Biology

for Secondary Schools

Student's Book

Form Two

Tanzania Institute of Education

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Biology for Secondary Schools

Student's Book
Form Two

THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF EDUCATION,
SCIENCE AND TECHNOLOGY

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Preface

This textbook, *Biology for Secondary Schools* is written specifically for Form Two students in the United Republic of Tanzania. The book is prepared in accordance with the 2005 Biology Syllabus for Secondary Education, Form I-IV, issued by the then Ministry of Education and Vocational Training (MoEVT).

The book consists of eleven chapters, namely: Classification of living things, Nutrition, Nutrition in animals, Digestive system, Nutrition in plants, Food processing, preservation, and storage, Balance of nature, Transport of materials in living things, Transport of materials in mammals, Transport of materials in plants, and Gaseous exchange and respiration. Each chapter contains illustrations, activities, and exercises. You are encouraged to do all the activities and exercises. Doing so will enhance your understanding and promote the development of the intended competencies.

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Chapter One

Classification of living things

Introduction

All living organisms are classified into groups based on similarities and differences in their characteristics. In Form One you learnt about the principles of classification of living things. Also, you learnt about Viruses and kingdoms Monera and Protoctista. In this chapter, you will learn about kingdoms Fungi and Plantae. Competencies developed from this chapter will enable you to explore the characteristics of organisms under these kingdoms and be able to classify them into their respective phyla or divisions.

Kingdom Fungi

The kingdom Fungi contains a variety of eukaryotic organisms that consist of bounded cell organelles such as mitochondria and nucleus. Most of them are multicellular (made up of many cells) and some are unicellular (made up of a single cell). Examples of unicellular fungi are yeasts such as *Saccharomyces* sp. (baker's yeast), and *Candida* sp. (yeast that causes candidiasis and thrush). Examples of multicellular fungi include *Rhizopus* sp. (bread mould), *Mucor* sp. (pin mould), and *Agaricus* sp. (mushroom). They are found in different habitats such as air, water, soil, plants, and animal bodies. Fungi are of different sizes and forms and have great ecological and economic importance to human beings, and other living organisms. They exhibit two modes of feeding, namely parasitic mode of feeding (living on or in another living organism), and saprophytic mode of feeding (digesting dead organic materials externally). They may also live as symbionts (associating with another organism) such as lichen and mycorrhiza. A lichen is a symbiotic relationship between an algae and a fungus. Mycorrhiza is a symbiotic relationship between a fungus and roots of vascular plants.

General characteristics of Fungi

Members of the kingdom Fungi have the following general characteristics:

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(i) they are found in various places including air, water, soil, food, and in the body of animals and plants;

(ii) they are eukaryotic organisms with true nucleus which is enclosed in a nuclear membrane;

(iii) they can be either unicellular such as yeast or multicellular such as mould and mushroom;

(iv) their body is made up of a mycelium consisting of a network of fine, tube-like filaments called hyphae (except yeast);

(v) they feed saprophytically for example, mushroom; but some of them are parasitic for example, *Candida albicans*;

(vi) some fungi form symbiotic associations with other species such as mycorrhiza and lichen;

(vii) they exhibit alteration of generations (gametophyte and sporophyte generations). (Their dominant generation is gametophyte);

(viii) they reproduce both sexually by spores and asexually by budding;

(ix) they produce a chemical substance called pheromone that facilitates sexual reproduction; and

(x) they store carbohydrates in the form of glycogen.

Distinctive characteristics of Fungi

Apart from general characteristics, members of the kingdom Fungi have the following distinctive features:

(i) they have cell walls made up of chitin, which is a substance containing protein and complex sugars;

(ii) their body is made up of a mycelium consisting of a network of fine, tube-like filaments called hyphae (except yeast); and

(iii) they feed saprophytically, for example mushroom; but some of them are parasitic, for example *Candida albicans*.

Phyla of the kingdom Fungi

The members of kingdom Fungi are classified into different phyla based on the structures they use to produce sexual spores. There are three main phyla in kingdom Fungi. These are Ascomycota, Zygomycota, and Basidiomycota.

Phylum Ascomycota

Members of this phylum are commonly called ascomycetes or sac fungi. This is because their spores are enclosed in sac like structures known as asci (singular ascus). Ascomycetes can reproduce both sexually through spores or asexually by budding. Some are single-celled (unicellular) organisms such as yeast (See Figure 1.1). Most yeasts such as

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Saccharomyces can ferment sugars to form alcohol. Majority of ascomycetes are multicellular organisms such as *Aspergillus* and *Penicillium*. In addition, most ascomycetes have a saprophytic mode of feeding and can grow on the surfaces of dead organic materials such as rotting fruit and other foods. Some are parasitic causing various diseases and infections, for example *Tinea* spp. that causes athlete's foot and ringworm diseases in humans; and *Erysiphe polygoni* that causes powdery mildew disease in beans and other legumes.

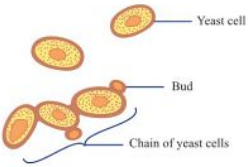

Figure 1.1: Yeast cells

Characteristics of ascomycetes

(i) Some are unicellular, for example yeast and others are multicellular, for example *Aspergillus* and *Penicillium*.

(ii) They grow and feed on decaying materials.

(iii) They have long tube-like filaments called hyphae with cross walls.

(iv) They reproduce sexually through ascospores, and asexually through fission, fragmentation, or budding (See Figure 1.2).

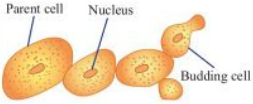

Figure 1.2: Yeast budding

Activity 1.1: Investigating the structure of yeast cells

Materials:
Dry yeast, water, methylene blue reagent, microscope, coverslips, microscope slides, dropper, pencil, and notebook

Procedure

1. Dissolve some dry yeast cells in water.
2. Using a dropper, place a drop of the yeast solution on a microscope slide and cover it with a cover slip.
3. Examine the specimen using the low-power objective lens of the microscope.
4. Identify some yeast cells.
5. Use the high-power objective lens of the microscope to examine the specimen in more detail and draw the structure of the yeast cells.

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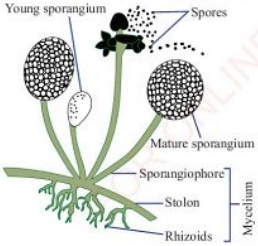
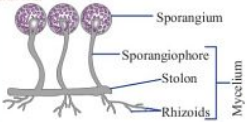
6. Compare your results with Figure 1.2.
7. Share your results with fellow students.

Phylum Zygomycota

The members of this group are known as zygomycetes. They are formed by fusion of two different cells. They have sexual spores known as zygospores, which are produced in the structures called zygosporangia. They also have asexual spores known as sporangiospores, which are produced in the structures called sporangia. Like other fungi, they have hyphae but without cross walls or septa. Zygomycetes grow as a mass of white tiny threads and feed on rotting or decaying food materials like bread, cassava, pawpaw, and tomato. Examples of organisms in this group include mucor and black bread mould or *Rhizopus stolonifer* (See Figure 1.3).



(a) Black bread mould *(Rhizopus)*



(b) Mucor

Figure 1.3: Examples of zygomycetes

Characteristics of zygomycetes

(i) They are multicellular.

(ii) They are saprophytic, growing on decaying organic materials.

(iv) They reproduce sexually through zygospores or asexually through sporangiosphores.

(v) Have hyphae without cross walls.

Activity 1.2: Investigating the structure of bread mould

Materials:

A piece of bread, petri dish or watch glass, hand lens, forceps, microscope, microscope slides, pencil, and notebook

Procedure

1. Take a slice of bread, put it on a petri dish and moisten it.
2. Leave the bread on the moist place for 2-3 days until a greyish or dark spots appear on it.
3. Observe the changes that might have occurred on the surface of the bread.

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4. Use a hand lens and observe the dark spots that have developed on the surface of the bread.
5. Take a small sample of the dark spots using forceps and place it on a microscope slide, add a drop of water, and cover with a coverslip.
6. Put the sample on the microscope stage and observe using the low, medium, and high objective lenses.
7. Record the findings and draw the structures you have observed. Compare your results with Figure 1.3 (a).
8. Share your findings with your fellow students.

Phylum Basidiomycota

Members of the phylum Basidiomycota are called basidiomycetes. Most basidiomycetes reproduce sexually. They have structures called basidia (singular is basidium) that produce sexual spores. The basidia are usually club-shaped structures. Hence, members of this group are also known as club fungi because they all possess basidia. Their sexual spores are called basidiospores. The common examples of basidiomycetes are mushrooms and toadstools such as *Agaricus bisporus* (edible mushroom). They are well recognisable in various habitats, especially in areas with soil rich in nutrients. Their body consist of hyphae, volva, stipe (stem-like structure), ring, cap, and gills, as shown in Figure 1.4. Gills contain spores that are enclosed in basidia found under the cap (pileus). When the gills mature, spores are shed and they can be dispersed by wind. Other examples of basidiomycetes include brackets, puffballs, and rust fungi.

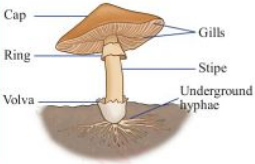

Figure 1.4: Structure of a mushroom

Characteristics of basidiomycetes

(i) They are multicellular organisms.

(ii) They are saprophytic, growing on decaying organic matter.

(iii) They reproduce both sexually and asexually.

(iv) They produce sexual spores called basidiospores contained in club–like structures known as basidia.

(v) They have hyphae with cross walls (septate).

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Activity 1.3: Investigating the structure of a mushroom

Materials:

Mushroom, hand lens, scalpel, petri dish, scissors or sharp knife, pencil, and notebook

Procedure

1. Use a hand lens to examine the mushroom structure.
2. Draw and label diagrams to show:
   (a) a view from the side; and
   (b) a view from the lower surface of the cap.
3. Use a scalpel or knife to cut the mushroom vertically into two equal parts.
4. Draw and label diagrams of:
   (a) the whole mushroom as seen from the side and
   (b) the cut surface of the mushroom.
5. Compare your results with Figure 1.4.
6. Discuss the results with your fellow students.

Advantages of fungi

Several types of fungi are advantageous to human being. Most strains of mushrooms and toadstools such as *Agaricus* sp. are edible. They are used as sources of food and they have a high content of proteins and vitamins. Other fungi such as yeasts *(Saccharomyces* sp.*)* are used in food manufacturing industries such as in bakeries (they make dough to rise). Yeast is also used in brewing beer by fermenting sugars to produce alcohol. Other fungi are also used in making lactic acid, citric acid, cheese, and commercial enzymes. In addition, some fungi are important in production of drugs, for example *Penicillium* spp. that is used to make penicillin. This is an antibiotic used to treat bacterial infections including bronchitis and laryngitis. Moreover, most fungi species are used in genetic engineering and biological researches.

Being saprophytic, most species of fungi are very important in the decomposition of dead organisms and waste materials. Through decomposition by fungi, important nutrients are released into the soil. The nutrients are then absorbed and used by plants.

Some types of ascomycetes and basidiomycetes develop symbiotic relationship called mycorrhiza with roots of higher plant. The hyphae of fungi spread apart and increase the surface area of the vascular plant roots. This helps the plant roots to absorb more nutrients from the soil.

Disadvantages of fungi

Some fungi are harmful to human beings and other organisms. Some of the diseases caused by fungi in humans include; athlete's foot, ringworm, meningitis, candidiasis, and skin infections. In some

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individuals, the fungal spores can cause allergic reactions.

Some fungi such as *Candida albicans* live in the body of human beings. They grow naturally in the human body, particularly in the mouth, throat, gut, and female reproductive tracts without causing any harm. However, *Candida albicans* can cause infection if they grow in excess and enter deep into the body organs and systems, such as in the blood stream, kidney, heart or brain.

Some parasitic fungi such as certain types of ascomycetes produce poisonous substances called mycotoxins. The most common mycotoxin is known as aflatoxin, which is commonly found in harvested maize, groundnuts and peanuts that have been left in damp places. Aflatoxin is a carcinogen (cancer causing agent).

In plants, some fungi such as ascomycetes cause various diseases like potato blight, wheat rust, maize rust, rice blast, and powdery mildew. They can also cause ergot which is a fungal disease that affects the developing cereal grains and grasses such as maize, rye, rice, wheat, and lemon grass. Some fungi attack timber used in building houses and making furniture.

Some fungi such as moulds and other parasitic fungi cause food spoilage such as rotting of meat, bread, cereals, fruits, and vegetables.

Exercise 1.1

1. Suppose you are in a class and your Biology subject teacher brings you an unknown specimen. Which characteristics will you look for to confirm that it belongs to the kingdom Fungi?
2. Name the phylum in which each of the following organisms belongs:
   (a) bread mould;
   (b) mushroom; and
   (c) yeast.
3. Explain the disadvantages of fungi.
4. Describe how yeast reproduce.
5. Explain the importance of fungi.

Kingdom Plantae

Kingdom Plantae is composed of a wide variety of plants. Members of this kingdom vary greatly in size, forms, habitat, means of reproduction, and morphology. Kingdom Plantae includes: moss, ferns, cone bearing plants, and flowering plants. Plants are found in various habitats such as on land, in oceans, and in fresh water.

General characteristics of members of the kingdom Plantae

(i) They are multicellular and eukaryotic organisms.

(ii) They have cell organelles called chloroplasts that contain

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chlorophyll pigments.

(iii) Green plants are said to be photoautotrophs. This means that they manufacture their own food using sunlight through the process of photosynthesis.

(iv) Some plants reproduce sexually through flowers or cones while others reproduce asexually by means of spores or development of parent plant parts (vegetative propagation).

(v) Their cells are organised into tissues, organs, and organ systems.

(vi) They show limited movement, for example opening and closing of flower petals and growth movements towards stimuli like light and water.

Distinctive features of members of the kingdom Plantae

(i) They have a cell wall made up of cellulose.

(ii) Higher plants have vascular tissues for the conduction of water, mineral salts, and manufactured food.

(iii) They store food in the form of starch.

Activity 1.4: Observation of plant parts

Materials:
A variety of plants and a hand lens

Procedure

1. Examine each of the plant parts using a hand lens.
2. Identify different parts such as roots, stems, leaves, flowers, and fruits. Do all plants have these parts?
3. Group the plants according to their similarities and differences.

Divisions of kingdom Plantae

The kingdom Plantae is divided into four main divisions. These are:

(i) division Bryophyta;

(ii) division Filicinophyta or Pteridophyta;

(iii) division Coniferophyta; and

(iv) division Angiospermatophyta also known as Angiospermophyta.

In this chapter, you will learn about two divisions of the kingdom Plantae, namely division Bryophyta and division Filicinophyta.

Division Bryophyta

Members of the division Bryophyta are called bryophytes, which are the most primitive plants. They are found in wet and shaded environments, such as on forest floors, rock surfaces, bare soil, cracks of paved surfaces, bricks, on trunks, and branches of trees. The reproduction process in bryophytes depends on availability of water that is why their distribution is restricted to shady and moist places. Examples of bryophytes are mosses and hornworts, as shown in Figure 1.5.

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(a) Mosses (b) Hornworts

Figure 1.5: Examples of bryophytes

General characteristics of bryophytes

(i) Bryophytes live in moist, damp, and shaded areas.

(ii) They do not produce flowers, fruits or seeds.

(iii) They have root-like structures called rhizoids.

(iv) They reproduce sexually and asexually by spores.

(v) They undergo alternation of generations with gametophyte and sporophyte generations.

Distinctive characteristics of bryophytes

(i) They are simple plants which lack true roots, stems or leaves.

(ii) They have either an erect or thalloid plant body, which is leafy in nature.

(iii) They have no vascular tissue, meaning that they have no xylem and phloem.

(iv) They usually depend on water for sexual reproduction.

(v) The dominant part of the plant body is gametophyte (the gamete producing plant body).

The structure of mosses

Mosses are primitive plants believed to be among the first plants to develop the ability to live on land. An example of a moss plants is *Funaria* sp. Moss plants have no true roots, stem or leaves. They also lack vascular tissues to transport water and nutrients from one part of the plant to another. This is the reason why

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most bryophytes do not grow tall but are short and spread out. Bryophytes grow on water-collecting surfaces to allow direct water absorption through the body surface. The absorbed water can move up by capillary action. The main moss structure is the gametophyte, which is the greenish stem-like and leaf-like body. The gametophyte have male and female reproductive structures and also carry out photosynthesis. The root-like strands of moss plants are known as rhizoids as shown in Figure 1.6. Rhizoids hold moss plants to their growing surfaces.

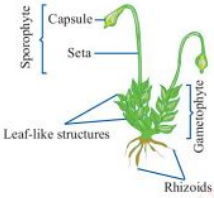

Figure 1.6: Structure of a moss plant

The reproductive parts of a moss plant are the antheridium (male organ) and archegonium (female organ). Both antheridium and archegonium are found on the same plant body called gametophyte.

Activity 1.5: Investigating the structure of bryophytes

Materials: Mosses and hand lens

Procedure

1. Use a hand lens to observe the structure of a moss plant.
2. Draw and label the observed structure to show the external features.
3. Compare your results with Figure 1.6.

Advantages of mosses

(i) They help to decompose dead logs and enhance nutrient circulation.

(ii) They are early colonisers of open woodland, hence they help in creating a favourable environment for the development of higher plants.

(iii) They are primary producers, therefore, they provide energy for heterotrophs such as insects, fungi, and bacteria.

(iv) They play a great role in preventing soil erosion by holding the soil particles together.

(v) They contribute in the production of oxygen to the atmosphere, which is used by animals and other organisms.

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Disadvantages of mosses

(i) Moss plants are common weeds in gardens and can be difficult to eliminate.

(ii) Sometimes, they grow on the surface and walls of buildings, making them look old and unattractive.

Division Filicinophyta (Pteridophyta)

Members of division Filicinophyta are called filicinophytes or pteridophytes. Examples of filicinophytes are ferns, horsetails and club mosses as shown in Figure 1.7. Filicinophytes are much more advanced than bryophytes because they have true roots, stems and leaves. Leaves of filicinophytes are called fronds. Fronds are usually composed of a leafy blade and petiole (leaf stalk). Leaf shape, size, texture and degree of complexity differ from one species to another. Unlike bryophytes where the dominant generation is gametophyte, the dominant generation in filicinophytes is sporophyte. The sporophyte is the spore producing plant body.

(a) Ferns

(b) Club mosses

(c) Horsetail

Figure 1.7: Examples of filicinophytes

General characteristics of filicinophytes

(i) They live in moist, damp and shady areas.

(ii) They are less dependent on water for survival and reproduction than bryophytes.

(iii) They have true roots, stems and leaves.

(iv) They have vascular tissues.

(v) They reproduce by means of spores.

(vi) They do not produce flowers and seeds.

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(vii) They undergo alternation of generations with gametophyte and sporophyte phases.

(viii) The dominant part of the plant body is sporophyte.

Distinctive characteristics of filicinophytes

(i) Their leaves bear spore-producing structures called sori (singular sorus). A sorus is a cluster of spore-producing structures called sporangia (singular sporangium).

(ii) Their leaves are arranged in a clump and are called fronds.

(iii) They have a simple vascular tissue.

The structure of ferns

A fern is a plant with true roots, stems, and leaves. Leaves develop from an underground stem (rhizome) as shown in Figure 1.8. A rhizome is a very short vertical stem at or near the soil surface. Each fern leaf is called a frond. A fern plant may have many fronds that are arranged in a conspicuously clumped manner. In some species, fronds may spread out along an underground stem. In fern trees, the aerial part consists of stems and leaves. The structure of fern fronds ranges from simple (undivided blade) to compound (blade is divided into leaflets known as pinnae).

Figure 1.8: Fern plant

Ferns differ from bryophytes in that they have a vascular system for transportation of water and nutrients. They bear neither seeds nor flowers. Leaves of different ferns have different shapes. They start as coiled structures called croziers. The fronds have spore producing capsules on the underside called sori (singular sorus). Sori are developed into various shapes and patterns. Thus, ferns reproduce by spores.

Activity 1.6: Investigating the structure of a fern plant

Materials: Fern plants, petri dish, and hand lens

Procedure

1. Use a hand lens to examine different types of ferns.
2. Draw them to show their external features.
3. Observe the underside of one of the fronds and draw the structure you have observed.

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Advantages of ferns

Ferns like other plants, have many advantages as follows:

(i) they constitute ground-cover in moist areas;

(ii) they are primary producers, thus produce food for themselves and for heterotrophic organisms in an ecosystem;

(iii) they are used for decoration in homes and offices;

(iv) they are the major components of coal, a fossil fuel which is made up of the remains of primitive plants; and

(v) ferns such as *Azolla* sp. are used as biological organic fertiliser. They are able to fix nitrogen from the air into compounds that can be absorbed by plants.

Disadvantage of ferns

They are regarded as weeds in many places. For example the giant fern plants are the worst aquatic weeds that threaten the life of other aquatic organisms. In terrestrial environment, some species of fern plants such as *Pteridium* sp. are common weeds.

Exercise 1.2

1. Mention the dominant generation in bryophytes and pteridophytes.
2. Name the divisions to which a moss and a fern plant belong.
3. List four characteristics of each division in which a moss and a fern plant belong.
4. Draw well-labelled diagrams of:
   (a) moss plant; and
   (b) fern plant.
5. What are the two generations that occur in bryophytes and pteridophytes.
6. Explain the characteristics of members of the kingdom Plantae.
7. Explain the advantages of:
   (a) mosses; and
   (b) ferns.

Chapter summary

1. General characteristics of fungi:
   (a) they are found in damp or wet places;
   (b) they have eukaryotic cells with a chitin cell wall;
   (c) they are made up of hyphae;
   (d) they are heterotrophic;
   (e) they store carbohydrates in the form of glycogen; and
   (f) they reproduce through spores.

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2. The main phyla of kingdom Fungi are:
   (a) phylum Ascomycota, for example baker's yeast;
   (b) phylum Zygomycota, for example black bread mould and mucor; and
   (c) phylum Basidiomycota, for example mushrooms, and toadstools.

3. General characteristics of members of the kingdom Plantae:
   (a) they are multicellular;
   (b) they are eukaryotes with cellulose cell walls;
   (c) they store carbohydrates in the form of starch; and
   (d) their cells are organised into tissues, organs, and organ systems.

4. The main divisions of kingdom Plantae are:
   (a) division Bryophyta, for example mosses;
   (b) division Filicinophyta or Pteridophyta, for example ferns;
   (c) division Coniferophyta, for example conifers; and
   (d) division Angiospermophyta, for example flowering plants.

Revision exercise 1

Section A

Choose the correct answer.

1. The following are diseases caused by fungi in plants and animals except _____.
   (a) wheat rust and maize rust
   (b) candidiasis
   (c) influenza
   (d) powdery mildew

2. Reason for Ascomycota to be called ascomycetes or sac fungi.
   (a) The spores can be transferred by wind
   (b) The spores can be produced sexually
   (c) Their spores are enclosed in sac-like structures called asci
   (d) They are single-celled organisms

3. The name of asexual spores in zygomycetes.
   (a) Zygospores
   (b) Sporangiosphores
   (c) Sporangia
   (d) Hyphae

4. Why are bryophytes the most primitive plants on earth?
   (a) They grow on wet areas
   (b) They do not produce seeds
   (c) They reproduce asexually and sexually
   (d) They lack vascular tissues

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5. Which is the advantage of bryophytes?
   (a) They cause fungal diseases in human beings
   (b) They help to retain water in the soil
   (c) They are used to brew alcohol
   (d) They are good sources of food substances

6. The following are divisions of the kingdom Plantae except_____.
   (a) Basidiomycota
   (b) Coniferophyta
   (c) Pteridophyta
   (d) Angiospermophyta.

7. The bread mould is an example of _____.
   (a) Pteridophyta
   (b) Bryophyta
   (c) Zygomycota
   (d) Basidiomycota

8. Match each item in **Column A** against its corresponding item from **Column B**.

Column A	Column B
(i) Sac-like structures which produce ascospores	(a) *Rhizopus*
(ii) An example of Zygomycota	(b) *Penicillium*
(iii) Groups of sporangia in a fern plant	(c) Asci
(iv) Female reproductive structures of a moss plant	(d) Pinnae
(v) Poisonous substance produced by fungi	(e) Aflatoxins
(vi) Leaflets of a fern plant	(f) Frond
(vii) Male reproductive structures of a moss plant	(g) Antheridia
	(h) Archegonia
	(i) Sori
	(j) Stipe
	(k) Hyphae
	(l) Stolon

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9. Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.
   (a) Yeasts can ferment sugar to form alcohol.
   (b) Fungi reproduce by means of spores and budding only.
   (c) In pteridophytes, the shape of the leaf, size, and texture are the same from one species to another.
   (d) A fern plant lacks true roots but have true stems and leaves.
   (e) Yeast reproduces asexually by budding.
   (f) Mushroom consists of gills.
   (g) Rhizoids are found in moulds, liverworts, and mosses.

Section B

10. Name the division of the kingdom Plantae in which the gametophyte is a dominant plant body?
11. What is meant by the term sporophyte?
12. Mention three examples of the members of the division Filicinophyta.
13. What are the advantages and disadvantages of the members of division Filicinophyta?
14. Draw and label a diagram of one of the members of the division Filicinophyta.
15. Name the chemical substance present in fungal cell walls that is a distinctive feature of the kingdom Fungi.
16. State three distinctive features of the kingdom Plantae.
17. A bread was put in a wet cupboard. After a few days black thread-like structures which ended up in club-like shape appeared on the bread.
    (a) Write the common name of the organism that grew on the bread surface.
    (b) Name the kingdom in which the observed organism belongs.
    (c) Name the phylum or division in which the observed organism belongs.
    (d) Outline the advantages of the members of the kingdom you mentioned in (b) above.

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Chapter Two

Nutrition

Introduction

Living things require food substances that are necessary for sustaining their lives. Such food substances perform different functions in the body. Some types of food provide energy to carry out various body activities such as movement, growth, and development. Other types of food serve as raw materials used in building, repairing, and keeping the body in a healthy condition. In this chapter, you will learn about the meaning and types of nutrition, as well as the importance of nutrition. The competencies developed from this chapter will enable you to differentiate heterotrophs from autotrophs based on their feeding modes. You will also be able to maintain healthy and general well-being of the body.

Meaning and types of nutrition

Nutrition is the process of feeding and utilisation of food for energy provision, growth, development, repair and maintenance of the overall body health.

Nutrition also refers to the study of the relationship between diet, health, and diseases. There are two major types of nutrition based on how organisms obtain their food. These are autotrophic and heterotrophic nutrition.

Autotrophic nutrition

Autotrophic nutrition is a type of nutrition whereby organisms manufacture their own food using energy sources available to them. An organism that manufactures its own food is called an autotroph. The term 'autotroph' comes from two Greek words 'autos' which means 'self' and 'trophy' which means 'feed'; hence 'autotrophy' means 'self-feeding'. This means that autotrophs are organisms that are capable of making their own food for their own use and for other organisms. They are very important because without them, no other organisms could exist or survive. Examples of autotrophic organisms include green plants, algae, and some bacteria such as cyanobacteria.

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The autotrophs can be divided into two groups based on how they obtain their energy. These are photoautotrophs and chemoautotrophs. Photoautotrophs are organisms that obtain their energy from sunlight in order to make their own food. They make their food using water and carbon dioxide in the presence of chlorophyll and sunlight through a process called photosynthesis. This is called photoautotrophic nutrition. Photoautotrophic nutrition is a type of nutrition in which organisms use light energy to make their own food. Examples of photoautotrophs include all green plants and some bacteria (cyanobacteria), euglena, and algae that carry out photosynthesis. These organisms produce food in the form of carbohydrates for themselves, which can also be used by heterotrophs like human beings.

Chemoautotrophs are organisms that obtain their energy from chemical substances like hydrogen sulphide, iron, methane, and ammonia. They use such chemicals to make their own food in the form of carbohydrates through a process called chemosynthesis. This is called chemoautotrophic nutrition. This is the type of nutrition in which organisms use chemical substances to make their own food. Examples of chemoautotrophs are some bacteria (archaebacteria) that live in harsh environments such as in the deep sea and around volcanic sites where there is no sunlight and where many other organisms cannot survive.

Heterotrophic nutrition

Heterotrophs are organisms that cannot make their own food and hence, are incapable of self-feeding. The term 'hetero' means different, and 'trophy' means feeding. Therefore, 'heterotroph' means 'different feeding'. Heterotrophs feed on either different food substances manufactured by other organisms or feed on other organisms directly. Examples of heterotrophs include all animals, fungi, most bacteria, and protoctists. The mode of feeding in which an organism is unable to make its own food, and instead depends on food already made by other organisms is called heterotrophic nutrition. There are various types of heterotrophic nutrition including holozoic, saprophytic, and symbiotic nutrition.

Holozoic nutrition

This mode of nutrition involves taking in complex food substances, digesting, absorbing, and assimilating the nutrients into the organisms' body. The undigested and indigestible food remains are finally

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egested as faeces. This type of nutrition is found in most animals. Holozoic nutrition is divided into three modes of feeding: carnivorous, herbivorous and omnivorous.

Carnivorous: This is a mode of feeding in which an animal feeds on other animals. Examples of animals that practise this type of feeding are driver ants, ground beetles, lions, tigers, and leopards. These animals are called carnivores because they eat other animals, usually of different species. In this kind of feeding relationship, animals that hunt other animals are called predators, while those that are hunted are called preys.

Herbivorous: In this mode of feeding, an organism feeds on plants. Animals that undergo this type of feeding are called herbivores because they eat plants or parts of plants. Examples of plant eaters or herbivores include grasshoppers, cattle, rabbits, goats, antelopes, and giraffes.

Omnivorous: This is a mode of feeding in which an organism feeds on both plant and animal food sources. They also feed on other organisms including fungi and algae. They are also known as opportunistic feeders because they feed on a variety of food sources. Examples of omnivorous animals include human beings, bears, chimpanzees, birds, pigs, turtles, lizards, and certain insects such as crickets, ants, and wasps.

Saprophytic nutrition

This is a mode of feeding in which an organism feeds on decaying organic matter. Such decaying matter may originate from plants, animals, and other decomposing materials. Organisms that obtain their food from dead and decaying organic matter are called saprophytes. In this mode of feeding, a saprophyte releases digestive enzymes externally on the substrate. The released enzymes convert complex organic molecules such as starch into simple molecules such as glucose. The glucose can be easily absorbed by body cells and used for various activities. Digestion which takes place by release of enzymes outside the cell is also called extracellular digestion. An example of a saprophyte is a mushroom growing on a log. The mushroom releases enzymes externally through their root-like structures called rhizoids. The enzymes cause decomposition and decay of the log from which the mushroom gets its nutrients. Another example of a saprophyte is bread mould that grows on the surface of decaying bread to obtain the nutrients, as shown in Figure 2.1.

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Figure 2.1: Bread mould grown on decaying bread

Symbiotic nutrition

This is a feeding relationship between two species in which one or both benefit from the relationship. Symbiosis can be in the form of commensalism, mutualism, or parasitism.

Commensalism: This is a feeding relationship between individuals of two different species in which one species benefits while the other is neither harmed nor benefiting. In most cases, the host individual is large in size compared to the commensal individual. The commensals benefit in various ways such as getting nutrients, shelter, support, or transport from the host. For example, small fishes like remora attach to the body of a large fish such as a shark. The shark enables remora to move in different areas without using its own energy but the shark is unaffected and it does not benefit from such a relationship. Other examples are epiphytes which are small plants that grow on different trees but do not harm the trees (See Figure 2.2). The epiphytes get access to nutrients, exposure to sunlight, and support from the trees while the trees are neither harmed nor benefit from the relationship.

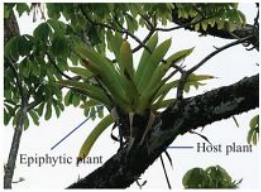

Figure 2.2: Host and epiphytic plants exhibiting commensalism

Mutualism: This is a symbiotic relationship between two species in which both species benefit. For example, bacteria living in the gut of a goat, sheep, or cow get their nutrients from the food digested by the animals. The bacteria in turn help the animals to digest cellulose as the animals cannot produce the enzymes used to digest cellulose.

Parasitism: This is a kind of feeding relationship between two species where one species benefits while the other is harmed. For example, the relationship between a tapeworm and a human being. The tapeworm lives in the human gut and gets nutrients from the human body while the human being is harmed by getting sick. The organism

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that benefits is called a parasite while the one that is harmed is called a host. In the human-tapeworm relationship, the human being is a host and the tapeworm is a parasite.

In parasitic mode of nutrition, the parasites depend on nutrients that are found in the body of their hosts. There are two types of parasites, namely ecto-parasites, and endo-parasites. Ectoparasites live outside the body of the host. Examples of ectoparasites include ticks, lice, fleas, and bed bugs. Endo-parasites live and obtain their food inside the body of the host. *Plasmodium*, *Ascaris,* and tapeworms are examples of endoparasites.

Exercise 2.1

1. Explain the meaning of nutrition.
2. Differentiate between autotrophic and heterotrophic modes of nutrition.
3. Outline the major types of autotrophic nutrition.
4. Briefly explain the following types of heterotrophic nutrition:
   (a) holozoic nutrition;
   (b) saprophytic nutrition; and
   (c) symbiotic nutrition.
5. Why are omnivores regarded as opportunistic feeders?
6. What is the role of enzymes in a saprophytic mode of feeding?
7. Why are large trees in the forest not harmed by the epiphytes that grow on their bodies?

The importance of nutrition

Nutrition is important in various ways. It encompasses the study of the relationship between diet, health, and diseases. People who study nutrition are called nutritionists or dieticians. They are professionals who advise people on how nutrition affects their health and well-being. Through nutrition, an organism can get necessary nutrients needed by the body to produce energy and support functioning of various life processes. Such life processes include growth and development of cells, tissues and organs, repair of damaged parts, and movement. Other processes are protection against infections and diseases, maintaining body temperature, and reproduction. Through nutrition the body can also synthesise important chemical substances such as enzymes and hormones.

Moreover, maintaining good nutrition helps to promote general body health so as to reduce the risk of getting chronic diseases such as heart attack, diabetes, stroke, blood pressure, osteoporosis, and certain types of cancer.

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Chapter summary

1. Living things need food to sustain their lives.
2. The process of feeding and utilising food for growth, development, repair, and maintenance of health is called nutrition.
3. There are two major types of nutrition, which are autotrophic, and heterotrophic nutrition.
4. Autotrophic organisms are capable of making their own food (self-feeding) without feeding on other organisms. Examples of autotrophic organisms are green plants, algae, *Euglena*, and cyanobacteria.
5. Heterotrophic organisms are incapable of making their own food, hence they feed on different kinds of food made by other organisms. Examples of heterotrophs include all animals, fungi, some bacteria, and protoctists.
6. There are various types of heterotrophic nutrition including holozoic, saprophytic, and symbiotic nutrition or symbiosis. Symbiosis can be in the form of commensalism (a kind of relationship where one organism benefits while the other is neither benefiting nor affected by the relationship); mutualism (a kind of relationship where each of the two organisms of different species benefits from one another); and parasitism (a kind of relationship where one of the two organisms benefits while the other is harmed).
7. Nutrition is important in various ways as it encompasses the study of the relationship between diet, health, and diseases. People who study nutrition are called nutritionists or dieticians. They are professionals who advise people on how nutrition affects their health and well-being.

   Through nutrition, an organism can get necessary nutrients needed by the body to produce energy, and support functioning of various life processes. Such life processes include growth and development of cells, tissues, and organs. Others are movement, reproduction, maintaining body temperature, repair of body parts as well as protection of the body against infections and diseases. Through nutrition, the body can also synthesise vital chemical substances such as enzymes and hormones. Moreover, maintaining good nutrition helps to promote general body health so as to reduce the risks of chronic diseases such as heart attack, diabetes, stroke, blood pressure, osteoporosis, and certain types of cancer.

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Revision exercise 2

Section A

1. Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.
   (a) Organisms that manufacture their own food are called chemoautotrophs.
   (b) Photoautotrophs are capable of manufacturing their own food using chemical energy.
   (c) Photoautotrophic organisms are capable of making their own food through chemosynthesis.
   (d) In carnivorous mode of feeding, an animal feeds only on herbivores.
   (e) An expert who studies nutrition is called a biologist.

Section B

2. Explain the meaning of heterotrophic nutrition.
3. Explain the meaning of the following:
   (a) commensalism;
   (b) parasitism; and
   (c) mutualism.
4. Differentiate feeding from nutrition.
5. What would happen to the heterotrophs if there were no autotrophs?
6. Briefly explain the importance of nutrition to living organisms.
7. Differentiate between:
   (a) chemotrophic and phototrophic nutrition;
   (b) saprophytic and holozoic nutrition;
   (c) herbivores and carnivores; and
   (d) omnivores and carnivores.
8. Explain why it is important to learn about nutrition.
9. Briefly explain the parasitic mode of nutrition.
10. Why are human beings, cats, and dogs regarded as omnivorous animals?

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Chapter Three

Nutrition in animals

Introduction

Animals get their food from plants or other animals. They exhibit a heterotrophic mode of nutrition. Animals need nutrients in order to get energy and grow. Those nutrients are obtained by consuming food. Proper nutrition helps animals to grow, develop, reproduce, and develop immunity to fight off infections. Nutrition in animals is the process by which animals utilise food for growth, development, reproduction, and repair of worn out tissues. In this chapter, you will learn about human nutrition, types of food nutrients, and their functions in the human body. You will also learn about balanced diet, nutritional requirements for different groups of people, nutritional deficiencies, and disorders in human beings. The competencies developed from this chapter will help you to maintain good eating habits so as to enhance general body health and well-being. This tendency will enable you to avoid the risks of getting nutritional diseases and disorders, as well as other nutritional problems.

Human nutrition

Human nutrition refers to the science of food and its relationship to the health and well-being of human beings. It also includes how nutrients are harnessed and utilised for various life processes.

Nutrients

Nutrients are chemical components of foods, which are essential to life and health. They are important for promoting growth and development, as well as regulating chemical processes in the body. Nutrients are obtained from various foods such as cassava, meat, and bananas.

There are five major types of nutrients which are carbohydrates, proteins, lipids (fats and oil), vitamins, and minerals. Water and roughage are also important.

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Nutrients can be divided into two categories depending on the quantity needed by the body. These groups are macronutrients and micronutrients. Macronutrients refer to nutrients that are needed by the body in large amounts. They include proteins, carbohydrates, and lipids. These nutrients contain calories which can be burned in the body to produce energy needed for various body functions. A calorie is a unit of measurement of food energy. Micronutrients are nutrients needed by the body in small amounts, but are very important for carrying out body functions. They usually assist in many aspects of body functions such as producing energy, digesting food substances, and making macromolecules. Examples of micronutrients are vitamins and minerals. Unlike macronutrients, micronutrients do not contain calories.

Activity 3.1: Classifying food items according to the nutrients they provide

Materials: A variety of food items

Procedure

1. Collect a variety of food items such as eggs, maize, beans, carrots, potatoes, and tomatoes.
2. In your discussion group, group such food items into different categories based on the type of nutrients they contain.
3. Discuss your findings with your teacher.

Question

How many food items were you able to classify?

Proteins

Proteins are organic compounds made of amino acids. There are two groups of amino acids: essential amino acids and non-essential amino acids. The essential amino acids are obtained from foods eaten, while non-essential amino acids can be made by the body. However, the body is not able to produce essential amino acids. Foods like beef, chicken, fish, termites, eggs, beans, lentils, peas, groundnuts, mushrooms, and milk and its products like cheese and butter are rich in proteins. Figure 3.1 shows examples of foods that are sources of proteins.

Figure 3.1: Sources of protein

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Functions of proteins

Proteins have several functions in the human body including building body cells, promoting growth, and making protoplasm. Proteins also help to repair damaged tissues such as replacement of damaged or lost cells in wounds, skin, and mucus membranes. Since proteins are major components of all cell membranes, they play a role in the transport of other molecules across the cell membranes. They form part of the cell structure, and aid in the contraction of muscles. They are sometimes used as a source of energy, especially when the body lacks carbohydrates and lipids. Each gram of protein provides four calories of energy. However, proteins are not the major source of energy in the body. Their primary function is to promote growth and repair of worn out body tissues. Proteins are very important for growing children, pregnant women, and people recovering from illness.

When proteins are consumed, they are broken down into amino acids that are absorbed into the blood stream and used by the body to produce its own proteins. For example, haemoglobin found in the red blood cells is one of the body proteins. Haemoglobin enables red blood cells to transport oxygen in our bodies. Other examples of body proteins include antibodies which provide immunity to the body, and enzymes that are involved in food digestion. In addition, hormones are protein in nature. They control and regulate various processes in the body.

Lipids

They are compounds made of carbon, hydrogen, and oxygen. They are insoluble in water. The main forms of dietary lipids are fats and oils. Fats are solid at room temperature while oils are liquid at room temperature. Lipids are made up of fatty acids and glycerol. Fatty acids can be essential or non-essential. Essential fatty acids are obtained from foods eaten while non-essential fatty acids can be made by the body. The body is not able to produce essential fatty acids. It is therefore important to eat foods that contain essential fatty acids. Examples of such foods are oily fish, nuts, avocados, oil, and seeds such as sunflower and sesame, as shown in Figure 3.2.

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Figure 3.2: Sources of lipids

Functions of lipids

(i) Lipids are a source of energy. They provide more energy than all other food substances. Each gram of lipid provides nine calories of energy.

(ii) They are important components of cell membranes.

(iii) Fat deposits surround and protect body organs such as the heart and kidneys.

(iv) Stores of fat in the adipose tissue under the skin help to regulate body temperature by insulating the body against loss of heat.

(v) Fat-soluble vitamins are also stored in fatty tissues.

(vi) Essential fatty acids are important for the formation of substances that help to control blood pressure and activate the body's immune response.

Carbohydrates

They are mainly made up of carbon, hydrogen, and oxygen. Sources of carbohydrates include maize, rice, bananas, potatoes, cassava, wheat, and yams, as shown in Figure 3.3.

Figure 3.3: Sources of carbohydrates

Functions of carbohydrates

Carbohydrates are a major source of energy in the body. In an ideal situation, we should get two-thirds of our energy from carbohydrates. They are broken down into glucose which acts as fuel for the body. Each gram of carbohydrate produces four calories of energy in the body to be used by the cells to perform work. Carbohydrates are also essential for proper functioning of the nervous system, heart, and kidneys. In addition, carbohydrates form genetic materials, which are DNA (Deoxyribonucleic Acid) and RNA (Ribonucleic Acid) in the cells.

Excess carbohydrates in the body are converted into either glycogen or fats in the liver. The glycogen is stored in the liver and muscles, while fats are

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stored as fat deposits in the lower abdomen, around kidneys, and under the skin. Glycogen acts as a source of energy when there is short supply of carbohydrates in the body. In the muscles and liver, glycogen is broken down to glucose for provision of energy when required, for example, during a vigorous physical activity. Also, carbohydrates combine with proteins and lipids to form glycoproteins and glycolipids respectively, which are important components of cell membranes.

Vitamins

Vitamins are complex organic micronutrients that are essential for body growth and survival. Animals need vitamins for proper body functioning and metabolism. Vitamins can be grouped into two categories which are water-soluble and fat-soluble vitamins.

Fat-soluble vitamins can be stored in the body. Vitamins A, D, E and K are examples of fat-soluble vitamins.

Water-soluble vitamins are not stored in the body. Vitamins B and C are water-soluble. Vitamin B is of various forms namely, vitamin B_1, B_2, B_3, B_6 , B_9 and B_{12}. These can be easily destroyed by heat.

Vitamins are formed by the combination of glucose and some mineral elements. Most of the vitamins are synthesised by autotrophs particulary green plants. Mammals can synthesise vitamins A and D using plant molecules obtained in their food.

Vitamins play an important role in the metabolic activities of both plants and animals. Examples of foods containing vitamins include fruits and vegetables, as shown in Figure 3.4.

Figure 3.4: Sources of vitamins

Vitamins play important roles in the body such as promoting functions of immune and nervous systems. They are also important in the formation of bone tissue and red blood cells. Deficiency and excess intake of vitamins can cause health problems. Table 3.1 shows examples of vitamins, their sources, functions, and deficiency symptoms.

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Table 3.1: Sources, functions, and deficiency symptoms of vitamins

Vitamin	Sources	Functions	Deficiency symptoms
Vitamin A (Retinol)	Liver, milk, eggs, oranges, and yellow vegetables	Formation of membranes of the eyes, and the respiratory tract	(i) Night blindness (ii) Increased risk of infections
Vitamin B_1 (Thiamine)	Lean meat, liver, eggs, mushroom, brown rice, and whole grain cereals	(i) Assists in carbohydrate metabolism (ii) Helps in muscle coordination	Beriberi, a disease characterised by loss of appetite, muscle cramps, nerve disorder, and heart failure
Vitamin B_2 (Riboflavin)	Liver, meat, mushroom, and whole grain cereals	Metabolism of all foods, and the release of energy to cells	(i) Cracks and sores around the mouth and nose (ii) Visual problems
Vitamin B_3 (Niacin)	Nuts, fish, meat, mushroom, brown rice, and whole grain cereals	Needed by many enzymes that convert food to energy	Pellagra, a disease characterised by skin lesions, loss of appetite, diarrhoea, and muscle weakness
Vitamin B_6 (Pyridoxine)	Meat, vegetables, mushroom, and whole grain cereals	Protein metabolism	(i) Nerve irritability (ii) Sores in the mouth and eyes (iii) Anaemia
Vitamin B_9 (Folic acid)	Liver, fish, green leafy vegetables, legumes, and folate fortified foods	(i) Synthesis of new cells (ii) Metabolism of carbohydrates	(i) Birth defects (ii) Anaemia (iii) Frequent infections
Vitamin B_{12} (Cyanocobal-amin)	Fish, meat, eggs, milk, and liver	(i) Helps in making genetic material (ii) Helps to form red blood cells	(i) Anaemia (ii) Nerve damage (iii) Weight loss

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Vitamin	Sources	Functions	Deficiency symptoms
Vitamin C (Ascorbic acid)	Tomatoes, fresh green vegetables, and citrus fruits such as oranges and lemons	(i) Antioxidant (ii) Improves absorption of iron (iii) Used in synthesis of collagen in the bones and gums	(i) Muscle weakness (ii) Easy bruising (iii) Joint pains (iv) Scurvy (bleeding gums) (v) Poor healing of wounds (vi) Frequent infections
Vitamin D (Calciferol)	Egg yolk, milk, oily fish, sunlight, and liver	Helps to build and maintain teeth and bones	(i) Rickets in children (ii) Osteoporosis (soft bones) in adults
Vitamin E (Tocopherol)	Corn or sunflower oil, butter, brown rice, and peanuts	(i) Antioxidant (ii) Prevents damage of cell membranes	(i) Nerve abnormalities (ii) Infertility
Vitamin K	Green vegetables, and liver	Needed for normal blood clotting	Defective blood coagulation resulting in excessive bleeding in case of injury

Minerals

There are different types of minerals needed for different activities in the body. These minerals are called essential minerals. Examples of essential minerals needed by the body include sodium, chlorine, potassium, calcium, phosphorus, magnesium, sulphur, zinc, iodine, copper, manganese and fluoride. Most minerals are important for enzyme activities. Other minerals are essential for maintaining balance of body fluids, development of bone tissue, synthesis of hormones, activation of enzymes, transmission of nerve impulses, as well as contraction and relaxation of muscles. Table 3.2 shows examples of minerals, their sources, functions, and deficiency symptoms in the body.

