Biology

for Secondary Schools

Student's Book

Form Four

Tanzania Institute of Education

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Biology

for Secondary Schools

Student's Book

Form Four

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Commissioner for Education

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BIOLOGY FORM 4.indd 2 09/03/2022 19:02

Table of Contents

BIOLOGY FORM 4.indd 3 09/03/2022 19:02

BIOLOGY FORM 4.indd 4 09/03/2022 19:02

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BIOLOGY FORM 4.indd 5 09/03/2022 19:02

Preface

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

The book consists of five chapters, namely Growth, Genetics, Classification of living things, Evolution, and HIV/AIDS and other STIs. Each chapter contains, illustrations, activities, projects and exercises. You are encouraged to do all the activities and exercises as well as other assigments that your teacher will provide. Doing so will enable you to develop the intended competencies.

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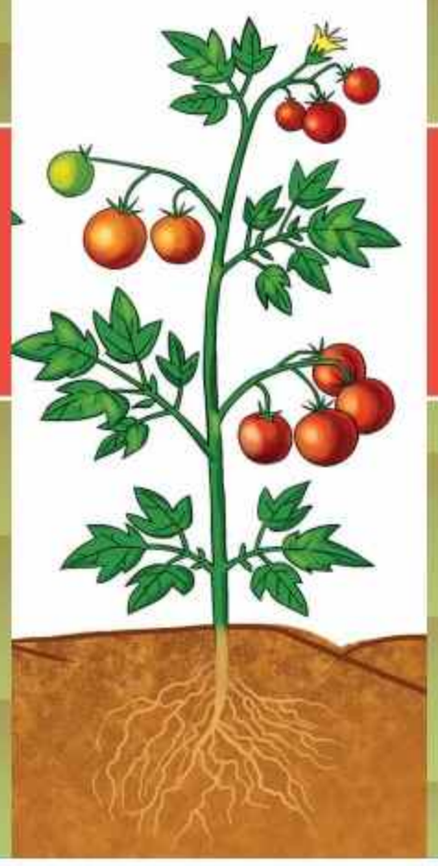
BIOLOGY FORM 4.indd 6 09/03/2022 19:02



Chapter

One

Growth

Introduction

Growth is one of the fundamental characteristics of living organisms. It enable organisms to increase in number of cells and size. In Form Three, you learnt about reproduction which results in the formation of new offsprings. In this chapter, you will learn about the concept of growth, mitosis and growth, growth and developmental stages in humans, and growth in flowering plants. The competencies developed will enable you to manage some factors affecting your own growth and development and that of other organisms.

Concept of growth

Growth is the irreversible process of increasing number of cells and size of an organism. The increase in number of cells is a result of the process called mitosis. In this process, the nucleus and cytoplasm of a cell divide to form two identical daughter cells. In animals, growth occurs in all parts of the body whereas in plants it occurs in specific regions of the body such as at the tips of the shoot and root.

Usually, the growth rate of an organism increases with time. This type of growth is known as positive growth. At later stages of an organism's growth, the rate of growth slows down. This type of growth is called negative growth. Positive growth occurs when synthesis of materials (anabolism) exceeds the breakdown of materials (catabolism) while negative growth occurs when catabolism exceeds anabolism. The growth of an organism is accompanied by development. Development is the increase in complexity of the organism and ability of the organism's structures to function. Development involves differentiation of cells. Differentiation is the process by which cells and structures become specialised for performing specific functions. It

BIOLOGY FORM 4.indd 1 09/03/2022 19:02

involves changes in both, the shape and the physiology of the cells. Differentiated cells are capable of carrying out specific functions.

Importance of growth and development in living organisms

In multicellular organisms, the newly formed individuals have certain structures that are not well developed. Growth and development enable the differentiation of cells in an organism, resulting in the specialisation of cells for different functions. The specialisation of cells during growth enables an organism to adapt to its environment. An example of specialised cells is guard cell in the plant leaves which control the opening and closing of stomata and blood cells used to transport different materials in various parts of the animal body.

Factors affecting growth and development in organisms

The growth and development of an organism are affected by various factors. These factors are categorised as external and internal factors. External factors are environmental factors whereas internal factors are factors within an organism's body.

External factors affecting growth and development in plants

Growth of plant and their spatial distribution are influenced by the environment. Any environmental factor that is not favourable to a plant becomes a limiting factor to plant growth. Limiting factors are also responsible for the geographical distribution of plants. For example, only plants adapted to limited amounts of water can survive in deserts. Therefore, it is important to understand the environmental factors that affect plant growth and distribution. These factors include light, temperature, water, nutrients, and gases such as carbon dioxide and oxygen as summarised in Figure 1.1.

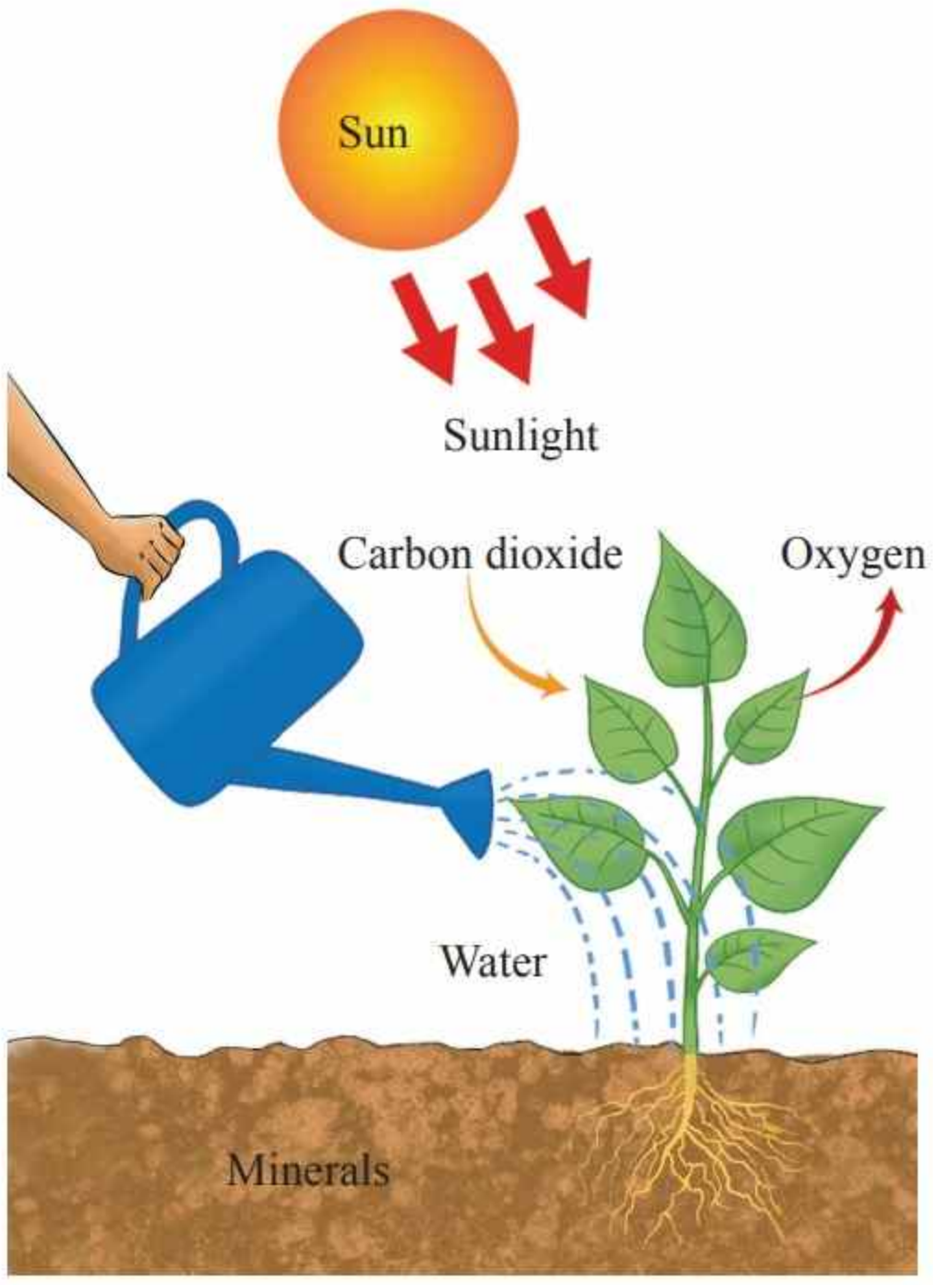


Figure 1.1: Factors affecting plant growth

Light: Plants need light to perform several functions including photosynthesis. The more sunlight a plant receives, the higher capacity it has to produce food through photosynthesis. As the intensity of sunlight decreases, the rate of the photosynthesis also decreases. This is because light

BIOLOGY FORM 4.indd 2 09/03/2022 19:02

supplies energy which plants use to synthesise food. When there is limited sunlight, stems of the plant become "leggy", meaning that they become long and thin as they try to reach the source of light. The absence of light also makes plants undergo chlorosis. Chlorosis is characterised by the yellowing of leaf tissue due to lack of chlorophyll.

Activity 1.1:

Investigating the effect of light on the rate of growth in plants

Materials: Six similar bean seedlings planted in 3 pots with soil rich in organic matter, a note book and a pen

Procedure

1. Mark the pots as A, B and C.
2. Place pot A in a place receiving direct sunlight, pot B in a place without direct sunlight, and pot C in a dark place. Continue watering the seedling in each pot every morning for seven (7) days.
3. Record what has happened to the bean seedlings in pots A, B and C after seven days.

Questions

(a) Why did the seedlings in pot A, B and C differ in their growth rate?

(b) What is the role of light in plants growth?

Temperature: Environmental temperature influences most plant processes including photosynthesis, transpiration, reproduction, respiration, germination and flowering. The effect of temperature on plant growth and productivity is dependent on plant variety. This is whether a plant is a warm-season or a cold season crop. The rate of all biological processes in plants are accelerated as the temperature rises to a plant optimum level and decelerates as the temperature deviates from the optimum level. Enzymes are responsible for metabolic activities that lead to growth. Enzymes work best at optimum temperature. At lower temperatures enzymes are inactive whereas at higher temperature enzymes are denatured. For example, if the environmental temperature is high for a long time, cool-season crops such as spinach will wilt. Similarly, high temperature for warm-season crops such as tomatoes can cause pollen to become unviable. Temperature also affects the flowering and pollination of flowers. Adverse temperature can also lead to stunted growth and poor-quality crops.

Nutrients: Plants need nutrients for growth and development. Normally, nutrients required by plants are found in the soil. Such nutrients include Nitrogen, Phosphorus, Potassium, Manganese, Magnesium, Calcium, and Sulphur. Other nutrients such as Carbon, Hydrogen, and Oxygen are obtained from the atmosphere and water. Nutrients required by plants in small amounts are known as micronutrients or trace elements. Examples of micronutrients include Zinc, Manganese

BIOLOGY FORM 4.indd 3 09/03/2022 19:02

and Iron. Nutrients required by plants in large amounts are known as macronutrients. Examples of macronutrients include Nitrogen, Phosphorus, and Potassium. Most of the nutrients that a plant needs are dissolved in water in the soil and then absorbed by its roots. Inadequate amount of nutrients affects the rate of growth and survival of plants.

Water: About 90% of the weight of a plant is made up of water. Water is one of the essential factors required for plant growth. It provides plants with nourishment and hydration. It plays a vital role in plant processes such as photosynthesis, respiration and transportation of minerals and other nutrients. Water is a medium through which biochemical reactions in a living organism take place. Water is also important in maintaining the turgor pressure of plant cells which maintains cell shape and ensures firmness of the plant. Through turgor pressure and other changes in the cell, water regulates the opening and closing of stomata. Stomata opening and closing allow transpiration and exchange of gases like carbon dioxide and oxygen. Evaporation of water from leaves during transpiration helps to cool the plant. The gradual evaporation of water from the leaf's surface through the stomata helps plant to stabilise plants temperature. Water also dissolves minerals in the soil. When plant absorbs water through their roots, minerals are also picked up and transported along with the xylem tissue. Humidity or water vapour in the air also influences plant growth by affecting photosynthesis, transpiration and pollination.

Amount of carbon dioxide and oxygen gases: Both carbon dioxide and oxygen are required for plants growth. Carbon dioxide is one of the raw material in the manufacturing of sugar through the process of photosynthesis. The produced sugar is the source of energy to the plant for various physiological activities. Such physiological activities result in growth and development in plant structures and increase of leaf area and size of the roots, which is crucial for the plant to grow and survive. Carbon dioxide and oxygen gas which are dissolved in water are taken by the plants through roots. Plants also take oxygen gas at night through the stomata of the leaves. Plants use oxygen for aerobic respiration that releases the energy required for growth.

At low carbon dioxide gas concentrations in the environment, the rate of photosynthesis is lowered, hence decreasing the rate of plant growth. As the carbon dioxide gas concentration increases the rate of photosynthesis also increases and plant growth become rapid.

Internal factors affecting the growth and development of plants

Internal factors that affect the growth and development of plants include plant growth hormones and genetic factors.

Plant growth hormones: These are chemical substances that regulate plant growth and development. Hormones help plants to respond to the stimuli such as sunlight, water and nutrients from the environment. Plant hormones include

auxins, gibberellins, cytokinins, ethylene and abscisic acid.

Auxins: Auxins are highly concentrated in growing parts of the plant such as at the tips of the shoots and roots. Auxins hormone stimulates the growth and development of plants. This hormone is also transported downward from the top to the bottom of the plant where it causes several responses in plants such as phototropism and geotropism. Auxins promote apical dominance, a process that prevents too many lateral buds and branches from growing on the side of the stem.

Gibberellins: These hormones cause similar effects as auxins in plants. They are present in young shoots, root and seeds. They stimulate cell division and elongation and promote elongation of the stem between the nodes. When the level of gibberellins increase, the internodes elongate and the stem length increases. Similarly, deficiency of gibberellin reduces the length of the stem between internodes resulting in dwarfism in plants. Gibberellins initiate seed germination by breaking seed dormancy and speeding up the germination. Hence, they contribute to plant growth and development.

Cytokinins: These hormones stimulate cell division and are often included in the sterile media used for growing plants from tissue culture. Cytokinins are produced in the root and transported upward to the stem through the xylem. They stimulate differentiation and growth of axillary buds and inhibit lateral root formation. Cytokinins also delay leaf ageing and death.

Ethylene: This hormone exists in gaseous form. It regulates the growth by inducing ripening of fruits and senescence of plants. It also causes plant leaves to drop. Often, plants increase ethylene production in response to stress. A high concentration of ethylene is often found within cells at the end of plant's life. An increase in ethylene in leaf tissue in the autumn is part of the reason why trees fall off their leaves during this period. Ethylene is also used to ripen fruits such as green bananas.

Abscisic acid: This hormone is important in seed development and maturation. It induces seed dormancy by preventing seed germination. It causes the abscission of leaves, fruits and flowers and induces the closing of stomata. A high concentration of abscisic acid in a plant cell during periods of drought plays a role in the closure of stomata. Closing of stomata reduces water loss, hence ensuring the survival of the plant.

Genetic factor: This is another internal factor to plant growth since their basis of expression is within the cells. Plant growth involves changing seeds into seedlings. Other changes occurring during growth include an increase in height, width, development of branching pattern, flowers, fruits and seeds. All of these changes are coded in the genetic material of the plant which is found in the nucleus of the cell. The genetic factors affect plant growth differently depending on whether the plants belong to the same species or different species. For example, a mango and baobab tree have different genetic materials hence

BIOLOGY FORM 4.indd 5 09/03/2022 19:02

their growth rates are different. Genetic factors also cause some crop varieties of the same species mature differently. For example, Pemba Red Dwarf coconuts (Kitamli), matured much earlier (at 4-5 years) compared to Local East African Tall coconuts (at 6-8 years). The genetic factors determine the characters of a plant. However, environmental factors influence the extent to which such characters are expressed.

External factors affecting growth and development in animals

Like in plant, growth and development in animals are also affected by external factors. These factors include temperature, nutrition, availability of oxygen gas, mutagens and risk behaviour.

Temperature: Changes in environmental temperature affect the growth and development of animals. For example, eggs of organisms such as grasshoppers, snakes, lizards and turtles will not hatch if the temperature is not optimum. Some animals such as toads depend on a specific range of temperature to breed. This implies that low temperature limits the breeding of such animals. Sometimes the breeding season is delayed until the temperature is optimal. Similarly, the optimum temperature is required to activate many enzymatic reactions within the animal body.

Nutrition: The growth and development of animals also depends on the availability of sufficient food. Some food substances are the raw materials for growth and others are the source of energy necessary for growth. For example, the development of a tadpole into a frog or toad depends on the availability of food and other nutrients. Humans also grow normally when they get sufficient food. Therefore, the availability of quality and adequate food has a direct effect on growth. For instance, protein is very important in the growth of young mammals. Its insufficiency in the diet will lead to stunted growth.

Oxygen gas: During respiration, oxygen gas is needed to release energy from the food. The energy released is used in different physiological processes which in turn bring about growth and development in an organism. Therefore, an inadequate supply of oxygen gas causes low metabolic rate which slows down the rate of growth. For example, the high nutrient load leads to depletion of oxygen gas levels in the aquatic ecosystems. This is because the decomposition of it uses oxygen gas. This in turn affects the growth and development of a living organisms in that habitat.

Mutagens and risk behaviours: Mutagens are agents of mutation that alters the genetic materials of organisms resulting in altered gene expression or protein function. For example, mutations in genes can promote or inhibit growth and cellular replication. Examples of mutagens include harmful radiations such as X-rays, gamma rays, and ultraviolet radiations. Some of the risk behaviours such as alcoholism, smoking marijuana and cigarettes also affect the growth of human being. Excessive alcohol consumption can lower the rate of growth in both adolescent boys and girls.

BIOLOGY FORM 4.indd 6 09/03/2022 19:02

Internal factors affecting growth and development in animals

The growth and development in animals are also affected by internal factors such as growth hormones, genetic factors, and enzymes.

Growth hormones: Growth and development in animals are affected by hormones. In humans, growth is regulated by the growth hormone from the pituitary gland. This hormone promotes the growth of bones and cartilages and stimulates some metabolic activities necessary for animal growth. For example the gonads, ovaries and testes also produce oestrogen and testosterone hormones which accelerate the development of secondary sexual characteristics during puberty.

Genetic factors: Animal growth and development are also influenced by genetic factors. This is more noticeable in livestock, where some animal breeds grow faster and become heavier or taller than others. Genetic factors greatly influence the growth rate of animals. For example, human babies born on the same day can vary in some features such as their height and weight due to variations in their genetic make-up.

Enzymes: These are the chemical substances that catalyse the rate of chemical reactions in the body of a living organism but at the end of the reactions remain unchanged. For example, human digestive enzymes catalyse the breakdown of food substances into simpler forms that can be absorbed by the body. This in turn facilitates the growth and development of organisms. When there is under-secretion, over-secretion or absence of enzymes, growth is affected because the process of metabolism will also be affected.

Exercise 1.1

1. Distinguish between "growth" and "development".
2. Give reason why a pruned single stemed plant develops many lateral buds and branches.
3. Explain three (3) external factors affecting the rate of growth in plants.
4. Describe how temperature affects the rate of growth and development in animals.
5. Explain the role of hormones in the growth and development of plants.

Mitosis and growth

For an organism to grow, the number of cells must increase. An increase in the number of cells of an organism is brought about by a process known as mitosis. Mitosis is the process of cell division whereby the cell nucleus and cytoplasm divide to produce two identical daughter cells each with similar sets of chromosomes as the parental cell. Mitosis involves the division of body cells called somatic cells. The somatic cells are diploid, meaning that they have two sets of chromosomes (2n). Chromosomes consist of two parallel strands called chromatids joined at a centromere as shown in Figure 1.2. Centromere is a region

BIOLOGY FORM 4.indd 7 09/03/2022 19:02

where two sister chromatids are held together after the replication of a chromosome. During cell division, microtubule-like structures known as spindle fibres are formed from the centrioles. The fibres are attached to a point known as kinetochore. Mitosis facilitates the growth and replacement of damaged cells.

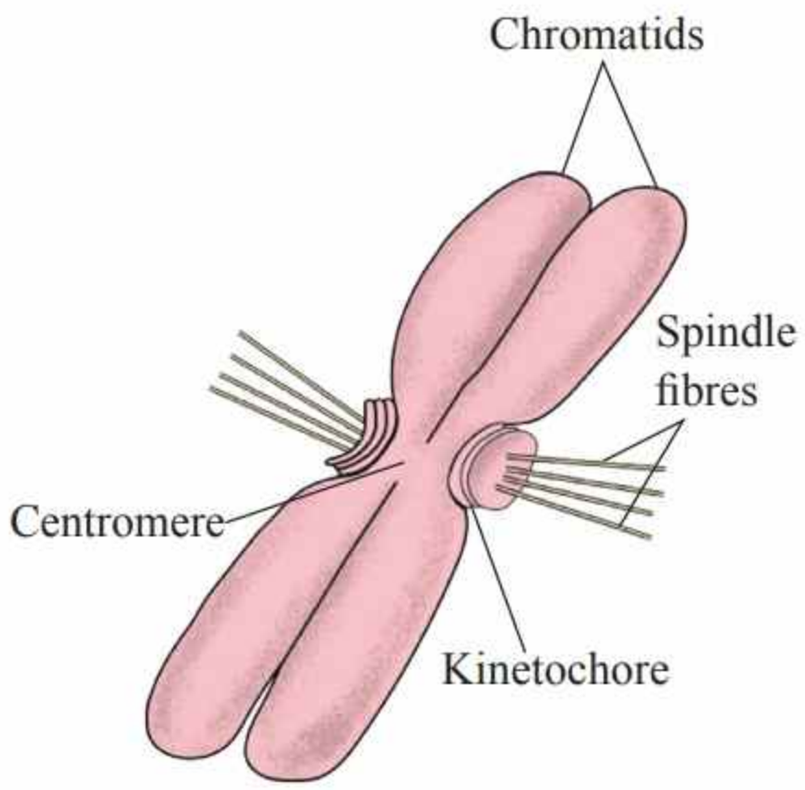


Figure 1.2: Structure of a chromosome

Stages of mitosis

Mitotic cell division involves a series of consecutive events that occur between one cell division and the next. This sequence of events makes up the cell cycle. The cell cycle is divided into three major phases: interphase (preparatory phase), mitotic phase (dividing phase), and cytokinesis as shown in Figure 1.3. Interphase involves the process of cell growth and DNA replication whereas the mitotic phase involves mitosis. Conversely cytokinesis phace involves the division of the cytoplasm to give two daughter cells. Mitosis is a continuous process involving four stages which are prophase, metaphase, anaphase, and telophase. The interphase stages precede these stages.

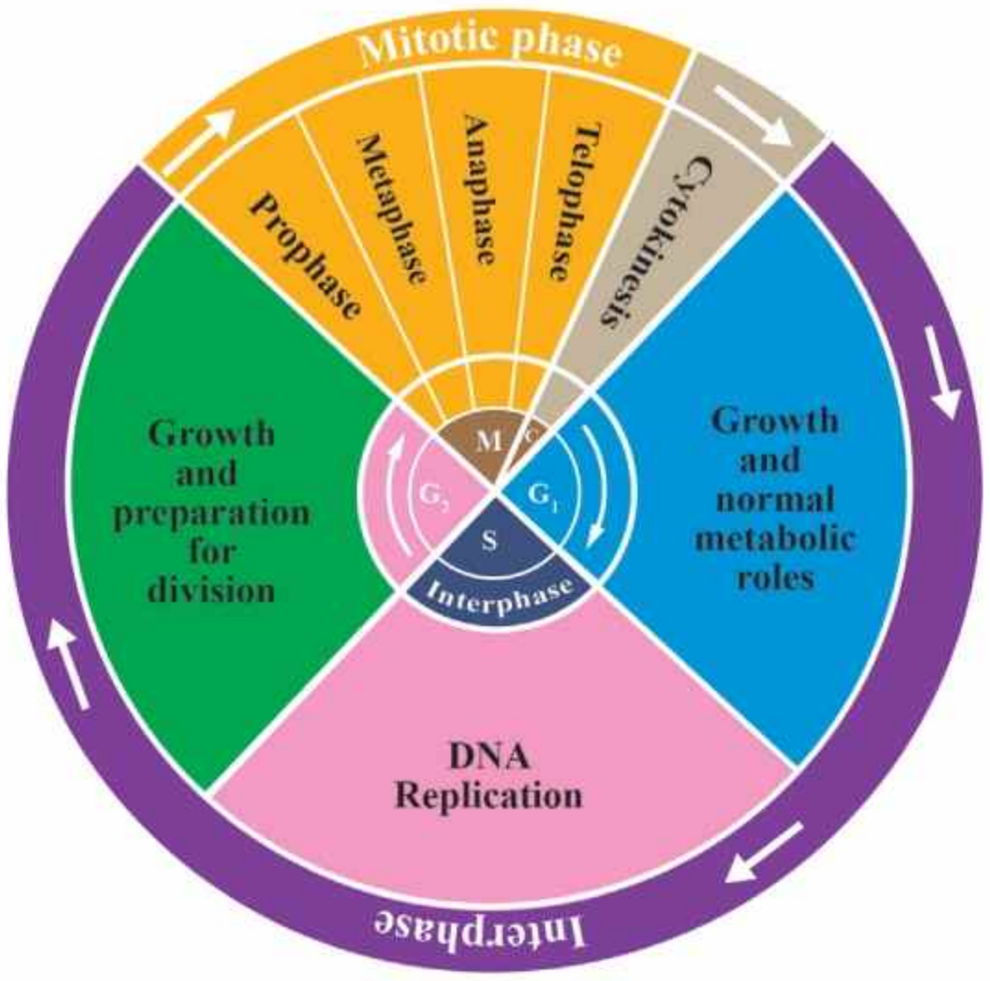


Figure 1.3: Cell cycle

Interphase

This is a non-dividing stage or phase that prepares cells for division. During the interphase stage, a cell is engaged in metabolic activities that prepare it for the mitotic division phase. In this phase, there is an intensive synthesis of cell organelles and the growth of the cell. Chloroplasts and mitochondria, if present, also replicate in this stage. It also involves the process of DNA replication to create two copies of DNA strands. At this stage, chromosomes are not clearly seen in the nucleus as seen in Figure 1.4. Each chromosome exists as a pair of chromatids held together by a centromere as shown in Figure 1.5.

BIOLOGY FORM 4.indd 8 09/03/2022 19:02

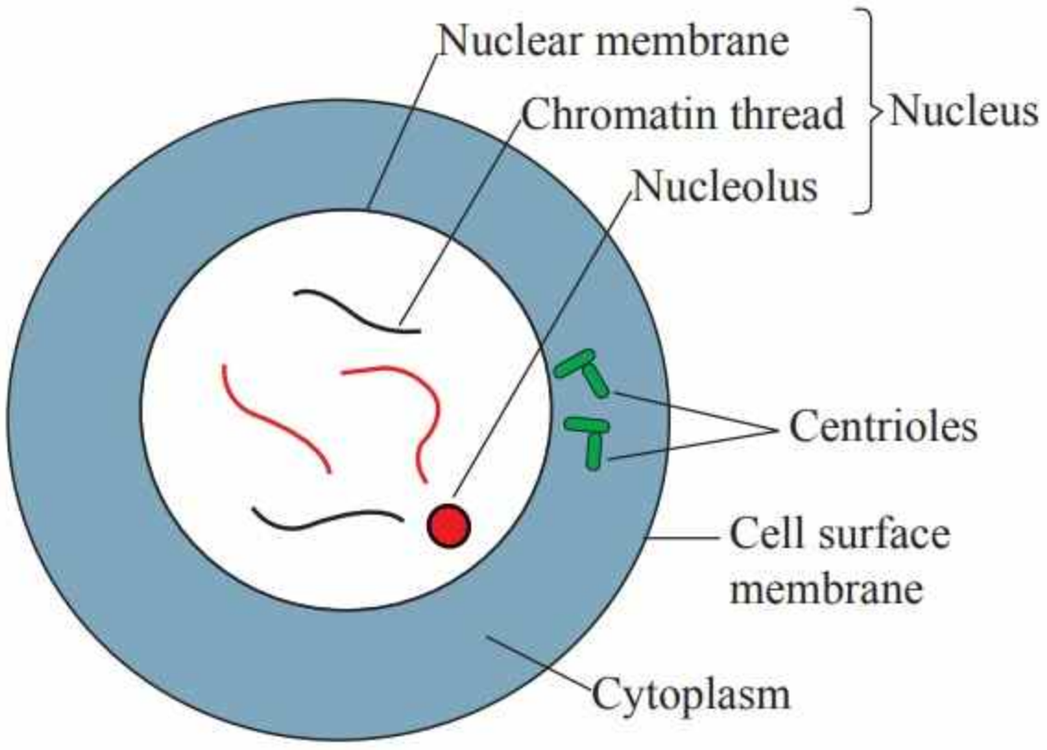


Figure 1.4: Interphase

Prophase

Prophase is the longest stage of mitotic cell division occurring after the interphase stage. At this stage, the chromatids tend to shorten, thicken and become visible. Centrioles move to the opposite poles of the cell as shown in Figure 1.5. Microtubules called spindle fibres develop from the centrioles. At the end of the prophase stage, nucleolus and nuclear membrane disintegrate and release chromosomes into the cell. The spindle fibres extend across the cell from one pole to another and are attached to the chromosomes. The role of the spindle fibres is to organise the chromosomes and move them during mitosis.

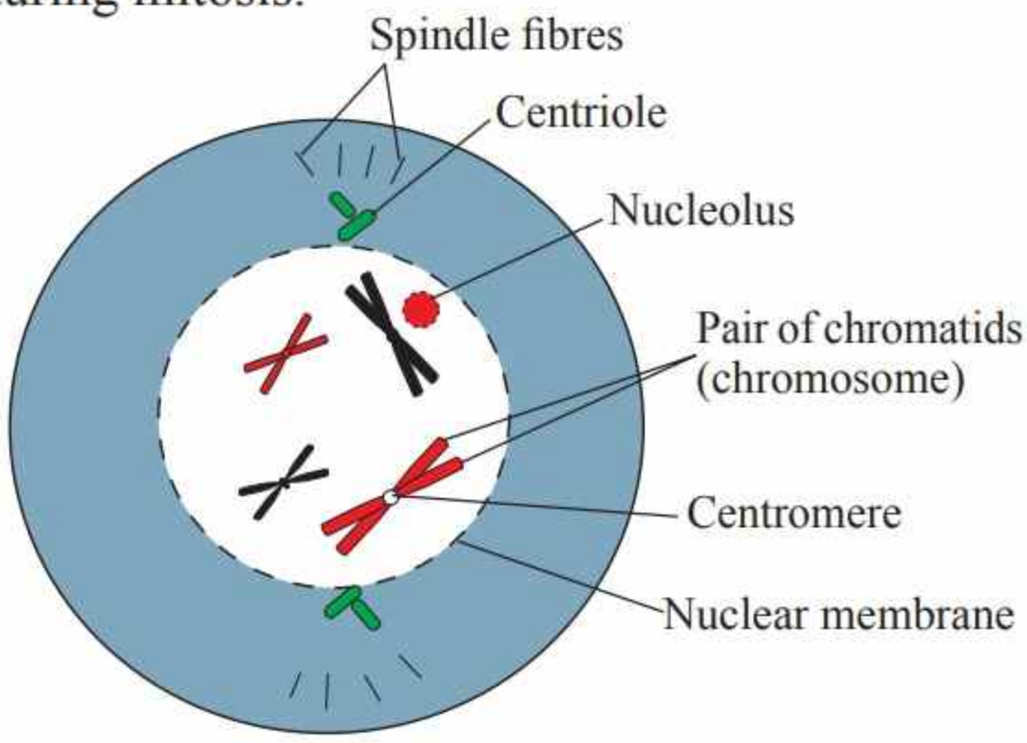


Figure 1.5: Prophase

Metaphase

During metaphase the chromosomes line up at the equator of the spindle fibre. Each chromosome consists of two chromatids. The chromosomes are attached to spindle fibres by their centromere. Nucleus and nuclear membrane disappear completely. The formation of spindle fibres is completed as seen in Figure 1.6.

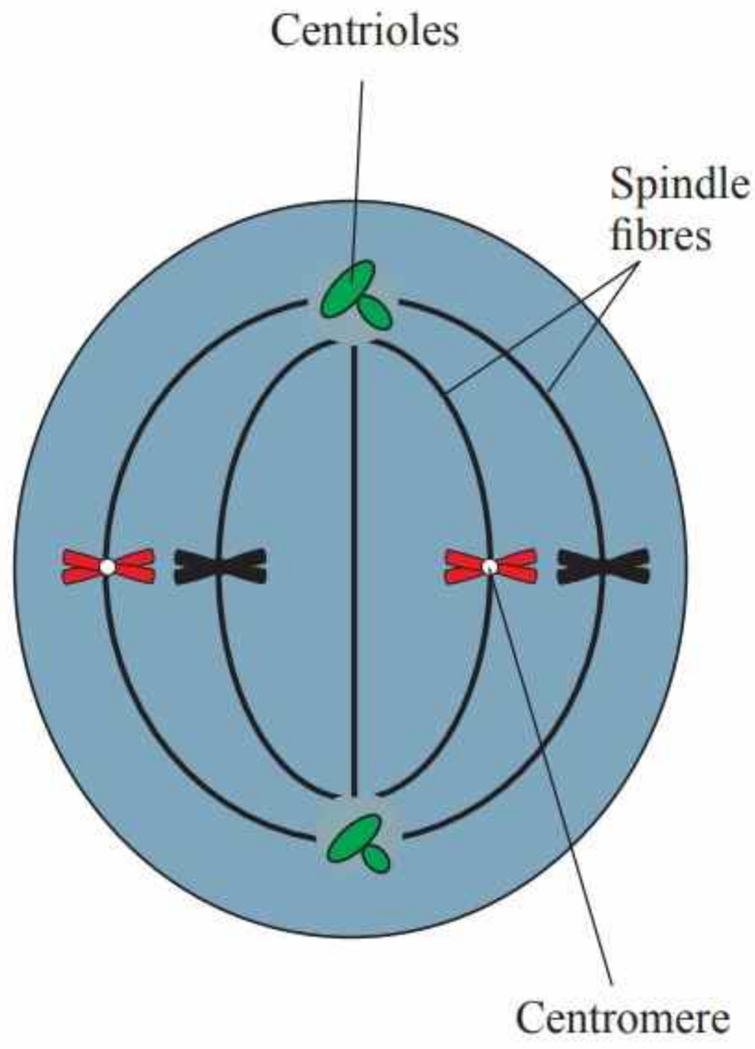


Figure 1.6: Metaphase

Anaphase

During anaphase, the centromere split and the spindle fibres contract, pulling the chromatids to the opposite pole of the cell. Spindle fibres lengthen and push the centrioles further apart. The cell elongates in preparation for division. See Figure 1.7.

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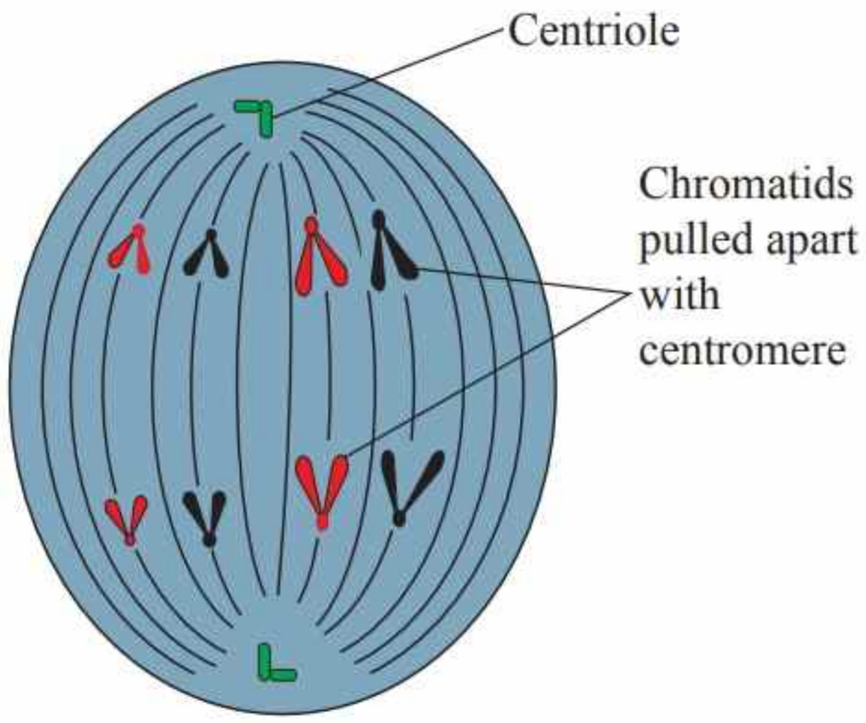


Figure 1.7: Anaphase

Telophase

During telophase, chromatids reach the opposite poles of the cell. On the poles, chromatids uncoil, lengthen, and are not clearly seen as seen in Figure 1.8. The spindle fibres disintegrate, and the centrioles replicate. Nuclear membrane re-forms around each set of chromosomes and nucleoli reappear.

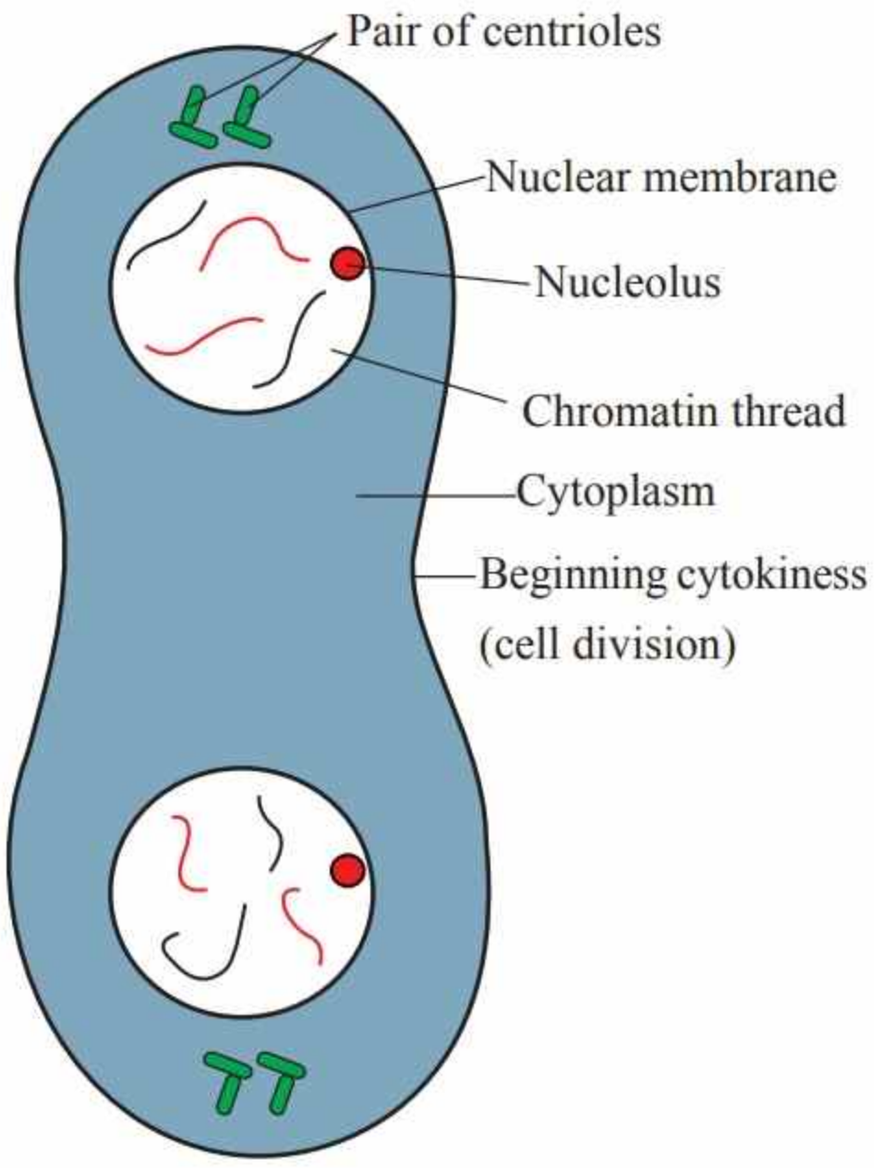


Figure 1.8: *Telophase*

Cytokinesis

After the telophase stage, the cytokinesis process occurs. Cytokinesis is the division of the cytoplasm to form two new cells. Cytokinesis in animal cell differs from that of plant cells due to the presence of the cell wall in plants cells. In animal cells, cytokinesis starts by constriction of the cell surface membrane from the outside inwards. Two cleavage furrows develop as the cells constrict inwards as seen in Figure 1.9. As constriction continues, the membrane pinches off and separates the two daughter cells each with one nucleus. In plant cells, instead of forming a cleavage furrow, a dividing structure known as cell plate forms between the two daughter cells. It divides the cell into two identical daughter cells.

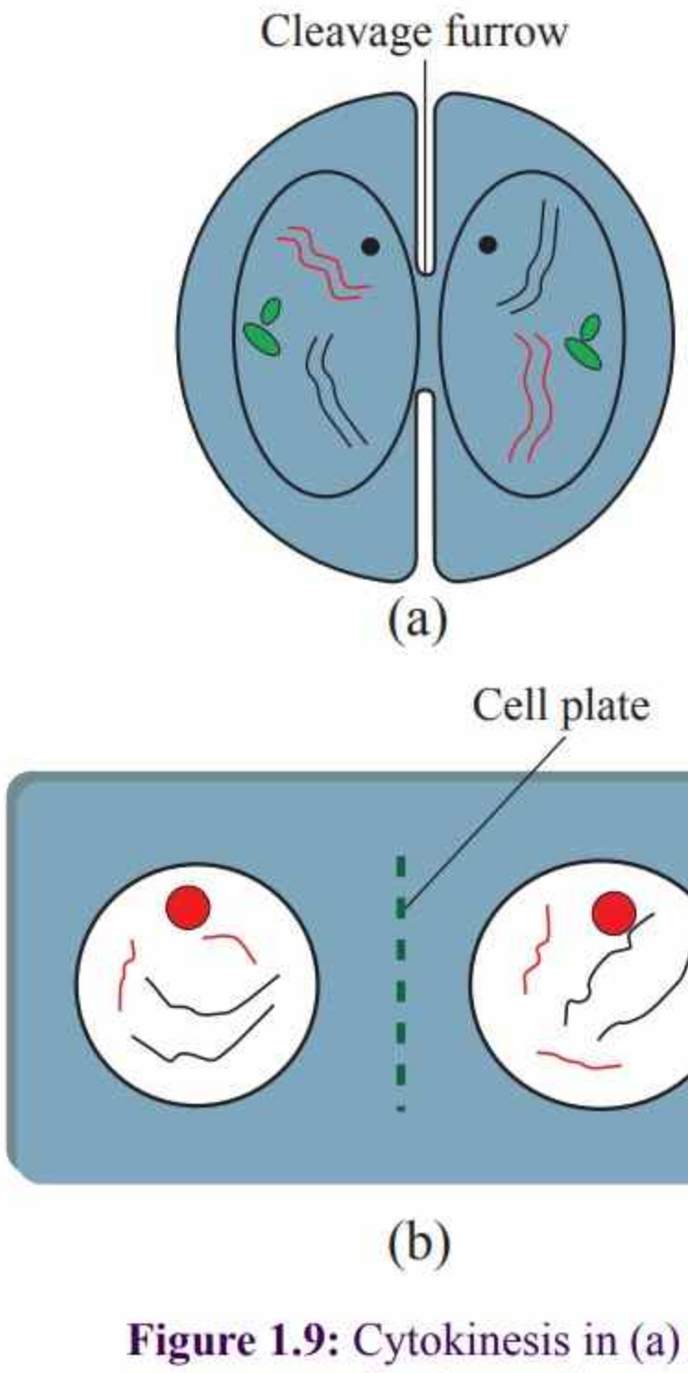


Figure 1.9: Cytokinesis in (a) animal cell (b) plant cell

BIOLOGY FORM 4.indd 10 09/03/2022 19:02

Activity 1.2:

Investigating changes in a plant cell nucleus undergoing mitosis

Materials: Prepared slide of a longitudinal section (LS) through the root tip of an onion or model showing stages of mitosis, microscope, notebook and a pen

Procedure

1. Use a low power objective lens to examine a prepared slide of a longitudinal section through a root tip showing cells at different stages of mitosis.
2. Move to a high-power objective lens to observe the chromosomes in cells at different stages of mitosis.
3. Identify different stages of mitosis on the slide or model by observing:
   (a) Cell morphology.
   (b) Nucleus morphology.
   (c) The appearance of chromosomes.
4. Draw and label diagrams of your observation in 3 above.

Significance of mitosis

Mitosis is important to all groups of organisms. The significance of mitosis to an organism can be explained in the following aspects.

Growth

The growth in a multicellular organism refers to the increase in the body size of an organism due to the increase in the number of cells within an organism through mitotic cell division. The cell division, therefore, is the basis for growth in multicellular organisms.

Cell replacement and regeneration

Mitosis helps in the healing and repairing of cells and tissues. Damaged cells are usually replaced with new cells. This is possible because mitosis produces new cells that are exact copies of the cells being replaced. For example, cells of the upper layer of the skin (epidermis), and cells on the lining of the gut and blood cells, need to be constantly replaced. Mitotic cell division enables the constant replacement of cells in these tissues. Some animals can regenerate lost parts of their bodies through mitosis. Examples of such animals include lizards and some crustaceans.

Retaining of chromosomes number after division

Mitosis results in the production of two diploid daughter cells with similar genetic properties as their parent cell. This supports the genetic stability since daughter cells are identical to parent cells.

Means of reproduction

The process of mitosis is used as a means of reproduction by unicellular organisms such as protozoans. These organisms reproduce asexually. Some plants also exhibit vegetative propagation through mitosis, producing offspring that are genetically identical to themselves.

BIOLOGY FORM 4.indd 11 09/03/2022 19:02

Similarities and differences between mitosis and meiosis

The similarities between mitosis and meiosis are as follows:

(a) Both take place in the cell nuclei.

(b) Both involve the division of the nucleus and cytoplasm.

(c) Both occur in the mitotic phase of the cell cycle.

(d) Both involve four stages of cell division. These stages are prophase metaphase, anaphase, and telophase.

(e) In both mitosis and meiosis, the synthesis of DNA occurs.

Although mitosis and meiosis processes are similar in some aspects, they have several differences as indicated in the Table 1.1.

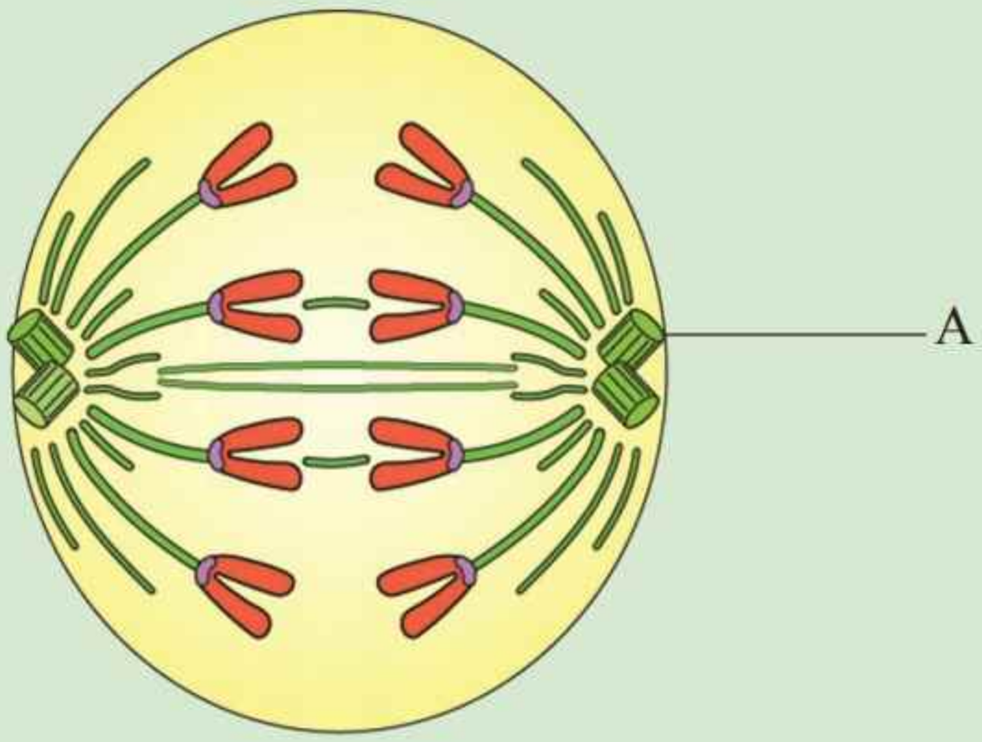
Table 1.1: Differences between mitosis and meiosis

Factor	Mitosis	Meiosis
Organisms involved	Occurs in all organisms except viruses	It occurs only in plants, animals, fungi and protoctists
Types of cells that are involved	Occurs in somatic or body cells such as skin cells and nerve cells	Occurs in reproductive/ sex cells
Number of daughter cells produced	Produce two identical daughter cells which are genetically similar to the parent cell	Produce four daughter cells that are genetically different from the parent cell
Division cycle	Involves only one cell division, thus, it is a single step cell division	Involves two successive cell divisions, thus it is a two-step cell division. The steps are Meiosis I and Meiosis II
Stages of division	Involve four (4) stages of cell division	Involve eight (8) stages of cell division since it has two rounds
Chromosomes of the daughter cells	Resultant daughter cells are diploid (2n) with two sets of chromosomes, similar to the parent cell	Resultant daughter cells are haploid (n) with one set of chromosomes. Daughter cells are called gametes
Chiasmata formation (crossing over)	Prophase is shorter and crossing over do not occurs	Prophase is longer and there is crossing over
Function	Enables body growth, repair, and cell reproduction	Enables genetic diversity through sexual reproduction

Occurrence of cytokinesis	Occurs in telophase	Occurs in telophase I and in telophase II
Mode of reproduction	It may lead to asexual reproduction in some organisms	It leads to sexual reproduction in organisms

Exercise 1.2

1. What are the major differences between cytokinesis in animal and plant cells?
2. Describe the changes that take place in the nucleus of a cell during mitosis.
3. Mitosis results in the formation of two daughter cells. Describe the genetic make-up of the daughter cells compared to that of the mother cell.
4. Explain the significance of mitosis.
5. Explain why interphase is called a preparatory phase.
6. Describe four similarities and differences between mitosis and meiosis.
7. Study the following diagram and then answer the questions that follow.



(a) Name the structure labeled A.

(b) What mitotic stage of the cell is shown in the diagram?

Growth and developmental stages in human

Human beings have diffused growth. Diffused growth is the one in which growth occurs in all parts of the body. Growth in humans involves a gradual increase in size until adulthood. However, the body does not grow at a constant rate. Different parts of

BIOLOGY FORM 4.indd 13 09/03/2022 19:02

the body grow at different rates and at different times. This type of growth is known as allometric growth. See Figure 1.10.

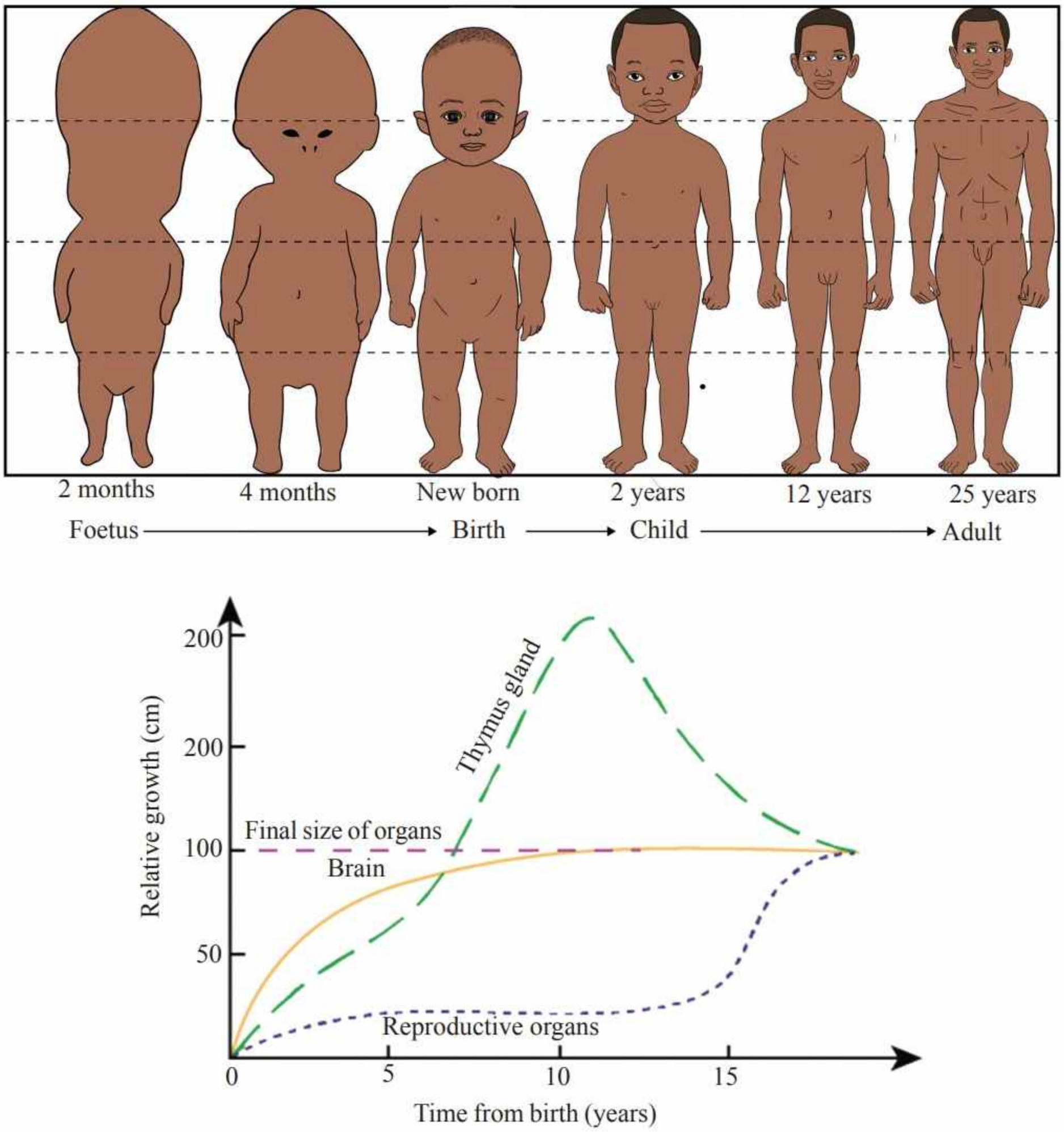


Figure 1.10: Growth rates of different parts of the human body

In humans, the processes of growth begin with the fertilisation and development follows an orderly sequence of events. Zygotes contain all the information necessary for the growth, development and reproduction. The zygote, which is a fertilised ovum consisting of one cell, begins to divide rapidly by mitosis. This division leads to the development of embryo as shown in Figure 1.11. Fertilisation and the initial stage of mitotic cell division occur in the oviduct. The early embryo migrates down the fallopian tube and completes most of its development in the wall of the uterus.

BIOLOGY FORM 4.indd 14 09/03/2022 19:02

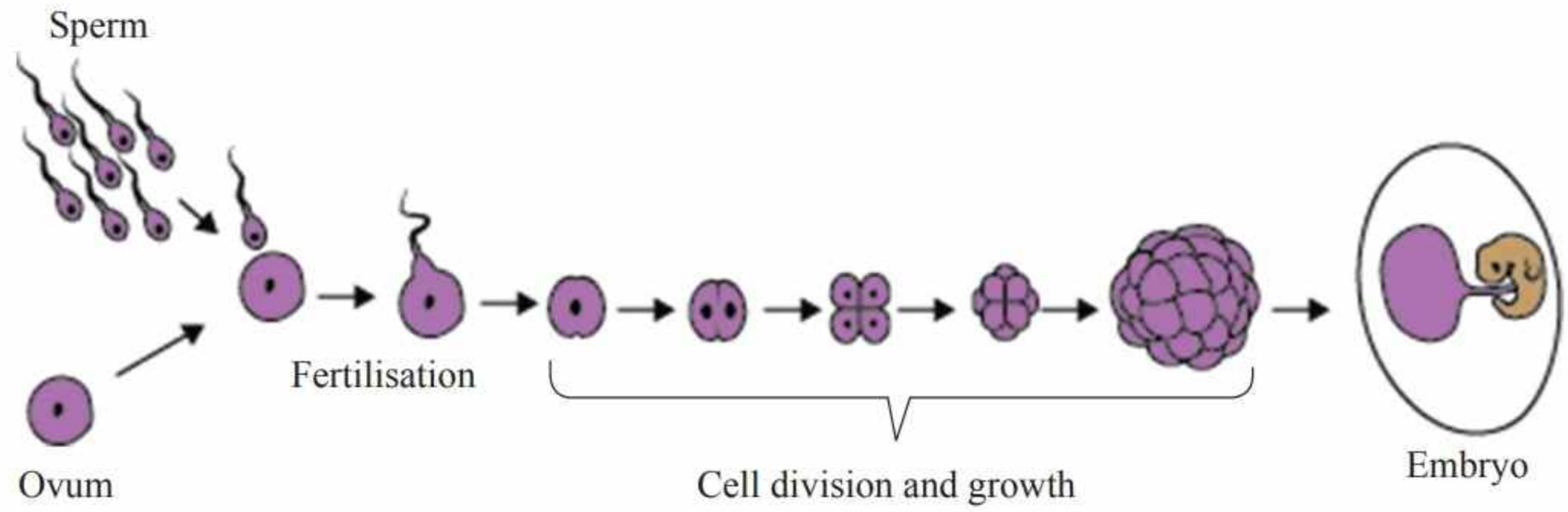


Figure 1.11: Fertilisation and development

During the development of an embryo, food and oxygen diffuse from the mother through the placenta to the foetus, conversely the waste from the foetus diffuses out to the mother. The umbilical cord is a foetal structure containing blood vessels that allow materials to be carried between the foetus and placenta in both directions.

Foetal development

This is a highly regulated process involving a series of embryonic development until a fully developed baby is formed. After three months, the fertilised embryo is referred to as a foetus. Body features such as the nervous system, sense organs, bones, muscles, excretory, circulatory and reproductive systems are formed. Other internal organs such as the liver and pancreas, and systems such as digestive and respiratory systems also become developed. Development of organs and other body features become completed by the end of six months of pregnancy. During the last three months, organs and other features such as eyes and lungs continue to develop.

Stages of human postnatal growth and development

There are five significant stages in human postnatal growth and development. The first stage is called infancy. It is the period from birth up to the age of 2 years. The second stage is known as childhood which runs from 2 to11 years. Adolescence or teenage is the third stage in human development which starts from around 11 to 18 years. Adulthood is the fourth stage just after adolescence from the age of 18 to 65 years old. The last stage is old age, which begins after a person attains 65 years. Depending on various factors, the growth rate of human beings can be either slow or rapid. However, by plotting the graph of growth rate against time, a typical S-shaped curve is obtained. The resulting S-shaped curve is also known as the Sigmoid curve. This growth curve indicates that the growth rate in human beings is rapid during infancy (0-2 years) and adolescence stage (11-18 years). However, there is a slow rate of growth during the childhood from 2 to 11

BIOLOGY FORM 4.indd 15 09/03/2022 19:02

years old. There is also a minimal growth rate during adulthood (18-65 years old). The growth rate becomes negative in the last stage when a person attains 65 years old as seen in Figure 1.12.

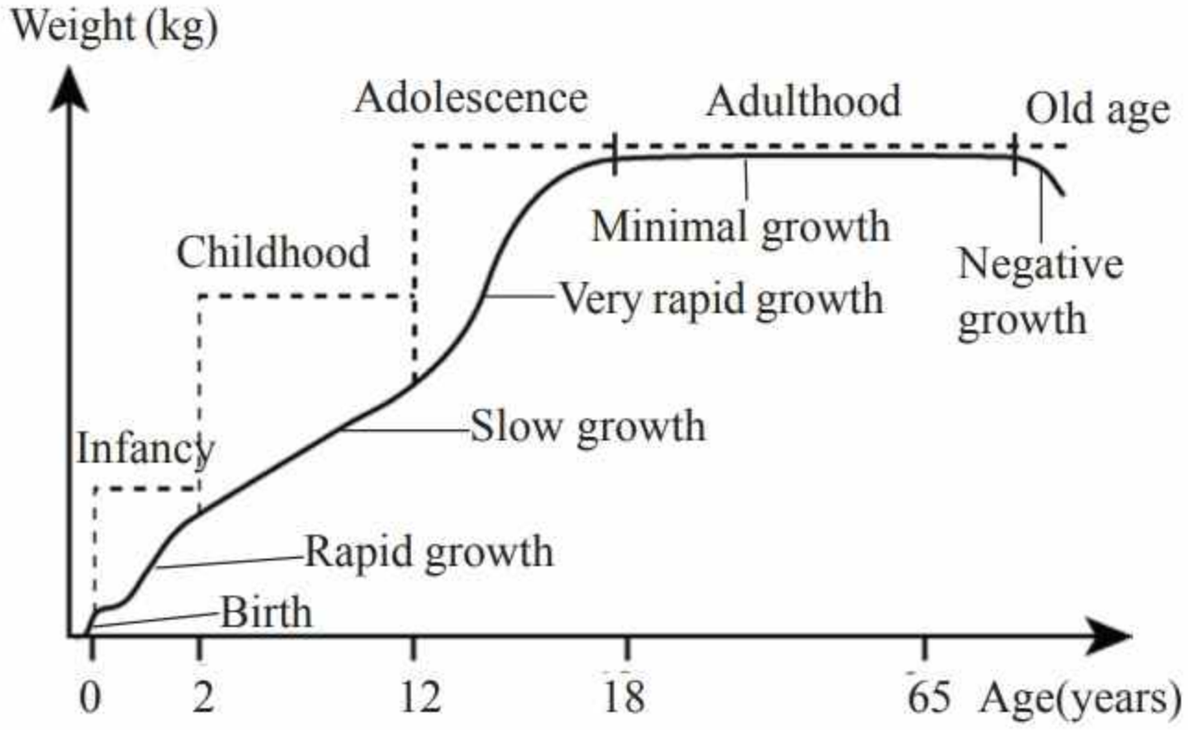


Figure 1.12: Human growth pattern

Infancy

This period ranges from birth to the age of two (2) years. It covers the period when every touch, movement and emotion in the young child' life translates into explosion of electrical and chemical activities in their brain. This is because billions of cells are organised into network requiring trillions of nerve impulses. As children grow into early childhood, they continue to change physically, psychologically and behaviorally. Physically, children become increasingly able to hold heads up, roll, sit, crawl and walk two to three steps without help. At age of two (2) years, the infant begins to run and climb up and down from furniture without support.

Psychological changes in children involve mental development which is characterised by the appearance of a set of new abilities at regular stages. These include increased memory towards the end of the first month, speech sounds by the first birthday, and connected speech by the second birthday.

Noticeable psychological changes during infancy include anger, happiness, sadness and fear. These changes are caused by an attachment of the infant to their parents and other close caregivers. Through this interaction, the infants learn to love and trust other people. Behavioural changes during infancy include improvement in recognition ability. Infants can recognise people who are always around and taking care of them. They usually develop fears of strange faces when separated from their parents or care takers. There are various needs and services that an infant need. The following are some of them.

(a) Close attention from the parents and caregivers to avoid injury.

(b) Adequate nutritional foods, preferably breastfeeding. The milk produced by the mother in the first few days after birth is known as colostrum. It is very important for the immunity of the newly-born baby because it contains antibodies from the mother which protect the baby from infections.

(c) Warm clothing.

BIOLOGY FORM 4.indd 16 09/03/2022 19:02

(d) Post-natal care services to check for normal growth and development.

Childhood

This period ranges from the age of 2 to 11 years. At this stage, there are various physiological changes. For instance a child gains height at the average rate of about 3 inches per year. Children at the end of this stage generally have an average height of about 106 cm. The weight of the child also increases to about 35 kg. The potential of a person should be nurtured during this period. Body proportions change markedly. There is also the development of milk teeth, especially during early childhood. There after the baby teeth begin to be replaced by permanent teeth. The child acquires various motor skills like catching, throwing, running, jumping, climbing, riding a bicycle, self-feeding, dressing, balancing, colouring, and drawing. Children also become more responsible for their physical care. They like to dress, eat, and bath on their own. During this period children also learn their social roles.

The development of more complex levels of intelligence at this stage is due to increased brain maturity and learning experiences. However, if appropriate kinds of stimulation are not available, this maturation may be more difficult to occur or may even fail to occur. This period provides children with time and opportunities for the brain to develop properly. These opportunities includes playing and interacting with older children and adults. Cognitive maturity occurs also through reading and learning. There are various needs and services needed during childhood. Some of these needs and services include:

(a) Good shelter and clothing.

(b) Nutritional diet.

(c) Conducive environment for playing.

(d) Proper health services.

(e) Regular cleanliness.

Adolescence

Adolescence is a developmental stage in human beings starting from puberty to adulthood approximately between 11–18 years of age. Puberty is the time in life when a boy or a girl becomes sexually mature and capable of reproducing. Puberty marks the beginning of adolescence. At puberty, a girl's ovaries and a boy's testes begin to function. Puberty is triggered when the hypothalamus begins to produce a hormone called a gonadotropin. This hormone increases the production of sex hormones; oestrogen in girls and testosterone in boys. Increased level of estrotegen and progesterone initiates secondary sexual characteristics in girls and boys respectively.

In boys, puberty may begin between the age of 10 and 16 years. The physical changes at puberty in boys usually start with enlargement of the testicles and growth of pubic hairs. The boy's arms, legs, hands and feet grow faster than the rest of his body parts. His shoulders broaden, and he gains much weight. Lastly, the boy become

BIOLOGY FORM 4.indd 17 09/03/2022 19:02

muscular and develop deep voice. Puberty may start earlier for girls between the ages of 8 and 13 years. For most girls, the first evidence of puberty is breast development and the growth of pubic hairs. The breast tissues become large, hair appear on the labia, and later similar hairs begin to grow under the arm pits. The hips and thighs also enlarge while arms, legs and hands grow bigger. Girls experience the first menstruation, which is one of the major signs of maturity.

Psychological and social changes during adolescence include an increase in the ability to think or increased cognitive and intellectual capability. Adolescents also develop reasoning skills, logical thinking and rational judgement. At this stage, an adolescent can also try to do something if there are any emerging social issues they come across. Adolescents also develop a sense of self-identity such as sexual identity. They also want to make decisions on different issues in their lives rather than being controlled by their parents. However, adolescents are not yet fully developed to make informed decisions. This means that disengaging them from parents can make them vulnerable depending on the people they interact with. Social values and norms greatly affect psychological and social changes in adolescents.

Behavioural changes in adolescents include being moody. Adolescents can be happy for some time and suddenly become sad for no good reason. They want to explore and try different experiences. Such a situation can make them prone to risky behaviours, such as drug abuse, alcoholism and involvement in unprotected sex. These rsik behaviours increases the chances of getting unplanned pregnancy, HIV/AIDS and other sexually transmitted infections (STIs). Various needs and services required by adolescents include:

(a) Balanced diet.
(b) Good shelter and clothing.
(c) Education on health and reproductive health.
(d) Physical exercises.

Adulthood

This is a period during which the rate of growth is minimal. This period ranges from the age of 18-65 years. During late adulthood, the rate of formation of new cells becomes low compared to the rate at which old cells are destroyed. This is the time when a human being attains full physical and intellectual maturity. An adult person is characterised by maturity, being practical and result-oriented, self-confidence, having sound decisions, and taking responsibility. The following are needs and services required during adulthood:

(a) Balanced diet.
(b) Proper lifestyle.
(c) Physical exercises.
(d) Good shelter and clothing.

Old age

This stage begins at the age of 65 years and above, and is characterised by negative growth. At this stage physical body strength decreases, hair becomes thin and turns grey, and skin develops wrinkles and foldings. There is also a decrease in vision and hearing ability. Sensitivity to smell and taste decreases, and skin loses elasticity. Psychological changes include loss of memory. The following needs and services enable elderly people to cope with the challenges of ageing.

(a) Sociocultural training.

(b) Maintaining personal hygiene.

(c) Balanced diet.

(d) Light physical exercises.

(e) Health services.

Factors leading to physical deterioration of the human body

Physical deterioration of the human body occurs as a person gets old. This is due to a decrease in the production of growth hormones. The rate of human growth is affected by various factors. These factors can be categorised as environmental and genetic factors.

Environmental factors

Various environmental factors can affect the rate of physical deterioration of the body. Such factors include:

Quality and quantity of food: nutritious food improves growth and development in human. Inadequate food causes malnutrition, hence decreasing the growth rate in human beings.

Diseases: diseases weaken the body cells and tissues thereby decreasing human growth rate.

Stress: emotional disturbances weaken the body immunity. The body becomes prone to diseases and infections.

Genetic factors

Some genetic disorders such as Werner syndrome cause rapid premature ageing. This disorder appears typically to individuals after puberty.

Exercise 1.3

1. With the aid of a well labelled diagram, describe the pattern of growth in human.
2. Describe the main differences in human postnatal development between male and females.
3. What are the changes that occur in girls during puberty?
4. Describe four factors that cause physical deterioration of the human body.
5. What are secondary sexual characteristics in a normal adolescent boy?

Growth in flowering plants

Growth in a flowering plant starts from a seed to a seedling that grows to a mature plant. The process by which a seed develops into a seedling is known as germination.

BIOLOGY FORM 4.indd 19 09/03/2022 19:02

The seed consists of the following parts:

(a) An embryo: this part consists of a radicle that develops into a root and a plumule which develops into a shoot after germination.

(b) A seed coat: this part is also known as a testa. It is a protective layer surrounding a seed.

(c) Cotyledons: This part grows to form embryonic first leaves after germination. It also stores and provides food for the young plants. Young plants depend on the stored food until they develop leaves which enable them to carry out photosynthesis. Seeds known as monocots such as maize seeds have one cotyledon. Seeds that have two cotyledons are known as dicot seeds. An example of a dicot seed is a bean seed.

(d) Micropyle: this is a pore through which water enters the seed during germination.

(e) Hilum: This is a scar that shows the seed's point of attachment to the ovary wall. See Figure 1.13.

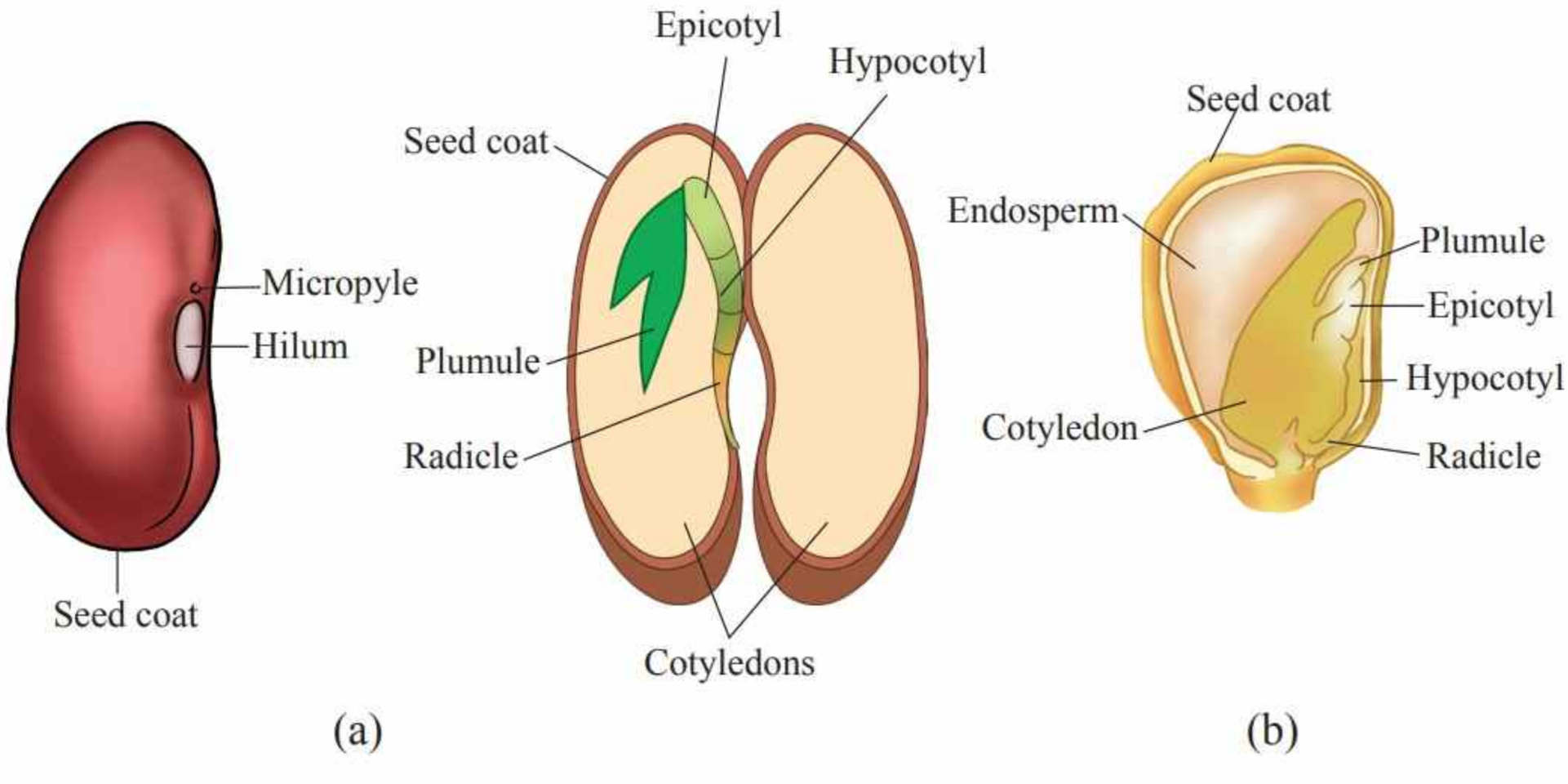


Figure 1.13: Structure of (a) dicot (b) monocot seed

Changes that occur during seed germination

During germination, physical and chemical changes occur in a seed. The physical changes include swelling of the seed after absorption of water through the micropyle. The water absorbed by the seed softens the seed coat and activates enzymes in the cotyledons. This process is followed by the bursting of the seed coat and the emergence of the radicle and plumule. The radicle is the one that forms a primary root and the plumule gives rise to a shoot. The radicle continues to elongate and give rise to many side roots. Chemical changes accompany the physical changes. As the seed absorbs water, the food stored in the cotyledon or endosperm is hydrolysed into a soluble form.

