loud noises cause the fluid within the vestibular canal to exert more pressure and the basilar membrane to vibrate to a greater extent. The resulting increased stimulation is interpreted by the brain as volume.

Sense of Equilibrium

The vestibular nerve originates in the semi-circular canals, saccule, and utricle. It takes nerve signals to the brain stem and cerebellum. Through its communication with the brain, the vestibular nerve helps us achieve equilibrium, but other structures in the body are also involved. There are two sets of mechanoreceptors for equilibrium. Mechanoreceptors in the semi-circular canals detect rotational and/or angular movement of the head. The mechanoreceptors in the utricle and saccule detect movement of the head in the vertical or horizontal plane. Both of these sacs contain little hair cells, whose stereocilia are embedded within a gelatinous material called an otolithic membrane. Calcium carbonate granules, or otoliths, rest on this membrane. When the head bends or the body moves in the horizontal and vertical planes, the otoliths are displaced. These data reach the cerebellum, which is vital to maintain balance and gravitational equilibrium. It processes information from the inner ear as well as visual and proprioceptive inputs. The motor cortex in the frontal lobe of the brain signals where the limbs should be located at any particular moment. After integrating all these nerve inputs, the cerebellum coordinates skeletal muscle contraction to correct our position in space if necessary.

Continuous stimulation of the stereocilia can contribute to motion sickness, especially when messages reaching the brain conflict with visual information from the eyes.

Otitis media is another name for a middle ear infection (an infection behind your eardrum). This kind of ear infection can happen after any condition that keeps fluid from draining from the middle ear. These conditions include allergies, a cold, a sore throat, or a respiratory infection.

Hearing loss can have many different causes. Sudden hearing loss in one ear may be due to earwax, an ear infection, a perforated (burst) eardrum or Ménière's disease. Sudden hearing loss in both ears may be due to damage from a very loud noise, or taking certain medicines that can affect hearing.

GUSTATORY (TASTE) AND OLFACTORY (SMELL) SYSTEMS

Taste and smell are called chemical senses because their receptors are sensitive to molecules in the food we ingest and the air we inhale.

Taste cells and olfactory cells carry chemoreceptors. Chemoreceptors are also in the carotid arteries and in the aorta where they are primarily sensitive to the pH of the blood. They communicate via sensory nerve fibres with the respiratory centre in the medulla oblongata. When the pH drops, they signal this centre. As a result, the breathing rate increases. Exhaling CO2 raises the pH of the blood. Chemoreceptors are plasma membrane receptors that bind to particular molecules. They are divided into two types: those that respond to distant stimuli and those that respond to direct stimuli. Olfactory cells act from a distance and taste cells act directly. pH receptors also respond to direct stimuli.

Sense of Taste

There are approximately 3,000 taste buds in adult humans. Most of them are located on the tongue but many taste buds also lie along the walls of the papillae. These small elevations on the tongue are visible to the naked eye. Isolated taste buds are also present on the hard palate, the pharynx, and the epiglottis. There are at least four primary types of taste (sweet, sour, salty, and bitter). A fifth taste, called umami, allows us to enjoy the savoury flavours of certain cheeses, beef, and mushrooms. Taste buds for each of these tastes are located throughout the tongue, although certain regions may be most sensitive to particular tastes. The tip of the tongue is most sensitive to sweet tastes. The margins of the tongue react to salty and sour tastes. The rear of the tongue responds to bitter tastes.

Taste buds open at a taste pore. They have supporting cells and a number of elongated taste cells that end in microvilli. When molecules bind to receptor proteins of the microvilli, nerve signals are generated in sensory nerve fibres that go to the brain. Signals reach the gustatory (taste) cortex, located primarily in the parietal lobe. There, they are interpreted as particular tastes. Humans can respond to a range of sweet, sour, salty, and bitter tastes. As the signals are received, the brain appears to survey their overall pattern. A "weighted average" of all taste messages is used by the brain as the perceived taste. For example, a glass of lemonade transmits sour, sweet, and perhaps bitter sensations. If you remember the taste of lemonade, your brain will recognise this pattern, and you'll think, "ahh, lemonade." Again, we can note that even though our senses depend on sensory receptors, the cortex integrates the incoming information and gives us our sensations.

Sense of Smell

Approximately 80-90% of what we perceive as "taste" actually is due to the sense of smell. This accounts for how bland food tastes when we have a head cold or a stuffed-up nose. Our sense of smell depends on between 10 and 20 million olfactory cells located within olfactory epithelium

high in the roof of the nasal cavity. Olfactory cells are modified neurons. Each cell ends in a tuft of about five olfactory cilia, which bear receptor proteins for odour molecules.

Each olfactory cell has only one out of several hundred different types of receptor proteins. Nerve fibres from similar olfactory cells lead to the same neuron in the olfactory bulb (an extension of the brain). An odour contains many aroma molecules, which activate a characteristic combination of receptor proteins. For example, a rose might stimulate one set of olfactory cells, while a carnation might stimulate a different combination. An odour's signature in the olfactory bulb is determined by which neurons are stimulated. When the neurons communicate this information via the olfactory tract to the olfactory areas of the cerebral cortex, we know we have smelt a rose or a carnation. The olfactory cortex is located in the temporal lobe. Some areas of the olfactory cortex receive smell sensations, while other areas contain olfactory memories. A certain aroma vividly brings to mind a certain person or place and can recreate emotions you feel about that person or place. The olfactory bulbs have direct connections with the limbic system and its centres for emotion and memory. The number of olfactory cells declines with age. This can be dangerous if an older person can't smell smoke or a gas leak. Older people also tend to apply excessive amounts of perfume or cologne before they can detect its smell.

SKIN. STRUCTURE AND FUNCTION. DISEASES AND PREVENTION

The skin is an organ consisting of all four tissue types: epithelial, connective, muscle, and nervous tissue. It has several accessory organs (hair, nails, sweat glands, and sebaceous glands), and it is sometimes referred to as the integumentary system.

In an adult, the skin has a surface area of about 1.8 square metres. It has numerous functions. Skin protects underlying tissues from physical trauma, pathogen invasion, and water loss. It also helps regulate body temperature and plays a significant role in homeostasis, the relative constancy of the internal environment. The skin synthesises certain chemicals that affect the rest of the body. Skin contains sensory receptors which helps us to be aware of our surroundings and communicate with others. The skin has two regions: the epidermis and the dermis. A subcutaneous layer (hypodermis), is found between the skin and any underlying structures, such as muscle or bone.

The Epidermis

The epidermis is made up of stratified squamous epithelium. New epidermal cells for the renewal of skin are derived from stem cells. Hardening takes place because the cells produce keratin, a waterproof protein. A thick layer of dead keratinized cells, arranged in spiral and concentric patterns, forms fingerprints and footprints that are genetically unique. Outer skin cells are dead and keratinized, so the skin is waterproof. This prevents water loss and it also prevents water from entering the body when the skin is immersed. Two types of specialised cells are located deep in the epidermis – macrophages (white blood cell that phagocytise infectious agents) and melanocytes (they produce melanin – the main pigment responsible for skin colour). Variation in skin colour is due to the amount of melanin produced and its distribution. When skin is exposed to the sun, melanocytes produce more melanin. This protects the skin from the damaging effects of the ultraviolet radiation in sunlight. In some people, this results in the formation of patches of melanin called freckles. Another pigment, called carotene, is present in epidermal cells and in the dermis. Certain cells in the epidermis convert a steroid related to cholesterol into vitamin D with the aid of a small amount of ultraviolet radiation. Vitamin D leaves the skin and helps regulate both calcium and phosphorus metabolism in the body. Calcium and phosphorus are important to the proper development and mineralisation of the bones.

Skin Cancer

Too much ultraviolet radiation is dangerous and can lead to skin cancer. To prevent skin cancer, you should stay out of the sun between the hours of 10 am and 3 pm. When you are in the sun use a broad-spectrum sunscreen that protects from both UV-A and UV-B radiation. Avoid tanning machines because, even if they use only high levels of UV-A radiation, the deep layers of the skin will become more vulnerable to UV-B radiation.

The Dermis

The dermis is a region of dense fibrous connective tissue beneath the epidermis. It contains collagen and elastic fibres. The collagen fibres are flexible but offer great resistance to overstretching and tearing. The elastic fibres maintain normal skin tension but also stretch to allow movement of underlying muscles and joints. The dermis also contains blood vessels that nourish the skin and play a role in temperature regulation. If body temperature starts to rise, the blood vessels in the skin will dilate and more blood will be brought to the surface of the skin for cooling. If the outer temperature falls, the blood vessels constrict, so less blood is brought to the skin's surface. The sensory receptors primarily in the dermis are specialised for touch, pressure, pain, hot, and cold and supply the central nervous system with information about the external environment.

The Subcutaneous Layer

This layer beneath the dermis is composed of loose connective tissue and adipose tissue, which stores fat. Fat is a stored source of energy in the body. Adipose tissue helps to thermally insulate the body from either gaining heat from the outside or losing heat from the inside.

Accessory Organs of the Skin

Nails, hair, and glands are structures of epidermal origin, although some parts of hair and glands are largely found in the dermis. Nails are a protective covering of the distal part of fingers and toes, collectively called digits. Nails grow from special epithelial cells. Hair follicles begin at a bulb in the dermis and continue through the epidermis where the hair shaft extends beyond the skin. Contraction of the erector pili muscles attached to hair follicles causes the hairs to "stand on end" and goosebumps to appear. Epidermal cells form the root of a hair, and their division causes a hair to grow. Each hair follicle has one or more sebaceous glands, which secrete sebum to lubricate the hair within the follicle and the skin. Acne is an inflammation of the sebaceous glands that most often occurs during adolescence due to hormonal changes. Sweat glands are numerous and present in all regions of skin. A sweat gland is a tubule that begins in the dermis and either opens into a hair follicle or onto the surface of the skin. Sweat glands play a role in modifying body temperature. When it starts to rise, sweat glands become active. Sweat absorbs body heat as it evaporates.

STRUCTURAL ORGANISATION OF LIVING SYSTEMS. CHEMICAL ELEMENTS AND INORGANIC COMPOUNDS

Matter refers to anything that takes up space and has mass. It can exist as a solid, a liquid, or a gas. Organisms have levels of organisation – atoms, molecules, cells, tissues, organs, organ systems, organisms, populations, community, ecosystem, and biosphere; they take materials and energy from the environment; reproduce; grow and develop; they are homeostatic; respond to stimuli; they have an evolutionary history and show adaptation to a way of life.

Elements

An element is one of the basic building blocks of matter; an element cannot be broken down by chemical means. There are only 92 naturally occurring elements. Over 90% of the human body is composed of only four elements: carbon (C), nitrogen (N), oxygen (O), and hydrogen (H). Other elements, such as iron (Fe), are important to our health. Macro elements are the natural elements of which the body needs more amount and are more important than any other minerals. Macro minerals include sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) which are cations; and two chlorine (Cl) and phosphorus (P) which are accompanying anions. Microelements in humans play several physiological functions including synthesis of enzymes, hormones and other substances, helping to regulate growth, development and functioning of the immune and the reproductive systems.

Atoms

An atom is the smallest unit of an element that still retains the chemical and physical properties of the element. An atom is the smallest unit to enter into chemical reactions. It contains even smaller subatomic particles, called protons and neutrons, located in the nucleus, and electrons which orbit about the nucleus.

Ions are particles that carry either a positive (+) or negative (−) charge. The attraction between oppositely charged ions forms an ionic bond. The balance of various ions in the body is important to our health. Too much sodium in the blood can contribute to high blood pressure. Calcium deficiency leads to rickets (a bowing of the legs) in children. Too much or too little potassium results in heartbeat irregularities and can be fatal. Bicarbonate, hydrogen, and hydroxide ions are all involved in maintaining the acid-base balance of the body.

Covalent Bonding

Atoms share electrons in covalent bonds. Each atom contributes one electron to the shared pair; they are counted as belonging to both bonded atoms. In a double bond, atoms share two pairs of electrons, and in a triple bond, atoms share three pairs of electrons between them.

Compounds

Cells need chemical substances to make new cytoplasm and to produce energy. The organism must take in food to supply the cells with these substances. All cells need water, oxygen, salts and food substances and all cells consist of water, proteins, lipids, carbohydrates, salts and vitamins or their derivatives.

Inorganic Compounds. Water

Inorganic compounds are important in the body and responsible for many simple functions. The major inorganic compounds are water (H2O), oxygen (O2), carbon dioxide (CO2), and some acids, bases, and salts. Oxygen is required by all cells for cellular metabolism and circulating blood must be well oxygenated for maintenance of life. Carbon dioxide is a waste product of cells and must be eliminated. A balance in acids, bases, and salts must be maintained to assure homeostasis of blood pH and electrolyte balance.

Most cells contain about 75% water and will die if their water content falls much below this. Water is a good solvent and many substances move about the cells in a watery solution. Water molecules take part in vital chemical reactions. For example, in green plants, water combines with carbon dioxide to form sugar. In animals, water helps to break down and dissolve food molecules. Blood is made up of cells and a liquid called plasma. This plasma is 92% water and acts as a transport medium for many dissolved substances, such as carbon dioxide, urea, digested food and hormones. Blood cells are carried around the body in the plasma. Water also acts as a transport medium in plants. Water passes up the plant from the roots to the leaves in xylem vessels and carries with it dissolved mineral ions. Water plays an important role in excretion in animals. It acts as a powerful solvent for excretory materials, such as nitrogenous molecules like urea, as well as salts, spent hormones and drugs. The water has a diluting effect, reducing the toxicity of the excretory materials.

The physical and chemical properties of water differ from those of most other liquids but make it uniquely effective in supporting living activities. Water has a high capacity for heat. This means that it can absorb a lot of heat without its temperature rising to levels that damage the proteins in the cytoplasm. However, because water freezes at 0 °C most cells are damaged if their temperature falls below this and ice crystals form in the cytoplasm. Water molecules are cohesive, meaning that they cling together, because of their polarity and hydrogen bonding. Frozen water is less dense than liquid water, so ice floats on water. Water is a solvent for polar (charged) molecules, and thus facilitates chemical reactions both outside and inside our bodies.

ORGANIC COMPOUNDS. CARBOHYDRATES AND LIPIDS

Four categories of organic molecules, called carbohydrates, lipids, proteins, and nucleic acids, are unique to cells. Organic refers to a molecule that contains carbon (C) and hydrogen (H) and is usually associated with living things. Each type of organic molecule in cells is composed of subunits. When a cell constructs a macromolecule, a molecule that contains many subunits, it uses a dehydration reaction (synthesis). To break down macromolecules, the cell uses a hydrolysis reaction in which the components of water are added.

Carbohydrate molecules are characterised by the presence of the atomic grouping H—C—OH. Carbohydrates function for quick and short-term energy storage in all organisms, including humans.

Simple Carbohydrates

If a carbohydrate is made up of just one ring, and its number of carbon atoms is low (from five to seven), it is called a simple sugar, or monosaccharide. Pentose means a 5-carbon sugar, and hexose means a 6-carbon sugar. Glucose is the hexose our bodies use as an immediate source of energy. Other common hexoses are fructose and galactose found in fruits and milk respectively.

A disaccharide is made by joining only two monosaccharides together by a dehydration reaction. When our hydrolytic digestive juices break down maltose, the result is two glucose molecules. When glucose and fructose join, the disaccharide sucrose forms. Sucrose, ordinarily derived from sugarcane and sugar beets, is commonly known as table sugar.

Complex Carbohydrates (Polysaccharides)

Macromolecules such as starch, glycogen, and cellulose are polysaccharides that contain many glucose units. Starch and glycogen are readily stored forms of glucose in plants and animals, respectively. Some of the macromolecules in starch are long chains of up to 4,000 glucose units. Starch and glycogen have slightly different structures. The polysaccharide cellulose is found in plant cell walls. In cellulose, the glucose units are joined by a slightly different type of linkage than that in starch or glycogen. We are unable to digest foods containing this type of linkage; cellulose largely passes through our digestive tract as fibre, or roughage. Starch has straight chains of glucose molecules. Some chains are also branched.

Lipids

Lipids are diverse in structure and function, but they have a common characteristic: they do not dissolve in water. They contain little oxygen and consist mostly of carbon and hydrogen atoms. Lipids contain more energy per gram than other biological molecules, and that way fats in animals and oils in plants function well as energy storage molecules. Phospholipids form

a membrane so that the cell is separated from its environment and has inner compartments as well. Steroids are a large class of lipids that includes, among other molecules, the sex hormones.

Fats and Oils

The most familiar lipids are those found in fats and oils. Fats, usually of animal origin (e.g., lard and butter), are solid at room temperature. Oils, usually of plant origin (e.g., corn oil and soybean oil), are liquid at room temperature. Fat has several functions in the body. It is used for long-term energy storage, insulates against heat loss, and forms a protective cushion around major organs. Steroids are formed from smaller lipid molecules and function as chemical messengers. Fats and oils form when one glycerol molecule reacts with three fatty acid molecules. Waxes are molecules made up of one fatty acid combined with another single organic molecule, usually an alcohol. Waxes prevent loss of moisture from body surfaces.

A fatty acid is a carbon-hydrogen chain that ends with the acidic group –COOH. Most of the fatty acids in cells contain 16 or 18 carbon atoms per molecule. Fatty acids are either saturated or unsaturated. Butter, which contains saturated fatty acids and no double bonds, is a solid at room temperature. Saturated fats contribute to the disease atherosclerosis in which atherosclerotic plaques are formed on the inside of blood vessels. The plaques narrow blood vessel diameter, choking off the blood and oxygen supply to tissues. Atherosclerosis is the primary cause of cardiovascular disease (heart attack and stroke). Even more harmful than naturally occurring saturated fats are the so-called trans-fats, created artificially using vegetable oils. Trans-fats are partially hydrogenated to make them semisolid. Trans-fats are found in shortenings and solid margarines. They also occur in processed foods (snack foods, baked goods, and fried foods).

Phospholipids

Phospholipids have a phosphate group. They are the primary components of cellular membranes. They spontaneously form a bilayer in which the hydrophilic heads face outward toward watery solutions, and the tails form the hydrophobic interior (hydrophilic means “water-loving” and hydrophobic is “water-fearing”).

Steroids

Steroids are lipids that have a backbone of four fused carbon rings. Each one differs primarily by the attached molecules, called functional groups, attached to the rings. Cholesterol is a component of an animal cell’s plasma membrane and is the precursor of several other steroids, such as the sex hormones estrogen and testosterone. The liver usually makes all the cholesterol the body needs.

NUCLEIC ACIDS – STRUCTURE AND TYPES

The two types of nucleic acids are DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Scientists called them nucleic acids because they were first detected in the nucleus of cells. DNA stores genetic information in the cell and in the organism. DNA replicates and transmits this information when each cell and organism reproduces. Researchers are beginning to understand how genes function, and are working on ways to manipulate them. The science of biotechnology is largely devoted to altering the genes in living organisms.

Function of DNA and RNA

Each DNA molecule contains many genes, and genes specify the sequence of the amino acids in proteins. RNA is an intermediary that conveys DNA's instructions regarding the amino acid sequence in a protein. If DNA's information is faulty, illness can result. The relationship between a gene, a protein, and an illness is illustrated by sickle-cell disease. (A sickle is a long, C-shaped knife used to cut long grass.) In sickle-cell disease, the individual's red blood cells are sickle shaped. This occurs because in one particular spot in the haemoglobin molecule, an amino acid called valine substitutes for an amino acid called glutamine. Exchanging one amino acid for another – a seemingly small change – makes red blood cells lose their normal round, flexible shape and become weak and easily torn. Profound effects on the person's health result. When these abnormal red blood cells go through small blood vessels, they clog the flow of blood and break apart. Sickle-cell disease is another cause of anaemia, and it also results in pain and organ damage.

Both DNA and RNA are polymers of nucleotides.

Nucleotide Structure

Every nucleotide is a molecular complex of three types of subunit molecules – phosphate (phosphoric acid), a pentose (5-carbon) sugar, and a nitrogen-containing base. The nucleotides in DNA contain the sugar deoxyribose, and the nucleotides in RNA contain the sugar ribose; this difference accounts for their respective names. There are four different types of bases in DNA: adenine (A), thymine (T), guanine (G), and cytosine (C). The base can have two rings (adenine or guanine) or one ring (thymine or cytosine). In RNA, the base uracil (U) replaces the base thymine. These structures are called bases because their presence raises the pH of a solution.

Polynucleotide Structure

The nucleotides link to make a polynucleotide called a strand, which has a backbone made up of phosphate-sugar-phosphate-sugar. The bases project to one side of the backbone. The nucleotides of a gene occur in a definite order, and so do the bases. After many years of work, researchers now know the sequence of the bases in human DNA – the human genome. This breakthrough is expected to lead to improved genetic counselling, gene therapy, and medicines to treat the causes of many human illnesses. DNA is double-stranded, with the two strands twisted about each other

in the form of a double helix. In DNA, the two strands are held together by hydrogen bonds between the bases. When coiled, DNA resembles a spiral staircase. When unwound, it resembles a stepladder. The uprights (sides) of the ladder are made entirely of phosphate and sugar molecules, and the rungs of the ladder are made only of complementary paired bases. Thymine (T) always pairs with adenine (A), and guanine (G) always pairs with cytosine (C). Complementary bases have shapes that fit together. Complementary base pairing allows DNA to replicate in a way that ensures the sequence of bases will remain the same. This is important because it is the sequence of bases that determine the sequence of amino acids in a protein. RNA is single-stranded. When RNA forms, complementary base pairing with one DNA strand passes the correct sequence of bases to RNA. RNA is the nucleic acid directly involved in protein synthesis. There are three types of RNA molecules – messenger (m RNA), transport (t RNA) and ribosomal (r RNA).

PROTEINS – STRUCTURE AND TYPES

Amino Acids: Subunits of Proteins

Proteins are macromolecules with amino acid subunits. The central carbon atom in an amino acid bonds to a hydrogen atom and also to three other groups of atoms. The name amino acid is appropriate because one of these groups is –NH2 (amino group) and another is –COOH (carboxyl group, an acid). The third group is the R residue for an amino acid. Amino acids differ according to their particular R residue. The R residues range in complexity from a single hydrogen atom to a complicated ring compound. Some R residues are polar and some are not. The amino acid cysteine ends with an –SH group, which often serves to connect one chain of amino acids to another by a disulphide bond, –S–S–.

Peptides

Two amino acids join by a dehydration reaction between the carboxyl group of one and the amino group of another. The covalent bond between two amino acids is called a peptide bond. When three or more amino acids are linked by peptide bonds, the chain that results is called a polypeptide. The atoms associated with the peptide bond share the electrons unevenly because oxygen attracts electrons more than nitrogen.

Shape of Proteins

Proteins cannot function unless they have their usual shape. When proteins are exposed to extremes in heat and pH, they undergo an irreversible change in shape called denaturation. For example, the addition of vinegar (an acid) to milk causes curdling. Similarly, heating causes egg whites, which contain a protein called albumin, to coagulate. Denaturation occurs because the normal bonding between the R residues has been disturbed. Once a protein loses its normal shape, it is no longer able to perform its usual function. Researchers hypothesise that an alteration in protein organization has occurred when Alzheimer disease and Creutzfeldt-Jakob disease (the human form of mad cow disease) develop. The process of denaturation can be reversible under certain circumstances.