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Table 3.2: Examples of minerals, their sources, functions and deficiency symptoms

Mineral	Sources	Functions	Deficiency symptoms
Calcium	Milk, yoghurt, cheese, sardines, eggs, and green vegetables	(i) Helps build strong bones and teeth (ii) Promotes nerve transmission (iii) Helps in muscle contraction (iv) Important in clotting of blood	(i) Weak bones and bleeding easily (ii) Impaired nerve activity
Phosphorus	Meat, milk, fish, eggs, and nuts	(i) Builds bones and teeth (ii) Helps maintain acid –base balance (iii) Aids formation of genetic materials	Poor bone and teeth formation
Potassium	Peanuts, bananas, orange juice, meat, and green beans	Helps maintain regular fluid balance needed for nerve and muscle function	(i) Poor muscle contraction (ii) Impaired nerve activity
Sodium	Table salt, soy sauce, milk, bread, vegetables, and processed foods	(i) Necessary for nerve transmission (ii) Needed for muscle contraction (iii) Necessary for protein making (iv) Needed for proper fluid balance	(i) Muscle cramps (ii) Poor nerve transmission

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Mineral	Sources	Functions	Deficiency symptoms
Chloride	Table salt, eggs, milk, meat, seafoods, and whole grain foods	Maintenance of water and ionic balance in the body and formation of hydrochloric acid in the stomach	Poor digestion of proteins
Magnesium	Spinach, pumpkin seeds, sesame seeds, beans, nuts, sea foods, and magnesium	(i) Maintaining a healthy immune system (ii) Making proteins (iii) Contraction of muscles (iv) Transmission of nerve impulses (v) Strengthening of bones	(i) Muscle weakness (ii) Irregular heartbeat (iii) weak bones
Iodine	Sea foods, dairy products, and iodized table salt	Production of thyroid hormone which regulate growth, development, and metabolism	(i) Goitre (enlarged thyroid gland) (ii) Growth retardation (iii) Mental retardation (iv) Still birth
Fluoride	Fish, fluorinated water or water naturally containing fluorine, and most varieties of tea such as green tea	(i) Development of teeth and bones (ii) Helps to prevent tooth decay	(i) Poor development of bones and teeth (ii) Tooth decay
Manganese	Found in most plant foods, kidneys, liver, tea, coffee, nuts, and fruits	(i) Helps in formation of bones (ii) Activation of enzymes (Coenzyme)	(i) Nausea (ii) Dizziness (iii) Loss of hearing (iv) Loss of bone mass

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Mineral	Sources	Functions	Deficiency symptoms
Copper	Whole grains, meat, drinking water, fish, liver, legumes, nuts, and other seeds	(i) Synthesis of bones and haemoglobin (ii) Activation of enzymes (Coenzyme)	(i) Bleeding under the skin (ii) Easy rupturing of blood vessels (iii) Bones and joints problems (iv) Anaemia
Iron	Liver, lean meat, fish, chicken, egg yolk, legumes, kidney, beans, and green vegetables	(i) Essential for making red pigment in blood (haemoglobin) (ii) Essential for energy production	Anaemia
Zinc	Oysters, shrimp, crab, meat, fish, chicken, whole grains, and vegetables	(i) Necessary for a healthy immune system (ii) Controls normal growth and sexual maturation (iii) Activation of enzymes (iv) Helps in wound healing (v) Helps in taste detection (vi) Promotes protein synthesis and DNA production	(i) Impaired taste (ii) Poor immune response (iii) Skin problems

Roughage

This is dietary fibre that is obtained from the indigestible part of plants (See Figure 3.5). Roughage does not have any nutritional value as it is not digested and absorbed in the body. However, it helps in the passage of food and faeces through the gut by aiding contraction and relaxation of the gut muscles (peristalitic movement). It also helps to control body weight, thus protects the body from diseases such as heart diseases. Sources of dietary fibre include cassava, potatoes, beans, fruits, cabbage, spinach, and whole grain cereals.

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Figure 3.5: Sources of roughage

Water

Water is essential in the human body as follows:

(i) it is a major constituent of body fluids such as blood, tears, and saliva;

(ii) it forms a large part of the cell cytoplasm and helps to maintain the shape of cells, tissues, and organs;

(iii) it helps in the process of breaking down food during digestion;

(iv) it lubricates moving parts of the body and prevents friction; and

(v) it helps in the regulation of body temperature. Sweating is one of the means by which water prevents the human body from overheating during hot weather. This is because evaporation of sweat from the surface of the skin helps the body to cool during hot conditions.

It is important to drink enough safe water, and eat safe raw vegetables and fruits, in order to maintain an optimal water content in the body. Lack of adequate amount of water in the body leads to thirst, dehydration and constipation. Losing more than 10% of water in the body can lead to death.

Balanced diet

Eating a balanced diet helps to promote good health. A balanced diet refers to a meal containing foods from all food groups in the right proportions. Proper diet helps an individual to remain healthy. For a young individual, a balanced diet helps him or her to grow and develop normally. It also helps to maintain an ideal body weight. Moreover, it minimises the risk of contracting long-lasting diseases like cancer, diabetes, obesity, high blood pressure and other life threatening diseases.

In order to promote a healthy lifestyle it is important to take in diets containing low fats, sugars and salts but having moderate amounts of food containing proteins, carbohydrates, vitamins, minerals and roughages. It is also important to drink adequate amounts of water and engage in regular physical exercises.

The following should be done in order to ensure a healthy lifestyle:

(i) take recommended amounts of proteins, fats or oils, sugars, and salts;

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(ii) take recommended amounts of fruits and vegetables in the diet;

(iii) eat a variety of foods including whole grains, fruits, vegetables, and food with roughage in order to provide the body with the required energy and nutrients;

(iv) maintain appropriate body weight to height ratio within the limits recommended by the World Health Organisation (WHO);

(v) do physical activities daily for 30 to 40 minutes;

(vi) replace red meat diet with fish, poultry, or lean meat;

(vii) take low fat dairy products and low salt foods;

(viii) limit the frequency of sugary drinks and all sweets; and

(ix) avoid processed and baked foods of all kinds.

Nutritional requirements for different groups of people

The ratio of nutrients needed by the body varies depending on the age, sex, health state, amount of activity, or general state of the body. Therefore, different groups of people such as pregnant women and lactating mothers, children, the elderly, and the sick have different nutritional needs.

Pregnant women and lactating mothers

Pregnant women and lactating mothers need to get enough nutrients in their meals. They should eat a balanced diet because they require enough nutrients for themselves and their growing foetus and babies, respectively. Food rich in protein is needed by pregnant women and lactating mothers to build the muscles, breasts, uterus, blood supply, and for proper functioning of tissues and organs of the foetus and baby.

Pregnant women are advised to eat food rich in folic acid and vitamin B. These help to lower the risk of birth defects such as spina bifida. This is a spinal disorder characterised by a hole in the spine. It results from incomplete formation of the spinal cord and the bones of the spine. Often, the spine protrudes through the hole and sometimes a fluid-filled sac may surround the protruding spinal cord.

Calcium helps in the development of the foetus and baby's bones. If the mother's diet does not contain adequate calcium, it will be derived from her bones for the foetus or the baby. This weakens the mother's bones.

Zinc is important for the proper progression of labour during delivery of the baby. It is also important for proper growth and development of the baby.

The pregnant woman requires iron for her blood supply needs. The foetus also needs to store iron for use during the first few months after birth.

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Pregnant women also require adequate amounts of dietary fibre to reduce the likelihood of constipation that is a common complaint during pregnancy. Their meal should contain adequate vegetables, fruits, and fibre sources. Pregnant women and lactating mothers should also drink plenty of water. Water is a major constituent of breast milk. Some hormones produced during breastfeeding increase thirst. Pregnant women and lactating mothers should avoid alcohol consumption. Alcohol can easily pass from their bodies to the foetus and babies during pregnancy and breastfeeding respectively, and affect their development.

Nutritional needs for a lactating mother increase during breastfeeding in order to satisfy the needs of her body and the baby.

Children

Young children are still growing and they are generally most active. They require diets that provide them with adequate nutrients to ensure proper functioning of their bodies. They need enough proteins for growth and development of the body tissues. Inadequate supply of proteins can lead to stunted growth. Minerals like calcium are necessary for the formation of strong bones and teeth. Zinc is important for body growth. It plays an important role in biological processes including cell growth, differentiation, and metabolism. Deficiency in zinc limits childhood growth and decreases resistance to infections. Vitamin B_{12} is required for the formation of red blood cells, since a growing body needs more oxygen and more blood. Vitamin B_{12} is essential for brain development as well as nervous and cognitive functions. Inadequate vitamin B_{12} during pregnancy and early childhood causes improper cognitive development for children. Vitamin C helps children to build their immunity and also functions as an antioxidant. An antioxidant is a substance that removes toxins from the body. Children also require enough carbohydrates and lipids because they are active.

The elderly

Elderly people require a balanced diet with adequate amounts of food rich in vitamins, minerals, and roughage to maintain their health. They also need food rich in minerals such as iron, zinc, and calcium. Iron is necessary because it helps to make red blood cells which carry oxygen around the body. Zinc is required for a healthy immune system and for regulating the healing of wounds. Old age comes with the loss of calcium from bones, leading to soft and weak bones that can break easily. Old people therefore require adequate

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amounts of calcium to strengthen their bones. They also need vitamin D to improve their mental health and overcome depression.

The elderly often have problems of chewing tough foods because of weakened teeth. Likewise, due to decreased production of saliva, they normally have swallowing problems. It is therefore important to ensure the elderly get foods that are nutritious and easy to chew and swallow. For example, they can get proteins from eggs or liver instead of meat.

Sedentary workers

These are individuals who stay in one place for a long time while performing their daily occupational activities. They include secretaries, tailors, clerks, and receptionists. Sedentary workers are encouraged to balance their daily diet with physical exercise. Due to their lifestyle and occupation, obesity is increasingly becoming common among them. They are also in a greater risk of developing non-communicable diseases such as diabetes as well as disorders of the muscles and skeleton. Therefore, it is recommended that they limit their intake of foods rich in carbohydrates and lipids.

The sick

Sick people require plenty of nutrients to help recover their health. Proper nutrition helps to keep their immune system strong and enables the body to fight against infections and diseases. It also helps the body to withstand strong medication. In addition, proper diet and exercise help to combat symptoms such as fatigue, nausea, diarrhoea, and high blood sugar. Excess caffeine products, sugary foods, fried foods, spicy foods, and alcohol should be avoided because they are harmful to a body whose immune system is already weak. Sick people are supposed to increase the intake of fruits, vegetables, and water. Fruits provide vitamins that are required to fight diseases. Vegetables provide essential minerals for proper functioning of many body systems. Water replaces the amount of water lost during sickness for example through diarrhoea or vomiting.

It is advisable to use the food guide pyramid in determining what to eat. The food guide pyramid is a chart showing the recommended amounts of variety of foods that dieticians consider as healthy eating. Figure 3.6 shows an example of a food guide pyramid. It is not a fixed rule of what to eat each day, but just a general guide that helps to choose the right healthy diet. It helps an individual to eat better every day. The base constitutes foods that are required in larger amounts while the apex constitutes foods that need to be

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taken in lesser amounts. The food guide pyramid is not universal for all groups of people, it depends on the needs and health status of a person. For example, a diabetic person should not consume a lot of carbohydrates as indicated in the pyramid. Similarly, the elderly require small amounts of carbohydrates, but more proteins and vitamins.

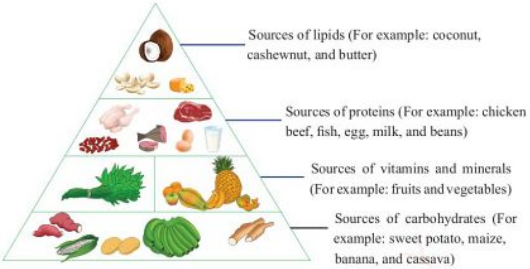

Figure 3.6: Food guide pyramid

Activity 3.2: Planning a balanced diet

Materials:

Various foods and charts showing different types of food

Procedure

1. In your class, divide yourselves into groups of five students.
2. Each group should plan a menu consisting of balanced meals for a day considering each of the following special groups of people: pregnant women and lactating mothers, children, the elderly, sedentary workers, and sick people.
3. In your menu, state what you would serve each special group for breakfast, lunch and dinner.
4. Present your menu and discuss it with the rest of the class.

Nutritional deficiencies and disorders

There are different types of nutritional deficiencies and disorders in human beings, which are generally called malnutrition. Malnutrition refers to lack of proper nutrition caused by imbalance of nutrients in the body. It is a result of not having enough nutrients or excess consumption of certain food nutrients.

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Nutritional deficiencies

These deficiencies arise when the body does not have sufficient supply of a particular food nutrient. Examples of common nutritional deficiencies in humans include marasmus (acute malnutrition), kwashiorkor (acute malnutrition with oedema), and rickets.

Marasmus

Marasmus is a form of malnutrition in children caused by lack of adequate amounts of food nutrients (starvation).

Symptoms of marasmus: A child suffering from marasmus shows weight loss, slowed growth, decreased activity and lack of energy. He or she also has wrinkled skin, extreme hunger and cries often.

Prevention of marasmus: Marasmus is prevented by giving a child adequate amounts of food that contains all the nutrients in the right proportions.

Kwashiorkor

Kwashiorkor is caused by a deficiency of proteins. It affects children, mostly after stopping to breast-feed or during weaning.

Symptoms of kwashiorkor: The symptoms of kwashiorkor include extremely thin arms and legs, poor growth, swollen abdomen due to enlargement of the liver, and reddish or yellowish thin and weak hair. Other symptoms are weakened immunity, diarrhoea, anaemia, dry skin that cracks easily, oedema due to accumulation of excess fluid in the body, and short temper.

Prevention of kwashiorkor: Kwashiorkor can be prevented by providing a child with a diet that has adequate amounts of protein and other food nutrients.

Rickets

Rickets is a condition whereby the bones of a child soften, leading to fractures and deformity. The cause of rickets is lack of vitamin D, phosphorus and calcium.

Symptoms of rickets: A child suffering from rickets can be identified by observable skeletal deformities such as bow legs, knock knees, an odd-shaped skull, and a deformed spine. The child feels bone pain, experiences dental problems such as weak teeth or delayed formation of teeth, and develops weak muscles. The child's bones can easily be fractured and shows slow growth. The child also gets muscle spasms and muscle cramps.

Prevention of rickets: Rickets can be prevented by increasing the amount of vitamin D, phosphorus and calcium in the diet. The condition can also be prevented by ensuring exposure to sufficient amounts of sunlight, and providing the child with enough milk, sardines, and green vegetables.

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Nutritional disorders

Nutritional disorders are conditions that occur when a person's dietary intake does not contain the right amount of nutrients for healthy functioning of the body. They are caused by the imbalance of nutrients in the body due to not having enough nutrients or excess consumption of food. The common nutritional disorders include obesity, anorexia nervosa, and bulimia nervosa.

Obesity

Obesity is a nutritional disorder characterised by excess body fat leading to overweight. It mostly results from eating large quantities of high energy foods (carbohydrates and fats) and not exercising enough to sufficiently burn the excess calories produced in the body. A person's sex, age and level of activity are among other factors that determine his or her ideal body fat. To maintain fertility, women need more body fat than men. Women also store more fat in their breasts, hips and thighs.

Body weight and health risks associated with it are expressed by the Body Mass Index (BMI). It gives the relationship between the estimated body fat and the risk of certain diseases or conditions. Based on height and weight ratio, people can check their Body Mass Index (BMI). The BMI is calculated by dividing a person's weight in kilograms (kg) by his or her height squared in metres (m). The World Health Organisation (WHO) recommends the normal levels of BMI to be in the range of 18.5-25.4. BMI is calculated using the following formula:

$$\text{BMI} = \frac{\text{Body mass}}{(\text{Person's height})^2}$$

Whereby:

BMI = Body Mass Index in kg/m^2

Body mass = Person's weight in kg

Person's height = Person's height in m

For example, if your height is 1.65 metres and your body mass is 60 kilograms, your BMI can be calculated as:

$$\frac{60}{(1.65)^2} = \frac{60}{2.7225} = 22.04 \ \text{kg}/\text{m}^2$$

If an individual BMI falls in the range of 18.5-25.4, this is considered to be healthy. On the other hand, if the BMI is over 30, one may be at risk of diseases associated with obesity. The following table shows a general guide of how different values of BMI are used to define the condition of the body.

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Table 3.3: The BMI guide for adults with 20 years and above

BMI	Body condition
18.5 and below	Underweight
18.5 to 25.4	Normal weight
25.5 to 29.4	Overweight or pre-obese
29.5 to 34.9	Class 1 obesity
35.0 to 39.9	Class 2 obesity
40 and above	Class 3 obesity (extreme or severe obesity

Sometimes children may suffer from obesity (childhood obesity) when their body weight is very high in relation to their age and height. The child becomes highly obese due to excessive accumulation of fat in the body.

Causes of obesity

The causes of obesity include overeating, inactivity, eating high amounts of energy foods especially fats and sugars, frequent eating, and genetic make up. Some people have genes that affect the way foods are processed in the body.

Effects of obesity

Obesity is accompanied by several health problems including shortness of breath and snoring. It also increases the likelihood of conditions such as high blood pressure, heart disease, stroke, diabetes, certain types of cancer, arthritis, and respiratory problems.

Prevention of obesity

Obesity can be prevented by eating properly and engaging in regular exercise. The intake of calories should balance one's physical activity. It is also important to avoid eating too much fatty foods such as butter, fatty meat, chips, margarine, sausages; and sugary foods such as sweets, cakes and chocolates. Eating too much of these foods contributes to obesity.

Anorexia nervosa and Bulimia nervosa

Anorexia nervosa is also called slimmer's disease or a self-starvation syndrome. It is a nutritional disorder that occurs when a person intentionally refuses to eat enough food, leading to a severe loss of body mass.

The symptoms of Anorexia are:

(i) Muscle wasting (including weakening of heart muscle);

(ii) Excessive loss of body mass;

(iii) Extreme fear of being fat; and

(iv) Distorted body image or feeling fat even when one is very thin.

Bulimia nervosa is a nutritional disorder, which involves excessive eating followed by an attempt to

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remove the food from the body. This attempt could involve self-induced vomiting, fasting, excessive exercising or taking drugs that stimulate emptying of the bowels or excessive urination. Bulimics usually have a normal body mass and keep their eating behaviour secret, hence, it may be difficult to tell that they have a problem.

Causes of Anorexia nervosa and Bulimia nervosa

Both Bulimia and Anorexia have underlying psychological causes, such as depression, low self-esteem on body image, bottled-up emotions and the need to fit contemporary standards of beauty. Bulimia and Anorexia mostly affect women.

Effects of Anorexia nervosa and Bulimia nervosa

The effects of Anorexia and Bulimia are demonstrated by heart problems due to weak cardiac muscles or an imbalance of mineral salts. They contribute to an impaired mental function because the brain lacks adequate amounts of glucose. Victims also exhibit dehydration. During vomiting, the acids present in the stomach come into contact with the teeth and gums. This eventually causes serious damage to the gums and erosion of the teeth. Other effects include anaemia, stomach ulcers, abdominal cramping and inflammation of the gut, irregular or absent menstrual periods and dry skin.

Prevention of Anorexia nervosa and Bulimia nervosa

Anorexia and Bulimia can be prevented by resolving the underlying psychological problems and seeing a medical practitioner who can prescribe a way of getting back one's health. They can also be prevented by adhering to the necessary lifestyle and dietary changes.

Activity 3.3: Investigation of nutritional deficiencies and disorders

Materials:

Notebook, pen and charts showing various nutritional deficiencies and disorders

Procedure

1. Visit a nearby health centre.
2. Ask a health personnel or a dietician about the nutritional deficiencies and disorders that are common in the area.
3. Discuss this with the health personnel and your classmates on the reasons for their prevalence.
4. Discuss how the nutritional deficiencies and disorders can be prevented.
5. Write down the important points in your notebook.

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Properties of food nutrients

Food nutrients have various properties that help to distinguish them. Such properties can be determined using various laboratory reagents and chemicals such as iodine solution, Benedict's solution, Sudan III reagent, copper sulphate, hydrochloric acid, and sodium hydroxide. Experiments conducted to identify properties of food nutrients are known as food tests.

Food tests

Food tests are tests used to determine which nutrients are present in a food substance. At this level, you will learn how to test for carbohydrates, proteins and lipids.

When doing the food test, the following are important things to consider: food to be tested, required materials, procedure, observation, and conclusion. For the report to be simple and easy to understand, a table with four columns is used, and consists of the following headings: Food tested, Procedure, Observation and Inference, as shown in Table 3.4.

Table 3.4: Food testing summary

Food tested	Procedure	Observation	Inference

Food to be tested: Food tested can be reducing sugar, non-reducing sugar, starch, lipids or protein. Most of food substances are mixed with water to make a solution or a mixture before testing. They can also be boiled or heated before testing to make them mix thoroughly with reagents used. The solution or mixture which is made from food substance is kept in a container and is referred to as a stock. A small portion of solution or mixture which is taken from the stock solution for experiment is termed as food sample.

Procedure: This involves the steps to be followed when carrying out the test for a particular food substance. Steps differ when testing for one food type from another. Failure to follow these steps often results into a wrong conclusion. Therefore, in each step, the procedures to be followed should be stated clearly. The amount of food sample which has been taken from the stock solution in a certain procedure should be stated together with its unit of measurement. The apparatus used should also be stated clearly.

Observation: It refers to series of changes that occur when carrying out an experiment. Different changes are experienced as a person attempts one stage after another. These changes can be colour, smell, sound or heat changes. The changes differ from one experiment to another. During observation, it is important to make sure the colour of the reagent is known so as to be clear with the new changes.

Inference: It refers to the conclusion that is made following the observation. The conclusion tells whether the type of food tested is present or absent.

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Test for carbohydrates

There are three types of carbohydrates, which are monosaccharide, disaccharides and polysaccharides.

Monosaccharides

These are also known as simple sugars (single sugar). They include glucose, fructose (fruit sugar) and galactose (milk sugar). These sugars dissolve in water to form sweet solutions. All monosaccharides have the ability to reduce copper in Benedict's solution from copper II (Cu^{2+}) which is blue to copper I (Cu^{+}) which is orange or brick red, hence, they are named as reducing sugars. During the reduction process, the colour of Benedict's solution changes from blue, to green, to yellow, and finally to orange or brick red depending on the concentration of the reducing sugar. If it is high, the colour change can reach to brick red but if it is low it can end up to the intermediate colours that have been mentioned. Some examples of food sources containing reducing sugars are onions and carrots.

The general formula for monosaccharide is $(CH_2O)_n$ where n represents the number of carbon (C) atoms, and has a value of between 3 and 6. For example, the formula for glucose is $C_6H_{12}O_6$.

Activity 3.4: Test for the presence of reducing sugars in an onion

Materials:

Benedict's solution, an onion bulb, a knife, mortar and pestle, measuring cylinder (10 ml), test tubes, test tube holder, heat source, water, filter funnel, dropper, and beakers

Procedure

1. Peel an onion and cut it into small pieces using a knife.
2. Grind the pieces of onion using mortar and pestle, then add water to make a mixture.
3. Decant and filter the mixture into a beaker to remove solid particles so as to get a solution.
4. Put 2 ml of the solution into a test tube.
5. Add 2 ml of Benedict's solution into the test tube.
6. Gently heat the mixture for 2-3 minutes.
7. Record the series of colour change occurring.

Questions

(i) What series of colour change was observed?

(ii) What was the final colour?

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Disaccharides

These are also known as double sugars. They are formed through condensation process when two monosaccharide molecules combine. For example, a glucose molecule and a fructose molecule combine to form sucrose, the sugar found in sugar cane. The general formula for this reaction is:

monosaccharide + monosaccharide → disaccharide + water

For example:

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$

glucose + fructose sucrose + water

Two glucose molecules combine to form maltose. Maltose is found in germinating seeds. A glucose molecule and a galactose molecule also combine to form lactose, a sugar found in milk. Disaccharides dissolve in water and form sweet solutions. Some disaccharides, for example maltose and lactose have the ability to reduce copper (II) ions (Cu^{2+}) to copper (I) ions (Cu^{+}) like monosaccharides. These are also called reducing sugars. Other disaccharides such as sucrose do not have the ability to reduce copper (II) ions to copper (I) ions. These are called non-reducing sugars. Therefore, non-reducing sugars cannot be tested directly by Benedict's solution. Instead, it is first converted to reducing sugar by using hydrochloric acid (HCl) in the process called hydrolysis as shown in the following example:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{HCl} C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose + Water Glucose + Fructose

The acidic mixture is heated and left to cool. It is then neutralised by using sodium hydroxide (NaOH) or sodium bicarbonate ($NaHCO_3$) for the Benedict's solution to work properly. Thereafter, steps for testing reducing sugars is carried out.

Activity 3.5: Test for non-reducing sugars in sugar cane

Materials:

Benedict's solution, hydrochloric acid, sodium hydroxide or sodium bicarbonate, a piece of sugar cane, a knife, mortar and pestle, test tubes, test- tube holder, heat source, water, filter funnel, dropper, measuring cylinder (10 ml), and beakers

Procedure

1. Peel a piece of sugar cane and cut it into small pieces using a knife.
2. Grind the pieces of sugar cane using mortar and pestle and add water to make a mixture.
3. Decant and filter the mixture to obtain a solution.

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4. Pour 2 ml of a sample solution into the test tube.
5. Add 1ml of dilute hydrochloric acid.
6. Gently heat the mixture for 2-3 minutes.
7. Cool the mixture, then add 1ml of sodium bicarbonate solution or sodium hydroxide.
8. Add 2 ml of Benedict's solution to the cooled mixture and heat gently.
9. Record the series of colour change occurring.

Questions

(i) What colour changes did you observe?

(ii) What effect did hydrochloric acid have on sucrose?

(iii) Why was sodium hydroxide or sodium bicarbonate added to the mixture?

Polysaccharides

Polysaccharides are formed by condensation of several monosaccharides. They are commonly used as a storage form of food. Examples of polysaccharides include starch which is a plant storage compound; glycogen which is an animal storage compound; cellulose which is structural material in plant cell walls; and chitin which is a component of the exoskeleton of arthropods and cell walls of fungi.

Starch: This is a carbohydrate made by the condensation of many glucose molecules. Starch occurs naturally in plant cells as small particles called granules. It is found in abundance in plants. Common starch-containing foods include potato, cassava, maize, rice, and wheat.

Properties of starch

Starch and other polysaccharides have the following properties:

(i) they are tasteless, that is, they are not sweet;

(ii) they are insoluble in water. (When put in water they form a suspension);

(iii) they coagulate when boiled in water; and

(iv) when mixed with iodine solution starch changes colour to blue black.

Activity 3.6 (a): Test for the presence of starch in an Irish potato

Materials:

Iodine solution, Irish potato, a knife, mortar and pestle, test tubes, test tube holder, heat source, water, sieve, dropper, and a beaker

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Procedure

1. Peel the Irish potato and cut it into small pieces using a knife.
2. Grind the pieces of potato and add water to make a mixture.
3. Decant and filter the mixture to make a solution.
4. Put 2 ml of the solution into a test tube.
5. Add 2-3 drops of iodine solution.

Question

What is your observation?

Activity 3.6 (b): Investigating the solubility of starch in water

Materials:

Maize or wheat flour, heat source, water, stirring rod, measuring cylinder (10 ml), and a beaker

Procedure

1. Take two full spatula of wheat flour and put it in a 100 ml beaker.
2. Add 50 ml of water and stir the mixture.
3. Leave it to settle for 3-4 minutes.
4. Observe and record the findings.
5. Take the mixture and boil for 3-4 minutes.
6. Observe and record the findings.

Questions

(i) What happened when the unboiled mixture of flour and water was left to settle?

(ii) Was there any difference when the unboiled mixture was allowed to settle and when it was boiled?

Test for lipids

Lipids are organic food substances consisting of carbon, hydrogen and oxygen just like carbohydrates. A lipid is composed of a glycerol molecule and fatty acids joined through condensation. Unlike carbohydrates, lipids have much less oxygen compared to carbon and hydrogen. For example, the formula of beef fat is $C_{57}H_{110}O_6$. Lipids occur naturally in the protoplasm of all living cells and in adipose tissues of animals. An adipose tissue is a fatty tissue under the skin containing large deposits of lipids.

Lipids can be either solid or liquid at room temperature. Some lipids remain in liquid form at 20°C while others solidify at this temperature. The solid lipids are called fats, and the liquid lipids are called oils. Some plant oils dry and harden when exposed to air and light at room temperature. Fats and oils are found in various food stuffs like groundnut, coconut, sunflower, margarine, and butter. Various types of oils are used for cooking.

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Properties of lipids

(i) Fats are insoluble in water.

(ii) When oil is shaken in water, the oil breaks down into droplets which disperse in the water. The water and oil separate into two layers after a while.

(iii) Fats and oils dissolve in organic solvents such as ether, chloroform, acetone, and alcohol.

(iv) When water is added to a fat or oil that has dissolved in an organic solvent, a white milky suspension is formed. This is called an emulsion.

(v) When fat is rubbed against paper, the paper becomes translucent.

(vi) In a mixture of water and oil, oil takes up Sudan III dye to form a red layer or ring on the top, leaving the water clear.

(vii) Oils react with osmic acid and stain black.

Activity 3.7: Test for the presence of lipids in groundnuts by the grease spot test

Materials:
Groundnuts seeds and a piece of white paper

Procedure

1. Peel the groundnuts seeds.
2. Rub the peeled seeds on a piece of paper.
3. Expose the paper to light.
4. Compare the part of the paper rubbed with seeds with the part that was not rubbed.
5. Record what you see.

Questions

(i) Is the area of piece of paper rubbed with seeds similar to the unrubbed section of the paper?

(ii) What did you see after exposing the paper to light?

(iii) What other seeds can you use to perform the grease spot test?

Activity 3.8: Test for the presence of lipids in cooking oil by using Sudan III reagent

Materials:
Sudan III reagent, 5 ml of cooking oil, test tube, measuring cylinder (10 ml), and water

Procedure

1. Pour 3 ml of water in the test tube followed by 2 mls of cooking oil.
2. Add 2 drops of Sudan III reagent in the mixture.
3. Shake well the mixture.
4. Leave the mixture for 3-5 minutes to settle.
5. Observe and record what happens.

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Question

What changes did you observe?

Test for proteins

Protein is a major nutrient that is essential for growth, building body parts and repair of damaged cells. It is the major building block of human body responsible for the building and maintenance of the body tissues. The main sources of protein are chicken, fish, milk, meat, eggs, beans, soybeans, and soybean products.

Properties of proteins

(i) Proteins are insoluble in water.

(ii) They coagulate on heating. This means small particles of protein clump together to form bigger particles when a mixture of protein and water is heated. The process is called denaturation.

(iii) Proteins react with sodium hydroxide (NaOH) and copper sulphate ($CuSO_4$) to produce a violet or purple colour. This is called the Biuret test.

(iv) The Biuret test can be used to identify a protein substance and confirm its presence.

Proteins are organic food substances consisting of carbon, hydrogen, oxygen, and nitrogen. They are large molecules made up of chains of amino acids. There are about 23 different types of amino acids in proteins. Each amino acid behaves as an acid as well as a base, this means it has amphoteric properties. The following activities will help you to identify properties of protein.

Activity 3.9: Investigating the presence of protein in egg white using the Biuret test

Materials:

Egg white, water, test tubes, test tube holder, droppers, measuring cylinder (10 ml), 20% sodium hydroxide solution, and 1% copper sulphate solution

Procedure

1. Pour 3 ml of water into a test tube followed by 2 ml of egg white.
2. Add 2 ml of 20% sodium hydroxide solution to a test tube containing the mixture of protein and water.
3. Shake the mixture.
4. Add 2 drops of 1% copper sulphate solution to the mixture and shake.
5. Record your observations.

Question

What was the colour change?

Activity 3.10: Investigating the solubility of protein in water and effects of heat on proteins

Materials:

Egg white, water, test tubes, measuring cylinder (10 ml), test tube holder, and heat source

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Procedure

1. Pour 3 ml of water into a test tube followed by 2 ml of egg white.
2. Shake the mixture.
3. Record your observations.
4. Heat the mixture for 2-3 minutes.
5. Observe and record your findings.

Questions

(i) What did you observe when the egg white was mixed with cold water?

(ii) Were there any changes after heating the mixture?

Chapter summary

1. There are various types of nutrients needed by the human body for its proper functioning. These are proteins, lipids, carbohydrates, vitamins, and minerals.
2. Proteins are obtained from foods like milk, meat, beans, peas, lentils, nuts, mushrooms, and sea foods. They are important for growth, repair, formation of cell membranes, muscle functioning, production of human protein and act as a source of energy during starvation.
3. Lipids are obtained from various fats and oils. Lipids are essential sources of energy, provide insulation, store fat-soluble vitamins, and protect internal organs. They are also involved in the formation of cell membranes, regulation of blood pressure in the body, and immune response.
4. Sources of carbohydrates include cassava, maize, potatoes, bananas, rice, and wheat. Carbohydrates are a major source of energy and also aid the formation of cell membranes.
5. Vitamins are either fat-soluble (vitamins A, D, E and K) or water-soluble (vitamins B and C). They boost the immunity of the body against diseases.
6. The human body requires minerals such as calcium, phosphorus, magnesium, potassium, iron, zinc, sodium, chlorine, iodine, fluorine, manganese and copper.
7. Apart from nutrients, there are other essential constituents of human diet needed by the body such as roughage and water.
8. Roughage or dietary fibre is indigestible. It helps to keep the digestive system clean and healthy, and easen the passage of food materials in the digestive tract.
9. Water is important in the formation

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of body fluids and cell cytoplasm, maintenance of body shape, digestion, lubrication, and cooling of the body.

10. A balanced diet constitutes all the necessary nutrients needed by the body in the right proportion.

11. Maintaining a healthy lifestyle is important for normal functioning of the body. Proper diet helps a person to remain healthy.

12. Nutritional requirements for different groups of people vary depending on age, sex, work, and general body condition of a person. For example, pregnant women and breastfeeding mothers need a diet that has adequate nutrients necessary to maintain their bodies and help their foetuses and babies grow properly.

13. There are different types of nutritional disorders and deficiencies in human beings. These are generally called malnutrition.

14. Malnutrition results from eating too little or too much food.

15. (a) Examples of nutritional disorders are:
    (i) obesity: excessive overweight ;
    (ii) anorexia nervosa: self-starvation in order to reduce weight; and
    (iii) bulimia nervosa: eating a lot of food then forcefully removing them from the body immediately.

    (b) Examples of nutritional deficiency diseases are:
    (i) marasmus (acute malnutrion): Lack of adequate amount of food nutrients;
    (ii) kwashiorkor (acute malnutrition with oedema): Lack of enough protein; and
    (iii) rickets: Weakened bones due to lack of enough vitamin D, calcium and phosphorus.

16. Food tests are used to determine the nutrients that are in certain food substances.

17. There are three types of carbohydrates, which are monosaccharides, disaccharides and polysaccharides. Monosaccharides are reducing sugars. They dissolve in water to form sweet solutions. Disaccharides are formed by combining two monosaccharide molecules through condensation. Some disaccharides (like maltose and lactose) are

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reducing sugars while others are non-reducing sugars (like sucrose). On the other hand, polysaccharides are formed by condensation of several mono-saccharides to form a long chain. They are all non-reducing sugars. They do not dissolve in water.

18. Benedict's solution is used to test for reducing sugars. When testing for non-reducing sugars, hydrochloric acid is used to hydrolyse disaccharides to monosaccharides. Then Benedict's solution is used to test for any monosaccharides produced. Iodine is used to test for starch.

19. Proteins are made of long chains of amino acids. Amino acids contain both acidic carboxyl groups and basic amino groups, so they can react with both bases and acids. Proteins form colloids instead of true solutions. They are also denatured by pH and strong heat. Biuret test is used to test for proteins.

20. Lipids are made up of glycerol and fatty acids. Lipids are insoluble in water but dissolve in organic solvents. The grease spot test, Sudan III test, and emulsion test are used to test for lipids.

Revision exercise 3

Section A

1. Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.

   (a) All disaccharides are soluble in water.

   (b) Galactose is a fruit sugar.

   (c) Proteins are the major source of energy.

   (d) The emulsion test is used to test for proteins.

   (e) The Biuret test is used for determining protein properties.

   (f) Nutrients are chemical components of food.

   (g) Macronutrients are required by the body in small quantities.

   (h) The calorie is a unit of measurement of food energy.

   (i) Nutrients contain calories which can be burned in the body to provide heat.

   (j) Carbohydrates are micronutrients because they are required by the body in large quantities.

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2. Match the statement in **Column A** against its corresponding item from **Column B**.

Column A	Column B
(i) A chart depicting the recommended amounts from different food groups that nutritionists consider as healthy eating	A. Malnutrition
(ii) Chemical components of foods	B. Protein
(iii) A substance that is important in the diet, but which cannot be digested and absorbed by human beings	C. Carbohydrate
(iv) Poor nutrition resulting from an insufficient or poorly balanced diet or from defective digestion or defective assimilation of foods	D. Roughage
(v) An organic compound composed of carbon, hydrogen and oxygen and is the main source of energy	E. Vitamins
(vi) An organic nutrient that an organism requires in small quantities	F. Food guide pyramid
(vii) An important nutrient for body growth and repair of worn out cells and tissues	G. Nutrients
	H. Marasmus
	I. Micronutrient
	J. Kwashiorkor
	K. Food test
	L. Rickets
	M. Biuret test

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Section B

3. Differentiate the following terms:
   (a) food and nutrient;
   (b) kwashiorkor and marasmus;
   (c) macronutrients and micronutrients;
   (d) monosaccharides and polysaccharides; and
   (e) oils and fats

4. Dina is 70 kg and 150 cm tall:
   (a) what is her BMI?
   (b) what dangers are facing Dina?
   (c) what advice will you give to Dina and why?

5. A 3 year old child has been brought to a dispensary following these complaints: He is very weak, cries and eats a lot, and has persistent diarrhoea. The child also looks skinny with extremely thin arms and legs, a swollen belly, wrinkled skin like an old person, and the hair looks yellowish and very thin.
   (a) Which nutritional disorder is the child suffering from?
   (b) What advise will you give to the child's parents?

6. What are the special nutritional needs of the following people?
   (a) A 65 years old person
   (b) A 4 years old child
   (c) A pregnant woman
   (d) A breast feeding mother

7. Briefly answer each of the following questions.
   (a) Vitamins are divided into how many groups? Name the groups of vitamins and give two examples of each.
   (b) Name the forms in which excess carbohydrates are stored in animals and plants.
   (c) Name the places in the body where excess carbohydrates can be stored.

8. Answer the following questions:
   (a) Name the process by which a monosaccharide can be converted into a disaccharide.
   (b) Give any two characteristics of monosaccharides.
   (c) How would you test for a monosaccharide?
   (d) When testing for a non-reducing sugar, the sample solution is mixed with hydrochloric acid. What is the use of the acid?

9. (a) What are polysaccharides? Give two examples.
   (b) Give any two characteristics of polysaccharides.

10. Answer the following questions.
    (a) Explain briefly how you would carry out the following:
       (i) Test for proteins
       (ii) Test for starch

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(b) What food substances are tested by the following tests:
   (i) Biuret test
   (ii) Grease spot test
   (iii) Sudan III test

11. Fill the gaps in the following table to show that the test is positive for the type of food being tested.

Test	Observation	Inference
Biuret test		
Emulsion		
Benedict's solution		
Iodine solution		

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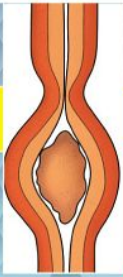

Chapter Four

Digestive system

Introduction

Food taken into the body cannot be utilised by the cells unless it is broken down and changed into simpler, soluble, and diffusible form. The break down of food into simple, soluble, diffusible, absorbable, and usable forms in the body is called digestion. Thus, the digested food is finally utilised by body cells to carry out various activities such as growth, repair of worn out tissues, supply of energy, and strengthening of the health of an individual. The process of digestion takes place in the alimentary canal. In this chapter, you will learn about the structure of human digestive system, digestion process, digestive system of ruminants, and disorders and diseases associated with human digestive system. The competencies developed from this chapter will enable you to practise a proper eating habit in order to avoid the disorders and diseases associated with the digestive system. It will also help you to understand how the digestion process takes place after you have eaten food and how food is finally utilised in the body.

Structure of the digestive system

The human digestive system is composed of alimentary canal, associated organs, and glands as shown in Figure 4.1. The main parts of the alimentary canal are the mouth, pharynx, oesophagus, stomach, small intestine (duodenum and ileum), and large intestine that comprises of colon, rectum and anal canal. The associated organs and glands are tongue, liver, pancreas, gall bladder, appendix, and salivary glands.

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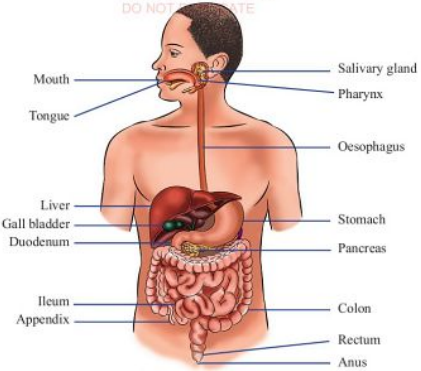

Figure 4.1: Digestive system of a human being

The digestion process

Digestion involves two sub-processes, which are mechanical and chemical breakdown of food nutrients. The mechanical process takes place in the mouth where large food particles are chewed by the teeth and broken down into small particles. The process continues in the stomach where such small particles are further broken down into tiny particles. The chemical breakdown of food into simpler molecules is done by chemical substances called enzymes found in the mouth, stomach, small intestine, and pancreas. The break down of food into the smallest particles is necessary to enable nutrients and organic molecules from the food to be absorbed and utilised in the body.

Digestion in the mouth

The process of digestion begins in the mouth and continues through the alimentary canal up to the small intestine. The first step before the beginning of the digestion process is called ingestion, which is the process of taking in food through the mouth. When food is in the mouth, digestion begins whereby food is broken down into small particles by the mechanical process known as chewing or mastication. The process of chewing is done by the teeth. In mammals, there are various types of teeth which differ in shape and size. This condition is known as heterodonty, where different teeth are specialised for various tasks like biting, tearing, grinding, and

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crushing food. There are four different types of teeth in human beings. These are incisors, canines, premolars and molars (See Figure 4.2).

Incisors

These are found in the front part of the mouth. They have sharp chisel-like shape specialised for biting and cutting food or other substances. An adult has eight incisors, four in the upper jaw and four in the lower jaw.

Canines

These are located next to the incisors. They have a sharp pointed shape specialised for grasping and tearing food. An adult person has four canines, two in the upper jaw and two in the lower jaw.

Premolars

These are located just behind the canines. They have a broad shape and are specialised for grasping and grinding food. An adult person has eight premolars, four in the lower jaw and four in the upper jaw.

Molars

They are located at the back of the mouth. They have a broader shape than premolars. They are specialised for grinding and crushing food into small particles that can be easily swallowed. An adult person has twelve molars, six in the lower jaw and six in the upper jaw.

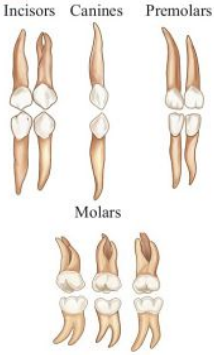

Figure 4.2: Types of human teeth

During development, mammals acquire two sets of teeth, which are milk teeth (temporary teeth) and permanent teeth. Most children develop a full set of primary teeth by the age of 3 years. A set of complete milk teeth in man consists of twenty teeth, in which there are eight incisors, four canines, eight premolars, and no molars. At the age of 6 years the milk teeth start to weaken and fall out. By the age of 6-12 years permanent teeth grow to replace the milk teeth. By the adult age all milk teeth are completely replaced with permanent teeth.

Teeth facilitate the chewing of food in the mouth. Chewing of food is necessary because it enables the break down of the large particles of food

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into smaller particles and mixes the food particles with saliva for easy swallowing. The presence of food in the mouth stimulates the salivary glands to release more saliva. Saliva contains a digestive enzyme called salivary amylase (ptyalin) that catalyses the break down of cooked starch into maltose. Also, saliva in the mouth helps to moisten the mouth, tongue and lips. This enables easy chewing and mixing of food in the mouth.