The stored food in the form of starch is converted into sugars by the enzyme called diastase. Then the growing seedling readily absorbs the dissolved stored food.

Conditions necessary for seed germination

For a seed to germinate, it requires certain conditions. These conditions include the following:

Water

Germination occurs when a seed is supplied with water. A seed absorbs water through the micropyle. Water plays an important role during seed germination. When a seed absorbs water, the embryo cells enlarge due to pressure. Such action leads to the rapture of the seed coat. Water softens the seed coat, hence increases seed permeability. Water also activates enzymes necessary for seed germination and growth.

Activity 1.3:

Investigating whether water is necessary for seed germination

Materials: Two beakers, bean seeds, water, cotton wool, note book and pen

Procedure:

1. Mark two beakers as A and B.
2. Place wet cotton wool in beaker A and dry cotton wool in beaker B.
3. Place bean seeds on cotton wool in each beaker as shown in Figure 1.14.
4. Keep the beakers at room temperature.
5. Observe what happened to seeds in beakers A and B after 4 days.

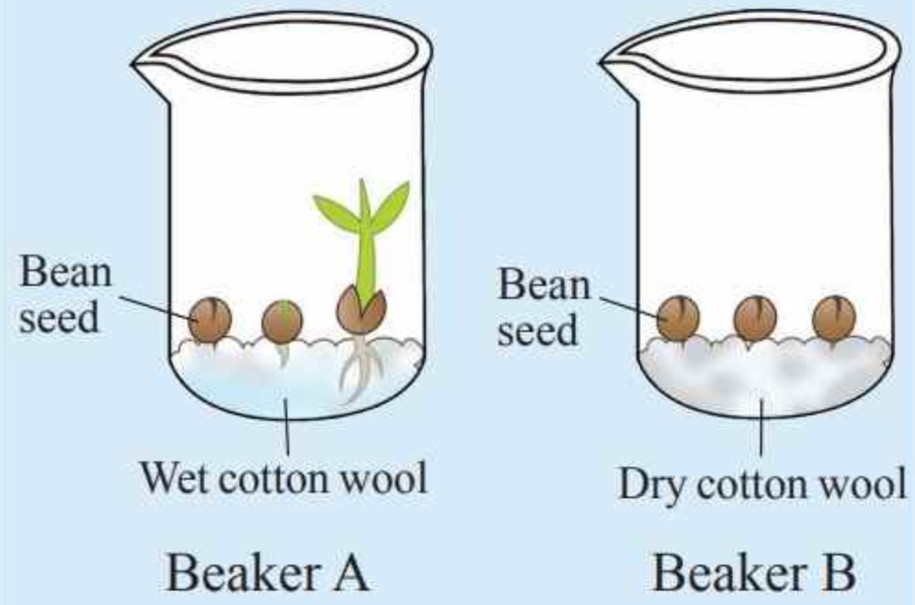


Figure 1.14: Experimental set-up to investigate the necessity of water in seed germination

Question

(a) Explain the results in beakers A and B.

(b) What is the importance of water in seed germination?

Oxygen gas

Oxygen gas is necessary for aerobic respiration to generate energy that is required for the growth of the embryo of a seed.

Activity 1.4:

Investigating whether oxygen is necessary for seed germination

Materials: Two conical flasks, cork, bean seeds, water, cotton wool, pyrogallic acid, test tubes tied with a string, note book and pen

BIOLOGY FORM 4.indd 21 09/03/2022 19:02

Procedure:

1. Mark two conical flasks as A and B.
2. Place wet cotton wool in each flask with some soaked bean seeds.
3. In conical flask A, hang a test tube containing tap water. Use the cork to hold the string in place so that the test tube is hanging in the correct position as shown in Figure 1.15.
4. In conical flask B, hang a test tube containing pyrogallic acid as shown in Figure 1.15. Pyrogallic acid is used to absorb oxygen.
5. Observe what happens to seeds in each conical flask for about 4 days.

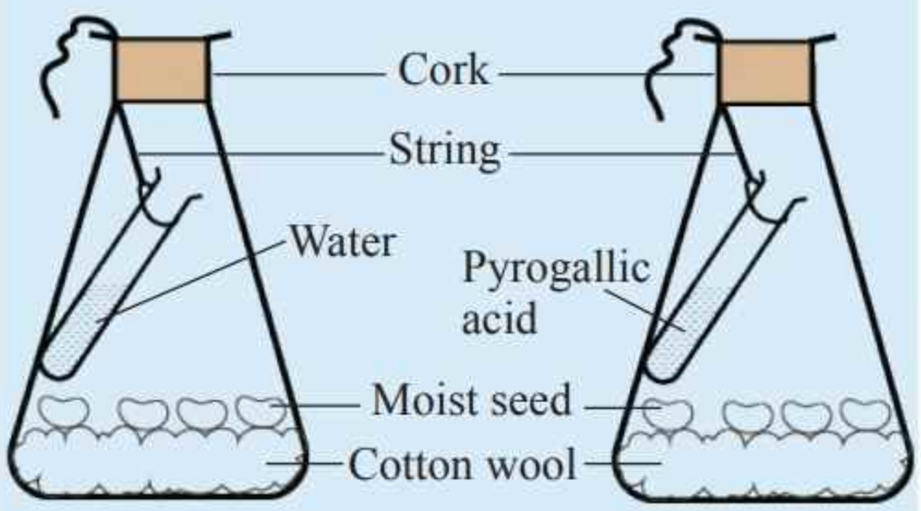


Figure 1.15: Experimental set-up to investigate the necessity of oxygen gas in seed germination

Question

(a) In which conical flask did the seeds germinate? Give reason for your answer.

(b) Explain why oxygen is important for seed germination?

Temperature

Seeds need the optimum temperature to germinate. The seed of each plant species has its optimum temperature for germination. Temperature is essential for the activation of enzymatic reactions during respiration. Respiration is important as it provides the energy required for germination.

Activity 1.5:

Investigating whether the suitable temperature is necessary for seed germination

Materials: Three beakers, bean seeds, water, cotton wool, pen and notebook

Procedure:

1. Mark three beakers as A, B and C.
2. Place bean seeds on wet cotton wool in each beaker.
3. Keep beaker A at room temperature and beaker B in a refrigerator at about 4^0C, and boil the content in beaker C and leave it at room temperature.
4. Observe what happens to seeds in beakers A, B and C for about 4 days.

Questions

(a) In which beaker did the seeds germinate?

(b) Explain the reason for your observation in beakers B and C.

(c) Explain why optimum temperature is necessary for seed germination.

Enzymes and hormones

The viability of seeds also depends on the presence of the relevant enzymes and hormones in the required amounts. These

help to break seed dormancy and catalyze all the metabolic activities associated with the process of germination.

Seed dormancy

Some viable seeds may fail to germinate even in the presence of all necessary conditions for germination. This condition is known as seed dormancy. Seed dormancy can be caused by internal factors, such as immature embryo, hardness of seed coat and presence of inhibitors. Hard seed coat restricts water uptake and gaseous exchange. Seed dormancy can also be caused by external factors such as lack of water, air, optimum temperature, PH, and light. Seed dormancy can be overcome by soaking the seed in water to soften the seed coat and remove inhibitors. Mechanical abrasion such as scratching or burning the seed can also weaken the testa. Soaking seeds in alcohol or concentrated acid for certain period of time also helps to overcome seed dormancy. Some seeds break seed dormancy after passing through the gut of specific animal species in which the hard coat is softened and germination inhibitors are removed.

Types of seed germination

There are two types of seed germination, namely epigeal and hypogeal germination.

Epigeal germination

This is the type of germination in which the cotyledons of the seed are pushed above the ground. Usually, the radicle is the embryonic root whereas the plumule is the embryonic shoot of the plant. The radicle emerges from the base of the embryo axis and the plumule is at the upper end of the embryo axis above the cotyledon. The radicle appears first before the plumule. The part of a seedling stem above the cotyledons is called epicotyl. The part below the cotyledons is called the hypocotyl. The stem of the plant known as the hypocotyl, elongates and arches upward through the ground pulling the cotyledons with it. Once the cotyledons are above the soil, the hypocotyl straightens and the leaves of the plumule open out, as shown in Figure 1.16. This type of germination is seen in most dicot seeds such as beans and castor.

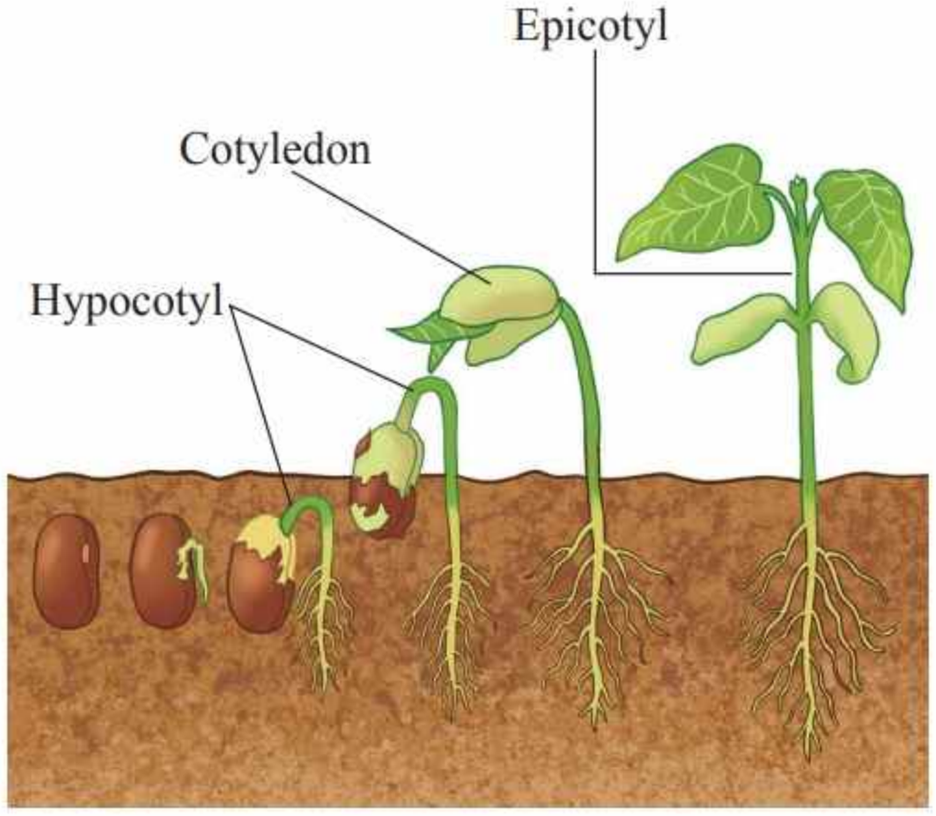


Figure 1.16: Epigeal germination

Hypogeal germination

This is a type of seed germination in which cotyledons remain below the soil surface. In hypogeal germination, elongation of the epicotyl causes the shoot to grow straight up through the soil leaving the

BIOLOGY FORM 4.indd 23 09/03/2022 19:02

cotyledons in the soil as shown in Figure 1.17. The shoot is protected by a sheath-like structure called the coleoptile. Once above the ground, the coleoptile stops growing and the first leaf bursts through it. This type of germination is seen in most monocot seeds such as maize and rice.

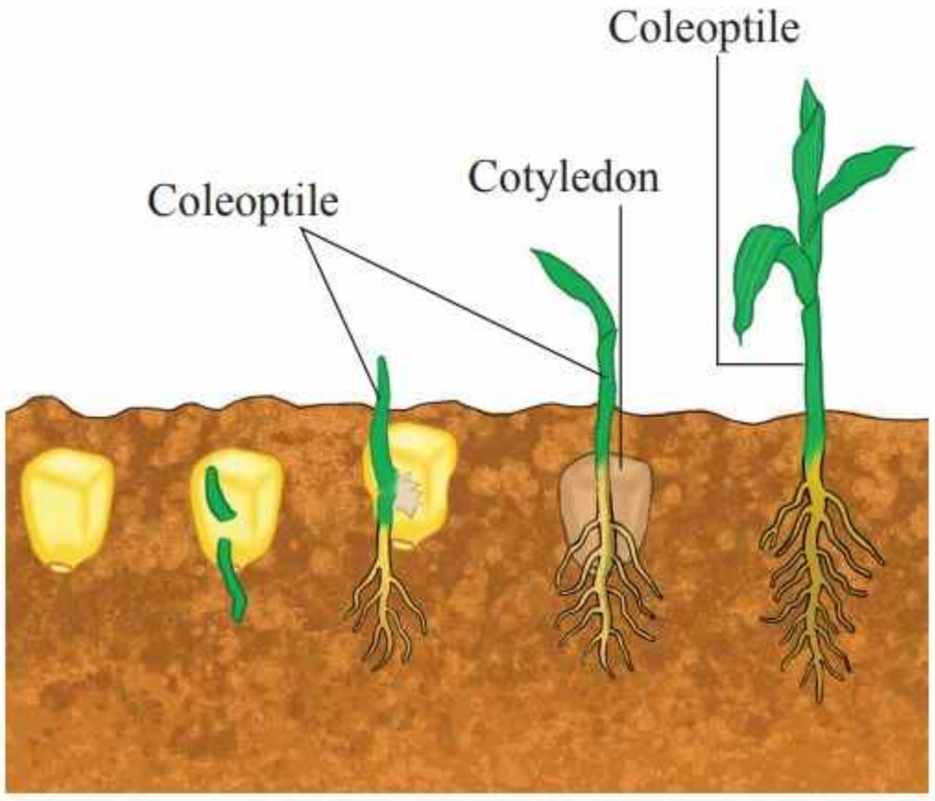


Figure 1.17: Hypogeal germination

Activity 1.6:

Observation of germination in maize grains and bean seeds

Materials: Two pots with soil, bean seeds, maize grains, water, pen and notebook

Procedure:

1. Plant maize grains in pot A and bean seeds in pot B.
2. Water both pots for at least seven days.
3. Observe the germination in both pots and compare them.

Question

Draw diagrams of the emerging maize seedling and bean seedling

The growth process in plants

Unlike growth in human, growth in flowering plants occurs in specific regions known as meristems. The regions are situated at the tips of the shoot and roots. There are three major growth zones in plants. These are the meristematic, elongation, and maturation zones as shown in Figure 1.18. The first two zones cause an increase in the plant size. The third one causes the formation and development of different plant structures such as root hair cells.

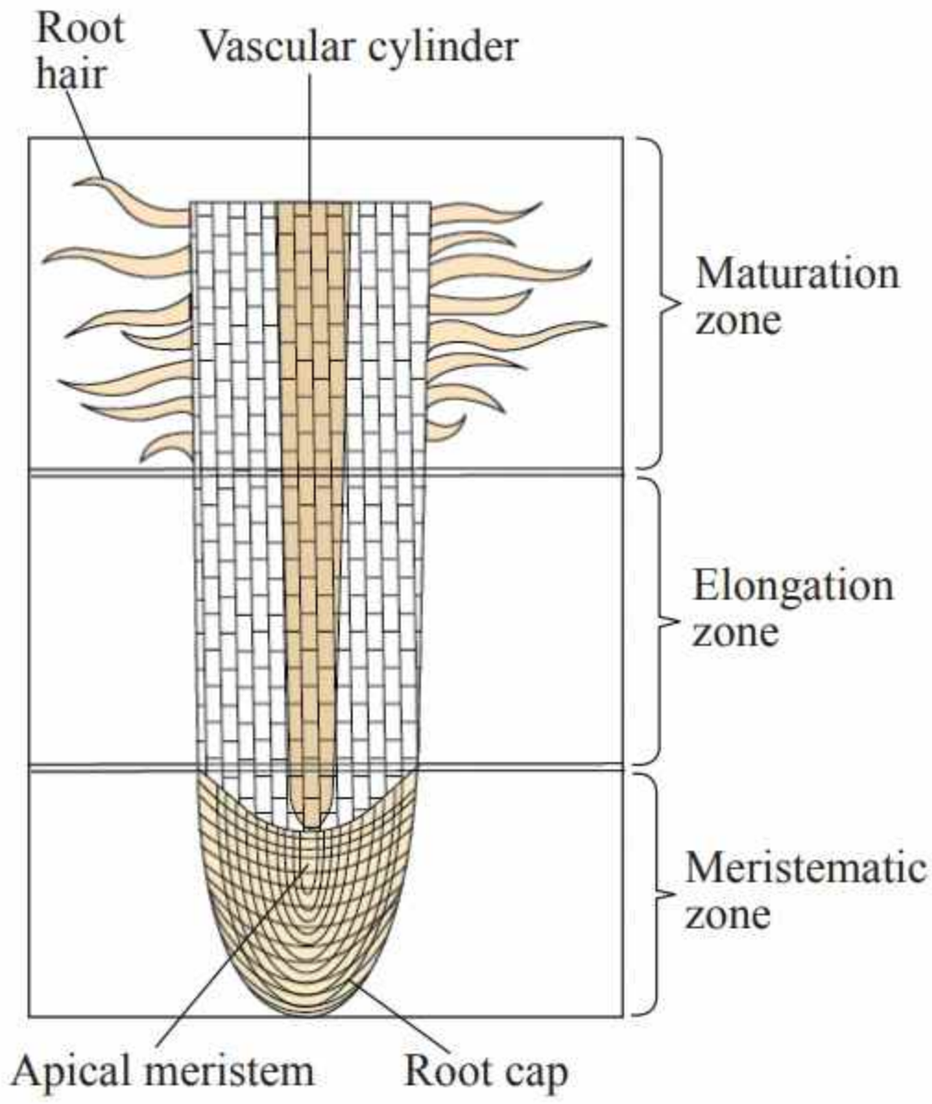


Figure 1.18: Growth zones in plants

Meristematic zone

The meristematic zone is located at the tip of plant roots and shoots. This zone consists of meristematic cells that are constantly dividing. The cells in this region have large nuclei and are rich in protoplasm and their cell walls are thin to allow rapid mitotic cell division.

BIOLOGY FORM 4.indd 24 09/03/2022 19:02

Elongation zone

The elongation zone is located next to the meristematic zone. Enlargement of cells, increase in vacuole size and formation of new cell walls take place in the elongation zone. The newly-formed cells increase in length thereby lengthening the root and shoot. Elongation is the permanent enlargement of cells prior to differentiation.

Maturation zone

Just next to the elongation zone and away from the shoot and root apices lies the zone of maturation which is also known as the zone of differentiation. Usually, the cells in this area have reached their maximum size with respect to their protoplasm and cell wall thickening. The cells differentiate into different types.

Differentiation occurs when the cells have stopped dividing and are beginning to mature and perform special or specific functions. During cell differentiation, cells undergo changes in the structure of protoplasms and that of cell walls. For example, to form tracheids, the elongated tissue that carries water in the xylem must lose its protoplasm. Cells also develop strong, elastic cell walls to allow water transportation across long distances.

Plant growth curve

The rate of growth of a plant or even parts of the plant is not always the same throughout its life span. Despite many factors affecting plant growth, the pattern of growth remains relatively the same. When the plant growth rate is plotted against time, a typical S-shaped curve (Sigmoid curve) is obtained as seen in Figure 1.19. In a normal plant growth curve, five major phases can be observed. The first phase is called the lag phase, the second phase is called the exponential or log phase, and the third phase is known as diminishing phase. The fourth phase is the stationary phase also known as steady phase. The last phase is senescence which is characterised by negative growth.

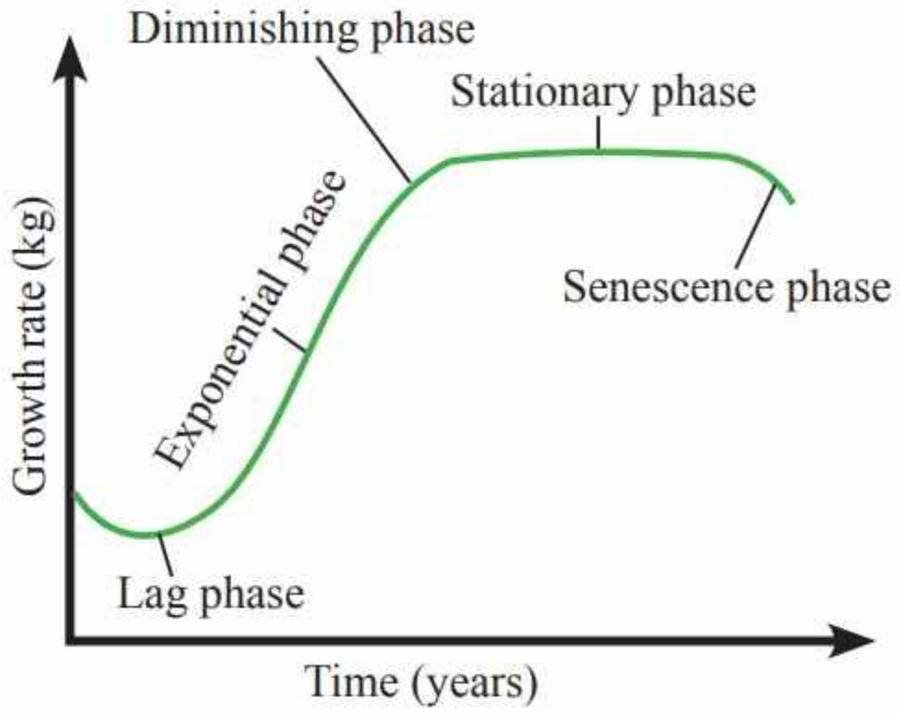


Figure 1.19: Growth curve of annual plants

The curve shows that the growth rate is lower during the initial phase (lag phase). The rate increases rapidly during the exponential phase and again slows down during the diminishing phase. The different growth phases result in 'S' shaped curve. Although, plant growth is affected by several external and internal factors, the S-shaped curve is unaffected. This growth curve suits the entire life of a flowering plant when measured in terms of dry weight against time.

At lag phase, the rate of growth is low because the new plant is not yet developed efficient shoot system for photosynthesis. Growth is limited by the amount of food reserve stored in the seed. When the emerged seedlings develop an adequate root system and enough leaf surfaces to support photosynthesis and anabolism, the rate of

BIOLOGY FORM 4.indd 25 09/03/2022 19:02

growth increases rapidly. This is called exponential phase. However, high metabolic rates are not maintained indefinitely. At diminishing phase, the rate of growth will start slowing down although the plant will be increasing but is at decreasing rate. The factors responsible for the decrease in growth rate are competition for essential metabolites, growth substances, water, light or the accumulation of inhibitors, toxic substances, and waste materials. At stationary phase, the rate of anabolism is the same as the rate of catabolism. Hence, there is no growth at this phase. The last phase of growth is senescence phase or negative growth. In this phase, the rate of catabolism is higher than anabolism leading to a decreased height and size. However, perennial wood plants show unlimited growth. The growth curve of such plants is characterised by a cumulative series of sigmoid curves as shown in Figure 1.20.

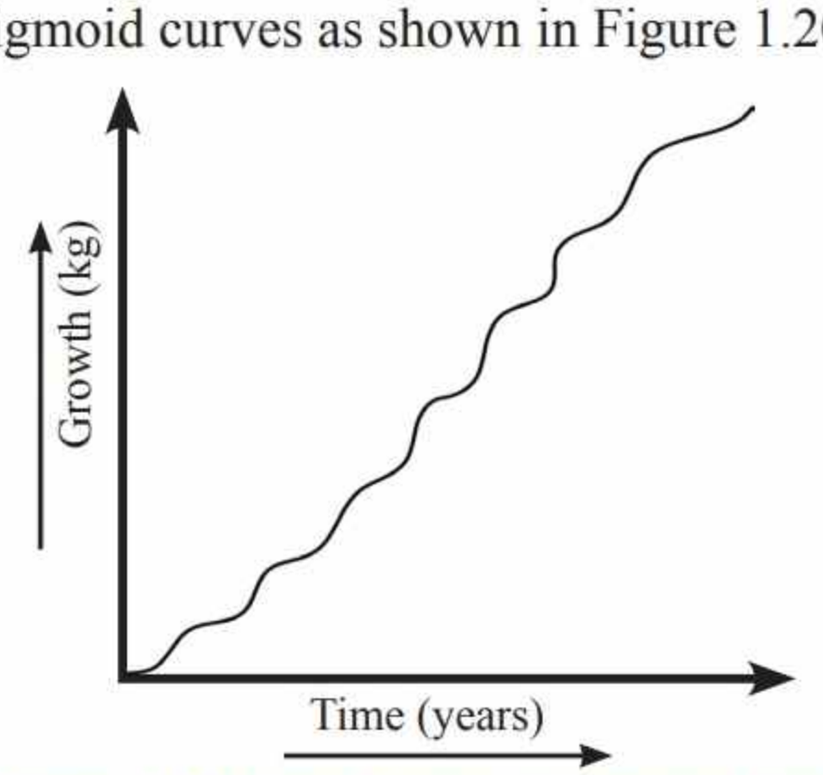


Figure 1.20: Growth curve of perennial plants

Stages of plant development

A typical plant goes through five stages in its development after germination. These stages are sprouting, seedling, vegetative budding, flowering, and adult plant, as shown in Figure 1.21.

Sprouting

This is the first stage in the development of a flowering plant after germination. Sprouting is the stage when the germinated shoot reaches the surface. Roots of sprouts absorbs water and nutrients from the soil and use sunlight energy and oxygen for growth. Each seed contains a small amount of nutrients that they need in order to germinate and begin growing their first pair of leaves.

Seedling

The seedling stage starts after the emergence of the first root and shoot, and lasts before the first tiller appears. As the seedling continues to grow, two more leaves develop. Leaves continue to be formed at the rate of one for every 3 to 4 days in some plant species. Hence, the seedling stage is characterised by rapid growth of root and shoot and beginning of photosynthesis.

Vegetative stage

The vegetative phase is characterised by development of tillers or shoots in some plants. There is also more formation of leaves and gradual increase in plant height. The number of days for the vegetative stage varies depending on the plant species. Nitrogen is mostly required at this stage.

Budding or reproductive phase

This is the phase in which a plant forms buds. Phosphorus is the most needed element at this phase. Inside the bud, a tiny but complete flower is formed. The sepals protect the bud before it opens. Over time, the bud opens and blossoms into a mature flower and the sepals appear as little green leaves at the base of the flower.

BIOLOGY FORM 4.indd 26 09/03/2022 19:02

Flowering phase

Flowering is a major sign of maturity in flowering plants. The flower is the reproductive structure of the plant. Potassium plays an essential role in the formation of starch, and in the production and translocation of sugars.

Adult phase

This is the last stage in plant development. At this stage, flowers develop into fruits. Seeds are formed inside the fruit and are capable of developing into new plants.

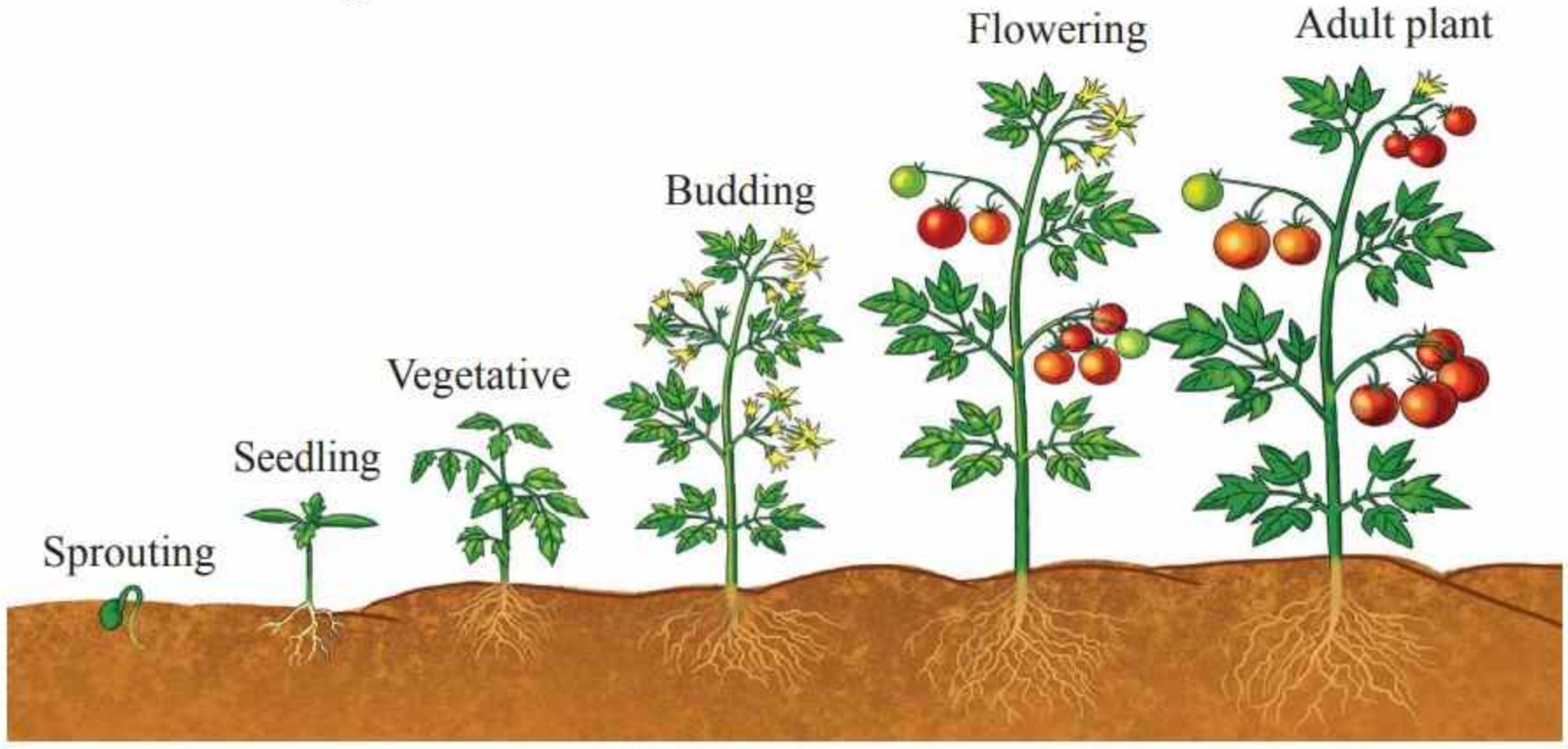


Figure 1.21: Plant developmental stages

Table 1.2: Differences between growth in plants and animals

SN.	Plant growth	Animal growth
1.	Plants possess well defined growing points or meristematic tissue	Growing points are absent in animals, growth occurs all over the body
2.	Growth is localised to certain regions mostly at the apex of roots and shoots	Growth is diffused. Diffuse growth is type of growth whereby growth occurs all over the body of the organism
3.	Often growth is indefinite or unlimited. Most plants keep growing as long as they live	Growth is definite or limited. The growth of animals is restricted with time. Growth stops in animals as soon as they mature, long before the appearance of senescence
4.	New organs continue to be formed throughout the life of a plant	All organs are formed at embryonic stage. No new organs are added during growth
5.	Old organs are replaced by new organs	There is no replacement of organs in most animals
6.	Growth in plants is by addition of new parts ahead or around the older ones	Growth involve only increase in size of organs but no new organs are added

BIOLOGY FORM 4.indd 27 09/03/2022 19:02

Revision exercise 1

Choose the most correct answer in the questions 1-11.

1. All of the following are external factors affecting plant growth, except _____.
   (a) hormones
   (b) water
   (c) nutrition
   (d) temperature

2. Which of the following refers to the process where a cell divides into two identical cells?
   (a) Cytokinesis
   (b) Gametogenesis
   (c) Mitosis
   (d) Meiosis

3. The following is a set of growth-regulating hormones in plants:
   (a) Auxin, cytokinin, gibberellins and abscisic acid
   (b) Auxin, ethylene, gibberellins and ptyalin
   (c) Cytokinin, ethylene, abscisic acid and formic acid
   (d) Gibberellins, auxin, cytokinin and formalin

4. The key stages of mitosis in the order of their occurrence are_____.
   (a) prophase, metaphase, anaphase, and telophase
   (b) anaphase, metaphase, telophase, and prophase
   (c) pro-metaphase, metaphase, anaphase, and telophase
   (d) prophase, metaphase, anaphase I, and telophase

5. Which of the following statements is applicable to the process of mitosis?
   (a) Separation of homologous chromosomes
   (b) Transverse splitting of chromosomes
   (c) Clear division of the cells which divide into two equal parts
   (d) Production of unlike daughter nuclei

6. When seed germinate their weight_____.
   (a) increases and carbon dioxide is produced
   (b) falls and carbon dioxide is produced
   (c) falls and oxygen is produced
   (d) increases and oxygen is produced

7. Growth in plant is apical, this means _____.
   (a) it occurs at the middle of the root
   (b) it occurs at the middle of the stem
   (c) it occurs at all regions
   (d) it occurs at the tips

8. The emerging shoot as the seed start to germinate is known as_____.
   (a) cotyledon
   (b) stem
   (c) plumule
   (d) radicle

9. In hypogeal germination, the cotyledons_____.
   (a) appear above the soil
   (b) remains in the ground
   (c) are brought above the soil
   (d) are slowly brought above the ground

10. A structure found in animal cells which form spindle fibres that aids separation of chromosomes.
    (a) Centrioles
    (b) Chromatins
    (c) Nucleus
    (d) Ribosome

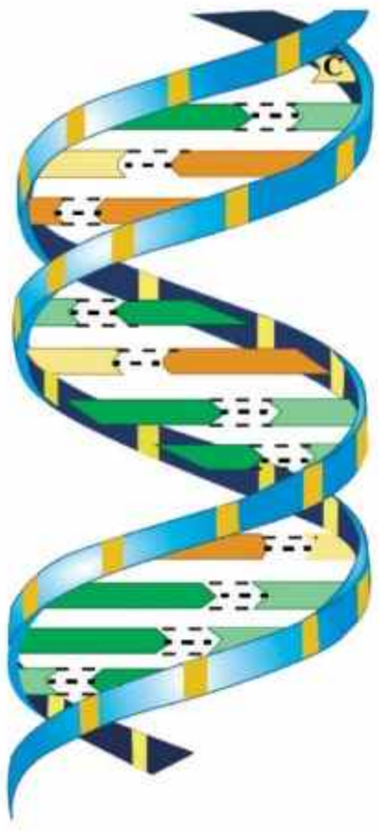
11. Lag phase in terms of growth it means_____.
    (a) growth is slow
    (b) growth has stopped
    (c) constant growth
    (d) rapid growth

12. Match the terms in column A with that of column B by writing a correct letter of the corresponding item from column B against roman number in column A.

Column A	Column B
i. A type of seed germination where by cotyledons are pushed above the ground.	A. Micropyle
ii. A pore which allows water into a seed during germination.	B. Meiosis
iii. Inability of a seed to germinate	C. Radical
iv. Prevent a viable seed to germinate	D. Viability
v. A type of cell division where by the same number of chromosomes is maintained from parent cell to daughter cell	E. Epigeal germination
	F. Hard seed coat
	G. Mitosis
	H. Dormancy
	I. Cotyledon
	J. Hypogeal germination

13. Outline the changes that take place inside a seed before it germinates.
14. What is the role of the centromere during mitosis?
15. Outline the differences between mitosis and meiosis.
16. Explain the conditions necessary for a viable seed to germinate.
17. Describe the stages of growth of plants after germination.
18. With examples, distinguish between epigeal and hypogeal germination in plants.
19. Describe the secondary sexual characteristics that develop during adolescence in:
    (a) boys (b) girls.
20. Explain the importance of chromosome replication before cell division.
21. Arrange the following events which occur during mitosis in the correct order.
    (a) Attachment of double stranded chromosomes to the spindle.
    (b) Pulling of chromosomes which are moved to opposite ends of the cell.
    (c) Disintegration of the nuclear membrane.
    (d) Nuclear membrane form around each set of chromosomes, forming two nuclei.
    (e) Synthesis of spindle fibres.
22. Outlines the main differences between growth in plants and animals.

BIOLOGY FORM 4.indd 29 09/03/2022 19:02



Chapter

Two

Genetics

Introduction

It is a common observation that siblings have certain resemblance with other family members. They also have noticeable differences, unless they are identical twins. The similarity and differences in appearance among siblings can be explained through genetics. In this chapter, you will learn about the concept of genetics, genetic material, principles of inheritance, sex determination, variation among organisms, genetic disorders and the application of genetics. The competencies developed will enable you to apply the knowledge on genetics in various fields such as agriculture, sociology, medicine and biotechnology. For example, application of genetics in agriculture includes improving crop and livestock production through selective breeding. You will also be able to cope with genetic disorders.

Concept of genetics

Genetics is the branch of science that deals with the study of heredity and variation among organisms. It describes why some organisms are similar or different regardless of the same physical environment in which they live. The passing on of features from parents to their offspring is called heredity, whereas genetic variation is the possession of characters that are different from those of parents. Genetic variation is brought about by the change in the genotype of an organism and not by the environment. For instance, maize and sorghum grown in infertile soil will be stunted. However, their leaves will still have parallel veins. Likewise, if two white laboratory mice are kept at different temperature regimes, their genetic make-up will remain unchanged. However, the environment in which the organism is living can influence the physical appearance of an organism. Nutrients, drugs, chemicals, temperature and light are among the environmental factors that can influence the physical appearance of an organism.

BIOLOGY FORM 4.indd 30 09/03/2022 19:02

Common terms used in genetics

The following are some of the common terms used in genetics:

Genome

Genome is the total set of genes or genetic information of an organism. It provides all the information the organism requires to function. In humans, every single cell contains a genome of approximately 3 billion DNA base pairs.

Chromosome

Chromosomes are thread-like structures of coiled DNA located in the nucleus of the cell. Chromosomes enclose hundreds to thousands of DNA molecules in the cell nucleus. The chromosomes are mainly made up of proteins known as histones and deoxyribonucleic acid. Humans have 46 chromosomes in their somatic (non-reproductive) cells and 23 chromosomes in their reproductive cells. Chromosomes play a vital role in heredity, cell division, variation and mutation.

DNA

DNA stands for Deoxyribonucleic Acid. It is the chemical name for a molecule that carries hereditary materials (genetic materials) in all living organisms. The number of DNA varies among living organisms. DNA contains segments of genes that contain instructions for making proteins or ribonucleic acid (RNA).

Gene

Gene is the unit of heredity that is transferred from the parent to offspring and carries information that determines the genetic characteristics of the offspring. The genetic informations are responsible for many genetical characteristics such as height, eye colour, blood type, hair colour, flower colour, branching patterns and leaf type.

A trait

A trait is a heritable genetic characteristic that an organism possesses and can distinguishes one individual from another. It also refers to the characteristic of an organism that can be passed from one generation to another. Examples of an organism's characters or traits include colour, shape, height, texture, length and width of various body parts. Traits are determined by genes and also by the interaction of the genes and the environment. The genetic contribution to a trait is called the genotype, where as the actual appearance of the trait is called the phenotype. Some traits are largely determined by genes while others are largely determined by environmental factors.

Allele

One of the two or more alternative forms of a gene that appear at a particular location on a particular chromosome is called an allele. For example, human beings have genes that determine eye colour. The different eye colours such as brown, blue and green are due to differences in alleles of the same gene. Alleles are responsible for determining contrasting characteristics of an organism. For instance, two alleles

BIOLOGY FORM 4.indd 31 09/03/2022 19:02

designated **T** and **t** may control the character for height, whereby **T** stands for tallness and **t** stands for shortness as seen in Figure 2.1. Alleles are also called allelomorphs.

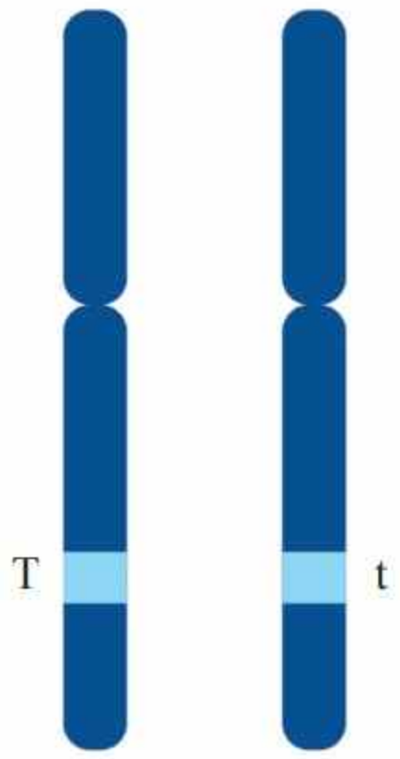


Figure 2.1: Homologous chromosomes showing alleles for body height

Locus

This is a specific position on a chromosome where a particular gene is located. Figure 2.2 shows the loci for thr genes for eye and hair colour. The plural of gene locus is gene loci.

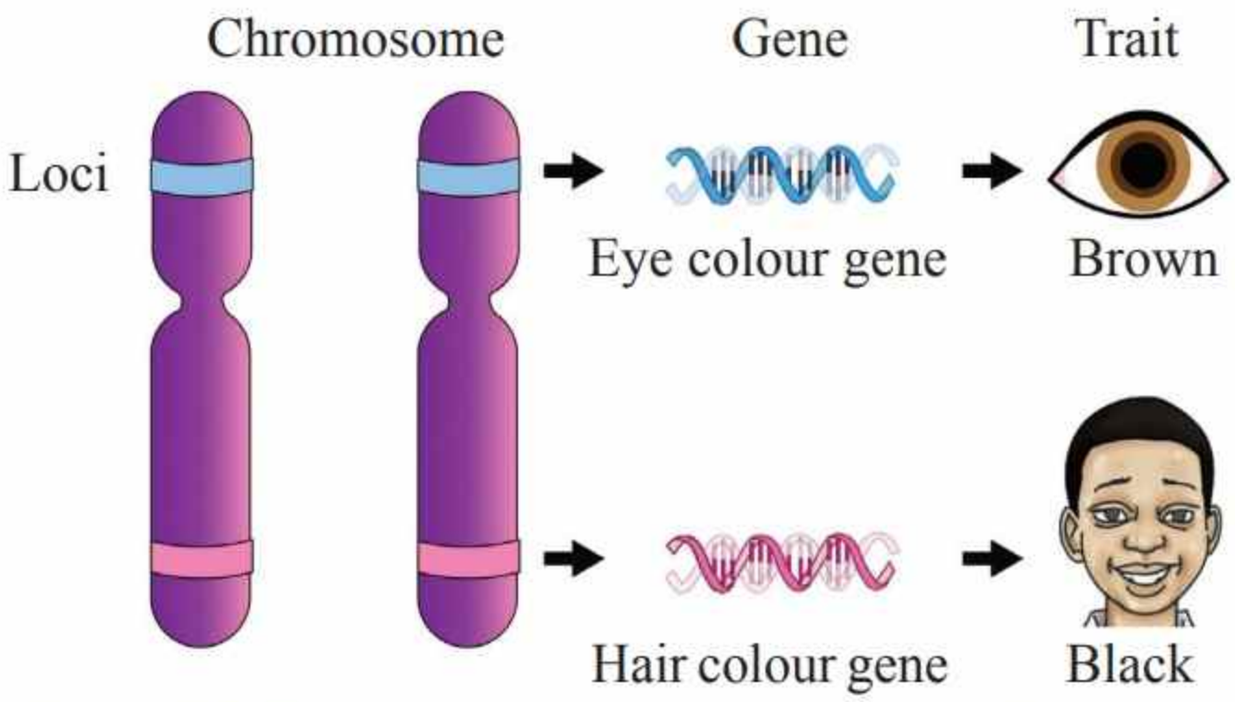


Figure 2.2: Homologous chromosomes showing different loci for eye and hair colours

Haploid versus diploid number of chromosomes

Haploid number of chromosomes refers to a half number of chromosomes in a nucleus of a cell. This number of chromosomes is denoted by letter "n". In human beings, gametes or reproductive cells are haploid and contain 23 chromosomes. The haploid number (n) of chromosomes in the reproductive cells results from meiotic cell division.

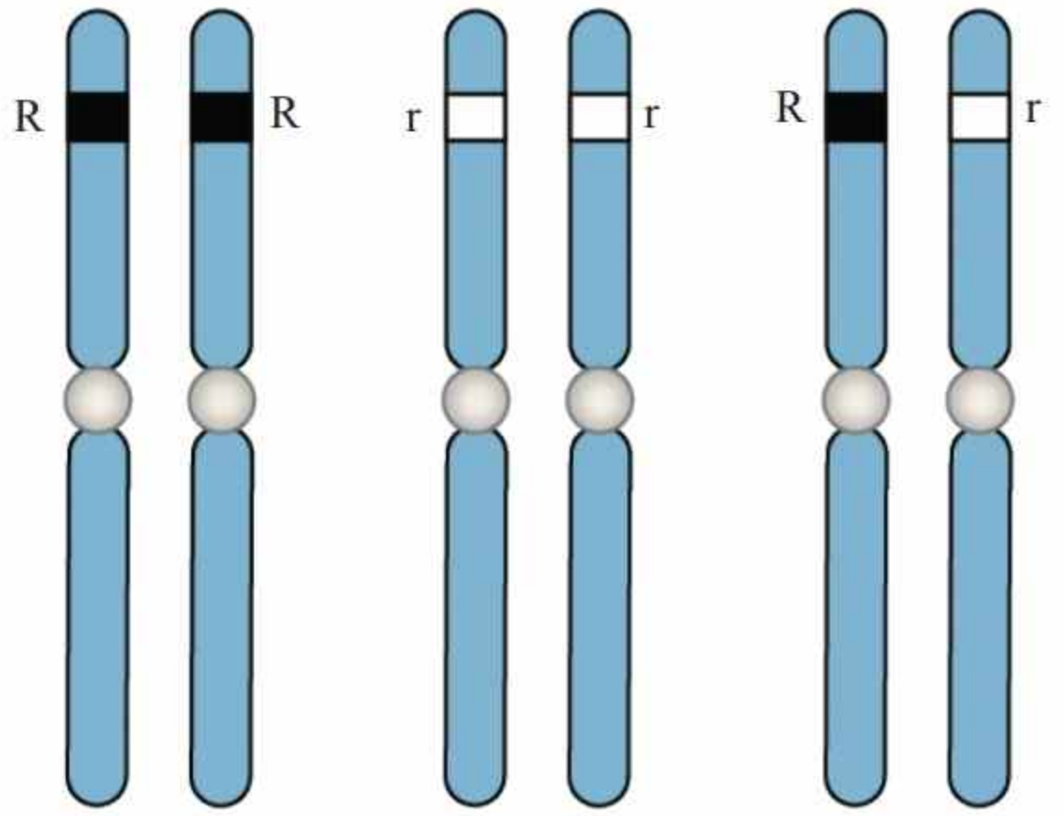
Diploid number of chromosomes refers to the complete set of a pair of chromosomes in the nucleus of the cell. This number is denoted by "2n" and implies 46 chromosomes. All somatic cells contain diploid number of chromosomes.

Homozygous versus heterozygous

Homozygous is a genetic term that describes the state for an organism that possess identical alleles of a particular trait on similar loci of paired chromosomes. An example of a homozygous state is RR for rough coat and rr for smooth coat. In cotrast, heterozygous is a genetic term that describes the state for an organism that possess different or non-identical alleles of a particular trait on similar loci on paired

BIOLOGY FORM 4.indd 32 09/03/2022 19:02

chromosomes. Usually, there are two alleles for a trait that can be similar or different. When they are identical (RR or rr) an organism is said to be genotypically homozygous. However, when the two alleles are different (Rr), they are regarded to be genotypically heterozygous as shown in Figure 2.3.



Homozygous rough coat | Homozygous smooth coat | Heterozygous rough coat

Figure 2.3: Expression of homozygous and heterozygous alleles

Dominant versus recessive allele

Dominance refers to the relationship between two alleles of the same gene controlling the same trait where one allele masks the expression of the other allele. In this relationship, the allele that masks the effect of the other is called a dominant allele whereas the other that does not express itself in the presence of the dominant allele is called a recessive allele. For example, TT is a homozygous tall individual, Tt is a heterozygous tall individual, and tt is a homozygous short individual. An organism with Tt has a dominant allele for tallness (T) and a recessive allele for shortness (t). The phenotype of the organism will be tall due to the dominant allele for tallness (T). Therefore, the recessive allele for shortness (t) is masked by the dominant allele for tallness (T).

Genotype versus phenotype

The genotype of an organism is the genetic constitution or the genetic expression of an organism. It can also refer to a single gene or set of genes that control certain trait or character. For example, BB, Bb, and bb are three different genotypes. Phenotype is the external appearance of an organism resulting from the interaction of its genotype and the environment. It includes visible characteristics, such as body height, eye colour, hair colour, size of a bird's beak, length of the tail and invisible traits, such as blood group. For instance in eye colour, BB and Bb are two different genotypes, but in terms of external appearance (phenotype), both stand for brown eye colour trait whereas bb stands for blue eye colour trait in humans as shown in Figure 2.4.

Environmental factors that may influence the phenotype include nutrition, temperature, humidity, light and stress.

BIOLOGY FORM 4.indd 33 09/03/2022 19:02

Genotype	Homozygous brown eye colour (BB)	Heterozygous brown eye colour (Bb)	Homozygous blue eye colour (bb)
Phenotype	Brown eye colour	Brown eye colour	Blue eye colour

Figure 2.4: Expression of genotypes and phenotypes in human eye colour

Parents

These are organisms that are capable of producing offsprings. They invariably belong to the same species with very few and rare exceptions. The first set of parents is referred to as the parental generation (or P-generation). The genotype of the first set of parents is the basis for predicting the genotype of their offspring, known as a filial generation.

First and second filial generation

The filial generation is a successive generation which is comprised of offspring resulting from a cross between two individuals from parental generation. First filial generation (F_1) refers to the generation produced by parental stock. It is denoted as F_1 generation. The second filial generation (F_2) refers to the generation produced by crossing organisms from F_1 generation.

Hybrid

A hybrid is an offspring resulting from crossing two parents of different breeds or varieties through sexual reproduction. The hybrid organism often possesses hybrid vigour or heterosis. Hybrid vigour is the set of beneficial characteristics which are not shown by either of the hybrid parents. It refers to a situation at a locus in which the phenotypic expression of the heterozygous offspring exceeds that of either of the homozygous parents. Hybrid vigour is a result of heterozygosity of individual traits as a result of gene mixing from two genetically distinct parents. Hybridisation is often applied in selective breeding to produce individuals that are superior in many aspects to their parents by combining desirable traits found in two or more different varieties. Hybridisation does not change the genetic contents of organisms, but it produces a new combination of genes. In agriculture, the desirable characteristics may include a high growth rate, high yields, stress tolerance and resistance to diseases and drought.

Selective breeding

Selective breeding involves choosing parents with particular characteristics to breed together and produce offspring with desirable characteristics. The process of selecting parents is also called artificial selection. Humans breed different plants and animals in order to produce individuals with desirable genetic characteristics. Selective breeding is one of the methods used to develop better or more useful breeds of plants and animals.

Pure breeding

Pure breeding is a kind of breeding in which the parents with particular genotype produces offspring only with the same genotype. Pure breed individuals are a group of identical organisms that always produce offspring of the same genotype when they are inter-crossed. Therefore, a pure-breed individual is the one whose all parents and descendants belong to the same breed. A pure breed can also refer to an offspring resulting from true-breeding. True breeding is a way of producing offspring that would carry the same genotype as that of their parents. Thus, a pure breed would always result when the parents are homozygous for particular traits.

Monohybrid and dihybrid inheritance

Monohybrid inheritance is the inheritance of single characteristic which is controlled by a single gene. Examples of this kind of inheritance include skin colour, hair texture or shape of an organism. Monohybrid inheritance results from monohybrid crossing. A monohybrid cross is a cross between two organisms with variations at one genetic locus of interest.

Dihybrid inheritance is the inheritance of two characteritics which are controlled by two genes. Dihybrid crosses lead to dihybrid inheritance among organisms. It involves two individuals that differ in two observable traits that are controlled by two distinct genes. For instance, crossing pea plants with round and yellow (RRYY) seeds with pea plants producing wrinkled and green (rryy) seeds.

Polyhybrid inheritance is the inheritance that deals with more than two contrasting characteristics from different allelic pairs, Polyhybrid is also known as polygenic inheritance. Examples of polygenic inherited traits in humans includes skin colour, height and shape.

Epistasis

Epistasis is a phenomenon in which the expression of one gene is affected by the expression of one or more independently inherited genes. It refers to the ability of an allele at one locus to affect the expression of one or more alleles at a different locus or different loci respectively. Epistasis occurs when there is the interaction between alleles of different gene pairs, in particular the suppression of the effect of one such gene by another. One gene is expressed and the other is suppressed. The gene whose phenotype is expressed is said to be epistatic, while the one whose phenotype is altered or suppressed is said to be hypostatic. One example of epistasis is the interaction between gene controlling hair colour and the one controlling baldness. A gene for baldness is epistatic and supresses that of hair colour. In this case, the genes for hair colour are hypostatic to those of baldness. As a result, baldness phenotype occurs regardless of hair colour.

Pedigree

Pedigree is a record of known lineage or ancestral record of an individual presented in a diagram or table. It indicates where the progeny has descended. This is a register recording a line of ancestors. The pedigree diagram can also represent the available

BIOLOGY FORM 4.indd 35 09/03/2022 19:02

information of the family members' traits. It may show the presence or absence of a certain trait associated with the relationship among parents, offspring and siblings.

Activity 2.1:

Investigating observable characteristics of the human body

Materials: A metre rule, a weighing balance, a note book and a pen

Procedure

1. Observe the following features from your fellow student: hair colour, eye colour, height and skin colour.
2. Measure the weight of your fellow student using a weighing balance.
3. Measure the height of your fellow student using the metre rule.
4. Prepare a chart to describe yourself (body features) based on the following body characteristics: hair colour, eye colour, weight (kg), height (cm) and skin colour.
5. Compare your body characteristics with those of your fellow student.
6. Discuss with your classmates the variations you have observed.

Questions

(a) Which characters were unique to you only?

(b) Which among the characteristics that you observed are determined by the environment and which are inherited from parents?

(c) List down any other characteristics that you have inherited from your parents.

Genetic material

Genetic material refers to the units within the nucleus of a cell that carry the hereditary information from one generation to the next. Genetic materials can be either deoxyribonucleic acid (DNA) in most organisms or ribonucleic acid (RNA) in some organisms. In eukaryotes, such as plants and animals, DNA is found in the nucleus of the cell. However, a small amount of it is found outside the nucleus, such as in the mitochondria and chloroplasts.

Chemical composition of the genetic material

Genetic materials DNA and RNA are composed of sub-units called nucleotides. These nucleotides join together to form unbranched chains called polynucleotides. Each nucleotide of the genetic materials is composed of three basic components namely: sugar, phosphate group, and nitrogenous bases, as shown in Figure 2.5.The sugar is a five-carbon compound (pentose sugar) and it exists in two forms; ribose and deoxyribose. Ribose is found in RNA and it has oxygen atom in the second carbon of its pentose sugar, while deoxyribose is found in DNA and it lacks oxygen atom in the second carbon of its pentose sugar. The phosphate group is a group that is derived from phosphoric acid and is the one that gives DNA and RNA their acidic nature. Nitrogenous bases are the building blocks of RNA and DNA. Nitrogenous bases are categorised into two groups namely; purine (double ring structure) and pyrimidines (single ring structure). Purines are composed of

Adenine (A) and Guanine (G) bases while pyrimidines are comprised of Cytosine (C), Thymine (T) and Uracil (U) bases. The Uracil (U) is only found in RNA and Thymine (T) is only found in DNA.

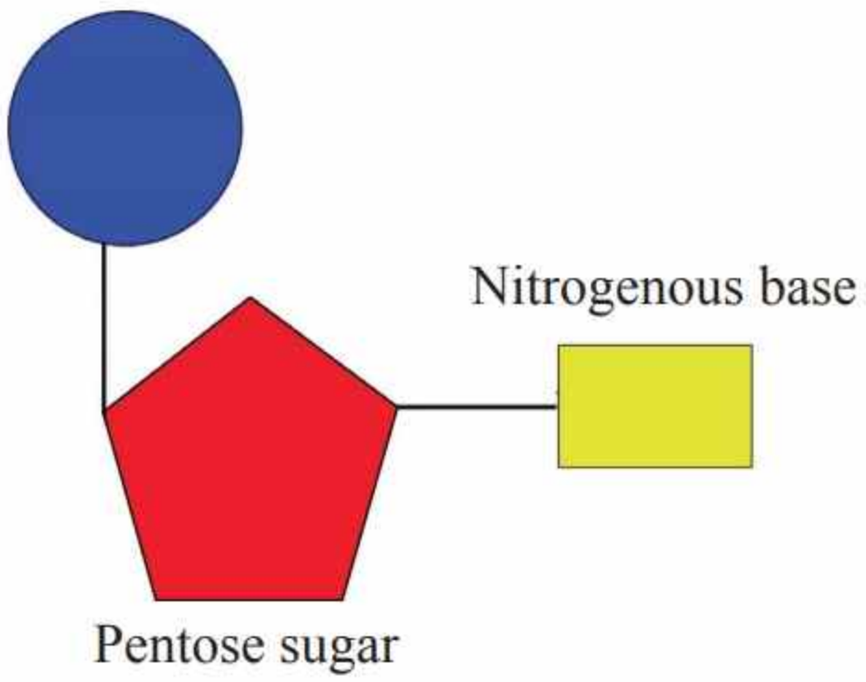


Figure 2.5: Basic structure of a nucleotide

Properties of genetic material

The following are some of the properties of genetic materials:

(a) They have ability to replicate and form their own copies which contain the same genetic information as the parent cell.

(b) They are stable, both chemically and physically.

(c) They contain hereditary information in the genes that code for specific traits.

(d) They are in the same quantity and quality in all somatic cells of healthy individuals.

(e) The structural elements of genetic material are universal in their distribution, meaning they are found everywhere in life forms.

Types of genetic material

There are two types of genetic material that are found in the body of a living organism. These are deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA). DNA is the genetic material of nearly all organisms except some viruses which have only RNA.

Deoxyribonucleic acid (DNA)

DNA is the polymer of nucleotides that carry the codes for a particular inheritable characteristics of an organism. DNA is a double-stranded molecule that is usually twisted like a ladder to form a double helix structure as shown in Figure 2.6.

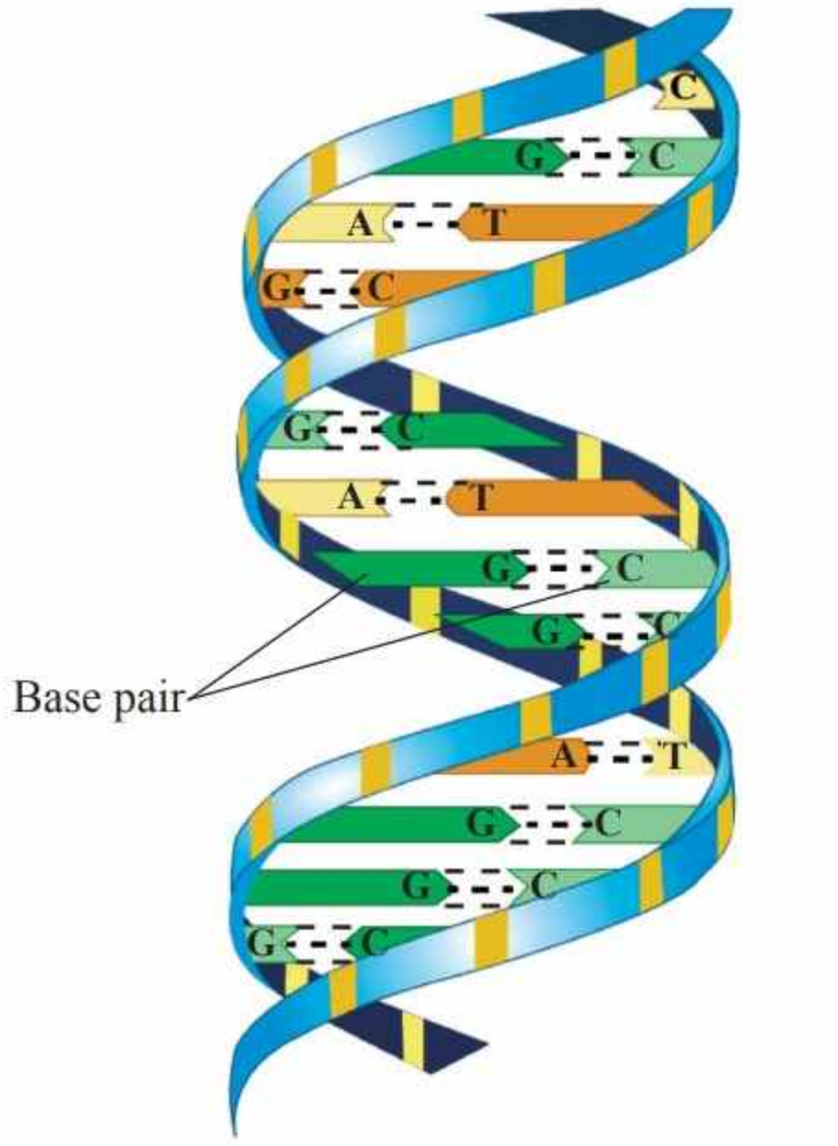


Figure 2.6: A fragment of the double-stranded DNA molecule

Components of DNA strand

The main components of the DNA include the deoxyribose sugar, phosphate group and nitrogenous bases. Deoxyribose sugar

BIOLOGY FORM 4.indd 37 09/03/2022 19:02

is a five-carbon sugar which is also called pentose sugar. It makes up each nucleotide which is part of the chain in the DNA strand. Phosphate group is linked to the pentose sugar to form the sugar-phosphate backbone as shown in Figure 2.7. It comprises of four organic bases, namely: Adenine (A), Guanine (G), Cytosine (C) and Thymine (T). These organic bases are found in a specific match of pairs that make up the rings of the ladder when they are in the strand. Adenine pairs with Thymine, whereas Guanine pairs with Cytosine in forming the double helix strands. This specific base pairing fashion allows for the formation of weak hydrogen bonds which holds the two strands together.

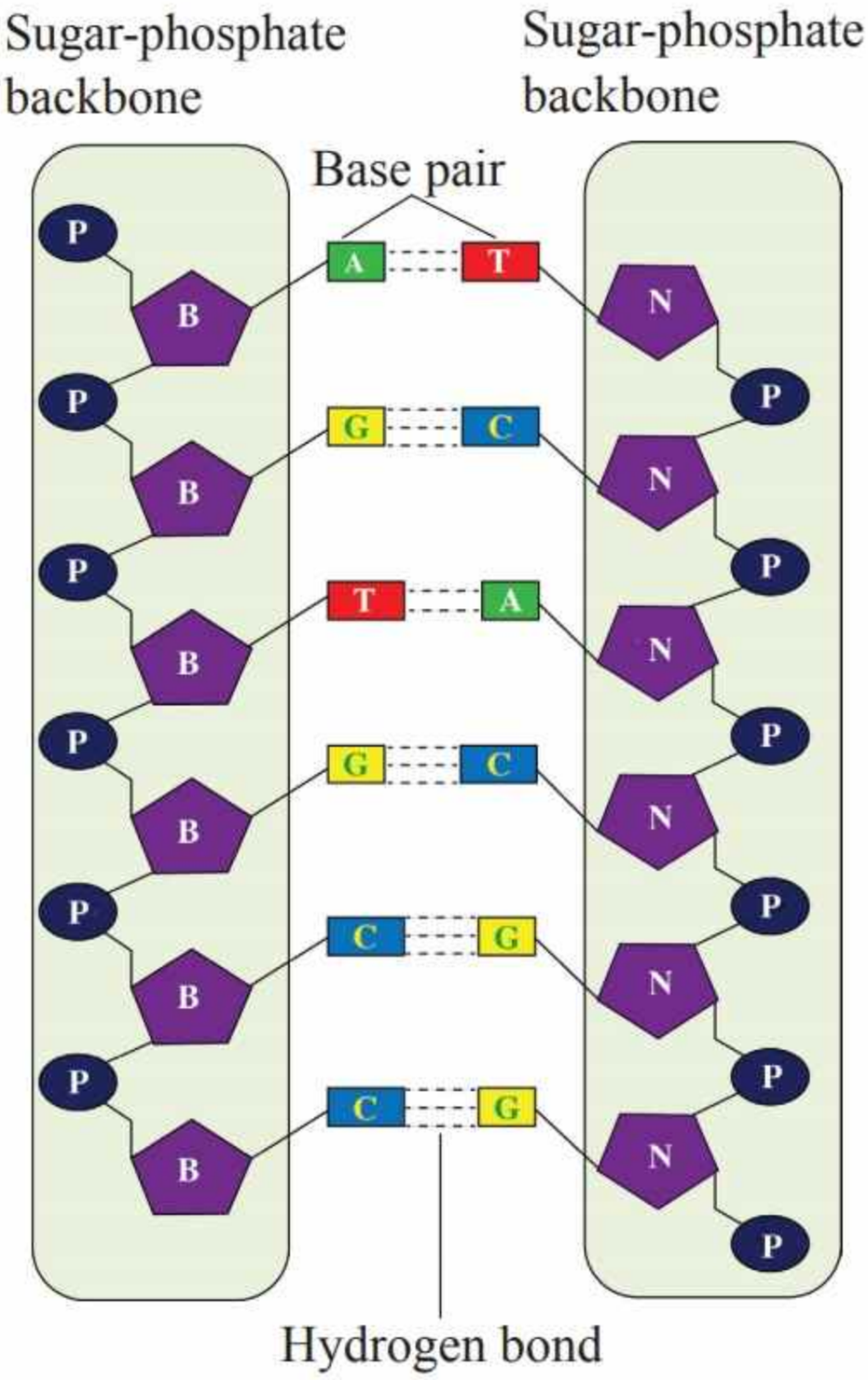


Figure 2.7: Untwisted DNA strand

Ribonucleic acid (RNA)

RNA is a single strand polynucleotide that in many organisms plays a role in conveying the codes of genetic instructions from the DNA in the nucleus. It is therefore, not only localised in the nucleus like DNA, but also found in the cytoplasm of the cell.

Components of RNA strand

Structurally, RNA is composed of ribose sugar, phosphate group and four types of nitrogenous bases which are Adenine (A), Guanine (G), Cytosine (C) and Uracil (U) as shown in Figure 2.8. The RNA strand resembles the structure of a single strand of DNA except that it possesses Uracil instead of Thymine.

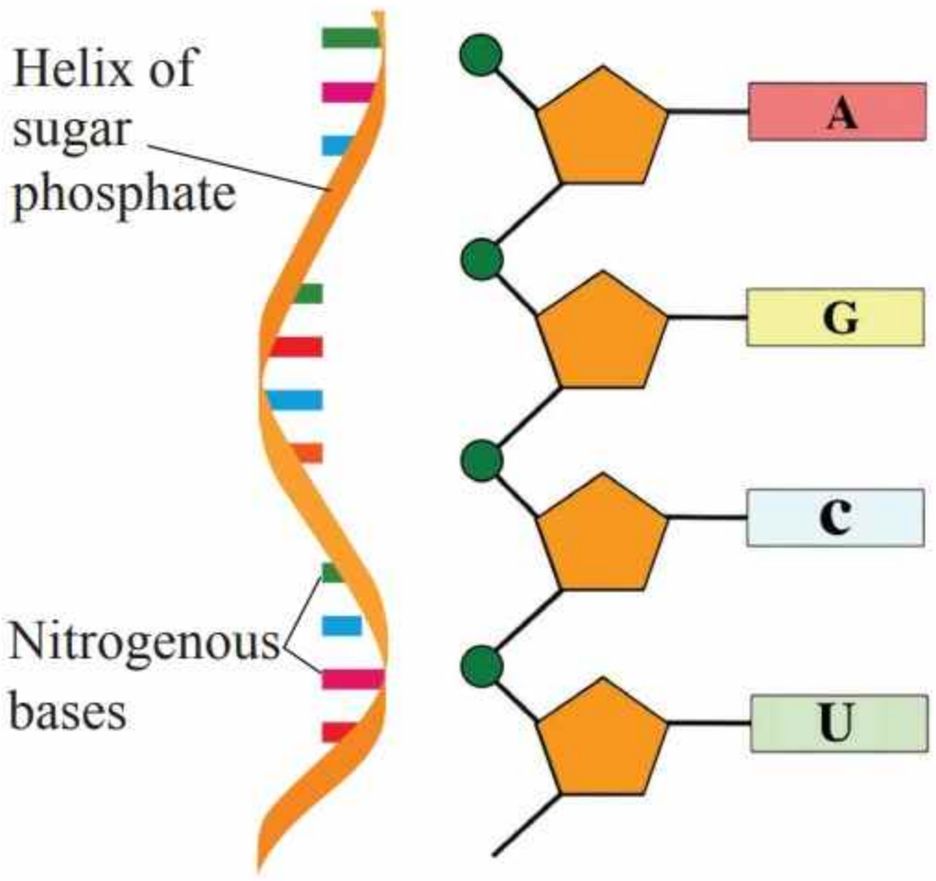


Figure 2.8: Basic structure of RNA

Activity 2.2:

Designing a model of DNA

Materials: Coloured paper or manila card, scissors, pencil, four marker pens, ruler, masking tape or glue and sticks

BIOLOGY FORM 4.indd 38 09/03/2022 19:02

Procedure

1. Cut two strips of coloured paper of about 50 cm long and 3 cm wide.
2. Use a pencil and a ruler to mark each inch along the strips.
3. Use different colour of marker pen for each base (Adenine (A), Thymine (T), Cytosine (C), and Guanine (G)).
4. Take 10 sticks of 10 cm long, colour half of each stick the colour you choose for A. Colour the other half the colour you choose for T.
5. Take another 10 sticks of 10 cm long and do the same as in procedure 4 for colouring C and G.
6. Join both strips of paper, put one strip on top of the other.
7. Insert a stick through the middle of the strips. Use the pencil marks as a guide. Continue until the end of the strips. Make sure all sticks are pushed halfway through the holes.
8. Gently, spread apart the two strips until they look like a ladder.

   Note: If any of the sticks fall, use glue or tape to stick it.
9. Tape one end of your model to a wall or board, then carefully, while holding the model twist it once around until it looks like a double spiral. Tape the other end to a flat surface.

Question

Draw the structure of your model and describe the function of each component labelled in the real DNA

Similarities and differences between DNA and RNA

DNA and RNA are the genetic material that carry genetic information in the cells of organisms. Both DNA and RNA:

(a) Are made up of sugar, organic bases and a phosphate group;
(b) Store genetic information; and
(c) Have three similar organic bases in their structures, namely Adenine, Guanine, and Cytosine.

However, DNA and RNA differ in various ways as shown in Table 2.1.