Levels of Protein Organisation

The structure of a protein has at least three levels of organisation and can have four levels. The first level, called the primary structure, is the linear sequence of the amino acids joined by peptide bonds. Each particular polypeptide has its own sequence of amino acids. The secondary structure of a protein comes about when the polypeptide takes on a certain orientation in space. Once amino acids are assembled into a polypeptide, the resulting C=O section between amino acids in the chain is polar, having a partial negative charge. Hydrogen bonding is possible between the C=O of one amino acid and the N–H of another amino acid in a polypeptide. Coiling of the chain results in an α (alpha) helix, or a right-handed spiral, and a folding of the chain results in a β (beta) pleated sheet. Hydrogen bonding between peptide bonds holds the shape in place. The tertiary structure

of a protein is its final three-dimensional shape. In muscles, myosin molecules have a rod shape ending in globular (globe-shaped) heads. In enzymes, the polypeptide bends and twists in different ways. In most enzymes, the hydrophobic portions are packed on the inside, and the hydrophilic portions are on the outside, where they can make contact with water. The tertiary shape of a polypeptide is maintained by various types of bonding between the R residues; covalent, ionic, and hydrogen bonding may occur. Some proteins have only one polypeptide, and others have more than one polypeptide, each with its own primary, secondary, and tertiary structures. These separate polypeptides are arranged to give these proteins a fourth level of structure, termed the quaternary structure. Haemoglobin is a complex protein having a quaternary structure; many enzymes also have a quaternary structure. Each of four polypeptides in haemoglobin are tightly associated with a non-protein haeme group. A haeme group contains an iron (Fe) atom that binds to oxygen, and in that way, haemoglobin transports O2 to the tissues.

PROTEINS – FUNCTIONS

Proteins are of great importance for the structure and function of cells. There are six main functions of proteins in humans.

Support – different proteins are structural proteins. Keratin, for example, makes up hair and nails. Collagen provides support to ligaments, tendons, and skin.

Catalytic Function – enzymes bind reactants together and speed chemical reactions in cells. They are specific for any particular type of reaction and only function at certain temperature and acidity.

Transport – channel and carrier proteins in the plasma membrane allow substances to enter and exit cells. Some other proteins transport molecules in the blood of animals; haemoglobin in red blood cells is a complex protein that transports oxygen and carbon dioxide.

Protection – antibodies are proteins which recognise foreign substances, called antigens, and prevent antigens from destroying cells and disturbing homeostasis. This is a form of immune response of the organism.

Regulatory Function – hormones are specific proteins that serve as intercellular messengers which influence the metabolism of cells. The hormones insulin and glucagon regulate the content of glucose in the blood and in cells. The presence of growth hormone determines the height of an individual.

Movement – the contractile proteins actin and myosin allow parts of cells to move and cause muscles to contract. Muscle contraction accounts for the movement of animals from place to place. The structures and functions of vertebrate cells and tissues differ according to the type of proteins they contain. For example, muscle cells contain actin and myosin; red blood cells contain haemoglobin; and support tissues contain collagen.

Enzymes

A catalyst is a substance that increases the rate of a chemical reaction and is not changed by the reaction. An enzyme is a protein that functions as a biological catalyst. An enzyme-controlled reaction involves three groups of molecules, although the product may be two or more different molecules: substrate → enzyme → product. The substance on which an enzyme acts is called its substrate and the molecules produced are called the products. When the enzyme combines with the substrate, an enzyme-substrate complex is formed temporarily. Then another temporary complex called an enzyme-product complex is produced. Then the product and the enzyme separate. An enzyme and its substrate have complementary shapes and bind at a specific structure called an active site. The names of enzymes usually end with -ase and they are named according to the substance on which they act, or the reaction which they speed up (an enzyme that acts on proteins may be called a protease; one that removes hydrogen from a substance is a dehydrogenase).

Properties

Enzymes demonstrate high specificity – each enzyme acts on only one substance (breaking down) or a pair of substances (building up). Enzymes tend to be very specific in the reactions they

catalyse, due to the complementary shape of the enzyme and its substrate. They can be denatured by changes in temperature and pH. A rise in temperature increases the rate of most chemical reactions; a fall in temperature slows them down. Above 50 °C the enzymes, being proteins, are denatured and stop working. Extremes of pH may denature some enzymes irreversibly. This is because the active site of the enzyme molecule can become deformed. The pH or temperature at which an enzyme works best is often called its optimum pH or temperature. The amount of substrate also affects their activity. The more enzyme molecules produced by a cell, the faster the reaction will proceed, provided there are enough substrate molecules available. An increase in the substrate concentration will speed up the reaction if there are enough enzyme molecules to bind with the additional substrate.

Enzyme inhibitors alter the catalytic action of the enzyme and slow down, or in some cases, stop catalysis. There are three common types of enzyme inhibition – competitive, non-competitive and substrate inhibition. Competitive inhibition occurs when the substrate and a substance resembling the substrate are both added to the enzyme. The lock and key theory utilises the concept of an "active site" – one particular portion of the enzyme surface has a strong affinity for the substrate. If we consider the enzyme as the lock and the substrate the key – the key is inserted in the lock, then it is turned, and the door is opened and the reaction proceeds. However, when an inhibitor which resembles the substrate is present, it will compete with the substrate for the position in the enzyme lock. When the inhibitor wins, the observed reaction is slowed down because some of the available enzyme sites are occupied by the inhibitor. If a dissimilar substance which does not fit the site is present, the enzyme rejects it, accepts the substrate, and the reaction proceeds normally. Non-competitive inhibitors are considered to be substances which when added to the enzyme alter the enzyme in a way that it cannot accept the substrate. Substrate inhibition will sometimes occur when excessive amounts of substrate are present. Additional amounts of substrate added to the reaction mixture after this point actually decrease the reaction rate because there are so many substrate molecules competing for the active sites on the enzyme surfaces that they block the sites and prevent any other substrate molecules from occupying them.

SUPRAMOLECULAR ASSEMBLIES. VIRUSES

A supramolecular assembly is a complex of molecules held together by noncovalent bonds. While a supramolecular assembly can be simply composed of two molecules (e.g., a DNA double helix or an inclusion compound), or a defined number of stoichiometrically interacting molecules within a quaternary complex, it is more often used to denote larger complexes composed of indefinite numbers of molecules that form sphere-, rod-, or sheet-like species. Colloids, liquid crystals, biomolecular condensates, micelles, liposomes and biological membranes are examples of supramolecular assemblies. The dimensions of supramolecular assemblies can range from nanometres to micrometres. Thus they allow access to nanoscale objects using a bottom-up approach in far fewer steps than a single molecule of similar dimensions. The process by which a supramolecular assembly forms is called molecular self-assembly.

Viruses are small obligate intracellular parasites, which by definition contain either a RNA or DNA genome surrounded by a protective, virus-coded protein coat. Viruses may be viewed as mobile genetic elements, most probably of cellular origin and characterized by a long co-evolution of virus and host. For propagation viruses depend on specialized host cells supplying the complex metabolic and biosynthetic machinery of eukaryotic or prokaryotic cells. A complete virus particle is called a virion. The main function of the virion is to deliver its DNA or RNA genome into the host cell so that the genome can be expressed (transcribed and translated) by the host cell. The viral genome, often with associated basic proteins, is packaged inside a symmetric protein capsid. The nucleic acid-associated protein, called nucleoprotein, together with the genome, forms the nucleocapsid. In enveloped viruses, the nucleocapsid is surrounded by a lipid bilayer derived from the modified host cell membrane and studded with an outer layer of virus envelope glycoproteins.

Viruses are grouped on the basis of size and shape, chemical composition and structure of the genome, and mode of replication. Helical nucleocapsids consist of a helical array of capsid proteins wrapped around a helical filament of nucleic acid. Icosahedral morphology is characteristic of the nucleocapsids of many “spherical” viruses. The number and arrangement of the capsomeres (morphologic subunits of the icosahedron) are useful in identification and classification. Many viruses also have an outer envelope.

The genome of a virus may consist of DNA or RNA, which may be single stranded (ss) or double stranded (ds), linear or circular. The entire genome may occupy either one nucleic acid molecule or several nucleic acid segments. The different types of genome necessitate different replication strategies.

Viruses are inert outside the host cell. Small viruses (e.g., polio and tobacco mosaic virus) can even be crystallized. Viruses are unable to generate energy. As obligate intracellular parasites, during replication, they fully depend on the complicated biochemical machinery of eukaryotic or prokaryotic cells. The main purpose of a virus is to deliver its genome into the host cell to allow its expression (transcription and translation) by the host cell.

Small virions are simple nucleocapsids containing 1 to 2 protein species. The larger viruses contain in a core the nucleic acid genome complexed with basic protein(s) and protected by a

single- or double layered capsid (consisting of more than one species of protein) or by an envelope.

The surface of viruses includes many copies of one type of protein that binds, or adsorbs, specifically to multiple copies of a receptor protein on a host cell. This interaction determines the host range of a virus and begins the infection process. Then the viral DNA or RNA crosses the plasma membrane into the cytoplasm. In the case of many bacteriophages, all capsid proteins remain outside an infected cell. The genome of most DNA-containing viruses that infect eukaryotic cells is transported (with some associated proteins) into the cell nucleus, where the cellular DNA is also found. Once inside the cell, the viral DNA interacts with the host's machinery for transcribing DNA into mRNA. The viral mRNA that is produced then is translated into viral proteins by host-cell ribosomes, tRNA, and translation factors.

The fact that the host range is generally restricted serves as a basis for classifying viruses. A virus that infects only bacteria is called a bacteriophage, or simply a phage. Viruses that infect animal or plant cells are referred to generally as animal viruses or plant viruses. A few viruses can grow in both plants and the insects that feed on them. The highly mobile insects serve as vectors for transferring such viruses between susceptible plant hosts. An example is potato yellow dwarf virus, which can grow in leafhoppers (insects that feed on potato plant leaves) as well as in potato plants. Wide host ranges are characteristic of some strictly animal viruses, such as vesicular stomatitis virus, which grows in insects and in many different types of mammalian cells. Most animal viruses do not cross phyla and some (e.g., poliovirus) infect only closely related species such as primates. The host-cell range of some animal viruses is further restricted to a limited number of cell types because only these cells have appropriate surface receptors to which the virions can attach.

VIRAL DISEASES IN HUMANS. DISTRIBUTION AND PREVENTION

Viruses are tiny particles made of genetic material inside of a protein coating. They cause infectious diseases such as the common cold, flu and warts, or severe illnesses such as HIV/AIDS, smallpox, chickenpox, common colds and Ebola. Viruses invade living, normal cells and use them to multiply and reproduce. This can kill, damage, or change the cells and make you sick. Different viruses attack certain cells in your body. When you get a virus, you may not always get ill. Your immune system may be able to fight it off.

For most viral infections, treatments can only help with symptoms while you wait for your immune system to respond. Antibiotics do not work for viral infections. There are antiviral medicines to treat some viral infections. Vaccines can help in building immunity.

Viruses are even smaller than bacteria and require living hosts – people, plants or animals – to multiply. Otherwise, they can't survive. When a virus enters your body, it invades some of your cells and takes over the cell machinery, redirecting it to produce the virus.

In some cases, it may be difficult to determine whether a bacterium or a virus is causing your symptoms. Many ailments – such as pneumonia, meningitis and diarrhoea – can be caused by either bacteria or viruses.

A blood test measures the amount of immunoglobulins (antibodies) in your blood. Antibodies are proteins made by the immune system to fight disease-causing substances, like viruses and bacteria. Your body makes different types of immunoglobulins to fight different types of these substances and the test usually measures three specific types of these called IgG, IgM, and IgA. If your levels of IgG, IgM, or IgA are too low or too high, it may be a sign of a serious health problem.

A viral infection can lead to a spectrum of symptoms from asymptomatic (no clear symptoms) to severe disease. Most commonly, viral infections involve the nose, throat, and upper airways, or systems such as the nervous, gastrointestinal, and reproductive systems. Doctors may base the diagnosis on symptoms, blood tests and cultures, or examination of infected tissues. Antiviral drugs may interfere with the reproduction of viruses or strengthen the immune response to the viral infection.

Types of viral infections

Respiratory infections are infections of the nose, throat, upper airways, and lungs. The most common respiratory infections are upper respiratory infections, which include sore throat, sinusitis, and the common cold. Other viral respiratory infections include influenza, pneumonia, and coronaviruses.

In small children, viruses also commonly cause croup (which is inflammation of the upper and lower airways) or lower airways (bronchiolitis). Respiratory infections are more likely to cause severe symptoms in infants, older people, and people with a lung or heart disorder.

Other viruses infect specific parts of the body: infections of the gastrointestinal tract like gastroenteritis are commonly caused by noroviruses and rotaviruses; liver infections result in hepatitis; some viruses, such as the rabies virus and the West Nile virus, infect the brain, causing encephalitis. Others infect the layers of tissue that cover the brain and spinal cord, causing meningitis or polio; viral infections that affect only the skin sometimes result in warts or other blemishes. Many viruses that affect other parts of the body, such as chickenpox, also cause a rash. Some viruses, such as the Zika virus, the rubella virus, and cytomegalovirus, can infect the placenta and fetus in pregnant women. Some viruses typically affect many body systems – enteroviruses (such as coxsackieviruses and echoviruses) and cytomegaloviruses.

Viruses are transmitted in various ways. They may be swallowed, inhaled, spread by the bites of insects (mosquitoes), certain biting flies, or ticks, spread sexually, or during transfusion of contaminated blood.

New human viruses sometimes develop from viruses that usually affect animals (SARS-CoV and SARS-CoV2). This happens when the infected animal host comes into close contact with susceptible humans.

Many viruses that were once present in only a few parts of the world are now spreading. These viruses include chikungunya virus, Crimean-Congo haemorrhagic fever virus, Japanese encephalitis virus, Rift Valley Fever virus, West Nile virus, Ross River virus, Zika virus, and louping ill virus. This is partly because climate change has resulted in more areas where the mosquitoes that spread the viruses can live. Also, travellers may be infected, then return home and be bitten by a mosquito, which spreads the virus to other people.

The body has a number of protection mechanisms against viruses: physical barriers (skin) or the immune system, which attacks the virus. When a virus enters the body, it triggers the body's immune defence. The processes begin with white blood cells (lymphocytes and monocytes), which learn to attack and destroy the virus or the cells the virus has infected. If the body survives the virus attack, some of the white blood cells remember the invader and are able to respond more quickly and effectively to a subsequent infection by the same virus. This response is called immunity. Immunity can also be produced by getting a vaccine.

STRUCTURE OF THE CELL

The cell theory states that the cell is the basic unit of life and nothing smaller is alive. A unicellular organism exhibits the seven characteristics of life, i.e. to reproduce, respond to stimuli, remain homeostatic, grow and develop, take in and use materials from the environment, and adapt to it. All living things are made up of cells and all cells in a multicellular organism are specialised in structure and function. New cells arise only from pre-existing cells.

Until the nineteenth century, most people believed that non-living objects could give rise to living organisms. The French scientist Louis Pasteur conducted a set of experiments using bacterial cells which proved that spontaneous generation of life from nonlife was not possible. When animals reproduce, a sperm cell joins with an egg cell to form a zygote (the first cell of a new multicellular organism). Parents pass a copy of their genes onto their offspring. The genes contain the instructions that allow the zygote to grow and develop into the complete organism.

Cells can be classified as either prokaryotic or eukaryotic. Both types of cells have a plasma membrane that regulates what enters and exits a cell. It is a phospholipid bilayer. The polar phosphate molecules form the top and bottom surfaces of the bilayer, while the nonpolar tails lie in between. This layer is selectively permeable – it allows certain molecules, but not others, to enter the cell. Proteins scattered throughout the plasma membrane play important roles in allowing substances to enter the cell. All types of cells also contain cytoplasm – a semifluid medium that contains water and various types of molecules suspended or dissolved in the medium. The presence of proteins accounts for the semifluid nature of the cytoplasm. The cytoplasm contains many different types of organelles (well-defined subcellular structures).

Bacteria are prokaryotes, lacking well-defined nuclei and membrane-bound organelles, and with chromosomes composed of a single closed DNA circle. They come in many shapes and sizes, from minute spheres, cylinders and spiral threads, to flagellated rods, and filamentous chains. They are found practically everywhere on Earth.

There are two different ways of grouping bacteria. They can be divided into three types based on their response to gaseous oxygen. Aerobic bacteria require oxygen for their health and existence and will die without it. Anaerobic bacteria can't tolerate gaseous oxygen at all and die when exposed to it. Facultative anaerobes prefer oxygen, but can live without it.

The second way of grouping them is by the way they obtain energy. Bacteria that have to consume and break down complex organic compounds are heterotrophs. This includes species found in decaying material as well as those that utilise fermentation or respiration. Bacteria that create their own energy, fuelled by light or through chemical reactions, are autotrophs.

The cell envelope is made up of two to three layers: the interior cytoplasmic membrane, the cell wall, and – in some species of bacteria – an outer capsule. Some species of bacteria have a third protective covering, a capsule made up of polysaccharides (complex carbohydrates). Capsules play a number of roles, but the most important are to keep the bacterium from drying out and to protect it from phagocytosis (engulfing) by larger microorganisms.

A rigid cell wall encloses each bacterium. It contains a protein-sugar molecule called peptidoglycan. The wall gives the cell its shape and surrounds the cytoplasmic membrane, protecting it from the environment. It also helps to hold the pili and flagella, which originate in the cytoplasm membrane and protrude through the wall to the outside.

The cytoplasm (protoplasm) of bacterial cells is where the functions of cell growth, metabolism, and replication are carried out. It is a gel-like matrix composed of water, enzymes, nutrients, wastes, and gases and contains ribosomes, a chromosome, and plasmids. Bacteria do not have a membrane enclosed nucleus. The chromosome, a single, continuous strand of DNA, is localised in a region of the cell called the nucleoid. All the other cellular components are scattered throughout the cytoplasm. Plasmids are small, extrachromosomal genetic structures made of a circular piece of DNA and carried by many strains of bacteria. They are not involved in reproduction. The nucleoid is not a membrane bound nucleus, but simply an area of the cytoplasm where the strands of DNA are found.

The cytoplasmic membrane is a structural component of bacteria which they share with all other living cells. It is a barrier that allows them to selectively interact with their environment. Membranes are highly organised and asymmetric having two sides, each side with a different surface and different functions.

Flagella (sg. flagellum) are hair-like structures that provide a means of locomotion for those bacteria that have them. They can be found at either or both ends of a bacterium or all over its surface. Many species of bacteria have pili (sg. pilus), small hair-like projections emerging from the outside cell surface. These structures help the bacteria in attaching to other cells and surfaces, such as teeth, intestines, and rocks.

Ribosomes translate the genetic code from the molecular language of nucleic acid to that of amino acids – the building blocks of proteins. Bacterial ribosomes are similar to those of eukaryotes, only smaller and with a slightly different composition and molecular structure.

BACTERIAL DISEASES IN HUMANS

There are records about infectious diseases as far back as 3000 B.C. In the 21st century, infectious diseases remain among the leading causes of death worldwide, despite advances made in medical research and treatments in recent decades.

The Plague of Athens impacted people living in overcrowded Athens and troops aboard ships that had to return to Athens. The scientists identified nucleotide sequences from a pathogenic bacterium, *Salmonella enterica serovar typhi*, which causes typhoid fever. This disease is commonly seen in overcrowded areas and has caused epidemics throughout recorded history.

The Plague of Justinian (from 541 to 750 AD) was a bubonic plague outbreak which eliminated one-quarter to one-half of the human population in the eastern Mediterranean region. The population in Europe dropped by 50 percent during this outbreak. One of the most devastating pandemics was the Black Death (1346-1361) that is another outbreak of bubonic plague caused by the bacterium *Yersinia pestis*. It is thought to have originated initially in China and spread along the Silk Road, a network of land and sea trade routes, to the Mediterranean region and Europe, carried by rat fleas living on black rats that were always present on ships. The Black Death reduced the world's population from an estimated 450 million to about 350 to 375 million. Although contracting bubonic plague before antibiotics meant almost certain death, the bacterium responds to several types of modern antibiotics; mortality rates from plague are now very low.

Tuberculosis, was under control in some regions of the world until re-emerging, mostly in urban centres with high concentrations of immunocompromised people. The WHO has identified certain diseases whose worldwide re-emergence should be monitored. Among these are two viral diseases (dengue fever and yellow fever) and three bacterial diseases (diphtheria, cholera, and bubonic plague).

Biofilms, complex colonies of bacteria acting as a unit in their release of toxins, are highly resistant to antibiotics and host defence. Biofilms are complex colonies of bacteria (often containing several species) that exchange chemical signals to coordinate the release of toxins that will attack the host. They are highly resistant to antimicrobial treatments and host defence. Biofilms form when microorganisms adhere to the surface of some object in a moist environment and begin to reproduce. They are responsible for diseases such as infections in patients with cystic fibrosis, Legionnaires' disease, and otitis media. Biofilms respond poorly or only temporarily to antibiotics.

Excessive use of antibiotics in animals or as imprudent medical treatments has resulted in the spread of antibiotic-resistant bacteria. An antibiotic is a chemical, produced either by microbes or synthetically, that is hostile to the growth of other organisms. One of the main causes of resistant bacteria is the abuse of antibiotics. Another major misuse of antibiotics is in patients with colds or the flu, for which antibiotics are useless. There is also the excessive use of antibiotics in livestock along with the routine use of antibiotics in animal feed, both of which promote bacterial resistance.

Foodborne diseases can be associated with bacteria-caused illnesses in both animal and plant-based food sources. Prokaryotes are everywhere and readily colonise the surface of any type of material. Most of the time, prokaryotes colonise food and food-processing equipment in the

form of a biofilm. A foodborne disease is an illness resulting from the consumption of pathogenic bacteria, viruses, or other parasites that contaminate food.

In the past, cases of botulism, the potentially fatal disease produced by a toxin from the anaerobic bacterium *Clostridium botulinum*, were quite common. Some of the sources for this bacterium were non-acidic canned foods, homemade pickles, and processed meat and sausages. The can, jar, or package created a suitable anaerobic environment where Clostridium could grow. Proper sterilisation and canning procedures have reduced the incidence of this disease.

Acne is a long-term skin disease that occurs when dead skin cells and oil from the skin clog hair follicles. Typical features of the condition include blackheads or whiteheads, pimples, oily skin, and possible scarring. It affects skin with a relatively high number of oil glands, including the face, upper part of the chest, and back. Genetics is the primary cause of acne. The role of diet and cigarette smoking in the condition is unclear, and neither cleanliness nor exposure to sunlight appears to play a part. In both sexes, hormones called androgens appear to be part of the underlying mechanism, by causing increased production of sebum. Another common factor is the excessive growth of the bacterium *Cutibacterium acnes*, which is present on the skin. Treatments for acne are available, including lifestyle changes, medications, and medical procedures.

Tetanus (lockjaw) is a serious infection caused by *Clostridium tetani*. This bacterium produces a toxin that affects the brain and nervous system, leading to stiffness in the muscles. If Clostridium tetani spores are deposited in a wound, the neurotoxin interferes with nerves that control muscle movement. The infection can cause severe muscle spasms, serious breathing difficulties, and can be fatal. Although tetanus treatment exists, it is not uniformly effective. The best way to protect against tetanus is to take the vaccine.

CELLULAR MEMBRANE – STRUCTURE AND FUNCTION

Structure

The plasma membrane marks the boundary between the outside and the inside of the cell. Its integrity and function are necessary to the life of the cell. The plasma membrane is a phospholipid bilayer with attached or embedded proteins. A phospholipid molecule has a polar head and nonpolar tails. The polar heads, being charged, are hydrophilic (attracted to water). The nonpolar tails are hydrophobic (not attracted to water). The fluid-mosaic model is a working description of membrane structure. It states that the protein molecules form a shifting pattern within the fluid phospholipid bilayer. Cholesterol lends support to the membrane.

