Sec. Biology F1 SB 2012 edition

New Syllabus

Secondary BIOLOGY

Third Edition

Form One Student's Book

KENYA LITERATURE BUREAU

Approved by the Ministry of Education

Sec. Biology F1 SB 2012 edition

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CHAPTER ONE

Introduction to Biology

1.1 What is Biology?

In the primary school level you learnt about animals, plants and environment in the Science course. In the secondary level, you will continue to learn more about the animals, plants and the environment in different subjects. These subjects are Agriculture, Biology, Chemistry and Physics. In Biology, you will learn more about living things and their environment in greater detail. Biology is a word that is derived from two Greek words *bios and logos. Bios* means life while *logos* means knowledge. Biology is the branch of science that deals with the study of living things. The aim of biology is to explain the living world in terms of scientific principles. Living things interact with non-living things in their physical environment, hence the study of biology has been expanded to include the study of non-living things. Also included in the study is the role human beings play in shaping their environment.

1.2 Branches of Biology

Biology is a large body of knowledge that is divided into two main branches namely: **botany** and **zoology**. Botany is the study of plants while zoology is the study of animals. These branches of biology are still wide and complex. Therefore, at more advanced and specialised levels, there are smaller branches of biology that exist. Examples are: **ecology** – the study of living things in their surrounding, **genetics** – the study of inheritance and variation, **entomology** – the study of insects, **parasitology** – the study of parasites. The list is long. As one becomes more interested and specialised in the study of biology, he/she becomes a biologist.

Study Question 1

Name at least six other smaller branches of biology.

1.3 Importance of Biology

In studying biology, one acquires very useful knowledge that can be used in many ways. Some of these are listed below:

(a) In solving **environmental problems** such as shortage of food, poor health services, pollution, misuse of environmental resources e.g. forests, wildlife, water and soil.

(b) Entry into **careers** such as medicine, agriculture, public health, veterinary practice, animal husbandry, horticulture and dentistry.

(c) The **scientific skills** that one develops while studying biology such as observing, identifying, recording, classifying, measuring, analysing and evaluating are all very useful in every day life.

(d) The biological knowledge acquired is useful in **international co-operation** in such cases as:
- Joint development of HIV/AIDS vaccine by Kenyan and British scientists.
- The co-ordinated fight against Severe Acute Respiratory Syndrome (SARS) involving scientists all over the world.
- The fight to save the ozone layer from depletion through various international agreements such as the Kyoto Protocol.
- Management of resources through international treaties such as the CITES (Convention against International Trade in Endangered Species).

Study Question 2

List five professional occupations that require the study of biology.

1.4 Characteristics of Living Things

Practical Activity 1

To observe living and non-living things

Requirements

A small animal such as grasshopper in a jar or a rat in a cage, appropriate feed for the animal, a piece of stone and a piece of stick or a ruler.

Procedure

1. Place the food near the animal and observe it.
2. Disturb the animal using a piece of stick or ruler. **CAUTION**: Do not hurt the animal. Observe the animal for five minutes.
3. Repeat these procedures using the piece of stone.
4. From your observations, list as many activities as possible which the animal did. Compare these activities with those of the stone.

Some of the activities you have observed on the animal are some of the characteristics of living things. These were; movement, feeding, response and gaseous exchange. You may also have observed excretion.

The remaining characteristics which you could not observe are respiration, reproduction, growth and development. These are the major characteristics of living things which are summarised below:

(a) Nutrition

Nutrition is a process by which living things acquire and utilise nutrients. Plants synthesise their own food using light energy, carbon dioxide, (carbon (IV) oxide), water and mineral salts, while animals feed on already manufactured foods.

(b) Respiration

Respiration is the energy producing process that occurs in all cells of living things. In this process, organic compounds are broken down to produce energy. During respiration, oxygen is usually used while energy, carbon (IV) oxide and water are the products.

(c) Gaseous exchange

When living things take in air rich in oxygen and give out air rich in carbon (IV) oxide across a respiratory surface, then the process is called gaseous exchange.

(d) Excretion

Excretion is the process by which waste or harmful materials, resulting from chemical reactions within cells of living things, are eliminated. Some of these materials if left to accumulate in the cells, they would cause poisoning of the living things.

(e) Growth and Development

Growth is an irreversible increase in size and mass. On the other hand, development refers to the irreversible change in the complexity of the structure of living things. Living things grow in order to attain the maximum size and mass which are essential for their body function.

(f) Reproduction

Reproduction is the process by which living things give rise to new individuals of the same kind. Only living things have the ability to give rise to new individuals of their own kind.

(g) Irritability

This is the ability of living things to perceive changes in their surroundings and respond to them appropriately. For instance, living things react to changes in temperature, humidity, light, pressure and to presence or absence of certain chemicals.

(h) Movement

Movement is a change in position by either a part of or the whole living thing. Progressive change in position by the whole living thing is called **locomotion**. Movement in animals include swimming, walking, running, flying, while in some plants, it is closing of leaves, folding of leaves, closing of flowers and growing of shoots towards light.

Study Questions

1. List the uses of the energy obtained from the process of respiration.
2. List three characteristics of living things.

Collection of Specimens

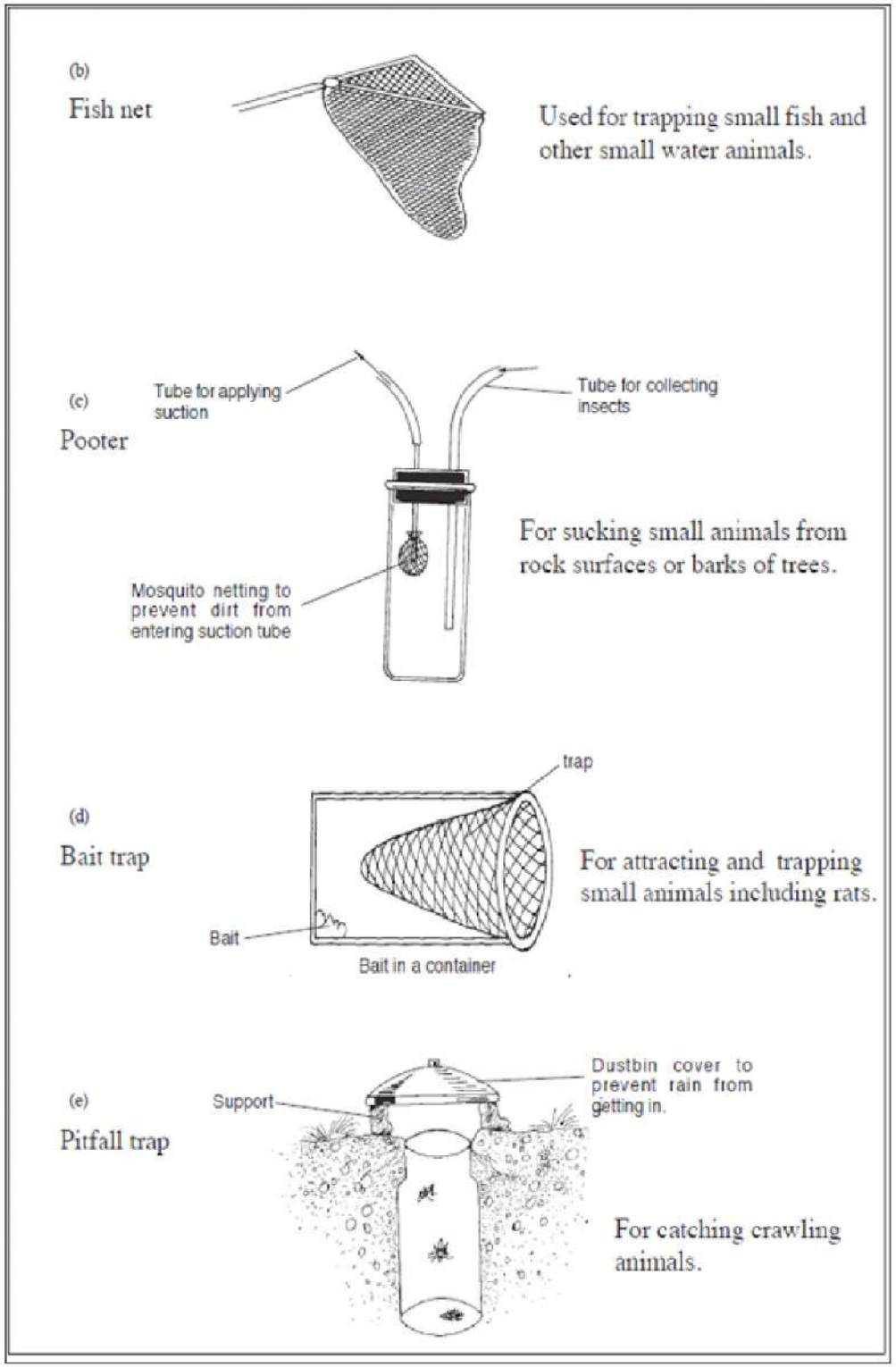
In the study of living things, you need to make collection of specimens for proper study in the laboratory. Therefore, knowledge of the apparatus used and precautionary measures to take while doing so, become necessary. Some apparatus used in collection and observation of specimens are shown in figure 1.1 (a) to (h).

(a)

A sweep net

A sweep net is used for catching flying insects

One of the common apparatus that is used in biology is the hand lens. The hand lens is made up of a convex lens mounted onto a frame and has a handle. It is used as a magnifier. The magnifying power of the lens is usually marked on the frame of the lens itself, such as X8 or X10. This magnification is the indication of how much larger the image will be compared with the object.



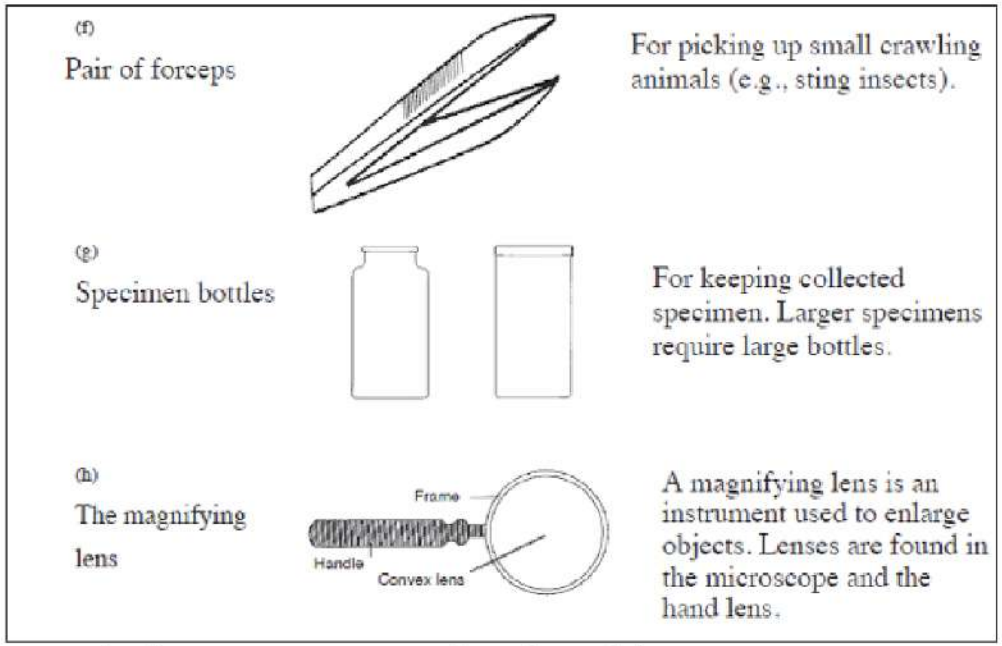


Fig. 1.1 (a –h): Common apparatus used to collect and observe specimens

Precautions during collection and observation of specimens

- Collect only the number of specimen you need.
- Do not harm specimens during the capture/collection exercise.
- Do not destroy the natural habitat of the specimens. After use, return any live specimens back to their habitat whenever possible.
- Dangerous/injurious specimens should be handled with care. Such include stinging plants or insects. Make use of forceps and hand gloves in such cases.
- For highly mobile animals, the teacher will assist you to immobilise them.

Activity 2: Collection of specimens

Requirements

Sweep net, pooter, bait trap, a pair of forceps, specimen bottle, hand lens and any other appropriate apparatus.

Procedure

1. Collect a wide variety of plant and animal specimens. e.g. grasshopper, earthworm, grass, pinus leaves.
2. Place them into the appropriate containers and carry them into the laboratory.
3. Observe the specimens collected and record common features observed in

(a) animals
(b) plants.

Note: Small organisms should be observed using a hand lens.

4. Preserve your collection.

Practical Activity 3

To collect and observe external features of plants and animals

Requirements

Jembe, sweep net, specimen bottle, forceps and potted plant.

Procedure

1. Identify a mature small plant and dig it out.
2. Using the sweep net provided, collect a grasshopper, put it in a specimen bottle and cover the bottle.
3. Observe the external features of the two specimens. Record your observations for each specimen.
4. Gently disturb the animal specimen and the potted plant with a blunt piece of stick or a ruler. Record your observation.
5. From your observations, record the major differences between plants and animals in a table as shown in table 1.1.