Table 2.1: Differences between DNA and RNA

SN.	DNA	RNA
1.	Has deoxyribose sugar	Has a ribose sugar
2.	Has a double helix strand	Has a single strand
3.	Is mostly found in the nucleus however, small amount of it is found in mitochondria and chloroplasts	Is found in the nucleus and cytoplasm only

BIOLOGY FORM 4.indd 39 09/03/2022 19:02

4.	Has Thymine as a fourth organic base	Has Uracil as a fourth organic base
5.	Lacks one Oxygen atom at the second carbon in its pentose sugar, hence the name deoxyribose	Has an Oxygen atom in the second carbon of its pentose sugar, thus it is a ribose sugar
6.	Determines the code for the formation of the protein molecule to be formed by the cell	Is not the main determinant of the kind of protein to be formed, it only conveys the message for protein formation, except in some viruses
7.	Carries many genes that are responsible for all the characters of the organism	Carries very few genes responsible for the characters of an organism
8.	Codes for all the activities of the cell	Conveys the coded information from the DNA to the cytoplasm
9.	Is the predominant genetic material in most of the organisms	Is the predominant genetic material in some viruses

Exercise 2.1

1. Explain the similarities and differences between DNA and RNA.
2. Explain at least three reasons for studying genetics.
3. Why is the DNA molecule called Deoxyribonucleic acid and RNA Ribonucleic acid?
4. With the help of a well-labelled diagram, describe the structure of the DNA molecule.
5. Describe four major characteristics of the genetic material.
6. Explain the relationship that exists between the DNA, chromosomes and gene.

Principles of inheritance

Inheritance is the basis of heredity, where traits are passed on from one generation to the next generation. Parents pass certain characteristics to their offsprings, hence the offspring may look like one of the parents or both.

Concept of inheritance

Each chromosome has nitrogenous bases arranged in a particular sequence to form the nucleotide sequence. This sequence of bases provides the genetic code. The genetic code is the specific information that determines the inheritance pattern in a particular organism. The sequence of base determine a kind of proteins that have to be synthesised for the development of certain traits. Each specific part that controls

BIOLOGY FORM 4.indd 40 09/03/2022 19:02

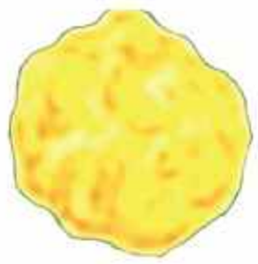
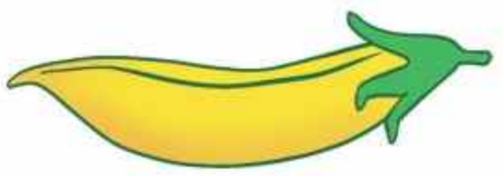
the inheritance of characters in DNA is called a gene. For example, genes from higher animals are passed on to the next generation through sexual reproduction. The resemblance and differences among individuals are influenced by the structure, functions of genes and the mechanisms of their transmission from generation to generation.

Mendel's experiments

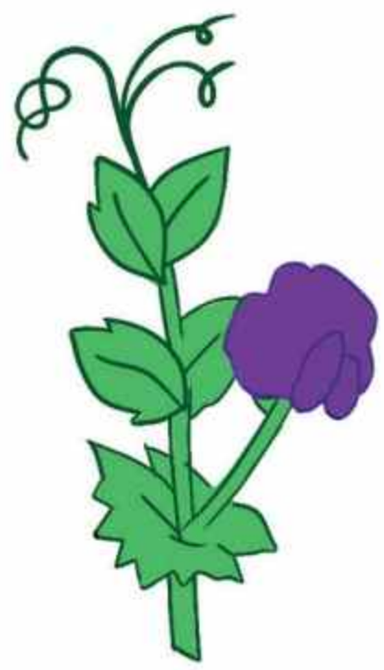
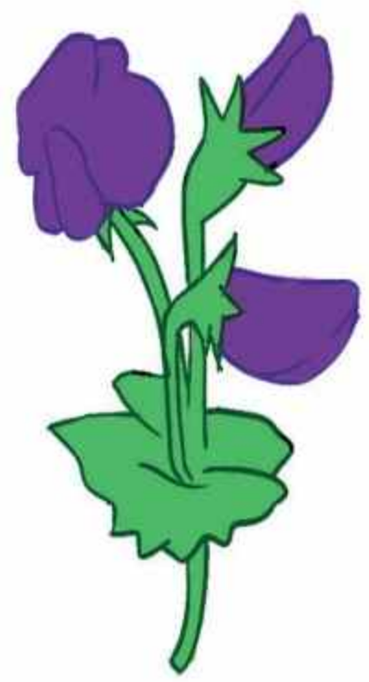
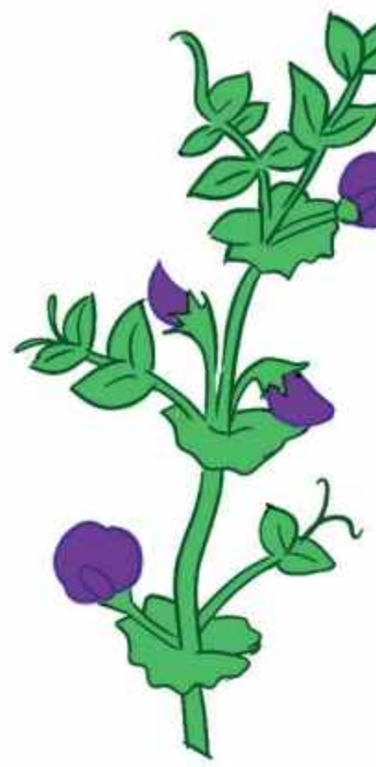
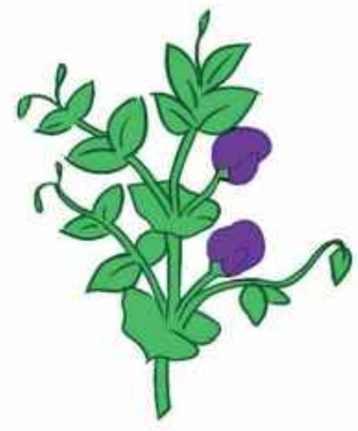
In 1856, Gregory Mendel began a series of experiments at the monastery to find out how traits are passed from one generation to next generation. At that time, it was thought that parents' traits were blended together in their offspring. Mendel discovered inheritance patterns by studying the common garden pea (*Pisum sativum)*. He chose garden peas because this plant mature in a short time, produce viable offsprings from the crosses and produce many seeds at once. Also, the garden peas are perfect bisexual flower that contains male and female parts which can be manipulated during pollination. Furthermore, garden peas show many phenotypically contrasting characters, making it possible to have a wide selection of traits to deal with at a time.

When doing his work, he selectively grew pea plants of different characteristics over many generations. He discovered that certain traits show up in offsprings without blending of parents' characteristics. Mendel demonstrated that heritable properties are transmitted in discrete units and are independently inherited. His experiments were based on seven distinct traits of peas. These were qualitative traits that could easily be measured and assigned value as dominant or recessive traits. These characteristics were visible and effectively used to study their effects in reproduction. The seven traits of the garden pea plants are shown in Table 2.2. The modern genetics began with experiments and principles proposed by Mendel. For this case, Mendel is regarded as the father of modern genetics.

Table 2.2: Pea-plant characters investigated by Gregory Mendel

S/N	Character	Dominant trait	Recessive trait
1.	Seed shape	**Round** 	**Wrinkled** 
2.	Pod colour	**Green** 	**Yellow** 

BIOLOGY FORM 4.indd 41 09/03/2022 19:02

3.	Seed colour	**Yellow** 	**Green** 
4.	Pod shape	**Inflated** 	**Constricted** 
5.	Flower colour	**Purple** 	**White** 
6.	Flower position	**Axial (at stem)** 	**Terminal (at tip)** 
7.	Stem length	**Tall** 	**Dwarf** 

BIOLOGY FORM 4.indd 42 09/03/2022 19:02

Mendel's procedure

In his experiments, Mendel choose pure line plants. Pure lines are plants that breed true by producing offsprings that closely resemble themselves when self-pollinated. By crossing pure lines, a uniform population of F_1 hybrid seed can be produced with predictable characteristics. This means that Mendel's pea plants in most cases were homozygous for the character. This was important as only the changes that he introduced through cross-pollination were the ones to be seen. He chose one trait to deal with at a time. He prevented self-pollination by wrapping or removing either the female or the male part of the flower, thus, leaving the possibility of cross-pollination only. Pea flowers contain both male (stamen) and female (pistil) parts, as shown in Figure 2.9. These plants usually undergo self-pollination. Self-pollination normally occurs before the flowers open, so the offspring is produced from a single plant.

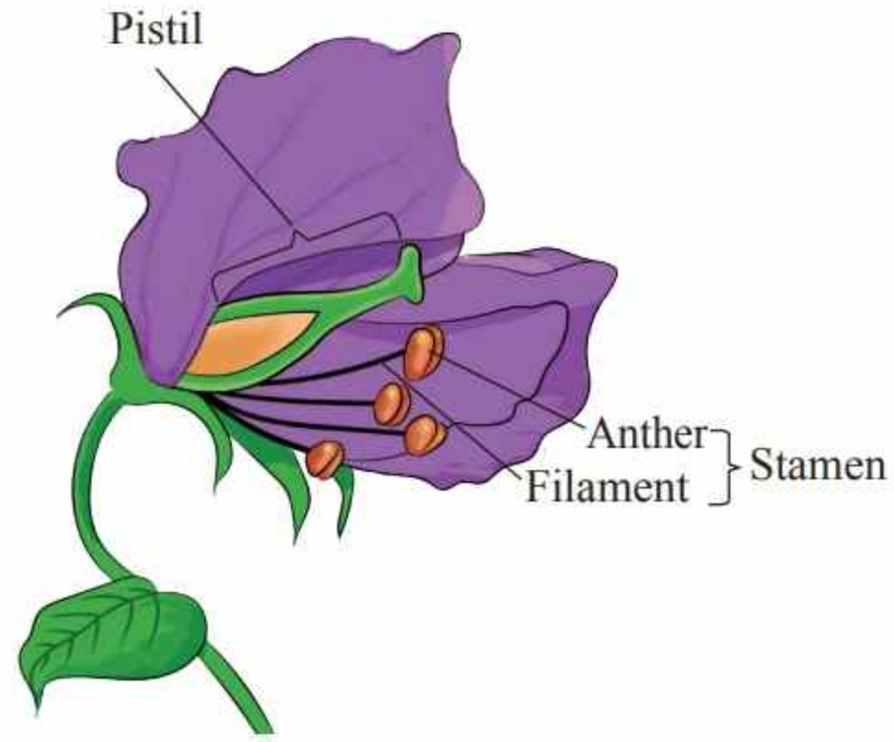


Figure 2.9: Pea flower showing male and female reproductive structures

Peas can also be cross-pollinated by hand, by simply opening the flower buds to remove their pollen-producing stamen in order to prevent self-pollination and dusting pollen from one plant onto the stigma of another. In his experiment, Mendel opened the flower buds to remove stamen before they were ripe. He used pollen from another plant and dusted the pistil to effect cross-pollination as shown in Figure 2.10.

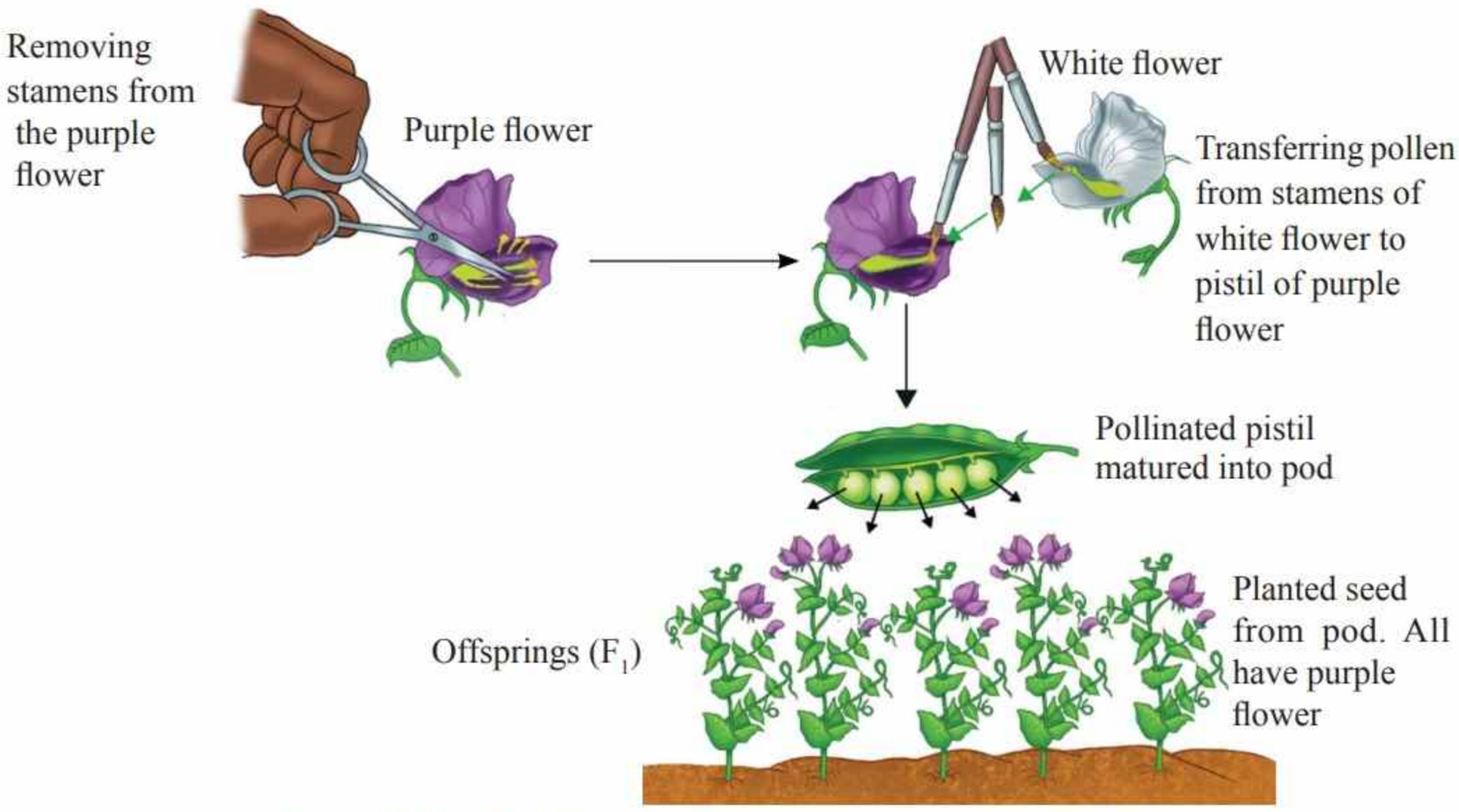


Figure 2.10: Mendel's procedures to carry out cross-pollination

BIOLOGY FORM 4.indd 43 09/03/2022 19:02

The result of his experiment showed that, only one character was phenotypically expressed in the first filial generation. When he allowed the F_1 generation to interbreed among themselves he obtained the F_2 generation which had a mixture of characters in the ratio of 3:1. Table 2.3 summarises the results of his experiments.

Table 2.3: The results from Mendel's experiments

Trait	Parent 1	Parent 2	F_1	F_2	F_2 ratio
Seed shape	round	wrinkled	All round	5474 round, 1850 wrinkled	3:1
Seed colour	yellow	green	All yellow	6022 yellow, 2001 green	3:1
Pod colour	green	yellow	All green	428 green, 152 yellow	3:1
Pod shape	inflated	constricted	All inflated	882 inflated, 299 constricted	3:1
Flower position	axial	terminal	All axial	651 axial, 207 terminal	3:1
Stem length	tall	short	All tall	787 tall, 277 short	3:1

The interpretation of the results was that every hereditary trait is controlled by two different factors, one from each parent. These factors are units of heredity that the pea plants pass on to future generations. These factors were later called genes. From Table 2.3, it is also obvious that the characters that were expressed in the F_1 generation were controlled by dominant genes where as those that were masked in the F_1 and reappeared in the F_2 were controlled by recessive genes.

Conclusion

The conclusion of Mendel's experiments can be summarised into three points:

1. The inheritance of each trait is determined by hereditary units called genes, which are passed from one generation to another without changing.
2. An individual offspring inherits one of those units from each parent.
3. A trait may not be expressed in an individual offspring (F_1) but can still be passed on to the next generation (F_2).

Mendel's laws of inheritance

Based on his experiments, Mendel recognized the phenomena of dominance and formulated the laws of inheritance. Mendel correctly suggested that characteristics were transmitted from parent to offspring by internal factors. He also postulated that the transmission of factors occurred through gametes, and that only one of a pair of factors could be present in each gamete. Mendel reasoned

that, factors must segregate from each other during gamete formation to retain the number of characteristics. After the Mendel discovery, these factors come to be called genes. The gametes which are formed are always pure for a particular character. A gamete may carry either the dominant or recessive character. Based on the observations of monohybrid cross, Mendel's proposed the law of inheritance which is called the principle of segregation or law of purity of gamete or Mendel's first law.

Law of segregation (Mendel's First Law)

It states that, "characteristics of an organism are controlled by internal factors (genes) occurring in pairs and only one of the factors forming the pair is carried in each gamete." Hence, half of the sex cells carry one allele and the other half carries the other allele.

Mendel's first law contributes to the understanding on how a pair of genes is segregated during gametes formation. In meiosis, the paternal and maternal chromosomes get separated and the alleles for the characters are segregated into two different gametes. The normal paired number of chromosomes is restored when the sperm and egg nuclei unite during fertilisation to initiate the development of the new individual as shown in Figure 2.11.

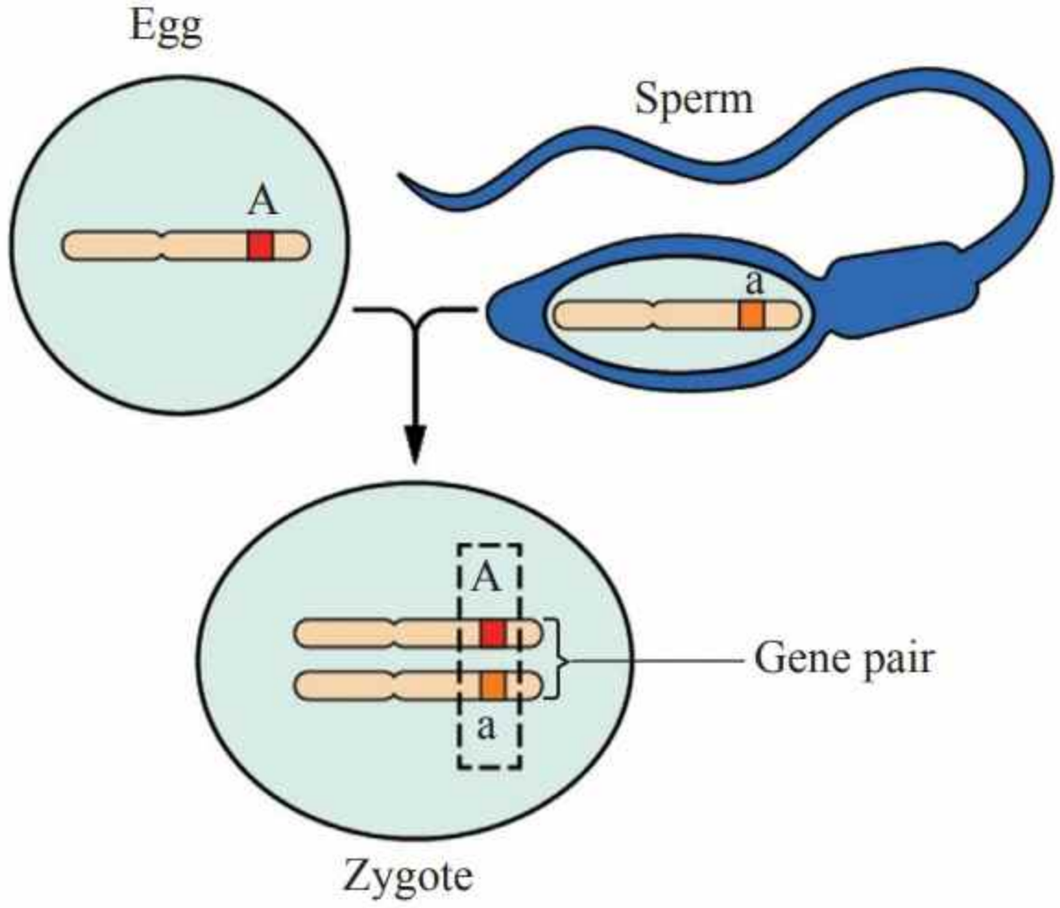


Figure 2.11: Gene pairing after fusion of an ovum and sperm nuclei

Law of independent assortment (Mendel's second law)

In one of his experiments to demonstrate dihybrid inheritance, Mendel crossed pure breeding pea plants having round yellow seeds with pure breeding wrinkled green seeds. The F_1 generation were all round yellow. When members of F1 generation were selfed, the F_2 offsprings were round yellow, round green, wrinkled yellow and wrinkled green in the ratio of 9:3:3:1 as shown in Figure 2.12. This discovery form the basis for Mendel's second law or the law of independent assortment which states that "A pair of trait segregate independently of another pair during gamete formation".

BIOLOGY FORM 4.indd 45 09/03/2022 19:02

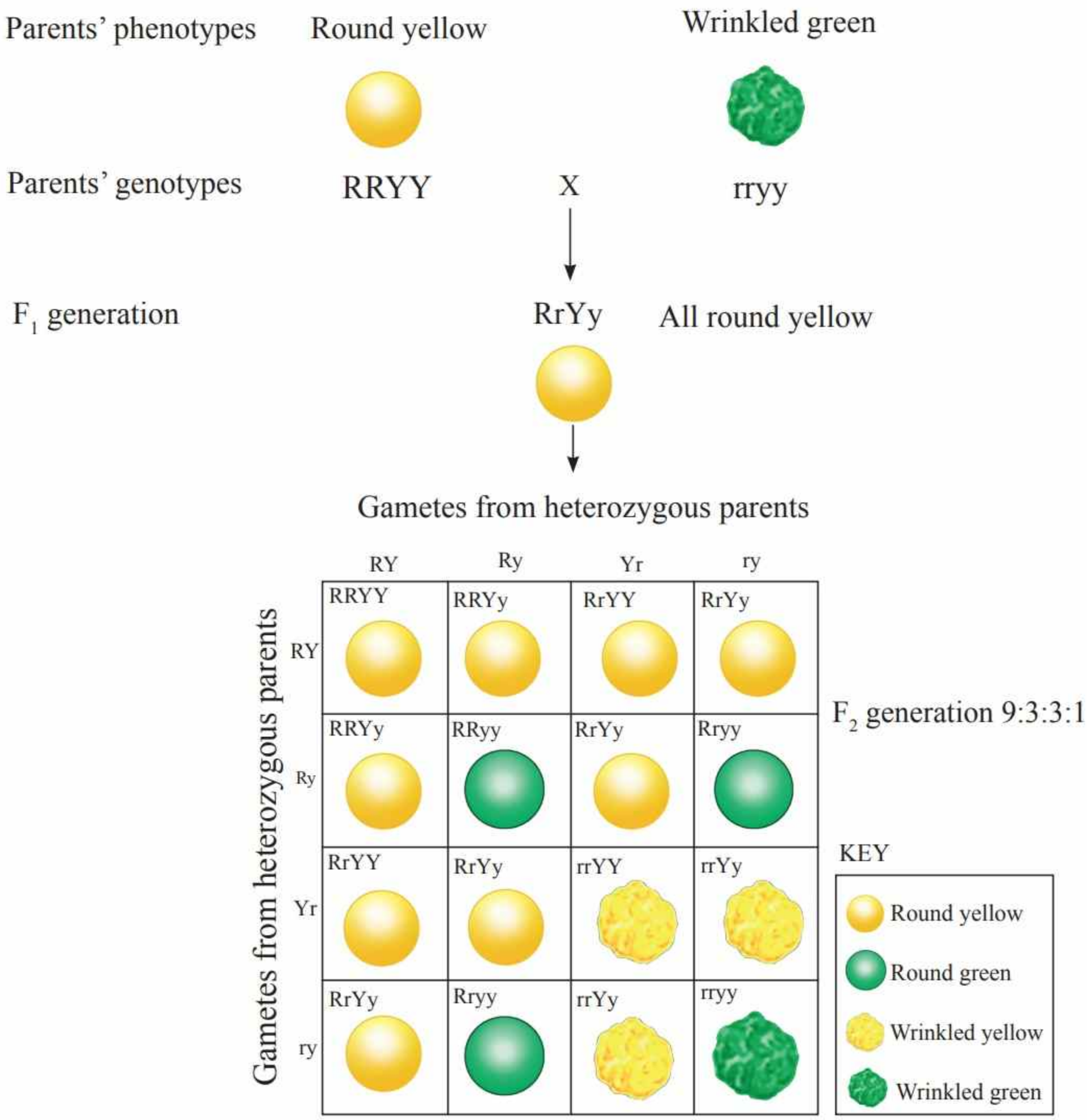


Figure 2.12: Results of Mendel's dihybrid cross

Based on those results he concluded that the two pairs of traits when combined in F_1 generation tend to assort independently from one another in subsequent generations. This means that allele for traits are passed on independently of each other. This forms the basis for Mendel's second law.

Law of dominance (Mendel's third law)

Dominance is a phenomenon in which a gene from one parent is capable of masking the expression of another gene, which is recessive. Law of dominance states that "when a pair of contrasting factors is present together, only one is

able to express itself while the other remains suppressed." The character which is expressed is a dominant character and the character which is suppressed is called a recessive character." This situation indicates complete dominance where by the gene which is dominant completely masks the effect of other gene in phenotypic appearance of their F_1 offsprings. The heterozygous offspring will have the same phenotype as that of the dominant homozygote and the recessive phenotype will be only visible in F_2 generation provided that the recessive gene has not undergone any alterations.

At this level of schooling the focus will be on monohybrid crosses rather than dihybrid crosses.

Example 2.1

A homozygous woman for a recessive trait of blue iris is married to a man with homozygous brown iris. What will be the genotypes and phenotypes of their F_1 and F_2 generation?

Let B represent the dominant gene for brown iris

Let b represent the recessive gene for blue iris

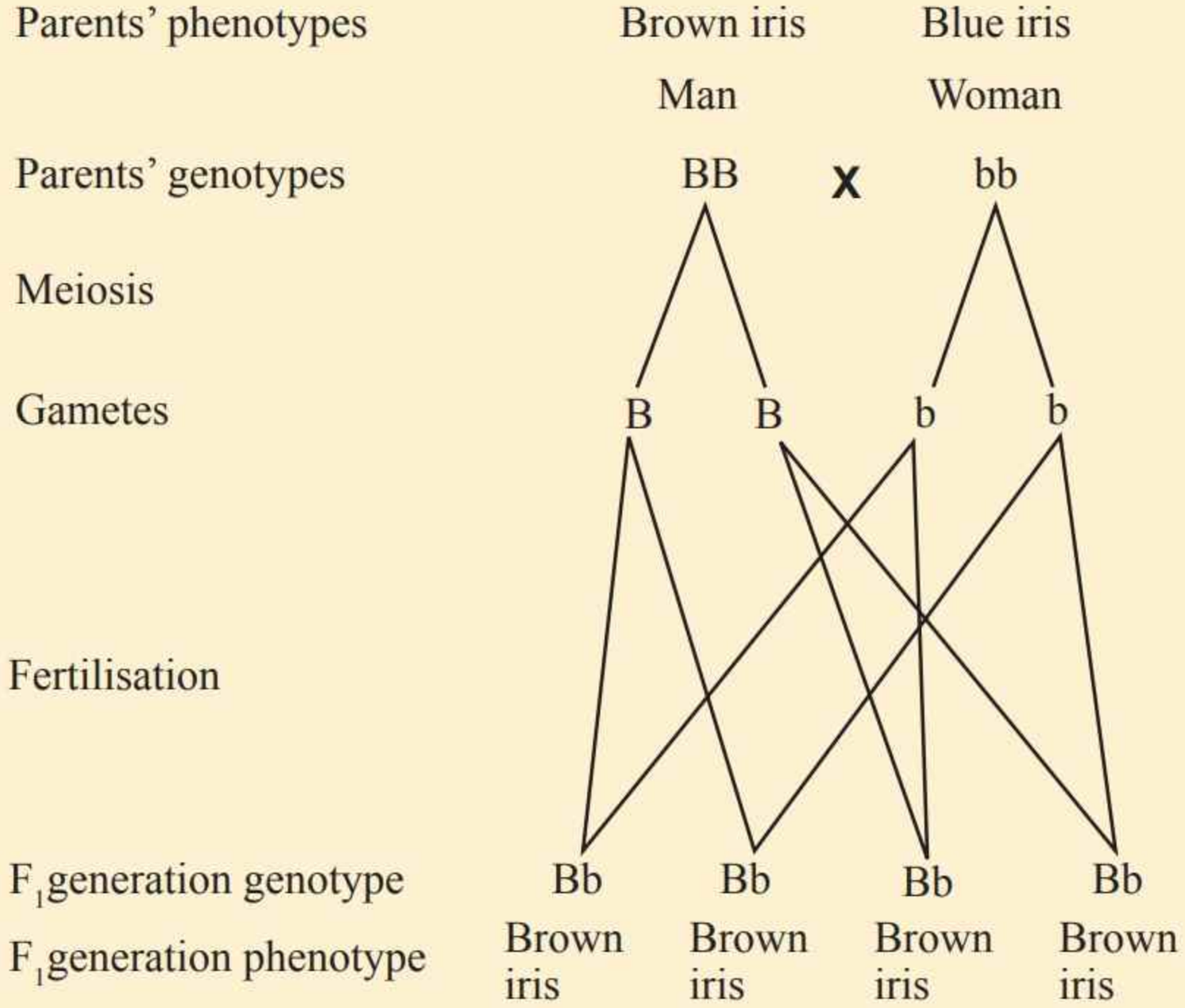


Figure 2.13: A cross between parents with a brown and blue iris

BIOLOGY FORM 4.indd 47 09/03/2022 19:02

Figure 2.13 shows that in F_1 generation, 100% of the offspring will be phenotypically brown iris and genotypically heterozygous brown iris. When F_1 generation offsprings are selfed to obtain F_2 generation, the results will be as follows:

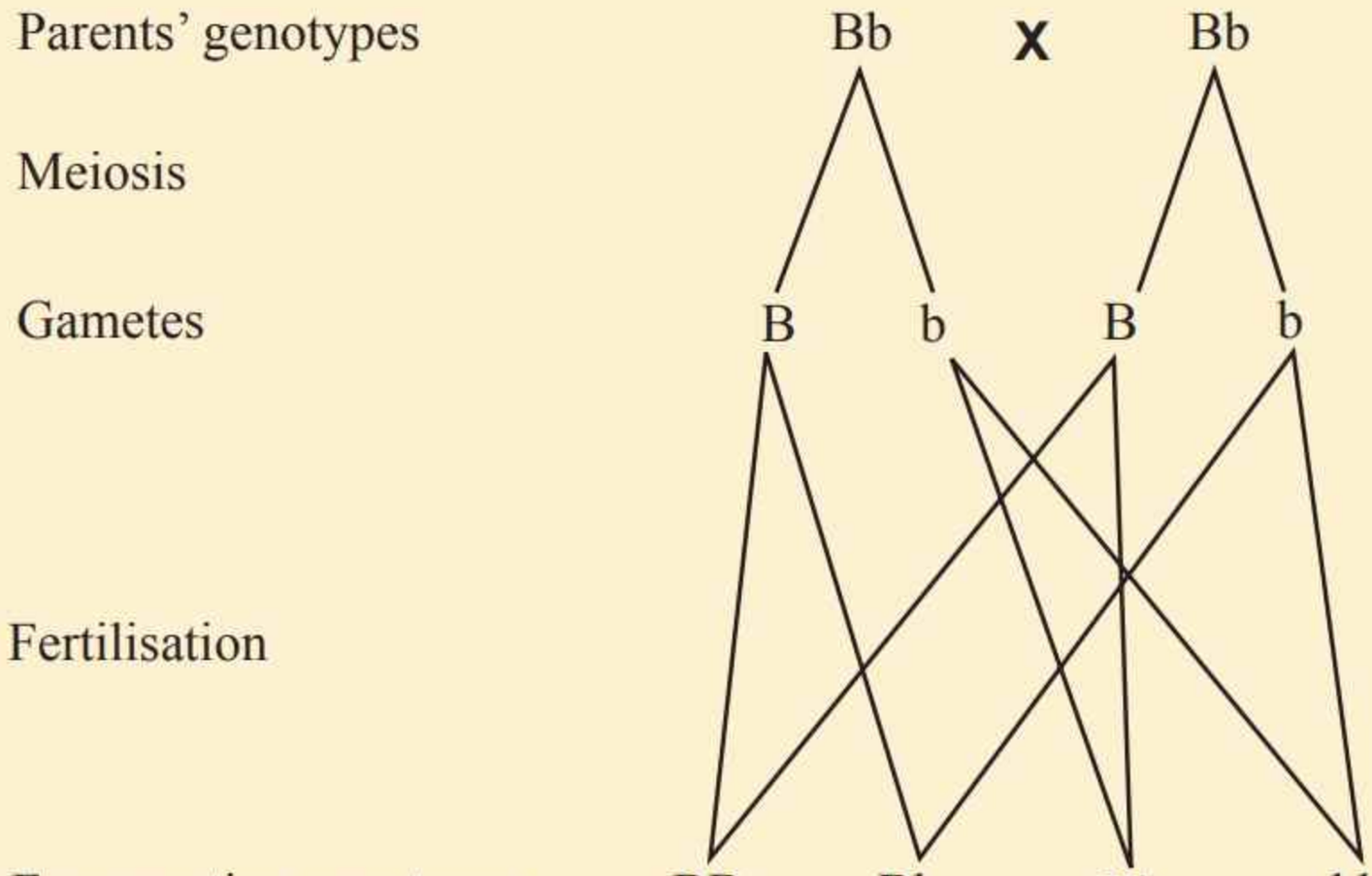


Figure 2.14: A cross between brown iris parents

Figure 2.14 shows that in F_2 generation, phenotypically 75% of the offsprings will have brown iris and 25% will have a blue iris. Genotypically 25% will be homozygous brown iris, 50% heterozygous brown iris, and 25% homozygous blue iris.

Example 2.2

A pure dominant purple flowered pea plant was crossed with a pure white flowered plant. What will be the genotypic and phenotypic ratios of their F_2 generation?

Solution

Let P represent the gene for purple flower and p represent the gene for white flower.

BIOLOGY FORM 4.indd 48 09/03/2022 19:02

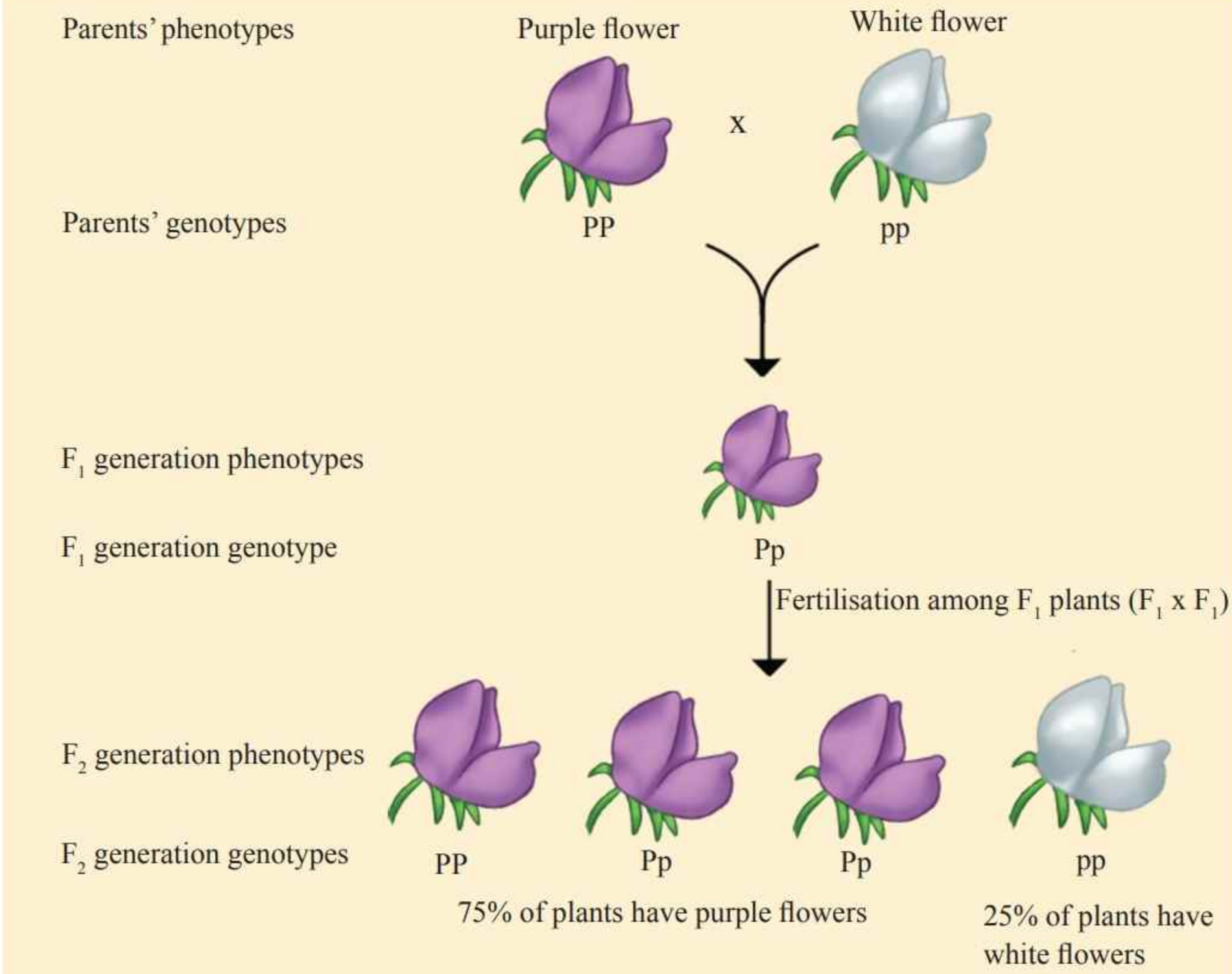


Figure 2.15: A monohybrid cross between pure purple and white flowered pea plants
Genotypic ratio 1:2:1
Phenotypic ratio 3:1

Activity 2.3:

To illustrate how gametes segregate and combine randomly

Materials: 10 red marbles, 10 blue marbles, and two bags each containing an equal number of red and blue marbles

Procedure

1. Assume that the red marbles are dominant over the blue marbles. With your eyes closed, pick a marble from one bag and then a marble from the other bag. Place the marbles together to form a pair. (Note: Any other two different colours can be used).
2. Repeat step (1) until you finish all the marbles from the bags.
3. Study two pairs. Classify them as homozygous (same-coloured marbles) or heterozygous (one red and one blue).
4. Discuss the results with your classmates.

BIOLOGY FORM 4.indd 49 09/03/2022 19:02

Punnet square

Punnet square is a square diagram or a table that is used to determine all possible outcomes or genotypes of a particular cross or breeding experiment.

This approach was devised by Reginald C Punnet in 1905. Since then, the diagram has been widely used to determine the probability of genotype of an offspring. The table summarises possible combinations of maternal and paternal alleles. In this way, the genotypic outcomes or probabilities of the offspring of a single trait (allele), or when crossing multiple traits from the parents can be visually examined. The female gametes are usually represented by the symbol ♀ and male gamete as ♂.

Example 2.3

A pure breed pea with green pods was crossed with a pure breed pea with yellow pods. If the genes for green pods are dominant over the genes for yellow pods, use punnet square to determine the phenotypic ratios of F_2 generation.

Solution

Let letter G represent the gene for green pods and g represent the gene for yellow pods.

♀ \ ♂	G	G
g	Gg	Gg
g	Gg	Gg

Figure 2.16: A punnet square for genes of green and yellow pods

Figure 2.16 shows that all the F_1 generation will be phenotypically green and genotypically Gg.

When the F_1 are selfed;

♀ \ ♂	G	g
G	GG	Gg
g	Gg	gg

Figure 2.17: A Punnet square for the F_1 cross for green pods genes

Phenotypic ratio is 3: 1
Genotypic ratio is 1: 2: 1

Figure 2.17 shows that when the F_1 offsprings were selfed, the result was green and yellow pods in the phenotypic ratio of 3:1 phenotypically. This is a basic Mendelian phenotypic ratio for a monohybrid cross.

Methods of determining unknown genotypes

Determination of genotype of an individual involve back cross and test cross.

Back cross

This is a cross between a hybrid with any of its parents or with an individual that is genetically similar to its parents. The aim of doing this is to get an offspring with certain qualities that the parents had. The backcross is useful in genetics studies for isolating certain characteristics in a related group of individuals. This is mostly applied in horticulture and animal breeding. In back cross, the F_1 hybrids may be crossed with either the homozygous dominant parent or homozygous recessive parent as shown in Figure 2.18.

BIOLOGY FORM 4.indd 50 09/03/2022 19:02

Parents round x wrinkled

RR rr

F_1 generation Rr

Crossing F_1 with homozygous dominant parent

Phenotype round x wrinkled

Genotype RR Rr

Gametes R R r r

Offspring

Gametes	Gametes	
	R	R
R	RR	RR
r	Rr	Rr

Phenotypically 100% will be round

Genotypically 50% will be RR and 50% will be Rr

Crossing F_1 with homozygous recessive parent

Phenotype round x wrinkled

Genotype Rr rr

Gametes R r r r

Offspring

Gametes	Gametes	
	R	r
r	Rr	rr
r	Rr	rr

Phenotypically 50% will be round and 50% wrinkled

Genotypically 50% will be Rr and 50% rr

Figure 2.18: Back cross between F_1 with its parents

Test cross

This is a cross between an organism showing a dominant trait but of unknown genotype with an organism that is homozygous recessive for a trait. Test cross is used to discover the unknown genotype of an individual showing a dominant trait. An example of test cross is shown in Figure 2.19.

Let Y represent the gene for yellow seed

Let y represent the gene for green seed

Parents Y? yy

Gametes from recessive genotype	Gametes from unknown genotype	
	Y	y
y	Yy	yy
y	Yy	yy

A test cross producing 1:1 ratio of yellow to green offspring indicates that the unknown genotype is heterozygous

Gametes from recessive genotype	Gametes from unknown genotype	
	Y	Y
y	Yy	Yy
y	Yy	Yy

A test cross producing all offspring with dominant trait indicates that the unknown genotype is homozygous dominant

Figure 2.19: Test cross to determine unknown parental genotype showing dominant phenotype.

BIOLOGY FORM 4.indd 51 09/03/2022 19:02

Test cross versus back cross

These are two different types of crosses that are extremely helpful in identifying the genotype of an individual. Table 2.4 summarises the difference between test cross and back cross.

Table 2.4: The major differences between the test cross and back cross

Test cross	Back cross
Involves crossing of the dominant phenotype with the homozygous recessive phenotype (parent)	Involves crossing of F_1 generation with one of its parents
All test crosses are backcrosses	A backcross can be considered as a test cross only if the parent is recessive.
The F_1 hybrid is crossed with a recessive genotype	The F_1 hybrid is crossed with either homozygous dominant or heterozygous genotypes
Helps in the identification of the genotype of the individual showing a dominant phenotype	Helps to identify the desired genotype by checking the segregation of genes at the time of gamete formation

Exercise 2.2

1. What is the phenotypic and genotypic ratio obtained after crossing the pure breeding tall plant with the heterozygous tall plant, assuming that the gene for tallness is dominant.
2. Why did Mendel choose garden pea plants for his experiments?
3. A black mouse mates with a white mouse and all the F_1 offspring were black.
   (a) What does this suggest about hair colour in mice?
   (b) Show all the crosses for the F_2 generation using a Punnet square.
   (c) What will be the phenotypic and genotypic ratio of F_2 generation?
4. Cyst fibrosis is controlled by a recessive allele. Using appropriate symbols complete a Punnet square to show the probable outcome of mating between a couple, both of them are heterozygous for this gene.
5. Describe two experimental innovations introduced by Mendel that allowed him to discover his laws of inheritance.
6. What were the major conclusions of the Mendel's experiments?
7. Why is Mendel's first law referred to as the law of segregation?

Non-Mendelian inheritance

Non-Mendelian inheritance is any pattern of inheritance that does not follow Mendel's laws of inheritance. In this case, traits observed in the resulting offspring do not segregate as suggested by Gregory Mendel. According to Mendel, each parent contributes one of the two possible alleles for a trait. In this way, Mendel's laws can be used to determine the distribution of phenotypes expected to the population of offspring if the genotypes of both parents are known. However, there are several situations in which the proportions of phenotypes observed in the progenies do not match with the predicted Mendelian ratios. In the patterns of Mendelian inheritance, the F_1 progenies of pure line parents have the same trait. When this pattern is not observed, the inheritance is said to be non-Mendelian. There are two main patterns of inheritance that are non-Mendelian. These are incomplete dominance and codominance.

Incomplete dominance

This is a pattern of inheritance whereby no gene completely masks the expression of the other gene. In this pattern, both of the contrasting genes blend equally and express themselves in the offspring. This results into the formation of an intermediate form of a character. For example, in four o'clock flower plant (*Mirabilis jalapa)* incomplete dominance occurs when homozygous red flowered plants (RR) are crossed with white flowered plant (WW). All of the resulting progenies are pink flowered plants (RW) as shown in Figure 2.20. These heterozygous individuals do not resemble any of the parents. Mendelian inheritance focuses primarily on situations where one allele at a gene locus is completely dominant over the alternative allele in phenotypic expression. Incomplete dominance can also be seen in the blending of colours among the *Bougainvillea* flowers.

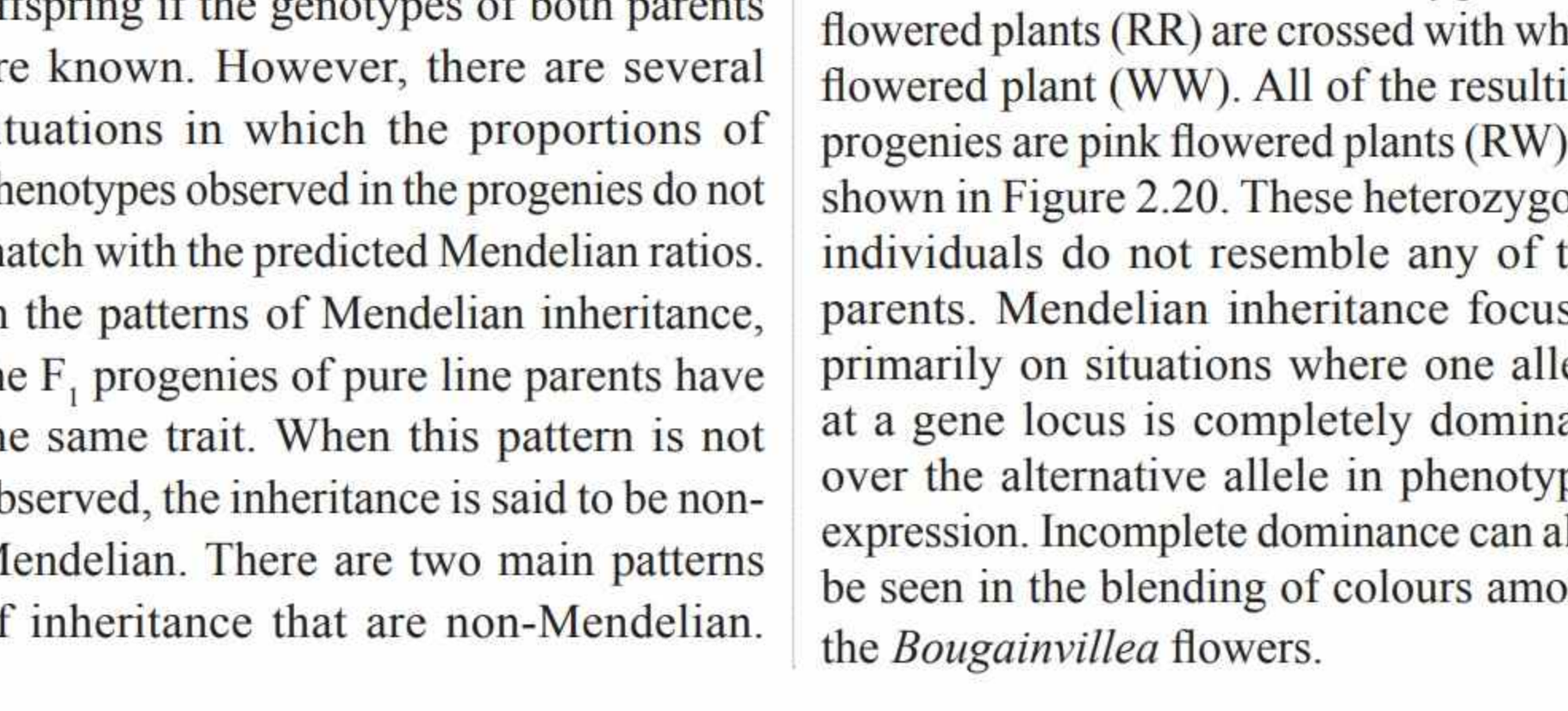


Figure 2.20: Incomplete dominance in *Mirabilis jalapa* flower

BIOLOGY FORM 4.indd 53 09/03/2022 19:02

Example 2.4

In a certain plant species, some individuals produce red coloured flowers while others produce white flowers. A plant that produces red flowers was crossed with a plant that produces white flowers, and all the F_1 generation progenies produced pink flowers.

(a) What were the genotypes of the F_1 generation progenies?

(b) Give the genotypic ratio of F_2 generation progenies.

Solution

Let the gene for red colour be R

Let the gene for white colour be W

(a)

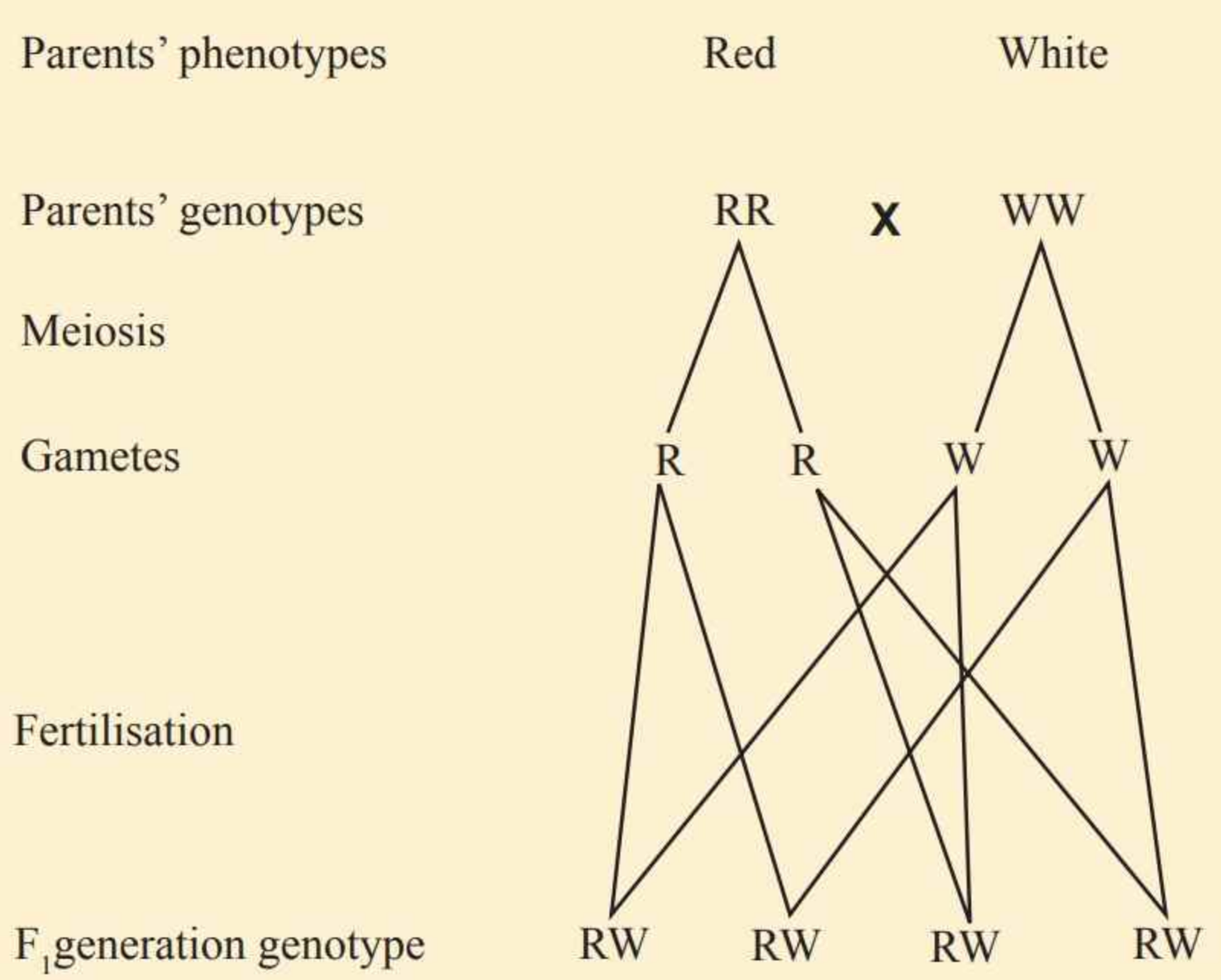


Figure 2.21: A cross between red and white flowered plants

Phenotype of F_1 progenies: all will be pink flowered

Genotype of F_1 progenies: all will be heterozygous RW.

BIOLOGY FORM 4.indd 54 09/03/2022 19:02

(b)

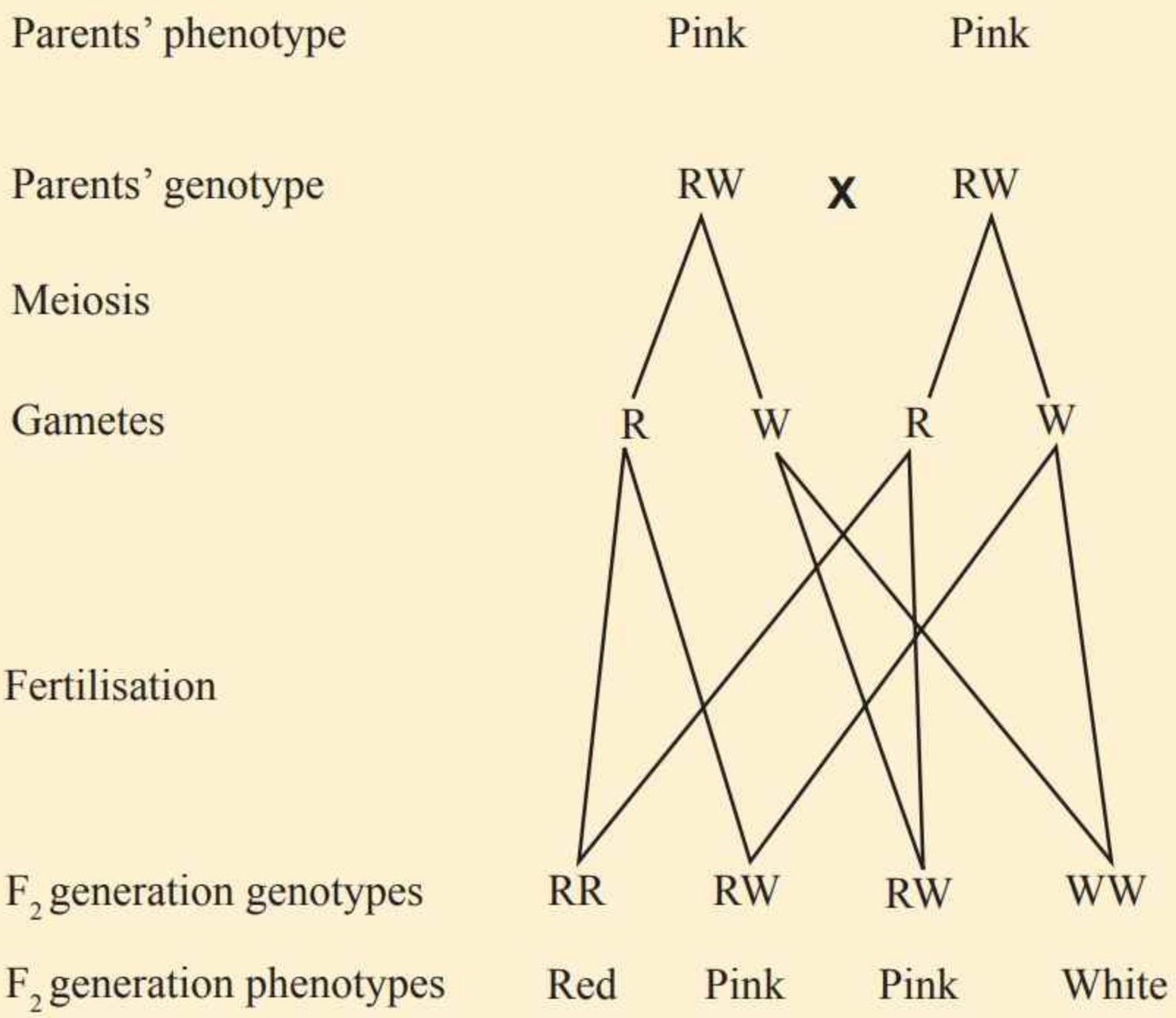


Figure 2.22: A cross between heterozygous pink flowered plants

From figure 2.22 the phenotypes of the F_2 generation will be red, pink and white flowers in the ratio of 1:2:1.

The genotype of the flowers will be homozygous red, heterozygous pink and homozygous white flower in the ratio of 1:2:1.

Codominance

Codominance occurs when both genes of an allelomorphic pair produce their effects in an individual as shown in Figure 2.23. In this situation, the genes for a particular trait are both dominant hence none of them masks the other and each gene expresses its character in the offspring. In heterozygous condition both genes are fully expressed. Thus, the trait is neither dominant nor recessive. A good example is shown when a black fur cow mates with a white fur bull. The F_1 generation offspring will have a mixture of white and black fur. Such fur is called roan, where by neither the white nor the black fur masked the other, but both are expressed in the offspring. However, in the F_2 generation

BIOLOGY FORM 4.indd 55 09/03/2022 19:02

there will be a mixture of the black, white, and the roan fur calves. When performing codominance crosses, different capital letters are used to indicate the genes, unlike in complete dominance where the contrasting characters are shown by small and capital letters.

Let B be gene for black fur
Let W be gene for white fur

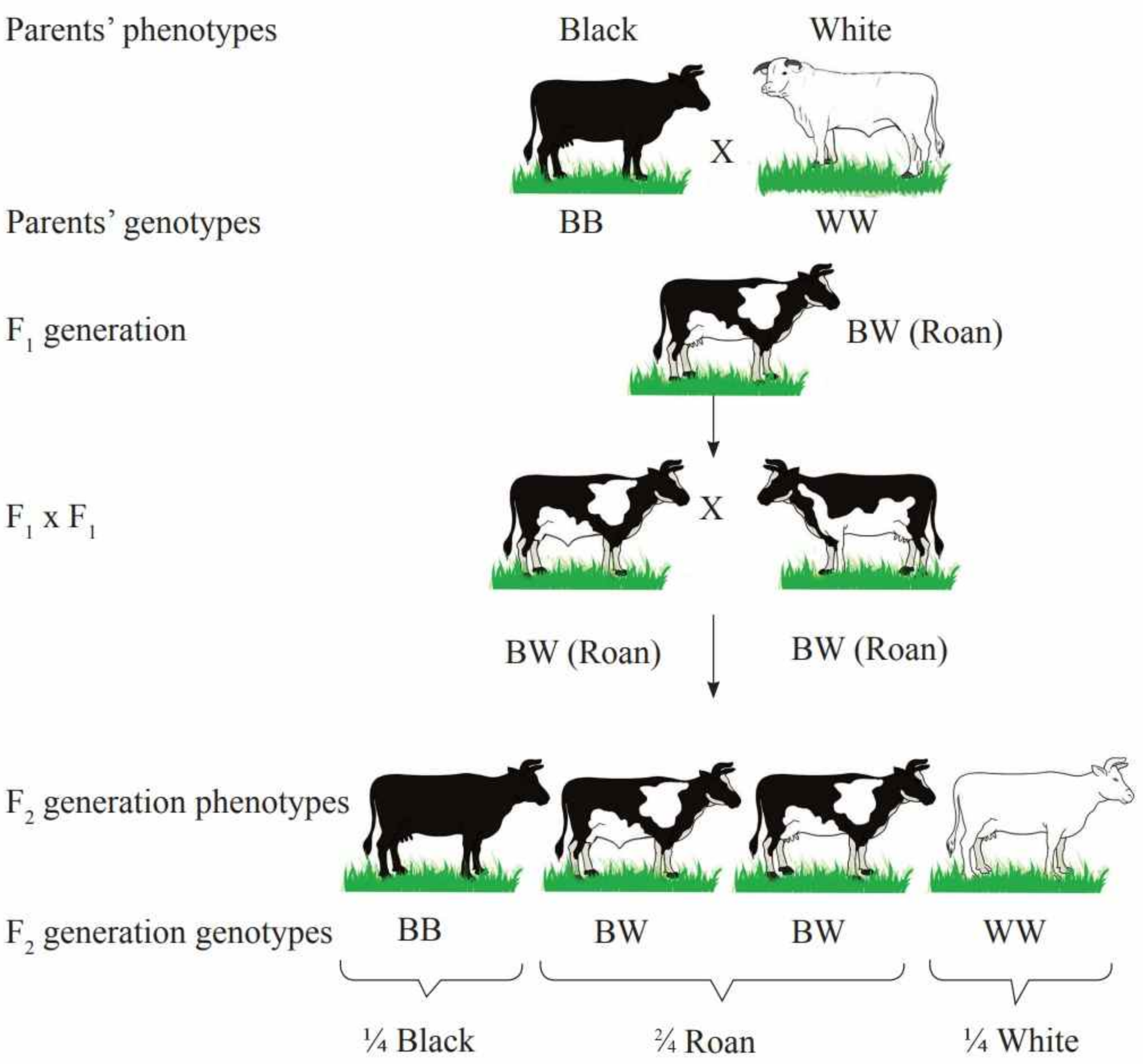


Figure 2.23: Codominance inheritance of coat colour in cattle

Consider the cross between a black fur cow and a white fur bull.
Let the allele for black fur cow be B and that for a white fur bull be W.
The parents' genotypes will be BB and WW.

BIOLOGY FORM 4.indd 56 09/03/2022 19:02

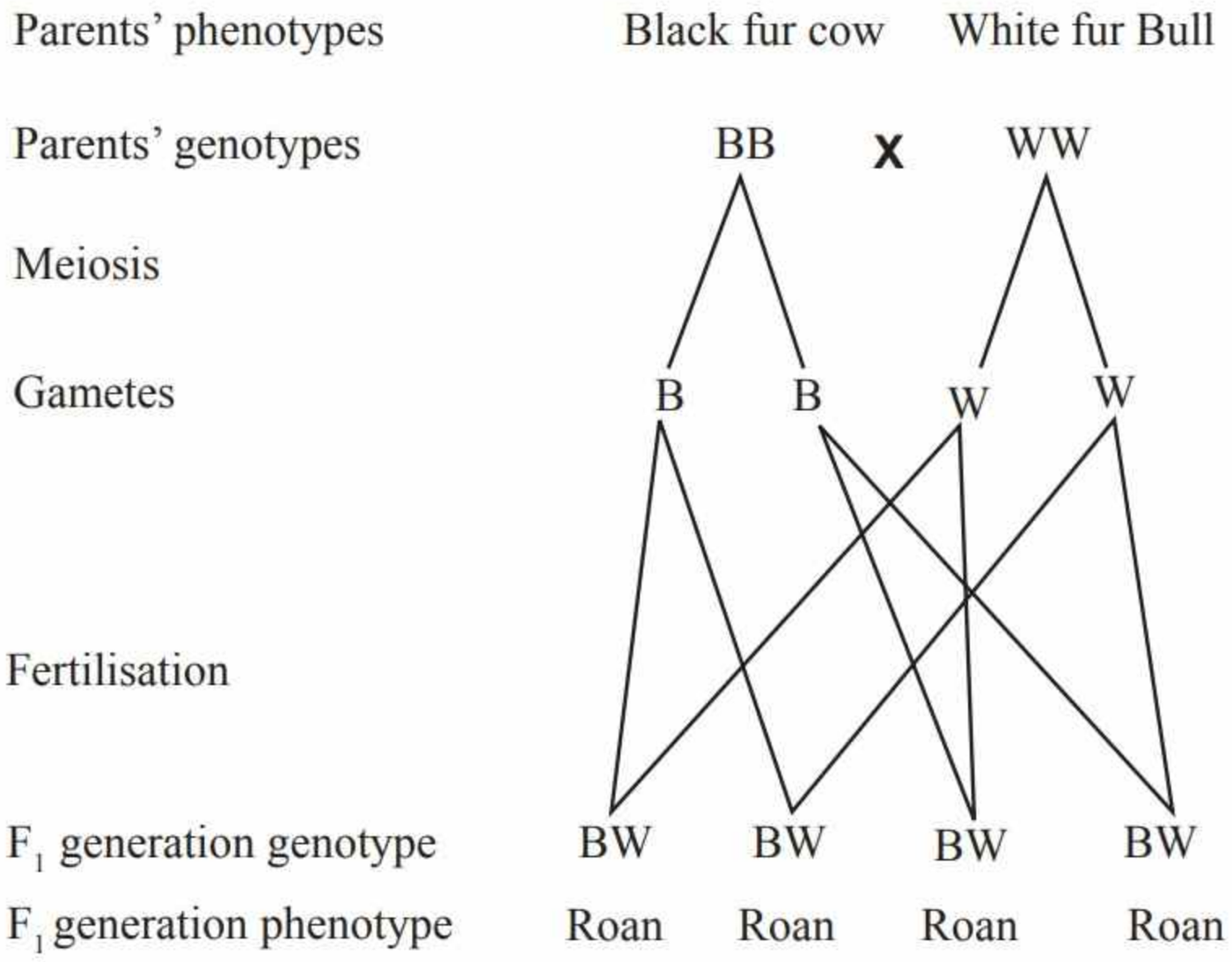


Figure 2.24: A cross between a black cow and a white fur bull

Figure 2.24 shows that all the offspring in the F_1 generation will be roan with a genotype of BW.

When the F_1 generation offspring are selfed, the resulting F_2 offspring will have BB, BW and WW in the ratio of 1:2:1 as shown in Figure 2.25.

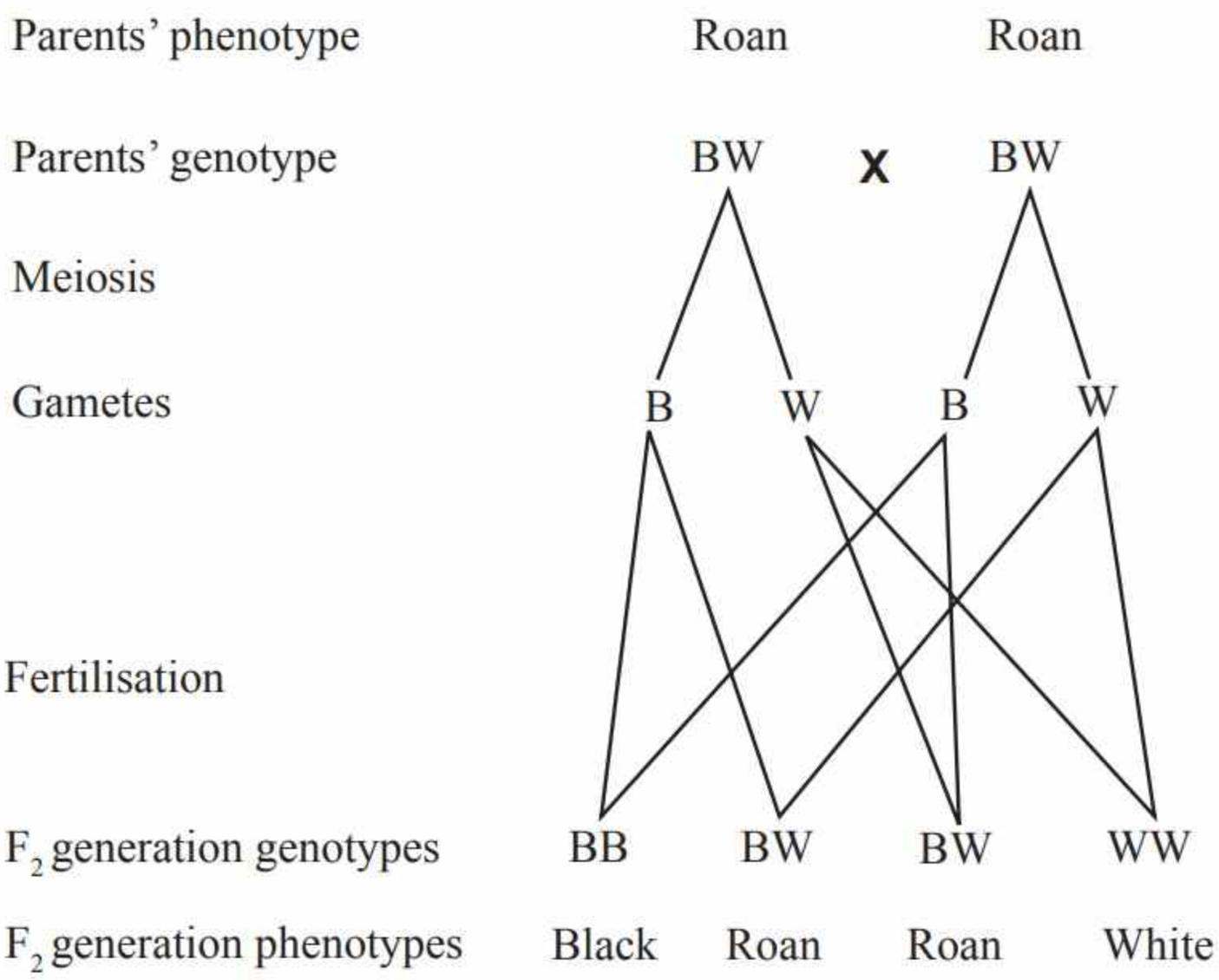


Figure 2.25: A cross between a roan cow and a roan bull

BIOLOGY FORM 4.indd 57 09/03/2022 19:02

Codominance inheritance of blood group

Just like eye or hair colour, human blood group is inherited from parents and is controlled by an autosomal gene. The gene locus is represented by symbol I. There are three genes which are represented by the letters A, B and O. The genes for blood group A and blood group B are dominant whereas those for blood group O are recessive to both. In this regard, the system is called the ABO system. Each biological parent donates one of two alleles to their offsprings. The possible human phenotypes for blood groups are A, B, AB, and O, as shown in Table 2.5. An individual's blood group depends on which genes they inherited from their parents. If one of the parents is homozygous blood group A and the other is homozygous blood group B the F_1 generation will be phenotypically AB for blood group and not A or B as it could be expected in the Mendelian dominance pattern. Both A and B genes are co-dominant, meaning that if a person inherits the AB blood genotype, both genes will be expressed as phenotype AB. Blood group A and B individuals can be either homozygous (I^AI^A or I^BI^B, respectively), or heterozygous (I^AI^o or I^BI^o, respectively). For an individual to have blood group O, he or she must inherit the recessive gene for blood group O from both parents (I^oI^o).

Table 2.5: Possible genotype of human blood groups

Allele from 1st Parent	Allele from 2nd Parent	Genotype of Offspring	Blood group of Offspring
I^A	I^A	I^AI^A	A
I^A	I^O	I^AI^O	A
I^B	I^B	I^BI^B	B
I^B	I^O	I^BI^O	B
I^A	I^B	I^AI^B	AB
I^B	I^A	I^BI^A	AB
I^O	I^O	I^OI^O	O

The frequency of ABO groups varies in different ethnic populations. Hence, this must be taken into account when recruiting representative blood donor panels.

Example 2.5

What would be the blood groups of children whose one of the parent has blood group O and another has heterozygous group A?

Solution

Parents' phenotypes	Blood group A	Blood group O
Parents' genotypes	I^AI^O	I^OI^O
Meiosis		
Gametes	I^A I^O	I^O I^O
Fertilisation		
F_1 generation genotypes	I^AI^O	I^AI^O I^OI^O I^OI^O
F_1 generation phenotypes	Blood group A	Blood group A Blood group O Blood group O

Figure 2.26: A cross between blood group A and group O parents

The genotypes of the offspring will be $I^A I^o$ and $I^o I^o$

From Figure 2.26, half of the children will have blood group A and the other half will be blood group O. Therefore, the phenotypic ratio will be 1:1.

Example 2.6

A woman with blood group A claims that a man with blood group B is the father of her child. A blood test reveals that the child's blood is group O. Is it possible that the alleged man is the biological father of the child?