Short chains of sugars are attached to the outer surface of some protein and lipid molecules. These are called glycoproteins and glycolipids. These carbohydrate chains, specific to each cell, mark it as belonging to a particular individual. Some plasma membrane proteins form channels through which certain substances can enter cells. Others are enzymes that catalyse reactions or carriers involved in the passage of molecules through the membrane.

Functions

The plasma membrane keeps a cell intact. It allows only certain molecules and ions to enter and exit the cytoplasm freely – it is selectively permeable. Small, lipid-soluble molecules, such as oxygen and carbon dioxide, can pass through the membrane easily. The small size of water molecules allows them to freely cross the membrane by using protein channels. Ions and large molecules cannot cross the membrane without more direct assistance.

Diffusion

This is the random movement of molecules from the area of higher concentration to the area of lower concentration, until they are equally distributed. Diffusion is a passive way for molecules to enter or exit a cell. No cellular energy is needed to bring it about.

Osmosis

This is the movement of water across a semipermeable membrane, from a solution with lower concentration to a solution with higher concentration. The membrane separates the two areas, and solute is unable to pass through the membrane. Water will tend to flow from the area that has less solute to the area with more solute. Tonicity refers to an osmotic property of a solution across a particular membrane, such as a red blood cell membrane.

Normally body fluids are isotonic to cells. There is the same concentration of non-diffusible solutes and water on both sides of the plasma membrane. Therefore, cells maintain their normal size and shape. Intravenous solutions given in medical situations are usually isotonic. Solutions that cause cells to swell, or even to burst, due to an intake of water are said to be hypotonic.

A hypotonic solution has a lower concentration of solute and a higher concentration of water than the cells. If red blood cells are placed in a hypotonic solution, water enters the cells. They swell to bursting. Bursting of red blood cells is termed haemolysis. Solutions that cause cells to shrink or shrivel due to loss of water are said to be hypertonic. A hypertonic solution has a higher concentration of solute and a lower concentration of water than do the cells. If red blood cells are placed in a hypertonic solution, water leaves the cells. They shrink. The term crenation refers to red blood cells in this condition. These changes have occurred due to osmotic pressure.

Facilitated Transport

Many solutes are transported by means of protein carriers within the membrane. During facilitated transport, a molecule is transported across the plasma membrane from the side of higher concentration to the side of lower concentration. This is a passive means of transport because the cell does not need to expend energy to move a substance down its concentration gradient. Each protein carrier binds only to a particular molecule, such as glucose.

Active Transport

During active transport, a molecule is moving from lower to higher concentration. Sodium (Na+) is sometimes almost completely withdrawn from urine by cells lining kidney tubules. Active transport requires a protein carrier and the use of cellular energy obtained from the breakdown of ATP. Proteins involved in active transport often are called pumps. Just as a water pump uses energy to move water against the force of gravity, energy is used to move substances against their concentration gradients. One type of pump active in all cells moves sodium ions (Na+) to the outside and potassium ions (K+) to inside the cell. This type of pump is especially associated with nerve and muscle cells.

Endocytosis and Exocytosis

During endocytosis, a portion of the plasma membrane invaginates to envelop a substance and fluid. Then, it forms an endocytic vesicle inside the cell. Some white blood cells are able to take up pathogens by endocytosis (phagocytosis). Cells take up molecules and fluid, and then the process is called pinocytosis. During exocytosis, a vesicle fuses with the plasma membrane as secretion occurs. A steady stream of vesicles move between certain organelles, before finally fusing with the plasma membrane. This is the way that signalling molecules, called neurotransmitters, leave one nerve cell to excite the next nerve cell or a muscle cell.

CYTOPLASM – STRUCTURE AND FUNCTIONS

Plant and animal cells greatly in size and shape depending on their function. All cells have a cell membrane, which is a thin boundary enclosing the cytoplasm. Most cells have a nucleus. Under a light microscope cytoplasm looks like a thick liquid with particles in it. In plant cells it may be seen to be flowing about. The particles may be food reserves such as oil droplets or granules of starch. Other particles are structures known as organelles, which have particular functions in the cytoplasm. Various chemical reactions which keep the cell alive by providing energy and making substances that the cell needs take place in the cytoplasm.

The liquid part of cytoplasm contains about 90% water with molecules of salts and sugars dissolved in it. There are larger molecules of fats (lipids) and proteins suspended in this solution. Lipids and proteins may be used to build up the cell structures, such as the membranes. Some of the proteins are enzymes. Enzymes control the rate and type of chemical reactions which take place in the cells. Some enzymes are attached to the membrane systems of the cell, whereas others float freely in the liquid part of the cytoplasm.

Plant cells differ from animal cells in several ways:

1. Outside the cell membrane they all have a cell wall which contains cellulose and other compounds. It is non-living and allows water and dissolved substances to pass through. The cell wall is not selective like the cell membrane. (Plant cells do have a cell membrane but it is not easy to see or draw because it is pressed against the inside of the cell wall.) Under the microscope, plant cells are quite distinct and easy to see because of their cell walls. Each plant cell has its own cell wall but the boundary between two cells side by side does not usually show up clearly. Cells next to each other appear to be sharing the same cell wall.

2. Most mature plant cells have a large, fluid-filled space called a vacuole. The vacuole contains cell sap, a watery solution of sugars, salts and sometimes pigments. This large, central vacuole pushes the cytoplasm aside so that it forms just a thin lining inside the cell wall. It is the outward pressure of the vacuole on the cytoplasm and cell wall which makes plant cells and their tissues firm. Animal cells may sometimes have small vacuoles in their cytoplasm but they are usually produced to do a particular job and are not permanent.

3. There are many organelles called plastids in the cytoplasm of plant cells. These are not present in animal cells. If they contain the green pigment chlorophyll, the organelles are called chloroplasts. Colourless plastids usually contain starch, which is used as a nutrient store.

The cytoplasm of animal and plant cells appears to be organised into a complex system of membranes and vacuoles. Organelles present include the rough endoplasmic reticulum, a network of flattened cavities surrounded by a membrane, which links with the nuclear membrane. The membrane binds ribosomes, giving its surface a rough appearance. Rough endoplasmic reticulum has the function of producing, transporting and storing proteins. Ribosomes can also be found free in the cytoplasm. They build up the cell's proteins either singly or in groups called polyribosomes. Proteins synthesised at ribosomes attached to the endoplasmic reticulum have a different destination from that of proteins manufactured at ribosomes free in the cytoplasm.

Mitochondria are tiny organelles, which may appear slipper-shaped, circular or oval when viewed in section. In three dimensions, they may be spherical, rod-like or elongated. They have an outer membrane and an inner membrane with many inward-pointing folds. Mitochondria are most numerous in regions of rapid chemical activity and are responsible for producing energy from food substances through the process of aerobic respiration. Prokaryotes do not possess mitochondria or rough endoplasmic reticulum in their cytoplasm.

Organelles in the cytoplasm have recognisable shapes and features. Other organelles are also present in plant cells such as chloroplasts and a cell wall.

The Golgi apparatus consists of a stack of slightly curved saccules, whose appearance can be compared to a stack of pancakes. Here, proteins and lipids received from the ER are modified. For example, a chain of sugars may be added to them. This makes them glycoproteins and glycolipids, molecules often found in the plasma membrane.

The vesicles that leave the Golgi apparatus move to other parts of the cell. Some vesicles proceed to the plasma membrane, where they discharge their contents. In general, the Golgi apparatus is involved in processing, packaging, and secretion.

Lysosomes, membranous sacs produced by the Golgi apparatus, contain hydrolytic enzymes. Lysosomes are found in all cells of the body but are particularly numerous in white blood cells that engulf disease-causing microbes. When a lysosome fuses with such an endocytic vesicle, its contents are digested by lysosomal enzymes into simpler subunits that then enter the cytoplasm. Even parts of a cell are digested by its own lysosomes (auto digestion).

The cytoskeleton consists of microtubules, actin filaments, and intermediate filaments that give cells their shape and allows organelles to move about the cell. Cilia and flagella, which contain microtubules, allow a cell to move.

METABOLIC PROCESSES IN THE CELL

Metabolism (from the Greek word “metabole” meaning “change”) is the set of life-sustaining chemical reactions in organisms. The three main purposes of metabolism are: conversion of food to energy to run cellular processes; conversion of food/fuel to building blocks for proteins, lipids, nucleic acids, and some carbohydrates; and elimination of nitrogenous wastes. These enzyme-catalysed reactions allow organisms to grow and reproduce, maintain their structures, and respond to their environments.

Metabolic reactions may be categorised as catabolic – the breaking down of compounds (for example, the breaking down of glucose to pyruvate by cellular respiration); or anabolic – the building up (synthesis) of compounds (such as proteins, carbohydrates, lipids, and nucleic acids). Generally, catabolism releases energy, and anabolism consumes energy. As a result of oxidation of nutrients in catabolic reactions the energy they contain is released and used for the proper functioning of cells – this type of processes are exothermic. Biological oxidation can also be designated dehydrogenation since hydrogen is released and carried by a special molecule – NAD. Anabolic reactions are processes of reduction catalysed by enzymes (endothermic).

The chemical reactions of metabolism are organised into metabolic pathways, in which one chemical is transformed through a series of steps into another chemical, each step being facilitated by a specific enzyme. Enzymes are crucial to metabolism because they allow organisms to drive desirable reactions that require energy that will not occur by themselves, by coupling them to spontaneous reactions that release energy. Enzymes act as catalysts – they allow a reaction to proceed more rapidly – and they also allow the regulation of the rate of a metabolic reaction, for example in response to changes in the cell’s environment or to signals from other cells.

Enzymes are crucial to metabolism because they allow organisms to drive desirable reactions that require energy. These reactions also are coupled with those that release energy. As enzymes act as catalysts they allow these reactions to proceed quickly and efficiently. Enzymes also allow the regulation of metabolic pathways in response to changes in the cell’s environment or signals from other cells.

Cellular respiration is an important component of metabolism, which includes all the chemical reactions that occur in a cell. Often, metabolism requires metabolic pathways, carried out by enzymes sequentially arranged in cells:

$$A \xrightarrow{1} B \xrightarrow{2} C \xrightarrow{3} D \xrightarrow{4} E \xrightarrow{5} F \xrightarrow{6} G$$

The letters, except A and G, are products of the previous reaction and the reactants for the next reaction. A represents the beginning reactant(s), and G represents the product(s). The numbers in the pathway refer to different enzymes. Each reaction in a metabolic pathway requires a specific enzyme. Enzymes are so necessary in cells, therefore their mechanism of action has been studied extensively.

The reactant(s) that participates in the reaction is (are) called the enzyme's substrate(s). Enzymes have a specific region, called an active site, where the substrates are brought together so they can react. An enzyme's specificity is caused by the shape of the active site. Here the enzyme and its substrate(s) fit together in a specific way, much as the pieces of a jigsaw puzzle fit together. After one reaction is complete, the product or products are released. The enzyme is ready to be used again. Therefore, a cell requires only a small amount of a particular enzyme to carry out a reaction. A chemical reaction can be summarised in the following manner:

$$E + S \rightarrow ES \rightarrow E + P$$

(where E = enzyme, S = substrate, ES = enzyme-substrate complex, and P = product). An enzyme can be used over and over again.

Coenzymes are non-protein molecules that assist the activity of an enzyme and may even accept or contribute atoms to the reaction. It is interesting that vitamins are often components of coenzymes. The vitamin niacin is a part of the coenzyme NAD+ (nicotinamide adenine dinucleotide), which carries hydrogen (H) and electrons.

The energy, released as electrons pass from carrier to carrier, is used for ATP production. The inner mitochondrial membrane contains an ATP synthase complex that combines ADP + P to produce ATP. The ATP synthase complex produces 38 ATP per glucose molecule. Each cell produces ATP within its mitochondria, and therefore, each cell uses ATP for its own purposes. Glucose breakdown leads to ATP build-up, and then ATP is used for the metabolic work of the cell. Muscle cells use ATP for contraction, and nerve cells use it for conduction of nerve impulses. ATP breakdown releases heat.

CATABOLIC PROCESSES IN THE CELL

After blood transports glucose and oxygen to cells, cellular respiration begins. As a result, glucose is decomposed to carbon dioxide and water. Three pathways are involved in the breakdown of glucose. They are called glycolysis, the citric acid cycle, and the electron transport chain. These metabolic pathways allow the energy within a glucose molecule to be slowly released, so that ATP can be gradually produced. Cells would lose a tremendous amount of energy if glucose breakdown occurred all at once. Much energy would be lost as heat.

Glycolysis

The term means sugar splitting. During glycolysis, glucose, a 6-carbon (C6) molecule, is split so that the result is two 3-carbon (C3) molecules of pyruvate. Glycolysis, which occurs in the cytoplasm, is found in almost every type of cell. That is why this pathway is believed to have evolved early in the history of life. Glycolysis is termed anaerobic, because it requires no oxygen. This pathway can occur in microbes that live in bogs or swamps or our intestinal tract, where there is no oxygen. During glycolysis, hydrogens and electrons are removed from glucose, and NADH results. The breaking of bonds releases enough energy for a net yield of two ATP molecules. Pyruvate is a key molecule in cellular respiration. When oxygen is available, the molecule enters mitochondria and is completely broken down. When oxygen is not available, fermentation occurs.

Citric Acid Cycle

This pathway completes the breakdown of glucose. As this cyclical series of enzymatic reactions occurs in the matrix of mitochondria, carbon dioxide is released. Hydrogen and electrons are carried away by NADH. In addition, the citric acid pathway also produces two ATP per cycle. Fats are digested to glycerol and fatty acids. When our cells run out of glucose, they primarily substitute fatty acids for glucose as an energy source. Fatty acids yield C2 molecules that can enter the citric acid cycle. Proteins are digested to amino acids whose carbon chain can easily enter the citric acid cycle. However, first the amino group has to be removed from the carbon chain. This step is primarily carried out in the liver because the liver has the appropriate enzymes to process amino groups. The liver converts the amino groups to urea, excreted by the kidneys.

Electron Transport Chain

NADH molecules from glycolysis and the citric acid cycle deliver electrons to the electron transport chain. The members of the electron transport chain are carrier proteins grouped into complexes embedded in the cristae of a mitochondrion. Each carrier of the electron transport chain accepts two electrons and passes them on to the next carrier. The hydrogens carried by NADH molecules will be used later. High-energy electrons enter the chain and, as they are passed from carrier to carrier, the electrons lose energy. Low energy electrons emerge from the chain. Oxygen serves as the final acceptor of the electrons at the end of the chain. After oxygen receives the electrons, it combines with hydrogens and becomes water. The presence of oxygen makes

the citric acid cycle and the electron transport chain aerobic. Oxygen does not combine with any substrates during cellular respiration. Breathing is necessary to our existence, and the sole purpose of oxygen is to receive electrons at the end of the electron transport chain. The energy, released as electrons pass from carrier to carrier, is used for ATP production. The inner mitochondrial membrane contains an ATP synthase complex that combines ADP + P to produce ATP. The ATP synthase complex produces 38 ATP per glucose molecule.

Each cell produces ATP within its mitochondria and each cell uses ATP for its own purposes. Glucose breakdown leads to ATP build-up, and then ATP is used for the metabolic work of the cell. Muscle cells use ATP for contraction, and nerve cells use it for conduction of nerve impulses. ATP breakdown releases heat.

Fermentation

This is an anaerobic process, meaning that it does not require oxygen. When oxygen is not available to cells, the electron transport chain soon becomes inoperative. This is because oxygen is not present to accept electrons. In this case, most cells have a safety option so that some ATP can still be produced. Glycolysis operates as long as it is supplied with "free" NAD+—NAD+ that can pick up hydrogens and electrons. Normally, NADH takes electrons to the electron transport chain and becomes "free" of them. However, if the system is not working due to a lack of oxygen, NADH passes its hydrogens and electrons to pyruvate molecules. This means that the citric acid cycle and the electron transport chain do not function as part of fermentation. When oxygen is available again, lactate can be converted back to pyruvate, and metabolism can proceed as usual. Fermentation can give us a burst of energy for a short time, but it produces only two ATP per glucose molecule. Also, it results in the accumulation of lactate. Lactate is toxic to cells and causes muscles to cramp and fatigue. If fermentation continues for any length of time, death follows. Fermentation takes its name from yeast fermentation. Yeast fermentation produces alcohol and carbon dioxide (instead of lactate). When yeast is used to leaven bread, carbon dioxide production makes the bread rise. When yeast is used to produce alcoholic beverages, it is the alcohol that humans make use of.

NUCLEUS – STRUCTURE AND FUNCTIONS

The nucleus and several organelles are involved in the production and processing of proteins. The nucleus, a prominent structure in cells, stores genetic information. It's the largest organelle inside the cell taking up about a tenth of the entire cell volume. This makes it one of the easiest organelles to identify under the microscope. Some eukaryotic cells lack a nucleus and are referred to as enucleate cells (e.g. erythrocytes) while others may have more than one nucleus (e.g. striated muscle cells).

In general, the nucleus has a spherical shape. However, it may appear flattened, ellipsoidal or irregular depending on the type of cell. For instance, the nucleus of columnar epithelium cells appears more elongated compared to those of other cells. The shape of a nucleus may also change as the cell matures.

Every cell in the body contains the same genes, segments of DNA. Each type of cell has certain genes turned on, while others are turned off. DNA, with RNA acting as an intermediary, specifies the proteins in a cell. Proteins have many functions in cells, and they help determine a cell's specificity. Chromatin is the combination of DNA molecules and proteins that make up the chromosomes. Chromosomes in the nucleus are tightly packed which makes it possible for very large amounts of the genetic material (DNA) to be contained in such a small space (each cell contains about 3 billion pairs). Chromatin can coil tightly to form visible chromosomes during meiosis (cell division that forms reproductive cells) and mitosis (cell division that duplicates cells). Most of the time, however, the chromatin is uncoiled. Individual chromosomes cannot be distinguished and the chromatin appears grainy in electron micrographs of the nucleus. Chromatin is immersed in a semifluid medium called the nucleoplasm. A difference in pH suggests that nucleoplasm has a different composition from cytoplasm.

Micrographs of a nucleus do show one or more dark regions of the chromatin. These are nucleoli (sg. nucleolus), where ribosomal RNA (rRNA) is produced. This is also where rRNA joins with proteins to form the subunits of ribosomes.

The nucleus is a membrane-bound organelle. It is separated from the cytoplasm by a double membrane known as the nuclear envelope. This is continuous with the endoplasmic reticulum (ER), a membranous system of saccules and channels. The nuclear envelope has nuclear pores of sufficient size to permit the passage of ribosomal subunits out of the nucleus and proteins into the nucleus.

ANABOLIC PROCESSES IN THE CELL. REPLICATION

DNA (deoxyribonucleic acid) is the genetic material. DNA is largely found in the chromosomes, located in the nucleus of a cell. Mitochondria also contain DNA. Any genetic material has to be able to do three things: (1) replicate so that it can be transmitted to the next generation, (2) store information, and (3) undergo mutations that provide genetic variability.

The central dogma of molecular biology describes the two-step process, transcription and translation, by which the information in genes flows into proteins: DNA → RNA → protein. Transcription is the synthesis of an RNA copy of a segment of DNA. RNA is synthesised by the enzyme RNA polymerase.

Replication of DNA

When cells divide, each new cell gets an exact copy of DNA. The process of copying a DNA helix is called DNA replication. During replication, the double-stranded structure of DNA allows each original strand to serve as a template for the formation of a complementary new strand. DNA replication is termed semiconservative because each new double helix has one original strand and one new strand. In other words, one of the original strands is conserved, or present, in each new double helix. Each original strand has produced a new strand through complementary base pairing, so there are now two DNA helices identical to each other and to the original molecule.

1. Before replication begins, the two strands that make up parental DNA are hydrogen-bonded to each other.

2. An enzyme unwinds and “unzips” double-stranded DNA (i.e., the weak hydrogen bonds between the paired bases break).

3. New complementary DNA nucleotides, always present in the nucleus, fit into place by complementary base pairing. These are positioned and joined by the enzyme DNA polymerase.

4. To complete replication, an enzyme seals any breaks in the sugar-phosphate backbone. The DNA returns to its coiled structure once again.

5. The two double-helix molecules are identical to each other and to the original DNA molecule.

Rarely, a replication error occurs making the sequence of the bases in the new strand different from the parental strand. But, if an error does occur, the cell has repair enzymes that usually fix it. A replication error that persists is a mutation, a permanent change in the sequence of bases. A mutation can possibly cause a change in the phenotype and introduce variability. Such variabilities make you different from your neighbour and humans different from other animals.

TRANSCRIPTION

The first step in gene expression is called transcription. The second step is called translation. During transcription, a strand of mRNA forms that is complementary to a portion of DNA. The mRNA molecule that forms is a transcript of a gene. Transcription means to make a faithful copy. In this case, a sequence of nucleotides in DNA is copied to a sequence of nucleotides in mRNA.

We can liken the DNA in the nucleus to a cookbook that contains recipes for making proteins. The original recipe is valuable and must be preserved. A copy (mRNA) is made, and the copy goes to the production centre (ribosomes) to prepare the food (protein).

During transcription, a segment of the DNA serves as a template for the production of an RNA molecule. Although all classes of RNA are formed by transcription, we will focus on transcription to form mRNA.

Forming mRNA

Transcription begins when the enzyme RNA polymerase opens up the DNA helix just in front of it so that complementary base pairing can occur. Then, RNA polymerase joins the RNA nucleotides, and an mRNA molecule results. When mRNA forms, it has a sequence of bases complementary to DNA. Wherever A, T, G, or C is present in the DNA template, U, A, C, or G is incorporated into the mRNA molecule. Now, mRNA is a faithful copy of the sequence of bases in DNA with U in place of T.

Processing mRNA

After the mRNA is transcribed in human cells, it must be processed before entering the cytoplasm. The newly synthesised primary mRNA molecule becomes a mature mRNA molecule after processing. Most genes in humans are interrupted by segments of DNA that are not part of the gene. These portions are called introns because they are intragene segments. The other portions of the gene are called exons because they are ultimately expressed. Only exons result in a protein product. Primary mRNA contains bases complementary to both exons and introns, but during processing, (1) one end of the mRNA is capped, by the addition of an altered guanine nucleotide. The other end is given a tail, by the addition of adenosine nucleotides. (2) The introns are removed, and the exons are joined to form a mature mRNA molecule consisting of continuous exons. This splicing of mRNA is done by a complex composed of both RNA and protein. Surprisingly, RNA, not the protein, is the enzyme, and so it is called a ribozyme. One of the small RNAs is involved in this process.

Ordinarily, processing brings together all the exons of a gene. In some instances, cells use only certain exons rather than all of them to form a mature RNA transcript. Alternate mRNA splicing is believed to account for the ability of a single gene to result in different proteins in a cell. Increasingly, small RNA molecules have been found that regulate not only mRNA processing but also transcription and translation. DNA codes for proteins but RNA regulates the outcome.

TRANSLATION

Protein synthesis requires the process of translation. Translation means to put information into a different language. In this case, a sequence of nucleotides is translated into the sequence of amino acids. This is possible only if the bases in DNA and mRNA code for amino acids. This code is called the genetic code. The genetic code is just about universal in living things. This suggests that the code dates back to the very first organisms on Earth and that all living things are related.

The genetic code is a triplet code. Each three-letter unit of an mRNA molecule is called a codon. The translation of all 64 mRNA codons has been determined. Sixty-one triplets correspond to a particular amino acid. The remaining three are stop codons, which signal polypeptide termination. The one codon that stands for the amino acid methionine is also a start codon signalling polypeptide initiation. Most amino acids have more than one codon. Leucine, serine, and arginine have six different codons, for example. This offers some protection against possibly harmful mutations that change the sequence of the bases.