After the food has been chewed, it is rolled by the tongue into small balls called boli (singular is bolus). The teeth, saliva, and tongue play important roles in rolling the food into bolus. In this form, the food is ready to be swallowed via the pharynx and oesophagus. During swallowing, the food bolus is pressed against the roof of the mouth and pushed into the pharynx by the muscular action of the tongue. The pharynx is the cavity behind the mouth, which is connected to the stomach by the oesophagus. It is also connected to the nostrils or air pathways by the nasal cavity. Furthermore, the pharynx is connected to the ears by the eustachian tubes and to the trachea by the epiglottis. Epiglottis is a flap of cartilage that controls entering of air into the trachea. It opens to allow air to enter the lungs through the trachea. When eating food, the epiglottis closes the trachea to prevent food from entering the air passage. After the bolus has entered the oesophagus, the epiglottis opens again to allow air to pass into the trachea and proceeds down to the lungs. From the pharynx, food goes into the oesophagus. Figure 4.3 shows the structure of the oral cavity and the position of the pharynx in the throat.

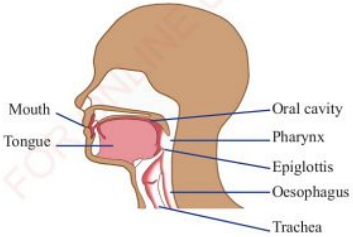

Figure 4.3: Structure of oral cavity

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The oesophagus is a muscular tube connecting the pharynx with the upper part of the stomach. The food passes through the oesophagus by a series of wave-like muscular contractions and relaxations of the oesophagus walls. Such series of muscular contractions are called peristalsis, which facilitate the movement of food from the mouth to the pharynx as shown in Figure 4.4. The oesophagus walls have two types of muscles called circular and longitudinal muscles that work antagonistically. As the food is swallowed, circular muscles above the food bolus contract and longitudinal muscles relax making the lumen smaller and squeezing food bolus downwards.

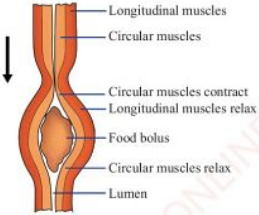

Figure 4.4: Peristaltic movement of food

Peristaltic movement of the food along the oesophagus continues until it reaches the stomach. At the junction between the oesophagus and the stomach, there is a ring of muscles called cardiac sphincter. When the food reaches this point, the muscles automatically relax and allow the food to enter the stomach. Once the food is in the stomach, the cardiac sphincter muscles contract and close the entrance into the stomach. This prevents the food from flowing back into the oesophagus.

Digestion in the stomach

The stomach has elastic muscular walls that can stretch to accommodate about two litres of food and drinks. The food is stored temporarily in the stomach before further digestion. That is why people do not need to eat food constantly. Figure 4.5 shows the structure of a human stomach.

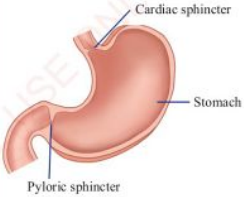

Figure 4.5: Structure of a human stomach

The walls of the stomach have gastric glands that secrete a chemical substance called gastric juice, which contains hydrochloric acid and enzymes. The contraction and relaxation of the muscles of the stomach wall cause the mechanical breakdown of the food into

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smaller particles. This process is called churning. The process supplements the mechanical breakdown of food that occurred in the mouth through chewing by the teeth. Churning allows food to mix well with the gastric juice. The stomach walls consist of circular and longitudinal muscles. These muscles contract and relax causing movement and thorough mixing of food with the gastric juice, forming a creamy semi-liquid substance called chyme. Thus, food is converted into a digestible form or chyme in the stomach. The gastric juice contains the following substances:

Hydrochloric acid (HCl)

It provides an acidic medium in the stomach for enzymes to work properly, kills disease-causing germs and converts pepsinogen into pepsin.

Pepsinogen

This is an inactive form of pepsin enzyme. This form cannot attack the walls of the stomach which are protein in nature.

Pepsin

This is an active form of pepsinogen. It is an enzyme responsible for the break down of proteins into smaller molecules called peptides and amino acids.

Rennin

This is an enzyme that coagulates milk. This allows milk proteins to stay in the stomach long enough to be broken down into peptides.

Mucus

This protects the stomach walls against damage by digestive enzymes and hydrochloric acid.

Water

Provides the medium for enzyme activity during digestion.

From the stomach, food in the form of chyme enters the duodenum which is the first part of the small intestine. The pyloric sphincter, which is a ring of muscles at the lower end of the stomach, relaxes to allow small quantities of chyme to enter the duodenum.

Digestion in the duodenum

Duodenum is the first part of the small intestine. When chyme reaches the duodenum, it stimulates the pancreas to release pancreatic juice that is transported into the duodenum through the pancreatic duct. The pancreas is located just below the stomach. Pancreatic juice contains sodium bicarbonate that provides an alkaline medium in the duodenum. This helps to neutralise the acidic condition of the chyme from the stomach. Pancreatic juice also contains digestive enzymes for the break down of proteins, carbohydrates, fats and oils. Such enzymes include the following:

Lipase enzyme

This catalyses the conversion of fats and oils into fatty acids and glycerol.

Pancreatic amylase enzyme

It catalyses the break down of starch

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which was not digested in the mouth into maltose.

Trypsin enzyme

It catalyses the conversion of proteins which were not digested in the stomach into peptides and amino acids. Trypsin is produced in an inactive form known as trypsinogen. This is converted into an active form known as trypsin by an enzyme called enterokinase, that is produced by the duodenal walls.

Also, there is bile which facilitates the digestion of fats and oils by breaking them into tiny droplets through a process called emulsification. This helps to increase the surface area for digestive enzymes to act on fats and oils. The bile is made in the liver and stored in the gall bladder. The gall bladder releases bile through the bile duct that joins the pancreatic duct before opening into the duodenum. Bile is a greenish-yellow juice containing a large amount of water and small amounts of greenish-yellow pigment, salts, mucin, and other substances. The bile pigments are formed from worn out red blood cells. The bile salts help to convert fat-soluble vitamins (vitamin A, D, E, and K) making them water soluble hence easily absorbed by the body cells. Also, bile contains sodium bicarbonate that provides an alkaline medium favourable for digestive enzymes in the duodenum.

Digestion in the ileum

The ileum is the final part of the small intestine. The process of digestion ends in the ileum. When chyme enters the ileum, it stimulates the intestinal wall of the ileum to secrete an intestinal juice known as succus entericus. This contains digestive enzymes for finalisation of the digestion of proteins, carbohydrates and lipids (fats and oils). The digestive enzymes found in the ileum include the following:

Lipase

This enzyme catalyses the conversion of the remaining fats and oils into fatty acid and glycerol.

Maltase

It catalyses the conversion of maltose into glucose.

Sucrase

It catalyses the conversion of sucrose into glucose and fructose.

Lactase

It catalyses the conversion of lactose into glucose and galactose.

Peptidase

It catalyses the conversion of the remaining peptides into amino acids.

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Exercise 4.1

1. Which enzyme is responsible for breaking down of ugali in the mouth?
2. Into which form is ugali converted in (1) above?
3. Which enzymes are responsible for breaking down fish and milk in the stomach?
4. Into which form are fish and milk converted in (3) above.
5. What is the function of incisors?
6. How are incisors adapted to their functions?
7. Match each item in **Column A** against its corresponding item from **Column B**.

Column A	Column B
(i) Pancreas	A. The chewed food rolled into a ball-like structure
(ii) Chemical breakdown	B. Movement of food along the oesophagus involving series of muscle contractions and relaxations
(iii) Mechanical breakdown	C. Part of the digestive system where the process of digestion ends
(iv) Lactase	D. The muscle that controls the opening into the stomach
(v) Sucrase	E. Part of alimentary canal used for swallowing food
(vi) Oesophagus	F. An enzyme that converts lactose to glucose and galactose
(vii) Bolus	G. An organ that secretes pancreatic juice in the duodenum
(viii) Peristalsis	H. The break down of food into tiny particles by using enzymes
(ix) Cardiac sphincter	I. An enzyme that converts sucrose to glucose and fructose
(x) Ileum	J. The break down of food into small particles during chewing by teeth

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The adaptation of ileum for digestion and absorption of food

(i) The ileum has secretory glands that secrete digestive enzymes. These enzymes finalise the digestion of food substances.

(ii) It contains mucus that ensures constant lubrication of the internal walls for effective digestion of foods.

(iii) There are various blood capillaries in the ileum, which join together to form the hepatic portal vein that transports blood to the liver. These blood capillaries ensure that food is absorbed from the ileum instantly and hence maintain the diffusion gradient. The liver filters harmful and toxic substances (detoxification) and stores fat-soluble vitamins as well as excess glucose in form of glycogen. Other products of digestion are distributed throughout the body through the blood stream.

(iv) The ileum is very long, about six metres. Therefore, food takes a long time to pass through the ileum. This ensures maximum absorption of the end products of digestion.

(v) The lining of the ileum is only one cell thick allowing easier absorption and diffusion of the nutrients in the body.

(vi) The inner lining of ileum wall is folded forming small finger-like structures called villi (singular – villus) as shown in Figure 4.6. The villi help to increase the surface area for absorption of the digested food into the blood stream.

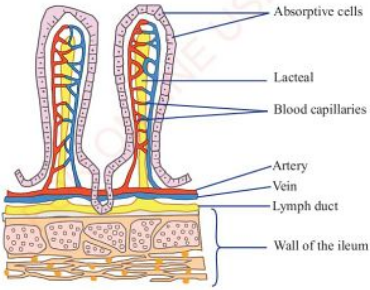

Figure 4.6: Structure of villi

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Absorption in the small intestine

The overall process of digestion involves the break down of large and complex food substances into small, simple, digestible, soluble, absorbable, and usable food molecules. The carbohydrate food substances are broken down by the catalytic actions of digestive enzymes and finally changed into fructose, galactose, and glucose. Proteins are broken down and finally changed into amino acids while fats and oils are finally changed into fatty acids and glycerol. Foods with vitamin sources are broken down and finally release vitamins A, B, C, D, E, and K. Foods with mineral sources are broken and finally release mineral elements such as potassium, sodium, iron, magnesium, iodine, calcium, chloride, fluoride, and nitrate, as shown in Table 4.1. Therefore, vitamins and minerals are released to the body as the food is being digested. For example, the digestion of meat will release amino acids together with mineral salts.

Table 4.1: The end products of digestion of food substances

Complex food substances	Simple, soluble, absorbable end products
Carbohydrates such as starch, and sucrose	Simple sugars, such as glucose, fructose, and galactose
Proteins such as beef, milk, chicken, and fish	Amino acids
Fats and oils such as butter, cheese, cooking oil, groundnuts, and coconuts	Fatty acids, and glycerol
Vitamins sources such as fruits, milk, and vegetables	Vitamins A, B, C, D, E, and K
Mineral sources such as vegetables, liver, fish, iodized salt, and water	Mineral elements like potassium, sodium, iron, magnesium, iodine, calcium, chloride, fluoride, and nitrate

Absorption of digested food takes place in the small intestine. The end products of digestion including glucose, galactose, fructose, amino acids, vitamins, and minerals are absorbed into the blood stream through blood capillaries of the villi. These products of digestion are transported to the liver through the hepatic portal vein.

The villi also have lymphatic vessels called lacteals. The lacteals absorb fatty

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acids and glycerol that are the end products of digestion of fats and oils. Thus, fatty acids and glycerol enter into the blood stream through the lacteals. The lacteals help to increase the rate of absorption of digested foods into the blood stream. After absorption of the final products of digestion into the blood stream, they are used by the body for various functions such as growth, body repair, respiration, excretion, and reproduction. This process is called assimilation.

Absorption in the large intestine

The large intestine is the part of the alimentary canal that joins with the ileum. It has large width compared to the ileum. Most water carried in the digestive system is absorbed in the colon. Its inner wall is folded to allow maximum absorption of water. The colon also has some bacteria that synthesise vitamins B_1, B_2, B_{12} and K, although these vitamins are also obtained from foods we eat.

There are no digestive enzymes in the colon. The undigested and indigestible food materials are passed into the colon from ileum by the process of peristalsis. Then, these materials are transported into the rectum and finally eliminated from the body as waste materials in the form of faeces. This is the last step which is called egestion. When there is enough accumulation of waste materials in the rectum, the sphincter muscles at the anus relax and allow faeces to pass out. This is called defecation or egestion. Table 4.2 shows the summary of enzymes involved and products of digestion in different parts of the digestive system.

Table 4.2: Summary of enzymes involved in digestion and products of digestion in each part of the human digestive system

Part of digestive system	Digestive juice	Enzyme Secreted	Substance digested	Product of Digestion
Mouth	Salivary juice	Salivary amylase	Cooked starch (Carbohydrate)	Maltose
Stomach	Gastric juice	Pepsin	Proteins	Peptides and amino acids
		Rennin	Soluble milk protein (caseinogen)	Insoluble milk protein (casein)

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Part of digestive system	Digestive juice	Enzyme Secreted	Substance digested	Product of Digestion
Duode-num	Pancreatic juice	Trypsin	Proteins	Peptides and amino acids
		Pancreatic amylase	Starch (Carbohydrate)	Maltose
		Pancreatic lipase	Lipid	Fatty acids and glycerol
Ileum	Intestinal juice	Maltase	Maltose (Carbohydrate)	Glucose
		Sucrase	Sucrose (Carbohydrate)	Glucose and fructose
		Lactase	Lactose (Carbohydrate)	Glucose and galactose
		Peptidase	Peptides	Amino acids

Activity 4.1: Observation of the digestive system of a mouse or rat

Materials:
Dissected mouse, forceps, and petri dish

Procedure

1. Observe the parts of the digestive system of a mouse displayed by your teacher.
2. Identify the oesophagus, stomach, liver, pancreas, duodenum, small intestine, and the large intestine.
3. Draw and label what you have observed.
4. Share your results with your fellow students.

Summary of the processes in the digestive system

The process from taking in food into the mouth, its utilisation until the point of giving out the undigested food from large intestine involves the following steps:

Ingestion: The process of taking in food through the mouth.

Digestion: The process in which complex food substances are broken down into simple substances mechanically by teeth, and chemically by enzymes.

Absorption: The diffusion of the end products of digestion into the blood stream

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from the small intestine.

Assimilation: The process in which absorbed nutrients are utilised by the cells and help in various metabolic processes.

Egestion: The elimination of undigested food material through the anus, a process called defecation.

The digestive system of ruminants

Ruminants are herbivorous mammals that obtain food from plant sources. The term ruminant comes from Latin word *ruminare* which means "to chew over again". Therefore, ruminants are animals that chew food, swallow it, and later return it to the mouth for further chewing. The returning of food to the mouth is called regurgitation. The food returned to the mouth is known as cud. Ruminants have a rumen that is an extended portion of the oesophagus where food is temporarily stored and periodically returned into the mouth. Examples of ruminant animals include goats, cattle, sheep, antelopes, and giraffes.

The digestive system of ruminants is divided into different parts which are mouth, pharynx, oesophagus, rumen, reticulum, omasum, abomasum, duodenum, ileum, colon, caecum, appendix, rectum, and anus. The associated organs and glands are the salivary glands, liver, pancreas, and gall bladder. Their stomach is divided into four compartments that are rumen, reticulum, omasum, and abomasum, as shown in Figure 4.7. The first three sections are known as 'false stomach' because they are merely an extension of the oesophagus and they do not secrete the gastric juice. The fourth section, abomasum is the only true stomach of the ruminants because it secretes gastric juice.

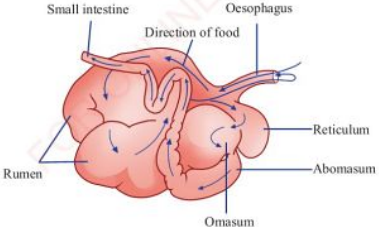

Figure 4.7: Parts of the ruminant stomach

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Digestion in a ruminant starts in the mouth when plant material is eaten and partly chewed by teeth. The partly chewed food is mixed with saliva from the salivary glands and then rolled into a bolus by the tongue. This partly chewed and rolled food is then swallowed through the oesophagus. It then enters the rumen where it is temporarily stored. The food stored in the rumen is coarse and greenish. The rumen is the largest part of the three chambers of the ruminant stomach, hence, the chamber can store a large amount of food at a time. In the rumen, there are bacteria that act upon the swallowed food and digest the cellulose contained in the plant materials. Figure 4.8 shows the internal structure of the ruminant's digestive system.

chewed, rolled and swallowed again. Instead of the food passing again into the rumen, it passes to the reticulum which is the second chamber of the stomach. In the reticulum, the food is mixed thoroughly with water and becomes soft, watery, and less greenish compared to food in the rumen. From the reticulum, the food passes to the third chamber of the stomach called the omasum that is the smallest among the four chambers of the stomach. In the omasum, the food is further mixed and some water is absorbed from it. In this chamber, the food is in the form of fine particles and less watery. Then, the food proceeds to the fourth chamber of the stomach, the abomasum. This is the true stomach similar to that of other mammals including human beings. The abomasum secretes gastric juices

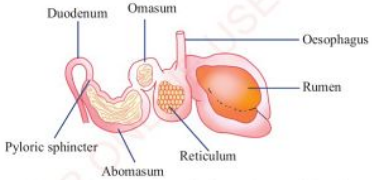

Figure 4.8: Internal structure of the ruminant's digestive system

When the ruminant animal is resting, the food stored in the rumen is brought back to the mouth (regurgitated) periodically for further chewing. The regurgitated food is thoroughly

that contain hydrochloric acid and digestive enzymes. The hydrochloric acid kills harmful bacteria and other germs that entered the body with the food. The gastric juices contain

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enzymes that digest carbohydrates, cellulose, proteins, and fats. From this point, the digestion process continues as in human beings.

Exercise 4.2

1. Why are cows and goats called ruminants?
2. How can you differentiate the stomach of a cow from that of a human being?
3. What are the major parts of the digestive system of ruminants?
4. Explain the adaptive features of the ruminant's digestive system.

Differences between the digestive system of human beings and that of ruminants

The digestive system of a ruminant is different from that of a human being. Ruminants have a more elaborate system to enable cellulose digestion. Like other mammals, including human beings, the digestive system of ruminants has different parts including the mouth, pharynx, oesophagus, stomach, duodenum, ileum, colon, caecum, appendix, rectum, and anus. However, the structure of the digestive system of ruminants differs from that of human beings as their stomach is divided into four chambers called rumen, reticulum, omasum, and abomasum. Only the abomasum is a true stomach because it secretes gastric juices. The other three chambers are false stomachs. Human beings have only one stomach.

Ruminants have the ability to regurgitate and re-chew swallowed food whereas human beings cannot. Ruminants have bacteria in their digestive system which produce cellulase enzyme that helps to break down cellulose or fibers. Human beings do not have bacteria that can break down cellulose. Another difference is that, ruminants have cellulase enzyme which is involved in cellulose digestion. This enzyme is found only in ruminants and other herbivores, it is not found in human beings. Furthermore, ruminants lack some of the teeth such as the upper incisors and canines. Instead, they have a horny pad, which helps in chewing of food. Human beings have upper incisors and canines. Ruminants also have a gap on the lower jaw known as diastema. Human beings do not have diastema.

Activity 4.2: Observation of the digestive system of a ruminant animal

Materials:

Wall chart with a diagram of external and internal structures of a ruminant digestive system, a notebook, and a pencil

Procedure

1. Observe the external part of the ruminant digestive system.

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2. Observe the internal part of the ruminant digestive system.
3. Draw diagrams to represent the structures you have observed.
4. Discuss your observations with your group members.

Disorders and diseases of human digestive system

There are several common disorders and diseases that affect various parts of the digestive system such as the teeth, oesophagus, stomach, ileum, and colon. Examples include dental caries, heartburn, indigestion, stomach ulcers, constipation, and flatulence.

Dental caries

This is usually known as tooth decay. It occurs when bacteria destroy the outer part of the tooth or enamel. Also, it occurs through drinking water with a high fluoride concentration. Dental caries develop over time. When there is food remains in the mouth, bacteria present in the mouth combine with saliva and food remains to form plaque. This is a sticky white substance often found between teeth. The plaque begins to form within 20 minutes after eating food. Bacteria in plaque convert food remains, especially sugar and starch into lactic acids. The produced acid dissolves the enamel of a tooth, forming a cavity or a hole in it and exposing the softer inner part or dentine. If this cavity or hole is not treated, it reaches the pulp cavity and nerve endings inside the tooth, causing an infection and serious pain. Figure 4.9 shows the development of dental caries.

Figure 4.9: Development of dental caries

Symptoms of dental caries

(i) Toothache, especially after eating sweet, cold, or hot foods.

(ii) Gums bleeding, especially during teeth brushing.

(iii) Development of holes or cavities in the teeth.

Prevention and control of dental caries

(i) Brush teeth regularly with recommended tooth paste, at least twice a day to get rid of plaque.

(ii) Use dental floss when necessary to remove the plaque between the teeth.

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(iii) Wash the mouth once you have taken a sugary food like cakes, chocolates, and biscuits.

(iv) Minimise intake of sugary foods. This helps to limit the amount of acid produced by bacteria, hence reduce risk of dental decay.

(v) Avoid taking very hot or very cold drinks or foods.

(vi) Visit dental clinics regularly for dental check-ups.

Heartburn

Heartburn is a burning or painful sensation in the oesophagus caused by reflux of the stomach contents. The hydrochloric acid in the stomach makes these contents acidic and irritating to the oesophagus. This causes a burning or painful sensation in the oesophagus, just below the breastbone or sternum.

The stomach contents flow back into the oesophagus because the cardiac sphincter is not closed completely. The incomplete closing of the muscles may be caused by certain types of foods such as pepper, citrus fruits, fatty foods, spicy foods, caffeine, sugary foods like chocolate, and carbonated drinks such as most of soft drinks. Eating foods with too much fats causes the food to stay long in the stomach causing the secretion of more acid in the stomach which reflux and cause irritation in the oesophagus. The habit of eating food late in the night, taking large portions of food just before bed or eating very hot or cold foods can trigger heartburn. Use of alcohol, cocaine, and tobacco can also initiate heartburn. Other causes of heartburn include pressure on the stomach due to pregnancy, obesity, stress, and vigorous activity.

Symptoms of heartburn

(i) A burning or irritating sensation in the chest or throat.

(ii) A sour taste in the mouth.

(iii) Excessive belching.

(iv) Difficult swallowing.

(v) Hoarseness or loss of voice.

Prevention and control of heartburn

(i) Minimise intake of foods that can cause heartburn such as too much fatty or too much sugary foods like sweets.

(ii) Avoid use of alcohol, caffeine, tobacco and recreational drugs.

(iii) Avoid obesity, and reduce body weight if you are obese.

(iv) Do not eat very hot or very cold foods.

(v) Do not eat large amounts of food just before going to bed.

(vi) Avoid late-night meals or engaging into vigorous body exercises immediately after eating food.

(vii) Avoid wearing tight clothes that put pressure on the stomach.

(viii) Use a wedge-shaped pillow to

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raise your head while sleeping.

(ix) Take measures to reduce stress.

(x) Drink enough water to dilute the acid in the stomach.

(xi) Change diet if you have a history of being affected by certain types of food.

Indigestion

This is a problem of the digestive system where digestion takes place very slowly. The affected individual lacks appetite and feels full most of the time, even after taking very little food. People who work under very high pressure may become 'stressed' and this can cause indigestion. Sick people also may be affected by indigestion, for example those with ulcers in the stomach or duodenum.

Poor eating habits, especially eating too much food, taking meals very late in the night, or eating much food shortly before bed can cause indigestion. Eating too much spicy or fatty foods can also lead to indigestion, and it could be worse if food is accompanied by cold drinks or alcohol. Indigestion is usually associated with pain and discomfort in the stomach. Depending on the type of food eaten, swallowing too quickly without proper chewing can also result into indigestion.

Symptoms of indigestion

(i) Tendency of feeling full for a long time, even 2-3 days.

(ii) Lack of appetite.

(iii) Stomach discomfort and restlessness.

(iv) Nausea and vomiting.

Prevention and control of indigestion

(i) Set and adhere to a meals timetable.

(ii) Avoid too spicy and too fatty foods.

(iii) Avoid stress, and maintain sensible life.

(iv) Ensure good work management.

(v) Eat balanced diet.

(vi) Time for taking meals should be planned properly so that there is enough time for each meal to be eaten in a relaxed way.

(vii) Seek medical advice for a prolonged indigestion problem.

(viii) Exercise to help digestion of food.

Peptic ulcers

These are sores that affect the lining of the stomach or the upper portion of the small intestine(duodenum). The ulcers in the stomach are called gastric ulcers while the ulcers in the duodenum are called duodenal ulcers. Ulcers, result from erosion of the mucus coating of these organs, thus exposing them to the action of digestive enzymes and acid. The mucus coating can be broken by the bacteria called *Helicobacter pylori*. Some types of medicines can also cause peptic ulcers. Smoking, taking

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excess alcohol and caffeine as well as emotional stress are additional causes of peptic ulcers.

Symptoms of peptic ulcers

(i) Burning pain in the stomach or in the middle of the thorax.

(ii) Tiredness and weakness.

(iii) Nausea and vomiting.

(iv) Blood drops in vomit or stool (a sign of bleeding ulcers).

(v) Heartburn.

Prevention and control of peptic ulcers

Peptic ulcers are prevented by avoiding smoking, excess alcohol, and caffeine. The ulcers are controlled by avoiding food that irritates the stomach such as peppery foods, citrus fruits, and acidic foods because they worsen stomach ulcers. Also a person should adhere to personal and food hygiene to avoid infections.

Constipation

Constipation is a condition which results in difficulty in emptying the bowel. It occurs when stool becomes dry and hard due to excessive absorption of water in the colon. This can be caused by low intake of liquids including drinking water. The body needs enough water for regulating most of the metabolic processes including digestion. Also, lack of adequate amounts of fibre or roughage in the diet can lead to constipation. This is because roughage is composed of indigestible materials that help the food to be moved through the digestive system at an appropriate rate. Lack of roughages in the diet decreases the rate of food digestion, hence food stays longer in the digestive system. Furthermore, lack of body exercises and sitting for a long time or engaging in sedentary life style can result into constipation. Other causes of constipation include effects of certain drugs and ignoring the urge for a long call.

Symptoms of constipations

(i) Lack of bowel movement for three or more days.

(ii) Hard stool that is difficult or painful to pass.

(iii) Getting the urge to go for a long call even after you have just gone.

Prevention and control of constipation

(i) Ensure eating foods with enough fibers such as vegetables and fruits.

(ii) Take enough drinking water and other liquids every day.

(iii) Engage in physical exercise regularly.

(iv) Go for a long call when you feel the urge.

(v) Seek medical help if constipation is persistent.

Flatulence

Flatulence is a condition of releasing gas from the digestive system through the anus. This condition is caused by excess gas in the digestive tract. This

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could be due to swallowed air or eating foods that produce gas, for example beans, cabbage, onions, garlic, milk, and bread. It can also result from eating meals that have too much fat, which leads to production of large amounts of carbon dioxide when fat is neutralised in the small intestine. Poor absorption of carbohydrates in the gut may also cause flatulence. The presence of excess gas in the digestive system causes discomfort and pain that are lessened when the gas is released either through the mouth or anus.

Symptoms of flatulence

(i) Abdominal pain.

(ii) Constant urge to pass out gas through the anus.

(iii) Excessive belching.

(iv) Bloating (an accumulation of gas in the stomach).

Prevention and control of flatulence

(i) Avoid foods such as certain pulses and green vegetables that produce gas or eat them in moderate amounts.

(ii) Those who are intolerant to lactose should avoid drinking or eating milk products.

(iii) Avoid lying down just after eating because it makes it easy for gas to pass from the stomach into the intestines.

(iv) Chew foods thoroughly to assist proper digestion of carbohydrates.

(v) Avoid eating foods containing too much fat or sugar.

(vi) Cover the mouth during yawning to avoid swallowing of air.

(vii) Minimise intake of aerated drinks.

Activity 4.3: Investigation of types of disorders of the human digestive system

Materials:

Charts and pamphlets on disorders of the human digestive system

Procedure

1. Visit a nearby health facility.
2. Ask a medical practitioner about the digestive system disorders that they commonly encounter. Take notes as he or she answers the questions.
3. Find out why those disorders are prevalent and how they can be prevented or controlled.
4. Read charts and pamphlets which give information on various disorders of the digestive system.
5. Write a summary of the information you have gathered and share with your fellow students.

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Chapter summary

1. The human digestive system is made up of the alimentary canal and associated glands and organs like the liver and pancreas.
2. Digestion is the process by which food is broken down into a simpler form that can be absorbed and utilised by body cells for carrying out various functions like growth, repair of worn out tissues, and supply of energy.
3. Digestion begins in the mouth. The teeth break down food into small pieces. The salivary gland secretes salivary amylase or ptyalin enzyme that begins to digest starch. Food is mixed with saliva and rolled by the tongue into a bolus (plural is boli or boluses).
4. Food is swallowed and moves through the oesophagus by the periodic contraction and relaxation of the muscles in the oesophagus wall. This kind of movement is called peristalsis.
5. The cardiac sphincter, which is a ring of muscles surrounding the opening between the oesophagus and the stomach, opens to allow food to enter into the stomach.
6. In the stomach, gastric juice is produced, which contains various substances including hydrochloric acid, pepsin, and rennin enzymes. Hydrochloric acid provides a suitable acidic medium for the action of enzymes in the stomach. Pepsin converts proteins into peptides and amino acids. Rennin coagulates milk. After food has been mixed well in the stomach it is changed into a creamy paste called chyme.
7. Food in the form of chyme moves into the first part of the small intestine called duodenum. This occurs when the ring of muscles surrounding the opening between the stomach and duodenum opens to allow food to enter the duodenum.
8. In the duodenum, food is mixed with pancreatic and bile juice. Pancreatic juice is secreted by the pancreas that is located below the stomach and joined to the duodenum through the pancreatic duct. The pancreatic juice contains different types of enzymes including trypsin, amylase, and lipase. The trypsin converts proteins into peptides and amino acids; amylase converts starch into maltose; and lipase converts fats and oils (lipids) into fatty acid and glycerol. Bile juice is produced by the liver. It is stored and released by the gallbladder that is located under the liver and connected to the duodenum by the bile duct. Bile juice contains mineral salts including sodium bicarbonate

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and potassium bicarbonate, which provide an alkaline medium in the duodenum. This is a suitable working condition for enzymes in this area. Bile salts also emulsify lipids. From the duodenum, food passes to the final part of the small intestine called ileum.

9. The ileum secretes intestinal juice which contains the following enzymes:
   (a) peptidase which converts peptides to amino acids;
   (b) lactase which converts lactose to glucose and galactose;
   (c) maltase which converts maltose to glucose;
   (d) sucrase which converts sucrose to glucose and fructose; and
   (e) lipase which converts lipids to fatty acid and glycerol.

   Furthermore, the inner wall of the ileum has villi, which are finger-like projections that facilitate the absorption of digested food. Food remains or undigested food pass to the large intestine.

10. In the large intestine, water is absorbed from the undigested and indigestible food materials releasing the solid materials or faeces. Absorption of water is a result of rhythmic movements of the large intestine.

11. Faeces are egested through the anus.

12. The digestive system of ruminants differs from that of human beings. The ruminant's digestive system has four stomach chambers while human beings have only one stomach. There is a gap in the lower jaw of ruminants called diastema. In human beings there is no diastema. The upper incisors and canines are missing in ruminants, but they are present in human beings. The digestive system of ruminants normally has bacteria that digest cellulose. Human beings do not have cellulose digesting bacteria. In addition, ruminants have the ability to regurgitate food that is swallowed. The food is returned to the mouth and re-chewed, then swallowed again. This is called chewing cud. Human beings do not have the ability to regurgitate swallowed food.

13. The human digestive system can be affected by various diseases and disorders including dental caries, heartburn, stomach ulcers, indigestion, constipation and flatulence. Observing health tips and good eating habits are the major preventive measures for most of those problems. It is also important to seek medical treatment from health facilities.

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Revision exercise 4

Section A

Choose the correct answer.

1. The absorption of end products of digested food takes place in the _____.
   (a) stomach
   (b) duodenum
   (c) ileum
   (d) colon

2. Food is prevented from entering the trachea by the _____.
   (a) larynx
   (b) pharynx
   (c) epiglottis
   (d) tonsils

3. Bile is produced in the _____.
   (a) pancreas
   (b) stomach
   (c) gall bladder
   (d) liver

4. Undigested and indigestible food material is prepared for elimination in the _____.
   (a) liver
   (b) large intestine
   (c) stomach
   (d) small intestine

5. The first site of protein digestion in the digestive system is the _____.
   (a) mouth
   (b) oesophagus
   (c) stomach
   (d) small intestine

6. Both mechanical and chemical digestion begin in the _____.
   (a) mouth
   (b) oesophagus
   (c) stomach
   (d) small intestine

7. _____enzyme converts starch to maltose.
   (a) Lipase
   (b) Sucrase
   (c) Peptidase
   (d) Amylase

8. Match each item in **Column A** against its corresponding item from **Column B**.

Column A	Column B
(i) Undigested materials excreted from the bowels	A. Duodenum
(ii) Wave-like muscular contractions that push food along the oesophagus	B. Oesophagus
	C. Rectum

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(iii) Connects the mouth to the stomach	D. Egestion
(iv) Grind food	E. Pyloric sphincter
(v) Absorbs water from undigested and indigestible food materials	F. Colon
(vi) Waste is stored here, ready to leave the body	G. Stomach
(vii) Contains an acidic medium for digestion	H. Faeces
(viii) First part of the small intestine	I. Peristalsis
(ix) A muscular ring-like valve which regulates the passage of food from the stomach into the small intestine	J. Molars
(x) The process of passing undigested materials from the body through the anus	K. Pancreas
	L. Cardiac sphincter
	M. Canines
	N. Ingestion
	O. Pharynx.

9. Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.

(a) Gastric juice is secreted in the ileum.

(b) Glucose is the final product of digestion for starch and other carbohydrates.

(c) The intestinal juice contains maltase, sucrase, lipase, lactase and peptidase enzymes.

(d) Pepsinogen is an active form of pepsin.

(e) Rennin coagulates fats.

(f) Digestion of protein starts in the mouth.

(g) The presence of villi in the ileum facilitates absorption of digested food.

(h) Water is not needed in the digestion process.

(i) Swallowing of food is assisted by peristalsis of the oesophagus muscles.

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(j) Canines help to crush and grind food into small particles for easy swallowing.

(k) The first part of the small intestine is called duodenum.

(l) Enzymes in the duodenum work under acidic conditions.

(m) The hardening of milk in the stomach is brought by pepsin enzyme.

(n) The lipase enzyme converts milk to simple sugars.

(o) The function of the salivary gland in the mouth is to secrete amylase enzyme.

10. Fill in the blanks using the following words: hydrochloric acid, pepsin, duodenum, oesophagus, coagulation, alkaline, acidic, and rennin.
    (a) Food moves through the _____ by peristalsis to the stomach.
    (b) The conversion of protein into peptides in the stomach is done by _____ enzyme.
    (c) The acidic condition in the stomach is provided by _____.
    (d) The hardening of milk in the stomach is called _____. This is facilitated by an enzyme called _____.
    (e) The digestive enzymes in the ileum function better under _____ medium.

Section B

11. What is flatulence?

12. Explain the prevention and control measures of flatulence.

13. Briefly answer the following questions.
    (a) What are the differences between the digestive system of a human being and that of a ruminant animal?
    (b) How is the ileum adapted to its functions?
    (c) Mention three components of gastric juice and state their functions.
    (d) Explain the process of digestion from the mouth to the ileum.
    (e) Explain the prevention and control of dental caries.

14. Mainda complains of having painful burning sensation around the middle of her chest whenever she eats spicy foods. She also has a problem of passing out very hard stool.
    (a) What are the possible digestive disorders she is facing?

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(b) What would you advise her in order to alleviate the problem?

15. Name the enzymes that are found in the duodenum of a human being and state the role of each.

16. Explain how the following habits can cause disorders and diseases in the digestive system.
    (a) Tendency of eating foods with a lot of sugar.
    (b) Taking meals with no or little fibre.
    (c) Eating foods with too much fats or oils or too much spices.
    (d) Habit of not drinking adequate amounts of water and other fluids.
    (e) Wearing very tight clothes that put pressure on the stomach.

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Chapter Five

Nutrition in plants

Introduction

Plants are unique organisms because they are capable of making their own food. Organisms such as plants and some types of bacteria, which can synthesise their own food are known as autotrophs. Nutrition in plants is a process by which plants manufacture their own food and utilise it for growth and repairing damaged parts. Although plants can make their own food, they require some chemical elements from the environment. Such chemical elements are important for normal growth and development. In this chapter, you will learn about roles of essential mineral elements in plants, photosynthesis process and its importance, as well as the structure of a leaf in relation to photosynthesis. The competencies developed from this chapter will enable you to explore the importance of plant nutrition and its relation to human health.

Essential and non-essential elements in plants

There are many chemical elements which are known to be important for plant growth and development. They are divided into two major groups, namely essential and non-essential elements. The essential elements are vital for plant development and survival.

The essential elements are very important for plant growth, development and reproduction. The plant cannot complete its life cycle without them. These include nickel (Ni), carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), calcium (Ca), iron (Fe), manganese (Mn), potassium (K), magnesium (Mg), sulphur (S), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and chlorine (Cl). The non-essential elements are used to stimulate growth in plants. Examples of non-essential elements include lithium (Li), iodine (I), sodium (Na), mercury (Hg), silver (Ag), tin (Sn), radium (Ra), silicon (Si), bromine (Br), and cobalt (Co). Also, some of these elements are very important to the health of animals that eat plants as sources of food. Such elements are sodium, iodine and cobalt.

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The essential elements can also be divided into two groups, which are macroelements and microelements. The macroelements are those elements that are required by plants in relatively large amounts. They are also known as macronutrients. These include phosphorus (P), potassium (K), nitrogen (N), sulphur (S), magnesium (Mg), calcium (Ca), carbon (C), oxygen (O), and hydrogen (H). Among the macroelements, some are non-minerals, such as carbon, oxygen and hydrogen, that are obtained from the air. Other macroelements are minerals such as magnesium, calcium, phosphorus and potassium. Both non-mineral and mineral elements are essential for normal plant growth and metabolic activities. For example, carbon is a major constituent of plants, hydrogen is required during photosynthesis and oxygen is required during respiration. The essential mineral elements are mainly absorbed by plants from the soil. They usually dissolve in water and are absorbed by plants in form of ions. The ions enter the plant through roots and are transported upward through the vascular system. Table 5.1 shows various sources of macroelements in plants.

Table 5.1: Sources of different macroelements in plants

Macroelement	Sources
Phosphorus	Obtained from commercial fertilisers, crop residues, and manure
Potassium	Obtained from soil minerals, organic materials, and commercial fertilisers
Nitrogen	Obtained from commercial fertilisers and from the air. *Rhizobium* bacteria in the roots of leguminous plants fix nitrogen from the air for use by the plants
Sulphur	Obtained from rainwater, gypsum, and commercial fertilisers
Magnesium	Obtained from soil minerals, organic material (such as compost), commercial fertilisers, and lime
Calcium	Obtained from lime, gypsum, and commercial fertilisers

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Functions of macroelements in plants

Each mineral element has a specific function in the plant body. Some are used in the formation of building materials for proteins and carbohydrates for plants while others play important roles in other metabolic activities of the plant. The deficiency of such elements will eventually affect plant growth and metabolic activities. Table 5.2 indicates the functions, signs of deficiency, and effects of excess macroelements in plants.

Table 5.2: Functions, signs of deficiency, and effects of excess macroelements in plants

Macroelement	Functions	Signs of deficiency	Effects of excess
Nitrogen	(i) Synthesis of proteins and transfer of energy (ii) Formation of chlorophyll (iii) Increases seed and fruit production (iv) Speed up growth rate	(i) Slow growth (ii) Yellowish or light green leaves as shown in Figure 5.1(b) (iii) Reduced yield of fruits and seeds (iv) Poorly developed leaves	(i) Very dark green succulent leaves (ii) Break down of vascular tissue and restricted transport of water (iii) Easily damaged stems because of excess sap
Phosphorus	(i) Germination and growth of seeds (ii) Production of flowers and fruits (iii) Growth of roots (iv) Ripening of seeds and fruits	(i) Reduced plant growth (ii) Delayed development (iii) Small leaves that drop early (iv) Bluish-green or purplish leaves as shown in Figure 5.1 (c)	Reduces the plant's ability to take up required micronutrients, particularly iron and zinc

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Macroelement	Functions	Signs of deficiency	Effects of excess
Potassium	(i) Steady growth (ii) Increases resistance to diseases (iii) Useful in protein formation	(i) Scorched brown leaf edges and tips as shown in Figure 5.1 (d) (ii) Rolling of leaves (iii) Susceptibility to diseases	Deficiency of calcium and magnesium
Magnesium	(i) Formation of chlorophyll (ii) Activation of plant enzymes necessary for growth	(i) Yellowish leaves as shown in Figure 5.1 (e) (ii) Leaves fall without withering	(i) Stunted growth (ii) Lack of food needed for growth and development due to impaired photosynthesis
Calcium	(i) Formation of cell walls (ii) Increases mechanical strength of the plant (iii) Growth of roots (iv) Normal transport and retention of other elements in the plant	(i) Poorly developed roots with weak tips (ii) Curling of leaf margins, as shown in Figure 5.1 (f) (iii) Hooked leaf tips (iv) Internal decay	Reduced uptake of essential elements, particularly, phosphorus and magnesium

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Macroelement	Functions	Signs of deficiency	Effects of excess
Sulphur	(i) Production of protein (ii) Formation of chlorophyll (iii) Improved root growth and seed production (iv) Resistance to cold	(i) Slowed growth (ii) Small leaves that roll up and are stiff and brittle (iii) Premature shedding of leaves (iv) Tips of buds die	Premature ageing of plants

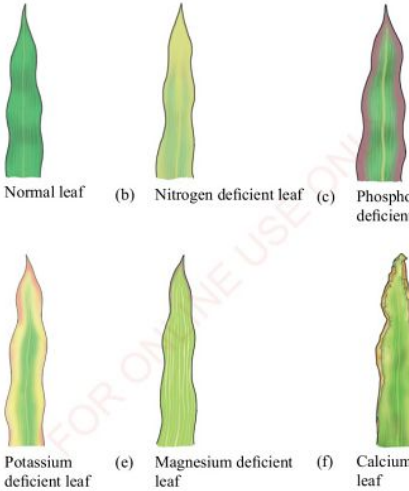

Figure 5.1: Signs of deficiency of some macroelements in a maize leaf

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Microelements are essential mineral elements that are needed for plant growth and survival but only in very small quantities. However, deficiency or excess of microelements in plants can have effects on physiological activities of plants. These elements are also referred to as trace elements. They include boron, copper, iron, chlorine, manganese, zinc, nickel, and molybdenum. Table 5.3 indicates functions of microelements in plants, deficiency signs, and effects of their excess levels.

Table 5.3: Functions, deficiency signs, and effects of excess microelements in plants

Macroelement	Functions	Signs of deficiency	Effects of excess
Boron	(i) Aids in the production of sugar and starch (ii) Aids in water intake by cells (iii) Important for seed and fruit development (iv) Keeps Calcium in a soluble form	(i) Distorted or dead growing tips (ii) Hollow stems (iii) Deformed fruits (iv) Discoloured leaves	(i) Scorched leaves (ii) Falling off of leaves
Copper	(i) Important for normal growth and development (ii) Aids in the formation of proteins	(i) Bluish-green leaves (ii) Withering of leaves (iii) Leaves failing to unfold (iv) Distorted growth tips	(i) Iron deficiency (ii) Suppressed growth
Chlorine	Important for plant metabolism	(i) Wilting (ii) Stumpy roots	Scorched leaf edges

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Macroelement	Functions	Signs of deficiency	Effects of excess
Iron	(i) Important for the formation of chlorophyll (ii) Important in transportation of oxygen	Yellowing of leaves between the veins	Brown spots on leaves
Manganese	(i) Catalyst for enzyme action (ii) Required for the formation of chlorophyll	(i) Yellowing of leaves between veins (ii) White or grey spots on leaves	(i) Iron deficiency (ii) Brown spots on leaves surrounded by a pale circle
Molybdenum	Helps in the formation of root nodules in legumes	(i) Yellow spots on leaves (ii) Dead spots on leaves (iii) Distorted or dead growing tips	(i) Pale-green leaves (ii) Rolled leaf margins (iii) Stunted growth
Zinc	(i) Important for regulation of plant growth and maturity (ii) Helps in the formation of proteins	(i) Yellowing of leaves between the veins (ii) Appearance of purple or dark spots on leaves (iii) Small, deformed leaves (iv) Reduced fruiting	(i) Iron deficiency (ii) Pale green leaves

The role of each of the essential mineral elements in plant growth can be investigated. This is done by growing plants in solutions prepared in such a way that each solution lacks one of the mineral elements necessary for healthy growth. Such solutions are called culture solutions. Plants grown in the prepared culture solutions are compared with plants grown in culture solutions containing all the necessary elements, which is also called a complete culture medium. Then, the effects of the presence or absence of certain mineral elements can be observed.

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Activity 5.1: Investigating the effects of mineral elements in plants

Materials:

Pots or tins, seeds such as maize and beans, fertilisers containing different minerals, notebooks, and a pen

Procedure

1. Prepare pots or tins for planting seeds.
2. Plant the same types of seeds in all the pots or tins.
3. Your teacher will explain what is in each type of fertiliser (for example, 'NPK' has Nitrogen, Phosphorus and Potassium) and the proper amounts of each type of fertiliser required by the plants.
4. Vary the amounts of fertiliser that you apply in the pots or tins as follows:
   (a) Do not put any fertiliser in the first pot or tin.
   (b) Put adequate amounts of fertiliser in the second pot or tin.
   (c) Put excess amounts of fertiliser in the third pot or tin.
5. Water all experimental pots or tins every morning and evening with the same amount of water for a period of 30 days.
6. Make daily observations of the plants in the pots or tins, including height and leaves colouration and record the observations.
7. Discuss the results with your group members and the teacher.