Table 1.1: Characteristics of Living Things

Characteristic	*The Plant*	*Grasshopper*
(i) Movement		
(ii) Colour		
(iii) Irritability		

From the observations you have recorded, give several differences between plants and animals. Compare your list with the summary shown in table 1.2.

1.5 Comparison between plants and animals

Table 1.2: Comparison between plants and animals

Plants	*Animals*
(a) Most are green in colour (have chlorophyll) henc are able to make their own food from simple raw materials in presence of sunlight.	(a) They lack chlorophyll hence feed on ready made food.
(b) Their cells have cellulose cell walls.	(b) Their cells lack cellulose cell walls.
(c) They respond slowly to changes in their environment.	(c) They respond quickly.
(d) Plants do not move about	(d) Most animals move about in search of food and shelter.
(e) They lack specialised excretory organs	(e) Have complex excretory organs

Revision Questions

1. (a) What is meant by the term Biology?
   (b) List two branches of biology and for each, give a definition.
2. State four reasons why biology should be studied.
3. List four differences between a plant and an animal.
4. A motor vehicle is able to move and break down fuel to carbon (IV) oxide (carbon dioxide) and water, yet it is not classified as a living thing. List other characteristics of living things that are not shown by a motor vehicle.

CHAPTER TWO

Classification 1

2.1 (a) Introduction

Living things are also called living organisms. There are numerous varieties of organisms. These forms of life have characteristics that distinguish them and enable biologists to arrange them into groups. Some of these living organisms have been discovered and described adequately in many biology textbooks. Some new living organisms continue to be discovered by research biologists.

2.1 (b) The Magnifying Lens

You recall that a magnifying lens is used for enlarging small objects. Figure 2.1 shows such a hand lens.

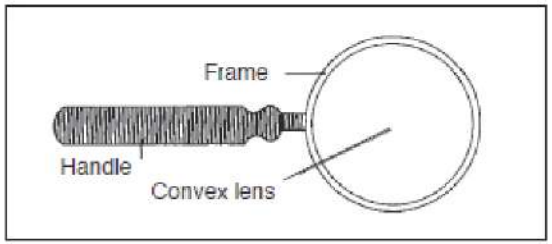


Fig. 2.1: A hand lens

In order to use the hand lens to magnify an object, you have to place the object on the bench and then move the hand lens with one of your hands from the object towards the eye. As the object comes into focus, an enlarged image will be seen.

If a hand lens is used in order to make a drawing of a specimen, the magnification of the lens, bears no relation to the size of the drawing.

To work out the magnification of your drawing, use the following formular:

$$\text{Drawing, magnification} = \frac{\text{Length of the drawing}}{\text{Length of the object}}$$

Figure 2.2 shows how this formula is applied.

2.2 (a) External Features of Plants and Animals

Study Question 1

What are the common external features observed in plants and animals?

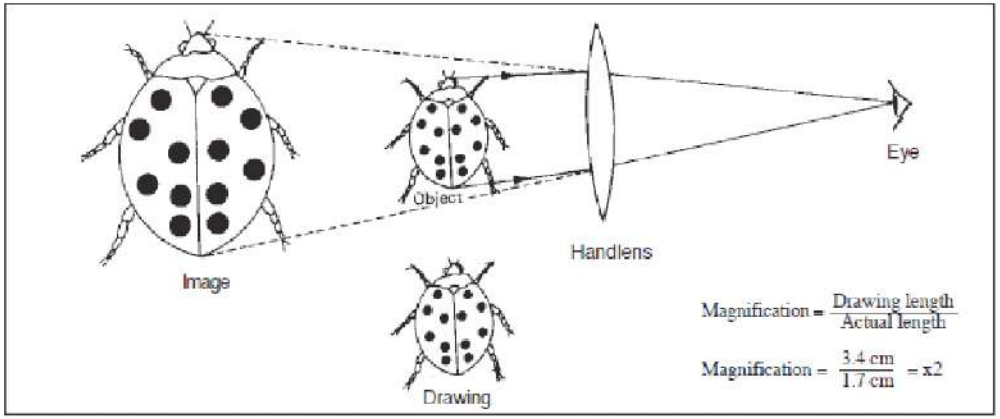


Fig. 2.2: A hand lens and magnification

From your answers, you notice that plants and animals have varied external features. Some of these are listed below:

External features of plants

(i) Rhizoids as in moss plant.
(ii) Fronds in ferns.
(iii) Roots, stems, leaves, flowers, seeds, fruits and cones in higher plants.

External features of animals

(i) Tentacles in hydra.
(ii) Feathers in birds.
(iii) Shells in snails.
(iv) Wings in birds.
(v) Fur and hair in mammals.
(vi) Scales and fins in fish.
(vii) Proglotids in tapeworms.
(viii) Mammary glands in mammals.
(ix) Locomotory structures e.g. limbs in insects.
(x) Body pigmentation.

Practical Activity 1

To collect and observe animal specimens

Requirements

Sweep net, specimen bottles or containers, forceps, hand lens/dissecting microscope, preserved specimens, insecticide/ether/ethanol and forked *jembe*/hoe.

Procedure

1. Use the provided equipment to collect animal specimens. Your collection should include:
   (i) earthworms
   (ii) snails
   (iii) millipedes
   (iv) ants /termites
   (v) locusts/grasshoppers
   (vi) butterflies.
2. Use forceps to pick up crawling or slow moving animals. For flying animals, use a sweep net.
3. Place each specimen into an appropriate container then close it.
4. After collecting a large variety of animal specimens, take them to the laboratory.
5. Immobilise the specimens in their containers using a suitable chemical.
6. Remove the specimens from their containers and spread them out on a working table or in a tray. Carefully, observe each specimen and record the main observable external features. Use a hand lens or a dissecting microscope to observe details of the small specimens.

Note: Do not throw away the collected specimens after the laboratory use. Preserve them for future use.

Practical Activity 2

To collect and observe plant specimens

Requirements

1. Moss plants with rhizoids.
2. Herbs or shrubs with tap roots, fibrous roots and adventitious roots.
3. Stem specimens that have:
   - thorny stems, smooth stems.
   - succulent stems, hard stems.
   - circular stems, irregular polygonal stems.
4. Leaves that show:
   - rough or toothed and smooth margins.
   - parallel veins, net-work veins.

Procedure

1. Take each specimen in turn and observe it carefully, using a hand lens where necessary.
2. Identify and illustrate:
   (a) the type of root.
   (b) type of leaf margin.
   (c) type of leaf venation.
   (d) type of stem.
3. For each diagram drawn, work out and indicate its magnification.

2.2 (b) The Diversity of Living Organisms

Before embarking on the meaning of classification, you should take a look at the different types of living organisms you had collected in activities 1 and 2. Compare with those shown in figure 2.3 to be able to appreciate why classification is necessary in the study of biology.

2.3 (a) What is Classification?

It is an area of biology that deals with the grouping of living organisms according to their structure.Those with similar structures are put under one group referred to as a **taxon** (Plural: taxa). The grouping also takes into account the evolutionary relationships (phylogeny) since all living organisms at one time had a common origin.

The science of classification is known as **taxonomy.** Biologists who study taxonomy are called **taxonomists.**

2.3 (b) Need for Classification

Classification is necessary because of a number of reasons listed below:

- To help in identifying living organisms into their correct groups for reference.
- Groupings bring together living organisms with similar characteristics but separate those with different features.
- To help us arrange the information about living organisms in an orderly manner to avoid chaos and confusion that would arise if this were to be done arbitrarily.
- To help us understand the evolutionary relationship between different organisms.

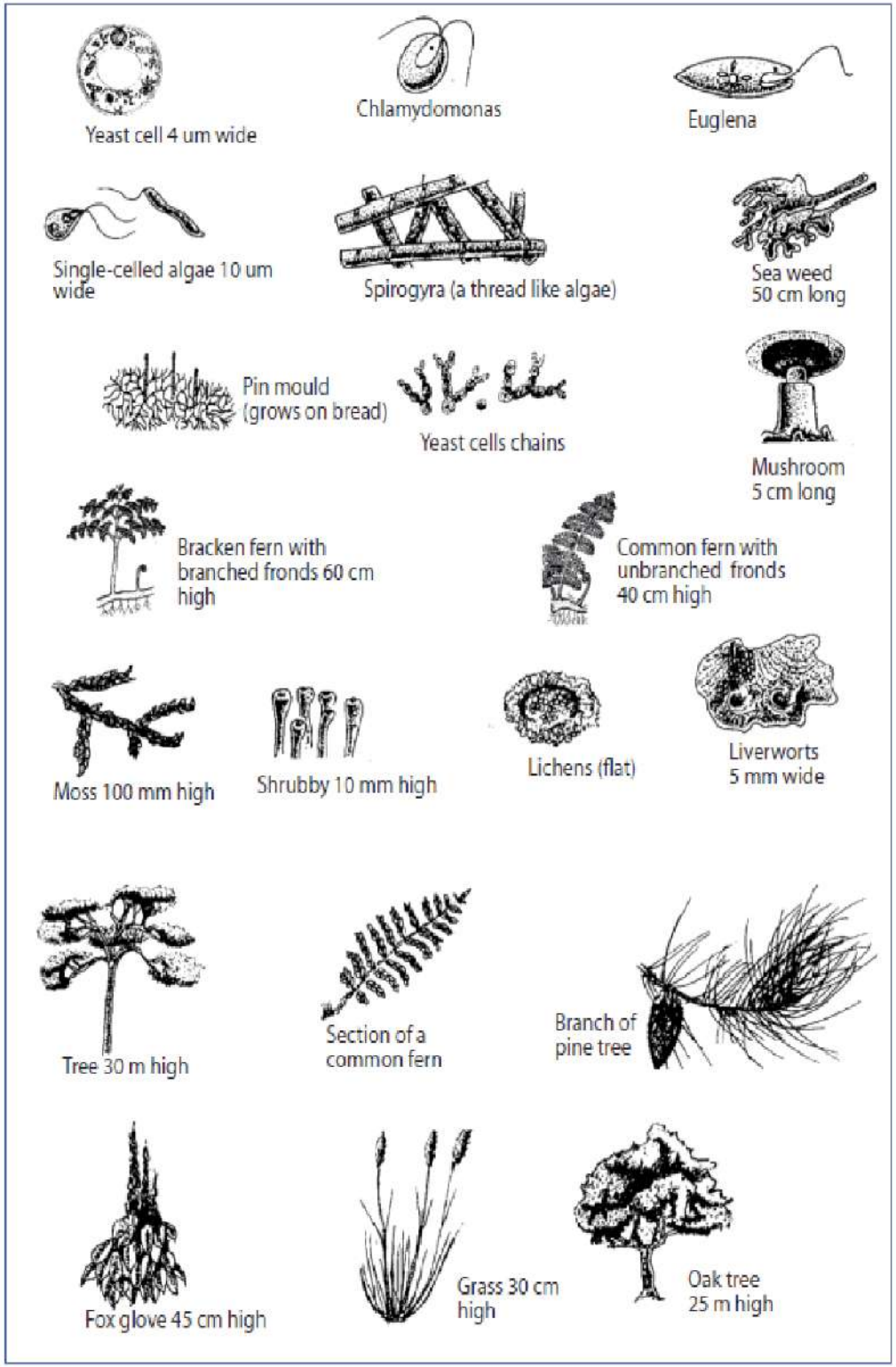
2.4 (a) Historical Background of Classification

In early times, classification was artificial since the placing of living organisms into groups was based on a few observable characteristics. Most of these characteristics were personal conveniences to the early biologists like Aristotle

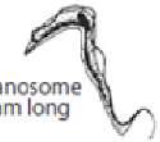
who lived between 384 and 322 B.C. This type of classification was in use for about 2,000 years. In one such method, living organisms were grouped into plants and animals. Plants were further grouped as herbs, shrubs and trees, while animals were grouped into several groups namely carnivores, herbivores and omnivores. Some biologists yet classified plants as edible and non-edible, fungi and bacteria.

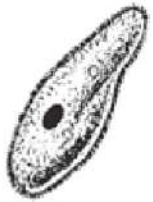
Modern classification has overcome the weaknesses of artificial classification. This classification uses evolutionary relationships between specimen and their ancestor. From the original parents, there arose new groups of organisms that underwent structural changes which enabled them to live in different habitats. This is what led to the diversity of living organisms observed today.

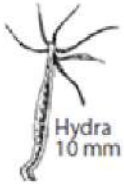
The Swedish biologist, Carolus Linnaeus, who lived between 1707 and 1778 is remembered for his pioneer work and development of the modern classification. Other scientists perfected it later after studying his works.