During translation, transfer RNA (tRNA) molecules bring amino acids to the ribosomes, where polypeptide synthesis occurs. A ribosome consists of a large and a small subunit that join together in the cytoplasm just as protein synthesis begins. Each ribosome has a binding site for mRNA, as well as binding sites for two tRNA molecules at a time. Usually, there are many tRNA molecules for each of the 20 amino acids found in proteins. The amino acid binds to one end of the tRNA molecule. Therefore, the entire complex is designated as tRNA-amino acid. At the other end of each tRNA is a specific anticodon, a group of three bases complementary to an mRNA codon. The tRNA molecules attach to the ribosome at the A (for amino acid) site where each anticodon pairs by hydrogen bonding with a codon.

The order in which tRNA-amino acids link to the ribosome is directed by the sequence of the mRNA codons. In this way, the order of codons in mRNA brings about a particular order of amino acids in a protein. The tRNA attached to the growing polypeptide moves to the P site of a ribosome.

Polypeptide synthesis requires three steps: initiation, elongation, and termination.

1. During initiation, mRNA binds to the smaller of the two ribosomal subunits. Then the larger subunit associates with the smaller one. Magnesium ions stimulate the process.

2. During elongation, the polypeptide lengthens, one amino acid at a time. An incoming tRNA-amino acid complex arrives at the A site and then receives the peptide from the outgoing tRNA. The ribosome moves laterally so that again the P site is filled by a tRNA-peptide complex. The A site is now available to receive another incoming tRNA-amino acid complex. The peptide grows, and the linear structure of a polypeptide comes about. The particular shape of a polypeptide is formed later.

3. Then termination of synthesis occurs at a codon that means stop and does not code for an amino acid. The ribosome dissociates into its two subunits and falls off the mRNA molecule. During elongation, about five amino acids are added to a polypeptide every second. However, many ribosomes are at work forming the same polypeptide. As soon as the initial portion of mRNA has been translated by one ribosome and the ribosome has begun to move down the mRNA, another ribosome attaches to the mRNA. Therefore, several ribosomes, collectively called a polyribosome, can move along one mRNA at a time. Several polypeptides of the same type can be synthesised using one mRNA molecule.

REPRODUCTION OF THE CELL. LIFE CYCLE

The cell cycle is an orderly process that has two parts: interphase and cell division. A human cell has a plasma membrane, which encloses the cytoplasm, the content of the cell outside the nucleus. In the cytoplasm are various organelles, which carry on various functions necessary to the life of the cell. When a cell is not undergoing division, the DNA (and associated proteins) within a nucleus is a tangled mass of thin threads called chromatin. Most of the cell cycle is spent in interphase. This is the time when the organelles carry on their usual functions and the cell gets ready to divide. It grows larger, the number of organelles doubles, and the amount of chromatin doubles as DNA synthesis occurs.

Interphase is divided into three stages: the G1 stage occurs before DNA synthesis, the S stage includes DNA synthesis, and the G2 stage occurs after DNA synthesis. Originally, G stood for the "gaps" – those times during interphase when DNA synthesis was not occurring. But now that we know growth happens during these stages, the G can be thought of as standing for growth.

G1 Stage

The cell returns to normal size and resumes its function within the body. A cell doubles its organelles (e.g., mitochondria and ribosomes), and it accumulates the materials needed for DNA synthesis.

S Stage

DNA replication occurs. A copy is made of all the DNA in the cell. DNA replication occurs, so each chromosome consists of two identical DNA double helix molecules. These molecules occur in the strands called sister chromatids.

G2 Stage

The cell synthesizes the proteins needed for cell division, such as the protein found in microtubules. The role of microtubules in cell division is described in a later section.

The amount of time the cell takes for interphase varies widely. Some cells, such as nerve and muscle cells, typically do not complete the cell cycle and are permanently arrested in G1. These cells are said to have entered a G0 stage. Embryonic cells spend very little time in G1 and complete the cell cycle in a few hours.

Following interphase, the cell enters the cell division part of the cell cycle. Cell division has two stages: M (for mitotic) stage and cytokinesis. Mitosis is a type of nuclear division. Mitosis is called duplication division because each new nucleus contains the same number and type of chromosomes as the former cell. Cytokinesis is division of the cytoplasm. During mitosis, the sister chromatids of each chromosome separate, becoming chromosomes distributed to two daughter nuclei. When cytokinesis is complete, two daughter cells are now present. Mammalian cells usually require only about 4 hours to complete the mitotic stage.

The cell cycle, including interphase and cell division occurs continuously in certain tissues. Right now your body is producing thousands of new red blood cells, skin cells, and cells that line your respiratory and digestive tracts. The process of apoptosis, programmed cell death, also occurs to do away with any cells dividing when they shouldn't.

Ordinarily, a cell cycle control system works perfectly to produce more cells only to the extent necessary. A benign tumour or a cancerous tumour develops when the cell cycle control system is not functioning properly. A benign tumour is confined to a particular location. A cancerous tumour is not confined. Cancer cells have a tendency to leave the original tumour by way of the blood and lymphatic vessels and start new tumours in other parts of the body.

Cell specialisation, also known as cell differentiation, is the process by which generic cells change into specific cells meant to do certain tasks within the body. Cell specialisation is most important in the development of embryos. In adults, stem cells are specialised to replace cells that are worn out in the bone marrow, brain, heart and blood.

Adults are made up mainly of cells called somatic cells, which do not change. The adult body also contains stem cells, which can be specialised to replace cells in the body that are worn out. Adult stem cells can be found in many areas of the body, including the brain, bones and bone marrow, heart, blood, skin, and reproductive organs. Blood-forming stem cells are called haematopoietic cells, while cells that form bone or tissue are called stromal cells.

Some animals are also capable of dedifferentiation, which is the opposite of specialisation. Dedifferentiation is a process in which specialised cells revert to being basic cells. These animals use this process to regenerate injured or severed limbs. Human beings do not have cells capable of dedifferentiation.

CELL DIVISION. MITOSIS

Mitosis is duplication division. The nuclei of the two new cells have the same number and types of chromosomes as the cell that divides. The cell that divides is called the parent cell, and the new cells are called the daughter cells. The parent cell and daughter cell have the same number and types of chromosomes, so they are genetically identical.

When mitosis is going to occur, chromatin in the nucleus becomes highly condensed. The chromosomes become visible. Replication of DNA occurred, so each chromosome is now duplicated. Each is composed of two identical parts, called sister chromatids, held together at a centromere. They are called sister chromatids because they contain the same genes. The complete number of chromosomes is called the diploid (2n) number.

During mitosis, the centromeres divide and the sister chromatids separate. Following separation, each chromatid is called a chromosome. Each daughter cell gets a complete set of chromosomes and is 2n. Therefore, each daughter cell receives the same number and types of chromosomes as the parent cell. Each daughter cell is genetically identical to the other and to the parent cell.

Another event of importance during mitosis is the duplication of the centrosome, the microtubule organising centre of the cell. After centrosomes duplicate, they separate and form the poles of the mitotic spindle, where they assemble the microtubules that make up the spindle fibres. The chromosomes are attached to the spindle fibres at their centromeres. An array of microtubules, called an aster (because it looks like a star), is also at the poles. The centrioles are short cylinders of microtubules that are present in centrosomes. The centrioles lie at right angles to one another. Although it has not been shown, they could possibly assist in the formation of the spindle that separates the chromatids during mitosis.

Phases of Mitosis

The phases of mitosis are prophase, metaphase, anaphase, and telophase. Although these stages are depicted as if they were separate, they are continuous, flowing from the other with no noticeable interruption.

PROPHASE. Several events occur during prophase that visibly indicate the cell is preparing to divide. The centrosomes outside the nucleus have duplicated, and they begin moving away from one another toward opposite ends of the cell. Spindle fibres appear between the separating centrosomes. The nuclear envelope begins to fragment. The nucleolus, a special region of the nucleus, disappears as the chromosomes coil and become condensed. The chromosomes are now visible. Each is composed of two sister chromatids held together at a centromere. Spindle fibres attach to the centromeres as the chromosomes continue to shorten and to thicken. During prophase, chromosomes are randomly placed in the nucleus.

METAPHASE. During metaphase, the nuclear envelope is fragmented, and the spindle occupies the region formerly occupied by the nucleus. The chromosomes are now at the equator (centre) of the spindle. Metaphase is characterized by a fully formed spindle. The chromosomes, each with two sister chromatids, are aligned at the equator.

ANAPHASE. At the start of anaphase, the centromeres uniting the sister chromatids divide. Then the sister chromatids separate, becoming chromosomes that move toward opposite poles of the spindle. Separation of the sister chromatids ensures that each cell receives a copy of each type of chromosome, and thereby has a full complement of genes. Anaphase is characterised by the 2n (diploid) number of chromosomes moving toward each pole.

The spindle brings about chromosomal movement. Two types of spindle fibres are involved in the movement of chromosomes during anaphase. One type extends from the poles to the equator of the spindle. There, they overlap. As mitosis proceeds, these fibres increase in length. This helps push the chromosomes apart. The chromosomes themselves are attached to other spindle fibres that extend from their centromeres to the poles. These fibres (composed of microtubules that can disassemble) become shorter as the chromosomes move toward the poles. Therefore, they pull the chromosomes apart. Spindle fibres are composed of microtubules. Microtubules can assemble and disassemble by the addition or subtraction of tubulin (protein) subunits. This is what enables spindle fibres to lengthen and shorten and what ultimately causes the movement of the chromosomes.

TELOPHASE. Telophase begins when the chromosomes arrive at the poles. During telophase, the chromosomes become indistinct chromatin again. The spindle disappears as the nuclear envelope components reassemble in each cell. Each nucleus has a nucleolus because each has a region of the DNA where ribosomal subunits are produced. Telophase is characterised by the presence of two daughter nuclei.

Cytokinesis

Cytokinesis is the division of the cytoplasm and organelles. In human cells, a slight indentation, called a cleavage furrow, passes around the circumference of the cell. Actin filaments form a contractile ring, and as the ring becomes smaller, the cleavage furrow pinches the cell in half. As a result, each cell becomes enclosed by its own plasma membrane. In plant cells a phragmoplast forms first which serves as a scaffold for cell plate assembly and subsequent formation of a new cell wall separating the two daughter cells.

MEIOSIS

Meiosis is reduction division. Meiosis involves two divisions, so there are four daughter cells. Each daughter cell has one of each type of chromosome and, therefore, half as many chromosomes as the parent cell. The parent cell has the diploid (2n) number of chromosomes, while the daughter cells have half this number, called the haploid (n) number of chromosomes. The daughter cells that result from meiosis go on to become the gametes.

At the start of meiosis, the parent cell is 2n, or diploid, and the chromosomes occur in pairs. The short chromosomes are one pair, and the long chromosomes are another. The members of a pair are called homologous chromosomes, or homologues, because they look alike and carry genes for the same traits, such as type of hair or colour of eyes.

Meiosis I

The two cell divisions of meiosis are called meiosis I and meiosis II. Prior to meiosis I, DNA replication has occurred, and the chromosomes are duplicated. Each chromosome consists of two chromatids held together at a centromere. During meiosis I the homologous chromosomes come together and line up side by side. This so-called synapsis results in an association of four chromatids that stay in close proximity during the first two phases of meiosis I. Synapsis is significant because its occurrence leads to a reduction of the chromosome number.

There are pairs of homologous chromosomes at the equator during meiosis I because of synapsis. Only during meiosis I is it possible to observe paired chromosomes at the equator. When the members of these pairs separate, each daughter nucleus receives one member of each pair. Therefore, each daughter cell now has the haploid (n) number of chromosomes. Each chromosome, however, is still duplicated. No replication of DNA occurs between meiosis I and meiosis II. The time between meiosis I and meiosis II is called inter-kinesis.

Meiosis II

During meiosis II, the centromeres divide. The sister chromatids separate, becoming chromosomes that are distributed to daughter nuclei. In the end, each of four daughter cells has the n, or haploid, number of chromosomes. Each chromosome consists of one chromatid. In humans, the daughter cells mature into gametes (sex cells – sperm and egg) that fuse during fertilisation. Fertilisation restores the diploid number of chromosomes in the zygote, the first cell of the new individual. If the gametes carried the diploid instead of the haploid number of chromosomes, the chromosome number would double with each fertilisation. After several generations, the zygote would be nothing but chromosomes. Meiosis I has four phases: prophase I, metaphase I, anaphase I, and telophase I. The stages of meiosis II are named similarly to those of meiosis I, except the name is followed by II.

Meiosis is a part of sexual reproduction. The process of meiosis ensures that the next generation of individuals will have the diploid number of chromosomes and a combination of characteristics different from that of either parent. Both meiosis I and meiosis II have the same four stages of

nuclear division as did mitosis – prophase, metaphase, anaphase, and telophase. The following description is about prophase I and metaphase I because special events occur during these phases.

Prophase I

In prophase I, synapsis occurs, and then the spindle appears. The nuclear envelope fragments and the nucleolus disappears. During synapsis, the homologous chromosomes come together and line up side by side. Now, an exchange of genetic material may occur between the non-sister chromatids of the homologous pair. This exchange is called crossing-over. Crossing-over means that the chromatids held together by a centromere are no longer identical. When the chromatids separate during meiosis II, the daughter cells will receive chromosomes with recombined genetic material. To appreciate the significance of crossing-over, it is necessary to realise that the members of a homologous pair can carry slightly different instructions for the same genetic trait. For example, one homologue may carry instructions for brown eyes and blond hair, while the corresponding homologue may carry instructions for blue eyes and red hair. Crossing-over causes the offspring to receive a different combination of instructions than the mother or the father received. Therefore, offspring could receive brown eyes and red hair or blue eyes and blond hair.

Metaphase I

During metaphase I, the homologous pairs align independently at the equator. This means that the maternal or paternal member may be oriented toward either pole. In humans, where there are 23 pairs of chromosomes, the number of possible chromosomal combinations in the gametes is a staggering 223, or 8,388,608. And this does not even consider the genetic variations introduced due to crossing-over.

The events of prophase I and metaphase I help ensure that gametes will not have the same combination of chromosomes and genes.

Meiosis is a part of gametogenesis, production of the sperm and egg. One function of meiosis is to keep the chromosome number constant from generation to generation. The gametes are haploid, so the zygote has only the diploid number of chromosomes.

RECOMBINANT DNA TECHNOLOGY. CLONING

Cloning

In biology, cloning is the production of genetically identical copies of DNA, cells, or organisms through an asexual means. Gene cloning can be done to produce many identical copies of the same gene.

Recombinant DNA Technology

Recombinant DNA (rDNA), which contains DNA from two or more different sources, allows genes to be cloned. To create recombinant DNA, a technician needs a vector, by which the gene of interest will be introduced into a host cell, such as a bacterium. One common vector is a plasmid. Plasmids are small accessory rings of DNA found in bacteria. The ring is not part of the bacterial chromosome and replicates on its own.

Steps for Gene Cloning

1. A restriction enzyme is used to cleave human DNA and plasmid DNA. The restriction enzyme creates a gap in plasmid DNA in which foreign DNA (e.g. the insulin gene) can be placed if it ends in bases complementary to those exposed by the restriction enzyme. To ensure this, it is only necessary to use the same type of restriction enzyme to cleave both human DNA containing the gene for insulin and plasmid DNA.

2. The enzyme called DNA ligase is used to seal foreign DNA into the opening created in the plasmid. The single-stranded, but complementary, ends of a cleaved DNA molecule are called "sticky ends." This is because they can bind a piece of DNA by complementary base pairing. Sticky ends facilitate the sealing of the plasmid DNA with human DNA for the insulin gene. Now the vector is complete, and an rDNA molecule has been prepared.

3. Some of the bacterial cells take up a recombinant plasmid, especially if the bacteria have been treated to make them more permeable.

4a. Gene cloning occurs as the plasmid replicates on its own. Scientists clone genes for a number of reasons. They might want to determine the difference in base sequence between a normal gene and a mutated gene. Alternatively, they might use the genes to genetically modify organisms in a beneficial way.

4b. The bacterium can also make a product (e.g. insulin) that it could not make before. For a human gene to express itself in a bacterium, the gene has to be accompanied by regulatory regions unique to bacteria. In addition, the gene should not contain introns because bacteria do not have introns. However, it is possible to make a human gene that lacks introns. The enzyme called reverse transcriptase can be used to make a DNA copy of mRNA. The DNA molecule, called complementary DNA (cDNA), does not contain introns.

If only small pieces of identical DNA are needed, the polymerase chain reaction (PCR), developed by Kary Mullis in 1985, can create copies of a segment of DNA quickly in a test tube. PCR is very specific. It makes copies of a targeted DNA sequence. The targeted sequence can be

less than one part in a million of the total DNA sample! PCR requires the use of DNA polymerase, the enzyme that carries out DNA replication. It also needs a supply of nucleotides for the new DNA strands. PCR is a chain reaction because the targeted DNA is repeatedly replicated as long as the process continues. The amount of DNA doubles with each replication cycle. DNA amplified by PCR is often analysed for various purposes. Mitochondrial DNA base sequences in modern living populations were used to decipher the evolutionary history of human populations. Little DNA is required for PCR to be effective, so it has even been possible to sequence DNA taken from mummified human brains. Following PCR, DNA can be subjected to DNA fingerprinting. Today, DNA fingerprinting is often carried out by detecting how many times a short sequence (two to five bases) is repeated. Organisms differ by how many repeats they have at particular locations. The greater the number of repeats at a location, the longer the section of DNA amplified by PCR. During a process called gel electrophoresis, these DNA fragments can be separated according to their size, and the result is a pattern of distinctive bands. If two DNA patterns match, there is a high probability that the DNA came from the same source. It is customary to test for the number of repeats at several locations to further define the source. DNA fingerprinting has many uses. When the DNA matches that of a virus or mutated gene, it is known that a viral infection, genetic disorder, or cancer is present. Fingerprinting DNA from a single sperm is enough to identify a suspected rapist. DNA fingerprinted from blood or tissues at a crime scene has been successfully used in convicting criminals.

Applications of PCR and DNA fingerprinting are limited only by our imagination. PCR analysis has been used to identify unknown soldiers and members of the royal Russian family. Paternity suits can be settled. Environmental law enforcement authorities can identify illegally poached ivory and whale meat using these technologies. These applications have shed new light on evolutionary studies by comparing DNA from fossils with that of living organisms.

GMO. MICROORGANISMS IN BENEFIT OF HUMANS

Today, bacteria, plants, and animals are genetically engineered to produce biotechnology products. Transgenic organisms are organisms that have had a foreign gene inserted into them.

FROM BACTERIA. Recombinant DNA technology is used to produce transgenic bacteria, grown in huge vats called bioreactors. The gene product is collected from the medium. Biotechnology products on the market produced by bacteria include insulin, clotting factor VIII, human growth hormone, tissue plasminogen activator (t-PA), and hepatitis B vaccine. Some transgenic bacteria have been produced to promote the health of plants. For example, bacteria that normally live on plants and encourage the formation of ice crystals have been changed from frost-plus to frost-minus bacteria. As a result, new crops such as frost-resistant strawberries are being developed. Bacteria can be selected for their ability to degrade a particular substance, and this ability can then be enhanced by genetic engineering. For instance, naturally occurring bacteria that eat oil can be genetically engineered to do an even better job of cleaning up beaches after oil spills. Further, these bacteria were given "suicide" genes that caused them to self-destruct when the job had been accomplished.

FROM PLANTS. Corn, potato, soybean, and cotton plants have been engineered to be resistant to either insect predation or herbicides that are widely used. Some corn and cotton plants have been developed that are both insect- and herbicide-resistant. If crops are resistant to a broad-spectrum herbicide and weeds are not, then the herbicide can be used to kill the weeds. When herbicide-resistant plants were planted, weeds were easily controlled, less tillage was needed, and soil erosion was minimized. A salt-tolerant tomato has already been developed. First, scientists identified a gene coding for a protein that transports Na^+ across the vacuole membrane. Sequestering the Na^+ in a vacuole prevents it from interfering with plant metabolism. Then, the scientists cloned the gene and used it to genetically engineer plants that overproduce the channel protein. The modified plants thrived when watered with a salty solution. Salt-tolerant crops would increase yield on saline land. Salt- and also drought- and cold-tolerant crops might help provide enough food for a growing world population.

Potato blight is the most serious potato disease in the world. About 150 years ago, it was responsible for the Irish potato famine, which caused the death of millions of people. By placing a gene from a naturally blight-resistant wild potato into a farmed variety, researchers have now made potato plants that are no longer vulnerable to a range of blight strains. Some progress has also been made to increase the food quality of crops. Soybeans have been developed that mainly produce the monounsaturated fatty acid oleic acid, a change that may improve human health.

FROM ANIMALS. Techniques have been developed to insert genes into the eggs of animals. It is possible to microinject foreign genes into eggs by hand. Another method uses vortex mixing. The eggs are placed in an agitator with DNA and silicon carbide needles, and the needles make tiny holes through which the DNA can enter. When these eggs are fertilized, the resulting offspring are transgenic animals. Using this technique, many types of animal eggs have taken up the gene for bovine growth hormone (bGH). The procedure has been used to produce larger fish, cows,

pigs, rabbits, and sheep. Pigs being bred to supply transplant organs for humans can be genetically modified in this manner also.

Gene pharming, the use of transgenic farm animals to produce pharmaceuticals, is being pursued by a number of firms. Genes that code for therapeutic and diagnostic proteins are incorporated into an animal's DNA, and the proteins appear in the animal's milk. Plans are under way to produce drugs for the treatment of cystic fibrosis, cancer, blood diseases, and other disorders by this method. The gene of interest is microinjected into donor eggs. Following in vitro fertilization, the zygotes are placed in host females, where they develop. After transgenic female offspring mature, the product is secreted in their milk. Then, cloning can be used to produce many animals that produce the same product. Female clones produce the same product in their milk.

Many researchers are using transgenic mice technology for various research projects in the laboratory. A section of DNA called SRY (sex-determining region of the Y chromosome) produces a male animal. This SRY DNA was cloned, and then one copy was injected into one-celled mouse embryos with two X chromosomes. Injected embryos developed into males, but any that were not injected developed into females. Mouse models have also been created to study human diseases. An allele such as the one that causes cystic fibrosis can be cloned and inserted into mice embryonic stem cells. Occasionally, a mouse embryo homozygous for cystic fibrosis will result. This embryo develops into a mutant mouse that has a phenotype similar to a human with cystic fibrosis. New drugs for the treatment of cystic fibrosis can then be tested in these mice.

Xenotransplantation is the use of animal organs, instead of human organs, in transplant patients. Scientists have chosen to use the pig because animal husbandry has long included the raising of pigs as a meat source, and pigs are prolific. The ability of pigs to express genes for human recognition proteins means that pig organs will be more readily accepted by humans and rejection will be less likely to occur.