Questions

(i) Is there any difference in growth of the plants in the three pots or tins? Give reasons.

(ii) Why is the same amount of water required in each pot or tin every morning and evening?

(iii) Which type of fertiliser did you apply in the second and third pots or tins?

(iv) Why was the fertiliser not applied in the first pot or tin?

Exercise 5.1

1. What is plant nutrition?
2. Explain the difference between essential and non-essential elements.
3. Why is phosphorus important for plant growth and development?
4. What are micro-elements?
5. Explain the differences between microelements and macroelements.

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Photosynthesis

Photosynthesis is the process by which green plants, some bacteria and protoctists make their own food using water and carbon dioxide in the presence of sunlight energy. Organisms that make their own food are called primary producers or autotrophs. They are the primary source of food for all other organisms. During photosynthesis, six molecules of carbon dioxide and twelve molecules of water combine to form one molecule of glucose (a simple sugar), six molecules of water, and six molecules of oxygen. The leaf is the main site of photosynthesis in the plants. However, photosynthesis can take place in other green parts such as stem in some plants. The following chemical equation represents the photosynthesis process.

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{12H_2O} \xrightarrow[\text{sunlight}]{\text{chlorophyll}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Water}}{6H_2O} + \underset{\text{Oxygen}}{6O_2}$$

Photosynthesis produces a six-carbon sugar molecule (a hexose) called glucose. Plants convert these hexose sugars into other carbohydrates such as complex sugars, starch and cellulose. Plants are also capable of converting hexose sugars into other organic compounds such as proteins and fats. The food formed by plants during photosynthesis is stored in the form of starch.

Biologists often use the presence of starch as an indication that photosynthesis has taken place. If a starch-free plant is kept under certain conditions and later tests positive for starch, the assumption is that photosynthesis has taken place in the plant.

Structure of the leaf in relation to photosynthesis

The internal and external structures of a leaf make it well adapted for photosynthesis. In most plants, the leaf is the main site of photosynthesis, although some plants such as cactus (plural is cacti) use their stems instead. The leaf has evolved into a structure that provides a very efficient means of absorbing carbon dioxide and sunlight.

External structure of a leaf

The external features of a leaf can be viewed using either a hand lens or with unaided eyes. Figure 5.2 shows the external structure of a leaf.

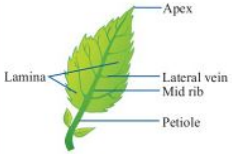

Figure 5.2: External structure of a leaf

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The petiole or leaf stalk attaches the leaf to the branch or stem. It keeps the lamina in a position that will enable it to get maximum amount of sunlight.

The lamina is the expanded portion or blade of a leaf. It has a large surface area. This maximizes the absorption of sunlight energy and carbon dioxide. The lamina is also thin so that carbon dioxide gas can diffuse and sunlight energy can penetrate over a short distance to reach cells.

The mid-rib and veins contain vascular tissues, namely xylem and phloem. Xylem transports water and minerals while phloem transports manufactured food and nutrients in the plants.

Activity 5.2: Observation of the external features of a leaf

Materials:

Leaves from various plants, hand lens, pencil, and notebook

Procedure

1. Observe each of the leaves using your unaided or naked eyes.
2. Observe each of the leaf using the hand lens. Note as many details as you can.
3. Draw each of the observed leaves and label them.
4. Discuss in your group how each part aids photosynthesis.

Question

State the observed differences among the variety of leaves.

Internal structure of a leaf

The internal features of a leaf can be viewed under a microscope. Figure 5.3 shows the internal structure of a leaf. The leaf has lower and upper parts which are covered by a thin waxy layer called cuticle. Immediately below the cuticle is the epidermis which is found on both upper and lower parts of the leaf. On the upper part of the leaf is the upper epidermis while the lower epidermis is located on the lower part of the leaf.

The lower and upper epidermis have small openings called stomata. Depending on the species of a plant and the environment in which it grows, the leaf can either have stomata on both sides or one side (lower or upper part). But in most plants, the lower epidermis has more stomata than the upper epidermis. Immediately below the epidermis is another tissue called mesophyll, that is photosynthetic because it contains chloroplasts.

The mesophyll tissue is divided into two parts, namely the palisade and spongy mesophylls. The palisade mesophyll cells are usually tightly packed. The

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spongy mesophyll has loosely packed cells. It also consists of air spaces and vascular tissues which are made up of xylem and phloem cells as shown in Figure 5.3.

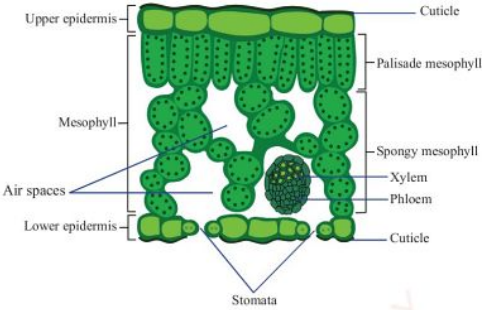

Figure 5.3: Internal structure of a leaf

The cuticle: This is the outermost transparent and waxy layer of the leaf. It allows light to penetrate into the photosynthetic cells. It also protects the leaf from injury, pests, and excessive loss of moisture. There is no cuticle on the stomata in order to allow gaseous exchange.

The epidermis: This is the outermost layer of cells found on both lower and upper surfaces of a leaf. It is transparent and only one cell thick, hence it allows sunlight to penetrate the leaf easily. The epidermis has pores called stomata.

Stomata: Stomata (singular is stoma) are small pores in the epidermis. They allow oxygen and carbon dioxide to diffuse in and out of the leaf. Stomata are surrounded by guard cells that close and open the pores. The guard cells also have chloroplasts to allow photosynthesis (See Figure 5.4). Broad leaves, such as those of bean plants, have more stomata on the lower epidermis than on the upper epidermis. Narrow-leaved species, such as grasses have roughly equal number of stomata on the lower and upper epidermis. The stomata allow atmospheric carbon dioxide to enter the leaf for use during

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photosynthesis. Oxygen, which is a by-product of photosynthesis, also escapes from the plant through the stomata.

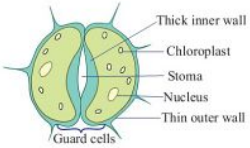

Figure 5.4: Structure of a stoma

Mesophyll: This is made up of palisade layer and spongy layer (See Figure 5.3). The palisade mesophyll is made up of cells that are elongated and arranged at right angles to the surface of the leaf. It is just below the upper epidermis. Being near the upper epidermis, the palisade cells are exposed to maximum sunlight. This enables the cells to absorb maximum amount of sunlight energy. Palisade cells also have chloroplasts where photosynthesis takes place.

The spongy mesophyll is just above the lower epidermis. It is a loosely constructed layer of irregularly shaped cells separated by large intercellular air spaces that connect with each other and linked to the atmosphere through the stomata pores. The intercellular spaces allow air containing carbon dioxide to circulate freely and reach most parts where photosynthesis takes place. The air spaces in the spongy mesophyll provide an immediate source of carbon dioxide.

Activity 5.3: Observation of the internal structure of a leaf

Materials:
Prepared slide of a transverse section of a leaf, microscope, notebook, and pencil or pen

Procedure

1. Mount the prepared slide on the microscope.
2. Observe the slide under the low power objective lens. What do you see?
3. Draw and label a diagram of what you have observed.

The process of photosynthesis

Photosynthesis takes place in cell organelles known as chloroplasts. These are mostly found in the green leaves. Chloroplasts contain chlorophyll that is responsible for trapping sunlight energy that is used during photosynthesis. Photosynthesis takes place in two stages, namely light reaction and dark reaction stages.

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The light reaction stage or light dependent reaction

This stage takes place in specialised structures of the chloroplast called grana. The grana (singular is granum) contain chlorophyll that absorbs light energy from the sun. The light energy sets up reactions that lead to the formation of energy. The formed energy is stored in a chemical compound called ATP (Adenosine Triphosphate). This energy is used in the dark reaction stage of photosynthesis.

Light energy also causes photolysis, a chemical process whereby water molecules (H_2O) are split into hydrogen ions (H^+) and hydroxyl ions (OH^-). This can be represented using the following equation.

$$H_2O \xrightarrow{\text{Light energy}} H^+ + OH^-$$

The hydroxyl ions undergo further reactions to produce water and oxygen. Some oxygen is released into the atmosphere. The rest of the oxygen is used for respiration in the plant. Hydrogen ions are used in the dark reaction stage to synthesise food together with carbon dioxide from the air.

The dark reaction stage or light independent reaction

This stage takes place in the stroma in the absence of light. The stroma is a colourless matrix of fine material found in the chloroplast. During the dark reaction stage, hydrogen ions from light reaction stage and carbon dioxide from the atmosphere combine to form glucose that is the simplest carbohydrate. Glucose is later converted to starch. Starch is insoluble and acts as a temporary storage of excess carbohydrates. It can easily be converted to glucose when a plant needs energy. Glucose may also be converted to cellulose (the structural material of plants). Lipids and proteins are also formed from glucose through complex processes.

Activity 5.4: Testing a plant leaf for starch

Materials:

A leaf, methylated spirit, iodine solution, source of heat, test tube, 250 ml beaker, dropper, forceps, water, white tile, notebook, and pencil

Procedure

1. Take a leaf from a plant that has been in the sunlight for at least 6 hours.
2. Put the leaf in boiling water for 2-3 minutes as shown in Figure 5.5. This stops further chemical reactions in the leaf because boiling kills the leaf cells.

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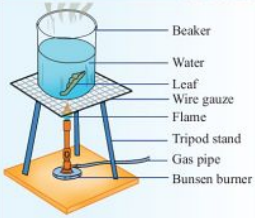

Figure 5.5: Experimental set-set-up when boiling a leaf

3. Put the leaf in the test tube containing methylated spirit. Place the test tube in a beaker of boiling water as shown in Figure 5.6. The methylated spirit dissolves the chlorophyll.

Warning: Do not heat methylated spirit directly because it is highly flammable.

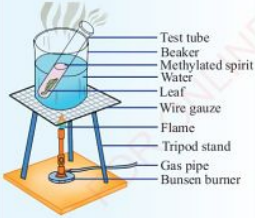

Figure 5.6: Experimental set-up when using methylated spirit to decolourise a leaf

4. Remove the leaf from the methylated spirit and rinse it in warm water. The water softens the leaf.

5. Put the leaf on a white tile. Add 2-3 drops of iodine solution on the leaf. What do you observe?

6. Discuss your observations with your group members and the teacher.

Note: The blue-black colour indicates the presence of starch.

Activity 5.5: An experiment to determine the importance of carbon dioxide in photosynthesis

Materials:

Conical flasks, thread, corks, soda lime, water, iodine solution, dropper, potted plant, notebook, methylated spirit, white tile, test tube, and pencil

Procedure

1. Place the potted plant in the dark for at least 24 hours to de-starch its leaves.

2. Enclose a leaf (A) in a conical flask containing soda lime as shown in Figure 5.7. This leaf will not have a supply of carbon dioxide from the air because soda lime absorbs carbon dioxide.

3. Enclose a second leaf (B) in a conical flask containing some water.

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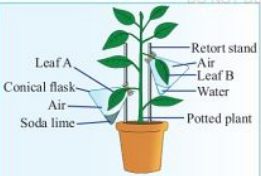

Figure 5.7: Experimental set-up to determine the importance of carbon dioxide in photosynthesis

4. Place the plant in sufficient light for 6 hours at room temperature.
5. Remove the two leaves (leaf A and B) from flasks.
6. Test for starch by using standard procedures.
7. Discuss your observations with your group members and the teacher.

Activity 5.6: An experiment to determine whether chlorophyll is necessary for photosynthesis

Materials:

Variegated leaves, iodine solution, alcohol or spirit, beaker, white tile, water, heat source, pencil, and notebook

Procedure

1. Pick a variegated leaf (example shown in Figure 5.8) from a plant that has been exposed to the sun for at least 6 hours.
   (Variegated leaves are green but mixed with patches of other colours such as yellow, red and white). The green areas have chlorophyll but areas with other colours do not have chlorophyll.

(a) Variegated leaf with red and yellow patches

(b) Variegated leaf with yellow patches

Figure 5.8: Variegated leaves

2. Draw a colour map of the leaf.
3. Test the leaf for the presence of starch using the standard procedure.

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4. Compare the stain patterns with the drawn colour map. What do you notice?
5. Discuss your observations with your group members and the teacher.

Question

Based on the results you have obtained, what conclusion can you make about variegated leaves in relation to photosynthesis?

Activity 5.7: An experiment to determine whether light is necessary for photosynthesis

Materials:

Potted plant, manila card, paper clips, methylated spirit, iodine solution, test tube, beaker, water, white tile, notebook, and pencil

Procedure

1. Place the potted plant in a dark place for 24 hours to de-starch its leaves.
2. Use manila card (opaque paper) and paper clips to cover the upper and lower epidermis of one leaf as shown in Figure 5.9.

Figure 5.9: Leaf in a potted plant covered with manila card

3. Put the plant in bright sunlight for 6 hours.
4. Detach the leaf that has been covered by manila card from the plant.
5. Remove the paper clips and manila card.
6. Test the detached leaf for starch using the standard procedure. What do you notice?
7. Discuss your observations with your group members.

Question

Why was an opaque paper used to cover part of the leaf?

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General conclusion

The above experiments have shown that chlorophyll, carbon dioxide, and sunlight are necessary for photosynthesis. The process of photosynthesis cannot take place in the absence of any of these. If sunlight or carbon dioxide are in low supply, the rate of photosynthesis will decrease. Moreover, photosynthesis cannot take place in the absence of water. In addition, magnesium and iron elements are essential for the production of chlorophyll. If they are in low supply, the rate of photosynthesis decreases because chlorophyll pigment is insufficient.

Activity 5.8: An experiment to verify that photosynthesis produces oxygen

Materials:

Test tube, 250 ml beaker, sodium hydrogen carbonate, filter funnel, pond weed, wooden splint, and a lighter

Procedure

1. Put the pond weed in a beaker containing water. Put one spatula of sodium hydrogen carbonate in the water. This serves as a source of carbon dioxide.
2. Put a plant under a funnel and collect the bubbles in an inverted test tube as shown in Figure 5.11.

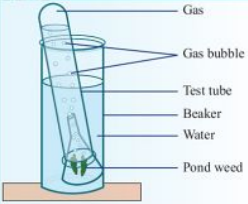

Figure 5.11: Experimental set-up to show that photosynthesis produces oxygen

3. Leave the set-up exposed to the sunlight for 6 hours.
4. Remove the test tube slowly, covering its mouth while it is still under water.
5. Open the test tube slightly but quickly and introduce a glowing splint. What do you observe?
6. Discuss what you have observed with your fellow group members.

Questions

(i) What did you observe when the experimental set-up was exposed to sunlight?

(ii) What did you observe when a glowing splint was introduced into the test tube?

(iii) Why did gas bubbles evolve from the bottom part of the experimental set-up?

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(iv) Name the gas that evolved from the experimental setup and give reason to support your answer.

(v) What conclusion can you make from this experiment?

The importance of photosynthesis

Photosynthesis is a vital process for the continuous survival of plants and other organisms on the earth. The food produced and stored in the form of starch and other organic substances as a result of photosynthesis is consumed by herbivores and omnivores. The herbivores in turn are the source of food to carnivores. Thus, photosynthesis plays an important role in food and energy conversion. It is also important in the production of oxygen gas, which is important in respiration. Furthermore, photosynthesis balances the amount of carbon dioxide produced by animals and various human activities. Therefore, photosynthetic plants act as a sink for carbon dioxide. The importance of photosynthesis is explained in detail in the following sections:

Production of oxygen

Photosynthesis produces oxygen. This replenishes the atmospheric oxygen that has been used during burning, respiration, rusting, and other processes. All aerobic organisms require oxygen for respiration.

Reduction of atmospheric carbon dioxide

The process of photosynthesis uses carbon dioxide from the atmosphere. Photosynthesis facilitates reduction of atmospheric carbon dioxide, since it is converted into carbohydrate in the presence of water, sunlight, and chlorophyll. Being a by-product of respiration, carbon dioxide is harmful if excessive amounts accumulate in the atmosphere. The accumulated carbon dioxide forms a layer which traps heat escaping from the earth's surface and reradiate it back to the earth's surface, thus causing global warming.

Conversion of solar energy into chemical energy

Photosynthesis converts sunlight energy from the sun into chemical energy. The sun is the primary source of all forms of energy used in life processes. This energy is used by plants as well as animals. It is made available to living things through photosynthesis. Animals obtain energy by feeding on plants or animals that eat plants. Thus, sunlight energy is converted into chemical energy that is stored in organic food molecules. The energy stored in organic food molecules is then released into the cells during respiration. This energy is used in life processes, such

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as movement, reproduction, sensitivity, growth, and excretion.

Production of fuel

Photosynthesis is a source of fuel. The remains of dead plants and animals decompose to form solid fossil fuels such as coal and liquid fossil fuel such as paraffin, petrol, and diesel. It is also the source of natural gas. Therefore, light energy produced by kerosene lamps or mechanical energy that is generated by the combustion of petrol or diesel originates from photosynthesis. Chemical energy from photosynthesis can also be obtained from plants in the form of firewood and charcoal.

Production of food

Photosynthesis produces food for the plants. Some animals such as cows, goats, and zebra depend directly on plants as their source of food. Such animals are called herbivores or plant-eaters. Other animals called carnivores such as lions, hyenas, and leopards feed directly on herbivores by killing and eating them. Animals such as human beings and monkeys depend on both plants and animals as their source of food, these are called omnivores. The food consumed by animals (heterotrophs) is the product of photosynthesis. Thus, heterotrophic animals depend either directly or indirectly on autotrophs as their source of food. Photosynthesis is therefore important for the lives of both plants and animals.

The extra food produced by plants is stored in various plant organs. The stored food is used by the plants during adverse conditions such as drought when the plant cannot synthesise adequate amounts of food. The underground storage organs of the plants are formed from modified stems, leaves or roots. The storage organs of plants become relatively large and fleshy in order to store large quantity of food. There are several types of underground storage organs such as bulbs, tubers, roots, corms, and rhizomes.

Bulb: This is an underground storage organ formed from the modification of the plant stem and leaves. An onion is an example of a bulb as shown in Figure 5.12.

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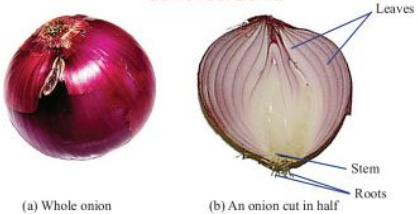

(a) Whole onion (b) An onion cut in half

Figure 5.12: Onion bulb

Tuber: This is a fleshy storage organ formed from either a stem or a root. Examples of stem tubers include Irish potato while the root tuber include sweet potato (See Figure 5.13). An Irish potato tuber is formed at the end of the underground stem. It can produce new shoots from the buds (eyes) on its skin. Sweet potatoes and cassava form tubers on their roots.

(a) Stem tuber (Irish potato) (b) Root tuber (sweet potato)

Figure 5.13: Tubers

Root tubers which are used solely as food storage organs are more or less permanent structures, and constantly replenish their reserves.

Taproot: Plants have three different types of root systems that are taproot, adventitious, and fibrous root systems. Taproot is the main root of the primary root system, which develops from the radicle of a germinating seed embryo. In many plants, the radicle dies just after maturation and the taproot develops a lateral fibrous or adventitious root system in the later stages of plant growth. Monocotyledonous plants have fibrous root system only while dicotyledonous plants have both taproot and adventitious root systems. The dicotyledonous plants have taproot as the main root system that becomes a thick, central, and dominant

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structure from which other roots (secondary and tertiary roots) continue to grow laterally. Some taproots are specialised for food storage such as carrot, sugar beet, and beetroot (See Figures 5.14).

(a) carrot (b) sugar beet (c) beetroot

Figure 5.14: Examples of taproots

Corm: This is an underground storage organ formed from the plant stem. It is a mass of solid tissues with a dry papery cover made of modified leaves. Examples of corms are yams, cocoyams and crocuses (See Figure 5.15).

(a) cocoyam (b) crocus

Figure 5.15: Structure of corms

Rhizome: A rhizome is a swollen underground stem, bearing leaves and roots, which grows horizontally on the surface or just below the surface. An example is ginger, as shown in Figure 5.16.

Figure 5.16: Ginger

Exercise 5.2

1. What are chloroplasts?
2. Explain the importance of chloroplasts in plants.
3. Draw a well labeled diagram of the internal structure of a leaf.
4. What are the roles of underground storage organs in plants?
5. Why are vascular bundles important in plants?
6. With examples, explain the importance of photosynthesis to living organisms.
7. Explain why it is not advisable to sleep in a room with a potted plant.

Chapter summary

1. Plants require both macroelements and microelements to survive.
2. The macroelements include nitrogen, phosphorus, potassium, sulphur, calcium, and magnesium.

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3. The microelements include boron, copper, iron, chlorine, manganese, molybdenum, and zinc.

4. Lack of the necessary elements affects growth and crop yields. However, excessive amounts also have negative effects. Plants should get minerals in adequate amounts.

5. Photosynthesis is the process by which green plants, some bacteria and some protoctists make their own food using carbon dioxide and water in the presence of sunlight.

6. Features of the leaf that make it well adapted to photosynthesis are:
   (a) a waxy transparent cuticle;
   (b) a thin epidermis with stomata;
   (c) palisade cells with chloroplasts;
   (d) palisade cells positioned just below the upper epidermis;
   (e) a spongy mesophyll with air space;
   (f) veins that have vascular tissue;
   (g) a broad flat lamina; and
   (h) a petiole to attach the leaf to the stem or branch at an appropriate angle to access sunlight.

7. Photosynthesis involves two stages, namely the light reaction stage and the dark reaction stage.

8. During the light stage, sunlight causes the production of ATP and splitting of water molecules into hydrogen and hydroxyl ions. This reaction is called photolysis.

9. In the dark reaction stage, carbon dioxide and hydrogen ions combine to form glucose. This reaction is called carbon dioxide fixation. Glucose is later used to make starch, proteins and lipids.

Revision exercise 5

Section A

Choose the correct answer.

1. Which of the following is NOT a type of an underground storage organ?
   (a) Bulb
   (b) Seed
   (c) Corm
   (d) Rhizome

2. The process by which plants and some bacteria use the energy from sunlight to produce glucose is called _____.
   (a) photolysis
   (b) hydrolysis
   (c) photosynthesis
   (d) plasmolysis

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3. Boron, copper, iron, chlorine, manganese, molybdenum and zinc are examples of_____.
   (a) microelements
   (b) macroelements
   (c) non-mineral elements
   (d) organic elements

4. NPK fertiliser contains all of the following elements, except _____.
   (a) potassium
   (b) phosphorus
   (c) nitrogen
   (d) sulphur

5. The part of a leaf that provides a large surface area for maximum absorption of sunlight and carbon dioxide is called_____.
   (a) petiole
   (b) stomata
   (c) lamina
   (d) apex

6. Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.
   (a) The leaf is not the main site of photosynthesis in plants.
   (b) Essential elements are necessary for plants' growth, development, and reproduction.
   (c) Carbon, oxygen, hydrogen, and nitrogen are non-minerals.
   (d) *Rhizobium* bacteria helps to fix nitrogen from the air into the soil.
   (e) Microelements are needed by plants in large quantities.
   (f) Copper is an example of a trace element.
   (g) Lamina is the external part of a leaf while midrib is the internal part.
   (h) A bulb is an underground storage organ formed from the plant roots.
   (i) Sunlight energy is not needed during photosynthesis.
   (j) Unlike heterotrophs, autotrophs make their own food in the form of carbohydrates.

Section B

7. Briefly explain the following:
   (a) carbon dioxide fixation;
   (b) photosynthesis;
   (c) palisade mesophyll; and
   (d) photolysis.

8. Differentiate the light reaction stage from dark or light independent reaction stage of photosynthesis.

9. Briefly answer the following questions.

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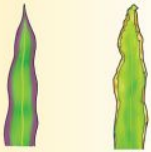
(a) Mention any two sources of sulphur in plants.
(b) Give any two signs of sulphur deficiency in plants.
(c) List down at least three functions of sulphur in plants.
(d) Why should a leaf be boiled in alcohol when testing for starch?
(e) List down the necessary conditions for photosynthesis.

10. Study the following diagrams which show two plant leaves and then answer the questions that follow:



(a) (b)

(a) For each of the signs shown in figures (a) and (b) above, name the microelement that is in limited supply.

(b) Outline the effects of excessive amounts of the macroelement stated in 10 (a) above.

11. An agricultural officer advised a farmer to apply fertiliser on his farm that contains nitrogen, phosphorous and potassium (NPK). Which signs were shown by plants that led the agricultural officer to give such advice to the farmer?

12. Describe how a plant leaf is adapted to photosynthesis.

13. Why is photosynthesis a vital process for all living organisms?

14. Why is it necessary to destarch a leaf in an experiment of investigating the importance of photosynthesis?

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Chapter Six

Food processing, preservation, and storage

Introduction

Proper methods of processing, preservation and storage are required to prevent contamination and spoilage of food. In this chapter, you will learn about the concept, importance, and methods of food processing, preservation and storage. You will also learn about the advantages and disadvantages of traditional and modern methods of processing, preserving, and storing food. The competencies developed from this chapter will enable you to use proper ways of processing, preserving and storing different kinds of food, hence, improving food safety, and human health.

Food processing

Food processing refers to the process in which food is transformed into different forms in order to make it edible, tasty, and safe for long time storage. It involves physical and chemical processes like pickling, sorting, peeling, washing, baking, grilling, grinding, drying, smoking and frying. Examples of food processing include making cheese from milk, or sugar from sugar cane. The common methods or techniques used in food processing include:

(i) removing unwanted outer layers for example peeling potatoes and cassava;

(ii) chopping or slicing for example bananas, mangoes and cassava;

(iii) liquefaction for example extraction of juice from fruits by squeezing;

(iv) fermentation for example making wine from bananas and grapes, and brewing beer from grains; and

(v) cooking including boiling, frying, steaming, grilling and baking.

Food preservation

This is a process of treating and handling food to prevent it from spoilage while maintaining their nutritional value, texture, flavour, and

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aroma for a long time. It involves delaying or preventing the growth of micro-organisms including bacteria and fungi on food.

Food preservation involves various special methods of food processing which include:

(i) canning or bottling: This process involves application of heat in foods to kill micro-organisms. It also involves sterilisation to avoid loss of nutrients such as vitamin C. Then foods are preserved in containers by removing oxygen through an airtight seal in order to prolong the food shelf life. Likewise, the process involves addition of acid, sugar or salt as preservatives to create unfavourable environment for the growth of micro-organisms such as bacteria;

(ii) pasteurisation and boiling: These involve the use of high temperature to kill micro-organisms that cause spoilage, for example ultra heated treated products such as packet milk;

(iii) refrigeration: This involves using very low temperatures to slow down the growth of micro-organisms;

(iv) irradiation: This involves using radiation such as gamma rays to kill micro-organisms that cause food spoilage;

(v) drying, smoking and using honey: These methods are used to remove moisture and limit the growth of micro-organisms; and

(vi) addition of salt, sugar, acid, or carbon dioxide: These methods are used to prevent food spoilage and physical changes in food.

Food storage

Food storage refers to the methods that are used to reserve food for future use. Food storage can be done on a small-scale basis at the family level, for example by using granaries or food store. Similarly, it can be done in a large-scale for large populations, for example in the grain storage towers (silos) and warehouses.

Activity 6.1: Investigation of various methods of food processing, preservation, and storage

Materials: A notebook and pen or pencil

Procedure

1. Visit places such as shops, markets, and small industries where foods are processed, preserved, and stored in your community.
2. Observe the methods used to process, preserve, and store food. Ask questions where you do not understand. Take notes in your notebook.

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3. When you get back to school, discuss with your group members about the food processing, preservation, and storage methods that you observed. What are their advantages and disadvantages?
4. Present your findings to the rest of the class.

The importance of food processing, preservation, and storage

Food processing, preservation, and storage are important because they prevent wastage of food; save money by preventing spoilage of food; and they maintain the quality of food. Food processing, preservation, and storage also prevent the growth of micro-organisms that can cause illness. Additionaly, they improve the flavour of food, and remove harmful toxins and micro-organisms from food. Food processing makes food available even when they are not in season. It also enables transportation of delicate and perishable foods such as milk and fruits over long distances. Therefore, food processing, preservation, and storage decrease wastage of food to ensure a continuous food supply.

Disadvantages of food processing, preservation and storage

Poor methods of food processing, preservation, and storage can affect its nutritional quality. For example, polishing of cereals affects their nutritional quality. Eating unpolished cereals is better than eating the polished ones. The polished cereals lose most of the important nutrients. In addition, improper food processing, preservation, and storage can cause food poisoning such as aflatoxin due to fungal infection. Fungi tend to grow on food such as maize, nuts, and spices when they have moisture and are not well preserved and stored. Eating food infected by fungi can lead to severe health problems. Fungal infections can spread to the brain, heart, kidneys, and blood vessels and may affect most of the body systems. Likewise, some pesticides used for preserving food such as grains are harmful to human beings. Furthermore, food processing, preservation, and storage can change the flavour of food.

Methods of food processing, preservation, and storage

Food can be processed, preserved or stored either in traditional or modern ways.

Traditional methods of food processing and preservation

Food can be processed and preserved by various methods including the following:

Curing

Curing is a method that involves the addition of substances such as salt, sugar, spices, and vinegar to animal products, mostly meat and fish. Curing binds or removes water from the food, making it unsuitable for the growth of micro-organisms. Therefore, it makes the food stay longer. It also improves

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the taste of food. Sausages, bacon, and corned beef are made by curing meat.

Drying in the sun

This method is used to preserve food and spices like rice, maize, cloves, bananas, beans, peas, lentils, meat, fish, cassava, and green leafy vegetables. Figure 6.1 shows the drying of cloves. During drying, the food is left in the sunlight for a long period of time in order to reduce its moisture content. Reducing the amount of moisture in the food limits the growth of micro-organisms. Some foods such as bananas and cassava are cut into small pieces to speed up drying. Dried grain or cassava can be pounded into flour.

Figure 6.1: Drying cloves in the sun

Smoking

Smoking is the process of preserving food by exposing it to smoke from burning or smoldering materials as shown in Figure 6.2. This reduces the moisture content of food to prevent growth of micro-organisms that can spoil the food. Grains, meat and fish can be dried slowly by smoking.

Figure 6.2: Drying fish by smoking

Cooking

Cooking includes boiling, deep frying, steaming, baking in hot ash, grilling, and roasting. These processes help to kill micro-organisms, soften food, improve flavours, and preserve food. For example, potatoes, green bananas and maize can be boiled before drying. Meat can be boiled, grilled, or deep-fried.

Salting

Salting is the addition of salt to food. Salt removes water from the food and kills micro- organisms that would spoil the food. Meat and fish are some of the foods that can be preserved by salting. It is advised to avoid using too much salt in food as it can cause diseases such as hypertension.

Fermentation

Fermentation is the conversion of carbohydrates, such as sugars into an alcohol or acid. Fermentation can occur naturally or can be induced artificially. Milk can be fermented into yoghurt by keeping it in a container for some time. Pickling foods such as cucumbers and

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mangoes can be done by putting them in salty water with vinegar. After some time, bacteria produce lactic acid that gives the food its distinctive flavour and helps to preserve it.

Modern methods of food processing and preservation

Modern methods of food processing and preservation include the following:

Pasteurisation

This involves heating food to moderate temperature usually less than 100°C for a short time in order to kill micro-organisms that can spoil it. Pasteurisation maintains the nutrient content and flavour of food. Examples of foods that can be pasteurised are fresh milk and fruit juice.

Liquefaction

This method involves production of liquids from solid foods. It is mostly applied to fruits in making juice. The juice is then pasteurised and stored in cans or containers.

Canning and bottling

In this method, food is preserved by heating it in airtight vacuum-sealed containers or bottles. The container is filled with food then the air is pumped out to create a vacuum. The container is sealed, and then heated and sterilised for killing micro-organisms, denaturing enzymes, and to avoid loss of nutrients such as vitamin C. Foods that can be bottled or canned include beef, fish, fruit juices, baked beans, and fruits such as tomatoes. Bottled and canned foods can be kept for months or even years.

Using additives

Chemicals such as sodium benzoate, sodium chloride and vinegar are added to the food to slow down the growth of micro-organisms. This is commonly used to preserve fruit juice, fish, and meat.

Drying

Food is dried using either hot blasts of air from a vacuum dryer or a freezer (freeze drying) (See Figure 6.3). After drying, the food is then sealed in moisture-proof containers.

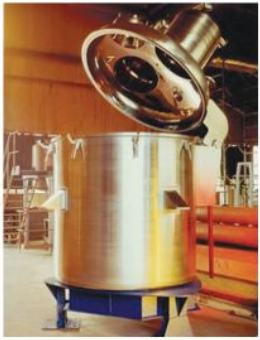

Figure 6.3: Vacuum dryer

Irradiation: Irradiation is the process in which energy rays are used to stop growth of micro-organisms in stored foodstuffs such as onions, beans, and

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potatoes. This makes food last longer. Irradition also prevents sprouting in onions and potatoes.

Traditional methods of food storage

Food is stored traditionally using the following ways:

Storage in granaries and pits

Dry grains are stored in granaries that are usually raised above the ground as shown in Figure 6.4. Raised granaries help to keep the stored food away from mice and other animals. The grains are sometimes mixed with neem leaf ash or groundnut oil for pests control. Granaries keep grains safe from pests, rodents and birds. Harvested yams, potatoes and cassava can be stored in large pits in the ground after drying.

Storage in pots and tins

Processed food such as flour, dried vegetables, and cassava can be stored in large dry pots or tins and tightly covered for future use. Through this method, foods can be stored for months without losing their quality.

Modern methods of food storage

Food may be stored by using modern methods. Modern methods of storing food include the following:

Refrigeration

Refrigeration is a temporary storage of food at low temperatures of up to 4°C in order to slow down the growth of micro-organisms. Refrigeration can be done in refrigerators or cold rooms. Examples of foods that can be refrigerated include

Figure 6.4: Traditional granary

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milk, fresh fruits, vegetables, juice, and butter.

Freezing

Freezing involves storing food at very low temperatures (below –10°C) in order to stop the growth of micro-organisms. Food is frozen in freezers. Foods that can be frozen include fish and various types of meat such as poultry meat and beef.

Storage in special bags (hermetic bags)

Hermetic bags are special plastic sacks for storing grains. They are made up of materials which block air passage hence restrict pests to destroy grains.

Advantages of traditional methods of food processing, preservation, and storage

(i) They are simple and can be applied by most people.

(ii) They use locally available materials and simple technology, hence low cost.

(iii) No harmful chemicals are added to the food.

(iv) They add a distinct flavor to the food, especially through curing and smoking.

(v) Most methods do not destroy nutrients.

(vi) The methods are relatively cheap and do not require skilled personnel.

Disadvantages of traditional methods of food processing, preservation, and storage

(i) Food can be preserved and stored for only limited periods of time.

(ii) Traditional methods are mostly manual, therefore, difficult to carry out on a large-scale.

(iii) The methods are highly limited to some foods that can be processed, preserved and stored. Therefore, not all foods can be preserved and stored using these methods.

(iv) Food can be contaminated by microbes if stored for a long period.

Advantages of modern methods of food processing, preservation, and storage

(i) Food can last for a long period of time.

(ii) Modern methods can process, preserve and store a wide variety of foods.

(iii) The advanced technology used is fast and can handle large quantities of foods.

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Disadvantages of modern methods of food processing, preservation, and storage

(i) Chemicals used as additives can be harmful if eaten in excess.

(ii) The advanced technology involved can only be used in certain areas. For example, refrigeration and freezing are used in areas with electric supply.

(iii) The processes used require special techniques, for example irradiation, canning, and pasteurising.

(iv) Sometimes nutrients are lost in the process, thus, lowering the nutritional value of food.

(v) The methods are costly and some need a highly skilled personnel.

Activity 6.2: Comparison of traditional and modern methods of food processing, preservation, and storage

Materials:
Texts and pictures of traditional and modern methods of food processing, preservation, and storage, pen or pencil, and notebook

Procedure

1. Study the provided pictures and read the texts on the methods of food processing, storage, and preservation.
2. In groups, use the provided pictures to identify and explain the methods of food processing, preservation, and storage that you use at home.
3. Discuss the following with your group members:
   (a) the advantages and disadvantages of each method ; and
   (b) the differences between modern and traditional methods of food processing, preservation, and storage.
4. Write down your points and present them in the class.

Chapter summary

1. Food processing refers to methods of treating food to make it edible, tasty, and safe; or to keep it fresh for a long period of time.
2. Food preservation refers to the methods used to prevent food from losing its quality.
3. Food storage is keeping food safe for future use.
4. Traditional methods of food processing, preservation, and storage include curing, drying, smoking, cooking, and storing in granaries or pits.

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5. Modern methods of food processing, preservation and storage include refrigeration, freezing, pasteurisation, canning, bottling, using additives, dehydration, and irradiation.

Remember

Read labels of all preserved and stored food.

Read the expiry date before consumption.

Read the ingredients in the packed food before consumption.

Do not treat spoiled food for consumption.

Revision exercise 6

Section A

Choose the correct answer.

1. Which among the following is a modern method of food processing?
   (a) Canning
   (b) Curing
   (c) Drying
   (d) Smoking

2. Transformation of animal products, vegetables, or marine foods into tasty, nutritious and safe food products is called _____.
   (a) canning
   (b) food storage
   (c) drying
   (d) food processing

3. The process of protecting food substance from spoilage is called_____.
   (a) storage
   (b) canning
   (c) irradiation
   (d) preservation.

4. The method of removing moisture from food is called_____
   (a) irradiation
   (b) smoking
   (c) freezing
   (d) canning

5. Which of the following is NOT preserved by drying?
   (a) Amaranthus
   (b) Fish
   (c) Oranges
   (d) Cassava

6. Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.
   (a) Sodium benzoate, sodium chloride and vinegar slow down the growth of micro-organisms.
   (b) Modern methods can be used to preserve and store food for only limited periods of time.

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(c) Curing, drying and smoking are examples of traditional methods of food storage and preservation.

(d) Canning involves heating, sealing and sterilisation.

Section B

7. Distinguish between:
   (a) food preservation and food storage;
   (b) refrigeration and freezing; and
   (c) curing and smoking.

8. Explain how the following methods help in preserving food:
   (a) smoking;
   (b) pasteurisation; and
   (c) using additives.

9. Your brother who is a fisherman caught many fish. Some fish were sold, others were given to friends and neighbours, and some remained. What would you advise him in order to preserve the remained fish, bearing in mind that there is no electricity in his area?

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Chapter Seven

Balance of nature

Introduction

Balance of nature is a state of equilibrium in nature resulting from constant interaction among living things and the non-living things in the environment. The change of any element in the natural environment disturbs the entire equilibrium. The balance of nature is maintained by adaptation, competition, and other interactions between organisms and their environment. In this chapter, you will learn about natural environment and its importance, biotic and abiotic components of the environment, and how they interact. You will also learn about interaction of organisms among themselves and with their natural environment, the concept of food chain and food web, as well as their significance in the ecosystem. You will further learn about the differences between a food chain and a food web. The competencies developed from this chapter will enable you to protect the environment, so as to ensure the balance of nature.

The natural environment

The environment can either be artificial or natural. The artificial environment is man-made. This includes environments such as dams, parks, and zoos. On the other hand the natural environment is made up of all living and non-living things that occur naturally on earth as shown in Figure 7.1. For example, non-living things in the natural environment include air, water, rocks, soil, nutrients, cloud cover, and sunlight. The living things in natural environments include organisms like animals, plants, and micro-organisms such as bacteria and some fungi. The study of the interactions between organisms and their environment is called ecology.

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Figure 7.1: Natural environment

The living things are constantly interacting with each other and with the non-living things to bring about a balance of nature in the environment. Balance of nature is a stable condition in which natural communities of animals, plants, and other organisms are maintained. The balance of nature is maintained through interactions among organisms such as cooperation, competition, predation, parasitism, as well as interactions between organisms and their environment. The change of any component in the natural environment can negatively disturb the entire equilibrium. For example, plants interact with the soil to obtain water and nutrients. They also get light and air from their surrounding environment. Various animals depend on plants as their source of food. In addition, bacteria and fungi decompose organic matter of the dead plants and animals to obtain their food while releasing nutrients to the soil. The released nutrients are absorbed by plants which use them for growth. In this process the nutrients previously locked in plant and animal bodies are recycled. Disturbances such as fire in the environment can kill the bacteria and fungi found in the soil and disrupt the entire nutrient recycling accomplished by these micro-organisms. The fire can also burn plants, leading to shortage of food to animals that feed on them. These animals can die and result to disruption of balance of nature.

In addition, plants produce oxygen gas that is used by animals for respiration. The removal of plants from the environment lowers the oxygen supply. Plants also regulate concentration of harmful gases such as carbon dioxide released in the environment by human activities. If plants are removed from the environment, the concentration of carbon dioxide in the atmosphere will increase and cause greenhouse effect and hence global warming. The balance of nature is therefore important in conserving the environment.

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Components of the natural environment

The natural environment includes living things and non-living things. The living things collectively make up the biotic component of the environment. The biotic component therefore includes all living organisms such as plants, animals, bacteria, and fungi that are found in the environment. The non-living component of the environment is called abiotic component. The abiotic component constitutes non-living things that include rocks, soil, air, water, and other factors like weather and climate. Both the biotic and abiotic components constitute the environment in which the organisms live. Organisms in the natural environment can be of the same or different species. Organisms of the same species living in a particular environment are referred to as a population. A group of different interdependent populations living together and interacting among themselves is called a community. Therefore, a community may contain several populations of plants, animals, and decomposers.

Activity 7.1: Observation of the components of the natural environment

Materials:
An exercise book and pen or pencil

Procedure

1. Carry out a study tour around your school compound.
2. Identify and record the components of the natural environment around the school.
3. Group the recorded components into two categories of biotic and abiotic components.
4. Compare your lists with those from other students. Are they similar?
5. Discuss with your classmates about biotic and abiotic components of the natural environment around the school.

Importance of the natural environment

Environment is a complete range of external conditions in which an organism lives. The natural environment is important because it provides food, shelter, and security for organisms. It also provides an appropriate setting for organisms to reproduce and increase in number. In addition, the natural environment provides space for living and non-living things to interact. For example, the natural environment provides needs to animals including human beings. Such needs to human beings include water, minerals, clean air, and herbal medicines for treating various diseases. In the natural environment, oxygen is produced by green plants and other

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autotrophs. The oxygen produced is vital for most organisms. The natural environment also regulates harmful gases released to the environment by human activities.

Interaction among components of the environment

Organisms interact with environmental factors such as air, temperature, water, oxygen, rainfall, humidity, and light intensity. Besides interacting with factors of the environment, organisms interact with each other. Organisms are therefore, part of the environmental factors. Environmental factors can be divided into two major groups, namely biotic factors and abiotic factors. Biotic factors interact with abiotic factors in the environment. For example, plants manufacture their own food through photosynthesis. In this process they use abiotic components which are light, carbon dioxide, and water for photosynthesis. Abiotic factors can therefore affect organisms in many ways including distribution, numbers, chances of survival, and their population size.

The interaction between biotic and abiotic components of the environment and among the biotic component form an ecosystem. An ecosystem refers to a natural unit made up of living and non-living things whose interaction leads to a self-sustaining system. An ecosystem is made up of communities of plants, animals and micro-organisms. In the ecosystem, communities constitute the biotic environment while the non-living part constitutes the abiotic environment. For example, a pond constitutes an ecosystem in which fish, snails, plants and micro-organisms make up the biotic components of such environment. In this ecosystem, sunlight, temperature, oxygen, nutrients in soil and water make up the abiotic components of the environment.

Similarly, in a grassland ecosystem, plants obtain nutrients and water from the soil. They also use carbon dioxide and light energy in producing their food. Herbivores animals feed on plants. Carnivores feed on the herbivores while bacteria and fungi feed on dead organic matter both from plants and animals. The bacteria and fungi are collectively called decomposers because they break down the remains of the dead organisms and cause them to decay. The decaying process is also called decomposition.

Biotic factors

Biotic factors refer to living components of the environment. This

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living component consists of organisms that influence the environment as they interact with each other. The interaction can be either among members of the same population or different populations. Usually, organisms interact with each other and their environment in order to obtain food, grow, and reproduce.

An animal can hunt, kill and eat another living animal of different species. An organism that feeds on the other is called a predator and the one which is eaten by a predator is called a prey. For example, lions kill antelopes for food and chameleons kill insects for food. The lions and chameleons are the predators and the antelopes and insects in this case are the preys. This type of interaction is called predator-prey relationship. In order to survive, predators must adapt themselves to catch their prey. A prey also needs to adapt in order to avoid being eaten by predators. One of the adaptations used by the prey to avoid being seen by the predator is camouflage. Camouflage refers to the mechanism by which an organism blends with its physical surroundings. In doing so, the camouflaging organism can hide itself in order to avoid predators. Chameleons and stick insects shown in Figure 7.2 are examples of organisms that do camouflage to avoid predators.

(a) Chameleon

(b) Stick insect

Figure 7.2: Camouflage in chameleon and stick insect

Parasites live on or inside another organism called a host. The parasites which live inside the host body are called endoparasites. Those which live on the host body are called ectoparasites. Some parasites cannot live without the host. These are called obligate parasites. The survival of parasites therefore depends on their hosts. Parasites get nutrients and shelter from their hosts. On the other

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hand some parasites called facultative parasites can survive without the host but sometimes live as parasites. Both hosts and parasites have to develop mechanisms that will ensure their survival.

Plants growing close to each other can compete for light and minerals. When plants grow very close to each other, they become slender, weak, and tall so that each can get maximum light for photosynthesis. Those which are not able to compete will usually die or become stunted. The plants capable of outcompeting others will grow fast, reproduce, spread, and dominate the environment. That is why crops such as maize, rice and coffee have to be planted at a certain distance apart to avoid or reduce competition for light, water and mineral salts. Also, weeding removes other plants which may compete with the crops for light, nutrients, and other resources.