Amoeba 1 cm across

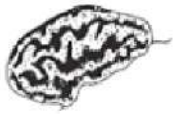

Trypanosome
0.3 mm long

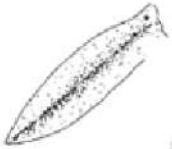

Paramecium
microscopic


Hydra
10 mm long

Jelly fish 10 cm long

Sea anemone
50 mm tall


Coral (colonial)


Planaria worm
100 mm

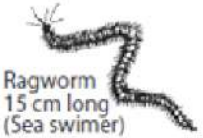
Schistosome
15 mm long

Tapeworm
5 m long

Yeast cells chains

Earthworm
15 cm long

Leach 5 cm
(sucks blood)


Ragworm
15 cm long
(Sea swimer)

Tubeworm 10 cm
long live in a tube
in sea

Snail 2 cm
long

Slug 10 cm
long

Mussel
5 cm long

Squid 30 cm long
including tentacles

Octopus 10 cm wide
excluding tentacles

Starfish
15 cm wide

Brittle star
10 cm wide

Sea urchin
10 cm wide

Shrimp
2 cm long

Centipede
25 cm long

Spider
1 cm wide

Locust 5 cm
long

Woodlouse
1 cm long

Millipede
2 cm long

Scorpion
10 cm long

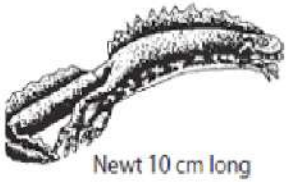
Butterfly
15 cm long

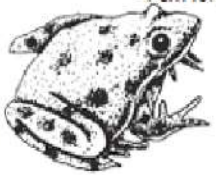
Shark maximum
length 18 m

Ray fish
30 cm wide

Minnow
5 cm long

Stickleback
4 cm long


Newt 10 cm long


Frog 6 cm long
excluding legs

Lizard
12 cm long

Crocodile
about 9 m long

Tortoise 20 cm wide

Python about
10 m long

Sparrow 15 cm long

Ostrich
2.5 m tall
(does not fly)

Kangaroo
2 m high

Lioness about 2 m long

Whale about 33 m long

Man 2 m
high

Fig. 2.3: Diversity of living organisms

2.4 (b) Taxonomic Units of Classification

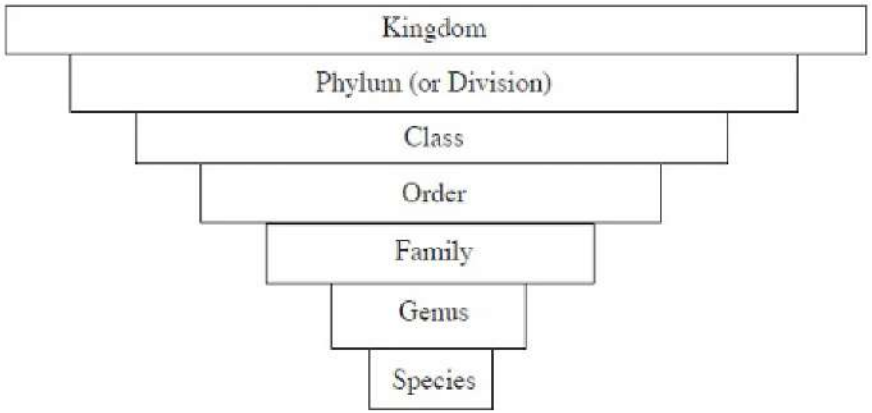
These refer to the groups (or taxa) into which organisms are placed as a matter of convenience. The grouping is based on easily observable characteristics that are common in the group. Each taxonomic unit reflects the position of an organism in relationship to the others in the classification scheme.

In a classification scheme, a hierarchy of groups is recognised and it proceeds from the first largest and highest group, the kingdom to the smallest and lowest unit, the species.

There are seven major taxonomic units as shown below.

The Kingdom

Living organisms are grouped into five kingdoms namely:
Kingdom **Monera** whose members are bacteria.
Kingdom **Protoctista** whose members include algae and protozoa.
Kingdom **Fungi** comprise moulds, yeasts and mushrooms.
Kingdom **Plantae** comprising moss plants, ferns, maize plants, garden pea, pine and Meru oak and many others.
Kingdom **Animalia** whose members include hydra, tapeworms, bees and human beings, among others.



A kingdom is divided into several phyla (or divisions in plants). The **phylum** (plural – phyla), which is the second grouping, sorts out organisms based on body plan and form. Within a phylum, members are further divided into groups called **classes.** The basis of a significant variation in the fundamental plan is usually in adaptation to a special way of life. Each class is further divided into small groups called **orders** using some structural features. Orders are also divided into **families** using some structural features, then families into **genera** (singular genus). In a genus structural features are not easily noticed by most people since the grouping is based on fairly recent common ancestral features that are less adaptive. However, the genus can be divided into smaller units called **species.** The species represent what scientists refer to as a kind of animal or plant. As we go down the hierarchy, the number of organisms in each group decreases but the similarities between them increases.

A species is the smallest unit of classification, which has hereditary distinction from that of any other group, and **whose members naturally interbreed to produce fertile offsprings.** Within the members of a species, minor differences are still exhibited. Such include skin colour in human beings and varieties in plants. The groups obtained on the basis of sub-division of a species are termed as varieties, races or strains. The differences are usually superficial unlike those which distinguish a species from another. These sub-species form additional ranks which may be added to the hierarchy of classification. See table 2.1.

2.5 Scientific Naming of Living Organisms

The present system of naming of living organisms was developed by Carolus Linnaeus in the 18th century. It involved giving an organism two names in Latin language. The Latin language was widely spoken and used by the scientists during Linneaus' time.

Generally, living organisms have their scientific names and common names. The common ones are the local names by which they are known in their local vernaculars. For example, cockroach is the English name for a common insect found in cracks of houses and joints of furniture in houses. The insect is known as *olwenda* in Dholuo, *nyenje* in Gikuyu and *komba mwiko* in Kiswahili language. If the scientists were to use local names, they would not be able to communicate with each other easily. This way, sharing of scientific information and knowledge would be difficult. This necessitated a need to develop a scientific language. This language is Latin.

The scientific names are the valid names by which living organisms are known all over the world. In scientific naming, an organism is given a specific name which adopts two names. This double-naming system is known as **binomial** system ("two name" system). In binomial system, an organism is known both by its **genus** and **species** name.

Table 2.1: Classification of a Human Being and Maize Plant

Taxonomic Unit	*Animal, e.g., human being*	*Plant, e.g., maize*
Kingdom	Animalia	Plantae
Phylum (or Division in plants)	Chordata	Angiospermophyta
Class	Mammalia	Monocotyledonae
Order	Primates	Graminales
Family	Hominidae	Graminae
Genus	*Homo*	*Zea*
Species	*sapiens*	*mays*
Scientific name	*Homo sapiens*	*Zea mays*

The assigning of scientific names to living organisms is governed by a definite set of rules which are internationally recognised and referred to as **binomial nomenclature**, which literally means the rule of double-naming system.

The principles of the binomial nomenclature requires that:

(a) The first part of the scientific name is that of the genus and it should begin with a capital letter, and the second name is that of species. The species name should be written in small letters. These are illustrated by the examples below.
The lion is *Panthera leo,* the leopard is *Panthera pardus,* the domestic dog is *Canis familiaris,* the human being is *Homo sapiens,* and the maize plant is *Zea mays.*

Study Question 2

Complete the table below

The information given above suggests that in a lion, *Panthera* is a genus name and *leo* is a species name. Further more, it suggests that the lion and leopard are closely related since they belong to the same genus. They are distantly related also because they belong to different species.

(b) The scientific names should be printed in italics in books and printed works, but in handwritten manuscripts and typed works, they should be underlined as separate words e.g. Panthera leo.

(c) The specific name is frequently written with the name of a scientist who first adequately described and named the organism, for example: *Balanus balanoides* Linneaus i.e. a common barnacle that was first described by a scientist known as Linnaeaus.

(d) Biologists must give a latinised name for a newly described animal or plant species where a Latin name is missing. For example, *Meladogyne kikuyuensis* is the scientific name of a nematode from Kikuyu while *Aloe Kilifiensis* is a plant of the Aloaceae family first discovered in Kilifi.

Taxon	*Lion*	*Domestic Dog*	*Garden Peas*	*Napier Grass*
Kingdom				
Phylum/ Division				
Class			Dicotyledonae	
Order	Carnivora		Rosales	
Family	Felidae	Canidae	Leguminosae	
Genus				*Pennisetum*
Species				*purpureum*
Scientific name		*Canis familiaris*	*Pisum sativum*	

Practical Activity 3

Naming of Organisms

Requirements

1. Your previous plant and animal collections.
2. Preserved plant and animal specimens.
3. Pictures of various organisms.

Procedure

1. For each specimen, attempt to write down:
   (i) The name in your local language.
   (ii) The English name.
   (iii) The scientific name.
2. For those organisms whose scientific names you have not known, get help from the following sources:
   (i) The biology teacher.
   (ii) Taxonomy text books.
   (iii) The National Museum.
   (iv) The East African Herbarium (at Nairobi National Museum).
   (v) The Nairobi Arboretum.
   (vi) The various Research Institutions such as Kenya Agricultural Research Institute (KARI), International Centre for Insect and Parasite Ecology (ICIPE), International Livestock Research Institute (ILRI) and Kenya Medical Research Institute (KEMRI).

Revision Questions

1. The scientific name for the black jack plant is *Bidens pilosa*. Which taxonomic group does the name *pilosa* refer to?
2. Define the term species. Explain why a leopard and a lion cannot breed yet they belong to the same genus.
3. List the differences between plants and animals.
4. What is the relationship between a genus and a species?
5. (a) What is the name given to the double-naming system of living organisms?
   (b) Give reasons why scientific names are given in Latin.
6. Distinguish between:
   (a) Common names and scientific names of living organisms.
   (b) Taxonomy and taxon.

CHAPTER THREE

The Cell

3.1 Introduction

Animal and plant bodies are made up of small microscopic units called cells. The cells make up the structures of the living organisms and are responsible for carrying out the various biological processes. Some organisms are composed of a single cell only and are said to be **unicellular,** e.g., amoeba. Others are composed of many cells and are said to be **multicellular,** e.g., the garden pea and the cow.

Therefore, **the cell is the basic unit of an organism**. A cell being a very small structure that cannot be seen with the naked eye, hence it requires the use of a powerful magnifying instrument known as the microscope.

In 1650, Zacharias Jansen invented the compound microscope which combines two lenses for greater magnification. In 1665, Robert Hooke used an improved compound microscope to observe cells.

Between 1650 and 1700 Antony van Leeuwenhoeck developed a better microscope with lenses which provided greater magnification. He used this instrument to observe the nuclei and unicellular organisms including bacteria. In the 1930s, the electron microscope was developed, enabling much of the internal structures of the cell to be observed. Since 1946 to date, the electron microscope has been widely used in biology showing more details of the internal structures of the cell.

3.2 The Light Microscope

In studying biology, some small objects require to be magnified so that details can be revealed. A hand lens could be used but in some cases where finer details are required, a microscope is used. A microscope is designed to give finer details of an object that would otherwise, not be seen by the naked eye or a hand lens. The commonly used microscope in schools is the light microscope. It is called a light microscope because it uses light for illumination of the specimen to be viewed. It is therefore important to know the parts of a microscope and how to use and care for it. See figure 3.1 and table 3.1.
A microscope is a very delicate and expensive instrument and should therefore be handled carefully.

3.3 (a) Handling and Care of a Microscope

When using a microscope the following rules should be observed.

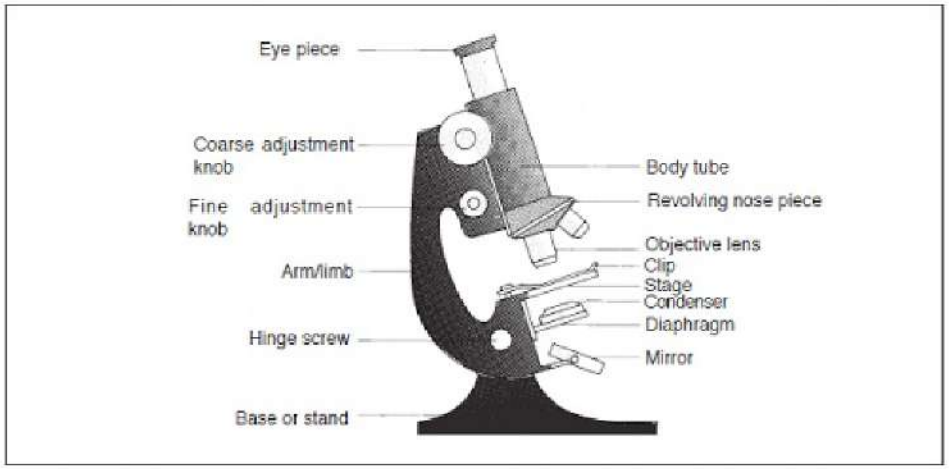


Fig. 3.1: The light Microscope

Table 3.1: Functions of Parts of a Microscope

Name of part	*Function*
Limb (arm)	Supports the body tube and stage.
Base	Provides firm and steady support.
Body tube	Holds the eye-piece and the revolving nose-piece.
Coarse adjustment knob	Raises or lowers the body tube for longer distances to bring the image into focus.
Fine adjustment knob	Raises or lowers the body tube through smaller distances to bring the image into sharper focus. It is mostly used with the high power objective lens.
Diaphragm	An aperture that regulates the amount of light passing through the condenser to illuminate the specimen.
Eye-piece	Contains a lens which contributes to the magnification of the specimen under review.
Objective lens	Brings image into focus and magnifies it.
Mirror	Reflects light through the condenser to the object.
Revolving nose-piece	Holds the objective lenses in place. Enabling change from one objective lens to the other.