REFERENCES AND NOTES

Human Biology – by Sylvia S. Mader and Michael Windelpecht, Fifteenth Edition, 2018, McGraw-Hill Education
Cambridge IGCSE Biology – by D. G. Mackean and Dave Hayward, Third Edition, 2014, Hodder Education

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https://www.timjamesscience.com/blog/-10-rules-for-scientific-debate

ADDITIONAL INFORMATION AND TASKS

The scientific method as a process consists of the following stages:
• making an observation;
• formulating a hypothesis;
• carrying out experiments and observations;
• coming to a conclusion;
• developing a scientific theory.
(Human Biology – by Sylvia S. Mader and Michael Windelpecht, Fifteenth Edition, 2018, McGraw-Hill Education)

Science topics for debate:
1. Ageing can be slowed down and reversed.
2. Should people be encouraged to opt for homeopathic medicine?
3. Should the government regulate fast-food chains?
4. Should genetic engineering of humans be considered ethical?
5. Genetically modifying livestock can be harmful in the long term.
6. Can vegetarianism save the Earth?
7. Is animal experimentation justifiable with humans' progress in medicine?
8. Should perceiving test-tube babies as different from normal babies be stopped?
9. Is it possible to create a virus in a lab?
10. Will GM food stop world hunger?
11. Should genetic screening for healthier offspring be legal?
12. Are e-cigarettes less harmful than smoking?
13. Should an alcoholic be denied a liver transplant?
14. Should human genes be patented?
15. Should health websites be used as a reliable source of information?
(https://owlcation.com/academia/80-Science-Debate-Topics-for-Students)

Tasks
Task 1. Do some research on stem cells. What are they? How can humans benefit from stem cell technology?

Task 2. Create 3D models of tissues. Use your imagination and traditional or new materials to present your ideas.

Task 3. Human organs and measures in the imperial system – find the examples and history of using proportions and 'royal' measures!

Task 4. Study the eating habits of your classmates. Provide schemes and graphs to illustrate the results. Compare their BMI to the healthy standard. What are your recommendations?

Task 5. Why are vitamins essential to our bodies? What would happen without them? Is an apple enough to keep the doctor away?

Task 6. Provide the dietary regimen of a student who does not practice any sport and the one for an active sportsperson your age.

Task 7. Trace the movement of food starting from the oral cavity and ending with the anus. Make a model of structures and enzymes acting on nutrients in each section.

Task 8. So some research on your family history in terms of any disorders affecting the digestive system. Present your survey in an appropriate manner using means at your choice.

Task 9. Perform some research with your classmates about their breathing capacity, compare the results and formulate a hypothesis on the dependence of results on age, sex, physical activity and other factors.

Task 10. Create a step-by-step guide on how to perform CPR.

Task 11. Discuss the advantages and disadvantages of dialysis and transplantation.

Task 12. Compose a guide for first aid in sprain, dislocation, fracture affecting different regions of the skeleton.

Task 13. Create a 3D model of the muscular system using computer software.

Task 14. Perform a study on the Corona viruses family and present HIV as a member of the group.

Task 15. Create a short list of recommendations about reproductive system health and prevention against STIs.

Task 16. Is conception a thing of God and should science interfere? Do a debate following a stage of research and analysis.

Task 17. Dos and don'ts in human upbringing – create a parents' guide including the peculiarities of development of human beings.

Task 18. Immunity and breast feeding vs. bottle feeding – compare the types of feeding and provide arguments in favour of the opposing views keeping in mind the social, physiological, religious and emotional aspects.

Task 19. Bacteria, viruses and fungi as disease agents – compare the history, diseases, treatment, prevention, reaction of the organisms (plants, animals, humans)

Task 20. Create a 3D animation of the reflex, synapse and the activity of the different divisions of the nervous system.

Task 21. 'Fight of flight' vs 'rest and digest' - do some research and present the mechanism of action, structures and substances involved. Provide examples.

Task 22. Peer pressure and drug abuse – advise a student on how to avoid the risks. Provide information about the groups of psychoactive substances and their effects.

Task 23. 'It's all about hormones' – why, what are they, what happens when they are out of control?

Task 24. Create a model of the eye using both standard materials and computer technologies.

Task 25. Create a model of the ear using both standard materials and computer technologies.

Task 26. What can certain smells evoke memories? Explain the connection between smell and taste. What is the role of each sense in the perception of the world around us?

Task 27. Create a model of the skin structure and functions using both standard materials and computer technologies.

Task 28. Make a glossary of chemical elements in the human body

Task 29. Create a short guide to the types of vitamins, their use and abuse

Task 30. People as organic matter – why are we carbon creatures? Carbon dating and its application – do some research and present the results

Task 31. Proteins – enzymes in human life. Find information about all types of application of enzymes and the industries involved.

Task 32. Lipids and their implementation in cosmetics and medicine – waxes and liposomes. Do some research and present the results.

Task 33. Food of the future – do some research on ways to resolve the food crisis and present information about replacements of traditional sources of carbohydrates, gluten-free and vegan choices.

Task 34. Compare viruses and bacteria in terms of infectiousness, ways of transmission, effects on the organism, consequences. Which ones are more dangerous and why? Are there any diseases caused by both?

Task 35. Create a model of the cell including all organelles that is edible. Describe the foods you have used and justify your choice.
Task 36. Represent catabolic pathways using your imagination and materials/technology at your choice.

Task 37. Use materials/computer to present a model comparing DNA and RNA and illustrating the central dogma in molecular biology.

Task 38. Do some research and describe all possible implementations of cloning and recombinant DNA technologies

Task 39. Present to your classmates information in the form of student's guide to jobs of the future including branches of science, universities and work opportunities.
(https://www.timjamesscience.com/blog/-10-rules-for-scientific-debate)

Magnification and Resolution

Magnification can be defined as:

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

This can be rearranged to:

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

There is no limit to the amount you can magnify an image. However, the amount of *useful* magnification depends on the **resolution** of the microscope. This is the ability of the microscope to distinguish two objects as separate from one another. The smaller the objects that can be distinguished, the higher the resolution. Resolution is determined by the wavelength of the rays that are being used to view the specimen. The wavelength of a beam of electrons is much smaller than the wavelength of light. An electron microscope can therefore distinguish between much smaller objects than a light microscope – in other words, an electron microscope has a much higher resolution than a light microscope. We can therefore see much more fine detail of a cell using an electron microscope than using a light microscope.

As cell are very small, we have to use units much smaller than millimetres to measure them. These units are micrometres, **µm**, and nanometres, **nm**.

$1\ \text{mm} = 1 \times 10^{-3}\ \text{m}$

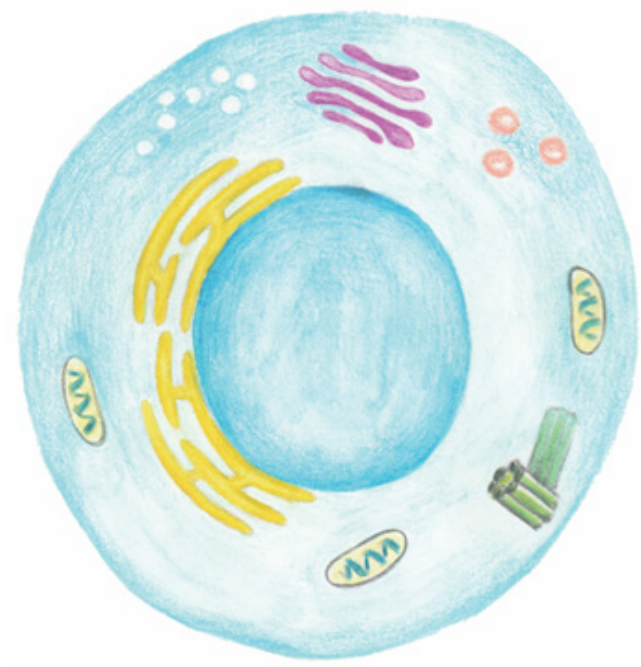
$1\ \mu\text{m} = 1 \times 10^{-6}\ \text{m}$

$1\ \text{nm} = 1 \times 10^{-9}\ \text{m}$

To change mm into **µm**, multiply by 1000.

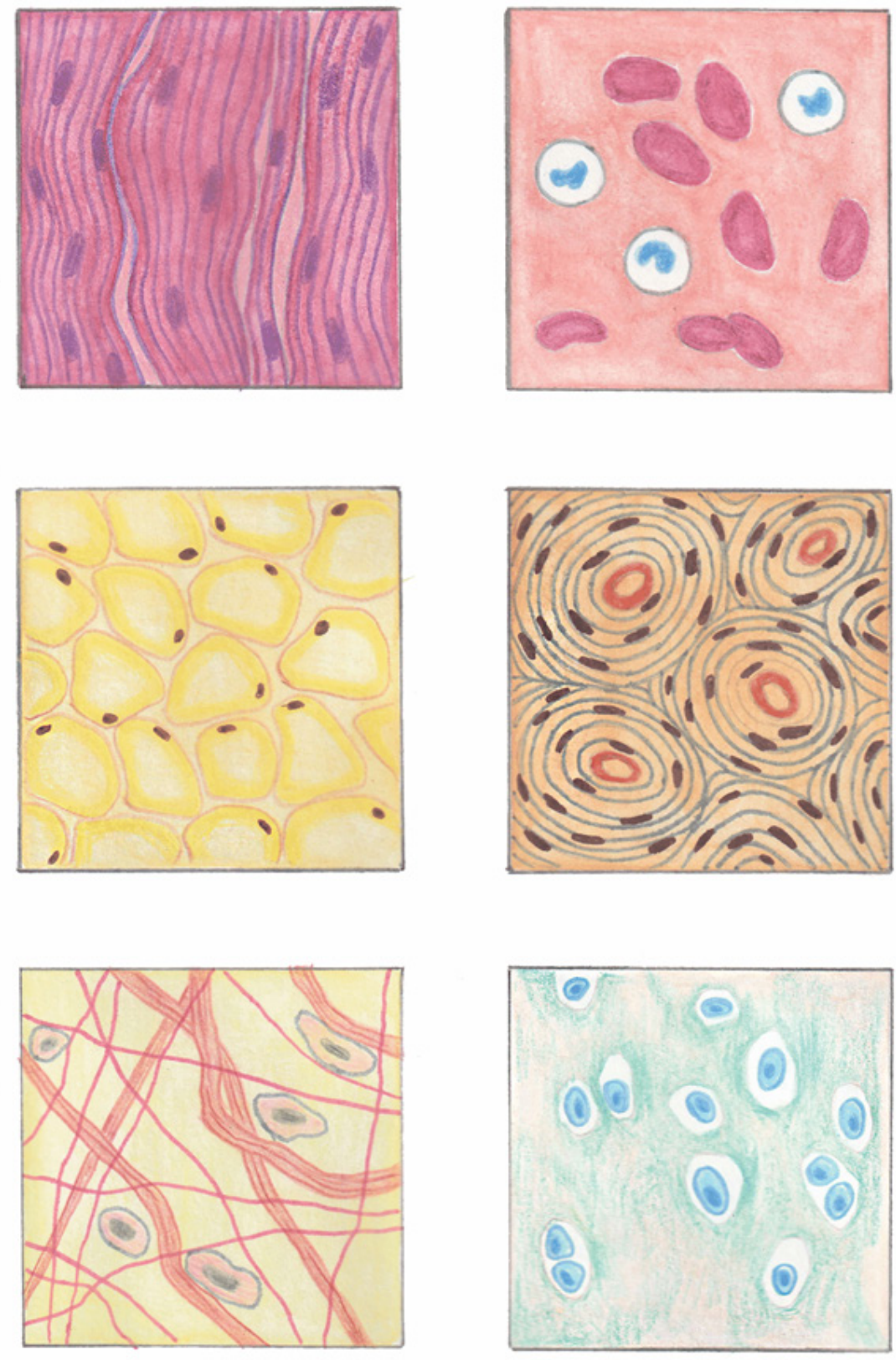
(Cambridge International A/AS – Level Biology Revision Guide)

