12. THE HUMAN BODY

12.1 THE SYSTEMS OF THE HUMAN BODY

The needs of the human body are met by a number of systems. For example, the need for support is met by the skeletal system, and the need to transport materials throughout the body is met by the circulatory system. Each system has a number of parts called organs that work together. For example, the skeletal system of an adult consists of 206 bones, and the circulatory system consists of the heart, the blood, and various blood vessels. The systems of the human body are listed below, with the main functions and organs for each. The positions of some of the main organs are shown in the diagram on the next page. The systems all depend on one another and they all work together in a coordinated way.

<table>
<thead>
<tr>
<th>System</th>
<th>Function</th>
<th>Main organs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulatory</td>
<td>Transport for oxygen, food and wastes</td>
<td>Heart, blood, blood vessels</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Breathing and respiration</td>
<td>Lungs, diaphragm</td>
</tr>
<tr>
<td>Digestive</td>
<td>Processing food</td>
<td>Mouth, stomach, intestines</td>
</tr>
<tr>
<td>Lymphatic</td>
<td>Drainage</td>
<td>Lymph vessels and nodes, spleen</td>
</tr>
<tr>
<td>Excretory</td>
<td>Removing wastes</td>
<td>Kidneys, bladder, lungs, liver, skin</td>
</tr>
<tr>
<td>Skeletal</td>
<td>Support, protection and leverage</td>
<td>Bones</td>
</tr>
<tr>
<td>Muscular</td>
<td>Movement</td>
<td>Muscles</td>
</tr>
<tr>
<td>Sensory-nervous</td>
<td>Sensitivity and coordination</td>
<td>Sense organs, brain, spinal cord, nerves</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Coordination of body chemistry</td>
<td>Endocrine glands</td>
</tr>
<tr>
<td>Reproductive</td>
<td>Making and delivering male gametes, ♂</td>
<td>Testes, penis</td>
</tr>
<tr>
<td></td>
<td>Making female gametes, ♀; growing and</td>
<td>Ovaries, uterus, vagina</td>
</tr>
<tr>
<td></td>
<td>delivering babies</td>
<td></td>
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</tbody>
</table>

The circulatory system was studied in Modules 8.2 – 8.4. It is a transport system that supports all the other systems of the body. The heart pumps blood through arteries that branch out to all parts of the body. At the end of each artery, the blood passes into tiny capillaries that allow the blood to reach every cell. After that, the capillaries lead the blood into veins that carry it back to the heart. The blood delivers oxygen (from the respiratory system) and food (from the digestive system) to every cell in the body. The blood also carries all the body’s waste products to the excretory system.

1. What are (i) cells, (ii) tissues, and (iii) organs?
2. Explain what is meant by a system of the human body. Are the systems of the body independent or interdependent?
3. The function of the sensory-nervous system is sensitivity and coordination. Explain briefly what this means.
The positions of some internal organs of the human body
12.2 THE RESPIRATORY SYSTEM

The human body is made of about 50 to 100 trillion \((10^{12})\) cells! There are many different kinds of cell, and every one is like a tiny chemical factory. Our cells carry out all the processes that keep us alive and active, and every cell needs oxygen (and food) for respiration.

\[
\text{food} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}
\]

The energy released by respiration helps to run all the chemical processes of our bodies depend on, including the processes that enable us to move. It also helps to keep our bodies at the correct temperature \((37^\circ \text{C})\). Before you read on, you should review Module 6.11 about breathing and respiration; you should also review Module 8.2 about the circulatory system.

The diagrams show the main organs of the respiratory system. The lungs are two large, spongy organs inside your chest, and the diaphragm is a large muscle under the lungs. Put your hand on your chest, just below your ribs, and take a long breath in and out. When you inhale (breathe in), the diaphragm moves down, and your ribs move up and out. This increases the space inside your chest and air is sucked in through your mouth or nose, and down your windpipe (trachea). The trachea divides into two bronchi (singular bronchus) which branch into smaller and smaller tubes called bronchioles. At the end of the smallest bronchioles are ‘air sacks’ like tiny bubbles called alveoli. Each alveolus is covered with capillaries carrying blood. A substance called haemoglobin in the red blood cells absorbs oxygen from air in the alveoli, and the blood plasma releases carbon dioxide and water vapour. When you exhale (breathe out), your diaphragm moves up, and your ribs move down and in. This forces out the stale air with its reduced oxygen, and increased carbon dioxide and water vapour. Meanwhile, the blood carries oxygen back to the heart which pumps it all over the body. When this blood reaches the capillaries, oxygen is released to every cell, in every tissue, for respiration. The plasma absorbs the bi-products of respiration (carbon dioxide and water) and carries them back to the lungs where the process starts again.

**Inhaled air is cleaned** by the cells that line the walls of the nose, the trachea and the bronchi. A few of the cells secrete a sticky liquid called mucus and the rest have tiny, movable hairs called cilia. The mucus traps dust and dirt in the air, and the cilia move it towards the mouth where it can be coughed out or swallowed!

**Gaseous exchange** means swapping oxygen in the blood for carbon dioxide and water in the tissues (and the reverse process in the lungs). Three factors make gaseous exchange as efficient as possible. (i) The alveoli and other tissues provide the maximum possible surface area for the exchange. (ii) These surfaces are always moist. (iii) The surfaces have a very rich blood supply through the arteries and capillaries.