Solution

The possible genotypes of woman can be $I^A I^A$ or $I^A I^o$ and the possible genotypes of the alleged father can be $I^B I^B$ or $I^B I^o$

BIOLOGY FORM 4.indd 59 09/03/2022 19:02

1st Case: Let the parents' genotypes be $I^A I^A$ and $I^B I^B$

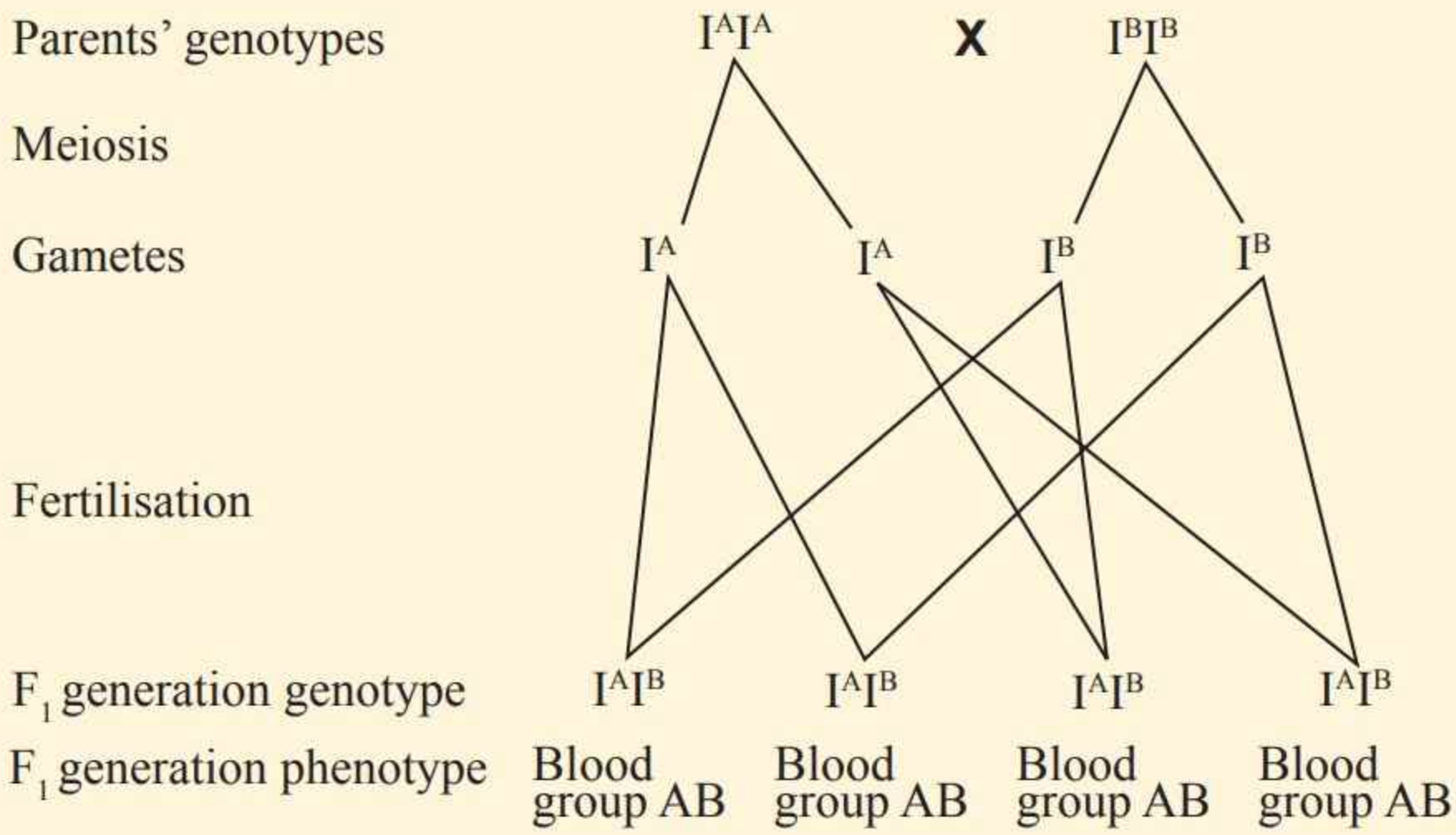


Figure 2.27: A cross between homozygous blood group A and group B parents

For the assumption of genotypes in 1st case, all the children will have type AB blood group.

2nd Case: Let the parents' genotypes be $I^A I^A$ and $I^B I^O$

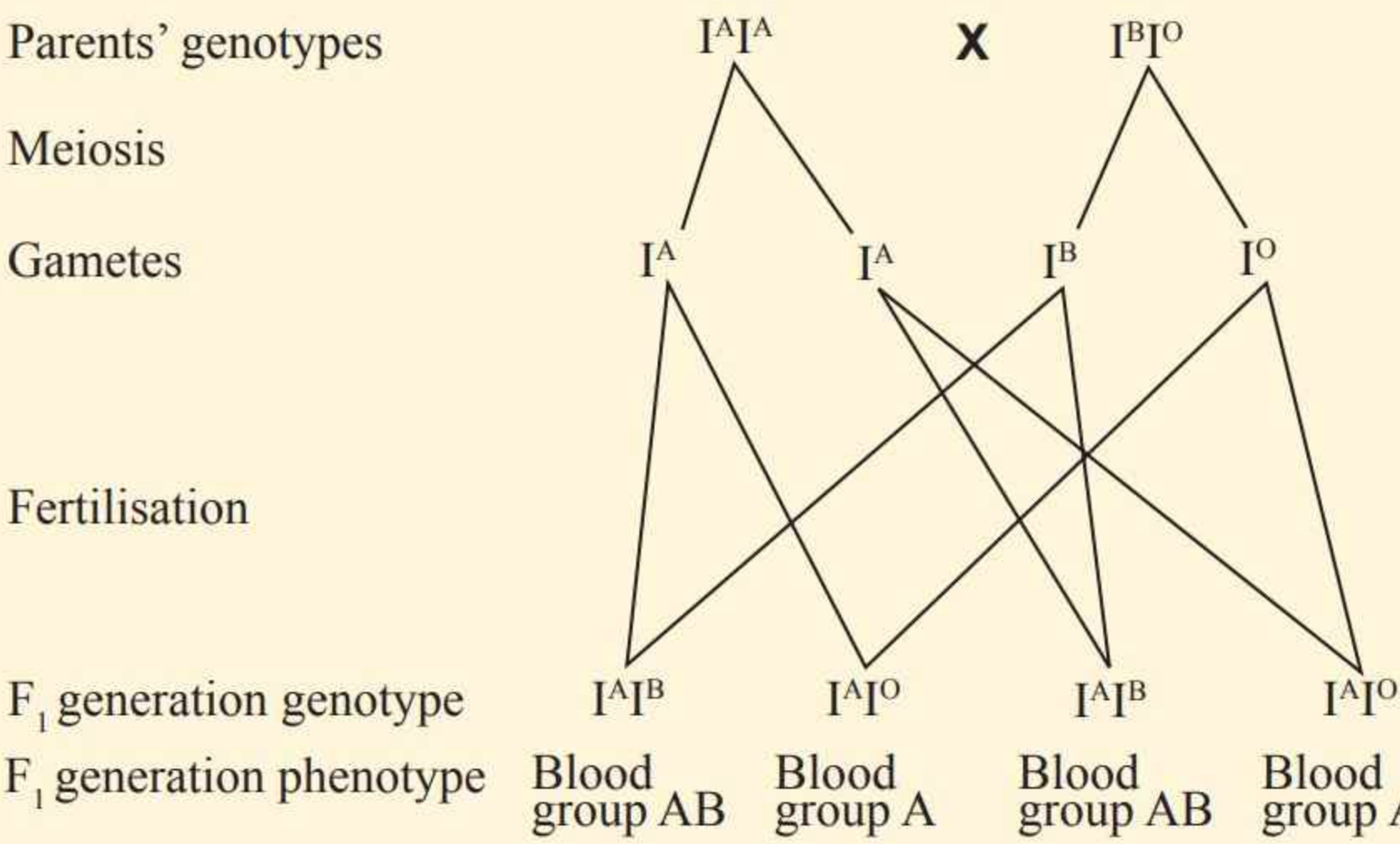


Figure 2.28: A cross between homozygous blood group A parent and heterozygous blood group B parents

The resulting offspring will have blood groups AB and A only.

BIOLOGY FORM 4.indd 60 09/03/2022 19:02

3rd Case: let the genotypes of the parents be $I^A I^O$ and $I^B I^B$

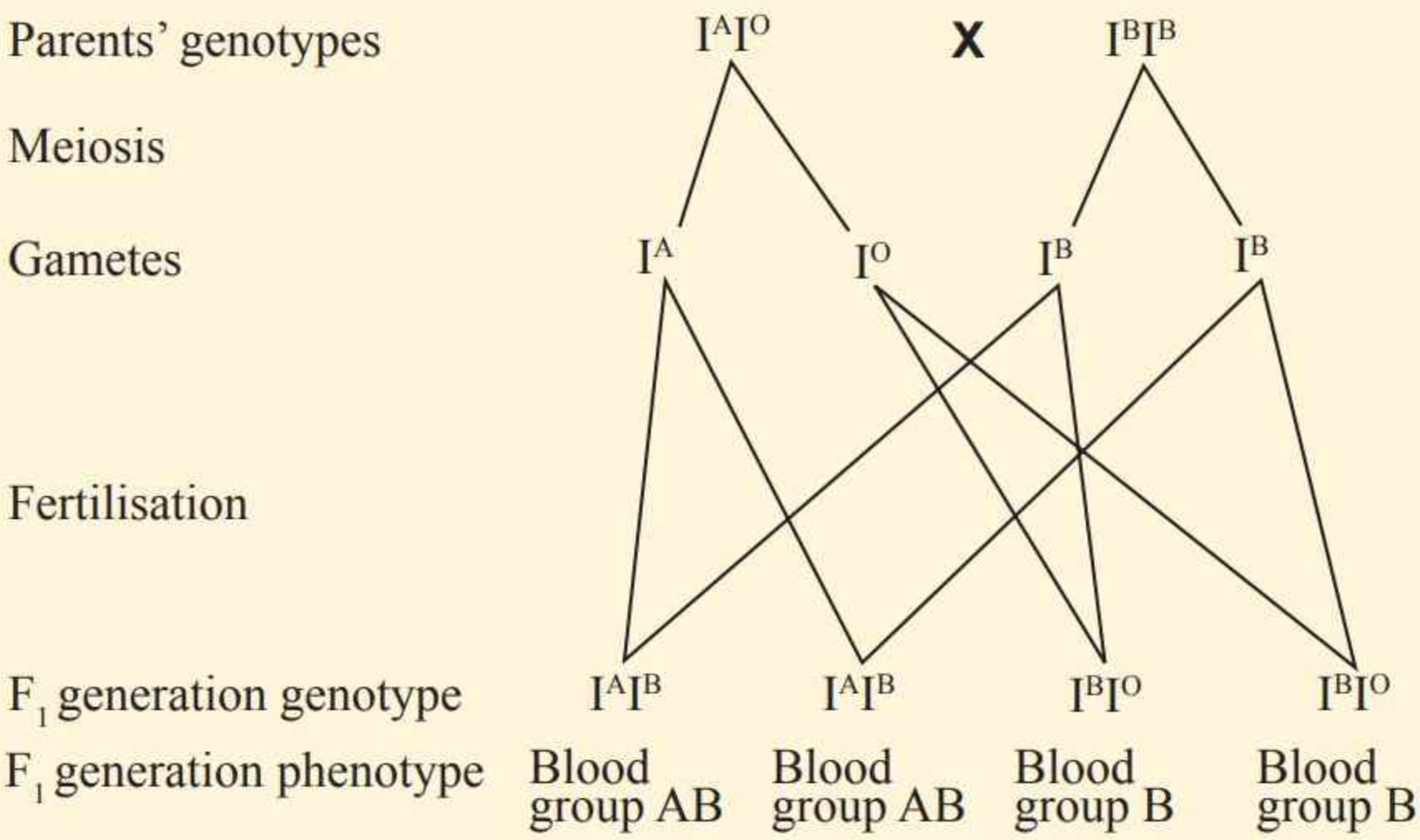


Figure 2.29: A cross between heterozygous blood group A and homozygous blood group B parents

The resulting offspring will have blood group AB and B only.

4th Case: let the genotypes of parents be $I^A I^O$ and $I^B I^O$

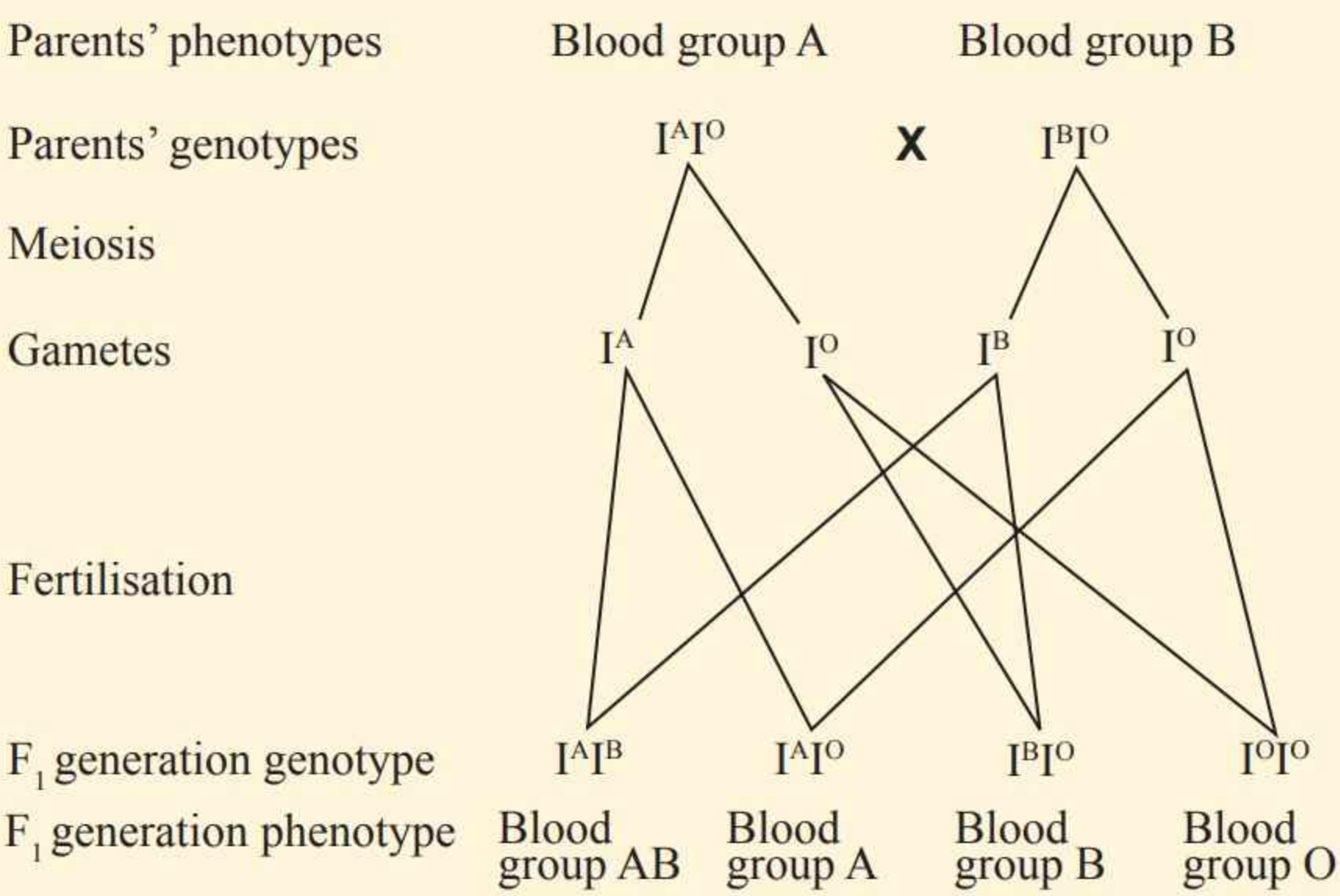


Figure 2.30: A cross between heterozygous blood group A and heterozygous blood group B parents

The resulting offspring will have blood type AB, A, B, and O.

BIOLOGY FORM 4.indd 61 09/03/2022 19:02

The child will have blood group O only if the genotype of the mother is I^AI^O and that of the father is $I^B I^O$. Therefore, the alleged man cannot be excluded as the possible biological father of the child.

Rhesus factor

The Rhesus factor, also denoted as Rh factor, is a type of protein found on the surface of red blood cells. This protein is genetically inherited from parents. About 85% of the world's human population possess this antigen and are described as Rhesus positive (Rh^+). Those without this type of protein are described as Rhesus negative (Rh^-).

Normally, blood group of an individual is classified with the positive or negative sign next to the blood group to indicate the presence or absence of the Rhesus factor on the surface of red blood cells. Human blood groups can be classified into eight groups, based on the presence or absence of antigens on the red blood cells as shown in Table 2.6. Although Rh positive is the most common blood type, having a Rh-negative typing does not indicate illness and usually does not affect the health of an individual.

Usually blood typing is done during blood donation and transfusion to determine blood type and Rh factor. Normally, someone with Rh^+ blood group can receive blood from both Rh^+ and Rh^- blood during transfusion, but those with Rh^- can only receive Rh^- blood. This is because Rh^+ blood transfusion can cause a person with Rh^- blood to make antibodies against the Rh factor. This can lead to transfusion reactions. In the case of pregnancy, problems may occur in subsequent birth after the first childbirth if the mother is Rh^- and a foetus is Rh^+. It is routine and important that the Rh factor for a mother and biological father be determined during pregnancy in order to predict the status of the unborn baby. This is because when a Rh^- mother is carrying a Rh^+ foetus, blood cells from the foetus may cross into the mother's blood during pregnancy, labour or delivery. In this case mother's immune system will treat the foetus blood cells as a foreign bodies and produce antibodies against them. First born are often not affected unless the mother had past miscarriage. However, the subsequent pregnancies will result into stillbirth or death after birth due to existence of antibodies against the positive Rh factor. Rh^- mothers are usually given treatment during pre-natal care to prevent this problem.

BIOLOGY FORM 4.indd 62 09/03/2022 19:02

Table 2.6: Rhesus factor classification in human blood groups

Blood group	Antigen on Red Blood Cells	Rhesus factor	Donating	Accepting
A^+	A	Present	A^+, AB^+	A^+, A^-, O^+, O^-
A^-	A	Absent	A^+, A^-, AB^+, AB^-	A^-, O^-
B^+	B	Present	B^+, AB^+	B^+, B^-, O^+, O^-
B^-	B	Absent	B^+, B^-, AB^+, AB^-	B^-, O^-
AB^+	A and B	Present	AB^+	Everyone
AB^-	A and B	Absent	AB^+, AB^-	AB^-, A^-, B^-, O^-
O^+	None	Present	O^+, A^+, B^+, AB^+	O^+, O^-
O^-	None	Absent	Everyone	O^-

Exercise 2.3

1. A man who is homozygous for brown iris marries a woman who has blue iris. Show the results of the F_1. What would be the colour of iris of the resulting offspring if two members of the F_1 are crossed? Assume brown colour to be dominant over blue.
2. A pure red flowered plant was crossed with a pure yellow flowered plant. The offspring for the first filial generation were all phenotypically red flowered plants. Show the genotypic and phenotypic ratio of F_1 and F_2 using Punnet square.
3. A red-flowered rose was crossed with a white flowered rose and all members of the F_1 were pink. When the pink flowered plants were selfed, a mixture of red, pink, and white flowered plants were obtained. Illustrate the above information using genetic cross diagrams.
4. A brown cow was mated with a white bull. In the F_1 generation all the offspring had equal patches of brown and white fur. Show the F_1 and F_2 genotypic and phenotypic ratios using Punnet squares.
5. In cattle, RR = brown, Rr = roan, and rr = white. What are the expected phenotypes and their frequencies in the offspring resulting from crosses between:
   (a) a brown bull and a white cow?
   (b) a brown bull and a roan cow?
   (c) a roan bull and a roan cow?
6. In peas, seeds may be round (R) or wrinkled (r). What proportion of the offspring in the following crosses would be expected to have wrinkled seeds?
   (a) RR x rr
   (b) Rr x Rr
   (c) Rr x rr (assume that the capital letters denote a dominant trait and lowercase letters the recessive trait)
7. What happens if a Rh^+ blood is given during transfusion to a Rh^- person?

BIOLOGY FORM 4.indd 63 09/03/2022 19:02

Sex determination and inheritance

The sex of an organism is determined by the gene located in the sex chromosomes. Every organism has a fixed number of chromosomes in its cells. In human beings there are 46 chromosomes in somatic cells which is equivalent to 23 pairs of chromosomes that carry different characteristics from one generation to another. Among the 23 pairs, only one pair is the sex chromosomes. This pair is responsible for sex determination and the remaining pairs are autosomal chromosomes (or simply autosomes). Autosomal chromosomes are the chromosomes that control different somatic characters. The two sex chromosomes are dimorphic and they are denoted as X and Y chromosomes.

The two sex chromosomes in the cells of females are similar in size and shape. They are both X chromosomes thus females are said to be homogametic organisms. In contrast, males have chromosomes with different sizes whereby one has longer tails (X chromosome) and the other has shorter tails (Y chromosome). The possession of X and Y chromosomes makes males to be called heterogametic organisms.

In human, female inherit an X chromosome from each parent, where male always inherit their X chromosome from their mother and Y chromosome from their father. Hence, when a Y chromosome fertilises the egg, the resulting offspring is male and if the X chromosome fertilises the egg, the resulting offspring is female, as illustrated in Figure 2.31.

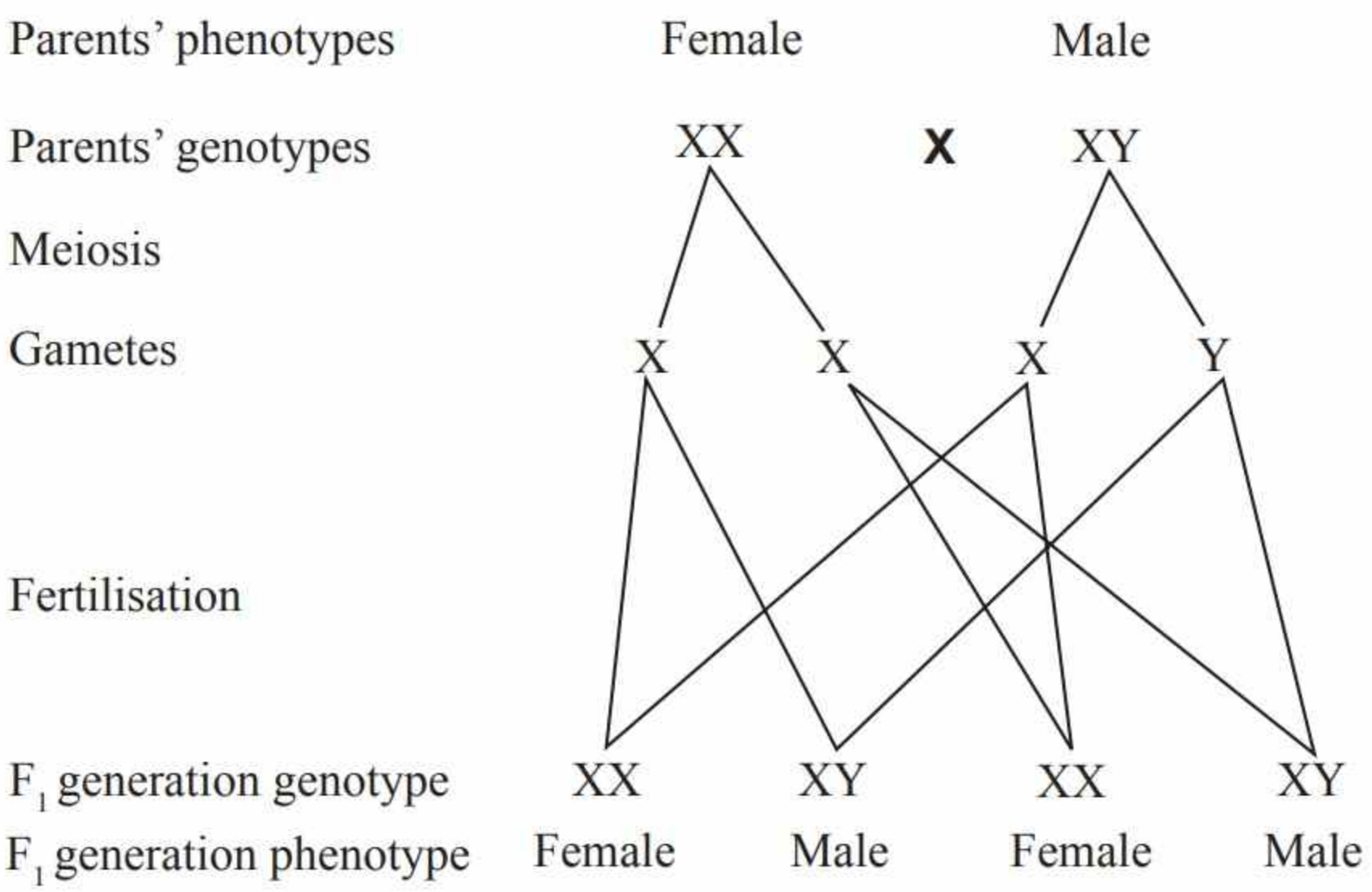


Figure 2.31: A cross for sex determination in the offspring

The ratio is 2 females: 2 males which is 1:1

From Figure 2.31, the genotype for the girl is XX while that of the boy is XY. In this respect, the determination of the sex of the child in human beings depends on the type of sperm that fuses with the ovum. The chance of producing a female offspring is 50% and that of male is 50%.

Sex linked characters

Sex-linked characters are observable features of an organism which are controlled by genes located on the sex chromosome. In human, these genes are carried on the X chromosome. Examples of a sex linked characters in human include haemophilia and colour blindness. It could be expected that the sex chromosomes could only have the genes concerned with sex but it is not so, rather the sex chromosomes carry genes other than the sex determining genes. Some somatic genes are also carried on these chromosomes. The somatic genes attached to the sex chromosomes are thus said to be sex linked genes. These genes have nothing to do with sex determination. They can thus carry other characteristics, hence those characters are said to be sex linked.

Most of the sex-linked genes are carried on the X chromosomes and not on Y chromosomes. This is because of the structural differences between the two chromosomes. X chromosomes have a longer tail which has ability to carry more genes than Y chromosomes. Y-linked traits are passed only from father to son. There are very few characters that are carried on Y chromosome, for instance the holandric gene that determine the growth of hairs on the pinna of some men. This character is only found in men as shown in Figure 2.32.

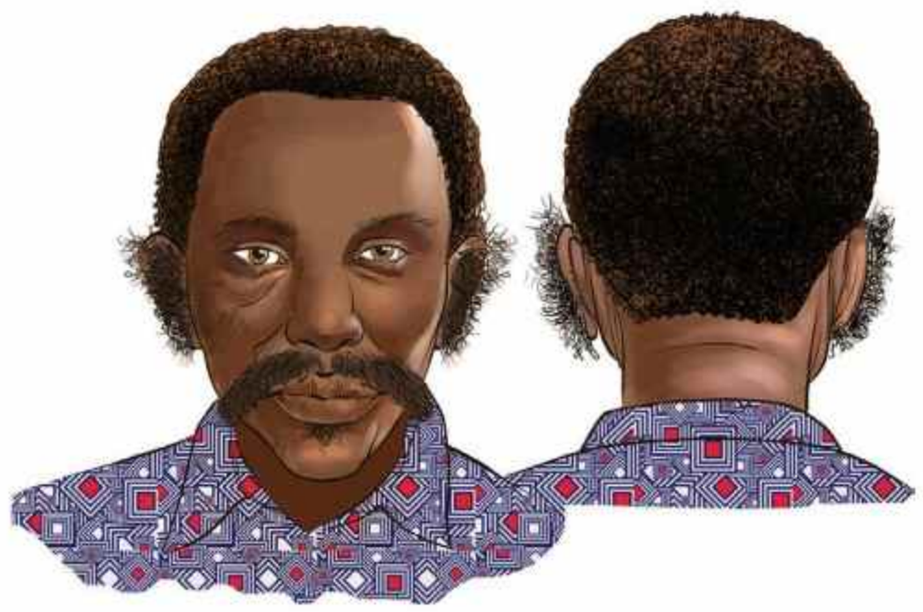


Figure 2.32: Hairy pinna

However, the most common and familiar sex linked characters are haemophilia and red-green colour blindness.

Haemophilia

This is a hereditary trait in which an individual's blood is unable to clot. Haemophilia is caused by lack of clotting factors or proteins in the blood. This leads to prolonged bleeding which can lead to serious blood loss and if measures to induce clotting are not taken can result into death. But this is usually not a problem when a haemophilic person has minor cuts or scratches. Haemophilia is also accompanied by the tendency of bleeding in joints, skin and muscles. The condition causes more deaths. This is especially among children because they are more likely to injure themselves compared to adults. Normally, when a person has a cut, substances in the blood known as clotting factors mix with blood cells called platelets to make the blood sticky and form a clot at the injured site. This eventually stops the bleeding. People with haemophilia do not have as many clotting factors as they should have in their blood. Haemophilia is a recessive sex linked blood disorder. The condition primarily

BIOLOGY FORM 4.indd 65 09/03/2022 19:02

affects males but females can also have this condition. A male inherits this gene on the X chromosome. Females can also have haemophilia, but it is much rare since both X chromosomes must have the gene for the disease to express itself. The probability for this to occur is very low. Only the homozygous recessive female individuals can show the phenotypic signs of the condition whereas heterozygous individuals are carriers of the trait. A carrier female can pass the affected gene on to her children. The condition can be minimised by avoiding marriage among close relatives. There is no cure for haemophilia, but clotting factor concentrates can be administered to replace the missing clotting factor proteins to stop excessive bleeding. These proteins are given in the form of injection. People with hemophilia should avoid sports such as football. They should also avoid certain painkiller medications such as aspirin and ibuprofen which can affect their blood's ability to clot. Lastly, they should have regular teeth and gums check-ups.

Example 2.7

A non-haemophilic man is married to a haemophilic woman. What will be the phenotypes of their resulting offsprings?

Solution

Let the gene for haemophilia be h and the gene for normal condition be H. The genotypes of the parents will be $X^H Y$ and $X^h X^h$.

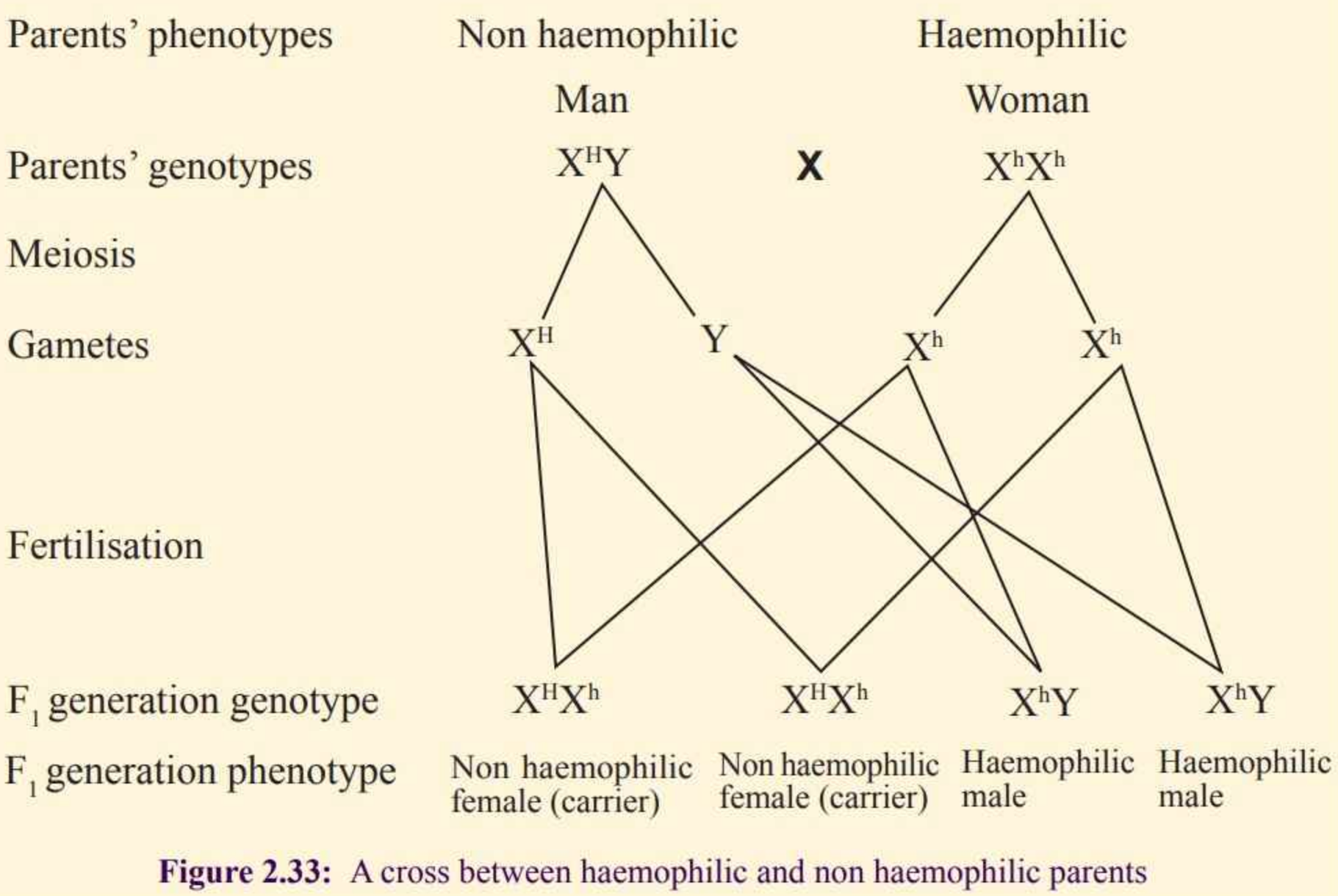


Figure 2.33: A cross between haemophilic and non haemophilic parents

BIOLOGY FORM 4.indd 66 09/03/2022 19:02

Figure 2.33 shows that, the family will have all the male offsprings affected with haemophilia whereas all the female offspring will be carriers, showing no symptoms.

Example 2.8

A certain woman who is a carrier of haemophilia was married to a haemophilic man. Is there any possibility of having phenotypically normal children from the couple?

Solution

Let h represent the gene for haemophilic and H represent the gene for normal condition.

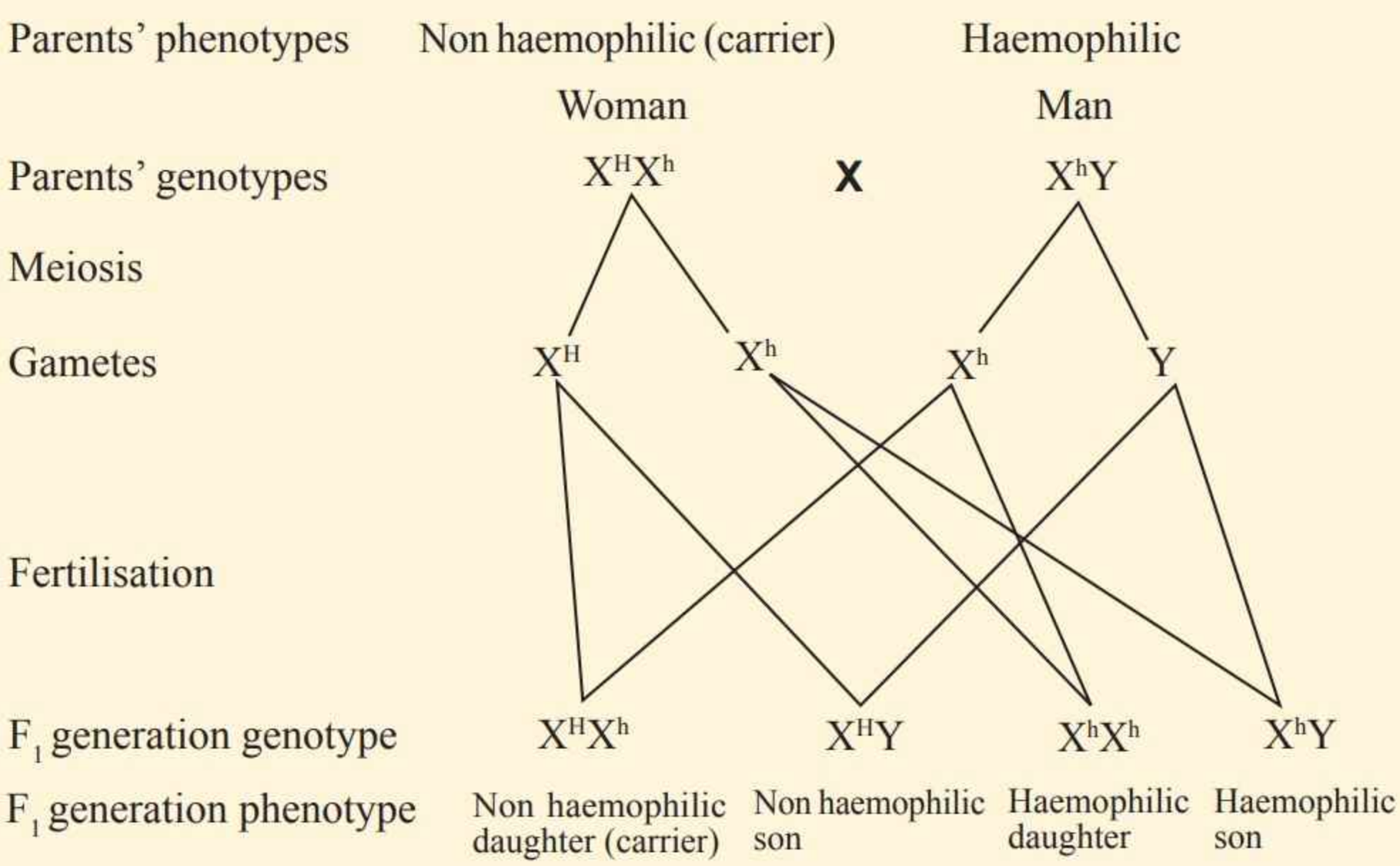


Figure 2.34: A cross between haemophilic and non haemophilic parents

Figure 2.34 shows that the couple will have 50% chance of having a normal child.

Colour blindness

This is the decreased ability to see or distinguish colours. Colour blindness is the most common type of inheritable colour vision deficiency. It is also known as deuteranopia. It is a sex-linked disorder in which a person fails to distinguish between red and green colours. This condition is caused by a recessive gene located on the X chromosome. Since

BIOLOGY FORM 4.indd 67 09/03/2022 19:02

it is passed down on the X chromosome, the disorder is more common in males. This is because males have only one X chromosome and if that chromosome has an allele for colour blindness, they will be colour blind. Currently, there is no treatment available for red-green colour blindness. However, corrective contact lenses may help to neutralise red-green colour blindness. These lenses are in the form of tinted lenses or filters that help a person to see red and green colours more clearly.

A colour blind boy cannot receive a colour blind allele from the father even if the father is a colour blind. This is because a father can only pass an X chromosome to his daughters and not his sons. A colour blind daughter must therefore have a father who is colour blind and a mother who is either a carrier or colour blind.

Example 2.9

A woman carrier of colour blindness was married to a normal man. What will be the probability of getting a normal colour visioned son?

Solution

Let the gene for colour blindness be b and the gene for normal be B. The genotype of the carrier mother is X^BX^b and normal father is X^BY.

Parents' phenotypes	Non colour blind (carrier)		Normal colour vision	
	Woman		Man	
Parents' genotypes	X^BX^b	X	X^BY	
Meiosis				
Gametes	X^B	X^b	X^B	Y
Fertilisation				
F_1 generation genotype	X^BX^B	X^BY	X^BX^b	X^bY
F_1 generation phenotype	Non colour blind daughter	Non colour blind son	Non colour blind daughter (carrier)	Colour blind son

Figure 2.35: A cross between a carrier colour blind woman and normal man

Figure 2.35 shows that there is a 50% chance of getting a normal colour visioned son.

Sex limited characteristics

These are characters that are only limited to a particular sex and cannot be found in the other sex. The sex limited traits are controlled by autosomal genes, meaning the genes are not carried on X and Y chromosomes. Therefore, genes from both parents (male and female) contribute to these traits. However, they are only expressed in one sex. In human beings there are some secondary sexual characteristics that only develop in one sex and are not found in the other. For instance, beards are more produced in males due to influence of male hormones. Another common example of sex limited characteristics is the presence of hairy pinna and semen in males. Other examples include milk production and ovulation in females.

Sex-influenced characteristics

These are genetically controlled characters that may appear in organisms of both sexes but are expressed to a different degree in each sex. They are also called sex-controlled characters. Although they may even have identical genotypes in both males and female, they become more noticeable in one sex and almost lost in the other sex. For example, in human beings mammary glands enlarge and become functional only in female. Likewise, other organisms have some characters that mostly develop in one sex and do not develop in another. For instance, the comb and colourful plumage of a cock, the tail feathers in peacock, the horns in male sheep (ram) and the mane in lions as shown in Figure 2.36.

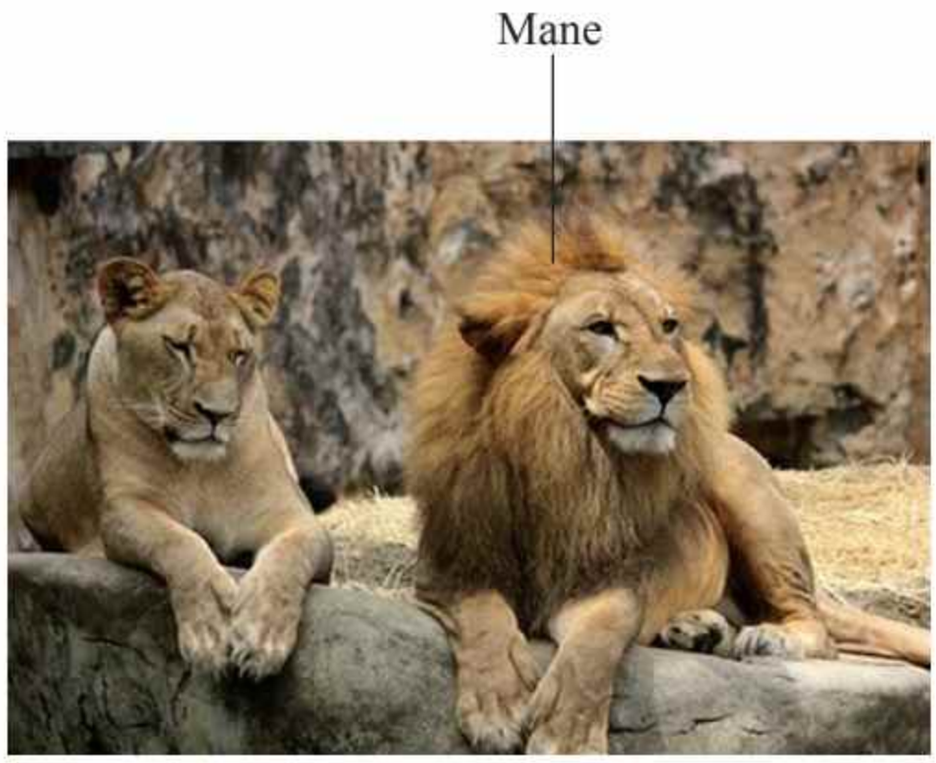


Figure 2.36: A picture showing female and male lion

Sex preference versus Sex selection

Sex preference is favouring a particular sex compared to the other. Sex selection is the process of using various means to achieve the desired sex of offspring. Sex preference and sex selection is usually due to several factors such as economic status, cultural beliefs and certain social prejudices towards a particular sex. Sex preference and sex selection can lead to discrimination and unfair treatment of individuals of particular sex. However, it should be noted that men determine the sex of the baby because 50% of the sperm carry X-chromosome and 50% carry the Y-chromosome while each female egg carry only one X-chromosome. The sex of the baby will depend on whether the egg was fertilised by a sperm carrying X or Y chromosome.

Exercise 2.4

1. Explain why colour blindness is more common in man than in woman?

BIOLOGY FORM 4.indd 69 09/03/2022 19:02

2. Using relevant genetic crosses, show how sex is determined in human beings.
3. With examples differentiate between sex limited and sex influenced traits.
4. What is the probability of having a normal son when a normal woman is married to the haemophilic man?
5. A red flowered plant (RR) is crossed with a white flowered plant (WW). If the gene for petal colour in these plants exhibit incomplete dominance, what will be the genotypic and phenotypic ratio of their offsprings in F_1 and F_2 generation?
6. In humans, the allele for normal blood clotting H, is dominant over the allele for hemophilia, h which is a sex-linked trait found on the X chromosome. A woman with normal blood clotting has four children: a normal son, a hemophiliac son, and two normal daughters. The father has normal blood clotting. What are the genotype for each member of the family?
7. Red-green colour blindness is a recessive sex-linked trait. If a normal-visioned woman whose father is colour blind marries a colour blind man.
   (a) What is the probability of their children being colour blind?
   (b) What is the probability of their sons being normal visioned?

Variation among organisms

Variations is the existence of the differences among organisms within a population. These variations may be in terms of morphology, physiology, cytology and behaviour of individuals. The variations can be caused by either genetic or environmental factors. Variations caused by environmental factors are not inheritable. These variations are generally called acquired variations while variations which are inherited are called inheritable variations. Examples of acquired traits are calluses on fingers, scars and possession of large muscles due to physical exercises.

Types of variations

There are two types of inheritable variations. These include discontinuous and continuous variations.

Discontinuous variations

These are variations that show a clear-cut gap between the extremes of comparison. There are no intermediate forms between the two extremes. The traits are determined by a single pair of genes, and the resulting phenotype is easy to distinguish. It can be simply regarded to be present or absent. The traits which exhibit discontinuous variation are also known as Mendelian traits. Examples of discontinuous variation includes ability to roll the tongue, albinism, blood groups, rhesus factors, fingerprints, sex and haemophilia. Figure 2.37 shows a tongue roller and a non-tongue roller.

BIOLOGY FORM 4.indd 70 09/03/2022 19:02

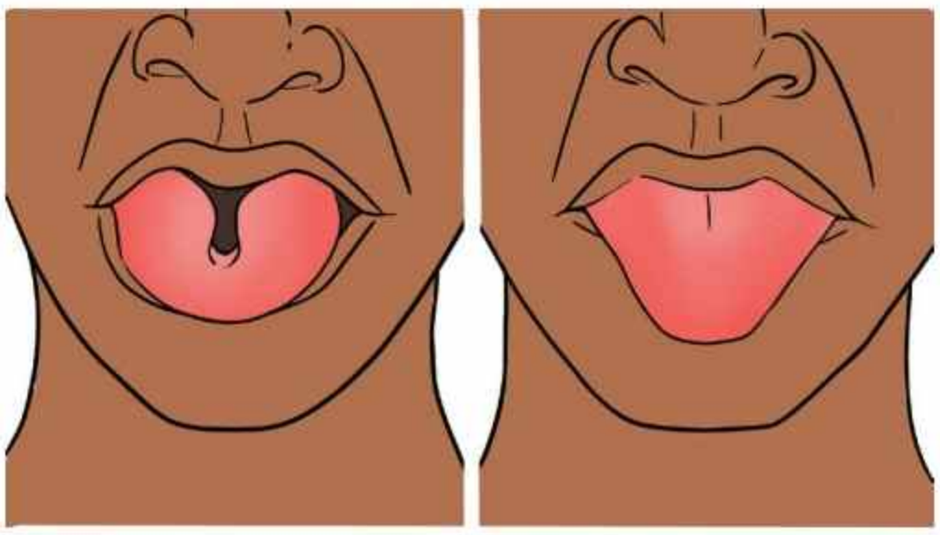


Figure 2.37: (a) Tongue roller (b) non-tongue roller

Continuous variations

These are the variations which are controlled by more than one pair of genes. These variations do not show a clear-cut gap between the two extremes. They usually have many intermediates such that when comparing one must have a point of reference from where one compares the extreme. A continuous trait displays a range of expression, such as those seen in height, weight, skin colour, and intelligence.

The inheritance of continuous traits does not show the phenotypic ratio as per the characteristic of Mendelian inheritance, though each of the genes contributing to the trait is inherited. These are also known as non-Mendelian traits. Skin colour inheritance in humans is a good example of continuous variation. Many genes contribute to the determination of a person's natural skin colour that leads to a wide variation in natural skin colour as shown in Figure 2.38.

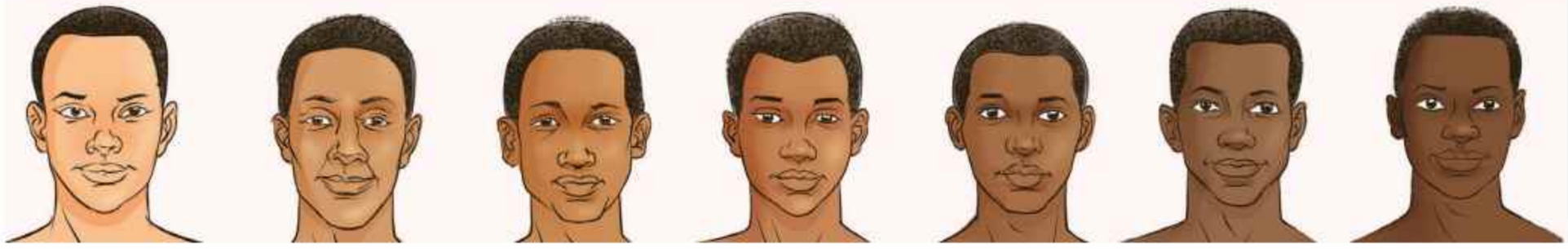


Figure 2.38: Skin colour variations in humans

Importance of variation

Genetic variations have a number of advantages in the population as follows:

1. Variation helps to reduce the occurrence of recessive genetic disorders.
2. Variation helps to increase resistance to certain disease-causing agents.
3. Variation improves the chance of survival of a particular species on the onset of unfavourable conditions.

However, continuous and discontinuous variations differ in many ways as shown in Table 2.7.

Table 2.7: Differences between continuous and discontinuous variation

S/N	Continuous variations	Discontinuous variations
1.	Have intermediate forms	There are no intermediate forms
2.	Are controlled by genes and environment	Are controlled by genes
3.	Tend to be quantitative	Tend to be qualitative.

BIOLOGY FORM 4.indd 71 09/03/2022 19:02

Causes of variations in organisms

Variations in organisms can be caused by a number of factors that are grouped into either genetic or environment factors.

Environmental factors

There are several environmentally related factors that can lead to variations among living organisms. These factors include space, population, food, water, climate, and diseases. All these factors lead to variations among organisms. However, these acquired variations cannot be inherited or passed from one generation to the next since they affect only the phenotype of the organism and not its genetic makeup (genotype).

Genetic factors

These are factors that cause inheritable variations that can be transferred from one generation to another. The genetic factors include crossing over that occurs in meiotic processes, fertilisation, independent assortment during metaphase I to anaphase II stage of meiosis, migration, and mutation.

Crossing over: This is a genetic recombination that occurs during prophase I of meiotic cell division. In this case, chromatids of homologous chromosomes break at the tips and randomly exchange their genetic material, leading to new recombinant chromosomes. This causes most of variations among members of a species to occur. Crossing over enables the swapping of genetic material of two homologous chromosomes. The number of combinations depends on the number of pairs of chromosomes at this stage. In human beings the number is $2n = 46$ chromosomes.

Fertilisation: This is the random fusion of the male and female gametes during sexual reproduction. Fertilisation occurs when a sperm fuses with an egg. When fertilisation occurs there is shuffling of genes. Meiosis and fertilisation create genetic variations by making new combinations of gene variants, the alleles.

Mutation: This is the change in the nucleotide sequence of a gene or in the number or structure of a chromosome(s). Mutation in reproductive cells may be passed on to successive generations. Mutation can occur spontaneously or can be induced by some chemicals and ionising radiations such as X-rays, cosmic rays and ultraviolet light. Some of the mutations can lead to death or serious effects including diseases while some other mutations can just lead to certain variations among individuals.

Independent assortment: The law of independent assortment states that "any one of a pair of characteritics may combine with another pair independently. Independent assortment, together with random fertilisation produce more possibilities for genetic variations among organisms to occur. Independent assortment is a source of genetic variation because it produces new combinations of alleles.

Migration: Migration introduces alleles into the recipient population, if the migrant interbreeds with the individuals in the recipient population. The introduced alleles could lead to increased genetic variations.

BIOLOGY FORM 4.indd 72 09/03/2022 19:02

Activity 2.4:

Investigating the variation among the finger prints

Materials: Ink pad, two plain papers, hand lens, sanitizer, soap, water and towel

Procedure

1. Clean your fingers using soap and water. If there are some stains that do not get easily removed use a hand sanitizer and dry your fingers using a towel.
2. Press the tip of your thumb of the right hand on the ink pad and then press it on the plain sheet of paper.
3. Fellow classmates should follow similar procedure until the papers are full.
4. Use a hand lens to observe the prints.

Questions

(a) Did you find any finger prints that were similar?

(b) Explain whether the observed variation are continous or discontinous?

Exercise 2.5

1. Using relevant examples explain the causes of variation among organisms.
2. How does independent assortment and crossing over leads to variation among organisms?
3. With examples, differentiate between continuous and discontinuous variations.
4. Explain the ways in the which genetic and environmental factors contribute to variations among organisms.
5. What is the importance of genetic variations in population?

Genetic disorders

A genetic disorder is a condition that occurs as a result of mutation. Some disorders can be inherited and passed from parents to offspring, while others are acquired due to changes in an individual's DNA that occur during their lifetime. Radiations and certain cancer-causing chemicals are examples of factors causing induced mutation. They are therefore referred to as mutagenic agents.

Some genetic disorders are fatal or can cause severe health problems, while others are not so harmful. These disorders may range from a defect in a single base mutation in the DNA of one gene to chromosomal abnormalities that involve deletion or addition of entire chromosomes or sets of chromosomes. There are four main classes of genetic diseases or disorders. These are:

(a) Mendelian or single-gene inheritance disorders.

(b) Chromosomal abnormalities or disorders.

(c) Multifactorial genetic inheritance disorders.

(d) Mitochondrial genetic inheritance disorders.

At this level of schooling, the focus will be on Mendelian or single gene inheritance disorder and chromosomal disorders.

BIOLOGY FORM 4.indd 73 09/03/2022 19:02

(a) Mendelian Disorders

Mendelian disorders are genetic disorders that are caused by mutations in one gene which follows Mendelian patterns of inheritance. They are thus called monogenic disorders or single-gene inheritance diseases. The genetic locus at which the mutation takes place may be at the sex chromosomes or in the autosomes. These disorders can either be autosomal dominant, autosomal recessive, sex-linked dominant, or sex-linked recessive.Contrary to sex linked disorders, in the autosomal related disorders both the females and males have equal chance of being affected. Mendelian disorders can be detected by family pedigree analysis.

Mendelian autosomal recessive disorders occur when the mutant gene is present in the homozygous state. Examples of autosomal recessive traits include albinism, cystic fibrosis, sickle cell anaemia and Tay-Sachs disease. On the other hand, Mendelian autosomal dominant disorders are caused by a dominant allele and occur when an individual carry one or both dominant allele on autosomes. Examples of autosomal dominant Mendelian disorders include Achondroplasia, Huntington disease and Marfan syndrome. Inheritance of sex linked disorders also follows patterns of Mendelian principles and their expression can be in recessive or dominant forms. Examples of sex-linked recessive traits includes haemophilia, tongue rolling, sickle cell anaemia and red-green colour blindness. Sex linked dominant disorders are very rare and occurs in female only because of having X sex chromosomes. An example of sex linked dominant is Rett syndrome. A genetic condition affecting brain development in girls.

The Mendelian sex linked disorder was discussed in the previous sections. In this section only the autosomal Mendel disorders will be discussed.

Albinism

Albinism is a genetic disorder caused by defects in one of the several genes that codes for production or distribution of melanin. In animals, albinism is characterised by the partial or complete lack of pigment in eyes, hairs, fur, feathers, skin, scales or cuticle. The organism with this type of condition is referred to as albino. In plants, albinism is usually caused by the partial or complete loss of chlorophyll. People with albinism are sensitive to the effect of the sun due to lack of skin pigments. This makes an individual more susceptible to sunburn and even risk of developing skin cancer. Melanin also plays a role in the development of optic nerves, therefore individuals with albinism may have vision problem. Although there is no cure for albinism, people with this disorder can take some measures to protect their skin and maximise their vision ability.

Since albinism is caused by a recessive allele, to express the trait an individual must inherit two copies of the alleles from parents.

Example 2.10

If an albino man marries a heterozygous women (carrier). What is the probability of having an albino child?

Solution:

Let the gene for a normal skin colour be **A** and the gene for albinism be **a**

Since albinism is caused by recessive allele, the genotypes of male parent will be **aa** and female parent **Aa.**

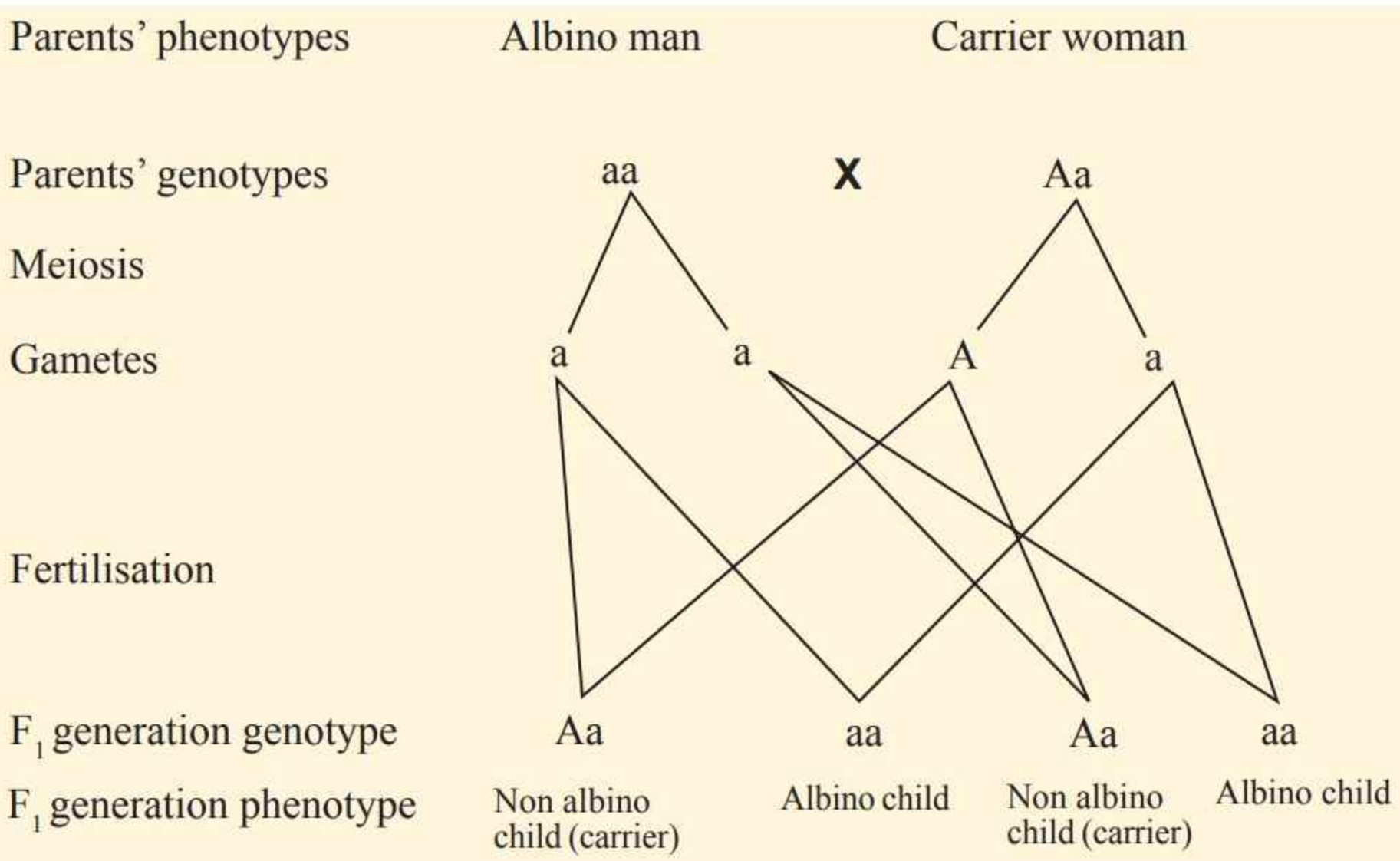


Figure 2.39: A cross between albino man and a carrier woman

The genotypes are 2 Aa and 2 aa

The genotypic ratio is 1:1

Figure 2.39 shows that there is 50% chance of having an albino child.

Example 2.11

Parents with normal skin colour got an albino baby two years after their marriage. The man is accusing his wife of cheating and he wants to divorce her. Using genetic cross diagrams, educate the man that there is a chance for them to have an albino baby.

Solution:

Let a gene for a normal skin colour be **A** and for albinism be **a**

Since albinism is caused by a recessive gene and both parents have a normal skin colour, the genotypes of the parents are either AA or Aa. If both are AA or only one of them is Aa, there is no chance of having an albino baby.

But if both parents are Aa (carriers), then;

BIOLOGY FORM 4.indd 75 09/03/2022 19:02

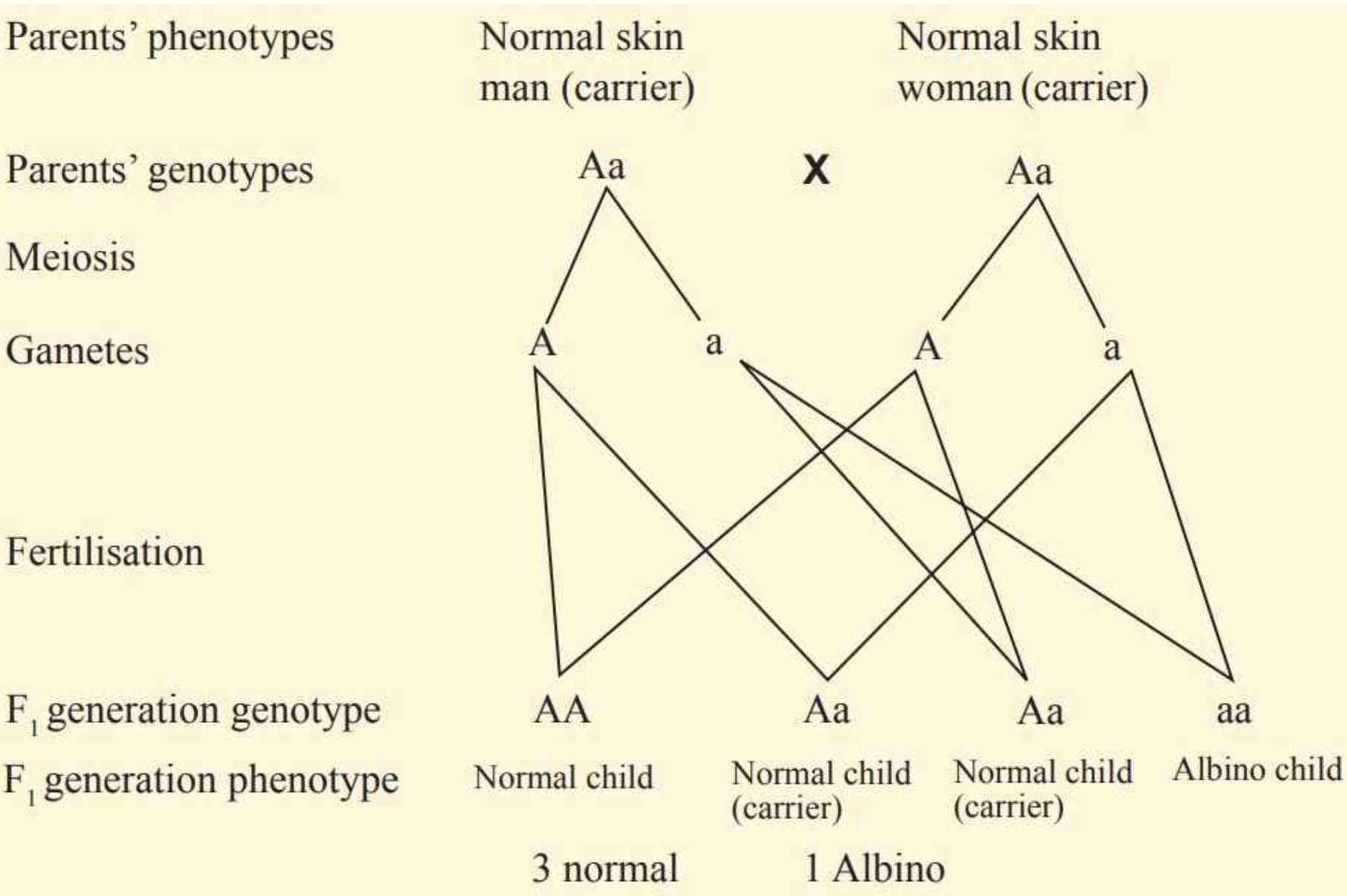


Figure 2.40: A cross between two heterozygous carriers of genes for albinism

Figure 2.40 shows that the chance of having an albino child is 25% if both parents are heterozygous for albinism alleles.

Tongue rolling

Some people can roll their tongues into a U-shape while others cannot. Tongue rolling is the genetic ability to roll the lateral edges of the tongue upwards to form a tube like structure. The tongue's internal muscles allow some people to roll their tongues into a U-shape. Rolling the tongue into a tube shape is often described as a simple Mendelian inheritance. It is a hereditary trait controlled by a dominant allele. In this aspect whoever happens to inherit one of the alleles will be phenotypically a tongue roller. But the individual who is homozygous recessive, will be a non-tongue roller as shown in Figure 2.41.

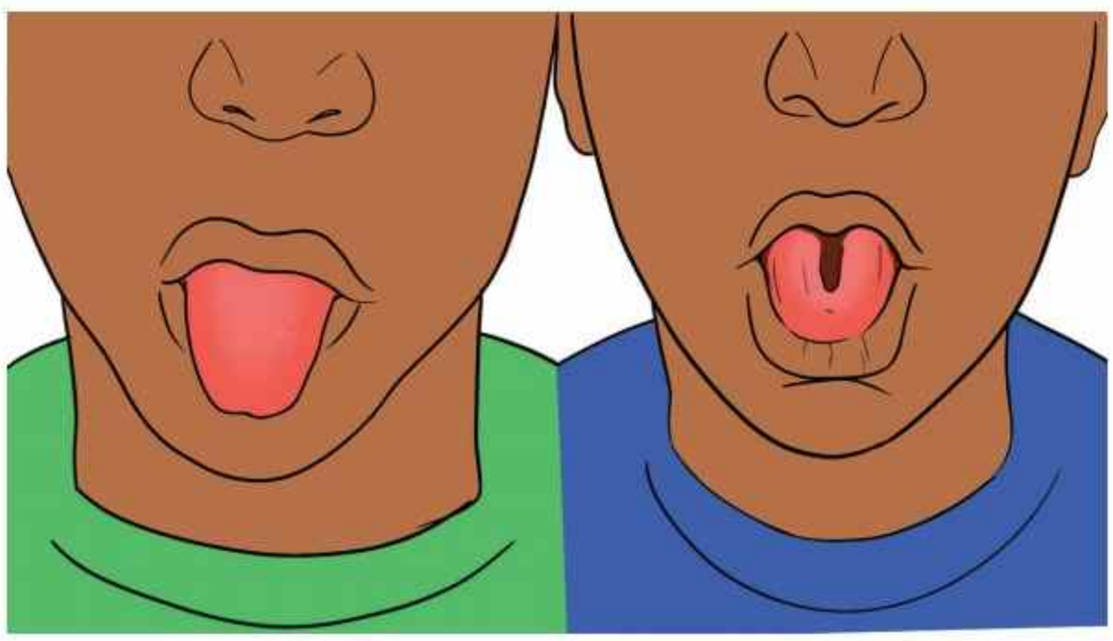


Figure 2.41: (a) Non- tongue roller (b) Tongue roller

Activity 2.5:

To investigate variation in tongue rolling

Materials: Notebook and pen or pencil

1. Make a group of five students.
2. Each student should push out the tongue and try to curl up the sides.
3. Observe and identify how many students can and how many cannot roll their tongues and record this in the notebook.
4. Discuss what causes variation in tongue rolling character in human being.

Example 2.12

A man who was a tongue roller married a woman who cannot roll her tongue. What will be the phenotypes of their children?

Let the gene for tongue rolling be R

Let the gene for non-tongue rollers be r

The genotypes of the man can be either RR or Rr, and that of the woman is rr, thus in crossing there will be two possible cases.

1st Case: Parents' genotypes can be RR and rr

Parents' phenotypes	Tongue roller man		Non tongue roller woman	
Parents' genotypes	RR	X	rr	
Meiosis				
Gametes	R	R	r	r
Fertilisation				
F_1 generation genotype	Rr	Rr	Rr	Rr
F_1 generation phenotype	Tongue roller child (carrier)	Tongue roller child (carrier)	Tongue roller child (carrier)	Tongue roller child (carrier)

Figure 2.42: A cross between a tongue roller and non-tongue roller parents

BIOLOGY FORM 4.indd 77 09/03/2022 19:02

Phenotypically all their children will be tongue rollers.

2nd Case: Parents can be Rr and rr

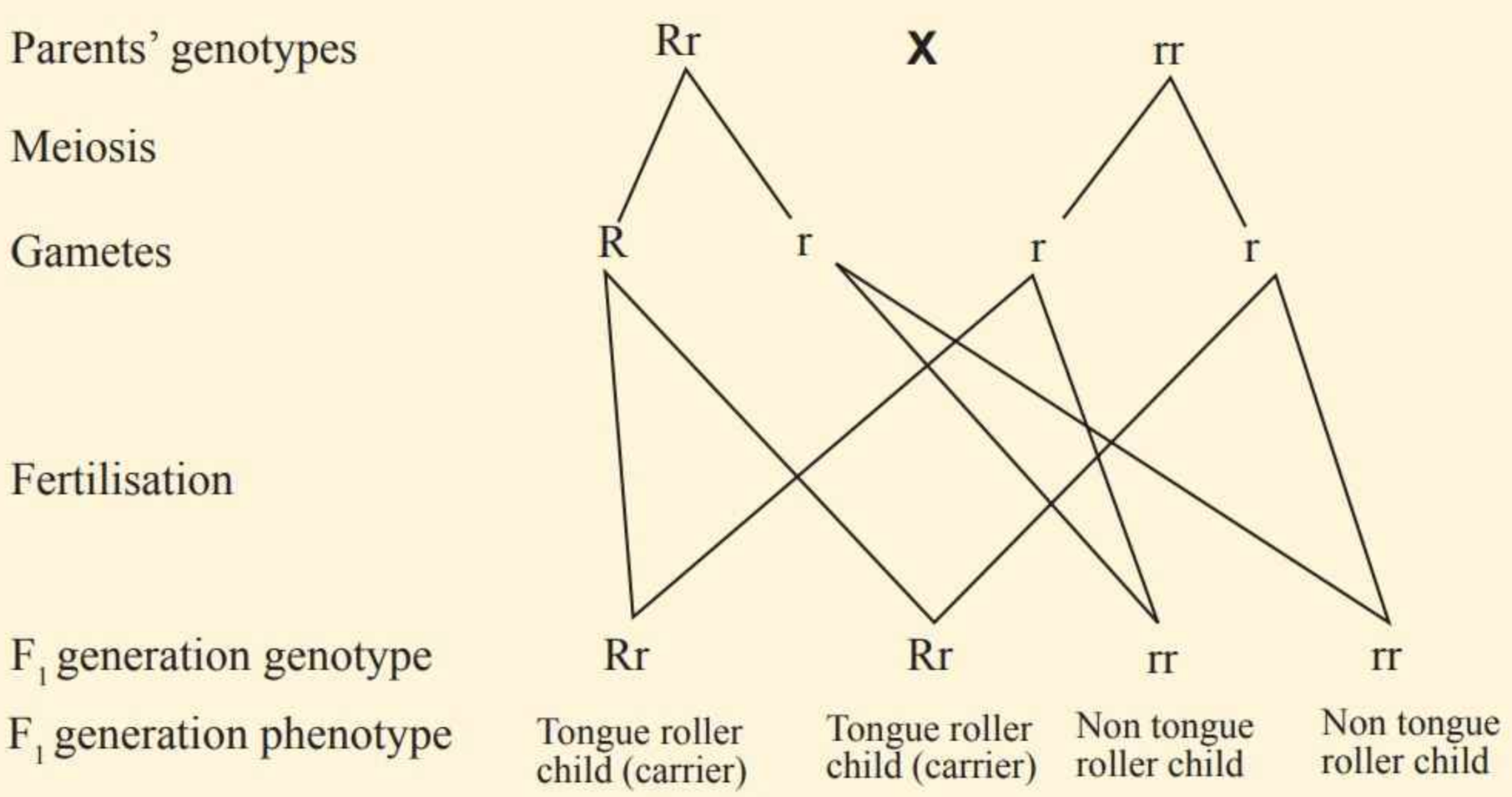


Figure 2.43: A cross between a tongue roller and non-tongue roller parents

Phenotypically half of the children will be tongue rollers, whereas the other half will be non-tongue rollers.

Sickle cell anaemia disorder

This is a genetic disorder that makes the red blood cells assume a sickle shape, as shown in Figure 2.44. The disorder is caused by gene mutation resulting from base substitution whereas thymine(T) is substituted with Adenine (A). This leads to the replacement of the amino acid glutamine with valine. The changes result into formation of abnormal haemoglobin denoted as Hb^S. The normal haemoglobin is denoted as Hb^A.

