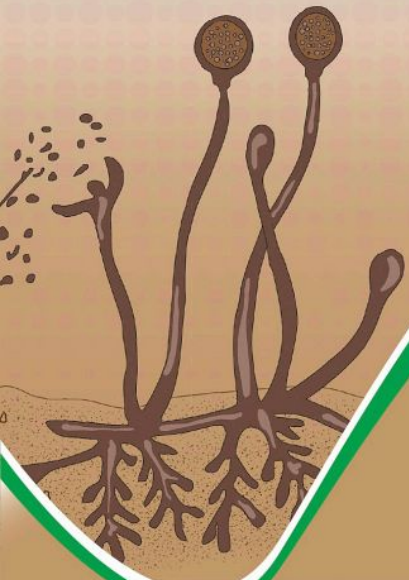
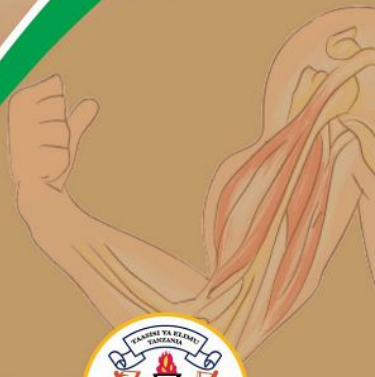
Biology

for Secondary Schools

Student's Book

Form Three





Tanzania Institute of Education

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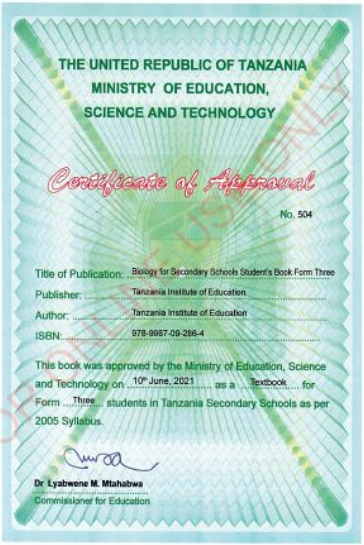
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Director General
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Preface

This Textbook, *Biology for Secondary Schools* is written specifically for Form Three students in the United Republic of Tanzania. It is prepared in accordance with the 2005 Biology Syllabus for Secondary Schools, Form I-IV issued by then, the Ministry of Education and Vocational Training.

The book consists of eight chapters, namely: Classification of living things, Movement, Coordination, Excretion, Regulation, Introduction to reproduction, Reproduction in plants and Reproduction in Mammals. Each chapter contains activities, illustrations, exercises and revision questions. You are encouraged to do all activities and exercises. Doing so will enhance your understanding, and promote development of the intended competencies.

Tanzania Institute of Education

Chapter

One

Classification of living things

Introduction

Plants are multicellular eukaryotic organisms as they are made up of many cells having membrane bound organelles. In Form Two, you learnt about the kingdom Fungi and its phyla. You also learnt about the kingdom Plantae (divisions Bryophyta and Filicinophyta or Pteridophyta). In this chapter, you will continue learning about the kingdom Plantae specifically divisions Coniferophyta and Angiospermophyta. You will learn about the general and distinctive features of the division Coniferophyta and Angiospermophyta, the structure of pines and classes of the division Angiospermophyta and their distinctive features. You will also learn about the structural differences between monocots and dicots and advantages and disadvantages of Coniferophyta and Angiospermophyta. The competencies developed will enable you to explore the similarities and differences of organisms under the kingdom Plantae and protect the environment for the survival of all living things.

Division Coniferophyta

Coniferophyta is one of the divisions of the Kingdom Plantae. Plants under the division Coniferophyta are sometimes called coniferous trees or simply conifers. These conifers are known for bearing cones and they are referred to as coniferophytes**.** Formerly this division was known as **Gymnospermae.** The word gymnosperm is derived from two Greek words, **gymno** meaning naked and **sperma** meaning seed, thus conifers are plants that contain naked seeds. The conifers are non-flowering plants whose seeds are not enclosed in ovaries, but are arranged spirally giving the shape of the cone. Conifers have sieve cells and albuminous cells which facilitate the movement of food in conifers. Examples of conifers include casuarinas, spruces, cedars, pines, and cypress plants as seen in Figures 1.1 and 1.2.

Figure 1.1: Branch of pine tree

Figure 1.2: Spruce tree

Activity 1.1:

Observing the distinctive features of conifers

Materials

A variety of conifers, example plants/ branches of pine, cedar, cypress and fresh or preserved cones

Procedure

1. Collect the branches of pine, cypress, and cedar plants from the school or home environment.
2. Observe the structural features that are possessed by these plants which are different from other plants.
3. Note down the distinctive features of conifers and discuss your findings with your classmates.

Questions

(a) What features have you observed?

(b) What is the difference between the features you have observed and the features of other plants?

General features of the division Coniferophyta

Division Coniferophyta possess the following features:

(a) They are non-flowering seed bearing plants.

(b) They produce naked seeds which are not enclosed in ovaries.

(c) They have reproductive structures called cones. There are male and female cones. The male cones are smaller and usually occur in clusters. They produce dust-like pollen which contain male sex cells or gametes that pollinate female cones. The female cones of most conifers have compound structure. They are larger and contain ovules which are attached to leaf-like scales of the cone. The cones are usually closed in order to protect the developing seeds that will eventually ripen and be released.

(d) Fertilisation in conifers does not require water, instead male gametes are carried by wind or insects to the female reproductive organs. Then they develop

pollen tubes which carry sperms to the ovule for fertilisation.

(e) They have simple xylem with only tracheids as conducting elements but no vessel elements. This is the reason why most coniferophytes produce soft wood.

(f) Their phloem tissues lack companion cells; instead, they are associated with albuminous cells.

(g) They have needle-like or scaled leaves with thick cuticle for protection and reduction of water loss.

(h) Conifers are widely distributed but commonly found in areas with cold climate where they form evergreen forests.

Distinctive features of the division Coniferophyta

The following features differentiate division Coniferophyta from members of other divisions of Kingdom plantae:

(a) These plants bear cones from which microspores (pollen grains) and megaspores (ovules) are produced.

(b) The pollen grain develops air bladder like structure which facilitate the movement of pollens by wind. Hence, they are wind pollinated plants.

(c) They have naked seeds which are not enclosed within the ovary.

(d) The mature seeds are typically winged. This is an adaptation for wind seed dispersal.

(e) They have seeds born in cones and not in a fruit.

Structure of pines

Activity 1.2:

Observing the reproductive structures of pines

Materials

Branches of pine tree with male and female cones

Procedure

1. Carefully examine the branch of a pine tree and identify the male cones which are relatively small and more herbaceous. Normally male cones occur in clusters at the axils of lower branches.
2. Carefully examine the features of a pine tree and identify the female cones which are relatively larger and woody.
3. Draw well labelled diagrams of male and female cones.
4. Discuss the findings with your classmates.

Questions

(a) What differences did you observe between male and female cones?

(b) Apart from male and female cones what other features have you observed?

Pines are the conifers which have needle-shaped leaves, thick and scaly bark, and are evergreen. They are among the most familiar coniferous trees which can thrive in temperate and tropical regions. The conifers live longer than other trees.

Structurally, pines are made up of roots, stem and leaves. The stem of most pines is thick and scaly but some species have a thin bark and they produce several branches that appear in whorls. The centre of the stem is called pith. It is made up of several concentric rings called annual rings. These rings help the plants to undergo secondary thickening.

Pines have green needle-shaped leaves, that can carry out photosynthesis. The leaves of pines are clustered into a short shoot in which adjacent internodes are very short. This type of leaves which occur as a clustered short shoot are called a fascicle. The cone is the reproductive part of the pines which contain female cones that produce seed and the male cones that produce pollen that is transferred by wind to female cones. The female cones have ovules that contain the female gamete. When pollen lands on the female cone, it develops a pollen tube that introduces the male nuclei into the ovule and fertilisation occurs. The male cones are relatively soft, herbaceous, and small while female cones are woody, and relatively larger as seen in Figure 1.3 and 1.4.

Figure 1.3: Male cones

Figure 1.4: Female cones

Advantages of the division Coniferophyta

Conifers are the evergreen plants which are grown in large forests and produce useful timber called softwood. Conifer forests are home to many birds and animals. They are used to make wood products such as furniture. They are also used to produce wood pulp for paper making. Turpentine which is used as cleaning agent for painting as well as production of disinfectants and insecticides is also a product of conifers. Furthermore conifer trees are used for firewood hence they are a source of heat. They are a source of food to organisms such as insects. Many *Pinus* sp plants are used as ornamentals when planted in parks and gardens. Cypress also are commercially grown and harvested for decoration during festivals such as Christmas. Conifers clean the atmosphere by removing carbon dioxide through photosynthesis.

Disadvantages of the division Coniferophyta

Coniferous forest completely shades the ground and prevents the growth of other plants. Wood products from conifers are soft and can be easily attacked by termites if not treated. They have needle like thorny leaves that can prick and cause injury. Resins which are produced by pines catch fire easily. Thus, in case of fire outbreak in a *Pinus* forest, fire is likely to spread rapidly because of the resins.

Exercise

1. What are the distinctive features of the division Coniferophyta?
2. Why are Coniferophyta said to be important plants?
3. What adaptation does pine pollen have for wind pollination?
4. Describe the general structure of pines.
5. In which ways does female cones differ from male cones?

Division Angiospermophyta

Activity 1.3:

Investigating the structure of flowering plants

Materials

Hibiscus flower, common bean plant, maize plant, elephant grass plant, hand lens and surgical or razor blade

Procedure

1. Collect *Hibiscus* plant, common bean plants, maize plants and elephant grass plants from the school environment. Make sure that you uproot the entire plant carefully in order to display their root system clearly except for *Hibiscus*.
2. Using a hand lens observe carefully leaves, flower arragement and roots of the collected plants and state the classes to which each plant belongs.
3. Using a surgical or razor blade make longitudinal section of *Hibiscus* flower and examine its parts.

Questions

a) Summarise in tabular form the morphological differences between the classes of the collected plants.
b) Draw a well labelled diagram of the section obtained after making longitudinal section of *Hibiscus* flower.

Angiospermophyta is the division in Kingdom Plantae which comprises plants commonly known as flowering plants or angiosperms. Angiosperms are the most diverse and a successful group of all the plants. They are found in most habitats such as aquatic, deserts, and terrestrial regions. They range in size from small plants such as herbs and grasses to big tree like baobab.

Unlike Coniferophyta, Angiospermophyta are flowering plants that produce seed which are enclosed in the ovary. They are not evergreen as Coniferophyta. Angiosperms can be classified according to their growth pattern into annual, biennial or perennial. They possess sieve tube

members as the specialised structures for conducting food substances. Sieve tubes have similar function with sieve cells found in Coniferophyta. They also possess companion cells similar in function to the albuminous cells found in Coniferophyta. Companion cells facilitate transport of food materials in angiosperm plants with the help of the conductive sieve tube members.

General features of the division Angiospermophyta

The general features of division Angiospermophyta include the following:

(a) Angiosperms are found in terrestrial (dry land), in freshwater and marine habitats.

(b) Angiosperms have a well-developed root system, stem and leaves.

(c) Their seeds are enclosed and protected in the ovary.

(d) Fertilisation is preceded by growth of the pollen tube. Usually the ovary develops into a fruit after fertilisation.

(e) They have well developed conducting tissues which contain xylem and phloem.

Classes of the division Angiospermophyta

The division Angiospermophyta is divided into two classes. These classes are Monocotyledoneae and Dicotyledoneae. The word "mono" means one and "Di" means two. Monocots have been named from having one cotyledon and dicots from having two cotyledons. Cotyledon is the part of seed that develops into the leaves after germination.

Distinctive features of the class Monocotyledoneae

This class contains plants with one cotyledon. Examples of monocots are maize, sugarcane, wheat, millet, sisal, coconuts and banana plants. The following are the distinctive features possessed by members of the class Monocotyledoneae that differentiate them from those of class Dicotyledoneae as seen in Figure 1.5 and 1.6.

(a) Monocots have parallel leaf venation.

(b) Flower parts normally occur in multiples of three.

(c) The embryo of monocot seeds bears one cotyledon.

(d) Monocot leaves are composed of an open or closed sheath which encloses the stem.

(e) Their vascular bundles in stems are scattered.

(f) They have fibrous root system.

(g) They have long and thin leaves.

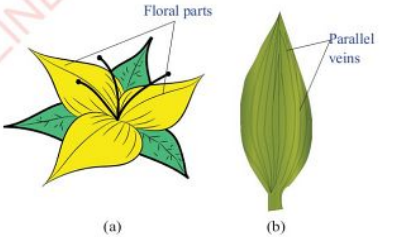


Figure 1.5: (a) floral arrangement (b) parallel venation in monocot leaf

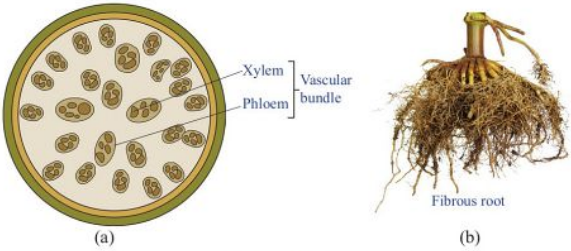


Figure 1.6: (a) vascular bundle scattered in stem (b) fibrous root system in monocot

Distinctive features of the class Dicotyledoneae

This class contains plants with two cotyledons. Examples of dicots are beans, mangoes, coffee, groundnuts and sunflower plants. Members of the class Dicotyledoneae as seen in Figure 1.7 and 1.8 differ from those of class Monocotyledoneae due to presence of the following features:

(a) Dicot leaves have net like venation.
(b) Their stems have vascular bundles which appear in a ring form.
(c) They have tap root system.
(d) Their seed embryo has two cotyledons.
(e) Floral parts are normally in multiples of four or five.
(f) Dicot plants have petioles that support the leaf.
(g) They have short and broader leaves.

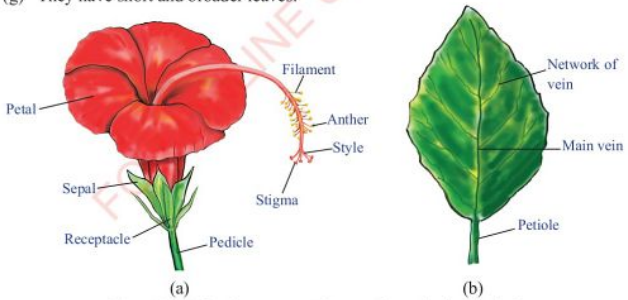


Figure 1.7: (a) floral arrangement (b) network venation in dicot leaf

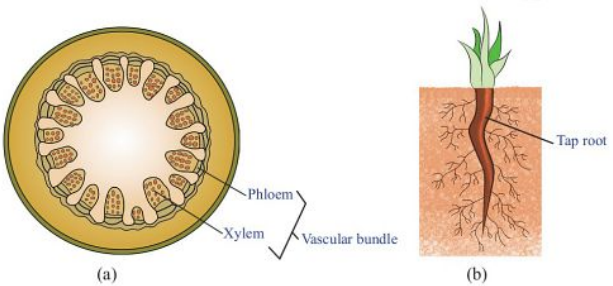


Figure 1.8: (a) vascular bundle in ring form in stem (b) tap root system

Advantages of the division Angiospermophyta

Angiosperms are important for the survival of animals including humans and herbivores. For humans, angiosperm provides foods such as beans, rice, maize, wheat, sugarcane, cabbage, lemons, and oranges. Some members of the grass family are used as food for livestock and also as habitat for many animals. Different types of angiosperm species are used as medicine for treating various diseases. Some angiosperms provide fibres that are raw materials for textile industries, for example cotton, flax, and hemp. Angiosperms form ground cover which prevents soil erosion. Some plants in this division make the environment attractive for example roses, lilies and hibiscus. They provide varieties of wood for furniture, paper, and building materials.

Disadvantages of division Angiospermophyta

Some angiosperms are poisonous. For example, *Datura stramonium* (thorn apple) and *Nerium oleander*. When eaten by humans and other animals they may cause death. Drugs from angiosperm can be dangerous if they are abused. For example, tobacco, marijuana, cocaine, and some caffeine varieties can be addictive. Some angiosperms for example star grass are weed plants which compete with food crops leading to reduction of crop yield. Others are parasites on other plant species. For example, *Cassyth filiformis* is a parasitic weed in crops such as mango, orange and cashew nut trees and they cause serious crop loss. Another example is *Striga* sp the witch weed which are parasite on millet, sorghum and maize. Some aquatic angiosperms such as water hyacynth can colonise water bodies and affect ecosystems as well as hindering fishing and boating activities.

Revision exercise 1

Choose the most correct answer.

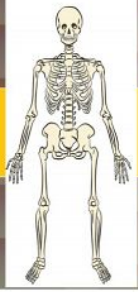
1. One among the following is an example of conifers.
   (a) Mango tree
   (b) Orange tree
   (c) Coconut tree
   (d) Pine tree.
2. A flowering plant with one embryonic seed leaf or cotyledon that usually appears at germination is _____.
   (a) bean
   (b) cashew nut
   (c) maize
   (d) apple
3. The leaves in dicot plants have ____.
   (a) parallel venation
   (b) fibrous roots
   (c) one cotyledon
   (d) net like venation
4. The following are the characteristics of Coniferophyta EXCEPT _____.
   (a) they lack flowers in their plants
   (b) they are cone bearing plants
   (c) their seeds are covered by ovaries
   (d) they have well developed tap root system

5. Match each item in **column A** against its corresponding item from **column B**.

Column A	Column B
(i) Conifers	A. Flower parts are in multiples of three
(ii) Fascicle	B. Used to produce turpentine
(iii) Monocotyledoneae	C. The xylem have only tracheids
(iv) Dicotyledoneae	D. Naked seeds
(v) Resins	E. Network venation
	F. Flowers are in multiples of three or four
	G. The leaf type of pine

Answer the following questions

6. Outline the differences between the two classes of the flowering plants.
7. What are the advantages and disadvantages of the Angiospermophyta?
8. A coconut tree is a monocot plant. Justify.
9. What are the similarities and differences between Coniferophyta and Angiospermophyta?
10. Why are Angiospermophyta said to be more successful compared to Coniferophyta.



Chapter

Two

Movement

Introduction

Living organisms require different materials which are necessary for their survival. These materials may not be found in their immediate environment, therefore they have to move from one place to another in order to find them. Movement is among of the characteristics of living things that differentiate them from non- living things. In this chapter, you will learn about the concepts of movement and locomotion, importance of movement and locomotion, and the structure and functions of the human skeletal system. You will also learn about adaptations of the human skeleton, types and functions of joints, adaptation of joints to movement, types and functions of muscles, adaptation of muscles to their functions, and movement in plants. The competencies developed in this chapter will enable you to develop an understanding of how movement takes place in vertebrates, invertebrates, and plants. You will also be able to take appropriate actions in addressing problems associated with movement and locomotion such as muscle cramps.

The concept of movement and locomotion

Locomotion and movement are two important terms in the study of motion in living organisms. Although both terms refers to motion in living organisms, they do not mean the same thing. Movement is a process by which a part or parts of an organism move without an organism changing its position. Movement includes change in shape, size and direction of the body parts or part in relation to the body axis. Locomotion on the other hand is the movement of the whole body of an organism from one location or place to another. This means that all forms of locomotion entails movement, but not all movements are locomotion. The table below summarises differences between movement and locomotion.

Table: Differences between locomotion and movement

S/n	Locomotion	Movement
1	Involves moving away from the original location	It happens without an organism moving away from the original location.
2	It is always voluntary	It can be either voluntary or involuntary
3	It involves the whole organism	It may involves the part or parts of an organism's body
4	Forms of locomotion include walking, running, jumping, crawling and dragging	Types of movement include amoeboid, ciliary, muscular and flagellar movement.
5	Exhibited by animals and some protoctists but not by plants	Exhibited by all living organism including plants and animals

There are various types of movement in living organisms which include flagellar movement, ciliary movement, amoeboid movement and muscular movement.

Flagellar movement

This is the type of movement in which an organism moves by using microscopic structures called flagella (singular: flagellum) as seen in Figure 2.1. The organism that moves by using flagella is known as flagellate. Flagella are whip-like outgrowths found in a flagellate organism. Organisms such as Euglena, Trypanosoma and some bacteria use flagella for movement. Also sperm follow this type of movement when moving towards the egg. Flagellates move in liquid medium as a result of wave- like undulation that passes along the flagella from the base to the tip. This wave-like undulation exerts a force in the surrounding liquid medium causing the organism to move. Flagella are very similar to cilia except that they are much longer.

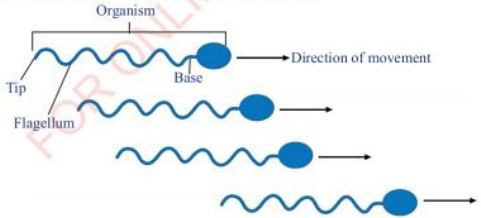


Figure 2.1: Flagellar movement

Ciliary movement

This is the type of movement exhibited by some protozoans such as Paramecium and larvae of some aquatic animals. Their body is covered by several small hair – like structures called cilia which help the organism to move. Movement is brought about by backward and forward beating of the cilia. When the organism beats cilia backward against water, it causes the organism to move forward. See Figure 2.2. Ciliary movement also occurs in most of internal tubular structures which are covered by a ciliated epithelium. For example, cilia movement in trachea helps vertebrates to remove dust particles and other unwanted particles during inhalation. The passage of ova along the female reproductive tract is also facilitated by ciliary movement.

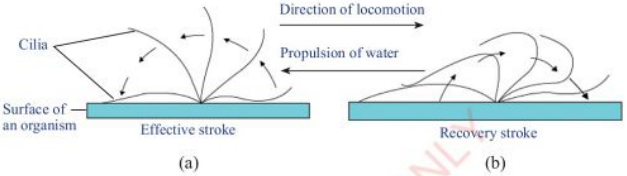


Figure 2.2: Ciliary movement (a) effective stroke (b) recovery stroke

Amoeboid movement

This is the type of movement that can be observed in some protozoans such as Amoeba and some mammalian white blood cells. When Amoeba moves toward a certain direction, the cytoplasm extends by flowing into that direction as seen in Figure 2.3. By doing so, it extends and forms a projection called pseudopodium (false feet). Further extension of the pseudopodium in the same direction causes more cytoplasm to move to it. As the result, Amoeba moves from one place to another. White blood cells also move in the same way in engulfing pathogens.

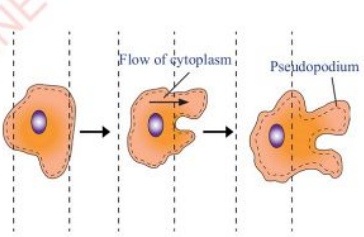


Figure 2.3: Amoeboid movement

Muscular movement

Muscular movement is the most complex type of movement in living organisms. The movement is brought about by the system of muscles in the body. It is the type of movement found in invertebrates such as worms and arthropods and vertebrates such as mammals, fish, reptiles and amphibians. Movement in these organisms is brought about by the relaxation and contraction of muscles. Relaxation and contraction of these muscles generate force which is transferred to cartilage, bone or body to enhance movement. See Figure 2.4. Most vertebrates exhibiting muscular movement have structures made up of cartilages or bone which act as levers which are organised to form a system called skeleton. Skeleton provides the point for muscles attachment. Hence, in vertebrates, movement is achieved by muscles that are attached to the skeleton. Some invertebrates such as worms use fluid at high pressure inside their body cavity as their skeleton, this is known as the hydrostatic skeleton.

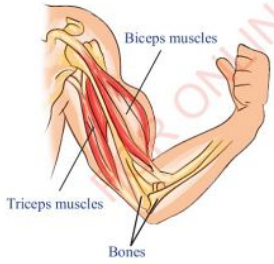


Figure 2.4: Muscles of the arm

The importance of movement in animals and plants

Movement is the fundamental aspect of life that enables plants and animals to survive. Movement enables plants and animals to move away from negative stimuli or danger. For example, avoiding predators and fire. Movement also helps them to avoid unfavourable environment such as chemicals. Likewise, movement enables plants and animals to find food, water and new favorable habitat. Moreover, movement facilitates the process of reproduction by bringing together organisms for mating or promote germination and seed dispersal in plants.

Activity 2.1:

Demonstrating movement and locomotion action

Materials

Chair, a table and a pen

Procedure

1. Put a pen on a table.
2. Sit on a chair.
3. Push your leg forward and backward while seated on the chair.
4. Stretch your hand to pick up the pen and then return it back.
5. Stand up and move forward four steps and turn back to your original position.

Questions

(a) Identify actions that demonstrate movement.
(b) Identify actions that demonstrate locomotion.
(c) Give reasons for your answer in a and b above.

Movement of human body

Skeletal systems

There are three main types of skeleton in living organisms. These are exoskeleton, hydrostatic skeleton and endoskeleton.

Exoskeleton or cuticle is a hard covering on the outer side of the body of arthropods such as insects, crustaceans and arachnids. It is made of a tough polysaccharide called chitin and it is usually covered by a water proof outer covering of wax. This type of skeleton limits the size of an organism and therefore such organisms only grow by ecdysis or moulting. Moulting is the periodic shedding of the exoskeleton. The function of an exoskeleton is to provide protection, support for the soft internal parts of the body, prevent dessication and provide area for muscle attachment.

Hydrostatic skeleton is a type of skeleton which is provided by fluid-filled cavity under pressure. It acts as skeleton for muscle movement and hence termed hydrostatic skeleton. The pressure maintains the shape of organism. This skeleton provides the major support in most invertebrates such as nematodes, earthworms, sea anemones and leeches. Similarly, in unicellular organisms and other cells, the support system is provided by hydrostatic skeleton. In the earthworm movement is brought about when muscles attached to the skin move against this fluid which is turgid enough to support them.

Endoskeleton is the type of skeleton in vertebrates made of a very hard tissue called bones. Bones are made up of widely spread living cells into which mineral salts are deposited. The main mineral salts are calcium phosphate, calcium carbonate and trace amounts of magnesium phosphate. The high mineral content makes bones much stronger and less elastic than cartilages. All vertebrates including human beings have endoskeleton. The function of endoskeleton is support of the body and provides area for muscle attachment.

Human skeletal system

The skeletal system is the system of the body consisting of bones, cartilage, tendons and ligaments. These components make about 20% of a person's total weight.

The structure of the human Skeleton

The human skeleton is a solid internal framework of the human body. Its structure consists of bones that are supported by ligaments and cartilage as seen in Figure 2.5. The human skeleton is made up of different bones joined together by ligament. This allows free movement of the bones and gives the ability of body parts to bend, turn, and twist in any direction. In addition, the skeleton provides a base for attachment of the muscles responsible for movement. Muscles are attached to bones by tendons. The contraction and relaxation of muscles cause muscular movement. The muscles work together with skeletal system to support and allow movement to occur.

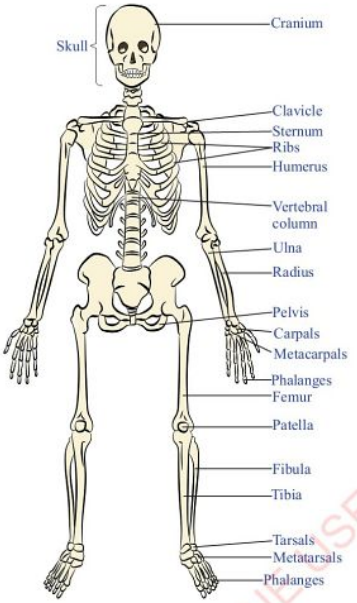


Figure 2.5: Human skeleton

Components of human skeleton

The major components of the human skeleton include; cartilage, bones, ligaments and tendons.

Cartilage

Cartilage is the main type of connective tissue found throughout the body such as in the joints, bones, vertebral column, lungs, ears and nose. It has a number of structural and functional importance. Cartilage is firm, soft, flexible, and more elastic than bones. The cartilage covers the tip of bones and protects bones from friction. Embryos of all vertebrates including human beings have their skeletons made of cartilage. In higher vertebrates, the embryonic cartilages are largely replaced by bone in early stage of development. However, cartilage persist in some organs such as the nose, ear pinna and between vertebrae as discs to provide cushioning to reduce shock.

Bone

Bones are rigid tissues consisting of cells tightly embedded in the hard intracellular material. They are made up of mainly collagen, calcium phosphate, calcium carbonate and a trace amounts of magnesium phosphate. The high mineral content makes a bone to be much stronger and less elastic than cartilage. The bone has a complex network of branching blood vessels in the bone marrow compartment which link the bone cells. A true bone or compact bone is made up of a hard part on the outside. The compact bone is covered by periosteum which is a layer

of tough fibrous tissue. Underneath the compact bone is a layer of spongy bone which has less mineral deposits than the compact bone. The spongy bone has spaces in it that make it light. In the central part of the bone is a cavity filled with bone marrow which is soft and has good supply of blood through the blood vessels. The bones are covered with a layer of cartilage at each end. Bones are classified as short bones, long bones, flat bones and irregular bones. The short bones support weight, allowing many small movements, for example bones of human feet. The long bones are strong, hollow, and light, containing a spongy bone at the end. Examples of long bones include bones in the legs and arms. The spongy bone has an open space and holes which contain bone marrow. Blood cells and platelets are made from the bone marrow. The flat bones are bones which support and protect body organs. They include ribs, breast bone, and shoulder bones. The irregular bones are for giving support. They are found in vertebral column and the three bones in the mammalian middle ear.

Ligaments

Ligament is a band of tough fibrous connective tissue that support internal body organs and hold one bone to another at the joints. They are composed of dense bundles of collagen fibres, fibrocyte cells and little ground substance. They are elastic to allow movement at the joints and hence movement of the body.

Tendons

These are tough connective tissues which attach muscles to bones. The tendons are inelastic tissue that firmly hold the muscles to the bones. Tendon may also attach muscles to body structures such as the eye ball.

Functions of the human skeleton

The human skeleton has three main functions which includes:

Support

Skeletons provide a strong framework that maintain the shape of the body. The skeleton supports the weight of the body against gravitational force. It raises up the body above the ground for efficient movement. Moreover, the skeleton provides attachment for many organs.

Protection

The skeleton protects delicate internal organs against mechanical damage and injuries. The skull for example forms a protective covering for the delicate tissues of the brain. It also houses other internal structures such as the inner ears and the eyeballs. The vertebral column protects the spinal cord. The ribcage in the thoracic region protects all the important organs in the thorax, such as the heart, thoracic blood vessels and the lungs. The pelvic girdle protects the abdominal organs particularly the urinary bladder and the reproductive organs of the female.

Locomotion

The skeleton provides attachment for the muscles of the body. The skeleton and the muscles operate as levers where the skeleton provides an attachment base for the muscle and the muscle pulls the skeleton to enhance locomotion.

Activity 2.2:

Observing human skeleton

Material

Model of the human skeleton

Procedure

1. Use a model of the human skeleton.
2. Observe carefully the model of the human skeleton.
3. Identify different parts of the human skeleton.

Questions

(a) Which components make up the human skeleton?

(b) Explain why the skeleton is able to facilitate movement.

(c) Draw a well labeled diagram of the human skeleton.

Exercise 2.1

1. Briefly explain the three types of skeleton.
2. Distinguish between movement and locomotion in living organism.
3. Give two examples of organisms that exhibit each of the following types of movement:
   (a) Ciliary movement.
   (b) Muscular movement.
   (c) Amoeboid movement.
4. Describe any five importance of movement in animals.
5. Explain the importance of skeleton in living organisms.

Major parts of human skeletal system

The human skeletal system is divided into two major parts namely the axial skeleton and appendicular skeleton.

Axial skeleton

The axial skeleton is composed of the skull, the sternum, ribcage and the vertebral column or the spine.

The skull

The human skull is the bony structure that forms the head. Skull consists of two parts namely cranium and visceral skeleton. The cranium is made up of flat bones joined tightly together to form immovable joints. These bones are called parietal bones and they enclose and protect the brain. The cranium also protects other sense organs such as eyes, olfactory organs, middle and inner ear. The cranium possesses a special occipital bone with occipital condyles which articulate with atlas vertebra to form a joint. This joint permits the nodding and other movement of the head. Visceral skeleton is made up of the jaws and teeth. The upper jaw or maxilla is fussed to the cranium and the

lower jaw or mandible is articulated to the cranium. Muscles connect the lower jaws to the cranium in such a way that allows chewing. Generally, the visceral skeleton is found on the front of the skull and make up the face. See Figure 2.6.

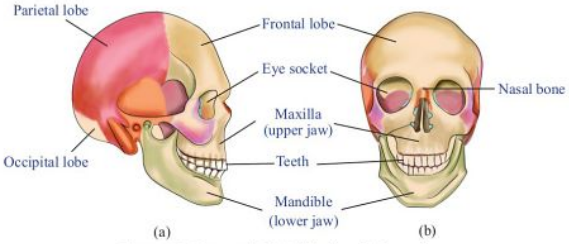


Figure 2.6: Human skull (a) side view (b) front view

The rib cage and sternum

Most mammals have 12 pairs of ribs. The ribs lie ventrally curved in the wall of the thorax and some are attached to the sternum. On the dorsal side the ribs are attached to the thoracic vertebrae. This is the reason why the rib cage is also known as thoracic cage. The 1st-7th pair of ribs, also called true ribs, are joined to the sternum by cartilage. The 8th -12th pair of ribs are called false ribs because they are not attached to the sternum. The last two pairs of false ribs are unattached at their ventral ends. They are therefore called floating ribs as seen in Figure 2.7. This arrangement of the ribs and the sternum form the rib cage that protects the heart and lungs. The point of articulation between the ribs, vertebral column and the sternum form joints that permit the movement of ribs during breathing.

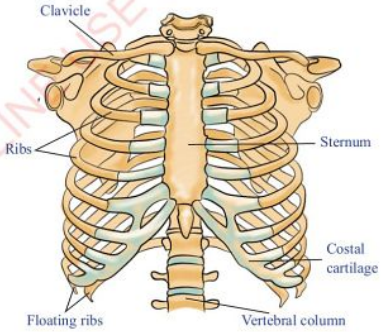


Figure 2.7: Bones of human thorax

Vertebral column

The human vertebral column is also known as the back bone. The vertebral column is composed of 33 small bones called vertebrae (singular vertebra) which extend from the base of the skull to the pelvis. See Figure 2.8. The vertebrae articulate with each other and are separated from each other by fibres and cartilage called intervertebral discs. These discs act as shock absorbers. The main function of the vertebral column is to support the body trunk. The vertebral column also accommodates spinal cord which runs through an arch of bone or neural arch. In this case, it protects the spinal cord against physical damage. The vertebrae are classified according to their location along the backbone. This classification system provides five types of vertebrae namely cervical, thoracic, lumbar, sacral and caudal vertebrae.

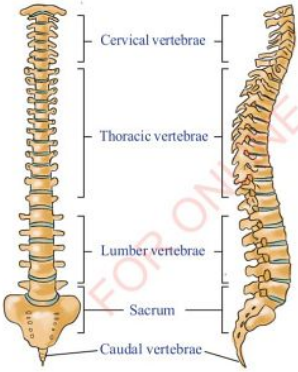


Figure 2.8: Vertebral column

(a) Cervical vertebrae

These are short bones that are found in the neck region. There are seven vertebrae that make the skeleton of the neck region. The first two cervical vertebrae are called atlas and axis respectively. See Figure 2.9. These two vertebrae permit the movement of the head. Between the skull and atlas is a joint that allows up and down movement of the head. Between the atlas and axis is a joint that allows the movement of head sideways. The cervical vertebrae are branched to increase surface area for muscle attachment as an adaptation to their function. They have spinal canal which houses and protects the spinal cord and nerves.

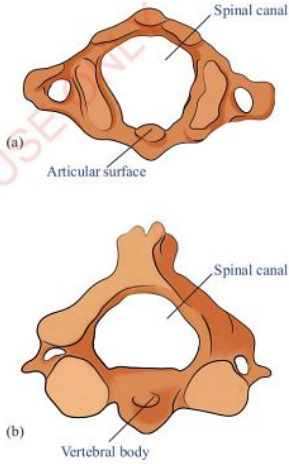


Figure 2.9: Cervical vertebrae (a) atlas (b) axis

(b) Thoracic vertebrae

The twelve thoracic vertebrae together with the ribs and sternum form the thoracic cage which protect the heart, lungs and some blood vessels against injuries. In addition, the thoracic vertebrae play a major role in breathing which is enhanced by movement of the intercostal muscles. The thoracic vertebrae are adapted to their role in the following ways; firstly, they have long neural spine that increases surface area for muscle attachment. They also have spinal canal for the passage of spinal cord as seen in Figure 2.10. Lastly they possess facets which facilitate articulation of bones. Facets are small rounded surfaces on the thoracic vertebrae on which the ribs are attached.

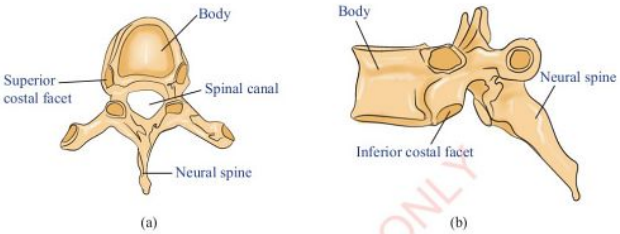


Figure 2.10: Thoracic vertebrae (a) anterior view (b) lateral view

(c) Lumbar vertebrae

These are found in the lumbar or abdominal region. Lumbar region is the lower back region of the vertebral column. There are five bones in humans that make lumbar vertebrae. They allow bending movements and rotation of the trunk. In order to allow this movement large number of muscles are attached in this region. Adaptations of lumbar vertebrae to their function include long transverse processes that increase surface area for abdominal muscles attachment as seen in Figure 2.11. They also have extra processes which increase surface area for attachment of muscles, the neural spine bone which is short and broader for muscle attachment and support. They also have large and thick centrum for support.

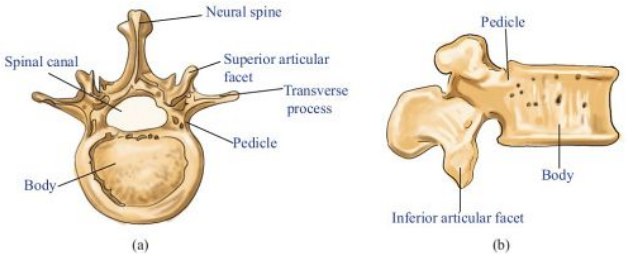


Figure 2.11: Lumbar vertebrae (a) anterior view (b) lateral view

(d) Sacral vertebrae

These are the vertebrae that are found in the sacral region or pelvic region of the vertebral column. They are fussed together to form a broader structure called sacrum as seen in Figure 2.12. Sacrum provides large surface area for muscle attachment. The anterior sacral vertebrae possess well-developed processes which are fussed to the pelvic girdle. It is through the sacrum that the weight of the body is transmitted to the pelvic girdle and the legs. The thrust or force is developed by hind limbs when moving forward, which is then transmitted via the pelvic girdle through the sacrum to the rest of the axial skeleton. Sacral vertebrae are adapted to their function in that, they have a sacrum which gives support and transmits the weight of the stationary state to the rest of the body. They also have numerous posterior foramens or canals which facilitate the passage of spine nerves. Their base is broader in order to provides large surface area for muscle attachment.

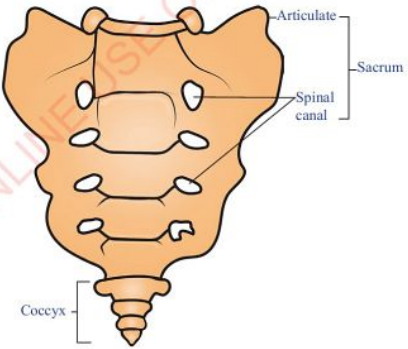


Figure 2.12: Sacral vertebrae

(e) Caudal vertebrae

These are the vertebrae found in the tail region. Depending on the length of the tail, the caudal vertebrae bone varies greatly from one mammal to another. In these vertebrae, the transverse processes, and neural arches become reduced in size and gradually disappear. This results to terminal vertebrae that consist only small centra. Human possess four caudal vertebrae that are fussed to form a coccyx as seen in Figure 2.13. This is a vestigial organ in human.

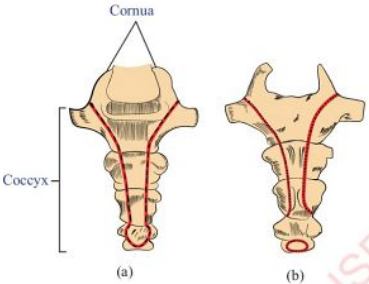


Figure 2.13: Caudal vertebrae (a) anterior surface (b) posterior surface

The appendicular skeleton

This consists of the girdles and the limbs. There are about 126 bones that form the appendicular skeleton. The pairs of upper limbs are attached to the axial skeleton by the shoulder or pectoral girdle while the lower limbs are attached by the pelvic girdle giving a figure that looks like a bridge. In humans, the upper limbs do not take any part in locomotion except for balancing. This results into a shift in the centre of gravity of the body.

The limbs

All mammals including human beings have limbs that are designed in the same plan of a pentadactyl limb plan. Pentadactyl limb means that each limb ends up with five digits. In human there are two types of limbs namely; upper limbs and lower limbs.

(a) Upper limbs

These consist of three parts; the upper arm, the forearm and the hand. The upper arm consists of a single bone called humerus. There are two bones in the forearm, the ulna and radius. The hand is made up of 27 bones that are grouped together into carpals or wrist, which articulate with the ulna and radius bones, and metacarpals and phalanges.

(i) The pectoral or shoulder girdle

This is a set of bones in the appendicular skeleton that connect to the arm on each side. It consists of two dorsal shoulder blades, the scapulae (singular: scapula) and a pair of ventral collar bones called clavicles. They are not fussed to axial skeleton but are flexible and attached to the vertebral column by ligaments and muscles. This arrangement enables the girdle

and its associated limbs to be moved through a great variety of planes and angles. The scapula is a flat triangular bone which covers a number of anterior ribs. At one end, the scapula has concave depression known as glenoid cavity which articulates with the head of humerus to form a ball and socket joint as seen in Figure 2.14. A spine runs along the outer surface of the scapula and at its free end there are two projections known as acromion and metacromion. These projections are used in the attachment of muscles. The scapulae are adapted to their function because of the long spine projections called acromion and metacromion. Also it has a broad and a flattened surface. These two surfaces provide large surface area for muscle attachment and allow the upper limbs to move in many planes and angles.

Figure 2.14: Scapula

(ii) Humerus

The upper part of the upper limb is made up of a single bone called humerus as seen in Figure 2. 15. There is a head at its upper end which articulates with the glenoid cavity of the scapula to form a ball and socket joint at the shoulder. The joint allows a wide range of movements. Near the head there are two roughened projections, between which is a groove called the bicipital groove. This is a groove in which the tendons of the biceps muscles pass. Adaptations of the humerus to its function include the presence of rounded head that fits into the glenoid cavity of the scapula. This allows for greater flexibility of movement of the arm. Humerus articulates with the forearm at the elbow joint. It has trochlea at the lower ends which articulates with forearm (at the ulna bone) that allows movement in one plane. Also, it has capitulum which articulates with the head of the radius. The humerus is long to provide large surface area for attachment of biceps and triceps muscles.

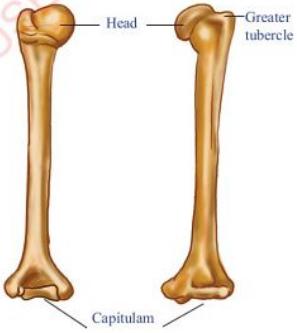


Figure 2.15: Humerus bone

(iii) Ulna and radius

The lower part of the upper limb is made of ulna and radius which forms the forearm. Ulna is longer than the radius. A notch called sigmoid notch at its upper end articulates with the humerus. Beyond the elbow joint is an olecranon process. This structure prevents backward movement of the forearm when it is stretched. This arrangement helps to prevent dislocation. The radius is found on the side where the thumb is located. It is a flattened bone which is slightly curved. In humans, the radius is not firmly bound to the ulna. See Figure 2.16. Muscles are able to rotate the radius about the ulna so that the palm of the hand can be turned downwards. To the lower end of the forearm, the ulna and radius articulate with a number of small bones called the carpals which form the wrist. The adaptation of ulna and radius to their role includes the length that provide large surface area for attachment of muscles of the forearm. They are also strong enough to support the forelimb. Ulna has olecranon process with sigmoid notch for articulation with trochlea of the humerus. This allows for movement in one plane.

Figure 2.16: Ulna and Radius

(iv) Carpals, Metacarpals and Phalanges

Carpals are small bones that make up the wrist. There are about nine bones forming wrist. The carpals articulate with the radius and ulna on the upper end and with metacarpals on the lower end. Metacarpals form the skeleton of the hand palm. There are five bones forming metacarpals. On the lower end, metacarpals articulate with phalanges. Phalanges form the skeleton of the fingers in pentadactyl form as shown in Figure 2.17.

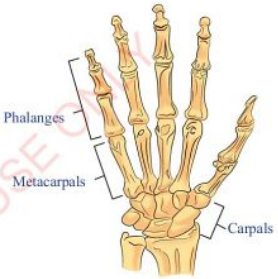


Figure 2.17: Skeleton of the human hand

(b) Lower limbs

The lower limbs are found on the posterior part of the body and they are attached to the axial skeleton. The lower limbs comprise of pelvic girdle, femur, tibia, fibula, tarsals, metatarsals and phalanges.

(i) Pelvic or hip girdle

Pelvic girdle is made up of two halves of bones known as pubic bones. Each half comprises three bones namely pubis, ilium and ischium. The pubic bones of each side join in the middle ventrally at the pubic symphysis. The ilium is fused to the sacrum of the vertebral column on each side. On the outer edge of each half, is a depression called acetabulum which articulates with the head of the femur to form the ball and socket hip joint as seen in Figure 2.18. Between the ischium and pubic bones, is a large hole called the obturator foramen through which blood vessels and nerves pass. The size of pubic cavity is very important in females during delivery because under the influence of hormones, it widens to allow the baby to pass during delivery. The girdle is adapted to its function because it has grooves that provide surface for articulation with the head of femur bone. This allows movement in all planes. It has a funnel like shape. This offers support of the weight of the upper part of the body. It is covered with a tough flexible connective tissue which provides surface area for attachment of muscles. The pelvic girdle is broad and flattened hence provide large surface area for attachment of muscles.

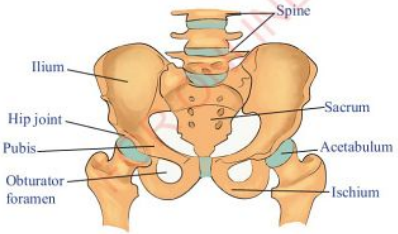


Figure 2.18: Pelvic girdle

(ii) Femur

It is the only bone located within the thigh. It is the longest and strongest bone in vertebrates extending from the hip to the knee. At its upper end, there is a large round head which articulates with the acetabulum of the pelvic girdle to form a ball and socket joint at the hip as seen in Figure 2.19. The processes called trochanters protrude below the head and provide area for attachment of the thigh muscles. The lower end of the femur has two curved convex surfaces called condyles which articulate with the tibia to form hinge joint at the knee. The patella or knee cap separates the two condyles. The adaption of femur to its role includes presence of the condyles which articulate to allow movement in one plane. It has a strong shaft bone that offers support of the body weight. It has a large round head which articulates with the acetabulum of the pelvic girdle to allow flexible movement of the leg. The long bone provides a large surface area for attachment of thigh muscles.

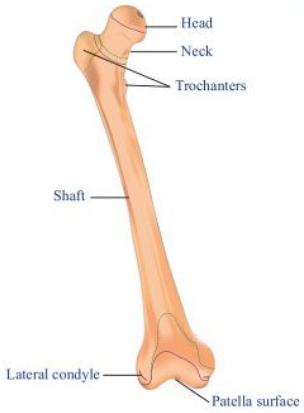


Figure 2.19: Structure of femur

(iii) Tibia and fibula

These are long bones of the lower limb. Tibia is longer than fibula and it is found on the side of the big toe. See Figure 2.20. It may be free or partly fused to the smaller fibula which lies alongside it. Fibula is much smaller in size and fused to the tibia in the lower part of the leg. A small round bone called patella or knee cap, lies in front of the knee joint. Patella prevents the leg from bending upwards at the knee in the forward direction. The tibia and fibula support the front part of the leg below the knee. They provide surface for attachment of the knee muscles. They articulate with femur to form knee joint and with metatarsals to form the ankle joint. At the lower end of the tibia and fibula, there are a number of tarsal bones or the ankle bones. Red blood cells are produced in the tibia and fibula bone marrow. The tibia and fibula are adapted to their role because they are strong bones, thus provide support for the body weight. They are long bones to provide large surface area for attachment of leg muscles.