1. List 4 differences between inhaled and exhaled air.
2. Describe the roles of mucus and cilia in the trachea.
3. When you run, you breathe faster! Explain why, and trace the route of an oxygen molecule from your lungs to your leg muscles and back to your lungs again.

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12.3 THE DIGESTIVE SYSTEM

Humans are omnivores. Almost everything we eat comes from either a plant or an animal. More than half of our solid food is actually water, and almost all the rest belongs to just four food groups.

<table>
<thead>
<tr>
<th>Food group</th>
<th>Main source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates (starch and sugar)</td>
<td>plants (fruits, seeds, roots, leaves)</td>
</tr>
<tr>
<td>Proteins</td>
<td>animals (lean meat) &amp; plants (seeds)</td>
</tr>
<tr>
<td>Lipids (oils and fats)</td>
<td>plants &amp; animals</td>
</tr>
<tr>
<td>Fibre (cellulose)</td>
<td>plants (cell walls)</td>
</tr>
</tbody>
</table>

Every cell in our body needs food, but a lot of the food we eat consists of large, insoluble molecules. Our digestive system has to breakdown these large molecules into smaller, soluble ones. The smaller molecules can then be dissolved in our blood and delivered to the cells. This chemical breakdown is assisted by special substances called enzymes.

Digestion starts in the mouth. When we bite and chew food, our teeth crush it into small pieces and mix it with saliva (spit) from salivary glands under the tongue. Saliva contains an enzyme that starts to change insoluble starch into soluble sugars. If you chew bread, or any starchy food, you will notice that it soon starts to taste sweet! Saliva also lubricates the food and makes it easy to swallow. When we swallow, a flap called the epiglottis makes sure that the food goes down our gullet into our stomach, and not down our windpipe into the lungs!

The stomach is an organ like a small sack under the diaphragm on the left side of the body (that is the right side of the diagram). In the stomach, the food is mixed with acid and a new enzyme that starts digesting proteins. The stomach walls are muscular and they churn and soften the food for several hours before it passes through a valve into the small intestine.

The small intestine is a tube about 2.5 cm in diameter and about 6 m long! It is coiled up in the belly under most of the other organs. The first part is called the duodenum. Here the food is mixed with a yellow-brown liquid called bile from an organ called the liver. The bile neutralises acid from the stomach and breaks up oils and fats into an emulsion of tiny droplets. This makes the oils and fats much easier to digest. The duodenum also receives three new enzymes from a gland called the pancreas. These enzymes finish the job of converting carbohydrates into a sugar called glucose; they also convert proteins into amino acids, and oils and fats into fatty acids. The walls of the intestine are covered with tiny projections called villi (singular villus). The products of digestion are absorbed through the villi into blood capillaries inside them as shown in the diagram. The blood delivers these products first to the liver for further processing, then to cells all over the body. The glucose is used for respiration and the amino acids for making all the new proteins that the body needs. The fats are used for making cell membranes and other structures in cells. Fats can also be used as an additional source of energy in respiration. Any excess fat is stored in various parts of the body for future use.

Undigested food, including fibre (which we cannot digest), passes into the large intestine which is about 1.5 m long. It lies curled around the small intestine. The walls of the large intestine absorb water from the remains of the food, and the rest is passed out through the anus as faeces. The yellowish brown colour of faeces is due to bile from the liver.

- 1. What is (i) a gland, (ii) an enzyme, (iii) peristalsis?
- 2. How does the intestine digest and absorb food? What features of the intestine help good absorption?
- 3. What is the soluble sugar that is needed for respiration and which food group does it come from? Describe the digestion of this food group.
The liver is a large, soft, pinkish-brown organ that lies on the right side of the body under the diaphragm. It is so big that it overlaps the stomach on the left side of the body and it is the heaviest internal organ in the body, weighing about 1.5 kg. The liver is an important and complex organ. In an introductory science course we can mention only a few of its functions. It receives blood directly from the digestive system (as well as from the lungs) and regulates many important processes in the body. The liver –

- makes bile which is stored in the gall bladder under the liver; the gall bladder releases bile into the duodenum to help with the digestion of fats (see Module 12.3);
- controls the level of glucose in our blood;
- converts excess amino acids (from the digestion or breakdown of proteins) into carbohydrates; the unwanted nitrogen is passed on to the excretory system (see Module 12.5);
- processes stored fat so it can be used to provide energy;
- stores iron for making haemoglobin in the red blood cells;
- protects us by changing poisons into harmless substances;
- produces heat and distributes it to the rest of the body.

The lymphatic system is the body’s drainage system. It is closely connected with the circulatory system and the blood. The lymphatic system consists of an extensive network of branching vessels that reach all parts of the body. In the circulatory system, blood is delivered to every tissue by tiny capillaries that have very thin walls. Some of the plasma (the part of the blood that is a clear liquid – see Module 8.4) leaks out and bathes the tissues surrounding the capillaries. This tissue fluid delivers food to every cell and removes the cell’s waste products. Most of the tissue fluid is reabsorbed back into the capillaries, and continues its journey around the body as part of the blood. However, a small part of the tissue fluid escapes and drains into the lymphatic system. The fluid in the lymphatic system is called lymph. In the small intestine, the villi contain tiny lymph vessels as well as capillaries. It is the lymph vessels, and not the capillaries, that absorb most of the emulsified oils and fats from the small intestine.

Unlike the circulatory system, the lymphatic system has no pump. The lymph is pushed along the lymph vessels by the normal movements of the muscles in the body, such as those involved in breathing and walking. As shown in the diagram on the right, some of the lymph vessels have valves that allow the lymph to move in one direction only. All the lymph vessels join up and empty into two large veins, just above the heart, where the lymph returns to the blood.