An individual with sickle cell anaemia must have inherited a recessive homozygous allele Hb^sHb^s. The heterozygous individual Hb^AHb^S is called a carrier of sickle cell trait. A sickle shaped cell is unable to carry enough oxygen. The sickle shape prevents the normal flow of the blood in the small blood vessels, thus leading to blockage of some blood vessels and causing swelling and pains.

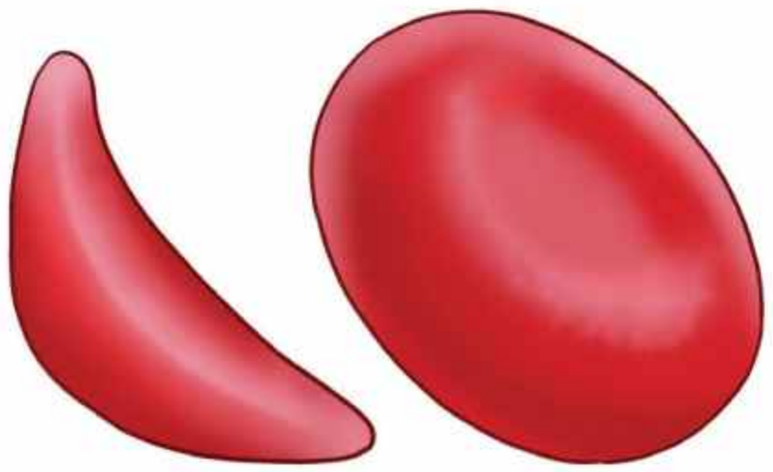


Figure 2.44: Red blood cells (a) Sickle shaped cell (b) Normal shaped cell

BIOLOGY FORM 4.indd 78 09/03/2022 19:02

Example 2.13

If a man with sickle cell disease marries a normal woman, what will be the probability that any of their offsprings will carry a sickle cell trait?

Solution

Let Hb^A be a gene for normal cell

Hb^S be a gene for sickle cell

1st case: If a sickle cell diseased man marries normal woman, the offspring will be:

Parents' phenotypes	Sickle cell trait		Normal haemoglobin	
	Man		Woman	
Parents' genotypes	Hb^SHb^S	X	Hb^AHb^A	
Meiosis				
Gametes	Hb^S	Hb^S	Hb^A	Hb^A
Fertilisation				
F_1 generation genotype	Hb^AHb^S	Hb^AHb^S	Hb^AHb^S	Hb^AHb^S
F_1 generation phenotype	Sickle cell trait	Sickle cell trait	Sickle cell trait	Sickle cell trait

Figure 2.45: A cross between homozygous normal woman and a sickle cell man

Figure 2.45 shows that all offsprings will carry a sickle cell trait.

2nd case: If a sickle cell man marries normal woman who is carrier, the offspring will be:

Parents' phenotypes	Sickle cell		Carrier haemoglobin	
	Man		Woman	
Parents' genotypes	Hb^SHb^S	X	Hb^AHb^S	
Meiosis				
Gametes	Hb^S	Hb^S	Hb^A	Hb^S
Fertilisation				
F_1 generation genotype	Hb^AHb^S	Hb^SHb^S	Hb^AHb^S	Hb^SHb^S
F_1 generation phenotype	Sickle cell trait	Sickle cell diseased	Sickle cell trait	Sickle cell diseased

Figure 2.46: A cross between a sickle cell man and carrier woman

Figure 2.46 shows that 50% of the offspring will carry the sickle cell trait and 50% will have the sickle cell disease.

BIOLOGY FORM 4.indd 79 09/03/2022 19:02

Achondroplasia

This is the genetic disorder which causes disproportionate dwarfism. The condition interferes with bone growth by preventing changing of cartilage to bone in long bones of the arms and legs. This leads to the shortened arm and legs and enlarged head as shown in Figure 2.47. The disorder is controlled by a dominant autosomal allele. In this respect, one copy of the allele from any of the parents can cause the disorder. The homozygous dominant genotype is lethal because it leads to extreme shortening of the bones and underdeveloped ribcage. Usually, foetus with such genotype are stillbirth or die shortly after birth.

Figure 2.47: Achondroplasia individual

Chromosomal Disorders

Another group of disorder is chromosomal disorders. These disorders usually result from a problem with cell division and arise because of duplication or absence of entire chromosomes or pieces of chromosomes. Alteration in the number and structure of the chromosomes leads to chromosomal disorders. A chromosomal disorder affects many genes at a time and can be fatal. It may occur due to the loss or gain of the whole chromosome. This leads to changes in the genotype which can be inherited from one generation to another. Mutations that occur in the reproductive cells are inheritable whereas those that occur in the somatic cells can only be inherited when the organisms reproduce by mitosis. Mutation can also occur in specific genes of the chromosomes. Such mutations are called point mutations or gene mutations. Gene mutation is the alteration of nucleotide sequence of gene within the chromosomes while chromosomal mutation or chromosomal aberration is the alteration in the structure and numbers of chromosome. Both chromosomal and point mutations are sudden change that occur due to deletion, substitution, addition (insertion) and inversion. The disorders can range from minor to more serious ones. Examples of these disorders include Turner's syndrome, Downs' syndrome, and Klinefelter's syndrome.

Down's syndrome: This is the genetic disorder caused by the presence of extra copy of chromosome number 21, making an individual to have 47 chromosomes instead

BIOLOGY FORM 4.indd 80 09/03/2022 19:02

of 46. This is caused by failure of a pair of chromosome number 21 to separate during anaphase I of meiosis. As a result, there are three homologous copies of chromosomes instead of two chromosomes after fusion of gametes. This is the reason why the disorder is named as trisomy. The presence of this extra chromosome leads to retarded physical and mental development. It also leads to malformation of the heart, a thick tongue and characteristic facial appearance. The condition is likely to occur in babies born from mothers and fathers who are over 40 and 55 years old respectively.

Klinefelter's syndrome: This is a genetic condition that results when a boy is born with an extra copy of the X chromosome. It is caused by the failure of the X chromosomes in one of the parents to separate during meiosis. This leads to production of gametes with an extra X-chromosome. If such a gamete is involved in fertilisation, the baby will have the XXY condition. Male with this condition have smaller than normal testicles and produce less testosterone. Hence, they produce little or no sperm, have smaller than normal penis, and cannot produce a child in a normal way. This condition occurs once in every 1 000 male births.

Turner's syndrome: This is a genetic disorder that affects females by completely or partially missing an X chromosome. In this disorder, an individuals' genotype will be X0 where the 0 indicates the absence of a chromosome. In this case, the individual is having 45 chromosomes instead of 46. This is caused by failure of the sex chromosome to separate during meiosis, thus leading to formation of gametes that are deprived of the chromosome. Sometimes, this interferes with the embryonic development thus leading to incomplete development. Affected people are females and are characterised by low intelligence (IQ), abnormal genitals, neck folds, heart abnormalities, kidney problems and abnormalities in physical development. It is a long life and random disorder which is uncommon. It is a rare case that can occur once in every 10 000 births.

Application of genetics

The advancement in Science and Technology has led to developments in the use of genetic knowledge in solving a variety of human problems. Phenotypic qualities such as high crop yields, drought tolerant crops, resistance to diseases, high quantity of milk production, large amount of meat and increased eggs production that were desired for many years can now be made possible.

Application in agriculture

Various principles and methods of genetics have been applied in the development of plants and animals, which have desirable traits to human beings. Controlled hybridisation and artificial selection have increased usefulness of many crops and livestock in agriculture. Hybridisation and selective breeding have been practised in agriculture for thousands of years to improve food production.

BIOLOGY FORM 4.indd 81 09/03/2022 19:02

Development of high quality varieties of plants and animals: Knowledge on genetics has been used to increase the number of plant and animal breeds that are important to humans. The increase in new varieties of plants and animals can be achieved by selecting genetic traits of interest and breed new varieties. Hybridisation is the method of combining characters of different plants or animals to produce new high quality varieties. Hybridisation is purposefully employed in the breeding of domesticated plants and animals. Example a cross breeding between cattle with high milk yield and cattle with low fat milk, produce cattle with high milk yield and low fat content. Figure 2.48 illustrates hybridisation between a high milk yield cow and a bull from low fat milk breed.

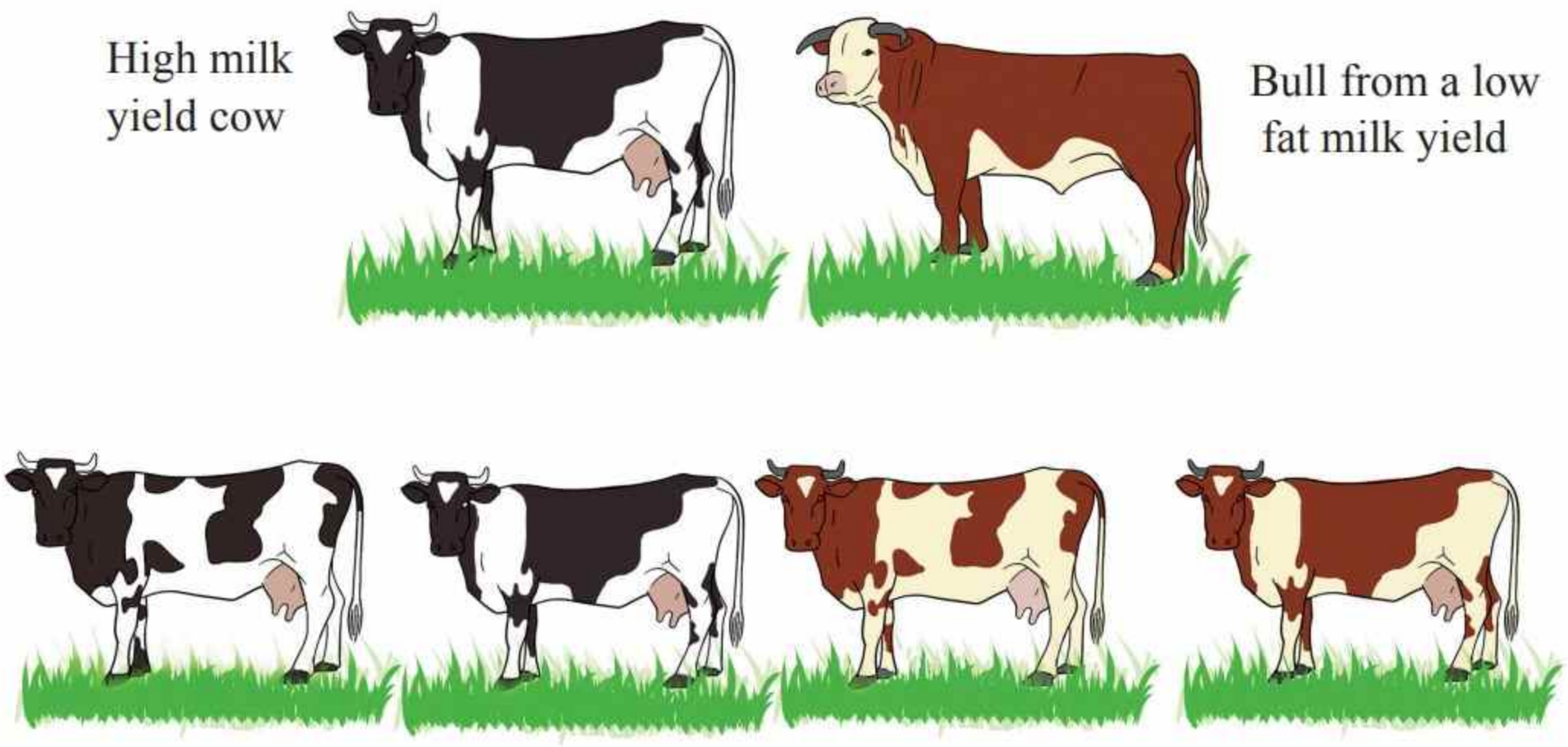


Figure 2.48: Selected cattle flock for high milk yield with low fat content

Plant geneticists produce new crop varieties such as hybrid grains with high drought and stress tolerance produced by crossing high yield rice strain and drought tolerant strain. Plant breeders also use the techniques of budding and grafting to maintain desirable gene combinations originally obtained from crossbreeding.

Increasing plant yields: Knowledge on genetics can also help to increase crop yields by selecting varieties and breeds based on their better performance. Organisms with desirable characteristics can be selectively bred by humans. These are varieties that are better adapted to the environmental conditions, resistant to pests and diseases and also produce higher yields. In agriculture, farmers have been practising selective breeding of different plants for several generations to produce high yield and better quality varieties. Figures 2.49 illustrate stages for selection of tomato variety with high yields and large fruits.

(a) Select plants with largest fruits and highest yield in the first generation

(b) Repeat selection in the next generations

(c) Better performance breed with high yield and large fruits

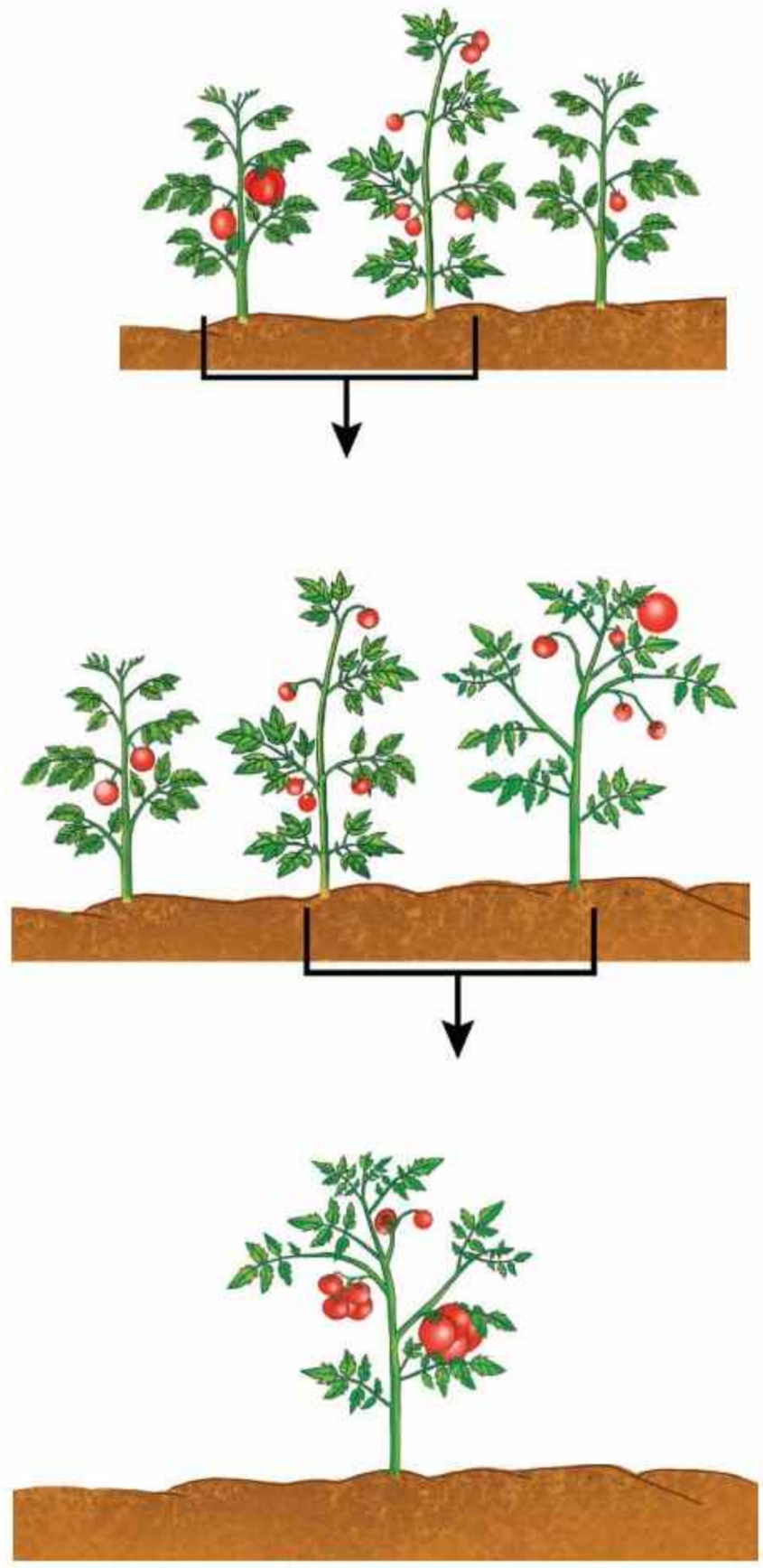
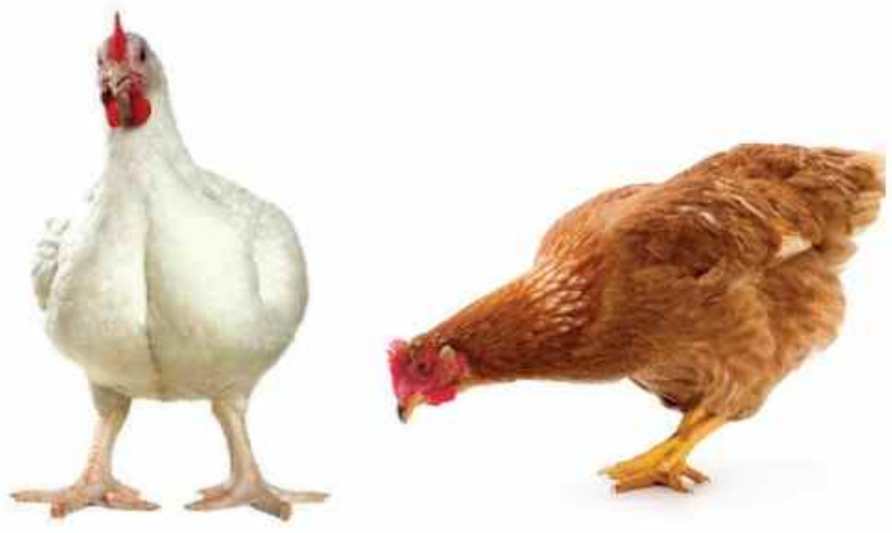


Figure 2.49: Selected tomato variety for a high yield and large fruits

Modern genetic techniques have made this process of selective breeding faster and more precise. However, even with these advances, selective breeding is still a slow process that takes place over many generations.

Increasing animal yield: The knowledge on genetic makeup of animals facilitates the mechanism for developing different desired breed lines for improved livestock production. The intensive agriculture practised around the world has made researchers, breeding societies and breeding companies apply modern breeding techniques in production of commercial breeds. Several commercial animal breeds with higher performance have been developed for mass production. In poultry industry, broiler chicken for meat production and layer chicken for egg production have been bred. See Figure 2.50.

BIOLOGY FORM 4.indd 83 09/03/2022 19:02



(a) (b)

Figure 2.50: The commercial poultry breeds; (a) broiler (b) layer chicken

Production of Genetically Modified Organisms (GMOs): A genetically modified organism is a plant, animal, microorganism or any other organism whose genetic makeup has been modified in the laboratory using genetic engineering technology. This technology creates combinations of plant, animal, bacterial, and virus genes artificially through inserting foreign segments of genes into the genetic make-up of the organism of interest. Genetic engineering technology allows the movement of genetic material across unrelated species. Specifically, individual genes that control particular characteristics are separated from the original source and transferred directly into the cells of an organism such as an animal, a plant, a bacterium or a virus. Genetic engineering provides a quick and more precise way of achieving this goal in one generation. Genetically modified crops offer improved yields, enhanced nutritional value, longer shelf life, tolerance to drought, and resistance to diseases, frost, or insect pests. Examples of GMOs are golden rice, Bt-corn and Flavr savr tomatoes. Despite their benefits, GMOs remain a highly controversial topic in many parts of the world because the negative effects associated with GMOs have not been thoroughly investigated or addressed.

In military, micro-organisms that can cause diseases are used to make biological weapons. Through genetic engineering the disease-causing organisms are cloned and introduced into the enemy's territory. This is the misuse of genetic engineering.

Application in medicine

Genetic techniques are used in medicine to diagnose and treat inherited diseases and other genetic disorders. The knowledge on genetics also allows prevention and control of genetic diseases. For example in gene therapy, the desired genes are inserted into a patient's cells and tissues to treat hereditary diseases. This therapy uses sections of DNA for this purpose. Genetic engineering in medicine has been used for mass production of insulin that is used to control diabetes, human growth hormones, follistim for treating infertility, human albumin, monoclonal antibodies, antihemophilic factors, different vaccines and many other drugs. Knowledge of genetics can also help in predicting the individual's likehood to develop a genetic disease so that early precautions or treatment can be planned. For example, early-onset of Alzheimer's disease, cancer, heart disease can be predicted early in life.

Application in vaccine development

Knowledge on genetics has influenced the discovery of various vaccines to combat animal and plant diseases. Vaccines are

BIOLOGY FORM 4.indd 84 09/03/2022 19:02

biological substance that stimulate the production of antibodies and provide immunity against a particular pathogen. Different vaccine technologies have been invented on the basis of genetics. Knowledge on genetics enables researchers to use viruses, mice, rats, apes and other animal species to develop different types of vaccines for human uses. The use of vaccines helps in overcoming several epidemic diseases. Vaccines are one of the most important public health achievements of the 20th century which have saved more lives than any other medical intervention. Thus, knowledge on genetics has contributed significantly in biological studies of organisms and it has been the leading discoveries in the field of medicine. For example, the vaccine against hepatitis B and corona virus disease-2019 (COVID-19) was made possible due to knowledge and application of genetics.

Application in industries

The knowledge on genetics has been widely used in industries to manufacture different products. Living organisms, especially microorganisms have been effectively employed in production of brewers, beverages and drugs. For example in brewing and baking industries, genetics is applied to improve strain of yeast that produce bread, alcohol and other products. Various pharmaceutical industries have massively developed specific strains of molds, bacteria, and other microorganisms for manufacturing different drugs and other commercial products. Special strains of fungi and bacteria have been isolated to greatly increase manufacturing of antibiotics and other drugs. Examples of pharmaceutical drugs produced include streptomycin from bacteria, Penicillin, cyclosporine, and ampicillin from fungi. Some fungi, such as *Aspergillus niger* are filamentous fungi commonly used in pharmaceutical industries to produce microbial citric acid which is an important organic acid widely used in food and beverage industries as well as in detergents and cosmetic industries.

Application of genetics in genetic counseling

Knowledge on genetics has been gradually used in genetic counseling. Genetic counseling is the process of advising and guiding individuals or families affected by or at risk of genetic disorders and helping them to adapt to the situation. This field is considered necessary for the implementation of genomic medicine and treatment or control of genetic disorders. The knowledge on genetics has created public awareness for active participation in genetic testing that may lead to early diagnosis of the genetic diseases. This facilitate the control or prevention. Genetic counselors help affected persons or families to understand the genetic conditions based on the personal, family and cultural contexts.

Application in protection and conservation of genetic resources

Genetic resources are genetic material of actual or potential value that safeguards the survival of a particular species and its global biodiversity. In recent years there has

BIOLOGY FORM 4.indd 85 09/03/2022 19:02

been an increase in global concerns over the loss of genetic resources of plants and animals. The future progress in crop and animal improvements for food security and other uses depends to a greater extent on the conservation of the rapidly vanishing genetic resources and their effective utilisation. It is desirable to maintain a diverse range of organisms as much as possible, particularly domesticated cultivars and their ancestors, in order to maintain a wide genetic base. The application of genetic technology enables the protection and conservation of the biodiversity, particularly the animal and crop varieties, which have survived in our environment for years.

Blood transfusion

In blood transfusion, the knowledge on genetics is applied to check blood compatibility. Blood transfusion is the transfer of blood from the donor to the recipient. Before this is done, blood of the donor has to be screened to realise its compatibility with that of the recipient. If the blood of the donor is not compatible with the blood of the recipient, then blood agglutination will occur.

Establishing paternity

The knowledge of genetics is applied in paternity testing to determine whether the alleged father is a biological father of the child. Paternity testing often uses samples collected by swabbing the inside of an individual cheek. The test proves parentage by analysing DNA from the corrected samples.

Revision exercise 2

Choose the most correct answer in the questions 1-18.

1. In crossing a homozygous recessive with a heterozygous individual, what is the chance of obtaining an offspring with the homozygous recessive phenotype?
   (a) 75%
   (b) 25%
   (c) 50%
   (d) 100%

2. A cross between an offspring and a homozygous parents is called_____.
   (a) back cross
   (b) test cross
   (c) crossing over
   (d) reciprocal cross

3. A gene can be described as _____.
   (a) hereditary unit in living organisms
   (b) hereditary unit in animals only
   (c) hereditary unit in plants only
   (d) hereditary unit in microorganisms only

4. Which one of the following nitrogenous base is found in RNA only ?
   (a) Cytosine
   (b) Adenine
   (c) Uracil
   (d) Thymine

5. Which of the following is a type of inheritance in which the phenotype of a heterozygote is intermediate between the phenotypes of the two homozygotes?
   (a) Particulate inheritance
   (b) Complete dominance
   (c) Incomplete dominance
   (d) Co-dominance

6. One of the following is the correct nitrogenous base pairing for DNA molecule?
   (a) Uracil (U) and adenine (A)
   (b) Adenine (A) and guanine (G)
   (c) Thymine (T) and cytosine (C)
   (d) Guanine (G) and cytosine (C)

7. Which of the following is an example of a sex-linked trait?
   (a) Sickle cell anaemia
   (b) Achondroplasia
   (c) Albinism
   (d) Haemophilia

8. Which of the following best describes the test cross? It is a cross in which _____.
   (a) one individual has the dominant phenotype and the other has the recessive phenotype.
   (b) one individual is heterozygous and the other has the dominant phenotype
   (c) one individual has the dominant phenotype and the other has the unknown phenotype
   (d) both individuals have the recessive phenotype

9. _____ is the set of observable characteristics and it can be influenced by genetic and environmental factors.
   (a) Genotype
   (b) Phenotype
   (c) Gene
   (d) Allele

10. Which of the following blood groups is codominant?
   (a) A
   (b) B
   (c) AB
   (d) O

11. Blood group in genetics is an example of_____.
   (a) dominance
   (b) continuous variation
   (c) epistasis
   (d) discontinuous variation

12. Which of the following best supports the belief that DNA rather than RNA is the basis of hereditary information?
   (a) DNA is formed from proteins and nucleic acids while RNA is formed from sugars and nucleic acids.
   (b) DNA is found mostly in the chromosomes while RNA is found mostly outside the chromosomes.

BIOLOGY FORM 4.indd 87 09/03/2022 19:02

(c) DNA is found in the nucleus while RNA is not found in the nucleus.

(d) RNA is a reverse copy of DNA and is complimentary to it.

13. Under complete dominance a recessive gene can_____.
    (a) express itself in homozygous condition
    (b) express itself in both heterozygous and homozygous condition
    (c) not express itself in heterozygous condition
    (d) not express itself in homozygous condition

14. When it is said a DNA molecule can replicate it means_____.
    (a) It can produce a copy of itself
    (b) It cannot produce a copy of itself
    (c) It can transform itself to an RNA molecule
    (d) It cannot produce RNA molecule

15. The characteristics of organism and some of their behavior are determined chemically by structures known as_____.
    (a) ribosome
    (b) genes
    (c) nucleolus
    (d) endoplasmic reticulum

16. In punnet square diagrams, the homozygous recessive genotype is represented by_____.
    (a) two capital letters of the same letter in the alphabet
    (b) one capital letter and one small letter of the same letter in the alphabet
    (c) two small letters of different letters in the alphabet
    (d) two small letters of the same letter in the alphabet

17. In monohybrid crossing diagrams, the homozygous dominant genotype is represented by_____.
    (a) a pair of small letters of the same letter in the alphabet
    (b) one capital letter and one small letter of the same letter in the alphabet
    (c) a pair of capital letters of the same letter in the alphabet
    (d) two capital letters of different letters in the alphabet

18. The basic unit of DNA molecule is_____.
    (a) pentose sugar
    (b) phosphate
    (c) a nucleotide
    (d) a nitrogenous base

19. Match the terms in column A with that of column B by writing a correct letter of the corresponding item from column B against the roman number in column A.

Column A	Column B
i. The cross between F_1 individual with homozygous recessive parent.	A. Sex-linked traits
ii. The cross between F_1 with either of the parent.	B. Mutagens
iii. Sudden change in the genotype of a cell	C. Trait
iv. Having two X chromosomes and one Y chromosome	D. Inbreeding
v. The mating of closely related organisms	E. Pedigree
vi. Family tree showing genetic relationships, normally with genetic trait	F. Turners' syndrome
vii. Characters that are more conspicuous in one sex than the other.	G. Sex influenced traits
viii. A disoder that cause red blood cells to take a crescent shape and break.	H. Heterozygous
ix. State where the alleles are dissimilar	I. Genes
x. Having an extra copy of chromosome 21	J. Punnett square
xi. A feature that can be passed on from parent to offspring.	K. Phenotype
xii. A unit of heredity that is passed on to future generation.	L. Test cross
xiii. Physical appearance of an organism	M. Mutation
xiv. Show clear cut difference between characters	N. Sickle cell anaemia
xv. Both alleles are simultaneously expressed in the heterozygote	O. Discontinuous variation
xvi. An organism that has inherited a recessive allele for a genetic trait and do not display that trait of the disease.	P. Carrier
xvii. Technique of changing the genotype of an organism	Q. Dominant character
xviii. Controlled by a gene that is in the X-chromosome.	R. Down syndrome
xix. Involves one pair of contrasting traits	S. Klinefelter's
xx. Deoxyribonucleic acid	T. Incomplete dominance
	U. Dihybrid cross
	V. Mendels'first law
	W. Monohybrid cross
	X. Double helix
	Y. Genetic engineering
	Z. Back cross

BIOLOGY FORM 4.indd 89 09/03/2022 19:02

20. Distinguish between the following;
    (a) Dominant and recessive
    (b) Gene and allele
    (c) Phenotype and genotype
21. A man with normal skin colour got married to a carrier woman (heterozygous). What is the probability of obtaining an albino child?
22. Using the symbol G and g to represent a particular genetic trait, predict the genotype of parents that would give the following in the first filial generation:
    (a) 100% offspring showing the dominant characteristics.
    (b) 75% offsprings showing the dominant trait.
23. Explain the causes and effects of genetic disorders.
24. A woman with blood group A has parents who both have blood group AB and a husband who has blood group B. What is the probability that one of her children will have blood group O?
25. Assume that in human beings the gene for brown eyes is dominant over that for blue eyes.
    (i) A brown-eyed man marries a blue-eyed woman, and they have eight brown-eye children. What are the genotypes of all the individuals in the family?
    (ii) What is the probability that the first child produced by parents who are both heterozygous for brown eyes will have blue-eyed?
    (iii) If the first child of the parents in (ii) above is a brown-eyed girl, what is the probability that the second child will be a blue-eyed boy?
26. Mzee Tumbotumbo is blaming his wife for bearing only daughters and no sons. Use your genetics knowledge to educate him that his wife is not supposed to be blamed.
27. Explain the causes and effect of the following:
    (a) Turner's syndrome
    (b) Down's syndrome
    (c) Klinefelter's syndrome
28. Explain the importance of genetics in our daily life.
29. A blood group A person may have the genotype I^AI^A or I^AI^0. Inheritance of I^A from one parent and I^B from the other produces the blood group AB.
    (a) What are the possible blood groups of children born from a blood group A mother and blood group B father? Explain your answer.
    (b) A woman with blood group A claims that a man of blood group AB is the father of her child. A blood test reveals that the child's blood group is O. Is it possible that the woman's claim is true? Explain your answer.

BIOLOGY FORM 4.indd 90 09/03/2022 19:02

30. Using genetic cross diagrams explain whether a male human being can be a carrier of colour blindness.
31. Why is it more efficient to perform a test cross with a homozygous recessive than a homozygous dominant genotype?
32. One family was quarreling due to their baby girl being an Albino while neither of the couple has albinism. The Father of the child was claiming that the mother was responsible for the child being an Albino. By using genetical diagrams that are well illustrated show how each of the two parents are responsible for albinism of their daughter and not the mother only. Using Capital "A" as the dominant gene.
33. In Rosa alba plats red flower is controlled by an allele R whereas white flower is controlled by an allele W. In an experiment, red and white flowered Rosa alba plants were crossed and all F_1 plants produced had Pink flowers.
    (a) Explain why such an observation
    (b) When two of F_1 plants were self-crossed, 1000 F_2 plants were produced. By the help of illustration show how many of F_2 plants will have;
        (i) Red flowers
        (ii) Pink flowers
        (iii) White flowers
34. A haemophilic man was married to a normal but carrier woman. By using genetical symbols work out to show the probability in their couple of getting;
    (a) haemophilic son
    (b) normal children
35. Briefly explain why sex-linked dominant traits occur more often in females than males

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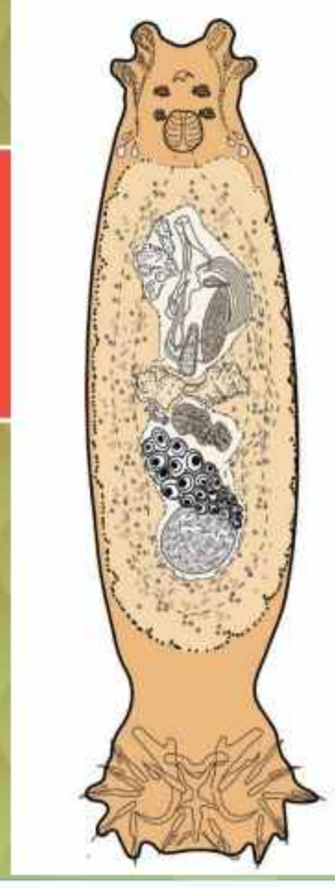

Chapter

Three

Classification of living things

Introduction

Living things are organised in particular groups based on their shared characteristics. For example, animals are eukaryotic, multicellular and heterotrophic organisms that make up kingdom Animalia. In previous classes, you learnt about kingdom Monera, Protoctista, Fungi and Plantae. In this chapter, you will learn about Kingdom Animalia, focusing on the general and distinctive features of some phyla and classes. The structures of organisms that belong to each class, and the advantages and disadvantages of members under each phyla will also be addressed. The competencies developed will enable you to ensure the survival of animals by avoiding actions that will harm them or destroy their habitats. This will also help to maintain the sustainability of ecosystems.

Kingdom Animalia

Kingdom Animalia comprises of wide varieties of animals. Animals vary greatly in their structure, morphology and the way their bodies function. Despite of these variations, members of this kingdom possess features that distinguish them from members of other kingdoms.

Depending on the presence or absence of the vertebral column (backbone), animals are categorised as vertebrates and invertebrates. Vertebrates are animals that possess vertebral column (backbone). Examples of vertebrates are fish, amphibians, reptiles, birds and mammals. Invertebrates are animals that do not possess the vertebral column. Examples of invertebrates are porifera, cnidarians, echinoderms, flatworms, roundworms, molluscs and arthropods. Vertebrates are animals that have a supporting structure called notochord in early stage of development. The notochord is a rod-like cartilaginous structure extending longitudinally along the dorsal side of an animal body. The function of a notochord is to provide support. In most vertebrates the notochord is replaced by the vertebral column during later stages of their development. Hence, the organisms possess notochord only in early stages of their

BIOLOGY FORM 4.indd 92 09/03/2022 19:02

development. However, in some chordates the notochord persists throughout life.

General features of animals

Members of Kingdom Animalia possess the following features:

(a) They are eukaryotes, therefore they possess a clearly defined nucleus and their cells have membrane bound organelles.
(b) They are multicellular, that means they are made up of more than one cell.
(c) Their mode of nutrition is heterotrophic, meaning that they depend on other organisms as a source of their food.
(d) Most animals are mobile and hence they can move from one place to another in search of shelter, food, mates, and safety.
(e) Most of the animals have bilaterally symmetrical bodies. This means that their bodies can be divided longitudinally into two equal parts.
(f) Most of the animals have high level of tissue differentiation and specialised body organs.
(g) Most of the animals have a well-developed nervous system.
(h) Most of the animals have anterior and posterior ends, with oral and anal openings.
(i) Most of the animals are triploblastic, as they are made up of three body layers. The outer layer is called ectoderm, middle layer is called mesoderm and inner layer is called endoderm.
(j) The majority of the animals digest food internally in the gut and store carbohydrates in the form of glycogen.

Distinctive features of animals

The following features differentiate members of kingdom Animalia from other organisms:

(a) They exhibit heterotrophic mode of nutrition. Heterotrophic is a mode of nutrition in which organisms depend on other organisms as source of food.
(b) Most of the animals digest food internally in the gut and store carbohydrates in the form of glycogen.
(c) Most animals are capable of locomotion, hence they can move from one place to another. Few animals such as oysters are sessile. They are found attached on rocks and other hard surfaces. They are not capable of self-locomotion.
(d) Animals have a well-developed nervous system that helps them in detecting changes in their surroundings. This allows them to be aware of the changes occurring in their environment.

Phyla of the kingdom Animalia

Kingdom Animalia comprises of several phyla. These phyla are Porifera, Cnidaria, Platyhelminthes, Nematoda, Annelida, Arthropoda, Mollusca, Echinodermata, and Chordata. However, only five phyla will be covered in this chapter. These are:

(a) Phylum Platyhelminthes which includes tapeworms (*Taenia* species), liver flukes (*Fasciola* species) and blood flukes (*Schistosoma* species).
(b) Phylum Nematoda formerly known as Aschelminthes which includes *Ascaris* species, hookworms and filarial worms.

BIOLOGY FORM 4.indd 93 09/03/2022 19:02

(c) Phylum Annelida which includes earthworms, leeches, and their marine relatives such as ragworms and lugworms.

(d) Phylum Arthropoda which includes prawns, crabs, ticks, spiders, butterflies, and cockroaches.

(e) Phylum Chordata which include advanced organisms such as human beings, cattle, fish, chicken, frogs, and snakes.

Exercise 3.1

1. With examples, explain the following;
   (a) triploblastic organism.
   (b) eukaryotic organism.
   (c) heterotrophic organism.
2. Differentiate between vertebrates and invertebrates.
3. Give reasons why animals and plants are placed in different kingdoms.
4. Explain the main functions of the notochord in animals.
5. Describe the distinctive features of animals.

Phylum Platyhelminthes

The term Platyhelminthes comes from two Greek words "Platy" meaning flat and "helminthes", meaning "worm". Therefore, members of the phylum Platyhelminthes are the flatworms. The worms can be free living or parasites. They are also called acoelomate worms as they lack coelom. A coelom is the body cavity located between mesodermal and endodermal body layers filled with body fluid in which organs are suspended. Examples of flatworms are *Taenia* species (tapeworms), *Fasciola* species (liver flukes), *Schistosoma* species (blood flukes) and turbellarians such as *Planaria* species. See Figure 3.1.

(a)

(b)

Figure 3.1: Examples of Platyhelminthes
(a) Turbellarians (*Planaria* sp.)
(b) Liver fluke (*Fasciola hepatica.)*

Activity 3.1:

Observing the external features of the flatworms

Materials: Preserved specimens of tapeworm, planaria, and liver fluke, three petri dishes, forceps, hand lens, notebook and pen

Procedure

1. Using forceps pick a liver fluke, tape worm and planaria from preserving containers and put each in different petri dishes.
2. Using a hand lens, carefully observe and identify the following external structures (if any): the mouth, suckers, body shape and the posterior region of the organism.
3. Draw a well-labelled diagram of each specimen.

Questions

(a) How does the body structure of a tapeworm differ from that of a liver fluke?

(b) What is the function of suckers in platyhelminthes?

General features of platyhelminthes

Members of the phylum Platyhelminthes possess the following features:

(a) They are triploblastic. Triploblastic organism are those whose body is derived from three germa layers which are the endoderm, mesoderm and ectoderm.

(b) They are acoelomate animals. This means that they have no body cavity.

(c) Most of its members such as liver flukes and tapeworms are parasites while few members such as planaria are free living.

(d) They have a dorso-ventrally flattened bodies. This is the reason why they are called flatworms.

(e) They have flame cells in the mesoderm for excretion and osmoregulation.

(f) Most flatworms have only one opening that is the mouth and no anus. However, tapeworms lack both mouth and anus.

(g) Some members have hooks and suckers for attachment to the host. Such members include tapeworms (*Taenia solium* and *Taenia saginata*) and the liver fluke (*Fasciola hepatica*).

(h) They have a very simple nervous system with two nerve cords which run down on either side of the body.

(i) They inhabit fresh water, marine water and land.

(j) They lack respiratory and circulatory systems. Transportation of oxygen for respiration and other materials takes place by simple diffusion.

(k) Some flatworms such as planaria have cilia on their outer body surface for locomotion. Others such as miracidium have cilia during their larval stage only.

(l) Their bodies are bilaterally symmetry. This means their bodies can be divided longitudinally into two equal parts.

(m) They are hermaphrodites, meaning that they have both male and female reproductive organs. Hence, their reproduction can either be by self-fertilisation or cross-fertilisation.

(n) They are heterotrophic, meaning that they get food from other organisms. Flatworms may be parasites, predators or scavengers.

BIOLOGY FORM 4.indd 95 09/03/2022 19:02

Distinctive features of platyhelminth

Platyhelminth possess various features that distinguish them from other animals. These features include the following:

(a) They are dorso-ventrally flattened with ribbon-shaped body.

(b) If present, their digestive system is incomplete. The digestive tracks have only a single opening which is the mouth with no anus.

(c) They have flame cells for excretion and osmoregulation.

(d) They have suckers, hooks or both for attachment to the host.

(e) They have distinctive larval stages, onchomiracidium in Monogenea and miracidium and cercaria in Trematoda.

Classes of the phylum Platyhelminthes

The phylum Platyhelminthes consist of four classes based on morphology and the mode of life. These classes include:

(a) Class Turbellaria which includes Planaria.

(b) Class Monogenea which includes skin flukes, which is the ectoparasites of fish.

(c) Class Trematoda which includes liver fluke (*Fasciola hepatica*).

(d) Class Cestoidea (formerly Cestoda) which includes pork tapeworm (*Taenia solium*) and beef tapeworm (*Taenia saginata*).

Class Turbellaria

Planarians are organisms belonging to class Turbellaria. Members of this class possess features that distinguish them from other flatworms. These features are as follows:

(a) They are free-living aquatic flatworms.

(b) They have delicate soft bodies.

(c) They have cilia for locomotion.

(d) They have sense organs. These organs are eye spots for sensing light and sensory lobes for sensing chemicals.

(e) They have an enteron (gut). See Figure 3.2.

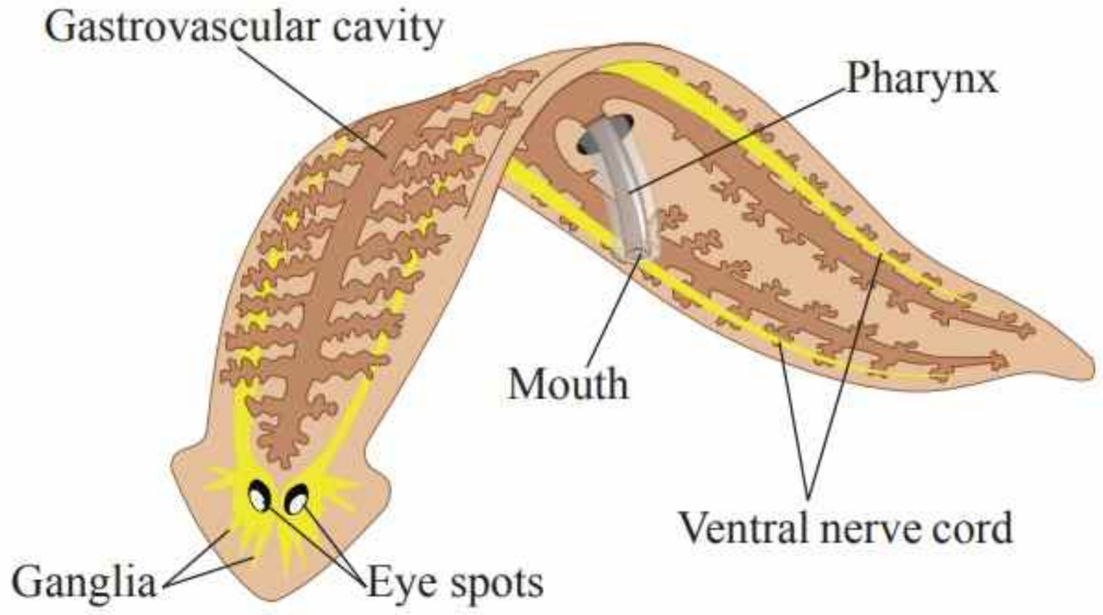

Figure 3.2: Planaria

Class Monogenea

Members of the class Monogenea are known as skin flukes or gill flukes. This is because they are ectoparasites found on the skin or gills of fresh-water and marine water fish. Examples of monogeneans include *Dactylogyrus vastator*, a parasite of fish which attach on the gills and *Gyrodactyllus salaris*, an ectoparasite living on the body surface of fresh water fish. See Figure 3.3.

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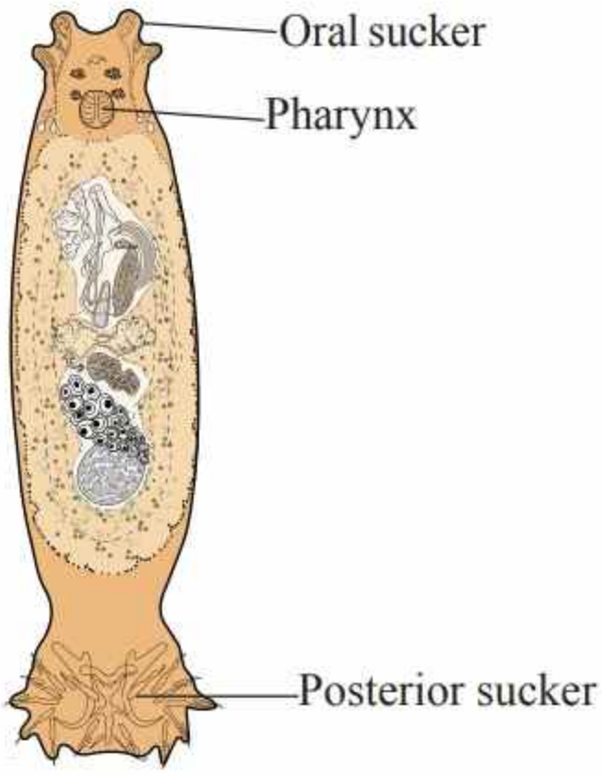


Figure 3.3: *Dactylogyrus vastator*

Distinctive features of the members of class monogenea include the following:

(a) They have a large posterior sucker (the opisthaptor) armed with large hooks for attachment on the skin or gills of their hosts. Oral sucker is either lacking or weakly developed.

(b) They have a direct life cycle, as they do not have intermediate host. They have a free-living ciliated larva called the onchomiracidium.

Class Trematoda

This class comprises of the flukes such as liver fluke (*Fasciola hepatica*) and the blood flukes (*Schistosoma haematobium* and *Schistosoma mansoni*). Features that distinguish members of this class from other classes include the following:

(a) They have leaf-like shape with ventral suckers and oral suckers around the mouth. Suckers are used for attachment to the host.

(b) They have a thick outer covering known as the tegument. This is used for protection.

(c) They are all endoparasites found in circulatory system such as blood flukes while others are found in the digestive system and associated organs.

(d) They also possess sense organs during larval stages and an enteron for digestion is found in the adults only.

Structure of a liver fluke

Morphologically, an adult liver fluke (*Fasciola hepatica)* has a flattened leaf shaped appearance as shown in Figure 3.4. In the anterior part, there is a triangular projection with a mouth surrounded by oral suckers at its apex. Ventrally, there is a ventral sucker and between the two suckers there is a genital pore. Posteriorly, there is a minute excretory pore. The body is enclosed in a protective tegument that has backward directed spines. Their muscle fibres have small glands with minute ducts. The mouth runs into the oesophagus that branches into two blind sacs.

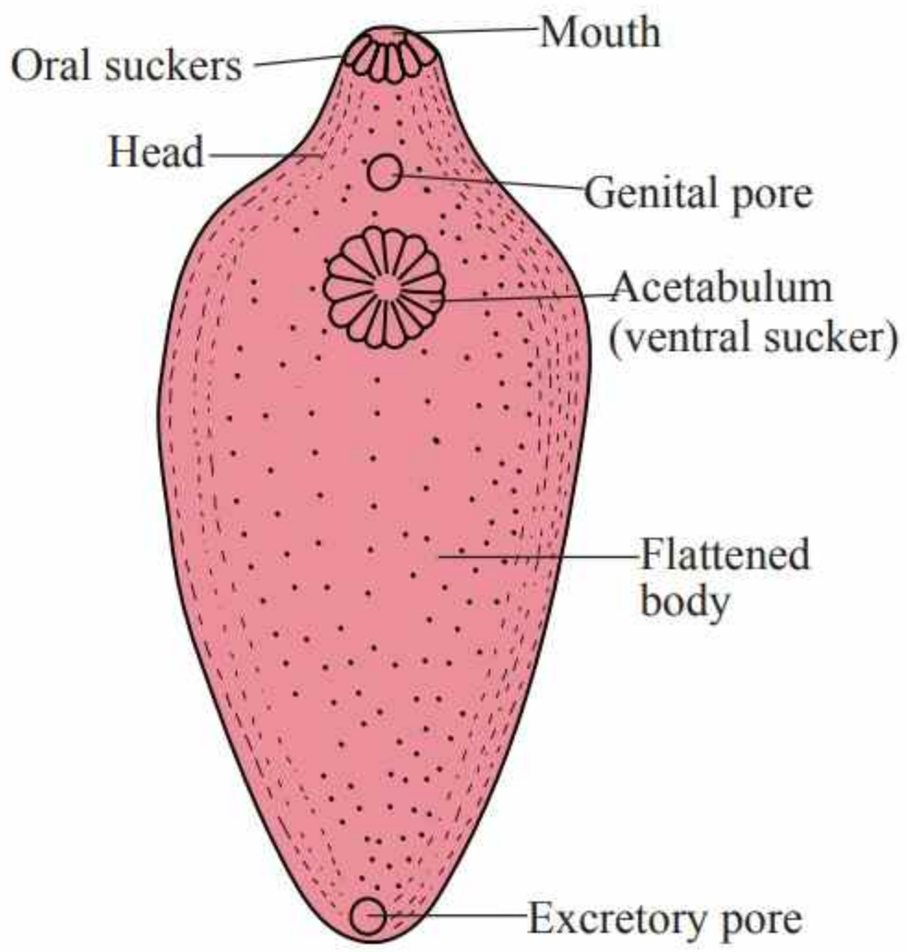


Figure 3.4: Structure of a liver fluke
(*Fasciola hepatica*)

BIOLOGY FORM 4.indd 97 09/03/2022 19:02

Class Cestoidea

Examples of worms belonging to class Cestoidea include; pork tapeworm (*Taenia solium*), beef tapeworm (*Taenia saginata*) and dog tapeworm (*Dipylidium caninum*). These organisms possess the following features that distinguish them from members of other classes:

(a) They are endoparasites feeding parasitically by absorbing nutrients from the host.

(b) They have an elongated and segmented bodies as shown in Figure 3.5 (a) and (b). The segments are known as proglottids.

(c) They possess suckers and hooks on the scolex (head) for attachment to the host.

(d) They have thick tegument with no cilia.

(e) They are hermaphrodites such that each segment has both male and female reproductive organs.

(f) They have no enteron as no digestion is required.

Figure 3.5 (a) : Beef tapeworm (*Taenia saginata*)

Figure 3.5 (b): Dog tapeworm (*Dypilidium caninum)*

Structure of a tapeworm

Mature tapeworms such as *Taenia* species consist of an elongated body that is divided into segments called proglottids. Towards the end of their bodies the proglottids are old and they are full of eggs. These segments may break off and can be egested in the faeces of the host. This increases the reproductive potential of tapeworms. Most species of tapeworms have a rostellum equipped with hooks and suckers for attachment to the intestinal walls of their hosts as shown in Figure 3.6. As long as the scolex and the neck are intact, the worm is alive and capable of growing. Rudimentary nervous and excretory systems run the length of the worm through the proglottids. However, they do not have digestive tract. These worm absorbs the host's digested food through its tegument. Tapeworms also lack sense organs because they are well protected inside the host's body. They are also hermaphrodite with each proglottid

BIOLOGY FORM 4.indd 98 09/03/2022 19:02

containing both male and female reproductive organs.

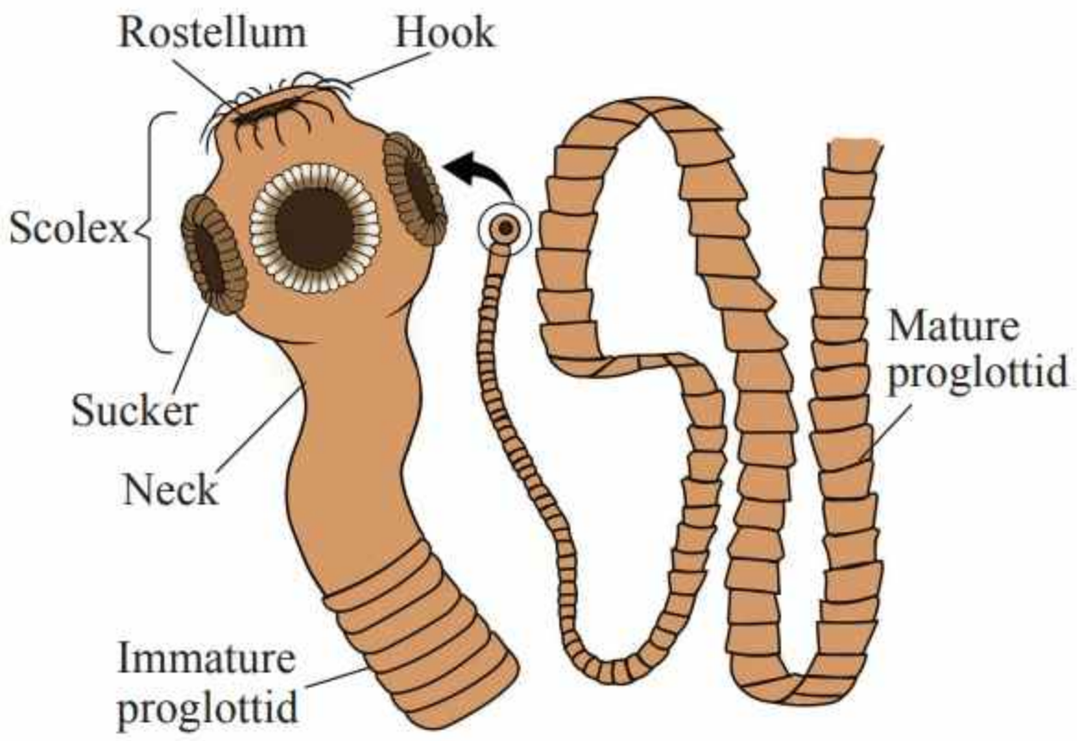


Figure 3.6: Structure of *Taenia solium*

Economic importance of flatworms

Some Platyhelminth play an important role in marine, freshwater and terrestrial ecosystems. However, some species are harmful parasites to human being and other animals.

Advantages of flatworms

(a) Some flatworms such as planaria are scavengers feeding on organic particles from dead bodies of other organisms.

(b) Some are used as biological specimens in field of education and medicine. Examples of such flatworms include members of the genus *Taenia* and *Fasciola*.

Disadvantages of flatworms

(a) Many species are parasites that cause diseases to man, livestock and wild animals as described below:

(i) *Taenia* ssp. causes taeniasis which is an intestinal tapeworm infection transmitted through consuming raw or undercooked beef infected with *Taenia saginata* or pork with *Taenia solium*. The infection caused by larval stages of *Taenia solium* can lead to heart attack or epilepsy depending on the location of larval infection. If the infection is located in the heart muscles it can cause heart attack and if it is located in the brain it can cause epilepsy.

(ii) *Fasciola hepatica* causes fascioliasis. This disease causes liver rot in sheep, cattle and humans.

(iii) *Schistosoma haematobium* and *Schistosoma mansoni* cause urinary and intestinal schistosomiasis respectively. If untreated, schistosomiasis may cause urinary bladder cancer or intestinal cancer.

(b) Parasitic flatworms can cause reduction in quality and amount of meat and milk produced by livestock due to infections. They can also cause stunted growth and even death in young animals.

BIOLOGY FORM 4.indd 99 09/03/2022 19:02

(c) They cause general body weakness and frequent hunger in the hosts as they depend on digested nutrients from the hosts. Working animals such as oxen cannot perform work to their full capacity if infected with a large number of parasitic flatworms.

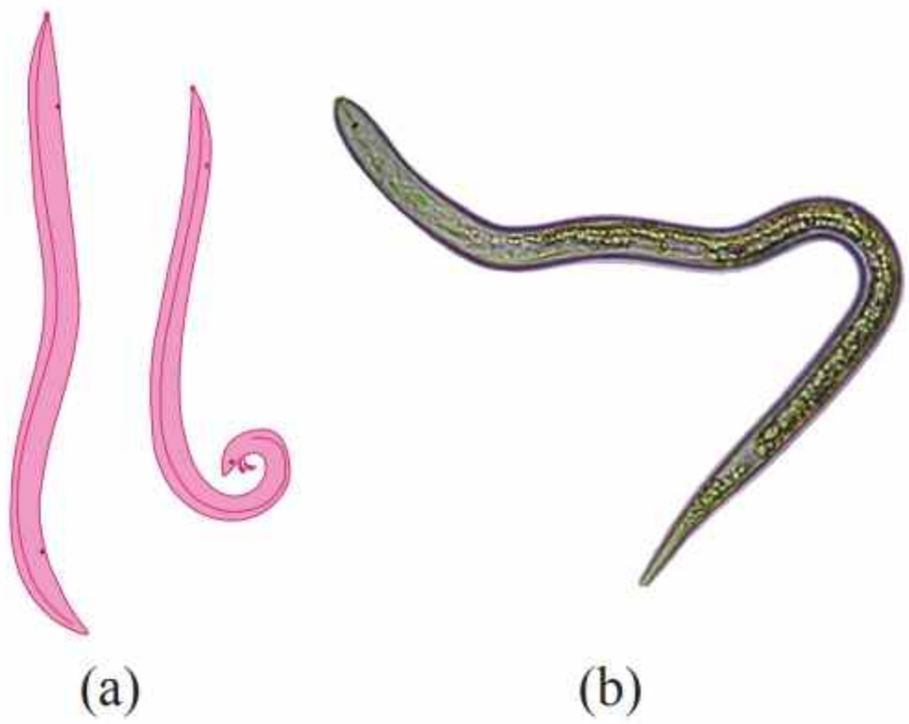
(d) Parasitic flatworms can also cause loss of income due to costs incurred for treatment.

Exercise 3.2

1. Decribe the distinguishing features of worms in class?
2. Explain the meaning of the following terms:
   (a) Bilateral symmetry
   (b) Hermaphrodite
3. What are the functions of proglottids in tapeworms?
4. With examples, describe the economic importance of parasitic flatworms.
5. Briefly explain why tapeworms do not have a digestive tract.

Phylum Nematoda

Phylum Nematoda comprises of round worms which are among the most numerous multicellular animals on the earth. They inhabit a wide range of environments including soil, marine and fresh water. Many nematodes are parasites causing diseases to both plants and animals including humans. Examples of nematodes include the free-living *Rhabditis* species, the animal parasites such as *Ascaris lumbricoides* and plant parasites such as eelworms. See Figure 3.7.



(a) (b)

Figure 3.7: Examples of nematodes (a) *Ascaris lumbricoides* (b) Eelworm (*Meloidogyne incognita*)

General features of nematodes

Nematodes possess the following features:

(a) They exhibit heterotrophic mode of nutrition. They feed as predators or scavengers in the soil and aquatic sediments or as endoparasites in a wide range of animals and plants.

(b) They have round, cylindrical, elongated and unsegmented bodies which taper at both ends. This means that they have pointed ends.

(c) They are triploblastic, in which their third germinal layer called mesoderm is formed between the endoderm and ectoderm.

(d) They are pseudocoelomate in nature. This means they have a body cavity that is only partially lined with mesoderm.

BIOLOGY FORM 4.indd 100 09/03/2022 19:02

(e) They have no blood circulatory system, therefore, transport is by simple diffusion through the thin moist cuticle or through the fluid-filled body cavity.

(f) Many species of nematodes are parasites of both animals and plants, but there are also many free-living species found in marine and freshwater sediments and in the soil.

(g) They are bilaterally symmetrical.

(h) They are dioecious with separate sexes. Males are usually smaller than females.

(i) Gaseous exchange take place by simple diffusion through the cuticle or through the fluid-filled body cavity.

(j) Their digestive system is complete, with both mouth and anal openings.

(k) Nematodes have a thin external cuticle made up of collagen fibres.

Distinctive features of nematodes

The following features differentiate nematodes from other animals:

(a) They have a cylindrical, elongated and unsegmented bodies with tapering ends (pointed ends).

(b) They have special sensory structures known as amphids and phasmids.

Structure of *Ascaris lumbricoides*

Morphologically, *Ascaris lumbricoides* are round, slender and un-segmented worms with tapering bodies at both ends. Their bodies are often said to be "a tube inside a tube". The alimentary canal forms the inner tube which extends from the mouth on the anterior end to the anus located near the tail as shown in Figure 3.8. The outer tube is made up of the cuticle, epidermis, muscle bundles and organs. Between these two tubes there is a fluid cavity known as pseudocoelom which form a hydrostatic skeleton.

Ascaris lumbricoides possess digestive, nervous, excretory and reproductive systems, but they lack distinct circulatory and respiratory systems. Male and female *Ascaris lumbricoides* differ in morphology, such that the male is smaller and more curved at its posterior end than the female. They both lack locomotory organs hence their movement is by undulating bodies in dorso-ventral waves.

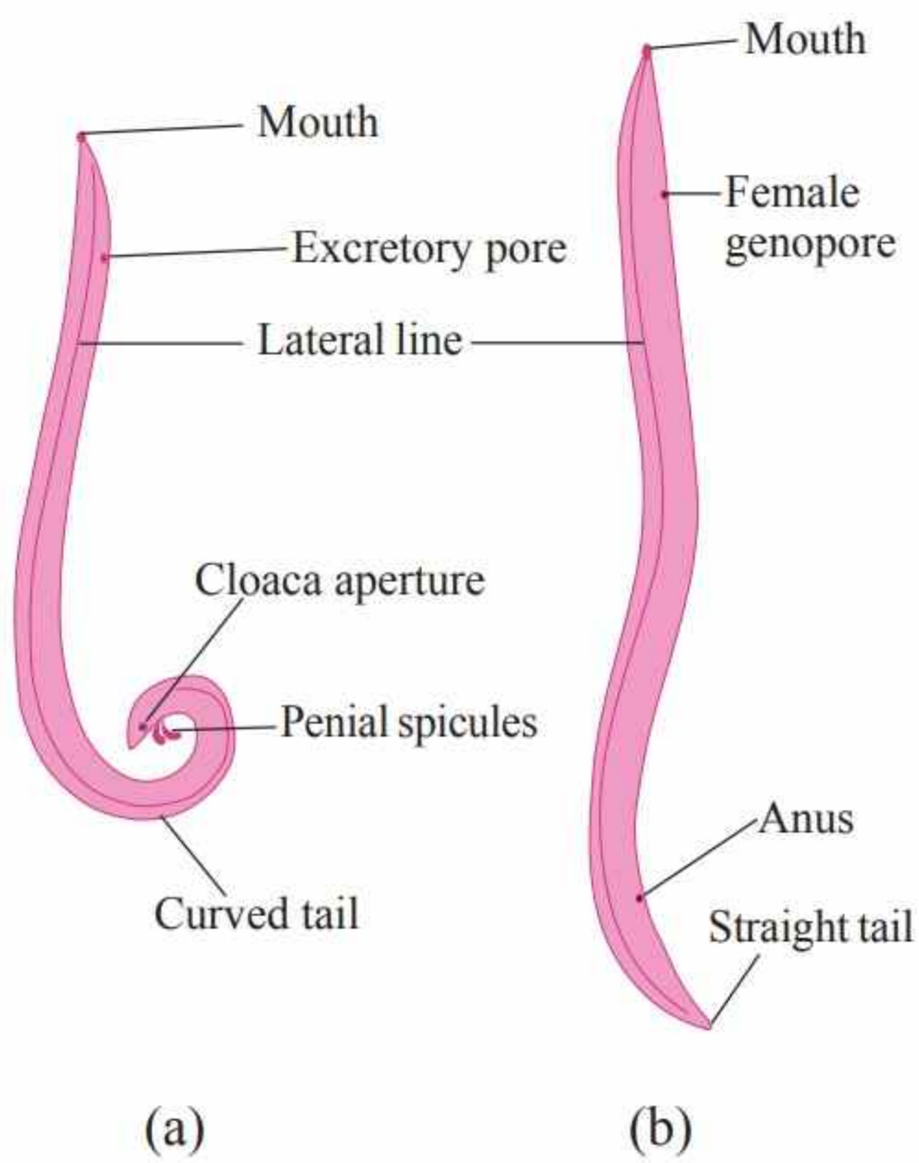


Figure 3.8: Structure of (a) male (b) female *Ascaris lumbricoides*

BIOLOGY FORM 4.indd 101 09/03/2022 19:02

Activity 3.2:

Observing external features of roundworms

Materials: Preserved specimen of *Ascaris lumbricoides* (female and male), hand lens, forceps, notebook, pen and two petri dishes

Procedure

1. Use forceps to pick up male and female specimens of *Ascaris lumbricoides* from preserving container and put them into two separate petri dishes.
2. Using a hand lens, carefully observe the specimens in both petri dishes to identify their external features.
3. Draw a well-labelled diagram of male and female *Ascaris lumbricoides*.

Question

What features distinguish roundworms from flatworms?

Economic importance of Nematodes (roundworms)

Some Nematodes are advantageous to human being and other organisms while others are disadvantageous as follows:

Advantages of nematodes

(a) Nematodes have been used in various biological studies. For example, some discoveries in the field of genetics involve the use of nematodes.

(b) Some nematodes are used as biological control agents for control of pests such as mosquitoes and locusts. They attack insects and kill or hinder their development. Parasitic roundworms attack and eat varieties of caterpillars.

(c) Soil nematodes are important in recycling of nutrients, hence contributing to soil fertility.

Disadvantages of nematodes

Many nematodes are parasites that cause diseases in plants and animals.

Some examples of parasitic nematodes and the disease they cause are described below;

(a) *Wuchereria bancrofti* which is a parasitic roundworm that causes a disease known as elephantiasis or bancroftian filariasis. This disease infects the human lymphatic system by blocking it. This result into accumulation of the lymph in legs, hands, mammary glands or scrotal sacs.

(b) *Meloidogyne incognita* is another roundworm that causes root knot galls in plants as it drains photosynthetic products. This in turn affects plant growth and reducing yields.

(c) *Onchocerca volvulus* is a roundworm which causes a disease called river blindness. This disease is called river blindness because the vectors which are black flies tend to breed in fast-flowing rivers.

(d) *Ascaris lumbricoides* is the human and pig endoparasite that causes ascariasis in humans and pig. This may lead to obstruction of the gut and may also cause anaemia.

BIOLOGY FORM 4.indd 102 09/03/2022 19:02

Exercise 3.3

1. What effects do parasites have on the health of the host?
2. How can a male and female roundworms be differentiated?
3. With the help of a diagram explain the structure of *Ascaris lumbricoides*
4. Explain the distructive features of Nematodes.
5. Explain the economic importance of roundworms.

Phylum Annelida

The word Annelid is derived from a latin word "annelus" which means little ring. Thus, members of this phylum are known as ringed or segmented worms. Annelida is a large phylum comprising of ragworms, lugworms, earthworms and leeches. They are adapted to various habitats. Some are aquatic living in marine and fresh water and others are terrestrial living in moist areas.

General features of annelids

Annelids possess the following features:

(a) They have a lip like extension on the first segment above the mouth called prostomium.

(b) Most annelids have chaetae. Chaetae is chitinous hair-like structures used for locomotion. These are absent in leeches.

(c) Some annelids have well-developed metameric segments throughout the body.

(d) They have bilaterally symmetrical bodies.

(e) Excretion takes place in convoluted tube-like structures called nephridia found in each segment.

(f) They have a moist outer covering called cuticle.

(g) They reproduce by both asexually and sexually.

(h) They have closed circulatory system whereby the blood flows within the blood vessels.

(i) They have a central nervous system with paired cerebral ganglia in which paired commissures around the gut lead to a double ventral nerve cord.

(j) They are eucoelomates meaning that their body cavities are lined by mesodermal tissues in both sides.

(k) They have triploblastic bodies.

Distinctive features of annelids

Features which distinguish annelids from other animals are as follows:

(a) Most annelids have hair-like structures called chaeta or setae made up of chitin. These are used for locomotion.

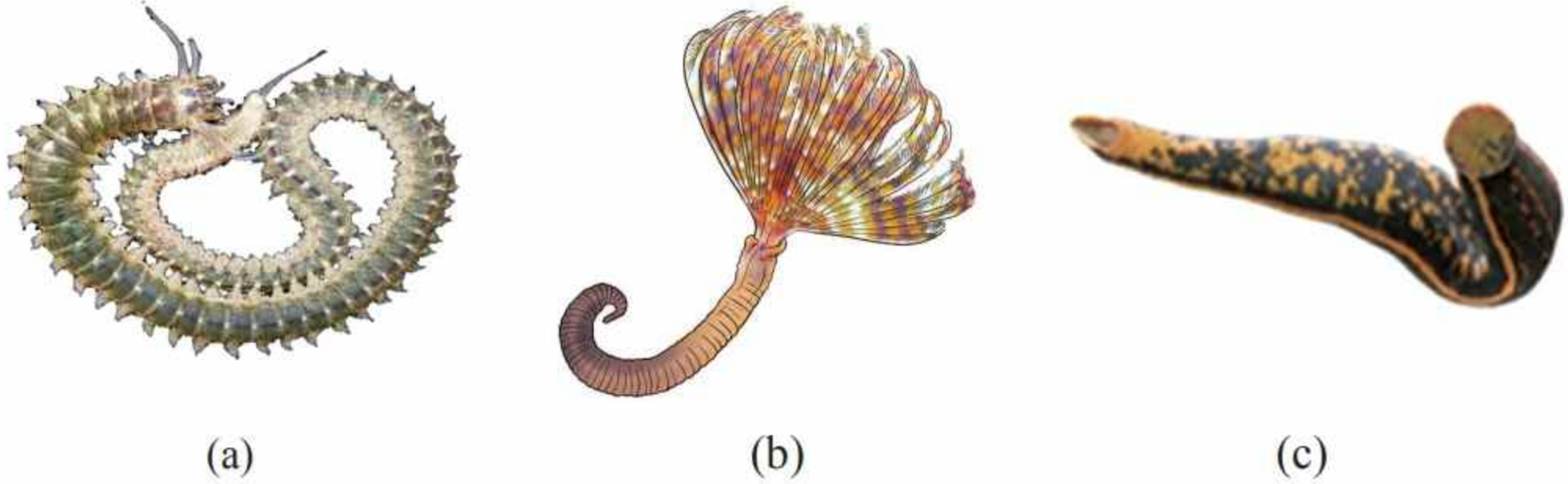
(b) They have perfect metameric segments throughout the body.

Classes of phylum Annelida

The phylum has three classes namely Polychaeta, Oligochaeta and Hirudinea. Class Polychaeta comprises the marine bristle worms with many chaetae and parapodia. Examples of Polychaetes include ragworms such as *Perinereis* species and lugworms *such as Arenicola* species. Class Oligochaeta comprises worms with few chaetae. They have no parapodia and live

BIOLOGY FORM 4.indd 103 09/03/2022 19:02

in moist soil or fresh water. These worms include *Lumbricus* sp. commonly known as the earthworms and *Tubifex* species also called sludge worm, or sewage worm. Class Hirudinea comprises of segmented worms with fixed number of segments and with neither chaetae nor parapodia. An example of hirudineans include the leeches (*Hirudo* species). See Figure 3.9.



(a) (b) (c)

Figure 3.9: Examples of annelids (a) marine ragworm (*Perinereis* sp.) (b) marine filter feeder (*Sabella* sp.) (c) blood-sucking leech (*Hirudo medicinalis)*

Structure of earthworm

An earthworm is an elongated, roughly cylindrical and metamerically segmented organism as shown in Figure 3.10. Each segment contains body systems such as circulatory, nervous, excretory and digestive systems. It has a complete digestive system that runs through the length of its body with both mouth and anus. The circulatory system is simple and closed. The earthworm has a central and peripheral nervous systems. The central nervous system consists of two ganglia above the mouth, one on either side. The ganglia are connected to a nerve cord running back along its length to motor neurons and sensory cells in each segment. It has a thin wet cuticle through which gaseous exchange takes place. The body wall of earthworm is characterised by circular and longitudinal muscles which are surrounded by the moist cellular epidermis and a thin cuticle. These muscles enable the earthworm to move. Similar sets of muscles line the gut and their actions move the food towards the worm's anus. Earthworms have a large number of chemoreceptors and sense organs which are located near the mouth. Hydrostatic pressure is maintained across each segment which helps to retain body rigidity, thus allowing muscle contraction and bending of the body without collapsing.