Figure 2.20: Fibula and Tibia bones

(iv) Tarsals, Metatarsals and Phalanges

Tarsals are six small bones in the ankle. Two of them are elongated and one projects backwards to form a heel bone. The tarsals provide surface area for attachment of ankle muscle. The heel bone prevents the foot from bending backwards. Tarsals articulate with fibula at the ankle joint and with metatarsals of the foot. Metatarsals are elongated bones in the foot. Humans have five metatarsal bones with each one leading to a phalange. The metatarsals provide surface area for

attachments of foot muscles. They also support and maintain the shape of the foot. Metatarsals articulate with phalanges which form toes as seen in Figure 2.21.

Figure 2.21: Skeleton of the foot

Joints

A joint is the area in the skeletal system where two or more bones meet. They hold the skeleton together to support movement. Usually tendons join muscles to the bones and ligaments join the bones to each other.

Types of joints

There are various types of joints in the human skeletal system. These joints are classified depending on the types of movement they allow. There are two major types of joints namely immovable or fixed joints and movable joints.

(a) Immovable or fixed joints

These are joints that do not allow any movement of the body parts in any direction. They are made up of a thin layer of connective tissue between the bones which holds bones firmly in position. They provide strength and support for the body as well as protection of delicate structures which cannot withstand any kind of deformation. These joints are found between bones of the cranium and they are commonly called sutures. They are also found between the sacrum and ilium of the pelvic or hip girdle.

(b) Movable joints

These are the joints that allow movements of body parts. Some joints allow only a small degree of movement while others allow a wide range of movement of body parts. Articulating bone surfaces are covered by cartilage and are separated from each other by synovial cavity containing synovial fluid. Joints with synovial fluid are referred to as synovial joints as seen in Figure 2.22. The synovial fluid reduces friction by lubricating the two surfaces of the bones. Examples of synovial joints include ball and socket joints and hinge joints found in hip, shoulder, and knee.

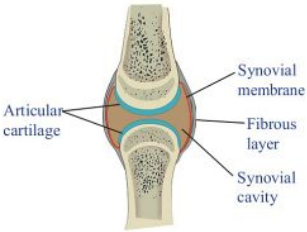


Figure 2.22: Structure of synovial joint

There are several types of movable joints which include the following.

(i) Gliding joints

This joint occurs between the surfaces of the flat shaped bones held together by ligament. These are joints that occur between vertebrae. They are found where two or more bone surfaces move over each other. It allows movement in two directions. See Figure 2.23. It also occurs at the wrist and ankle allowing the hand and foot to be moved up and down or to rotate slightly. In the vertebrae, they lack fluid between them, and instead they have a layer of cartilage called intervertebral disc that reduces friction and act as the shock absorber.

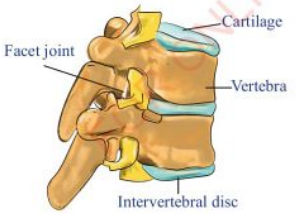


Figure 2.23: Gliding joint in vertebrate

(ii) Hinge joints

This is the type of joint which allows movement of bones in only one direction (plane) as seen in Figure 2.24. This type of joint is called hinge joint because it operates like the hinge of a door which allows movement in only one direction. The joint of this type is found at the elbow, knee, and phalanges of fingers and toes.

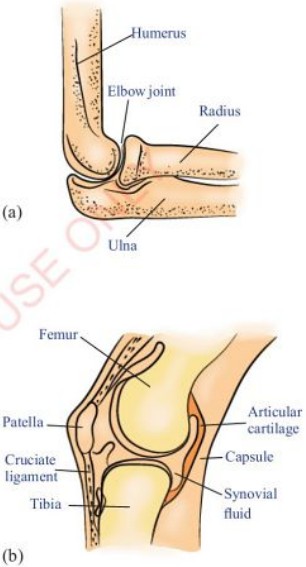


Figure 2.24: Hinge joint (a) elbow joint (b) knee joint

(iii) Ball and socket joints

This is a type of movable joint in which a ball moves within a socket so as to allow rotation in every direction. See Figure 2.25. This type of joint allows the greatest flexibility of all joints. Examples of ball and socket joints are hip joint and shoulder joint. It is called ball and socket joint because the round head which look like a ball of one bone fits into a socket of another bone. At the shoulder for example, the rounded head of the humerus fits into the socket of the pectoral bone. At the hip, the rounded head of the femur fits into the socket of the hip bone called pelvic girdle.

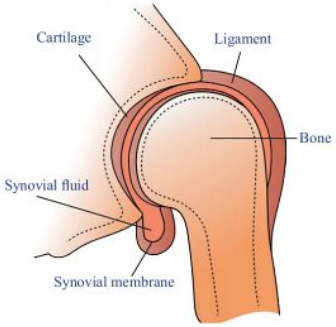


Figure 2.25: Ball and Socket joint

(iv) Pivot or peg and socket joints

This type of movable joint found between the first cervical vertebra called the atlas and the second cervical vertebra called axis. In this case, a pivot or peg of the axis fits into a ring or socket of the atlas. This allows the pivot or peg to turn within a ring or socket. The pivot joint allows rotation of the head as seen in Figure 2.26 a and b.

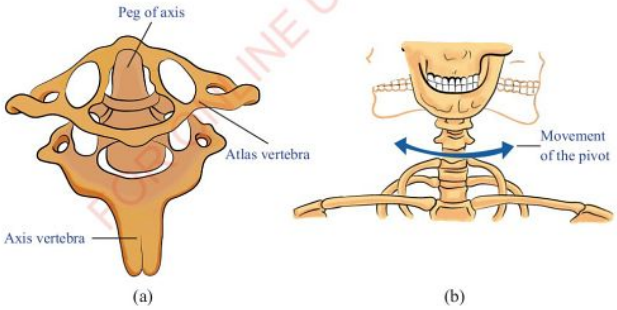


Figure 2.26: Pivot joint

Adaptations of joints to movement

Joints have different features that make them perform their role effectively without friction and dislocation. Friction in movable joints is prevented by synovial fluid and dislocation is prevented by ligaments which hold the bones together. Joints which support weight are provided with cushion. The cushion absorbs compression caused by weight. Cushioning effect in the joint is provided by discs of cartilage. The cushion also prevents strain and knocking of bones against each other. Most bones have surface area for attachment of muscles which aid in movement.

Concept of muscles

Movement of body parts is made possible by the presence of muscles. The skeleton alone cannot bring about locomotion and movement. A muscle is a contractile tissue specialized for relaxation and contraction to bring about movement and locomotion. The muscles are attached to bones, and are composed of many elongated cells called muscle fibres which are able to contract and relax. During relaxation, the once stretched muscle fibres tend to regain their original size and shape due to their elasticity as seen in Figure 2.27.

Muscles are made up of specialized tissues which are known as contractile tissues. When these tissues contract, they become short and tight as a result, movement takes place. Muscles work in pairs to bring about movement. One produces movement in one direction and the other pair produces movement in the opposite direction. Pairs of muscles work antagonistically, that is opposing each other. For example, the muscles above the humerus become thin when stretching the arm, while those below humerus become thick. Therefore, bending and straightening of the arm is brought about by the two sets of muscles. The muscles above the humerus are called biceps and those at the back are called triceps. Bending of the arm is brought about by contraction of the biceps and relaxation of triceps, while straightening of the arm is brought about by contraction of triceps and relaxation of biceps. Biceps and triceps are also known as flexor muscles and extensor muscles respectively.

The muscles are attached to bones at both ends by strong inelastic fibers called tendons. The muscles are well supplied with blood vessels which bring nutrients and oxygen. The vessels also take away metabolic waste products such as carbon dioxide.

Muscles act as the 'engine' that the body uses to propel itself. Although they do not work in the same way as a car engine, muscles do the same function as done by a car engine. They turn energy into motion. It would be impossible to do anything without muscles.

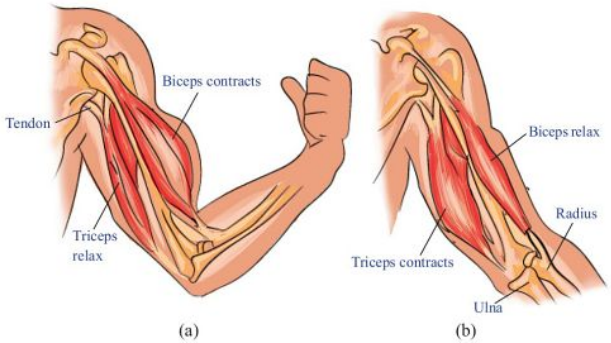


Figure 2.27: (a) bending of the arm (b) straightening of the arm

Activity 2.3:

Examining the structure of different muscles

Materials

Prepared photomicrograph slides of striated, cardiac and smooth muscles and a light microscope

Procedure

1. Mount the prepared slide on the light microscope.
2. Observe carefully each mounted slide and identify the type of muscles.

Questions

(a) State the types of muscles observed.
(b) Draw each type of muscles observed.

Types of muscles

There are three distinct types of muscles in human body which include: skeletal muscles, smooth muscles and cardiac muscles.

Skeletal muscle

These are the specialised contractile tissues found in vertebrates. They are responsible for locomotion and voluntary movements of the body parts. Skeletal muscles are made up of a long bundle of fibres as seen in Figure 2.28. They are also known as striated or voluntary muscles. Skeletal muscles are surrounded by a membrane. The skeletal muscles can contract and relax quickly but get fatigue in a relatively short time. They are controlled by the voluntary nervous system by receiving nerve impulses from it. The skeletal muscles bring about

movements in organisms due to the presence of tendons between the muscles and the bones and the presence of ligament attachment between bones. The skeletal muscles in the skull connect with the skin and are responsible for facial expressions and movement of the jaws during chewing. Similarly, skeletal muscles are used to move the foot.

Figure 2.28: Skeletal muscles

Smooth (involuntary) muscle

Smooth muscles are unstriated or involuntary muscles made up of long and tapered end cells as seen in Figure 2.29. They are found in most of the internal organs such as the alimentary canal, kidney, liver, uterus, sperm ducts and blood vessels. They are not made up of fibres and are controlled by the involuntary nervous system. Compared with skeletal muscles, smooth muscles contract slowly and they do not fatigue easily. The spindle-shaped cells and their smooth structure facilitate movement of food through the gut and the movement of blood through blood vessels. In the eye, smooth muscles in the iris control the size of the pupil in response to changes in light intensity. In the intestinal walls, contraction of smooth muscle pushes food through the digestive tract. In the bladder, contraction of smooth muscles makes urination possible. The skin also has smooth muscles which allows hair to rise in response to cold condition or fear.

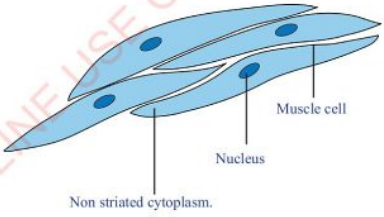


Figure 2.29: Smooth muscles

Cardiac muscles

Cardiac muscles are also called heart muscles or myocardium. They are only found in the heart. It is a special type of muscles that are able to contract without suffering from fatigue and is not under the influence of the central nervous system. They are influenced by the autonomic nervous system. The striated nature of cardiac muscles

enable continuous pumping of blood in the body for the life time of the animal. Cardiac muscles have branched cells which form a highly net like structure in the heart. These cells are connected to each other by a strong but permeable membrane structure called intercalated disc. They are connected end to end forming muscle fibres as seen in Figure 2.30. They are somewhat similar to skeletal muscle in that they possess contractile units called sarcomere. However, the rhythmic contraction of cardiac muscles is not under voluntary control, it is regulated by sinoatrial node of the heart.

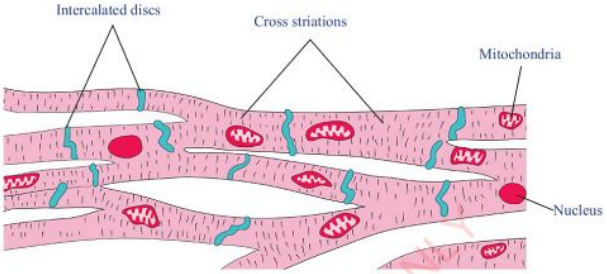


Figure 2.30: Cardiac muscles

Structure of muscles

Generally, muscles are made up of small units called muscle fibres which are long and cylindrical in shape. They are arranged parallel to each other. See Figure 2.31. The muscle fibres are filled with specialised cytoplasm called sarcoplasm. Each muscle fibre is surrounded by a membrane called sarcolemma. Each muscle fibre has many nuclei which are scattered all over the sarcoplasm. Internally, the muscle fibres are made up of numerous muscle threads called myofibrils which help the muscles to contact.

Muscles are multinucleated and contain myofibrils made of proteins known as myofilaments. They are of two types: thick filaments made of myosin protein and thin filaments made of actin protein. Basically, contraction and relaxation of the muscles are brought about by an interaction of protein filaments, a thick myosin and a thin actin. Cardiac muscles have specialised cells called pacemaker which control contraction in the heart by receiving signals from the nervous system that prompt them to either speed up or slow down the heart rate. Pacemakers

are connected to the cardiac muscle cells allowing them to pass signals to these muscles to contract.

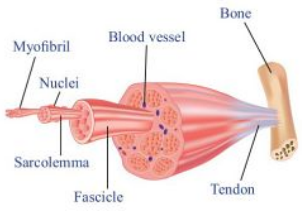


Figure 2.31: Structure of muscles

Adaptation of muscles to their roles

Muscles are composed of different features that make them perform their role effectively. The muscles are elastic and have elastic myofibrils which provide the ability to stretch and contract. Muscles are supplied with blood vessels and nerves. The blood vessels supply nutrients and oxygen to power contraction and remove wastes. The nerves trigger and control muscle contraction. For example, they facilitate movement of materials along the gut or blood through the blood vessels. The folds in striated muscles store calcium ions that regulate muscle contraction. Skeletal muscles have tendons that attach them to bones so that stretching and contraction result in movement of the bones. See Figure 2.31. Cardiac muscle cells have numerous mitochondria which act as 'power houses'. Mitochondria constantly produce energy for contraction and relaxation processes. The smooth muscles have cells with tapering ends which allow for continuous contraction. The smooth muscles are connected to the involuntary nervous system. This enables contraction and relaxation to occur without the influence of will. The skeletal muscles have long fibres which provide large surface area for relaxation and contraction.

How muscles facilitate movement

A muscle contraction occurs when a muscle cell shortens. Locomotion in higher animals is possible only through coordinated and repeated contraction of many muscles. Contraction is a function of the central nervous system which is made up of the brain and spinal cord. Muscle contraction usually occurs as a result of a conscious effort originating in the brain. The brain sends signals in the form of action potentials to the motor neuron that innervates the muscle fibre. However, smooth muscles and cardiac muscles do not contract as a result of conscious effort.

Activity 2.4:

Examining how muscles facilitate movement

Procedure

1. Grasp the muscles of the upper arm of your fellow student but not too tightly.

2. While grasping the arm, ask your fellow student to bend and straighten the lower arm several times.
3. Observe what happens to the muscles during bending and straightening of the arm.

Questions

Explain what happens to the muscles during bending and straightening of the arm.

Locomotion in animals cannot take place unless there are muscles. The skeletal muscles are attached to bones at two points. At one point a muscle is usually attached to an immovable bone, and at the other end a muscle is attached to a movable bone. The muscles may be attached directly or indirectly to the bones by means of tendons. Tendons are tough whitish cords of fibrous materials which connect a bone and a muscle. The muscles can contract and relax. When a muscle contracts, it becomes short and thick and hence exerts a pulling force on the bone to which it is attached. When the muscle relaxes, it become long and thin as shown in Figure 2. 27. Most of the muscles act in pairs in such a manner that when one member of the set contracts the other member relaxes. This means that they never contract or relax at the same time. These muscles produce opposite effects at the joint. This means they have to contract at different time, otherwise the arm will not move. The nervous system ensures that this does not happen. Each muscle has its own nerve supply so that when messages are sent to the biceps muscle informing it to contract, they stop being sent to the triceps and vice versa. Those muscles that produce opposite effects in this way are called antagonistic muscles for example, flexor muscles such as the biceps cause bending of the limbs while the extensor muscles such as the triceps straighten the limbs. There are also flexors and extensors in the legs which play an important part in walking and running.

Muscle cramps or muscle spasm

This is an involuntary contraction of muscles that can cause great pain. The cramp may involve part of the muscle, the entire muscle, or several muscles that usually act together. Any of the muscles that are at our voluntary and involuntary control can undergo cramping except cardiac muscles.

Muscle cramps can be caused by prolonged physical exercise, for example, swimming. It may also be caused by a shortage of salts in the body. Stretching and warming the affected muscles can help to relieve muscle cramps.

Causes of muscle cramps

Different factors can lead to muscle cramps, these include loss of important salts such as potassium, calcium, magnesium or sodium chloride from the body through sweating. Cramps can also be caused by over use of muscles due to vigorous exercise. For example, a 'stitch' is a type of muscle cramp that occurs in the abdominal muscles

usually after tough exercise. Other causes of muscle cramps include dehydration, use of certain medicines, dialysis, pregnancy, and limited blood flow to the muscles.

Prevention of muscle cramps

Muscle cramps can be prevented by drinking a lot of water (hydration) and avoiding vigorous physical exercise. It is also advised to have regular physical exercise to prevent muscle cramps. Muscle cramps can also be prevented through stretching the muscles more often.

Assisting a person with muscle cramps

Muscle cramps can be relieved by softly massaging the involved muscles. Stretching the muscle and applying ointment on the affected area can relieve muscle cramps or applying heat on the cramped muscle using a warm tower or heat pad. In case the cramps persist, consult a health provider for medical advice and treatment.

Exercise 2.2

1. In which ways does the skeleton facilitate movement in human beings?
2. What is the difference between movable and immovable joints?
3. How are muscles adapted to their functions?
4. Explain the similarities and differences between cardiac and skeletal muscles.

Movement in plants

Normally plants remain fixed on the ground and they are incapable of moving from one place to another. However, parts of plants such as leaves, stems and roots show some growth responses away or towards stimuli such as water, light and gravity. These responses result into movement called movement of curvature. Movement of curvature enables plants to get their requirements such as food and water. Plant response can be either towards or away from the stimulus. If the response is towards the stimulus it is referred to as (+) positive response, but if the response is away from the stimulus it is referred to as (-) negative response. Movement or growth of curvature is categorised in two major groups. These are self-controlling growth movement also called autonomic or spontaneous movement and paratonic or induced movement controlled by external factors such as light, water, chemicals, touch and gravity. Example of self-controlling movement in plant is the growth of shoots and roots.

Paratonic movement is divided into two types which are tropic movement or tropism and nastic movement.

Tropic movement

These are plant movements which are determined by the direction of the stimulus. Tropic movement is the unidirectional growth movement shown by a fixed part of a stationary plant towards or away from stimulus. Tropic movements are also known as tropism movements. If

the response is toward the stimulus, the movement is referred to as (+) positive tropic movement. But if the response is away from the stimulus it is referred to as (-) negative tropic movement.

Tropic movements take place at a very slow pace. The growth movement is caused by an increased or decreased rate of growth on the side of the organ which is under the influence of the stimulus with respect to the opposite side. This results in growth curvature. There are various types of tropic movements, these types are:

Phototropism or phototropic movement

This is the growth movement of a plant part or organ in response to unilateral source of light. This occurs when a stationary plant is receiving light coming from one side. For example, growth movement of shoot in response to unilateral source of light. The shoot of the plant exhibits a positive phototropic response as it grows toward light as seen in Figure 2.32.

Figure 2.32: Phototropism in plant

Geotropism (geotropic movement)

This is growth movement in response to gravitational pull. For example, the growth of roots toward gravitational force is positive geotropism but growth of shoot away from the gravitational pull is negative geotropism. If the plant is kept horizontally, the shoot will bend and grow upward (negative geotropism) while the roots will bend and grow downwards (positive geotropism) as seen in Figure 2.33.

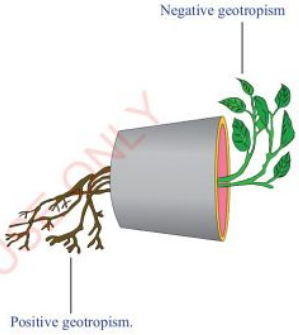


Figure 2.33: Geotropism in plant

Hydrotropism or Hydrotropic movement;

This is the growth movement in response to water. Growth movement of root in response to source of water is an example of hydrotropism. Roots are generally positively hydrotropic as seen in Figure 2.34.

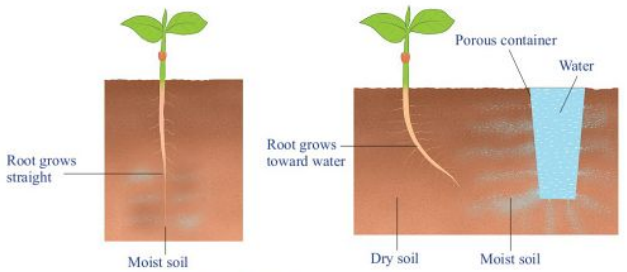


Figure 2.34: Hydrotropism in plant

Thigmotropism or Thigmotropic movement

This is the growth movement of a part of a fixed plant in response to touch. This movement is found in tendril and twining plants. Tendrils of climbing plants bend around objects that they come in contact with as seen in Figure 2.35. this is a typical example of positive thigmotropism.

Figure 2.35: Thigmotropism in plant

Chemotropism or Chemotropic movement

This is a growth movement of plants towards chemicals. This type of movement can be seen in the growth of the pollen tube from the style toward the ovary and finally the ovule induced by a sugary substance. See Figure 2.36.

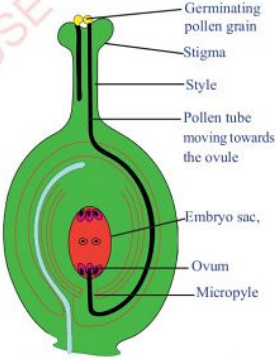


Figure 2.36: Chemotropism in plant

Thermotropism or Thermotropic movement

This is a movement of plant parts in response to temperature. Some flowers close when the temperature drops, and some leaves fold when the temperature is too high. For example, petals of tulip (*Tulipa* sp) close at low temperature and re-open at high temperature.

Nastic movement

These are non-directional movements of part of a stationary plant in response to external stimuli such as folding of leaves in warm weather, opening and closing of flowers in response to intensity of light, and closing of leaves when touched. Such movements occur as a result of changes in turgor pressure in a certain cell from any direction of the stimulus. Nastic movements are reversible movements which occur repeatedly in response to stimuli. Based on the nature of stimuli, nastic movements can be divided into the following groups:

Photonasty

This is a movement of plant parts in response to light intensity but not toward light. This kind of movement is shown by the prayer plant (*Maranta*) which is an ornamental house plant. Prayer plant petals are horizontal during the day to maximize the exposure to sunlight. At night, the petals fold vertically and appear like a pair of hands in prayer. At sunrise the process reverses and the petals again open horizontally as seen in Figure 2.37. This process of changing petal leaf position helps to conserve water and heat. Other examples of photonastic movement can be observed in Dandelion flower, moon flower and the flower of *Cestrum nocturrum*

Figure 2.37: Nastic movement in flower (a) during the day the flower opens (b) during the night the flower closes

Chemonasty

This is a plant's response to chemical stimuli. It includes inhibition of cellular elongation and production of thick-walled supporting tissue. Examples include the chemical ethylene which inhibits growth of certain crops and keeps them short and bushy. Another example is when an insect gets stuck on the leaves of a Venus fly-trap. Tentacles on the leaf curl around to hold the insect until it is digested. This response is due to the presence of organic nitrogen compounds from the insect. See Figure 2.38.

Figure 2.38: Chemonasty in plant

Seismonasty or Thigmonasty

This is the movement of plant parts in response to touch. Seismonastic movement is also called thigmonastic movement. It results from physical contact or mechanical disturbance. A good example of seismonastic movement is the folding of the leaves of *Mimosa pudica* in response to touch. When the leaves of this plant are touched the leaflets fold. Removing the touch stimulus causes the leaves to unfold as seen in Figure 2.39. Normally the leaves of *Mimosa pudica* remain expanded during the day and close at night hence exhibit nyctinasty. This response in plants is an important defensive mechanism.

Figure 2.39: Nastic movement in the leaflets of Mimosa plant (a) unfolded leaves (b) folded leaves

Nyctinasty

This is a nastic movement which occurs in response to diurnal changes of temperature (thermonasty) or light intensity (photonasty). Opening and closing of the petal of some flowers is a good example of nyctinasty. This occurs in response to alternation in the duration of day and night. Sleeping movement of leaves of some leguminous plants in response to the onset of darkness is another example of nyctinasty. Plants such as *Mimosa pudica* also exhibit nyctinasty in responce to day and night changes.

Experiments to investigate tropism in plants

Experiment 1:

To investigate phototropism in shoots

Aim: To investigate the effect of light on plant seedling.

Materials

Two potted bean plant seedlings, two cardboard boxes, clinostat and source of light

Procedure

1. Select two potted bean seedling which are at the same stage of growth. Place one bean seedling in a cardboard box with a window cut on one side of the cardboard that allows light to pass through and reach the bean seedling from one direction.
2. Place the second potted bean seedling in a cardboard which also has a window cut on one side like that of the first seedling, but the second bean seedling should be placed on a slowly rotating clinostat that allows the potted bean seedling to rotate so that light can reach all sides of the seedling.
3. After seven days, remove the two potted plants from the cardboard boxes and observe them carefully. See Figure 2.40.

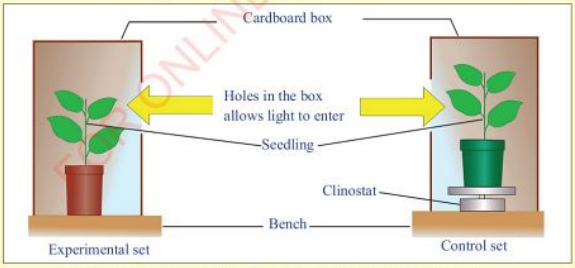


Figure 2.40: Experiment set up to investigate phototropism in shoots

Observation

In the second potted bean plant (b), the seedling will grow vertically and hence there is no movement of curvature observed. This is because the bean seedling received light equally from all sides. The first potted bean seedling (a) which was exposed to light in only one direction will grow towards the source of light. This indicates that the shoot grows towards light and hence exhibit positive phototropism. All plant shoots are positively phototropic. See Figure 2.41.

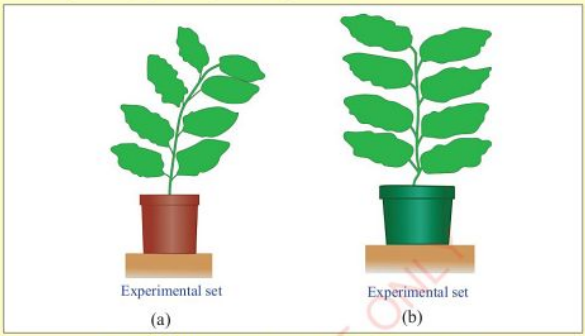


Figure 2.41: Experiment results of phototropism in shoots

Experiment 2:

To investigate phototropism in roots

Aim: To investigate the effect of light on plant seedling roots.

Materials

Four bean seeds, one cardboard box, cotton wool, dish and source of light

Procedure

1. Place four bean seeds on wet cotton wool on a dish placed in a cardboard with a window cut on one side which allows light to reach the bean seeds in only one direction.
2. Leave them for seven days to allow them to germinate. Then remove the cardboard carefully.
3. Observe the changes in the developing roots and shoots

Observation

The elongated roots and shoots will be bent such that the roots will grow away from the source of light indicating that their growth movement is negatively phototropic. See figure 2.42.

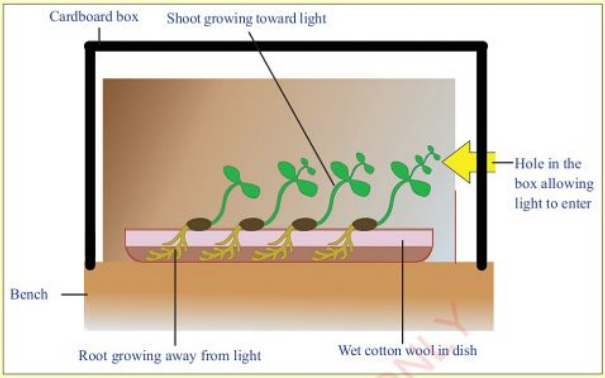


Figure 2.42: Experiment to investigate negative phototropism in roots

Experiment 3:

To investigate geotropism in shoots and roots

Aim: to investigate the effect of gravitational pull on plant seedling.

Materials

Two germinating bean seeds which are at the same stage of growth, clinostat, two benches and cardboard box

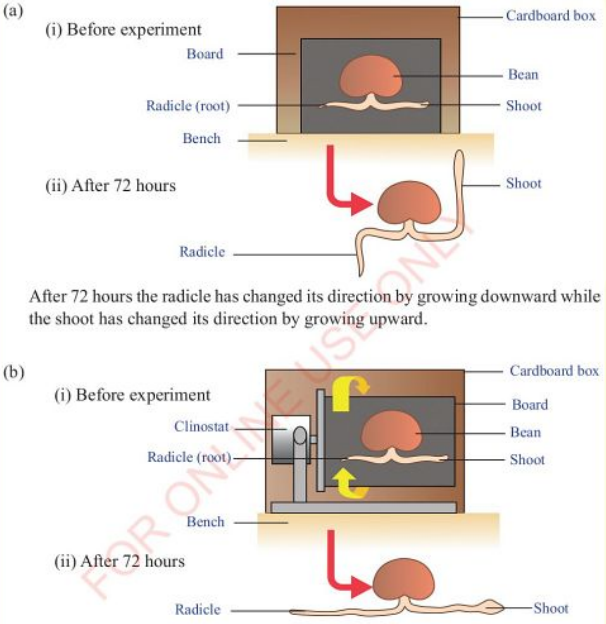
Procedure

1. Place one bean seedling in a cardboard in such a way that the shoot and the root are in horizontal position.
2. Take the second bean seedling and place in a cardboard with a slowly rotating clinostat in such a way that both root and shoot are in horizontal position. The clinostat ensures that there is equal pull of gravity in all direction.
3. Supply light equally to both cardboards.

4. Leave the setting for three days and then remove the cardboards and observe the seedlings carefully.

Observation

After three days, the shoot and root of the bean seedling in a clinostat will still grow horizontally while the shoot in the first setting will grow upwards and the roots will grow downwards. This indicates that the growth movement of shoot is negatively geotropic and the growth movement of root is positively geotropic. See Figure 2.43.



After 72 hours the radicle has changed its direction by growing downward while the shoot has changed its direction by growing upward.

After 72 hours the radicle and shoot are still growing horizontally

Figure 2.43: Experiment to investigate geotropism using bean seedling

Revision exercise 2

Choose the most correct answer.

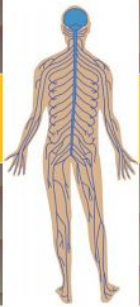
1. Which of the following is not necessary for locomotion to occur.
   (a) Temperature
   (b) Skeleton
   (c) Propulsion
   (d) Stability
2. The growth or movement of a plant towards or away from gravity is_____.
   (a) movement
   (b) geotropism
   (c) response
   (d) nastic movement
3. All of the following are functions of the human skeleton except_____.
   (a) support
   (b) protection
   (c) transport
   (d) shape
4. The sheet or band of tough, fibrous tissue connecting bones or cartilage at a joint or supporting an organ is a _____.
   (a) tendon
   (b) muscle
   (c) joint
   (d) ligament
5. Which of the following is aresponse towards a unilateral source of light.
   (a) Phototropism
   (b) Photonasty
   (c) Nyctinasty
   (d) Photoperiodism
6. The growth of roots away from light is _____.
   (a) positive phototropism
   (b) negative phototropism
   (c) positive photonasty
   (d) negative photonasty

7. Match each item in **column A** against its corresponding item from **column B**.

Column A	Column B
(i) Muscles	A. muscles that are able to contract without suffering fatigue and they are not under the influence of the nervous system
(ii) Smooth muscles	B. slender threads running along the length of the muscle fibre
	C. fibrous tissue which joins one bone to another bone
(iii) Cardiac muscles	D. connective tissue which attaches muscles to bone
(iv) Skeletal muscles	E. muscles made up of long and tapered end cells found in most of the internal organs, such as the alimentary canal, kidney and liver, uterus, sperm ducts and blood vessel
(v) Myofibril	F. Muscles made up of long fibres that cover the bones
(vi) Ligament	G. contractile tissue specialized for relaxation and contraction to bring about movement and locomotion
(vii) Tendon	H. Space between bone and bone
	I. Smooth muscles with a disc between cells
	J. Biceps and triceps muscles
	K. Have no ability to relax and contract

Answer the following questions

8. Explain the meaning of the following terms:
   (a) Movement
   (b) Tropic movement
   (c) Locomotion
   (d) Stimuli
   (e) Nastic movement
9. Outline the significance of the following:
   (a) Movement in animals.
   (b) Tropism in plants.
10. Describe the components of the axial skeleton and appendicular skeleton.
11. What are the adaptation of the muscles to its functions?
12. What features of the joint enables it to reduce friction?
13. Explain how antagonistic action of biceps and triceps bring about movement.



Chapter

Three

Coordination

Introduction

Living organisms are made up of different body parts. These parts work together in a coordinated manner to perform various body functions. Working together of these different body parts in a coordinated way is called coordination. Coordination enables animals and plants to detect changes in their internal and external environments and respond to these changes. In this chapter, you will learn about the concept of coordination and ways in which it is brought about. You will also learn about the structure and roles of motor, sensory, and relay neurones. The components of the central and peripheral nervous system and their functions will also be discussed. In addition, you will also learn about types of reflex actions, sensory organs and their functions. Furthermore, you will learn about the meaning of drugs, drug abuse and correct ways of handling and using drugs, and causes and effects of drug addiction. Endocrine glands and the role of the hormones as well as their disorders will also be discussed. The competencies developed will enable you to be aware of the factors that may affect the nervous and endocrine system and avoid risk behaviours that may affect them.

The concept of coordination

All simple and complex organisms need to coordinate their body functions in order to be able to detect changes in their environment and respond to them. The linking together of different activities in the body of an organism so that they work at the appropriate time and rate required by an organism is called **coordination**.

Coordination of various body parts of an organism requires a system which should be able to detect changes in the environment. It should also be able to transmit that information from the environment to the appropriate parts in the body. This enables the organism to react to those changes in a way which ensures its survival. Without coordination, the activities in the body

would be disorderly and the body would fail to function properly. The changes in the environment to which the organisms respond and react are called stimuli (singular: stimulus). Living organisms show response to stimuli such as light, heat, cold, sound, smell, taste, touch, pressure, pain, water and force of gravity. The ability to perceive, interpret and respond to stimuli is called irritability or sensitivity.

There are two types of stimuli which are external and internal. External stimuli are associated with the surrounding environment which include wind, temperature, light, pressure, touch, water and gravity. Internal stimuli occur within the organism; for example, sense of body position, glucose level and blood pressure.

When an organism detects a stimulus it initiates a response. A response is a behavioral, physiological or muscular activity initiated by a stimulus. For example, if you touch a very hot object accidentally, you will quickly pull your hand away from the hot object. In this example heat is the stimulus and the reaction of moving away the hand from the hot object is the response. Coordination in simple multicellular animals such as invertebrates takes place mostly through the nervous system. The control and coordination in higher animals such as vertebrates, takes place through the nervous system as well as hormonal system called the endocrine system. Coordination in plants is under the control of plant hormones called phytohormones.

Nervous coordination in humans

In humans, nervous coordination is done through the nervous system. The mammalian nervous system is made up of central nervous system and peripheral nervous system. The central nervous system (CNS) is made up of the brain and spinal cord whereas peripheral nervous system consists of nerve fibres. These nerve fibres branch from the central nervous system to all parts of the body as seen in Figure 3.1.

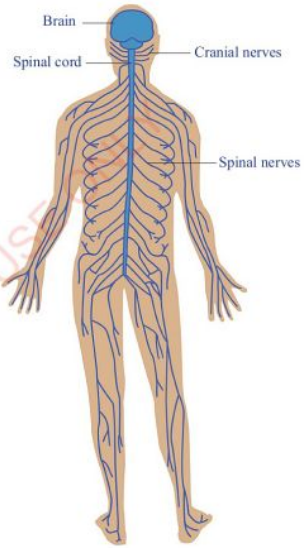


Figure 3.1: Human nervous system

Coordination is accomplished through a set of signals channeled into a series of nerve cells. Coordination in mammals involves three main components which are receptors, coordinators and effectors as illustrated in Figure 3.2.

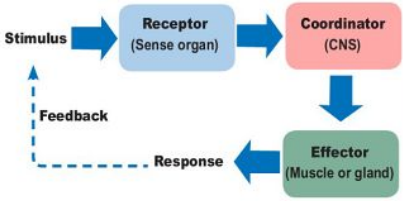


Figure 3.2: Components of coordination in mammals

Stimulus: A change in the external or internal environment to which an organism responds. Examples of stimuli are touch, pain, smell and sound.

Receptors: These are specialised cells that detect the changes in the environment. Examples of receptors are sense organs, including the eye, ear, nose, skin and tongue.

Coordinator: An organ that receives and interprets message from the receptors. Coordinators include the brain and the spinal cord. A coordinator uses messages to link activities in the body. The messages received are called nerve impulses.

Effectors: These are the cells, organs or organelles which receive motor impulses from the brain or spinal cord and bring about an appropriate response. The effectors include: Muscles, cilia, flagella and glands.

Response: This is any change shown by the organism responding to stimulus. Response may involve the movement of the whole or part of the organism's body. This movement can be either towards or away from the stimulus. Examples include the quick removal of the leg if pricked by a sharp object, or pulling the hand away if it accidentally touches a hot object.

Feedback: The animal decides what to do after the response.

Activity 3.1:

Investigating ways in which coordination is brought about

Materials

Books of the same size and a table

Procedure

1. Put several books of the same size in an upright position on a table in a straight line.
2. Push the first book so that it hits the second book.

Questions

1. What happens to the third book and the rest? Comment on the results.
2. What would happen if the chain of coordination components is broken?

The structure of neurones

The nervous system is mainly composed of specialised cells called neurones or nerve cells. Neurones are the conducting cells of the nervous system found between the receptors and effectors. They are basic structural and functional units of the nervous system. They are found throughout the body of an organism forming a network of communication. Neurones have properties which distinguish them from other cells in the animal's body. Compared to other cells, they are highly responsive to stimuli. They are also highly capable of conducting nerve impulses (messages). They are responsible for transmission of impulses from one part of the body to another.

Structurally, the neurone has a cell body which contains a nucleus with at least two protoplasm processes. The cell body may be angular, oval, polygonal or star-shaped with dense granulated cytoplasm. Extending from the cell body are one or more extensions called dendrites. These receive signals from the sensory receptors and direct them to the cell body. A neurone also contains long extension called an axon as shown in Figure 3.3. An axon is a long, stem-like part of the cell that sends signals to the next cell. Inside the axon there is a space called axoplasm which contains charged ions. In some cells, axons are covered by a fatty layer known as myelin sheath. Inside the myelin sheath there is a cellular layer called neurilemma which form the outer layer of Schwan cells. The myelin sheath have periodic gaps called nodes of Ranvier in the insulating myelin sheath. These serve to facilitate the rapid conduction of nerve impulses. Myelin sheaths are therefore essential for rapid propagation of nerve impulses. They also nourish and insulate the axon. The terminal end of the axon is extended to form axon terminal.

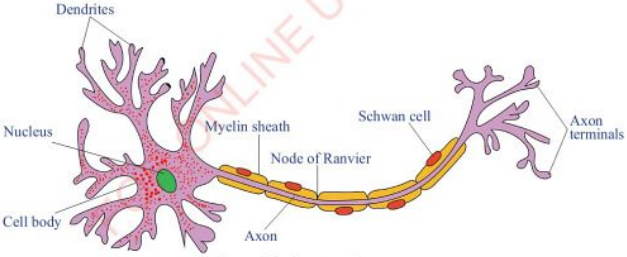


Figure 3.3: Structure of neurone

In higher animals neurones or nerve cells occur in bundles and they are called nerves. They are wrapped in a layer of connective tissues.

Activity 3.2:

Comparing the structure of a typical neurone and electrical cable

Materials

Electrical cable covered with plastic insulators

Procedure

1. Take a piece of electrical cable covered with plastic insulator.
2. Cut it to observe its cross section.

Questions

1. Which part of the cable is equivalent to;
   (a) neurone? (b) myelin sheath?
2. Compare the structure and function of the electrical cable and that of Figure 3.3.

Types of neurones

Based on the structure and functions, there are three types of neurones which are sensory, interneurone (intermediate or relay) and motor neurones.

Sensory neurone

Sensory neurones are also known as afferent neurones. These are neurones with a long dendron and short axon as shown in Figure 3.4. The cell body and dendrites of the sensory neurones mostly lie outside the brain and spinal cord. They are responsible for transmitting nerve impulses from the sensory receptors to the central nervous system (CNS) for interpretation. Sensory neurones have two long fibres, a dendron, which conducts impulses from a sense organ to the cell body of the neurone, and axon, which conducts impulses from the cell body to the central nervous system.

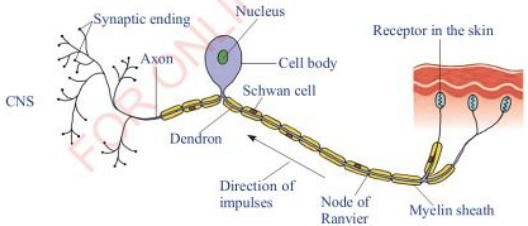


Figure 3.4: Structure of sensory neurone

Motor neurones

Motor neurones are also called efferent neurones. They have short dendrites and a long axon as shown in Figure 3.5. Their dendrites and cell bodies are located in the CNS and the end part of the axon is located in an effector organ. Motor neurones transmit nerve impulses from the CNS to the effector organs such as muscles or glands. The cell body collects impulses from other neurones through hundreds of tiny fibres called dendrites. A long, single axon carries these impulses from the cell body to a muscle fibre or gland. At the point where an axon of a motor neurone enters a muscle fibre, there is a structure called a motor end plate. When impulses reach the motor end plate, they set off chemical reactions that result in muscular contraction.

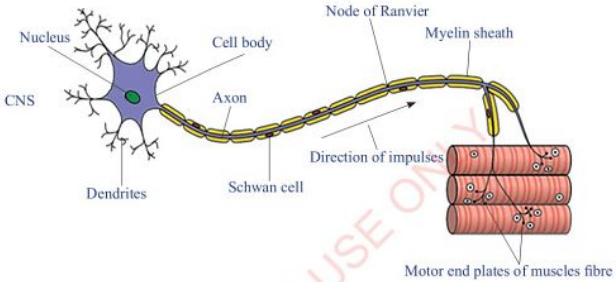


Figure 3.5: Structure of motor neurone

Interneurones (relay or intermediate neurones)

These are neurones which are found exclusively in the central nervous system (brain and spinal cord). They are also called connector neurones. They are much smaller nerve cells with many interconnections. Unlike sensory neurones, these neurones have short dendrites and short or long axon as shown in Figure 3.6. They connect the sensory neurones and motor neurones thus, facilitating the transmission of nerve impulse between sensory and motor neurones. The terminal part of a dendron of the interneurone receives impulses from the terminal part of the axon of the sensory neurone. Impulses from the axon of the interneurone are passed to the dendrites of the motor neurone.

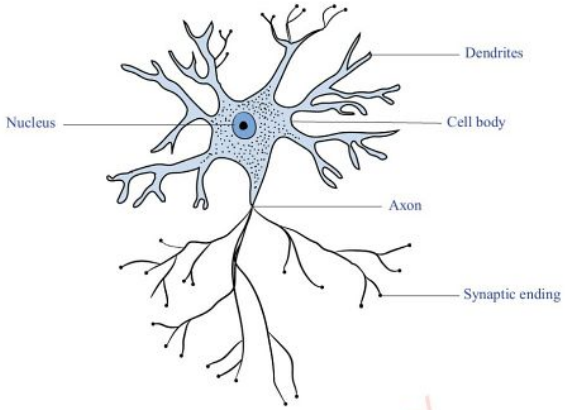


Figure 3.6: Structure of interneurone

Adaptation of a neurone to its function

There are several features which enables neurones to carry out their functions efficiently. Axons of some neurons are covered by myelin sheath which offers protection and insulation to the cell. The myelin sheath also facilitates rapid transmission of impulses. Neurones have Schwann cells that secrete myeline sheath. In addition, a neurone is provided with many dendrites which provide large surface area for transmission of impulses. Neurones are distributed in all parts of the body of living organism in order to facilitate effective transmission of impulses from one part of the body to the other. Some neurons have elongated axons so that they can carry information in the body over long distances. Presence of tiny branches, the dendrites at the end of each neurone facilitates it to receive nerve impulse from other neurones.

Nerve impulse

A nerve impulse is the electrical signal that travels along the axon. These signals are produced when the nerve cells are activated. Since the nerve fibre of one neurone is not in direct contact with that of another neurone, there is a gap at the point where the axon terminals of one neurone are in association with the dendrite or cell body of another neurone, or an effector organ. This is called a synapse and its gap is called synaptic gap or synaptic cleft.

Exercise 3.1

1. Explain how the neurone is adapted to its function.
2. With the aid of a diagram describe the components of coordination in mammals.
3. Explain the structural differences between motor and sensory neurones.
4. Describe the differences between sensory neurone and interneurones. How are the two related?
5. In which ways is coordination important to organism?

The Central Nervous System

The central nervous system (CNS) is the part of the nervous system consisting primarily of the brain and spinal cord. The CNS is named so because it integrates the received information, coordinates and influences the activities of all parts of the body. It is composed of a mass of nerves. The central nervous system analyses impulses received and determines what actions should be taken in response to stimuli. The spinal cord serves as an impulse-conduction pathway. Nerve impulses transmitted by the spinal nerves are relayed to the brain. Nerve impulses from the brain are sent to the spinal cord. From the spinal cord, impulses are transmitted to the effector organs.

The brain

The human brain is a specialized organ that is responsible for thinking, memory storage, and coordinating the functions of many body organs. The brain makes up the largest portion of the central nervous system. It is delicate and it is encased in the skull where it is protected by the cranium as shown in Figure 3.7. The brain is housed in a system of membranes called meninges. The human brain enables a person to think or reason and perform complex physical and mental activities. The brain also coordinates simple reflex actions. A reflex action is a rapid and automatic response to a stimulus. Generally, the functions of the brain includes, receiving impulses from all sensory organs of the body, interpreting the message, sending off motor impulses to glands and muscles and storing information. It also associates various stimuli from different sense organs. The association centres and motor areas coordinate body activity so that the mechanical and chemical actions of the body work efficiently. The mammalian brain consists of three main parts; the fore brain, the mid brain and the hind brain.

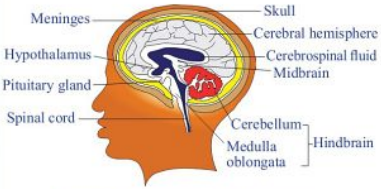


Figure 3.7: Structure of the human brain

Forebrain

The forebrain is the anterior part of the brain. It is composed of olfactory lobes, which are concerned with smell, and the cerebrum which interlinks impulses and coordinates responses. The roof of the forebrain is enlarged and folded to form the cerebrum. This makes the brain more efficient because it increases the surface area of the brain and the amount of neurones within it. The cerebrum is the largest part of the brain. It is divided into two halves and these halves are called cerebral hemispheres. The two hemispheres are connected by nerve fibres and are in constant communication with each other. The outer portion is grey in colour due to the concentration of cell bodies of the nerve cells and is called grey matter. The inner portion is white in colour due to high concentration of axons and it is called white matter. The cerebrum controls all voluntary activities of the body. It is responsible for speech, reasoning, memory, decision making, behaviour and imagination. The cerebrum also controls activities such as running, walking, eating and playing. It is also the centre of intelligence and will power. The cerebrum is extremely active in humans compared to other animals. Thus humans are the most imaginative animals and are said to be the most intelligent organisms.

Midbrain

The midbrain is the smallest part of the brain that connects the hindbrain with the forebrain. The optic lobes are found between the forebrain and hindbrain. The function of the midbrain is to convey information between the forebrain and hindbrain. The optic lobes convey information between the forebrain and the eyes. Optic nerves which link the brain and the eyes originate from this region.