ILLUSTRATIONS

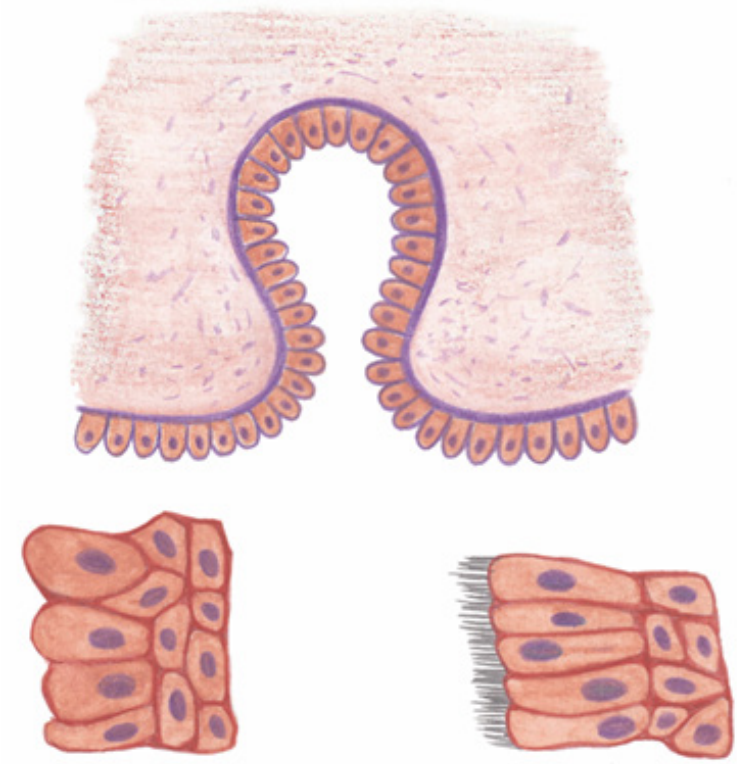


Animals

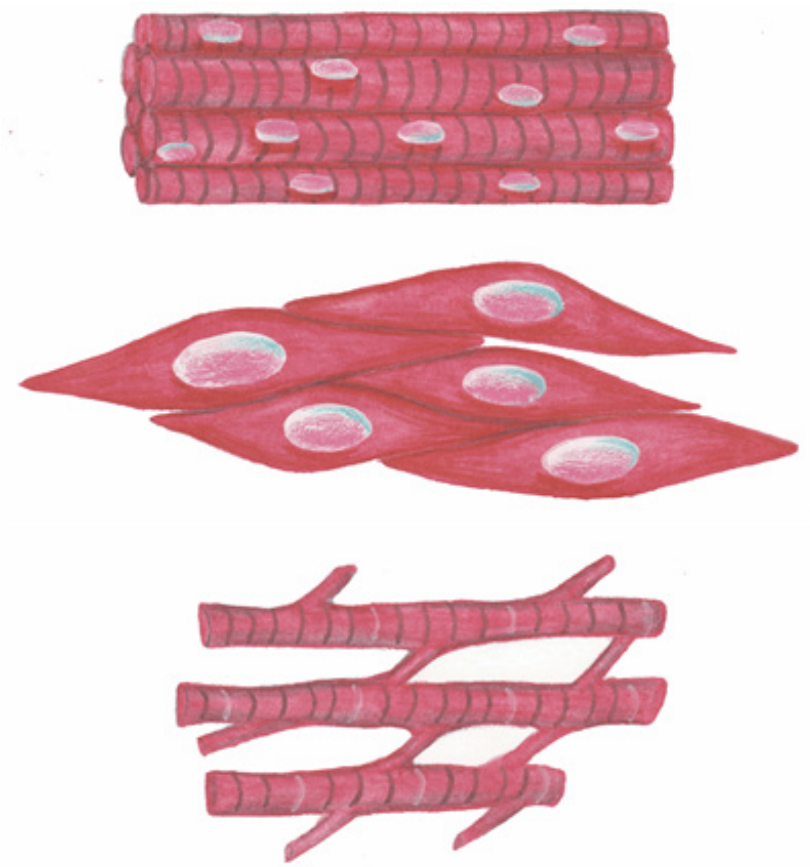
Plants



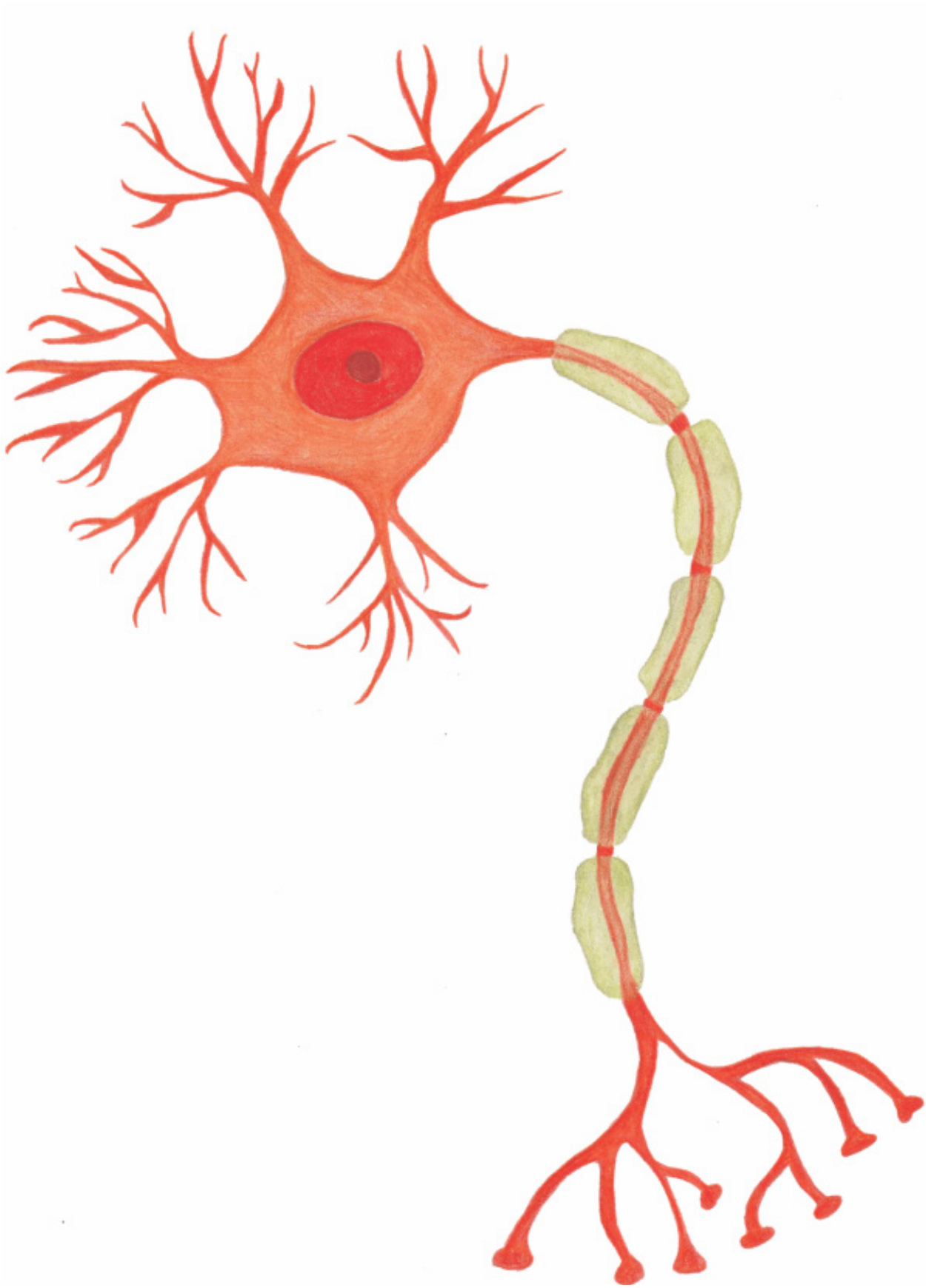
Connective Tissue



Epithelial Tissue

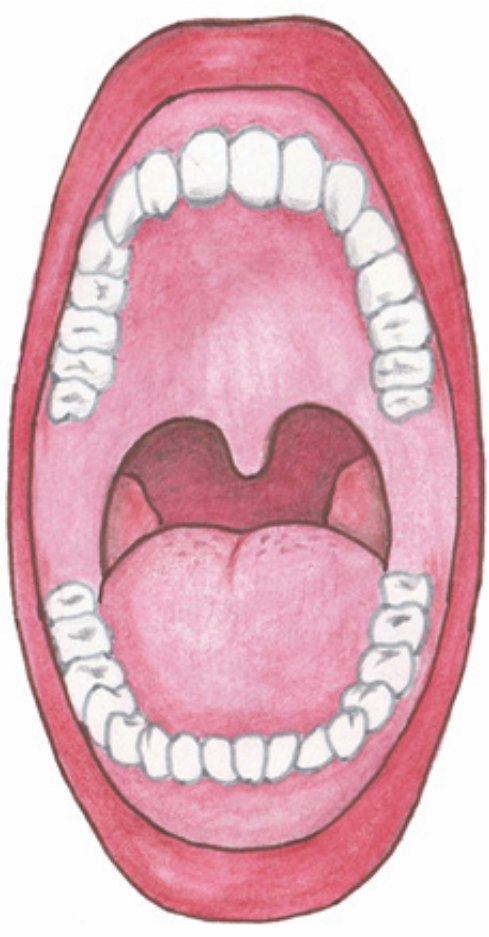


Muscle Tissue

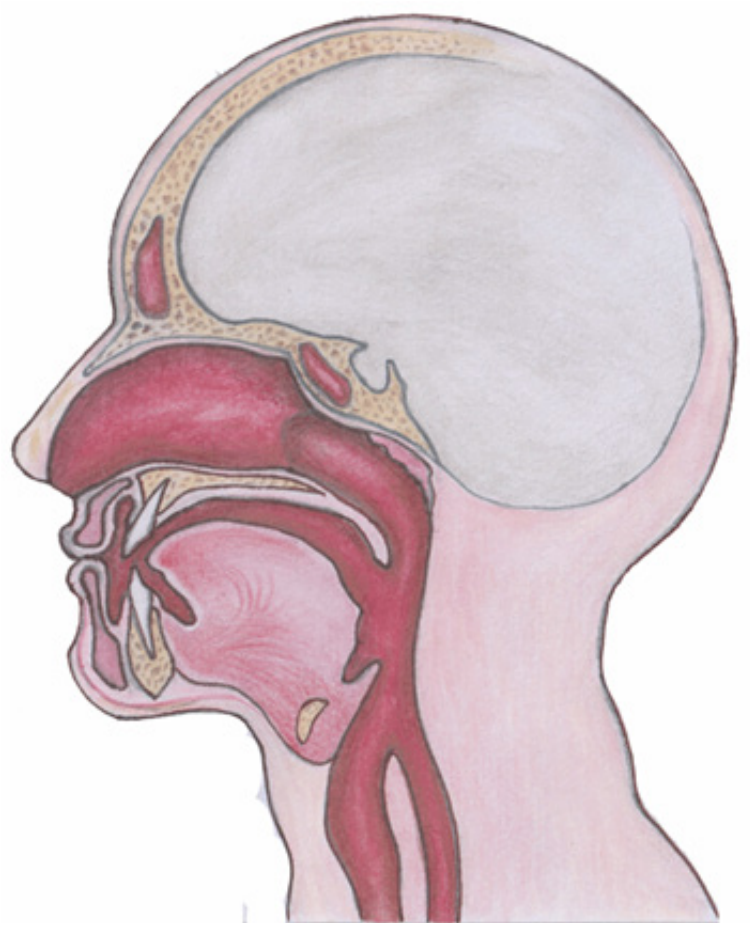


Nervous Tissue

DIGESTIVE ORGANS. MECHANICAL DIGESTION

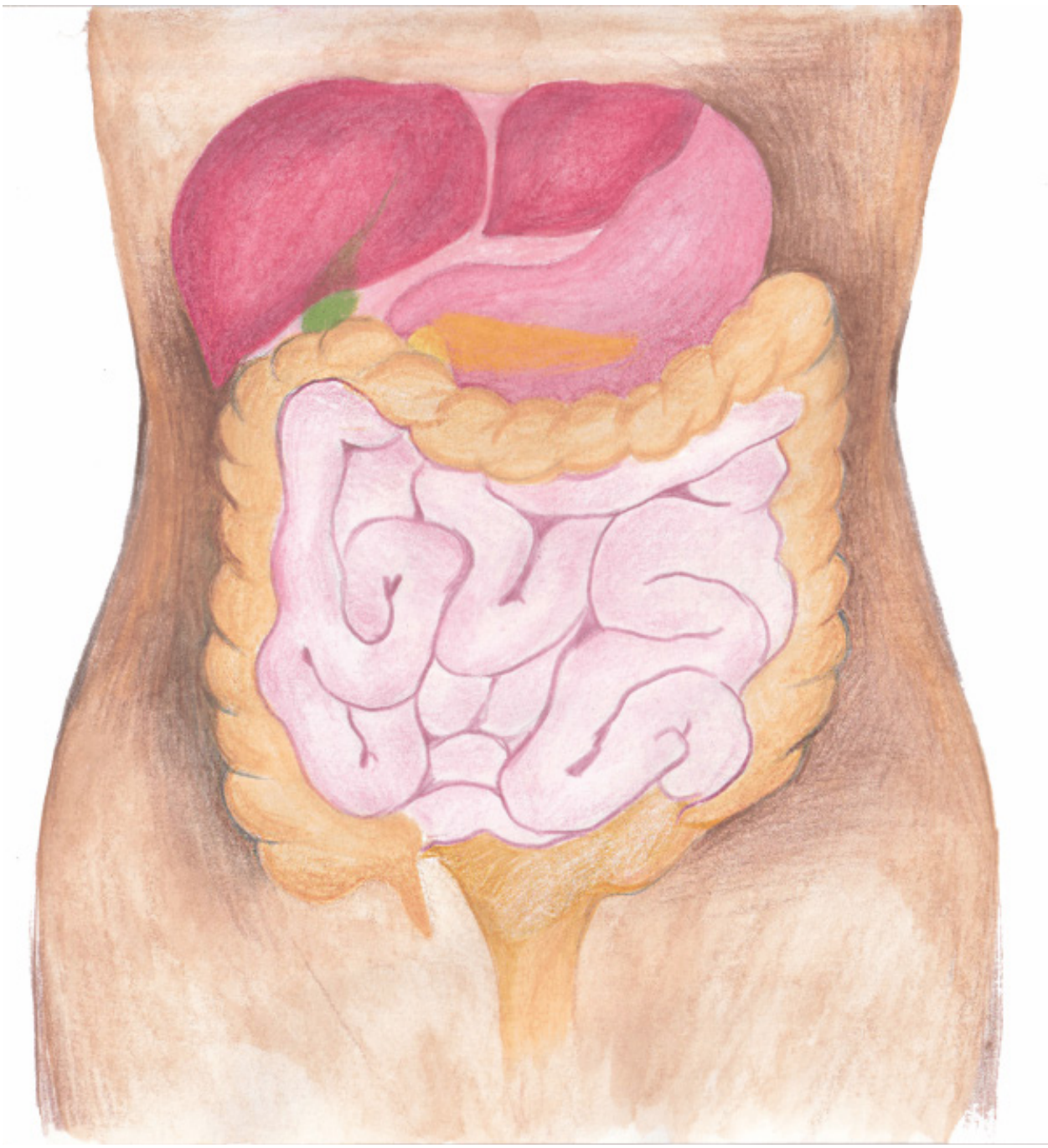


Oral Cavity

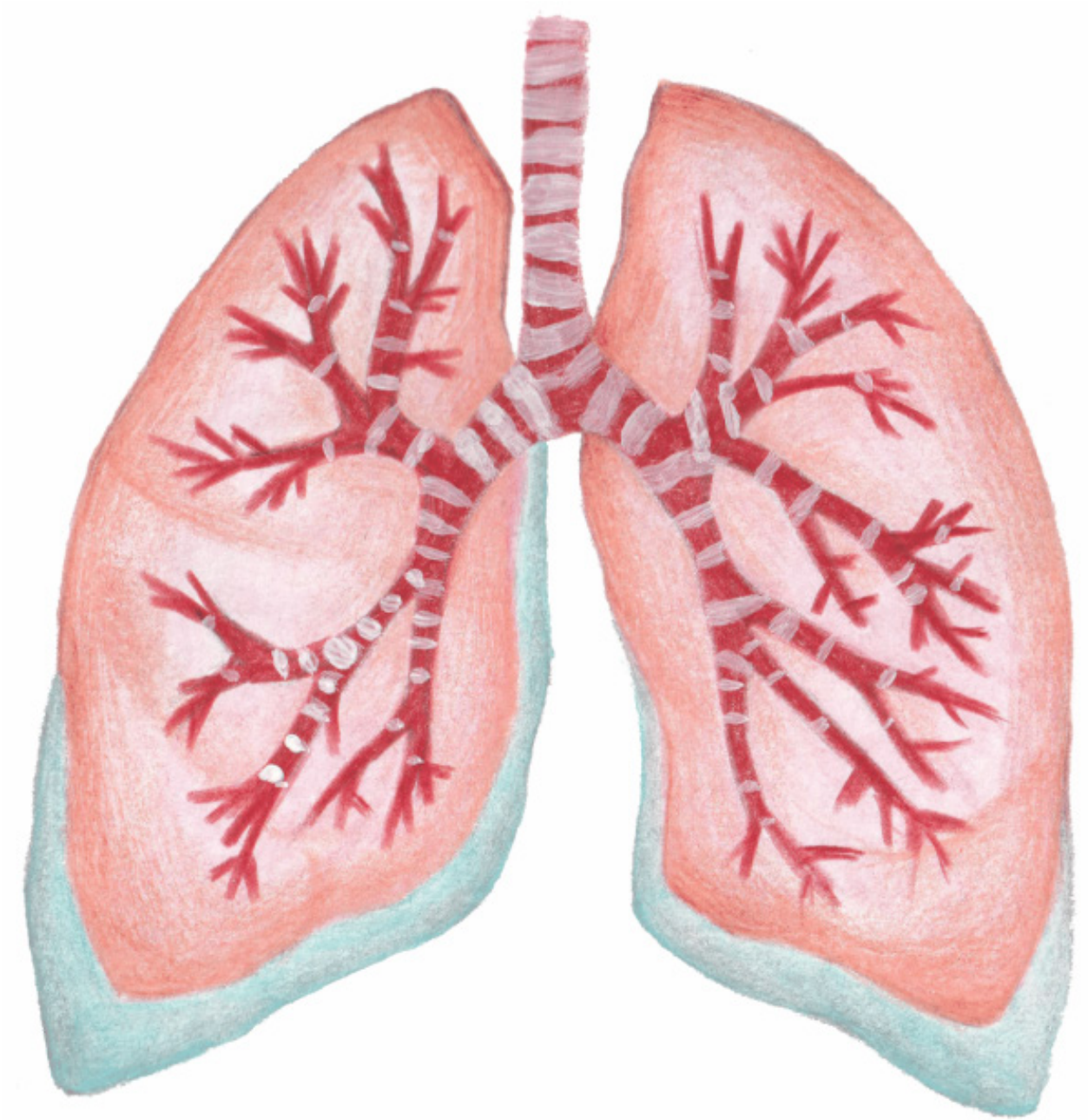


Pharynx

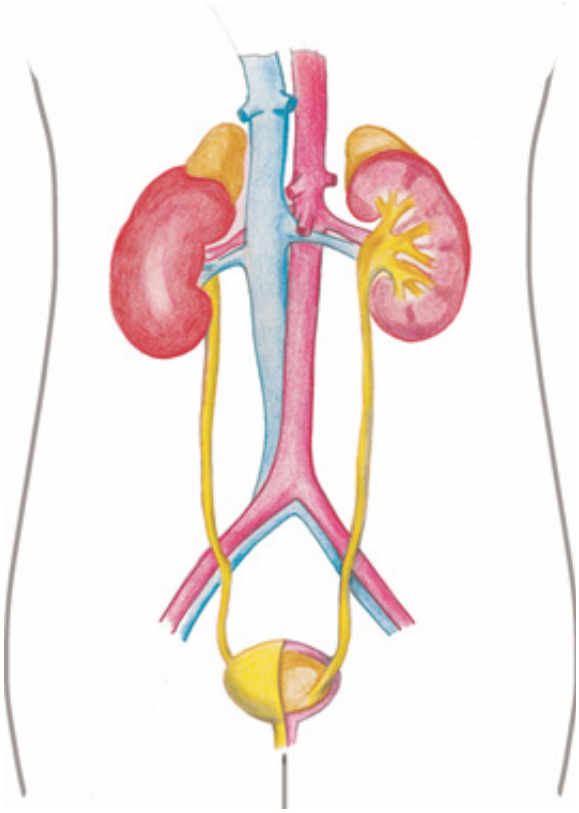
DIGESTIVE ORGANS IN THE ABDOMINAL CAVITY. CHEMICAL DIGESTION AND ABSORPTION



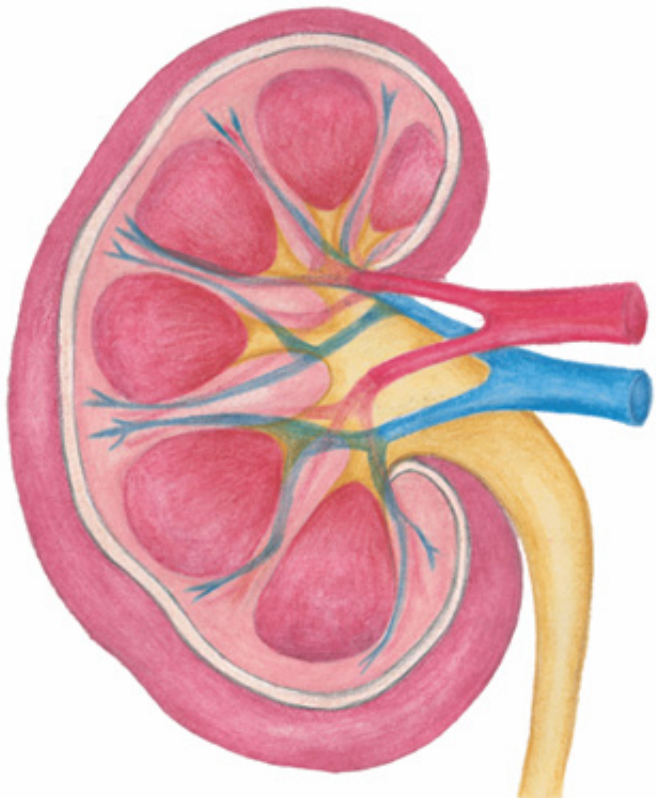
RESPIRATORY SYSTEM. MECHANISM OF BREATHING



EXCRETORY SYSTEM. MECHANISM OF URINE FORMATION



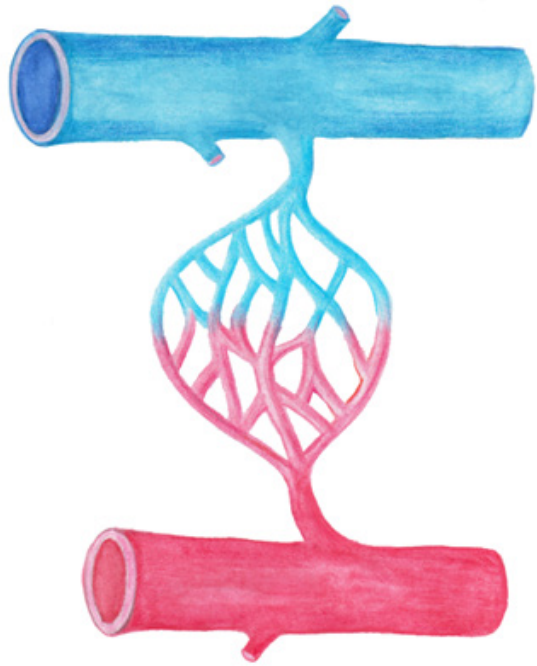
Excretory System



Kidney

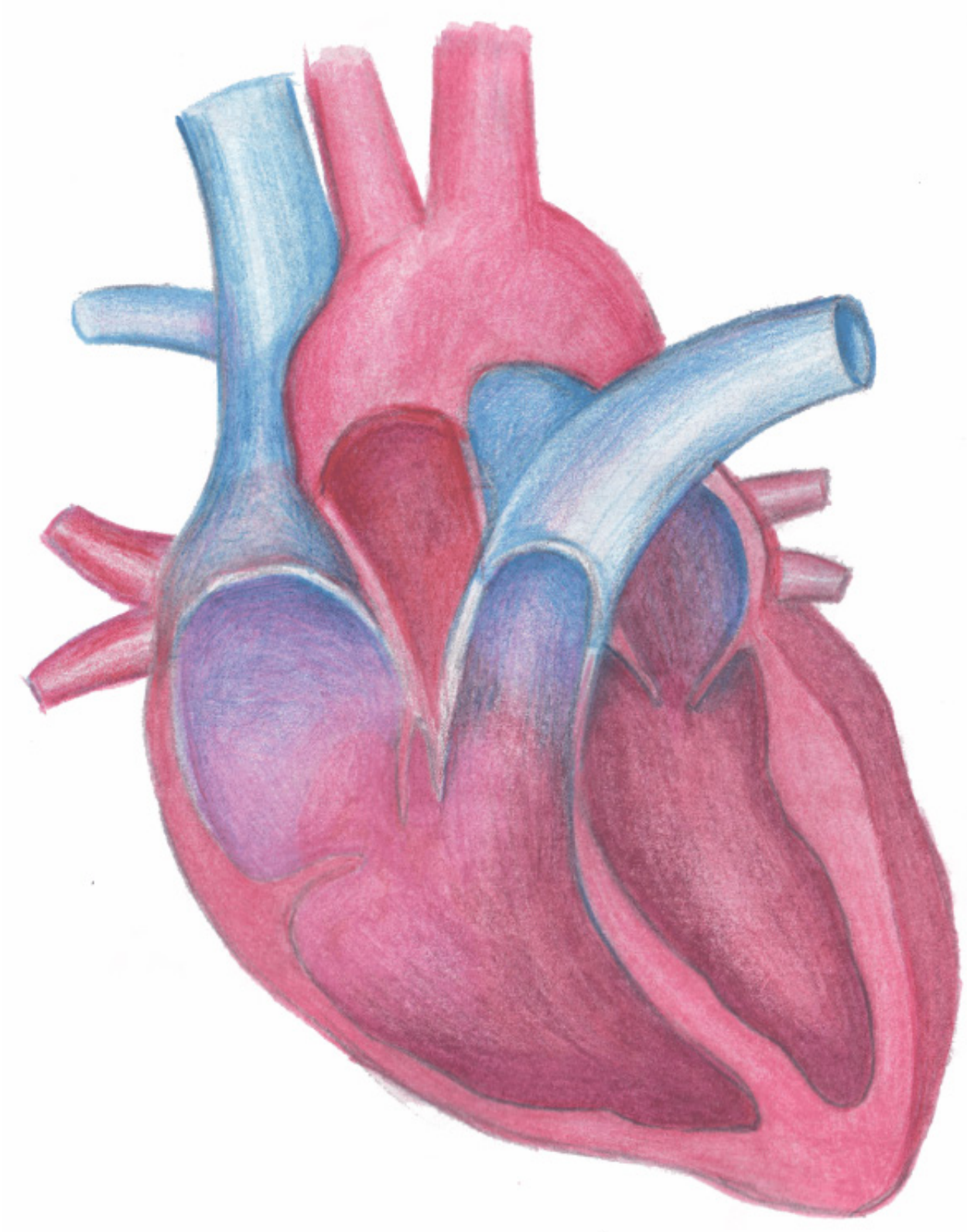
CARDIO-VASCULAR SYSTEM. BLOOD – COMPOSITION AND FUNCTIONS