Earthworms are hermaphrodite meaning that each individual has both male and female reproductive organs. In addition, earthworms have clitella (singular: clitellum) which secret a cocoon in which eggs are deposited. The mouth is overhang by a flap called a prostomium. Earthworm has chitinous hair-like structures called chaeta which project from their cuticle and enable movement of the worm.

BIOLOGY FORM 4.indd 104 09/03/2022 19:03

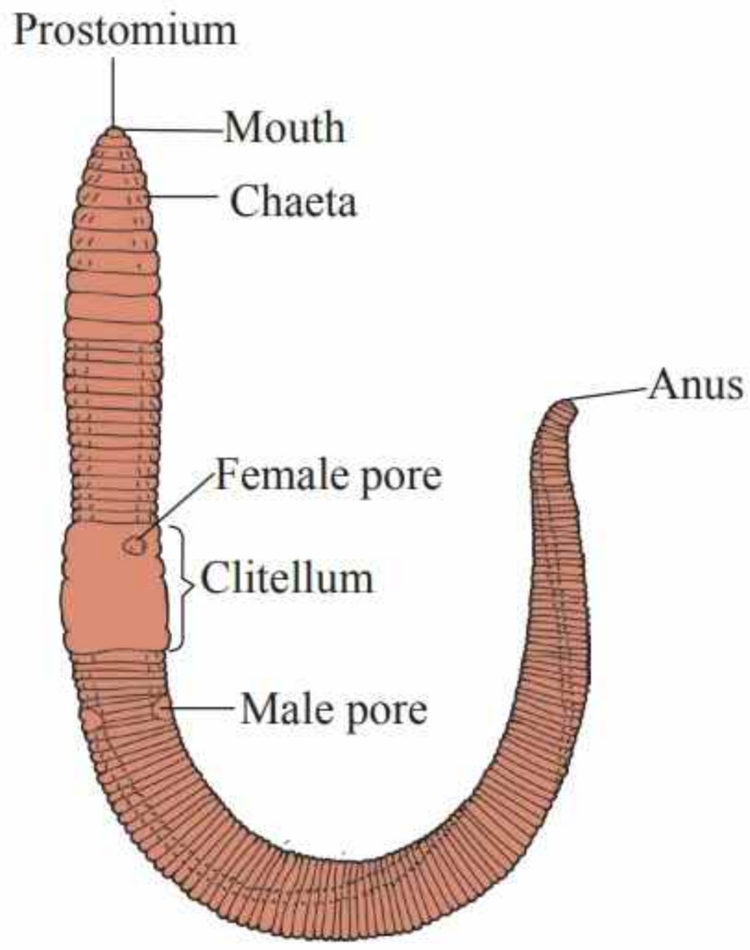


Figure 3.10: Structure of the earthworm

Activity 3.3:

Observing external features of the earthworm

Materials: Preserved or live specimen of earthworm, hand lens, petri dish, note book, pen and forceps

Procedure

1. Using forceps, pick an earthworm from preserving container and put it in a petri dish.
2. Using a hand lens observe the specimen carefully to identify its external features.
3. Draw a well-labelled diagram of the earthworm to indicate its mouth, anus clitellum and chaeta.

Questions

(a) How are the earthworms adapted to their environment?

(b) Explain two features that distinguish earthworms from bristle worms.

Economic importance of annelids

Annelids are both ecologically and economically important. However, some of them are harmful to animals and the environment.

Advantages of annelids

(a) Some annelids improve soil aeration through burrowing and mixing up of soil layers. Earthworms play very important role in improving soil aeration, hence maintaining soil fertility.

(b) They are used for commercial production of compost manure in the process known as vermicomposting.

(c) Some annelids are used as a bait in the fishing industry. Examples of annelids used as bait include earthworms and lugworms.

(d) They are used as source of nutritious food for some fish and birds. They are rich in proteins and vitamins.

(e) Some annelids are ecological decomposers. Hence, they contribute to nutrient circulation because they feed on decaying organic matter.

(f) They remove pollutants from the soil and clean the environment by transforming organic wastes during feeding.

(g) Faeces and urine of some annelids have considerable value as manure and increase soil fertility.

(h) They are used as specimens in biological studies.

(i) The excretory waste of some annelids which are in the form of cast increases sticking together of soil particles. This in turn increases water holding capacity of the soil.

BIOLOGY FORM 4.indd 105 09/03/2022 19:03

Disadvantages of annelids

In some cases annelids are harmful. The harmful effects of the annelids include the following:

(a) Some annelids damage young roots of the growing plants.

(b) Leeches are harmful to mammals, reptiles and fishes because they suck blood.

(c) Earthworms can increase soil porosity and aeration which may cause water loss by seepage from the farms.

Exercise 3.4

1. Explain how earthworms are important to man.
2. What features distinguish earthworms from leeches?
3. What morphological features differentiate earthworms from tapeworms?
4. With the help of well labelled diagram describe the structure of earthworm.

Phylum Arthropoda

The term arthropoda comes from two Greek words, "arthron" meaning joint and "podos" meaning foot. Literally, arthropods are organisms with jointed appendages. The appendages are modified for various functions. For example, mouthparts are modified for feeding, antennae and palps for sensation and legs for locomotion. Arthropods are the most successful animals and they are found almost in every habitat including marine, fresh water and terrestrial habitats. They vary widely in their habitats and feeding habits. Examples of arthropods include tiger prawn, scorpion, tick, beetle and butterfly as shown in Figure 3.11.

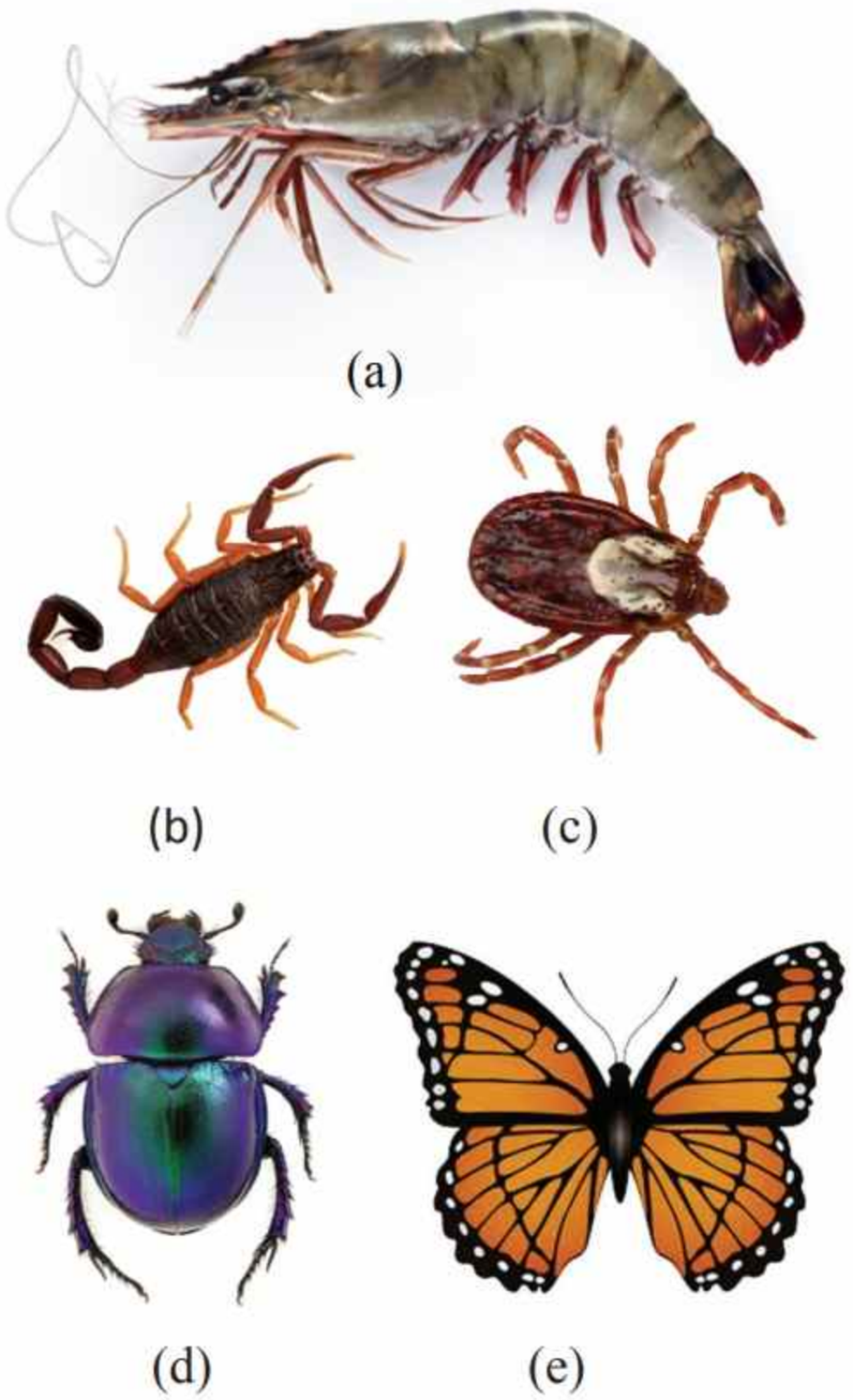


Figure 3.11: Examples of Arthropods
(a) tiger prawn (b) scorpion
(c) tick (d) dung beetle (e) butterfly

General features of arthropods

Arthropods possess the following features:

(a) They have jointed and paired appendages that may be modified in various ways to form structures such as antennae, mouthparts, legs and reproductive organs. The modified appendages are used for various functions such as feeding, gaseous exchange, locomotion and sensation.

BIOLOGY FORM 4.indd 106 09/03/2022 19:03

(b) They have segmented bodies which are organised into regions called tagmata. These regions are the head, thorax and abdomen (opisthosoma). The head of some arthropods such as arachnids and crustaceans is fused with the thorax to form a structure called cephalothorax or prosoma. Therefore, such arthropods have two tagmata which are prosoma and opisthosoma.

(c) They have a coelom that is reduced and confined to cavities of excretory organs and reproductive duct. They also have another cavity called haemocoel which is formed during their development.

(d) They have exoskeleton made up of chitin covering their body. In some arthropods the exoskeleton is shed during growth. The exoskeleton serves different purposes such as muscles attachment, support and protection against physical damage. The process of shedding off the exoskeleton during growth is called moulting or ecdysis.

(e) They have a ventral nervous system.

(f) They have open circulatory system which is dorsally positioned.

(g) Their body plan is bilaterally symmetrical.

(h) They have compound or simple eyes.

Distinctive features of arthropods

The following are distinguishing features of the arthropods:

(a) They have jointed appendages which serve different purposes such as feeding, locomotion, and sensation.

(b) They have segmented bodies organized into regions called tagmata.

(c) They have an exoskeleton which is made up of a chitin. The exoskeleton is usually stiff, rigid or flexible.

Classes of phylum Arthropoda

Based on the presence of antennae, position and numbers of appendages, habitats, life histories, and habits, arthropods are classified into five classes. These are class Crustacea which includes crabs and lobsters; class Arachnida which includes spiders and scorpions; class Chilopoda which include centipedes; class Diplopoda which include millipedes; and class Insecta which includes cockroaches, termites, and grasshoppers.

Class Crustacea

Members of this class are mainly found in marine and fresh water and few occupy terrestrial habitat. Examples of organism that belongs to this class are crabs, lobsters, prawns, shrimps, barnacles and crayfish. A woodlice found in leaf litter is an example of terrestrial crustacean. Members of this class pass through several larval stages during their development.

Distinctive features of Crustaceans

Crustaceans possess unique features that differentiate them from other Arthropods. These features include the following:

(a) They have two pairs of antennae.

(b) Most have branched appendages (biramous).

(c) Their bodies are covered with a hard shell called a carapace which act as a protective shell.

BIOLOGY FORM 4.indd 107 09/03/2022 19:03

(d) In most crustaceans, gaseous exchange is by means of gills. Gills are formed as an outgrowth of the body wall or limbs.

(e) Their bodies are divided into two parts namely cephalothorax and abdomen. The head and thorax are fused together to form the cephalothorax.

(f) Most of them have a pair of compound eyes which can be stalked or sessile.

Structure of a crab

The body of a crab is divided into two parts namely the cephalothorax and abdomen. Their body is covered with a thick chitinous exoskeleton called carapace as show in Figure 3.12. Chitin is strengthened by calcium carbonate. This protects them from predators. Generally, the body of a crab is flat with the abdomen curved below the cephalothorax and hidden under the carapace. The head bears two pairs of antennae. Crab is equipped with a pair of claws called pincers which are very important for grasping, eating and subduing the prey. Pincers are also used as weapons during fighting. Crabs possess pleopods which in males are modified for copulation. In females, pincers are modified for carrying eggs. Crabs have compound stalked eyes.

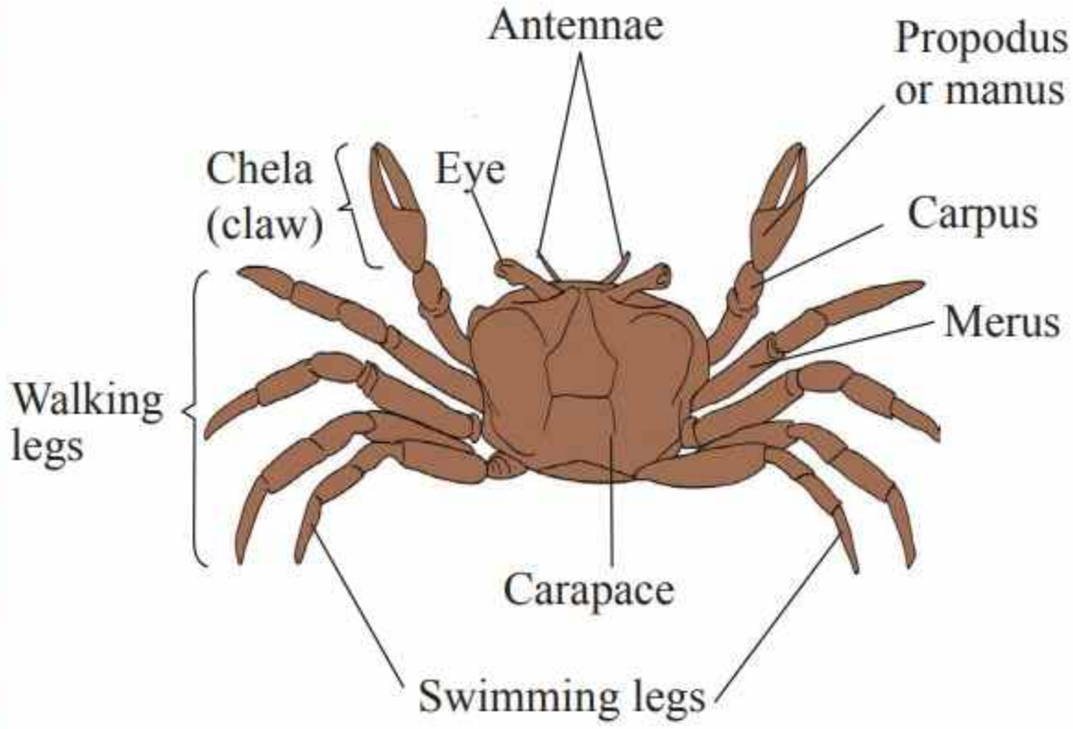


Figure 3.12: External structure of a crab

Activity 3.4:

Observing external features of crabs

Materials: Preserved specimens of crabs, petri dish, notebook, pen and hand lens

Procedure

1. Put the specimen in a petri dish.
2. Using a hand lens observe the specimen carefully to identify its external features.
3. Draw a well-labelled diagram of the specimen.

Question

(a) What is the function of a carapace in the crab's body?
(b) What are the functions of a pincer?
(c) List two features which shows that the crab is a crustacean

Economic importance of crustaceans

Crustaceans are advantageous and disadvantageous to human beings and other animals as follows.

BIOLOGY FORM 4.indd 108 09/03/2022 19:03

Advantages of crustaceans

(a) Crustaceans are a good source of food for human beings and other animals. They are rich in protein and calcium minerals. Examples of edible crustaceans are lobsters, prawns, shrimps, and giant mud crabs.

(b) They are used in the production of livestock feeds.

(c) They are used in biological studies and research.

(d) Crustaceans attract tourists especially those species found alongside the beaches.

(e) Some crustaceans are used for decoration purpose especially crabs and crayfish.

(f) The crustacean fishery provides employment and income to fishing communities.

Disadvantages of crustaceans

Despite the advantages of crustaceans to humans and other animals, some of them have harmful effects. Some can bite humans when provoked causing injuries and severe pains. Also, some crustaceans such as isopods are ectoparasites and cause economic losses in fishery industry by killing, stunting or damaging fishes. Additionally, some crustaceans can transmit disease causing organisms such as helminthes and blood parasites.

Class Arachnida

Arachnids are terrestrial arthropods consisting of animals whose bodies are divided into two regions; prosoma and opisthosoma. In some arachnids the two region are separated by a narrow waist-like constriction. The prosoma is partly or completely covered with a carapace-like shield. Members of this class lack antennae and the majority are carnivores which feed on other invertebrates or small vertebrates. Others archnids such as ticks and some mites are ectoparasites which feeds on the blood of vertebrates. Examples of arachnids are spiders, mites, ticks and scorpions.

Distinctive features of arachnids

Arachnids possess various unique features which distinguish them from other Arthropods. These features include:

(a) They have no antennae, instead they have a pair of pedipalps which they use for defense and detection of stimuli.

(b) They have four pairs of walking legs that are attached to the cephalothorax.

(c) They have only simple eyes used for vision, while others are completely blind.

(d) Gaseous exchange in arachnids is by means of book lungs or trachea.

(e) They lack mandibles instead they use two pairs of appendages originating from prosoma. The first pair called chelicerae is modified into venomous fangs in spiders which is used for killing prey and defending themselves. The second pair called pedipalps hold the prey in place when they chew or inject the prey with venom.

BIOLOGY FORM 4.indd 109 09/03/2022 19:03

Structure of the spider

Structurally the body of a spider is divided into two main parts called cephalothorax or prosoma and opisthosoma as shown in Figure 3.13. They have six pairs of appendages which include four pairs of legs, chelicerae (mouthparts) and pedipalps. On the ventral part of the abdomen, there are two hardened plates covering the book lungs. The spinnerets which extrudes silk are also found in the abdomen. They possess very small eyes which are often clustered.

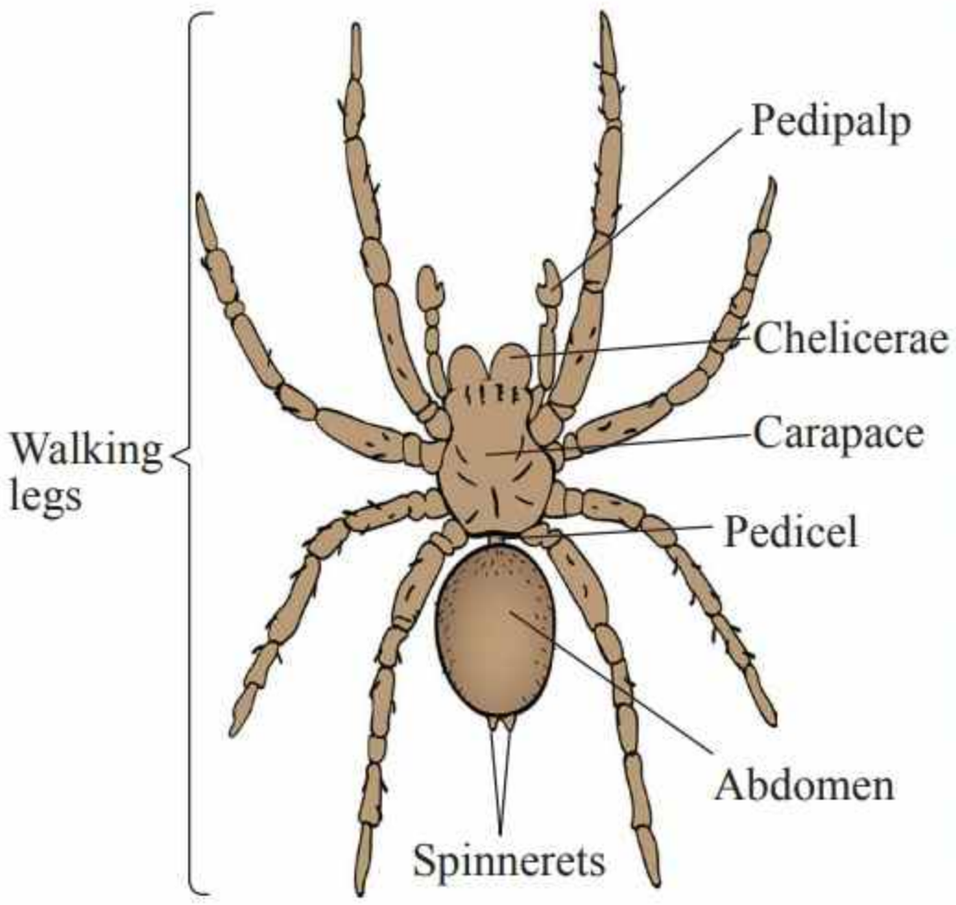


Figure 3.13: External structure of a spider

Economic importance of arachnids

Arachnids are both advantageous and disadvantageous to human being and other organisms as follows;

Advantages of arachnids

(a) Some arachnids such as mites play an important role in the formation of humus from decomposed leaf litter and wood.

(b) Many arachnids are used as food by other animals. For example, spiders are used as source of food by frogs, lizards and birds.

(c) Spiders and other arachnids feed on wide range of pests, thus helping to keep the population of pests under control.

(d) Silk from spiders can be harvested for production of useful products such as surgical threads and bullet-proof vests.

(e) They are used in biological studies and research.

Disadvantages of arachnids

(a) Some arachnids such as scorpions can sting human beings and release their venom that cause severe pains. The bite from some spiders such as the black widow *Latrodectus* species can cause serious health problems in children and even death.

(b) Some arachnids are parasites to mammals and other vertebrates. Examples of such arachnids are ticks and mites which usually bite humans and other animals causing pain. They can also transmit diseases.

(c) Some arachnids destroy crops and other properties. Examples of such arachnids are mites that attack food crops (on farm and in storage) and timber.

Class Chilopoda

Members of this class are known as centipedes. These are terrestrial animals

BIOLOGY FORM 4.indd 110 09/03/2022 19:03

abundant in moist areas such as in leaf litter, under logs or rocks. They possess a pair of antennae that enables them to detect stimuli.

Distinctive features of chilopods

Centipedes possess various unique features that distinguish them from other Arthropods. These features include the following:

(a) Their bodies are composed of a chain of flattened segments. Each segment has a single pair of walking appendages, except the one behind the head and the last two. Appendages of the first segment are modified into venomous claws that are used to immobilize a prey.

(b) They are carnivores feeding mainly on small invertebrates such as insects, spider and worms. They hunt and paralyse these invertebrates using their venomous claws.

(c) They have distinct head while other body segments are similar. The trunk is not obviously divided into thorax and abdomen. The head bears one pair of antennae

Structure of a centipede

The body of a centipede is dorso-ventrally flattened and segmented with one pair of legs on each segment as shown in Figure 3.14. The legs of the first body segment are modified into venomous claws called forcipules or foot jaws. These claws are used for defense as well as for capturing and paralysing preys. The last pair of legs are usually long and are used for grasping the prey. Centipedes have a distinct head that bears one pair of antennae. Antennae help them to locate their preys. They have tracheal system for gaseous exchange.

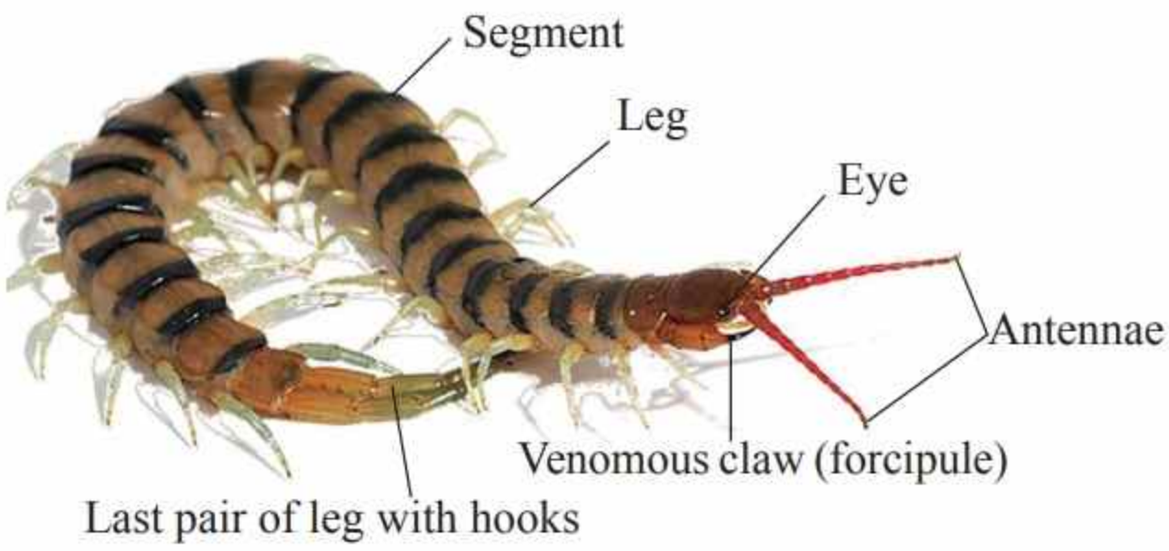


Figure 3.14: External structure of a centipede

Economic importance of chilopods

Chilopods are both advantageous and disadvantageous to human beings and other animals as follows;

Advantages of chilopods

Many chilopods such as centipedes are used as food since they are a good source of proteins to other animals such as shrews, toads, badgers and birds. They are also used in biological studies and research. They help in the elimination of harmful insects in the houses as they feed on smaller insects such as ants, termites and bugs.

Disadvantages of chilopods

Members of class Chilopoda such as centipedes have venomous claws. They can bite humans and other

BIOLOGY FORM 4.indd 111 09/03/2022 19:03

animals causing pain, small wounds and blisters.

Class Diplopoda

This class is comprised of animals that mainly live in moist habitats. Members of this class include millipedes. They are scavengers or herbivores that feed on decaying organic matter such as leaves and compost. Most diplopods have simple and compound eyes, although some lack compound eyes. They breath using the tracheal system.

Distinctive features of diplopods

Diplopods have unique features which differentiate them from other arthropods. These include:

(a) The have segmented bodies with two pairs of walking appendages on each segment.

(b) Their bodies are divided into two parts with a clearly defined head and trunk. The head bears one pair of antennae and mouthparts (the jaws).

(c) They are herbivores.

Structure of a millipede

The body of millipede is elongated, cylindrical, and segmented as shown in Figure 3.15. The body consist of a series of segments whose number varies depending on the species. The segments contain glands that secrete a noxious chemical to repel predators. Each trunk segment bears two pairs of walking legs with exception of the segment behind the head . Millipedes also have a head with one pair of antennae that help them to detect stimuli from the surroundings. The head also has one pair of mouthparts that is found in front of the head. Most millipedes have simple eyes located above the jaws. Such millipedes have ability to see. However, some millipedes have no eyes at all, so that they can not see.

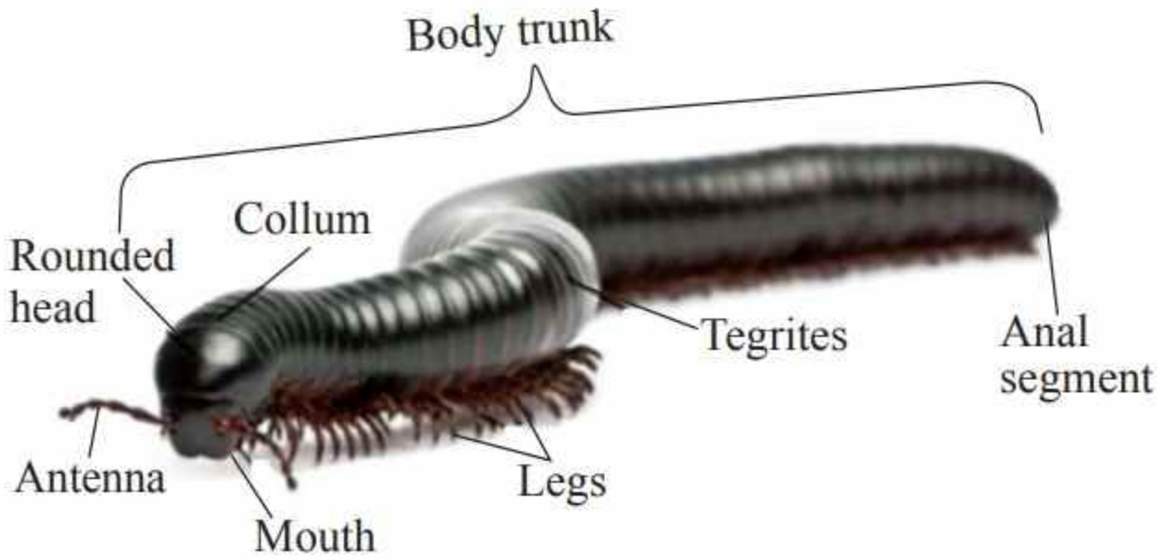


Figure 3.15: External structure of a millipede

Economic importance of diplopods

Diplopods are both advantageous and disadvantageous to both plants and animals including human being.

Advantages of diplopods

Most diplopods are used as source of food to other animals including birds, reptiles and amphibians. They are also used in biological studies and research. Since diplopods feed on decaying plants and animal matter, they help in the recycling of nutrients in the ecosystem.

Disadvantages of diplopods

Some herbivorous millipedes can cause damage to crops in the field. Burrowing diplopods can cause some damage to the roots or germinating seeds.

BIOLOGY FORM 4.indd 112 09/03/2022 19:03

Activity 3.5:

Observing the external structure of specimens/pictures labelled P_1, P_2, and P_3.

Materials: specimens/pictures labelled P_1, P_2, and P_3, notebook, pen and hand lens

Procedure

Carefully observe the following specimens/pictures labelled P_1, P_2, and P_3 in the figure 3.16 and then answer the questions that follows.

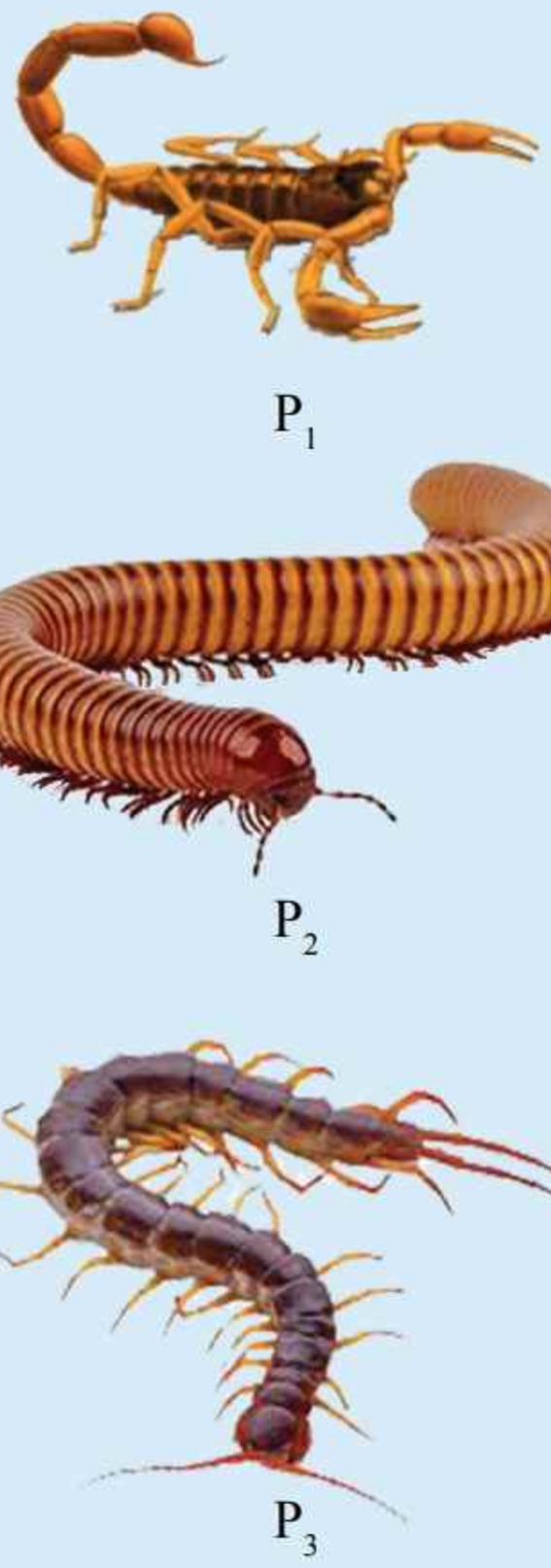


Figure 3.16: Specimen P1, P2, and P3

Questions

(a) Give the common names of specimens $\mathbf{P_1}$, $\mathbf{P_2}$, and $\mathbf{P_3}$.

(b) Name the classes to which the specimens $\mathbf{P_1}$ and $\mathbf{P_3}$ belong.

(c) List down two observable features that have enabled you to place the two specimens in (b) above into their respective classes.

(d) What is the economic importance of specimen $\mathbf{P_2}$?

Class Insecta

Members of class Insecta are the most diverse and most abundant animals on the earth. They are found in all environments or habitats including freshwater, terrestrial, and marine habitats. Common features shared by members of the class Insecta include the following:

(a) Their bodies are divided into three distinct parts; the head, thorax and abdomen.

(b) They have three pairs of walking legs.

(c) Their heads bear one pair of antennae. The antennae are used as sense organs for detection of odour molecules in the air, changes in the concentration of water vapour, sounds and for gauging air speed.

(d) Most insects have one or two pairs of wings located on second and third thoracic segment. The wings enable them to fly to different places in the habitat to escape from enemies and for searching for food. Wings also

BIOLOGY FORM 4.indd 113 09/03/2022 19:03

help the insect to cover the body and protect it from cold, thus making it active even at low temperatures.

(e) They usually have three pairs of mouthparts which are mandibles, maxillae, and fused labium. These parts are modified in different ways in order to suit various functions such as piercing, sucking, chewing and biting. This enables insects to feed on different diets.

Examples of organisms belonging to class Insecta include grasshoppers, butterflies, houseflies, cockroaches, beetles, bees, ants, wasps and termites.

Insects may be carnivores such as dragonflies, herbivores such as grasshoppers and bees, or scavengers such as cockroaches and termites.

Distinctive features of insects

Insects differ from other arthropods in the following ways;

(a) Their bodies are divided into three main regions or tagmata, namely the head, thorax and abdomen.

(b) They have three pairs of jointed walking appendages.

(c) They have a highly developed mechanism of gaseous exchange through trachea. They have holes called spiracles located on the abdomen and joined to the tracheal tubes which help to ensure efficient gaseous exchange.

(d) Majority have one or two pair of wings, few lack wings for example fleas and lice.

Structure of a grasshopper

A typical example of an organism in the class Insecta is a grasshopper. The body of a grasshopper is elongated and segmented. It is divided into a head, thorax and abdomen as shown in Figure 3.17. The head of the grasshopper has a pair of antenna and compound eyes. Each compound eye is made up of thousands of tiny units closely packed together. The head also consists of three pair of mouthparts namely mandibles, first maxillae and second maxillae. The thorax is subdivided into three parts namely prothorax, mesothorax and metathorax. Each of these segments bears one pair of legs. The hind legs of the grasshopper are long and muscular and they are used for hopping and jumping. The two pairs of front legs are short and they are used for walking. The thorax of the grasshopper also bears two pairs of wings as in most other adult insects. The abdomen of the grasshopper consists of eleven segments, although some may not be easily seen. Each segment bears spiracles. The abdomen also has external reproductive structure and an anus through which undigested food materials are egested from the body. The body of the grasshopper is covered by a rigid exoskeleton called cuticle secreted by the epidermal layer. The exoskeleton occurs in jointed sections or plates to allow body movements. The exoskeleton is made up of a chitin. It is coated with wax which is impermeable to water. The exoskeleton provides point of attachment for body muscles. Grasshoppers breathe through a series of openings called

BIOLOGY FORM 4.indd 114 09/03/2022 19:03

spiracles which are located along the sides of the abdomen. Most grasshoppers are green or brown coloured in order to blend or resemble with their local environment.

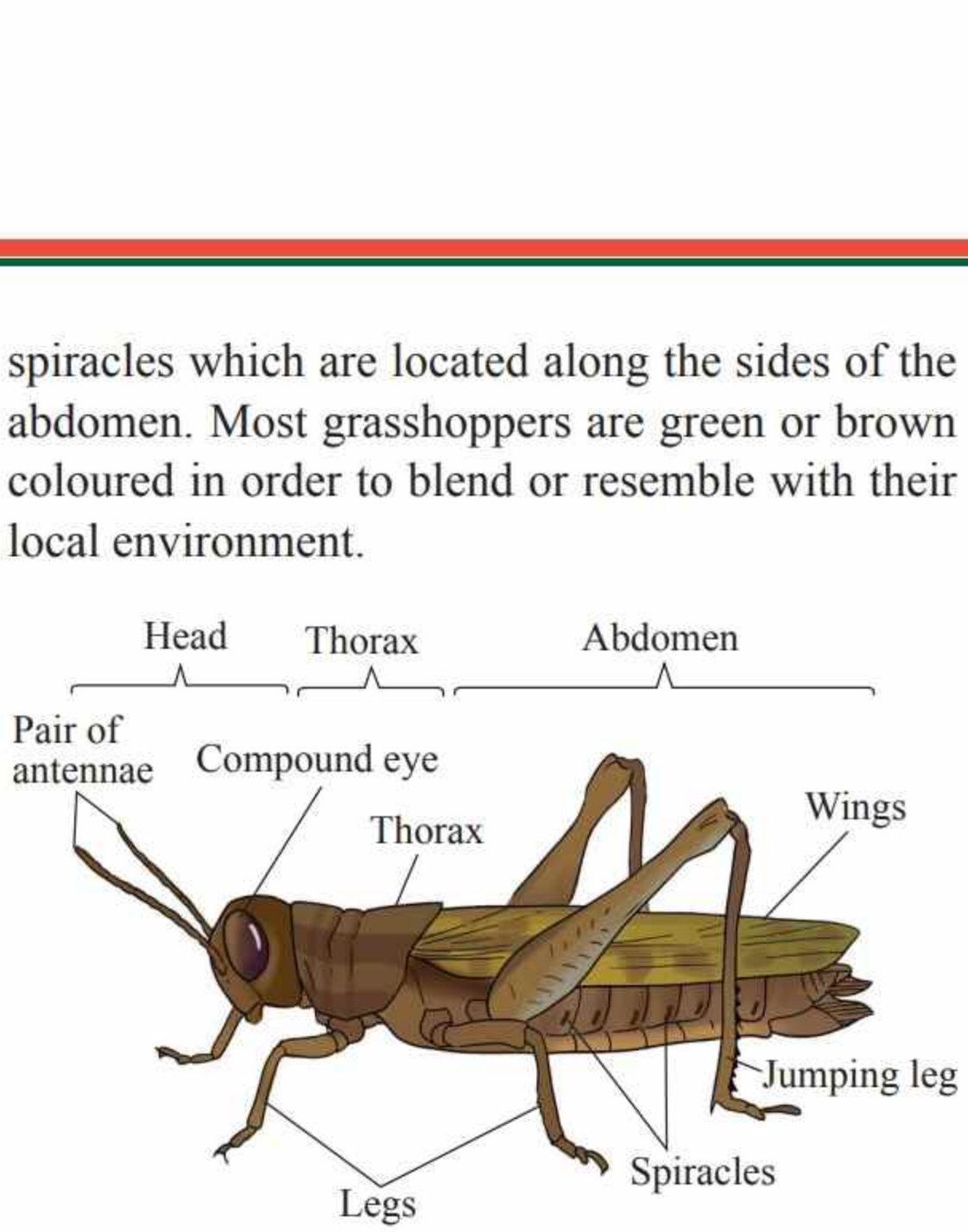


Figure 3.17: External structure of a grasshopper

Activity 3.6:

Observing the external structure of a grasshopper, housefly and beetle

Materials: Preserved or immobilised live specimens of grasshopper, housefly and beetle, three petri dishes, note book, pen, forceps and hand lens

Procedure

1. Using forceps place each specimen in a separate petri dish.
2. Using a hand lens, carefully observe each specimen to identify its external features.
3. Outline the external features you have observed.
4. Draw a well-labelled diagram of each specimen.

Questions

(a) Which features shows that the specimens are insects?

(b) What two external features distinguish houseflies from beetles?

(c) How hind limbs of the grasshopper are adapted for hopping?

Economic importance of insects

Insects are both advantageous and disadvantageous to humans and other organisms.

Advantages of insects

(a) They are used for production of various substances. For example, honey bees produce honey, wax and bee venom, silk worms produce silk that can be used for commercial purpose.

(b) They are used in biological control of pests. Insects have been used effectively as predators to kill or control pests. For example, lady beetles are used to kill aphids. Aphids are the insect pests that transmit viruses to plants.

(c) Insects such as bees and butterflies are useful in agriculture as they act as pollinators. Many plants depend on insects for pollination.

(d) They are used in scientific research particularly in fields of physiology, genetics and

BIOLOGY FORM 4.indd 115 09/03/2022 19:03

evolution. The fruit flies (*Drosophila melanogaster*) are among the insects used for this purpose.

(e) Some insects are used in the production of medicine. Such insects include blister beetles that produce cantharidin which is used for treatment of urino-genital diseases.

(f) Many insects are used as food. They are a good source of proteins for human beings and other animals. Examples of such insects include winged termites, edible grasshoppers, locusts, cockroaches, larvae of beetles, butterflies and moths.

(g) Some insects are scavengers and feed on rotten or decayed materials hence helping in reducing rubbish and ensuring nutrient recycling in the ecosystem. Examples of such insects are cockroaches.

(h) Some insects improve aeration and soil fertility. For example, termites breakdown plant tissues thus improving soil fertility.

Disadvantages of insects

(a) Some insects such as wasps and bees can cause painful bites and stings. Stinging insects that live in colonies can cause significant injury and even death.

(b) Some insects are vectors of animal and plant diseases. For example, mosquitoes carry *Plasmodium* spp. which cause malaria. Tsetse flies carry *Trypanosoma* spp., a parasite which cause sleeping sickness to human beings. In addition, white flies carry tomato yellow leaf curl virus which cause chlorosis in plants.

(c) Some insects destroy trees and crops. Examples of such insects include locusts and the caterpillars.

(d) Some insects are ectoparasites of mammals. For examples jiggers and bedbugs which tend to suck blood from their hosts.

(e) Some insects destroy human properties. Example cockroaches which spoil food, termites, beettle and carpenter bee that eat wooden furniture and moth larvae that feed on carpets and clothes.

Exercise 3.5

1. Outline the three external features which distinguish spider from beetle.
2. Give reasons why arthropods are considered to be the most successful animals on earth?
3. In what ways do humans benefit from arthropods?
4. What external features show that black ants belong to class insecta?

Phylum Chordata

This phylum comprises of animals with a high degree of body organisation. Animals under this phylum possess a notochord during embryonic development that strengthens and supports the body. In protochordates, the notochord persists throughout life, but in most vertebrates it is replaced by the vertebral column in adulthood.

General features of chordates

Chordates possess the following features:

(a) They are triploblastic animals.

(b) They are coelomate animals.

(c) Their bodies are metamerically segmented and bilateral symmetry.

(d) Some members of phylum Chordata such as cartilaginous fish, bony fish, amphibians and reptiles are poikilotherms. This means their body temperature fluctuate with the temperature of their surroundings. Other chordates such as birds and mammals are homoiotherms. This means their body temperature remain constant regardless of the changes in environmental temperature.

(e) Most chordates have a ventral heart.

(f) Most chordates have a closed circulatory system.

(g) Most have endoskeletons made up of bones and cartilages.

(h) Some chordates have central nervous system made up of the well-developed brain and a spinal cord.

(i) They occupy both terrestrial and aquatic habitats.

(j) Some chordates are viviparous in which their young develop inside the body while others are oviparous as their young develop outside the body.

(k) Most chordates have a complete digestive system with two openings, the mouth and anus.

(l) Most chordates have segmented muscle blocks called myotomes, one muscle block on either side of the body.

Distinctive features of chordates

Chordates have unique features that differentiate them from other animals. They have the following features at some stages of embryological development:

(a) A notochord.

(b) Pharyngeal pouches or gill slits.

(c) A post-anal tail.

(d) A dorsal hollow tubular nerve cord.

Classes of phylum Chordata

The classes of the phylum Chordata include:

(a) Class Chondrichthyes, examples sharks, rays, skates and chimaeras.

(b) Class Osteichthyes, examples tilapia, catfish and lungfish.

(c) Class Amphibia, examples frogs, toads, newts and salamanders.

(d) Class Reptilia, examples lizards, crocodiles and snakes.

(e) Class Aves, examples chicken, parrots, eagles and pigeons.

(f) Class Mammalia, examples mice, bats, rabbits, monkeys and humans.

Class Chondrichthyes

This class contains the cartilaginous fish whose skeletons are made up of cartilage instead of bones. Most members of this class are marine but few live in fresh water. They have fleshy paired pectoral and pelvic fins that are used for swimming. Fertilisation is internal in most cartilaginous fish. Some members of the class Chondrichthyes such as rays and skates are dorso-ventrally flattened while others are spindle-shaped. All members

BIOLOGY FORM 4.indd 117 09/03/2022 19:03

of this class have paired fins, paired nares, jaws and two chambered heart. Examples of organisms that belong to this class include sharks, skates, rays and chimaeras. See Figure 3.18.

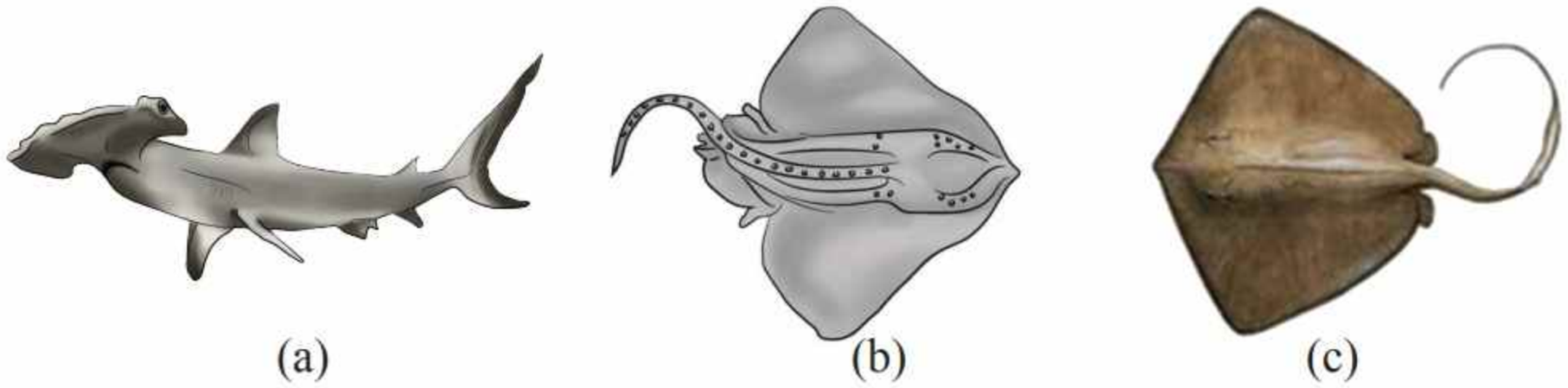


Figure 3.18: Cartilaginous fish (a) hammer-head shark (b) skate (c) ray

Distinctive features of cartilaginous fish

Cartilaginous fish possess various unique features that distinguish them from other chordates. These features include the following:

(a) They have cartilaginous endoskeleton made up of soft supporting tissue called cartilage.
(b) They have placoid scales, which are teeth like scales which protect their bodies against physical injuries.
(c) Most cartilaginous fish have five to seven pairs of visceral clefts. These are separate gill slits for gaseous exchange. Their gills have no gill covers (opercula; singular: operculum). This implies that the gills are in direct contact with the outside environment.
(d) They have an asymmetrical (heterocercal) caudal fin (tail fin).
(e) Males have copulatory structures called claspers found on pelvic fins.

Structure of a shark

A shark has rounded and tapering body at both ends, as shown in Figure 3.19. Its body is covered with placoid scales and has lateral lines that run along the side of its body. The lateral lines are used for detecting vibrations and changes in water pressure. The mouth is located ventrally with teeth which are constantly replaced. A shark has small eyes with round pupil. The lower lids are used to cover the eyes during feeding. A shark also has pectoral fins which are located anterior to the pelvic fins. Males have the pelvic fins claspers (pterygopodes) which are used as copulatory organs. The caudal fin of shark is asymmetrical and heterocercal in shape. Shark also has gill slits which are naked with no operculum. In addition, a shark has a spiracle on the top of the head, which is a modified gill slit. The spiracle provides oxygenated blood directly to the eye and brain through a separate blood vessel. Shark has a short digestive system with various adaptive features such as a high- piched folds called spiral valves. These valves control food passage through the intestines and speed up the rate of food digestion and absorption.

BIOLOGY FORM 4.indd 118 09/03/2022 19:03

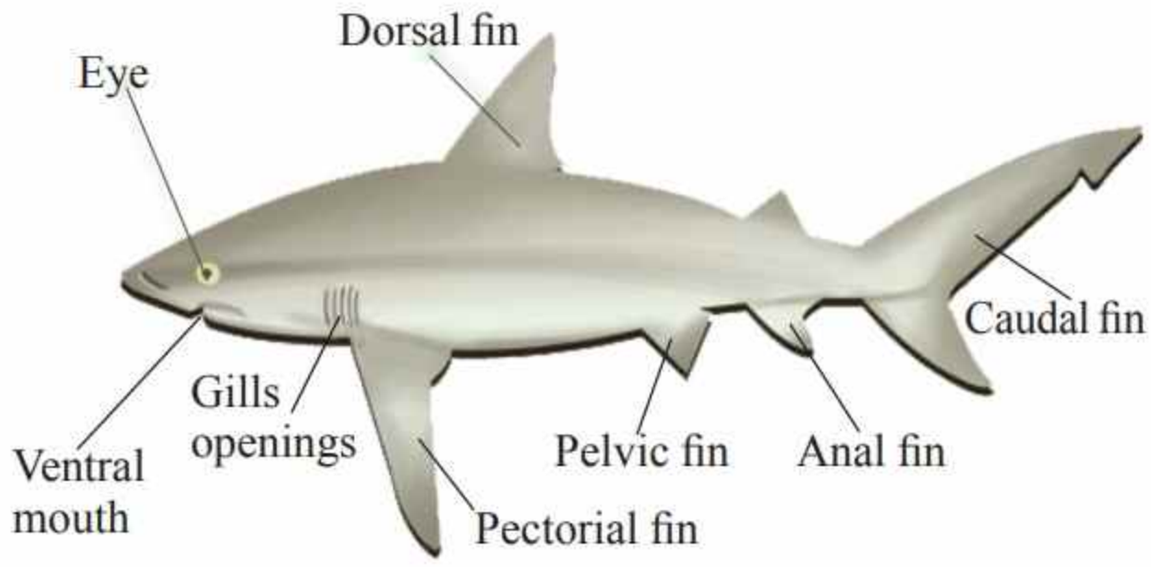


Figure 3.19: External structure of a shark

Economic importance of cartilaginous fish

Cartilaginous fish are both beneficial and harmful to human and other animals.

Advantages of cartilaginous fish

Cartilaginous fish are rich in proteins. They therefore are used as source of food by humans and other animals. The fishery activities of cartilaginous fish also provide income and employment to fishing communities. Products of cartilaginous fish are used to manufacture animal feeds. Oils produced from the fish can be used as medicine. Some cartilaginous fish are kept for ornamental purpose. Some cartilaginous fish are also used in biological studies and research.

Disadvantages of cartilaginous fish

Some sharks can attack people and cause injuries or death. Sting rays can attack humans when provoked causing severe pain, nausea and fainting. If they are not disposed properly in the environment, they produce bad smell.

Class Osteichthyes

This class comprises of the bony fish. Their skeleton is made up of hard bones instead of cartilage. Bony fish vary in form, size and habitats. Most members of this class have paired pectoral and pelvic fins supported by bony rays. The majority of members have scales while others such as catfish lack scales. Their scales are impermeable to water. Hence, they are capable of reducing water loss in marine environment and restricting entry of water in fresh water environment. They have streamlined body shape. They also have a lateral line that allows them to detect vibrations and changes in water pressure. The heart of bony fish is two chambered with one atrium and one ventricle. Bony fish inhabit both marine and freshwater. Examples of bony fish include tuna, tilapia, Nile perch, herring, butterfly fish and catfish as shown in Figure 3.20.

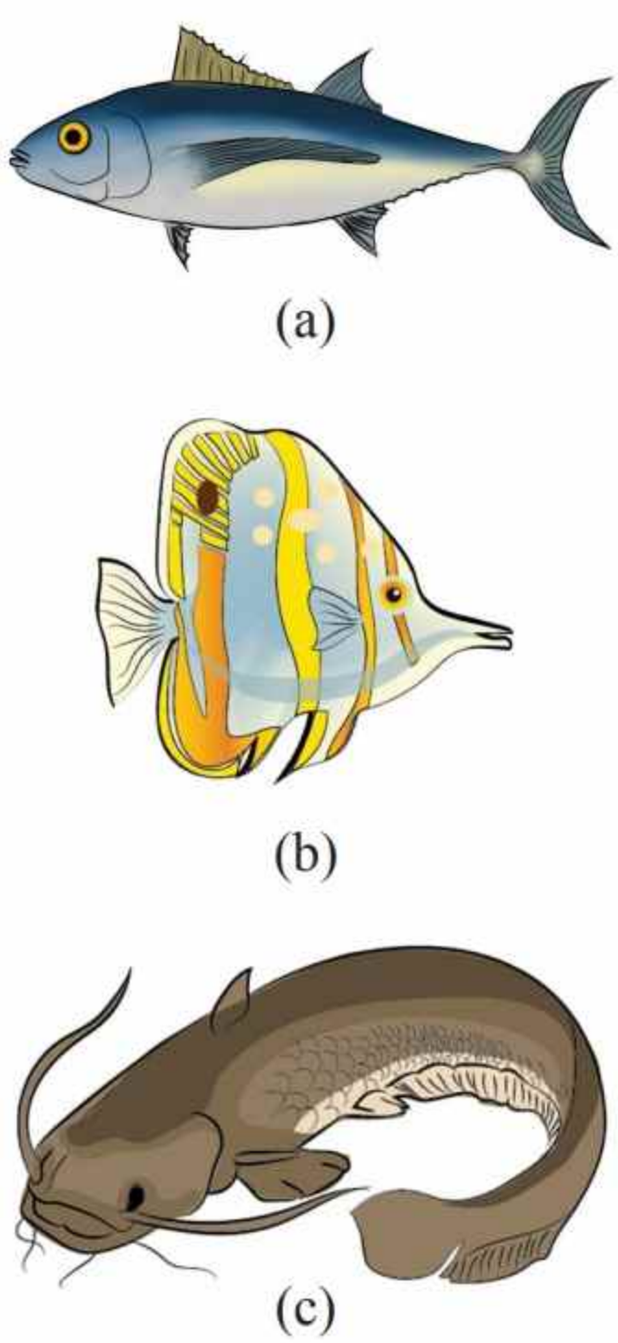


Figure 3.20: Examples of bony fish
(a) tuna (b) butterfly fish (c) catfish

BIOLOGY FORM 4.indd 119 09/03/2022 19:03

Distinctive features of bony fish

The following features differentiate bony fish from other chordates:

(a) They have four pairs of visceral clefts as their gill openings. These are covered by an operculum.

(b) Most of bony fish have swim or air bladder which provides them buoyancy during swimming.

(c) Most have a bony endoskeleton and their skin is covered by glands producing mucus that make them slippery.

(d) Most have symmetrical or homocercal caudal fins. This means that their caudal fins can be divided into equal parts.

(e) They have terminal mouth.

Structure of a Tilapia

Tilapia fish has a laterally-flattened body that tapers at both ends. It has a streamlined body shape that enables it to overcome water resistance during swimming. The surface of its body is covered with overlapping scales as shown in Figure 3.21. In addition, tilapia has a lateral line that runs along the side of its body. The lateral line is a series of sensory organs called neuromasts that help the fish to sense vibrations and water pressure.

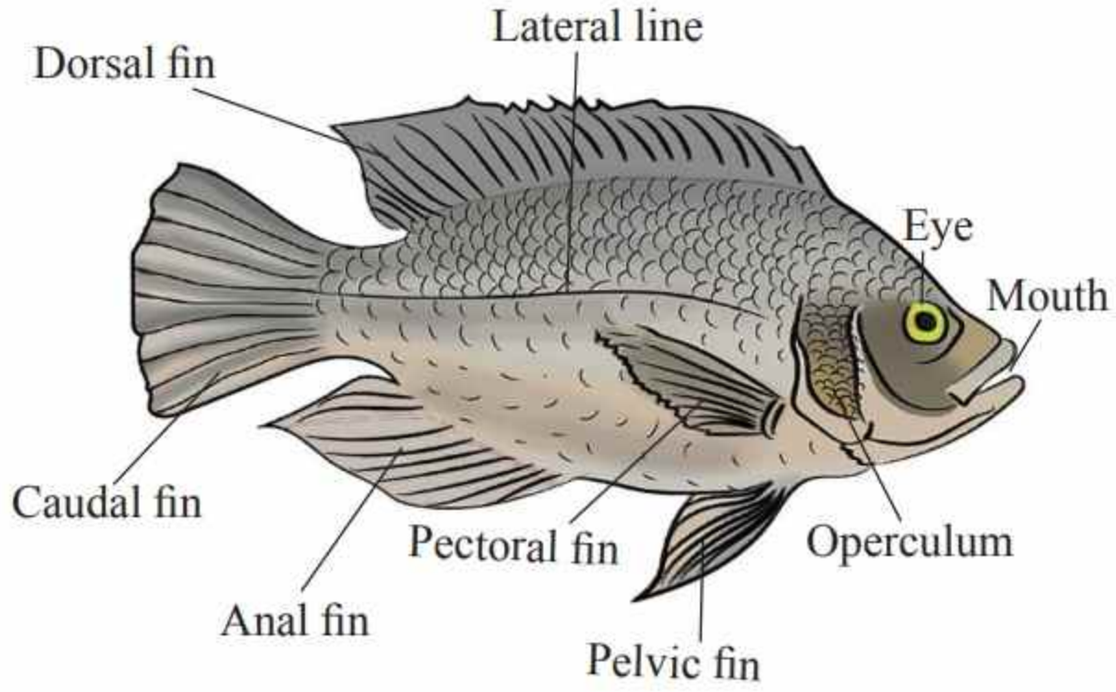


Figure 3.21: External structure of tilapia

Economic importance of bony fish

Most bony fish have both advantages and disadvantages to humans and other animals.

Advantages of bony fish

Most bony fish are rich in protein, hence, they are used as food to human and other animals. They are also source of income to fishing communities. Industrially processed fish products such as bones can be transformed into usable goods such as chicken feed. Oil produced from the fish are also useful as medicine. Some bony fish are used for ornamental purpose. Additianally some bony fish are used in biological studies and research.

Disadvantages of bony fish

Sting from some bony fish such as stonefish can cause pain, swelling, necrosis and even death. Shocks from electric eels and electric catfish can cause injury or death due to drowning. Also, some exotic bony fish when introduced into a new habitat can cause extinction of endemic fauna due to competition and predation.

BIOLOGY FORM 4.indd 120 09/03/2022 19:03

Activity 3.7:

Observing the external features of bony fishes

Materials: Preserved or fresh specimens of tilapia, tuna, catfish, hand lens, scalpels, notebook, pen and plain paper

Procedure

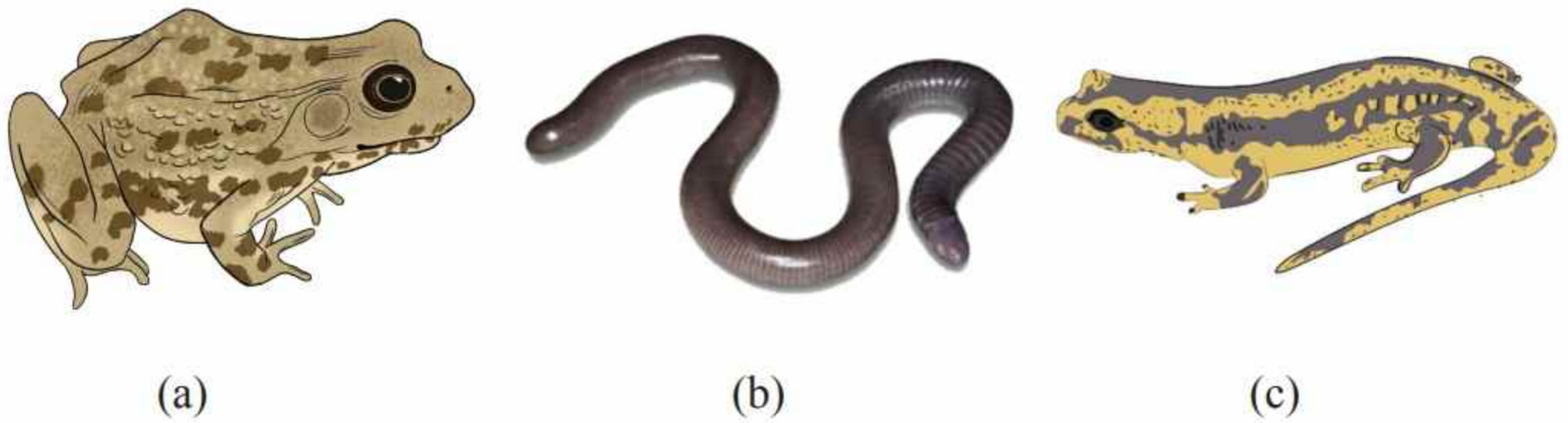
1. Place each specimen on a plain paper.
2. Observe each specimen carefully, noting the arrangement of scales, presence of gills, type of fins and the shape of each specimen.
3. Using the scalpel, remove the gills from each specimen and observe them by using hand lens.
4. Draw a diagram of the gills.

Question

What features distinguish bony fish from a cartilaginous fish?

Class Amphibia

The term Amphibia comes from two Greek words "amphi" meaning "both" and "bios" which means "life". Therefore, amphibia literally mean double life. This is due to the fact that amphibians live both in water and on land. Most amphibians spend their life partly in aquatic environment and partly in terrestrial environment. They have two pairs of pentadactyl limbs for locomotion except caecilians which are limbless. The forelimbs of some amphibian have less musculature while the hind limbs of frogs and toads are long with powerful muscles for jumping. All amphibians lay eggs in water except some caecilians and some toads. Due to their life cycle and physiology, many amphibians are "tied" to water bodies in order to survive and reproduce. Most amphibians undergo metamorphosis from aquatic larval stage to a terrestrial adult stage. Amphibians have a sticky tongue that helps them in capturing prey. Amphibians also are poikilotherms. This means that their body temperature fluctuates with the environmental changes. Examples of members of class Amphibia include frogs, toads, newts, caecilians and salamanders as shown in Figure 3.22.



(a) (b) (c)

Figure 3.22: Examples of amphibians (a) the toad (b) a caecilian (c) salamander

BIOLOGY FORM 4.indd 121 09/03/2022 19:03

Distinctive features of amphibians

Amphibians have the following unique features that differentiate them from other chordates:

(a) They have protruding eyes for wide visibility of prey.

(b) Amphibian eggs have a jelly structure which is prone to dehydration when exposed to air.

(c) During the larval stage, amphibians use gills for gaseous exchange. In adult stage, amphibian use their skins when they are in water and lungs when they are on land.

(d) They have moist skin and most occupy both water and land environments.

Structure of a frog and a toad

The body of the adult frog and toad is dorsal-ventrally flattened and divided into two parts, namely the head and trunk. The neck and tail are absent. The head is blunt rounded and the mouth is terminal with two flexibly movable jaws. The mouth has a muscular tongue attached inside the lower lip which is used to catch insects. The head bears external nares which is a pair of nostrils that lead into nasal passages. The eyes are large, bulged and covered by a nictitating membrane that protects them while in water. Eyelids are poorly developed. Behind the eye, there is a circular patch called a tympanum or eardrum which receives sound signals. The trunk widens in the middle but tapers towards the ends. They have two pairs of legs that help the organism in swimming and jumping. The hind limbs end in five digits, they are larger and more muscular than the fore limbs that end in four digits as shown in Figure 3.23. In frogs, the digits are webbed for swimming purpose.

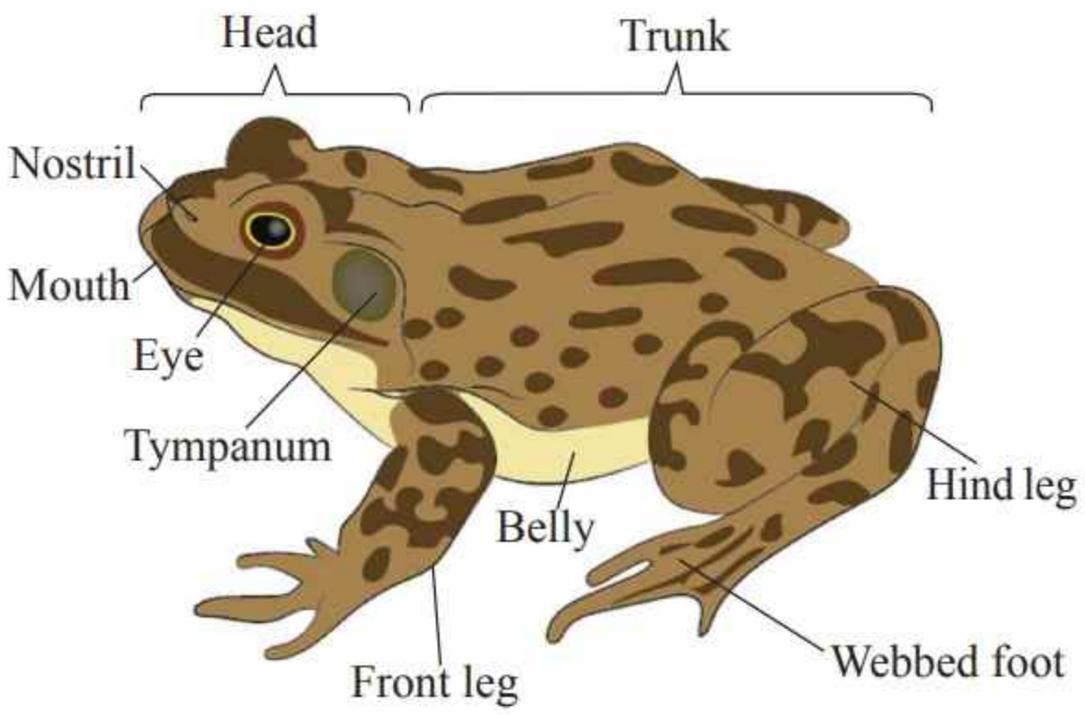


Figure 3.23: External structure of a toad

Economic importance of amphibians

Amphibians have both advantages and disadvantages to humans and other organisms as follows:

Advantages of amphibians

Some amphibians are source of food to humans and other organisms such as snakes and birds. They are also used in biological studies and research. For example, frogs and toad are dissected in school laboratories to study various body systems. Since they eat flies, they help in eliminating disease vectors such as houseflies. In addition, some amphibians have unique features that attract

BIOLOGY FORM 4.indd 122 09/03/2022 19:03

researchers and tourists, hence act as the source of income. The Kihansi Spray Toad (*Nectophrynoides asperginis*) for example has unique biological feature of giving birth to live youngs. In the Amazon basin, secretions from some amphibians are used by natives to produce toxin darts used for hunting purpose.

Disadvantages of amphibians

During breeding period, some amphibians such as male frogs and toads make loud noise thus annoying people living in that environment. They also contribute to water pollution by laying their eggs on the surface of water. Some frogs, toads and newts produce toxins which cause skin irritation and severe symptoms if ingested. Toxins from cane toads can cause seizures, cardiac effects and even death.

Class Reptilia

Reptiles are among a diverse group of egg-laying vertebrates. Their bodies are covered with scales or scutes. Reptiles include animals such as turtles, crocodiles, alligators, chameleons, tortoises, snakes and lizards. They undergo internal fertilisation and their fertilised yolky eggs are laid on land. However, some reptiles such as snakes are ovoviparous. This means they lay eggs which remains in the mothers' body until they are ready to hatch. Reptiles are found in diverse habitats such as deserts, mountains, rocks, tree tops and in water. They are mostly terrestrial with few aquatic members such as crocodiles, turtles and terrapins. They are ectothermic (poikilotherms) vertebrates, implying that their body temperature fluctuates according to the change in environmental temperature. Most reptiles have two pairs of pentadactyl limbs as shown in Figure 3.24 (a), (b) and (c). Some members such as snakes and some lizards are limbless. See Figure 3.24 (d).

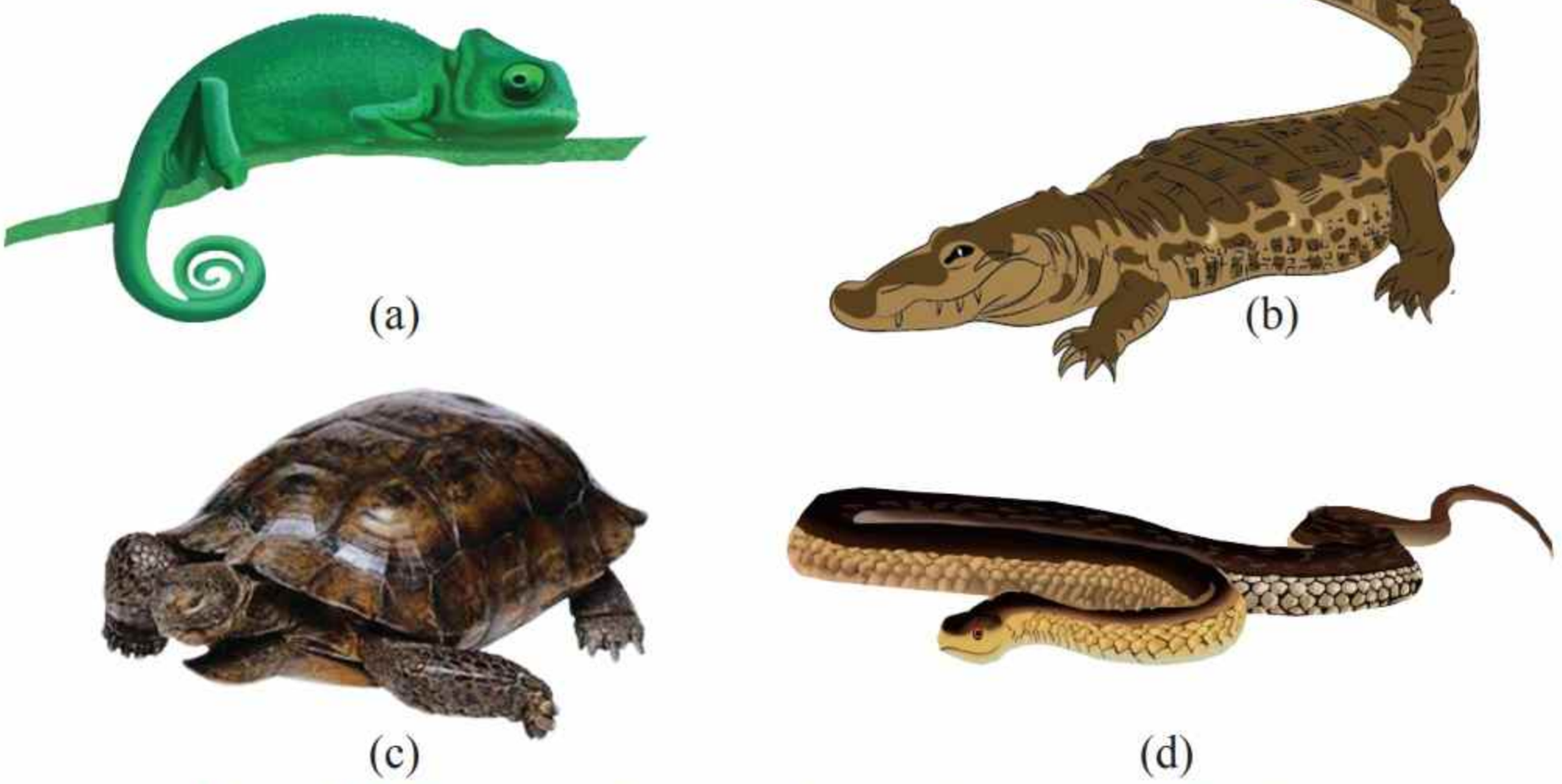


Figure 3.24: Reptiles (a) chameleon (b) crocodile (c) tortoise (d) snake

BIOLOGY FORM 4.indd 123 09/03/2022 19:03

Distinctive features of reptiles

Reptiles possess the following distinctive features:

(a) They have dry skin covered with horny scales or scutes.