Hindbrain

The hindbrain is composed of the cerebellum and medulla oblongata. The cerebellum is concerned with balance and posture. It receives impulses from skeletal muscles, tendons and the inner ear. These impulses are relayed to the forebrain where they are processed. The cerebellum also receives impulses from the organs in the inner ear and from stretch receptors in joints and muscles. Stretch receptors measure the degree of bending at a joint and the degree of tension in muscle fibres. This information is used to achieve balance and muscular coordination in activities such as walking, running or riding a bicycle.

The medulla oblongata is the most posterior part of the brain. It controls involuntary and reflex activities such as breathing, heartbeat, digestion, dilation and constriction of blood vessels, secretion of juices from glands and temperature regulation. Most of the time a person is not aware of these processes. However, excessive stimulation of the medulla may result in impulses being sent to the cerebrum where conscious activities are processed. In addition, during periods

of emotional stress impulses travel from the cerebrum to the medulla causing an increased rate of sweating, heartbeat and breathing. Therefore, prolonged emotional stress can result in high blood pressure.

Cranial nerves

Cranial nerves are pairs of nerves that connect the brain to different parts of the head, neck, and trunk. There are different cranial nerves, each being named depending on its function or structure. An example of cranial nerves include olfactory nerves which transmit sensory information regarding smell to the brain from the nose, optic nerves which link the eyes and brain, and vestibulocochlear nerves which are involved in hearing and balance of the body.

Hypothalamus

The hypothalamus is a small region of the brain located at the base of the brain near the pituitary gland. Although it is very small, it plays a crucial role in many important functions such as releasing hormones and regulating body temperature. It also controls involuntary activities such as appetite and sleeping.

Pituitary gland

The pituitary gland is a small pea-sized gland that plays a major role in regulating vital functions and general wellbeing of the body. It is referred to as the master gland because it controls the activity of most other hormone-secreting glands.

Activity 3.3:

Investigating the structure of brain and spinal cord

Materials

Model of the human brain and spinal cord

Procedure

1. Study a model of the human brain and spinal cord.
2. Examine the external surfaces of the brain. Is the surface smooth or folded? Think about the biological significance of this type of surface.
3. Identify the regions of the brain. Comment on their size.

Question

Draw and label the diagram of the brain to show its different parts.

The spinal cord

The spinal cord runs from the head to the end of the trunk and is encased in meninges. It lies in the canal of the vertebral column and thus it is protected from mechanical damage. A cross section of the spinal cord in Figure 3.8 shows that it is made up of two identical halves. The two halves enclose the spinal canal which is at the centre of the spinal cord. The spinal canal is filled with cerebrospinal fluid, which helps to protect the spinal cord from shocks. The inner region of the spinal cord consists of grey matter. The grey matter is grey in colour due to

high concetration of cell bodies of neurons. The cell bodies transmit impulses between sensory and motor neurones. The outer region of the spinal cord consists of white matter. The white matter is composed of the nerve fibres or axons of sensory and motor neurones. The myelin sheath of the nerve fibres gives this region the white colour. These nerve fibres are known as spinal nerves. The spinal nerve divides close to the spinal cord to form two branches; dorsal and ventral roots. Sensory fibres enter through dorsal root while motor fibres leave the spinal cord through ventral root.

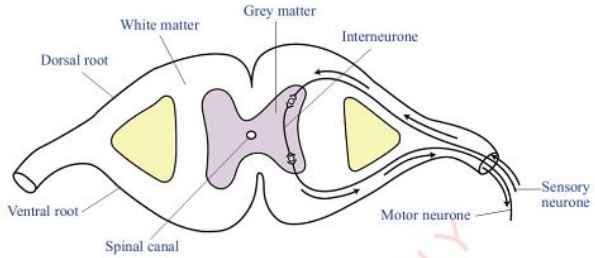


Figure 3.8: Cross-section of spinal cord

Function of spinal cord

The spinal cord serves as a nerve impulse conduction pathway. Nerve impulses transmitted by the spinal nerve are relayed to the brain. Nerve impulses from the brain are sent to the spinal cord. From the spinal cord nerve impulses are transmitted to the effector organs. Furthermore, the spinal cord acts as a coordinating centre. It controls involuntary actions. Involuntary actions are the actions which are fast and automatic and cannot be controlled by will-power and need not to be learnt. Such responses are called reflex actions. Examples of reflex actions include; coughing, sneezing, blinking and removing a hand or leg when it accidentally touches a hot or sharp object.

Exercise 3.2

1. Explain the functions of the hypothalamus.
2. Name the components that make up the spinal cord.
3. What are the structural and functional differences between white matter and grey matter of the spinal cord?
4. Draw a well labelled diagram showing the structure of the human brain and describe the function of each part.

The peripheral nervous system

All nerves that link the body to the brain and spinal cord make up the peripheral nervous system. The peripheral nervous system can be divided into voluntary (somatic) and involuntary (autonomic) nervous system as shown in Figure 3.9. The voluntary nervous system is composed of sensory and motor neurones that link the central nervous system and skeletal muscles. It is concerned with activities under the direct control of the brain, such as kicking a football. The involuntary nervous system is composed of sensory and motor neurones that link the central nervous system and smooth muscles of the internal organs. It is concerned with unconscious activities in the body, such as the heartbeat, peristalsis and sweating. The peripheral nervous system is summarized in a flow chart below.

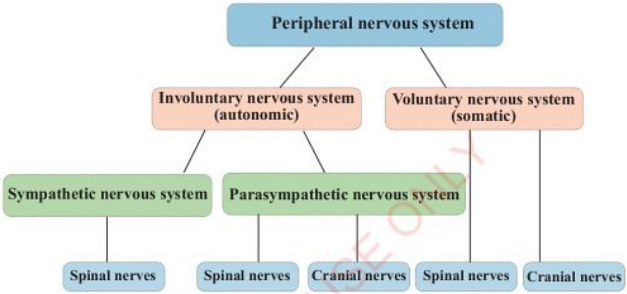


Figure 3.9: Peripheral nervous system

The peripheral nervous system also comprises of cranial and spinal nerves. The cranial nerves arise from the brain and they form receptors and effectors in the head. Generally, the function of these nerves is to transmit impulses from the sensory organ to the brain for interpretation. The spinal nerves arise from the spinal cord through the inter-vertebral foramen of the vertebrae. The spinal nerves occur in pairs and each with two roots namely dorsal and ventral root. These two roots join together before they pass through the inter-vertebral foramen. The dorsal root is made up of sensory nerve fibres whereas ventral root is made up of motor nerve fibres.

The autonomic nervous system controls the involuntary actions of smooth muscles and certain glands. It is divided further into the sympathetic nervous system which has mainly excitatory effect on the body, and the parasympathetic nervous

system which has mainly calming influence. The two systems oppose each other in action. For example, if the sympathetic system causes the muscles to contract, the parasympathetic system causes the muscles to relax. Also, if the sympathetic system constricts the arteries, the parasympathetic system dilates the arteries. Other examples are shown in Figure 3.10.

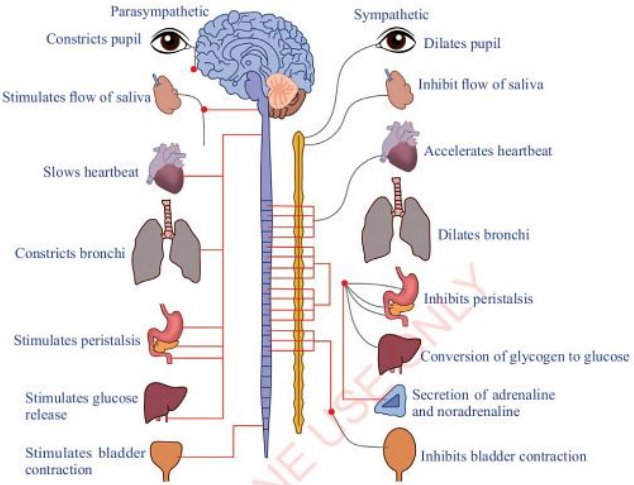


Figure 3.10: Sympathetic and parasympathetic nervous system.

Activity 3.4:

Exploring the reactions of the sympathetic and parasympathetic nervous systems.

1. From your experiences and also by referring to figure 3.10, explain various occasions where your sympathetic nervous system took control of your body. What caused you to become excited? What kind of feelings did you get?
2. Describe what happened when your parasympathetic nervous system took over for each occasion in question 1 above. Give reasons.

Reflex action

A reflex action is a rapid, automatic response to a stimulus. A reflex action is made possible by neural pathways called reflex arcs which carry the impulses to and from the spinal cord. Thus, this pathway does not involve the brain. Examples of reflex action includes; the changes in size of the pupil when subjected to bright or dim light, sudden withdrawal of hand or leg when pricked by a sharp or hot object, coughing or sneezing, knees jerk in response to a blow or someone stamping the leg, and salivation at the sight or smell of food.

The neural pathway of a reflex action

A reflex arc is a neural pathway that links sensory receptors and effectors, such as muscles. In its simplest form, three neurones are involved in the reflex arc: sensory, intermediate and motor neurones. Figure 3.11 shows a reflex action involving the quick removal of the hand from hot plate. Temperature and pain receptors in the skin stimulate sensory neurones and impulses generated are conducted to the spinal cord for interpretation. Impulse travels from one nerve cell to another via a gap called synapse. It is also a transmission site between a neurone and an effector cell or organ. They are microscopic gaps that separate terminal buttons of one neurone from dendrites of another. The synapse is also known as neural junction. The sensory neurones carrying the impulse enter the dorsal root of the spinal cord from synapse with intermediate neurones in the grey matter. The intermediate neurones synapse with motor neurones. The motor neurons carrying the interpreted impulse leave the spinal cord by the ventral root and stimulate muscle cells to contract and eventually pull the hand from the hot plate. When a sufficient number of muscle fibres contract, the hand will automatically pull away from the hot plate.

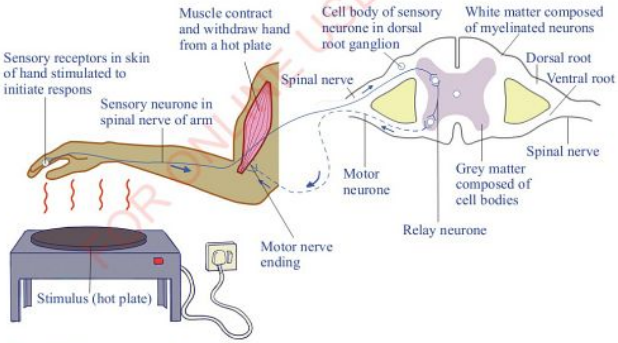


Figure 3.11: Example of reflex arc showing sequence of events when responding to painful stimulus.

Distinguishing a simple reflex action from a conditioned reflex action

A simple reflex action is an automatic response that is not learnt. Simple reflex actions are always quick and automatic. An example of reflex action is knee jerk. The knee jerk reflex produces the same response even if it is done many times. This is the characteristic of reflex action that is, the same stimulus will always result into the same response. In reflex action response is coordinated by the spinal cord. In the simplest reflex action there is no involvement of relay neurone. The stimulus passes directly from the sensory to motor neurone and only one synapse is involved.

There are various reflex actions taking place in the body that we do not become aware of. These actions allow the body to maintain internal body environment. Examples of such actions include breathing rate and blood pressure.

A conditioned reflex is a type of reflex action where the response is affected by past experience. Conditioned reflexes are acquired through learning, but can subsequently be performed without conscious thought. These reflexes are coordinated by the brain. Examples of conditional reflex action is when a dog salivates when it sees food presented to it. If a bell is rung just before food is presented to the dog routinely the dog will learn to associate bell ringing with food. In human beings conditioned reflex is seen during riding a bicycle, driving a car and typing documents on a computer or typewriter. These are learned behaviours that become automatic with experience.

Table 3.1: The differences between Simple Reflex action and Conditioned Reflex Action

S/N	Simple Reflex Action	Conditioned Reflex Action
1	Inborn response to external stimuli that is not learnt	Learnt or modified patterns of behavior gained through experience
2	Are the same in all members of a species	Differ from one member to another of the same species
3	Initiated by a related stimulus	Initiated by an unrelated stimulus substituted by the one which normally initiates the response
4	Single stimulus brings about response	Combined stimuli that when the pattern is repeated brings about response
5	Response coordinated by spinal cord	Response coordinated by the brain

Activity 3.5:

Observing the reflex actions

Materials
Chair

Procedure

1. Sit on a chair with your right leg resting on the knee of the left leg and swinging freely. Ask your partner to tap the patella tendon (just below the knee cap).
2. Press your left hand hard onto the thigh of your right leg. Ask your partner to tap the patella tendon again.

Question
Discuss your observations with your classmates.

Exercise 3.3

1. Differentiate between the following;
   (a) Autonomic and somatic nervous system
   (b) Simple and conditioned reflex action
2. Explain the neural pathway of the reflex action.
3. Explain the importance of simple reflex actions in human body.
4. What types of neurons are involved in a simple reflex arc?

Sense organs

The body of a living organism gathers information about its external and internal environment through sensory or receptor cells. Receptors are the cells or nerve endings or groups of nerve endings specialised for reception of stimuli and change the stimuli into specific nerve impulse. The coordinated activity of an organism relies upon a continuous input of information from internal and external environments. The specialised cell of the body which has the ability of detecting the stimulus is known as sensory receptors.

Sense organs are specialised organs composed of sensory receptors responsible for receiving and responding to stimuli around us. These stimuli include touch, heat, pressure, light, smell, taste and sound. In mammals, there are five major sense organs namely; the ear, the eye, the nose, the tongue, and the skin. Each sensory receptor responds to only one specific stimulus. For example; the sense organ sensitive for smell will not detect the stimulus of heat.

Activity 3.6:

Observing sense organs in human body

Materials
Plain mirror

Procedure
1. Hold a mirror in front of your face with one hand.
2. Look at the mirror while your mouth is open.

Questions
(a) Which sense organs can you see?
(b) Explain the functions of the sense organs you have seen.

The mammalian skin

The skin forms the outer covering of the body of the living organism. It is the largest organ in the body. It protects the body and helps to regulate body temperature, and responds to pain, pressure, touch, heat, and cold sensations. Structurally, the skin consists of two main layers namely; the epidermis and the dermis as shown in Figure 3.12. The epidermis is the outermost layer of the skin consisting of three layers called malpighian, granular and cornified layers. The malpighian layer consists of living and dividing cells. Granular layer contains living cells on its inner surface close to the Malpighian layer. The outer layer is composed of dead cells which eventually form the cornified layer. The cornified layer form the outer most layer of the skin. This layer is formed by dead horny cells. It prevents the entry of germs into the body and also reduces water loss.

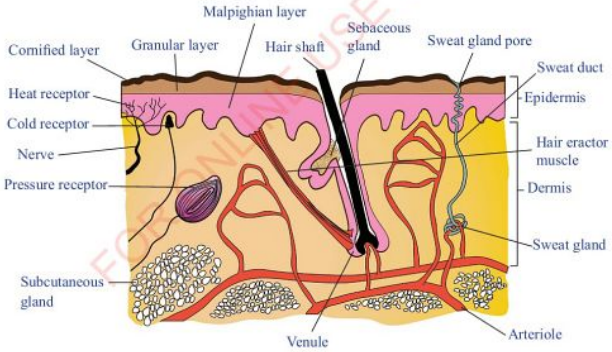


Figure 3.12: Cross section of human skin

The dermis has numerous blood capillaries, nerve endings, fat deposits, hair follicles (roots) and the inner ends of the sweat glands. The structures found in the dermis have different functions. For example, sweat glands produce a waste fluid called sweat. The evaporation of sweat cools the body. Erector muscles raise the hairs in the skin. Raised hair and fat help to conserve heat in the body. Sebaceous glands secrete sebum, an oily fluid which prevents cracking of the epidermis. The dermis also contains touch, pain, pressure and temperature receptors as seen in Table 3.2. The blood vessels assist in maintaining body temperature and nourishing the skin by supplying food and oxygen to the skin and remove excretory products.

Table 3.2: Skin receptors

Receptor	Location	Function
Thermoreceptors	In the dermis	Sensitive to temperature changes
Low temperature (cold) receptors	In the dermis, at the base of the dermis	Sensitive to low temperature
High temperature receptors	In the epidermis (malpighian layer)	Sensitive to high temperatures, above 30°C
Touch receptors	In the lower part of the dermis	Sensitive to touch. They enable a person to distinguish between different textures. They are more concentrated on fingers
Pressure receptors	In the lower part of the dermis, evenly distributed throughout the skin	Sensitive to pressure
Pain receptors	Free nerve endings below the dermis	Sensitive to pain Protect the body against harmful stimulus by initiating reflex actions

The functions of the skin

The skin has many functions. These functions include;

1. **Protection**: the skin protects the body against desiccation, wear due to friction with external bodies and entrance of bacteria that cause disease. The skin also produces melanin which protects the body from ultraviolet radiation which can cause skin cancer.
2. **Excretion**: sweat glands produce a fluid called sweat. Sweat consists of water and small quantities of nitrogenous waste. Salts are also excreted through sweat.
3. **Temperature regulation**: heat produced by respiration is distributed by the blood and is largely lost to the air as blood flows through the capillaries in the skin. Heat is lost from the skin by radiation, convection, conduction and evaporation.
4. **Manufacturing of vitamin D:** the skin manufactures vitamin D through exposure to sunlight. The fatty layer of the skin is converted into vitamin D under the influence of sunlight.
5. **Sensation**: the skin is responsible for sensation of pain, pressure, touch, and temperature change.

Adaptation of skin to its function

Human skin is adapted to its functions as the sensory organ by having the following features;

1. Skin has sweat glands which produce sweat that helps to cool the body. During a hot day, the glands produce sweat through pores on the skin. Evaporation of sweat lowers body heat and hence helps to cool the body.
2. It has hair erector muscles which controls the erection and laying down of hairs depending on the changes of temperature in the environment.
3. It is supplied with nerve endings which transmit impulses to central nervous system for interpretation.
4. Presence of the blood vessels which dilate when the body temperature is high to facilitate heat loss by radiation and constrict when the temperature is low to reduce heat loss. The blood vessels also supply food and oxygen to the skin and remove excretory products.

The mammalian ear

The ear is the organ for hearing and maintenance of body balance. It detects sound waves and vibration. It also provides information on the position of the organism. The mammalian ear is composed of three parts; the outer ear, the middle ear and the inner ear as shown in Figure 3.13.

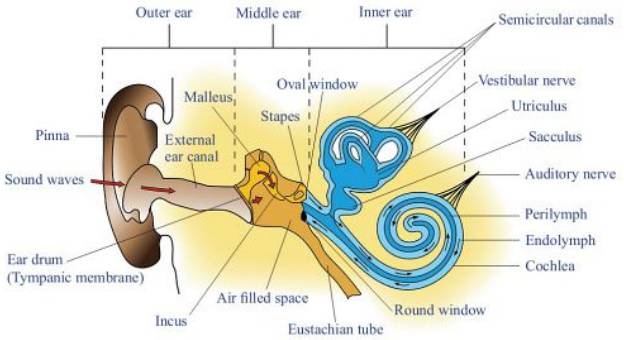


Figure 3.13: Structure of the mammalian Ear

Outer ear

The outer ear is made up of an external flap of skin covered by an elastic cartilage called pinna. The pinna collects sound waves and directs them into the ear canal. The canal is called external auditory meatus and its function is to pass sound waves to the middle ear. Across the end of ear canal is a tympanic membrane or ear drum which separates the outer ear from middle ear. The opening of the auditory canal is lined with fine hairs and glands which secretes ear wax. The glands are located in the upper wall of the auditory canal. Ear wax guards the ear against entrance of foreign materials such as dust and microorganisms.

Middle ear

The middle ear is positioned between tympanic membrane and ends up at a bony wall containing two small openings covered by membranes. The two openings are oval window which is also called fenestra ovalis and round window which is also known as fenestra rotunda. The middle ear is made up of three bones or ear ossicles held in position by muscles. These ear ossicles are malleus (hammer), incus (anvil) and stapes (stirrup) as shown in Figure 3.14.

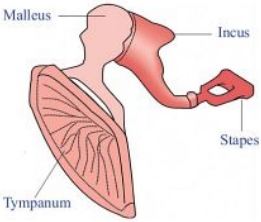


Figure 3.14: Structure of middle Ear

The middle ear is filled with air which maintains equal pressure outside and inside the ear to prevent damage to the ear drum. There is a Eustachian tube (auditory tube) which connects the middle ear to the pharynx. Air enters and leaves the middle ear via this tube during swallowing to equalize pressure.

Inner ear

The inner ear consists of a cavity containing fluid called perilymph. It contains a membranous and bony labyrinth composed of two large sac-like structures, known as the utriculus and sacculus. There are also three semicircular canals and a coiled tube called the cochlea as shown in figure 3.13.

The semicircular canals are attached to the utriculus. Each canal has a swollen base known as the ampulla. The ampulla is concerned with balance. The cochlea is the organ of hearing. It has a tube filled with a fluid called endolymph. This fluid is present in all parts of the bony tubes of the inner ear (labyrinth). The cells lining the inner surface of the cochlea and the ampulla are sensory and are connected to auditory nerves, which send impulses to the brain.

Mechanism of hearing

The pinna collects sound waves from the surroundings and direct them to the middle ear through external auditory meatus which end up to the tympanic membrane. Sound waves cause the membrane to vibrate. When the tympanic membrane vibrates back and forth, it forces the ossicles that is malleus, incus and stapes to vibrate in the same way. This causes the stapes to move rapidly forwards and backwards like a piston in the oval window. The connected ossicles increase the force of vibration and as a result it amplifies the sound waves.

The vibrations of the stapes against the oval window set up waves in fluids in the cochlea. The vibrations of the fluid cause the basilar membrane to vibrate. This stimulates the sensory hair cells (organ of corti) on basilar membrane to send the nerve impulses to the brain through auditory nerves. When the waves reach the auditory area of the cerebral cortex, they are interpreted as sound. The magnitude of the impulses transmitted to the brain determines the pitch or loudness of the sound. The louder the sound, the greater the number of sensory hair cells that will be stimulated at any point of the basilar membrane. See Figure 3.15.

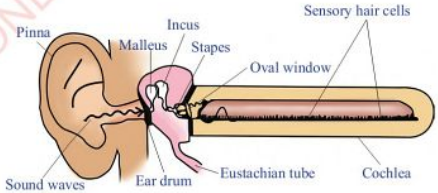


Figure 3.15: Mechanism of hearing

Balance

The semicircular canals and vestibular apparatus (utriculus and succulus) shown in Figure 3.16 are concerned with balance of the body. They contain sensory receptors which detect movements of the head. The three semicircular canals contain fluid called endolymph which communicates with the middle chamber of the cochlea via the utriculus and sacculus. When the head moves, the endolymph also moves. Semicircular canals are stimulated mainly by rotational movement whereas the utriculus responds to positional changes. The inner surface of utriculus and sacculus contain sensory cells. The sensory hair cells have protruding hair embedded in jelly-like substance containing particles of chalk known as otoliths. When the head is tilted to one side the otolith is moved in the opposite direction, pulling the sensory hairs. The sensory cells send nerve impulses to the brain which interprets them as a change in posture. If you spin around for some time and then stop, you feel dizzy because the fluid in your ears keeps on moving even after you have stopped.

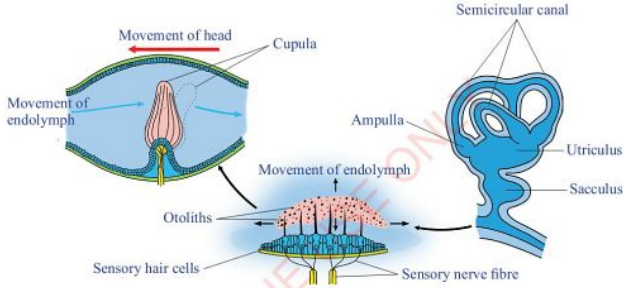


Figure 3.16: Positions of the semicircular canals, ampular, utriculus and sacculus

Disorders of the ear

Proper hearing depends on the efficient transmission of sound waves from the external ear to inner ear and the response of the sensory cells. Any interference with these will result into hearing disorders.

Deafness is the most obvious disorder of the ear. It can be caused by damaged ear drum, malfunctioning of the ear or a diseased ear ossicle. People who are deaf because of damage of the ear drum or ear ossicles can be helped by wearing a hearing aid. The hearing aids picks up sounds and transmits them through the osscicles to the cochlea.

Ear infections often occur through the throat because the ear is connected to the throat by the **Eustachian tube**. Microbes

can pass from the throat through the Eustachian tube in the chamber of the middle ear. The infection may stop the ear ossicles from vibrating freely and cause some degree of deafness. Sometimes infection can reach the balancing organs of the ear and cause dizziness.

Hearing disorders can also be caused by damage of auditory nerves due to nervous disease, improper administration of medication, accidents and exposure to loud sound.

Activity 3.7:

Investigating the mechanism of balance

Procedure

In pairs, spin around for some time and then stop.

Questions

What happened after spinning around and stopping? How did you feel?

Adaptation of the ear to its functions

The following are the adaptations of the ear to its functions:

1. The presence of pinna which helps to collect the sound waves from the external environment and directs them into the ear canal.
2. The presence of the tube-like canal which directs the sound waves to the ear drum.
3. The existence of the ear ossicles which increase the force of the vibration and amplify the sound.
4. Presence of fluid filled semicircular canals and utriculus which help the body to maintain its balance.
5. The presence of the sensory hair cells that facilitate the detection of the sound waves.

The mammalian eye

The eye is an organ for vision which receives light from the environment and converts it into electrical impulses. It is roughly spherical in shape and located in a bony socket called orbit in the skull. The orbit protects the eye against physical damage. The eye has also a layer of fat deposits around the eyeball which offers protection by acting as shock absorber against mechanical injuries. The principal function of the eye is to control the amount of light entering it and focus the image from the surroundings so that the objects can be seen.

Externally, the eye is protected by eyelids, eye lashes and eyebrows as shown in Figure 3.17. An eyelid is a thin fold of skin that covers and protects the eye externally against entry of foreign particles. There are two eyelids namely upper and lower eyelids. They are able to move and as the result keep the surface of the eye moist. The movement of eyelids is called blinking. The upper eyelid of the eye secretes a saline fluid which contains enzymes that offer protection to the eye by killing microorganisms that can attack the eye. Eye lashes are fine hairs that grow at the edge of eyelid. They perform the function of protecting the eye from entry of small foreign particles such as sand and dust. The eyebrow is an area of thick, short hairs above the eye that follows the shape of the lower margin of the brow riges. Their main function is to prevent sweat, water, and other debris from falling

down into the eye socket. They are also important in human communication and facial expression.

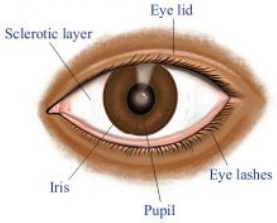


Figure 3.17: Front view of mammalian external eye

Structurally the eye is made up of three layers of tissues which are called sclerotic layers or sclera, choroid and retina. The outer most layer of the eye is extremely tough and it is called the sclera. This layer protects, supports, and maintains the shape of the eyeball. The sclera is white in colour except the front part which is transparent and it is called cornea. It also contains elastic connective tissues. The cornea is the transparent part of the eyeball which is continuous with the sclera and is covered with a thin membrane called conjunctiva. Cornea is convex so that light rays can be refracted, and since it is transparent, it allows light to pass through.

The conjunctiva is a thin transparent membrane which is found inside of the eyelids covering the front of the sclera as shown in Figure 3.18. Conjunctiva helps to cover and protect the cornea because it has tough and transparent membrane. Thus, it offers protections of the inner part and also allows light to pass through.

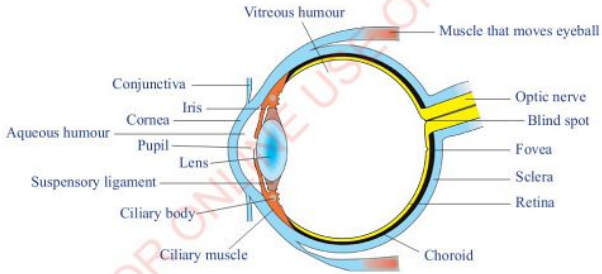


Figure 3.18: Vertical section of human eye

The middle layer is choroid; this layer is highly pigmented. It is a nutritive layer which is located just next to sclera. The layer extends to the front part of the eye where it forms ciliary body and iris. The choroid also contains a network of blood vessels which nourish and supply oxygen to the eye. This layer has black coloured pigments on its wall. All the light entering the eye is absorbed by the black pigment in the choroid.

Iris is a ring of contractile muscles which is an extension of the ciliary body. This part is made up of two sets of muscles called circular and radial muscles. These muscles are able to contract and relax. The contraction and relaxation of these muscles control the size of the pupil and amount of light entering the eye. The iris is highly pigmented and offers the eye its colour. The colour of the iris differs from one individual to another and may be black, blue or brown.

Ciliary body is a circular structure that is an extension of the iris and it is the coloured part of the eye. The ciliary body produces the fluid called aqueous humor. It also contains the ciliary muscles. When the eyes focus on an object they contract and relax, and they change the shape of the lens.

Pupil is an opening at the centre of the iris through which light enters the eye. The pupil changes in size as the iris changes in shape when one is in dim or bright light. It appears black because light rays entering the pupil are absorbed by the black pigment of the choroid.

Lens is a biconvex transparent structure behind the iris held in position by the suspensory ligaments. The shape of the lens is altered by the action of the ciliary muscles. The process of changing the lens shape is called focusing. The lens is transparent; therefore, it allows light to pass through it.

Retina is the inner layer of the eye. It contains light sensitive cells (photoreceptors) which are the rods and cones. Rods are very sensitive to light of low intensity, and are used for vision in dim light while cones are sensitive to light of high intensity (bright light) and enable us to see colours. Cones are highly packed together in a region called fovea which increases the visual acuity. The **fovea** centralis (yellow spot) is the region that is directly opposite to the lens and is the most sensitive part of the retina.

Blind spot is the area found in the retina through which the optic nerves leave the eyeball. The blind spot is not light sensitive because it does not contain rods or cones.

The eyeball contains two cavities; a large posterior portion which is filled with transparent jelly-like fluid called vitreous humour and a small anterior portion filled with watery fluid called aqueous humour. The humours maintain the shape of the eye. Vitreous humour is replaced continuously. Both vitreous and aqueous humour refract light and since they are transparent they allow light to pass through. Some parts of mammalian eye have similar functions as the parts of a camera as shown in Table 3.3.

Table 3.3: Comparison between mammalian eye and camera

Part in mammalian eye	Part in camera	Function
Iris	Diaphragm	Regulate amount of light entering
Lens	Convex lens	Focuses light
Retina	Sensitive film	Formation of image
Lens changes in thickness	Lens move back and forward	Accommodation (adjustment to different focuses)
Choroid	Black surface	Prevent internal reflection of light.

Activity 3.8:

Investigating the control of the intensity of light entering the eye

Materials

Source of light and a mirror

Procedure

1. Work in pairs. Examine the pupil of your partner's eye in dim light.
2. Shine the light in the eye and note the effect.
3. Look at your right eye in a mirror. Cover your left eye by hand for one minute remove the hand and observe in a mirror.

Questions

(a) Explain the changes in pupil size in each case.

(b) What does step 3 tell you about the mechanism controlling pupil size in both eyes?

Accommodation

This is the ability of the eye to adjust the structure of the lens in order to focus the image on the retina. Accomodation involves two processes namely; reflex adjustment of the pupil's size and refraction of light rays. When the eye focuses on a nearby object, the divergent light rays are refracted by cornea, ciliary muscles contract while suspensory ligaments relax, the lens becomes more convex (fatter) and light rays is focused on retina as shown in Figure 3.19(b). When the eye focuses on distant objects, parallel rays are refracted by the cornea, ciliary muscles relax while suspensory ligaments contract, lens become less convex (thinner) and light rays are focused on the retina as shown in Figure 3.19(a).

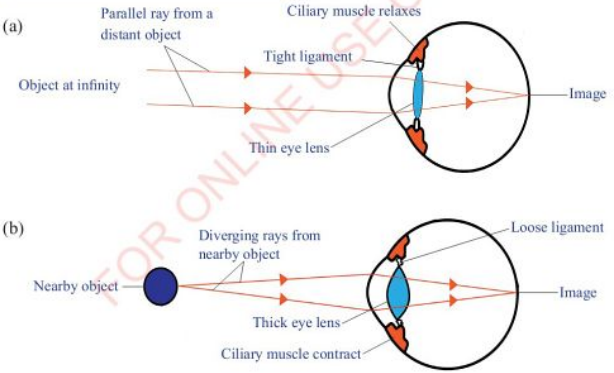


Figure 3.19: Accomodation of an eye (a) distant object (b) nearby object

Mechanism of seeing

The eye works on the same principle as the camera works. Light rays from an object travel through the conjunctiva, cornea, aqueous humour, pupil, lens, vitreous humour and finally fall on the fovea centralis of the retina. In the process light is refracted (bent) before it falls on the retina to form an image. The curved surface of both cornea and lens bends the light rays that enters the eye in such a way that the image is formed on the retina. The image formed will be upside down (inverted) and smaller than the real object as shown in Figure 3.20. When the light rays strike the photoreceptors in the retina, impulses are created and transmitted in the sensory nerve fibres, which join to form the optic nerve. The optic nerve transmits the impulses to the brain where they will be integrated to enable a person to see the object in its correct orientation and its real size.

There are two types of light-sensitive cells in the retina which are rods and cones. The rods are stimulated by light of low intensity and are important for seeing in dim light. Rods are also responsible for black and white vision. In contrast, cones are sensitive to bright light and produce mainly a coloured image in the brain.

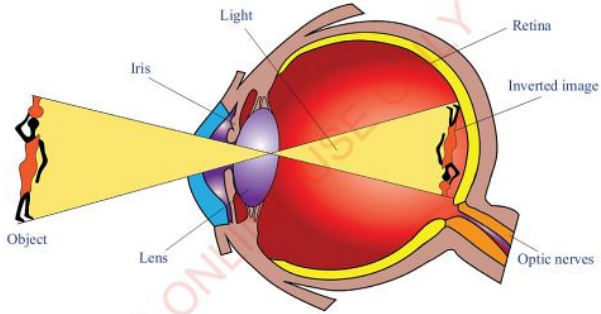


Figure 3.20: Structure of mammalian eye showing physiology of seeing

Defects of the mammalian eyes

These are functional and structural deviations of the eye that alter the focusing mechanism of an eye. The common defects of the eyes are short sightedness (myopia) and long sightedness (hypermetropia). However, there are other defects of the eye which include astigmatism and presbyopia.

Short sightedness (Myopia)

This is a defect of vision in which far objects appear blurred but near objects are seen clearly. The image of an object is focused in front of the retina in vitreous humour rather than on the retina as seen in Figure 3.21. This occurs because the refractive power of the eye's lens is too strong or the eyeball being too long which result in an increased distance between the lens and retina.

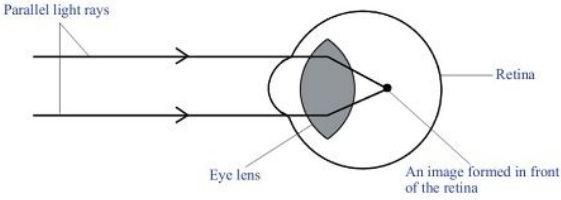


Figure 3.21: Short sightedness

This defect can be corrected by using a suitable concave spectacle lenses, which diverge the light rays entering the eyes to the correct extent and bring them into focus on the retina as seen in Figure 3.22.

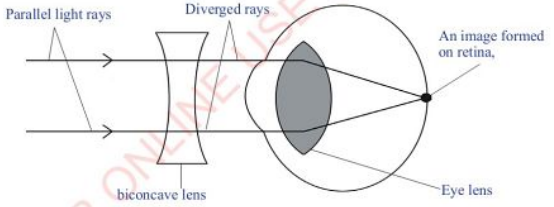


Figure 3.22: Short sightedness correction by concave lens

Long sightedness (hypermetropia)

This is a defect in which near object appear blurred but far objects can be seen clearly. The image is focused behind the retina rather than upon it as shown in Figure 3.23. This occurs when the refractive power of the eye's lens is too weak or when the eyeball is too short which result in shortening of the normal distance between lens and retina.

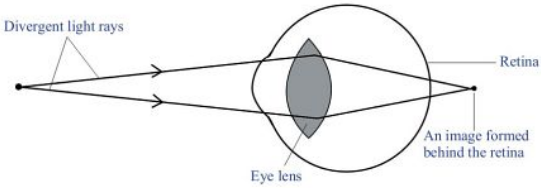


Figure 3.23: Long sightedness defect

This condition can be corrected by the use of a suitable **convex** spectacle lens, which converges the light rays entering the eye to the correct extent and brings them into focus on the retina as shown in Figure 3.24.

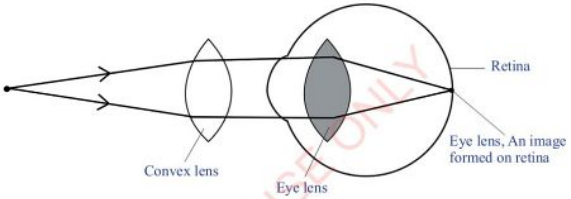


Figure 3.24: Long sightedness defect correction by convex lens

Astigmatism

This defect occurs when the eye does not focus light evenly on the retina, instead some light is focused on the retina while some is focused behind or in front of the retina. This is usually caused by a non-uniform curvature of the cornea. A typical symptom of astigmatism is if you are looking at a pattern of lines placed at various angles, the lines running in one direction appear sharp whilst those in other directions appear blurred. Astigmatism can usually be corrected by using a special spherical cylindrical lens. This is placed in the out-of-focus axis.

Cataract

Cataract is another eye defect that happens when the lens become opaque and will not let light through at all. This can be corrected through surgical removal and replacement of the lens with an artificial one.

Presbyopia

Presbyopia is an eye defect related to aging process. It is caused by gradual thickening and the loss of natural lens flexibility. Presbyopia occurs mostly to people over age of 40 years. The changes occur within the proteins in the lens by making the lens harder and less elastic over time. The changes also occur in the muscle fibres surrounding the lens. Because of the poor elasticity it becomes difficult for the eye to focus on close objects. It is corrected by wearing eye glasses with progressive lenses or bi focal lenses.

The nose

Humans detect smell by the use of receptor cells located at the roof of the nasal cavity in ciliated sensory cells. The nose is the olfactory organ with cells which detect smells in the nasal passages. See Figure 3.25. The epithelial layer of the nasal cavity has a special group of sensory cells that can be stimulated when chemicals dissolve in the moisture on their surface. These sensory cells are elongated, with processes that reach out in the mucus covering the epithelial layer of the nasal cavity. The mucus is secreted by certain cells in the epithelial layer and it keeps the surface of the nose moist at all times.

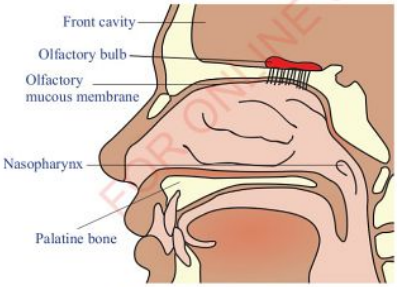


Figure 3.25: Human nose

The tongue

The tongue is a muscular organ in the mouth that is used to manipulate food for chewing and swallowing. The primary function of the tongue is to taste various substances. The lower surface of the tongue is smooth, while the upper surface is rough due to the presence of stratified squamous epithelium, with numerous papillae. These are sensory cells in the upper lining layer of the tongue. Sensory cells are also called gustatory cells and they have hair like processes projecting above the surface of the papillae.

Groups of sensory cells form taste buds. When these taste buds are stimulated they generate a nerve impulse in the brain through sensory fibre and particular type of taste can be distinguished. Test buds are located on the upper surface of the tongue. Each taste bud contains about 25 sensory receptor cells with tiny taste hairs exposed to drink and food dissolved in saliva. There are five primary types of taste; sweet, sour, salt, bitter and a savoury or

meaty taste (umami) as shown in Figure 3.26. The tip of the tongue is most sensitive to sweet foods, the sides of tongue is more sensitive to sour and salty foods, and the back of the tongue is sensitive to bitter foods. The tongue canal senses the texture of food and its temperature.

The senses of smell and taste are closely related. For example, if a person has a cold it is difficult to identify both the smell and taste of food. Some foods that have a characteristic taste become either tasteless or have different taste compared to the normal one if held in the mouth while the nose is plugged.

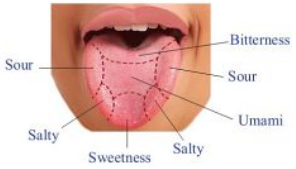


Figure 3.26 Taste buds in human tongue

Activity 3.9:

Investigating the distribution of taste buds on the tongue

Materials

Sugar, lemon, common salt, coffee and water

Procedure

1. Prepare the following: sugar solution (sweet), lemon juice (sour), common salt solution (salty) and coffee solution (bitter).
2. Use a drinking straw to place a drop of sugar solution on the back, front, sides and middle of the upper surface of the tongue.
3. Repeat step 2 using the other three solutions. Rinse your mouth with distilled water each time you have completed a test.

Questions

(a) Which area of the tongue mostly sense sweet taste? Draw a map of the tongue showing the areas.

(b) Draw the map of the tongue indicating each area which test each solution in procedure 1 above.

Exercise 3.4

1. Explain how the retina is adapted to its role.
2. Describe the importance of human skin.
3. Explain the functions of the taste buds of the tongue.
4. How is the ear adapted to its functions?
5. What are the functions of the mucus found in the nose?

Drugs and drug abuse in relation to nervous coordination

The brain can be affected by external influences, particularly drugs. A drug is any substance natural or synthetic that when taken by man alters the way the body works. This can change an organism's body physiologically or psychologically.

Drugs normally are used for treatment of diseases or for the alleviation of pain. When drugs are used for unintended purpose or used in excess, it is called **drug abuse**. Therefore, drug abuse is the excess use of drugs or use for reasons other than medical. Psychoactive drugs are substances that when taken in or administered into one's system affect the central nervous system. They produce false sense of wellbeing and relief from tension, stress, pain and anxiety. This means the nervous system of the organism is affected. These drugs fall into several groups as follows:

Sedatives

Are drugs that slow down the functions of the brain and make a person feel sleepy. They are used to make someone feel more relaxed. They are also called depressants. Sedatives include tranquillisers and sleeping pills. Tranquillisers, such as valium (diazepam), mandrax and amphetamines have a calming effect and are often given to people suffering from anxiety. Barbiturates are among the most powerful relaxant drugs that are used to provide relief from depression. Sedatives are known to interfere with impulse transmission and with the functioning of the medulla oblongata.

Depressants are drugs that inhibit the function of the central nervous system (CNS). They suppress the part of the brain responsible for sensing pain. They are among the most widely used drugs in the world. These drugs operate by affecting neurones in the CNS, which leads to symptoms such as drowsiness, relaxation, decreased inhibition, anaesthesia, sleep and even death. Examples of these drugs includes alcohol, opium, morphine, valium, cocaine, ether and chloroform.

Stimulants

These are drugs which stimulate or excite the nervous system by elevating mood, increasing energy and feelings of wellbeing, and alertness. They speed up the reaction or action of the brain and make someone more alert. Examples include cocaine, caffeine, heroine, nicotine, marijuana (bhang) and tobacco. Caffeine is a less dangerous stimulant and commonly used in our environment since it is found in coffee, tea, some diet pills as well as in some soft drinks such as cola. But cocaine and heroin are dangerous drug for the user. They are taken either by smoking or by sniffing through the nose.

Narcotics

These are the substances that dull the senses and relieve pain by depressing the cerebral cortex in the brain. They also affect the thalamus which is the regulatory center of the body. Examples of narcotics include heroin and pharmaceutical drugs like Oxycontin, vicodin, codeine, morphine, methadone, and fentanyl. Most of these drugs are used to reduce pain and suppress cough. Usually codeine is found in most cough medicines for reducing pain. Morphine is used to dull severe pains since it is stronger than codeine.

Hallucinogens

These are drugs that distort visual and auditory perception. They interfere with the way brain interprets impulses from the sensory organs. The interference can be either by altering the information about real things producing illusion or by producing false image; hence, causing hallucinations. They cause a person to hallucinate (hear and see) things which are not real. The effect of these drugs depends on several factors such as type of chemicals used, the amount taken (dosage), and emotional state of the user. Users of these drugs show signs of violence, mental illness with confusion, fear and depression. Examples of such drug includes cannabis (marijuana, bhang, hashish or charas), lysergic acid diethylamide (LSD), phencyclidine and mescaline.

Inhalants

Inhalants are products which include spray, paints, markers, glues, kerosene, toluene, petroleum and cleaning fluids. These products contain dangerous substances that have psychoactive (mind-altering) properties when inhaled. People who use inhalants breath in the fumes through their nose or mouth usually by sniffing, snorting, bagging or huffing.

Correct ways of handling and using drugs

Drugs such as sedatives and pain killers, can be very helpful to people if taken with a doctor's prescription. However, they must be taken in the right amounts and at the right time because they can be extremely harmful if not taken correctly. The reasons for this is that, drug may impair a person's judgments and make him or her clumsy. For example, a person may become addicted to cigarette smoking. Drugs might also cause injury by damaging cells of the body. For example, alcohol consumption kills cells in the brain and liver. Sniffing glue is dangerous because it damages cells in the kidneys, liver and brain. Thus, drugs must be carefully handled. The correct ways of handling drugs include;

1. Never take a drug without a doctor's prescription;
2. Take the drug correctly according to doctor's prescription. Never take more or less than what is prescribed by a doctor;
3. Always keep drugs away from the reach of children or persons who are addicted to drugs; and
4. Never use expired drugs.

Drug abuse

This is excessive use of drugs or using them for reasons other than medical. Some people take drugs for pleasure. When drugs are taken for this purpose it may lead to drug addiction. A drug addict comes to be dependant upon a drug so that life becomes unbearable without it. Drug addicts suffer withdrawal symptoms if they stop suddenly using drugs. Withdraw symptoms refers to physical and mental symptoms that depend on the type of drug

being discontinued. The intensity and duration of withdrawal symptoms vary widely depending on the type of drug and biological make up of a person. The symptoms can be extremely unpleasant and may be fatal. The symptoms associated with withdrawal include change in appetite, fatigue, muscle pain, nausea, sleeping difficult and sweating.

Reasons for taking drugs

There are different reasons that make people take drugs, some of them include the following:

1. Some people take drugs so that they can be accepted by members of their peer group, this is because of the influence of peer groups.
2. Some people take drugs as refreshment with a belief that the drug will excite them.
3. Some people believe that drugs will improve their intelligence or perception.
4. Some take drug to escape from reality of life such as poverty, hunger, family conflict.
5. Others take drugs for medical treatment and desire to satisfy curiosity about the effect of the drugs.

Effects of drug addiction

Although different drugs have different effects in the body, generally the common effects include damaged immune system and therefore susceptibility to infections, heart attacks, collapsed veins, liver failure, abdominal pains and stroke.

Tobacco smoking is linked with cancer of the lungs, mouth, throat and larynx. It is also linked with thinning and weakening of lung tissues, blockage of arteries in the heart and chronic bronchitis. Smoking appears to delay the healing of stomach ulcers, reduces the sense of smell and taste, and slows down reflexes.

Women who smoke during pregnancy tend to have increased chance of having low-birth weighted babies than non-smokers. Moreover, babies of woman who smoke may be born dead or die shortly after birth.

Alcohol, found in beverages and liquors, is a depressant, although a small amount has a stimulant effect. Relatively large amounts distort vision and interfere with hearing. Also, alcohol interferes with the transmission of nerve impulses. Heavy drinking can cause liver and stomach cancer.

Other effects of drug abuse which are not health related includes loss of employment, break up of relationship, homelessness, and risky sexual behavior.

Activity 3.10:

Exploring the effect of drug addiction

Procedure

1. Organise yourself into three different groups.
2. Each group should organize a role play on drug abuse showing the effect of drug on
   (i) walking
   (ii) driving
   (iii) speaking

Question

1. Why do drug users behave in the way you have demonstrated?
2. What are likely long term effects of drugs to the drug abuser?

Preventive and control measures against drug abuse

Many youth are the victims of drug abuse, therefore, measures should be taken to prevent them from drug abuse. Prevention programmes have a clear aim to stop the use of illegal drugs by providing information that is factual and credible and teaching young people to be responsible for their actions. Some social aspects for prevention of drug abuse include:

1. Reduce the availability and need to use drugs. This depends mainly on law enforcement.
2. Look after the psychological and social wellbeing of young people. It is more effective to offer the youth good psychosocial environments and services.
3. Make sure that the preventive measures are appropriate for young people: For example;
   (a) Schools can provide students with opportunities to develop their social participation and potential. Teachers should integrate drug abuse issues within existing school subjects, such as health and reproductive education, culture, social science, psychology and religious studies.
   (b) Young people should be educated on how to manage their free time and also should be provided with opportunities for social learning in groups.
   (c) Policy-makers should be sensitive to the problems of drug addiction and take appropriate measures to address the problem.