Abiotic factors

These are the non-living components. They include chemical and physical factors of the environment that affect the living organisms. Such abiotic factors may include temperature, sunlight, wind, water, salinity, wave action, altitude, relief, humidity, coral reef, and soil.

Temperature

This is the degree of hotness or coldness of a place, object, or body. Temperature has influence on the distribution of organisms because it determines the physical state of water. Some organisms have no ability to live in conditions in which the temperature is below 0°C or above 45°C. Organisms adapt to the temperature in their habitats in various ways. For example, some plants shed their leaves or roll them when the temperature is too high and evaporation is excessive. This minimise leaf surface area directly exposed to sunlight in order to avoid excessive loss of water. Animals such as polar bears which live in very cold places have a thick fat layer below their skin for insulation to prevent heat loss and therefore help to maintain their body temperature.

Light

Light from the sun affects different processes in plants such as germination, opening of stomata and flowering. Light energy is important during photosynthesis. It also affects the behavior of organisms. For example, some animals such as hawks hunt in bright daylight; lions hunt at dusk or dawn when there is dim light; while animals such as owls and bats hunt at night. Light also has an effect on the distribution of plants. Most plants

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require bright light while others are adapted to live in shady areas.

Wind

This is moving air. It affects organisms in various ways. Wind increases the rate of evaporation in water bodies as well as from the bodies of living organisms. Plant leaves lose water in the form of vapour during the day and lose more water when the weather is windy. Wind is also important in rain formation, pollination, and dispersal of some plant seeds.

Water

It serves as a habitat for a variety of organisms. It also serves as a solvent, a medium of transportation, and as temperature regulator. Water is found in the form of ice, liquid, or as water vapour in the atmosphere. Water collects in the environment and flows via streams and rivers to form water bodies such as oceans, lakes, and ponds.

Salinity

This is the concentration of dissolved salt in water. Most plants will not survive in soil or water that contains a high concentration of salt. Few plants such as mangroves are adapted to live in salt water (saline water) by having special structures which help them to get rid of excess salt. Some aquatic organisms are adapted to live in freshwater while others such as sea grasses live in salt water.

Wave action

This causes movement of water in oceans and seas. The waves are caused by wind blowing over the water surface of the ocean or lakes. Wave action is important for organisms that live in the shores. As the wind blows over the ocean, it causes waves, which move towards the shores aided by wind as swash. The waves usually run back as backwash. The organisms which live on the shores are covered by water during the swash and exposed again to air during the backwash. A similar situation occurs to organisms that live in an intertidal zone during low and high tides. These organisms are covered by water during high tide and exposed to air during low tide. Examples of such organisms include seaweeds, crabs, clams, oysters, snails, and polychaetes.

Altitude

This is the elevation above sea level. At high altitudes, atmospheric pressure, temperature, and oxygen concentrations are generally low. This affects distribution of both plants and animals. For example, at the foothill of high mountains like Kilimanjaro in Tanzania, living organisms such as plants are abundant and form a forest. The forest decreases progressively uphill forming grassland and ultimately alpine desert at the peak as seen in Figure 7.3. At the top of the mountain, there are very few plants or animals because it is very cold and oxygen level is very low.

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Figure 7.3: Distribution of plants in higher attitudes

Relief

It refers to the variations in elevation and slope of an area of the land that is how steep, gentle, or flat the land is, as shown in Figure 7.4.

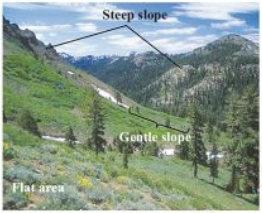

Figure 7.4: Slope

Soil erosion is more prominent on the steep slope, moderate on the gentle slope, and low on flat terrain. The eroded soils tend to accumulate on the flat land leading to formation of deep fertile soils needed for plant growth. Soils on steep slopes are usually shallow due to repeated erosion, hence, they are not fertile. The flat hill tops as in most plateaus have relatively well developed soils because the rate of erosion is low. This condition is more favourable for plant growth.

Humidity

This refers to the amount of water vapour in the atmosphere. Humidity affects the rate at which water evaporates from the surface of organisms such as through transpiration or sweating. This in turn affects the distribution of organisms on the earth because some plants prefer humid areas while others are adapted to thrive in dry environments.

Coral reefs

These are large underwater structures composed of skeletons of marine invertebrates called corals. Coral reefs are made up of large calcium carbonate rocks formed from deposition of skeletons of the corals. Coral reefs support animal and plant life under water by providing food and habitat to a variety of marine life including fishes. The coral reef also affects the distribution of marine organisms.

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Soil

This is another abiotic factor which greatly affects plants and other organisms living on or in it. Soil is the thin upper layer of the earths' crust which support plants growth. It includes attributes such as soil texture, soil composition, soil pH, and soil's parental material.

Soil texture: This refers to the coarseness or fineness of soil particles. The size of particles determines the type of soil, namely sand, silt, and clay, as shown in Figure 7.5.

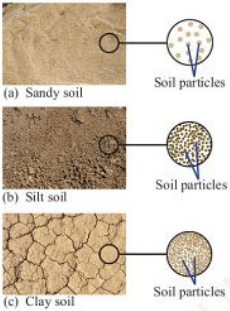

Figure 7.5: Types of soil

Clay soil particles are relatively very small compared to sand soil particles. Silt soil particles are relatively medium sized. Soil which has approximately equal proportion of clay, silt, and sand is called loam. Loam soil is preferred by most plants. Soil texture affects water infiltration and retention. It also determines the amount of air and nutrients in the soil. Soil with large particles such as sand cannot retain water for plant growth for a long time, but it is well aerated. Clay soils have very small particles. They are usually waterlogged and hence not well aerated. Waterlogging is a condition whereby all air spaces in the soil are completely filled with water. Loam soils have optimal water holding capacity and are well aerated and fertile. These factors together influence the distribution of plants and soil-dwelling animals such as earthworms, insects, and burrowing animals.

Most plants will not survive in clay soil because it holds water for a long time, thus causing waterlogging. As such, plants cannot get air and therefore die. Sandy soil does not hold water. Therefore, most plants do not survive in sandy soil due to lack of water. Most plants grow in loam soil because of its capacity to hold adequate amounts of air and water. Some plants such as paddy are adapted to thrive well in clay soil while others such as sweet potatoes are adapted to thrive in sand soil.

Soil composition: This is the proportion of the components of soil, including mineral salts, air, micro-organisms, water, and remains of living things. These components affect soil fertility and hence plant growth. Most plants grow well in soils with required proportions of mineral salts, air, and water for plant growth. For example, deserts which have infertile soils have scattered vegetation.

Soil pH: This is the degree of acidity or alkalinity of soil. Different types

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of plants grow in soil with different pH values. For example, tomatoes and pineapples grow in slightly acidic soils, while onions and cabbages prefer slightly alkaline soils. This is because soil pH determines availability of some nutrients in the soil. Some nutrients can be available in acidic soil that is low pH while others are more available in soils with high pH which are alkaline.

Soil's parental material: This refers to the various types of rocks that disintegrate to form soil in an area. The chemical composition of soil is determined by the chemical composition of the underlying or deposited parent rock. The soil pH and fertility are greatly determined by the composition of the parent rock.

Importance of the interaction among the components of the natural environment

The interaction of biotic and abiotic components of the environment is important for the natural cycles such as the water cycle, the carbon cycle, and the nitrogen cycle. Also, it is through these interactions that the living organisms obtain their food, grow, and reproduce. In addition, the interaction of biotic and abiotic components ultimately sustains stability and existence of ecosystems.

Water cycle

Water cycle is also known as hydrological cycle. It refers to how water circulates in the environment. Movement of water in the environment occurs as shown in Figure 7.6.

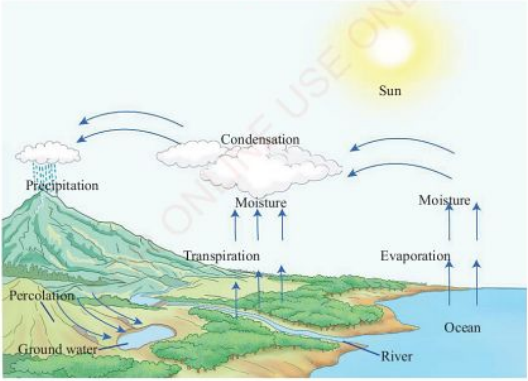

Figure 7. 6: Water cycle

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The water cycle involves the following stages:

(i) water from the ground and run-off (for example water from rain and snowmelt) flows into streams and rivers;

(ii) the streams and rivers flow into lakes and oceans;

(iii) water from water bodies such as oceans, lakes, ponds, and rivers evaporates into the atmosphere. Similarly, water from plants evaporates to the atmosphere through transpiration to form water vapour;

(iv) water evaporating from water bodies is discharged to the atmosphere, and condenses to form clouds;

(v) wind causes clouds to move in the atmosphere above the ocean and move further inland;

(vi) as condensation continues, the air in the atmosphere becomes saturated to the extent that it cannot hold more moisture. The clouds become large and too heavy to be moved by wind; and

(vii) therefore, clouds start to precipitate and fall in drops to the ground and water bodies as rain or snow. Some water is absorbed by plants and some flows into water bodies and the cycle begins again.

Forests act as water catchment areas and prevent excess loss of water from the land. Wetlands, such as swamps and marshes, help to control flooding and are also important for water purification

The carbon cycle

Carbon cycle refers to a biogeochemical cycle in the environment whereby carbon compounds are interchanged between different reservoirs of the earth as shown in Figure 7.7.

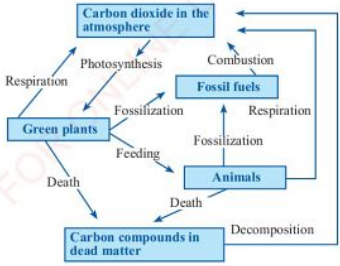

Figure 7.7: Carbon cycle

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Carbon dioxide from the atmosphere is absorbed by plants and used for photosynthesis. These plants serve as food for herbivores whereby the herbivores are eaten by carnivores. The carbon from plants is therefore incorporated into herbivores and later carnivores through feeding relationships. When plants and animals die, they are decomposed by micro-organisms such as bacteria and fungi. The decomposing bodies release carbon dioxide gas into the atmosphere during decomposition. The remains of plants and animals accumulate and after millions of years results in the formation of fossil fuels such as coal, natural gas, and oil. When these fuels are burnt, they release carbon dioxide into the atmosphere. Respiration by living things also releases carbon dioxide into the atmosphere. The carbon dioxide is absorbed again by plants and then the cycle starts over again.

The nitrogen cycle

Nitrogen cycle refers to a biochemical cycle in the environment whereby nitrogen is converted in many forms and moves through living and non-living things including atmosphere, soil, water, plants, animals, and bacteria. Nitrogen makes up approximately 78% of air in the atmosphere. However, most plants and all animals cannot absorb it in this form. It must first be converted into either nitrates or ammonium compounds by nitrogen fixing bacteria and blue green algae. Figure 7.8 shows the nitrogen cycle.

The nitrogen cycle involves the following processes:

(i) lightning converts atmospheric nitrogen into nitrates;

(ii) nitrogen-fixing bacteria in the soil and in root nodules of legumes carry out nitrogen fixation by converting atmospheric nitrogen to nitrates;

(iii) plants absorb nitrate (nitrogen compounds) and use it to produce plant proteins;

(iv) the nitrogen contained in plant tissues is consumed by animals when they feed on plants;

(v) animals use nitrogen obtained from plants to produce their proteins;

(vi) when plants and animals die, decomposers such as bacteria and fungi feed on them. The decomposers release ammonia gas (NH_3) which contains nitrogen. The ammonia is converted by bacteria first into nitrites and then into nitrates; and

(vii) denitrifying bacteria release nitrogen from nitrates back into the atmosphere and the cycle starts over again.

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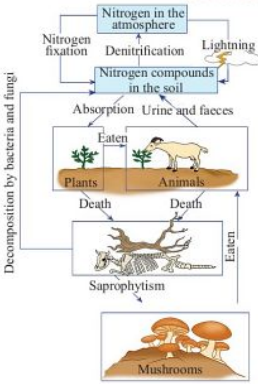

Figure 7.8: Nitrogen cycle

Exercise 7.1

1. Define the term natural environment.
2. Explain at least five importance of natural environment.
3. Explain the two main components of the natural environment.
4. Why is the interaction among the components of natural environment important?
5. Describe three examples of natural cycles.

Interaction among living organisms

The relationship among organisms in the environment can be explained in the form of predation, competition, and symbiosis. Symbiosis can be in a form of mutualism, commensalism, neutralism, parasitism, synnecrosis, and amensalism.

Predation

This is the relationship in which one organism captures, kills and feeds on another in order to get nutrients. For example, cats eat mice and sharks eat smaller fish.

Competition

This is a feeding relationship whereby two organisms both struggle for the same limited environmental resources for survival. For example, lions and leopards both hunt antelopes and zebras. Hence, lions and leopards are competitors (interspecific competition). Organisms from the same species can also be competitors (intraspecific competition), for example cows competing for grasses. Plants can also compete for nutrients and other resources such as light and water.

Symbiosis

This is a relationship involving a close association between two organisms of different species. In some symbiotic relationships, one of the species can benefit from the other without harming it or by causing harm or death to

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it. In other symbiotic relationships both organisms can benefit from the association. Therefore, symbiosis could take various forms, such as mutualism, commensalism, neutralism, parasitism, synnecrosis, and amensalism.

Mutualism

This is a relationship in which two organisms benefit from each other. For example, the rhizobium bacteria in the root nodules of legumes convert nitrogen into nitrates for use by the plant. The bacteria in turn get protection and nutrients from the plant.

Commensalism

This is a realationship in which only one organism benefits but it does not cause any harm to the host. For example, when a bird builds a nest on a tree. The bird benefits but the tree neither benefits nor loses.

Neutralism

This is lack of interaction between two organisms. It is mostly used to refer to a relationship in which two types of organisms get neither benefits nor harm from each other. An example is gazelle and wildebeest in Tanzania's National Parks.

Parasitism

In this association one organism benefits while the other is harmed. An example is the plasmodium parasite that causes malaria in human beings or a tick, which feeds on blood from a cow or goat.

Synnecrosis

Synnecrosis is a parasitic relationship between two living organisms, which results in death of one or both of them. It is usually short-lived and rare in nature. An example of organisms in this relationship includes plasmodium parasite, which causes malaria in humans. In plants synnecrosis can be exemplified by *Cassytha filiformis* shown in Figure 7.9, which is a parasitic plant that grows and feeds on other plants such as orange and mango trees. In both cases the parasite can cause death of the host (human, orange, and mango trees). Once the host is dead the parasite also dies.

Figure 7.9: Example of synnecrosis

Amensalism

This interaction is harmful to one species and neutral to the other organism. An example is the black walnut tree which secretes juglone, a chemical that kills some neighbouring plants.

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Activity 7.2: Investigation of the interactions among the living organisms with their environment

Materials:
Note book and pen or pencil

Procedure

1. Work in a group of five students.
2. Survey your school surroundings and identify types of organisms found in it.
3. Record and describe interactions which you think occur among the different identified organisms from the school surroundings.
4. Explain ways in which the identified organisms interact with the non-living components of the environment.
5. Present your findings during further class discussions.

Questions

(i) What are the common biotic components in your school surroundings?

(ii) What are the common abiotic components in your school surroundings?

Food chains and food webs

Food chains and food webs are diagrammatic representations, which show the flow of nutrients and energy among organisms in the ecosystem. Organisms with the same feeding habits represent a trophic level. A trophic level is the position that an organism occupies in a food chain. For example, the first trophic level includes producers such as green plants and photosynthetic bacteria. Other trophic levels include primary consumers like herbivores and secondary consumers like carnivores. The flow of energy and nutrients in the ecosystem begins with producers. Producers are organisms such as green plants and photosynthetic bacteria that can manufacture their own food. They constitute the first trophic level. Producers are eaten by primary consumers that are herbivores such as rabbits, cows, buffaloes, wildebeests, goats, and sheep. These form the second trophic level. Secondary consumers form the third trophic level. They feed on primary consumers and they usually include small carnivores like frogs, fish, birds, and snakes. This level is followed by tertiary consumers such as owls, which feed on secondary consumers. Quaternary consumers constitute the fifth trophic level. They feed on tertiary consumers and they usually include apex predators like vultures, eagles, hawks, killer whales (orca), lions, and tigers. An apex predator is an animal at the top food chain with no natural predators of its own.

Decomposers such as bacteria and fungi feed on dead plants and animals and break them down, thus causing decay. This process is called decomposition.

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Through decomposition nutrients locked in dead animals and plants are released for use by other living organisms. The relationship between organisms at different trophic levels can be presented diagrammatically as shown in Figure 7.9.

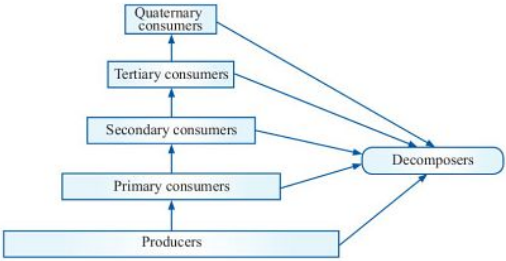

Figure 7.9: Diagrammatical representation of various trophic levels

Food chains

A food chain is a diagrammatic representation, which shows a sequence of organisms through which the energy flows and each organism is the food of the next one in the sequence. A food chain starts with a producer and ends with the top consumer. Population of organisms decreases from producers to highest trophic level. This is because at each trophic level, some of the energy is used to drive different life processes such as excretion and movement. The energy will not be available for use in the subsequent trophic level. Therefore, there is a decrease in the amount of energy from the bottom to the top trophic levels. Arrows are used to show the direction of the flow of energy. The following are examples of food chains.

(i) Grass → zebra → lion

(ii) Phytoplankton →zooplankton → fish → bird

(iii) Maize plant→ grasshopper → frog

(iv) Grass → cow → human being

Food webs

In a real situation, feeding relationships are not as simple as illustrated in food chains. Most organisms have more than one source of food and other organisms are eaten by various consumers. For

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example, a man is omnivorous and therefore eats both plants and animals. As a result, the environment is made up of interconnecting food chains known as food webs. Food web refers to a network of food chains that are interconnected at various trophic levels to form many feeding connections among different organisms. Examples of food webs are as shown in Figure 7.10.

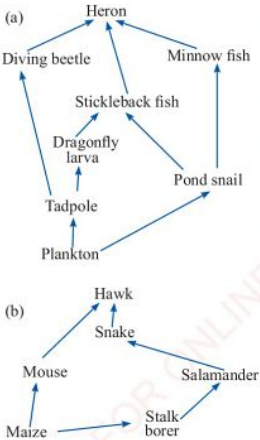

Figure 7.10: Food webs

Activity 7.3: Investigation of differences between food chains and food webs

Materials:

Note book and a pen or pencil

Procedure

1. List the organisms found in your environment.
2. Draw food chains showing how the organisms identified in your environment interact.
3. Draw food webs to show how the feeding relationships among those organisms are interconnected.

Question

What are the differences between food chain and food web.

The importance of food chains and food webs

Food chains and food webs are important because they facilitate the flow of energy in the environment. The interdependence of organisms in a food chain or a food web helps to maintain the balance of the population of organisms in an ecosystem. For example, in the food chain involving grasses, grasshopper, frog, and snake (grasses → grasshopper → frog → snake), if any trophic level is disturbed, the subsequent trophic levels will also be disturbed. If there are very few frogs in the food chain, the number of grasshoppers will increase. The

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number of grasshoppers will keep on increasing until they are too many for the grasses to be sufficient for them. As a result, many of the grasshoppers will starve and die. Fewer grasshoppers means less food available for the frogs hence, the frogs will also starve and die. If many frogs die their population decreases thus reducing the amount of food for the snakes. As a result, some snakes will also starve and die, hence the number will be reduced.

Exercise 7.2

1. Explain the common interactions among living organisms in the natural environment.
2. Why are the primary producers important in the environment?
3. Differentiate between the following:
   (a) mutualism and parasitism; and
   (b) primary consumers and tertiary consumers.
4. Explain the importance of food chains and food web.
5. Construct two food chains and food webs using the following organisms:

   Gazelle, Zebra, Shrubs, Cheetah, *Rhizopus*, Grasses, Lion, and Buffalo.

Chapter summary

1. The natural environment consists of living and non-living components.
2. Biotic factors are all living components of the environment. They include plants, animals, and micro-organisms.
3. Abiotic factors are all the non-living components of the environment. They include soil, altitude, light, temperature, wind, atmospheric pressure, and water.
4. The environment is important because it provides an organism with food, shelter, security, and the chance to interact with other organisms in order to obtain food, grow, and reproduce.
5. The water cycle, carbon cycle, and nitrogen cycle are some of the important cycles in which biotic and abiotic components interact in order to sustain ecosystems.
6. The interaction among living organisms can be predatory, competitive, or symbiotic.
7. The symbiotic relationship can be in form of neutralism, mutualism, commensalism, and parasitism.
8. A food chain is a diagrammatic representation, which shows how each living organism obtains its food. Each link is food for the next link.

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9. A food web is made up of several interconnected food chains.

10. Food chains and food webs are important because they facilitate the flow of energy from one organism to another in the environment. They also help to maintain the balance of the total number of organisms in an ecosystem.

Revision exercise 7

Section A

1. Match each item in **Column A** against its corresponding item from **Column B**.

Column A	Column B
(i) Interconnected food chains	A. Biotic factors
(ii) The living components of the environment	B. Abiotic factors
(iii) Organisms that make organic food molecules from carbon dioxide, water and other inorganic raw materials	C. Predation
(iv) A position occupied by a group of organisms in a food chain or food web through which energy is passed in the form of food	D. Commensalism
(v) All living and non-living things that occur naturally on earth	E. Food web
(vi) Interaction that is beneficial to all the organisms involved	F. Producers
(vii) Breaks down the remains of dead organisms to release nutrients for use by other organisms	G. Neutralism
(viii) Interaction in which one organism captures, kills, and feeds on another	H. Water cycle
(ix) Temperature, wind, light, soil, water, atmospheric pressure, and altitude	I. Food chain
	J. Natural environment
	K. Competition
	L. Carbon cycle
	M. Mutualism
	N. Apex predator

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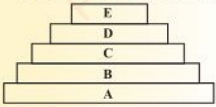
(x) A feeding relationship in which organisms struggle for the same limited resources in the environment	O. Primary consumer P. Decomposers Q. Trophic level
(xi) An animal with no natural predators of its own	

2. Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.
   (a) Examples of producers are plants and animals.
   (b) A human being is a biotic component of the environment.
   (c) Camouflage enables an organism to hide from its potential predators.
   (d) An example of mutualism is a feeding relationship between a tick and cow.
   (e) A food web is made up by many interlinked food chains.

Section B

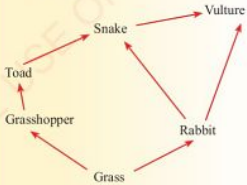
3. The figure below represents different trophic levels in the ecosystem. Study it and then answer the questions that follow:



   (a) Why do the trophic levels form a pyramid shape?
   (b) State the role of the organisms in the trophic level A of the diagram.

4. Draw the following cycles and explain their significance.
   (a) Water cycle
   (b) Nitrogen cycle

5. Study the following food web and then answer the questions that follow.



   What would happen if:
   (a) All the grass wither and die?
   (b) All the snakes are killed?
   (c) The rabbits are doubled in number?
   (d) The number of toads multiplies?

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6. Form Two students at Maweni Secondary School, carried out a survey to determine the number of organisms in their school garden. They recorded their findings in a table as shown below.

Organism	Number of organism
Grasshoppers	310
Grass	450 000
Birds	20
Hawks	44

(a) Which of the above organisms are:

(i) producers; and
(ii) primary consumers.

(b) Draw a possible food chain to show the energy flow in the garden.

(c) (i) Is the food chain in 6 (b) above stable?
(ii) Give reasons for the answer given in 6 (c) (i) above.
(ii) What can be done to sustain the food chain in the school garden?

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Chapter Eight

Transportation of materials in living organisms

Introduction

The basic characteristics of all living things are nutrition, respiration, excretion, growth, movement, reproduction, and sensitivity. For these processes to take place in the body, necessary materials should be transported from one place to another. The transported materials are obtained either from the environment or inside the body of an organism. In this chapter, you will learn about the concept of transport of materials in living things and the mechanisms of transport of materials, which are diffusion, osmosis, and mass flow. The competencies developed from this chapter will enable you to maintain a healthy lifestyle that promotes efficient transportation of materials in the body. You will also be able to support the survival of other living things such as plants by ensuring efficient supply of materials they need.

Concept of transportation of materials

Transportation of materials is the movement of materials either from the environment into the organisms or from one part of the organism to another. It can also be the movement of materials from the organism to the environment. Organisms require a transport system to carry out various life processes that include nutrition, respiration, excretion, coordination, growth, and development. For example, during nutrition, organisms take in food substances that they need for producing energy, growth, and carrying out other life processes. The food substances consumed by organisms from the environment are metabolised into different nutrients and transported to different parts of the body for assimilation and storage. Then, the by-products and wastes are excreted from the organisms to the environment.

Ways of transportation of materials

Life processes in organisms take place in the cell. Therefore, it is necessary for materials to move in and out of the

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cells. Movement of materials is through the cell membrane. There are two ways through which materials can move across the cell membrane, which are active transport and passive transport.

Active transport occurs in the presence of energy in the form of ATP. It enables the movement of materials across the cell membrane. During active transport, substances move against concentration gradient from an area of low concentration to an area of high concentration. For example, the uptake of glucose in the small intestine of human beings when the concentration of glucose in the blood becomes higher than that of the small intestine. Another example is the uptake of mineral salts into root hair cells of plants.

Passive transport occurs spontaneously without the need of energy to transport materials through the cell membrane. For example, the transport of materials in the cells through diffusion, osmosis, and mass flow.

Diffusion

This is the passive movement of particles from an area of high concentration to an area of low concentration as shown in Figure 8.1. The difference in the concentration of a substance between two areas is known as a concentration gradient. When the difference in concentration between the two areas is great, the concentration gradient becomes steep and the rate of diffusion increases. As the difference in concentration between the two areas decreases the rate of diffusion slows down. This process continues until the substances are distributed evenly throughout the two areas. When the particles are evenly distributed, they move at the same rate in either direction.

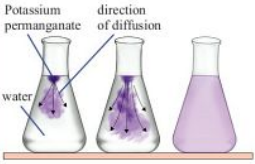

Figure 8.1: Experimental set-up to demontrate diffusion process

Roles of diffusion in living things

Diffusion is important in living things. It helps in the movement of substances in the body, including:

(i) movement of oxygen gas from the alveoli to the blood capillaries;

(ii) movement of oxygen gas from the blood capillaries to the tissue fluid;

(iii) movement of oxygen gas from the tissue fluid to the cell;

(iv) movement of carbon dioxide gas from the cell to the tissue fluid;

(v) movement of carbon dioxide gas from the tissue fluid to the blood capillaries;

(vi) movement of carbon dioxide gas

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from the blood capillaries to the alveoli;

(vii) movement of air from the atmosphere to the leaves;

(viii) movement of carbon dioxide gas from the intercellular space to the palisade cells;

(ix) movement of oxygen gas from the palisade cells to the intercellular spaces of spongy mesophyll;

(x) movement of oxygen gas from the intercellular spaces to the atmosphere;

(xi) movement of water vapour from the leaves to the atmosphere; and

(xii) movement of digested food substances from the ileum to the blood circulatory system.

Factors which affect the rate of diffusion

The rate of diffusion can be affected by the following factors:

Concentration gradient: When there is a big difference in concentration of molecules between the two areas, high rate of diffusion occurs.

Surface area to volume ratio: The larger the surface area to volume ratio, the larger the number of particles that will be able to move in a given time hence, the higher the diffusion rate.

Distance over which diffusion takes place: When the distance over which the material is transported is long, the rate of diffusion decreases. If the distance is short, diffusion occurs faster because the materials do not have to travel far. For example, in a thin layer of cells the rate of diffusion increases.

Activity 8.1: Demonstration of diffusion in liquids

Materials:

Potassium permanganate or copper sulphate or laundry blue, beaker or test tube, test tube rack, water, a pencil and a notebook

Procedure

1. Fill one beaker or test tube with water. Leave it for some time, until water settles completely.
2. Put a crystal of potassium permanganate into the water then observe what happens.
3. Draw a labelled diagram to show how the colour is distributed in the beaker or test tube.
4. Leave the mixture completely undisturbed overnight.
5. Draw a second labelled diagram to show how the colour is distributed.
6. Repeat the activity using copper sulphate or laundry blue instead of potassium permanganate.
7. Discuss your observations with your fellow students.

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Questions

(i) How did the colour of potassium permanganate spread in the water in a test tube?

(ii) How long did it take for the colour to spread evenly in the test tube?

Osmosis

Osmosis is the passive diffusion of water through a semi-permeable (partially permeable) membrane. It is regarded as a special form of diffusion because it involves movement of water molecules through a semi-permeable membrane. Osmosis is defined as the process by which water molecules move from a low concentrated solution into a high concentrated solution through a semi-permeable membrane, as shown in Figure 8.2. The partially permeable membrane is only permeable to water and some solutes (dissolved substances). For osmosis to take place, there must be two solutions separated by a semi-permeable membrane. One solution should have a greater volume of water and a lesser quantity of solute than the other solution. This solution is hypotonic, meaning that it has a lower solute potential or higher water potential. The second solution should have a lesser volume of water and a greater quantity of solute than the other solution. This solution is hypertonic, meaning that it has a higher solute potential or lower water potential. If the two solutions have the same water or solute potential then they are said to be isotonic.

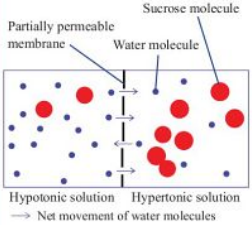

Figure 8.2: Movement of water molecules during osmosis

Activity 8.2: Demonstration of osmosis using a cellophane membrane

Materials:
Cellophane membrane, beaker, sugar solution, water, thistle funnel, and a clamp

Procedure

1. Using a rubber band, tightly cover the open end of a thistle funnel with a cellophane paper.
2. Invert the thistle funnel and fill it with sugar solution.
3. Mark the level of sugar solution in the thistle funnel using a marker pen.

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4. Slowly immerse the thistle funnel in the beaker containing water as shown in Figure 8.3.

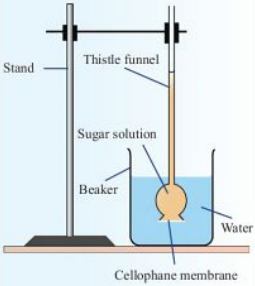

Figure 8.3: Experimental set-up to demonstrate osmosis

5. Leave the set-up undisturbed for about 3 hours.
6. Mark the levels of the sugar solution in the thistle funnel and the level of water in the beaker.

Questions

(i) What did you observe on the levels of water and the sugar solution?

(ii) What are the reasons for your observation? Discuss with your fellow students.

Activity 8.3: Demonstration of osmosis using potato cubes

Materials:
Three raw potatoes, sugar solution, water, source of heat, and beakers or dishes

Procedure

1. Peel three potatoes.
2. Boil one of the potatoes to kill the cells.
3. Cut each potato into half and make a shallow hole on each half.
4. Place each half of the potato in a beaker or dish that contains water. The water should not cover the potato.
5. Put some sugar solution in the shallow hole in one raw potato and the boiled potato. Leave the other raw potato empty. Label these set-ups as (a), (b), and (c) respectively.
6. Mark the level of water in each beaker or dish.
7. Leave the set-ups undisturbed overnight.
8. Discuss your observation with your classmates.
9. Study Figure 8.4 and compare with your results, then write a short summary.

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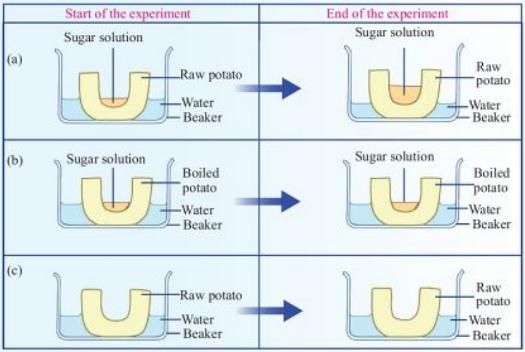

Figure 8.4: Experimental set-up to demonstrate osmosis

10. Share your summary with your fellow students.

Questions

(i) What differences did you observe in set-ups (a), (b), and (c)?

(ii) Explain your observation in each case.

The importance of osmosis

Osmosis is an important process in both plants and animals. In plants, osmosis aids the absorption of water by the roots. Osmosis also aids opening and closing of the stomata. When guard cells absorb water the stomata open and when they lose water, the stomata close. Osmosis also plays a key role during germination of seeds. It enables the absorption of water that softens the seed coat, hence, increasing seed permeability for dissolved minerals and oxygen. This promotes the growth of seed embryo during germination.

In animal cells, osmosis is important for reabsorption of water in the colon and kidneys. This helps to maintain water balance in the body. In addition, the process of osmosis is used to preserve food by salting. This causes food such as meat to lose water and become dry. Salting makes food to stay longer without being contaminated by germs.

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In lower organisms such as *Amoeba*, osmosis helps to remove waste and excess water from their bodies.

Effects of osmosis in living organisms

Osmosis is one of the most important processes that helps to keep the organisms body conditions stable for their survival. However, the process of osmosis has various effects in the cells of living things as described below.

Osmosis in animal cells: Animal cells take in and lose water by the process of osmosis. However, when an animal cell is put in a hypotonic solution, it absorbs water. If it remains in the solution for a long time, it absorbs excess amounts of water. A cell that does not have a mechanism for removing excess water bursts due to the excessive internal pressure.

When an animal cell is placed in a hypertonic solution, it loses water. If it remains in the solution for a long time, it loses a lot of water, shrinks, and shrivels. These effects of osmosis on animal cells can be observed in red blood cells. Under normal conditions, the osmotic pressure of red blood cells is equal to that of the blood plasma implying that they are isotonic. Thus, there is equal movement of water in and out of the cells. This helps to maintain the disc shape of these cells.

When red blood cells are placed in a hypotonic solution, they absorb water, causing the cell volume to increase. Excessive amounts of water cause haemolysis (bursting).

When red blood cells are placed in a hypertonic solution, they lose water, leading to shrinking of the cell. This is referred to as crenation (See Figure 8.5).

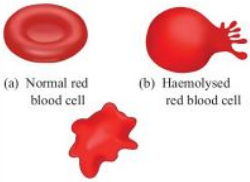

Figure 8.5: Effects of osmosis on a red blood cell

Osmosis in plant cells: In an isotonic solution, plant cells neither lose nor gain water. In a hypotonic solution, plant cells absorb water, causing the cell membrane to push against the cell wall. The cell is then said to be turgid. That is, it does not burst because the cell wall resists pressure exerted from the cell membrane and restricts additional intake of water. Turgidity helps plant cells to maintain their shape.

In a hypertonic solution, plant cells lose water. This causes the vacuole to shrink and the cell surface membrane to pull away from the cell wall, making the cell flaccid. The flaccid cell is said to be plasmolysed and the process is

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called plasmolysis. If a plasmolysed cell is placed in a hypotonic solution, it absorbs water and becomes turgid (See Figure 8.6).

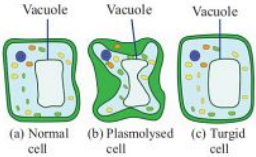

Figure 8.6: Effect of osmosis on a plant cell

Osmosis in unicellular organisms: Unicellular organisms that live in fresh water such as *Amoeba* and *Euglena*, are hypertonic to their surroundings. Hence, water enters into the organisms by osmosis. These organisms have a contractile vacuole, which collects the excess water and removes it from the cell as shown in Figure 8.7. This prevents the cell from bursting. Osmosis is also used for regulating their body mineral contents.

Exercise 8.1

1. Explain the importance of transportation of materials in the human body.
2. Give the meaning of the following terms: (a) osmosis (b) diffusion
3. Explain the effects of osmosis in animal cells.
4. Differentiate a hypotonic solution from a hypertonic solution.
5. What is an isotonic solution?

Mass flow

This is the bulk movement of substances from one region to another due to differences in pressure between the two regions. Mass flow occurs within a cell or along a vessel. This mode of transport is important in large and complex organisms where substances are required in large amounts. Mass

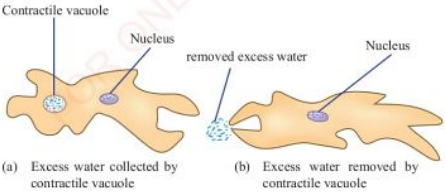

Figure 8.7: Water balance in amoeba through contractile vacuole

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flow occurs when the materials need to be transported over a long distance. Thus, diffusion alone is not sufficient to ensure physiological processes. Examples of systems where mass flow occurs include:

(i) the blood circulatory system in animals;

(ii) the lymphatic system in animals;

(iii) transport of manufactured food material in plants from the site of manufacture, mostly in leaves to the point of utilisation through the phloem. (This process is called translocation); and

(iv) transport of water from the roots to different parts of the plant.

Activity 8.4: Demonstration of mass flow in plants

Materials:
Potted plant and scalpel or knife

Procedure

1. Remove a ring of bark from the potted plant as shown in Figure 8.8. The bark contains phloem.

Figure 8.8: Potted plant with a ring of bark removed

2. Leave the plant undisturbed for a week.

3. Observe the plant. What do you observe in the upper part of the shoot? Compare your results with Figure 8.9.

Figure 8.9: Potted plant with an accumulation of organic substances above the ring

4. Discuss your observations with your fellow students.

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The differences between diffusion, osmosis and mass flow is summarised in Table 8.1.

Table 8.1: Differences between diffusion, osmosis and mass flow

Characteristic	Diffusion	Osmosis	Mass flow
Substance transported	Gases, liquids, and ions	Water	Solids, liquids, and gases
Transportation structures	None	Semi-permeable membrane	Cytoplasm or vessels
Cause of movement	Diffusion gradient	Osmotic pressure	Difference in pressure

Chapter summary

1. Transport is necessary for the movement of substances within, into, and out of cells so as to enable vital life processes to take place.
2. Transportation of materials in living organisms can be carried out through diffusion, osmosis, or mass flow.
3. Diffusion is the movement of molecules and ions of liquids or gases from a region of high concentration to a region of low concentration.
4. Concentration gradient is the difference in the concentration of a substance between two regions.
5. Factors which affect the rate of diffusion include the concentration gradient, surface area, and distance over which the diffusion takes place.
6. The important processes in the body that involve diffusion include gaseous exchange in the lungs, absorption of nutrients into cells, absorption of digested food in the small intestine, absorption of oxygen into the cells, and removal of waste materials from cells.
7. Osmosis is the movement of water molecules from a dilute solution to a concentrated solution through a semi-permeable membrane.
8. A hypotonic solution has a low solute potential and higher water potential.

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9. A hypertonic solution has a high solute potential and low water potential.

10. A red blood cell haemolyses in a hypotonic solution and crenates in a hypertonic solution.

11. A plant cell becomes turgid in a hypotonic solution and plasmolyses in a hypertonic solution.

12. The important processes in the body that involve osmosis include reabsorption of water in the large intestine and kidneys. This enables the body to maintain water balance.

13. In plants, osmosis is important for the absorption of water by plant roots and for opening and closing of stomata.

14. Mass flow is the bulk movement of substances due to pressure differences between the two regions.

15. Mass flow involves movement of solids, liquids, and gases while osmosis involves movement of water molecules.

16. Examples of mass flow include the flow of blood in the circulatory system, the flow of lymph in the lymphatic system, transport of manufactured food mostly from leaves to other parts of the plant, and transport of water and minerals from the roots.

Revision exercise 8

Section A

Choose the correct answer.

1. The dissolving of coffee particles in a cup of hot water is an example of _____.
   (a) liquid flow
   (b) solid flow
   (c) mass flow
   (d) diffusion

2. A semi permeable membrane is the one which _____.
   (a) allows certain materials to pass through and prevent others
   (b) do not allow any material to pass through
   (c) forms a thin layer between two cells
   (d) allows all materials to pass through

3. The following are the basic life processes, except_____.
   (a) movement
   (b) feeding
   (c) sleeping
   (d) respiration

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4. The hypotonic solution has _____.
   (a) high water potential
   (b) high affinity to water
   (c) low water potential
   (d) low affinity to water

5. Fill in the following blanks.
   (a) Active transport in cells occurs in the presence of _____.
   (b) The difference in the concentration of a substance between two regions is called _____.
   (c) Potassium permanganate granules can be used to demonstrate _____ process.
   (d) A solution with high water potential is called _____.
   (e) The plant cells become _____ when put into a hypotonic solution.

Section B

6. Mention the processes in the human body that involve:
   (a) diffusion;
   (b) osmosis; and
   (c) mass flow.

7. Briefly explain the meaning of the following:
   (a) passive transport;
   (b) isotonic solution;
   (c) crenation;
   (d) turgidity; and
   (e) mass flow.

8. Differentiate between the following, use examples where necessary.
   (a) Osmosis and diffusion
   (b) Hypotonic solution and hypertonic solution
   (c) Plasmolysis and haemolysis
   (d) Passive transport and active transport
   (e) Osmosis and mass flow

9. Give reasons for the following:
   (a) an animal cell bursts when placed in pure water, whereas a plant cell does not; and
   (b) an animal cell shrinks when placed in a concentrated solution.

10. Similar types of three animal cells were placed in 3 different solutions, namely A, B and C. After some time, the cell in solution A bursted, the cell in solution B shrank and shriveled and the cell in solution C did not change.

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(a) Which types of solutions were A, B and C?

(b) Explain the reasons for such observation.

11. Explain three factors that affect the rate of diffusion.

12. Explain how unicellular organisms like amoeba avoid bursting as a result of excessive absorption of water by osmosis.

13. Describe what would happen to the rate of oxygen diffusion into the cell if the thickness of the cell membrane changes from 15 nm to 20 nm.

14. What is the importance of mass flow in plants?

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Chapter Nine

Transport of materials in mammals

Introduction

A transport system is required in multicellular organisms for transportation of nutrients and other materials. Complex animals like mammals have an elaborate and efficient transport system called the circulatory system that ensures effective circulation of nutrients, respiratory gases, and other materials in the body. The circulatory system is made up of the heart, blood, and blood vessels. In this chapter, you will learn about the mammalian heart, the blood, blood groups, blood transfusion, blood circulation in humans, and the lymphatic system. The competencies developed from this chapter will enable you to explore the components and functions of the human circulatory and lymphatic systems. You will also be able to maintain a healthy lifestyle that helps to control or prevent some of the diseases and disorders of the blood circulatory system.

The mammalian heart

The human heart is an example of a mammalian heart. It is located in the center of the chest cavity between the two lungs. Usually, it slightly points to the left side of the chest. Its major function is to pump blood throughout the body via the blood vessels. Blood circulation enables the supply of oxygen, nutrients, and hormones to cells throughout the body. It also enables transportation of carbon dioxide and other wastes from the cells of the body.

The external structure of the mammalian heart

The mammalian heart is broader at the top and narrower at the bottom. It is enclosed in a double layer of tough inelastic membranes called the pericardium. The pericardium is a thick, membranous, fluid-filled sac which encloses, protects, and nourishes the heart. It prevents the heart from over-expanding when it is beating very fast. The pericardium also protects the heart from mechanical injury. It provides enough room for vigorous pumping of

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the heart. In addition, the pericardium keeps the heart in place to reduce friction between the heart and other structures. This is because it secretes a fluid called pericardial fluid, which lubricates the heart. Also, pericardial fluid allows for smooth movement of the heart when it beats.

Just beneath the pericardium, the heart's wall consists of three layers. The outermost layer is called epicardium. The middle layer is called myocardium, which contains a special type of muscle known as cardiac muscle that contracts and relaxes during heart movement. The cardiac muscle in the heart never gets fatigued, they work continuously as long as a person is alive. This type of muscle is found only in the heart. The inner layer is called endocardium.

There are various blood vessels attached to the heart. The coronary artery supplies the heart muscles with oxygenated blood. The coronary vein carries deoxygenated blood containing waste materials away from the heart. The vena cava is the largest vein that carries deoxygenated blood from the rest of the body to the heart. The pulmonary artery transports deoxygenated blood from the heart to the lungs. The pulmonary vein carries oxygenated blood from the lungs to the heart. The aorta is the largest artery that carries oxygenated blood from the heart to the rest of the body. Figure 9.1 shows the external structure of the mammalian heart.

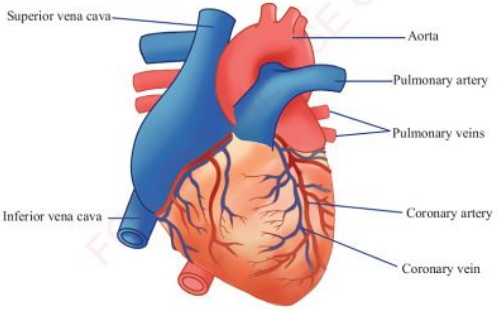

Figure 9.1: External structure of the mammalian heart

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The internal structure of the mammalian heart

Internally, the human heart consists of four chambers, which are the right auricle, right ventricle, left auricle, and left ventricle as shown in Figure 9.2. The auricles are also called atria (singular is atrium). The walls of the ventricles are thicker than those of the auricles. This is because the ventricles pump blood to a longer distance than the auricles. Auricles or atria pump blood to the ventricles and then ventricles pump blood to all other parts of the body. The walls of the left ventricle are thicker than the walls of the right ventricle because it pumps oxygenated blood to the rest of the body. Therefore, much pressure is required to pump the blood. The right ventricle pumps blood to the lungs. The lungs are close to the heart, therefore, it does not require much pressure to pump blood.