Condenser	Concentrates light on the object on the stage.
Stage	Flat platform where specimen on the slide is placed. It has two clips to hold the slide in position.

1. Always use both hands when carrying a microscope. One hand should hold the base to provide support while the other hand holds the limb.
2. Never place the microscope too close to the edge of the working bench or table.
3. Do not touch the mirror and the lenses with your fingers.
4. Dirty lenses should be cleaned using a special soft lens tissue paper or tissue paper moistened with ethanol.
5. Other parts of the microscope may be cleaned using a soft cloth or tissue paper.
6. Do not wet any part of the microscope.
7. Make sure the low power objective lens clicks into position in line with the eye-piece before and after use.
8. After use, always clean and store the microscope in a safe place, free from moisture and dust.

3.3 (b) Using the Microscope

1. Place the microscope on the bench with the stage facing away from you. See plate 3.1.
2. Turn the low power objective lens until it clicks into position.
3. Ensure that the diaphragm is fully open.
4. Look through the eye-piece with one eye; meanwhile adjust the mirror under the stage to ensure that maximum light can pass through. The circular area seen is referred to as the field of view.
5. Place the slide containing the specimen on the stage and clip it into position. Make sure that it is in the centre of the field of view.
6. Again, look through the eye-piece while adjusting the mirror under the stage to ensure that sufficient light is passing through the specimen.
7. Use the coarse adjustment knob to bring the low power objective lens to the lowest point. Viewing through the eye-piece, turn the coarse adjustment knob gently until the specimen comes into focus.
8. Use the fine adjustment knob to bring the image into sharp focus.
9. Make a drawing of what you see.
10. For higher magnifications, turn the medium power objective lens into position and adjust the focus using the coarse adjustment knob. For sharper images, use the fine adjustment knob.
11. If finer details are required, turn the high power objective lens into position. Now use only the fine adjustment knob to bring detailsinto sharper focus.

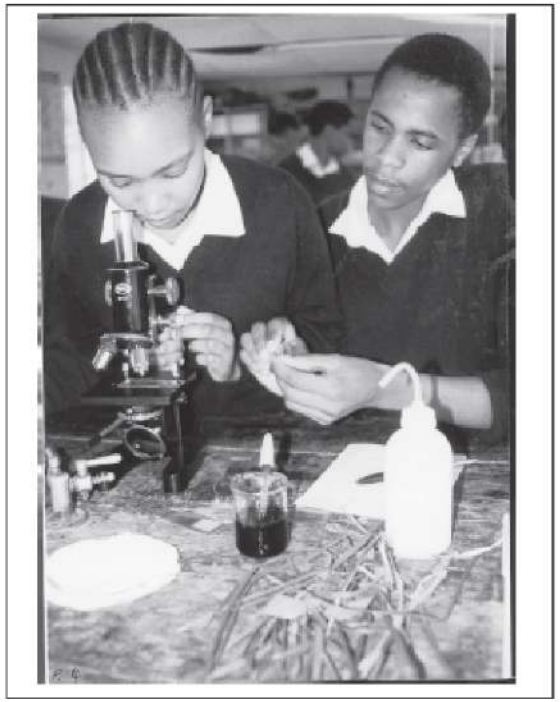


Plate 3.1: Using the microscope

3.3 (c) Magnification

The magnification of the object viewed is calculated by multiplying the eye-piece lens magnification by the objective lens magnification.

Example

If the eye-piece lens has a magnification of X5 and the low power objective lens has a magnification of X10, then the total magnification is 5 x 10 = 50. This is the number of times the detailed structure being viewed has been magnified by the microscope.

Study question 1

Copy and complete table 3.2 in your exercise book.

Table 3.2: Magnification

Condenser	Concentrates light on the object on the stage.
Stage	Flat platform where specimen on the slide is placed. It has two clips to hold the slide in position.

1. Always use both hands when carrying a microscope. One hand should hold the base to provide support while the other hand holds the limb.
2. Never place the microscope too close to the edge of the working bench or table.
3. Do not touch the mirror and the lenses with your fingers.
4. Dirty lenses should be cleaned using a special soft lens tissue paper or tissue paper moistened with ethanol.
5. Other parts of the microscope may be cleaned using a soft cloth or tissue paper.
6. Do not wet any part of the microscope.
7. Make sure the low power objective lens clicks into position in line with the eye-piece before and after use.
8. After use, always clean and store the microscope in a safe place, free from moisture and dust.

3.3 (b) Using the Microscope

1. Place the microscope on the bench with the stage facing away from you. See plate 3.1.
2. Turn the low power objective lens until it clicks into position.
3. Ensure that the diaphragm is fully open.
4. Look through the eye-piece with one eye; meanwhile adjust the mirror under the stage to ensure that maximum light can pass through. The circular area seen is referred to as the field of view.
5. Place the slide containing the specimen on the stage and clip it into position. Make sure that it is in the centre of the field of view.
6. Again, look through the eye-piece while adjusting the mirror under the stage to ensure that sufficient light is passing through the specimen.
7. Use the coarse adjustment knob to bring the low power objective lens to the lowest point. Viewing through the eye-piece, turn the coarse adjustment knob gently until the specimen comes into focus.
8. Use the fine adjustment knob to bring the image into sharp focus.
9. Make a drawing of what you see.
10. For higher magnifications, turn the medium power objective lens into position and adjust the focus using the coarse adjustment knob. For sharper images, use the fine adjustment knob.
11. If finer details are required, turn the high power objective lens into position. Now use only the fine adjustment knob to bring detailsinto sharper focus.

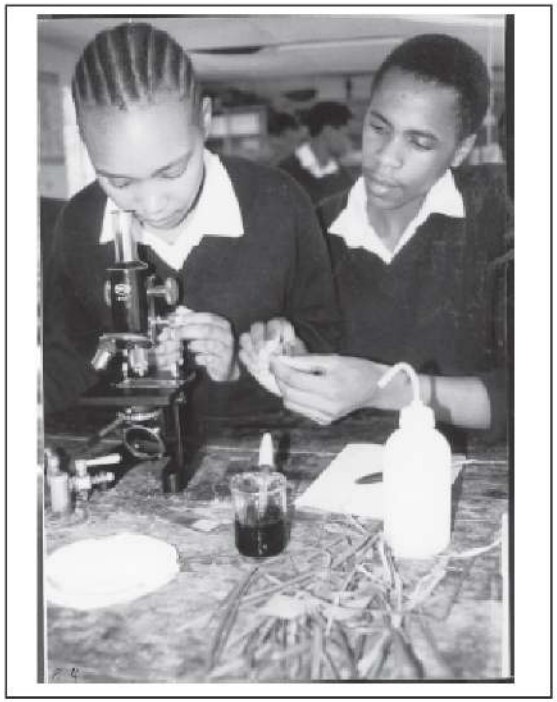


Plate 3.1: Using the microscope

3.3 (c) Magnification

The magnification of the object viewed is calculated by multiplying the eye-piece lens magnification by the objective lens magnification.

Example

If the eye-piece lens has a magnification of X5 and the low power objective lens has a magnification of X10, then the total magnification is 5 x 10 = 50. This is the number of times the detailed structure being viewed has been magnified by the microscope.

Study question 1

Copy and complete table 3.2 in your exercise book.

Table 3.2: Magnification

Eye-piece lens magnification	*Objective lens magnification*	*Total magnification*
X5	X4	X20
X10	X5	
X10		X100
	X40	X600
X10	X100	

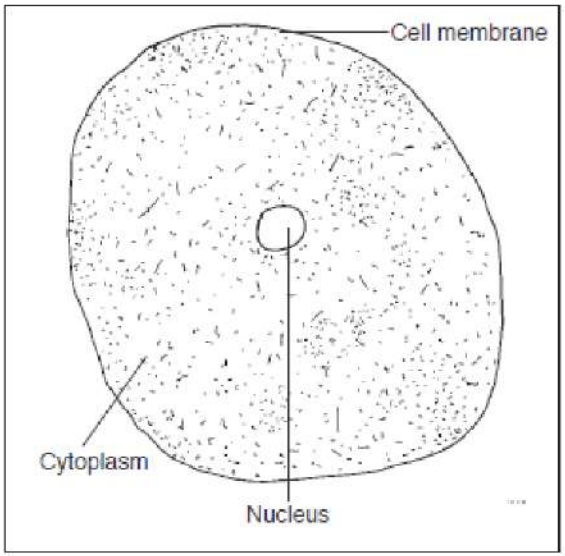


Fig. 3.2 (a): Generalised animal cell

Practical Activity 1

The Microscope

Requirements: Microscope

Procedure

1. Examine the light microscope provided and identify its parts.
2. Draw and label the parts of the microscope provided.
3. State the functions of the parts that you have labelled.
4. Using the microscope provided, calculate the magnification using the objective and eye-piece lenses. Record the information in the form of a table. Refer to table 3.2.

3.3 (d) Cell structures seen under the light microscope

Some cell structures can be seen under the light microscope. These structures include the cell wall, cell membrane, cytoplasm, nucleus, vacuole and chloroplasts. See figure 3.2 (a) and (b). The structures within the cell are called **organelles**. These organelles perform specific functions within the cell.

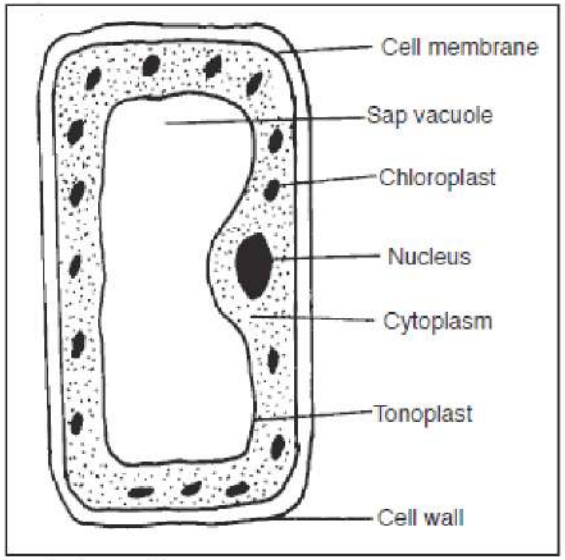


Fig. 3.2 (b): Generalised plant cell

3.4 (a) The Electron Microscope

The electron microscope is more powerful than the light microscope. It has more complicated parts. The electron microscope can magnify up to 500,000 times and has a high resolving power. The high resolving power of the electron microscope enables it to make out as separate things, objects which lie close to one another. This high resolving power makes the electron microscope an important research tool. The electron microscope uses a beam of electrons instead of light to illuminate the object. Research scientists with the aid of an electron microscope have prepared some of the detailed electron micrographs that will be observed in the study of the cell. A picture of a scientist, using an electron microscope is shown in Plate 3.2.

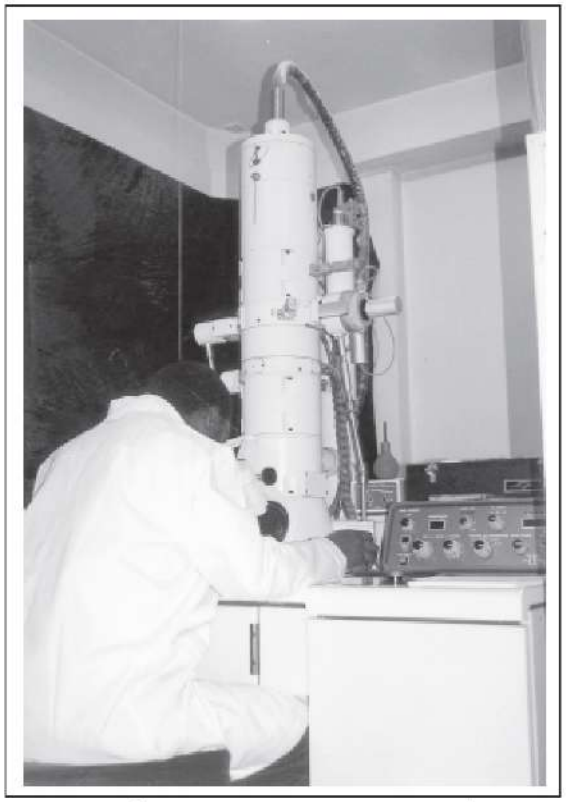


Plate 3.2: A scientist using an electron microscope courtesy of KEMRI

Study Question 2

From figures 3.2 (a) and (b), list the structures seen under the light microscope in:

(a) animal cells.
(b) plant cells.

Practical Activity 2

To observe permanent slides of plant and animal cells

Requirements

Microscope, permanent slides of cheek cells and onion epidermal cells.

Procedure

1. Place the slide of onion epidermal cells on the microscope.
2. Observe under the medium power objective lens.
3. Draw a well labelled diagram of one cell.

Repeat procedure 1, 2 and 3 using the slide of cheek cells.

Under the electron microscope, greater details of the cell can be seen. Some of the structures are as shown in figures 3.3 and 3.4.

Cell membrane

The cell membrane is also known as plasma membrane or plasmalemma. It is seen to consist of three layers under the electron microscope. The three layers are composed of one layer of phospholipid sandwiched between two protein layers. See figure 3.5.