The endocrine system

The endocrine system is the system that is composed of a series of glands called endocrine glands as seen in Figure 3.27. They are called endocrine glands because they are ductless. The system is different from "exocrine" glands that use ducts to convey the chemical substances they secret to the target cells. Endocrine glands secrete chemical substances called hormone. A hormone is a chemical substance that is produced in one part of the body but has an effect in another part. It regulates various physiological activities of the body. The endocrine organs do not have ducts. Their secretions pass directly

into the bloodstream and are carried to different parts of the body. Exocrine glands, in contrast, have ducts through which secretions pass to different parts of the body. Examples of exocrine glands includes salivary glands, sweat glands, the pancreas and the liver.

Activity 3.11:

Identifying the position of endocrine glands in the body

Materials
Model or picture showing endocrine glands

Procedure
1. Observe the model or displayed picture of human body showing endocrine glands.
2. Discuss with your classmate the position of different endocrine glands in the body.
3. In tabular form write down the name of the gland and its position in the body.

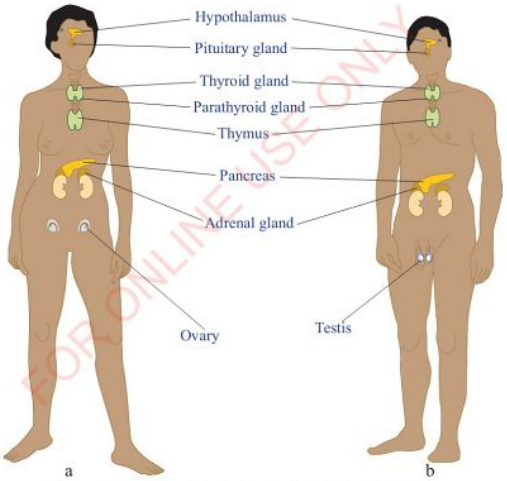


Figure 3.27: Position of endocrine glands in (a) female (b) male

The interaction between hormonal and nervous systems

Both nervous system and endocrine system control various physiological activities in organisms through coordination. The process of coordination in an organism is achieved by the two systems acting together. Although the nervous system and the endocrine system are two different systems, both release chemical substances as a means of communication between cells. The major centres for linking the two systems are the pituitary gland which is the control centre for endocrine glands and the hypothalamus which is the control centre for the nervous system. The hypothalamus is the gland which receives information from the brain and blood vessels and sends it to the pituitary gland.

The pituitary gland is located at the base of the brain just below the hypothalamus. This gland directly or indirectly controls the secretions of other glands. It is therefore, known as the master gland. The pituitary gland is divided into two distinct regions called the anterior and posterior lobes. **Anterior lobe** is the one that is connected by blood vessel called portal system to the hypothalamus. It secretes various hormones under the influence of the hypothalamus. The anterior lobe secretes two groups of hormones namely:

(a) Tropic hormones

These are the hormones that stimulate other glands to secrete hormones. Examples of tropic hormones include gonadotropic hormones which stimulate the secretion of luteinizing hormone that causes ovulation and the follicle stimulating hormone which controls the development of graffian follicles in the ovary. Another example of tropic hormone is the thyroid stimulating hormone (TSH) which acts on thyroid gland and stimulates secretion of thyroxine hormone which controls metabolism in cells.

(b) Growth hormones

Growth hormones are the hormones that stimulate the growth and development of an organism by controlling the tissues responsible for growth and development. When there is under secretion of the growth hormones the result is a disorder called dwarfism. Over secretion of this hormone results in abnormally large size of the body, a condition known as giantism. When over secretion occurs in adults it results into acromegaly. This is a situation whereby some body parts such as face, hands and feet become large in terms of thickness rather than length.

(c) Prolactin

Prolactin is another hormone secreted by the anterior lobe. This hormone stimulates the production of milk in lactating mothers.

Posterior lobe is the extension of the brain which facilitates the secretion of antidiuretic hormone (ADH) or vasopressin and oxytocin hormone which are produced by neurosecretory cell bodies.

(a) Antidiuretic hormone (ADH (vasopressin))

This is the hormone that acts on the kidneys and regulates the amount of water reabsorbed in the kidney tubules. The

hormone is released in response to a fall in the water content in blood plasma and leads to an increase in the permeability to water at distal convoluted tubule in the nephron of the kidney. The deficiency of this hormone results to a condition called diabetes insipidus. Diabetes insipidus is associated with the production of large quantities of dilute urine.

(b) Oxytocin

This is another hormone secreted by the posterior lobe which stimulates the contraction of the muscles of the uterus during child birth. The hormone causes the muscles of the uterus to contract and push the baby out. Oxytocin hormone also stimulates ejection of milk from nipples by contraction of the ducts of the mammary gland in lactating animals.

Adrenal hormones

These are hormones secreted by adrenal glands. These glands are located slightly above each kidney. Structurally each gland is made up by two types of cells that have different origins. The glands have two regions, the outer region called the cortex and the inner region called the medulla. The hormones secreted by these glands include adrenaline, aldosterone and cortisol. Adrenaline prepares the body for emergency during fight or flight action. It prepares the body wherever there is a frightening or an anxious situation. This hormone is produced and released into the blood stream causing an increase in blood pressure. Thus, the rate of heartbeat, blood sugar level and supply of blood to the muscles increases. Adrenaline can also be produced during passion, anxiety, pain, excitement and shock. Aldosterone is the hormone that controls the amount of water and salts content in the body. The hormone stimulates the conservation of sodium ions and chloride ions and removal of potassium ions. It also prevents the loss of sodium ions through urine and saliva, thus maintains osmotic concentration.

Cortisol is another hormone produced by the adrenal gland. Its function is to stimulate the metabolism of carbohydrates and proteins by promoting gluconeogenesis and breakdown of plasma proteins. It also helps in the prevention of inflammation and allergic reactions.

Thyroid hormones

These are hormones produced and released by the thyroid gland. Thyroid gland is found in the neck region. It is divided into two lobes which are surrounded by collagenous connective tissues. Thyroxine is an iodine containing hormone which is secreted by this gland. The role of this hormone is to regulate the basal metabolic rate of different food substances such as carbohydrates, proteins and lipids. Also, thyroxine promotes normal skeletal growth and it is essential for normal growth and development of the brain. Deficiency of this hormone during infancy causes a condition called cretinism which is accompanied by thickened facial features, retarded and stunted growth, abnormal bone development and mental retardation. Undersecretion of thyroxine in adulthood leads to a condition called myxoedema. This condition is characterised by low metabolic rate, increase in body

fluid and fatigue. Insufficient iodine in diet leads to abnormal development of the thyroid gland, a condition is called colloid goitre. This happens because the thyroid gland enlarges to create more space so that it can extract much iodine from the blood. On the other hand, when there is over secretion of thyroxine, it results into a condition called exophthalmic goitre. Calcitonin is another hormone secreted by thyroid gland, it regulates the level of Calcium in the blood by decreasing the level of Calcium in blood.

Parathyroid: This gland is found within the thyroid gland, it secretes the hormone called Parathyroid hormone (PTH). Like calcitonin, this hormone increases the level of calcium in the blood.

Pancreatic hormones

These are the hormones produced by pancreas. Pancreas gland that contains a cluster of cells called islets of Langerhans. It is located in the abdominal cavity. This gland is surrounded by different organs such as small intestine, liver and spleen. The pancreas performs two main functions which are exocrine and endocrine functions. Through exocrine function, pancreas produces different enzymes that are used in the digestion of food. As an endocrine gland the pancreas produces two important hormones called insulin and glucagon. These hormones are directly released into the blood stream. Insulin hormone is released when there is raise in blood sugar. It accelerates the rate through which glucose is converted to glycogen in the liver. It also facilitates the uptake of glucose in muscle cells and the liver. Apart from that, insulin promotes the rate of protein synthesis in the cell. When pancreas fails to produce sufficient amount of insulin in the body, it results into a disorder called diabetes mellitus. This is the condition caused by the increase in amount of sugar in the blood. Excess blood sugar is excreted through urine. It is characterized by frequent urination and excretion of sugar in urine. Glucagon hormone is secreted when there is a fall in blood sugar. It converts glycogen in the liver cells to glucose, resulting into an increase of the level of glucose in the blood.

Gonadal hormones

These are hormones produced by gonads. The gonads include ovaries and testes. These organs are also called sex organs. They produce both hormones and gametes. The testes produce testosterone hormone which facilitates the development of secondary sexual characteristics and the production of sperms. Testosterone is one of the important androgen hormones secreted in males. It controls the development of secondary sexual characteristics in males such as deepening of voice, growth of beard and growth of pubic hair. On the other hand, the ovary produces oestrogens and progesterone hormones. These hormones control the development of secondary sexual characteritics in females such as development of mammary gland, pubic hair, high pitched voice and broadening of the hips. It also causes thickening of the lining of the uterus. Apart from that, the progesterone hormone prepares the lining of the uterus for implantation. Table 3.4 gives a summary of the components and functions of the endocrine system.

Table 3.4: The major endocrine glands, position, the hormones they secrete, the functions of each hormone and their disorders when they are in excess or deficient

Endocrine gland	Position	Hormone produced	Role of the hormone	Effects of deficiency	Effect of excess production
Pituitary gland	Below the hypothalamus	Somatotropic growth hormones (GH)	Controls growth	Dwarfism	Gigantism
		Thyrotropic hormone or thyroid stimulating hormone (TSH)	Controls production of thyroxine hormone from the thyroid gland	Less thyroxine hormone produced	More thyroxine hormone produced
		Adrenocorticotropic hormone(ACTH)	Stimulates activities of the adrenal cortex	Less water reabsorbed	More water reabsorbed
		Follicle-stimulating hormone (FSH)	Causes development of the follicle in the ovary	Poor ovarian function	Ovarian failure Testicular failure
		Luteinising hormone (LH)	Causes ovulation	Infertility in both men and women	Infertility in both men and women
		Antidiuretic hormone (ADH)	Regulates the amount of water reabsorbed in the kidney tubules	Less water reabsorbed	More water reabsorbed
		oxytocin	Controls the contraction and relaxation of the uterus muscles during birth Causes milk secretion from the mammalian gland	Delaying of birth Poor milk secretion	Premature birth
Thyroid gland	Below larynx in the neck region	Thyroxine	Regulates metabolic rate in mammals	Retardation of physical and mental development (cretinism)	Exophthalmic goitre
Parathyroid gland	Associated with thyroid gland	Parathyroid hormone (PTH)	Regulate Calcium concentration in the blood stream	Causes Calcium/ Phosphorus imbalance in the body leading to muscle pains	Bone thinning due to low availability of Calcium
Pancreas (Islets of Langerhans)	In the abdominal cavity	Insulin	Regulates sugar levels, causing conversion of glucose to glycogen	High blood sugar (diabetes mellitus) Hyperglycaemia	Low blood sugar (hypoglycaemia)
		Glucagon	Regulates sugar levels, causing conversion of glycogen to glucose	Low blood sugar (Hypoglycaemia)	High blood sugar (Hyperglycaemia)

Endocrine gland	Position	Hormone produced	Role of the hormone	Effects of deficiency	Effect of the excess production
Adrenal glands	Above kidney	Adrenaline	Causes increased heartbeat, conversion of glycogen to glucose, dilation of pupils and increased blood flow to skeletal muscles. Prepares the body to cope with a dangerous situations	Slow response to an emergency	Over reaction on the emergency
		Hydrocortisone	Controls metabolism of carbohydrates, lipids and proteins	Less glycogen is stored in the liver and muscles	More glycogen stored in the liver and muscles
		Aldosterone	Promotes retention of sodium chloride and bicarbonate ions	The kidneys excrete too much sodium, chloride and bicarbonate ions	There will be little secretion of sodium, chloride and bicarbonate ions
Gonads (ovaries and testes)	Abnominal cavity and pubic region	Androgens	Causes development of secondary sexual characteristics in female	Sexual traits fail to develop in female	Excess androgen in females leads to male traits.
		Oestrogen	Causes development of secondary sexual characteristics in male	Sexual traits fail to develop in male	Excess oestrogen in males leads to female traits.
		Progesterone	Inhibits ovulation and prepare the uterus for embryo implantation by making its lining thicker and more vascularised	May cause miscarriage	
		Androgen Testosterone	Promotes the growth and development of reproductive organs in males and development of male sexual characteritics. Promote spermatogenesis and development of male secondary sexual characteritics	Failure of growth and development of reproductive organs and also failure to develop male secondary sexual characteritcs Poor sperm production	Premature development of reproductive organs and secondary sexual characteritics in males Excess androgen in females leads to male traits and excess

The differences between nervous and hormonal coordination

1. Nervous coordination is quick and the response is immediate while hormonal coordination is slow and the response takes much longer.
2. Nervous coordination involves specialised cells while hormonal coordination does not require specialised cells.
3. Nervous coordination uses nerve cells for conducting nerve impulses while hormonal coordination needs blood stream to transport hormones to different parts of the body.
4. Transmission of information in nervous coordination is of electrical nature while hormonal coordination is of a chemical nature.
5. Nervous coordination controls activities which require fast response while hormonoal coordination control slow or long term activities such as growth and sexual development.
6. The origin of message in nervous coordination involves receptors and brain while in hormonal coordination it involves endocrine glands.

Exercise 3.6

1. Explain the effect of drug addiction to an individual's health status, personality and social life.
2. Explain any four disorders of hormonal coordination in humans.
3. What measures should be taken to prevent drug abuse?
4. In which ways does hormonal coordination differ from nervous coordination?

Coordination in plants

Plants do not have a nervous system and sense organs like the animals, but they can still detect changes in the environment. Plants can detect and respond to stimuli such as light, gravity, chemicals, water and touch.

Although plants can respond to various stimuli around them, the response to such stimuli is not the same as in animals. Plants respond to environmental changes by using hormones. The hormones in plants do not act in the same way as in animals.

The effect of hormones on growth of the plant can result in the movement of a part of the plant such as shoot (stem) or root towards or away from a stimulus.

Plant hormones

Plant hormones or plant growth hormones are chemical substances that regulate plant growth. They are also known as phytohormones or plant growth regulators. Plant hormones are signal molecules produced within the plants and usually occur in low concentration. They control all cellular activities related to growth and development in the plants. Auxins, abscisic acid, gibberellins and cytokinin are examples of plant hormones.

Auxins are also called growth promoters since they influence plant growth and assist in producing a response which results into growth. They affect the growth of plants positively by influencing the formation

of buds, cell division, enlargement and initiation of root formation in plants. Auxins also promote the production of other hormones such as cytokinin which regulates the growth and development of the shoot, roots and fruits. Cytokinin helps in delaying senescence (ageing) of tissue and promotes cell division and shoot formation. Normally, the higher concentration of auxins promotes the growth of shoots while low concentration promotes growth of roots.

Ethylene is another growth hormone which promotes growth of shoots and roots. Other examples of growth hormones include gibberellins and abscisic acid.

Ethylene affects the growth of cells of the plants and shape of the cells. When a new shoot emerges and is exposed to light, the plant starts to decrease the production of ethylene. This causes the cells of the leaf and shoot to expand. But if the growing shoot hits an obstacle while it is still underground, production of ethylene increases to prevent cell elongation. This results to the swelling of the stem, making the stem stronger, a condition which enables the stem to pass through the obstacle.

Concept of tropic and nastic responses

Plants detect and respond to a variety of stimuli that are important for their survival in the environment. These responses allow the plants to survive, grow, develop and reproduce. There are two types of growth movements in plants, namely nastic movement and tropic movement.

The movement of plants in the direction or away from stimuli is known as 'tropism'. Tropisms are growth responses of plants that result in curvatures of plant organs toward or away from specific stimuli. The plant shows positive tropism if it bends toward a stimulus and negative tropism if it bends away from a stimulus.

Important tropisms shown by plants include phototropism, geotropism, hydrotropism and chemotropism.

Effect of auxins in phototropism

Activity 3.12:

Determining the effect of light on shoot growth

Materials

Bean seeds, two pots and cardboard box with a hole in one side

Procedure

1. Allow two bean seeds to germinate in separate pots.
2. When the shoots are 5cm long, place one pot in a cardboard with a hole in one side and keep the other pot in a place where it can get full light.
3. Leave the two pots for 4 days and observe the changes.

Question

1. Explain the changes that take place in the shoot.
2. What is the significance of such growth in plants?

Phototropism is the tendency for plant organs to bend in response to unidirectional light source. For example, light streaming in a window from one direction will often cause the stems of plants to bend toward the light source as shown in Figure 3.28.

This is positive phototropism. The distribution of growth hormones (auxin) in plants depends on the presence of light. Light causes more auxins to move to the part of the plant that does not get enough light. By doing so the growth rate of the region where there is a high concentration of auxin will be higher than that with low concentration of auxin. Therefore, the plant will bend towards the direction of light.

Figure 3.28: Phototropism

Importance of phototropism

1. Phototropism drives the plant shoot toward light for photosynthesis to take place.
2. The light gained through phototropic response, influences the opening of the stomata pores. This is important for gaseous exchange.

Effects of Auxins in geotropism

Activity 3.13:

Determining the effect of gravity on shoot and root growth.

Materials

Bean seeds, blotting paper and petri dishes

Procedure

1. Allow two bean seeds to germinate two petri dishes
2. After the plumules and radicles have emerged, take the two seedlings into separate petri dishes. In one petri dish place the seedling horizontally and in the other petri dish place the seedling vertically with its radicle pointing downward.
3. Leave them for 3 days in a dark place to eliminate the effect of light.
4. Observe what happens to the direction of growth of plumules and radicles.

Questions

Why do shoots grow upward and roots grow downward even when placed horizontally?

Geotropism is the movement of a part of the plant towards the force of gravity. In plants, roots grow downward towards the force of gravity while shoots grow upward against gravity. Plant roots grow towards gravity and are said to be positively geotropic whereas plant

shoots grow away and they are said to be negatively geotropic. See Figure 3.29. When the seed is planted it germinates into seedling. At this stage more auxins will be concentrated at the lower part of the shoot and root due to the force of gravity. Higher concentration of Auxins facilitates growth of shoot while lower concentration facilitates growth of roots. Thus, in the seedling the lower side of the shoot will grow faster than the upper side causing the shoot to grow vertically upward. On the other hand, the growth rate of the root will be slower in the lower part of the root since higher concentration of auxins inhibits the growth of roots. This will result into the downward growth of the roots.

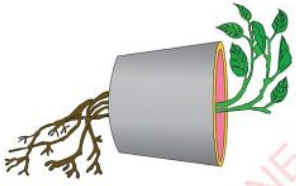


Figure 3.29: Geotropism

Importance of Geotropism

Geotropism is important to plants because of the following reasons:

1. It enables the plants to send roots into the ground; hence, anchoring the plant firmly into the soil.
2. It enables plant roots to absorb water and mineral salts from the soil.
3. Negative geotropism exhibited by the shoot enables the shoot to grow upwards, exposing the plant leaves to sufficient sunlight for effective photosynthesis.

Hydrotropism

Activity 3.14:

Determining the effect of water on root growth

Materials

Wire gauze, bean seedling, cotton wool and two retort stand

Procedure

1. Secure a wire gauze horizontally using two retort stands.
2. Place the bean seedling on the wire gauze in such a way that the radicles pass through the pores of the wire gauze.
3. Put wet cotton wool above the gauze.
4. Leave the set for 4 days. Make sure that the cotton wool is kept wet.
5. After 4 days observe what happens to the roots.

Question

Explain the changes that occur after 4 days.

Hydrotropism is the growth movement of a plant or part of a plant in response to a source of water. Plant roots normally grow towards moisture. They are therefore positively hydrotropic, whereas shoots grow away and are said to be negatively hydrotropic. If you grow a plant near a water source such as porous pot or river,

the root will always grow towards water as seen in Figure 3.30.

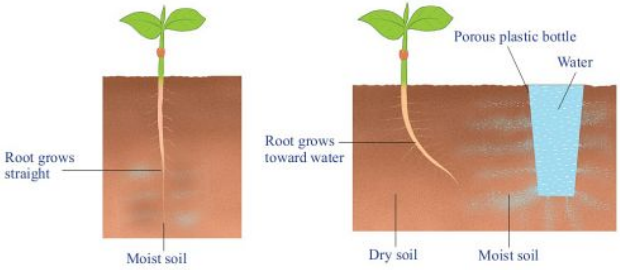


Figure 3.30: Hydrotropism

Importance of Hydrotropism

It enables the plants to absorb dissolved minerals and water. Water is necessary for various functions such as:

1. Photosynthesis.
2. Numerous physiological reactions that take place within plant cells.
3. Turgor pressure which aid in plant support.
4. Dissolution of mineral salts and their transportation throughout the plant.

Nastic movement

These are non-directional movements of a part of stationary plant in response to external stimuli. For example, folding of leaves in warm weather, opening and closing of flowers in response to intensity of light and closing of leaves when touched. Such movements occur as a result of changes in turgor pressure in a certain cells. Based on the nature of stimuli, nastic movements can be divided into the following groups; thigmonasty, chemonasty, thermonasty and photonasty.

Thigmonasty

Refers to response of a plant or part of plant to stimulus of touch. The best example of nastic movement is folding of leaves of *Mimosa pudica* plant when its leaves are touched with fingers or any object as shown in Figure 3.31. The leaves fold even when swayed by wind. Also the specialised touch-sensitive tendrils of many vining plants such as peas, will bend towards the side receiving a touch stimulus. Continual stimulation can lead to the coiling of the tendrils around an object, which enables vining to grasp objects on which they can climb as shown in Figure 3.32. This ability is possible due to the presence of auxin hormone which moves from the part of plant in contact with the object. Thus the part of plant that is in contact with the object has lower concentration of auxin hormone than the part which is not in contact with the object. As the result, the side that is not in contact with the object grows faster than the part in contact with the object. This will cause the plant to coil around the object.

Figure 3.31: *Mimosa pudica* responding to touch

Figure 3.32 Thigmonasty in climbing plant stimulus

Importance of Thigmonasty

1. Thigmotropism enables crawling plants to climb up higher plants and expose their leaves to sunlight for optimum photosythesis.
2. It enables the insectivorous plants such as the *Venus flytrap* to trap insects and digest them to obtain nutrients.

Thermonasty

This is a movement of plant parts in response to temperature. For example, sun flowers close when the temperature drops, or some leaves fold when the temperature is too high.

Chemonasty

This is the movement of plant parts in response to chemical stimuli. For example, sundew plants close glandular hairs due to chemicals produced by an insect when it lands on it. This prevents the insect from escaping.

Photonasty

This is the movement of plant parts in response to light. For instance, some flowers or leaves fold in response to sun shine, or the opening and closing of flowers during the day and night.

Exercise 3.6

1. With examples distinguish between tropic and nastic responses.
2. How is the concentration of auxins in the stem of a young plant related to phototropism?

Revision exercise 3

Choose the most correct answer.

1. The type of drug that slows down the brain and makes a person feel sleepy is called a_____ .
   (a) stimulant
   (b) hallucinogen
   (c) sedative
   (d) depressant
2. The most posterior part of the brain, which merges with the spinal cord is the_____ .
   (a) medulla oblongata
   (b) forebrain
   (c) midbrain
   (d) hindbrain
3. A neurone that carries impulses from the brain or spinal cord to the effector organ where the response takes places is _____ .
   (a) sensory neurone
   (b) relay neurone
   (c) motor neurone
   (d) intermediate neurone
4. Coordination is brought about through _____ .
   (a) nervous and endocrine systems
   (b) digestive and respiratory systems
   (c) circulatory and nervous systems
   (d) immune and reproductive systems
5. Among the following are functions of forebrain EXCEPT _____ .
   (a) imagination
   (b) thinking
   (c) balance
   (d) seeing
6. The following are examples of a reflex action EXCEPT _____ .
   (a) blinking of the eye
   (b) dilation of pupil
   (c) knee jerking
   (d) rubbing the eyes
7. _____ has glands for regulating body temperature.
   (a) Skin
   (b) Sweat gland
   (c) Blood vessel
   (d) Brain
8. Which section of the ear contains two large sac-like structures?
   (a) Outer ear
   (b) Inner ear
   (c) Middle ear
   (d) Eardrum

9. Match each item in **column A** against its corresponding item from **column B**.

Column A	Column B
(i) Myopia	A. Drugs that inhibit the function of the central nervous system (CNS).
(ii) Brain	B. Organ for hearing and maintenance of the body balance.
(iii) Endocrine gland	C. A defect of vision in which there is difficulty with vision of nearby objects but far objects can be seen clearly.
(iv) Test buds	D. Gland without duct in which secretion pass directly to the blood stream.
(v) Motor neurone	E. Movement of leg in the body.
(vi) Eye accomodation	F. A defect of vision in which far objects appear blurred but nearby objects are seen clearly.
(vii) Hallucinogens	G. The ability of the eye to focus near and distant object during vision.
(viii) Exocrine gland	H. Transmits nerve impulses from the sensory receptors to the central nervous system for interpretation.
(ix) Depressant	I. A specialised organ that is responsible for thought and movement of the body.
(x) Reflex action	J. Gland with duct through which secretion pass to different parts of the body.
(xi) Long sightedness	K. Groups of sensory cells in the tongue
(xii) Sensory neurone	L. Drugs that distort visual and auditory perception.
	M. A rapid, automatic response to a stimulus.
	N. Transmit nerve impulses from the CNS to the effector organs.

Answer the following questions

10. What is the meaning of drug addiction?
11. Briefly outline four reasons why people become dependent on drugs.
12. Explain why alcohol is a drug.
13. List ways in which cigarette smoking can affect your health.
14. With examples differentiate between an exocrine and an endocrine glands.
15. Briefly explain three differences between nervous and hormonal coordination.
16. Describe the sequence of events that take place in the nervous system which makes the hand to be withdrawn from a sharp object once pricked.
17. Explain how balance is maintained while walking.
18. What are the causes of;
    (a) Long sightedness
    (b) Astigmatism?
19. How does sound pass from the tympanic membrane (ear drum) to the oval window?
20. Many people especially the youth engage in bad habits of using drugs such as cocaine, heroine and marijuana. What do you think are the causes of the youth to engage in drug abuse?
21. Explain how concentration of sugar in blood is maintained constant in humans.
22. Compare the functions of parts of the mammalian eye and a camera.

Chapter

Four

Excretion

Introduction

There are different reactions that take place in the cells of living organisms which enables an organism to carry out the life processes. These reactions are called metabolism. Metabolism produces useful products as well as toxic by-products. These toxic substances have to be removed because they are harmful if allowed to accumulate in the body. The removal of metabolic waste products from the body of an organism is known as excretion. In this chapter, you will learn about the concept of excretion, excretory organs in humans, urinary system and its adaptive features, process of urine formation and complications and disorders of the excretory system. You will also learn about the causes, symptoms, effects and control measures of common complications and disorders of the excretory system. Excretory products eliminated by plants and their importance will also be discussed. The competencies developed will enable you to understand how wastes are removed from human body and plants and how to rectify the disorders related to excretory system.

Concept of excretion

Living organisms require different nutrients which enable them to obtain energy for various physiological processes such as growth and movement. These processes produce waste products which should be removed because if allowed to accumulate in the body they become toxic. Excretion is the process of removing metabolic or cellular waste products from the body of an organism. The major excretory products are carbon dioxide, excess water and salts, and nitrogenous compounds like ammonia, urea and uric acid. Carbon dioxide and water are produced in the process of cellular respiration. Nitrogenous compounds are formed from the breaking down of proteins and amino acids. Excess water and salts in

the body also need to be excreted. Through excretion, organisms maintain homeostasis. In animals, water is removed in three physiological processes, urinary excretion, evaporation from the lungs through breathing and skin through sweating. Urinary excretion removes the largest amount of water. In mammals, nitrogenous excretory products are eliminated as urine which consists mainly of water, urea and salts.

Excretion facilitates the removal of toxic wastes which when allowed to accumulate may inhibit actions of many enzymes involved in various metabolic pathways. Excretion also helps in the regulation of water content of the body fluids. Excretory nitrogenous wastes are removed from the bodies of living organisms in a form which is determined by the availability of water. Excretion regulates the movement of water and mineral salts inside and outside the cell membranes, therefore, maintaining osmotic balance. In the absence of excretion, the equilibrium of these materials shifts and disrupts homeostasis and osmotic balance. The pH of the body fluid is also regulated by excretion process. Table 4.1 presents the summary of the various excretory products produced by different organisms.

Table 4.1: Examples of excretory products produced by organisms

S/n	Excretory product	Source	Excretory organ	Type of organism
1	Carbon dioxide	Cellular respiration	Lungs, plant leaves	Animals and plants
2	Oxygen	Photosynthesis	Plant leaves and green stems (when light is available)	Plants
3	Excess water	Metabolic activities	Kidney, skin and lungs, plant leaves and stems	Animals and plants
4	Bile pigments	Breakdown of haemoglobin by liver cells	Liver	Vertebrate animals
5	Ammonia	Deamination of amino acids	Liver	Many aquatic animals

Excretion in humans

There are four main excretory organs in humans. The first organ is the kidney which excretes nitrogenous wastes in the form of urine. Nitrogenous wastes such as urea, ammonia, and uric acid result from breakdown of proteins and nucleic acids. The lung is also an excretory organ in mammals which excretes carbon dioxide and water vapour. Carbon dioxide is produced as a result of cellular respiration. Excretion of mineral salts and water in the form of sweat is carried out by the skin. The fourth organ is the liver which excretes bile made from the breakdown of worn out red blood cells in the liver.

Major excretory products in animals.

The major excretory products in animals are nitrogenous compounds such as urea, ammonia, and uric acid from breakdown of proteins and nucleic acids, carbon dioxide from cellular respiration and excess water.

(a) Nitrogenous waste products

Breakdown of nitrogen containing molecules such as amino acids results in excess accumulation of Nitrogen that must be removed from the body. Amino acids are broken down by the body in order to generate energy or converted into fats or carbohydrates. Amino acids as byproducts must be removed because they are highly toxic to the body. Excess nitrogen may be excreted in the form of ammonia, urea, or uric acid.

(i) Ammonia

Ammonia is extremely toxic and highly soluble waste substance in the body, it needs sufficient water to flush it out from the body. If ammonia is diluted with sufficient amount of water it can be easily eliminated from the body rapidly and safely. Animals that excrete nitrogenous waste products in the form of ammonia tend to live in aquatic environment. Therefore, it is excreted mostly by fish and other aquatic animals whose gills or body surface are in direct contact with water. Animals which excrete nitrogenous wastes in the form of ammonia are called ammonotelic.

(ii) Urea

Urea is a major product of ammonia metabolism in vertebrates. Animals like sharks, adult amphibians, and mammals usually excrete urea as their nitrogenous wastes. Urea is less toxic and less soluble than ammonia. It can be excreted in a moderately concentrated solution. Excretion of ammonia in the form of urea allows body water to be conserved. This is an important advantage for terrestrial animals with limited access to water. The animals which excrete ammonia in the form of urea are termed as ureotelic.

(iii) Uric acid

Uric acid is not toxic and it is insoluble in water. Poor solubility is an advantage if water conservation is needed. Uric acid can be concentrated even more readily than urea. It is usually excreted by insects, reptiles, and birds. These are collectively termed as uricotelic animals. Conversion of ammonia to uric acid is a complex and energy consuming process compared to the conversion of ammonia to urea. Uricotelic animals excrete uric acid waste in the form of a white paste and powder.

(b) Carbon dioxide

Respiration process results into the production of carbon dioxide gas which is toxic to the body, hence should be removed from the body. Thus, carbon dioxide is carried in the blood stream in the form of carbonic acid and excreted through breathing as carbon dioxide.

(c) Excess water

Different metabolic activities produce excess water. This excess metabolic waste in the form of water is removed from the body in the form of water vapour, sweat or urine.

The urinary system

Activity 4.1:

Examining the urinary system of the mammals

Materials: Dissected animal or model (rat, mouse or rabbit), hand lens

Procedure

1. Use hand lens to observe the displayed urinary system of the provided mammal
2. Draw the structure of the urinary system of the displayed mammal

Question

What components make up the urinary system of the animal?

The urinary system is also known as renal system. It consists of the kidneys, ureters, urinary bladder, and the urethra. The urinary system eliminates metabolic waste products and maintains the correct concentration of water and salt in the body fluids. The urinary system also plays a significant role in controlling blood composition, blood pressure, and the pH of body fluids.

The kidneys are a pair of reddish-brown bean-shaped organs found on each side of the back of the lower portion of the abdominal cavity. The left kidney is located a bit higher than the right kidney. The kidneys are well protected by muscles and ribs as well as the fats that surround them. There is an adrenal gland above each kidney which secretes adrenaline hormone. For each kidney, there is a renal artery that supplies oxygenated blood to it and renal vein which carries deoxygenated blood to the vena cava. The function of the kidneys is to excrete urine by filtering wastes and excess water from the blood.

The ureters are two tubes of smooth muscle that extend from the pelvic region of the kidney to the urinary bladder. Their major function is to carry urine from the kidney to the urinary bladder. The entrance to the bladder has a ureterovesical valve that prevents the urine from flowing back to the kidney.

The urinary bladder is a spherical muscular sac that is located within the pelvic cavity. The waste fluid that is created in the liver and collected in the kidney is transferred into the urinary bladder where it is temporarily stored before being discharged out of the body. At the base of the urinary bladder there is a sphincter muscle that prevents the bladder from emptying the urine until it reaches a certain level.

The urethra is a thin, fibromuscular tube that begins at the lower opening of the bladder and extends through the pelvis to the outside of the body. The wall of the urethra is composed of mucous membrane and fibrous smooth muscle tissue. These are the muscles that release the urine to the outside of the body. The urethra also connects to the ductus deferens in males to enhence ejaculation of sperm. See Figure 4.1.

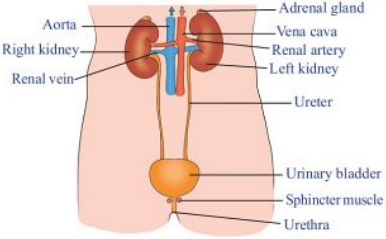


Figure 4.1: Human urinary system

The structure of the kidney

Activity 4.2:

Examining the internal structure of the kidney

Materials

A fresh kidney from sheep, goat or cow, hand lens, surgical razor blade, dissecting tray, cotton wool and scalpel

Procedure

1. Form groups.
2. Each group should obtain two identical halves of the given kidney using a surgical blade.
3. Use a hand lens to observe the internal structure of the kidney and draw a large diagram showing the internal parts.

Question

How does the structure of the kidney facilitate removal of metabolic wastes?

The kidneys are two bean- shaped organs in the renal system. It has an outer convex side and an inner concave side called the **renal hilus.** The renal artery supplies blood to the kidney and the renal vein removes blood from the kidney through the renal hilus. The kidney is surrounded by fibrous connective tissue.

The transverse section of the kidney has three distinct regions, the outer darker layer called the **cortex**, the inner region called the **medulla,** and the **pelvis**. Pelvis is an expanded portion of the ureter. See Figure 4.2. The pelvis is the region into which urine temporarily accumulates before it is drained into the urinary bladder. A thin connective tissue called fibrous capsule surrounds each kidney. This capsule maintains the kidneys shape and protects the inner tissues.

The cortex contains parts of nephrons, numerous glomeruli (singular: glomerulus) and capsules. The medulla mainly consists of the loop of Henle and collecting ducts as well as the blood vessels of nephrons which together form the renal pyramid. The renal pyramid project into the pelvis leading to the ureter. Kidneys are well supplied with blood vessels forming a network of blood capillaries. The blood in human body is filtered several times a day by the kidneys. This is why about 8% of all oxygen absorbed through the lung is used by the kidneys. Oxygen is used by the kidneys to provide energy needed to filter the blood and produce urine.

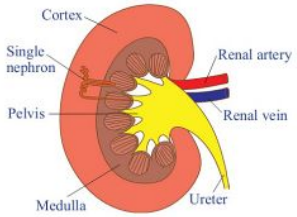


Figure 4.2: Internal structure of mammalian kidney

Exercise 4.1

1. Why is excretion an important process in humans?
2. Explain how each excretory organ works.
3. Briefly describe different metabolic wastes excreted by humans and their sources.
4. Explain how the kidneys function.

The Nephron

This is the basic functional unit of the kidney involved in the production of urine. It is also known as a kidney tubule. Each kidney consists of a mass of nephrons, capillaries and connective tissue. In the cortex, the nephron starts at an invaginated cup shaped capsule called the Bowman's capsule. Within the capsule there is a loop of blood capillaries twisted into a ball-shaped structure called the glomerulus. See Figure 4.3. Blood flows into and out of the glomerulus through tiny arteries called arterioles. Bowman's capsule facilitate ultrafiltration of the substances carried by blood. Ultrafiltration is the process whereby small molecules carried by blood such as water, glucose, amino acids, urea and mineral salts are filtered out in Bowman's capsule due to high hydrostatic pressure. Glomelur filtration is called utrafiltration because blood is finely filtered through all membranes such that all plasma substances are passed except the proteins.

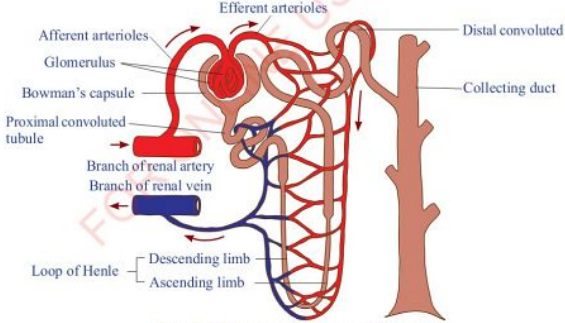


Figure 4.3: Structure of the mammalian nephron

Bowman's capsule joins the first convoluted region of the kidney tubule called the proximal convoluted tubule. This tubule is coiled and surrounded by blood capillaries. The tubule has a long U-shaped structure called the loop of Henle. As the filtrate passes through the tubule, its composition is altered because of the secretion of some substances into it and by the selective reabsorption of water and mineral salts from it. Selective reabsorption is the process in which certain essential filtrate substances are taken back or reabsorbed to the blood. This process occurs in the convoluted tubules. The loop of Henle joins the proximal convoluted tubule at one end and the distal convoluted tubule at its ascending end. The distal convoluted tubule is also surrounded by blood capillaries and joins the collecting ducts. The collecting ducts drain the urine formed into the pelvic region of the kidney.

Table:4.2: Summary of parts of the kidney and their functions

S/N	Parts of the kidney	Description
1	Renal hilus	An indentation near the centre of the concave side of the kidney where the renal vein and ureter leave the kidney and the renal artery enters the kidney
2	Capsule	A tough, fibrous membrane, surrounding the kidney. It consists of dense, irregular connective tissues which protect and help to maintain the kidney's shape. It is also surrounded by fatty tissue which helps to protect the kidney from damage
3	Cortex	The outer reddish part of the kidney that has a smooth texture. It is where the Bowman's capsule, glomeruli, proximal and distal convoluted tubules and blood vessels are found
4	Medulla	The inner striated red-brown part of the kidney. It have tubular parts that contains loop of Henle's and blood vessels
5	Renal pyramids	The stripped and triangular shaped structures within the medulla, which are made of straight tubules and corresponding blood vessels.
6	Renal pelvis	The funnel-shaped cavity that receives urine drained from the nephrons through the collecting duct.

7	Renal artery	The blood vessel that delivers oxygen- rich blood to the kidney; it enters the kidney through the hilus and divides into smaller arteries which further divide into afferent arterioles that serve each of the nephrons.
8	Renal vein	The blood vessel that receives deoxygenated blood from the kidney and returns it to the systemic circulation.
9	Afferent arteriole	The blood vessel that delivers oxygen-rich blood to the glomerulus under high pressure.
10	Efferent arteriole	The blood vessel that receives oxygenated blood from the glomerulus.
11	Kidney nephrons	The functional units where the kidney's main functions are performed. There are about a million nephrons in each kidney.
12	Collecting duct	The part of the kidney nephron through which several other tubules empty their contents to the pelvis of the kidney.
13	Ureter	The tubular structure which conveys urine from the pelvis of the kidney to the urinary bladder.

The process of urine formation

Activity 4.3:

Describing how urine is formed using a nephron model

Materials

Model of mammalian nephron

Procedure

1. Form groups of about five students each.
2. In your groups construct the model of mammalian nephron.
3. Use the constructed model to explain how urine is formed based on three steps (Ultra filtration, selective reabsorption and removal of the urine).

Question

What are the adaptive features of the urinary system?

The blood from afferent arteriole which enters Bowman's capsule is rich in glucose, fatty acids, amino acids, vitamins, proteins, urea and excess salts. A nephron is the structural and functional unit of a kidney which is concerned with excretion and homeostasis. The formation of urine involves three steps, which all occur in the nephrons of the kidneys as shown in Figure 4.4. The steps are glomerular filtration (ultrafiltration), reabsorption (selective reabsorption) and secretion or removal of materials.

Glomerular filtration(ultrafiltration)

This is the first step in the formation of urine from the blood. Ultrafiltration occurs in the glomerulus (plural: glomeruli). The lumen of the afferent arteriole is significantly smaller than the efferent arteriole. As a result, a very high hydrostatic pressure is set in the glomerulus when blood passes through it. This pressure forces plasma through the capillary walls in the glomerulus. The plasma contains water, glucose, amino acids, urea, salts, uric acid, vitamins, hormones, white blood cells, blood platelets and plasma. Red blood cells and proteins are retained in the blood capillaries because they are too large to pass through the wall. This process is called ultrafiltration and the fluid which passes into Bowman's capsule is known as the glomerular filtrate. The glomerular filtrate collects in the capsule and enters the renal tubule at the proximal convoluted tubule which is coiled to increase the surface area for reabsorption of substances.

Reabsorption (selective reabsorption)

As glomerular filtrate moves along the tubules, most of the substances are reabsorbed back into the blood. When the blood passes in proximal convoluted tubule, glucose, amino acids and some amount of water are reabsorbed. As filtrate moves to the descending limb of loop of Henle, most of the salts are reabsorbed then the filtrate moves to the distal convoluted tubule where more salts and water are reabsorbed. Finally, the filtrate moves to the collecting duct where more water is reabsorbed.

Reabsorption involves both diffusion and active transport. Active reabsorption is the transport against concentration gradient. This process uses energy in the form of ATP. The waste-containing fluid that remains after reabsorption is urine. Tubular secretion is the passage of certain substances out of the capillaries directly into the renal tubules. Tubular secretion is another way of getting waste materials into the urine. For example, drugs such as penicillin are secreted into the renal tubules from the capillaries. Urea and uric acid that may have been reabsorbed are also secreted. Excess potassium ions are also secreted into the urine. Tubular secretions maintain the pH of the blood.

Removal of materials

In the distal convoluted tubule, water is reabsorbed into the blood by osmosis. The tubule is highly coiled to increase the surface area for reabsorption. The glomerular filtrate then flows into the collecting tubules where more water is

reabsorbed. At this stage the filtrate forms urine which flows into the collecting duct, then into the pelvis of the kidney. It then flows into the ureter and is temporarily stored in the bladder. When the bladder is full, impulses are sent to the brain to create an awareness of the presence of urine in the bladder. A person then feels the need to urinate. During urination, the bladder muscles contract, sphincter muscles relax, and the urine is expelled via the urethra. Urine formation is essential for maintaining homeostasis which is the ability of the body to maintain constant internal environment.

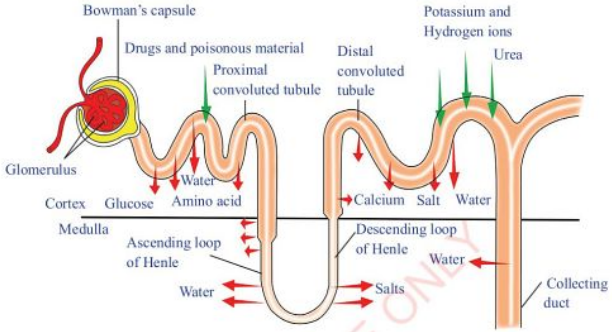


Figure 4.4: Urine formation

Adaptive features of urinary system

There are several adaptations that enable the kidney to perform its functions properly. The kidney has large afferent arteriole and narrow efferent arteriole. This arrangement enables building-up of a very high pressure in the glomerulus. This hydrostatic pressure facilitates ultrafiltration of materials. Glomerulus capillaries are highly coiled and semipermeable. A high pressure in the glomerulus causes ultrafiltration. The glomerular capillaries and tubule are semipermeable structures to allow selective movement of materials in and out of the nephron. This process is called selective reabsorption. The epithelium is thin and leakier than normal capillaries to reduce diffusion distance for faster passage. This in turn enhances reabsorption of materials. The urinary system is also connected to a collecting duct, which channels urine out to the ureter to allow continuous functioning of the nephron. Apart from that, the proximal convoluted tubule and the distal convoluted tubule are coiled so as to increase the nephron's length and hence

more surface area for efficient reabsorption to take place. The Bowman's capsule is cup-shaped to provide maximum surface area for filtration. The tubule is supplied with a network of blood capillaries for maximum reabsorption. The nephrons are numerous in number for efficient excretion of waste products. Lastly, the urinary bladder has sphincter muscles that remain contracted to prevent urine from leaking before a certain level is reached. When relaxed, the muscles allow movement of urine out of the body.

Exercise 4.2

Answer the following questions

1. Explain the importance of selective reabsorption in urine formation.
2. Explain the adaptation of the kidney to its role in excretion.
3. Discuss how distal convoluted tubules facilitate urine formation.
4. Describe the structure of a nephrone.

Other excretory organs in humans

Liver

The liver is one of the largest organs in the body of humans. It is located beneath the diaphragm. It plays the role of excretion of bile pigments from the decomposition of haemoglobin and urea. The liver also regulates the amount of food substance which is released to the blood and tissue fluid. It does this by absorbing and storing food it receives, and then releases it into the circulatory system as per body needs.

The human liver has two lobes with many blood capillaries. Gall bladder is located between the lobes. The liver is made up of hepatic cells organized in small groups called lobules. Each lobule is composed of a great number of liver cells. Between lobules there are small blood vessels and small bile ducts. Major blood vessels in the liver include hepatic artery which brings oxygenated blood and hepatic portal vein which brings blood rich in digested food from the alimentary canal. Hepatic vein carries away deoxygenated blood from the liver.

Functions of the liver as an excretory organ

1. The liver breaks down excess amino acids in a process called deamination. This process involves changing amino group to poisonous ammonia.
2. The liver also performs detoxification in which ammonia and other harmful compounds are converted to less toxic compounds. These compounds are then excreted through urine.
3. The liver is also involved in the formation of bile. When red blood cells break down green and yellow pigments are formed. These pigments are removed from the blood by the liver and excreted in the bile. Bile is stored in the gall bladder and used for emulsifying fats.
4. The liver also breaks down hormones. The liver destroys almost all types of hormones for the purpose of balancing them to the required level. Testosterone and aldosterone are rapidly destroyed

whereas female sex hormones are destroyed slowly. In this way the liver balances the levels of these hormones in the body.

The Skin

Skin is the largest organ in the body. It plays a role in excretion through the production of sweat by sweat glands. Sweating helps in the elimination of excess water, urea, lactic acid, waxes and sodium chloride. However, sweating is more important in temperature regulation than as a means of excretion.

Common complications and disorders of the excretory system

Excretory disorders involve infections or conditions affecting any of the excretory organs. There are several complications and disorders associated with the excretory system. These include:

(a) Kidney or renal failure

This is the failure of the kidney to function adequately due to partial or total destruction of nephrons. It can be caused by several factors including the damage of the kidney due to accident or complications during surgery. It may also be caused by low blood volume due to excessive bleeding, poor intake of fluids and medication. Medicines such as diuretics or water pills may cause excessive water loss. Some chronic diseases gradually cause the kidneys to stop functioning. Examples of such diseases include high blood pressure and high blood sugar. Obstruction of renal artery may also lead to kidney failure because it blocks the flow of blood to the kidneys. Toxicity from heavy metals can also cause kidney failure. Heavy metals such as Cadmium (Cd), Mercury (Hg), Lead (Pb), Chromium (Cr), Arsenic (As) and Platinum (Pt) are major environmental and occupational hazards that play a significant role in development of renal failure. The effects of renal failure include oedema. Oedema is swelling of the legs, ankles, feet, face or hands due to excess fluids and high levels of urea in the blood. Symptoms of oedema include vomiting, nausea, weight loss, blood in urine, difficulty in urinating and loss of appetite. Kidney failure also causes a rise in Potassium levels leading to failure of the body to produce enough erythroprotein for adequate red blood cell production. As a result, a person suffers from anaemia.