The heart has various valves that control the flow of blood between the atria and ventricles. The valves have flaps that ensure the blood flows in one direction only. The tricuspid valve is found between the right auricle and right ventricle. The bicuspid valve is found between the left auricle and left ventricle. Semilunar valves are located at the bases of the pulmonary artery and aorta to prevent blood from flowing back into ventricles. Valves close when blood tries to flow back. The left and right sides of the heart are separated by the septum, which is a muscular wall that prevents mixing of oxygenated and deoxygenated blood.

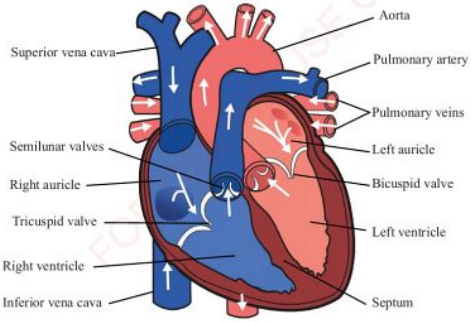

Figure 9.2: Internal structure of the mammalian heart

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Activity 9.1: Examining the external and internal features of the mammalian heart

Materials:

Preserved specimen of a mammalian heart, model of a mammalian heart, scalpel, hand lens, and forceps

Procedure

1. Observe the model of a mammalian heart to identify the external features.
2. Observe the preserved specimen of a mammalian heart to identify the internal features such as auricles, ventricles, pulmonary artery, pulmonary vein, aorta, vena cava, and septum.
3. Compare the walls of the right ventricle with those of the left ventricle.
4. Draw and label the internal and external structures of the mammalian heart in your exercise book.

The flow of blood through the heart

The heart is an organ that pumps blood throughout the body. It is divided into two separate pumping systems, the right side and the left side. The right side of the heart receives deoxygenated blood from the vena cava and pumps it to the lungs where it picks up oxygen gas and releases carbon dioxide gas. The left side of the heart receives oxygenated blood from the lungs and pumps it through the arteries to the rest of the body where oxygen gas is released and carbon dioxide gas is picked up. Apart from transporting gases, the blood also transports nutrients and water needed in the metabolic processes of the body.

Deoxygenated blood has a high concentration of carbon dioxide. The vena cava has two branches that are superior vena cava and inferior vena cava. The superior vena cava transports deoxygenated blood from the upper parts of the body such as the head, neck, and upper limbs to the heart. The inferior vena cava transports deoxygenated blood from the lower parts of the body such as the lower limbs, kidney, liver, stomach, and intestines to the heart. The inferior vena cava and the superior vena cava, unite to form the vena cava that connects to the right auricle.

The right auricle receives deoxygenated blood from the body and pumps it to the right ventricle through the tricuspid valve. When the right auricle relaxes, it is filled up with deoxygenated blood from the vena cava. The increased pressure in the right auricle causes muscles to contract and pump the blood through the tricuspid valve. In the right auricle, there is a small patch of muscle called the sinoatrial node (SAN). This node acts as a pacemaker, setting the time and rate of cardiac muscle

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contraction. When muscles of the right ventricle relax, the ventricle is filled up with blood. The tricuspid valve closes to prevent blood from flowing back into the right auricle.

The right ventricle pumps the deoxygenated blood to the lungs through the pulmonary artery. When the right ventricle is full, the increased pressure causes the muscles to contract, and the semilunar valve in the pulmonary artery to open. The blood flows into the pulmonary artery and the semilunar valve closes to prevent back flow of blood. The pulmonary artery transports deoxygenated blood to the lungs. Blood picks up oxygen in the lungs, and thus becomes oxygenated.

The oxygenated blood flows from lungs to the heart through the pulmonary vein. This vein is connected to the left auricle. When the left auricle relaxes, the blood from the pulmonary vein flows into it. Pressure increases in the left auricle as it fills up with blood which causes the muscles of the auricle to contract and pump blood through the bicuspid valve into the left ventricle. The muscles of the left ventricle relax, allowing blood to flow in. The bicuspid valve closes to prevent blood from flowing back into the left auricle. Pressure builds up in the left ventricle as blood flows in. The muscles of the left ventricle contract, pumping blood through the semilunar valve into the aorta. The aorta branches into smaller arteries that transport blood to all parts of the body.

The heart beats in such a way that when the auricles contract, the ventricles relax and vice versa. Usually an adult heart, beats about 60 to 80 times per minute. A baby's heart beats faster than the adult heart, about 70 to 190 beats per minute because babies have a higher metabolic rate than adults.

Exercise 9.1

1. Explain the major functions of the heart.
2. Where is the bicuspid valve located in the heart?
3. What is the difference between pulmonary artery and pulmonary vein?
4. Explain the function of the aorta.
5. Draw a well-labeled diagram showing external structure of the heart.

Adaptation of the heart to its functions

The heart has several features that enable it to function well. Table 9.1 shows how the heart is adapted to its functions.

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Table 9.1: Adaptation of the heart to its functions

Adaptive feature	Function
Muscular walls	Contract to pump blood
Cardiac muscles	Contract and relax continuously without getting fatigued to ensure continuous pumping of the blood
Valves	Ensure blood flows in one direction
Septum	Separates the left and right sides of the heart to prevent mixing of oxygenated and deoxygenated blood
Sinoatrial node	Sets time and rate of contraction of cardiac muscles
Coronary artery and coronary vein	The coronary artery nourishes the heart and supplies it with oxygen. The coronary vein removes waste that would harm the heart if left to accumulate
Connection with pulmonary artery and pulmonary vein	Enables the heart to pump out deoxygenated blood to the lungs and receives oxygenated blood from the lungs
Pericardial fluid	Prevents friction as the heart beats
Connection with vena cava and aorta	Enables the heart to receive deoxygenated blood and pumps out oxygenated blood

Blood vessels

Blood vessels are channels through which blood is distributed to the various parts of the body. They are distributed throughout the body. Mammals have three types of blood vessels which are arteries, veins, and capillaries.

Arteries

Arteries are thick-walled, muscular, and elastic vessels that transport blood from the heart to all parts of the body (See Figure 9.3). All arteries transport oxygenated blood, except the pulmonary artery which transports deoxygenated blood from the heart to the lungs.

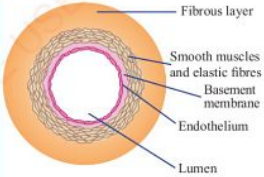

Figure 9.3: Cross-section of an artery

The wall of an artery consists of three layers. The endothelium is the innermost layer of the artery which is attached to a basement membrane. It has only one layer of cells. The endothelium

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surrounds the lumen (a hollow passage through which blood flows). The lumen of an artery is narrow and smooth. This helps the artery to transport blood at high pressure. The muscular layer is made up of smooth muscles and elastic fibres. Smooth muscles are arranged in circles around the endothelium. This layer makes it possible for the artery to contract and relax for the efficient movement of blood.

The outermost layer is the fibrous layer made up of connective tissues such as collagen. The fibres are arranged parallel to the length of the vessel. They enable the artery to withstand the pressure caused by the blood coming from the heart. Arteries branch to form arterioles. An arteriole is a small artery that leads to a capillary. Arterioles have the same three layers as arteries, but the thickness of each is greatly reduced.

When the ventricles contract, the arteries relax allowing blood to flow from the heart to them. When the ventricles relax the arteries contract, pushing the blood forward. This contraction and relaxation of arteries is felt as a pulse. Pulse or heart rate is the number of heart beats per minute. The pulse rate reflects the heartbeat. An adult human's heart beats at an average of 72 times a minute. However, this can increase or decrease due to physical activity, emotional state, or health factors.

Activity 9.2: Examining the pulse rate

Materials:

Stopwatch or wristwatch, a notebook, and a pen or a pencil

Procedure

1. Get into pairs. Put the fingers of your right hand on your wrist as shown in Figure 9.4. Can you feel the pulse?

Figure 9.4: Examining the pulse rate

2. Use the stopwatch to count the number of pulses in one minute. Record your answer.
3. Repeat step 2 three times and find the average. This will be your pulse rate.
4. Do a physical exercise like jumping for a few seconds, then repeat steps 1, 2, and 3.
5. Record the pulse rate. Is it the same as the earlier pulse rate?

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6. Compare your results with your colleague.

7. Discuss your results with your classmates.

Question

How do you compare your pulse rate with that of your classmates?

Veins

Veins are blood vessels that transport blood to the heart from all parts of the body. All veins transport deoxygenated blood except the pulmonary vein. The pulmonary vein transports oxygenated blood from the lungs to the heart. Veins have a larger lumen and less muscular walls than arteries as shown in Figure 9.5. This is because the blood in the veins flows at low pressure.

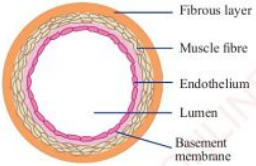

Figure 9.5: Cross-section of a vein

Veins have valves at regular intervals. These prevent the back flow of blood, as shown in Figure 9.6. The muscles next to the veins squeeze the veins, which force the blood to flow towards the heart. The contraction and relaxation of the muscles of the ribs during breathing also help to squeeze some veins and keep blood flowing. Veins branch to form venules. Venules are small veins that connect capillaries and veins.

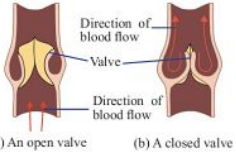

Figure 9.6: Functioning of a valve

Capillaries

Capillaries are the smallest blood vessels. The capillaries connect the smallest branches of arteries and veins. The capillaries also help to exchange molecules between the blood and the cells across their walls. They are one cell thick, they are narrow and have thin walls as shown in Figure 9.7.

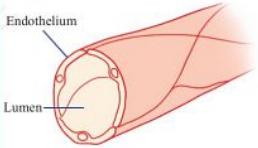

Figure 9.7: Cross-section of a capillary

Capillaries are in direct contact with the tissues of the body. They form a network for the efficient diffusion of substances. Their thin walls maximise

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the rate of diffusion. The thin walls of the capillaries enable oxygen and nutrients to diffuse from the blood to the cells. They also enable carbon dioxide and other waste products to diffuse from the cells into the blood. Table 9.2 gives a summary of the structural and functional differences between arteries, veins, and capillaries.

Table 9.2: Comparison of structure and function of arteries, veins, and capillaries

Feature	Arteries	Veins	Capillaries
Lumen	Have narrow smooth lumens	Have wide irregular lumens	Have narrow smooth lumens
Valves	Lack valves except where they are connected to the heart	Have valves at regular intervals	Lack valves
Pressure	Transport blood at high pressure	Transport blood at low pressure	Transport blood at high pressure
Direction of blood flow	Transport blood away from the heart	Transport blood towards the heart	Transport blood within the tissues
Function	Transport oxygenated blood, except the pulmonary artery	Transport deoxygen-ated blood, except the pulmonary vein	Transport either oxygenated or deoxygenated blood
Blood flow	Contract and relax to create a pulse	Blood flows smoothly	Blood flows smoothly
Wall layers	Have three wall layers	Have three wall layers	Have one wall layer
Wall thickness	Have thick muscular walls	Have thin muscular walls	Extremely thin walls (single cell thick)

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The blood

Blood is a specialised fluid tissue in humans and other vertebrates. It consists of four main components which are plasma, red blood cells, white blood cells, and platelets. Its major function is to transport oxygen gas and nutrients throughout the body. Other functions are to remove waste products from the body, transport hormones, and to form blood clots that prevent excessive loss of blood upon injury. Also, it is involved in immune response to infections. An adult human has about 4 to 6 litres of blood. The pH of blood is 7.4.

Activity 9.3: Examining the components of blood

Materials:

Prepared slides of human blood components, microscope, a pencil, and a notebook

Procedure

1. Mount the prepared slide of human blood on the microscope.
2. Observe the specimen using low power, medium power, and high power objective lenses.
3. Draw what you have observed.
4. Discuss with your classmates the components of the blood.

Plasma

This is a mild alkaline pale-yellow fluid of the blood. Approximately 55% of the blood is plasma. It is mostly made up of water. Other substances in the plasma include dissolved proteins (for example serum, albumins, globulins, and fibrinogen), dissolved salts, enzymes, oxygen, and food nutrients. Plasma also contains other components like antibodies, hormones, and clotting factors. These substances make up 8% of plasma while water makes up 92%. Plasma carries the blood components throughout the body along the circulatory system. The major functions of plasma are to transport the following substances:

(i) nutrients from the digestive system to other parts of the body;

(ii) red blood cells containing oxygen to the tissues and carbon dioxide to the heart and lungs;

(iii) wastes such as carbon dioxide and urea to the excretory organs;

(iv) white blood cells and antibodies to sites of infection;

(v) hormones to the target organs;

(vi) mineral ions such as sodium, potassium and chlorides so as to ensure ionic balance in the body; and

(vii) platelets to sites of bleeding so as to initiate blood clotting.

Plasma is also important for distributing heat to all parts of the body; regulating the pH of body fluids; and maintaining a normal balance of body fluids.

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Red blood cells

These are red, round, biconcave cells with no nucleus when mature as shown in Figure 9.8. They are also called erythrocytes. One millilitre of blood has approximately 5 to 6 million red blood cells. Erythrocytes are formed in the red bone marrow. Their lifespan is about 120 days. The liver and the spleen destroy old red blood cells and release haemoglobin for the formation of new cells. Haemoglobin is a red pigment in the erythrocytes, which gives them a red colour. Haemoglobin has a high affinity to oxygen.

Figure 9.8: Red blood cell

Functions of red blood cells

The function of red blood cells is to transport oxygen from the lungs to the body cells and carbon dioxide from the body cells to the lungs. The features that facilitate adaptation of red blood cells to its function are the presence of haemoglobin pigment, its biconcave shape, and their large numbers. Another feature is the lack of a nucleus which increases the total surface area for loading respiratory gases. Also, their membrane is very flexible and able to bend in many directions without being damaged. This helps them to pass through the capillaries.

Transport of oxygen: In the lungs there is a high concentration of oxygen gas. Haemoglobin combines with oxygen gas to form oxyhaemoglobin. This is an unstable compound which releases oxygen by diffusion when it reaches a tissue fluid that has a low concentration of oxygen gas. The formation of oxyhaemoglobin and the release of oxygen gas and haemoglobin can be shown using the following equation of a reversible reaction.

$$\text{Haemoglobin} + \text{oxygen} \rightleftharpoons \text{oxyhaemoglobin}$$

Oxygen diffuses out of the red blood cells, through the capillary walls to the tissue fluid.

Transport of carbon dioxide: This occurs when carbon dioxide combines with haemoglobin in the red blood cells to form carbaminohaemoglobin. This combination occurs in the tissue fluid where the concentration of carbon dioxide is high. The formed compound is transported to the lungs where carbon dioxide is released and expelled from the body through exhalation.

White blood cells

These are irregular shaped cells with nuclei as shown in Figure 9.9. They are also called leucocytes. They help

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the body to fight against diseases and infections. One milliliter of blood has approximately 5,000 to 10,000 white blood cells. They are produced in the white bone marrow and in the lymph nodes. White blood cells do not possess haemoglobin and they are capable of motility. Their motility enables them to get into the site of infection.

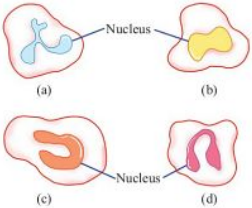

Figure 9.9: White blood cells of different shapes

Functions of white blood cells

The function of white blood cells is to protect the body against infection. They perform this function by:

(i) engulfing and destroying pathogens, a process called phagocytosis as shown in Figure 9.10;

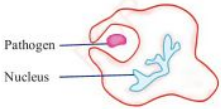

Figure 9.10: Phagocytosis in a white blood cell

(ii) producing substances that neutralise toxins produced by pathogens;

(iii) causing clumping together of foreign materials in the body; and

(iv) killing infected body cells.

The effects of HIV on white blood cells

The Human Immunodeficiency Virus (HIV) attacks a type of white blood cells called T-helper. These cells are essential for body immunity. When they encounter an antigen, the T-helper cells divide themselves to form new cells. This increases the number of cells available to fight the infection. After the infection, some cells remain as memory cells to activate an immune response if the infection happens again. In addition, the T-helper cells activate other cells in the immune system.

HIV has a protein envelope that can only bind to its receptor called CD4. The CD4 are found on the cell membrane of the T-helper cell. When it enters the human body, HIV fuses its protein envelope with the CD4 then enters the cell. Once inside the cell, the virus becomes part of the T-helper cell and replicates together with it as it undergoes division. This increases the number of HIV in the blood. The HIV destroys T-helper cells resulting in the reduction of the number of T-helper cells and reducing the CD4 count. Figure 9.11 shows HIV attacking the T-helper cell.

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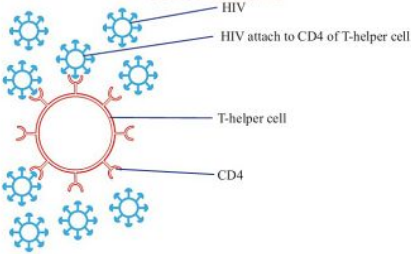

Figure 9.11: HIV attacking T-helper cell

HIV destroys T-helper cells in the following ways:

(i) it reproduces inside the T-helper cell, then ruptures the cell's membrane and the new viruses are released;

(ii) it alters the T-helper cells so that when it responds to an infection, it kills itself instead of dividing to form new cells;

(iii) it marks T-helper cells as targets for destruction by other cells in the immune system; and

(iv) it causes the fusion of many T-helper cells to form a 'giant' cell. A giant cell can survive but it cannot perform normal T-helper cell functions.

Thus, HIV lowers the body's immunity to a great extent making it vulnerable to opportunistic infections.

Platelets

Platelets are small fragments of cells produced in the bone marrow. They are also known as thrombocytes (See Figure 9.12). They do not have nuclei and cannot reproduce.

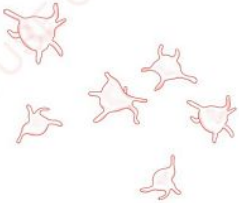

Figure 9.12: Blood platelets

Functions of platelets

Platelets play an important role in the clotting of blood.

The clotting process: Blood clotting

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or coagulation is an important process that prevents excessive bleeding when a blood vessel is injured. Blood platelets and proteins in the plasma work together to stop the bleeding by forming a clot over the injury.

Blood platelets at the site of an injury produce thromboplastin which starts off the clotting process. Thromboplastin, with the help of vitamin K and calcium, neutralises heparin, an anticoagulant in the blood; and converts prothrombin, which is an inactive plasma protein to thrombin. This is an active plasma protein which catalyses conversion of soluble fibrinogen to insoluble fibrin. Fibrin forms a network of fibers that trap debris and blood cells. These result into a clot at the site of the wound preventing further loss of blood. The clear fluid called serum which oozes out of the wound remains when the rest of the blood clots. The clot stops further bleeding and prevents entry of bacteria into the body through the wound.

Blood groups

Grouping of human blood is done using the ABO system and the Rhesus factor. Blood group is inherited from the parents.

The ABO system

The ABO system of grouping blood is the classification of human blood based on two factors. First is the presence or absence of antigen A or antigen B on the membranes of the red blood cells. Second is the presence or absence of antibody *a* or antibody *b* in the blood plasma.

A person cannot have a certain antigen on the membrane of the red blood cell and the corresponding antibody in the plasma. For example, one cannot have both antigen A and antibody *a*. This would cause agglutination or clumping together of red blood cells. Agglutination can be fatal. There are four major groups of blood which are group A, group B, group AB, and group O. Table 9.3 shows a summary of blood groups with the antigens and antibodies present in them.

Table 9.3: Blood groups according to ABO system

Blood group	Antigen on the membrane of the red blood cell	Antibody in the plasma
A	A	*b*
B	B	*a*
AB	A and B	None
O	None	*a* and *b*

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Rhesus factor

This factor is named after the Rhesus monkey in which it was first observed. The Rhesus factor is found on the surface membrane of the red blood cells. When the Rhesus factor is present on the red blood cell membrane, a person is said to be Rhesus positive. This is abbreviated as Rh^+. If it is absent, the person is rhesus negative. This is abbreviated as Rh^-. Thus, a person's blood is said to be A^+ if it is blood group A and has the Rhesus factor Rh^+, or is said to be A^- if it is blood group A but lacks the Rhesus factor. There are also B^+ or B^-, O^+ or O^- and AB^+ or AB^- blood groups. Usually the Rh^+ is more common in a population than the Rh^-. If a rhesus negative woman marries a Rhesus positive man, their children are highly likely to be rhesus positive. During the last months of pregnancy, the Rhesus antigen from the foetus may pass into the mother's blood if the foetal blood leaks into the mother. This causes the mother's body to produce antibodies which destroy some of the foetus's red blood cells. This destruction is minimal in the first child pregnancy. For the children that follow, a lot of destruction can take place and death of the foetus may occur. This is called an Rh disease or haemolytic disease of the newborn or erythroblastosis foetalis. To prevent this, the mother is treated with anti-rhesus globulin. This prevents her body from forming antibodies against the rhesus antigen. However, if there is no leakage that causes mixing up of the two blood samples, no effect will occur.

Blood transfusion

Blood transfusion is the transfer of blood from one person, the donor to another person, the recipient. It is necessary to replace blood when the recipient has a blood disorder or has lost a lot of blood due to surgery or an accident. For blood transfusion to be successful, the blood of the donor and that of the recipient must be able to mix without agglutination. When this happens, the two blood samples are said to be compatible but if the blood samples are incompatible, agglutination occurs that can cause death. Blood compatibility depends on the blood groups of the donor and the recipient. For example, if a person of blood group A receives blood from a person of blood group B, the recipient's body produces antibodies against antigen B. This is because the antigen is seen as foreign material. Therefore, transfusion considers the reaction between the antigen of the donor's blood and antibodies of the recipient's blood.

Individuals with blood group AB are called universal recipients. They can

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receive blood from people of any blood group because they have no antibodies *a* and *b* in their blood. However, they can only donate blood to someone with blood group AB. Those with blood group O are universal donors. They can donate blood to people of all blood groups because they have no antigen. However, they can only receive blood from someone with blood group O because the plasma contains both antibodies *a* and *b*. Table 9.4 shows compatibility of different blood groups.

Table 9.4: Compatibility of blood groups

Donor's blood group	**Recipient's blood group**			
	A	B	AB	O
A	✓	×	✓	×
B	×	✓	✓	×
AB	×	×	✓	×
O	✓	✓	✓	✓

Key:

✓ means compatible

× means incompatible

If blood from a rhesus positive person is transfused to a rhesus negative person, the recipient produces rhesus antibodies. If such a transfusion is done for a second time, massive agglutination can occur. This can lead to death.

Precautions taken during transfusion

Blood from the donor must be checked for compatibility with the blood from the recipient in terms of both ABO blood group and Rhesus factor in order to avoid agglutination. The donor's blood must be screened to ensure that it does not have pathogens that can cause diseases such as HIV and AIDS, syphilis and hepatitis B. Donated blood is stored in special bags in a refrigerator and an anticoagulant is added to prevent it from coagulating. Transfusion should be done only when extremely necessary.

Advantages of blood transfusion

(i) It ensures rapid replacement of blood lost from the body, for example during surgery, due to an accident, or during and after delivery.

(ii) It is used to manage diseases such as sickle-cell anaemia.

Disadvantages of blood transfusion

(i) There are chances of developing a reaction to transfused blood in such a way that patient's blood destroys transfused blood. This is because blood is a complex tissue

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that contains many different substances. One person's blood cannot be exactly the same as another's.

(ii) Transfused blood may cause infections if it is not well screened.

Blood circulation in human beings

Blood circulation is the movement of blood from the heart to all parts of the body, and back to the heart as shown in Figure 9.13.

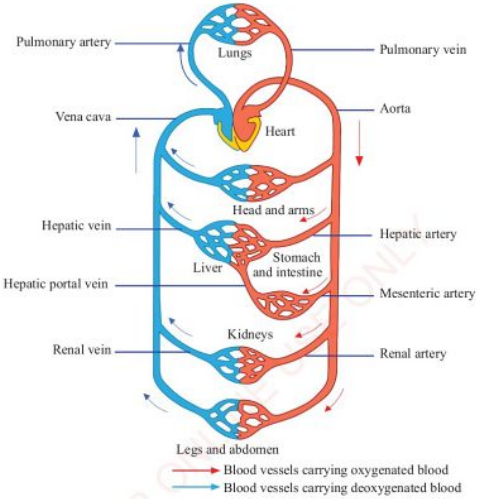

Figure 9.13: Blood circulation in the whole human body

Human beings exhibit double circulation, whereby the blood passes through the heart twice for each complete circulation. Double circulation includes pulmonary circulation and systemic circulation as shown in Figure 9.14. In other less complex organisms like fish, blood goes through the heart only once. This is known as single circulation.

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Pulmonary circulation

Pulmonary circulation transports blood between the heart and the lungs. It transports deoxygenated blood to the lungs where gaseous exchange occurs. In the lungs, the blood is oxygenated. It then flows back to the heart through the pulmonary vein as shown in Figure 9.14. The movement of blood between the heart and the lungs is called the pulmonary cycle.

Systemic circulation

The systemic circulation provides different parts of the body with oxygen and other vital substances. In systemic circulation, the pulmonary vein transports blood to the left auricle as shown in Figure 9.14. The left auricle then pumps the blood into the left ventricle. The left ventricle has strong muscles that pump blood to all parts of the body through the aorta. After the tissues have obtained their requirements from the blood, the blood flows back to the heart through the vena cava. This movement of blood between the heart and various parts of the body is called the systemic cycle. Therefore, systemic circulation is the circulation of blood between the heart and all other parts of the body except the lungs. Oxygenated blood from the left ventricle is pumped to various parts of the body through the aorta. The deoxygenated blood from different parts of the body is brought into the right auricle through the vena cava.

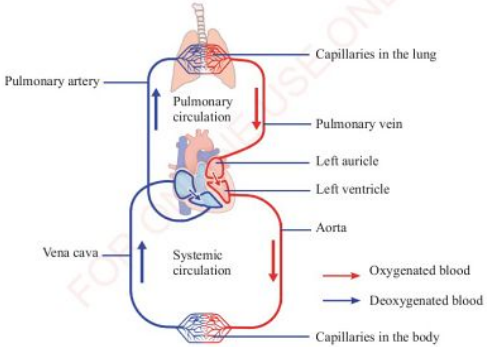

Figure 9.14: Double circulation in human beings

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Formation of tissue fluid

Tissue fluid is a kind of fluid formed from blood plasma by a diffusion and filtration process. This fluid occupies much of the intercellular spaces in the body and blood capillaries. They form a connecting link for transportation of nutrients, gases and other materials between blood capillaries, tissues, and lymphatic vessels.

The aorta, which is the largest artery in the body, branches into smaller arteries that in turn branch into even smaller vessels called arterioles as shown in Figure 9.15. Arterioles branch into smallest vessels called arterial capillaries that are in contact with the tissues of the body. The capillaries have tiny pores that allow some components of blood to filter into the tissues.

In the same way, the vena cava which is the largest vein branches into smaller veins called venules as shown in Figure 9.15. These branch into smallest vessels called venous capillaries that are in contact with the body tissues.

At the arterial end of the capillary, there is high blood pressure. This forces fluid out through the tiny pores in the capillaries. The fluid is composed of water, oxygen, hormones, and nutrients. This fluid bathes the cells. It is called tissue fluid or interstitial fluid.

The substances in this fluid diffuse into the cells through the cell membranes. In addition, the waste products from the cells diffuse into the tissue fluid. These wastes include carbon dioxide, minerals, and nitrogenous wastes. Figure 9.16 shows the formation of tissue fluid.

Tissue fluid constitutes internal environment in which tissue cells bath. The cells get their oxygen and nutrients from the fluid and excrete their metabolic wastes into it.

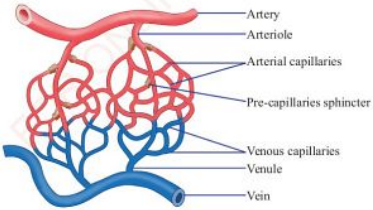

Figure 9.15: Arterial and venous blood capillaries

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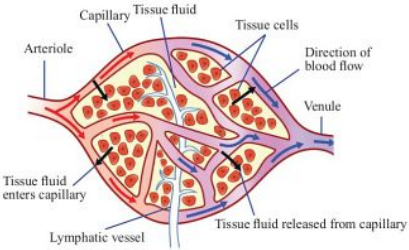

Figure 9.16: Formation of tissue fluid in a capillary bed

At the venous end of the capillary, blood pressure is low; water potential is also low. The pressure of the tissue fluid is high. This forces the tissue fluid back into the capillaries. Diffusion also helps in the re-entry of tissue fluid into the capillary. However, some tissue fluid remains within the cells. It later enters the lymphatic system to form lymph fluid.

The capillaries join to form venules. The venules join to form veins, which transport blood back to the heart. Veins in the lower part of the body unite to form the inferior vena cava while those in the upper part of the body unite to form the superior vena cava. These two large veins join to form the vena cava which transports blood to the right auricle of the heart.

Importance of blood circulation

Blood circulation enables the transportation of cell requirements such as oxygen and nutrients to all tissues. It also ensures that waste products from the cells are removed in order to prevent accumulation. The accumulation of waste products is harmful to the body.

Blood circulation is also important for the regulation of body temperature. Heat is transported to all parts of the body through this system. Moreover, blood circulation transports hormones from the organs that produce them to the organs where they are needed. For example, insulin hormone from the pancreas is necessary for the regulation of blood sugar levels.

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Blood pressure

When ventricles contract and the blood is pumped into arteries, it causes systolic pressure. On the other hand, when the auricles contract and pump the blood into ventricles, it causes diastolic pressure. The pressure developed during these actions can be felt in the arteries. Blood pressure is measured by considering the systolic pressure and the diastolic pressure. It is measured in millimeters of mercury (mmHg). For example, if the pressure during systole phase is 120 mmHg and the pressure during diastole phase is 80 mmHg, the blood pressure is 120/80 mmHg. This is the average blood pressure in a normal human being. The instrument used to measure blood pressure is called a sphygmomanometer.

Activity 9.4: Measuring blood pressure

Materials:

Sphygmomanometer and a note book

Procedure

1. Watch closely as your teacher or the health officer demonstrates how to use the sphygmomanometer to measure blood pressure, as shown in Figure 9.17.

Figure 9.17: Measuring blood pressure

2. Under the guidance of your teacher, measure the blood pressure of your fellow student. Your fellow student should also measure your blood pressure.
3. Compare your results with those from the rest of the class members. Are they the same?

Diseases and disorders of the human circulatory system

Diseases and disorders of the human circulatory system affect blood, blood vessels, and the heart. Diseases and disorders may be caused by genetic factors, unhealthy eating habits, and other lifestyles. Eating food with high levels of cholesterol and fat causes narrowing of blood vessels due to their deposition in blood vessels. Stress and lifestyles such as smoking, lack of exercise, and alcohol consumption cause a great risk of developing heart diseases including coronary heart disease, and high blood pressure.

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Arteriosclerosis

Arteriosclerosis is the hardening of arteries. It happens when there are fat depositions on the wall of the artery or when fibrous tissues form in the artery wall causing the narrowing of the lumen of the artery (See Figure 9.18). It can also occur when the artery wall degenerates. This hinders the normal working of the artery, affecting the efficiency of blood flow.

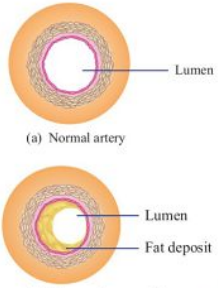

Figure 9.18: Effect of arteriosclerosis

As a result, the heart has to pump harder in order to supply the tissues with enough blood. The result of this is high blood pressure (hypertension). High blood pressure usually has no specific symptoms. However, it can cause headache, dizziness, and ringing in the ears.

Causes of arteriosclerosis: Arteriosclerosis is mainly caused by any of the following: excessive alcohol intake; smoking; stress; too much fat in the diet; lack of exercise; and old age.

Effects of arteriosclerosis: Arteriosclerosis causes swelling of part of a blood vessel and rupturing of the artery walls. It also causes total blockage of an artery, thus depriving some tissues of oxygen. This can cause severe damage or death of the affected tissue.

Prevention of arteriosclerosis: People can reduce chances of developing arteriosclerosis by avoiding excessive alcohol intake and smoking, reducing stress, minimising intake of fatty foods, and engaging in regular exercises.

Sickle-cell anaemia

This is a genetic disorder resulting from production of abnormal haemoglobin and malformed red blood cells. Its effect is the reduction of the blood's capacity to transport oxygen. The disease gets its name from the crescent or sickle shape of the red blood cells, as shown in Figure 9.19.

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Figure 9.19: Normal and sickle shaped red blood cells

Symptoms of sickle-cell anaemia: Sickle-cell anaemia is characterised by fatigue or excessive tiredness, shortness of breath during exercise, headeaches, dark-coloured urine, abdominal pain, abnormal heartbeat, and general body weakness.

Prevention of sickle-cell anaemia: It is difficult to prevent sickle-cell anaemia since it is inherited, although premarital screening of sickle-cell anaemia may help to reduce the disorder. However, patients can be helped by making sure that they avoid excessive physical exercise and eat a well-balanced diet that is rich in minerals and vitamins.

Leukaemia

Leukaemia is a type of blood cancer. It is caused by over production of white blood cells and suppressed production of red blood cells. The excess white blood cells infiltrate body organs, for example, the liver and the spleen. This causes reduced efficiency in the functioning of these organs and abnormal enlargement.

Symptoms of leukaemia: Leukemia is characterised by abnormally high numbers of white blood cells and abnormal bleeding. For example, nose bleeding, bleeding even from minor cuts, extreme body weakness, anaemia, as well as throat and mouth infections that may be recurrent.

Prevention of leukaemia: The risk of getting leukaemia can be minimised by maintaining a proper lifestyle including exercising, avoiding smoking and maintaining healthy eating habits.

High blood pressure (Hypertension)

The blood pressure of a normal human being is 120/80 mmHg. Very high blood pressure (over 140/90 mmHg) strains the blood vessels and causes hypertension and sometimes heart failure. An increase in blood pressure may be caused by high fat levels due to over-consumption of

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fatty foods, lack of exercise, obesity, high emotional stress, alcoholism, smoking, and arteriosclerosis.

Symptoms of hypertension: The signs and symptoms of hypertension include feeling dizzy, ringing sound in the ears, severe headache, and raised blood pressure over 140/90 mmHg recorded in 3-4 consecutive days.

Prevention of hypertension: Hypertension can be prevented by engaging in regular physical exercises, avoiding alcoholism, and smoking. It can also be prevented by eating a balanced diet with low fats to control weight, and reducing stress as much as possible.

Coronary thrombosis

Coronary thrombosis occurs when blood clots occur in the blood vessels that supply blood to the heart, called coronary arteries. This prevents blood from reaching some tissues of the heart. Thus, the affected tissues lack adequate amounts of oxygen and waste materials accumulate in the cells to toxic levels.

Symptoms of coronary thrombosis: Coronary thrombosis is characterised by uncomfortable pressure or sharp pain in the chest, sometimes extending to the neck, shoulders, and arms. Other symptoms include excessive sweating, dizziness, fainting, nausea, severe indigestion, and shortness of breath.

Effects of coronary thrombosis: Coronary thrombosis can cause death of some cardiac tissue or sudden human death.

Prevention of coronary thrombosis: People can avoid coronary thrombosis by doing regular physical exercise, avoiding sudden strenuous activity such as aerobics, avoiding alcohol and smoking, minimising intake of fatty foods, minimising intake of salt by consuming 5 g of salt per day, and avoiding stress.

Stroke

Stroke occurs when there is an interference in the amount of blood flowing to the brain. Such an interference can be due to blockage or rupture of an artery supplying blood to the brain. This hinders adequate supply of oxygen and nutrients to the brain cells.

Symptoms of stroke: Symptoms of stroke include sudden numbness or weakness especially on one side of the body, abrupt confusion or trouble in understanding or speaking, and unexpected poor vision in one or both eyes. The individual also experiences sudden dizziness, loss of balance, trouble when walking or poor coordination, and severe headaches.

Effects of stroke: Stroke has severe effects on the victim such as weakness or paralysis on one side of the body, leading to difficulties in movement

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and coordination. It also causes lack of sensation on one side of the body, speech or language problems, and loss of memory. Other effects are behaviour changes, exhaustion, and difficulty when swallowing.

Prevention of stroke: Stroke can be prevented by avoiding alcohol and smoking, maintaining blood pressure within the normal range, and exercising regularly. Eating a low-fat diet and low-salt diet (salt should not exceed 5 g per day) can also help to minimise chances of getting stroke.

Exercise 9.2

1. Differentiate arteries from veins.
2. Describe the components of blood.
3. Explain the role of red blood cells in the body.
4. Explain the importance of blood circulation.
5. Describe what will happen to the flow of blood in the left side of the heart if the bicuspid valve stops to function effectively.
6. Briefly explain the effects of HIV on white blood cells.

The lymphatic system

The lymphatic system is a network of vessels, tissues, and organs that help to collect the tissue fluid and bring it back to the circulatory system. The lymphatic system closely resembles the blood circulatory system. The lymphatic system connects with the blood circulatory system at the superior vena cava.

Components of the lymphatic system

The lymphatic system consists of lymph, lymph nodes, and lymphatic vessels, which are similar to the veins and capillaries of the circulatory system. Also, it consists of lymphoid organs and tissues such as thymus, adenoids, tonsils, and spleen, as shown in Figure 9.20.

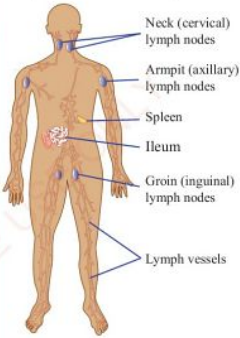

Figure 9.20: Lymphatic system

Lymph or lymphatic fluid

Is a collection of extra fluid drained from cells and tissue. It contains various substances like proteins, minerals, fats, nutrients, damaged cells, and foreign pathogens. Lymph transports

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infection-fighting white blood cells (lymphocytes).

Lymph nodes

Lymph nodes are bean-shaped glands. They are found in areas between the head to around the knee. Some exist as a single node, while others are closely connected groups called chains. They are located deep inside the body, such as around the lungs and heart, or closer to the surface, such as under the arm or groin. Lymph nodes monitor and cleanse the lymph as it filters through them. The nodes filter out the damaged cells. These lymph nodes also produce and store lymphocytes and other immune system cells, that attack and destroy pathogens and other harmful substances in the fluid. Lymph nodes are connected to each other by lymphatic vessels.

Lymphatic vessels

Lymphatic vessels are the network of capillaries and large network of tubes located throughout the body that transport lymph away from tissues. Lymphatic vessels collect and filter lymph at the nodes as it continues to move towards larger vessels called lymphatic ducts. These vessels operate very much like veins. They work under very low pressure and have a series of valves in them to keep the fluid moving in one direction.

Lymphatic ducts

Lymphatic ducts are divided into two branches which are right lymphatic duct and left lymphatic duct. Lymphatic vessels empty the lymph into these two ducts. These ducts connect to the subclavian vein which returns lymph to the bloodstream through vena cava. Returning lymph to the bloodstream helps to maintain normal blood volume and pressure. It also prevents excessive buildup of fluid around the tissues, a condition called oedema.

Spleen

Spleen is the largest lymphatic organ which is located on the left side of the body just above the kidney. The spleen acts as a blood filter. It recognises old or damaged red blood cells and removes them from the body by breaking them down and saving any useful components such as iron. It also stores blood and produces white blood cells that fight infections.

Thymus

It is an organ that is a part of the lymphatic system in which T-lymphocytes (also called T-cells) grow and multiply. Thymus is located in the chest just above the heart. It stores immature lymphocytes and prepares them to become active T-cells which help to destroy infected cells.

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Tonsils and adenoids

Tonsils are large clusters of lymphatic cells found in the pharynx. Adenoids are tissues that sit in the back of the nasal cavity. Tonsils and adenoids defend the body against pathogens that enter through the mouth or nose.

How the lymphatic system works

After the cells get their requirements from tissue fluid, not all the fluid flows back into the capillaries. Part of it flows into lymph vessels. Once it is in these vessels, the fluid is called lymph. Lymph vessels unite to form larger vessels called lymphatic ducts.

The right lymphatic duct empties its contents into the right subclavian vein while the left lymphatic duct empties its contents into the left subclavian vein. The two veins join to form the superior vena cava. In this way, the contents of lymph enter the blood circulatory system.

Lymphatic ducts form nodule-like structures called lymph nodes. These nodes are found throughout the body including the abdomen, groin, armpits, and neck. Lymph nodes are important sites for the production of white blood cells. They also filter out foreign materials such as bacteria and dead tissue before they enter the bloodstream.

The flow of lymph depends greatly on the squeezing of lymph vessels by breathing movements, intestinal movements, and muscular movements. The lymph vessels have valves to prevent back flow of lymph.

Importance of the lymphatic system

The lymphatic system plays important roles in the body such as protecting the body from pathogens, helping to absorb fats from the digestive tract, maintaining body fluid levels, and removing cellular wastes.

Protecting the body from pathogens

Lymph nodes produce lymphocytes that help the body to fight diseases. Also, the spleen, adenoids, and tonsils produce antibodies which help to fight against disease-causing micro-organisms.

Absorbing fat from the digestive tract

Lacteals enable absorption of fatty acids and glycerol after digestion.

Maintaining body fluid levels

Lymphatic system collects excess fluid that drains from cells and tissues throughout the body and returns it to the blood stream. The fluid is then re-circulated through the body.

Removing cellular waste

The spleen destroys worn out red blood cells in the body.

Disorders and diseases of the lymphatic system

There are many diseases and disorders that affect the vessels, glands, and organs that make up the lymphatic system. Some

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occur during development before birth or during childhood. Others develop as a result of disease or injury. Some of these diseases and disorders are explained below.

Lymphatic filariasis

This is a disease that is caused by filarial worms. Such worms block the lymph vessels causing accumulation of lymph that leads to swelling of the arms or legs, as indicated in Figure 9.21.

Figure 9.21: Person with lymphatic filariasis

Filarial worms are transmitted by mosquitoes such as *Culex* and *Anopheles*. The disease can be prevented by avoiding mosquito bites and destroying mosquito breeding sites such as bushes and stagnant water. Individuals can avoid mosquito bites by using mosquito nets, applying insect repellents on the skin, and wearing long clothes.

Oedema

This is the swelling of body tissues due to excessive lymph. It is caused by increased blood pressure in the capillaries. This leads to production of large amounts of lymph that the lymphatic system cannot transport efficiently. Pregnancy, obesity, and protein deficiency can also cause oedema. Protein helps to hold salt and water inside the blood vessels so that fluid does not leak out into the tissues.

Oedema can be controlled by taking measures to reduce blood pressure. Pregnant women can control oedema by keeping the feet slightly raised when sitting or lying down, and eating a well-balanced diet. Other measures include reducing body weight by exercising, and avoiding eating excessive amounts of food.

Lymphoma

Lymphoma is the term used to refer to cancers that affect the lymphatic system. These cancers cause abnormal growth or functioning of the components of the lymphatic system. The result is weakened immune response in the body.

Symptoms of lymphoma: The symptoms of lymphoma include painless swollen lymph nodes often in the neck, armpit, upper chest, or groin. Other symptoms are fatigue, weight loss, night sweat, persistent fever, and itching.

Prevention of lymphoma: Lymphoma is prevented by changing life style such

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as avoiding unnecessary exposure to radiation and certain chemicals like weed killers and insecticides, maintaining a normal weight, and eating a healthy diet.

Tonsillitis

This is the swelling of the tonsils due to bacterial or viral infection. The bacteria or virus enter the body through the nasal sinuses or the mouth. Tonsils provide defense against diseases. The role of tonsils is to produce white blood cells that help the body to fight against infections. Tonsils combat bacteria and viruses that enter the body through the mouth. Although they offer protection against the infections, tonsils are also vulnerable to some infections due to foreign invaders that enter the body.

Symptoms of tonsillitis: The symptoms of tonsillitis include red and swollen tonsils, and difficulty in swallowing or experiencing pain while swallowing. Other symptoms include sore throat, stiff neck, fever or chills, muscle ache, tiredness, and tenderness in the jaw and neck due to swollen lymph nodes.

Prevention of tonsillitis: There are various ways of preventing tonsillitis. These include washing hands often, especially before touching the nose or mouth; avoiding sharing food, drinks, or utensils with infected persons; and replacing one's toothbrush regularly.

Exercise 9.3

1. Explain the meaning of double circulation of the human blood.
2. How is blood pressure measured?
3. Mention any three disorders of the human blood circulatory system.
4. Explain the symptoms and ways of controlling the disorders you have mentioned in question 3.
5. What is the role of lymph nodes in the human body?
6. Explain control measures against any three disorders of the lymphatic system.

Chapter summary

1. The mammalian heart is responsible for pumping blood to all parts of the body. It has four chambers: two auricles (atria) and two ventricles.
2. Valves in the heart and veins prevent the back flow of blood.
3. The flow of blood in the heart is as follows:
   (a) deoxygenated blood from the body enters the right auricle through the vena cava;
   (b) the right auricle pumps blood to the right ventricle;
   (c) the right ventricle pumps blood to the lungs through the pulmonary artery;

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(d) oxygenated blood from the lungs enters the left auricle through the pulmonary vein;

(e) the left auricle pumps blood to the left ventricle; and

(f) the left ventricle pumps blood to all parts of the body through the aorta.

4. The main blood vessels are arteries, veins, and capillaries.

5. Arteries are muscular vessels that transport blood away from the heart. Arteries contract and relax, hence, creating a pulse.

6. Veins are less muscular than arteries. They transport blood towards the heart.

7. Capillaries are very small vessels whose walls are one cell thick. They are in direct contact with the body tissues.

8. Blood is a fluid tissue consisting of plasma, red blood cells, white blood cells, and platelets.

9. Plasma is the fluid part of blood. It transports dissolved substances, and helps to regulate body temperature and pH. It also acts as a site for the exchange of nutrients and waste products.