Throughout the lymphatic system, are many lymph nodes. These organs are roundish lumps where lymph vessels come together, especially in the neck, the armpits, the groin and central parts of the body. The lymph nodes contain white blood cells called lymphocytes which help to protect the body from disease by destroying harmful bacteria and viruses.

The spleen is a gland about 10 cm long that is found behind the stomach. It makes lymphocytes, cleans the blood by removing damaged cells, and contains a reserve of blood for emergencies.

- 1. Why do you think the liver is such a big organ?
- 2. What are (i) plasma, (ii) lymph, (iii) lymphocytes, (iv) lymph nodes?
- 3. If you sit for many hours without moving around, your feet may swell up. Try to guess why this happens.
12.5 THE EXCRETORY SYSTEM

To keep us alive and active, every cell in our body carries out complex chemical reactions all the time. Some of these reactions produce unwanted substances that we have to remove, for example carbon dioxide and water from respiration. If we did not remove these waste products, they would build up in the body and cause problems – in fact, they would poison us. Another issue is that all the cells in our bodies, except the nerve cells, wear out quite quickly! Every day, billions of worn-out cells are replaced with new cells, by the process of cell division (see Module 5.4). The old cells are broken-down into various substances, all of which have to be either reused or removed from the body. The removal of waste products from the body is called excretion.

The main organs concerned with excretion are the lungs, the skin, the liver and the urinary system. The waste products of respiration (carbon dioxide and water) are absorbed by the blood plasma in the tissues and carried to the lungs. In the lungs they are excreted when we breathe out as described in Module 12.2. Water is also excreted in urine and, if necessary, more water can be excreted through the skin as sweat. We will discuss this again in Module 12.9 which is about the skin. Now we will focus on the excretory roles of the liver and the urinary system.

The liver has many functions and two important ones involve excretion. Haemoglobin is the red pigment (coloured substance) that carries oxygen in the red blood cells. Every day, millions of red cells die and are removed by the spleen which starts breaking them down. The liver completes this breakdown, forming new pigments that become part of the bile. Bile is stored in the gall bladder under the liver (see Module 12.4). The gall bladder excretes the bile into the duodenum where it helps with the digestion of fats. Most of the bile is later reabsorbed in the small intestine, but some passes out with the faeces and is responsible for their yellowish brown colour.

Compounds of nitrogen, formed by the breakdown of proteins, are sometimes called nitrogenous wastes. They would soon poison the body if they were not excreted. The liver converts nitrogenous wastes into a substance called urea, \((\text{NH}_2\text{CO})\), which dissolves in the blood and is excreted by the urinary system.

The urinary system is illustrated on the right. It is often just called the excretory system. The main organs are the two kidneys located at the back, behind your intestines. The kidneys act like special filters that remove water, urea, salt and other waste products from the blood. The liquid they produce is called urine. The urine passes down two tubes called the ureters into an organ called the bladder which is situated low down at the front of the body. The bladder has elastic walls and can store 500 ml or more of urine. At the base of the bladder is a narrow tube called the urethra. The exit from the bladder is controlled by a sphincter muscle. When this muscle is relaxed, urine is expelled from the body by muscles in the bladder walls, and by the stomach muscles.

The yellow colour of urine is due to chemicals called urobilins, formed by the breakdown of bile. The kidneys control the excretion of water, so the colour of urine varies depending on the needs of the body. When you drink more than you need, the kidneys have to excrete a lot of water. You have to urinate often and your urine is pale in colour, or even colourless. When you do not drink enough, your kidneys excrete as little water as possible and your urine becomes strongly yellow coloured.

- 1. Explain why excretion is necessary. How are (i) carbon dioxide and (ii) nitrogenous wastes excreted?

- 2. Explain the roles of the (i) kidneys, (ii) ureters, (iii) bladder, (iv) sphincter muscle, and (v) urethra.
The skeletal and muscular systems are illustrated on the next page. Some of the main bones and muscles have been labelled. The bony skeleton supports and protects the other organs of the body and the muscles are responsible for movement, both internally and externally. Joints between bones allow the body to move easily and enable the bones to act as levers.

**Bones.** The hard material that constitutes the main part of bones, and that gives them strength, is calcium phosphate. Most bones are hollow. Inside there is spongy bone near the ends and a soft marrow in the middle. The spongy bone has a rich blood supply and the marrow is where red blood cells, and most white blood cells, are made.

**Support and protection.** Bones provide support for other organs of the body and help us to maintain an upright posture. Many bones also have an important role in protecting delicate internal organs. The skull is the strongest bone in the body and protects the brain. The ribs protect the heart and lungs and other internal organs. The backbone protects the spinal chord which is vital for coordinating most of our movements (see Module 12.7).

**The backbone** (also called the spine or vertebral column) is a column of bones called vertebrae. A ‘top view’ of a single vertebra is shown on the left. Vertebrae from the head to the lower back are separated by discs of a tough, flexible material called cartilage. This allows each vertebra to move a little, so the backbone is flexible and we can bend our backs.

**Muscles** are found all over the body. They consist of bundles of long, thin muscle cells which contract in response to impulses from nerves. At each end, a muscle is drawn out into a tough tendon which attaches the muscle to a bone or other organ. Examples of muscles and tendons are shown in the diagram on the next page. Muscles are responsible for internal as well as external movement; examples include the beating of the heart, peristaltic movements in the gut, and the emptying of the bladder.