(b) Kidney stones (renal calculi)

Kidney stones are hard deposits of inorganic materials and organic substance that crystalizes in the kidney. They lead to pain when passing through the urinary tract. They are formed in the pelvic region of the kidney. They can be made up of uric acid, calcium oxalate or a mixture of calcium, magnesium and ammonium phosphates. Kidney stones may result into obstruction of urine flow. There are often no symptoms of kidney stones unless the stones move from their original

position. When the stones move into the ureter they cause severe pain which can be felt from the lower back. This may be accompanied by vomiting and sweating. There may also be blood in the urine. Kidney stones can be detected by x-ray. Small stones may pass down the ureter and out through the bladder without the need for treatment. Untreated kidney stones may lead to inflammation of the kidneys, a situation known as nephritis. It may involve the tubules, glomeruli, and tissue around these structures. Treatment of kidney stones involves drinking a large amount of water. The water can remove small stones while larger stones can be removed through surgery.

(c) Uraemia

This is a condition in which there is an abnormally high concentration of urea in the blood. It is a dangerous condition that occurs when the kidney is no longer filtering substances from the blood. Uraemia may be caused by the formation of cysts in the kidney tubules. It may also be a result of reduction in blood supply to the glomeruli as a result of contraction of the renal artery. The whole kidney shrinks and blood flow is further impaired, leading to severe hypertension. Symptoms of uraemia includes yellow colouration of the skin, itching of the skin, smelling of urine and nausea. This disorder may result into kidney failure. Uraemia can be controlled by taking a diet with low concentration of salts especially Sodium and Potassium. The affected person should undergo dialysis in order to remove excess urea in the blood.

(d) Urinary tract infections (UTIs)

UTI is an infection in any part of the urinary system. It can be an infection of the kidneys, bladder, ureters or urethra. In most cases UTI affects the lower part of the urinary tract. Urethritis is an infection of the urethra while cystitis is an infection of the bladder. Cystitis is caused by bacteria *Escherichia coli* or other infectious agents which pass through the bladder to the ureter. Urethritis is caused by bacteria or viruses that may enter through urethra opening. Women experience more cases of urethritis because they have a shorter urethral pathway than men. Females also have urethra close to their vagina. Sexually transmitted infections such as gonorrhoea, herpes, Chlamydia and mycoplasma may also result into urethritis.

Symptoms of UTI includes smelling urine, frequent and burning urination, clouded colour urine, inability to empty bladder completely, fatigue, fever, and leg cramps. Untreated UTI can lead to chronic kidney infections. Another effect of UTI in pregnant women is premature birth or delivering an infant with low birth weight. Men may experience urethral narrowing.

Preventive measures against UTI include proper cleaning of the area around anus

after bowel movement by wiping from the front to the back followed by cleaning with clean water. This is to ensure that faeces are always moving away from the urethra. It is also advised not to wear tight fitting pants. Another preventive measure is emptying bladder often or soon after sexual intercourse. Urinating soon after sexual intercourse may help to flush bacteria out of the urethra, thereby helping to prevent UTI. Drinking enough water to keep the body hydrated helps to prevent UTI. Patients should seek medical advice from a recognized health centre. If barrier contraceptive such as intra uterine device are used, they must be changed regularly.

(e) Urinary tract obstruction

This is a condition caused by the blockage or constriction of any point in the urinary tract. This prevents the normal flow of urine and causes urine to be retained in the bladder or kidneys. This condition can be caused by sexually transmitted diseases such as syphilis and gonorrhoea. It can be controlled through prevention against sexual transmitted diseases (STDs) and seeking medical assistance in case of symptoms of the diseases.

(f) Diabetes insipidus

This is excessive production of very dilute urine. It is caused by deficiency of vasopressin hormone which is released by the posterior lobe of the pituitary gland. Vasopressin or antidiuretic hormone (ADH) facilitates the reabsorption of water by the distal convoluted tubule and collecting duct of the nephron. Hence, lack of this hormone causes accumulation of water in the renal fluid causing excessive water to be lost through urine. This can be prevented through regular physical exercise and healthy eating. Diabetic insipidus patients are advised to go to a health facility for medical advice and proper treatment.

(g) Gout

This is another disorder of the excretory system. It is caused by abnormally high plasma concentrations of uric acid. Excessive quantities of uric acid are deposited in joints and tissues. This results in inflammation and pain. Toe joints are the most commonly affected. It may also affect hands and other joints. Life style that increases risk of developing gout includes taking excess alcohol and persistent consumption of food rich in purine. Red meat is an example of high purine food. Medication such as diuretics also increases the risk of gout because they stimulate and raise the level of uric acid in the body. Lastly overweight increases the risk of developing gout. Effects of gout include the formation of kidney stones. This means that uric acid crystals are collected in the urinary system and develop into kidney stones. Recurrent gout causes damage to the joints and tissues surrounding the kidneys.

Maintaining high fluid intake, avoiding excess alcohol and maintaining a healthy body weight are some preventive

measures against gout. Individuals with gout can also reduce symptoms by taking balanced diet regularly.

(h) Liver cirrhosis

This is a condition in which liver cells degenerate and fibrous tissue is formed leading to scarring and liver failure. It may be caused by many factors including alcohol intake, worms infestation in the liver, hepatitis or obstruction of the gall bladder. Symptoms includes headache, nausea, vomiting, lack of appetite and weight loss. The person with this disorder should be given fat free food and stop taking alcohol. The person is also advised to undergo medical treatment on gall bladder stones and worm infestation or hepatitis if they are found to be the cause. Later stages of liver cirrhosis may lead to jaundice. Jaundice is a medical condition in which the skin, sclera and mucous membranes turn yellowish because of high level of bilirubin. Bilirubin is a bile pigment. Jaundice may be caused by hepatitis, gallstones and tumours. Symptoms of jaundice includes yellowing of the skin, gastrointestinal bleeding, abdominal swelling, weight loss and fatigue.

Exercise 4.3

1. Explain the disorders of the urinary system.
2. State four causes of kidney disorders.
3. Briefly describe the control measures against kidney failure.

Excretion in plants

Types of excretory products eliminated by plants

Excretion also occurs in plants. However unlike animals, plants do not have a specialized system used to remove waste products from their bodies. Excretory products in plants include nitrogenous compounds, carbon dioxide, excess water and oxygen. Oxygen, carbon dioxide and water are produced as end products of plants metabolism. Excess water is excreted from the plant body through stomatal pores, from the surface of fruits and stem. Over 90 percent of water from plants is excreted in this way and enters the water cycle. The remaining water is used in photosynthesis and other metabolic processes. Another excretory product in plants is oxygen which is released as a by-product of photosynthesis. Oxygen diffuses into the atmosphere for use by other organisms. Another gaseous excretory product in plants is carbon dioxide. Carbon dioxide in plants cells is a waste product from aerobic respiration. Plants need to excrete excess carbon dioxide to prevent it from turning toxic. Excretion of excess carbon dioxide is through stomata by diffusion.

Plants also metabolise nitrogen and carbon dioxide to produce tannins and other organic acids. Some of these excretory products are stored in leaves and are lost from the plants

when the leaves fall. Many organic waste products of the plants including gum, resin and latex are stored within dead permanent tissue such as heart wood or barks which are removed periodically. The barks of most perennial plants are composed of dead tissues into which the excretory materials are passed on. Most of these products are used in the production of paints, turpentine, varnishes, soap, cosmetics, rubber, bubble gums and golf balls.

Plants do not need a specialised excretory system like animals because the rate of producing waste products in plants is much lower than in animals. Most excretory products from plants are also removed by diffusion through the stomata or lenticels. Lenticels are small pores in woody stems where the cells are loosely packed. This allows gaseous exchange and removal of waste products. Major excretory products of plants are in gaseous form, for example, carbon dioxide, oxygen and water vapour. In addition, plants have large vacuoles which store waste substances often accumulating at concentrations that lead to crystal formation in form of oil droplets or granules.

Most excretory products play a role in the development and survival of plants and other organisms.

The importance of common excretory products of plants

Many products from plants are recycled. For example, oxygen released as a by-product during photosynthesis is used in respiration by animals and plants. The carbon dioxide released during respiration is used for photosynthesis by the plants. Water is released into the atmosphere where it enters the water cycle. Plants also produce less poisonous substances compared to the nitrogenous wastes produced by animals. Water is also used by plants in photosynthesis to produce oxygen. This excretory product of plants is a vital component of respiration. Other waste products from plants are used as dyes, oils, perfumes and for medicinal purposes. Generally, plant excretory products are important in various ways. Some products are used as drugs in small quantities by man. For example, quinine is used to treat malaria, morphine and cannabis to produce painkillers, and nicotine to produce insecticides and stimulants. Some are taken as mild stimulants so as to increase mental activities and reduce fatigue. Examples include caffeine and theophylline. Tannins are used in treatment of leather. Some plants excrete products used to manufacture rubber goods such as tyres. Products such as papain are used in industry as a meat tenderizer.

Activity 4.4:

Identifying different excretory products produced by plants

Materials

Different plants around the school environment

Procedure

1. Move around the school environment and identify various products produced by different plants.
2. In groups share what you have collected from the tour.

Questions

(a) What are the importance of different types of excretory products produced by plants?

(b) Explain why plants lack specialised excretory organs.

(c) Why is it often difficult to determine whether substances produced by plant cells are really excretory products or secretions?.

Exercise 4.4

1. In what ways are waste products produced by plants important to humans?
2. How does excretion in plants take place?
3. How does deamination differ from excretion?

Revision exercise 4

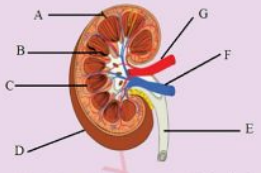
Choose the most correct answer.

1. Which of the following is a human excretory organ?
   (a) Gall bladder
   (b) Kidney
   (c) Urethra
   (d) Urinary bladder
2. The major excretory products in animals are_____.
   (a) carbon dioxide, exces water and urea
   (b) excess water, protein, glucose and urine
   (c) sweat, carbon dioxide, urea and oxygen
   (d) faeces, bile, excess water and urea
3. One of the most important functions of excretion in the human body is_____.
   (a) to maintain homeostatic conditions in the body
   (b) to reduce the amount of blood sugar in the body
   (c) to remove extra food from the stomach
   (d) to help the digestion process to proceed
4. The following are waste products excreted through the skin, except
   (a) water
   (b) lactic acid
   (c) carbon dioxide
   (d) urea

5. Which part of the nephrone in the glomerulus is invaginated?
   (a) Capsule
   (b) Kidney
   (c) Bowman's capsule
   (d) Malpighian body
6. In the human body kidneys act as_____.
   (a) water reservoirs
   (b) blood filters
   (c) blood stores
   (d) blood pumps
7. Normal urine contains the following dissolved substance:
   (a) Ammonia
   (b) Uric acid
   (c) Urea
   (d) Glucose

Answer the following questions

8. What do you understand by the terms excretion and ultrafiltration?
9. Explain how carbon dioxide is excreted from plants.
10. Describe the excretory organs of animals.
11. Explain the common disorders of the urinary system in human.
12. Describe the mechanism of urine formation
13. Carbon dioxide, excess water and urea are the waste products excreted by the human body:
    (a) Name parts of the body where each waste is produced
    (b) Name the major organ through which each waste is excreted
    (c) What will happen if these wastes are not excreted?
14. Study the figure of the human kidney below then answer the questions that follows



    (a) Name the structure labelled A to G
    (b) Which parts of the kidney are well supplied with blood capillaries? What is the function of these blood capillaries?
    (c) How is the human kidney adapted to its role?
15. Conduct a library search on how dialysis is conducted and present your findings to your teacher for clarification.
16. Plants do not need an elaborate excretory system similar to that of animals. Explain.

Chapter

Five

Regulation

Introduction

Living organisms contain tissue fluid whose conditions such as pH, glucose concentration, salt, temperature and pressure should be kept relatively constant regardless of the fluctuations in the internal and external environment. The ability of the organism to maintain a constant internal environment enables them to survive in different habitats. In order to keep the internal environment relatively constant, the body requires a system of constant adjustment since both internal and external environment of the cells keep on changing. In this chapter, you will learn about the concept of regulation, various types of regulation, concept of temperature regulation in animals, the mechanism of temperature regulation in mammals, concept of osmoregulation and factors that affect salt and water balance in the body. You will also learn the mechanisms of regulating blood sugar level. The competencies developed will enable you to maintain good health and behaviours which will make the body to function efficiently.

The concept of regulation

Regulation is a dynamic process that constantly monitors body systems to detect change and provides the mechanism that react to internal and external changes to restore stability. The external environment of living organisms is in constant change. Sometimes there is change in temperature, water availability, and salinity. Maintaining constant internal conditions of the organism despite changes in the external environment is known as regulation. The internal environment refers to the immediate surroundings of the cells comprising of fluid called interstitial, intercellular or tissue fluid. The external environment refers to immediate surroundings of the organism which may be marine, freshwater

or terrestrial. The process of maintaining the internal environment of an organism to be more or less constant is called regulation or homeostasis. Therefore, regulation is a process that moderates the frequency, rate or extent of a biological process. Biological processes are regulated by various mechanisms including the nervous system and hormonal system. Example of homeostasis is the control of the concentration of carbon dioxide in the blood. Homeostasis is a regulatory procedure in living organisms for maintaining the internal physiological conditions in case of changes in environmental conditions. Homeostasis regulates ratios of the body water and minerals, body temperature and levels of chemicals. Homoeostasis is therefore regarded as the ability of an organism to resist against changes in the external environment. Furthermore, it is taken as a self-regulatory process that regulates internal substances necessary to sustain life of an organism.

Importance of regulation

The process of regulation is important for the survival of living organisms because it maintains favourable conditions of body tissue fluids for proper functioning of cells, tissues and organs. It enables organisms to get rid of body wastes such as excess water and salts from the body. As a result excess materials are stored in another form which is not harmful to the organism. For example, excess sugar is converted into glycogen or fat deposits that cushions body organs such as heart and kidney.

Homeostatic mechanisms

For the body to maintain homeostasis, various organ systems must function in an integrated form. Homeostatic mechanisms have three interdependent components: a receptor, integrating or control centre, and an effector as seen in Figure 5.1. Receptor is the sensing component that monitors and detects changes in the environment of an organism. An example of a receptor is chemoreceptors, which detect changes in the organism's blood pH. The role of receptor organs is to sense changes in the external or internal environment and send the information to the control centre. The detectable changes in the internal or external environment that result in a functional activity or response is called stimulus. The control centre receives information from the receptors and initiates appropriate response to maintain homeostasis. The most important example of an integrating centre is the hypothalamus which is located near the pituitary gland found in the brain. It plays a crucial role in many important body functions such as releasing hormones and regulating body temperature. The result of that response feeds the effector, either enhancing it with positive feedback or depressing it with negative feedback. An effector is any organ or cell that receives information from the

control centre as a feedback. It acts to bring about the changes needed to maintain homeostasis. One example of an effector organ is the kidney which tends to retain water when blood pressure of an organism is too low.

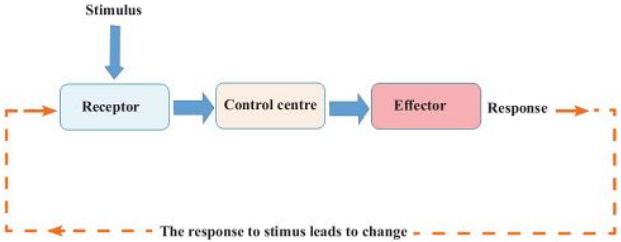


Figure 5.1: Components of the homeostatic control mechanism

Feedback from the control centre to the effector organs is an instruction of either to enhance the environmental change by positive feedback or depressing it with negative feedback. **Negative feedback** occurs when the response to a stimulus reduces the activated environmental stimulus. **Positive feedback** occurs when the response triggered by the control centre to a stimulus increases the occurrence of the stimulus. Positive feedback mechanisms are designed to accelerate the response created by the control centre through stimulus that has already been activated in the receptors. This is achieved when the body initiates a series of cascading processes that build to increase the effect of the stimulus. Examples of body processes that apply positive feedback loops are as follows:

1. Childbirth process – in this case, stretching of uterine walls during delivery causes contractions that further stretch the walls. This stretching continues until child birth. See Figure 5.2.
2. Lactation process – the breast feeding through sucking stimulates milk production which causes further feeding. This will also continue until the baby stops sucking.
3. Ovulation process – During ovulation, the follicle releases oestrogen hormone which stimulates the release of luteinizing hormone and follicle stimulating hormone which in turn promote further follicular growth.
4. Blood clotting process – During blood clotting, blood platelets release clotting factors which cause more platelets to aggregate at the site of injury.

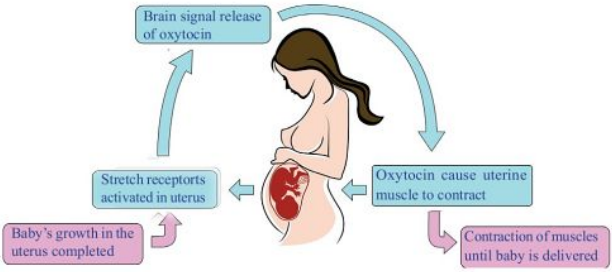


Figure 5.2: Positive feedback mechanism of oxytocin hormone during delivery of the baby

Negative feedback mechanism involves enhancing a response that works to reverse the change detected through a stimulus. It occurs when a change detected by a receptor and an effector organ or tissue is activated to induce an opposite effect. As a result, negative feedback mechanisms reduce a stimulus to return an organ or system to its normal functions. The process of regulating blood pressure is an example of negative feedback. Blood vessels contain sensors known as baroreceptors that detect the blood pressure. The signal about the level of blood pressure is sent to the hypothalamus. The hypothalamus then provides a message to the heart, blood vessels, and kidneys, which are the effector organs for blood pressure regulation. When the blood pressure is too high, the heart rate decreases because of vasodilation of the blood vessels. In this case the kidneys will retain less water. These changes in the effector organs will cause the blood pressure of a person to return to its normal range. This process is reversed when blood pressure of a person decreases in which the blood vessels constrict and the kidneys increase water retention. See Figure 5.3. Other examples of body processes that utilise negative feedback mechanism include thermoregulation, blood sugar regulation, and osmoregulation.

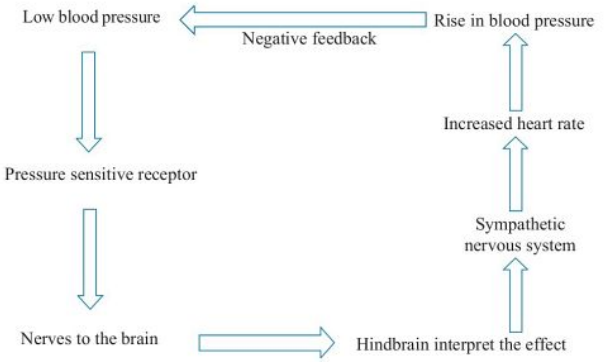


Figure 5.3: Negative feedback of blood pressure

Types of regulation

There are several mechanisms that are used to maintain internal body environment constant. These includes temperature regulation (thermoregulation), blood sugar regulation and osmoregulation.

Thermoregulation

Thermoregulation is the ability of the organism to maintain relatively constant body temperature regardless of the changes of external temperature. The thermoregulatory system regulates the temperature of the body in response to changes in the external temperature.

Animals that maintain a stable body temperature regardless of fluctuations in the environmental temperature are called **homoiotherms**. The term comes from Greek word **homo** meaning 'same' and **thermo** meaning 'heat'. The heat is generated internally by metabolic activities and hence they are also called **endotherms.** Mammals and birds are examples of homoiothermic animals.

Animals with a varying body temperature according to the changes in the environmental temperature are called **poikilotherms**. The term comes from Greek word **poikilos** meaning 'various' and **thermo** meaning 'heat'. These animals obtain most of their body heat from outside their bodies. They are therefore referred to as **ectotherms**. Examples of poikilothermic organisms include reptiles, amphibians and fish. With the exception of birds and mammals, most animals are ectotherms.

Temperature regulation in homoiotherms

In order to keep their body temperature more or less constant, homoiotherms must have mechanisms and structures to detect temperature changes. They also need to have a mechanism to restore the internal body temperature to its normal level. Temperature changes are detected by sensory cells located in the skin. The changes in temperature stimulate the sensory cells which in turn initiate impulses in sensory nerve endings. These impulses are sent to the brain's thermoregulatory centre. The thermoregulatory centre interprets these changes and sets off a series of body reactions which may either lead to increase or decrease in temperature. When the temperature of the surrounding environment is lower than the body temperature, animals lose heat to the surroundings. Heat is lost from the body surface through radiation, evaporation and conduction. See Figure 5.4.

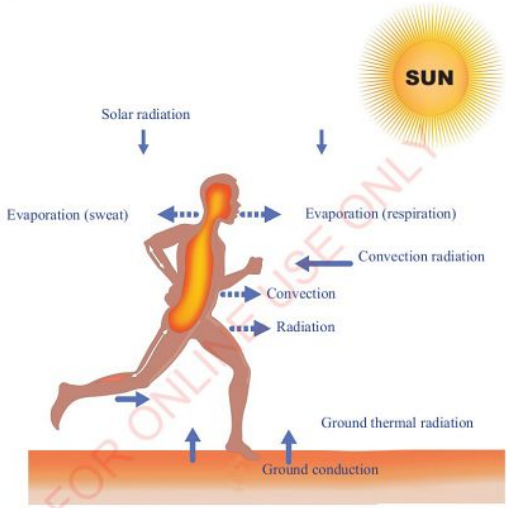


Figure 5.4: Thermoregulatory mechanism

When the temperature of the surroundings is low, the temperature of the animal begins to fall. In order to raise the body temperature to its normal level, the body of the animal responds by one or more of the following actions:

Increased metabolic rate

The body initiates chemical reactions that change carbohydrates and fats into energy. The energy is used by the body to perform various activities. Some energy is released in the form of heat. The heat increases body temperature. Metabolism is mostly carried out by the liver and skeletal muscles. The increased activity of adrenal, thyroid and pituitary glands results into secretion of hormones. These hormones help to increase the body metabolic rate. Additional heat produced in the body as a result of increased metabolic rate raises body temperature to the required level. Increased metabolic rate of the body requires increased food consumption. This is the reason why animals in cold climates require a larger amount of food compared to those in hot climates.

Shivering

Shivering is a body response to cold environmental conditions. In cold conditions, the skeletal muscles undergo rhythmic involuntary contractions which increases the amount of heat produced in the body.

Vasoconstriction

When the animal is subjected to cold conditions, the superficial arterioles are constricted. This process is called vasoconstriction. When vasoconstriction occurs blood flow is slowed down to reduce heat loss through the skin. Most of the blood passes beneath the insulating layer of subcutaneous fats, therefore little heat is lost to the environment. See Figure 5.5.

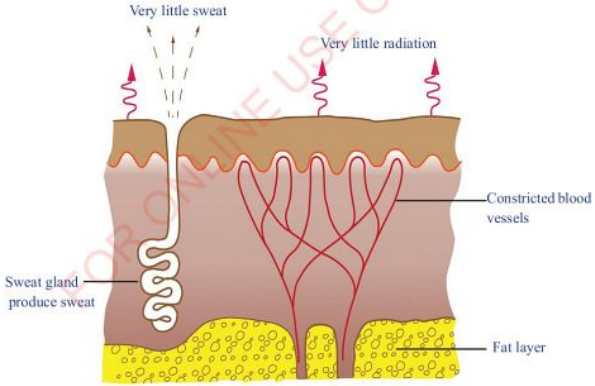


Figure 5.5: Vasoconstriction

Other means of increasing body temperature is through hair erection. In hairy homoiotherms, the hairs stand erect. In this way the fur acts as an insulator by trapping a layer of warm air close to the skin thus preventing heat loss by convection and radiation.

When body temperature rises, the temperature of blood also rises. The blood flowing to the brain stimulates the thermoregulatory centres. These centres trigger the following actions:

Vasodilation

This is the widening of the superficial blood vessels near the body surface. Vasodilation occurs when the smooth muscles in the blood vessels relax. When the body temperature rises, the superficial arterioles dilate in order to allow blood to flow close to the skin surface. Heat from the blood is conducted through the lower epidermis to the skin surface where it is radiated away from the body. See Figure 5.6.

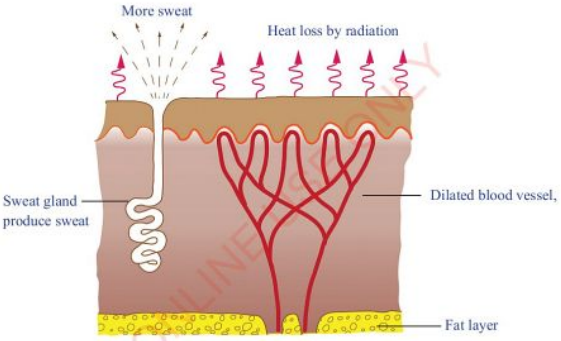


Figure 5.6: Vasodilation

Sweating

Human beings have the ability to control body temperature through sweating. This is because their bodies have a large number of sweat glands. These sweat glands are found beneath the skin over the whole body enabling them to be more efficient at cooling through sweating. Some animals with fur have limited sweat glands which are confined to areas that do not have fur, for example pads of the feet in dogs and cats. Excess heat in the body of mammals is detected by the hypothalamus; which sends

nerve impulses to the sweat glands under the skin. The nerve impulses cause the sweat glands to increase the production of sweat. Evaporation of sweat takes heat from the surface of the skin, which in turn cools the body. This process is reversed during cold conditions.

Relaxation of hair erector muscles

Hair present on the skin of the animal helps to control body temperature. The hair tend to lie flat when the environmental condition is warm and rise during cold weather. When the hair erector muscles relax, the hairs lie flat and reduce the thickness of insulating warm air. As a result, they give chance for heat to escape from the skin surface. Therefore, the temperature of the body is cooled down.

Panting and licking

These are mechanisms for reducing body temperature in the dog family and in birds. Panting is a thermoregulatory mechanism in which an animal breathes with short, rapid and quick gasp with its mouth open and tongue hanging out. When a bird pants, it breathes quickly with the mouth wide open. This allows air to move across the moist surface of its lungs, throat and mouth. The moisture then evaporates, and it absorbs heat from the bird's body. Dogs do not have sweat glands over most of their skin. Sweat glands in dogs are only found in the pads of their feet and nose. During panting, a dog hangs out its tongue and water evaporates from the surface of the tongue and nose. As a result temperature of its body is cooled as seen in Figure 5.7. Opening the mouth provides a large surface area for heat loss in these mammals. Some animals lick their bodies to deposit saliva onto their body surface. Licking is the action in which an animal passes the tongue over its body surface. This in turn provides the means of evaporative cooling. Licking is common in animals that do not sweat instead they make use of their saliva to cool their bodies. Rabbits for example, lick their front legs and chest, cats lick their front paws and spread saliva across the ears.

Figure 5.7: Panting in dog

Body extremities

Body extremities are external body parts of an organism such as limbs, ears, tails, genitalia and antennae. Animals in warm climates usually have large extremities such as ears and a bushy tail. They are well supplied with blood vessels and covered by relatively short hairs, making them good radiators of heat. Generally, animals that live in hot temperature conditions have less subcutaneous fat. These features help them to reduce insulation

and increase heat loss. Subcutaneous fat is the fat deposit just beneath the skin. Its purpose is to protect muscles and bones and to insulate bodies of organisms. In some animals such as camels and some breeds of cattle, fat is localized in the hump.

Behavioural mechanism

Many animals regulate their body temperature by using different behavioural mechanisms. Animals such as mice, rodents and bats avoid the hottest time of the day by being nocturnal. Nocturnal behaviour is the tendency of an animal to be active during the night and inactive during the day. This minimizes the rate of body metabolic activities during the day when it is hot.

Temperature regulation in poikilotherms

Poikilotherms, in contrast to homoiotherms, do not have physiological mechanisms to regulate their body temperature. When the environmental temperature falls, their bodies lose heat to the environment. This results into a fall in their body temperature. Under such conditions, their rate of metabolic reactions becomes low and the animal becomes inactive. Poikilotherms are thus faced with a problem of being overcooled if they are subjected to low temperatures. They overcome this problem by either moving away from cold areas or by hibernating.

When the environmental temperature rises, the body gains heat from the surroundings. Consequently, the rate of metabolism increases and the animal becomes active. However, prolonged exposure to high temperatures may lead to death of the animal due to overheating. In order to avoid this, poikilothems move to cooler areas or hibernate in burrows and nests. Most adjustment of body temperature in poikilotherms are by behavioural means which include sun basking, huddling, hibernation, aestivation, migration, and burrowing.

Sun basking

Ectothermic animals may use radiant heat from the environment to warm their bodies. Sun basking is a common means of warming up using sun rays. Reptiles and some amphibians bask in the sun with their bodies spread out to increase the surface area for heat absorption. When it is too hot, they hide in the shade or in water bodies to allow their bodies to cool.

Hibernation and migration

During winter some animals undergo a period of long deep sleep. This state of dormancy is called hibernation. Hibernation is a state where an animal greatly reduces its metabolic activities and slows the heart rate for the purpose of conserving energy. This enables the animals to survive in cold condition without consuming much energy. During this time, the metabolic rate can be reduced by 20-98%. As a result, the animal reduces food and oxygen utilisation. Animals with no suitable insulators such as fur or fat cannot hibernate. They avoid extreme low temperature by migrating to warmer places.

Aestivation

Aestivation is a form of hibernation during hot conditions when animals go into the state of dormancy to reduce body metabolic activities. During the hot and dry condition, some animals hide in nests or burrows. Thus their body metabolism slows down and the animals become inactive. They also protect themselves from high temperature by resting in shady or cool places. This resting state enables them to survive in hot and dry environmental conditions.

Huddling

Huddling is a mutualitic gathering or crowding together of animals in a close mass. This body contact increases body temperature. In cold regions, animals are usually active during the day and huddle together during the night. Huddling of individuals is also another common way of reducing heat loss. Some animals are able to crowd together in a tightly packed group to keep them warm and reduce heat loss that would occur when an individual animal is exposed to cold open air.

Advantages and disadvantages of poikilotherms

Since poikilotherms do not need to generate heat internally, they have low food consumption. They are able to modify their behavioral pattern to regulate body temperature. For example, they are able to undergo hibernation. One of the disadvantages of being poikilothermic is that they have low metabolic rate and therefore they become inactive when external temperature is low. During low temperatures the organism goes into hibernation and sometime this tendency causes death. Since poikilotherms rely more on external temperature, they take more time to respond to a stimulus.

Advantages and disadvantages of homoiotherms

Because their body temperature does not fluctuate with that of environment, homoiotherms tend to exploit a wide range of habitats. They have a high metabolic rate, hence remain active throughout their life. They are independent from external environmental temperature therefore, their enzyme controlled reactions proceed without any interruptions. They respond faster to stimuli than poikilotherms. The disadvantages of homoiotherms include consuming a lot of food. They do so in order to be in a position of generating heat internally. This is metabolically expensive. They need food with high calorific value such as fats to generate heat to keep the body warm especially in cold seasons.

Sometimes homoiotherms expend a lot of energy for temperature regulation. For example, when they migrate over a long distance in order to avoid adverse climate such as very low temperature. Such kind of movement is energy consuming. Migration can be observed in both homoiotherms and poikilotherms.

Activity

Investigating the effect of physical exercise on body temperature

Materials
Thermometer and playing ground

Procedure
1. Group yourself into pairs.
2. Measure the temperature of your partner and record it.
3. Run around the playing ground twice.
4. After completing running, measure the temperature again and record it and compare it with the first recording.
5. Rest for five minutes then measure your temperature again and record it.

Questions
1. Was there any changes in temperature before and after running?
2. What caused the changes?
3. Explain the significance of regulation of temperature in the human body.

Exercise

1. Differentiate between internal environment and external environment of an organism.
2. Why is regulation important in human beings?
3. How is temperature in human beings maintained in warm and cold environments?
4. Explain four processes through which animal body heat can be gained or lost.

Osmoregulation

The concept of osmoregulation in mammals

The amount of water and mineral salts in a mammal's body must be kept fairly constant. This is because all physiological processes in the organism's body need a particular range of water and mineral salts concentration to operate efficiently. The process of controlling the concentrations of mineral salts and water in the body is called osmoregulation. In osmoregulation, the osmotic pressure in the body is maintained at a constant level. Osmoregulation is achieved by either removing excess water or removing solutes. This is because movement of water into and out of cells is controlled by the concentration of salts. For example, if there is a high concentration of salts in the blood, water will move by osmosis out of cells into the blood. This will result into diluting the blood and thereby lowering fluid osmotic pressure. When there is a high concentration of salts in the cells, water will move from the blood into the cells hence the osmotic pressure in the cells will increase. The maintenance of constant osmotic pressure of the body fluid is very important for the proper

functioning of the cells. In case the osmotic pressure of the intercellular fluid falls below that of the intracellular fluid, cells gain water by osmosis. This leads to the swelling of the cells, which may even result into the bursting of the cells. If osmotic pressure of intercellular fluid rises above that of the intracellular fluid, cells will lose water by osmosis as a result the cells will shrink. Both effects disrupt the biological processes in the body.

Factors affecting the content of salts and water in the body

Environmental changes in a particular place may affect a mammal's body water and salt content. For example, during hot conditions mammals lose water and salts by sweating. Conversely, in cold condition sweating is reduced and hence the concentration of water and salts do not change considerably. Another factor is the type of food consumed. The type of food a mammal eats will govern the amount of water and salts entering its body. This is particularly true for humans. For example, drinking a lot of water and eating succulent fruits such as watermelons and cucumbers increases the amount of water in the body.

Mechanisms of Osmoregulation

The regulation of osmotic pressure is controlled by a hormone called Anti-Diuretic Hormone (ADH) also known as vasopressin. This hormone is produced in the pituitary gland and protects the body against excessive water loss or gain. When the amount of water in the body falls as a result of dehydration, the osmotic pressure rises. Osmoreceptors in the hypothalamus of the brain are stimulated and send the information to the pituitary gland to release ADH into the bloodstream. When it reaches the kidneys, ADH causes the membrane of distal convoluted tubules and collecting ducts to be more permeable to water. The higher permeability of the membrane increases the reabsorption of water into the bloodstream. This returns the water balance to normal.

When the osmotic pressure of the blood and tissue fluid falls due to the large intake of water, then the pituitary gland is less stimulated. This results into the reduced secretion of ADH into the bloodstream. Therefore, permeability of the membrane of distal convoluted tubules and collecting ducts to water decreases. Hence less water will be reabsorbed resulting in excretion of large amount of dilute urine.

When the osmotic pressure in the blood falls due to a low concentration of salt ions, particularly sodium and chloride ions, another hormone called aldosterone is released from the adrenal glands into the bloodstream. This hormone stimulates reabsorption of sodium and chloride ions from the kidney tubules and loop of Henle. The overall effects of these mechanism helps the animal to conserve water.

For example, a camel is a mammal with the longest loop of Henle which enables it to conserve salt ions. This in turn

increases the rate of water reabsorption in the kidney tubules hence it can live in dry areas.

Regulation of the pH of the body fluid

The pH is the negative logarithm of hydrogen ion concentration. In mammals the pH of the body fluid is maintained within a narrow range of between 7.2 and 7.4. This is the optimum range for the activity of intracellular enzymes. Deviations of pH outside this range leads to denaturation of enzymes and disruption of biological processes. Many body processes produce acids or bases which are then relesead into the body fluid causing the pH to increase or to decrease. Respiration produces pyruvic acid, lactic acid and carbon dioxide which decrease the hydrogen ion concentration in the body. The liver produces ammonium ions during deamination of excess amino acid and hence increases the pH of the body fluid. A fall in pH, means hydrogen ions are at higher concentrations. The kidney distal convoluted tubule regulates this by excreting excess hydrogen ions into the glomerular filtrate as a result pH rises to normal.

Regulation of blood sugar level

The process of digestion of carbohydrates ends up by producing simple sugars mainly glucose. Glucose is absorbed from the alimentary canal to the blood stream through active transport. In human beings, the level of blood glucose is maintained within a narrow range of between 90 and 100 mg per 100 ml of blood. However, fluctuations occur due to large intake or increased utilisation of glucose. For example, it may fall to about 80 mg per 100 ml of blood before breakfast and rise to about 140 mg per 100 ml after heavy intake of carbohydrates. It is important that the level of blood glucose is maintained relatively constant.

The pancreas is the major endocrine gland in the body that plays an important role in maintaining a constant level of glucose in the blood. The pancreas produces two hormones, glucagon and insulin from a specialized group of pancreatic cells called islets of Langerhans. The alpha cells of the islets of Langerhans secrete glucagon whereby the beta cells secrete insulin. These two hormones work antagonistically; that means they work together but in opposite directions. Their function is to ensure that the level of sugar stays within the range of 90 to 100 mg per100 ml of human blood. Insulin is produced when blood sugar level is higher than required, while glucagon is released when the blood sugar level is lower than normal. The hormones are regulated by negative feedback.

Insulin reduces the glucose level in the blood by stimulating the cells of the body except the brain cells to take up glucose from the blood. It lowers glucose in the blood by converting glucose to glycogen

and stores it in the liver and muscle cells. Insulin also blocks the conversion of amino acids and glycerol to glucose.

The liver stores carbohydrates as glycogen. The cells of the liver are extremely sensitive to glucagon. Glucagon directs the liver cells to convert glycogen to glucose. Glucagon initiates the release of glucose back into the blood circulation when glucose level is low in the blood. Glucagon and insulin are critical hormones in blood glucose control and they work cooperatively with the liver. Although nutrition is a key factor in stabilising the level of blood sugar, there are other factors that can cause fluctuation in blood sugar levels.

Causes, symptoms and effects of low blood sugar levels

Hypoglyacemia

Hypoglycemia is a condition in which the level of glucose in the blood is abnormally low. With the help of several glands and the hormones they produce, the body maintains the blood sugar at a constant level. Factors such as disease or poor diet can alter the mechanisms that regulate sugar levels in the blood leading to hypoglyacemia.

Causes

Hypoglyacemia can be caused by drugs, hormone deficiencies, tumours, failure of organs such as kidney, liver or heart. It may also be caused by strenous exercise immediately after eating and gastrointestinal surgery.

Symptoms

The brain is the first organ to feel the effects of hypoglyacemia. Signs and symptoms includes headaches, excessive sweating, blurred vision or dizziness, trembling, depression, anxiety, heart palpitations, slurred speech, seizures, and coma. Frequent hunger can be a sign of hypoglyacemia, indicating that the blood sugar level is too low.

Effects

Inadequate supply of glucose can result in impairment of body functioning. Effects of hypoglyacemia can include coma, permanent brain damage and even death.

Causes, symptoms and effects of high blood sugar levels

Hyperglyacemia

Hyperglyacemia or high blood sugar is the condition in which glucose concentration in the blood is above normal. If the pancreas is removed or fails to secrete insulin, there will be drastic increase in the concentration of blood sugar. Therefore, a mechanism is needed to correct it. Eventually glucose begins to appear in the urine, a condition known as glucosuria. Glucosuria is a common symptom of diabetes mellitus.

Diabetes mellitus

Diabetes mellitus is caused by deficiency of secretion of insulin from the pancreas. The disease is characterized by very high amount of blood glucose within a range of 400 to 800 mg per 100 ml of blood. Diabetes mellitus is caused by failure of glucose to diffuse into the cells. This level of blood glucose is above the kidney reabsorptives capacity of 180 mg per 100 ml of blood. The result is that glucose is excreted through urine and the condition is known as glucosuria. The excretion of urine is accompanied by high frequency of urination. This condition is called polyuria. Polyuria results into excessive thirst leading to the intake of large volumes of water. The kidney is forced to excrete excess glucose with a relatively large amount of water. Provision of insulin to diabetes patients lower the blood glucose level. In the long term other complications may occur to persons with diabetes which may be difficult to cure using insulin.

Causes of diabetes mellitus

High blood sugar can be caused by diabetes, obesity, or eating disorders. Individuals with diabetes mellitus have an increased blood sugar level which exceeds the reabsorption capacity of the kidneys. The kidneys are unable to reabsorb sugar back into the bloodstream. This causes production of more urine. That is why a person with diabetes mellitus urinates frequently.

Obesity is one of the most common cause of chronic non-diabetic hyperglyacemia. Many individuals can reduce the risk of non-diabetic hyperglyacemia by eating properly and exercising regularly in order to lower the body's excess white fat reserves. These fat reserves interfere with the body's ability to absorb and utilise glucose. Eating disorders, such as bulimia nervosa are also known to cause hyperglyacemia.

Symptoms of diabetes mellitus

Symptoms of hyperglyacemia in people with diabetes mellitus includes frequent hunger, thirst and urination. Other signs include blurred vision, fatigue, weight loss, poor healing of wounds, dry mouth, and dry or itchy skin. Diabetes mellitus can also be characterised by impotency in males and recurrent infections such as vaginal yeast infections, groin rashes or external ear infections.

Effects of diabetes mellitus

Hyperglyacemia can have adverse effects on the brain. The increased glucose level has been linked to increased cerebral lactate, which in turn causes local brain tissue acidosis and disruption of the blood–brain barrier. It also promotes cerebral oedema. Celebral oedema is the excess accumulation of fluid in the intracellular and extracellular spaces in the brain which leads to brain swelling. Hyperglyacemia can also affect stroke patients by impairing their cerebrovascular brain reactivity.

Diabetes inispidus

This is a disease that results from the failure of pituitary gland to produce sufficient ADH. The person passes out large amount of dilute urine, a condition known as **polyuria**. Such a person may even pass out up to 20 litres of urine per day and get dehydrated very fast. He or she has to compensate for the loss by drinking a lot of water and eating watery food.

Homeostasis in plants

Similar to other living organisms, plants also have the need to maintain the internal environment constant in order to survive and thrive in a changing external environment. They have a number of ways to maintain their internal environment relatively constant. They have leaves for maintaining homeostasis. Plant leaves possess an epidermis which protects internal tissues and permits exchange of materials with the external environment. They have stomata which open and close to allow exchange of gases. By the action of stomata, they regulate the quantity of gas to take in and that to let out. Stomata holes open and close to get the right amount of carbon dioxide and oxygen. Stomata regulate photosynthesis but they also maintain plant water at an optimum level. This is a form of homeostasis.

Revision exercise 5

Choose the most correct answer.

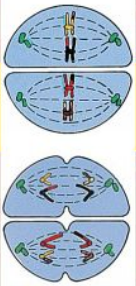
1. Beta cells in the islets of Langerhans secrete_____.
   (a) glucagon
   (b) insulin
   (c) thyroxine
   (d) aldosterone

2. Tissue fluid contains the same composition as blood but lacks_____.
   (a) carbon dioxide
   (b) cells and plasma protein
   (c) glucose and amino acids
   (d) fatty acids and hormones

3. The following actions regulate temperature in mammals.
   (a) Sweating, shivering, swimming and urinating
   (b) Shivering, vasodilation, sweating, and vasoconstriction
   (c) Conduction, radiation, convection and swimming
   (d) Vasodilatation, swimming, sweating and locomotion

4. One among the following processes is used in forming the tissue fluid.
   (a) Osmosis
   (b) Ultrafiltration
   (c) Filtration
   (d) Diffusion

5. Which of the following is not an advantage of homoiothermy?
   (a) High metabolic rate
   (b) Active throughout
   (c) Respond faster to stimuli
   (d) Consume a lot of food
6. Anti-duretic hormone(ADH) is secreted by_____.
   (a) pituitary gland
   (b) thyroid gland
   (c) pancrease
   (d) adrenal gland
7. A condition in which glucose is passed in urine is called _____.
   (a) hypoglycemia
   (b) diuresis
   (c) glucosuria
   (d) polyuria
8. In which ways is body temperature regulated physically?
9. State any four advantages of homoiotherms over poikilotherms.
10. Explain the meaning of regulation, thermoregulation and osmoregulation.
11. State the role of insulin and glucagon in blood sugar regulation.
12. Outline any four factors that can affect the content of salt and water in the body.
13. What is the function of the hypothalamus in temperature regulation?
14. Explain how blood sugar and body fluid pH can be regulated
15. Mammals use both behavioral and physiological mechanisms in regulating body temperature. Explain how this takes place.
16. In cold and humid weather, humans usually produce a larger quantity of urine that is colourless. Comment on this statement.



Chapter

Six

Introduction to reproduction

Introduction

Reproduction is one among the fundamental characteristics of living organisms. It is the biological process which enables living organisms to produce their offsprings. It ensures existence and continuation of generations of living things. Reproduction is categorised into asexual and sexual reproduction. In this chapter, you will learn about the concept of reproduction, importance and types of reproduction. You will also learn about the process of meiosis and its significance in sexually reproducing organisms. The competencies developed will enable you to sustain advantageous traits of both plant and animal species.

The concept of reproduction

Reproduction is a fundamental process by which biologically matured living organisms produce offsprings that are genetically similar to them. It is the ability of an organism to produce new individuals of the same species. Reproduction ensures survival and continuity of different types of individuals in the population. The new individuals produced undergo growth and development before they reach the period of being capable to reproduce. There are two types of reproduction namely asexual and sexual reproduction. In asexual reproduction there is no fusion of gametes or change in number of chromosomes. Sexual reproduction involves the fusion of male and female gametes. It is preceded by a process called meiosis. Meiosis process results into the formation of gametes with a reduced number of chromosomes by half. Most unicellular organisms exhibit asexual reproduction while humans and other complex multicellular organisms such as plants exhibit sexual reproduction.

Importance of Reproduction

The process of reproduction is important to plants and animals because it results into an increase in number of individuals in a population. It therefore maintains the size of the population as dead organisms are replaced by new ones. In this way, continuity of species is ensured. It is also a means of variation among individuals in a population. This is because reproduction involves the transmission of genetic materials from one generation to the other.

Activity 6.1:

Observing types of reproduction in organisms

Requirements

Varieties of plants around school environment

Procedure

1. Observe different types of plants found in your school environment
2. Discuss with your classmates whether the plants observed reproduce sexually or asexually.
3. Tabulate your findings of at least five species of plants showing the name of plant and the type of reproduction.

Types of reproduction

There are two types of reproduction which are asexual and sexual reproduction.

Asexual reproduction

Asexual reproduction is the type of reproduction whereby only a single individual give rise to new offspring. It does not involve the fusion of gametes. As a result, the offspring reproduced asexually are genetically identical to their parents. In animals, asexual reproduction is widely found in unicellular organisms and it leads to rapid population growth. In plants, asexual reproduction occurs when there is growth of a new plant from a stem, leaf, root or bud. There are different forms of asexual reproduction depending on the type of organism. These forms include the following:

1. Fission

In this form of asexual reproduction, a parent separates into two or more individuals of equal size. Fission can be binary or multiple fission.

(a) Binary fission

This is the process whereby an organism divides into two equal parts. Each part grows to attain the original size of the parent cell under favourable conditions as seen in Figure 6.1. In the process of binary fission, duplication of genetic materials occurs when the nucleus splits and each new organism formed receives the same copy. Each part becomes a separate and independent organism. This is because each part carries a copy of DNA from the parent cell. Organisms such as Amoeba, Paramecium, Euglena and Trypanosoma undergo binary fission.

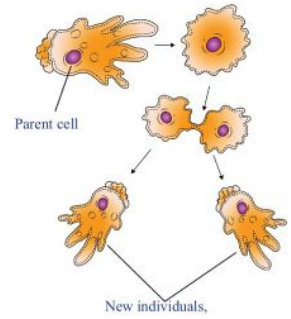


Figure 6.1: Binary fission in Amoeba

(b) Multiple fission

Multiple fission occurs when a parent cell divides into many parts rather than just two parts. The nucleus repeatedly divides to form several nuclei and each nucleus absorbs a little amount of cytoplasm and forms a membrane around each structure as seen in figure 6.2. This form of asexual reproduction occurs in organisms such as Plasmodium and Amoeba species. In Amoeba, multiple fission occurs only when the environmental condition does not fovour binary fission especially during drought.

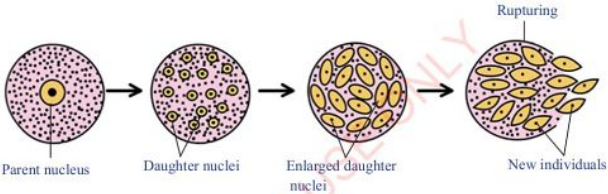


Figure 6.2: Multiple fission in plasmodium

2. Fragmentation

This is a form of asexual reproduction where by an organism breaks down into fragments (pieces) and each fragment develops into a mature organism containing features identical to those of the parent. Example of an organism that undergoes reproduction by fragmentation is the sponge as seen in Figure 6.3. When a sponge breaks into fragments; each fragment develops into a complete sponge. Other organisms which undergo fragmentation includes some algae and cnidarians.