(b) Their eyes are located at the front part of the head to facilitate binocular vision. Some reptiles can move each eye independently. This helps to increase their visibility hence locating their food and escaping from predators.

(c) They lay soft shelled eggs called amniotic eggs which protect the embryo from drying out. The eggs have yolk which nourishes the embryo and enables it to develop outside the water environment.

(d) All reptiles have a three-chambered heart except crocodiles, which have a four-chambered heart.

(e) Most have clawed feet.

Structure of lizards

A lizard is a typical example of a reptile. The body of a lizard is divided into three parts namely head, trunk and tail. Lizards have a dry scaly skin, external ear openings and most of them have clawed feet. They also possess two pair of legs as shown in Figure 3.25. In most species the tail is fragile and easily broken but regenerates later. They have shortened legs which help them in walking, but other lizards such as *Delma* species are legless. They also possess eyes with movable eyelids. The two eyes can move independently, thus helping lizards to find food and escape from predators.

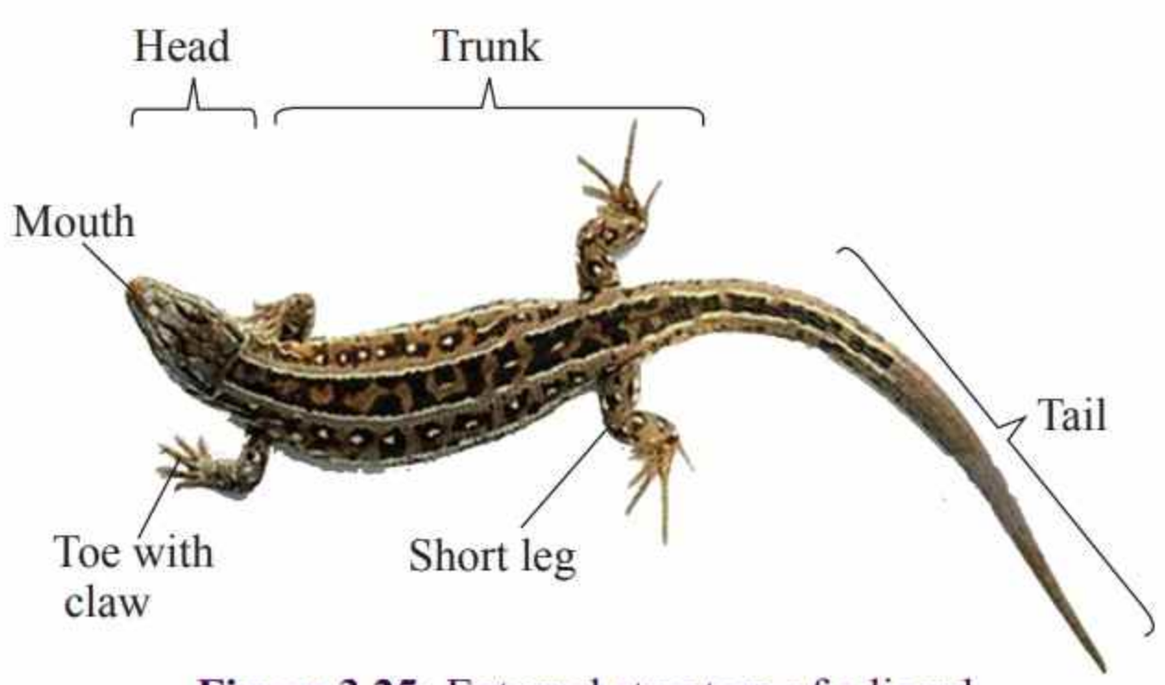


Figure 3.25: External structure of a lizard

Economic importance of reptiles

Reptiles are both advantageous and disadvantageous to humans and other organisms as follows:

Advantages of reptiles

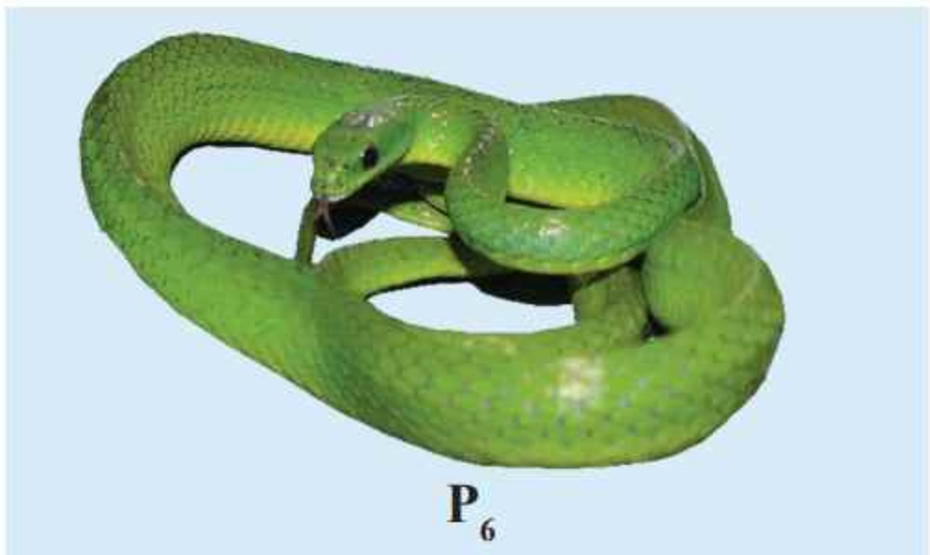
Reptiles are used by other animals as source of food. For example birds eat reptiles such as snakes, lizards and chameleons. Some reptiles such as crocodiles, turtles and snakes are a source of human food in some communities. Some reptiles also provide valuable skin used in making different products. For example the crocodile skin is used in making belts, shoes and handbags. Since reptiles eat small insects they help to reduce harmful insects in the environment or ecosystem. For example, lizards feed on mosquitoes and cockroaches, hence reduce their population in the environment. Furthermore, some reptiles or their products are used for ornamental purposes. For example, tortoises are used for decoration in homes. Tortoise shells are used to make combs, ornaments and traditional

BIOLOGY FORM 4.indd 124 09/03/2022 19:03

medicine. In addition, reptiles are used in biological studies and research.

Disadvantages of reptiles

Some reptiles such as crocodiles can attack livestock and humans causing serious injury or death. A bite from venomous snakes can also cause serious health problems or death to humans and other organisms.



P_6

Figure 3.26: Specimens

Questions

(a) Name the classes to which the specimens P_4 and P_5 belong.

(b) List down the observable features that have enabled you to place the two specimens into their respective classes.

(c) What is the economic importance of specimen P_4?

(d) What are the natural habitats of specimens P_5 and P_6?

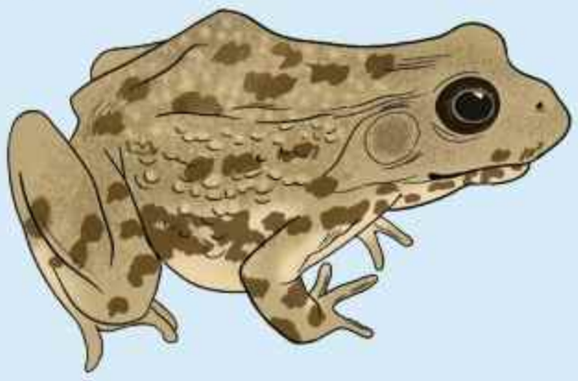
Activity 3.8:

Observing external structures of a frog, lizard, and snake

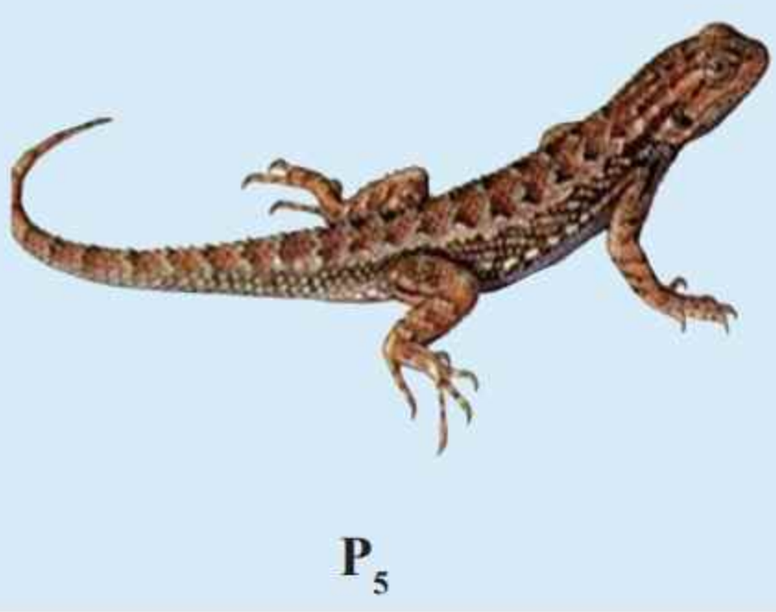
Materials: picture specimens labelled P_4, P_5, and P_6, notebook and pen

Procedure

Carefully observe each picture/specimen labelled P_4, P_5, and P_6 as shown in Figure 3.26 and then answer the questions that follows.



P_4



P_5

Class Aves

The class Aves comprises of birds. It is a distinctive and successful class characterised by the presence of feathers and a bony beak with no teeth. Members of this class vary in size, form and habitats. Some birds are small such as a sunbirds while others are large such as ostriches. Birds feed on a wide range of food types such as nectar, plant leaves, seeds, insects, amphibians, reptiles, small mammals, fish, and even other birds. Some birds such as pigeons are diurnal as they are active during the day only, while others such as owls are nocturnal as they are active during the night. Birds are endothermic (homoeothermic) animals, because they are able to maintain a constant

BIOLOGY FORM 4.indd 125 09/03/2022 19:03

body temperature. Birds have a four chambered heart that enable them to get more oxygen and avoid mixing oxygenated and deoxygenated blood. They have a well-developed brain and vision. Their retina is provided with many cones hence they can locate and see food, and escape easily from enemies. They have a cylindrical body with a long neck connecting the head to the trunk. Examples of organisms that belong to class Aves include chicken, owl, pigeons, ostriches, hawks and eagles as shown in Figure 3.27. Birds are found in habitat with various climatic conditions. For example, some birds live in very cold and snow climates while others live in warm or hot tropical climates.

(a)

(b)

(c)

Figure 3.27: Examples of birds (a) ostrich (b) African fish eagle (c) owl

Distinctive features of birds

Birds possess various features that distinguish them from other chordates. These features include the following:

(a) Their bodies are covered with feathers except the legs which are covered with scutes. The feathers are pointed backwards to reduce air resistance during flying. The feathers also increase the surface area for flight and make the birds less dense, hence reducing the weight for flight. Feathers also provide protection against mechanical damage to the skin. Lastly feathers enables body insulation to prevent heat loss.

(b) They have two pairs of pentadactyl limbs, but the fore limbs are modified into a pair of wings which bear flight feathers. The hind limbs on the other hand are covered by scutes and are adapted for perching, walking or swimming.

(c) They have hollow bones with air sacs filled with air making the bird lighter for buoyancy and flight.

(d) Some birds have a large keel-shaped sternum which provides large surface area for attachment of pectoral (flight) muscles. These muscles provide contractile movement to enable up and down stroke of wings during flight.

(e) Their mouth parts are modified into various types of beaks (bills) for different functions such as feeding and defense.

(f) Most birds have oil glands above the cloaca (uropygial gland). The oil enables the birds to preen the feathers making them waterproof. The gland is

absent in amazon parrots and most flightless birds such as ostrich and kiwi.

(g) Birds have air sacs connected to the lungs to ensure unidirectional flow of air across the gaseous exchange surface.

(h) They produce hard calciferous shelled eggs which keep the embryo independent of aquatic environment and hence enabling its survival on dry land.

(i) Their alimentary canal has additional chambers called crop and gizzard. The crop stores and softens the food, while the gizzard helps in crushing and churning the food.

Structure of a pigeon

The pigeon has a streamlined and spindle shaped body that is divided into head, neck, trunk and tail. Most parts of the pigeon's body are covered by feathers. The head is small, round and anteriorly pointed into a beak as shown in Figure 3.28. The head is provided with a pair of prominent eyes that help them in vision. It also has a pair of ears with small apertures on the posterior side of the eye. The trunk is the greatest and widest part of the body. It is boat-shaped and bears a pair of wings and a pair of legs. The legs are covered with horny scutes. The cloaca aperture is located at the near end of the trunk.

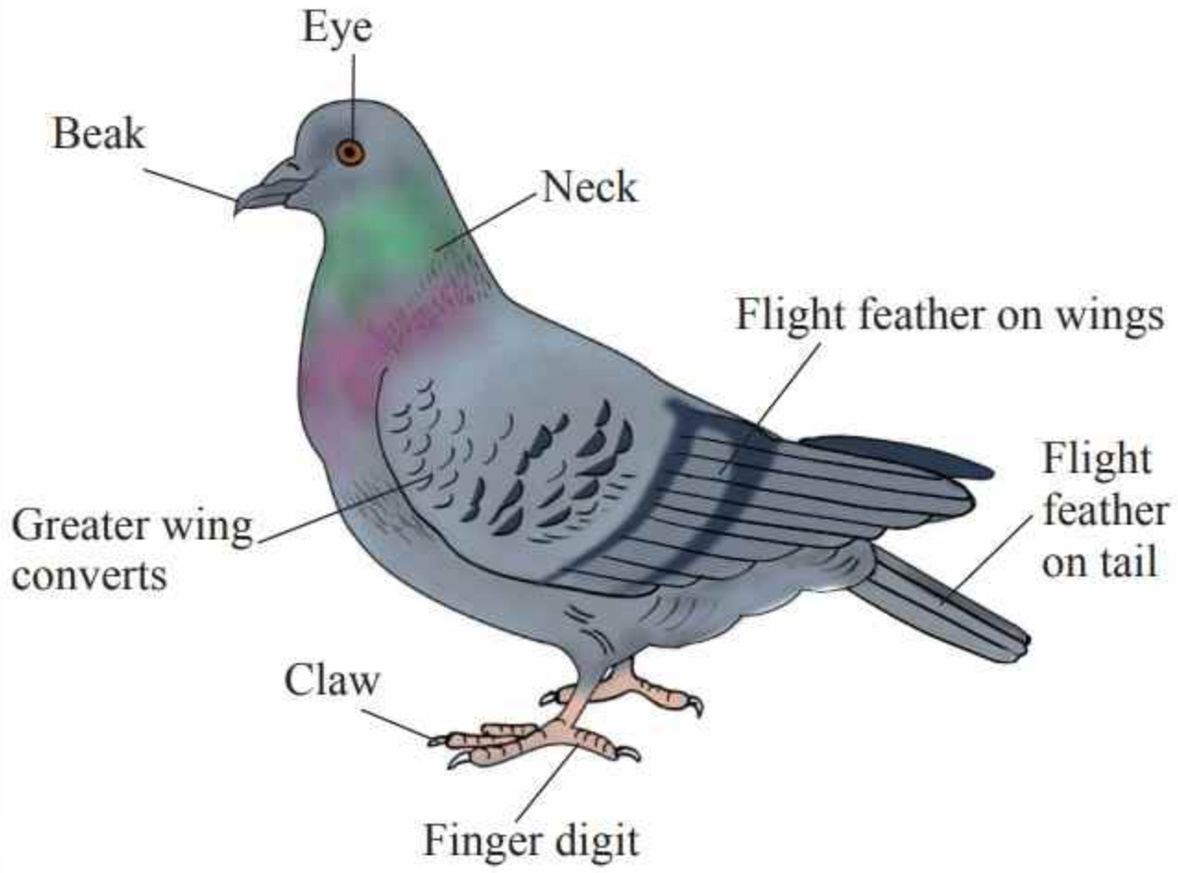


Figure 3.28: External structure of the pigeon

Economic importance of birds

Birds are important in the survival of humans and other animals. However, there are some birds that are harmful to human being.

Advantages of birds

Some birds like chicken, ducks and turkeys are source of food for human beings and other animals. Birds also produce eggs that are rich in protein. These eggs are eaten by human beings and other animals. Eggs are also sold, thus they are source of family income. Feathers are used for ornamental purpose by traditional dancers. Birds faeces are source of manure (guano) since they have high nitrogen content hence increases soil fertility when applied in the field. In addition, some birds such as ostrich attract tourists due to their peculiar colour, size, feeding habits and appearance. Birds also take part in the pollination of flowers and in seed dispersal. Some species of birds are used for biological control of pests such as disease-transmitting snails.

BIOLOGY FORM 4.indd 127 09/03/2022 19:03

Disadvantages of birds

Some birds such as *Quelea quelea* are serious crop pests, causing heavy losses in cereal crops. Birds are also agents for diseases transmission. For example bird flu which is caused by a virus is transmitted by birds. Birds such as hawks and eagles are predators of domestic animals such as chicken and duck, hence cause loss to farmers. Their excreta have bad smell hence annoy people and can pollute water bodies such as lakes, ponds and rivers. If a large amount of excreta enters into water bodies, it may cause excessive algal growth and decreased oxygen level. This in turn could leads to death of aerobic organisms.

Class Mammalia

The class Mammalia consists of mammals. It is a very advanced group in the Kingdom Animalia. The bodies of mammals are covered with hairs or fur and they have mammary glands which in lactating females produce milk for their young. Most mammals have highly developed brain, hence they are said to be intelligent. Human beings, antelopes, giraffe, chimpanzee, mice, rabbits, cattle, lions, bats, whales, kangaroos and duck-billed platypus are some examples of mammals. See Figure 3.29. Members of this class vary in size, form and occupy different habitat. Some mammals such as rats and bats are small while elephants and whales are large in size. Fertilisation in mammals takes place inside their bodies and in most cases the embryo develops in the uterus. However, most mammals are viviparous in nature. Monotremes such as the duck-billed platypus and echidnas lay eggs. Mammals use lungs for gaseous exchange. They have heterotrophic mode of nutrition. They are endothermic and homoeothermic as they are able to maintain constant body temperature.

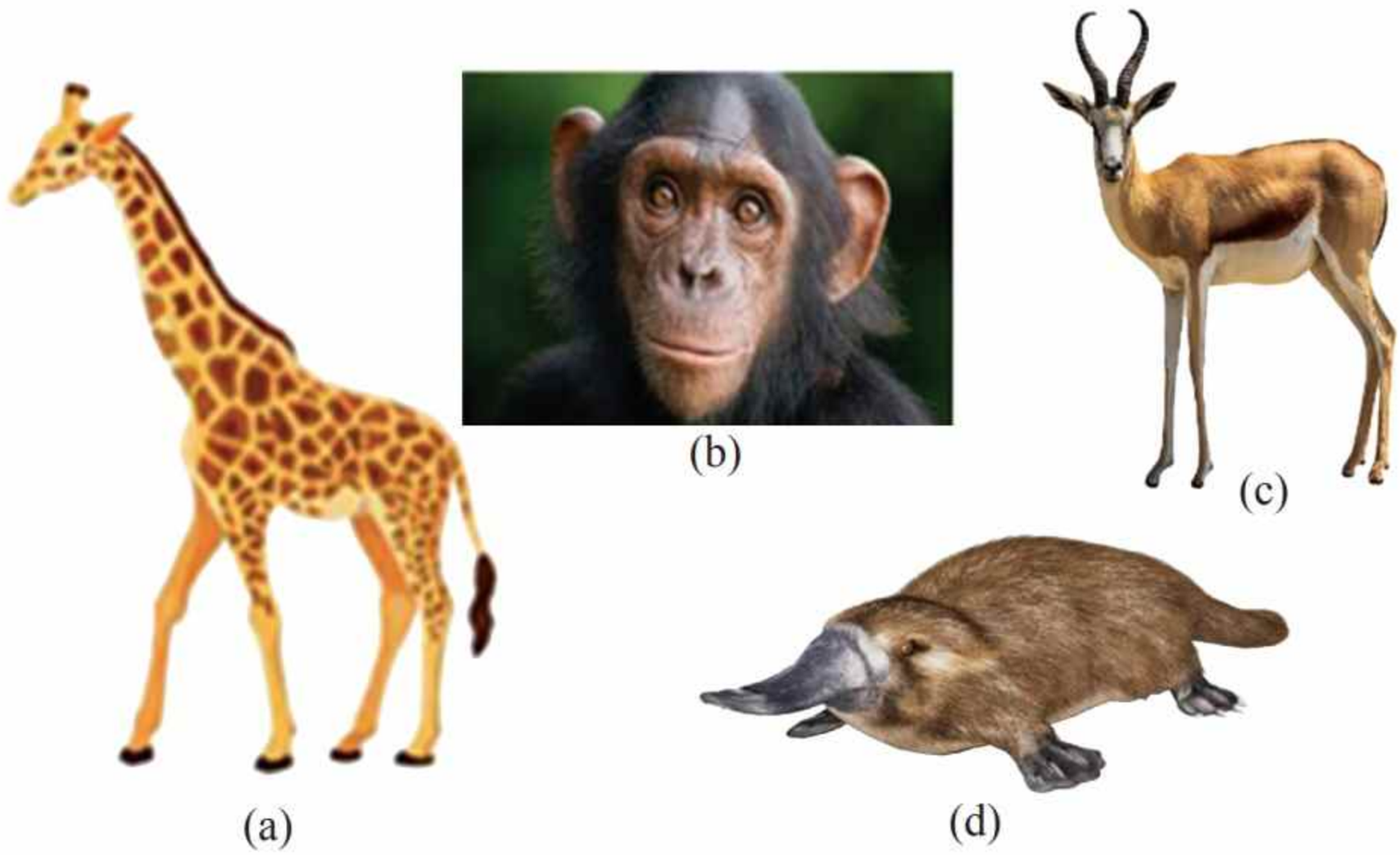


Figure 3.29: Examples of mammals (a) a giraffe (b) chimpanzee (c) an antelope (d) duckbilled platypus

BIOLOGY FORM 4.indd 128 09/03/2022 19:03

Distinctive features of mammals

Mammals possess unique features that distinguish them from other chordates. These features include the following:

(a) They have fur or hairs that cover their skins.

(b) They have mammary glands for feeding their young ones. They also have other secretory glands such as sweat, sebaceous and scent glands.

(c) Their teeth are of different size and shapes (heterodont dentition). Teeth are replaced only once in life time.

(d) They have three soft bones namely malleus, incus and stapes in their middle ear.

(e) The lower jaw of mammals is made up of a single bone called the mandible.

Structure of a mouse

A mouse is typical example of mammal. The body of mouse is divided into head, neck, trunk, and tail. The head bears external ear flaps called pinnae, eyes, nostrils and a mouth. The neck is short and wide and connects the head to the trunk. The trunk bears four limbs, two hind limbs and two long front limbs. Each of these limbs usually has five digits. The trunk also bears a long tail which is either hairless or has sparse covering. The whole body is covered by fur called pelage as shown in Figure 3.30.

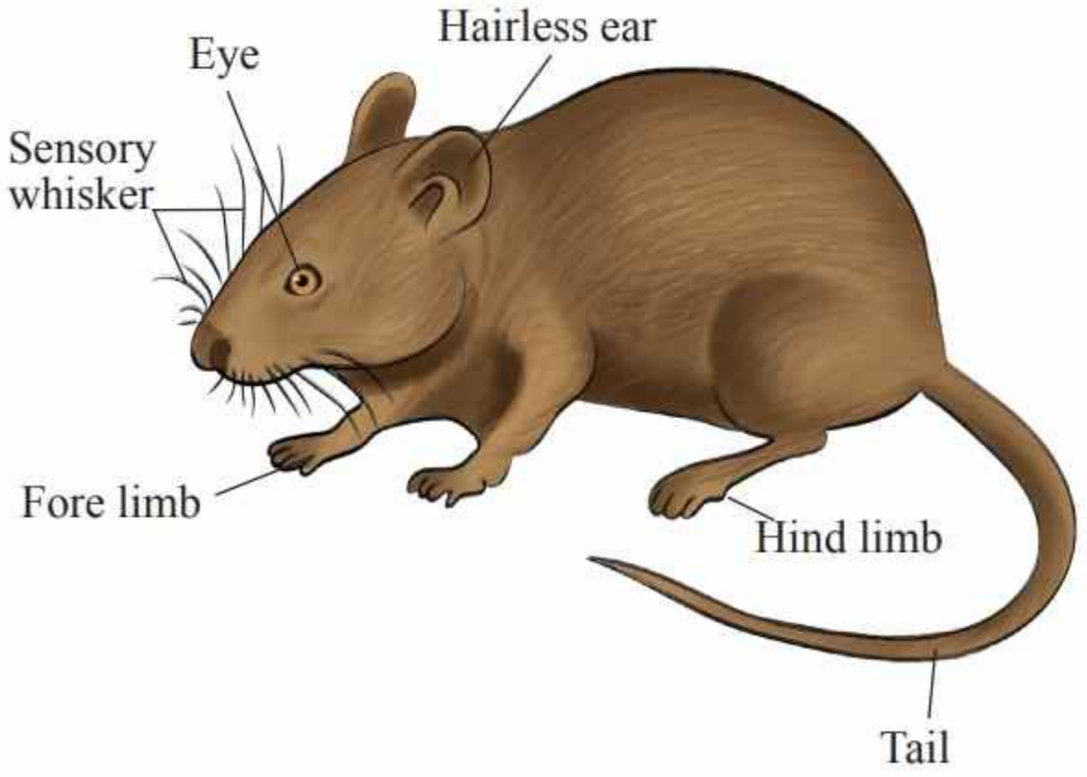


Figure 3.30: External structure of a mouse

Economic importance of mammals

Mammals are both advantageous and disadvantageous to human being and other organisms.

Advantages of mammals

(a) Mammals such as goats, sheep, cattle and buffalo are used as source of food to human beings and other animals. These animals produce meat and milk as a source of food to human being.

(b) Their excreta in the form of faeces or dung are used as organic manure which adds nutrients to the soil, thus improving soil fertility.

(c) Products from mammals have commercial value as they are used in making different products used by human beings. For example, cattle, sheep and goats provide skin which is used for making leather in tannery industries. Leather is used to make belts, bags, shoes and clothes. Elephants provide ivory and many other mammals provide

BIOLOGY FORM 4.indd 129 09/03/2022 19:03

horns and hooves which are used for making buttons and ornaments. The bones of mammals are ingredients used in making chicken feed. Sheep provide wool that is used for production of various products including clothes.

(d) Some mammals such as rats (rodents) are used in scientific research. They are trained to detect narcotics at airports and landmines. They are also used to detect explosives buried underground during the war. They are also used to diagnose diseases, such as tuberculosis. Police dogs are used to track down criminals.

(e) Some domestic mammals such as cattle and donkeys are trained to perform different duties such as cultivation of crops and transportation of goods.

(f) Some mammals are source of income. Live animals and animal meat are sold in domestic and foreign markets, hence they are an important source of local and foreign currency. Others are kept in zoos, national parks and game reserves to attract tourists.

(g) Their excreta are used for production of biogas which is used as a source of energy.

Disadvantages of mammals

(a) Some mammals are dangerous because they can attack humans causing injury or death. Examples of such mammals are lions, leopards, buffalo, elephants and hyenas.

(b) Some mammals are vectors of diseases. For example cats and rats spread fleas which transmit bacteria and other pathogens that cause diseases such as plague. Infected dogs can also transmit rabies which is a viral disease of dogs.

(c) Some mammals are crop pests, destroying crops in storage or in the field. Examples of such mammals include monkeys, rats, and pigs.

(d) Some ruminant mammals such as cattle, sheep and goats produce methane gas when belching. This contributes to global warming.

Activity 3.9:

Observing external features of birds and mammals

Materials: freshly-killed or preserved specimens of a pigeon, a mouse and a bat, notebook, pen, tongs and dissecting dish

Procedure

1. Using tongs place each specimen on plain paper.
2. Carefully observe the external features of a pigeon, bat, and mouse.
3. Draw a well labelled diagram of the pigeon, mouse and bat.

Questions

(a) Explain how birds are adapted for flight.

(b) What external features distinguish birds from bats?

BIOLOGY FORM 4.indd 130 09/03/2022 19:03

Revision exercise 3

Choose the most correct answer in the questions 1-7.

1. Which of the following groups of organisms belong to the same class?
   (a) *Amoeba*, *Plasmodium*, *Hydra* and snail
   (b) Rat, elephant, whale and bat
   (c) Grasshopper, mosquito, bee and spider
   (d) Crocodile, turtle, tilapia and shark

2. Birds can be distinguished from bats in that birds have_____.
   (a) wings
   (b) feathers
   (c) claws
   (d) eyes

3. Which of the following is among the characteristics of flatworms?
   (a) They have elongated, cylindrical and segmented bodies
   (b) They have flame cells used for excretion and osmoregulation
   (c) They live in marine and fresh water habitats
   (d) They are endoparasites

4. Which of the following is not a characteristic of Class Aves?
   (a) Fertilisation is external
   (b) Body is covered by feathers
   (c) Legs have scutes
   (d) Body is streamed

5. Which of the following groups of animals are ectothermic?
   (a) Fish, man, frog, and crocodile
   (b) Dog, fish, alligator and frog
   (c) Bat, cow, bird and cat
   (d) Frog, Alligator, crocodile and fish

6. One of the following features is a unique feature of chordate.
   (a) A pseudocoelom
   (b) A notochord
   (c) Elongated body divided into segments called ploglottids
   (d) A chitinous skeleton

7. Which of the following statements is correctly matched?
   (a) Dolphin - Flying mammal
   (b) Giraffe - Omnivorous mammal
   (c) Kangaroo - Placental mammal
   (d) Bat - Aquatic mammal

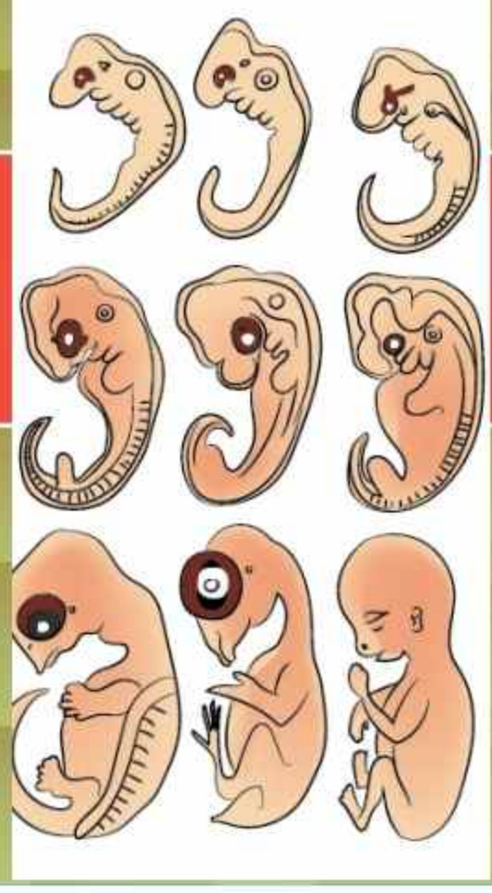
BIOLOGY FORM 4.indd 131 09/03/2022 19:03

8. Match each of the items in column A with that of column B by writing a correct letter of the corresponding item from column B against a roman number in column A

Column A	Column B
(i) Hermaphrodites	A. An infestation of small intestine with a round worm B. A disease caused by the filarial worm called *Onchocerca volvulus* C. Is the body cavity located between mesoderm and endoderm D. An infestation caused by filarial worms and infects the lymph vessels and skin tissue E. Rod-like structure running longitudinally along the dorsal side of chordates F. Animals which have a notochord or vertebral column G. Possess both male and female reproductive organs H. Animals without a notochord or vertebral column I. A body with two layers, ectoderm and endoderm J. A body with three layers: ectoderm, mesoderm, and endoderm
(ii) Notochord	
(iii) Chordates	
(iv) Ascariasis	
(v) Triploblastic	
(vi) Bancroftian filariasis	
(vii) Diploblastic	
(viii) Coelom	

9. What are the advantages of tilapia to human beings?
10. List down the distinctive features of amphibians.
11. Describe how birds are adapted for flight.
12. Explain the economic importance of chordates.
13. List down the distinctive features of chordates.
14. Why are nematodes described as "pseudocoelomates"?
15. How are the following organisms adapted to their modes of life?
    (a) Earthworm (b) *Ascaris*
16. Explain the adaptive features of mammals.
17. Giving examples in each case, explain the advantages of the members of the following classes:
    (a) Insecta (b) Chondrichthyes
    (c) Arachnida
18. Classify each of the following organisms to class level; monkey, blood fluke, snake, mite, housefly, crab, grasshopper, scorpion, toad and shark.
19. Reptiles are organisms whose body temperature is affected by environmental temperature. Briefly explain two ways that help reptiles to survive in different weather condition.
20. A group of animals have the following characteristics: three body parts, three pairs of walking legs and a pair of antennae.
    (a) Name the phylum and class to which the animals belong.
    (b) State the characteristics of the kingdom to which the animals belong.
    (c) What features make the organisms belong to that class?

BIOLOGY FORM 4.indd 132 09/03/2022 19:03



Chapter

Four

Evolution

Introduction

All species have arisen through the process of evolution. This process involves a series of changes that cause species to emerge, adapt to the environment, and also become extinct. Evolution is the study of changes in the heritable characteristics of a population over successive generations. In this chapter, you will learn about the concept of organic evolution, theories of the origin of life, theories of organic evolution, and evidence of organic evolution. The competencies developed will enable you to apply evolutionary principles in artificial selection, ecology and medicine.

Concept of organic evolution

Organic evolution is the gradual change in the heritable characteristics of biological populations over successive generations. Continuous evolution over many generations results in the development of new species. Likewise, failure to adapt to the environmental changes can often lead to extinction. Extinction is the dying out or termination of one or several species. It plays an important role in the evolution of life because it opens up opportunities for new species to emerge. Evolution and its underlying theories are important due to the following reasons:

(a) Evolution and its associated theories help to understand the origin of organisms especially human beings and the relationships with other living organisms.

(b) Evolution and its associated theories help to explain how different species are genetically related.

(c) Knowledge of evolution helps us to understand how species change over time and how they adapt to the changes.

(d) Knowledge on the theories of organic evolution help to solve biological problems that impact human lives. For example, researchers study the evolutionary history of disease-causing genes in order to control hereditary diseases.

BIOLOGY FORM 4.indd 133 09/03/2022 19:03

Activity 4.1:

Observing different forms of organisms

Procedure

You are provided with a phylogenetic tree showing different organisms that lived many years ago and those living today.

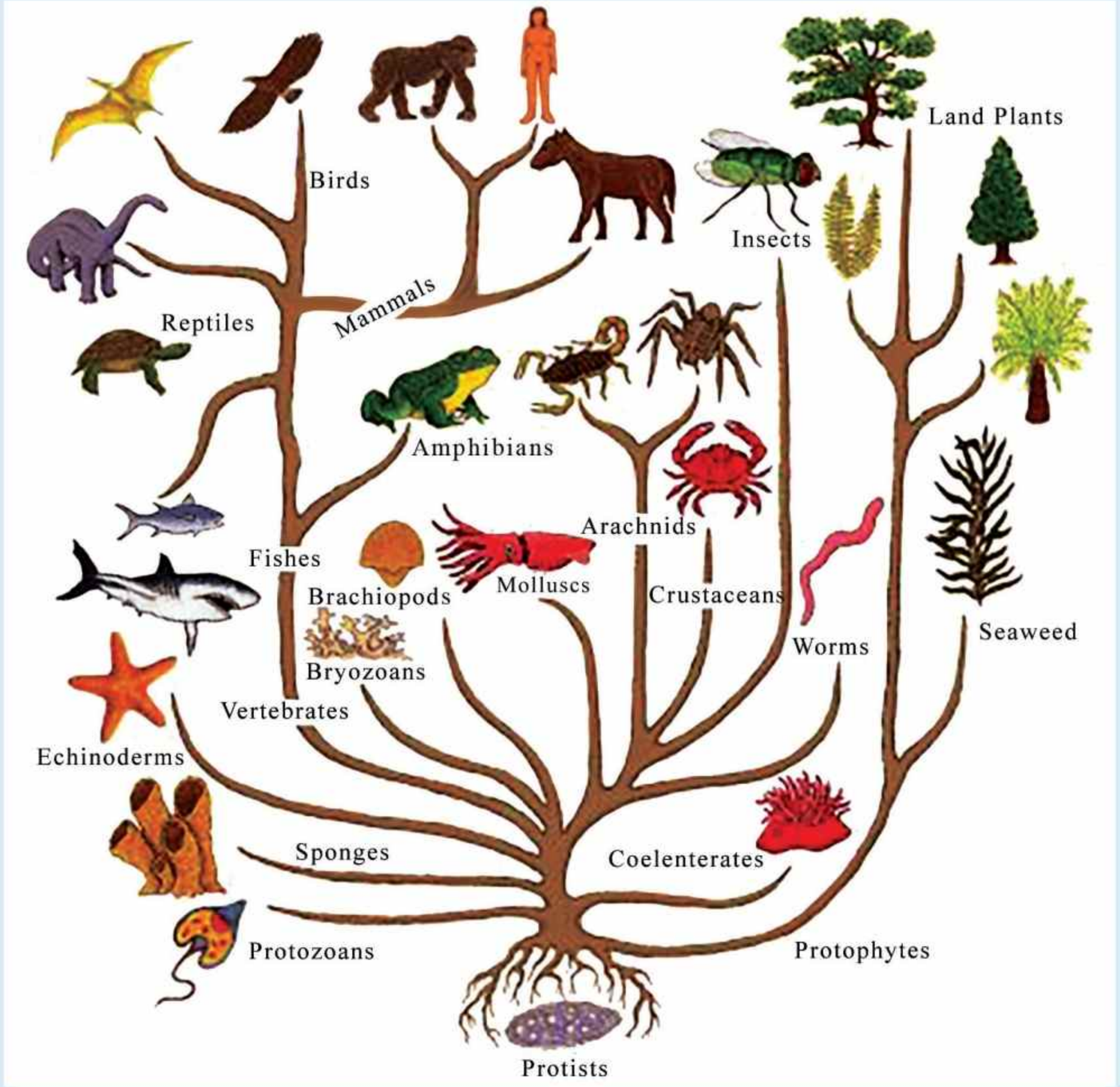


Figure 4.1: A phylogenetic tree showing some animals that lived in the past and those living today

Observe the external features of each organism in the given phylogenetic tree.

Questions

1. Identify the animals that have evolved recently.
2. What group of vertebrates is considered to be the ancestors of mammals?

BIOLOGY FORM 4.indd 134 09/03/2022 19:03

Theories of the origin of life

There are different explanations on how life originated on the earth. Origin of life is the most controversial topic in Biology. There are several theories that explain the possible mechanisms by which life originated. The following are some of these theories:

Special creation theory

This theory states that, the earth and all organisms living on it were created in their present form by God. This is the most widespread and popular theory. This belief is found in holy books of most major religions in the world. For example, in Islamic studies, it has been stated that God created heaven and the earth in six distinct phases and Adam from a sounding clay. In Christianity, it is believed that, God created the universe, plants, animals and Adam as the first human beings in six natural days.

Strengths and weaknesses of the special creation theory

The theory is purely based on religious belief or faith. It opened up the minds of scientists to speculate on the origin of life on earth. However, there is no scientific evidence to support the theory since it is based on faith. The existence and different ages of fossils prove that living organisms appeared on earth in different time frames.

Spontaneous generation theory

The theory of spontaneous generation states that living things arose from non-living materials on a number of distinct occasions. This theory is also known as abiogenesis. Abiogenesis is the hypothetical process in which life is generated from non-life. This happens when there are favourable conditions and that no causal agent such as parents are needed. This was explained by the Greek philosopher Aristotle who believed that certain particles of matter contained active principles which could produce living organisms under favourable conditions. Examples of active principles include fertilised eggs, seeds, sunlight, wheat, decaying meat, and mud. There are several observations supporting this theory. For example, hair of horse tail dipped in the water gives rise to the horse hair worm called gordius. Another evidence is that fly larvae (maggots) tend to develop on rotten meat.

Strengths and weaknesses of the spontaneous generation theory

The theory is scientific since it can be proved by scientific experiments and research. It offers the mechanisms to argue on how life arose on the earth. However, the theory was criticised by Lazzaro Spallanzani, Francisco Redi, and Louis Pasteur. These great scientists performed scientific experiments on spontaneous generation and concluded that organisms arise from the pre-existing organisms in the biogenesis process rather than on non-living matter. Therefore, the theory violates the law of biogenesis which stipulates that life arises from pre-existing life.

BIOLOGY FORM 4.indd 135 09/03/2022 19:03

Activity 4.2:

Investigating the origin of life based on spontaneous generation theory

Materials: two flasks, two pieces of boiled meat, wooden stopper, water, source of heat, and beaker

Procedure

1. Boil 500 ml of water in a water bath.
2. Sterilise the two flasks by bathing them in boiled water.
3. Label the flasks that you have sterilised in step 2 as A and B.
4. In each flask place a piece of boiled meat.
5. Plug tightly one flask using a stopper. Leave the second flask open as shown in Figure 4.2.
6. Place the two flask on a table.
7. Record your observations in each flask after five days.

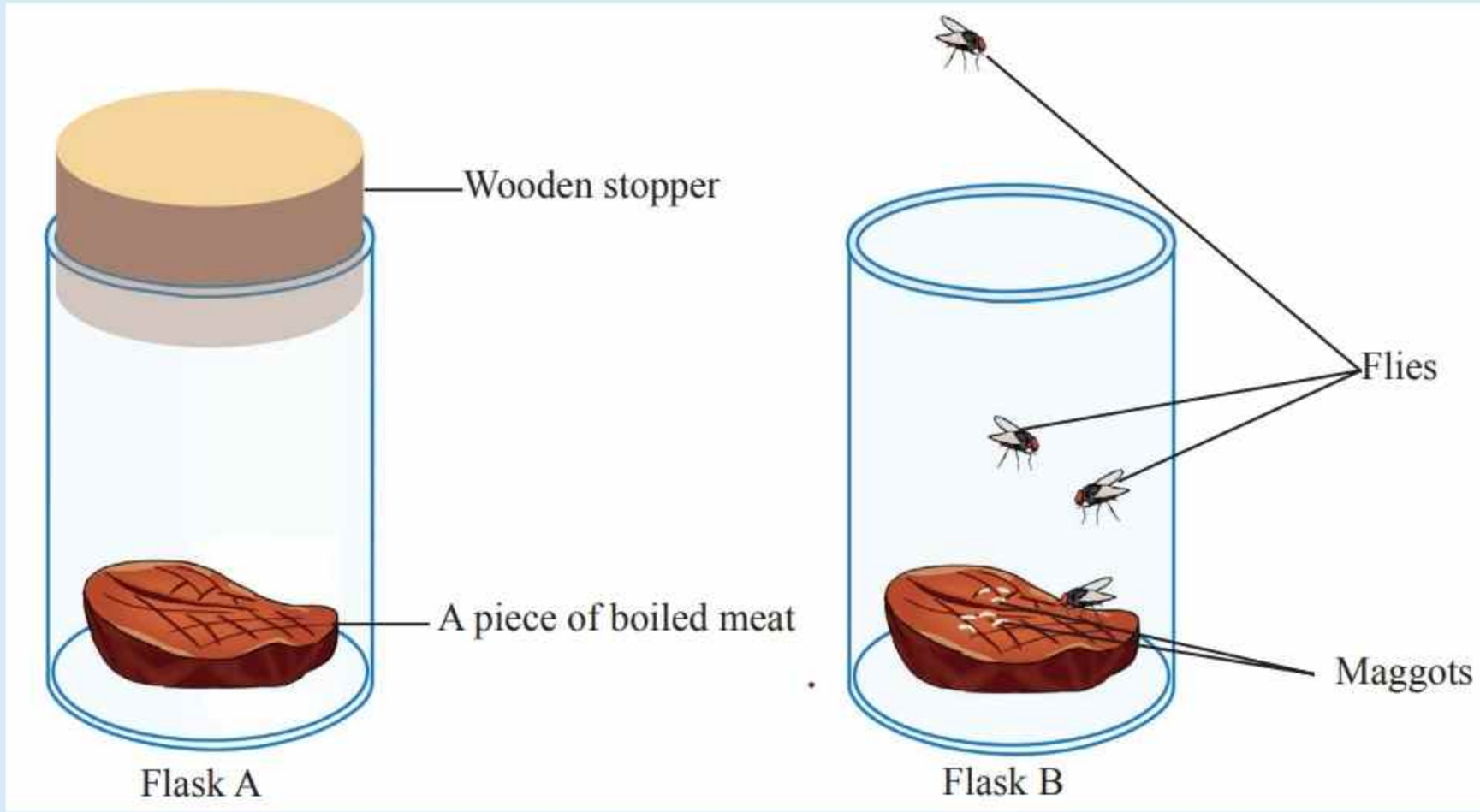


Figure 4.2: Experimental setup on spontaneous generation

Questions

(a) Why were the flasks sterilised in boiling water?
(b) Why were the pieces of meat boiled first?
(c) Based on the theory of spontaneous generation, comment on the results of the investigation.

BIOLOGY FORM 4.indd 136 09/03/2022 19:03

Cosmozoic theory

The theory states that life on the Earth was brougth from outer space in the form of spores which grew and evolve into different organisms . This means that life did not originate on earth, rather it originated somewhere in the universe and then brought to earth as readymade material. The theory was put forward by Richter (1865) who proposed that life reached the earth with cosmic dust in the form of spores, germs or other simple particles from the unknown parts of the universe. Since the condition of earth were supportive, these spores grew and evolved into different organisms.

Strengths and weaknesses of the cosmozoic theory

Life is truly supported on earth. The theory is supported from the fact that fossils of microorganisms were found by scientists in meteorites in 1961. A meteorite is a rock that falls to Earth from space as a meteor. However, life forms crossing the space may not be possible since the living matter cannot survive the extreme cold, dryness, and ultraviolet radiation from the sun in the outer space. Furthermore, the theory does not clearly explain the mechanisms through which life was brought to earth. The theory does not state where life originated and therefore it cannot be called the theory of origin of life. Additionally there is no explanation on the mechanism of transfer of spores from other planet to the earth. There is no scientific experiment to support the cosmozoic theory.

Steady state theory

According to steady state theory, the earth has no origin. It has always been able to support life and it has undergone very small changes since then. The theory also explains that life had no origin and it has always been supported on earth. Thus, the living organisms had no origin, they only change their members by increasing or decreasing or they become extinct.

Strengths and weaknesses of the steady state theory

It is true that the earth supports life and it undergoes slight changes. However, the assumption that life have no origin is against the law of biogenesis which indicates that life arises from pre-existing life. The theory cannot answer the question of where life existed before the formation of Earth. If species had no origin, then the origin of life on earth cannot be tested experimentally.

Biochemical or naturalistic theory of origin of life

This theory was suggested by the Russian scientist Alexander Oparin and British geneticist J.B.S. Haldane. The theory states that life arose on Earth because of physical and chemical reactions of naturally occuring elements and molecules. These molecules gradually accumulated in the oceans and formed a hot primordial soup. The cooling of the primordial earth favoured reactions among the gaseous molecules such as carbon, hydrogen, nitrogen, and oxygen. The reactions led to the formation of simple

BIOLOGY FORM 4.indd 137 09/03/2022 19:03

organic compounds, such as amino acids, nucleic acid and sugars. The nucleotides and nucleic acid that are the main components of all living cells marked the beginning of life. The theory was demonstrated by Stanley L. Miller and Harold C. Urey through the Miller-Urey experiment as shown in Figure 4.3.

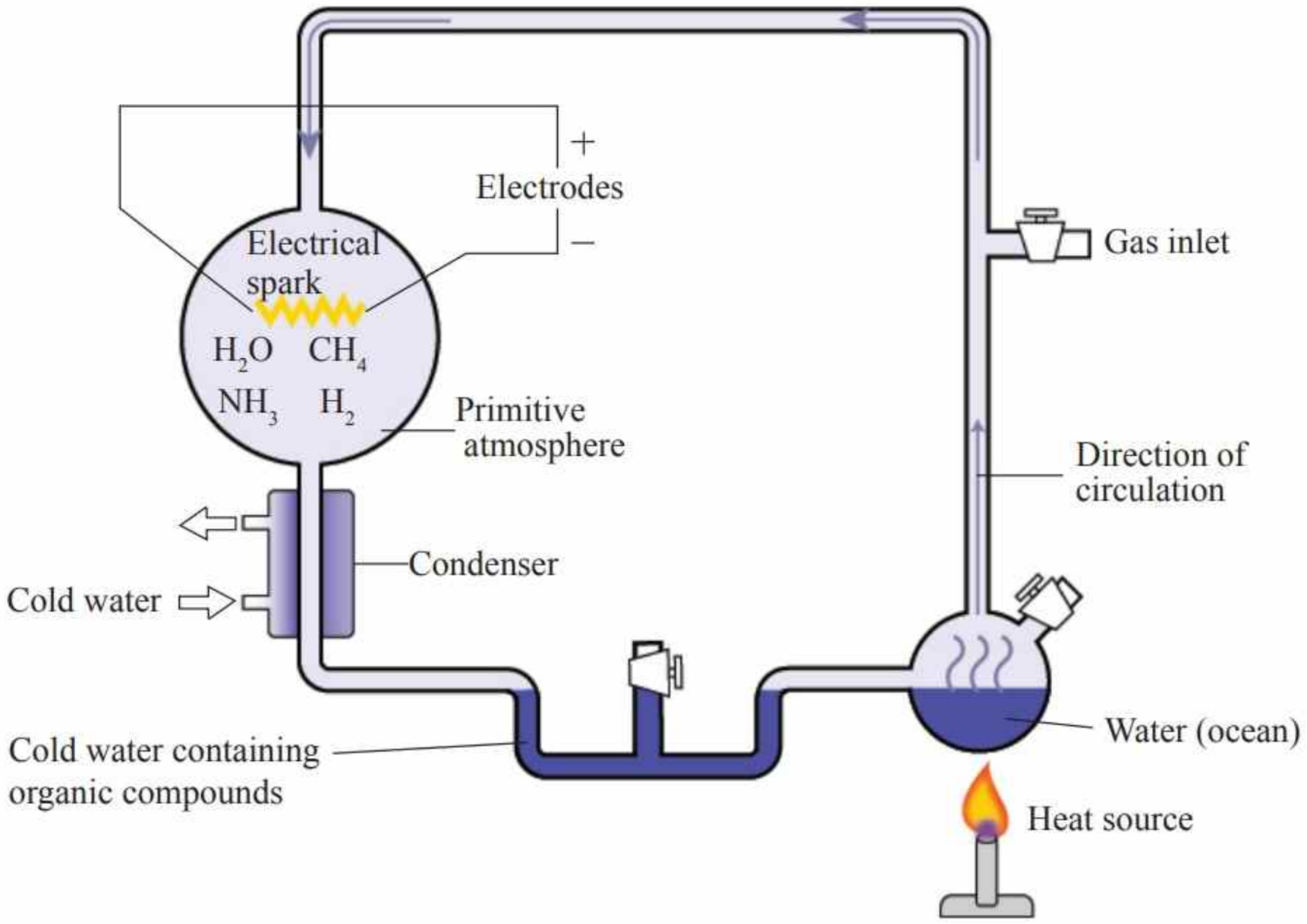


Figure 4.3: Miller-Urey experiment of biochemical evolution

Strengths and weaknesses of the biochemical theory of origin of life

Biochemical evolution theory is scientific and therefore, it can be tested experimentally. The theory also recognises the role of amino acids and proteins in forming the basis of life. The theory encourages critical thinking and thus enhances the development of inquisitive mind. However, the theory failed to provide a viable mechanism to generate a primordial soup. Its unguided chemical processes cannot explain the origin of the genetic code. The theory also fails to explain the transition from complex organic molecules to living organisms.

Exercise 4.1

1. Explain the main ideas in the special creation theory of the origin of life.
2. Differentiate between Spontaneous generation theory and Steady state theory.
3. Describe two strengths and two weaknesses of the cosmozoic theory.
4. What are the major arguments of the cosmozoic theory on the origin of life?
5. Outline the main ideas in the biochemical theory of origin of life.

BIOLOGY FORM 4.indd 138 09/03/2022 19:03

Theories of organic evolution

Organic evolution is a slow gradual, continuous and irreversible change through which existing complex forms descend from their simple pre-existing forms. It is a slow change in the genetic structure of a population over successive generations leading to the formation of new species from the pre-existing ones. Generally, organic evolution is characterised by a gradual change of organisms from primitive to advanced forms. Through organic evolution it can be stated that the recent types of plants and animals originate from pre-existing forms called ancestors. The existing differences between ancestors and modern descendants are due to modifications over many generations.

There are various theories that explain the mechanism by which organic evolution operates. Some of these theories include the Lamarck's and Darwin's theory.

Lamarck's theory of evolution

In 1809, French scientist Jean-Baptiste Lamarck (1744 – 1829) proposed a theory to account for the mechanism of evolution. His theory is based on use and disuse of the organism's organs and inheritance of acquired characters. According to him, inherited characteristics are defined as the changes that develop in the body of an organism from normal characters in response to the changes in environment. Lamarck postulated that an acquired character is produced by the organism's behaviour, which is usually a response to the environment.

Lamarck came up with two conditions, the first was the use and disuse of an organism's organs and the second was inheritance of acquired characteristics. According to Lamarck, the environment creates the need that may lead to a change of pattern of behaviour of an organism. This change can lead to either use or disuse of certain body parts or structures. The more the body part is used, the stronger and more efficient it becomes. But if the body part is less or not used, it gradually weakens or disappears. Lamarck's theory of evolution was based on the principle that physical changes in organisms during their lifetime, such as development of an organ or a part through increased use or disuse could be transmitted to their offspring. Examples of Lamarck's observation are:

Development of long necked giraffe

The classic illustration used to explain the concept of use and disuse is the elongated neck and fore legs of giraffes. According to Lamarck, ancestral giraffes had short necks and fore legs. They lived in plains and fed on grasses. When the environmental conditions changed, grasses became unavailable. This forced the giraffe to feed on the leaves of tall trees. For giraffes to reach the leaves, they had to stretch their neck muscles and fore legs as shown in Figure 4.4. Continuous stretching of the fore legs and neck muscles resulted in longer neck and fore legs as seen in modern day giraffe. These acquired new characteristics (long neck and fore legs) were inherited from one generation to another until the modern giraffe emerged.

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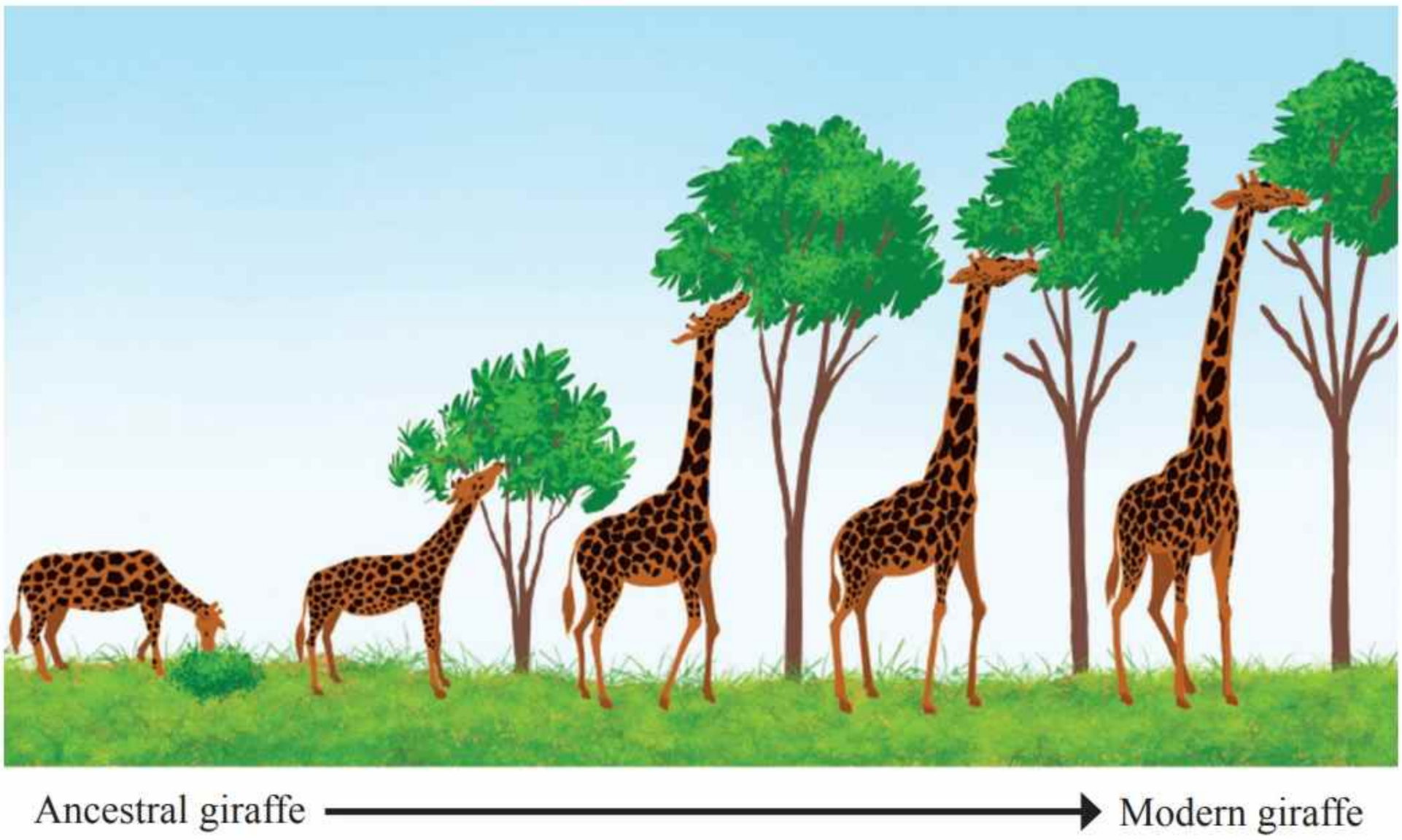
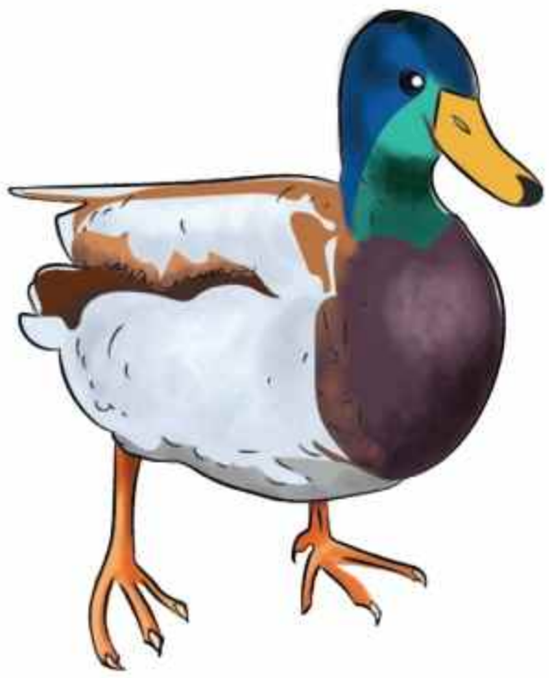


Figure 4.4: Evolution of long necked and long legged giraffes

Development of webbed feet in ducks or aquatic birds

According to Lamarck, ancestral ducks were originally terrestrial dwellers. Due to competition for food and escaping from predators, some ducks moved to aquatic environment. The constant spreading of their toes during swimming resulted in the stretching of the skin between the toes and gave rise to the webbed-feet ducks as seen in Figure 4.5. This acquired characteristic was inherited in sucessive generations. This shows that originally ducks had their feet well adapted for walking and searching for food on the land. Lamarck also suggests that disuse of a structure or organ would cause it to be reduced. Since the wings of the ducks were only used for swimming in water and not for flying, they were later reduced and eventually the duck lost their ability to fly. The similar case is observed in penguins. Their wings became smaller than those of other flying birds because they no longer use them for flight. Penguins use their wings for propelling forward when under water.



(a)

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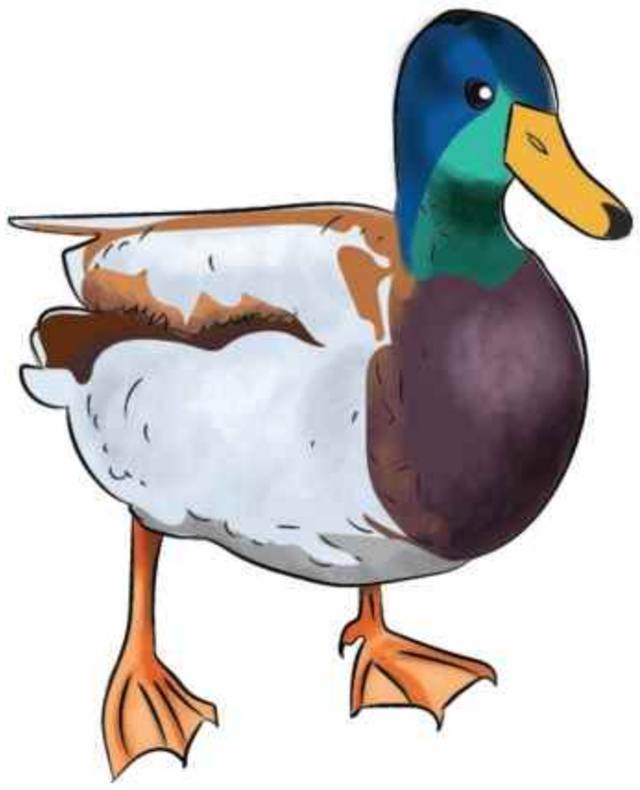

(b)

Figure 4.5: (a) unwebbed (b) webbed feet of the duck

Strengths and weaknesses of Lamarck's theory

Lamarck's work stimulated and opened up the minds of scientists to think, study, and debate on the causes and effects of organic evolution. Lamarck's theory also recognised the role of the environment in evolution. For example, the environment plays important role in producing a phenotypic change of an organism as in the case of body building exercises which increase the size and strength of the body muscles. However, the use or disuse of the body parts or structures does not determine their existence. The acquired traits affect only the phenotype and not genotype. Since they have no influence on the genotype, they cannot be passed from one generation to another. Lamarck's theory cannot be proven experimentally. Organisms do not form new organs simply by their wish or requirement. All these weaknesses were due to the fact that Lamarck did not have knowledge of genetics.

Darwin's theory of evolution

Charles Darwin (1809-1882) was a naturalist who studied variation in plants, animals, and fossils. Darwin specifically studied tortoises, finches and mocking birds during his visit to the Galapágos Islands in Ecuador. During his studies, Darwin developed the theory of evolution based on the concept of natural selection. Natural selection is a mechanism by which organisms that are better adapted to their environment survive and reproduce, while the less adapted fail to survive. The better adapted organisms are more likely to pass on their characteristics to the successive generations. Species tend to change from generation to generations as they do so, they adapt to a new environment. Darwin's theory is based on the following observations and deductions:

1st Observation: Overproduction of offsprings

Darwin observed that all living things are capable of producing more offspring than the environment can support. For example sea turtles can lay from 70 to 190 eggs at a time as shown in Figure 4.6. Oysters can also lay between 60 and 80 million eggs at a time.

BIOLOGY FORM 4.indd 141 09/03/2022 19:03

(a) (b)

Figure 4.6: Sea turtle (a) laying eggs and (b) hatchlings crawling to the ocean

2nd Observation: Population of each natural species remain more or less constant in number

Despite the high rate of reproduction among the members of the species, the number of individuals remain fairly constant over long periods of time in many species. From these observations Darwin reached the following deduction:

1st Deduction: There is struggle for existence

Darwin concluded that over reproduction results in competition among the newly produced organisms due to limited resources including food, shelter, space, and breeding mates. Many organisms either fail to reproduce or die before reaching the reproductive age.

3rd Observation: Members of the same species show variation in characteristics

Members of the same species show variation in characteristics such as colour, shape, size or behaviour.

2nd Deduction: Natural selection or survival of the fittest

In the struggle for existence, only those organisms with favourable adaptive characteristics have reproductive and survival advantages. Those with unfavourable characteristics have limited chances in the struggle for existence and therefore perish. Darwin concluded that, nature selects only those organisms which carry favourable characteristics. Organisms selected naturally are better adapted to their environment and can transmit their survival traits to their offspring.

4th Observation: Some characteristics are inherited and passed on to the next generation

The observation was that many advantageous characteristics are passed on from parents to offspring.

3rd Deduction: Inherited features

The characteristics that favour an organism to survive in a particular environment are selected in a natural way. For natural selection to act on certain characteristics there must be variations. The variations have to be heritable.

Strengths and weaknesses of Darwinism

Darwin's theory of evolution have several streghths. The theory put more emphasis on the role of the environment in evolution. It also explained clearly the concept of the struggle for existence of organisms as they compete for limited resources. It emphasised on the existence of variations among species. According to Darwin's theory, new species arise from pre-existing species by means of natural selection. The species do not remain fixed but they rather change from simple to complex forms.

However, Darwin's theory had a number of drawbacks since he had poor knowledge in genetics. Hence, the Darwin's theory lacked an adequate account on inheritance, making it logically incomplete. In addition, Darwin's theory could not explain what were the causes of variation. The concept of how the advantageous characteristics are naturally created and maintained was not clearly explained.

Modern synthesis theory of evolution

This theory is also called Neo-Darwinism. It combines Darwin and Mendel ideas by studying how populations change genetically over successive generations. It uses evidences derived from genetics, molecular biology, palaeontology and biogeography to explain the process of evolution. According to this theory, evolution occurs when the genetic composition of a population change over successive generations. The five main forces of evolution are non random mating, genetic drift, mutation, gene flow and natural selection. Out of these, natural selection leads to adaptive evolution. Adaptive evolution is the process in nature through which organisms in a population change and adapt to the environment. Normally, in any population there are natural variations among its members. Some phenotype features increase survival and reproduction and over time such perculiar phenotypes increase and spread through the population. Hence, alleles for such traits increase in frequency over successive generations. These changes in the genetic composition of the population lead to the formation of new species.

Strengths and weaknesses of modern synthesis theory of evolution

It managed to explain the role of genetics in evolution. Furthermore, the theory was able to demonstrate the existence of micro-evolution. Micro-evolution is the change in genetic structure of a population. However,

BIOLOGY FORM 4.indd 143 09/03/2022 19:03

the theory has a number of drawbacks. The theory does not explain the origin of species of distinctive form and behaviour. The theory also explains adaptation or micro-evolution as a means of species creation. For example, the theory assumes that there are random genetic variations followed by selection. However, modern genetics has demonstrated the role of directed mutations in adaptive response. Genes are said to respond to environmental circumstances by random adaptive mutations which in turn result in the creation of new species rather than just adaptation.

Note: One of the general weaknesses of evolutionary theory is that it does not explain the origin of life on the Earth. The evolutionary theory explains only how species change over successive generations. Thus, the origin of life is not the central focus of the evolutionary theory. The evolutionary theory deals exclusively with how life changed after its origin to produce the diversity of organisms seen today.

Exercise 4.2

1. What do you understand by the following concepts explained by Darwin?
   (a) Survival of the fittest
   (b) Natural selection
2. State the strengths and weaknesses of the Lamarck's theory of evolution.
3. Based on the theories of organic evolution, describe the development of:
   (a) Webbed-feet in ducks
   (b) Long necks in giraffes
4. Describe the Darwin's key observations pertaining to natural selection from his voyage around the world.
5. Explain the major deductions made by Darwin after observations from his voyage around the world.
6. Explain the ways in which the modern synthesis theory of evolution is different from Darwin theory in explaining the mechanism of evolution.

Evidence of organic evolution

Organic evolution is validated by evidence from fossil records, comparative embryology, comparative anatomy, comparative physiology, cell biology, biogeography and genetic variations.

Evidence from fossil records (palaeontological evidences)

Fossils are the remains, traces, or imprints of life that have been preserved by natural processes. Fossil records are obtained through palaeontology, which is the study of remains of organisms that existed in the past. The most common fossils are found in sedimentary rocks, mud or volcanic ash in rivers and lakes. They emanate from hard parts of organisms including shells,

BIOLOGY FORM 4.indd 144 09/03/2022 19:03

bones, teeth, and woody stems. When plants and animals die, their remains are either decomposed by bacteria, fungi and other decomposers or they are preserved as fossil. In most cases the soft parts are not preserved, but hard parts such as bones, teeth, shells, and plant woody parts can be preserved. These fossils give records of past changes through time.

Evidence to support evolution has been generated through fossil records of previous organisms by studying their structures and deducing their functions. The study of fossil records supports that evolution has taken place and organisms have gradually evolved from simple to complex.

Number and nature of fossils in early rocks

The rocks of early era contain large number of fossils than the rocks of later or recent era. Meaning that, fossils were plenty in the beginning than in later stage. Likewise, the fossils of simple marine invertebrates are found in the rocks. This is due to the fact that life originated in the sea as a simple form.

Distribution of fossils in the successive strata

The distribution of fossils shows that early fossils present in the bottom rocks are simple compared to more complex recent fossils found in the upper layers of the rocks. This confirms that, fossil forms become more complex as we proceed from earliest to the recent rocks. The rocks of the Proterozoic era which spanned from 2500 to 541 million of years ago contain few fossils compared the rocks of cretaceous period which spanned from 145 to 66 million years ago.

Difference between the past and present forms of life

The fossil record suggests that the complex and advanced forms of plants and animals evolved from simple and primitive forms of life. This evidence supports the fact that there has been a tremendous variety of living things. Some extinct species had characteristics that were transitional between major groups of organisms. For example, research on fossils has shown that the earliest fossils were Monera followed by Protoctista and then Fungi. Plants and animals appeared later. The oldest fossils of animals are those of fishes followed by amphibians, reptiles, birds and the latest are mammals. For example, the history of the horse from fossil record found in the North American sedimentary rocks is used as one of the best examples of evolutionary changes. These occurred through various generations as the animal adapted to the changes in the environment. The development of horse was gradual from simple primitive *Hyracotherium* spp. of the Eocene times to complex advanced *Equus* of the Pleistocene times. The changes in structures of the horse are as shown in Figure 4.7.

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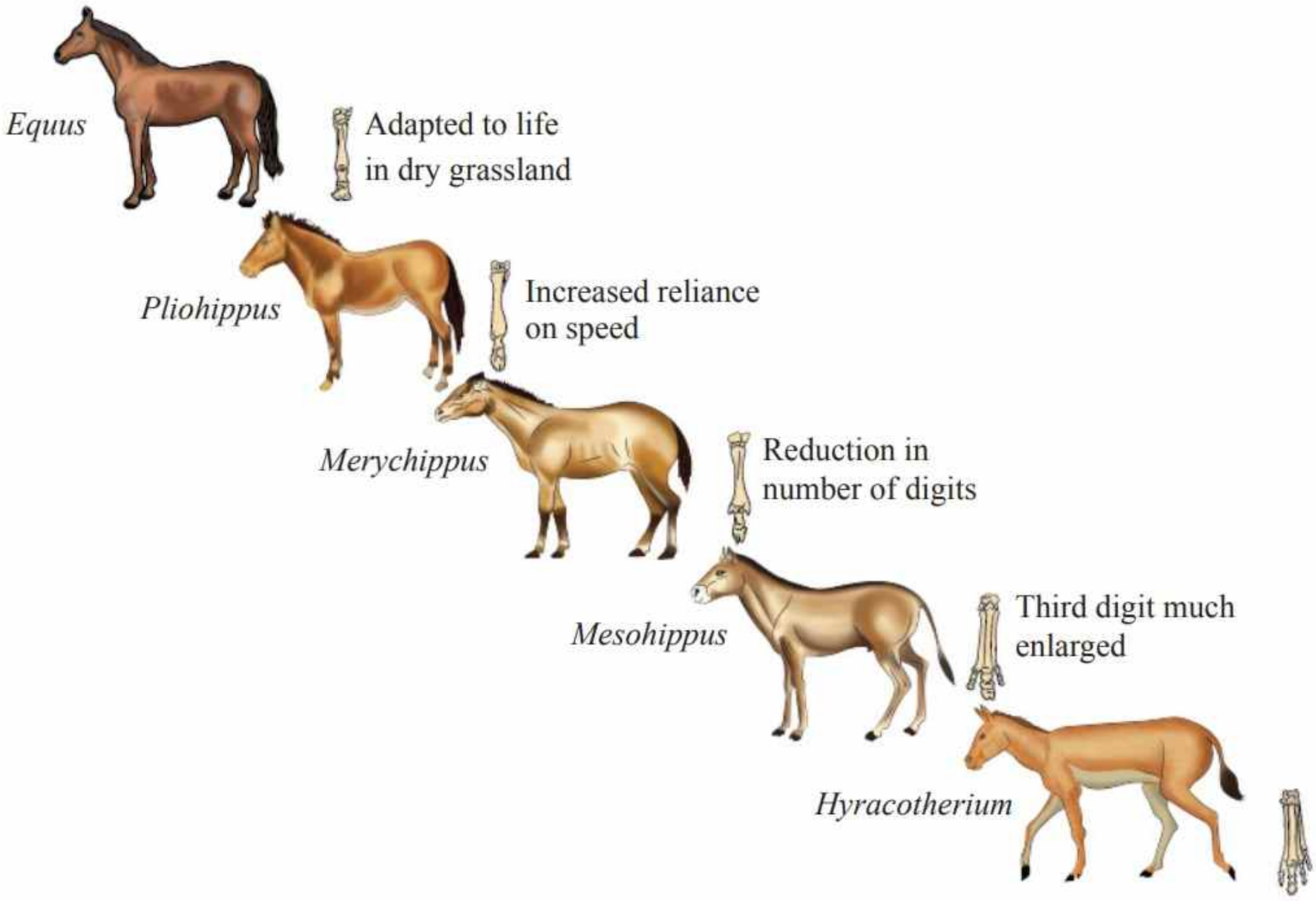

Figure 4.7: Evolution of horse from primitive form to complex form

Strengths and weaknesses of evidence from fossils records

Fossils records as evidence of evolution are useful sources for tracing the evolutionary history of organisms. But the lack of continuity in the fossil records is a major limitation in tracing the descent of biological species. The reasons for the discontinuity in fossil records include the fact that some organisms do not fossilise and some die in conditions that does not favour fossilisation. Distortion due to flattening of parts of organism during sedimentation also is another factor that hinders fossil records as evidence for evolution. There have been subsequent natural geological events that have destroyed some fossils. These include earthquakes, erosion and faulting. In addition, most fossils convey information on external features, but provide little information on the functioning of organism's internal organisation.