3.4 (b) The Cell Structure as seen under the Electron Microscope

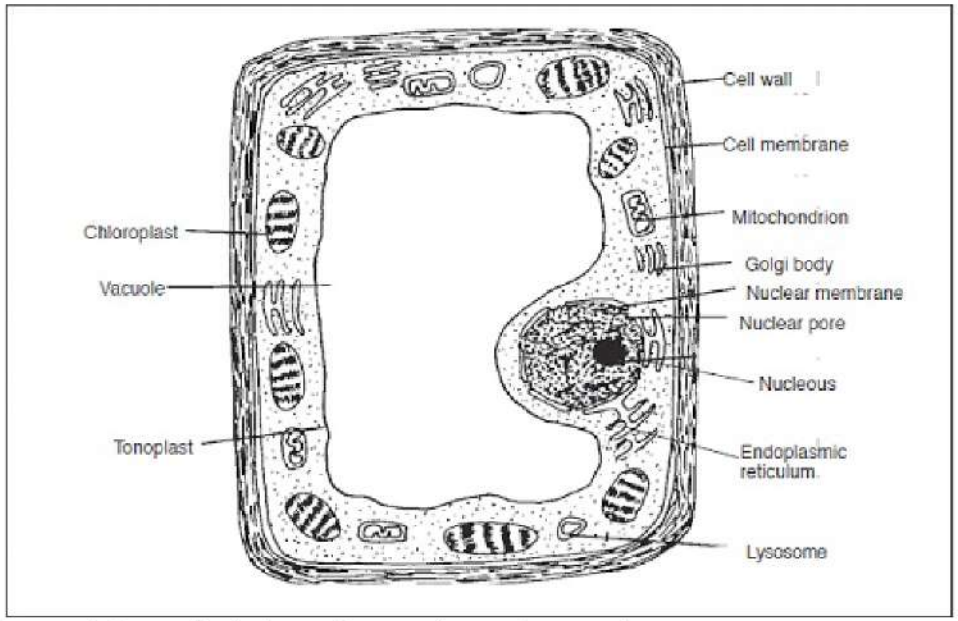


Fig. 3.3: A Generalised plant cell as seen in an electron microscope

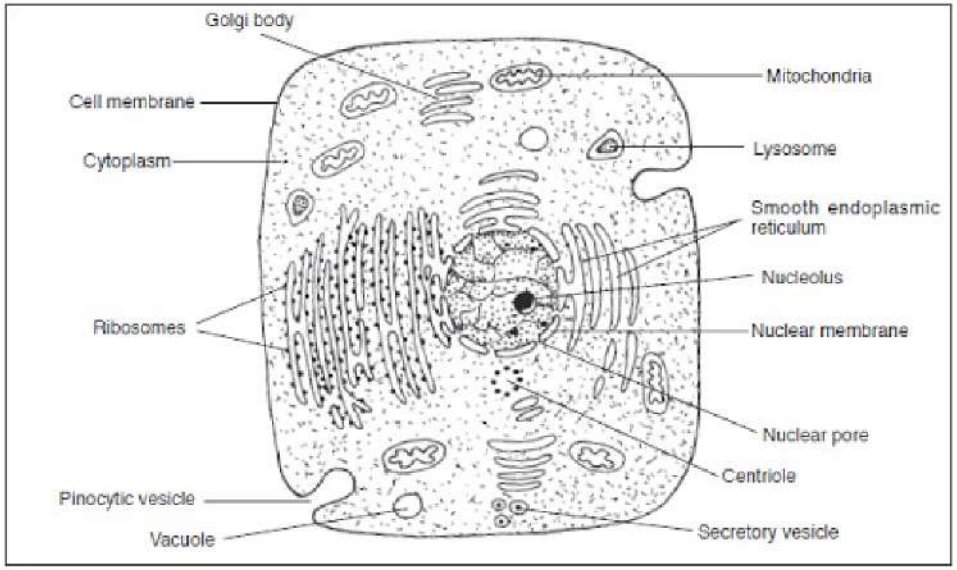


Fig. 3.4: A generalised animal cell as seen under the electron microscope

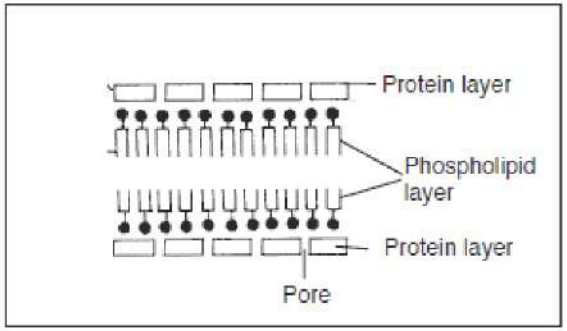


Fig. 3.5: Cell membrane

The cell membrane is flexible and has pores. The main functions of the cell membrane are:

1. The three layers give it strength to **enclose** the cell contents.
2. The pores allow movement of particles into and out of the cells. The phospholipid layer controls the movement of water-soluble and fat-soluble molecules in and out of the cells. The cell membrane is thus said to be **selectively permeable** or **semi-permeable.**

Cytoplasm

Cytoplasm consists of a fluid medium in which chemical reactions take place. It contains organelles and other inclusions such as starch, glycogen, fat droplets and many other dissolved substances. The cytoplasm is not static but has a movement known as cytoplasmic streaming.

Mitochondria (Singular-mitochondrion)

These are sausage-shaped and are **sites** of **respiratory reactions** that yield energy for the cell. Mitochondria are bound by two membranes. The inner membrane is greatly folded into cristae to increase the surface area for respiration as seen in figure 3.6.

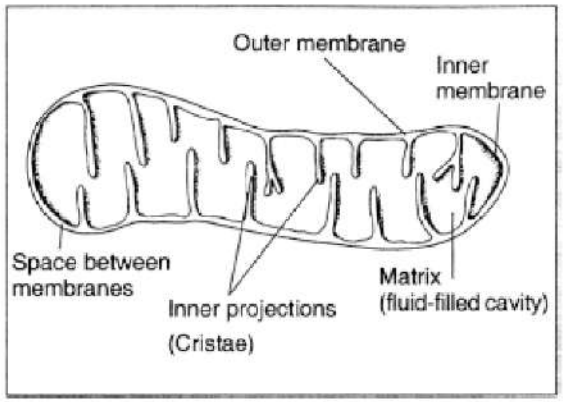


Fig. 3.6: The mitochondrion

The arrangement and number of mitochondria in a cell depends on the cell energy requirement. Cells, which require large amounts of energy, contain many mitochondria. Such cells include muscle cell, sperm cell, apical meristems and the kidney cell.

Endoplasmic Reticulum (ER)

Endoplasmic reticulum appear as a series of **interconnected channels**, running throughout the cytoplasm as shown in figure 3.7(a) and (b). It is continuous with the outer membrane of the **nuclear membrane**. Some endoplasmic reticula (plural of reticulum) have granules called ribosomes on their surfaces and are therefore, referred to as rough or granular endoplasmic reticula. The others are not associated with ribosomes and are thus referred to as smooth endoplasmic reticula. The rough endoplasmic reticulum **transports proteins** while the smooth endoplasmic reticulum **transports lipids.**

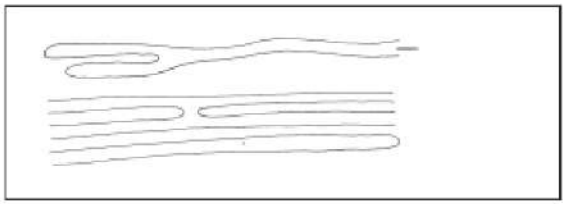


Fig. 3.7 (a): Smooth Endoplasmic

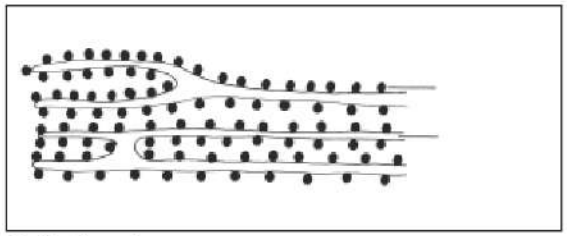


Fig. 3.7 (b): Rough Endoplasmic

Ribosomes

Ribosomes are spherical in shape. Some are scattered within the cytoplasm while others are bound to the surface of rough endoplasmic reticulum. They form sites for **protein synthesis.**

Lysosomes

Lysosomes are spherical sac-like organelles bound by a single membrane. They contain **lytic enzymes** which break down large molecules, destroy worn out organelles or even the entire cells.

Golgi bodies (Golgi apparatus)

These are stacks of membrane–bound **tube like sacs**. They are found close to the cell membrane. Their functions are **packaging** and **transport** of glycoproteins. They are often involved in **secretion** of synthesised proteins and carbohydrates. See figure 3.8.

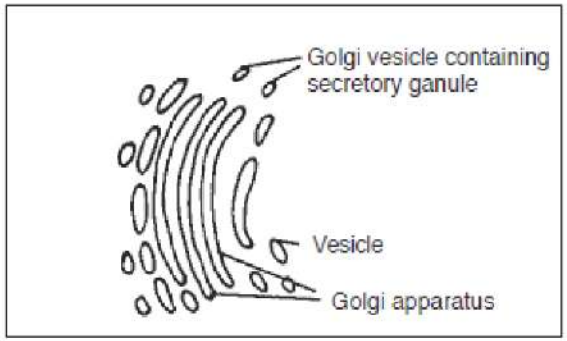


Fig. 3.8: The golgi apparatus

Centrioles

Centrioles are rod-shaped structures located just outside the nuclear membrane.

They take part in **cell division** and in the **formation** of **cilia** and **flagella** in cells where these structures occur. Plant cells lack centrioles.

Chloroplasts

Chloroplasts are **egg-shaped**. They are surrounded by **two membranes** and contain a gel-like **stroma** through which runs a system of membranes that are stacked together to form **grana**. The granum contains **chlorophyll**. The chlorophyll traps light energy that is used during photosynthesis.

Chloroplast is the organelle in which **photosynthesis** takes place. Refer to Chapter 5, figure 5.3 on the structure of a chloroplast.

Vacuoles

Vacuoles are sacs that are **filled with fluid** called cell sap. They vary in size. Animal cells contain small vacuoles while in plant cells the vacuoles are large. Sap vacuoles store sugars and salts, therefore, contribute to the osmotic properties of the cell. In some unicellular organisms, food vacuoles store and digest food while contractile vacuoles excrete unwanted materials from the cell.

Cell Wall

The cell wall is the rigid outer cover of plant cells and some lower organisms. In plants, it is composed of cellulose fibres. It gives the plant cell a **definite shape** as well as providing **mechanical support** and **protection** against mechanical injury. The cell wall allows gases, water and other substances to pass through it.

Nucleus

Under the electron microscope, the nucleus is seen to have a double membrane called a **nuclear membrane**.

The membrane has pores which allow the passage of materials in and out of the nucleus. The nucleus is made of viscous fluid known as **nucleoplasm** in which the **nucleolus** and **chromatin** materials are suspended. It **controls** all the activities of a cell. The nucleolus is responsible for the manufacture of ribosomes, while chromatin contains hereditary materials.

Study Question 3

(a) State at least five activities of the cell that are controlled by the nucleus.
(b) List the organelles found in both plant and animal cells.

Comparison between plant and animal cells

Plant and animal cells have a lot of similarities in their structures and functions. However, there are several differences between plant cells and animal cells. These are shown in table 3.3.

3.5 Preparation of Temporary slides

To observe specimen under the microscope, we need to prepare slides. There are two types of slides, namely temporary or fresh slides for immediate use during a laboratory exercise and permanent slides which can be preserved for reuse.

Practical Activity 3

To prepare and observe temporary

Table 3.3: Differences between plant and animal cells

Plant Cell	*Animal Cell*
1. Usually large.	1. Often smaller.
2. Regular in shape.	2. Irregular in shape.
3. Has a cell wall.	3. Has no cell wall.
4. Usually has a large central vacuole.	4. Usually has no vacuoles but when present, they are temporary and small structures within the cytoplasm.
5. Cytoplasm and nucleus are usually located towards the periphery.	5. The cytoplasm occupies most space in the cell with the nucleus usually centrally placed.
6. Some have chloroplasts.	6. Has no chloroplasts.
7. Usually store starch, oils and proteins.	7. Store glycogen and fats.
8. Has no centriole.	8. Has centriole.

slide of onion cells under the light microscope

Requirements

Microscope, clean microscope slides, coverslips, scalpel or a new razor blade, distilled water, iodine solution, onion bulb, pair of forceps, dropper and mounted needle.

Procedure

1. Cut the onion bulb vertically into four parts.
2. Separate a fleshy leaf from one of the parts.
3. Remove a thin piece of epidermis from this leaf using forceps as illustrated in figure 3.9. Trim down the epidermis to about 5 mm long.
4. Place a drop of water on a clean slide and quickly spread the piece of epidermis onto the drop of water.
5. Using a mounted needle, lower a clear coverslip on to the epidermis strip. Do this gently to avoid trapping air bubbles. See figure 3.9(d).
6. Examine this temporary slide under the low and medium power objective lenses of microscope.
7. Repeat the above procedure with another epidermal strip using a drop of dilute iodine solution instead of distilled water to stain the cells.

Exercise

1. Make a large, neat, well-labelled drawing of two cells as observed under medium power objective lens.
2. What improvement is there when viewing the stained cells compared to the unstained ones?