Blood

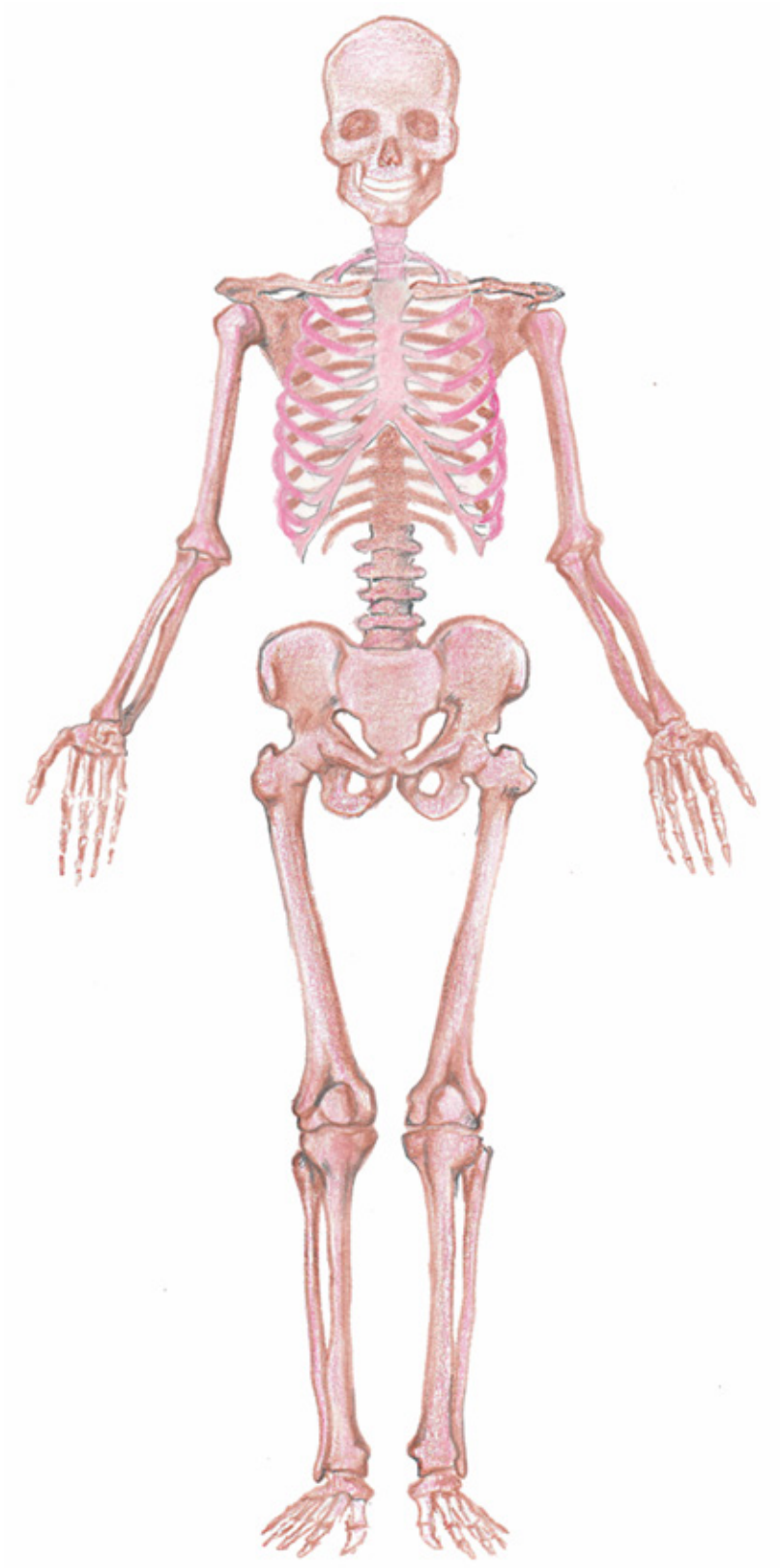


Blood Vessels

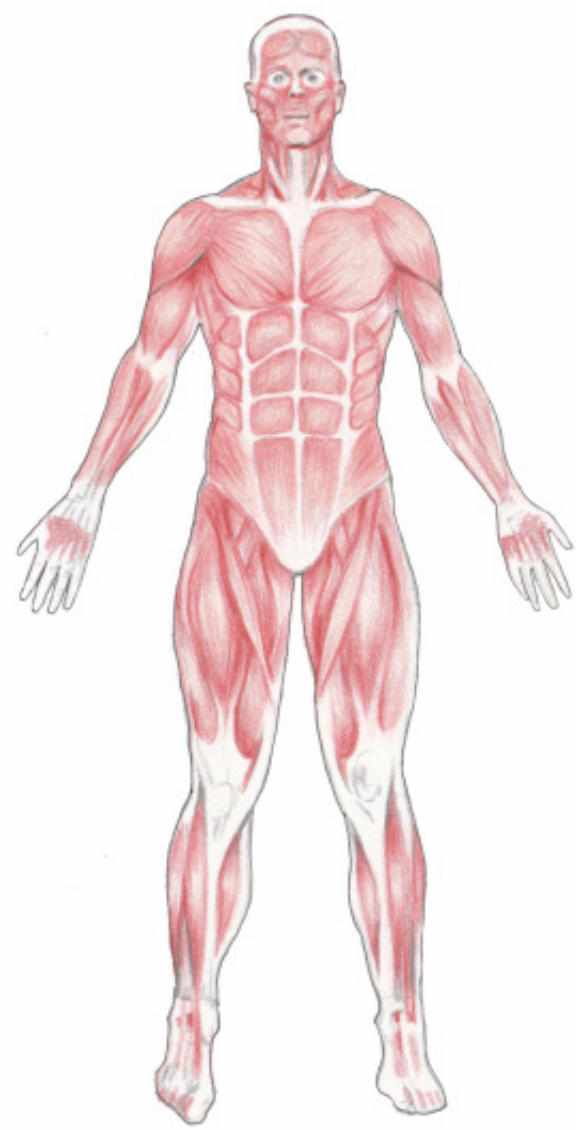
HEART AND BLOOD VESSELS. BLOOD CIRCULATION. LYMPH CIRCULATION

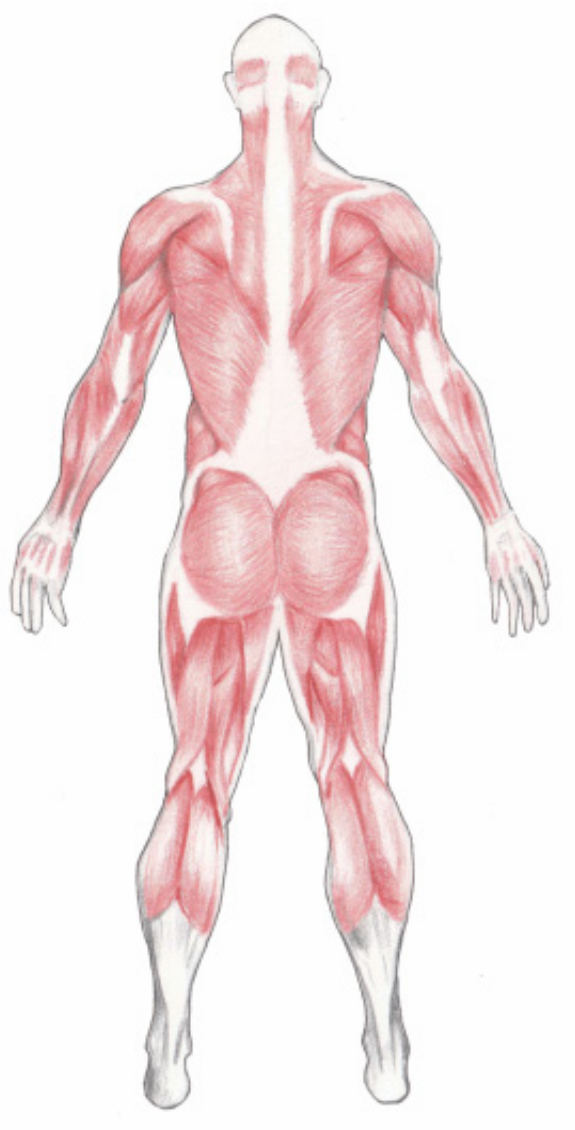


SKELETON. APPENDICULAR SKELETON

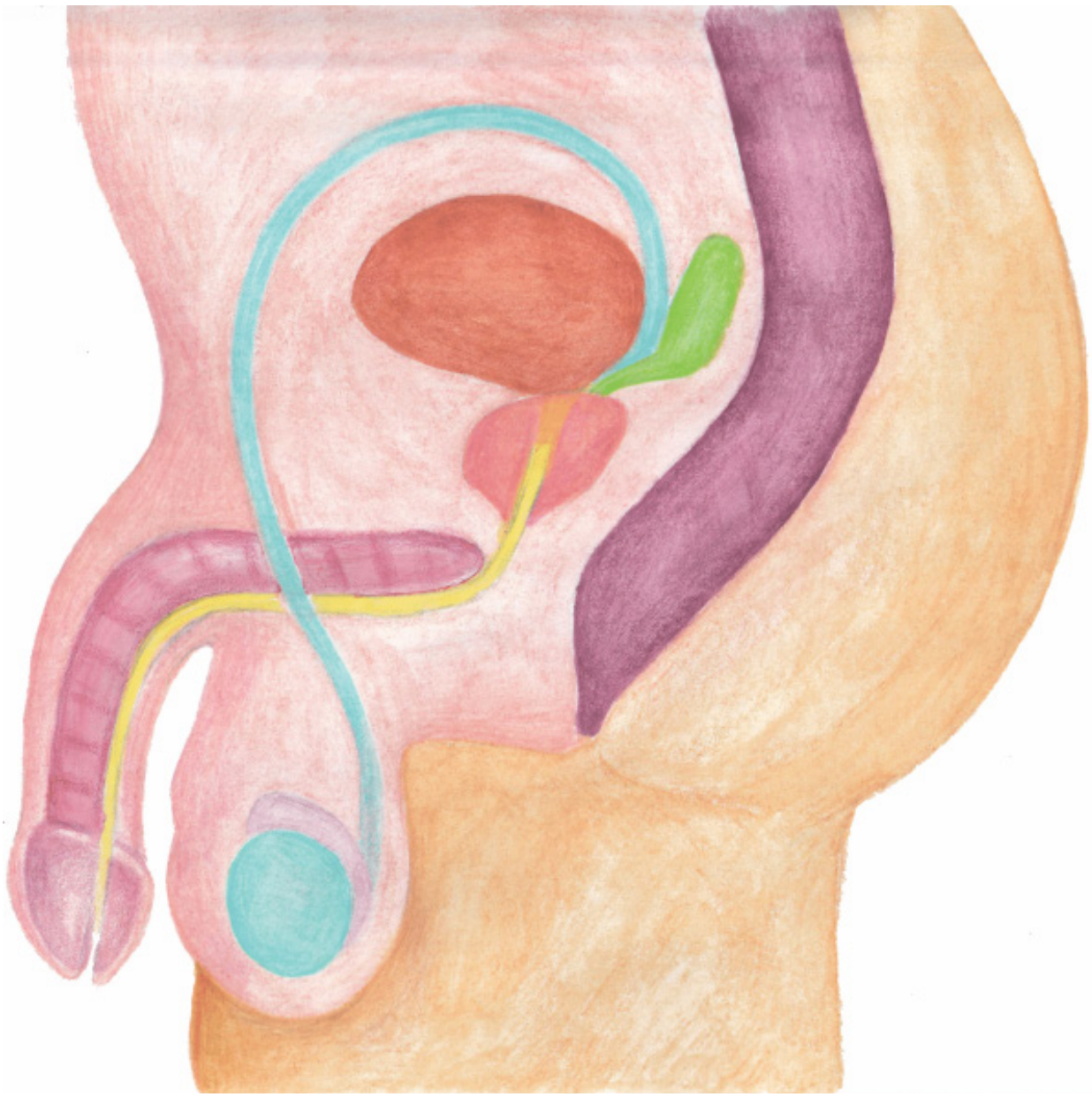


SKELETAL MUSCLES

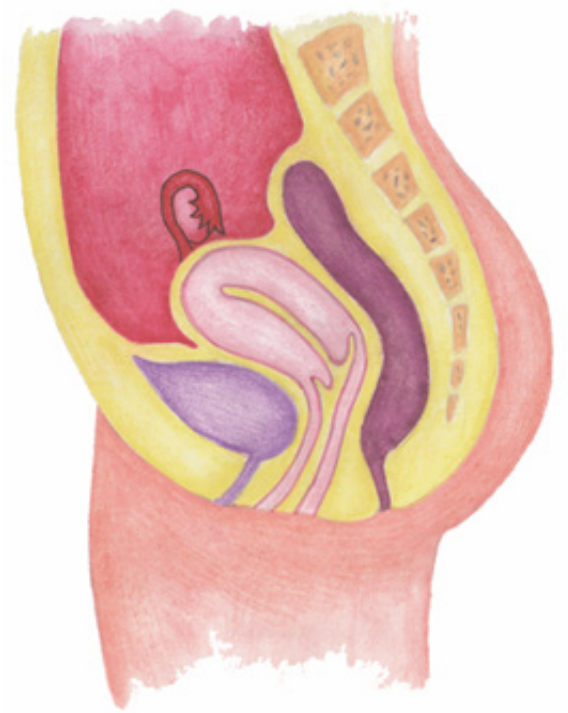




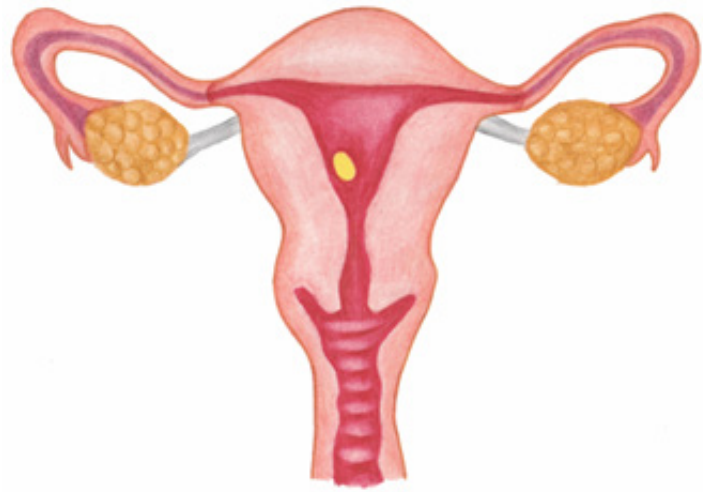
MALE REPRODUCTIVE SYSTEM



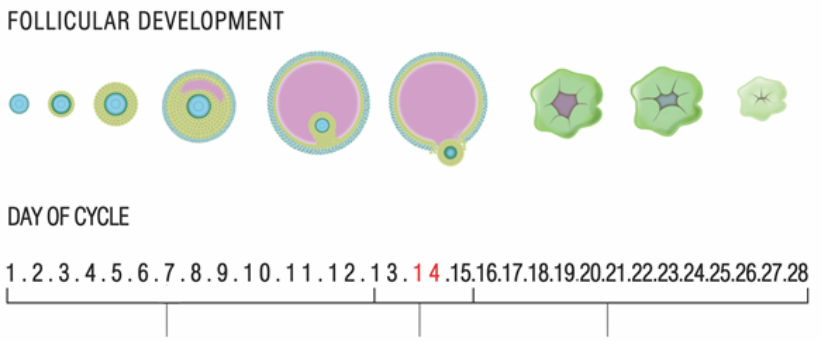
FEMALE REPRODUCTIVE SYSTEM

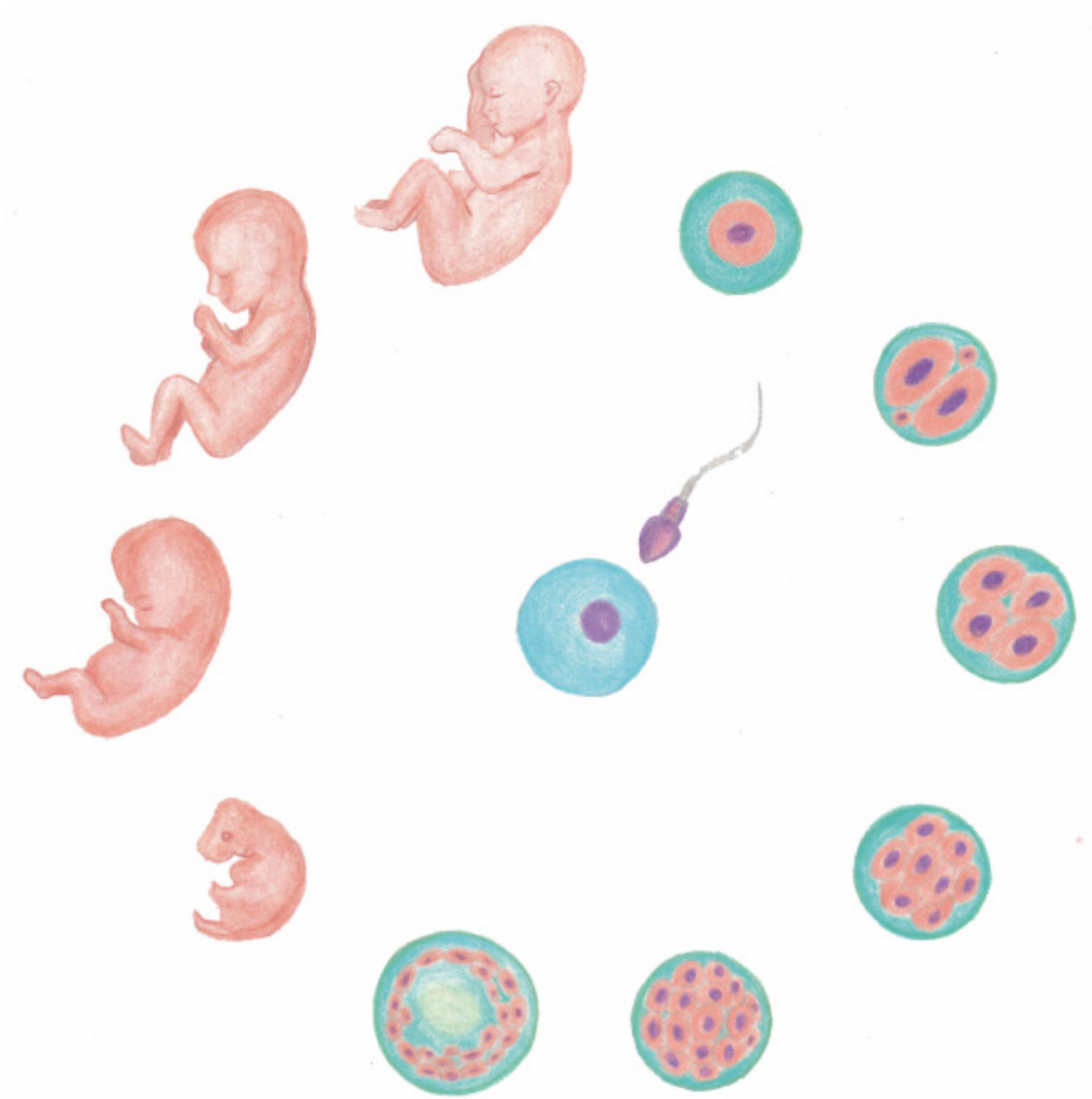


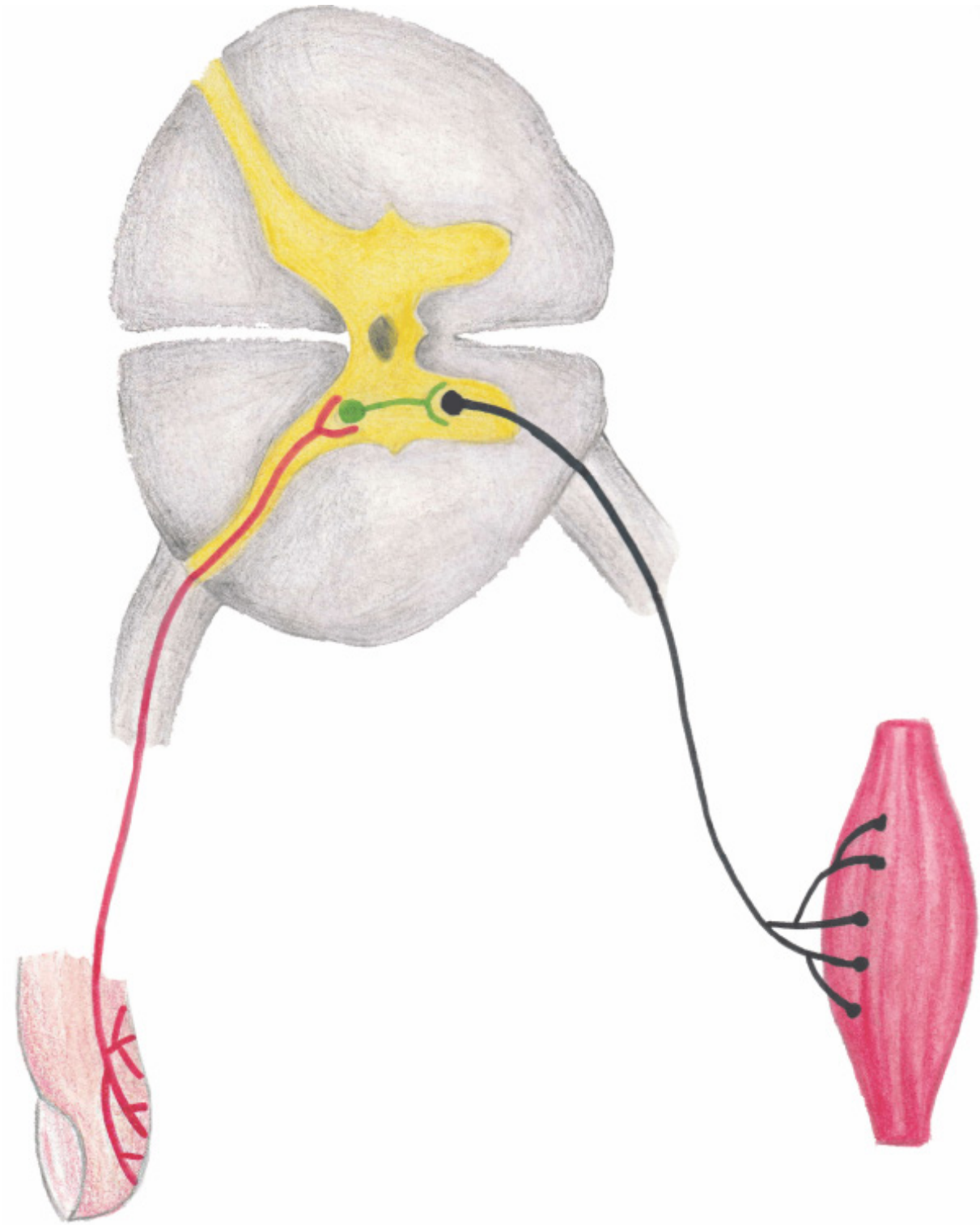
Female Reproductive System



Uterus and Ovaries



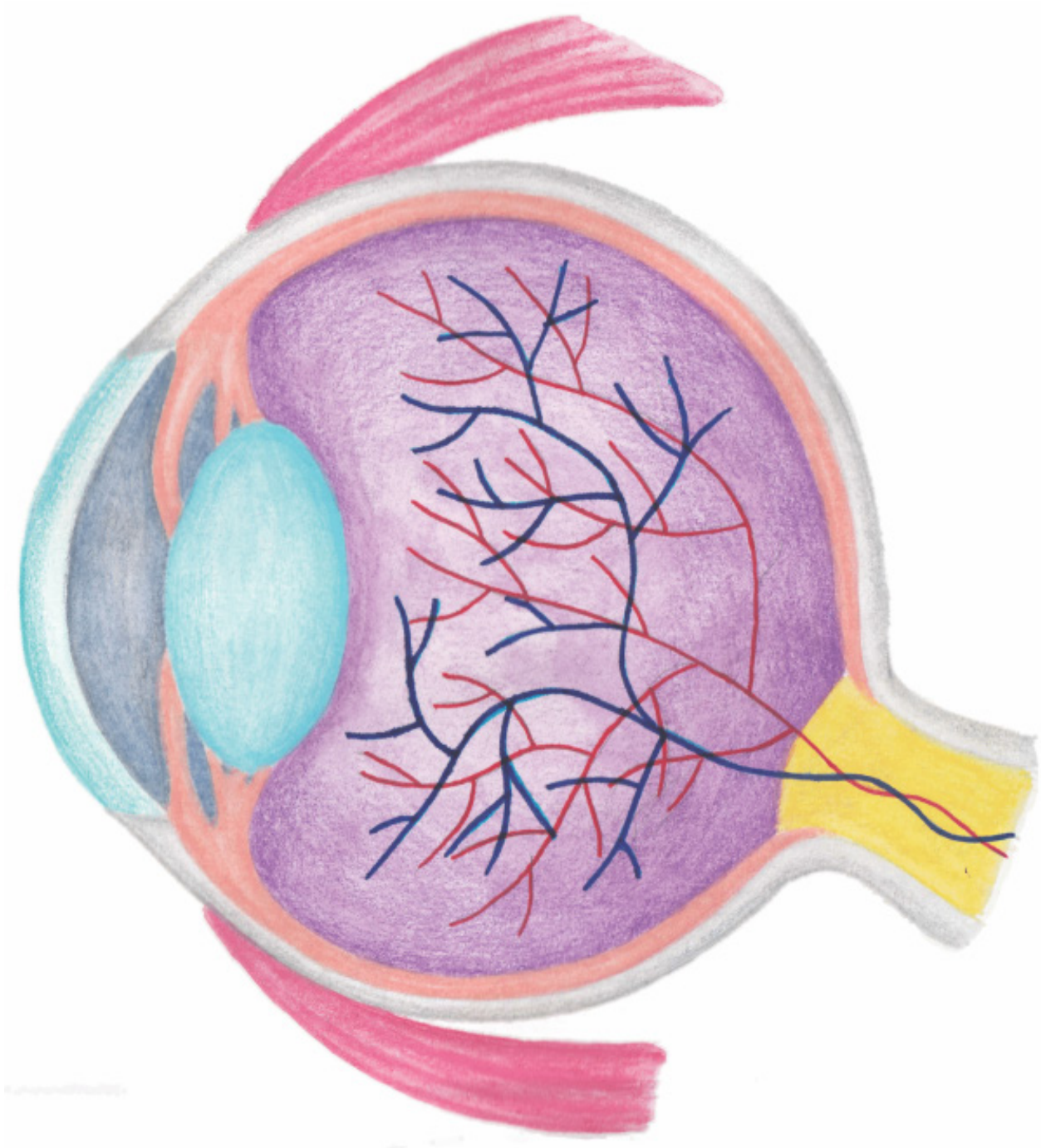




Spinal Cord

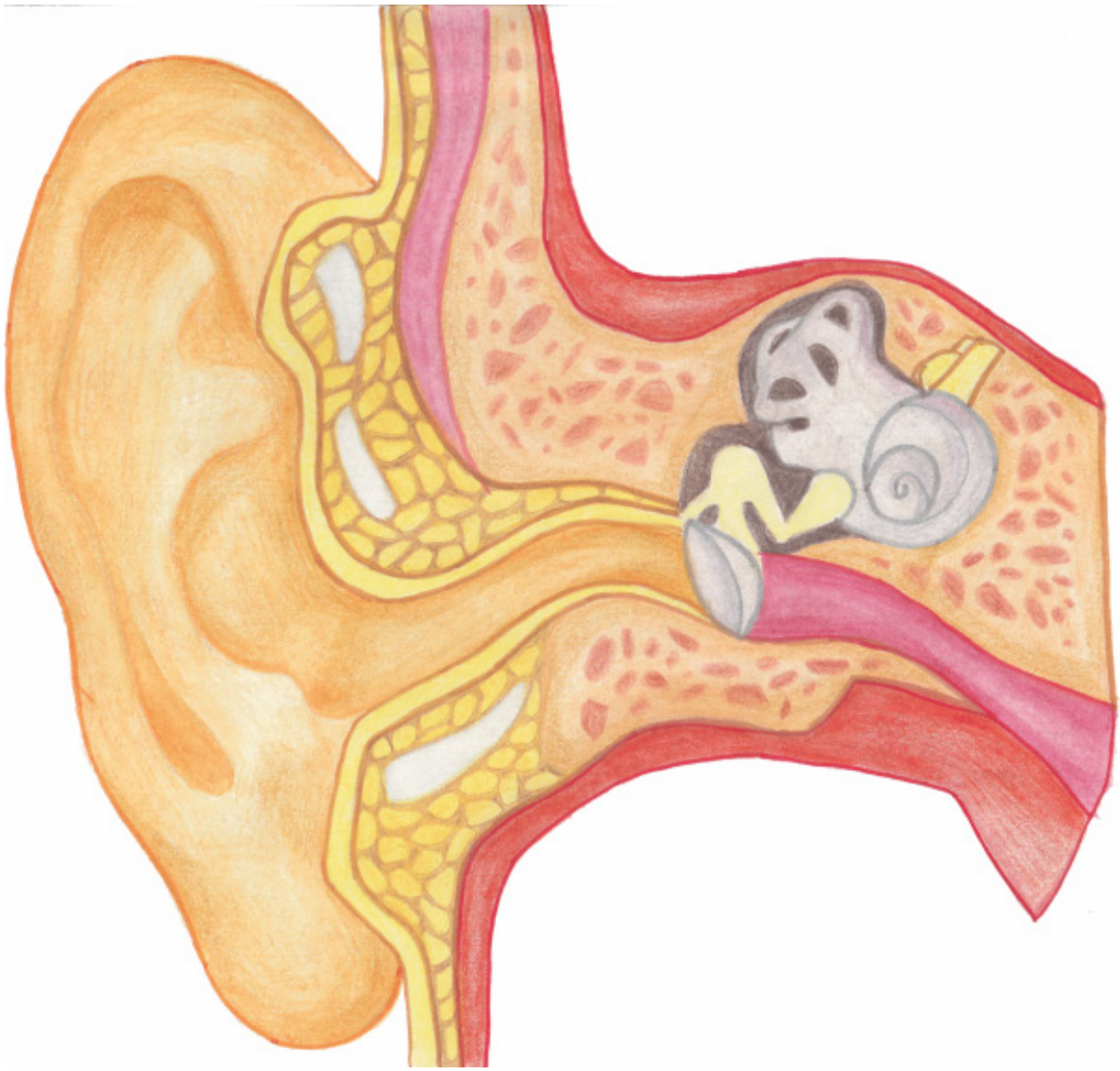