Evidence from comparative embryology

Embryology is the study of the development of embryos from fertilisation to a foetus. Comparative embryology is the study which compares and contrasts embryos of different species to show how animals are related. The greater the similarities of structures, the more closely related the species are and the more recent their common ancestor is. For example, the development of embryos

BIOLOGY FORM 4.indd 146 09/03/2022 19:03

of all vertebrates in the early stage is very similar and they tend to be different as they continue to develop as shown in Figure 4.8. They have tails, external branchial grooves (visceral cleft) in the pharyngeal region and a series of internal paired gill pouches. In fish, these pouches join to form gill slits for gaseous exchange. In other organisms, the perforation develops and become eustachian tube and the auditory canal involved in hearing.

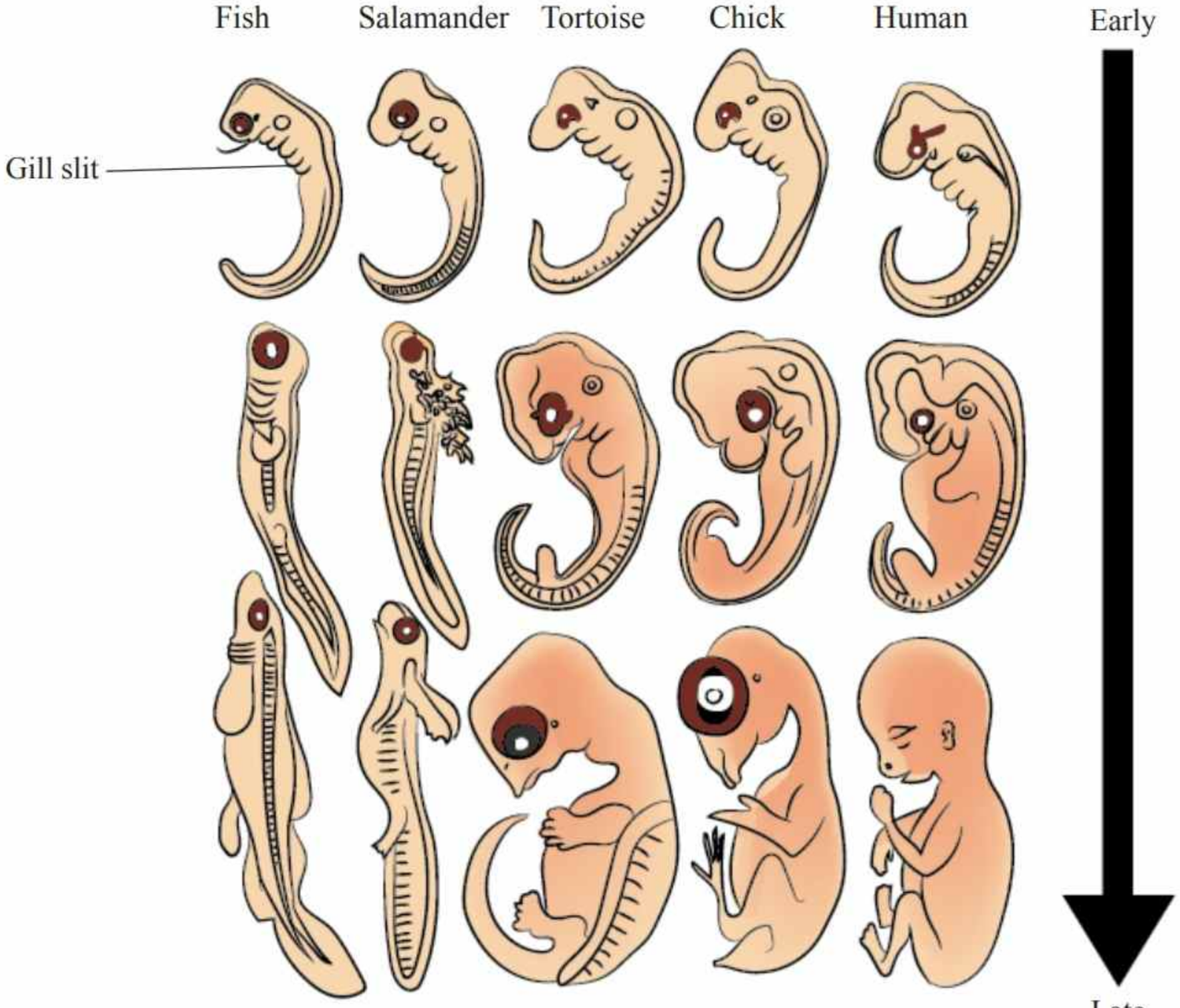

Figure 4.8: Stages of embryological development in vertebrates

Evidence from comparative anatomy

Anatomy is the study of structure and function of organs in the body of living organisms. Comparative study of the anatomy of groups of animals and plants reveals a greater similarity in certain structural features. According to this evidence, organisms with basic structural similarities have a common or related ancestry. Organisms whose anatomical structures show much difference have less evolutionary relationship. In comparing how organisms are closely related using anatomical structures, the presence of basic structures, homologous and analogous structures as well as vestigial structures are used.

BIOLOGY FORM 4.indd 147 09/03/2022 19:03

Basic structures

Anatomically, diverse groups of organisms share certain basic structures. These common basic structures suggest that those organisms have common ancestry. For the case of evolution, there should be many anatomical similarities among varieties and species that have diverged from common ancestors. Those species with the most recent common ancestor should share most traits. For instance, many anatomical similarities among wolves, dogs, and other members of the genus *Canis* are due to the fact that they descended from the same ancient canine species. Wolves and dogs also share similarities with foxes, indicating a slightly more distant ancestor as shown in Figure 4.9. Another example is the presence of the same basic structure of flowers in all angiospermophytes. This suggests that all angiospermophytes evolved from a common ancestor. The similarities among mouth parts of insects is another example of basic structure that shows that all insects have common ancestry.

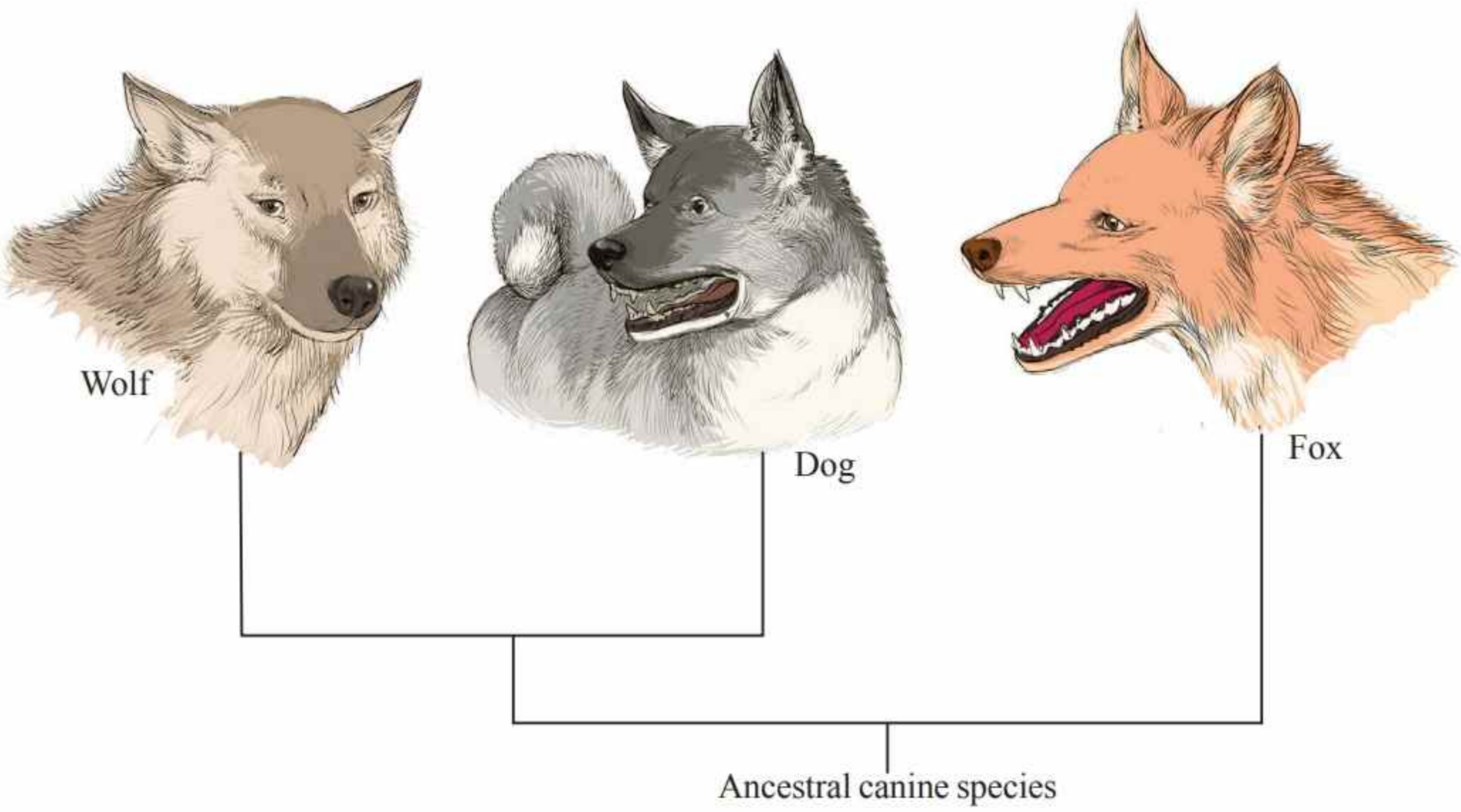

Figure 4.9: Phylogenetic relationship of wolf, dog and fox

Homologous structures

Homologous structures are body parts or organs of different species that share similar basic form or structure. They may perform different roles in the different species. These structures may have the same origin. For example, beaks in all birds have common embryonic origins and basic structure. But depending on the mode of feeding, their basic structure is modified in length, shape and size to adapt to different roles they perform including insect catching, probing, seed eating, and fruit eating as shown in Figure 4.10.

BIOLOGY FORM 4.indd 148 09/03/2022 19:03

Another example is the fore limbs of tetrapod vertebrates that are built on the same basic pattern called pentadactyl pattern. These limbs are adapted to perform different roles such as swimming for alligators, flying for birds and bats, grasping for human beings, and walking for monkeys.

Figure 4.10: Structures of beaks in birds

The pentadactyl limbs have humerus, radius, ulna, and carpals in each forelimb, as shown in Figure 4.11. Although the limbs of bat, birds, crocodile, and human look strikingly different on the outside and vary in function, they are very similar in skeletal or anatomical structure. More significantly, they are derived from the same structures in the embryo. Although these animals look different, a comparison of these homologous structures indicates that they are quite similar. This suggests that these animals are likely to have descended from a common ancestor. This is an example of divergent evolution. Divergent evolution is an evolutionary pattern in which species sharing a common ancestor become more distinct due to differential selection.

BIOLOGY FORM 4.indd 149 09/03/2022 19:03

Activity 4.3:

Observing the pentadactyl limbs of animals

Materials: Picture or specimens of fore limbs of penguin, crocodile, bat, and human

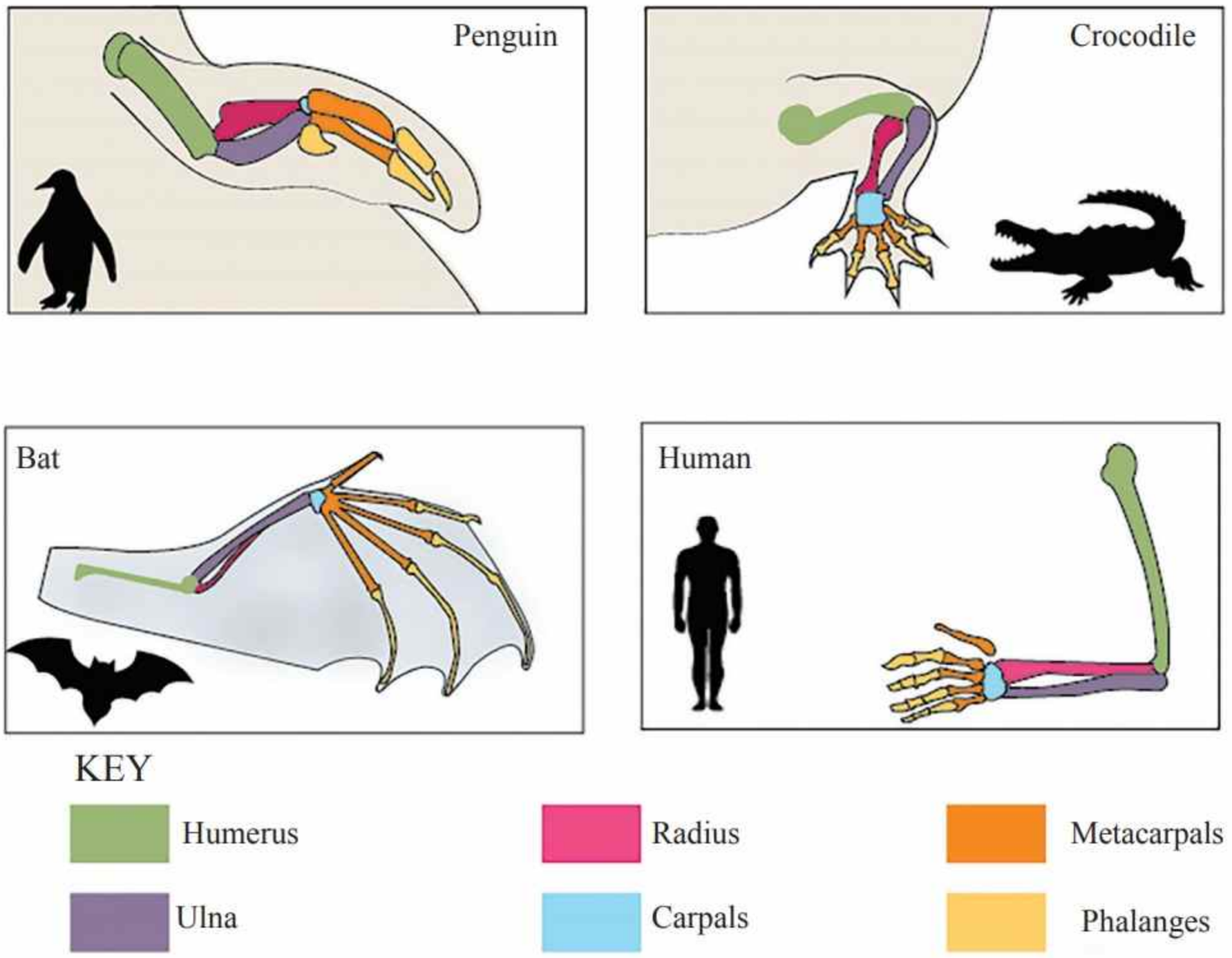

Figure 4.11: Anatomical structure of the forelimb of penguin, crocodile, bat and human

Procedure

1. Carefully observe the picture of the forelimb of penguin, crocodile, bat, and human.
2. Note the number, arrangement and structures of bones of the forelimb in each picture or specimen.
3. Write down the structural similarities and differences you have observed.

Question

Based on the results obtained, what conclusion on the relationship between the forelimbs of bird, bat, crocodile, and human can you make?

BIOLOGY FORM 4.indd 150 09/03/2022 19:03

Activity 4.4:

Observing the variations among the beaks of birds

Materials: A chart showing different kinds of birds beaks as shown in Figure 4.12

Procedure

1. Observe the pictures showing different beaks of birds as shown in Figure 4.12.

Passerine (*Quelea quelea*)

Hornbill

Sunbird

Kingfisher

Secretary bird

Nightjar

Figure 4.12: Beaks of different birds

Question

Briefly explain the importance of each type of beak in these birds.

Analogous structures

Analogous structures are body parts or organs of different species which have different anatomical structure and origin but performs similar function. Examples of analogous structures are the wings of bats and those of insects as shown in Figure 4.13. The function of wings is similar as they are used for flying by both bats and insects. But they do not possess the same origin, therefore, these organs did not evolve from the same common ancestor.

BIOLOGY FORM 4.indd 151 09/03/2022 19:03

Another example of analogous structure is the eyes of octopus and those of mammals. Eyes are used for vision by both organisms, but they have different evolutionary origin, since these two structures arose embryonically from two different tissues. These analogous structures only bear superficial similarities, but have different origins and therefore support convergent evolution. Convergent evolution is the development of particular body structures that have similar function to organisms with unrelated evolutionary ancestry. This structure indicates that, nature selects similar type of organs for a particular habitat, although they do not possess identical anatomical structures.

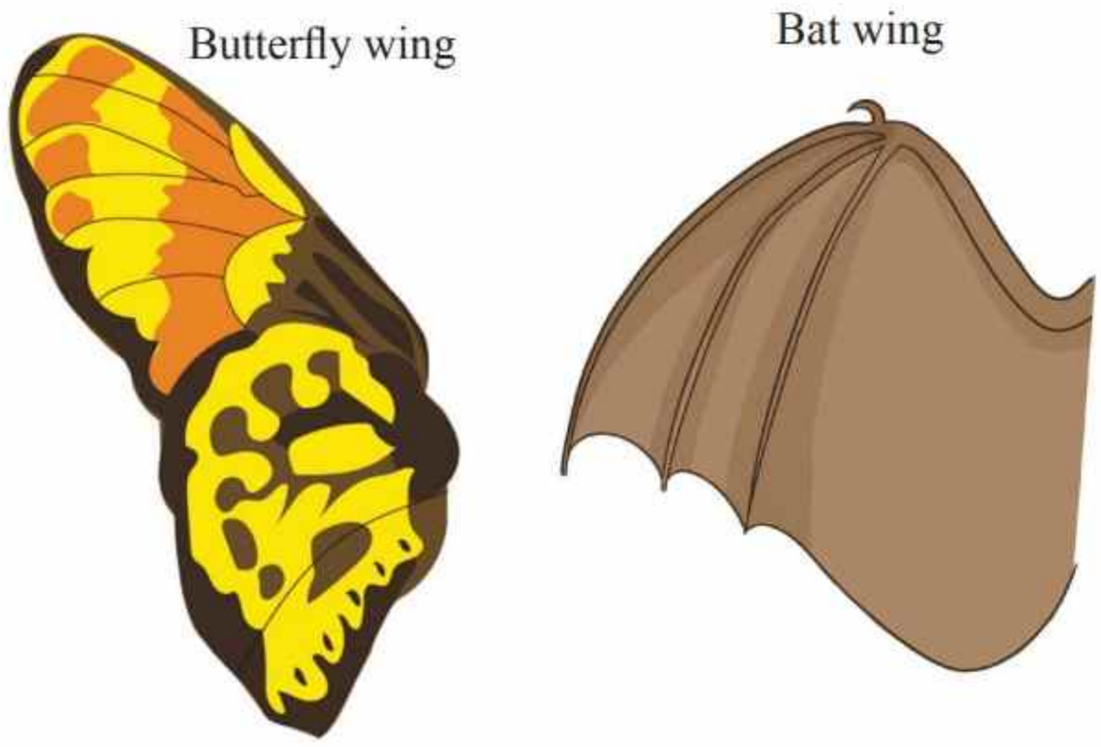

Figure 4.13: Analogous structures in butterfly and bat wings

Vestigial structures

These are the structures in some species with no apparent function. They are often smaller and simpler in structure than the corresponding functional parts in the ancestral species. Vestigial organs are typically functional in the ancestral species but are currently non-functional or have changed their functions. For example, in humans the appendix has lost its original function, but in non-ruminant herbivores such as the rabbits it helps in the digestion of cellulose. The wings of the flightless birds such as ostrich and emu is another example of vestigial structures. These birds have wings that are reduced in size and hence not used for flight. The existence of vestigial structures suggests that organisms have common ancestry to species where the structures were functional.

Evidence from comparative physiology

Various groups of organisms share similar physiological processes. For example, chordates have hormones that perform the same function in different groups. Insulin hormone extracted from cattle or pigs is chemically and structurally similar with insulin found in humans. This hormone is used to treat human diabetes. This suggests that cattle and pigs share a common ancestor. Another example includes the action of thyroxine hormone in a tadpole. If the thyroid gland is removed from a tadpole, it will not metamorphose into adult frog or toad. However, if the tadpole is injected with thyroxine hormone extracted from humans, cattle, or goat, it will metamorphose and develop into an adult frog or toad. This shows that these groups of organisms share common ancestor.

Evidence from cell biology

Different groups of organisms share similar basic cellular components. For example, the

components of haemoglobin of humans, gorillas, and chimpanzee is almost the same. The chemistry and composition of chlorophyll is similar in all plants. Furthermore, the chemical composition of nucleic acid is similar in all organisms. The similarity in cellular composition suggests common ancestory of the organisms. Thus, since these similarities can be traced back to bacterial cells, it shows thatthere is an evolutionary relationship between prokaryotes and eukaryotes. All living things on earth share the ability to create complex molecules out of carbon and a few other elements. In fact, 99% of the proteins, carbohydrates, fats, and other molecules in living things are made from only 6 of the 92 most common elements. These elements are Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur and Phosphorous. This suggest evolutionary relationship among living organisms.

Evidence from biogeography

The study of the past and present geographical distribution of organisms on earth is called biogeography. It provides more evidence for evolution. The presence of related organisms across continents suggest that such organisms share common ancestry. This is supported by the continental drift theory which explains that once upon a time all the continents of the earth were joined together as one land mass. However, due to the earth's movements such as plate tectonics, the land was divided into the continents existing today. Evidence have shown some similarities of fossils from different continents which suggests that the fossils were in one place but separated by continental drift. For example, fossils of the same type of ancient amphibians, arthropods, and ferns are found in South America, Africa, India, Australia and Antarctica that can be dated to the Palaeozoic era. During this era, these regions were a single land mass called Gondwanaland. The fossil remains of the presently extinct reptile *Mesosaurus* spp. found in Permian sediments in Africa and South America also provided one of the earliest clues about former connection between the two continents. See Figure 4.14.

Figure 4.14: Fossil remains of *Mesosaurus* species

Genetic variation

The change in genetic composition of organisms in a population through successive generations might lead to the formation of new species from the pre-existing ones. The higher the genetic variation that exists in a population, the greater the chance for

BIOLOGY FORM 4.indd 153 09/03/2022 19:03

evolution to occur. Moreover, the higher the genetic variations in a population, the more likely some individuals will survive under certain environmental crisis. The earth's environment is constantly changing. When the changes go beyond what most members of the population can tolerate, widespread deaths normally occur. However, as Charles Darwin observed, not all individuals always perish. Those individuals whose characteristics allow them to survive in an environmental crisis are likely to persist and reproduce. Subsequently, their traits will be more common in the population and the new population will evolve.

Generally, organisms such as bacteria that mature and reproduce in large numbers within a short period of time have a potential for very fast evolutionary changes. For example, when a lethal dose of antibiotic is added to incubated petri dish of bacteria living in a nutrient medium, there will be mass mortality. However, a few of the bacteria might have immunity and survive. When such survivors reproduce, the next generation will be composed of bacteria that are resistant to the antibiotic, as shown in Figure 4.15. Hence the new bacteria population will evolve.

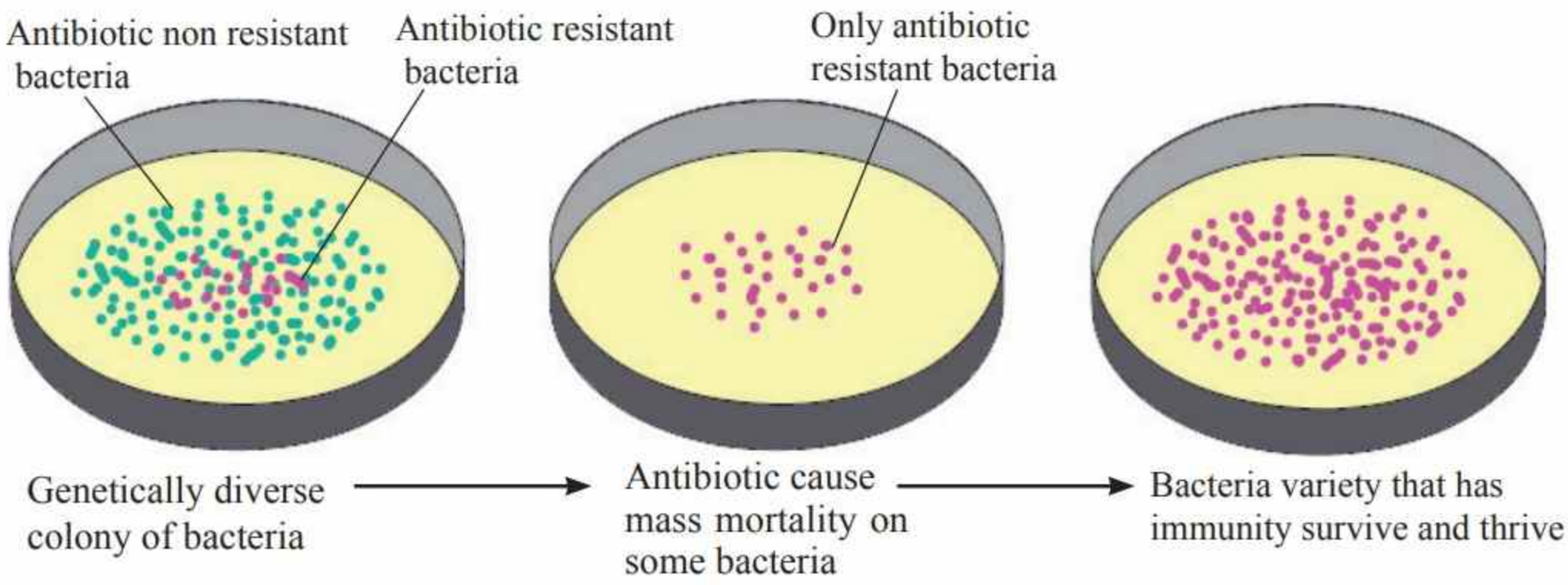

Figure 4.15: Evolution of antibiotic resistant bacteria

Organic evolution in real life situations

Organic evolution has been observed in real life situations such as change in the frequency of melanic forms in moths. There are some organisms that exist in two or more distinct forms. This phenomenon is known as polymorphism. Polymorphism can be seen in the peppered moths (*Biston betularia*) which have light colour and the melanic moths which have dark colour as shown in Figure 4.16. The moths are normally found on the trunks and branches of trees where they camouflage against predators. During industrial revolution, branches of most trees became darkened by soot. Hence, light coloured moths became more conspicuos to predators while dark coloured moths become more abundant. This is because they were being better camouflaged and hence less affected by predation. As a result, the light coloured moths became rare. This is an example of organic evolution by natural selection mechanism.

BIOLOGY FORM 4.indd 154 09/03/2022 19:03

(a)

(b)

Figure 4.16: (a) Light (b) dark coloured *Biston betularia* moths

Another example of organic evolution is the persistence of sickle cell disorder in areas where malaria is endemic. Sickle cell disorder is a hereditary disorder in which the red blood cells assume a sickle or crescent shape, making them less efficient in transportation of oxygen. The condition makes people with sickled cells become resistant to malaria than normal people. Hence sickle cell is more persistent in malaria endemic areas. A third example is the development of drug and insecticide resistance in areas where there is a widespread use of the drugs or insecticides.

The effect of evolution can be easily observed in viruses and bacteria since they have very short generation times. The common flu virus evolves almost yearly that forced a new flu vaccine to be produced to protect humans from repeated infections. In addition, a significant number of bacteria strains have evolved and become antibiotic-resistant to the drugs that previously would have killed them. The antibiotic action against the pathogens can be seen as an environmental pressure. Therefore, those bacteria which have been favoured by mutation were allowed to survive and reproduce. They will then pass this trait to their offspring, which will result in a fully resistant colony.

Revision exercise 4

Choose the most correct answer in the questions 1-14.

1. Palaentology is the study of_____.
   (a) physics
   (b) science
   (c) botany
   (d) fossils
2. Organisms undergo gradual changes in order to adapt to their environment. This process is called_____.
   (a) degeneration
   (b) evolution
   (c) extinction
   (d) adjusting

BIOLOGY FORM 4.indd 155 09/03/2022 19:03

3. The theory of natural selection was proposed by _____.
   (a) Gregor Mendel
   (b) Jean-Baptiste Lamarck
   (c) Charles Darwin
   (d) Stephen Gould
4. Which of the following is Not an example of homologous structures?
   (a) Pentadactyl limbs in vertebrates
   (b) Beaks in birds
   (c) Wings in birds and insects
   (d) The heart structure in cows and monkeys
5. The concept that living organisms arise from non-living matter is called _____.
   (a) biogenesis
   (b) evolution
   (c) speciation
   (d) abiogenesis
6. Structures with a common ancestral origin but with different functions are called_____.
   (a) vestigial structures
   (b) analogous structures
   (c) homologous structures
   (d) rudimentary structures
7. Which of the following statements about man is false?
   (a) Shows bipedalism
   (b) High intellectual capacity
   (c) Forelimbs are used for manipulation
   (d) Apposable toes
8. The emergence of new species from the pre-existing ones is known as_____.
   (a) organic evolution
   (b) speciation
   (c) mutation
   (d) reproduction.
9. The theory of use and disuse was put forward by_____.
   (a) Aristotle
   (b) Pasteur
   (c) Lamarck
   (d) Darwin
10. Which statements is false about evolution?
   (a) It brings about new species.
   (b) It brings about variation in organisms.
   (c) It brings changes that adapt the organisms to their environment.
   (d) It is always disadvantageous.
11. The theory of special creation postulates that_____.
   (a) Organisms emerged from nonliving matter
   (b) Organisms arose from preexisting forms
   (c) A supernatural being created the earth and all the living things
   (d) Life started after elements joined to form organic compounds.
12. The major objection to Lamarck's theory of use and disuse was_____.
   (a) Disuse of an organ leads to its disappearance
   (b) Acquired traits are non-heritable

BIOLOGY FORM 4.indd 156 09/03/2022 19:03

(c) No organ is disused since all organs have specific functions

(d) Aquared traits affect only the genotype.

13. The ability of an animal to stand upright with its hind limbs is called _____.

(a) Pentadactyl
(b) Bipedalism
(c) Homology
(d) Analogy

14. Which theory suggests that life arose from the evolution of simple organic molecules into more complex ones and their ultimate evolution into cells.

(a) Spontaneous generation theory
(b) Cosmozoan theory
(c) Biochemical evolution theory
(d) Steady state theory

15. Match the terms in column A with that of column B by writing a correct letter of the corresponding item from column B against the roman number in column A

Column A	**Column B**
i. Emergency of new species	A. Artificial selection
ii. Scientific theory of evolution	B. Palaeontology
iii. The study of fossils	C. Darwinism
iv. Acquired characteristics can be inherited	D. Larmackism
v. Principle which states that organisms sharing same chemical characteristics are related.	E. Mutant
vi. All mammals has similar embryonic structures	F. Mutation
vii. Have no biological function in organism	G. Natural selection
viii. Wings of birds and wings of insects	H. Survival for the fittest
ix. Sudden change in genetic structure	I. Struggle for existence
x. Only organisms fitted for a certain environment survives while others die	J. Use and disuse
	K. Analogous structures
	L. Homologous structures
	M. Vestigial structures
	N. Comparative anatomy
	O. Comparative embryology
	P. Biochemical evolution
	Q. Divergent evolution.

BIOLOGY FORM 4.indd 157 09/03/2022 19:03

16. How does cosmozoic theory explain the origin of living things on earth?
17. Give reasons as to why the study of fossils records is important in evolution.
18. How does the law of use and disuse explain the neck elongation in giraffes?
19. With examples, briefly explain how comparative embryology provides evidence to support evolution.
20. How does the modern synthesis theory differ from the Darwin's theory in explaining the occurrence of evolution?
21. Explain why fossil records as evidence of organic evolution are usually incomplete?
22. With examples, describe the role of vestigial structures in evolution.
23. Why is Lamarck's theory of evolution no longer accepted?
24. Why do certain drugs become ineffective in curing a disease after many years of use?
25. Giving example in each case, distinguish between divergent and convergent evolution
26. Explain the advantages of natural selection.
27. How do the following support the theory of organic evolution?
    (a) Comparative anatomy
    (b) Cell biology
    (c) Biogeography
28. Use an example to explain how natural selection occurs.
29. State three ways in which the vertebrate Pentadactyl limb has evolved to suit different modes of life.
30. How does biochemical thery support evolution? briefly explain.
31. What is the difference between natural selection and artificial selection?
32. Giving examples, describe the following terms.
    (a) Analogous structure
    (b) Homologous structures
    (c) Vestigial structures
33. Explain the strengths and weaknesses of the Darwin's theory of evolution.

BIOLOGY FORM 4.indd 158 09/03/2022 19:03

Chapter

Five

HIV / AIDS and other STIs

Introduction

Sexually Transmitted Infections including Human Immunodeficiency Virus (HIV) and Acquired Immunodeficiency syndrome (AIDS), are among the major global public health concerns. In this chapter you will learn about the concept of HIV / AIDS and STIs, relationship between HIV / AIDS and other STIs, management and control of HIV / AIDS and STIs, and client initiated HIV testing and counselling (CITC). The competencies developed will enable you to protect yourself from HIV infections and other STIs. You will also be able to take precautions while interacting with people living with HIV and AIDS and avoid stigmatisation against them.

Concept of HIV / AIDS and other STIs

Human Immunodeficiency virus (HIV) is a retrovirus that causes the immune system to lose its efficiency, thus causing AIDS. HIV infects human cells and uses the energy and nutrients of the host cells to grow and reproduce. A person infected with HIV is said to be HIV positive. HIV enters the human body and increases chance of getting AIDS. This is because the virus destroys and kills a specific type of white blood cells called T-helper cells. The T-helper cells have CD4 protein on their surface which plays an important role in maintaining the body immune system. CD4 T-cells are considered "helper" cells because they do not neutralise infections but rather trigger the body's response to infections. T-helper cells provide help to other cells in immune response by recognising foreign antigens. The depletion of T-helper cells leads to low CD4 cell count. Normally CD4 cell count gives an indication of the strength of the immune system and its capability to produce natural defense against infections. Progressive loss of the CD4-T cells weakens the body immune system. The overall effect of this is that the body becomes vulnerable to opportunistic infections such as tuberculosis, gonorrhea

BIOLOGY FORM 4.indd 159 09/03/2022 19:03

and syphilis. The CD4 count is a test that determines the strength of the person's immune system. However, it is advisable that all persons with HIV infection should start taking antiretroviral treatment (ART) regardless of the status of their CD4 count. The CD4 count tends to increase as a result of effective antiretroviral drugs (ARVs) administration. This is because ARVs prevents HIV virus from multiplying and destroying CD4. People living with HIV develop AIDS when the number of CD4 cells in the immune system becomes too low, usually below 200 cells per mm^3 of blood. CD4 count for a healthy person ranges between 500-1200 cells per mm^3 of blood.

Acquired Immunodeficiency Syndrome (AIDS) is a condition resulting from infection by a virus called Human Immunodeficiency Virus (HIV). The virus weakens and destroys white blood cells called T-helper cells that help the body to fight against infections. The weakened immune system is prone to diseases, thus the infected person eventually loses the ability to fight against infections and develop AIDS. However, people can have HIV infection with few or no symptoms for years before it advances to AIDS. Some people with certain genetic mutation are resistant to HIV infection and will not develop or get AIDS. Similary, most people with HIV do not develop AIDS if they are taking antiretroviral drugs effectively.

Sexually transmitted infections (STIs) are infections that are transmitted from an infected person to another person who is not infected mainly through sexual intercourse. STIs can also be transmitted by sharing personal items such as towels, underwear, and swimsuits. Some STIs such as gonorrhoea and syphilis can also be transmitted from mother to child during pregnancy or delivery. These infections are mainly caused by pathogens such as fungi, bacteria, viruses, and protozoans.

Relationship between HIV / AIDS and STIs

People living with HIV / AIDS are more vulnerable to other infections including STIs such as syphilis, chlamydia, and gonorrhoea. Likewise, STIs increase a person's risks of getting HIV infection. In addition, risk behaviours and practices that can lead to both HIV infection and other STIs are the same. Some STIs such as syphilis can cause open wounds or ulcers in the genital area. These wounds, provide HIV a direct route into the bloodstream. STIs can cause an increase in the concentration of CD4 T- helper cells in the genital area. The increased concentration of these cells provide HIV with a favourable target for infection.

Differences between HIV / AIDS and other STIs

HIV is among the member of viruses known as retroviruses and causes AIDS. HIV infects human cells and uses the energy

and nutrients of those cells to grow and reproduce. A person infected with HIV is said to be HIV positive. AIDS is a late stage of HIV infection in which the immune system weakens and become unable to fight against opportunistic infections. STIs include syphilis, gonorrhoea, genital herpes, chlamydia, and chancroid. It is not possible to confirm if someone is infected with STIs or HIV just by looking. Only clinical test can confirm whether a person is infected or not. All STIs and HIV can be transmitted through unprotected sexual intercourse with an infected person. Therefore, HIV infection is a form of STI.

A major difference between HIV infection, AIDS and other STIs is that HIV infection and AIDS are incurable, while most other STIs can be treated and cured. However, all STIs including HIV can be prevented by abstaining from sexual intercourse until marriage, avoiding sharing sharp objects such as needles and blades and screening blood for transfusion. Some STIs such as Hepatitis B have vaccine, but up to date there is no vaccine for HIV infection.

Impact of HIV / AIDS in the community

HIV and AIDS have consequences in social and economic development of the community. The following are the effects of HIV and AIDS:

(a) Loss of family and community resources that are redirected to support and care for people living with HIV and AIDS (PLWHA).

(b) HIV/AIDS decreases man power which results to low production. HIV and AIDS have claimed the lives of farmers, industrial workers, educators, corporate leaders, health-care professionals and government officials.

(c) Individuals' capacity to work and support their families is reduced when they are sick. Higher health-care expenditures associated with HIV and AIDS severely reduces family income.

(d) Children who are living with HIV or who have lost both parents due to HIV and AIDS are less likely to obtain their basic human needs including food, shelter and good education.

(e) Some youth drop out of school to help their parents and siblings who are living with HIV and AIDS.

(f) PLWHA are sometimes stigmatised and denied the opportunity to live a happy life. Discrimination and stigmatisation against PLWHA are usually due to lack of awareness on outdated beliefs.

(g) Reduces the life expectancy.

Project 5.1:

Assessing the impact of HIV / AIDS, and other STIs on the community

Materials: Note book and pen

Procedure

1. Visit a nearby health facility.
2. Ask the specialist on the extent of HIV and other STIs transmission and their impact in the surrounding community.

BIOLOGY FORM 4.indd 161 09/03/2022 19:03

3. Note down the points given by the specialist.
4. Discuss with your classmates on what you have noted in the discussion with the specialist.
5. Write a summary report to explain the impacts of HIV / AIDS and other STIs in the surrounding community.

Management and control of HIV / AIDS and other STIs

HIV / AIDS and STIs are health concerns which have a great impact on the community. It is therefore important to manage and control them.

Controlling the transmission of HIV and other STIs

Some people that are interacting with you may have HIV, but you may not know it because they look healthier. This is especially if they are in the early stages of the illness. It is also possible that you could have HIV infection without knowing it. Clinical test can confirm whether a person is living with HIV or not.

HIV positive individuals especially in the early stage of infection cannot be identified by physical appearance. Yet, they can transmit the virus to other people. Therefore, it is important to take precautions when interacting with others. This will reduce the chance of getting infections.

The following are the ways and methods of preventing HIV and other STIs infections.

(a) Abstaining from sexual intercourse until marriage.

(b) Avoiding sharing sharp objects, such as needles, syringes, and razors blades.

(c) Avoiding sharing unsterilized instruments such as circumcision instruments

(d) Covering cuts or scratches with a dressing until they are healed.

(e) Wearing gloves when attending a sick person or touching other people body fluids.

(f) Having regular checkup for STIs.

(g) Taking Pre-Exposure Prophylaxis (PrEP) for people working or exposed to a higher risk of getting infected with HIV.

(h) Taking Post-Exposure Prophylaxis (PEP) immediately after being involved in HIV infection risk situation.

(i) PLWHA should be given antiretroviral drugs (ARVs) to slow down the progression of AIDS.

Management of HIV and AIDS

The following are the ways or methods used to manage HIV / AIDS:

(a) HIV infected individuals should adhere to the recommended Antiretroviral treatment (ART).

(b) PLWHA should have periodical checkup of viral load and CD4 cells count to monitor the ART response.

(c) PLWHA should adhere to advice from medical practitioners to avoid further transmission.

(d) HIV infected individuals should eat balanced diet and other necessary nutritional supplements.

(e) PLWHA should have enough time to rest.

(f) PLWHA should get counselling from professionals on how to live with HIV and AIDS.

(g) PLWHA should avoid risk behaviours such as unprotected sex, smoking, and alcoholism.

Activity

Assume you are invited to participate on World AIDS Day in your village or street and you are asked to talk about the theme "Ending the HIV pandemic: Equitable Access, Everyone's Voice". Prepare and write a speech concerning the theme.

Life skills needed for home-based care to help people living with HIV and AIDS

PLWHA need the same care, support and sympathy from relatives and friends just like any other sick person. Providing care and support to people living with HIV and AIDS will:

(a) Make them feel happy, secure and not isolated as shown in the Figure 5.1.

(b) Help them to reduce stress, hence live longer.

(c) Reduce the risk of other infections.

(d) Reduce the fear of death.

PLWHA are often afraid, lonely and despaired. One of the best things you can do for them is to spend time with them. In this way, you will let them know that they still have family or friends who care for them. Simple gestures such as shacking hands, hugging, sitting nearby or just talking to them can often be the best remedy for their fear and loneliness. PLWHA can be cared and supported through the following ways:

(a) Showing them love, respect and giving them all necessary support.

(b) Keeping their bedding and clothing clean. This will keep them comfortable.

(c) Keeping their bodies clean.

(d) Giving them a balanced diet, this includes proteins, carbohydrates, vitamins, mineral salts, lipids, water and roughages.

(e) Encouraging them to get treatment when they are sick. Most infections are easily treated and cured, even if a person is HIV positive.

(f) Encouraging them to stop smoking and drinking alcohol.

(g) Allowing them to have enough time to rest.

(h) Offer moral and spiritual support.

(i) Offer financial support where possible.

When caring for PLWHA, the following precautions should be observed:

(a) Wear protective gloves and wash your hands after changing beddings and clothes used by PLWHA.

(b) Keep wounds covered, especially places likely to come into contact with the victims' bedding or clothing.

(c) Do not share toothbrushes and sharp objects such as needles, syringes, nail cutters or razors blades.

BIOLOGY FORM 4.indd 163 09/03/2022 19:03

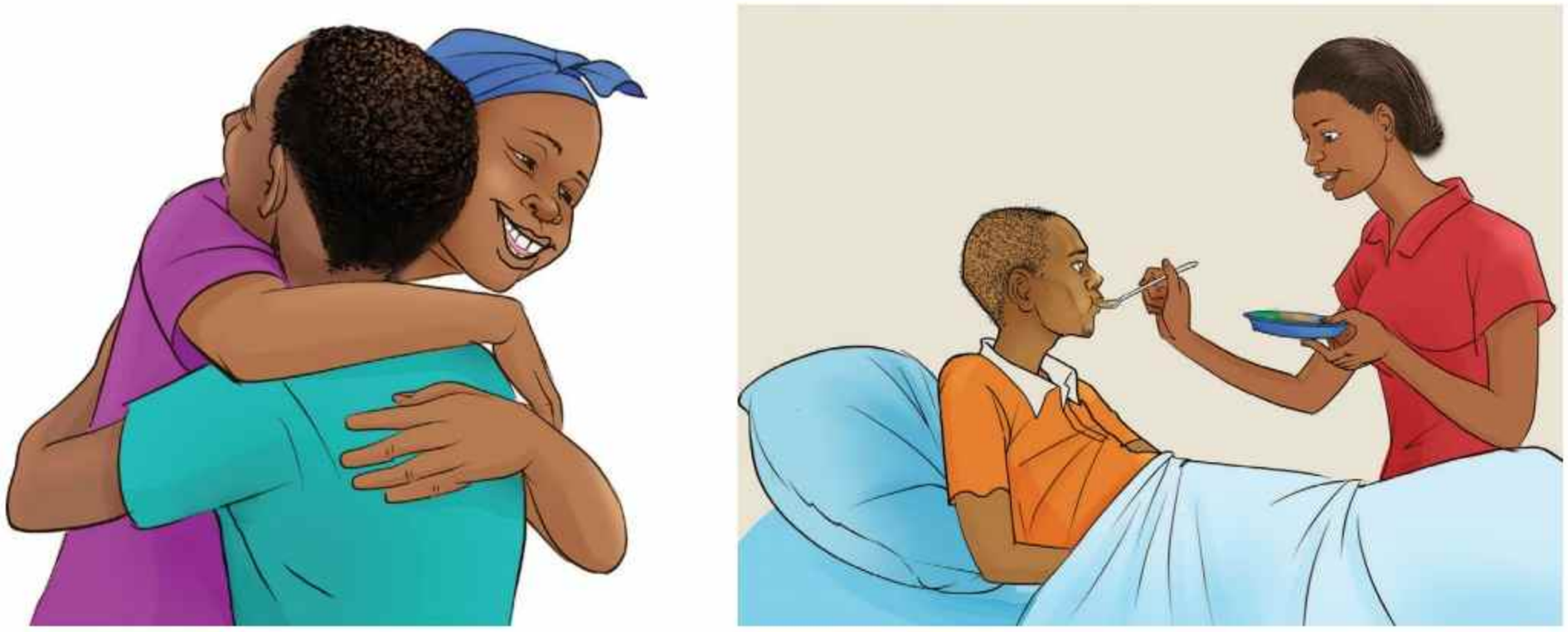

Figure 5.1: Support to people living with HIV and AIDS

The discrimination and stigma towards people living with HIV/AIDS and other STIs can have profound effects on them. It could make them feel unhappy. Without care and support from family and friends, their health may deteriorate hence shortening their life. Therefore, it is important to care and support them.

Project 5.2:

Explore the different ways in which PLWHA can be supported

Materials: Note book and pen

Procedure

1. Visit a nearby health facility.
2. Ask the health practitioner to explain to you on how PLWHA can be supported.
3. Note down each point given by the health practitioner.
4. Discuss your findings with your classmates.
5. Write a summary explaining the kind of supports that PLWHA can be given.

Exercise

1. What are the advantages of providing care and support to people living with HIV and AIDS?
2. Explain the important precautions which must be taken when caring for people living with HIV and AIDS.
3. Write an essay on the negative impact of stigmatisation against people living with HIV and AIDS.
4. How does HIV affect the health of a person?
5. Describe the importance of knowing CD4 cell count in the management of HIV infection.
6. Explain how HIV is related to AIDS and other sexual transmitted infections (STIs).
7. What are the differences between HIV, AIDS and other STIs?

Client initiated HIV testing and counselling (CITC)

This is the type of HIV testing where a person on his or her own will choose to undergo counselling and make decision on whether he or she should take a HIV test. CITC involves both pre and post counselling. This process gives opportunity to the client to learn their HIV status. The process differs from provider-initiated testing and counselling (PITC) in which the health care provider initiates testing and counselling.

CITC can be carried at individual level where an individual visits the health centre to seek for the service. It is also provided to couple or community level. In all cases, the clients are not coerced but are allowed to decide how, when, and where they wish to be tested for HIV.

CITC is also known as Voluntary Counselling and Testing (VCT). The program aims at educating the public in aabout of HIV and AIDS while providing free testing services. People who test positive for HIV are then counselled to ensure their continued well-being.

CITC is important in fighting the HIV and AIDS pandemic through prevention and care. It is made available through public health facilities, where it is integrated into family planning and STIs services. It is also available in separate facilities alongside other community services. It can also be provided to commercial enterprises such as in mines, farms and factories.

Prevention strategies that can be linked to CITC

If a pregnant woman tests positive through CITC, it will be easy to provide her with medication that will prevent transmission of HIV from mother to child. CITC can also include, STIs prevention, screening and treatment, access to education about behaviour change, access to antiretroviral drugs (ARVs) and access to family planning.

Testing for HIV

HIV is usually diagnosed by using blood sample taken from the arm. The sample is tested in a laboratory to check whether there are antibodies against HIV in an individual's blood. Antibodies are chemicals produced by white blood cells to fight against a specific pathogen. If the test detects antibodies for HIV, it indicates that the person has been infected with HIV. Such a person is said to be 'HIV positive' or seropositive for HIV. To ensure accurate results and avoid false positive or false negative results, the test should follow the Tanzania National Testing Algorithim. A person testing negative during the process is not subjected to the second test. A person testing positive is subjected to a second test. A third test is done if a person tests positive in the first and negative in the second test.

BIOLOGY FORM 4.indd 165 09/03/2022 19:03

Voluntary counselling procedure

Voluntary counselling includes counselling before and after the test for HIV. Pre-test counselling includes a private session with a counsellor who explains the testing procedure, importance of testing, and how the results will be given. The individual seeking CITC service is given an opportunity to ask questions about the test and share any fears or worries. Then, the person is allowed to decide whether he or she wants to be tested for HIV.

In post-test counselling, the counsellors support the clients as they give them the results of the test. The counsellor makes sure that the individual client understands the results and allow him or her to express how they feel. In case a person is tested positive, the counsellor helps the person to make immediate plans and provides referrals for medical care. The counseller will also advise a person with ongoing counselling and opportunities to talk to people who can help him or her understand more about HIV and AIDS.

In voluntary counselling and testing, results are kept confidential. It is the decision of the person being tested to decide whether she or he wants to reveal the results.

CITC is being actively promoted by increasing access, availability and uptake. In Tanzania and other African countries CITC has been recognised as:

(a) A public health and developmental priority.

(b) A cost-effective preventive measure.

(c) A way to help individuals to plan for the future and gain access to appropriate health and support services.

(d) A way to reduce stigma associated with HIV and help PLHWA to accept and cope with their status.

Significance of client initiated counselling and testing in controlling HIV and other STIs

This programme is not only an important measure to control the HIV infection but also it provides the following benefits:

(a) Counselling helps to prepare the clients to take the test.

(b) Counselling helps those living with HIV and AIDS to receive relevant information and advice that enable them to live normal life.

(c) Counselling helps to provide support to PLHWA.

(d) Voluntary testing helps the person to know his or her HIV status. This may help to prevent further infections after the person has known his or her HIV status.

(e) Testing helps the victim to start taking ART early enough under the supervision of medical personnel.

(f) Testing helps one to plan his or her life.

(g) Knowing one's HIV status helps one to take better care for himself or herself.

(h) It helps to increase HIV and AIDS awareness.

BIOLOGY FORM 4.indd 166 09/03/2022 19:03

Project 5.3:

Determining the factors that hinder voluntary testing

Materials: Note book and pen

Procedure

1. Visit a nearby health facility.
2. Ask the medical practitioner to explain to you the advantages of voluntary testing and factors that hinder voluntary testing.
3. Note down each point explained by the medical practitioner.
4. Discuss your findings with your classmates.
5. Write a summary report explaining the factors that hinder voluntary testing and provide suggestions to address those factors.

Revision exercise 5

Choose the most correct answer in the questions 1-6.

1. The virus that causes AIDS is called?
   (a) HIV
   (b) Papovirus
   (c) Retrovirus
   (d) Opportunistic virus
2. Which of the following is not transmitted by sexual contact?
   (a) HIV/AID
   (b) Dysentery
   (c) Hepatitis
   (d) Gonorrhoea
3. ……is caused by virus.
   (a) Trichonomiasis
   (b) Syphilis
   (c) Genital Herpes
   (d) Gonorrhoea
4. Caring of people living with HIV/ AIDS is important because;
   (a) It can cure AIDS
   (b) It gives the patient hope
   (c) The patients get many visitors
   (d) It makes the patient feel like a boss
5. Which is the best way to prevent hepatitis B?
   (a) Vaccination
   (b) Using mosquito nets
   (c) Eating a balanced diet
   (d) Not shaking hands with infected persons.

BIOLOGY FORM 4.indd 167 09/03/2022 19:03

6. HIV weakens the immune system by destroying a specific type of blood cells called _____ .
   (a) red blood cells
   (b) erythrocytes
   (c) CD4
   (d) T-helper cells

7. Match the terms in column A with that of column B by writing a correct letter of the corresponding item from column B against roman number in column A

Column A	Column B
i. Drugs used to reduce severity of HIV	A. ART
ii. Cells which defend the body against infections	B. ARV
iii. Entails taking medicine to prevent HIV after possible exposure.	C. T-Helper cells
iv. A Virus that causes AIDS	D. HIV
v. A sexual transmitted disease caused by fungus.	E. Chlamydia
vi. A medicine taken to prevent a person from getting HIV	F. Candidiasis
vii. Gives an indication of the strength of the person's immune system	G. PEP
viii. Infections which are transmitted sexually	H. STIs
	I. STDS
	J. Diaphragm
	K. CD4 count

8. State four ways of controlling the spread of HIV and other STIs.
9. Explain the relationship between HIV and AIDS.
10. Name two opportunistic diseases that PLWHA may contract.
11. Explain the ways in which HIV can be transmitted.
12. Describe five ways in which AIDS can affect the community.
13. Explain three precautions to be taken when caring for PLWHA or other STIs.
14. Explain the meaning of CITC. How does it help in fighting the HIV and AIDS pandemic?
15. What is the difference between HIV and AIDS?
16. Why is HIV testing important?
17. How can stigma against people living with HIV be reduced?
18. Explain how HIV weakens the body's immune system.

BIOLOGY FORM 4.indd 168 09/03/2022 19:03

19. Briefly explain how the following risky behaviours can contribute to HIV/AIDS infection.
    (a) Sexual intercourse
    (b) Drug use and abuse
    (c) Sharing cutting and piercing objects
    (d) Drinking alcohol
    (e) Going clubbing
    (f) Watching ponography

20. In what ways are people living with HIV/ AIDS being stigmatized in society?
21. Mention the ways in which you can take care of people living with HIV/ AIDs.
22. Explain the procedure of carrying out guiding and counseling to people with HIV/AIDS
23. Differentiate between responsible behaviour and risky behavior

BIOLOGY FORM 4.indd 169 09/03/2022 19:03

Glossary

A

Abiogenesis — a theory that postulates that life originated from non-living matter. It is the opposite of biogenesis

Abscisic acid — a plant hormone involved in the abscission of leaves, flowers and fruits and the dormancy of buds and seeds

Abscission — dropping of leaves and fruits

Adaptation — the process by which organisms changes the structure or its function in order to fit and survive in a new environment

Adenine — a nitrogenous purine base in the nucleotides involved in making DNA and RNA

AIDS — Acquired Immunodeficiency Syndrome

Allele — an alternative form of a gene located at the same position or at gene locus

Allelomorphic — any one of two or more genes that may occur alternatively at a given site

Anaphase — stages of mitotic and meiotic cell division in which the chromosomes move to opposite end of the nuclear spindle fibre

Anatomy — study of internal structure of an organism

Ancestor — an individual / organism from whom one is descended

Antibodies — proteins produced by the immune system to fight against disease(s)

Antigen — a foreign body substance such as a pathogen or toxic substance that triggers an immune response

ART — Antiretroviral treatment

ARVs — Antiretroviral drugs used to prevent the HIV from multiplying

Auxin — plant hormone that regulate various functions including cell division, elongation and differentiation

B

Biodiversity — is the variety of plant and animal life existing in a particular habitat or ecosystem

BIOLOGY FORM 4.indd 170 09/03/2022 19:03

Biogenesis	theory that prostulates that life on the earth originates from pre-existing life forms
Buoyancy	an upward force exerted by a fluid that opposes the weight of a partially or fully immersed object
C	
Calluses	thickened layers of skin often on hands or feet where friction repeatedly occurs
Camouflage	an adaptation that allows an organism to blend into its environment
Cell replacement	replacement of dead cells by new ones that are exact copies
Centrioles	cylindrical organelles involved in the development of spindle fibres during cell division
Centromere	condensed and constricted region of a chromosome to which the spindle fibre is attached during mitosis and meiosis
Character	a structure, function or an attribute determined by a gene or group of genes
Chaetae	chitinous hair-like structure projecting from the cuticle in annelids
Chemoreceptor	receptor that responds to chemical stimuli
Childhood	the time from two years of age to puberty
Chromatid	the strands of a replicated chromosome which are joined by a single centromere
Chromosome	a thread like structure found in the nucleus of eukaryotic cells and also the main gene-carrying structure of a prokaryotic cell
CITC	an abbreviation for client initiated HIV testing and counseling
Codominance	a condition where both genes of an allelomorphic pair produce their effect in an individual
Coelom	Fluid filled cavity lined by an epithelium derived from the mesoderm.
Coleoptile	sheath-like structure protecting the shoot in hypogeal germination

BIOLOGY FORM 4.indd 171 09/03/2022 19:03

Competition	struggle among and between organisms for the limited resources
Continuous variation	variations within a population, in which a graded series of intermediate phenotype falls between the extremes
Convergent evolution	the process whereby distantly related organisms independently evolve similar traits to adapt for a similar function
Cosmozoic theory	the theory which states that life on the earth was brought from somewhere else in the universe
Cotyledon	seed leaf within a plant embryo
Cross-breeding	process of producing offspring through mating two pure breeding individuals
Cross-pollination	transfer of mature pollen grains from the anther of the flower of one plant to the stigma of a flower of another plant of the same species
Cuticle	outer protective layer found in nematodes, annelids and arthropods. It is made up of non-living material (collagen fibres or chitin) secreted by the underlying epidermal layer
Cytokinin	plant hormone that stimulates cell division and elongation
Cytokinesis	division of the cytoplasm of the cell followed the division of the nucleus
Cytosine	a nitrogenous base in DNA and RNA

D

Degeneration	having lost one or more functions, characteristics or structures through evolution
Denticle	tooth-like structure found in some organisms
Desiccation	drying out of an organism or substance by removing or extracting moisture from it
Deuteranopia	the type of red-green colour blindness, characterized by inability to distinguish red and green pigments
Development	a change in shape, form and degree of complexity of a living organism which lead to maturity

BIOLOGY FORM 4.indd 172 09/03/2022 19:03

Diaphragm	a muscular organ that separates the thorax from the abdomen in some vertebrates
Differentiation	the process by which unspecialised structure become modified and specialised for a particular function
Dioecious	having male and female reproductive organs in different individuals of the same species
Discontinuous variation	variation within a population, in which there is no intermediate phenotypes between the extreme phenotypes
Diurnal	active during the day
DNA	deoxyribonucleic acid, the genetic material that an organism inherits from the parents
Dominant gene	a gene that is expressed in preference to a recessive gene
Down's syndrome	a genetic disorder caused by the presence of an extra copy of chromosome number 21

E

Ecdysis	periodic shedding of the old exoskeleton and skin in anthropods and some reptiles respectively
Ectoparasite	parasite that lives on the surface of a host organism
Elephantiasis	disease caused by the nematode *Wuchereria bancrofti*. Also known as Bancroftian filariasis
Embryo	an organism in the very early stages of development from a zygote
Embryology	the study of embryonic development
Endocrine gland	gland that produces and secretes hormones directly into the blood stream
Endocrine system	system of endocrine glands
Endoderm	innermost layer in diploblastic and triploblastic animals
Endoparasite	a parasite that lives within a host organism

BIOLOGY FORM 4.indd 173 09/03/2022 19:03

Endosperm	a tissue inside the seed of flowering plants that surrounds and supplies nutrients to the embryo
Enteron	a gut or alimentary canal
Epidermis	the outermost layer of the skin
Epigeal germination	type of seed germination where the radicle grows downward first then the stem (hypocotyl) grows upwards pulling the cotyledons with it
Epinasty	a downward bending of leaves or rather plant parts resulting from excessive growth of the upper side
Ethylene	a plant hormone that exists in gaseous form that induces ripening and causes leaves to drop
Eugenic	improvement of human race by controlling human inheritance. Associated with racist ideology
Evolution	change in genetic makeup of a population over successive generations
Excretion	a process where normal waste products of metabolism, such as nitrogenous compounds derived from proteins degradation are removed from the body
Extinction	a process in evolution which leads to the disappearance of a species of population from the earth's surface

F

Fallopian tube	funnel-shaped tube that allows an ovum to pass through from the ovary to the uterus
Fertilisation	fussion of male and female haploid gametes to form an embryo during sexual reproduction
First filial generation(F_1)	first generation of offspring resulting from a cross between two parents
Flame cells	a specialised excretory cell found in invertebrates including flatworms
Foetus	the unborn young of a vertebrate having a basic structural resemblance to the adult

Fossil	a preserved remnant or impression of an organism that lived in the past
G	
Gamete	a specialised sex cell which contains the haploid number of chromosomes
Gene	a sequence of nucleotides in DNA that controls the trait of a particular organism
Genetic code	is the sequence of nucleotides in deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) that defines the amino acid sequence of proteins
Genetic disorder	a disorder caused by an abnormality in an individual's DNA
Genetic material	material that is directly transmitted from the parents to offspring and it is therefore responsible for the transmission of inheritable characteristics
Genetics	scientific study of heredity and genetic variation
Genotype	genetic makeup of an organism
Germination	a process where seed develop into seedling
Gibberellin	plant hormones that regulate various developmental process including stem elongation, germination, dormancy, flowering, flower development, and leaf and fruit senescence
Growth	an irreversible increase in the size and dry mass of an organism
Growth regulators	synthetic compounds or natural hormones extracted from plants tissue, which are applied to plants to regulate growth
Guanine	a nitrogenous base in the nucleotides of DNA and RNA
H	
Heredity	transmission of genetic characteristics from the parents to their offspring
Heterotrophs	organisms that are unable to synthesise their own food instead they obtain nutrients from other organisms

BIOLOGY FORM 4.indd 175 09/03/2022 19:03

Heterozygous	having two different alleles for a particular trait at the same loci on homologous chromosomes
Hilum	the scar left on seed where it was attached to the placenta of the fruit
HIV	Human Immunodeficiency Virus; the virus that causes AIDS
Homozygous	having two identical alleles for a particular trait at the same loci on homologous chromosomes
Hormone	a chemical substance produced by a ductless gland and transported by blood stream to effect an activity, such as growth or metabolism
Hybrid vigour or heterosis	the superiority of hybrid offspring over its parents for quantitative traits, enhanced as a result of mixing the genetic contributions from its diverse parents
Hybridisation	is the method of producing new varieties by crossing two genetically different individuals to improve their performance
Hypocotyl	stem of plant growing upwards during germination
Hypogeal germination	the type of germination where the shoot from a seed grow straight up through the soil, leaving the cotyledons in the soil

I

Immunodeficiency	inability to mount a normal immune response. Immunodeficiency can be due to a genetic diseases or HIV infection
Incomplete dominance	a type of inheritance in which the phenotype of a heterozygote is intermediate between the phenotypes of the two homozygotes
Infancy	the time from birth to two years of age
Interphase	the first stage of mitosis and meiosis I, when the cell prepares for division

K

Kinetochore	either of the two submicroscopic attachment points for chromosomal microtubules, present on each centromere during the process of cell division

BIOLOGY FORM 4.indd 176 09/03/2022 19:03

L

Larva	newly hatched form of an organism that is completely different from adult
Life expectancy	number of year a person is expected to live

M

Macronutrients	essential nutrients needed in relatively large amount
Malpighian tubule	slender tube for excretion of nitrogenous waste in arthropds which lie in coelom and open into the posterior region of the almentary canal
Menopause	period in women's life around the age of 45 to 55, when menstruation ceases
Mesoderm	middle layer in triploblastic animals
Metamerism	segmentations, such as those found in annelids and arthropods
Metamorphosis	a drastic change in the shape and form of young animal into the adult form after birth or hatching
Metaphase	stage of mitosis and meiosis I where the spindle fibres align the chromosomes along the middle of the cell nucleus
Micronutrients	essential nutrients that are needed in relatively small amount
Micropyle	small hole in the ovary of a flowering plant that allows entry of pollen tube
Microtubules	hollow tube-like structure involved in supporting and shaping the cell
Mitosis	cell division in which the nucleus divides into two nuclei each with identical genetic materials as the parent cell
Monohybrid cross	an experimental mating of individuals that differ at one genetic locus
Mutation	a change in nucleotide sequence of gene or in the number or structure of a chromosome (s)

BIOLOGY FORM 4.indd 177 09/03/2022 19:03

N

Natural selection	the natural process whereby organisms with characteristics that are well adapted with the environment tend to grow and reproduce, and pass their characteristics on to the future generation, while those with less favoured characteristics fail to survive
Nocturnal organism	organism that are mainly active during the night
Nymph	intermediate form of some organisms during metamophosis before the adult form formed mostly in insect

O

Offspring	new organism resulting from reproduction of parental organism(s)
Operculum	a protective flap of tissue that covers the gills in bony fish
Osmoregulation	active regulation of the osmotic pressure of the body fluid, water and solute so that they do not become excessively diluted or concentrated
Over-reproduction	production of more offsprings than the environment can support
Ovum	female gamete usually capable of developing into new organism after fertilisation

P

Palaeontology	scientific study of the history of life and evolution through investigstion of fossils remains
Parasite	an organism that lives in or on an organism of another species
Pentadactyl	having five digits or toes on each hand and foot
PEP	Post Exposure Prophylaxis, the drug taken to prevent HIV after a possible exposure to HIV infection
Phenotype	a set of observable traits of an organisms such as height and skin colour
Photoreceptor	receptors that are sensitive to light

Photosynthesis	process whereby plants and some other organisms use sunlight energy to synthesize nutrients from carbon dioxide and water
Phototropism	orientation of plant or other organism in response to light
Phylogenetic tree	diagram that depict the lines of evolutionary descent of different species from common ancestry. The tree is useful in organizing knowledge of species diversity, classifying organisms and in describing events that occur during evolution. Phylogenetic tree determine which species are most related.
Placenta	a membranous vascular organ that develop in some female mammals during pregnancy, lining the uterine wall and partially enveloping the foetus to which it is attached by the umbilical cord. In flowering plants, the placenta is ridged, soft and fleshy tissue to which the ovules are attached
Plumule	part of plant embryo that develops into a shoot
PLWHA	an abbreviation for People Living with HIV and AIDS
Poikilothermic	having a body temperature that varies with the external temperature
Pregnancy	period from conception to birth during which one or more offsring develop inside a woman's body
PrEP	Pre-Exposure Prophylaxis is the drug taken as an emergency situation to prevent or reduce chances of HIV infection for high risk groups
Progeny	children, descendants or offspring
Proglottid	a segment of a tapeworm, containing male and female reproductive organs
Prophase	first stage of mitosis and meiosis I
Puberty	stage of adolescence in which an individual become physiologically capable of sexual reproduction
Punnett square	a square diagram used to predict the genotype of a particular cross
Pupa	non-feeding 'cocoon' state when an organism undergoes metamorphosis from the larval stage to the adult form

BIOLOGY FORM 4.indd 179 09/03/2022 19:03

R

Radiation	a stream of particles or electromagnetic waves emitted by the atoms and molecules of a radioactive substance as the result of nuclear decay
Radicle	part of plant embryo that develops into a root
Recessive gene	a gene that is masked by the dominant gene
Recessive trait	a trait that is expressed only in homozygous state. Can be masked by other traits
Regeneration	renewal of body parts
Reproduction	production of new individuals from existing ones
RNA	ribonucleic acid which is found in the cell and carries information for making proteins and enzymes
Rostellum	a protruding part of the anterior end of the tapeworms

S

Scolex	a knob-shaped head with hooks or suckers; used by the tapeworm to attach itself to its host
Secondary sexual characteristics	physical changes in the body that occurs at puberty
Second filial generation(F_2)	the generation of offspring resulting from crossing members of a first filial generation
Senescence	process of deterioration of an organism associated with ageing and ultimately death
Seropositive	giving a positive result for the presence of a particular pathogen in a test of blood serum i.e. give a positive reaction especially in a test for the presence of an antibody
Sex determination	determination of sex of the offspring, which is governed by sex chromosome
Sex-limited trait	are traits that are controlled by autosomal chromosomes and are limited to a particular sex and cannot be found in other sex
Sex-linked trait	a trait of an organism that is controlled by genes located in the sex chromosome
Sexual discrimination	one sex is preferred over the other

Sex-influenced trait	a trait that is only visible within one sex
Sexually transmitted infections (STIs)	infections that are transmitted from one person to another through sexual contact
Somatotropin	a hormone produced by pituitary gland that stimulates growth
Special creation theory	theory which states that everything on the earth was created by God
Spindle	structural fibres formed from microtubules during cell division
Spinneret	silk extracting organ possessed by spiders
Spiracle	openings in the trachea of some arthropods which allow gas to enter and leave the tracheal system
Spontaneous generation theory	theory which states that life on the earth arose from non-living matter
Steady state theory	theory which states that life on the earth has no origin
Stigma	a female part of a flower which receives pollen
Survival of the fittest	a selection process where nature selects organisms that are best fitted for survival
Swim bladder	a thin-walled air filled sac in the abdominal cavity of most ray-finned fishes

T

Taeniasis	disease caused by tapeworms infection mainly from undercooked beef of pork
Telophase	stage at the end of cell division (mitosis and meiosis) when new membrane form around the daughter nuclei
Tegument	outer covering made up of the living epidermal cells, found in flatworms
Testa	seed coat which is the protective outer covering of the seed
Test cross	is the cross between an individual with unknown genotype and a recessive organism in order to know whether the dominant trait is homozygous or heterozygous.

BIOLOGY FORM 4.indd 181 09/03/2022 19:03

Thymine	one of the nitrogenous pyrimidine base in a nucleotide of DNA
Tiller	lateral shoot from the base of the stem of a plant, especially in a grass or cereal
Trachea	organ for respiration in arthropods such as insects, centipede, and millipedes
Triploblastic	having three germ layers which are ectoderm, mesoderm and endoderm
Turner's syndrome	a genetic disorder where by the female is born with a missing X chromosome

U

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 waste
Uracil	one of the nitrogenous pyrimidine base in a nucleotide of RNA
Uterus	hollow muscular organ in the female reproductive system where the embryo or foetus grow and develops

V

Variation	marked differences or deviation between organisms caused by either genetic or environmental factors
Vegetative reproduction	asexual reproduction in plants without seeds or spores
Vestigial organ	an organ that has lost its function in organisms, yet persists from one generation to the next
Viviparity	giving birth to living offspring that develop inside the body of the mother

Z

Zygote	fertilised egg that results from the fusion of a male gamete with a female gamete

BIOLOGY FORM 4.indd 182 09/03/2022 19:03

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BIOLOGY FORM 4.indd 183 09/03/2022 19:03

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BIOLOGY FORM 4.indd 184 09/03/2022 19:03

Index

BIOLOGY FORM 4.indd 185 09/03/2022 19:03

C

BIOLOGY FORM 4.indd 187 09/03/2022 19:03

G

H

BIOLOGY FORM 4.indd 188 09/03/2022 19:03

I

J

K

L

BIOLOGY FORM 4.indd 189 09/03/2022 19:03

M

N

O

BIOLOGY FORM 4.indd 190 09/03/2022 19:03

P

BIOLOGY FORM 4.indd 191 09/03/2022 19:03

R

S

BIOLOGY FORM 4.indd 192 09/03/2022 19:03

T

U

BIOLOGY FORM 4.indd 193 09/03/2022 19:03

V

W

X

Y

Z

BIOLOGY FORM 4.indd 194 09/03/2022 19:03

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Student's Book

Form Four

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