10. Red blood cells are biconcave in shape, lack a nucleus at maturity, and contain haemoglobin. Their function is to transport oxygen and carbon dioxide.

11. White blood cells are irregularly shaped. They are mainly responsible for body immunity.

12. Blood platelets are fragments of cells. They help in blood clotting during injuries.

13. Grouping of human blood is done according to the ABO system and the Rhesus factor.

14. Blood transfusion is the transfer of blood from a donor to a recipient of the same species.

15. Agglutination occurs if transfused blood is incompatible with the recipient's blood.

16. Blood circulation is the movement of blood from the heart to all parts of the body. Blood circulation in humans beings involves a double circulation system whereby there are two cycles:

    (i) pulmonary cycle (from the heart to the lungs and back); and

    (ii) systemic cycle (from the heart to all parts of the body and back).

17. Diseases and disorders of the human circulatory system include high blood pressure, arteriosclerosis, sickle-cell anaemia, stroke, coronary thrombosis, and leukaemia.

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18. Blood pressure is measured by considering the pressure when the ventricles contract (systole) and the pressure when the auricles contract (diastole).

19. Lymph is formed from tissue fluid that does not flow back into the capillaries.

20. Disorders of the lymphatic system include lymphatic filariasis, oedema, lymphoma, and tonsillitis.

Revision exercise 9

Section A

Choose the correct answer.

1. Which of the following is NOT a component of blood?
   (a) Erythrocyte
   (b) Platelets
   (c) Plasma
   (d) Lymph duct

2. Which of the following is NOT a heart valve?
   (a) Tricuspid
   (b) Bicuspid
   (c) Pulmonary
   (d) Semilunar

3. All of the following are found suspended in the plasma except _____.
   (a) red blood cells
   (b) platelets
   (c) capillaries
   (d) white blood cells

4. Which of the following is NOT transported by blood plasma?
   (a) Faeces
   (b) Nutrients
   (c) Respiratory gases
   (d) Hormones

5. Which of the following is NOT a disease of the blood circulatory system?
   (a) Hypertension
   (b) Oedema
   (c) Arteriosclerosis
   (d) Leukaemia

6. Which of the following is NOT a way of controlling hypertension?
   (a) Daily exercise
   (b) Reduce stress
   (c) Injecting insulin
   (d) Control of body weight

7. Which of the following does NOT cause cardiovascular disease?
   (a) Dietary fibre
   (b) Smoking
   (c) Fatty foods
   (d) Lack of exercise

8. People with blood group O have _____.
   (a) antigen B
   (b) antigens A and B
   (c) antigen A
   (d) no antigen

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9. People with blood group AB have _____.
   (a) antibody *b*
   (b) antibody *a*
   (c) antibodies *a* and *b*
   (d) no antibody

10. The lymph nodes are found in the following parts of the body, except _____.
   (a) abdomen
   (b) groin
   (c) armpits
   (d) neck

11. Choose a term from the box that best matches each of the phrases below.

arteriosclerosis, hypertension, cardiac cycle, bicuspid, pulmonary vein, vena cava, veins, artery.

   (a) A valve between the left atrium and left ventricle of the heart.
   (b) A large vein that empties blood into the left atrium of the heart.
   (c) The tubes that form a branching system and carry blood to the heart.
   (d) Hardening and narrowing of an artery.
   (e) A disorder in which high blood pressure is the primary symptom.

Section B

12. Explain what would happen if:
   (a) spleen and tonsils are removed from the body;
   (b) capillaries had thick walls; and
   (c) left ventricle had thin walls.

13. Explain the following:
   (a) how being thick-walled, muscular and elastic help arteries to transport blood from the heart to the rest of the body;
   (b) why arteries do not need valves; and
   (c) why small organisms such as amoeba and paramecia do not need the blood circulatory system.

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14. The heart has its own supply of blood from vessels that run all over its surface.
    (a) Name these vessels.
    (b) In some people, the above mentioned vessels can be blocked by a blood clot. Explain the effects of these vessels getting blocked.
15. Explain:
    (a) how lifestyle and diet may cause problems in the circulatory system; and
    (b) why the heart beats faster during exercise.
16. Explain how lymph is formed.
17. Explain the importance of thrombocytes.
18. Differentiate the following:
    (a) pulmonary circulation and systemic circulation;
    (b) lymph and blood;
    (c) artery and vein;
    (d) thrombin and prothrombin; and
    (e) universal donor and universal recipient.
19. What are the causes, symptoms, and effects of the following disorders of the circulatory system?
    (a) Leukaemia
    (b) Hypertension
    (c) Stroke
    (d) Sickle-cell anaemia
20. Briefly describe the process of blood circulation in human beings.
21. Why do arteries have thicker walls than veins?
22. How is oxygen transported in the blood?

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Chapter Ten

Transport of materials in plants

Introduction

Plants need a transport system to transfer manufactured food from the photosynthetic sites mostly in the leaves, to other parts of the plant. The transport system is also required to move water and dissolved minerals from the roots to the rest of the plant. The transportation of raw materials, minerals, water, and food in plants occurs through a systematic network of tissues that make up the vascular system. In this chapter, you will learn about the vascular system in plants, absorption and movement of water and mineral salts in plants, and transportation of manufactured food. The competencies developed from this chapter will enable you to use proper measures to maintain the survival of plants.

The vascular system

Transportation of materials in plants occurs through the vascular system. In plants, the vascular system works as a transport system because it is made up of specialised cells that form tiny straw like tubes. The vascular system is composed of a collection of conducting tissues and associated supportive fibres. The conductive tissues are of two types namely, xylem and phloem tissues (See Figure 10.1). These two tissues together with their associated fibres are collectively known as vascular bundles. The xylem tissue has the role of transporting water and mineral salts absorbed from the soil through roots to all parts of the plant. The phloem tissue is responsible for transporting manufactured food from the sites of photosynthesis to all parts of the plant.

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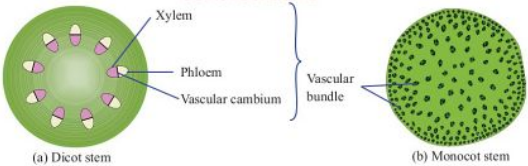

Figure 10.1: Vascular bundle in the stem

Xylem

Xylem is one of the conducting tissues in plants, which primarily transports water and dissolved minerals from roots to stem and leaves. It also provides mechanical strength to the plants. It mostly occurs in the inner part of the vascular bundles. The movement of substances in the xylem of the main stem is always upward. Xylem is a complex tissue composed of four different kinds of cells which are xylem vessel elements, tracheids, fibres, and parenchyma cells. Figure 10.2 shows the structure of the xylem tissue.

Xylem vessel elements

Xylem vessel elements are one of the two water and mineral salts conducting structures of the xylem tissue. Mature xylem vessel elements are long, cylindrical, and tube like structures. Their walls are made up of cellulose and lignin. Lignin is deposited on the cell walls of xylem vessel elements to strengthen and make them rigid. Therefore, due to strength and rigidity of the xylem vessel element, it has an additional function of giving support to the plant.

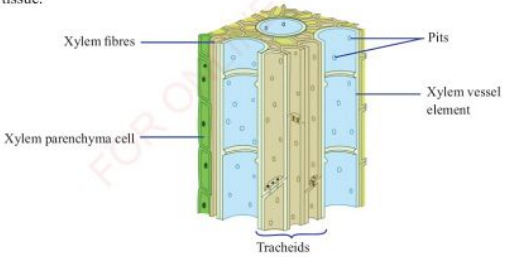

Figure 10.2: Structure of the xylem

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A xylem vessel element is made up of tiny hollow cells without end walls. Each of these cells are called vessel elements and are joined end-to-end to form a pipe-like structure or a hollow tube as shown in Figure 10.3. Xylem vessel elements begin in the roots through the stem and branch up to every leaf of the plant. Xylem vessel elements have no cytoplasm and nuclei at maturity. Thus, they are said to be dead. Absence of cytoplasm and nuclei make them to be hollow tubes, which then act as pipes. This enables them to transport a larger volume of water and mineral salts. The xylem vessel elements are found in flowering plants (angiospermophytes) only.

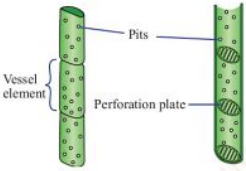

Figure 10.3: Xylem vessels

Tracheids

Tracheids are series of interconnected dead, elongated, tube-like cells with tapering ends as shown in Figure 10.4. They are the only xylem conducting tissue in coniferophytes and pteridophytes. In angiospermophytes both tracheids and xylem vessel elements are present. Like vessels, tracheids have a thick lignified wall and lack protoplasm, that is cytoplasm, and nuclei. Both xylem vessel elements and tracheids are involved in transportation of water and mineral salts in plants. Tracheids and vessel elements differ in their shapes and structures. Tracheids are longer than vessel elements. They are connected laterally to enable continuous flow of water and mineral salts while the vessel elements are connected end to end to form long tubes called xylem vessels. Tracheid end walls have holes unlike xylem vessel elements end walls that have perforations. Tracheids have small lumen and are narrower than xylem vessel elements. This makes tracheids less efficient in conduction of water compared to xylem vessel elements.

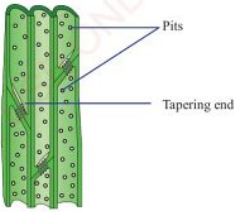

Figure 10.4: Tracheids

Xylem fibres

Xylem fibres are dead cells with lignified walls and a central lumen. They are narrow and elongated cells with tapering ends, located between tracheids and xylem vessels. Their function is

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to provide protection and mechanical support to xylem vessels and tracheids.

Xylem parenchyma

Xylem parenchyma are non-specialised simple cells with thin cell walls. They are the only living cells of xylem. They help in storing water and food in the form of carbohydrate.

Phloem

Phloem is one of the transporting tissues in plants that conducts substances such as hormones and food synthesised in the leaves to all parts of the plant. The process of transporting food from synthesising organs such as leaves to the storage organs such as tubers is called translocation. Phloem is usually located on the outer side of the vascular bundles. Phloem is a complex tissue made up of various specialised cells which are sieve tubes, companion cells, phloem fibres, and phloem parenchyma cells. Figure 10.5 shows the structure of phloem tissue.

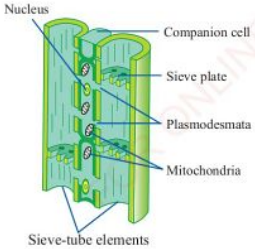

Figure 10.5: Phloem tissue

Sieve tubes

Like xylem vessels, a sieve-tube is made up of cells that are joined end-to-end. However, the end walls of these cells are not completely broken down but have perforations or pores that form sieve plates as shown in Figure 10.5. These cells contain cytoplasm but they have no nucleus. Fibres run through the pores thereby connecting adjacent sieve-tube cells.

Companion cells

Each sieve-tube element is associated with a living cell called a companion cell. The two cells are separated by a thin wall made up of parenchyma cells with pores called plasmodesmata, which allow exchange of materials between the cells. Companion cells have a high concentration of mitochondria that provide the sieve-tube elements with energy for transportation of food.

Phloem parenchyma cells

These are cells which are associated with the phloem tissue. They are located near the finest branches and terminations of sieve tubes in leaf veins, stem, and flowers. The function of phloem parenchyma cells is transportation of foods such as sugars in a dissolved form. Based on this function, they are called transfer cells.

Phloem fibres

These are elongated and unbranched fibers with a cylindrical shape. They are dead cells associated with the phloem tissue. These fibres provide mechanical support to the conducting cells of the

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phloem and strength to the stem.

Phloem and xylem constitute the major transport system in plants, but they differ from each other in many aspects. Table 10.1 summarises the major differences between phloem and xylem tissues.

Table 10.1: Differences between phloem and xylem tissues

Feature	Phloem	Xylem
Function	Transports food and substances such as sugars and amino acids from leaves to the storage organs and growing parts	Transports water and dissolved minerals from the roots to aerial parts of plants
Structure	Phloem has elongated and tubular-shaped structures called sieve tubes with sieve plate	Xylem has tubular-shaped structures called xylem vessels with perforated cross walls
Components	Phloem is made up of sieve tubes, companion cells, phloem parenchyma, and phloem fibers	Xylem is made up of tracheids, vessel elements, xylem parenchyma, and xylem fibers
Fibres	Phloem fibres are wide	Xylem fibres are narrow
Cells	Phloem is composed of living cells with little cytoplasm but no nucleus	Xylem is composed of dead cells at maturity with hollow tubes
Location in the vascular bundle	Occurs on the outer side of the vascular bundle	Occurs toward the inner part of the vascular bundle
Movement of materials	Materials in the phloem move in both upward and downward directions	Materials in the xylem of the main stem move in only one direction which is upward direction

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The distribution of vascular bundles in plants

Arrangement of vascular bundles in the roots, stems, and leaves of monocots and dicots differs in various aspects.

Activity 10.1: Investigating the distribution of vascular bundles in plants

Materials:

Microscope, microscope slides, sunflower root and stem, maize root and stem, iodine solution, and scalpel

Procedure

1. Cut very thin cross-sections of the stems and roots of sunflower and maize to obtain a specimen.
2. Place the specimen on the microscope slide.
3. View the cross-section of the sunflower stem under the microscope. What do you observe?
4. Stain it with a drop of iodine solution then observe it again under the microscope.
5. Draw and label what you have observed.
6. Repeat steps 2 to 5 using the sunflower root, maize stem, and maize root and compare your observation with the prepared slides.
7. Compare the structure of monocot and dicot stems and roots.

Questions

(i) What differences have you observed in the arrangement of vascular bundles between monocot and dicot roots?

(ii) What differences have you observed in the arrangement of vascular bundles between monocot and dicot stems?

Monocotyledonous root

Monocot plants have fibrous roots. This type of roots form a wide network of thin roots that originate from the stem and they do not grow deep into the soil but remain close to the surface. The vascular structures are arranged in a circular pattern around the central pith as shown in Figure 10.6. The pith consists of ground tissue called parenchyma.

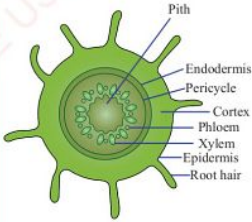

Figure 10.6: Cross-section of monocot root

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Dicotyledonous root

Dicots have a tap root which is a single thick root that grows deep into the soil and has smaller lateral roots. The vascular bundles of dicot roots are located in the middle of the root. The xylem is lobed, centrally positioned and star-shaped. The phloem is found between the extensions of the xylem, as shown in Figure 10.7.

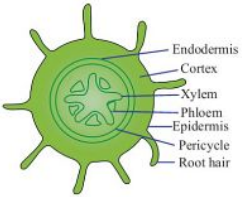

Figure 10.7: Cross-section of a dicot root

Monocotyledonous stem

The arrangement of vascular bundles in roots and stems differs significantly. In monocot stems the arrangement of vascular bundles is random or scattered as indicated in Figure 10.8. Most of the vascular bundles are concentrated towards the periphery of the stem and are more scattered towards the centre. These vascular bundles are surrounded by parenchyma cells in the cortex region. There is no pith in the monocot stem.

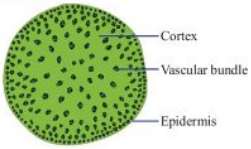

Figure 10.8: Cross-section of monocot stem

Dicotyledonous stem

In a dicot stem, the vascular bundles are arranged in a ring around the central pith, as seen in Figure 10.9. In each vascular bundle, the xylem and phloem are separated by a vascular cambium that contains cells which divide to expand the girth of the stem. The vascular cambium also replaces the old xylem and phloem tissues. Within the vascular bundles, the xylem is located interior to the vascular cambium ring, and the phloem is exterior. In between the vascular bundles and the epidermis, there are parenchyma cells forming the cortex region.

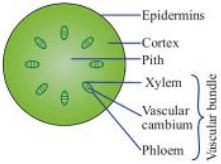

Figure 10.9: Cross-section of dicot stem

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Vascular bundles in leaves

Both the monocot and dicot leaves have vascular bundles surrounded by a bundle sheath. The bundle sheath has one or more layers of ground tissue called parenchyma cells. The main function of the bundle sheath is to protect the leaf veins.

Monocotyledonous leaves

In monocot leaves, vascular bundles form parallel veins. The phloem tissue is located towards the lower epidermis of the leaf while the xylem tissue is located towards the upper epidermis as shown in Figure 10.10.

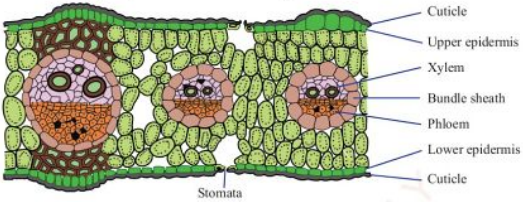

Figure 10.10: Cross-section of a monocot leaf

Dicotyledonous leaves

In the dicot leaf, vascular bundles form net-like veins. Like in the monocot leaf, the xylem tissue in a dicot leaf is located towards the upper epidermis of the leaf. The phloem tissue is located towards the lower epidermis of the leaf as shown in Figure 10.11.

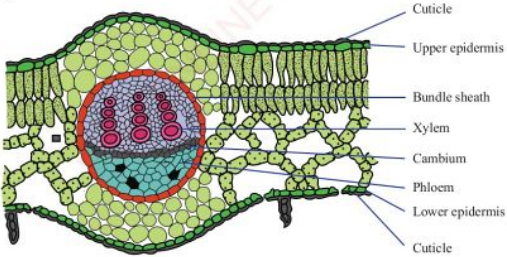

Figure 10.11: Cross-section of a dicot leaf

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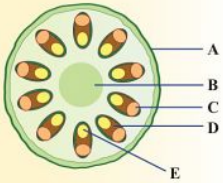
Exercise 10.1

1. The diagram below represents a transverse section of a young stem.



   (a) Name the parts labeled A to E.
   (b) State the functions of the parts labeled C, D and E.
   (c) List three differences between the section shown above and that of the root of the same plant.

2. State how xylem vessels are adapted to their functions.

3. Explain the meaning of translocation and how it occurs.

Absorption and movement of water and mineral salts

Plants absorb water and mineral salts from the soil through root hairs. The root hairs are found just behind the root tip. They are in contact with the soil and soil water.

Activity 10.2: Investigating the absorption of water by plant roots

Materials:

A plant with variegated leaves or light coloured flowers, coloured water, and a beaker

Procedure

1. Uproot the plant gently, taking care not to break or damage the roots.
2. Dip the plant in a beaker containing coloured water. Ensure that the plant roots are immersed in the water.
3. Leave the set up overnight.
4. Observe the variegated leaves or the petals of the plant.

Questions

(i) What have you observed?
(ii) What can you conclude?

Structure and functions of root hairs

Root hairs are extensions of the epidermal cells of the root. Figure 10.12 shows the structure of a root hair.

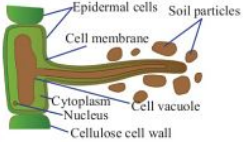


Figure 10.12: Structure of a root hair

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Root hairs are long and slender to provide a large surface area for the absorption of water and mineral salts from the soil. The large number of root hairs increases the total surface area of the roots for absorption of water and mineral salts. Root hairs contain vacuoles filled with cell sap. The root hair cell sap is usually hypertonic; that is, more concentrated than the surrounding water. Hence, water enters the root hair cells by osmosis. They have permeable cell walls which are hydrophilic in nature. Hydrophilic means water loving. Thus, root hairs are always in search of water supply. If root hair cells have a higher concentration of mineral salts than their surroundings, mineral salts are therefore absorbed by active transport. Root hairs are very thin in order to provide a short distance over which the absorbed water and mineral salts have to travel to reach the cell.

As the main roots elongate, the older root hairs die and are replaced with new ones. This helps the plant to have a constant supply of water and mineral salts from the soil.

Movement of water and dissolved mineral salts

When water is absorbed by the root hairs, it dilutes the contents of the cell sap vacuole. This causes the cells of the cortex, which are adjacent to the epidermis to have less water than the root hair cells hence, hypertonic. Therefore, water moves from the root hair cells to the cortex cells by osmosis. It moves the same way from the cortex into the cells of the endodermis, then into the pericycle and then into the xylem vessel (See Figure 10.13).

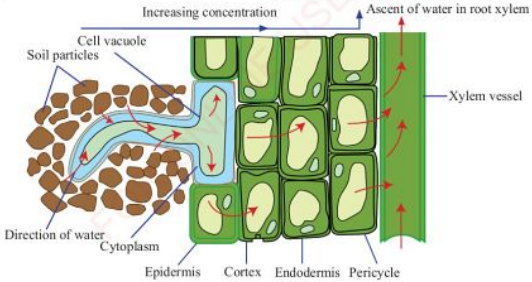

Figure 10.13: Movement of water from a root hair to the xylem

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Once in the xylem, water and the mineral salts dissolved in it move up the xylem vessel by transpiration pull, capillarity, and root pressure.

Transpiration pull

Transpiration occurs when water evaporates from the plant through the stomata in the leaves. As water is lost, the mesophyll cells draw water from the xylem in the leaf which in turn draws water from the xylem in the stem. This creates a tension called transpiration pull, which draws water from the roots. Thus, transpiration pull is the biological process by which plants draw water in the upward direction as a result of transpiration. This results in a continuous column of water through the xylem from the roots to the stem and leaves. This column of water is called transpiration stream (See Figure 10.14).

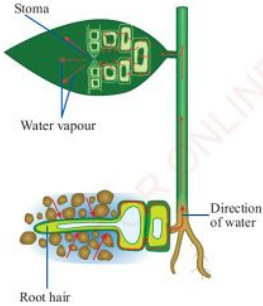

Figure 10.14: Transpiration stream

Capillarity

Capillarity is the ability of water to flow through narrow tubes. Xylem vessels are structurally adapted for capillarity, because they are long and have a narrow lumen which makes it possible for water to rise in them by capillarity. Capillarity is made possible by cohesive and adhesive forces. Cohesive force is the force of attraction between molecules of the same type as opposed to adhesive force which involves attraction between different molecules. Cohesive force makes the water molecules stick to each other whereby adhesion occurs between water molecules and the surface of the xylem. Adhesive force causes water molecules to adhere to the xylem vessels. Capillarity occurs when the adhesion of water molecules to the walls of the vessel is stronger than the cohesive forces between the water molecules.

Activity 10.3: Demonstration of capillarity

Materials:

Glass tubes of different diameters, beaker, coloured water, and retort stand

Procedure

1. Pour coloured water into the beaker.
2. Put glass tubes of different diameter in the water but not touching the bottom of the beaker. Clamp the tubes to hold them in place (See Figure 9.15).

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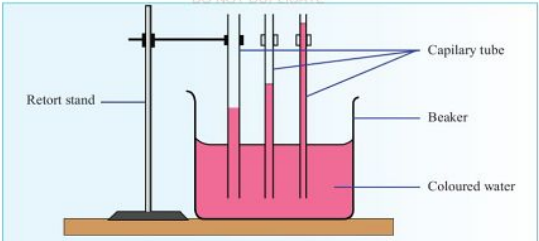

Figure 10.15: Experimental set-up to demonstrate capillarity

3. Observe how water rises in the glass tubes.
4. Compare the levels of water in the tubes. What have you observed?
5. Share your findings with your classmates.

Question

What caused differences in the levels of water observed in the three tubes?

Root pressure

Root pressure pushes water and dissolved mineral salts upwards from the root. This happens because the cells of the endodermis push mineral salts into the xylem. This increases osmotic pressure in the xylem thereby creating a force that moves the water and dissolved mineral salts up the xylem vessel. When a plant is cut, sap oozes out from the remaining stem or stump as shown in Figure 10.16. This is proof that root pressure drives the fluid upward through the xylem vessels.

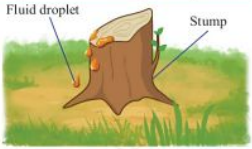

Figure 10.16: Stump oozing sap

Transpiration

Transpiration is a process by which plants lose water through the stomata in the leaves.

Water flows from the roots to the leaves through the xylem vessels. It enters the spongy mesophyll of the leaf by osmosis. The spongy mesophyll has substomatal air spaces in which water enters in the form of water vapour. As a result, the concentration of water vapour in the substomatal air spaces becomes higher than the concentration of water vapour in the air. This causes water to diffuse into the atmosphere through the stomata (See Figure 10.17).

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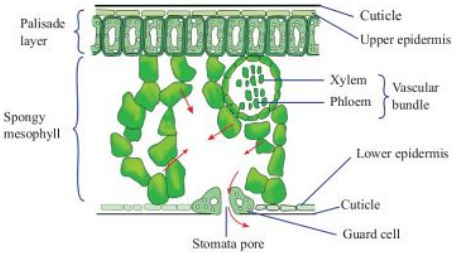

Figure 10.17: Movement of water through the leaves

Activity 10.4: emonstration of transpiration

Materials:

Potted plant, knife, polythene bag, weighing scale, and rubber bands

Procedure

1. Set up the experiment as shown in Figure 10.18.

Figure 10.18: Experimental set-up to demonstrate transpiration

2. Weigh the potted plant and record its weight.
3. Leave the set-up in sunlight for several hours.
4. Weigh the potted plant after 24 hours and then calculate the change in weight.
5. Discuss your findings with your classmates.

Question

What caused the change in the weight of the potted plant after 24 hours?

Types of transpiration

There are three types of transpiration as explained below:

Stomatal transpiration

This occurs through the stomata on the leaves. It accounts for approximately 90% of the water loss in plants.

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Cuticular transpiration

This occurs through the cuticle of leaves. The cuticle is a waxy layer that covers the surface of leaves. A thick cuticle prevents excessive loss of water.

Lenticular transpiration

This occurs through the lenticels. Lenticels are pores found on the bark of stems or roots in woody plants.

Factors affecting the rate of transpiration

The rate of transpiration in plants is affected by plant features as well as environmental factors.

Plant features

Plant features which affect the rate of transpiration include the following:

(i) **The size of the leaves:** A large leaf has more stomata than a small leaf. Therefore, plants with large leaves lose more water than those with smaller leaves.

(ii) **An extensive root system:** Plants that have extensive roots absorb more water and can therefore lose more water than those with fewer roots.

(iii) **Leaf cuticle:** A thick cuticle resists water loss by transpiration while a thin cuticle makes water loss by transpiration easier.

(iv) **Number of stomata:** The more stomata a leaf has, the higher the rate of transpiration. This is because during respiration water evaporates from the plant through the stomata.

(v) **Position of stomata:** Stomata on the upper surface of the leaf lose water more easily than those on the lower surface. If a plant has leaves with more stomata on the upper surface, the rate of transpiration is higher compared to a plant that has leaves with more stomata on the lower surface. Leaves with stomata on both lower and upper surfaces have the highest rate of transpiration.

(vi) **Size of substomatal air spaces:** Larger air spaces allow a higher rate of transpiration because the leaves can hold more water vapour. Smaller substomatal air spaces slow down the rate of transpiration.

(vii) **Sunken stomata:** Sunken stomata occur in pits. They are not exposed to moving air in order to slow down transpiration rate.

(viii) **Epidermal hairs:** Epidermal hairs trap water vapour on the surface of the leaves, thus decreasing the rate of transpiration.

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Environmental factors

(i) **Temperature:** Transpiration rate increases as temperature rises. Higher temperatures cause the stomata to open hence increasing the rate of water loss to the atmosphere. Lower temperatures cause the stomata to close or reduce the size of stomata pores, hence, preventing or slowing down transpiration process.

(ii) **Relative humidity:** As the relative humidity of the surrounding air rises, transpiration rate decreases. It is easier for water to evaporate into dry air than into air saturated with moisture.

(iii) **Wind and air movement:** Increased movement of air around a plant results into a higher transpiration rate. Wind moves the air around and replaces the more saturated air close to the leaf with drier air.

(iv) **Availability of soil moisture:** When soil moisture is low, plants begin to senesce (age prematurely) resulting in leaf loss and reduced transpiration. Also, less water is absorbed by the roots when the soil is dry.

(v) **Light:** Brighter sunlight increases the rate of photosynthesis in the guard cells, causing them to become turgid and open the stomata. Higher light intensity also increases the plant's internal temperature and hence increases the rate of transpiration. Also, light increases the rate of water absorption and results into increased turgidity of the two guard cells. Turgidity of the guard cells brings about the opening of the stomata, hence increases the transpiration rate.

(vi) **Atmospheric pressure:** At high altitude, the atmospheric pressure is low. This allows more rapid diffusion of water. The plants in high altitudes experience high rate of transpiration because of low atmospheric pressure.

Activity 10.5: Determining the effect of environmental conditions on transpiration rate

Materials:
Plant, potometer, beaker, trough, clock, and fan

Procedure

1. Cut off the shoot of the plant while immersed in water to prevent air bubbles from entering the xylem of the stem.

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2. Place the cutting in the potometer as shown in Figure 10.19. Allow the shoot to transpire for a few minutes while the end of the capillary tube is out of water to introduce an air bubble in the tube. Then immerse the end of the capillary tube in water.

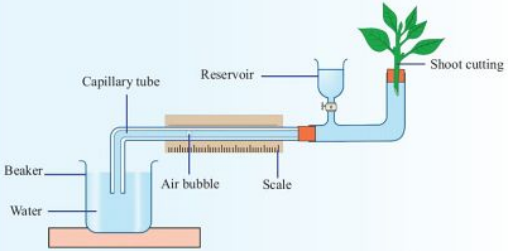

Figure 10.19: Experimental set-up to investigate the rate of transpiration

3. Leave the apparatus for two hours in bright sunlight.

4. Observe the position of the water bubble. The distance the bubble travels shows how much water the stem has taken up.

5. Repeat the experiment under different conditions, for example use a fan to create air movement or apply some petroleum jelly on some of the leaves to reduce the number of stomata.

6. Record your results and compare them with those obtained in step 4 using a tabular form. The distance moved by an air bubble can be recorded every minute and used to indicate the rate of water uptake by the plant.

Significance of transpiration

(i) It helps to maintain transpiration pull which is important for maintaining a constant stream of water and minerals between the roots and the leaves.

(ii) It enables the loss of excess water from the plant.

(iii) It helps to cool the plant.

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(iv) It enables the absorption and conduction of water and mineral salts to different parts of the plant.

(v) It helps to balance water levels within the plant through continuous elimination of water from the plant body.

(vi) It maintains osmosis and keeps the cells rigid.

Guttation

Guttation is the oozing out of drops of water on the tips or edges of leaves of some vascular plants. Guttation occurs at night when the rate of transpiration is low because the stomata are closed. In addition, at night the soil is relatively moist, hence water will enter the plant roots. Guttation can also occur when there is too much water in the soil. In this case, water potential in the roots is lower than that of the surrounding soil. As a result, water will enter the root hairs and become accumulated in the xylem and set the root pressure. This pressure forces some water to exit the leaf tip or edge structures called hydathodes or water glands, and form drops. At night root pressure drives the flow of water out of the plant leaves, rather than transpiration pull. The differences between guttation and transpiration are shown in Table 10.2.

Table 10.2: Differences between guttation and transpiration

Guttation	Transpiration
(i) Occurs early in the morning and at night	(i) Occurs during the day
(ii) Takes place through hydathodes	(ii) Takes place through the stomata
(iii) Takes place at low temperatures	(iii) Takes place at high temperature
(iv) Water is lost in liquid form through the hydathodes	(iv) Water is lost in form of vapour via the stomata
(v) Root pressure plays a vital role in this process	(v) Root pressure is not involved in this process
(vi) Takes place on the margin of the leaf	(vi) Takes place mostly in the lower surface of the leaf
(vii) Hindered by dry conditions	(vii) Favoured by dry conditions

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Guttation	Transpiration
(viii) Never results in wilting of the plant	(viii) Excessive transpiration results in wilting of the plant
(ix) Cannot be regulated since hydathodes do not open or close	(ix) Can be regulated since stomata can open and close

Exercise 10.2

1. What is the function of root hairs in plants?
2. Explain the difference between root pressure and transpiration pull.
3. How does transpiration occur in plants?
4. What is guttation? How does it differ from transpiration?
5. Explain the importance of stomata in a leaf.

Chapter summary

1. The vascular system in plants is made up of xylem and phloem tissues.
2. Xylem transports water and mineral salts from the roots to all parts of the plant.
3. Phloem transports manufactured food from the site of photosynthesis to other parts of the plant.
4. The distribution of vascular bundles is different in roots, stems and leaves of dicotyledonous and monocotyledonous plants.
5. Root hairs are extensions of the epidermal cells of the root. They absorb water and mineral salts from the soil.
6. Water is absorbed from the soil by the process known as osmosis.
7. Mineral salts are absorbed from the soil by active transport.
8. Water and dissolved minerals move up the xylem by transpiration pull, capillarity, and root pressure.
9. Transpiration is the process by which plants lose water through their stomata. Transpiration is important because it:
   (a) helps to maintain the transpiration stream;
   (b) enables the loss of excess water in a plant;
   (c) enables absorption and distribution of water and mineral salts in a plant;
   (d) helps to cool the plant; and
   (e) maintains osmosis and keeps the cells rigid.

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10. Transpiration is affected by the features of the plant and environmental factors. These features of the plant include leaf size, number of leaves, size of root system, thickness of leaf cuticle, size of air spaces within the leaf mesophyll, number and position of stomata, the extent at which stomata are sunken, and the presence of epidermal hairs. Environmental factors include temperature, wind and air movement, availability of soil moisture, relative humidity, light intensity and atmospheric pressure.

Revision exercise 10

Section A

Choose the correct answer.

1. The food-conducting cell in a plant is called _____.
   (a) meristem
   (b) sieve-tube element
   (c) epidermis
   (d) stomata

2. Which of the following does NOT contribute to the movement of water through the xylem vessel?
   (a) Capillarity
   (b) Transpiration pull
   (c) Root pressure
   (d) Gutation

3. The vascular bundles in a cross-section of a dicot stem are arranged in a _____.
   (a) random pattern
   (b) circular manner
   (c) ring around the central pith
   (d) peripheral position

4. Which of the following is NOT a factor that determines transpiration rate?
   (a) Phloem
   (b) Temperature
   (c) Humidity
   (d) Air movement

5. Which of the following is involved in the transpiration process in plants?
   (a) Epidermis
   (b) Xylem
   (c) Cortex
   (d) All of the above

Section B

6. Briefly explain the meaning of the following:
   (a) capillarity;
   (b) sieve-tube elements;
   (c) root hair; and
   (d) transpiration stream.

7. Fill in the blanks in the following 'concept map' to bring meaningful relationship of the key concepts concerning transport in plants.

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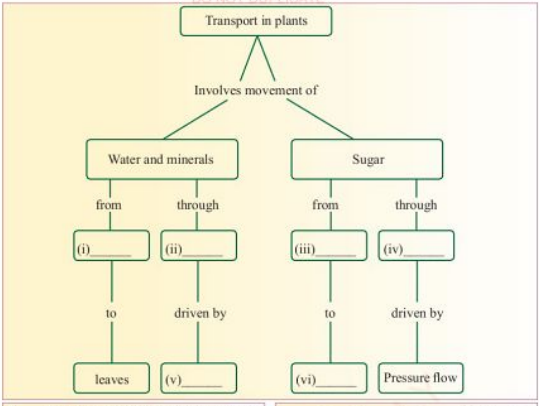

8. Draw and label a diagram to show:
   (a) movement of water through the root cells to the xylem;
   (b) the structure of a phloem tissue; and
   (c) the cross-section of a dicot stem.

9. Use the diagrams below to answer the following questions:

(a) (b)

   (a) Name the tissues labeled (a) and (b).
   (b) State the role of each tissue named in 9 (a).
   (c) Give two adaptations of each tissue named in 9 (a).

10. Answer the following questions:
   (a) What is transpiration?
   (b) Explain four plant features and four environmental factors that affect the rate of transpiration.
   (c) Give two reasons why transpiration is important in plants.

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(d) Differentiate transpiration pull from root pressure.

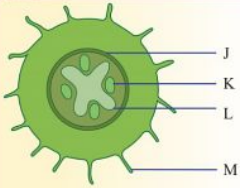
11. Distinguish between guttation and transpiration.

12. What is the importance of root hairs in plants?

13. Describe how water moves from the soil to the leaves in a tree.

14. Explain how the following contribute to the movement of water up to the xylem vessel.
    (a) Capillarity
    (b) Root pressure

15. Study the following diagram which represents a transverse section through a plant organ and answer the questions that follow.



(a) From which plant organ was the section obtained?

(b) Give two reasons for your answer in (a) above.

(c) Name the parts labeled J, K and L.

(d) State two functions of the part labeled M.

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Chapter Eleven

Gaseous exchange and respiration

Introduction

Respiration is one of the characteristics of living things. It is important for the survival of living things as it leads to the production of energy used for various body activities. Respiration in aerobic organisms is accomplished by gaseous exchange. Gaseous exchange involves the exchange of oxygen and carbon dioxide gases across the respiratory surface. In this chapter, you will learn about gaseous exchange in mammals and plants, factors affecting the rate of gaseous exchange, types of respiration, as well as infections and diseases of the respiratory system. The competencies developed from this chapter will enable you to maintain a healthy life style that helps to prevent infections and diseases of the respiratory system.

Gaseous exchange

Gaseous exchange is the process by which gases move passively by diffusion across a surface, for example, the exchange of oxygen gas and carbon dioxide gas across the respiratory surface. It takes place in different ways in various organisms. For example, unicellular organisms carry out gaseous exchange by diffusion across the cell membrane. Large organisms cannot carry out diffusion efficiently, instead they have well developed and specialised organs for gaseous exchange called respiratory surfaces. Table 11.1 shows examples of respiratory surfaces in various organisms.

Table 11.1: Respiratory surfaces in various organisms

Organism	Respiratory surface
Amoeba	Cell membrane
Insects	Tracheal system
Spiders	Book lung

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Organism	Respiratory surface
Fish	Gills
Plants	Leaves, stems, and roots
Amphibians	Skin, gills, lungs, and buccal cavity
Mammals	Lungs
Birds	Lungs
Reptiles	Lungs
Earthworms	Skin

Characteristics of respiratory surfaces

(i) They are thin in order to reduce the diffusion distance.

(ii) They are moist in order to dissolve gases that diffuse in a solution form.

(iii) They are highly branched, folded, or flattened in order to increase the surface area for gaseous exchange.

(iv) They are surrounded by blood capillaries so that gases can be taken to and from the cells easily.

(v) They are well ventilated so that gases can pass through them easily.

Activity 11.1: Examining sites of gaseous exchange in various organisms

Materials:

Organisms from the environment such as insects, fish, a variety of leaves, hand lens, notebook, and pencil

Procedure

1. Collect various organisms from the environment.
2. Observe the organs for gaseous exchange in the collected organisms using a hand lens.
3. Compare organs for gaseous exchange in different organisms.
4. Record their similarities and differences in a tabular form.
5. Share your findings with your fellow students.

Gaseous exchange in mammals

Gaseous exchange is the process which enables mammals to obtain oxygen gas in their body for various uses such as energy production. Gaseous exchange is possible through the respiratory system. The components of the respiratory system of mammals include the nostril, nasal cavity, pharynx, trachea, bronchi, lungs, bronchioles, alveoli, intercostal muscles, diaphragm, and ribs, as shown in Figure 11.1.

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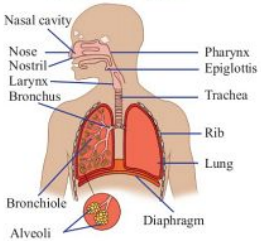

Figure 11.1: Human respiratory system

Each component of the mammalian respiratory system performs a particular function and has various adaptive features that enable its functions as shown in Table 11.2.

Table 11.2: Adaptations and functions of parts of the mammalian respiratory system

Part	Adaptive features	Functions
Nose and nasal cavity	Mucus lining and hairs (cilia)	Traps dust and micro-organisms
Glottis	Presence of epiglottis	Closes the trachea during swallowing to prevent food from entering the respiratory system
Trachea, bronchus and bronchioles	Blood vessels near the surface	Warm the air
	Have rings of cartilage tissue along their length	Prevent collapse of the respiratory tract
	Mucus lining and cilia	Trap and filter dust and micro-organisms
Lungs	Spongy with numerous air spaces (alveoli)	Main organ of mammalian respiratory system Air spaces hold inhaled air

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Part	Adaptive features	Functions
Alveoli (singular is alveolus)	Numerous in number	Provide large surface area for gaseous exchange
	Thin membranes	Reduce distance for diffusion of gases
	Moist surface	Enables gases to dissolve into solutions before diffusing
	Have dense network of capillaries	Transport oxygen from the alveoli to the tissues and carbon dioxide from the tissues to the alveoli
	Constantly contain air	Maintain shape to avoid collapsing
Pleural membrane	Contain pleural fluid	Lubricates the membranes so that the lungs can slide smoothly over the thoracic cavity during breathing
Ribs	Are made of hard bone tissue	Protect the lungs from mechanical injury
Intercostal muscles	Move antagonistically: when one muscle contracts the other relaxes and vice versa	Allow expansion and contraction of the thoracic cavity
Diaphragm	Muscular sheet of tissue	Separates the thorax from the abdomen Allows gaseous exchange by becoming dome-shaped or relaxed

Activity11.2: Observation of the parts of the mammalian respiratory system

Materials:

Dissected mouse, chart and model showing the mammalian respiratory system, notebook, and pencil

Procedure

1. Observe the displayed specimen of the mammalian respiratory system.
2. Draw and label what you have observed.
3. Identify all the structures of the mammalian respiratory system that you have observed.

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4. Compare your drawings with those of your classmates.
5. Share the observed findings with your classmates.

Mechanism of gaseous exchange in mammals

Gaseous exchange in mammals occurs as a result of inhalation and exhalation. Inhalation is the process of breathing in air into the lungs. Exhalation is the process of breathing out air from the lungs. The composition of inhaled air is different from exhaled air, as shown in Table 11.3.

Table 11. 3: Composition of inhaled and exhaled air

Constituent	Inhaled air	Exhaled air
Oxygen gas	20.95%	16.40%
Carbon dioxide gas	0.03%	4.00%
Nitrogen gas	78.10%	78.10%
Noble gases	0.94%	0.94%

Inhalation

Inhalation helps to bring air into the respiratory system. During inhalation, air enters the body through the nasal cavity. As air passes through the nasal cavity, it is moistened and warmed to body temperature. This is possible due to presence of mucus which protects the tissue from direct contact with air. Mucus has high amount of water therefore as air crosses these surfaces of the mucus membranes, it picks up water. This process helps to equilibrate the air temperature with the body temperature, hence reducing any damage that cold, hot, or dry air can cause. Also, mucus helps in trapping dust particles that enter the nose.

During inhalation the muscles of the diaphragm contract, pulling the diaphragm downwards. As this happens, the external intercostal muscles contract while the internal intercostal muscles relax and pull the rib cage upward and outward as shown in Figure 11.2. These movements result to an increase in the volume and decrease in the air pressure of the thorax. This makes air to rush into the lungs through the nostrils, trachea, bronchus, bronchioles, and alveoli.

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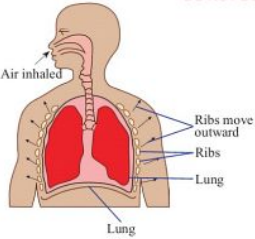

Figure 11.2: Inhalation

Exhalation

Exhalation helps to remove carbon dioxide gas from the body. Carbon dioxide is a cellular waste product. During exhalation, the muscles of the diaphragm relax and the diaphragm resumes its dome shape as shown in Figure 11.3. The external intercostal muscles relax while the internal intercostal muscles contract, pulling the ribcage inward and downward. As a result, the volume of the thorax decreases and the pressure inside it increases. This forces air out through the bronchioles, bronchus, trachea, and nostrils.

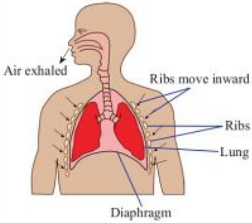

Figure 11.3: Exhalation

Differences between inhalation and exhalation

The process of inhaling and exhaling gases in human beings can be differentiated based on the changes that occur in the parts of the respiratory system such as the ribs, intercostal muscles, and diaphragm. Table 11.4 summarises the differences between inhalation and exhalation.

Table 11. 4: Differences between inhalation and exhalation

Inhalation	Exhalation
(i) External intercostal muscles contract	(i) External intercostal muscles relax
(ii) Internal intercostal muscles relax	(ii) Internal intercostal muscles contract
(iii) The ribcage moves outward and upward	(iii) The ribcage moves inward and downward
(iv) The diaphragm contracts and flattens	(iv) The diaphragm relaxes and becomes dome-shaped

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Inhalation	Exhalation
(v) The volume of the thoracic cavity increases as the pressure decreases. This allows air to enter the lungs	(v) The volume of the thoracic cavity decreases as pressure increases. This forces air out of the lungs
(vi) Air enters the alveoli through the nostrils, pharynx, glottis, trachea, bronchioles, and finally alveoli	(vi) Air leaves the alveoli through the bronchioles, trachea, glottis, pharynx, and finally nostrils

Activity 11.3: Demonstration of breathing in and out

Materials:

Bell jar or large empty plastic water bottle, rubber sheet or cellophane material, rubber stopper, Y-shaped glass or plastic tube, two balloons, petroleum jelly, knife, scissors or razor blade, and a string

Procedure

1. Set up the materials as shown in the Figure 11.4. Make sure the jar is airtight by filling the gaps using petroleum jelly.

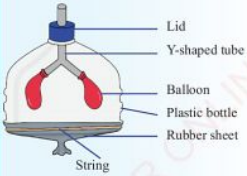

Figure 11. 4: Experimental set-up to demonstrate the breathing process

2. Push the rubber sheet inward as shown in Figure 11.5. What happens to the balloon?

Figure 11. 5: Pushing the rubber sheet inward

3. Pull the rubber sheet downward gently as shown in Figure 11.6. What happens?

Figure 11. 6: Pulling the rubber sheet downward

4. Note down the results for each action you have performed.

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5. Discuss with your group members the reason for each of the observations.
6. Compare parts of the respiratory system represented by each item in this experimental set-up with the mammalian respiratory system in Figure 11.1.
7. Discuss with your teacher for more clarification.