BRAIN

SENSORY SYSTEMS. VISUAL SYSTEM



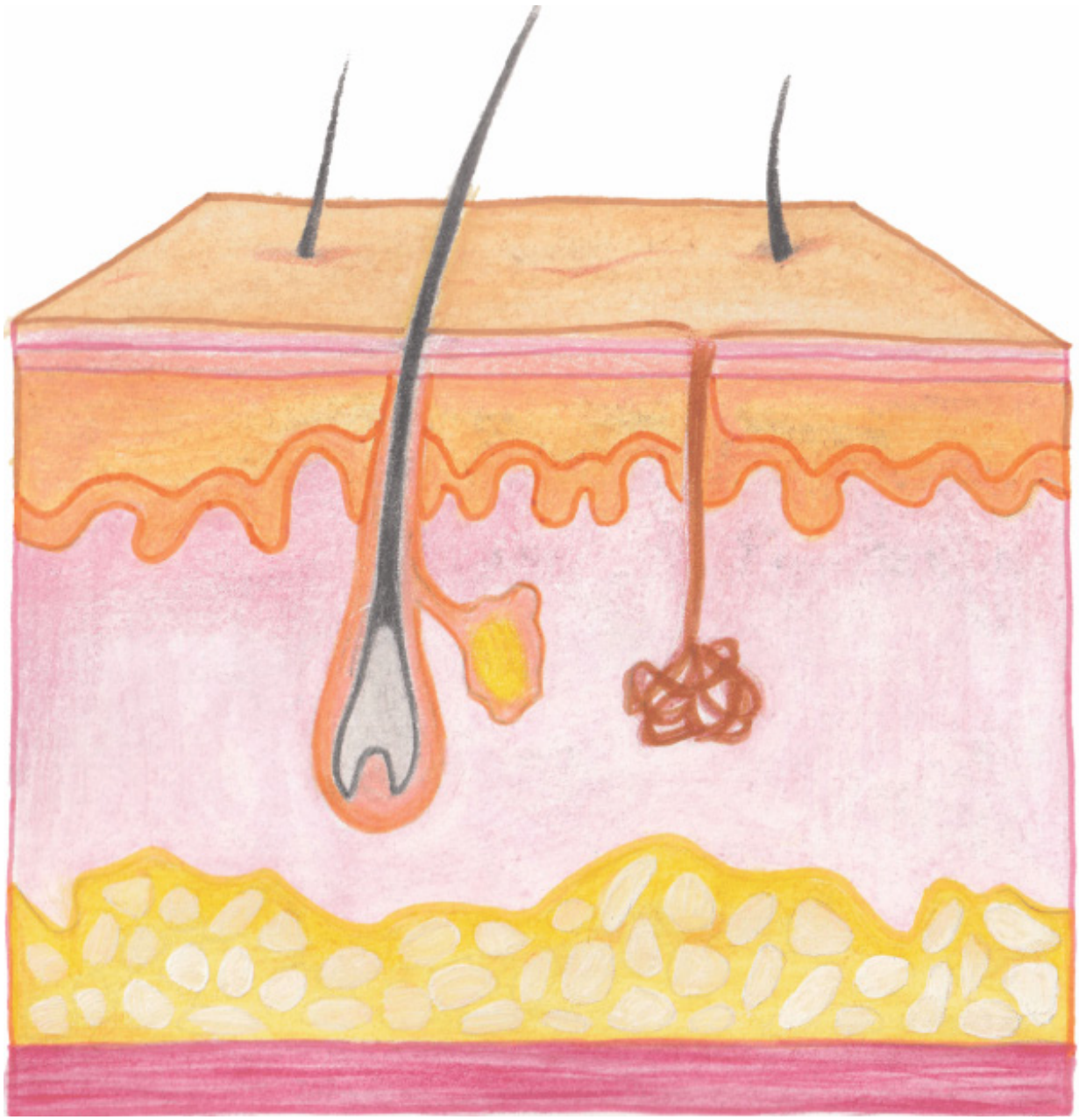
Eye

AUDITORY AND EQUILIBRIUM SYSTEM

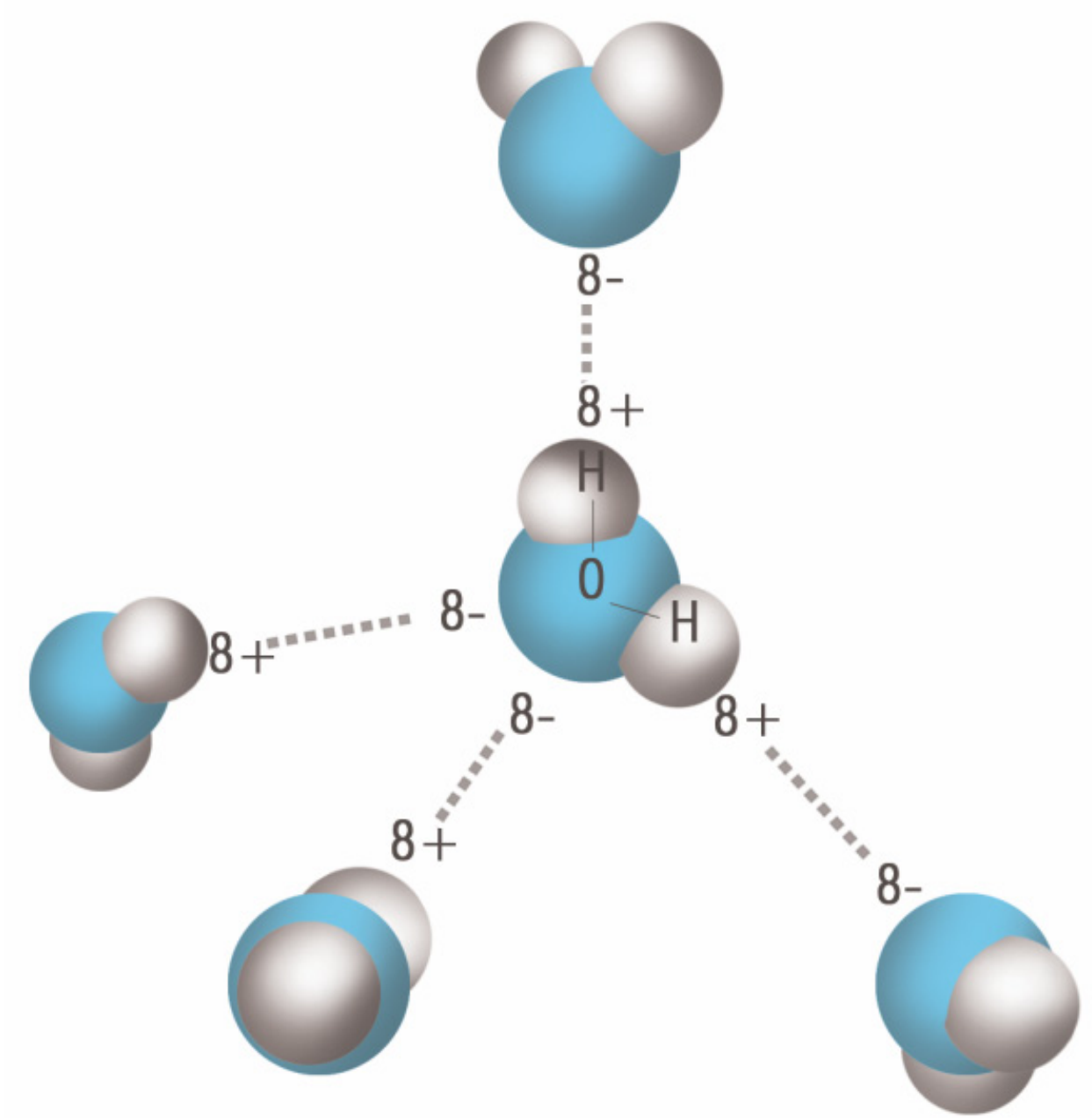


Ear

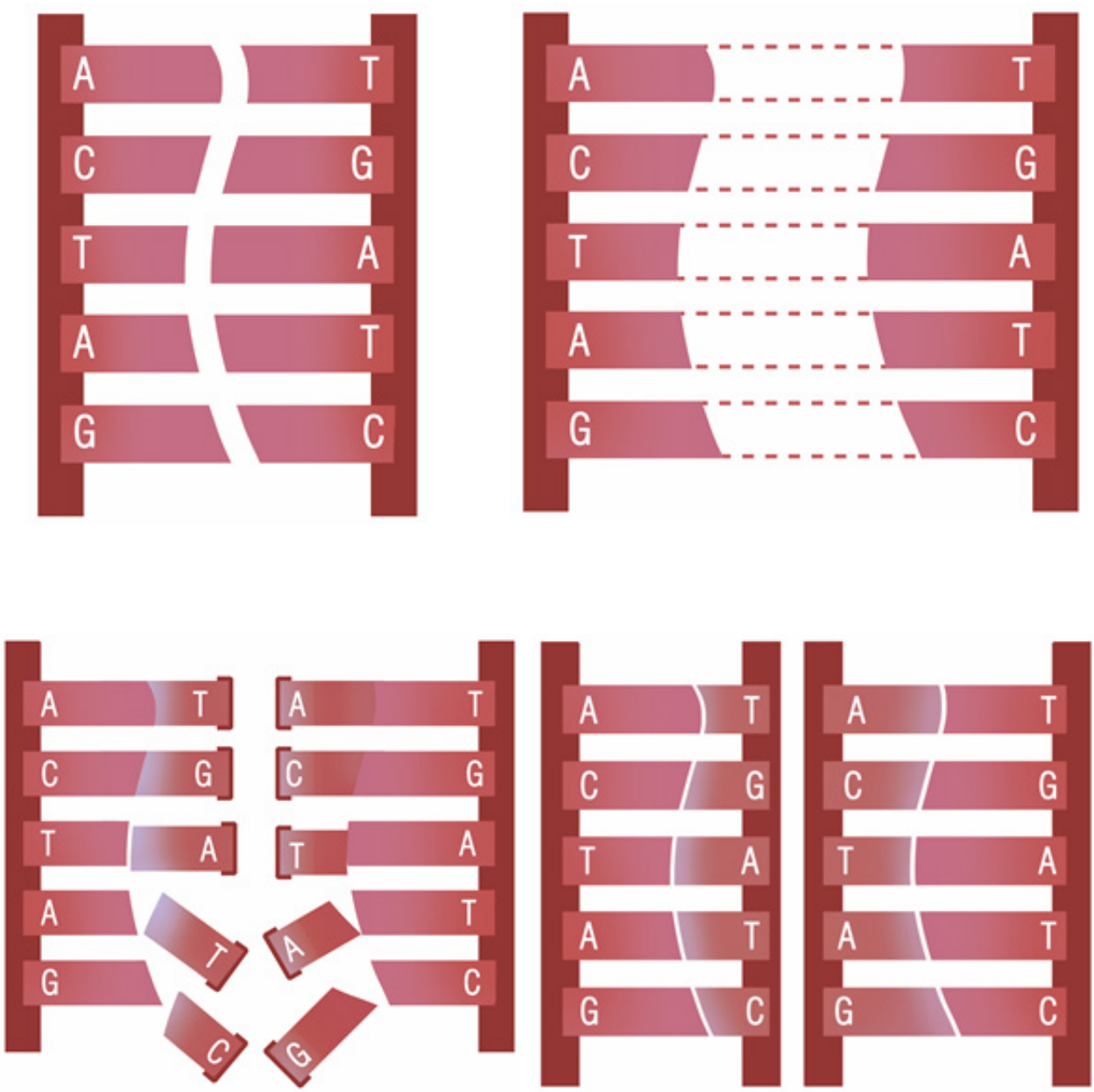
SKIN. STRUCTURE AND FUNCTION. DISEASES AND PREVENTION



Skin

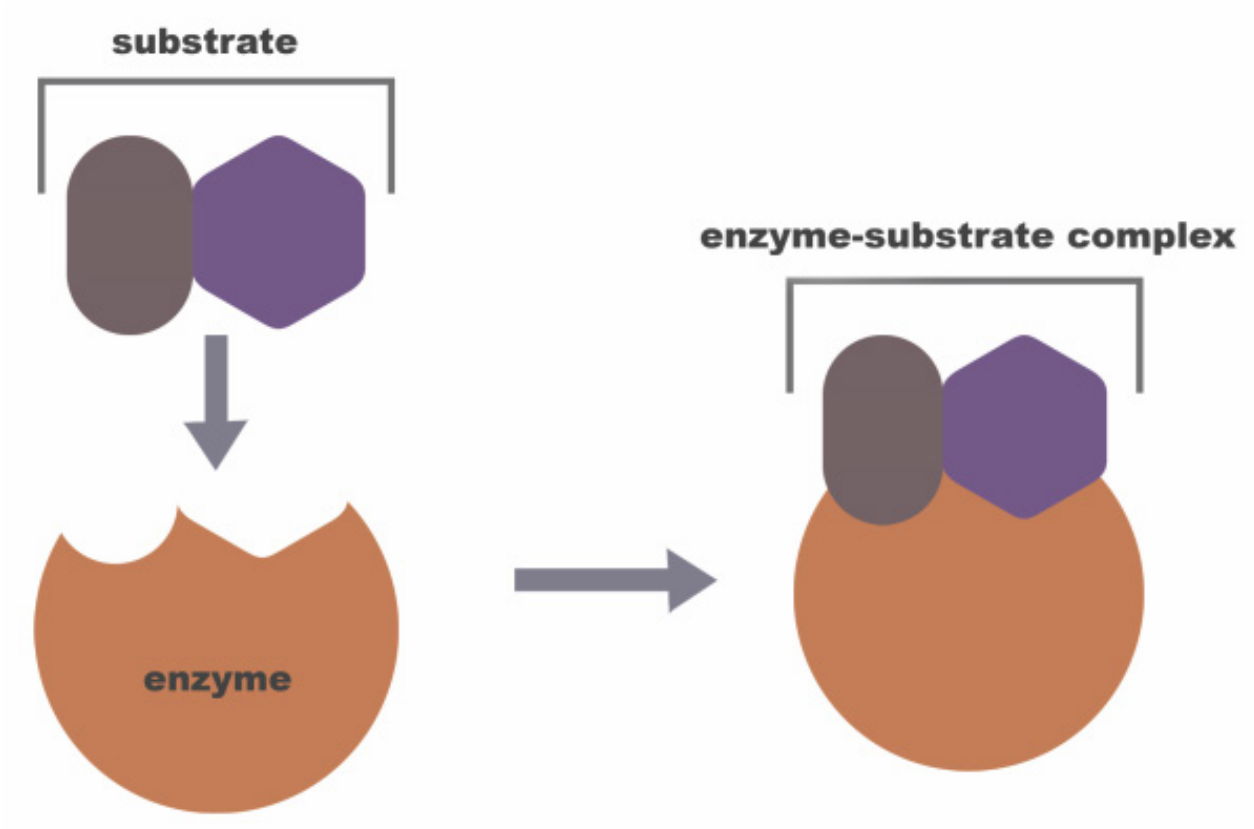


Water Molecule

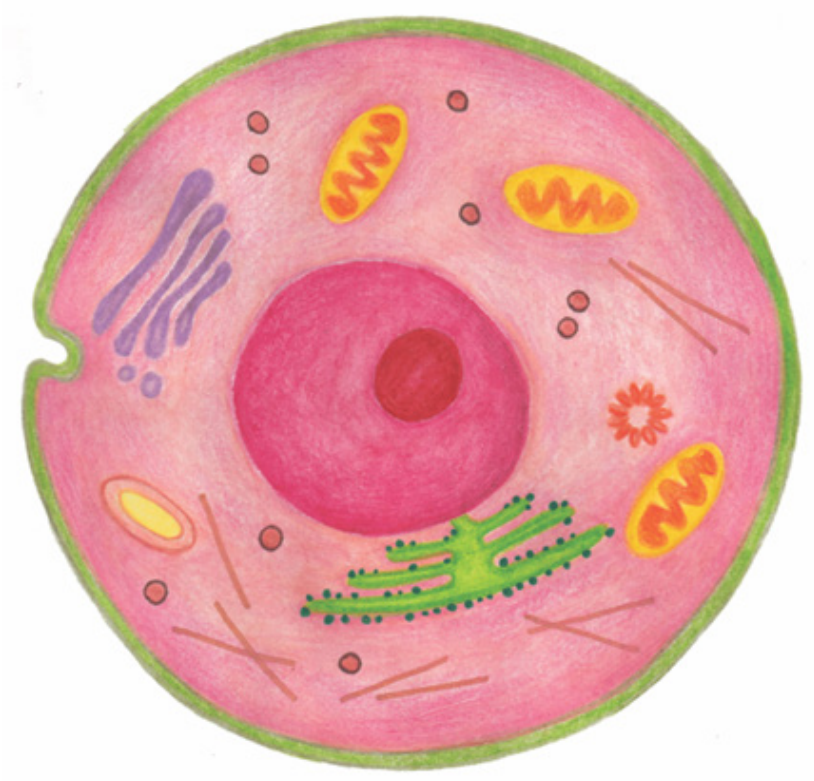


Nucleotide Sequence

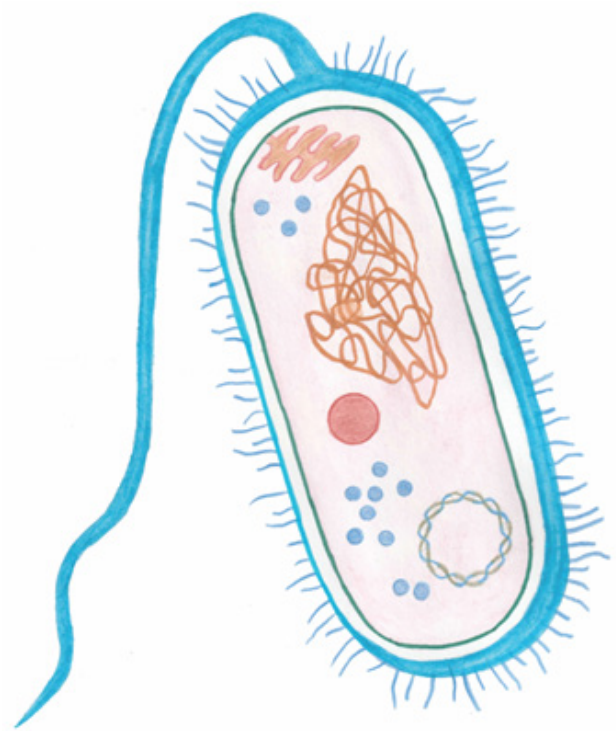
PROTEINS



STRUCTURE OF THE CELL

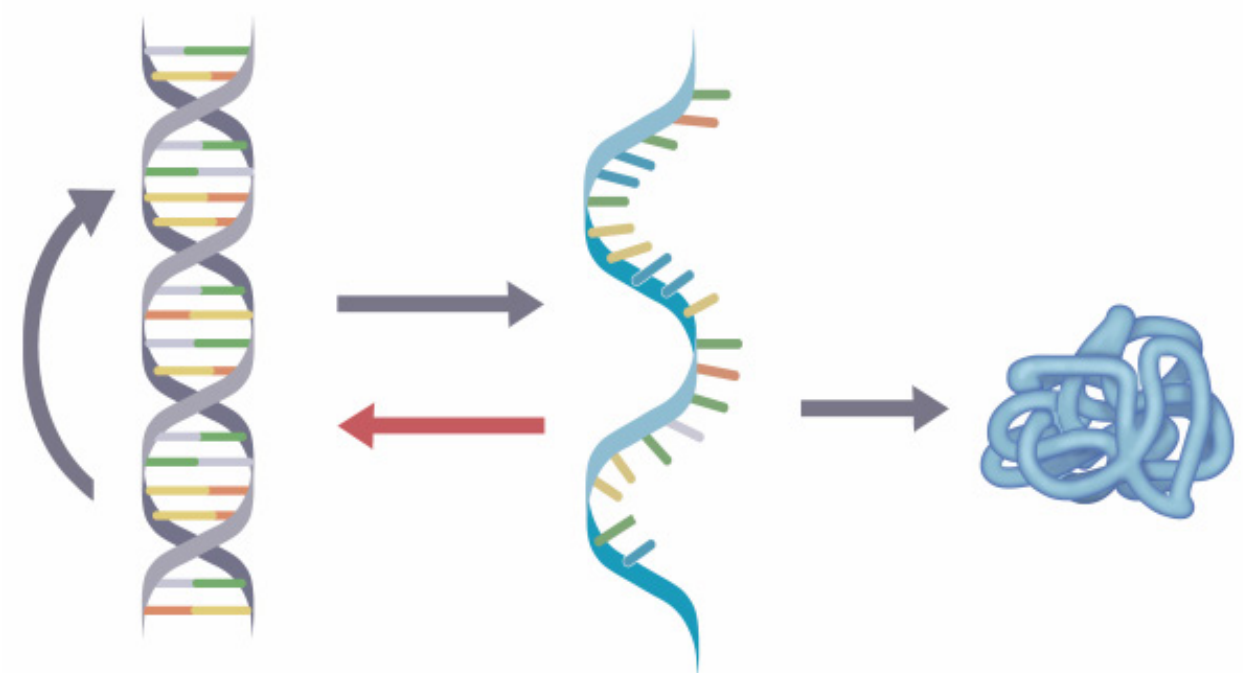


Eukaryote



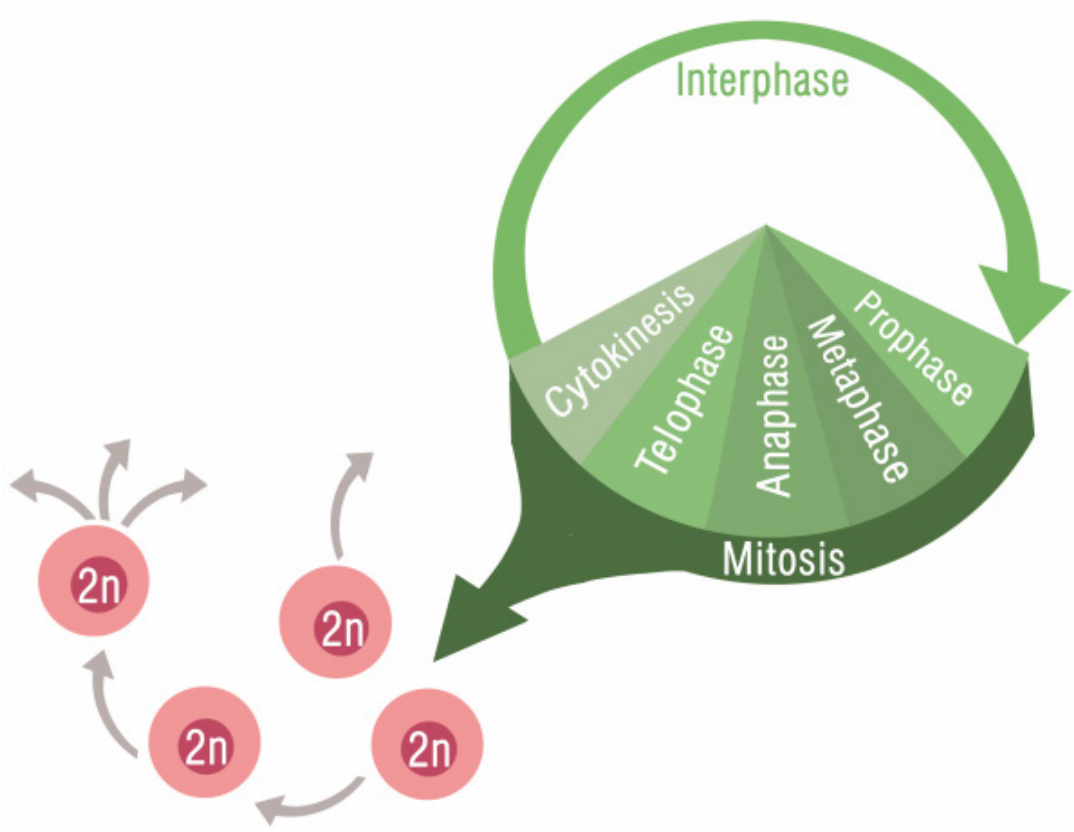
Prokaryote

TRANSLATION



DNA *RNA* *Protein*

REPRODUCTION OF THE CELL. LIFE CYCLE



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