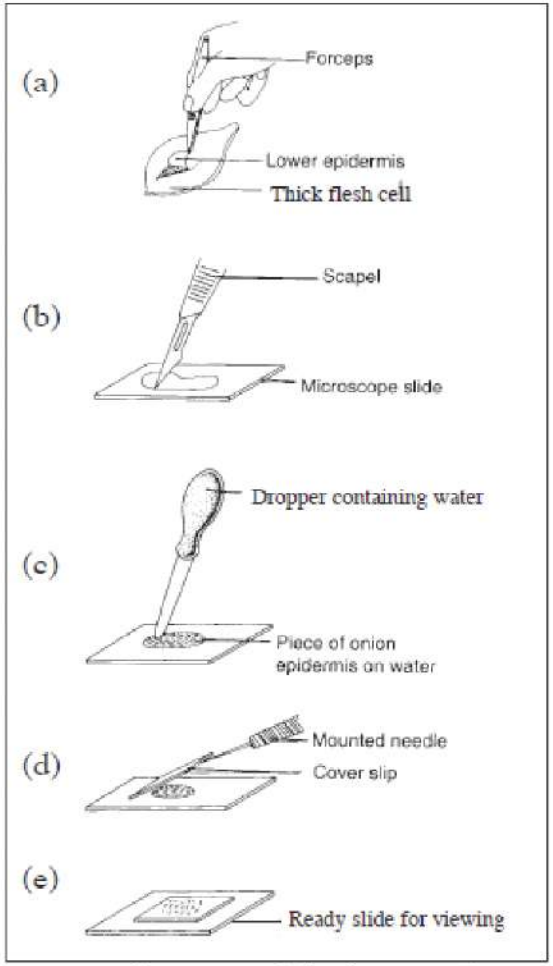


Fig. 3.9: (a) – (e) Preparation of temporary slide of onion epidermis strip

3.6 Estimation of Cell Size

The size of a cell can be estimated by use of a light microscope. Most cells are shorter than a millimetre and therefore, their sizes are measured in smaller units called micrometre(μm).

1 millimetre (mm) = 1 000 micrometres.

1 μm = 1 000 nanometres (nm)

Practical Activity 4

To estimate the size of onion epidermal cells

Requirements

Microscope, transparent ruler marked in millimetres and prepared slide of onion epidermis.

Procedure

1. With the low power objective lens in place, keep a transparent ruler on the stage of the microscope.
2. Focus so that the millimetres marks on the ruler are seen as thick dark lines.
3. Estimate the diameter of the field of view by counting the one-millimetres spaces between the first mark and the last one across the field of view as shown in figure 3.10.

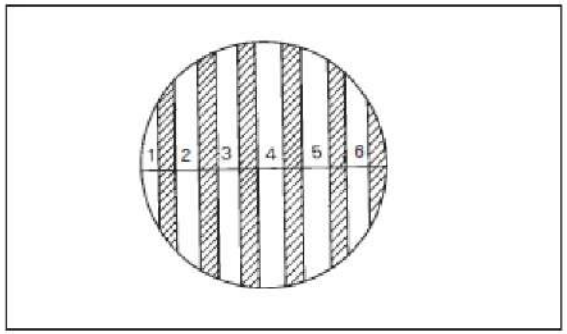


Fig. 3.10: Diameter of field of view

From figure 3.10 the diameter of the field of view is estimated as 6.0 mm.

4. Convert the diameter of the field of viewfrom millimetres to micrmetres.

   1 mm = 1 000

   ∴ 6 mm = (6 × 1 000)
   = 6 000

   Use similar method to work out the diameter of field of view in micrometres.
5. Remove the ruler and place the prepared slide of the onion epidermis.
6. Count the number of cells along the diameter of the field of view. See figure 3.11.

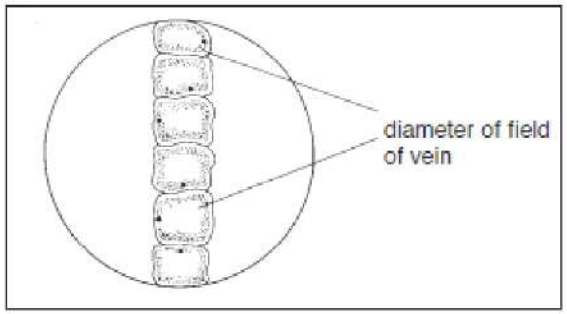


Fig. 3.11: Estimating the number of cells

7. Calculate the diameter of one cell using th following formula

$$\text{Cell Diameter} = \frac{\text{Diameter of field of view in } \mu m}{\text{No. of cell in the field of view}}$$

Using the example above:

$$\text{Cell Diameter} = \frac{6\,000}{6 \text{ cells}} \ \mu m = 1\,000 \ \mu m$$

∴ Diameter of 1 cell = 1 000

Follow these steps to calculate the diameter of the cells you have observed.

Study Question 4

(a) This procedure for measuring sizes of cells has certain limitations. List three such limitations.

(b) Considering that cells vary in shape, what other dimensions or parameters of the cell could be used to estimate cell size?

3.7 Cell Specialisation; Tissues, Organs and Organs Systems

1. Cell Specialisation

Cells are structurally differentiated or modified to perform specific functions. Such cells are said to be **specialised**. For example, the root-hair cell has extended surface for absorption. A sperm cell has a taillike extension for swimming towards the ovum see fig. 3.12 (a, b) examples of specialised cells.

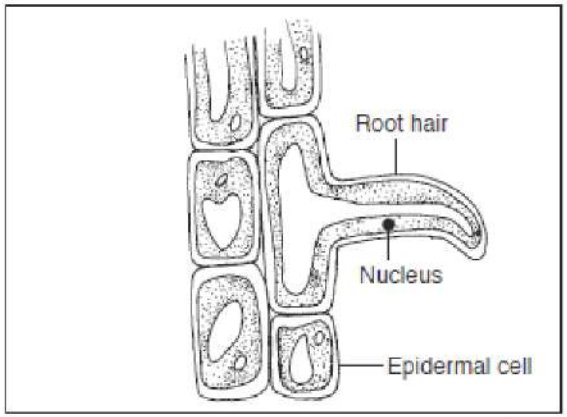


Fig. 3.2(a): Root hair cell

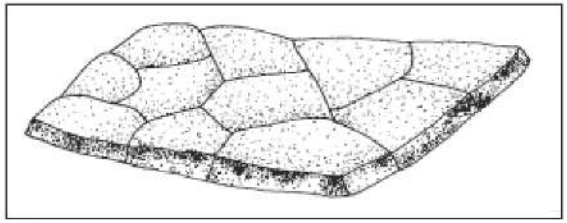


Fig. 3.2 (b): Sperm cell

2. Tissues

These are cells of a particular type that are grouped together. They perform the same function. Refer to the figures 3.13 (a) to (d) and 3.14 (a) to (d).

Tissue types in animals

- This is a thin continuous layer of cells, for **Lining and protection** of internal and external surfaces.

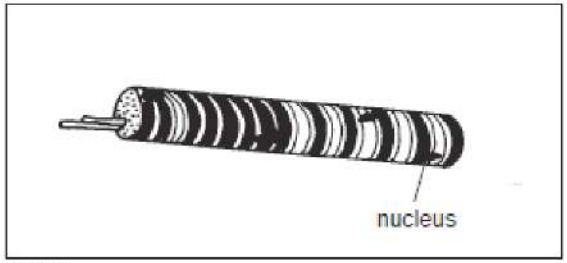


Fig. 3.13 (a): Epithelial tissue

- It is a bundle or sheets of elongated cells with fibres that can contract. Its contraction and relaxation brings about movement.

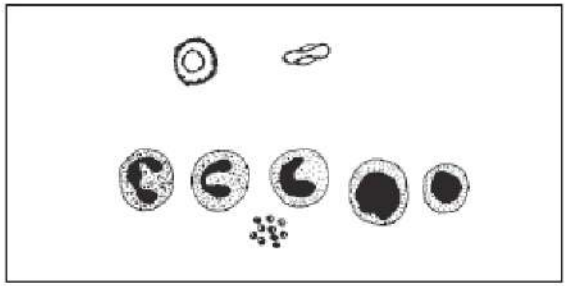


Fig. 3.13 (b): Skeletal muscle

- This is a fluid containing red blood cells,white blood cells and platelets.
- It **transports** many substances including gases, nutrients and **protects** the body against infection.

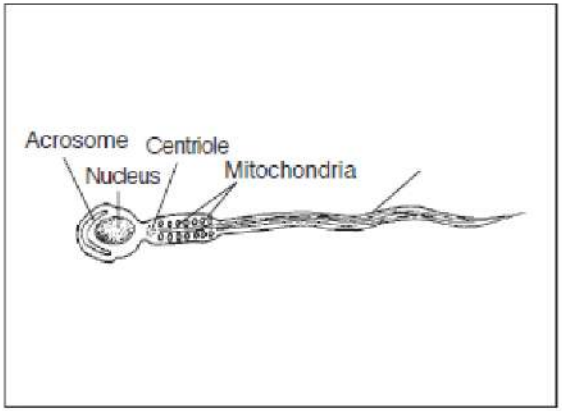


Fig. 3.3 (c): Blood Tissue

- Consists of strong fibres, that connects other tissues and organs **holding** them together in position.

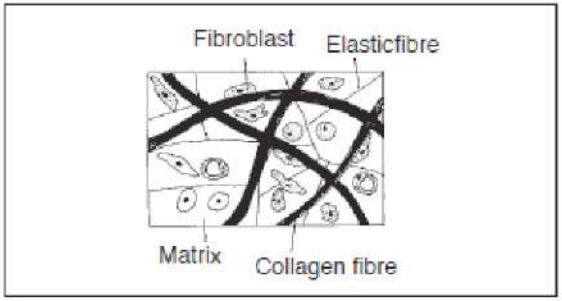


Fig. 3.13 (d): Connective Tissue

Fig. 3.14: Tissue types in plants

- It is a single thin layer of cells covering the outer surfaces. It **Protects** inner tissues of plants from mechanical damage and infection.

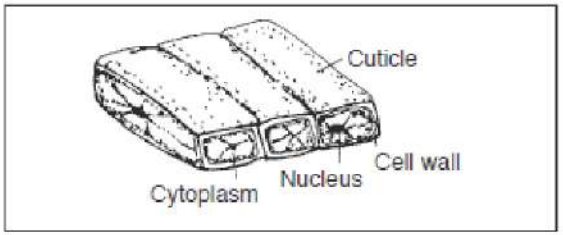


Fig. 3.14 (a): Epidermal tissue of a leaf

- This is a group of cells rich in chloroplasts containing chlorophyll. It has site for the absorption of light energy and manufacture of food by **photosynthesis.**

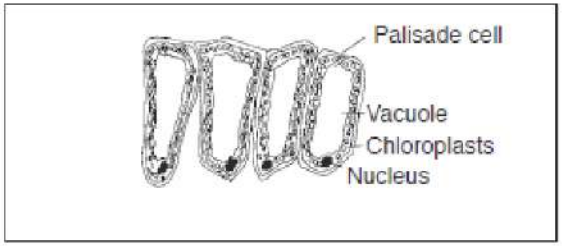


Fig. 1.14 (b): Palisade tissue

- Consists of special thin walled irregularly shaped cells. They form packaging and storage cells.

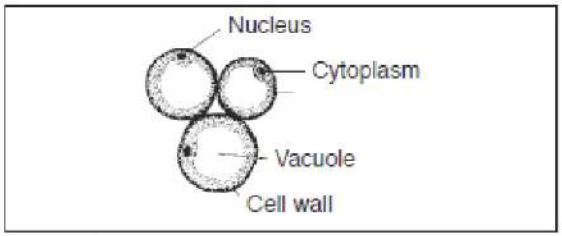


Fig. 3.14 (c): Parenchyma tissue

- Consists of xylem and phloem. Xylem conducts water and the dissolved mineral salts in a plant. Phloem conducts food substances in solution.

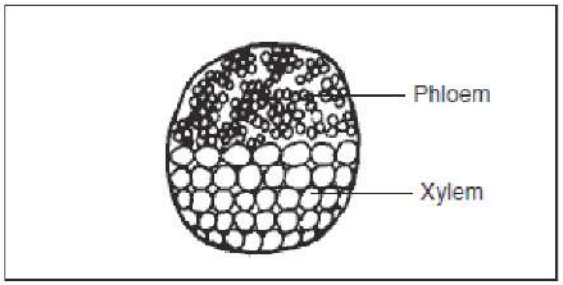


Fig. 3.14 (d): (Vascular Bundle) conducting tissue

3. Organs

Various tissues occur in living organisms. These tissues may be specialised and grouped together to form a functional unit called **organ**. In plants, the organs include roots, leaves, flowers and stem. In animals, the main organs are heart, kidneys, brain, lungs, stomach and liver.

4. Organ systems

Several organs whose functions are co-ordinated and synchronised to realise an effective action in a living organism is referred to as an **organ system**. In animals, some of the organ systems are digestive, circulatory, excretory, respi-

ratory, reproductive and nervous. For example, the digestive system is composed of organs like the oesophagus, stomach, intestines and the associated glands.