**Joints** allow movement and enable the bones act as levers that magnify the movements of the muscles. Two important kinds of joint are ball and socket joints (hips and shoulders), and hinge joints (elbows, knees, fingers and toes). Look at the diagram of the femur at the top of the page. The ball fits into a socket in the pelvis, and the hinge fits with a similar hinge on the tibia. Cartilage on the ends of the bones helps to protect the moving parts from wear. The diagram on the left shows how the bones of the lower arm act as a Type 3 lever (see Module 10.9). Observe how a small contraction of the biceps moves the hand up a long way – in this case the movement is multiplied by about six!

- 1. What bones protect the (i) heart, (ii) spinal chord, (iii) brain, and (iv) lungs?
- 2. What is cartilage? Where do we find it and what does it do?
- 3. In the diagram above, what do you think the triceps muscle does?
- 4. In the diagram above, estimate the force your biceps use to lift a 10 kg mass?
The muscular and skeletal systems

- pectoral muscle
- deltoid
- biceps
- calf muscle (back of leg)
- abdominal muscles
- hamstring (back of leg)
- quadriceps
- tendons of quadriceps
- skull
- teeth
- lower jaw bone
- collar bone
- shoulder blade
- humerus
- ribs
- vertebra (part of backbone)
- ulna
- pelvis
- radius
- femur or thigh bone
- cartilage
- knee cap
- fibula
- tibia

*The muscular and skeletal systems*
12.7 THE SENSORY-NERVOUS SYSTEM

Sensitivity is a characteristic of all living things – they react to the world around them. All but the simplest animals have sense organs that collect information about their surroundings, and a nervous system that transmits information and controls action. In humans the sense organs include the eye for seeing (Module 7.12), the ear for hearing and balance (Module 7.15), the tongue for tasting, the nose for smelling, and the skin for touch, heat, pressure and pain.

The central nervous system consists of the brain and the spinal chord, which runs up through the vertebrae in the backbone and joins the brain. From the spinal chord, nerves lead to all parts of the body. Motor nerve cells (illustrated left) are found mainly in the spinal chord. They have many tiny extensions called dendrites and one long extension called a nerve fibre. Inputs received by the dendrites pass down the nerve fibre as electric impulses. These impulses may be passed on to another nerve cell, or to a muscle (making it move), or to a gland (making it secrete something). Nerve fibres can be more than a metre long. For example, the fibre from a nerve cell in the spinal column may reach all the way to muscles in the foot. Sensory nerve cells are found throughout the body. They are similar to motor nerve cells and their long nerve fibres all lead back to the central nervous system. They receive information from various sense organs and pass it on to the spinal column or the brain. The nerves linking the central nervous system and other parts of the body, consist of bundles of nerve cells of both kinds (sensory and motor) in a protective sheath as illustrated above.

Voluntary and reflex actions. Voluntary actions are ones that we consciously control. For example, light scattered from a ripe fruit might reach the sensory nerve cells in the retinas at the back of your eyes. Impulses from these cells pass on to your brain through your optic nerves. You see the fruit and you decide whether to eat it or not. If you decide to eat it, your brain sends impulses down your spinal chord to the appropriate motor nerve cells, and these send impulses to muscles in your arm and hand to pick the fruit. Reflex actions are ones where our bodies react to something automatically, without conscious control. For example, if your hand accidentally touches a very hot object, an impulse goes from the sensory nerve cells in your hand to the spinal chord. There it triggers an impulse in the motor nerve cells that lead back to your hand and arm, causing muscles to contract and snatch your hand away. This all happens very quickly without the brain making any decision. Other common examples of reflex actions are coughing, sneezing and blinking.

Coordination means the linking together of various actions so that they support each other. When you reach out to pick a fruit, for example, your nervous system must coordinate the image your eyes are seeing, with the movements of different muscles in your arm and hand. Then your mouth must open at exactly the right time to take a bite and you must make saliva at the right time to start digesting it! Coordinating the activities of the body, including automatic activities such as breathing and the beating of the heart, is an important function of the sensory-nervous system.

- 1. What are the 3 kinds of nerve cells mentioned in this module? State all that you know about each of them.
- 2. Describe the activities coordinated by your nervous system when you listen to and answer a question.
12.8 THE ENDOCRINE SYSTEM

The sensory-nervous system coordinates the activities of our bodies from second to second. The endocrine system helps to coordinate our activities on a scale from minutes to years! Endocrine glands (shown in the diagram on the right) release chemicals called hormones directly into the blood to control certain events. The blood carries the hormones to all parts of the body including the brain where some hormones may affect our moods. The liver destroys hormones, so they do not remain in the blood for long after a gland has stopped producing them.

The pituitary is a very small gland at the base of the brain. Most of the hormones it secretes activate, or control the activity of, the other endocrine glands. For this reason it is sometimes called the ‘master gland’! The pituitary gland also secretes a hormone that controls our growth. People who have too much growth hormone become extremely tall, an effect known as ‘gigantism’.

The thyroid is a gland at the front of the neck, in front of the trachea. It produces an important hormone that controls the rate of our growth and development when we are young. In adults, it controls the rate of chemical activity in the body including the rate of respiration. If our thyroid gland produces too little hormone, we may tend to become sluggish and overweight. If it produces too much, we may tend to become thin and overactive.