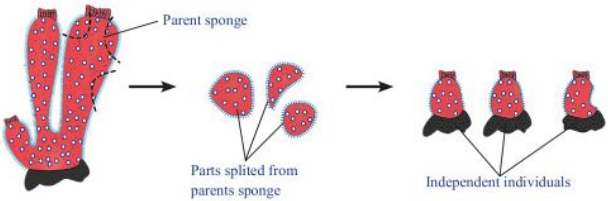


Figure 6.3: Fragmentation in a sponge

3. Spore formation (sporulation)

This is the type of asexual reproduction whereby an organism reproduces new organisms by reproductive cells called spores. Spores are small unicellular structures which are capable of developing into new individuals. Spores are also called reproductive cells but not gametes. They are produced in specialised structures known as sporangia (singular sporangium). In ferns, sporangium is called a sorus (plural sori) and in moss they are known as capsules. When the spores are fully developed, the sporangium burst to release the spores to the ground as shown in Figure 6.4. The spores can be dispersed by wind or animals. When spores land on a suitable environment they germinate into new organisms. Examples of organisms that reproduce by sporulation includes bacteria, protozoans, fungi, mosses and ferns.

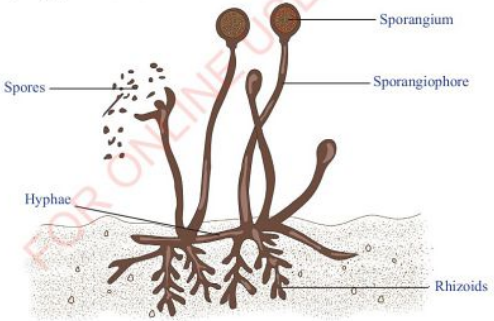


Figure 6.4: Multiple fission in *Rhizopus*

4. Budding

This is a form of asexual reproduction in which a new individual is produced as an outgrowth of the parent. The outgrowth is called a bud. The bud remains attached to the mother plant until it is fully grown. After maturity, the outgrowth detaches from the parent plant and becomes an independent organism which is identical to the parent. Yeast and hydra reproduce by budding as shown in Figure 6.5.

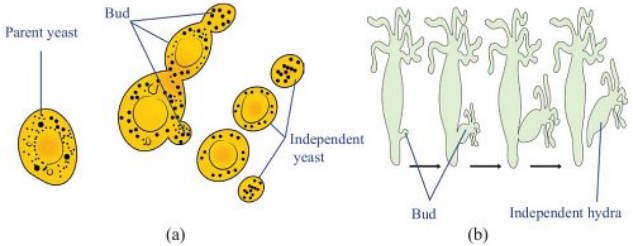


Figure 6.5: Budding in (a) yeast (b) hydra

5. Vegetative propagation

In plants asexual reproduction is called vegetative propagation. This occurs when a new plant grows from a fragment of a parent plant or through specialised reproductive structures such as leaves, roots, stems or buds. Vegetative propagation can be achieved either naturally or by artificial means. The details of both natural and artificial vegetative propagation are in chapter seven.

Advantages and disadvantages of asexual reproduction

There are several advantages of asexual reproduction. One of the advantages of asexual reproduction is that it produces an organism with the same genetic composition as its parent. This is because asexual reproduction involves only one parent. If these organisms are well adapted to their environment, successful traits are preserved in offsprings. Another advantage is that it results into many offsprings which mature faster than sexually produced organisms. This enables the farmers to have more products than through sexual reproduction. Asexual reproduction saves time because the organisms do not waste time to find their mates. This is beneficial to farmers who need fast growing plants. Asexual reproduction does not depend on other processes. For example, in plants it does not involve pollination, fertilisation and dispersal of fruit and seeds. In addition, the new organism is able to obtain nourishment from the parent and can temporarily survive when conditions are unfavourable.

However, asexual reproduction also has some disadvantages. Parents may pass undesirable characteristics to the offspring since organisms produced are genetically identical to the parents. Competition for resources such as food and shelter may also occur due to large number of organisms being produced. Since only one parent is involved, the genetic diversity among asexually reproducing organism is very low. Genetic diversity is crucial for survival and adaptability. Organisms with low genetic diversity are at greater risk of extinction when the environmental conditions become unfavourable. A small change in the environment may eliminate the entire population.

Sexual reproduction

This is the type of reproduction which involves two individuals. One parent is a male and the other is a female. Sexual reproduction involves sperms and eggs which are specialised sex cells called gametes. It occurs when the sperm from the male parent is fused with the egg from the female parent to produce a new organism as illustrated in Figure 6.6. These gametes are either formed by a single organism or by different individuals of different sex. The two gametes differ in form and function. In animals, gametes are produced in organs called the ovaries and testes. In flowering plants, gametes are produced in anthers and ovaries. The process of fusion of male and female gametes is called fertilisation. In most animals, male and female gametes are produced in different sexes. In plants, male and female gametes may be produced by the same plant or different plants. An organism is capable of sexual reproduction only when it is sexually matured. This is because reproductive organs in young organisms are not fully developed. Example of plants that reproduce sexually are maize, beans and mangoes. Animals such as lion, elephant, human beings, cattle and chicken reproduce sexually.

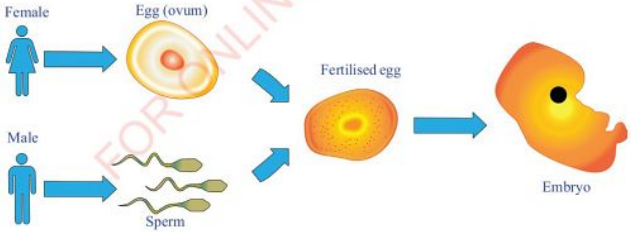


Figure 6.6: Fertilisation process in human

Advantages and disadvantages of sexual reproduction

There are various advantages of sexual reproduction. This types of reproduction produces variation in the offsprings because they inherit genes from two different parents. Genetic variation increases the survival and adaptability of the population. This reduces the chance of extinction when the environmental factors become unfavourable. It also reduces the risk of genetic disease because of recombination process.

Sexual reproduction also has some disadvantages. For example this mode of reproduction spends a large amount of energy and time as it needs two organisms, except in hermaphrodites. This results into slow population growth. Genetic recombination exercised in sexual reproduction can lead to mutation. Thus, harmful mutation can be passed on to the offsprings. Sexual reproduction can also transfer diseases from one organism to another especially sexual transmitted diseases. Moreover, this reproduction is uncertain as it involves processes like pollination and fertilisation, all of which are not guaranteed and involve some risks. Gametes can be lost because there is no guarantee that the male and female gametes will fuse to form a zygote. Undesirable characteristics may also emerge as the genetic makeup of the offsprings are not identical to the parents. Example of diseases that are inherited through sexual reproduction include haemophilia and sickle cell anaemia.

Table: Comparison between sexual and asexual reproduction

Sexual reproduction	Asexual reproduction
Male and female gametes are involved	Gametes are not involved
Two organisms or parents are usually involved	One organism or parent is involved
Population increases slowly	Population increases rapidly
New organism is not genetically identical to parents (there is variation)	New organism is genetically identical to parents (no variation)
Meiosis is essential for gamete formation	Mitosis is essential in formation of new individual
Diploid zygote is formed through fertilisation	There is no formation of zygote

Exercise

1. What is the difference between sexual and asexual reproduction?
2. Describe the advantages of genetic variation created during meiosis.

3. How does binary fission differ from multiple fissions?
4. What are the advantages of asexual reproduction?
5. How does reproduction in unicellular organisms differ from that of multicellular organisms.
6. State the type of reproduction that takes place in the following organisms.
   (a) Amoeba
   (b) Annelids
   (c) Yeast
7. Explain the disadvantages of sexual reproduction.

Meiosis

Meiosis is a form of cell division that reduces the number of chromosomes in the parent diploid sex cell by half. It is a crucial process in sexually reproducing organisms that has to occur in reproductive cells before the actual reproduction begins. In this process, one diploid sex cell produces four gametes, each with half the number of chromosomes. Sexual reproduction requires the union of two reproductive cells, the male and female reproductive cells. These cells might be from one organism as in case of some plants or from two different organisms as the case in most animals. These cells are called gametes and the process of fusion of these cells is called fertilisation. Sexual reproduction involves the formation of haploid cells which unite to form a diploid cell. A haploid cell is a cell with a single set of unpaired chromosomes. A diploid cell on the other hand is the cell obtained from fusion of two haploid cells. This means that, a diploid cell has a pair of each type of chromosome. One pair is from the female reproductive cell and the other pair from the male reproductive cell. Before sexual reproduction starts, the number of chromosomes in each parent must be reduced to a half so that on union, the diploid number is restored. Chromosomes are thread-like structures found in the nucleus of the cell. Chromosomes carry hereditary information (DNA) that are passed from parents to offspring. The gametes produced by meiosis are eggs (ova) from a female organism and sperms from a male which are needed for sexual reproduction.

Meiosis is also termed as reduction division as it reduces the number of chromosomes from the diploid number (2n) to haploid number (n). Meiosis forms the basis of sexual reproduction and can only occur in eukaryotes. During meiosis, a chromosome is replicated once and separated twice. This leads to the production of four sets of haploid cells each containing half the number of the original chromosomes as shown in Figure 6.7.

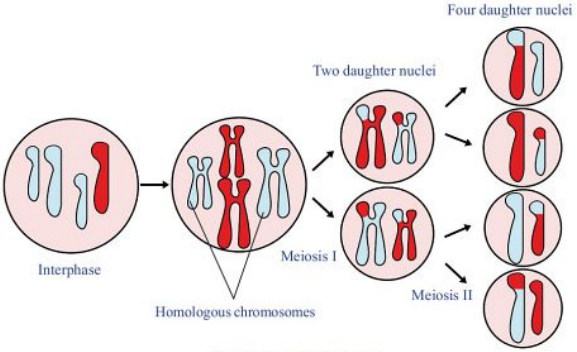


Figure 6.7: Meiosis process

Mechanism of meiosis

The process of meiosis is accomplished in two consecutive cycles or phases namely; meiosis I and meiosis II (First meiotic division and Second meiotic division). Both phases are preceded by a non–dividing stage called interphase. For a single cell, the first meiotic division produces two haploid cells. The two nuclei then enter the second meiotic division and each cell produces two daughter cells making a total of four haploid daughter cells. Generally, the whole process of meiosis involves the division of the nucleus, the cytoplasm and the cell.

Interphase

This is the stage during which the cell prepares itself for division. This stage is mistakenly termed as the resting stage. However, cells never rest unless they are dead. During interphase stage the cell have the following features;

Chloroplasts and mitochondria, if present in plants, replicate followed by the replication of other cell organelles. The cell also grows. There is also replication of DNA in this stage. There is an increase of energy stored in the cell. Centrioles, if present, replicate. The chromosomes replicate and each has a pair of chromatids held together by centromere as shown in Figure 6.8.

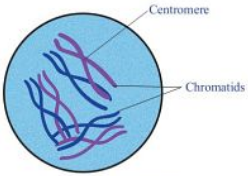


Figure 6.8: Interphase

First meiotic division (Meiosis I)

This is the first cycle of the two consecutive meiotic nuclear divisions. Its principle role is to reduce the number of

chromosomes to half before the second meiotic division. Meiosis I involves four consecutive stages namely prophase I, metaphase I, anaphase I and telophase I.

Prophase I

It is the longest phase of meiosis. It includes early, middle and late prophase I stage.

(a) Early prophase I: Homologous chromosomes contract, thicken, shorten and became visible. Nucleolus disintegrates and disappears as shown in Figure 6.9.

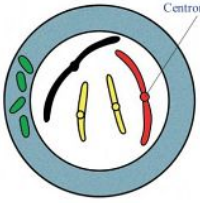


Figure 6.9: Early prophase I

(b) Middle prophase I: Homologous chromosomes pair up forming bivalents as shown in Figure 6.10.

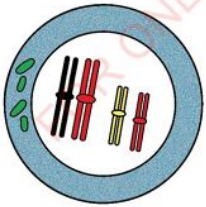


Figure 6.10: Middle prophase I

(c) During the late prophase I, DNA is exchanged between homologous chromosomes in a process called homologous recombination as shown in Figure 6.11. This often results in chromosomal crossover. The new combinations of DNA created during crossover are a significant source of genetic variation, and may result in beneficial new combinations of alleles. The paired chromosomes are called bivalents or tetrads, which have two chromosomes each and two chromatids, with one chromosome coming from each parent. The process of pairing of the homologous chromosomes is called synapsis. At this stage, non-sister chromatids may cross-over at points called chiasmata (singular chiasma) which result in exchange of chromatid parts.

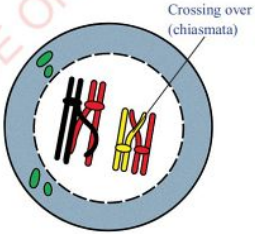


Figure 6.11: Late prophase

Metaphase I

The bivalent of homologous chromosome moves to the equator of the cell and are attached on spindles. Nucleoli and nuclear membrane disappear completely. The

spindle fibres are completely formed. The homologous chromosomes align themselves at the equator with their centromere being held by spindle fibre as seen in Figure 6.12.

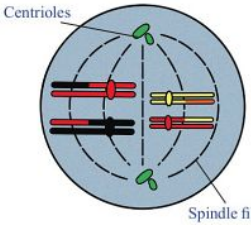


Figure 6.12: Metaphase I

Anaphase I

During anaphase I, the spindle fibres contract, pulling the homologous chromosome pairs away from each other and towards each poles of the cell. During this time disjunction occurs, which is one of the processes leading to genetic diversity as each chromosome can end up in either of the daughter cells. Spindle fibres lengthen, pushing the centrioles further apart. The cell elongates in preparation for division as seen in Figure 6.13.

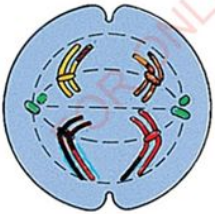


Figure 6.13: Anaphase I

Telophase I

The first meiotic division ends when the chromosomes arrive at the poles. Each daughter cell now has half the number of chromosomes but each chromosome consists of a pair of chromatids. The microtubules that make up the spindle fibres disappear, and a new nuclear membrane surrounds each haploid set at the pole. The nucleolus reappears. The chromosomes uncoil back into chromatin. Chromosomes number are halved but the chromosomes are composed of two chromatids.

Cytokinesis, the pinching of the cell membrane in animal cells or the formation of the cell wall in plant cells occurs completing the creation of two daughter cells. Sister chromatids remain attached during telophase I. This is why meiosis I is often called **reduction division.** See Figure 6.14.

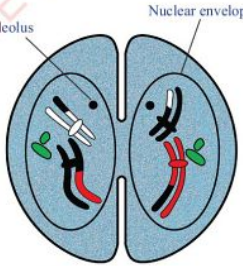


Figure 6.14: Telophase I

Two new cells are formed, each with half the number of chromosomes of the parent cell.

Second meiotic division (meiosis II)

Meiosis II is the second part of the meiotic process, the process is similar to mitosis, though its genetic results are fundamentally different. The end result is production of four haploid cells (with 23 chromosomes in humans) from the two haploid cells consisting of two sister chromatids produced in meiosis I. There are four main steps of meiosis II which are prophase II, metaphase II, anaphase II, and telophase II.

Prophase II

In animals interphase II usually precedes the prophase II stage, but it does not involve DNA replication. During prophase II stage the nuclear membrane and nucleolus disappear and the spindle fibres forms and centrioles duplicate. The two pair of centrioles separate and migrate to the opposite poles, followed by shortening and thickening of the chromatids as shown in Figure 6.15.

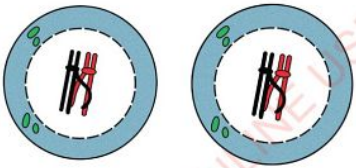


Figure 6.15: Prophase II

Metaphase II

During metaphase II, chromosomes arrange themselves on the equatorial plane of the spindles. The spindle fibres attach to each chromosome at its centromere as shown in Figure 6.16.

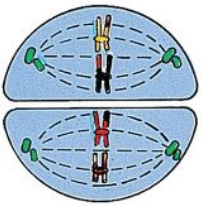


Figure 6.16: Metaphase II

Anaphase II

During this stage, centromeres split and the spindle fibres pull the sister chromatids apart. The separated chromatids are now called chromosomes. Then, cleavage furrow starts to develop in each cell as shown in Figure 6.17.

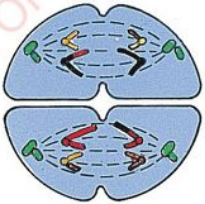


Figure 6.17: Anaphase II

Telophase II

During telophase II, the chromatids reach the opposite poles of the spindle. The chromosomes uncoil and lengthen. The spindle disappears and centrioles replicate.

A new nuclear membrane forms around each group of chromosomes as shown in Figure 6.18. In animal cells, cytokinesis or cleavage of the cell give a four haploid daughter cells which are differentiated and mature into gametes, either sperm or ovum.

In plant cells, a cell plate develops along the equator of the spindle fibres formed from vesicles. This plate separates the cytoplasm of the two daughter cells. New cell walls are formed to enclose the four daughter cells.

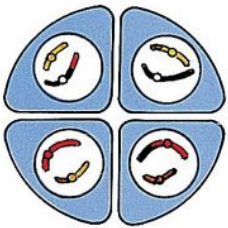


Figure 6.18: Telophase II

When meiosis II is complete, there are a total of four daughter cells, each with half the number of chromosomes.

Significance of meiosis in sexually reproducing organisms

The process of meiosis results into formation of haploid cells. This ensures a constant number of chromosomes in all species. Without meiosis the number of chromosomes during fertilisation would result into different species. Meiosis is a source of genetic variation. This is because the gametes produced in meiosis are not genetically identical to the parent cells or to each other. The diversity is due to crossing over and independent assortment of the chromosomes during anaphase I. Crossing over during prophase I involves the exchange of pieces of genetic information or materials between the paternal and maternal chromosomes leading to new combination of genetic information in the gamete.

Activity

Observing meiotic stages of cells

Material

Prepared slides showing stages of meiosis and a light microscope

Procedure

1. Place the light microscope on a table and set it in order to be used in observation.
2. Place the prepared slides on light microscope stage.
3. Observe each of the prepared slides under the light microscope one after another.
4. Draw and label the diagrams of what you have observed under the light microscope for each prepared slide and name the stage of meiosis represented in each slide.

Revision exercise 6

Choose the most correct answer.

1. Production of seeds by a maize plant is an indication of_____ reproduction
   (a) asexual
   (b) sexual
   (c) neither sexual nor asexual
   (d) both sexual and asexual.
2. One of the advantages of sexual reproduction is that it increases organism's_____.
   (a) adaptation ability
   (b) number of cells
   (c) number of organs
   (d) number of tissues
3. Variation is possible in sexual reproduction because the process involves_____.
   (a) plasmolysis
   (b) hydrolysis
   (c) meiosis
   (d) mitosis
4. During meiosis disappearance of the nuclear membrane happens at _____.
   (a) prophase I and metaphase II
   (b) prophase II and metaphase I
   (c) prophase I and anaphase II
   (d) prophase I and prophase II

5. Match each item in **column A** against its corresponding item from **column B**.

Column A	Column B
(i) Adaptation	A. Stage where chromosomes are pulled to the opposite ends of the cell.
(ii) Chromatids	B. Chromosomes in the cytoplasm.
(iii) Metaphase	C. The process that involves the use of gametes
(iv) Bivalents	D. The nucleus repeatedly divides to form a large number of nuclei.
(v) Interphase	E. A pair of homologous chromosomes
(vi) Meiosis	F. A stage where chromosomes align at the equatorial region of the cell.
(vii) Sexual reproduction	G. A stage where cell metabolism stops
(viii) Multiple fission	H. Nuclear division in which the chromosome number is halved from the diploid number (2n) to haploid number (n).
(ix) Binary fission	I. A stage where cell organelles replicate
(x) Centromere	J. Type of reproduction where a cell divides into two equal parts.
	K. Holds the chromatids together at one point
	L. The two strands of a copied chromosome.
	M. Is enhanced by variation in organisms.
	N. Growth of a cell.

Answer the following questions

6. Explain the importance of reproduction in living organisms.
7. Provide one example of a plant that undergoes each of the following types of asexual reproduction
   (a) Binary fission
   (b) Multiple fission
   (c) Fragmentation
   (d) Sporulation
   (e) Budding
   (f) Vegetative propagation
8. Compare and contrast between asexual and sexual reproduction.
9. With the aid of illustrations explain how variation is likely to be brought about in organisms that reproduce sexually.
10. What is the advantage of asexual reproduction over sexual preproduction?
11. Explain the role of meiosis in sexual reproduction.
12. Distinguish between prophase I and II.
13. Explain the role of spindles fibre in meiosis.
14. What happens to a cell at interphase stage?
15. With proper illustrations explain the stages of meiosis I.

Chapter

Seven

Reproduction in plants

Introduction

Plants are multicellular eukaryotic organisms that are capable of manufacturing their own food through photosynthesis process. In chapter six, you learnt about the concept of reproduction, importance and types of reproduction, processes of meiosis and its significance in sexually reproducing organisms. Some plants accomplish reproduction process sexually while others asexually. In this chapter you will learn about reproduction process in both flowering and non-flowering plants in which structure of flower, pollination and fertilization process will be discussed. The competencies developed will enable you to participate in sustaining plant species by taking care of the agents that facilitate the process of reproduction.

Asexual reproduction in plants

In plants, asexual (vegetative) reproduction involves the growth of a new plant from other parts of plant such as a stem, leaf or root but not from the seed. People use vegetative reproduction to grow new plants from a root, stem or leaf. This is what is referred to as vegetative propagation.

Activity 7.1:

Identifying plants which reproduce by seed and without seed.

Materials

Varieties of plants which reproduce by seed and without seeds.

Procedure

1. In groups collect varieties of plants from the surroundings.
2. Then separate the collected plants into two group one which reproduce by seed and the other without seed.
3. Compare your findings with the findings of other groups.

Vegetative propagation

Vegetative propagation is any form of asexual reproduction in plants in which a new plant grows from a fragment of a parent plant and not from seeds. Similar to other types of asexual reproduction this form of reproduction does not involve gamete formation and fertilisation. Vegetative propagation uses parts of the original plant such as stems, leaves and roots to initiate a new plant. Plants such as bananas, sweet potatoes, cassava and pineapples have the ability to reproduce by vegetative propagation. Vegetative propagation is also known as vegetative reproduction or vegetative multiplication. Many plants can reproduce by vegetative propagation either naturally or by artificial means. Natural propagation occurs without human intervention. Artificial vegetative reproduction is the propagation which occurs as a result of human intervention and manipulation.

Natural vegetative propagation

There are various plant structures through which natural vegetative propagation can occur. Vegetative structures that enable natural vegetation reproduction include rhizome, stolon, bulb, corm, tubers suckers, and bulbils.

(a) Rhizome

A rhizome is a type of plant stem situated on the soil surface or underground. It contains nodes from which roots and shoots originate. New shoots from the node will grow upward to form a new plantlet as shown in Figure 7.1. Rhizome is usually an organ of perennation as well as vegetative propagation. They are storage sites for food substances such as proteins and starch. Some examples of plants that are propagated by rhizome include ginger, turmeric, irises, and lily.

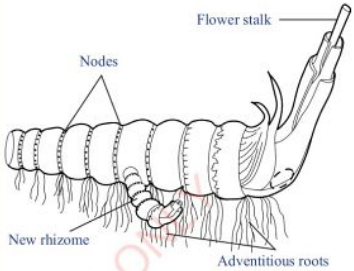


Figure 7.1: Iris rhizome

(b) Stolons

Stolons or runners are horizontally growing stems that creep along the ground surface. They have nodes and internodes as shown in Figure 7.2. Unlike rhizomes, stolons originate from the existing stem. Usually plantlets tend to form along the stolon. This happens when roots emerge at the point of attachment of the node to the ground. When the connection of plantlets and the mother plant breaks, the plantlet develops into an independent plant. The stolon is not an organ of perennation. Examples include red-currant (*Ribes sanguineum*), blackcurrant (*Ribes nigrum*), blackberry (*Rubus* sp) and sweet potatoes (*Ipomoea batatas*).

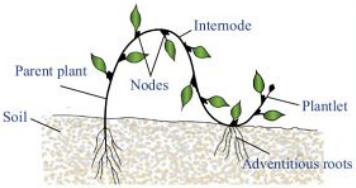


Figure 7.2: Generalised plan of a stolon

(c) Bulb

This is a modified underground stem surrounded by fleshy modified leaves which store food. It has one or two buds which develop to become a shoot. It also has adventitious roots which grow from the stem. An example of a plant that undergoes this type of vegetative propagation is the onion as seen in Figure 7.3.

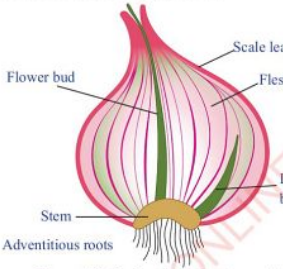


Figure 7.3: Section through a dormant bulb

(d) Tubers

These are swollen underground storage organs formed either on roots or stems. Stem tuber has terminal bud, lateral buds and scale leaves. They form axillary (lateral) buds called eyes that are capable of initiating shoots that grow into a new plant. Tubers store foods mainly as starch. In root tuber, the food can be stored in tap root as in carrots or it can be stored in the adventitious roots as in cassava. Stem tubers do not possess roots as in root tubers. Examples of stem tubers are carrot and irish potatoes as seen in Figure 7.4.

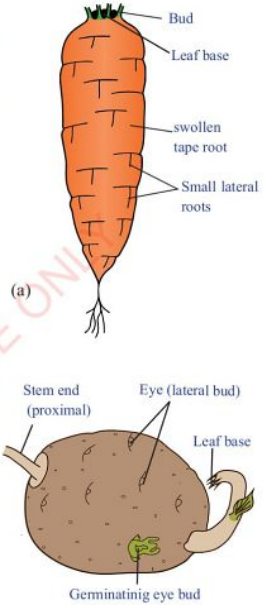


Figure 7.4: (a) Root tubers of carrot
(b) Stem tuber of irish potato

(e) Corm

This is a short swollen underground stem which has scale leaves, adventitious roots and leaves at its upper part. They also have lateral and terminal buds producing new corm and shoot. The physical appearance of the corm can be confused with that of bulbs. However, corms have a solid internal tissue while bulbs have layers of leaves. Examples of plants that develop from corm includes taro, yam, crocus and Anthericum. See Figure 7.5.

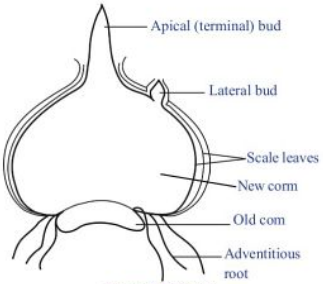


Figure 7.5: Corm

(f) Suckers

A sucker is a shoot that develops from a lateral bud at the base of the plant emerging from the soil near the parent plant as shown in Figure 7.6. They tend to compete for food with the parent plant. A sucker can be removed from the mother plant and transplanted in a new place. Examples of plants that can be propagated through suckers include banana and raspberry.

Figure 7.6: Suckers in banana

(g) Bulbil

These are small, young plants that are reproduced vegetatively from axillary buds on the parent plant stem as seen in Figure 7.7. They are not flowers. Plants that can be propagated this way are called viviparous plants- 'giving birth to live young'. An example of plant that can be propagated using bulbil is sisal.

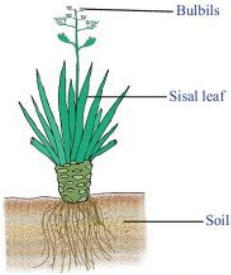


Figure 7.7: Bulbils of sisal plants

Artificial propagation

This is the form of propagation that is done through manipulation by human beings. This can be done through cuttings, grafting, budding or layering.

(a) Propagation by cuttings

When a portion of a stem or root is cut off and then planted in the moist soil, the cutting develops adventitious roots. A new independent plant will then develop as shown in Figure 7.8. Plants propagated by stem cutting includes sugarcane, sweet potato, and cassava. Blackberry, raspberry and lilac can also be propagated through root cuttings.

Figure 7.8: Propagation by cuttings (a) sugarcane (b) cassava

(b) Propagation by grafting

It involves transfer of part of a plant onto another rooted plant as shown in Figure 7.9. The part of plant which is transferred is called scion and the one which receives the transferred part is called the stock. This type of propagation can be carried out between plants of the same species or closely related species. Example of these plants are orange and lemon. For grafting to be successful, the xylem and phloem of both plants must be in direct contact. This is to ensure easy movement of materials between the two parts of the plant.

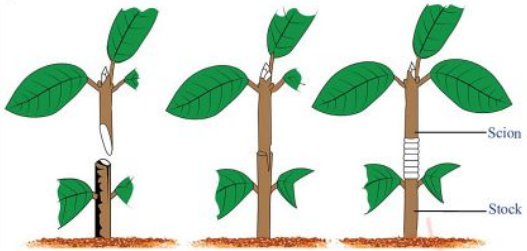


Figure 7.9: Propagation by grafting

(c) Propagation by layering

In this case a branch of a plant is bent down until it touches the ground then it is covered with soil as shown in Figure 7.10. With time, the portion of the branch under the soil develops adventitious roots. This attached stem with its developing roots is known as a layer. If the branch is cut off from the main plant it develops into independent plants. Example of plants that can be propagated by layering are roses and strawberries.

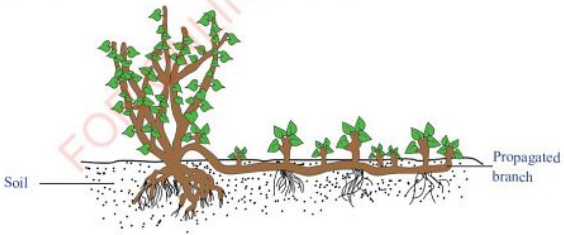


Figure 7.10: Propagation by layering

(d) Propagation by budding

It is similar to propagation by grafting. However, in this case buds are used instead of stems as seen Figure 7.11

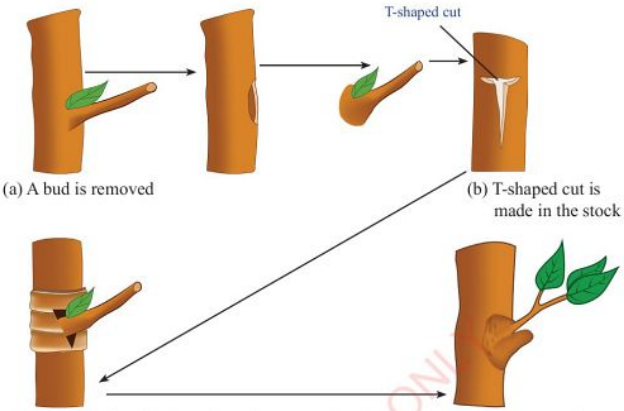


Figure 7.11: Propagation by budding

Exercise 7.1

1. What are the differences between natural and artificial vegetative propagation?
2. Describe how budding is done during vegetative propagation.
3. What are the advantages of vegetative propagation ?
4. Give three examples of plants that reproduce by corms.
5. State the type of vegetative reproduction that takes place in the following plants.
   (a) Onion
   (b) Banana
   (c) Sweet potatoes
   (d) Ginger
   (e) Sugar cane
6. Explain how propagation by grafting and cutting is done.

Sexual reproduction in plants

Reproduction in non-flowering plants

Plants that do not develop flowers as their reproductive structure are known as non-flowering plants. Their means of reproduction is through spores. Bryophytes such as moss and pteridophytes such as fern are non-flowering plants. They produce spores instead of seeds. Spores are microscopic specks of living material. For example, ferns tend to produce their spores on the undersides of their leaves which are called fronds. In moss, spores are housed in the brown capsule that sits on the seta. As the spores ripen they are dispersed from the capsule, and some land in areas where there is enough moisture for them to grow. However, some non-flowering plants especially those which belong to division gymnosperms tend to develop seeds. These seeds are not enclosed in the ovary and are termed as naked seeds.

Reproduction in non-flowering plants is more complex than in flowering plants. This is because there is an extra step in their process of reproduction. Instead of going straight from seed to plant to seed again, non-flowering plants reproduce through alternation of generations that involve two phases of generations. The two phases of generations are often morphologically, and sometimes genetically different from each other. This means that in one generation, a plant produces half of the genetic material needed to create a new plant and the next generation provides the remaining half. Alternation of generation is the rotation of a sexual phase and asexual phase in the life cycle of an organism. Reproduction of fern will be taken as an example of reproduction in non-flowering plants involving spores.

Reproduction process in ferns

In order to understand how reproduction in ferns occurs, it is vital to know the parts of a fern. There are different shapes of ferns. However, they have three major parts namely; the rhizome, the fronds and the reproductive structures called sporangia. The rhizome is the stem of a fern plant. The fronds are the leafy branches made up of leaflets called pinnae. On the underside of pinnae there are some spots which contain spores. However, not all fronds have pinnae with spot of spores. New fronds are produced from the rhizome. Fronds have two functions. They are used in photosynthesis and for reproduction. Fronds that have pinnae with spores are called fertile fronds. The spores grow and develop inside the casings known as sporangia as seen in Figure 7.12. In the majority of ferns, the sporangia are found in a clump clustered together to form a sorus (plural sori). These are the brown, black or orange patches that can be seen on the underside of fronds. When the sporangia break open, they release the spores. Spores are tiny structures that contain the genetic material needed to grow a new fern. They may be green, yellow, black, brown, orange, or red. In most ferns, sporangia are protected by membranes known as indusia. In other fern species, the sporangia are exposed to air.

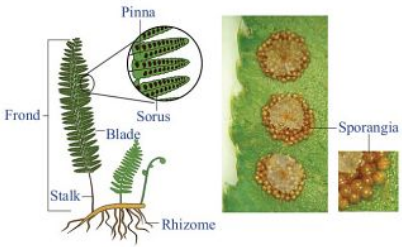


Figure 7.12: Fern plant

In ferns, spores usually do not develop into leafy sporophyte. This is different when compared to seeds of flowering plants which usually develop into a leaf plant. In fern, sporophyte produces a haploid generation. In this state, each of its cells contains one set of chromosomes or half the genetic information complement. This is just like a human sperm or egg cell. This version of the fern plant resembles a little heart-shaped plantlet. The biological name of plantlet is prothallus or gametophyte. The prothallus is haploid, while the sporophyte is diploid. It has tiny leaflets and fibrous rhizoids. Once the egg is fertilized, the true fern plant will grow from this plant structure.

Life cycle of a fern

The reproduction process in fern has two phases; sexual and asexual stages. The sexual phase is called the gametophyte generation. This generation produces gametes, or sex cells. The asexual phase is known as sporophyte generation and produces spores asexually. The gametophyte is haploid, and the sporophyte is diploid. In ferns and bryophytes such as mosses and liverworts, the gametophyte is the dominant life phase. This is different from angiosperms and gymnosperms where the sporophyte is dominant life phase. It is usually difficult to observe clearly all generations since one of the generation is often very small and microscopic.

The adult generation of a fern is known as sporophyte. This stage is known so because it is a diploid stage of the plant life cycle. Sporophyte means spore plant. Spores are dispersed by wind or any other agent from the plant once they reach maturity. If a spore lands in a suitable conditions such as in soil with enough water, nutrients and the right temperature, it will develop into a small plant called a gametophyte. Gametophyte is considered as the plant's next generation phase.

Gametophytes contain a plant's gametes or reproductive cells. It is called gametophyte since it results into the haploid cells. Hence, it produces gametes or haploid sex cells. One part of the gametophyte contains a single egg and another contains sperm. The sperm is flagellated. This means it develops a tail-like structure that allows it to swim to the egg through a film of water. Once the sperm fertilizes the egg, a sporophyte plant develops and the plant's life cycle is complete.

The life cycle of a fern has the following stages:

1. The diploid sporophyte fern produces haploid spores by the process of meiosis, the same process that produces eggs and sperm in animals and flowering plants.
2. Through mitosis, each spore grows into a photosynthetic prothallus, the gametophyte. The number of chromosomes in each cell of the prothallus is made haploid as a result of mitosis. A plantlet in the form of gametophyte is much smaller than sporophyte fern.
3. Each prothallus produces gametes through the process of mitosis. In this case, meiosis is not required because the cells are haploid. A prothallus fern usually produces both sperms and eggs on the same plantlet. Sporophyte fern is made up of fronds and rhizomes, while the gametophyte consists of leaflets and rhizoids. During gametophyte phase, sperms are produced inside the structure known as antheridium. The eggs on the other hand are produced within the structure called an archegonium.
4. In the presence of water and when conditions are favourable, sperm employs their flagella to propel and swim towards an egg to fertilize it.
5. The fertilized egg remains attached to the prothallus. The egg is a diploid zygote formed by the combination of DNA from the egg and sperm.
6. The zygote grows through mitosis into the diploid sporophyte to complete the life cycle as seen in Figure 7.13.

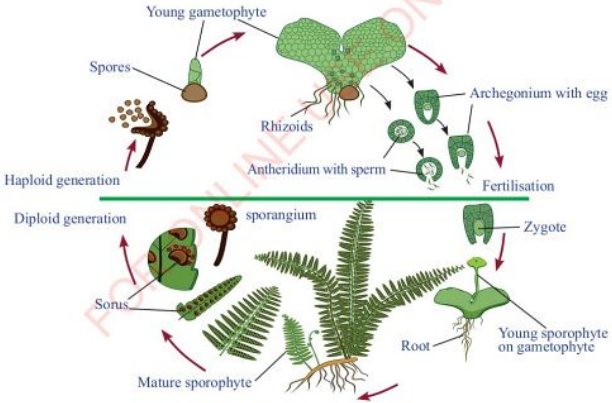


Figure 7.13: Life cycle of a fern

Sexual reproduction in flowering plants

A flower is the reproductive structure of angiosperms. It is formed when the plant reaches maturity and some of the leaves in the shoot system are modified and develop into specialised structures called flowers. In terms of structure flowers have four main parts, namely pistil, stamen, calyx and corolla. The calyx consists of sepals, the number of sepals can be three (or multiples of three) four or five or multiples of five. The corolla consists of petals. The number of petals can be three (or multiples of three) four or five (or multiples of five). Stamen is the male part which consists of anther and filament. Pistil (Carpel) is the female part of flower found at the center and consists of ovary, style and stigma. Other parts of flower are pedicel and receptacle. The carpel produces female gametes and stamens produce male gametes. During fertilisation the male gamete and female gamete fuse to form a zygote. Flowers which contain both female part (carpel) and male part (stamen) are termed as bisexual or perfect flowers while those which contain either carpel or stamen alone are termed as unisexual or imperfect flowers. Figure 7.14 shows the generalized structure of a flower.

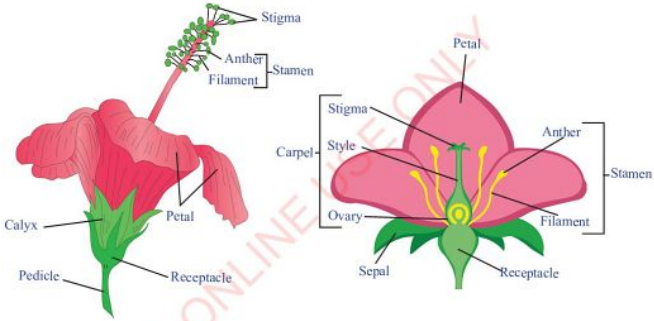


Figure 7.14: Generalized structure of a flower

There is great variation in morphology among flowers of different species, but generally, a typical flower has the four main floral parts described below.

Sepals form the outermost ring of floral leaves. They are collectively termed as calyx. Sepals are small, green and morphologically leaf-like in structure located at the base of the flower. The main function of sepals (Calyx) includes protecting the inner parts

of a flower during the bud stage. They also carry out photosynthesis since they contain chlorophyll. In some plants they are brightly coloured to attract insects for pollination, for example in *Bougainvillea* sp. In some plants, sepals are retained to cover the fruit or seeds for protection.

Petals form a ring of floral parts next to the calyx. The collection of petals is called corolla. In insect pollinated flowers, petals are brightly coloured and have glandular swellings referred to as nectaries at the base. Nectaries release a sugary substance known as nectar which attracts insects. The sepals and petals are collectively referred to as perianth. The main function of petals is to attract insects for pollination. They also offer protection to the inner parts of the flower and they are large to provide a broad landing area for insects.

The **stamen** is the male reproductive organ of a flower. The male reproductive structures are collectively referred to as the androecium**.** Stamen consists of anthers and a stalk or filament as seen in Figure 7.15. The anther consists of four pollen sacs containing pollen grains which are powdery substance. The filament is a thin long stalk that supports the anthers on its top. Generally, the main function of anthers is to produce pollen grains which contain the male gametes.

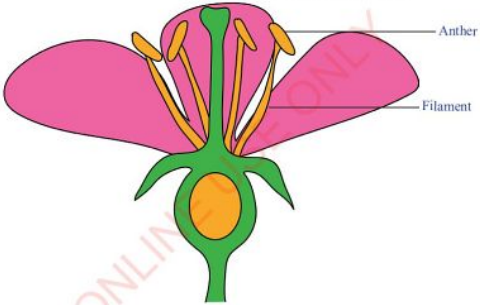


Figure 7.15: Stamen

Pistil is the female part of the flower. The female reproductive structures are also called gynoecium. Flowers may consist of one or many carpels. When a flower has one carpel it is called monocarpous. A flower with two or more carpels is called polycarpous. Pistil consists of three parts namely stigma, style, and ovary as shown in Figure 7.16. The style connects stigma to the ovary. The style is hollow to allow growth of the pollen tube during fertilisation. Stigma is a glandular sticky structure found as the swelling at the tip of the style. It receives the pollen grain during pollination. The

ovary is an expanded hollow base which contains ovules. Ovules are unfertilised female gametes. They are attached to the ridges of a soft fleshy tissue called the placenta. The arrangement of the ovules and the placenta within the ovary is called placentation. After fertilisation, the ovary develops into a fruit while ovules develop into seeds. See Figure 7.16.

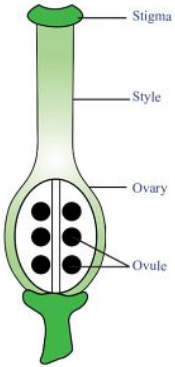


Figure 7.16: Typical pistil

The other parts of the flower include the following:

Flower stalk or pedicel is the modified branch or stem on which the flower develops. In some plants it is branched so that it can bear many flowers called inflorescence. The branch of each flower is called a pedicel.

Receptacle is a swelling that develops at the tip of the flower stalk into which the floral parts are attached in rings or whorls. Basing on the position of ovary, there are two types of ovaries namely: Inferior ovary and superior ovary as shown in Figure 7.17. Inferior ovary is the ovary positioned below the attachment of the petals, sepals and stamens. In this case, other floral parts occur above the ovary. A flower with inferior ovary is referred to as epigynous flower. Examples includes guava, rose and apple flowers. Superior ovary is the ovary positioned above the attachment of the petals, sepals and stamens. The ovary develops above the position of the other floral parts. A flower with a superior ovary is referred to as hypogynous flower. Examples include orange, *Hibiscus* sp and bean flowers.

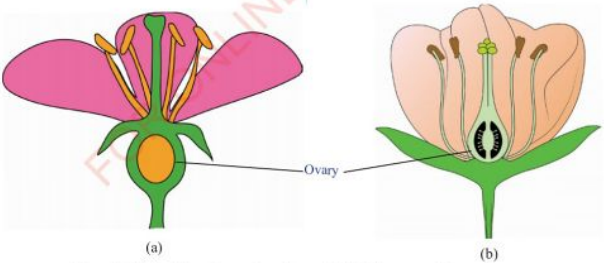


Figure 7.17: Position of ovary in a flower (a) inferior ovary (b) superior ovary

Activity 7.2:

Examining reproductive organs of the flower

Materials

Hibiscus sp flower, hand lens and surgical or razor blade

Procedure

1 Collect *Hibiscus* sp flowers from the surroundings.
2 Observe the collected flowers carefully and draw the observed parts.
3 Remove the sepals and petals from the flowers and carefully remove the stamen and draw it.
4 Touch the anther with your finger. What do you feel?
5 Using a razor or surgical blade peel off the stamen tube downward and draw the remaining part.

Question

What is the function of each observed part?

Classification of flowers

Flowers are classified into two groups depending on the structure and their composition. These groups include complete flowers and incomplete flowers. Complete flowers are those that have all the floral parts, that is, sepals, petals, stamens and pistil. A complete flower is said to be a bisexual flower. Examples of bisexual flowers includes sunflower, *Hibiscus* sp and tomatoes. An incomplete flower is the one that lacks some of the floral parts, for example *Clematis* sp. Incomplete flowers can be pistillate or staminate. Staminate or male flower is an incomplete flower that has stamens only. In this flower the female reproductive organs are missing. Pistillate or female flower is an incomplete flower that have pistil only. In this flower the male reproductive organs are missing. Incomplete flowers are also known as unisexual flowers.

A unisexual flower is an incomplete flower in which either the stamen or the pistil is missing. It is the flower with only one sex. Examples of unisexual flowers are maize, and pawpaw flowers. A bisexual flower is a flower with both male and female reproductive organs. If both male and female flowers are found on the same plant, the plant is said to be **monoecious**. An example of monoecious plants include maize, banana, and squashes. When male and female flowers are on separate plants then the plant is said to be **dioecious**. Example of dioecious plants include pawpaw, date palm, spinach, and yam.

Flower symmetry is another factor used to classify flowers. Basing on this factor there are two types of flowers which are actinomorphic and zygomorphic flowers. Actinomorphic flowers are flowers that can be divided into two equal halves by any vertical section passing through the centre. These flowers are also referred to as the regular flowers. They are radially

symmetrical. Zygomorphic flowers are flowers that can be divided into two equal halves by only one plane passing through the centre. These flowers are also referred to as irregular flowers. They are bilaterally symmetrical as shown in Figure 7.18.

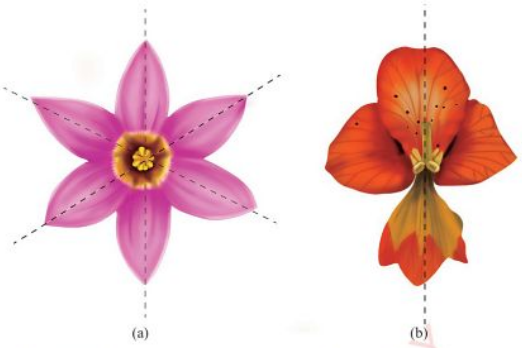


Figure 7.18: Flower symmetry (a) actinomorphic flower (b) zygomorphic flower.

Pollination

For fertilisation to take place male and female gametes must come into contact. Although these gametes are produced in different structures and in some cases from different individuals. The process of fertilisation takes place in the ovary, thus the male gamete must move from where they are produced to where fertilisation takes place. This is possible because when the anthers are matured the pollen sacs of the anther burst open to liberate pollen grains. Pollen grains from the anther are carried to the stigma by agents of pollination such as wind, insects, birds and water. Pollination is the transfer of pollen grains from the anthers to the stigma of a flower.

There are two types of pollination namely: self-pollination and cross-pollination. Self-pollination is the transfer of mature pollen grains from the anther of a flower to the stigma of the same flower or to the stigma of another flower on the same plant. In self-pollination, the male parts of the flower are located above the female parts, thus the pollen grain fall easily onto the stigma. For self- pollination to take place the plant must have both male and female flowers on the same plant. Examples includes peas, maize and *Hibiscus* sp. cross-pollination is the transfer of mature pollen grains from the anther of one flower to the stigma of a flower of another plant of the same species as shown in Figure 7.19. Examples includes pawpaw, maize and sorghum.

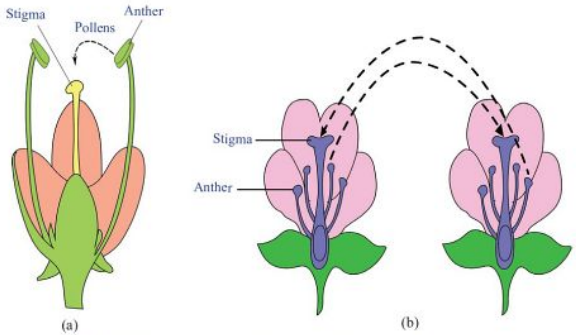


Fig 7.19: Pollination (a) self-pollination and (b) cross pollination

Agents of pollination

There are some plants whose anthers and stigma are so close to almost touching one another, but also there are some plants whose petals do not open unless pollination has taken place. In this case no outside agent is required to transfer pollen grains from the anther to the stigma. In other plants there is a wide gap between the anther and stigma and since the pollen grain are immobile, they must be carried from the anther to the stigma. In such plants, wind, water, animals and insects act as the agents of pollination. Each species of plant employs its own particular agent of pollination and has features which enable them to carry out that kind of pollination. These agents of polination are also known as pollinators.