Revision Exercise

1. Explain why only the fine adjustment knob should be used when focusing a specimen using the high power objective lens of the light microscope.
2. A drawing of 5 cm in length, was made of a beetle whose actual length was one centimeter. Calculate the magnification of the drawing.
3. What is:
   (a) a cell?
   (b) an organelle?
4. Define the following:
   (i) A tissue.
   (ii) An organ.
   (iii) An organ system.
5. If the nucleus of a cell is removed, what would happen to that cell? Why?
6. Name the organelles that would be found in large numbers in cells of a:
   (i) rapidly respiring tissue.
   (ii) secretory gland. In each case, give a reason for your choice of the organelle.
7. Compare the structure of plant and animal cells.
8. Name the cell organelles that can be observed only under an electron microscope and for each state its functions.

CHAPTER FOUR

Cell Physiology

4.1 Introduction

The study of the functions of cell structures is called **cell physiology**. Some of the functions carried out by these cell structures include production of carbohydrates through the process of photosynthesis in chloroplasts, energy production by the process of respiration in mitochondria and protein synthesis in ribosomes. For these physiological processes to occur, the cell must take in raw materials such as carbon (IV) oxide, oxygen, mineral salts and glucose. During the processes, waste products are released. Some of these waste products are harmful and must be got rid of from the cell. Hence, there is a constant flow of substances into and out of the cell across the cell membrane in order to maintain life in a cell and an organism.

In this chapter we shall discuss the **movement of materials** in and out of cells.

4.2 Membrane Structure and Properties

A membrane is a surface structure which encloses the cell and organelles. Such membranes include the cell membrane, tonoplasts, nuclei membranes, mitochondrial membrane and chloroplast membrane. These membranes have a common basic structure which regulates the flow of materials in and out of a cell or organelle. One such membrane which is important to a cell is the cell membrane.

Cell Membrane Structure

The cell membrane as seen earlier is composed of a phospholipid layer sandwiched between two protein layers. Thus the membrane is a lipoprotein layer (made up of a lipid and protein layer). This gives the cell membrane a three layered structure of about 7.5 nm thick, which is perforated by small pores that allow the passage of substances into and out of a cell as shown in figure 4.1.

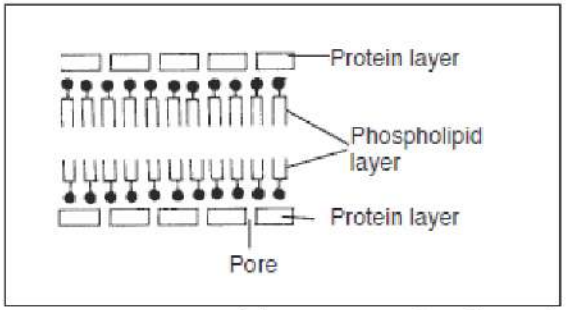


Fig. 4.1: Diagrammatic representation of the structure of a cell membrane

Study Question 1

How is the cell membrane adapted to its functions?

Properties of Cell Membrane

(a) Semi-Permeability

The pores that occur on a cell membrane allow molecules of small sizes to pass but not those with large sizes. For example, when a cell is surrounded by a dilute sugar solution, water molecules will enter the cell but not the larger sugar molecules. The membrane is therefore, said to be **semi-permeable**. However, the cell wall allows both sugar and water molecules to pass through because it has large pores and it is referred to as being **permeable**. This property allows the membrane to select what enters and leaves the cell.

(b) Sensitivity to Changes in Temperature and pH

Cell membranes have a layer of protein. These proteins are adversely affected by extreme changes in temperature and pH. Such changes alter the structure of the membrane and therefore, its normal functioning is hindered.

(c) Possession of Electric Charges

A membrane has both positive and negative charges. These affect the manner in which substances are moved in and out of the cell. This property also helps the cell to detect changes in the environment.

Study Question 2

Explain how variation of temperature and pH is likely to affect the normal functioning of the cell membrane.

4.3 Physiological Processes

One major function of the cell membrane is its ability to control the movement of substances into and out of the cell. This function is achieved through physiological processes that include **diffusion, osmosis** and **active transport**.

4.3 (a) Diffusion

Particles in a gas or a liquid are constantly moving freely, bumping into each other and bouncing off randomly. As this occurs, the molecules move from a region of high concentration to a region of low concentration. This results in the particles being evenly spread out in the space available. **The process by which particles move from a region of high concentration to a region of low concentration is known as diffusion.**

For example, the scent of a flower experienced by an individual is as a result of diffusion of particles of the scent from the source.

Practical Activity 1

To demonstrate diffusion using potassium manganate (VII)

Requirements

Potassium manganate (VII) crystals, glass tubing, 100 cm^3 beaker and water.

Procedure

1. Hold a glass tubing vertically in a beaker so that one end of the tubing rests flat on the bottom of the beaker.
2. Cautiously and quickly drop a crystal of potassium manganate (VII) through the upper opening of the glass tubing.
3. Close the upper end of the glass tubing with the thumb.
4. Half-fill the beaker with water.
5. Carefully withdraw vertically the glass tubing so that the crytstal is left undisturbed at the bottom of the beaker. See figure 4.2.
6. Record your observations for the first 15 minutes.
7. Explain your observations.

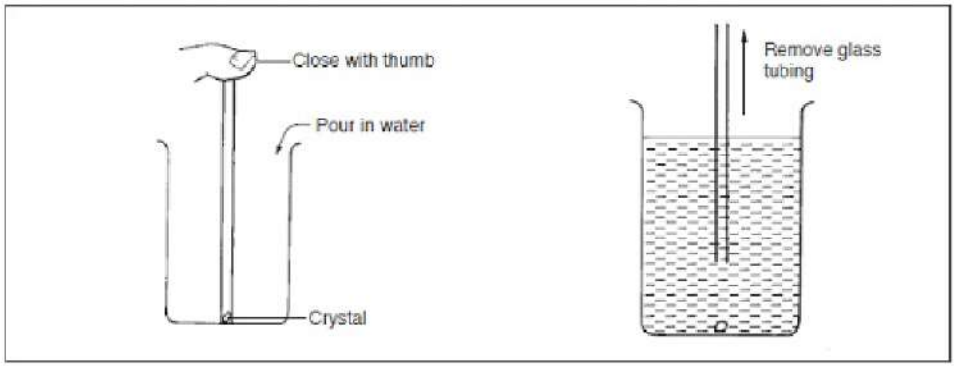


Fig. 4.2: To demonstrate diffusion with potassium manganate (VII) crystal

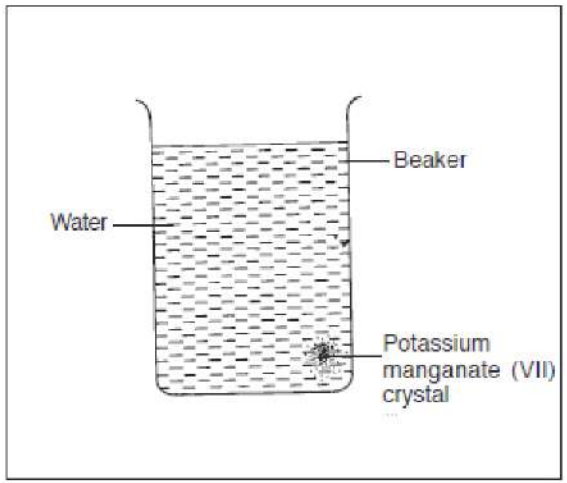


Fig. 4.3 (a): At the beginning

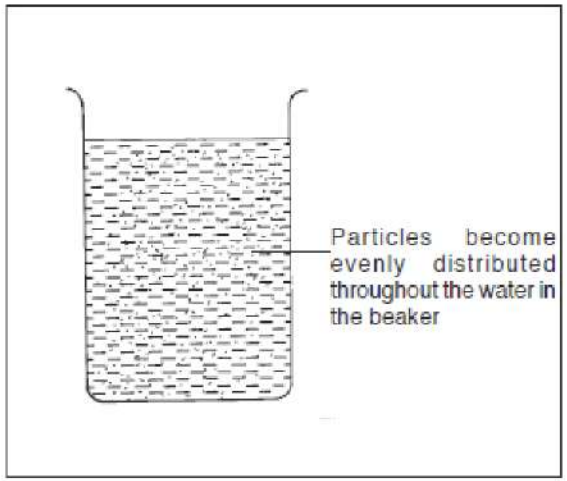


Fig. 4.3 (b): At the end

From the demonstration, you notedthat after some time, the purple colour of the potassium manganate (VII) spread throughout the water and eventually

all the water turned purple. The explanation for this observation is that in the crystals, the particles of potassium manganate (VII) are very concentrated. The potassium manganate (VII) particles break away from the crystals, dissolve in water and then **diffuse** through the water until they are evenly distributed. See figure 4.3 (a) and (b). The difference in concentration of particles between the region of high concentration and the region of low concentration is known as the **diffusion gradient**.

Role of Diffusion in Living Organisms

(a) Absorption of Materials

In plants, many salts dissolve in soil water to form ions which are small enough in size to pass through the pores of cell membranes of root cells.

This process will take place when the concentration of ions is higher in the soil water than in the root hair cells. Digested foods, for example amino acids and glucose, diffuse across the wall of the ileum into the blood for transport to other parts of the animal body.

(b) Gaseous Exchange in Plants and Animals

(i) Plants take in carbon (IV) oxide and give out oxygen in the presence of sunlight during photosynthesis. Some of the oxygen is used in respiration and the excess is given out. At night only respiration takes place and therefore, plants take in oxygen and give out carbon (IV) oxide as a waste product. These gases pass in and out of plants through stomata in leaves and lenticels in stems by diffusion.

(ii) In animals, several structures are used as surfaces of gaseous exchange through diffusion. These are gills, skins, tracheal system and lungs. These structures provide large surfaces for gaseous exchange. In animals where blood is used for transport, respiratory gases oxygen and carbon (IV) oxide, move in and out of body tissues by diffusion.

(iii) Excretion of nitrogenous wastes.

(iv) Diffusion is one of the mechanisms involved in the transport of manufactured food from leaves to other parts of the plant.

Study Question 3

(a) What is the significance of diffusion to plant pollination?

(b) Is diffusion an energy-driven process? Explain.

Factors Affecting Diffusion

(a) Diffusion Gradient

A greater diffusion gradient between two points increases rate of diffusion. Increasing concentration of diffusing molecules also increases diffusion gradient with corresponding regions hence increases diffusion rate.

(b) Surface Area to Volume Ratio

The rate of diffusion in and out of a body depends on surface area to volume ratio. The higher the ratio, the greater the rate of diffusion and the lower the ratio, the less diffusion takes place. This implies that small organisms expose a large surface area to the surrounding when compared to big organisms. The relationship is illustrated in table 4.1. Therefore, small organisms depend on diffusion as a means of transport of foods, respiratory gases and waste products. Large organisms, in addition to diffusion have transport systems to increase the efficiency of diffusion.

(c) Thickness of Membranes and Tissues

The thicker the membrane or tissue, the lower the rate of diffusion. This is because the distance to be covered by the diffusing molecules is greater. However, if the membrane is thinner, the rate of diffusion is higher.

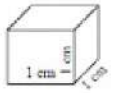
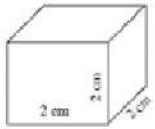
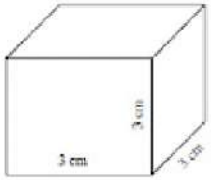
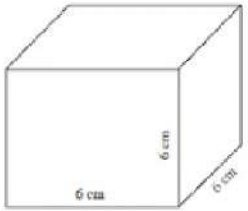
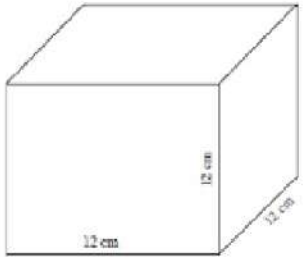
(d) Size of Molecules

Small and light molecules diffuse faster than large and heavy molecules.

(e) Temperature

An increase in temperature increases the energy content in molecules and this causes them to move faster. Hence, an increase in temperature increases rate of diffusion while decreases in temperature decreases the rate of diffusion.

Table 4.1: Relationship between surface area and volume

Object	Surface Area cm^2	Volume cm^3	Surface Area to Volume ratio
	6	1	6:1 = 6:1
	24	8	24:8 = 3:1
	54	27	54:27 = 2:1
	216	216	216:216 = 1:1
	864	1728	864:1728 = 1:2

4.3 (b) Osmosis

Osmosis is a special type of diffusion which involves a semi-permeable membrane. This process can be demonstrated using a visking tubing. Visking tubing is a commercial synthetic transparent semi-permeable membrane.

Practical Activity 2

To demonstrate osmosis using a visking tubing

Requirements

A 500 cm^3 beaker, a piece of visking tubing 8 cm long, a piece of thread 30 cm long, glass rod, concentrated sugar solution and 500 cm^3 distilled water.

Procedure

1. Into the beaker, put 350 cm^3 of the distilled water.
2. Dip the visking tubing in water to moisten it. Open the visking tubing and tie one end with the thread provided.
3. Half-fill the visking tubing with the sugar solution provided and then tie the open end of the tubing. Ensure no sugar solution spills out of the tubing.
4. Immerse the visking tubing into the distilled water in the beaker and suspend it using the glass rod provided as shown in figure 4.4.
5. Leave the set up for about 30 minutes.
6. Record your observation.
7. Explain the observations made.