The pancreas is a gland that is found just below the stomach. As we learnt in Module 12.3, it secretes enzymes directly into the duodenum to help with the digestion of our food. It also secretes a very important hormone into the blood. This hormone, which is called insulin, controls how the body processes sugars. If the pancreas does not produce enough insulin, the amount of sugar in our blood varies wildly and we suffer from a serious condition called diabetes. Diabetes can be controlled by regular injections of insulin.

The adrenal glands are located just above the kidneys. They secrete a number of hormones of which the best known is called adrenaline. Adrenaline is released into the blood very quickly when we need to take sudden and vigorous action, for example when we are in danger. Adrenaline speeds up our breathing and the rate of our heartbeat, diverts blood from other parts of the body to our muscles, and opens the pupils of our eyes as wide as possible. It also produces a feeling of excitement or fear. It prepares the body for fighting or running away, so it is sometimes called the ‘fight or flight’ hormone.

The ovaries are found only in females. They are attached to the uterus in the lower part of the body, below the kidneys. The ovaries produce female sex cells, or ova (see Module 5.5). They also secrete female sex hormones called oestrogens into the blood. Oestrogens control the development of a girl’s secondary sexual characteristics between the ages of about 10 and 17 (see Module 12.11). They also regulate various processes connected with the conception and birth of babies. A young woman’s moods and behaviour may depend significantly on variations in her oestrogen levels.

The testes are found only in males. They hang below the body, behind the penis, in a small sack called the scrotum. The testes (singular testis) produce male sex cells, or sperm (see Module 5.5). They also secrete a male sex hormones called androgens into the blood. Androgens controls the development of a boy’s secondary sexual characteristics between the ages of about 12 and 20 (see Module 12.10). A young man’s moods and behaviour may depend significantly on variations in the androgen testosterone which is associated with aggression and showing off!

- 1. Why is the pituitary gland called the master gland?
- 2. What causes (i) gigantism, and (ii) diabetes?
- 3. Look at the photo. Explain the roles that are probably being played by the dogs’ hormones!
12.9 THE SKIN

The skin is the largest organ of the human body! It provides us with a tough, waterproof, self-repairing covering that protects our internal organs. It contains sense organs that help to make us aware of our surroundings, and it helps to control the temperature of the body. The diagram below shows a simplified section through the skin.

The skin has two main layers. The outer layer is called the epidermis. It contains cells that are living and dividing to produce new epidermis, and these are covered by a tough layer of dead cells on the outside. As the dead cells wear away, they are replaced by new cells from below. The epidermis also contains pigments that determine the colour of our skin and protect us from the harmful rays of the sun. The thicker, inner layer of the skin is called the dermis. This contains a rich network of blood capillaries to supply food and oxygen to the skin, and carry away wastes. Only a few of the capillaries are shown in the diagram. The dermis also contains a number of different organs and tissues. Under the dermis there is a layer of fat cells which help to insulate and protect the body and provide a store of energy.

The sense of touch depends on several kinds of nerves labelled ‘N’ in the diagram. N1 is a free nerve-ending that detects cold. N2 is a tiny organ that detects pressure. N3 is associated with a hair root and detects both touch and pain. N4 is another tiny organ that detects touch on parts of the skin that do not have hair.

Hair is one of the characteristics of all mammals. The cells that form a hair become filled with a horny substance called keratin and die, but the hair continues to grow as new cells are added from the lower end. A hair usually grows for about 4 years, then falls out and starts growing again. Each hair is lubricated by a gland that produces an oil to make it repel water. The oil is also a mild antiseptic for the skin. Every hair is controlled by a tiny muscle that can make the hair ‘stand on end’! This happens when any mammal is alarmed or angry and is one of the effects of the hormone adrenaline. It makes the animal look bigger and warns off other animals.

Temperature control is an important function of the skin. If we are getting too hot because of the sun, or vigorous activity, the skin helps to cool us in two ways. First, blood capillaries in the skin dilate (expand) so that there is more blood close to the surface. This is why people who are very hot may look red in the face! Heat from this blood is carried away by direct radiation, and also by the air through convection (see Modules 7.2/4). Second, sweat glands extract water from the capillaries and release it through pores on the surface of the skin. The water absorbs heat as it evaporates into the air and this cools the skin (see Module 3.4). If we are getting too cold, the opposite changes occur. Sweating is decreased, and capillaries in the skin constrict (contract) so that less blood flows near the surface and less heat is lost. This is why people who are cold may look pale. If we are cold, our hair stands on end too, trapping air which is a good insulator.

- 1. What are (i) epidermis, (ii) dermis, (iii) capillaries?
- 2. What is the role of the fat cells under the skin?
- 3. Describe how the skin responds to cold.
- 4. What makes your hair ‘stand on end’??
12.10 THE HUMAN LIFE CYCLE

Reproduction is an important characteristic of all living things. All the different kinds of organisms continue to exist only because they reproduce. In Chapter 5, we used the term *life cycle* for the process of adults reproducing and having young, who grow into adults who reproduce and have young — and so on! When adults die, there are always younger adults to replace them. In the next few modules we will be looking at different aspects of human reproduction.

Like all mammals, human beings use sexual reproduction with internal fertilisation. These terms were introduced in Module 5.5 and are summarised again in the box below.

The human life cycle differs quite a lot from that of other mammals. Because we walk on two legs, the human pelvis differs from that of other mammals and the birth canal is much narrower. However, our brains are much bigger. For this reason, human babies must be born long before their brains are fully developed, otherwise they would not be able to get out! Compared to the young of other mammals, human babies are very helpless! The young of most mammals can walk within a few minutes of birth, but a human baby takes a year. Not only do humans take a long time to mature, both mentally and physically, they also have a lot more to learn than other mammals, including speech, manual skills and social skills. For all these reasons, human children depend on their parents for between 10 and 20 years. The main stages of the human life cycle are summarised below.