Wind pollinated flowers

In wind pollinated flowers, wind transfers pollen grains from anthers to the stigma. The anther and the stigma of wind-pollinated flowers are exposed. This makes it easy for the wind to blow the pollen that can easily land on the stigma. Examples includes flowers of most grasses such as rice, maize and sorghum. Wind-pollinated flowers are also referred to as anemophilous flowers. The name is derived from the word *anemo* which means wind. Wind-pollinated flowers have small petals with exposed anthers and stigma. They have dull-coloured petals that do not attract insects or birds. They also have large anthers which produce large amount of pollen grains so as to increase the chances of pollination. Their anthers are loosely attached to the filament and hang freely to allow the anthers to be easily blown by the wind. Their pollen grain are small, light, smooth and dry so that they can be easily picked and carried by wind. They have a sticky

stigma that traps pollen grains. Large freely-hanging stigma provides a large surface area on which the pollen grains can land. Also have a long hairy style to expose the stigma out of the flower. They do not have nectarines. Wind-pollinated flowers are mostly unisexual. Example: in maize, the maize cob is pistillate while the tassel is staminate as shown in Figure 7.20.

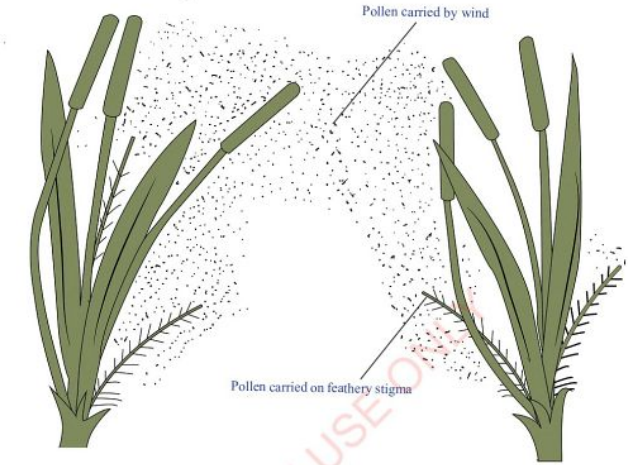


Figure 7.20: Wind pollinated flower

Insect-pollinated flowers

Insects visit a flower and are dusted with pollen grains from the ripe stamens. When they visit another flower some of the pollen is transferred to the stigma. Insects such as bees, butterflies and moths aid in pollination of flowers. Insect-pollinated flowers are also known as entomophilous flowers. The term entomophilous is derived from the word entomophily which means to be carried by insects. Insect-pollinated flowers have large brightly-coloured petals which attract insects as shown in Figure 7.21. The flowers are scented to attract insects to the flower and they produce nectar which attracts insects. Nectar is a jelly – like material containing sugar and is sweet to insects and birds. Flowers have a small sticky stigma that insects get in contact with while collecting nectar. The stigma and anthers are held firmly in position within

the flower to ensure that when an insect lands on the flower the stigma is not broken. Anthers are small in size and produce few but large pollen grains. Such pollen grains have a higher chance of being transferred to a stigma for pollination. The pollen grains are large, heavy and sticky. This enables them to stick to the body of an insect.

Figure 7.21: Insect pollinated flowers

Activity 7.3:

Investigating the features of insect and wind pollinated flowers

Materials

Hibiscus sp flower, common bean flower, maize flower, elephant grass flower and hand lens

Procedure

1. Collect the above listed flowers and observe each flower carefully.
2. State which among those flowers are large, conspicuous flowers with brightly coloured petals, flowers which are scented and have nectar, flowers which are not scented and lack nectar. Note whether the stigma is small and sticky, large and feathery. Note also whether the pollen grains are long, heavy and sticky, lighter smooth.
3. Write down your findings.

Question

Among those flowers, which flowers are wind pollinated and which ones are insect pollinated? Explain.

Fertilisation in flowering plants

In plants fertilization process starts after successful pollination. When a pollen grain lands on the stigma of the same species, the stigma starts to secrete a sugary substance. This sugary substance acts as a source of food for the pollen grain. The pollen grains absorb the sugar solution from the stigma tissue and germinate to form a pollen tube as shown in Figure 7.22. The pollen tube grows through the style toward the embryo sac with the tube nucleus at the tip. It enters the ovule through a small hole called micropyle. After that the tip of the pollen tube bursts and releases the male gametes into the embryo sac. When the pollen tube bursts it releases male gametes. One male gamete fuses with the nucleus of the functional egg cell to form a diploid zygote. The other gamete fuses with two polar nuclei to form a triploid nucleus called the endosperm. This type of fertilization is called double fertilisation and it is a unique feature of flowering plants. The other nuclei (antipodal and synergids) degenerate.

The zygote undergoes a rapid cell division to form a multicellular embryo. Fertilisation in which gametes of the same plant are involved is called self-fertilisation and if fertilisation involves gametes from different plants of the same species it is called cross-fertilisation.

After fertilisation process, the embryo undergoes many changes and then differentiates into a young shoot called plumule, a young root called radicle and simple leaves called cotyledons. This embryo remains enclosed in the ovule for protection. After maturity the fertilised ovule becomes a seed and the endospem becomes a nutritive tissue. The mature ovary becomes the fruit and the ovary wall is differentiated into a fruit wall called the pericarp. The pericarp is then differentiated into three layers called exocarp (is the outer most layer), mesocarp (the middle layer) and endocarp (the inner part of the fruit). The other remaining parts of the flower such as stamen, petals and sepals wither and fall off. See Figure 7.22.

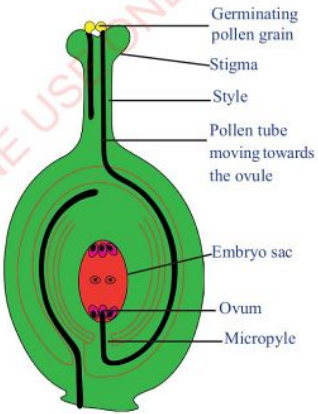


Fig 7.22: Fertilisation in flowering plant

Differences between flowering and non-flowering Plants

The main differences between flowering and non-flowering plants in their reproduction are summarized in the table.

Table: Differences between flowering and non-flowering Plants in reproduction

S/n	Flowering plants	Non-flowering plants
1.	Flowering plants rely on pollination for reproduction	Non-flowering plants rely on dispersion to continue their life cycle.
2.	Possess a highly differentiated reproductive organ, the flowers.	Do not produce flowers.
3.	The ovule develops within the ovary.	No development of ovule within the ovary
4.	Internal fluids are not necessary for fertilisation.	They need at least internal fluids for fertilisation.
5.	The spermatozoids are non-motile	The spermatozoids are mostly motile.
6.	The pollen tubes carry male nuclei or gametes towards the ovum	There is no formation of pollen tube
7.	There is double fertilization forming a diploid embryo and a triploid endosperm	Double fertilization does not occur
8.	A true seed is formed within a fruit	There is no formation of true seeds

Exercise 7.2

1. Give the meaning of the following
   (a) Dioecious
   (b) Monoecious
   (c) Fertilisation
   (d) Pollination
2. Distinguish between pistillate and staminate flowers.
3. By which process does embryo and endosperm form in plants.
4. Explain the function of each of the following
   (a) Anther
   (b) Calyx
   (c) Filament
   (d) Ovary
   (e) Carpel
5. List any four characteristics of insect pollinated flowers.
6. Draw a well labeled diagram of a typical *Hibiscus* sp flower.

7. What are the characteristics of plants pollinated by wind?
8. Give two examples of plants which undergo self-pollination and three examples of plants that undergo cross- pollination.
9. Explain the importance of fertilisation in plants.
10. What changes take place in the flower after fertilisation.
11. Give the meaning of the following terms
    a) Spores
    b) Prothallus
    c) Antheridia
    d) Alteration of generation
    e) Archegonium
12. With a well labelled diagram, explain the life cycle of a fern plant.
13. Give at least three differences between gametophyte and sporophyte generation.

Revision exercise 7

Choose the most correct answer.

1. Which one of the following is the correct order of events in plants?
   (a) Maturation, pollination, fertilisation.
   (b) Pollination, fertilisation, maturation.
   (c) Implantation, ovulation, fertilisation
   (d) Fertilisation, maturation, implantation.
2. Banana is propagated by _____.
   (a) cutting
   (b) layering
   (c) suckers
   (d) seed
3. In flowering plants fertilisation takes place in the_____.
   (a) pollen tube
   (b) ovary
   (c) stigma
   (d) style
4. Asexual reproduction in plants _____.
   (a) bears late fruits
   (b) live longer
   (c) have large crown
   (d) form true copy of parent

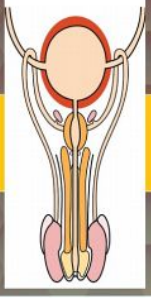
5. Match each item in **column A** against its corresponding item from **column B**.

Column A	Column B
(i) Rhizomes	A. Part of the plant which is transferred to a rooted portion of the plant during vegetative vegetation.
(ii) Scion	
(iii) Bud	
(iv) Pollination	B. Is the transfer of pollen grains from the anthers to the stigma of a flower.
(v) Stamen	
(vi) Monocarpous flower	C. Consists of the filament and the anther.
(vii) Carpel	
(viii) Ovules	D. A flower with one carpel.
(ix) Dioecious	E. An outgrowth on the parent plant.
(x) Pedicel	F. Unfertilised female gamete.
	G. Banana.
	H. Ginger.
	I. Transfer of pollen from the anther to the stigma.
	J. A fragment from the parent plant
	K. Male and female flowers are found on separate plant.
	L. Flower stalk.
	M. Consists of the stigma, style and ovary.
	N. A rooted portion of the plant that receives another part of the plant during vegetative propagation.

Answer the following questions

6. Distinguish between natural and artificial vegetative propagation.
7. Write the similarities and differences between bulb and bulbil.
8. Explain the importance of vegetative propagation.
9. Distinguish between the following terms as applied in artificial vegetative propagation.
   (a) Grafting and budding
   (b) Layering and cutting
   (c) Scion and stock

10. How are the functions of stamen related to those of carpel in flowers?
11. Explain the meaning of the following terms as applied in flowers
    (a) Monoecious plant
    (b) Incomplete flower
    (c) Pistillate flower
    (d) Actinomorphic flower
12. Draw a well labeled diagram of a zygomorphic flower
13. Explain the role of the following structures in flowers
    (a) Petal
    (b) Stigma
    (c) Ovary
    (d) Style
14. Describe the importance of pollination in plants.
15. Outline the differences between wind and insect pollinated flowers.
16. Differentiate between the reproduction in fern and that of flowering plant.



Chapter

Eight

Reproduction in mammals

Introduction

Mammals reproduce sexually through internal fertilisation as opposed to external fertilisation by fish, amphibians and most aquatic invertebrates. Internal fertilisation is the union of an egg and sperm cells during sexual reproduction inside the body of a female organism. In chapter seven you learnt the reproduction process in flowering and non-flowering plants. In this chapter, you will learn about reproduction in mammals with the focus on humans. You will learn about the reproductive system, the process of gamete formation and the secondary sexual characteristics in humans. Issues related to ovulation, menstruation, fertilisation, pregnancy and childbirth in female humans will also be covered. Lastly, you will learn about family planning methods, disorders of the reproductive system, sexual health, and responsible behaviours. The competencies developed will enable you to understand the reproductive system and avoid risky behaviors that can cause disorders in the system.

Sexual reproduction in mammals

Sexual reproduction in mammals involves the production and fusion of male and female gametes which are produced by separate individuals. When the male and female gametes fuse a zygote is formed. Later the zygote develops to attain the characteristic body form of the species. The male produces gametes called sperms or spermatozoa and the female produces gametes called ova or eggs. Spermatozoa and ova differ in structure and size. Gonads or reproductive organs are the special organs for gamete production. The process of gamete production is referred to as **gametogenesis**. Sperms are produced in special organs called testes (singular: testis) whereas ova are produced in a special organ called an ovary. The process by which male and female gametes fuse is known as

fertilisation. Fertilisation can be internal, meaning that it takes place inside the body of an animal or external that it takes place outside the body of the animal.

Animals that produce eggs which develop and hatch outside the mother's body are called **oviporous**. Examples of such animals includes birds, most fish and reptiles. Majority of fish lay their eggs outside and fertilisation takes place outside the body. Animals that produce eggs that are hatched within the body to produce a live young but without placental attachment are called **ovoviviparous**. Example of such animals includes sharks and sea horses. Animals in which fertilisation occur internally and the females retain the zygotes in their body and nourish them are called **viviparous**. Such animals include humans, cattle, and elephants.

Humans and other higher mammals have specialised organs for reproduction known as reproductive organs. These organs form a system called the reproductive system. The male and female reproductive systems are different.

The human male reproductive system

The human male reproductive system is composed of several organs: the testes, epididymis, vas deferens, prostate gland, Cowper's gland, seminal vesicle, urethra and penis as shown in Figure 8.1.

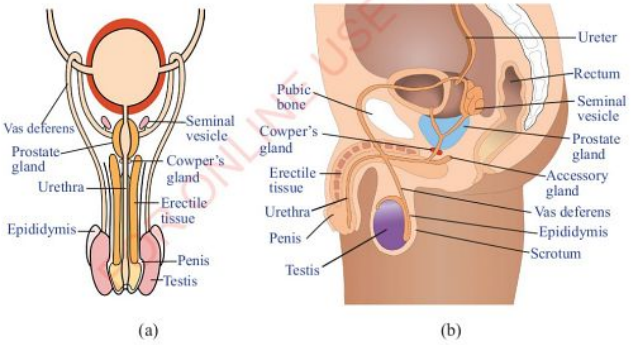


Figure 8.1: Male reproductive system (a) front view (b) side view

Testes

The testes (or testicles) are the main male reproductive organs. They are enclosed in a sac-like pouch called the scrotal sac or scrotum. They are oval in shape. They are found between the thighs, behind and below the penis. Testes are organs where sperms and male sex hormones are produced. They hang outside the body to ensure that their temperature is lower than that of the body. Sperms develop better at a lower temperature than that of the body. Within the testes there are thousands of tube-like structures called seminiferous tubules consisting of actively dividing cells which give rise to sperms. Seminiferous tubules unite to form the epididymis which is a much coiled tube. The epididymis stores sperms and pass them to a wider tube called the vas deferens or sperm duct. From the vas deferens, sperms are passed to the urethra which is the ejaculatory duct. Urethra has two functions which are passage of sperms and passage of urine.

Scrotum (scrotal sac)

It is a poach like sac of skin that holds testis together. It hangs behind the penis. It is well supplied with nerves and blood vessels. It protects testes from mechanical injury. Being outside it makes the temperature of the scrotum to be lower by about 2-3 degree centigrade compared to body temperature. This temperature is suitable for sperm production and storage.

Seminiferous tubules

These are small coiled tubules inside the testes. This is a place where sperms are produced. They contain interstitial cells which produce testosterone hormone.

Vas efferentia

These are much smaller tubes that collect sperm from inside the testis and transfer them to the epididymis.

Epididymis

Is a long coiled tube located at the back of each testicle. The epididymis stores the sperms produced in seminiferous tubule. They also produce a fluid that helps in the storage and nourishment of the sperms. One end of epididymis is attached to the testis and the other to the sperm duct. The lining of the epididymis has cilia which propel the sperms forward. The contraction of the walls of the epididymis also aids in the movement of sperms through the sperm duct during ejaculation. Sperms stored in the epididymis may be absorbed in the body if ejaculation does not occur. Sperms remain alive within epididymis for 2-4 weeks after which they degenerate and are then absorbed into the body.

Vas deferens

This is long muscular tube that transports sperms from testes to urethra. It is also called the sperm duct. Vas deferens has a narrow lumen and muscular walls which contract during ejaculation, propeling sperms towards the urethra.

Accessory glands

These include Cowper's glands, prostate gland and seminal vesicles. These glands generally produce the fluids which mix up with sperm to form the semen. The fluid provides the medium for the sperm

to swim. The fluid also provides nutrients for the sperm. Cowper's gland are pea-sized structures located just below the prostate. They produce alkaline fluid that neutralises any acidity resulting from remaining urine in the urethra. It secretes mucus which lubricates the urethral walls and provide a conducive environment for swimming of sperms. This gland produce an alkaline fluid that protects sperms against acidic medium of the vaginal environment. Seminal vesicle produces fluid which nourishes the sperms and helps in sperm mobility. This fluid contains fructose which during respiration provide energy needed for swimming of sperms. Prostate gland is an accessory gland located below the urinary bladder in front of the rectum.

Penis

Penis is a copulatory organ which is used to introduce sperms into the vagina during sexual intercourse or copulation. The tissues of the penis are highly supplied with blood vessels. The penis has spongy tissues called erectile tissues in which the blood accumulates. When the spongy tissue is filled with blood, the penis becomes firm and erect. This enables the penis to penetrate into the vagina. The head of the penis is known as the glans which is very sensitive to stimulation. The glans is protected by the foreskin which is called prepuce. The foreskin is usually removed during circumcision to reduce the risk of STIs and STDs infection as well as for hygienic purposes. During ejaculation, urethra muscles contract. Contraction of urethra muscles propels semen out of the erect penis. Semen is a fluid made up of sperm and fluid from various glands in the male reproductive system.

The human female reproductive system

The female reproductive system consists of several organs: the ovaries, fallopian tubes, uterus, cervix and vagina as shown in Figure 8.2.

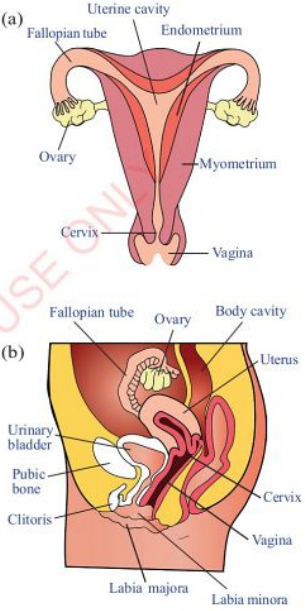


Figure 8.2: Female reproductive system (a) front view (b) side view

Ovaries

The ovaries are the main female reproductive organs. They are oval-shaped cream-coloured organs found in the lower part of the abdominal cavity. There is one ovary on either side of the uterus. Ovaries are attached to the uterus by a membrane. They produce the female gamete called the egg or ovum and female sex hormones which are oestrogen and progesterone. Oestrogen is important in repair of the uterine lining after menstruation. Progesterone is involved in maintaining the thickness of the uterine wall ready for implantation. Each ovary has two layers, an outer cortex and an inner medulla. The medulla has blood capillaries, nerve fibres and smooth muscles. The cortex has follicles which give rise to ova. Each follicle consists of an immature ovum surrounded by epithelial cells.

Fallopian tube (oviduct)

This is the tube through which the ovum moves from the ovary to the uterus. The oviduct is funnel-shaped at the end adjacent to the ovary to enable the released ovum to be directed towards the uterus. Normally fertilisation takes place in the fallopian tube. The walls of the oviduct have cilia that assist in the movement of the ovum towards the uterus.

Uterus

This is a thick-walled muscular organ in which the embryo implant grows, develops, and obtains its nourishment during pregnancy. The outer layer of the uterus is called myometrium and the inner layer is called endometrium. After fertilisation the embryo is implanted in the uterus wall and develops until birth. The uterus has elastic tissues that allow its expansion during development of foetus and can attain its original size after delivery. It is around 7.5 cm in length and 5 cm in width but it can enlarge four to five times of this size in order to accommodate the fully grown foetus.

Cervix

The cervix is a ring of muscles that closes the lower end of the uterus. Cervix separates the uterus from the vagina. It allows sperm to pass through during copulation. It also produces mucus, which helps the sperm to swim through the uterus. The cervix is narrow to ensure that the embryo is not expelled from the uterus before the right time. During birth, the cervix expands to allow the baby to pass through into the vagina. The cervix also allows the menstrual blood to flow out of the uterus.

Vagina

This is a muscular tubular structure that links the uterus to the outside of the body. Vagina is also called copulatory canal or birth canal. During sexual intercourse, the sperms are deposited into the vagina. Then

they pass through the cervix into the uterus and up into the oviduct where fertilisation takes place. The vagina has elastic walls that stretch during sexual intercourse and during birth. The opening of the vagina is surrounded by flaps of tissue called labia which protect the vaginal opening. There are two sets namely labia majora and labia minora. The main functions of the vagina are to allow the baby to pass during birth, to pass out menstrual blood and receive male organ during sexual intercourse.

Vulva

This is the external opening of the female genitalia that surrounds the opening to the vagina. Its walls contain **vestibule glands**, which release mucus when the female is sexually aroused, the mucus reduces friction during sexual intercourse.

Activity 8.1:

Identifying parts of mammalian reproductive system

Materials

Dissected male and female mouse or rat and hand lens

Procedure

1. Using hand lens observe the dissected male and female mouse or rat.
2. Draw a well labelled diagram of the male and female reproductive system as seen in a dissected mammal.

Question

Which organs make female reproductive system and which ones make male reproductive system.

Gamete formation in mammals

Gametes are formed by the process called gametogenesis. This is the production of haploid gametes by diploid multicellular organisms through the process of meiosis. This process takes place in the male and female gonads; that is in the ovaries in female and testes in males. The testes produce spermatozoa or sperm by a process called spermatogenesis and the ovaries produce ova or egg by a process called oogenesis.

Spermatogenesis

Spermatogenesis is the process whereby mature sperm cells are produced within the seminiferous tubules of the testes. The outermost layer of the seminiferous tubules is called germinal epithelium. The germinal epithelial cells undergo repeated mitotic division to form a large number of cells known as spermatogonia. The spermatogonia undergo cell enlargement to form primary spermatocytes. The primary spermatocytes undergo Meiosis I (first meiotic division) to form secondary spermatocytes. Each secondary spermatocyte undergoes Meiosis II (second meiotic division) to form spermatids. The spermatids are nourished by sertoli cells and become differentiated to form spermatozoa (mature sperms) as seen in Figure 8.3.

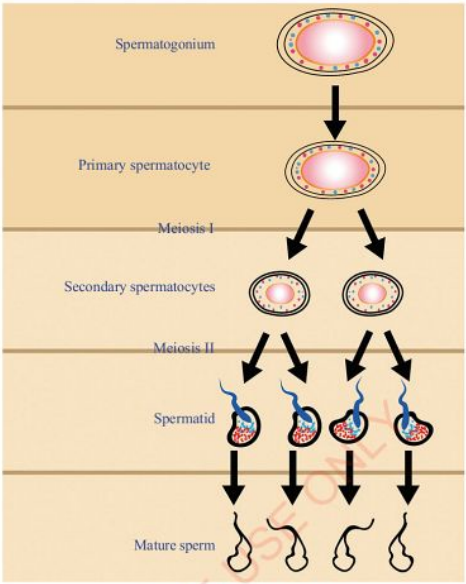


Figure 8.3: Spermatogenesis

Structure of sperm

The male gamete is made up of three main parts namely head, middle piece and tail. The head of the sperm is oval-shaped with a large nucleus and a long whip-like tail for swimming. The head region consists of the acrosome and nucleus as shown in Figure 8.4. The nucleus carries the genetic materials while acrosome contains a lytic agent. This is a chemical which dissolves the membrane of the egg during fertilisation.

The middle piece contains mitochondria which provide energy for movement of sperm in the uterus to facilitate fertilisation. Sperms are adapted to their role as they are produced in large numbers to increase the chances of fertilisation to take place. They have a large number of mitochondria to provide energy needed for propulsion and they have the acrosome containing lytic enzymes that digest the egg membrane to facilitate fertilisation.

They also have a long whip-like tail used for propulsion or swimming.

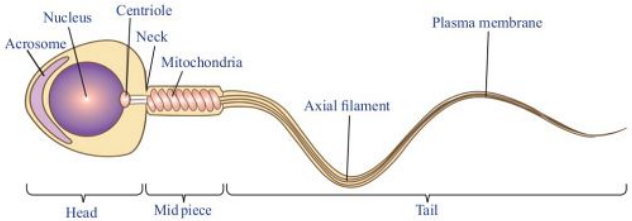


Figure 8.4: Structure of sperm

Oogenesis

Oogenesis is the formation of female gametes (ova or eggs). Oogenesis takes place in the ovary. The germinal epithelial cells of the ovary undergo repeated mitotic division to give rise to cells called Oogonia. Few oogonia enlarge to form the primary oocytes which become detached from the ovary lining to the centre of the ovary but most of them degenerate and disappear. The primary oocyte undergoes Meiosis I (first meiotic division) to form two secondary oocytes. One of the two secondary oocyte divides to form a mature oocyte and one polar body. The second secondary oocyte divide to form two polar bodies as shown in Figure 8.5. The secondary oocyte is enclosed in a layer of cells called follicle cells. The function of the follicle cells is to provide nourishment to the oocyte. The oocyte together with the mass of follicle cells is known as the primary follicle. The mature primary follicles are called Graafian follicles. The Graafian follicle raptures during ovulation to release the mature ovum into the funnel end of the fallopian tube.

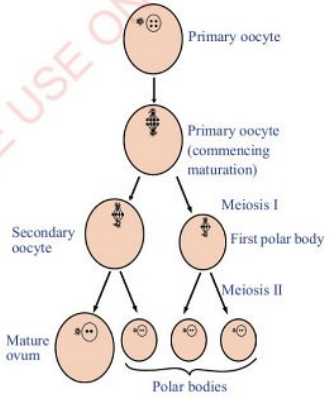


Figure 8.5: Oogenesis

Structure of ova

The **ovum** is a mature female reproductive cell. The human ovum is a large cell reaching about 0.1mm in diameter. It is much larger than the sperm. It contains a nucleus which carries hereditary materials. It also contains cytoplasm and granules. The egg is surrounded by the corona radiata as shown in Figure 8.6. The vitelline membrane (plasma membrane) encloses the cytoplasm (yolk). The membrane also controls what goes in and out of the cell. The zona pellucida (jelly coat) is a thick proteinous layer outside the vitelline membrane. It protects the egg, and also prevents more than one sperm from fertilising a single egg. At the center of the egg, there is a nucleus surrounded by nuclear membrane. In the nucleus there is a nucleolus containing the genetic materials.

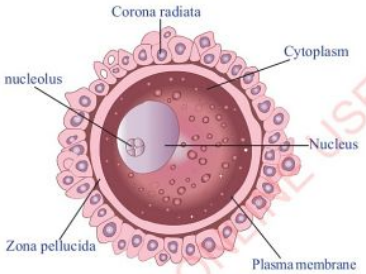


Figure 8.6: Structure of an ovum

Human secondary sexual characteristics

In both males and females, secondary sexual characteristics begin to appear at puberty. Puberty is the period when an individual changes from childhood to adulthood. It is the period where the sexual organs in both girls and boys are capable of sexual reproduction. The changes that occur are induced by hormones that are produced by pituitary gland. Normally girls attain puberty at the ages of 9 -13 years, while boys attain puberty at the age of 12-14 years. At puberty the boys secrete male sex hormone known as testosterone that bring about the development of male secondary sexual characteristics and girls secrete the female hormone called oestrogen that brings about the development of female secondary sexual characteristics.

Males

There are various secondary sexual characteristics that occur in males during puberty. These includes rapid increase in body weight and height, growth of pubic hair and hair under the armpit, change of voice to become deeper and increase in perspiration. Others are appearance of pimples on the face, widening of the shoulder and chest, and changes in the legs and arms which become more musculine. There is also development of a beard and moustache; beginning of ejaculation and wet dreams; and enlargement of the penis.

Female

During puberty females develop various secondary sexual characteristics. These include rapid increase in body weight and height, gradual enlargement of the breasts, growth of pubic hair and hair under the armpit and change of voice to a smooth tone. Other features include: increase in perspiration, appearance of pimples on the face, widening and broadening of the hips. Also, there is enlargement of uterus and vulva, and the start of ovulation and menstruation cycles.

Both girls and boys begin to experience emotional and psychological changes. This happens because the transition to adulthood requires a change from dependence into independence from the parent, development of self-recognition, self-esteem, and development of self-awareness.

Exercise 8.1

1. Describe the functions of the following parts of reproductive system
   a. Fallopian tube
   b. Testes
   c. Uterus
   d. Scrotum
   e. Cervix
2. Explain the secondary sexual characteristics that occur both in males and females.
3. What is the adaptation of placenta to its functions?
4. Describe the changes that occur in males and female during puberty.
5. What are the differences between a sperm and an ovum?
6. Draw a well labeled diagram of side view of male and female reproductive systems.
7. With examples, explain how ovoviviparous animals differ from viviparous and oviparous animals in terms of reproduction.

Ovulation and menstruation

Ovulation and menstruation are processes that depend on each other and they only occur in females. At puberty the development of ova continues in such a way that only one ovum matures in every 28 days. The developing ovum is surrounded by a group of cell called follicles. Then the mature ovum is released from the ovary. The maturation and liberation of ova that takes place after every 28 days alternates between the two ovaries. Release of an ovum from the ovary is referred to as ovulation. The ovum is released directly into the fallopian tube and starts its journey to the uterus. Usually ovulation starts between the ages of 9 and 15 years. It is controlled by hormones which are secreted from the pituitary gland. Before ovulation follicle stimulating hormone from the pituitary gland is released to stimulate the growth of follicles to mature Graafian follicle. Usually one Graafian follicle from one of

the two ovaries is developed in a month as shown in Figure 8.7. Luteinizing hormone is released in order to make the mature Graafian follicle to rapture and release the ovum (ovulation). The remains of the ruptured follicle form the corpus luteum, which act as an endocrine gland and begins to produce progesterone hormone to maintain the thickness of the uterine wall. The ovum stays for about 12-24 hours after ovulation, then moves along the oviduct aided by beating of cilia.

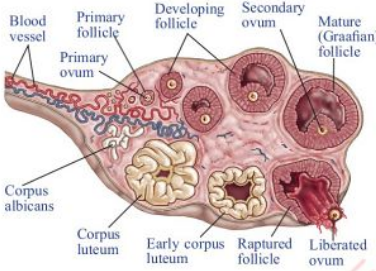


Figure 8.7: Ovulation and menstruation

If fertilisation does not occur the production of progesterone stops and its level becomes low and further maintenance of the thickness of the uterine wall stops.

Therefore, the uterine wall breaks down and blood is released out together with the degenerated ovum and mucus through the vagina. This phenomenon is called menstruation.

Follicle stimulating hormone is released by the pituitary gland in order to make another follicle to grow and develop to Graafian follicle, at the same time oestrogen is produced by the ovary to build again the uterine lining and the cycle continues.

Menstruation is the process that involves the discharge of an egg, uterine tissue and mucus through the vagina. Women experience menstruation once a month, from puberty to menopause. On average, menstruation takes three to seven days. For some individuals it might take up to 15 days or more which is not common. This period is called the menstrual period. Individuals who experience long and irregular menstruation should seek medical consultation. In some women, menstruation is accompanied with slight or severe pain in the lower abdomen and slight tenderness of the breasts. Those who experience severe pain or excessive bleeding during menstruation should also seek medical advice. The onset or duration of menstruation can be affected by diseases, stress, anxiety, drugs, food and hormonal contraceptives.

The menstrual cycle is regulated by the following hormones: Gonadotropic hormone (GnRH), Follicle stimulating hormone (FSH), Oestrogen, Progesterone and Luteinizing hormone (LH)

as shown in Figure 8.8. These hormones interact in the following ways; GnRH stimulates the anterior pituitary gland to secrete FSH. FSH travels in the blood to the ovaries and stimulates the development of several follicles. Usually one follicle will complete the development in a month. The cells of the developing follicle start to produce Oestrogen which stimulates repair and development of the endometrium in the uterus. This prepares for the possibility of pregnancy.

Oestrogen also inhibits the secretion of FSH to prevent the possibility of further follicles being stimulated so that only one egg is produced at a time. At the midpoint of the cycle oestrogen levels increase, this triggers the secretion of luteinizing hormone (LH). LH causes ovulation in the ovary. During ovulation the secondary oocyte detaches from the wall of the follicle, and is released into the body cavity and passes into the fallopian tube. The ovulated oocyte contains the part of Graafian follicle which is stimulated by LH to develop into corpus luteum (yellow body). The corpus luteum continues to secrete oestrogen as well as progesterone. Progesterone stimulates the uterus to maintain its thickening and also stimulates glandular cavity. The anterior pituitary gland inhibits release of LH and FSH. Release of progesterone is associated with a rise in body temperature of the female just after ovulation.

If fertilisation does not occur, the corpus luteum starts to degenerate about the 28th day of the cycle. Once it starts to degenerate, levels of oestrogen and progesterone decline, so the inhibition of FSH is altered. The endometrium also breaks down to cause menstruation. This lasts for about three to seven days and the cycle start again. See Figure 8.9.

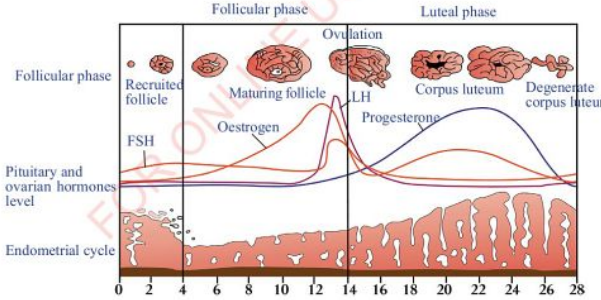


Figure 8.8 Changes occurring during Menstrual cycle

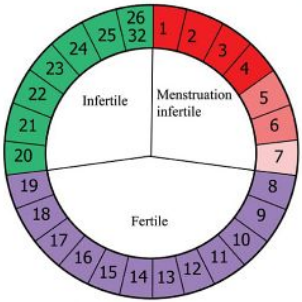


Figure 8.9: Menstrual cycle

Menopause

This is the period in a woman's life during which her menstruation become irregular and subsequently stops. This period occurs between 45 and 55 years of age. During menopause the ovaries stop releasing ova and production of hormones.

Exercise 8.2

1. Explain how the process of ovulation in mammals is linked with menstruation.
2. Give the meaning of the following terms
   (a) Ovulation
   (b) Menstruation
   (c) Ejaculation
3. Briefly describe hormonal control of menstruation cycle in mammals.
4. What factors affect the onset and duration of menstruation?

Fertilisation, pregnancy and childbirth

Fertilisation

Copulation is the process of inserting the erect penis into the vagina. When a man is sexually stimulated; the penis is filled with blood and becomes firm and erect. The erect penis is inserted into vagina and moved back and forth during copulation. This movement stimulates sense organs in the penis and ejaculation occurs resulting into the movement of semen from the epididymis through the sperm duct into the vagina. Ejaculation is the release or discharge of semen. Once the sperms are deposited in the vagina they start swimming towards the oviduct. The climax of sexual excitement in humans is known as orgasm, it is accompanied by a feeling of extreme pleasure.

Fertilisation is likely to take place if the sperms come in contact with a mature egg. During sexual intercourse sperms are deposited in the upper region of the vagina and swim through the cervix to the uterus and then enter the fallopian tube. Sperms take less than an hour to reach the uterus. During sexual intercourse, millions of sperms swim through the cervix but only a few reach the oviduct. Sperms can survive for about 72 hours from the time of their deposition. An ovum can remain viable in the oviduct for 36 hours from the time of release from the ovary. Fertilisation is the process whereby a sperm nucleus and an ovum nucleus fuse to form a diploid cell called **zygote** as

shown in Figure 8.10. During fertilisation, the head of the sperm, which contains the nucleus, enters the ovum and fuses with the nucleus of the ovum to form a zygote. The zygote cell then begins to divide to form an embryo. The time when fertilisation is likely to occur is called the fertile period of a woman. Ovulation is likely to occur on the 14th day, from the first day of menstruation. However, it can also occur one or two days before or after the 14th day. Therefore, there is high possibility of fertilisation if copulation takes place between the 11th and 17th day after menstruation. Inspite of millions of sperms released during ejaculation, only one sperm enters an ovum and others are prevented from entering due to formation of a tough membrane around the ovum.

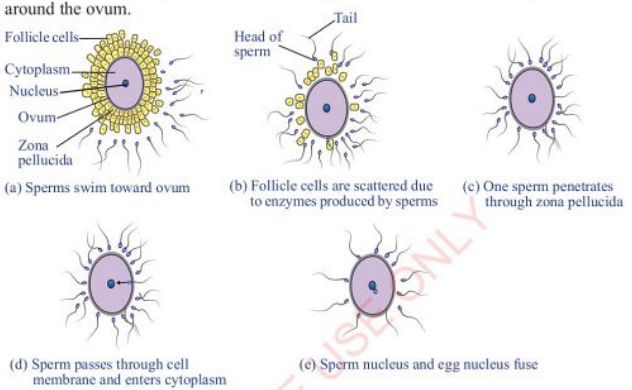


Figure 8.10: Fertilisation of an ovum by a sperm

Factors hindering fertilisation

There are several factors that can prevent fertilisation. These includes the absence of an ovum in the upper part of the fallopian tube, production of small number of spermatozoa (below 20 million), the presence of spermicides or other barriers, blockage in the fallopian tube, blockage of vas deferens, weak or immature sperm that cannot swim well and deformed sperm, for example sperm without a tail.

Pregnancy (conception)

Soon after fertilisation a zygote is formed. It starts to undergo rapid mitotic division. The division continue to produce a ball of cells. While the zygote is dividing it travels along the oviduct towards the uterus. It takes 4 to 6 days for the zygote to reach the uterus. During this time it grows to become an embryo. When the embryo reaches the uterus it attaches itself to the uterine wall by the finger- like

projections called tripoblastic villi which help the embryo to absorb nutrients from the uterine wall. This process is called implantation.

The implanted embryo in the uterine wall continues to divide and the cells are differentiated into three parts. One part becomes the **placenta** and attaches firmly to the uterine wall. Another part forms a chamber, which completely surrounds the embryo. This chamber is known as the **amniotic cavity** and is filled with a fluid called **amniotic fluid**. The fluid cushions the embryo and acts as a shock absorber, protecting it as the mother moves around. The third part develops into a foetus.

After 8 to 12 weeks, the foetus develops basic human features, including a head, brain, limbs, heart and lungs as seen in Figure 8.11. In its final stage of development, the foetus have a fully developed brain and sensory organs, such as eyes, ears, nose and tongue. During the whole period of pregnancy, it is advisable that the mother should refrain from heavy physical activity, smoking and drinking alcohol.

The survival of the foetus during pregnancy is entirely dependent on the placenta. The foetus obtains dissolved oxygen and the necessary food substances, such glucose, amino acids and salts, from the blood of the mother by diffusion across the placenta. Food substances reach the embryo through the **umbilical cord**. Waste products, such as carbon dioxide, urea and other nitrogenous compounds from the foetus, pass into the blood vessel in the umbilical cord and diffuse to the blood of the mother through the placenta. The waste products diffuse into the mother's blood and are excreted in the usual way as seen in Figure 8.12.

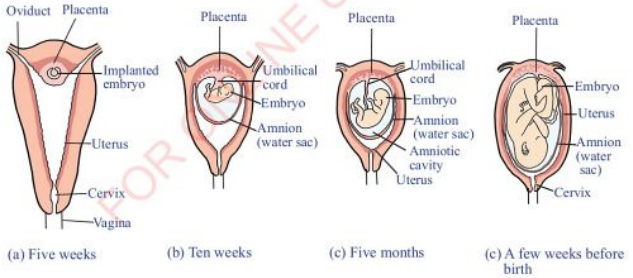


Figure 8.11: Growth and development of foetus in the uterus

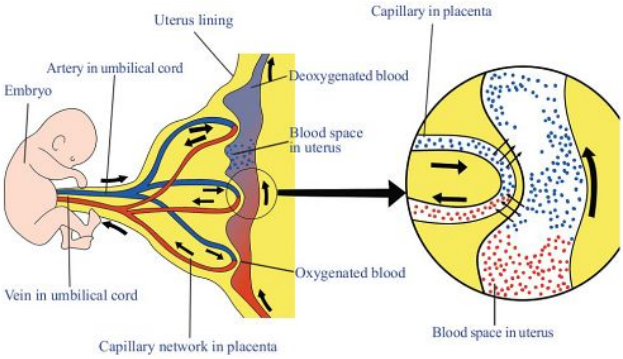


Figure 8.12: Exchange of substances between the blood of the embryo and the mother

Childbirth

Childbirth occurs after the period of gestation. Gestation period is the time between fertilisation and birth. It varies in mammals for example, it is 9 months in human beings, 22 days in mice and 18 months in elephants. Child birth is the process whereby a fully developed foetus is expelled out of the mother's womb. Towards the end of the gestation period, the foetus turns upside down. At the beginning of childbirth, a woman enters a period of labour. The process of labour is divided into three phases or stages and it is greatly controlled by hormones. The first phase is the cervical dilation phase; which involves regular rhythmic contractions of the uterine muscles to bring about dilation and stretching of the cervix and vagina. This is followed by breaking of the amnion and hence the flow of amniotic fluid. The second phase is the parturition phase which involves stronger and longer contractions of the uterine muscles. This results in further stretching of the cervix and vagina; the head of the baby appears at the vulva. Strong uterine contractions push the baby forward and finally the baby is forced out.

As soon as the baby is born, the umbilical cord is clamped in two parts and the baby is separated from the mother. The baby starts crying as it gulps air into its lungs for the first time. The last phase is expulsion phase which involves discharge of the placenta.

Artificial insemination

This is the artificial introduction of sperms into the female reproductive system for the purpose of fertilisation or achieving pregnancy by other means than sexual intercourse. Although it is rarely done in humans, it is commonly practiced in domestic animals such as cattle. In this process the sperms are collected from the male and preserved to be used when they are needed. The sperms are introduced into the female reproductive system ready for fertilisation to take place. The process is done when the animal is in heat or ovulation. The importance of artificial insemination includes the following: It enables farmers to get desired characteristics of their animals such as resistance to diseases and high milk production. It provides a rapid means of attaining the desired characteristics of a particular male throughout a stock. In humans, it enables women whose partners cannot make them pregnant to conceive and give birth to their own child. It enables men to preserve sperms so that their partners can conceive when they are away from home for a long period or even after their death. Also it gives a woman chance to choose the father of her child as she can select sperm from different men in the stock or sperm bank.

Multiple pregnancies

In some cases, more than one ovum can be released from the ovary which may be fertilised leading to multiple pregnancies. Multiple pregnancies is a term used to refer to a situation when more than one foetus is carried in a single pregnancy and results in the birth of more than one offspring at a time. Multiple pregnancies may be caused by genetic factors and sometimes by the use of fertility drugs which may cause several eggs to be produced at the same time. The most common form of multiple pregnancy is birth of twins. However, triplets, quadruplets or even quintuplets can occur.

Twins

In humans usually only one embryo develops at a time in the uterus. When two embryos develop at the same time, they are known as twins. Twins are either fraternal twins as shown in Figure 8.13 or identical twins as shown in Figure 8.14. Identical twins develop from a single fertilised ovum. This occurs when a fertilised egg splits into two parts and each part develops into a complete individual. In this type of twins only one sperm fertilises the egg. The egg divides into two after fertilisation. The twins are of the same sex, very much alike and genetically identical. Identical twins share a placenta with separate amniotic sacs. Sometimes the fertilised egg splits but does not separate completely leading to joined or Siamese twins. However, this is an exceptionally rare phenomenon. Fraternal twins develop when two eggs are released from the ovaries, and each egg is fertilised by a different sperm. These twins do not look alike and can either be of the same sex or different sexes. They are also genetically different. Each of the fraternal twins has a separate placenta and amniotic sac.

Figure 8.13: Fraternal twins

Figure 8.14: Identical twins

Exercise 8.3

1. How do identical twins differ from fraternal twins?
2. Give the meaning of the following:
   (a) Childbirth
   (b) Twins
   (c) Artificial insemination
3. Describe the events that take place in a female reproductive system after fertilisation of an egg.
4. State the causes of multiple pregnancies.
5. What are the factors that may hinder fertilization from taking place?

Disorders of the reproductive system

There are several disorders that can interfere with the male and female reproductive systems.

Disorders of the female reproductive system

Disorders that can interfere with the female reproductive system includes the following:

Infertility

Infertility is a condition where a woman is unable to conceive. In women, infertility might be caused by abnormalities of the reproductive organs. Hormonal imbalances which affect ovulation can also cause infertility. The presence of a tumour in the reproductive system and blockage of the fallopian tube caused by sexually transmitted infections (STIs) such as gonorrhea and chlamydia is another cause of infertility. Poor nutritional status and physical injuries may lead to infertility.

In females surgical operation to unblock the fallopian tubes can be done to address the problem. Hormonal supplements can also be used in case of hormonal imbalance. Eating a balanced diet may also help to alleviate the problem.

Frigidity

This is the condition in which a woman fails to respond to sexual stimulus. Thus, the woman fails to reach orgasm, that is, the climax of enjoyment during sexual intercourses. Frigidity can be caused by underproduction of oxytocin or other progestins in the body, psychological factors, female genital mutilation and breast feeding. Frigidity may be corrected by using balanced diet, hormonal therapy, such as testosterone, oestrogen or progestins, vitamin supplements, and psychotherapy.

Amenorrhoea

Amenorrhoea is a condition where a woman stops having menstrual periods. It can be caused by hormonal imbalance, especially under-secretion of oestrogen, long illnesses, such as malaria and HIV and AIDS, a change in activities or work and a change of environment. Experience of extreme shock or grief, poor diet and malformed uterus can also cause amenorrhoea. Amenorrhoea may be corrected by oestrogen injection, early treatment in the case of curable diseases such as malaria, an adequate and balanced diet or control of stress by counselling and psychotherapy.

Dysmenorrhoea

Dysmenorrhoea is a condition where a woman has very painful menstrual periods. Some women experience this condition a few days before menstruation. The major causes are high levels of the oxytocin hormone, which causes painful contractions in the uterine wall or a narrow cervix. Dysmenorrhoea may be corrected by exercises and relaxation or widening the opening of the cervix, which occurs after childbirth and surgery.

Disorders of male reproductive system

There are various disorders of the male reproductive system. These disorders includes the following:

Infertility

In men, infertility might be caused by inability to produce sperm, production of deformed or non-viable sperm, blockage of the vas deferens due to STIs such as gonorrhea and Chlamydia. Low sperm count, undescended testes, poor nutritional status and drug abuse can also cause infertility in men. Infertility can be treated by balanced diet, surgical operation to unblock the sperm ducts or hormonal supplements.

Impotency

Impotency is the inability of a man to attain an erection of the penis. Men may be totally impotent, that is, never have an erection or develop impotency as they grow old. Impotency can be caused by illness such as diabetes, blood pressure medication, and hardening of the arteries supplying the penis, prostate surgery, stress and depression. Other reasons include loss of interest in women due to psychological reasons, underproduction of testosterone and other hormones, or serious injury at the lower parts of the

spinal cord, especially the lumbar region, which can cause paralysis. Impotency may be treated by hormonal supplements, such as testosterone, vitamin supplements, such as vitamins A, D and E, use of drugs, and psychotherapy.

Premature ejaculation

Premature ejaculation is a condition whereby a man expels semen before or immediately after insertion of the penis into the vagina. It may be caused by hormonal or psychological problems. Premature ejaculation may be corrected by talking to peers or using techniques to improve self-confidence.

Prostate problems

The prostate glands may become enlarged due to infection or cancer, as a result they block the urethra and cause difficult during urination.

Project

Finding out common types of human reproductive disorders, their causes and effects in the community.

Materials

Note book and pen

Procedure

1. Visit a nearby hospital or health facility.
2. Ask the doctor/medical practitioner to explain to you on various types of human reproductive disorders, their causes and effects.
3. Note down each point explained by the doctor.
4. Discuss with your classmates what you have noted in the discussion with the doctor.
5. Make a table to show the types of reproductive disorders, their causes and effects to the human body.

Complications during pregnancy

There are several types of complications during pregnancy which may affect the foetus before gestation period. These include the following;

Ectopic pregnancy

An ectopic pregnancy occurs when the embryo is implanted in a place other than the uterus, usually the fallopian tube. Tiny protrusions or vill on the zygote enable the embryo to burrow and start to grow. Growth of embryo in the tube is dangerous because as the embryo continues to grow it rupture the fallopian tube. This can lead to bursting of blood vessels leading to internal bleeding and possible death of the expectant mother if not attended immediately. Immediate surgery is needed to save the life of the expectant mother. Ectopic pregnancy is mostly caused by a defect or disease of the fallopian tube, such as gonorrhea, syphilis or cancer.