Gaseous exchange across the alveolus

The actual exchange of oxygen and carbon dioxide takes place in the alveoli found in the lungs. Alveoli are tiny balloon-like air sacs located at the end of each bronchiole where the exchange of oxygen from the lungs and carbon dioxide from the blood occurs. One mammalian lung has millions of alveoli. The number of alveoli in the lungs can differ from one person to another. The alveoli are surrounded by a network of capillaries, as shown in Figure 11.7.

When we breathe in, air accumulates in the alveoli. This brings higher concentration of oxygen in the alveoli than in the blood capillaries. Therefore, oxygen diffuses from the alveoli into the blood capillaries. It combines with haemoglobin to form oxyhaemoglobin.

The oxygen gas is then transported to the body cells. Once in the body cells, the oxyhaemoglobin breaks down to release oxygen and haemoglobin. The cells use oxygen for respiration whereby carbon dioxide is produced as a by-product. This causes the levels of carbon dioxide to become higher in the cells than in the blood. As a result, carbon dioxide diffuses into the blood capillaries and combines with haemoglobin to form carbaminohaemoglobin. The blood transports carbon dioxide in this form to the alveoli. This leads to higher concentration of carbon dioxide in the blood capillaries than in the alveoli. Therefore, carbon dioxide diffuses from

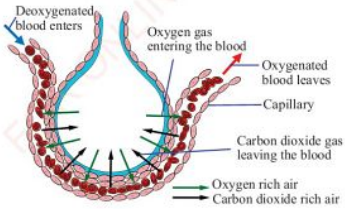

Figure 11. 7: Gaseous exchange across the alveolus

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the capillaries into the alveoli. It is then transported through the bronchioles, trachea, glottis, pharynx and finally nostrils into the atmosphere.

Factors affecting the rate of gaseous exchange in mammals

Gaseous exchange is affected by many factors including the following:

Carbon dioxide concentration

High concentration of carbon dioxide in the blood increases the rate of gaseous exchange. The increase in the rate of gaseous exchange provides the cells with adequate concentration of oxygen and lower concentration of carbon dioxide in the blood.

Haemoglobin concentration

Haemoglobin is a reddish protein molecule containing an iron atom, which is responsible for transporting oxygen and carbon dioxide in the blood of vertebrates. Haemoglobin transports oxygen gas from the lungs to the body cells and carbon dioxide from the body cells to the lungs. Efficient transportation of gases takes place when the body has adequate concentration of haemoglobin. When a person is anaemic, the body has a low concentration of haemoglobin therefore, a low level of oxygen can be transported at a time. This results into the increase of the rate of gaseous exchange so that the body cells can get enough oxygen.

Physical activity

A more active body requires more oxygen than a less active body. During physical exercise the muscle cells respire more than when the body is at rest. Therefore, the rate and depth of breathing increases. This ensures that more oxygen is absorbed into the blood and more carbon dioxide is removed. As a result, the rate of gaseous exchange increases when there is increased body activity.

Health status

Generally, the rate of gaseous exchange increases when a person is sick. This is due to increased metabolism by the liver during removal of the toxins released by disease-causing micro-organisms or break down of the drugs taken. Certain diseases such as asthma make the body weak and slow down the breathing process. Asthma is an inflammation in the respiratory airways which affects gaseous exchange. The inflammation happens due to allergic reaction caused by allergens such as pollen, smoke, and strong smell in the air. Asthma makes breathing difficult because the respiratory airways become very narrow when they are inflamed. This reduces the rate of gaseous exchange.

Altitude

Altitude is the height above sea level. At high altitudes, the concentration of oxygen is lower than at low altitudes. This is due to reduced pressure at high altitudes compared to low altitudes.

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Breathing rate is also higher at high altitudes than at low altitudes due to decreased atmospheric pressure resulting in breathing difficulty. Therefore, the rate of gaseous exchange has to increase in order to obtain enough oxygen.

Age

Young people are generally more active than old people. Also, many growth processes take place in the bodies of young people compared to adults. This increases the demand for oxygen hence increases the rate of gaseous exchange.

Gaseous exchange in plants

Gaseous exchange in plants is the process whereby oxygen gas leaves and carbon dioxide gas enters the plant during the day. During the night oxygen gas enters and carbon dioxide gas leaves the plant. Gaseous exchange mostly takes place through the stomata on the leaves and lenticels on the stem. In some plants such as mangrove, gaseous exchange is carried through breathing roots, also called pneumatophores, which usually project above the water surface.

Gaseous exchange in the leaves

Atmospheric air moves in and out of the leaf through the stomata. Gaseous exchange mostly takes place in the air spaces within spongy mesophyll of the leaf, as shown in Figure 11.8. The spongy mesophyll is a suitable site for gaseous exchange because it has numerous air spaces between the cells due to their loose arrangement.

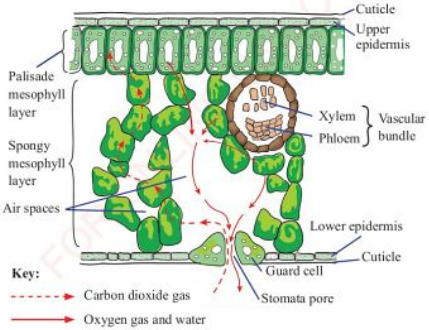

Figure 11.8: Gaseous exchange through the leaf

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Activity 11.4: Demonstration of the presence of stomata on the leaves

Materials:

Leaves, source of heat, forceps, water, and beaker

Procedure

1. Boil water in a beaker then turn off the source of heat.
2. Dip a fresh leaf in the hot water. Be careful not to touch the hot water. Do you see bubbles coming from the leaf?
3. Repeat procedure 2 using different types of leaves.

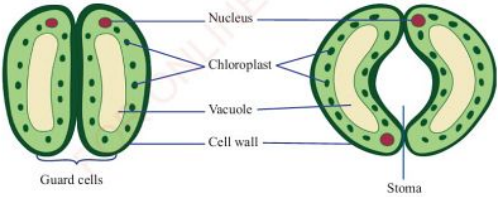
Question

(i) Which type of leaves produces the most bubbles?

(ii) What caused the formation of bubbles?

During the day, green plants carry out photosynthesis to produce glucose. This takes place also within the guard cells that surround the stomata. As a result, the cell sap of guard cells becomes hypertonic and draws in water from the neighbouring cells by osmosis.

The guard cells become turgid and the stomata open, as shown in Figure 11.9 (b). Air from the atmosphere enters into the air spaces in the spongy mesophyll. The cells next to the air spaces have more oxygen that is produced by the cells during photosynthesis and less carbon dioxide as it is used up during photosynthesis.



(a) Closed stoma (b) Opened stoma

Figure 11.9: Structure of a stoma

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Carbon dioxide and oxygen diffuse in opposite directions depending on their concentration gradients. Carbon dioxide diffuses to neighbouring cells until it reaches the site of photosynthesis. Oxygen moves out through the open stomata to the atmosphere.

At night, there is no sunlight, therefore light reaction of photosynthesis ceases. This means that little or no glucose is produced hence the guard cells do not absorb water by osmosis. Therefore, the stomata remain partially closed. On the other hand respiration continues during the night. The partially open stomata allow in a small amount of air to accumulate in the air spaces.

Oxygen diffuses into the plant cells while carbon dioxide diffuses out into the intercelluar spaces and eventually into the atmosphere through the partially opened stomata.

Gaseous exchange through the lenticels

Lenticels are made up of loosely packed cork cells located on some parts of the bark of woody stems and roots, as shown in Figure 11.10. These loosely arranged cells create many small pores through which gaseous exchange occurs. The air spaces between the cells are called intercellular air spaces.

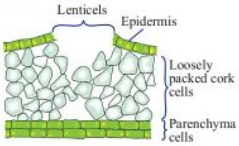

Figure 11.10: Structure of the lenticels

The loose arrangement of the cells facilitates the movement of gases between them. The cells have a thin layer of moisture so that gases diffuse in and out in solution form.

The concentration of oxygen is higher in the intercellular air spaces than in the cork cells. Oxygen therefore diffuses into the cork cells surrounding the lenticels. The cork cells use oxygen for respiration and produce carbon dioxide. Thus, the concentration of carbon dioxide in the cork cells becomes higher than in the intercellular air spaces. Carbon dioxide therefore, diffuses out through the cork cells into the intercellular air spaces and then out through the lenticels.

Gaseous exchange through the roots

Gaseous exchange occurs through breathing roots. Plants with breathing roots have a very thin epidermal layer which enables the root to carry out gaseous exchange. Oxygen is at a higher concentration in the soil than in the root cells. Therefore, oxygen diffuses into the root cells through

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the epidermis. During respiration, plants use oxygen gas and produce carbon dioxide gas. This causes the concentration of carbon dioxide in the root cells to be higher than in the soil. Carbon dioxide diffuses out from the root cells to the soil through the epidermis.

Importance of gaseous exchange in plants

(i) It enables plants to obtain carbon dioxide gas, which is one of the raw materials necessary for photosynthesis.

(ii) It enables plants to obtain oxygen gas, which is necessary for the production of energy. Energy is produced during respiration.

(iii) It enables plants to remove excess carbon dioxide gas during the night. If not removed, carbon dioxide gas would harm the plant.

Respiration

Respiration is the process by which food substances are broken down to release energy. It is controlled by enzymes. Enzymes are substances that affect the rate at which a reaction occurs, although they are not used up in the reaction. Respiration takes place in the cytoplasm and mitochondria of a cell. There are two types of respiration namely, aerobic respiration and anaerobic respiration.

Aerobic respiration

This is a type of respiration whereby oxygen is used to break down glucose to release energy, carbon dioxide, and water. This type of respiration takes place in all organisms including animals and plants except some bacteria and fungi. The following is the chemical equation representing the aerobic respiration process:

Glucose + Oxygen → Carbon dioxide + Water + Energy

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

The energy produced is in the form of ATP (Adenosine Triphosphate).

Mechanism of aerobic respiration

Aerobic respiration involves three main stages, which are glycolysis, Krebs' cycle and electron transport chain. In this chapter you will learn two stages which are glycolysis and Krebs' cycle.

Glycolysis: Glycolysis is the process by which a molecule of glucose is converted into two molecules of pyruvic acid (pyruvate) and ATP. It takes place in the cytoplasm and does not require oxygen. Glycolysis occurs in both aerobic and anaerobic respiration.

During glycolysis, enzymes catalyse the break down of glucose to form two molecules of pyruvic acid and ATP. The pyruvic acid can further be broken down in the presence or absence of

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oxygen. If there is oxygen, pyruvic acid proceeds to the next stage of aerobic respiration, called Krebs' cycle or citric acid cycle. If there is no oxygen, anaerobic respiration occurs.

Krebs' cycle: It occurs in the mitochondria. Krebs' cycle starts with the products of glycolysis, which are the two molecules of pyruvic acid. The Krebs' cycle involves a series of reactions and produces carbon dioxide gas, water, and ATP.

Activity 11.5: Investigating the significance of oxygen in respiration

Materials:

Two conical flasks, cork, two test tubes, two glass tubes, bean seeds, cotton wool, pyrogallic acid, water, and string

Procedure

1. Prepare two sets of bean seeds and put them on a wet cotton wool.
2. Put each set in a separate conical flask and label one flask as A and the other as B.
3. In conical flask A, suspend a test tube containing pyrogallic acid as shown in Figure 11.11. Pyrogallic acid absorbs oxygen in the air.
4. In conical flask B, put a test tube with water.

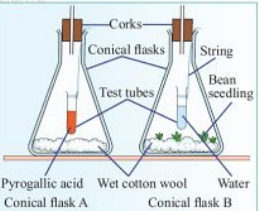

Figure 11.11: Experimental set-up to demonstrate the significance of oxygen in respiration

5. Cover each flask with a cork holding a short glass tube.
6. Set up the experiment as shown in Figure 11.11.
7. Leave the experiment aside for five days and make observations.
8. Write down the results and discuss with your group members.

Question

What conclusion can you make from the experiment?

Activity 11.6: Demonstration of respiration in animals

Materials:

Mouse, bell jar, two conical flasks, lime water, soda lime, thistle funnel, corks, delivery tubes, filter pump, and petroleum jelly

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Procedure

1. Set up the apparatus as shown in Figure 11.12.

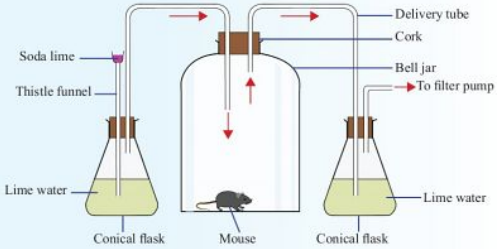

Figure 11.12: Experimental set-up to demonstrate respiration in animals

2. Apply petroleum jelly on all the openings to prevent air from entering the apparatus.
3. Note the colour of lime water in each flask.
4. Switch on the filter pump so that a stream of air is drawn through the set-up.
5. Observe any changes in the lime water.

Question

What can you conclude from your observation?

Activity 11.7: Demonstration of respiration in plants

Materials:

Potted plant, polythene paper, black cloth, bell jar, conical flasks, cork, lime water, soda lime, thistle funnel, delivery tubes, filter pump, and petroleum jelly

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Procedure

1. Set up the apparatus as shown in Figure 11.13.

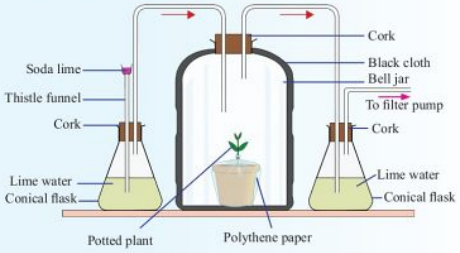

Figure 11.13: Experimental set-up to demonstrate respiration in plants

The black cloth prevents photosynthesis. The polythene paper prevents carbon dioxide from the soil to interfere with the results. Soda lime absorbs all carbon dioxide.

2. Apply petroleum jelly to prevent air from entering the apparatus.
3. Note the colour of lime water in both flasks.
4. Switch on the filter pump to draw a stream of air through the apparatus.
5. Observe any changes in the lime water.

Question

What can you conclude from your observation?

Anaerobic respiration

Anaerobic respiration takes place in the absence of oxygen. It releases a relatively small amount of energy in the cells through the break down of glucose in the absence of oxygen. Glucose is not completely broken down, thus less energy is released than during aerobic respiration. It converts the by-products from glycolysis (pyruvate) to form either ethanol or lactic acid and a small amount of energy. Anaerobic respiration occurs when cells need energy but there is no oxygen for aerobic respiration.

Organisms that respire anaerobically are called anaerobes. They include bacteria and fungi. There are two types of anaerobes which are obligate anaerobes and facultative anaerobes.

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Obligate anaerobes

These are organisms which can only live and respire in the absence of oxygen. They die in the presence of oxygen. Examples include *Bacteroides* and *Clostridium* species.

Facultative anaerobes

These are organisms which can respire both in the presence and in the absence of oxygen. Example of such organisms include yeast and bacteria species such as *Escherichia coli.*

In plants and yeast, anaerobic respiration is also called fermentation. It involves the breaking down of glucose by bacteria or fungi to form alcohol, carbon dioxide and energy. This is represented by the following equation:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{Energy}$$

Glucose → Ethanol + Carbon dioxide +Energy

In animals, anaerobic respiration leads to the formation of lactic acid and energy as shown in the following equation:

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + \text{Energy}$$

Glucose → Lactic acid + Energy

Anaerobic respiration occurs when the body's oxygen supply does not meet the body's needs. For example, during vigorous activity such as sports, lactic acid is accumulated in the muscles. Accumulation of lactic acid in the muscles prevents them from contracting and relaxing due to its toxicity, and can also cause pain. When this occurs, oxygen is required to oxidise lactic acid into water and carbon dioxide. The oxygen required in such situation is known as oxygen debt.

Oxygen debt causes the animal to breathe rapidly and deeply in order to get enough oxygen required to convert the lactic acid to carbon dioxide and water. Some of the lactic acid is converted to glucose. Breathing goes back to normal when the acid has been broken down.

Activity 11.8: Investigation on anaerobic respiration in yeast

Materials:

Yeast, glucose solution, two test tubes, delivery tube, weighing scale, clamps, cork, measuring cylinder, oil, and lime water

Procedure

1. Mix 2 grams of yeast with 5 ml of glucose solution in a test tube.
2. Pour some oil on the surface of the mixture. The oil prevents oxygen from entering the mixture.
3. Put some lime water in another test tube.
4. Set up the apparatus as shown in Figure 11.14.

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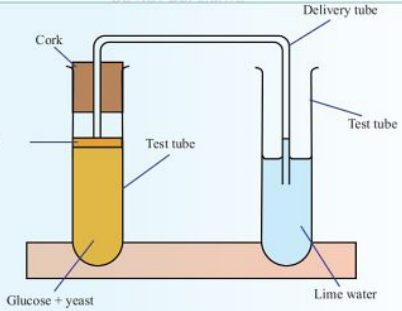

Figure 11.14: Experimental set-up to investigate anaerobic respiration

5. Leave the set-up in a warm place for an hour.
6. Observe any changes. Discuss the reasons for your observation with your group members.

Table 11. 5: Differences between aerobic and anaerobic respiration

Aerobic respiration	Anaerobic respiration
(a) Oxygen is used	(a) Oxygen is not used
(b) Large amount of energy is produced	(b) Little energy is produced
(c) Water is produced	(c) Water is not produced
(d) Food substances are completely broken down	(d) Food substances are not completely broken down
(e) It starts in the cytoplasm and ends in the mitochondria	(e) Takes place in the cytoplasm
(f) Carbon dioxide and water are the end-products	(f) Lactic acid is produced in animals and alcohol is produced in plants

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Factors affecting the rate of respiration

The rate at which respiration takes place varies depending on the state of an organism or that of the environment. Hence, respiration is sometimes fast and at other times slow. The factors affecting the rate of respiration are discussed below.

Temperature

Respiration is controlled by enzymes. The functioning of enzymes is affected by temperature. The rate of respiration is slow at low temperatures and increases with increase in temperature to the optimal level. Optimal temperature is the temperature at which the enzymes function best. At optimum temperature the rate of respiration reaches its maximum. If the temperature is raised above the optimal level, the enzymes are denatured and the rate of respiration is reduced. Similarly, when the temperature is lowered below the optimal level, the enzymes become inactive and the rate of respiration decreases.

Activity

When an organism is involved in a vigorous activity, it requires more energy than when it is at rest. For example, a human being requires less energy when sitting than when running.

Size

Small organisms lose heat faster than larger organisms. This is because small organisms have a larger surface area to volume ratio. The ratio of surface area to volume in a small organism is greater than that of a large organism. For example, if an organism has a volume of 8 cm^3 and surface area of 24 cm^2, its ratio of surface area to volume will be 24/8, which is equal to 3. On the other hand a smaller organism with the volume of 4 cm^3 and a surface area of 16 cm^2, has surface area to volume ratio of 16/4 which is equal to 4. Therefore, small organisms need to respire faster than larger organisms to replace the energy lost through heat.

Age

Generally, young organisms respire faster than older organisms. This is because they need more energy for growth. In addition, young organisms are usually more active than older organisms hence they need more energy.

Infections and diseases of the respiratory system in humans

There are several airborne infections and diseases which affect the human respiratory system. The common ones are pneumonia, bronchitis, asthma, lung

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cancer, tuberculosis, and COVID-19 (acute respiratory distress syndrome).

Most of the airborne infections result from close contact with an infected person. When the sick person breathes out, coughs, or sneezes, the pathogens are released into the air. Hence, a nearby person can be infected. Sometimes, droplets may contaminate items such as clothes and surfaces used by the sick person.

Airborne infections can be controlled by isolation of the infected person; proper disposal of infectious secretions such as sputum; living in a well-ventilated house; and avoiding overcrowding.

Pneumonia

Pneumonia is an inflammation of the lungs. It is caused by bacteria, viruses, fungi or by inhaling chemical toxins or irritants. Pneumonia is normally followed by other illnesses such as cold or flu.

Signs and symptoms of pneumonia

(i) Fever

(ii) Chills

(iii) Shortness of breath associated with pain in the lower ribs

(iv) Increased mucus production

(v) Cough

Prevention and control of pneumonia

(i) Staying warm

(ii) Avoiding overcrowded areas

(iii) Avoiding cold food or drinks. (Hot drinks are more preferred as they loosen secretions).

(iv) Getting treatment as early as possible.

Bronchitis

Inhaling air containing bacteria, viruses and irritating substances can cause the lining of the respiratory system to become inflamed. This causes a disease called bronchitis. Bronchitis can be acute or chronic.

Acute bronchitis

This is caused by whooping cough or recurrent attacks by influenza. Smoking can also cause acute bronchitis.

Signs and symptoms of acute bronchitis

(i) Pain in the chest

(ii) Rapid breathing

(iii) Fever

(iv) Coughing

(v) Headaches

Prevention and control of acute bronchitis

(i) Staying warm. Cold temperatures make the body more susceptible to bacterial infections.

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(ii) Early treatment for all respiratory infections.

Chronic bronchitis

Chronic bronchitis is caused by heavy smoking and recurrent acute bronchitis.

Signs and symptoms of chronic bronchitis

(i) Coughing, with the production of thick sputum

(ii) Breathing difficulties

Prevention and control of chronic bronchitis

(i) Avoid smoking
(ii) Avoid very smoky or dusty areas
(iii) Live in a well-ventilated house
(iv) Keep your body warm
(v) Seek medical help

Asthma

Asthma can be caused by:

(i) allergic reactions. Allergy is a severe sensitivity to certain substances called allergens which include dust, pollen, spores, and animal fur;

(ii) hereditary diseases of the respiratory system;

(iii) extremely cold weather; and

(iv) frequent viral or bacterial lung infections.

Signs and symptoms of asthma

(i) Narrowing of bronchioles resulting in breathing difficulties and a wheezing or hissing sound when breathing.

(ii) Excessive production of mucus.

(iii) Dilation of blood vessels, leading to low blood pressure. Low blood pressure can be fatal.

Prevention and control of asthma

(i) Avoid allergens (things that cause allergic reactions).

(ii) Get treatment for respiratory infections as early as possible.

(iii) Keep the body warm.

(iv) Muscle relaxants in the form of sprays, pills, and injections are used to prevent the narrowing of the bronchioles.

Lung cancer

The main cause of lung cancer is smoking. Nicotine in cigarette smoke stops the cilia in the trachea from expelling foreign materials. This leads to respiratory infection.

Signs and symptoms of lung cancer

(i) Chest pain
(ii) Breathing difficulty
(iii) Weight loss
(iv) Persistent cough
(v) Abnormal production of mucus

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Prevention and control of lung cancer

(i) Stop smoking

(ii) Maintain a healthy lifestyle for example by eating a balanced diet and exercising

Tuberculosis

Tuberculosis is a disease which mainly affects the lungs. It can also affect other parts of the body such as the spine. Tuberculosis is caused by a bacteria called *Mycobacterium tuberculosis*. It is spread by inhaling droplets from the coughs or sneezes of an infected person.

Signs and symptoms of tuberculosis

(i) Persistent cough for about three weeks

(ii) Chest pain

(iii) Night sweats

(iv) Coughing blood

(v) Loss of appetite

(vi) Loss of weight

(vii) Fatigue (extreme tiredness)

Prevention and control of tuberculosis

Tuberculosis is prevented by vaccination. Bacille Calmette-Guerin (BCG) vaccine is given to children to prevent tuberculosis. It can also be prevented by adhering to hygienic rules such as washing hands after coughing or sneezing and covering the mouth when coughing or sneezing. It can also be prevented by isolation.

COVID-19 (Acute respiratory distress syndrome)

This is a pandemic disease caused by the corona viruses that can trigger respiratory tract infection which may lead to severe acute respiratory syndrome. It normally affects the upper respiratory tract (sinuses, nose, and throat) or lower respiratory tract (windpipe and lungs).

Signs and symptoms of COVID-19

Signs and symptoms of COVID-19 include the following:

(i) fever;

(ii) coughing;

(iii) difficulty in breathing;

(iv) fatigue;

(v) chills;

(vi) body aches;

(vii) headaches;

(viii) sore throat;

(ix) loss of sense of smell and taste;

(x) nausea;

(xi) diarrhoea;

(xii) chest pain; and

(xiii) muscle ache.

Prevention and control of COVID-19

(i) Wash your hands often with soap and running water for at least twenty seconds or clean them with an alcohol-based sanitizer.

(ii) Practice both social and physical distancing.

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(iii) Cover the nose and mouth in crowded environments with a face mask.

(iv) Avoid touching the face particularly the nose, mouth, and eyes.

(v) Clean and disinfect the frequently touched surfaces with soap and water or alcohol-based sanitizer.

(vi) Quarantine.

(vii) Isolation.

Chapter summary

1. Gaseous exchange is the exchange of oxygen and carbon dioxide through a respiratory surface.

2. Features of a respiratory surface are:
   (a) thin membrane;
   (b) large surface area;
   (c) moist lining; and
   (d) dense network of capillaries.

3. The components of the respiratory system of mammals are nose, pharynx, glottis, trachea, lungs, bronchioles, alveoli, ribs, pleural membranes, and diaphragm.

4. Gaseous exchange is affected by the amount of haemoglobin in the blood and carbon dioxide concentration.

5. In plants, gaseous exchange can take place through the stomata in the leaves, lenticels in woody stems, or in breathing roots.

6. Respiration is a process by which food substances are broken down to release energy.

7. Aerobic respiration takes place in the mitochondria in the presence of oxygen.

8. Aerobic respiration involves three stages: glycolysis, Krebs' cycle, and electron transport chain.

9. Anaerobic respiration takes place in the cytoplasm, in the absence of oxygen.

10. Infections and diseases that affect the respiratory system include bronchitis, asthma, pneumonia, tuberculosis, lung cancer, and acute respiratory distress syndrome (COVID-19).

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Revision exercise 11

Section A

Choose the correct answer.

1. The following are the characteristics of a respiratory surfaces except _____.
   (a) thin
   (b) moist
   (c) large surface area
   (d) dry

2. Where does exchange of gases take place in the lungs?
   (a) Alveolus
   (b) Bronchus
   (c) Trachea
   (d) Bronchiole

3. The following are infectious diseases which affect the human respiratory system, except _____.
   (a) pneumonia
   (b) common cold
   (c) tuberculosis
   (d) leukemia

4. All of these are respiratory surfaces except _____.
   (a) gills
   (b) lungs
   (c) leaves
   (d) heart

5. Which of the following is among the products of anaerobic respiration in plants?
   (a) Ethanol
   (b) Lactic acid
   (c) Oxygen
   (d) Hydrogen

6. Air is warmed and humidified in the nasal passages. This helps to _____.
   (a) prevent infection
   (b) decrease sensitivity during breathing
   (c) prevent damage to the lungs
   (d) all of the above

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

Column A	Column B
(i) Gaseous exchange	A. The break down of glucose in the presence of oxygen
(ii) Anaerobic respiration	B. A thin tube that branches from a bronchus within the lung
(iii) Alveolus	C. Chemical reactions that release energy from food molecules in the absence of oxygen
(iv) Trachea	D. One of the small pores on the bark of woody plants which is responsible for gaseous exchange
(v) Bronchiole	E. One of the millions of tiny sacs within the lungs where gaseous exchange occurs
(vi) Lenticel	F. Breathing out air from the lungs
(vii) Stoma	G. A specialised organ for gaseous exchange in reptiles, birds, and mammals
(viii) Guard cells	H. Specialised cells in plants that control the opening and closing of the stomata
(ix) Lungs	I. Thinnest tissue where respiration takes place
(x) Exhalation	J. Controls passage of food in the oesophagus
	K. Small opening in the plant that controls the passage of gases and water
	L. Movement of gases across the respiratory surfaces
	M. Part of the respiratory system that allows the passage of air to and from the lungs

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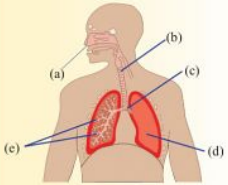
Section B

8. Label parts (a) - (e) in the following diagram of the respiratory system and describe the functions of each of the labeled parts.



9. Explain why:
   (a) the rate of breathing increases during physical exercise; and
   (b) your breathing rate does not go back to normal as soon as you stop exercising.

10. Answer the following questions briefly.
    (a) Why is it better to breathe through the nose than through the mouth?
    (b) What would happen if the epiglottis is removed from the human body?
    (c) Explain how breathing takes place in human beings.

11. Explain the causes, signs, symptoms, prevention, and control methods of the following diseases:
    (a) asthma;
    (b) lung cancer; and
    (c) pneumonia.

12. How does the structure of alveoli maximize gaseous exchange?

13. Differentiate between gaseous exchange and respiration.

14. Where does gaseous exchange take place in the human body?

15. Explain the differences between inhalation and exhalation.

16. Explain the importance of gaseous exchange in human beings.

17. What are the differences between aerobic respiration and anaerobic respiration?

18. Write the chemical equations representing aerobic respiration and anaerobic respiration.

19. Explain the main characteristics of respiratory surfaces.

20. Briefly explain any three factors that can affect the rate of gaseous exchange in the human body.

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Glossary

Abiotic factors
All non-living components of the environment such as light, water, soil, and rocks

Active transport
Transport of materials against concentration gradient that involves utilisation of energy

ATP
Adenosine Triphosphate. The form in which energy is produced and stored during respiration

Aerobic respiration
A type of respiration whereby oxygen is used to break down glucose, releasing energy, carbon dioxide, and water

Aflatoxin
Poisonous substances produced by fungi, which are mostly found in maize and groundnuts

Agglutination
Clotting of blood

Alveolus
Air sac, which is the site of gaseous exchange in the lungs

Amino acids
Building blocks of proteins

Anaerobic respiration
A type of respiration that takes place in the absence of oxygen

Anorexia nervosa
Eating disorder in which a person intentionally refuses to eat enough food leading to a severe loss of body mass

Antheridia
The male reproductive structure of a moss and fern plants

Antibody
A protein molecule produced by the body's immune system to fight an antigen

Antigen
A material recognised by the body as foreign that triggers an immune response

Antioxidant
Molecules that fight free radicals in the body. Free radicals are molecules that contain unpaired electrons and can cause harm if their levels become high in the body

Aorta
The main artery in the body carrying oxygenated blood from the heart to other parts of the body

Archegonia
The female reproductive structure of a moss and fern plants

Artery
Thick-walled, muscular, and elastic blood vessel that transports blood from the heart to all parts of the body except lungs

Asci
Sac-like cells found in sac fungi for storage of spores (ascospores)

Ascomycota
Fungi which produce spores in sac-like cells called asci

Assimilation
The process by which the body uses up the absorbed products of digestion

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Atrium
One of the two upper chambers of the heart

Autotrophic nutrition
Type of nutrition in which organisms manufacture their own food from simple inorganic substances

Basidia
Microscopic club-shaped structure in basidiomycetes such as mushrooms in which sexual spores are produced

Basidiomycota
Fungi which produce basidia

Benedict's solution
A reagent which is used to test for the presence of reducing sugars

Bile
A liquid with salt substance produced by the liver and stored in the gall bladder for digestion of fats

Biotic factors
All the living components of the environment

Biuret test
A test which is used to confirm the presence of proteins without heating

Body Mass Index (BMI)
A value derived from the mass and height of a person

Bryophyta
A division of the kingdom Plantae in which moss plants belong

Budding
The formation of a daughter cell from a mother cell as it happens in yeast

Bulimia nervosa
Eating disorder which involves excessive eating followed by efforts to remove food from the body

Camouflage
Adaptive mechanism whereby an organism is physically similar to its environment in order to avoid predation

Canning
Preservation of food by heating in airtight vacuum-sealed tins or cans

Capillarity
The action that causes water to move up in narrow tubes

Capillaries
Thin-walled blood vessels that connect the arterioles and venules and penetrate deep into tissues

Carbohydrates
Compounds made up of carbon, hydrogen, and oxygen in the ratio of 1:2:1

Carnivores
Animals that feed on flesh of other animals

CD4 Cells
Type of proteins found on the surface of the immune cells such as T-helper cells. They are usually encoded by CD4 genes and are transmitted from one generation to another

Chitin
A rigid protective cell wall of fungi. It is also found in the exoskeleton of insects

Chlorophyll
The green pigment found in the leaves of green plants, some algae, protoctists, and bacteria

Chloroplast
Cell organelle with chlorophyll in which photosynthesis takes place

Churning
The mechanical breakdown of food into smaller particles caused by contraction and relaxation of the muscles of the stomach wall

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Chyme
Semi-liquid substance produced as a result of mixing of food with gastric juice in the stomach

Cohesion
Attraction force between molecules of the same type

Colon
Part of large intestine of animals that helps in absorption of water

Commensalism
A symbiotic relationship between two species in which one species benefits while the other does not benefit and remain unaffected

Community
A group of organisms of different species living in a specific area and capable of interacting

Consumers
Organisms that cannot manufacture their own food but obtain food by feeding on other organisms

Cortex
The part of the stem or root of a vascular plant between the pericycle and endodermis

Crenation
Shrinking and shrivelling of cells leading to abnormal notched cell surface. This occurs due to loss of water when cells are placed in a hypertonic solution

Decomposers
Organisms that break down organic materials. Examples of such organisms include bacteria and fungi

Dehydration
Removal of water from a substance or compound

Detoxification
The process of removing harmful or toxic substances from blood. It mainly takes place in the liver.

Diastema
The space on the lower jaw of a herbivore

Diastole
The phase in the cardiac cycle when the auricles contract to pump blood into the ventricles

Dicotyledon plant
A plant that produces seeds with two cotyledons, for examples, bean plant

Diffusion
The movement of molecules or ions of liquids or gases from a region of high concentration to a region of low concentration

Digestion
The process by which food is broken down into simpler forms that can be absorbed and used in the cells of an organism

Disease
A condition that interferes with the normal functioning of the body

Disorder
Disruption of normal physical and mental functions of the body

Division
Second highest taxonomic rank in classification of plants. It is equivalent to phylum in animal classification

Duodenum
The first part of the small intestine

Ecology
The branch of Biology which deals with the study of the relationship between living things and their environment

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Ecosystem
A system made up of living and non-living things that function together as a unit

Egestion
The process by which faeces pass into the rectum and are eventually passed out of the body through the anus

Environment
The surroundings in which an organism lives

Epidermis
Outer most part of the stem or root of a vascular plant

Epiglottis
A flap of cartilage and fibrous connective tissue which closes the windpipe during swallowing

Eukaryotic organism
An organism that has a clearly defined nucleus surrounded by a nuclear membrane. It also possesses membrane bound organelles such as mitochondria, endoplasmic reticulum, and lysosomes

Excretion
The process by which harmful by-products of metabolism are removed from the body of an organism

Exhalation
The process of expelling air from the lungs

Fern
A vascular plant with leaves called fronds which produces spores mostly underneath the leaves

Filicinophyta
A division in the kingdom Plantae in which fern plants belong. It is also called Pteridophyta

Flatulence
The act of passing out intestinal gas through the anus

Food chain
A sequence of living things in which each organism is the food of the next one in the sequence

Food preservation
A process whereby food is processed in order to prevent it from spoiling or going bad

Food processing
Treatment of food in order to make it edible, appetizing, safe to eat, and fresh for a long time

Food sample
The small portion of solution or mixture which is taken from the stock for food test experiments

Food storage
A process of keeping reserves of food for future use

Food web
A set of inter-connected food chains

Fronds
Leaves of a fern plant. They are made up of leaflets called pinnae

Fungi
Saprophytic organisms that digest food externally and absorb the resulting soluble nutrients

Gametophyte
The gamete producing phase exhibited by plants that undergo alternation of generations

Gastric juice
Digestive juice secreted by the gastric glands in the stomach

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Greenhouse effect
The warming of earth's surface and lowest layer of the atmosphere caused by presence of carbon dioxide and other gases found in the atmosphere

Growth
A permanent and irreversible increase in size and weight of an organism

Habitat
A specified area or surrounding in which an organism lives

Haemoglobin
The red pigment in red blood cells (erythrocytes) which is responsible for transportation of oxygen

Haemolysis
Bursting of red blood cells when placed in a hypotonic solution

Herbivores
Animals that feed on plants only

Heterotrophic nutrition
A type of nutrition where organisms obtain already manufactured food

Holozoic nutrition
A type of nutrition where organisms take food and digest it internally to get important nutrients

Hypertonic solution
A solution with a high solute concentration

Hyphae
Filaments or thread-like structures making up the fungi

Hypotonic solution
A solution with a low solute concentration

Ileum
The second part of the small intestine

Immunity
The ability of the body to resist infection and disease

Indigestible
Refers to food items that are difficult or impossible to digest for example roughages

Inhalation
Drawing in air into the lungs

Iodine solution
A reagent which is used to test for the presence of starch

Irradiation
A food preservation method that involves the use of radiation energy to stop growth of pests and micro-organisms in stored foodstuffs

Isotonic solutions
Two or more solutions with the same solute concentrations

Kwashiorkor
A form of malnutrition in children caused by deficiency of proteins in the body

Lenticels
Loosely packed cork cells located on the bark of woody stems

Lignin
Tough material deposited on the walls of xylem vessels and tracheids

Lipids
Compounds containing carbon, hydrogen, and oxygen. They are mainly fats and oils

Locomotion
The ability of living things to move from one position to another

Lumen
The hollow part of tubular structures such as an artery, vein, or an intestine

Lung
The organ for gaseous exchange mostly in mammals, reptiles, and birds

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Lymph
A pale-yellow fluid found in the lymphatic ducts

Lymph duct
A vessel that forms the lymphatic system and helps in transportation of lymph

Macroelements
Elements required by an organism in relatively large amounts for their growth and survival

Malnutrition
The condition that occurs when the diet taken does not contain the right amount of nutrients. Can either contain excess nutrients or inadequate nutrients

Mammals
Animals which give birth and suckle their young

Mass flow
The bulk movement of substances in the body of an organism from one region to another due to the difference in pressure between the two regions

Mesophyll
The palisade layer and the spongy layer of the leaf

Microelements
Elements that are needed for growth and survival by organisms in small quantities

Mineral
A solid naturally occuring inorganic substance. In nutrition, minerals are nutrients that an organism requires for proper body functioning

Monocotyledon plant
A plant that produces seeds with one cotyledon, for example a maize plant

Moss
A small non-vascular plant with stem-like structure anchored by root-like structures called rhizoids

Movement
The act of changing the position of the part of the body

Multicellular organism
An organism that is made up of many cells. All multicellular organisms are eukaryotes, meaning that their cells have well defined nuclei and organelles

Muscle cramps
Sudden, involuntary and painful contractions of a single muscle or a group of muscles in the body

Mutualism
A symbiotic relationship whereby both species benefit from the relationship

Mycelium
The dense network of hyphae in fungi

Nitrogen fixation
A chemical process by which nitrogen from the atmosphere is converted to ammonia (NH_3) or related nitrogenous compounds in the soil

Nutrient
A chemical component of food. It is a substance needed by an organism for various activities such as growth, body repair, and maintenance.

Nutrition
The process by which living things feed on materials from their environment

Oesophagus
A muscular tube that conveys food boluses from the pharynx to the stomach

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Omnivores
Animals that feed on both plants and other animals

Organ
A group of tissues that carry out the same function

Organelles
Small structures found inside cells, having a specialised function, for example mitochondria, chloroplasts, or vacuoles

Osmosis
The process by which water molecules move from dilute solution to a concentrated solution through a semi-permeable membrane

Palisade
The part of the leaf below the upper epidermis with elongated cells that are arranged at right angles to the surface of the leaf. They contain chloroplasts which are the sites of photosynthesis

Pancreatic juice
Digestive juice secreted by the pancreas and released into the duodenum

Parasitism
A symbiotic relationship whereby one organism (the parasite) benefits while the other (the host) is harmed

Passive transport
The transport of materials that does not require energy

Pasteurisation
A method of preserving food that involves heating food to high temperature for a short time in order to kill micro-organisms that can cause spoilage

Pathogen
A disease-causing organism

Peristalsis
The waves of muscular contractions and relaxations that propel food through the oesophagus into the stomach

Pharynx
The cavity at the back of the mouth and nose

Phloem
Tissues made up of sieve-tube elements and companion cells that transport manufactured food in vascular plants

Photolysis
The process whereby water molecules are split into hydrogen and hydroxyl ions during the light reaction stage of photosynthesis

Photosynthesis
The process by which green plants make their own food using carbon dioxide, water, and sunlight energy

Plasma
A pale-yellow fluid which forms the bulk of blood

Plasmodesmata
Pores found in phloem which allow exchange of materials

Plasmolysis
The process by which a plant cell loses water when placed in a hypertonic solution

Platelets
Types of cells found in blood that are responsible for the clotting of blood. They are also called thrombocytes

Population
The total number of a certain species of organisms in a community, for example the number of frogs in a pond

Predator
The animal that captures, kills, and feeds on another animal in a predation-prey mode of feeding

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Prey
An animal that is fed on by a predator

Producers
Organisms that can manufacture their own food, for example green plants and photosynthetic bacteria

Proteins
Organic compounds made of amino acids

Prothallus
A heart shaped young gametophyte of fern plant formed immediately after spore germination.

Pulmonary artery
An artery that transports deoxygenated blood from the heart to the lungs

Pulmonary circulation
Movement of blood between the heart and the lungs

Pulmonary vein
A vein that transports oxygenated blood from the lungs to the heart

Pulse rate
The number of times a person's heart beats in one minute

Rectum
The last part of the large intestine that stores faeces temporarily before they are passed out

Reservoir
A place where anything is kept

Respiration
The process by which food substances are burned inside the cells to produce energy

Respiratory surface
A thin and moist epithelial surface through which oxygen can cross into the body and carbon dioxide can cross out of the body

Rhizoids
Root-like structures of fungi and other non-vascular plants like mosses

Rickets
A nutritional disorder caused by deficiency of vitamin D. It is manifested by bow legs

Root hair
Thread-like extension of the epidermal cells of the roots which increases root surface area for absorption of water and minerals

Root pressure
The pressure that pushes water and dissolved mineral salts up the plant

Ruminant
An animal that chews cud (food that is chewed, swallowed and then returned to the mouth for further chewing, a process also called regurgitation). Ruminants have a four-chambered stomach

Saccus entericus
The alkaline secretion produced by glands in the wall of the duodenum. It is also called intestinal juice.

Saliva amylase
A digestive enzyme in the mouth that catalyses the break down of cooked starch and change it into maltose

Saprophytism
A type of nutrition in which an organism absorbs nutrients from dead organic matter. It involves external digestion

Semi-permeable membrane
A membrane which allows only certain substances to pass through

Sense organs
Groups of tissues that enable us to perceive and respond to stimulus such as light, smell, sound, taste and touch

Sensitivity
Ability to detect and respond to stimuli. It is also referred to as irritability

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Septum
The thick muscular wall separating the left and the right sides of the heart

Sieve tube element
A component of the phloem tissue which acts as a passage for manufactured food during translocation

Sink
The point of use or storage of manufactured food in a plant.

Sori
A group of sporangia on the leaf of a fern plant

Specimen
A representative item, portion, or quantity of an individual used to represent a group or species in scientific studies.

Spina bifida
A spinal disorder in which spine and spinal cord of the foetus fail to develop properly

Sphygmomanometer
An instrument used to measure blood pressure

Sporangia
Spore-producing organs of fungi and some plants

Spore
Reproductive cells in fungi and some plants

Sporophyte
The spore-producing phase in a plant that undergoes alternation of generations

Sterilisation
The process of destroying micro-organisms by using temperature greater than 100ºC

Stimulus
Anything in the environment that may make an organism respond

Sting
A piercing attack by a needle-like structure found in bees, hornets, and wasps

Stomach
A highly elastic muscular organ that acts as a temporary store of food and where major part of food digestion occurs

Stomata
Small pores in the epidermis of leaves that allow gaseous exchange and transpiration to occur in plants

Storage organs
Modified stems, roots, or leaves which act as food reserves for certain types of plants. Examples are bulbs, corms, tubers, and rhizomes

Sudan III test
A test used to confirm the presence of lipids in a food sample

Symbiosis
A type of nutrition which involve a close feeding relationship between two species

Systemic circulation
The movement of blood between the heart and the various parts of the body

Systole
The phase of heart beat when the ventricles contract and pump blood into the arteries

Tissue
A group of specialised cells performing a specific function.

Tongue
The organ for tasting

Trachea
The tube made up of rings of cartilage conveying air to the lungs. It is also called windpipe

Tracheids
Long tapered cells with pitted walls that form a system of xylem and conduct water

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in plants

Transfusion
The transfer of blood from one person (the donor) to another (the recipient)

Translocation
The process by which plants transport manufactured food substances throughout their bodies

Transpiration
The process by which water evaporates from the plant through the stomata in the leaves or lenticels on the stems

Transpiration pull
A tension which draws water from the roots to upper parts of a plant

Trophic level
The position of an organism in the food chain

Turgid
A state whereby the vacuole of a plant cell is full of water after being placed in a hypotonic solution

Unicellular organism
Single-celled organism

Vaccination
A procedure that is intended to trigger a response by the immune system to a pathogen or a weakened form of it in order to stimulate a long-term defence against the pathogen

Valves
Flaps of tissues which prevent backward flow of blood in veins and in the heart

Vascular cambium
The tissue that divides to form new phloem and xylem

Vein
A vessel that transports blood to the heart from all parts of the body

Vena cava
The largest vein in the body which returns blood to the heart

Ventricle
Each of the two lower chambers of the heart

Villi
Finger-like projections found in the walls of the ileum, which are important in the food absorption process

Vitamins
Complex organic micronutrients essential for growth and protection against diseases

Water cycle
The circulation of water in the environment

WHO (World Health Organisation)
An agency of the United Nations, concerned with improving public health and preventing or controlling diseases

Xylem
Tissue made up of xylem vessels and tracheids that transport water and minerals in vascular plants

Zygomycota
Fungi which produce sexual spores in structures called zygosporangia

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