**Infant:** From birth to about 5 years, an infant depends entirely on its parents or other adults for food, shelter and protection. Physical development is relatively slow but speech, physical skills and social skills develop more quickly from the age of 2 or 3 onwards.

**Child:** From about 5 to 12 years, children rapidly develop speech, physical skills and social skills. They tend to mix a lot with other children and usually go to school. They still depend on adults for many things, but they gradually become able to cope with many situations themselves. In some cultures, children of 11 or 12 may start to take on some adult roles.

**Adolescent:** The teenage years are a time of rapid change, physically, socially and emotionally. Substantial growth occurs but is usually completed by the end of this period. Both girls and boys develop secondary sexual characteristics, and sex hormones stimulate them to become interested in one another. In many cultures this is also a time of intensive formal education.

**Young adult:** The years from about 20 to 40 are when most people form stable relationships, get married and raise their own families. In most cultures, one or both parents work to support their own families and to contribute to the development and success of their communities.

**Mature adult:** In the modern world, mature adults are those from about 40 until retirement, which can vary from the 50’s to the 60s or beyond. Improved health standards in many countries mean that more people remain active for a long time after raising their children. Because of their experience, these mature adults are often valued leaders in their communities.

**Senior citizen:** Life expectancy is increasing all the time and many people now live into their 70s, 80s and beyond. As grandparents, or great grandparents they usually have a respected role in caring for younger generations and in passing on the wisdom that they have acquired.
12.11 THE MALE REPRODUCTIVE SYSTEM

The main parts of the male reproductive system are shown in the diagrams on the right and below.

The two testes (singular testis) are suspended below the body in a small sack called the scrotum. The testes produce the male gametes (sex cells) which are called sperm and are represented by the symbol ♂. Sperm cells are the smallest cells in the human body but they are very mobile and swim with the aid of a long tail. The testes hang outside the body to keep them cool, because sperm cells die if they become too hot.

The penis hangs down in front of the scrotum. It is made of erectile tissue which contains a network of blood vessels. At times of sexual arousal, the erectile tissue fills with blood and the penis becomes stiff and erect. This happens often from puberty onwards and is known as an erection. At the time of sexual intercourse (mating), the testes release millions of sperm cells. These pass down a tube called the sperm duct, into the urethra, and out through the end of the penis. A valve in the urethra prevents urine and sperms from passing down the urethra at the same time. Glands, including the seminal vesicle and the prostate, produce a fluid that flushes out the urethra and provides a medium for the sperm cells to swim in. The milky coloured fluid, including the sperm it contains, is called semen. It is rich in nutrients, including sugars and vitamins. These provide a source of energy for the sperm which can live inside the female for about two days.

Puberty refers to the time of rapid growth in adolescence when the body of a child changes into the body of an adult. This is the time when secondary sexual characteristics develop. In boys, puberty may start from the age of about 12 and physical growth may continue until about 20, but the timing of each change varies for different individuals. Puberty is started by the pituitary gland which releases hormones that stimulate the activity and growth of the testes. Male sex hormones (androgens) from the testes then accelerate the process. First the testes and then the penis grow larger, and pubic hair starts to grow on the surrounding area. At about this time, males become capable of producing semen and may have ‘wet dreams’, when semen is ejected from the penis while sleeping. Hair also starts to grow on the face, the armpits and the body, and the voice becomes deeper. In addition to growing taller, boys also grow broader in the chest and develop larger muscles. During puberty, the secretion of oils in the skin is increased and this may lead to blocked pores which become infected and cause a rash of acne spots on the face, upper chest and shoulders. This happens in girls as well as boys. Good hygiene can help to limit, but not cure, acne. It usually clears up after puberty.

**Behavioural changes** usually occur during puberty. In boys these are often related to changing levels of androgens in the blood. Changes include the onset of sexual feelings and activities, moodiness, clumsiness, aggression, and sleeping a lot.

- 1. What are (i) testes, (ii) erectile tissue, (iii) semen?
- 2. What causes acne and how can it be minimised?
- 3. Why are the testes suspended outside the body?
- 4. What starts the changes associated with puberty?
12.12 THE FEMALE REPRODUCTIVE SYSTEM

The main parts of the female reproductive system are shown in the diagrams on the right and below.

The two ovaries are situated at the ends of two tubes called the fallopian tubes or oviducts. These tubes lead to the uterus (womb) which is situated low in the body, behind the bladder. The ovaries produce the female gametes (sex cells) which are called ova (eggs) and are represented by the symbol ♀. After puberty, an ovum is released into the fallopian tube from one ovary every month. If it is not fertilised by a sperm, it is flushed out of the body during the girl's period. If the ovum is fertilised, it grows into a baby inside the uterus. The mouth of the uterus is closed by a muscle called the cervix, and the vagina is a passage that connects the cervix to lips of the vulva on the outside of the body. The vagina is the passage through which sperm can enter to fertilise the ovum.