Abortion

Normally a baby is born after 40 weeks of pregnancy. However, if the pregnancy ends after only 28 weeks it is described as a premature delivery or

abortion. There are two types of abortion: spontaneous abortion (miscarriage) and induced abortion. Spontaneous abortion (miscarriage) occurs when the foetus is expelled from the uterus unintentionally. An induced abortion is carried out purposely to end the pregnancy. Induced abortion can be carried out in a health facility by a recognized surgical team, in order to save the life of the mother or to remove an unwanted pregnancy. Most cultures and religions regard this kind of abortion as immoral.

All abortions, both spontaneous and induced, should be treated with great care. This is because they may result to injuring of blood vessels, damaging of reproductive organs, excessive bleeding and sometimes death. Abortion may also damage the cervix causing future spontaneous abortions, infections, bleeding and blood poisoning.

Miscarriage or spontaneous abortion

Spontaneous abortion occurs when the foetus is expelled from the uterus unintentionally. It is referred to as miscarriage because at this stage the baby cannot survive on its own since the foetus is not fully developed.

Miscarriage is caused by either maternal or foetal factors. Maternal factors include strenuous physical activities by the mother during early pregnancy, injury of mother's abdomen, emotional stress or shock, and diseases or infections such as syphilis, german measles, cervical incompetence and malaria. Other causes can be hormonal imbalance, poor nutrition of the mother and exposure to poisonous chemicals and medications. Foetal factors includes abnormal implantation, poor attachment of the placenta, poor development of the foetus and abnormality of the foetus. Bleeding from the vagina is one of the first sign of miscarriage. When bleeding is accompanied by pain and uterine contractions, then miscarriage is inevitable.

Stillbirth

This is the intrauterine death of a baby although the foetus may be fully developed. Stillbirth may be caused by: using harmful drugs, such as alcohol and cigarettes, taking non-prescription drugs and accidents. Others are inheritance of a harmful genetic factor, such as a lethal gene, a chronic illness, such as diabetes mellitus, and narrow pelvis, that can cause difficulties in delivery, severe malnutrition and strangulation of the baby by the umbilical cord during delivery. Stillbirth can have several effects on individuals, including psychological suffering and physical ill health. Other complications can also arise, such as high blood pressure.

Premature birth

This involves giving birth after six months and above but before 9 months. At this stage the foetus is not fully developed, but it can survive if it is put in an incubator and other techniques such as "kangaroo method" to continue to grow until they can support themselves. The final weeks of gestation

in the womb are crucial for a foetus health, weight gain and for the full development of various vital organs, including the brain and lungs.

Preeclampsia

This is a condition of pregnancy characterised by high blood pressure and protein in the urine. The woman with preeclampsia experiences sudden weight gain, swelling of the face, hands and feet, severe headache, abdominal pain and blurred vision. If not treated, it can develop into eclampsia which is a severe complication of preeclampsia that might be fatal due to convulsions.

Breech Birth

This is the situation whereby during birth, the bottocks or feet of the foetus enters the maternal pelvis before the head. In this situation if the process of delivery is too fast may result in damage of the mother or baby and if delivery takes too long may cause oxygen deprivation to the baby, which may result into the death of the baby. Most babies in the breech position are delivered through operation. (ceasarean section).

Lifestyle and socio-cultural factors that may cause complications in the reproductive system

The following are some factors that may cause complications of the reproductive system. Sexual behaviour, such as having sexual intercourse with more than one partner can cause infections and diseases including STIs, HIV and AIDS. Early pregnancy may cause complications later in life. Poor hygiene can increase the chance of getting infections. Poor nutrition during childhood can increase the chance of complications. Drinking alcohol, drugs and drug abuse, such as cigarette smoking, and using other harmful drugs, can damage the foetus. Tough work during pregnancy can put women at higher risk of abortion or stillbirth. Domestic violence such physical abuse of pregnant women may also result in abortion or stillbirth. Furthermore, accidents, stress and depression may also result into abortion.

Control measures to minimise complications in the reproductive system

Measures that should be taken in order to minimise complications of the reproductive system includes avoiding sexual intercourse at an early age, avoiding sexual intercourse with more than one partner to reduce chances of contacting sexually transmitted disease such as HIV/AIDS and eating a well-balanced diet. Other measures includes avoiding drug abuse, avoiding early pregnancies, maintaining personal hygiene especially in reproductive organs, attending clinic regulary during pregnancy, practising heathly life styles such as physical exercise and seeking medical advice in case of experiencing unusual signs or symptoms.

Sexuality, sexual health and responsible sexual behaviour and sex drive

Sexuality is the way people experience and express themselves sexually. It is the expression of self-identity. Sexuality can

be expressed in different forms including; physiological, psychological, social, behaviour, cultural, political and spiritual or religious aspects. Sexual health is the state of physical, emotional, mental and social well-being in relation to sexuality.

Sexual behaviour

In most societies there are rules about sexual behaviour. These rules vary in different cultures and religions. Sexual behaviour in most people is influenced by the norms of the culture or society in which they live. For example, in some religion and cultures, it is forbidden to have sexual intercourse before marriage. Gender identity is an aspect of human sexuality that is affected by the social environment, such as rules governing what kind of clothes to wear and so on. Sex drive is shown when a person is attracted to a member of the opposite sex. Some problems associated with sex drive includes the inability to concentrate, day dreaming, teasing and feelings of guilt.

Responsible and irresponsible sexual behaviour

Responsible sexual behaviour

These are the sexual behaviours that are legally and morally accepted within the society. These include those aspects which allow men and women to interact in a way that shows respect to each other. These practices include being faithful to one's partner and practice safe sex. Respect, means being polite and have consideration for people of the opposite sex, avoiding obscene language and unacceptable exposure of private parts in public as well as avoiding watching pornography and sexual practice that are not accepted such as same sex relationships, prostitution and others.

Irresponsible sexual behaviour

These are those sexual practices that are not legally, socially and morally accepted by the society. They include practicing unsafe sex, having many sexual partners, promiscuity and unfaithfulness to one's sexual partner, unaccepted exposure of private parts in public, prostitution and illegal practice such as rape, defilement and incest. Irresponsible behaviour can be caused by several factors including lack of proper counseling and guidance, influence from bad friends, lack of proper parental care, marriage breakdown and lack of accurate and appropriate information about sexuality. Inadequate knowledge and skills on sexuality can also lead to irresponsible behaviour.

Consequences of irresponsible sexual behaviour

It is very important for adolescent to have responsible behaviours because there are consequences of irresponsible sexual behaviours. Irresponsible behaviours promote the spread of sexually transmitted diseases such as syphilis, gonorrhea and HIV/AIDS. Also it leads to irresponsible parenthood, unwanted pregnancy which eventually leads to abortion, increases

poverty, death, disagreement between family members which leads to divorce and separation. Apart from that, it may lead to legal tussle and imprisonment and single parenthood when one gets pregnant before marriage. Inadequate life skills and scientifically inaccurate information can lead to early pregnancy. The consequences of early pregnancy affect the child, young mother, parents and the whole community.

Effects on the child

Since a young mother or father is not economically and socially ready to take care of the baby, the baby may suffer from malnutrition and even death. The underage parents may also harm or kill the baby or abandon a child if they feel that they are not ready to raise them.

Effects on the underage parents

The recommended age for child bearing is 20 years old and above. Early pregnancy can lead to complications of pregnancy and child birth and sometimes death of the mother. Induced abortion is one of the effects of early pregnancy. Moreover, future prospects of the underage mother are affected. This can lead to the depression, poverty and prostitution. The underage fathers also may come across the same or more complications similar to the underage mother. They can also drop out from school and get into forced child labour, crimes, and drug abuse.

Effects on the parents

Normally parents feel disappointed when their daughters drop out of school due to early pregnancy. In some cases, they drive the child away from home which may lead to prostitution and increased number of street children.

Effects on the community

The community in which there are prominent cases of early pregnancies, parental guidance in that society can be described as a failure. The prosperity of the community is also affected economically, socially and morally.

Methods of reducing irresponsible sexual behaviour

In order to remain safe, choose friends carefully and avoid peer pressure, adopt good practices and attitudes from people who are well respected, observe and obey school rules and regulations, be assertive and make informed decisions. Also, having appropriate knowledge and facts about reproductive health and using the information to make correct decisions can help to address irresponsible behaviour. Self-control and self-discipline will also help in avoiding irresponsible behaviour. Intergrating sex education in curriculum as well as imposing strict government laws against rape and other sexual abuse cases are very important in dealing with irresponsible behaviour.

Life skills required to cope with adolescent sexuality and sexual behaviour

Life skills is the ability to develop adaptive and acceptable behaviour that enables individuals to deal effectively with everyday life challenges. The necessary life skills for young adults include communication skills, assertiveness, decision making, self-awareness and creative thinking. Providing support and care to the adolescent on how to manage their physiological and emotional changes is also important. Provision of guidance and counseling by teacher, parents or professional people will help the youth to avoid irresponsible behaviour. Engagement in different activities that will keep them busy is another strategy to cope with adolescent sexuality and sexual behaviour. Adolescents need to be aware of their rights and responsibilities in the family, community and at school. Teachers at school should encourage students to speak out about their rights as young citizens.

Family planning and contraception

Family planning is a practice where a couple decides when to have a child and the number of children they want. Family planning allows people to attain their desired number of children and determine the intervals between their babies. This can be achieved through the use of contraception or birth control, which is the use of devices or practices that prevent conception. Contraception involves either blocking the fusion of a sperm with an egg cell and, therefore, preventing fertilisation, or making the female reproductive system hostile to sperms and implantation. There are several methods of contraception. These methods are grouped into four major groups which are; natural, chemical, mechanical and surgical methods.

Natural methods

These are methods of contraception which do not involve pills or devices. In this method, the woman monitors and records different changes during her menstrual cycle to find out when she is likely to get pregnant. These methods includes abstinence, rhythm method and withdrawal.

Abstinence

This refers to the avoidance of sexual intercourse when the woman is likely to get pregnancy. This is said to be 100 per cent successful in preventing pregnancy. However, it needs discipline in both partners. Usually the following techniques are used during periodic abstinence.

(i) The rhythm (calendar) method

This is the abstinence from sexual intercourse during the fertile period, that is, the time of ovulation. Sexual intercourse is avoided three to four days before as well as four days after ovulation. The time of ovulation can be estimated as 12th to 16th days before the start of the menstrual period.

(ii) Cervical mucus

A woman can check the cervical mucus, together with the menstrual cycle to identify the fertile period. This will enable a woman to identify safe period when she is unlikely to get pregnant. Checking mucus starts after menstrual period. A thin, slippery, clear and stretchy (just like that of egg white) indicates the time of ovulation. Soon after ovulation cervical mucus changes and become very sticky, white or creamy-like. This method is natural and widely acceptable since it has no cost. However, it requires good knowledge and good record keeping so that the fertile period and safe period can be well established.

(iii) Basal body temperature

This is the temperature of a body when a person is fully at rest. Ovulation may cause a slight rise in basal body temperature. The temperature change is caused by increased level of progesterone. The increase in temperature for three days is a signal that ovulation has occurred. So a woman is required to monitor her body temperature daily soon after menstruation, in this way one can know the fertile period.

Coitus Interruptus (withdrawal)

Coitus interruptus or withdrawal is another natural method of birth control in which a male withdraws his penis from a female tract before ejaculation. Coitus interruption requires a high degree of will power in a couple. Although, the method is costless, it is not one hundred percent safe because fluid released from the penis just before ejaculation may contain viable sperms. Sperms may also leak from the penis before it is withdrawn. This method deprives both partners the pleasure of sexual intercourse.

Chemical methods

Chemical methods of contraception involve the use of chemicals or drugs to prevent ovulation or inactivate the sperm. This involves the use of artificial hormones that inhibits the production of follicle stimulating hormones (FSH) which stimulate the development and maturation of Graafian follicles. If the Graafian follicle does not develop, ovulation cannot take place. Common chemical methods includes the use of contraceptive pills, implants spermicidal creams and birth control injections.

Contraceptive pills

The pills contain oestrogen and progesterone hormones. These hormones inhibit the production of follicle stimulating hormones (FSH) which stimulate the development and maturation of Graafian follicles. As the results ovulation cannot take place. The pills are taken daily as shown in Figure 8.15. These pills are very effective and do not interfere with the process of sexual intercourse. However, side-effects such as heart and related cardiovascular diseases, weight gain and breast tenderness in some women arise. Women should seek medical advice concerning the use of such pills and perform regular medical checkup.

Figure 8.15: Birth control pills

Injection

Injection contains progesterone hormones which are administered to the woman once after every 1, 2, or 3 months depending on the type. They suppress ovulation creating a hostile environment within the reproductive system. See Figure 8.16.

Figure 8.16: Birth control injection

Implants

These are a thin plastic rods that contain progesterone hormone. They are placed under the skin in the upper arm of a woman by a medical expert and left there for two to five years, depending on the brand. The hormone is absorbed gradually by the body and it prevents ovulation. The rod can be removed any time if the women decide to get pregnant or for any other reasons. Figure 8.18 shows how birth control implants are placed under the skin.

(a)

(b)

Figure 8.17: (a) implant (b) implant inserted under the skin

Mechanical methods

Mechanical methods of contraception involve the use of some kind of device (barrier) to prevent the entry of sperm into the oviduct or create a hostile environment for implantation to take place. They include the use of a condom (sheath), sponge, diaphragm and intrauterine devices.

Condom

This is a thin rubber sheath, which prevents sperms from entering the female tract. There are two types of condom which are male condom and female condom.

Male condom

The male condom is one of the most widely used barrier method in the world. This is the covering made to fit over the erect penis. It collects semen during ejaculation and provides a complete barrier between the penis and vagina so that sperm do not get deposited into the woman's vagina. As a result fertilisation cannot take place hence no pregnancy. It is a reliable method of contraception and also prevents the transfer of viruses and bacteria that may cause sexual transmitted disease (STIs or STDs). Figure 8.18 shows an example of a male condom.

Figure 8.18: Male condom

Female condom

The female condom is a thin, loose rubber fitting made up of two flexible plastics rings on either ends. It is inserted into the vagina before sexual intercourse. A female condom is closed at one end and open at the other end as shown in figure 8.19. The ring at the closed end of the tube covers the cervix during sexual intercourse and holds it inside the vagina and the other ring at the open end of the tube stays outside the vagina. Female condom collects semen during ejaculation to prevent pregnancy and also protects the partners from sexual transmitted diseases.

Figure 8.19: Female condom

Intra-uterine device (IUD)

This is a small plastic or copper strip bent into a loop or coil as shown in figure 8.20. It is placed in the uterus by a qualified medical care provider and left there. As it is a foreign body, the IUD creates a hostile environment for implantation. The disadvantage of this method is that the IUD could be expelled unnoticed from the uterus. Moreover, it can irritate or puncture the uterus, thereby causing bleeding and cramps in some women.

Figure 8.20: Intra uterine device

Surgical methods

When the couple have obtained the number of children they wanted, they may decide to undergo surgery to prevent unintended pregnancy. Such kind of surgery is called sterilisation. There are two types of sterilisation which are male sterilisation and female sterilization as shown in Figure 8.21. Male sterilisation is also called vasectomy. It involves the cutting and sealing off the vas deferens (sperm duct). Vasectomy does not affect hormonal secretions, therefore, sexual intercourse and ejaculation are not affected. Female sterilisation is called tubal ligation. It involves cutting and sealing off the fallopian tubes in a way that the ovum cannot descend into the uterus. Male and female sterilisation are permanent methods. That means once done they cannot be reversed.

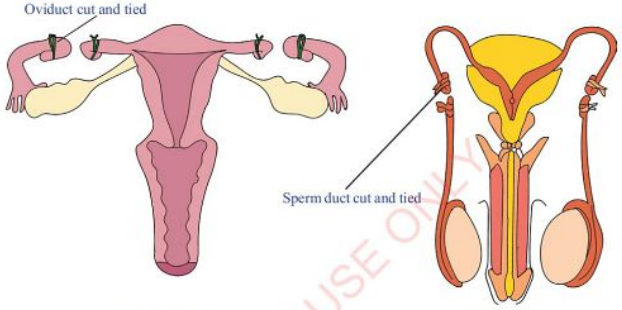


Figure 8.21: Sterilisation by surgery

Sociocultural practices that enhance family planning

In the society there are sociocultural factors that can encourage or prohibit the use of family planning. Positive factors which encourage the use of contraception includes education, employment and communication with partners. Couples with correct information about contraception methods are likely to choose and use the right methods. Employed women are likely to use contraception as it will increase efficiency in their employment. Moreover, in the society where there is free communication about sexuality issues, it is easier for the couple to use contraception.

The negative factors which reduce the use of contraceptives include attitudes towards contraception. Male partners

dislike the use of contraceptives, religious beliefs and cultural norms on fertility. Some women or societies believe that contraceptive results into reproductive health problems such as infertility. Most contraceptive methods require the agreement between couples. Therefore, if the male partner does not agree with the use of a particular family planning methods it will be difficult for the female partner to use it.

Some religious beliefs discourage the use of contraceptives as they believe that contraception is depriving the right of life of the intended child. However, this belief has minor effects on individuals. Some societies believe that having many children create manpower for the family and society. Therefore, such a society is not likely to have wide use of contraception.

Importance of involving men in family planning

Family planning should not be left to women alone, the men should also be involved. There are various advantages for the men to be involved in the family planning. Such reasons include to ensure that both partners accept the chosen methods. If both partners agree on the method, they are likely to continue using it. Some contraceptive methods require the agreement of the partners. For example, natural methods and the use of condoms. Therefore, there is no way such methods can be practiced if men are not involved. Male involvement strengthens marriage and loving relationship between partners.

Maternal and child health care

A pregnant woman needs care and consideration for the better health of the mother and the child. Basically there are three types of care given to pregnant women. These are pre-natal, natal and post-natal care. The care given before birth is called pre-natal care and the care given during birth is called natal care. A pregnant woman also needs care and support after birth of the child. The care and support provided after birth is called post-natal care.

Antenatal care or pre-natal

Antenatal care is a routine health care given to an expectant mother. Important routine check-ups are carried out at an antenatal clinic. A general examination of the expectant mother is carried out by a doctor or nurse, to assess the general health of both the mother and foetus, and advice is given. An abdominal examination is carried out to check the position of the foetus in the uterus and to see if there is any immediate action needed. Laboratory urine and blood tests help to identify any risks. The mother's urine is tested for sugar and protein content. Different abnormalities can be detected, such as kidney failure. The mother's blood is checked for malaria parasites STI, and haemoglobin level, which are very dangerous during pregnancy. Anaemia can be treated with iron tablets and nutrition. However, HIV and AIDS and blood group test is crucial if in case surgical delivery is needed. The mother's blood pressure is checked to see

if it is too high or low. The mother's height and weight are taken regularly. Too much weight gain or loss within a short time can affect the expectant mother's health.

It is important that the expectant mother should have a well-balanced diet during pregnancy. The pregnant woman's partner has an important role to play during the pregnancy. They should understand the physical and emotional changes taking place in her body and take a full role in taking care for her needs. They could help pack the various items needed by the mother during delivery, such as clean towels, nightwear, baby clothes, nappies, sanitary pads and toiletries. Maintaining general body cleanliness all the time is also important. During this period, the expectant mother should avoid the following: doing manual work, example, lifting heavy loads, and taking any medicine without consulting a doctor. Drugs such as alcohol, and cigarettes which could be detrimental to the unborn baby, tight clothes and high heeled shoes are not recommended. It is advised to avoid situations which can lead to contracting venereal diseases such as gonorrhea, syphilis and AIDS which might affect the baby. It is also advised to avoid situations that might lead to stress.

Care during birth

Natal period is the period when the pregnant woman gives birth to the child she has been carrying in her womb for about nine months. A number of things need to be considered during natal period. An expectant mother needs to undergo labor under supervision of a trained nurse or trained health care provider. If any complications that cannot be solved occur, the expectant mother should be referred to the next level health facility for medical assistance. In case the newborn baby is pre-mature, appropriate services should be given for a normal pattern of growth and development.

Post-natal care

Postnatal care is the special care given to a mother and baby after delivery. The most important event after birth is to complete the removal of the placenta from the uterus. The umbilical cord should be securely tied and cut using a sharp, sterile instrument. The cord should be kept dry and clean at all times. The mother should be helped to wash her body with soap and water. The mother should drink plenty of fluids and have a nutritious diet, in order to recover body fluids and help milk production. The mother's partner has a key role in supporting the mother and baby at this time. The baby must always be well covered to keep it warm. It should be dressed in clean fitting clothes made from cotton or soft woolen fabric. The baby should be immunised against common childhood diseases, such as measles, tetanus, whooping cough, diphtheria, polio and tuberculosis.

Child care

Immediately after birth the baby starts breast feeding. It remains under the care

of the mother to facilitate exclusive breast feeding for the first six months of life. It is important that the baby is properly fed for proper growth and development. Mothers should breast-feed the child on demand. Breasts develop the capacity for milk secretion midway during pregnancy. The hormones prolactin and oxytocin ensure milk production and secretion during breast-feeding. Breast milk is a complete diet in itself because it contains all the necessary nutrients the baby needs for growth and development.

Advantages of breast feeding are:

1. Breast milk, especially colostrum produced in the first few days after delivery, protects the baby from infection by boosting natural body immunity.
2. It is safe and will not cause infection unless the mother is sick.
3. Breast milk provides a balanced diet for the baby.
4. It creates an emotional bond between the mother and the baby.
5. Breast milk is at the right temperature and does not require heating.
6. Breast feeding does not require complicated preparations such as those used in bottle feeding; the mother is just required to be clean before feeding the baby.
7. Breast milk can protect the baby from developing obesity.
8. Breast milk can protect the baby from developing allergies.
9. The mother becomes less fertile while breast feeding and therefore, helps to control the interval between pregnancies.

Bottle feeding is a practice where the baby is fed on milk other than breast milk. It usually involves the use of a bottle with a teat or nipple and the milk used is either fresh from an animal or an artificial milk formula. There are two types of bottle feeding, these are temporary and permanent bottle feeding. Temporary bottle feeding is when the baby is fed on artificial milk when the mother is shortly absent. After the mother returns, the baby is fed on breast milk again. This is mostly practiced by working mothers. Permanent bottle feeding is used when the mother has an infection, such as tuberculosis, HIV/AIDS, or when she cannot produce enough breast milk.

However, bottle feeding is not recommended to babies because it has some disadvantages which include a high risk of infection from dirty milk or teats or both. If the formula is incorrectly prepared, the baby might not receive the correct composition of nutrients and it may become undernourished. The emotional bond between the mother and the baby may be reduced. Bottle feeding is also very expensive.

Weaning is the process of gradually stopping the use of breast milk and introducing liquids and other food substances. The amount of liquid and supplementary foods should be increased slowly as time goes. The weaning process

starts when the baby is able to swallow and digest newly introduced food without problems. The supplementary diet should be well balanced. The best foods to use in weaning are cow's milk, enriched porridge, cereals, fruits and vegetables. The following should be considered when weaning a baby: introduce a little amount of food at the beginning and gradually increase the amount. If the baby rejects food or reacts negatively to it, the food should be stopped and should then be introduced later. If possible, introduce one type of food at a time so that it is easy to monitor the reaction of the baby to different types of food. Some children are allergic to certain foods. Make sure the feeding environment is clean.

Socio-cultural practices affecting the maternal and child care

There are various practices that affect the the maternal and child care in the society. These practices include the belief in some societies that expectant women should not drink milk or eat meat, fish, eggs other animal product and should eat only vegetables. The reason given is that she will give birth to a bald child. This taboo deprives the expectant women and her foetus of important nutrients needed for good health.

The traditional practice of applying cow dung on the umbilical cord of a newly born baby is dangerous and could cause infection, especially tetanus. In some traditions, the father is always given the best food while the mother and children are often given an insufficient share. Some societies prohibit the use of colostrum for babies as they think it is dirty. This practice deprives the baby proper nutrients and antibodies needed at this stage of life. Lack of knowledge and inability to afford proper treatment can cause maternal and child death.

Some religions teach that maternal and child diseases are caused by evil spirits. People in such communities may delay seeking proper medical treatment until the traditional option proves failure.

Maternal and child care for people living with HIV and AIDS

People living with HIV and AIDS need to be given special attention in their diet and access to medical services. This helps to optimize their immunity and ability to fight opportunistic infections. They also need good maternal and child care as well as regular health check-ups to help them know when it is necessary to take antiretroviral drugs. Lactating mothers with HIV may be advised not to breast feed their babies on medical grounds. This is because the babies may become infected with HIV through breast milk. In such cases, the babies should be given a nutritious diet to ensure healthy growth, improve their immune system and protect them from nutritional disorders such as marasmus and kwashiorkor. People living with HIV and AIDS need to be cared for, and treated with love and empathy. They should not be stigmatised in any way.

Revision exercise 8

Section A

Choose the most correct answer.

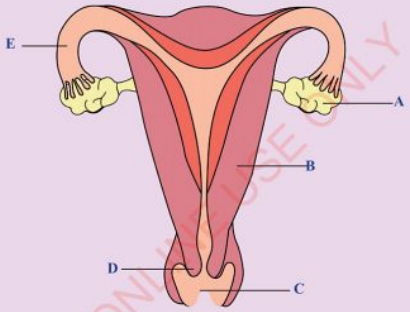
1. Which one of the following is the correct order of events?
   (a) Fertilisation, implantation, ovulation.
   (b) Ovulation, fertilisation, implantation.
   (c) Implantation, ovulation, fertilisation
   (d) Fertilisation, ovulation, implantation.
2. Shortly after an egg is fertilised the product is known as the
   (a) zygote
   (b) embryo
   (c) foetus
   (d) young baby
3. In human beings fertilisation takes place in the_____.
   (a) vagina
   (b) uterus
   (c) fallopian tube
   (d) cervix
4. Sexual reproduction involves the fusing of_____.
   (a) oogonia
   (b) ova
   (c) gametes
   (d) zygotes
5. The male reproductive organ which store sperm is called_____.
   (a) scrotum
   (b) vas efferentia
   (c) epididymis
   (d) penis
6. Fraternal twins develops as a result of_____.
   (a) two embryos developing at the same time.
   (b) two eggs from ovaries being fertilised separately.
   (c) a fertilised egg spliting into two.
   (d) the egg dividing but sharing the same placenta.
7. The menstrual cycle is regulated by the following hormones except;
   (a) gonadotropin
   (b) oxytocin
   (c) luteinizing hormone
   (d) oestrogen
8. _____ is a tube that is funnel-shaped at the end, adjacent to the ovary enabling the released ovum to be directed towards the uterus.
   (a) Cervix
   (b) Vagina
   (c) Oviduct
   (d) Vulva

5. Match each item in **column A** against its corresponding item from **column B**.

Column A	Column B
(i) Sexuality	A. Implantation of the embryo in a place other than the uterus, usually in the fallopian tube
(ii) Breech birth	B. A condition whereby a man expels semen before or immediately after insertion of the penis into the vagina
(iii) Ectopic pregnancy	**C.** A condition of pregnancy in female humans characterized by high blood pressure and protein in the urine
(iv) Fertilisation	D. A situation in which the woman fails to respond to sexual stimulus in order to reach orgasm
(v) Preeclampsia	E. Natural method of birth control in which a male withdraws his penis from a female tract before ejaculation.
(vi) Frigidity	F. The production of a new organism from a single organism without the use of sex cells
(vii) Coitus interruptus	G. Behaviours that are legally and morally accepted within the society
(viii) Premature ejaculation	H. Sexual behaviours that are not legally, socially and morally accepted by the society
(ix) Responsible sexual behaviour	I. The process whereby sperm nuclei and ovum nucleic fuse to form a diploid cell called zygote
(x) Irresponsible sexual behaviour	J. Situation where a baby is born feet or buttocks first
	K. Planning which involves a couple arranging when to have children and how many children and ensuring that they are able to take care of them properly
	L. The process whereby mature male sperm cells are produced within the seminiferous tubules of the testes
	M. The process by which the zygote is attached to the uterine wall
	N. The way people experience and express themselves sexually

Answer the following questions

6. How does responsible behaviour differ from irresponsible behaviour?
7. What is the role of males in family planning?
8. Explain the socio-cultural factors that affect maternal and child care.
9. Explain three disorders of the male reproductive system and two disorders of the female reproductive system.
10. In which ways can reproductive disorders in males and females be avoided?
11. How are male gametes formed?
12. Give the names of the hormones that control secretion of milk in mammary glands and development of female secondary sexual characteristics.
13. In which ways do fertilisation differ from implantation?
14. Why is breast feeding preferable to bottle feeding?
15. Study carefully the diagram below then answer the questions that follow



(a) Mention the name of the figure above.
(b) Name the parts labelled A-E
(c) In which part in the figure does fertilisation take place?
(d) What is the role of the part labelled B and C?

Glossary

Accomodation	ability of the eye to focus near and distant objects
Adrenaline	hormone secreted by adrenal glands that regulate blood sugar level, heartbeat, blood pressure and eye pupil size in order to prepare the body for danger
Amniotic fluid	a fluid that fills the amnion to protect the embryo
Annuals	plants that last or live for one year
Appendicular skeleton	part of skeleton that include arm, legs, pectoral girdle and pelvic girdle
Auditory canal	passage leading from the outer ear to the inner ear through the middle ear
Axial skeleton	part of human skeleton that includes the skull, vertebrae, ribs, and breastbone
Axon	long protoplasmic process from the cell body of a neurone
Behavioural regulation	when an animal changes its behaviour to maintain homeostasis
Biceps	flexor muscles in the arm and leg that help to bend the upper and lower limbs.
Biennials	plants that last or live for two years
Blind spot	the point where the optic nerve leaves the retina. It is an area that has no image detection
Blood vessels	tubes that carry blood around the body
Bones	the hard rigid structures that make up the vertebrate skeleton and provide support to human or other vertebrate body
Bowman's capsule	cup-shaped capsule at the start of a nephron
Brain	part of the central nervous system that enables a person to perform physical and mental activities. It also receives information from all sensory organs of the body, coordinates them and sends motor impulses to effector organs
Calyx	outermost whorl of a flower
Carpel	one or several carpels make up the gynoecium in a flowering plant
Central nervous system	the brain and spinal cord
Centromere	the most condensed and constricted region of a chromosome to which the spindle fibre is attached during mitosis and meiosis

Cerebellum	a cauliflower-shaped brain structure located just above the brainstem, beneath the occipital lobes at the base of the skull.
Cerebral hemispheres	the two halves of the cerebrum
Cerebrospinal fluid	fluid filling the spinal canal, which helps to protect the spinal cord from shocks
Cerebrum	part of the brain involved in learning, memory, thought, personality, and voluntary actions
Cervix	ring of muscles at the lower end of the uterus
Chiasma	the point where two homologous chromosomes exchange genetic material during chromosomal cross-over
Childbirth	when a foetus moves through the cervix and vagina into the outside world
Choroid	middle, dark coloured layer of the wall of the eye
Chromatid	either of the two daughter strands of a replicated chromosome that are joined by a single centromere and separate during cell division to become individual chromosomes
Chromosome	a thread-like structure which carries genetic or hereditary information found in the nucleus of eukaryotic cell and in cytoplasm of prokaryotic cell
Ciliary muscles	muscles on the wall of the eyeball that are attached by ligaments to the lens
Cochlea	coiled tube in the inner ear; it is the organ of hearing.
Collecting ducts	the ducts collecting urine into the pelvic region of the kidney
Colostrum	breast milk produced at the end of pregnancy and in the first few days after birth
Concave lens	a spectacle lens that diverges light rays and bring them to focus on the retina to correct short sightedness
Conditioned reflex	a type of reflex action where the response is affected by past experience
Condom	stretchy plastic-like impermeable material placed over the penis or in the vagina before sexual intercourse to prevent conception, and prevent sexually transmitted infections
Conduction	transmission of heat through a medium
Cone	The seed-bearing part of a conifer
Cones	light-sensitive cells in the retina that are important for colour vision
Conifers	cone bearing plants whose seeds are not enclosed in ovaries but are arranged spirally in cones
Contraception	the use of devices or practices that prevent conception.

Contraceptive pills	pills containing oestrogen and progesterone that are taken daily to prevent conception
Convection	transfer of heat through a liquid or gas by motion of molecules.
Convex	a spectacle lens that converges light rays and bring them to focus on the retina. It is used to correct long sightedness
Coordination	the linking together of the functions of different organs so that they work at the time and rate required by the body
Coordinator	an organ that receives messages from receptors and uses it to link activities in the body, i.e. the brain and spinal cord.
Cornea	transparent layer at the front of the eye
Cornified layer	the outermost layer of the epidermis of the skin
Corolla	part of a flower enclosing the reproductive organs; it is usually made up of petals
Cortex	this is the outer layer of an organ, such as the kidney, human ovaries, adrenal gland, the thymus and portion of the brain including cerebral cortex.
Cotyledon	seed leaves found within a plant embryo
Cowper's glands	glands located on either side of the urethra beneath the prostate gland; they secrete lubricating mucus
Cranium	bone enclosing the brain
Crossing over	exchange of genetic material in meiosis
Cross-pollination	transfer of mature pollen grains from the anther of one plant to the stigma of a flower of another plant of the same species.
Cystitis	inflammation of the urinary bladder
Cytokinesis	division of the cytoplasm of a cell following the division of the nucleus
Dendrite	short branched protoplasmic process from the cell body of a neurone or from an axon
Depressant	a drug that suppresses the part of the brain responsible for sensing pain
Dermis	the layer of skin below the epidermis
Diaphragm	(1) the membrane that separates the chest cavity from the abdomen (2) circular piece of rubber that fits over a woman's cervix and prevents conception
Dicot or dicotyledon	a flowering plant with two embryonic seed leaves or cotyledons that usually appear during germination
Diploid	contains the full set of genetic material of an organism in two sets of chromosomes

Distal convoluted tubule	a tubule situated at the end of ascending limb of the loop of Henle in the kidney
Drug	any substance natural or synthetic that alters the way the body works
Drug abuse	excessive use of a drug or use for reasons other than medical
Drug addiction	behaviours resulting from prolonged use of a drug that are motivated by emotions, ranging from craving to compulsion
Ear ossicles	bones connected to the tympanic chamber: the malleus, incus and stapes, associated with transmission of sound to the inner ear
Ectotherm	an organism that regulates its body temperature largely by exchanging heat with its surroundings, a poikilotherm
Effector	a muscle, gland or organ capable of responding to a stimulus, especially a nerve impulse
Embryo	an organism in the very early stages of development from a zygote
Endocrine glands	glands that produce hormones and secrete them directly into the bloodstream
Endocrine system	system of endocrine glands
Endolymph	fluid filling the cochlea
Endometrium	inner layer of the uterus
Endotherm	an organism that generates or releases heat to maintain its body temperature, homoiotherm
Entomophilous	insect pollinated flower
Epidermis	the outermost layer of skin
Epididymis	densely coiled tube formed from the seminiferous tubules, where sperm are stored
Erector muscles	muscles that raise the hairs in the skin
Eustachian tube	tube connecting the middle ear and the throat
Evaporation	the process by which water turns from liquid into vapour
Exocrine glands	glands that produce secretions that pass through ducts into another part of the body
External auditory canal	narrow canal leading off from the tympanum to the pinna
Fallopian tube	funnel-shaped tube that allows an ovum to pass through from the ovary to the uterus
Family planning	Is the practice of controlling the number of children and when to have children by means of contraceptive or natural methods

Fenestra ovalis	oval window in the middle ear
Fertilisation	the fussion of haploid male and female gametes during sexual reproduction
Fibrous root system	a root system with no main root
Filament	part of the stamen in a flower holding the anther
Filtration	separation of large and small molecules; in the kidney this takes place in the glomeruli of nephrons.
Flower	reproductive organ of angiosperm plant
Foetus	the unborn young of a vertebrate, with a basic structural resemblance to the adult animal
Follicle-stimulating hormone	hormone produced by the pituitary gland responsible for ovulation
Forebrain	the anterior part of the brain.
Fovea centralis	most sensitive part of the retina, directly opposite to the lens
Fraternal twins	results from the fertilisation of two separate eggs during the same pregnancy
Gamete	a specialised cell of sexual reproduction which contains the haploid number of chromosomes
Gametogenesis	process of making gametes
Glomerulonephritis	a form of nephritis characterised by inflammation of the renal glomeruli
Glomerulus	a bundle of blood capillaries in the cortex of the kidney, involved in filtration of blood.
Glucagon	a hormone produced by the pancreas that stimulates an increase in blood sugar level, thus opposing the action of insulin
Glucose	Is a simple sugar. It is formed in plants as a result of photosynthesis, and is the end product of carbohydrate digestion in animals
Glycogen	a form in which sugar/glucose is stored in the animal body
Gout	a disease in which defective metabolism of uric acic causes arthritis especially in small bones of the feet. It is characterised by painful inflammation of the joints, especially the feet and the hands
Graafian follicle	mature ovarian follicle
Gymnosperms	cone bearing, non-flowering plants
Gynoecium	collective name for the female reproductive organs of a flowering plant. It is sometimes called a pistil

Hallucinogen	a drug that causes hallucinations
Haploid	containing half the genetic information of the organism
Hermaphrodite	organism with both male and female reproductive organs.
Hibernation	when animals go into a deep sleep, slowing down their metabolic rate usually for survival purposes
High blood pressure	raised blood pressure above the normal that can be a result of prolonged emotional stress
Hindbrain	posterior region of the brain composed of the cerebellum and medulla oblongata
Homeostasis	ability or tendency of an organism or cell to maintain internal equilibrium by adjusting its physiological processes
Hormone	a substance, usually a peptide or steroid produced by one tissue and transported by the bloodstream or duct to effect an activity, such as growth or metabolism
Hymen	thin web of skin at the vaginal opening
Hyperglycaemia	an abnormally high concentration of glucose in the blood
Hypermetropia	long sightedness, ability to see clearly at long distances but not close objects
Hyperthermia	unusually high body temperature
Hypoglycaemia	an abnormal low level of glucose in the blood
Hypothermia	unusually low body temperature
Identical twins	offspring resulting from splitting of a single fertilised egg
Implants	These are small plastic or copper strip of progesterone inserted in the upper arm of the woman and left in place for a number of years for birth control purpose
Incus (anvil)	one of the ear ossicles
Induced abortion	abortion carried out on purpose to end a pregnancy
Inner ear	the inner part of the ear beyond the middle ear
Injectables	these are progesterone-like hormones injected to suppress ovulation
Impulse	signal that travels along the length of the nerve fibre
Insulin	a polypeptide hormone secreted by the islets of Langerhans; it regulates blood sugar
Intercalated discs	permeable membrane foldings joining the cells of cardiac muscle
Intrauterine device	small plastic or copper strip that is placed in the uterus to prevent implantation. It is a form of birth control
Iris	part of the eye that surrounds the pupil

Joint	a place where two or more bones are joined
Kidney	one of a pair of bean-shaped organ in the dorsal region of the vertebrate abdominal cavity, which filters metabolic wastes in blood
Kidney stone	a small, hard mass in the kidney that chiefly forms from deposits of phosphates and urates
Labia	fleshy folds protecting the vaginal opening
Lactation	secretion of milk by the mammary gland
Lens	structure in the eye that focuses light coming through it
Ligament	a sheet or band or tough, fibrous tissue connecting bones or cartilages at a joint or supporting an organ
Loop of Henle	u-shaped part of a kidney tubule
Lumbar vertebrae	vertebrae located between the lower ribs and the pelvic girdle
Malleus (hammer)	one of the ear ossicles
Malpighian layer	the inner layer of the skin epidermis
Medulla	the inner layer of the kidney, it is also found in other organs such as human ovaries and adrenal gland
Medulla oblongata	a portion of the hindbrain that controls autonomic functions such as breathing, digestion and heart rate
Meiosis	eukaryotic cell division that results into half number of chromosomes of the parent cell
Meninges	three layers of membranes covering the brain
Menstruation	the release of the uterine lining and unfertilised egg
Micropyle	small hole in the ovary of a flowering plant that allows entry of a pollen tube
Midbrain	middle part of the brain
Middle ear	middle part of the ear containing the tympanic chamber and the ear ossicles
Mitosis	eukaryotic cell division where the nucleus divides into two nuclei with identical genetic material.
Monocarpous	a flower with one carpel
Monocot or monocotyledon	a flowering plant with one embryonic seed leaf or cotyledon that usually appears during germination
Motor neurone	a neuron that conducts nerve impulses away from the brain or spinal cord to an effector organ
Myelin sheath	cylinder of fatty substances surrounding a nerve fibre
Myometrium	external muscular layer of the uterus
Nephron	one of the numerous filtering units of the kidney that remove

	wastes from the blood
Nerve fibre	the cell body of a neuron with its associated dendrites and axon
Nervous system	network of neurons that transmits signals and coordinates actions
Neurone	a nerve cell that sends and receives electrical signals over long distances within the body
Nodes of Ranvier	gaps in the myelin sheath surrounding a nerve fibre that occur at regular intervals along the fibre
Oculomotor nerve	cranial nerve III, a sensory nerve linking the brain and the eyes
Oedema	swelling due to water retention or increased tissue fluid.
Olfactory lobes	Part of the forebrain concerned with smell
Oogenesis	The process of producing ova
Optic nerve	cranial nerve II, a motor nerve linking the brain and the eyes
Osmoregulation	active regulation of the osmotic pressure of body fluids so they do not become excessively diluted or concentrated
Osmoregulatory system	system that regulate the osmotic pressure of body fluids
Outer ear	the visible part of the ear, mades up of cartilage and muscles
Ovary	female reproductive organ that produces an egg or ovum
Ovulation	release of a mature egg from the ovary
Ovules	the female gametes of a flowering plant.
Ovum	female gamete of an animal
Pancreas	a long, irregularly shaped gland in vertebrates; positioned behind the stomach. It secretes pancreatic juice into the duodenum and insulin, glucagon and somatostatin into the bloodstream.
Panting	hanging out the tongue while breathing, to increase evaporation of liquid and so cooling the body usually in dogs
Papillae	hair-like sensory cells in the upper lining of the tongue
Parasympathetic nervous system	the part of the autonomic nervous system that has a mainly calming influence
Pelvis	the lower part of human body between the abdomen and thighs
Penis	male sex organ
Perennials	plants that live more than two years
Perilymph	fluid inside the inner ear
Peripheral	all the nerves outside the brain and spinal cord

nervous system	
Petals	the colourful part of a flower making up the corolla used to attract pollinators
Photoreceptor	receptor that is sensitive to light
Physiological regulation	when an organism changes its physiology to maintain homeostasis
Pinna	the trumpet-shaped part of the outer ear that directs sound waves onto the ear drum; leaflets of the frond of a fern
Placenta	a membranous vascular organ that develops in female mammals during pregnancy, providing oxygen and nutrients to the growing baby. In flowering plants the placenta is a ridged, soft and fleshy tissue to which the ovules are attached
Placentation	the arrangement of the ovules and the placenta within the ovary on a flowering plant
Pollen	the male gametes of a flowering plant
Polycarpous	a flower with two or more carpels
Poikilothermic	having a body temperature that varies with the external environment
Pollination	transfer of pollen grains from the male to the female part of a flower
Pregnancy	period from conception to birth
Prostate gland	gland just below the bladder in males which produces some of the fluid in semen
Proximal convoluted tubule	the first convoluted part of a kidney tubule that joins the descending loop of Henle
Puberty	stage of adolescence in which an individual becomes physiologically capable of sexual reproduction.
Pupil	central portion of the eye responsible for light entry
Radiation	emission and propagation of energy in the form of waves, rays or particles that travel through the space
Reabsorption	active transport of amino acids, ions and glucose from the tubules back into the blood
Receptacle	enlarged upper end of a flower stalk that bears the flower or flowers
Receptor	an organ or cell that responds to an external stimulus and transmits signals to a sensory nerve
Reflex arc	a nerve pathway running through the spinal cord, involving sensory, intermediate and motor neurons

Relay neurone	a neuron that forms an intermediate link between a sensory and motor neurone
Resins	substances produced by plants that help in defence against fungal and insect attacks
Response	a reaction of an organism in responding to a specific stimulus
Responsible sexual behaviour	being accountable for ones sexual behaviour
Retina	inner layer of the wall of the eye, containing millions of photoreceptors
Rhythm method	abstinence from sexual intercourse during the fertile period
Rods	light-sensitive cells in the retina that produce a black and white image and are important for seeing in dim light
Sacculus	sac-like structure in the inner ear
Sclerotic layer (sclera)	a dense connective tissue of the eyeball that form the white part of the eye
Scrotal sac	sac-like pouch enclosing the testes
Sebaceous glands	glands situated in the dermis that secrete oily fluid which prevents cracking of the epidermis
Secondary sexual characteristics	physical changes in the body that occur at puberty
Secretion	Substance released from a gland where it is produced, usually into the blood
Sedative	a drug that slows down the brain and makes a person feel sleepy
Self-pollination	transfer of mature pollen grains from the anther to the stigma of the same flower or of another flower in the same plant
Semicircular canals	three tiny fluid filled tubes in the inner ear. They are involved in body balance
Seminal vesicle	glands found behind the bladder in males; they produce most of the fluid in semen
Seminiferous tubules	tube-like structures within the testes, where sperms are produced
Sensory neurone	a neurone that conducts impulses from the sense organs to the brain or spinal cord
Sepals	leaf-like structures in plants, making up the calyx
Sexual reproduction	production of offspring by fusion of gametes to form a diploid zygote which develops into the mature organism
Skeleton	internal or external framework of bone and cartilage or other

	rigid material that protects and supports the soft organs, tissues and other parts of an organism.
Sperm	the male gamete
Spermatid	a cell produced from spermatogonia by meiosis that goes on to differentiate into a mature sperm cell
Spermatogenesis	the process of producing sperm
Spermicidal cream	creamy substance put into the woman's vagina before sexual intercourse to kill sperms
Spinal cord	Part of the central nervous system that serves as an impulse-conduction pathway; it also acts as a reflex centre
Spontaneous abortion	when the foetus is expelled from the uterus unintentionally
Stamen	male reproductive organ in a flower, made up of an anther and a filament
Stapes (stirrup)	one of the ear ossicles
Sterilisation	surgery to prevent a couple from having children.
Stigma	part of the carpel in a flowering plant
Stimulant	a drug that speeds up the action of the brain and makes a person more alert
Stimulus	anything capable of causing a response in an organism.
Style	Part of the carpel in a flowering plant connecting the stigma and the ovary
Sweat glands	glands situated in the dermis that produce sweat
Sweating	loss of liquid through glands on the surface of the skin which cools the body when it evaporates
Sympathetic nervous system	the part of the autonomic nervous system that has a mainly excitatory effect
Taste buds	group of receptor cells on the tongue
Tap root system	a root system with a main root
Tendon	a band of tough, inelastic fibrous tissue that connects a muscle to the skeleton.
Testa	seed coat
Thermoregulatory system	regulatory mechanism that keeps the body temperature constant.
Triceps	an extensor muscle in the arm or leg that helps to straighten the upper or lower limb.
Tympanum	the ear drum
Umbilical cord	flexible cord-like structure connecting a foetus at the abdomen with the placenta and containing two umbilical arteries and

	one vein that transport nourishment to the foetus and remove its wastes
Urea	a water-soluble compound that is the major nitrogenous end product of protein metabolism and the chief nitrogenous component of urine
Ureter	long, narrow duct that conveys urine from the kidneys to the urinary bladder
Ureteritis	inflammation of the ureter; characterised by pain, swelling, redness and heat
Urethra	canal through which urine is discharged from the bladder in most mammals and through which semen is discharged in males
Urinary bladder	an elastic, muscular sac situated in the interior part of the pelvic cavity in which urine collects before excretion
Urine	waste product secreted by the kidneys and discharged from the body through the urethra
Uterus	a place where the fertilised egg or embryo implants
Utriculus	sac-like structure in the inner ear
Vagina	muscular cavity connecting the cervix to the outside of the body
Vagus nerve	cranial nerve X, a mixed motor and sensory nerve that runs between the brain and the heart, gut and part of the respiratory tract
Vasectomy	surgical sterilisation procedure in men, involving cutting and sealing the sperm ducts
Vasoconstriction	constriction of the arterioles and capillaries near the skin, which reduces blood flow and conserves body heat
Vasodilation	dilatation of the arterioles and capillaries near the skin which increases blood flow and helps the body to lose excess heat
Vegetative reproduction	asexual reproduction in plants without seeds or spores
Vitreous humour	jelly-like fluid filling the posterior cavity of the eyeball
Weaning	the process of gradually stopping feeding a baby on breast milk and introducing other liquids and food substances
Withdrawal	in the context of family planning, this means removal of the penis from the vagina before ejaculation
Withdrawal symptoms	symptoms that may be experienced when person stops taking a drug that they are addicted to
Zygote	a diploid cell resulting from the fusion of a male gamete with a female gamete

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