Puberty is the time of rapid growth in adolescence when the body of a child changes into the body of an adult. This is the time when secondary sexual characteristics develop. In girls, puberty may start from the age of about 10 and growth may continue until about 18, but the timing of each change varies for different individuals. Puberty is started by the pituitary gland releasing hormones that stimulate the activity and development of the ovaries. Hormones from the ovaries then accelerate the process. The first signs of puberty are usually the gradual development of the breasts and then of pubic hair around the vulva. At the same time, the uterus and the ovaries increase in size and a girl's monthly periods of menstrual bleeding usually start from about the age of 12. Over the next few years, the breasts continue to develop and the hips become broader. As with boys, increased oiliness of the skin sometimes leads to blocked pores and a rash of acne spots on the face, upper chest and shoulders. Acne can be limited by good hygiene and usually clears up after puberty.

The menstrual cycle or monthly period usually starts from the age of about 12. It is controlled by oestrogens from the ovaries and it may take a few years before the following pattern becomes fully established. There are three stages. The first stage lasts about two weeks and is called the follicular stage. At the beginning of this stage, the lining of the uterus bleeds away through the vagina. This may be accompanied by cramps and pains and usually lasts from 3 to 5 days. At the same time, an ovum starts to develop in a follicle (tiny sack) in one of the ovaries, and the lining of the uterus starts to grow thicker again. The second stage is called ovulation which occurs when the ripe ovum from the follicle is released into the fallopian tube. Ovulation usually occurs on the 13th to the 15th day of the period. The third and last stage of the cycle is called the luteal stage. The fallopian tubes are lined by cilia which move the ovum towards the uterus. The journey takes about 3 days and a temporary endocrine gland (corpus luteum) in the ovary starts preparing the body for pregnancy. If the ovum meets sperm cells in the fallopian tube, it may be fertilised and grow into a baby in the uterus (see next module). If it is not fertilised, the body's arrangements for pregnancy are cancelled. About two weeks after ovulation the next period starts and the ovum is flushed out of the uterus.

- 1. What are (i) ovary, (ii) follicle, (iii) corpus luteum (iv) oviduct, (v) uterus, (vi) cervix, (vii) vagina, (viii) vulva?
- 2. Make a table showing the names, timing and happenings for the three stages of the menstrual cycle.
Conception. When a man and woman decide to have sex, the man pushes his erect penis into the woman’s vagina and moves it rhythmically in and out. This stimulates the testes to release millions of sperm cells. Semen containing the sperm is ejected from the tip of the penis, close to the cervix at the mouth of the uterus. The scientific term for having sex is sexual intercourse. After sexual intercourse, the sperm cells swim into the uterus and on into the oviducts. If there is an ovum in one oviduct, the fastest and strongest of the sperm cells will fuse with and fertilise the ovum forming a zygote. When this happens, conception has occurred and the woman is pregnant.

Pregnancy is divided in three trimesters starting from the first day of the woman’s last period. The first trimester lasts until week 12. Fertilisation occurs early in week 3 and the zygote immediately starts to divide, forming a ball of cells called the embryo. The embryo moves into the uterus in week 4 and implants into the lining of the uterus where it continues to grow. By week 9, the embryo is still only 3 cm long but it has already started to develop all the organs it will have at birth. From this stage onwards it is called a foetus. The foetus is protected inside the womb in a bag of amniotic fluid. It obtains the food and oxygen it needs from the blood of its mother through the placenta which is an organ that develops in the wall of the uterus. The placenta is full of blood capillaries that exchange materials with capillaries in the wall of the uterus. The placenta is joined to the foetus through a tube called the umbilical cord.

The second trimester lasts from week 13 to 28 and is a time when the mother-to-be often feels very healthy and energised. The foetus continues to grow and the swelling of the mother’s tummy becomes noticeable. She may begin to feel her baby moving from about week 21. The third trimester starts from week 29. During this stage the foetus turns head downward ready for birth and the baby has a good chance of survival even if it is born early.

Birth usually occurs between weeks 37 and 42; it takes several hours. First the cervix starts to dilate (open) and the uterus starts a series of contractions to push out the baby. The bag containing the amniotic fluid breaks and the fluid escapes through the vagina; this is called the breaking of the waters. When the cervix has dilated enough, the contractions of the uterus, assisted by the mother’s abdominal muscles, force the baby out, head first, through the vagina. As soon as it comes out, the baby has to start breathing with its own lungs for the first time. Soon after the baby, the placenta comes out; it is sometimes called the afterbirth. The placenta is still joined to the baby by the umbilical cord; this has to be cut off and tied hygienically. The place where it was attached to the baby is called the navel (tummy button).

- 1. What are (i) a zygote, (ii) an embryo, (iii) a foetus, (iv) amniotic fluid, (v) your navel?
- 2. At what time during a woman’s menstrual cycle is sexual intercourse most likely to lead to pregnancy?
- 3. When does a pregnant woman usually start to feel her baby moving for the first time?
- 4. What are the roles of the placenta and umbilical cord?
12.14 THE DEVELOPMENT OF INFANTS

Unlike the young of other mammals, human babies are completely helpless for a long time after they are born. Only after 5 or 6 years are they ready to leave home for a few hours a day to go to school. Before that, infants and young children depend entirely on their parents or other adults for food, for physical and emotional security (care and love), and for stimulation and learning.

Physical development follows a similar pattern for most infants – but every child is different too!

0 – 6 months: A new baby has to be handled very carefully. It cannot support its own head and if put to sleep on its tummy, it cannot roll over. It is born with a strong sucking reflex and when not asleep it is usually feeding at its mother’s breast. A baby may smile for the first time by about 1 month and can usually hold up its head and follow a moving object with its eyes by 3 months. By 6 months, a baby can roll over, can reach for and grasp objects (which it puts in its mouth), and can sit up with support.

6 – 12 months: This is a time of rapid development. The first teeth appear, the first words are spoken, and the weaning of the baby from milk onto solid food begins. The baby learns to crawl, can sit unsupported and points at things it wants. Soon it learns to pull itself up to standing and dangerous objects have to be put out of reach!

1 – 2 years: At about 1 year, or soon after, most infants start to walk. If free to do so, they will actively explore their familiar surroundings. Hand to eye coordination improves and the infant can understand and follow very simple instructions.

2 – 5 years: By about 2 years of age, most infants can run, already know a hundred words or more, and can put together sentences of two or three words. Three and 4 are the ages for asking questions and the young child’s strength and coordination improve rapidly. By 5, most children speak fluently, dress and undress themselves, and can go to the toilet without help. They are ready to go to school.

Nutrition. A baby’s digestive system and kidneys can deal only with milk for the first 6 months. In most situations, breast feeding is better than bottle feeding. Breast milk contains everything that the baby needs for healthy growth, and also antibodies that protect it against disease. Breast feeding also helps to establish the bond between mother and child. Bottle milk is expensive and is often a cause of diarrhoea and other diseases because of poor hygiene or inappropriate kinds of ‘milk’. After the first 6 months, soft food like mashed fruit and vegetables can be introduced alongside milk, but sugar and salt must be avoided. Babies can be gradually weaned from milk onto solid foods between 6 and 12 months.

Stimulation and learning. Babies have a lot to learn – especially physical skills and speech - and they need a lot of help and stimulation from their parents and siblings. Play is important, and learning is stimulated by having a wide variety of different kinds of objects to play with. Learning is also stimulated by interaction with others, and parents should talk to infants as much as possible right from the start. This is essential for the learning of speech. From the age of about 2, children enjoy being read to and this also teaches them to value books.

Social development. Interacting with others, and especially other children, is essential for a child to develop social skills. At the age of 2, children playing together like to imitate each other, but do not interact much. However, a big change occurs between the ages of 3 and 4 when they start learning to cooperate and share. Children of this age enjoy role-playing which helps them to understand the adult world; it is also valuable in developing language and social skills.

1. When can an infant first (i) eat solid food, (ii) crawl, (iii) walk, (iv) use simple sentences, (v) play cooperatively?
CE stands for Common Era (or Current Era). It is a system for numbering years that can be used to replace the old AD (Anno Domini) and BC (Before Christ). AD and BC are based on the Christian calendar and this is not appropriate in some communities.

12.15 POPULATION ISSUES

*Population* is a term used by biologists to refer to all the individuals of an organism, in a given place, at a given time. It is also used for the *number* of those individuals. The table and graph opposite show the human population of the Earth during the last 4000 years. In 3500 years, from -2000 to 1500 CE, the population increased from about 30 million to 500 million. In the next 300 years, up to 1800 CE, it doubled to 1 billion. And in just over 200 years since then, it has shot up to about 7 billion!

This *exponential growth* in population is largely the result of improved technology, especially in agriculture and health in the 19th and 20th centuries. Improved agriculture means that more people can be fed, and improved health means that more people survive illnesses and accidents, and that most people live longer. Obviously the present rate of growth can not continue for ever! Less than 30% of Earth's surface is land, and 75% of that land is not suitable for growing food because of mountains, deserts or cold climates. This limits the number of people that we can feed. It is already difficult to find safe drinking water in many parts of the world, and the fuels and other materials that we need for our factories and transport systems will run out one day. The waste we produce is becoming a problem too. Land, water and even the air we breathe are becoming *polluted*. We can summarise the situation by saying that our present rate of growth is *unsustainable*. Recycling materials can help to make them last longer, and improved laws and better technology can help to reduce pollution. However, there is a limit to the human population that the Earth can support. Nobody knows exactly what that limit is, but many people think that we are now close to it.

Traditional communities and poor people tend to have big families. Until recently, many children died as infants and most parents wanted as many surviving children as possible so they would be well cared for in old age. They didn’t want to control the size of their families and didn’t know how to. In the modern world, more and more people realise that quality is better than quantity! It is better to have fewer children, because it is very hard to feed and educate too many. In China, the government decreed in 1979 that parents could have only one child, but many people believe that two children is a good compromise. Limiting how many children we have is called *family planning* and this depends on *contraception* (preventing pregnancy). The most common methods of contraception are summarised in the table but no method is 100% guaranteed!

<table>
<thead>
<tr>
<th>Method</th>
<th>Description and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural method</td>
<td>Sexual intercourse is avoided on fertile days (11 – 17) in a woman’s period.</td>
</tr>
<tr>
<td>Condom</td>
<td>The man puts a thin rubber sheath over his penis to catch the semen.</td>
</tr>
<tr>
<td>The pill</td>
<td>With a doctor’s advice, the woman takes a contraceptive pill every day. This uses hormones to stop ovulation.</td>
</tr>
<tr>
<td>Interuterine device</td>
<td>A doctor places a device in the woman’s uterus to prevent implantation; it is removed when parents want to conceive.</td>
</tr>
<tr>
<td>Sterilisation</td>
<td>A doctor cuts the man’s sperm duct or the woman’s oviduct – this is permanent!</td>
</tr>
</tbody>
</table>

1. What are (i) exponential and sustainable growth, (ii) pollution, (iii) family planning?
2. Explain *fertile days* in a woman’s period and evaluate the natural method of family planning.