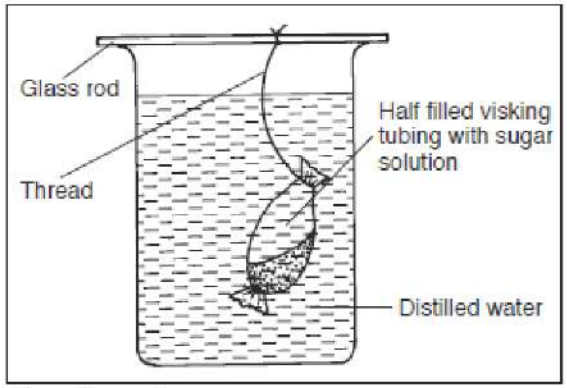


Fig. 4.4: Demonstration of osmosis

From the demonstration you have carried out, you observed that the visking tubing became swollen as a result of increase in its contents. See figure 4.5 a) and (b).

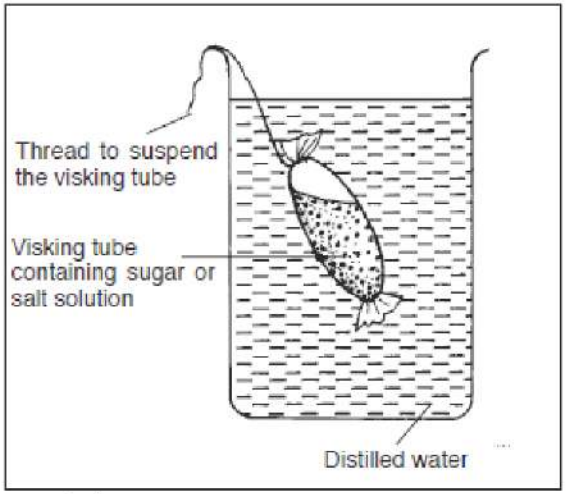


Fig. 4.5 (a): Osmosis at the beginning

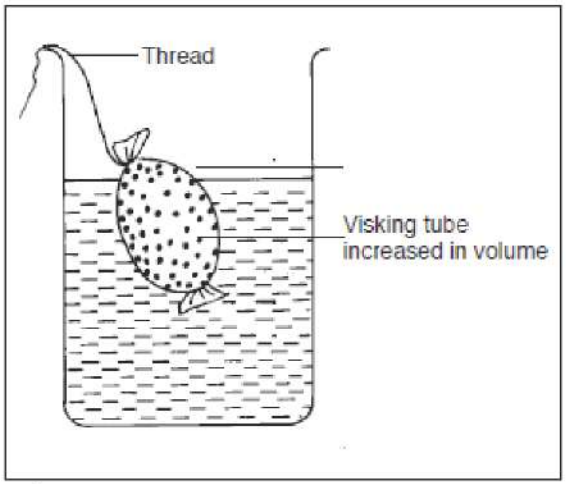


Fig. 4.5 (b): At the end

What explanation did you give for your observation?

Since the visking tubing contains both water and sugar molecules, it can safely be assumed that the beaker contains a higher concentration of water molecules than the visking tubing. The water molecules have therefore, diffused from a higher concentration to a lower concentration, that is, into the visking tubing and thereby increasing its contents. Besides, the wall of the visking tubing allowed only the small water molecules, to pass through but not the large sugar molecules. The membrane is therefore, said to be semi-permeable. See figure 4.6.

The process where the solvent molecules (water) move from a lowly concentrated (dilute) solution to a highly concentrated solution across a semi-permeable membrane is known as osmosis. The movement of solvent molecules may continue until the two separate solution achieve the same concentration. Such solutions are described as **isotonic**. A lowly concentrated solution (dilute) is described as **hypotonic** because it has less of the solute molecules, but more of the solvent molecules. A highly concentrated solution on the other hand, can be described as **hypertonic** because it has more of solute molecules but less of solvent molecules.

Osmosis can also be described as a **special type of diffusion** because it involves the movement of solvent (water) molecules from their region of high concentration to region of low concentration across a semi-permeable membrane.

In practical activity 2 you have demonstrated that osmosis occurs in a non-living material, the visking tubing. In the next activity you will investigate osmosis in a living tissue.

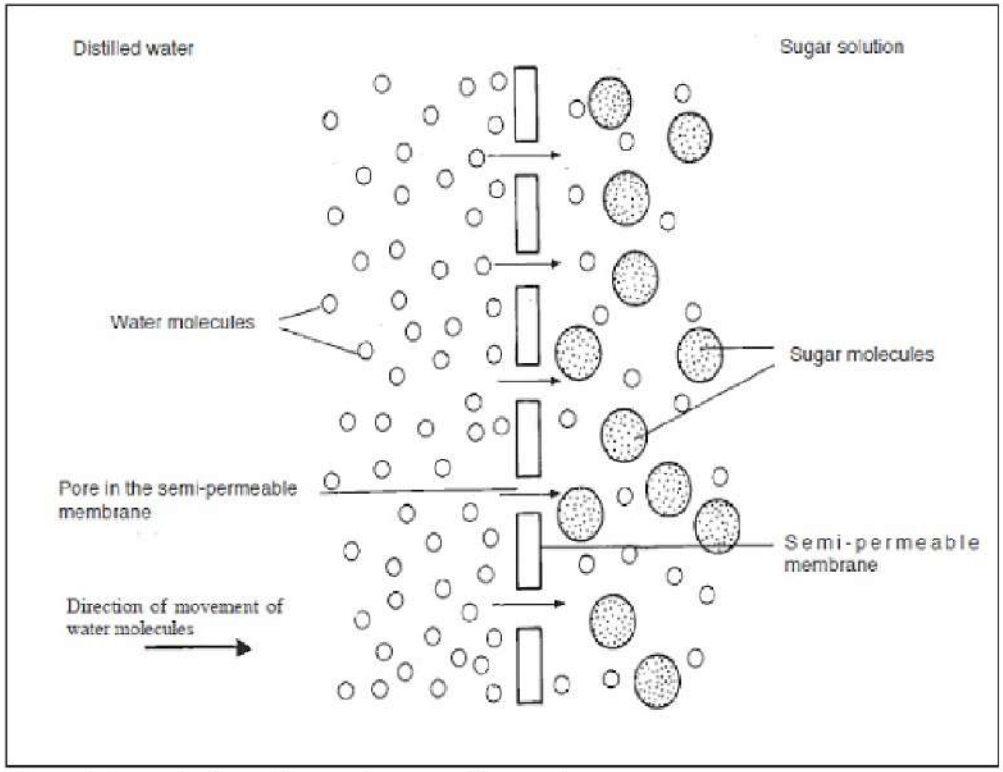


Fig. 4.6: Osmosis through a semi-permeable membrane

Study Question 4

(a) Distinguish between osmosis and diffusion.
(b) Name the solvent molecules involved in osmosis.

Practical Activity 3

To investigate Osmosis in potato tissue

Requirements

Cork borer 0.5 cm diameter, scapel or sharp razor blade, distilled water, ruler, Irish potato, strong sugar solution, tissue paper and two boiling tubes.

Procedure

1. Push a cork borer through a large potato tuber and remove the cylinder of tissue from the borer. Repeat this to obtain another five cylinders.
2. Chip off one end of each cylinder as shown in figure 4.7.
3. Starting from the chipped end, measure exactly 50 mm length and cut the cylinder. Repeat this for the other five cylinders. Consider the firmness and flexibility of cylinders.
4. Place three cylinders in a boiling tube containing distilled water and the other three cylinders in the other boiling tube containing a strong solution of sugar. Leave them for 40 minutes.
5. Remove the cylinders and mop them up with the tissue paper.
6. Measure and record the length of each cylinder from each boiling tube. Record your results in the format shown in table 4.2.
7. Explain the differences in the average length of the potato cylinders.

Table 4.2: Osmosis in potato tissue

Cylinders in boiling tube with sugar solution	*Initial length of cylinders*	*Final length of cylinders*	*Average length*	*Average change in length*
1. 2. 3.	— — —	— — —	—	—
Cylinders in boiling tube with distilled water.				
1. 2. 3.	— —	— —	—	—

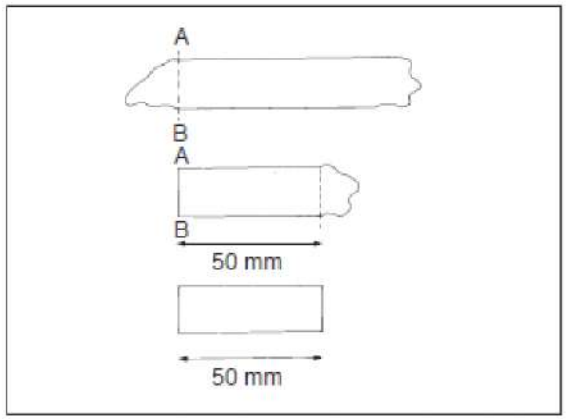


Fig. 4.7: How to make potato cylinders

Osmotic Pressure

When a concentrated solution is separated from distilled water by a semi-permeable membrane, the solution develops a force with which it draws water through the semi-permeable membrane from the distilled water. On the other hand, a pressure can be applied against the semi-permeable membrane to stop water molecules from the distilled water entering the concentrated solution or to stop osmosis from taking place. This pressure is referred to as **osmotic pressure**. The osmotic pressure of a solution is measured by an instrument called **osmometer**.

Osmotic Potential

Osmotic potential is the **hidden pressure** of a **concentrated solution** that only becomes real when the solution is separated from distilled water by a semi-permeable membrane. It is a measure of the pressure a solution would develop to withdraw water molecules from pure water when separated by a semi-permeable membrane.

Water Relations in Animals

The cell membrane of animal cells is semi-permeable just like the visking tubing, dialysis tubing or cellophane. The cytoplasm contains dissolved salts and sugars in solution form. If an animal cell, for example a red blood cell, is placed in distilled water or hypotonic solution, there would be a net flow of water into the cell by osmosis.

The cell would swell up and eventually burst. The cell membrane is weak and is not as strong and as firm as the additional cellulose cell wall found in plant cells. The cellulose cell wall in plants prevents the outward pressure and eventually prevents the cell from bursting. The bursting of the red blood cell is

Practical Activity 3

To investigate Osmosis in potato tissue

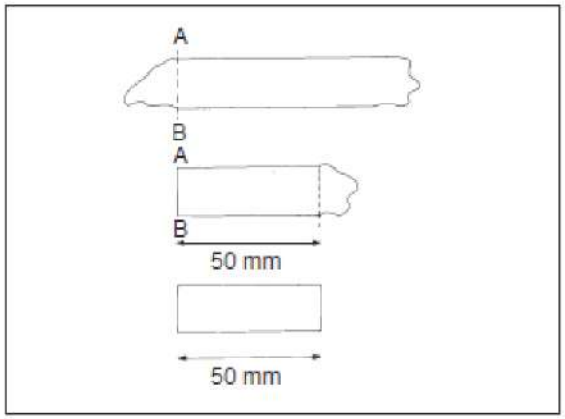
Requirements

Cork borer 0.5 cm diameter, scapel or sharp razor blade, distilled water, ruler, Irish potato, strong sugar solution, tissue paper and two boiling tubes.

Procedure

1. Push a cork borer through a large potato tuber and remove the cylinder of tissue from the borer. Repeat this to obtain another five cylinders.
2. Chip off one end of each cylinder as shown in figure 4.7.
3. Starting from the chipped end, measure exactly 50 mm length and cut the cylinder. Repeat this for the other five cylinders. Consider the firmness and flexibility of cylinders.
4. Place three cylinders in a boiling tube containing distilled water and the other three cylinders in the other boiling tube containing a strong solution of sugar. Leave them for 40 minutes.
5. Remove the cylinders and mop them up with the tissue paper.
6. Measure and record the length of each cylinder from each boiling tube. Record your results in the format shown in table 4.2.
7. Explain the differences in the average length of the potato cylinders.

Table 4.2: Osmosis in potato tissue



Cylinders in boiling tube with sugar solution	*Initial length of cylinders*	*Final length of cylinders*	*Average length*	*Average change in length*
1. 2. 3.	— — —	— — —	—	—
Cylinders in boiling tube with distilled water.				
1. 2. 3.	— —	— —	—	—

Fig. 4.7: How to make potato cylinders

Osmotic Pressure

When a concentrated solution is separated from distilled water by a semi-permeable membrane, the solution develops a force with which it draws water through the semi-permeable membrane from the distilled water. On the other hand, a pressure can be applied against the semi-permeable membrane to stop water molecules from the distilled water entering the concentrated solution or to stop osmosis from taking place. This pressure is referred to as **osmotic pressure**. The osmotic pressure of a solution is measured by an instrument called **osmometer**.

Osmotic Potential

Osmotic potential is the **hidden pressure** of a **concentrated solution** that only becomes real when the solution is separated from distilled water by a semi-permeable membrane. It is a measure of the pressure a solution would develop to withdraw water molecules from pure water when separated by a semi-permeable membrane.

Water Relations in Animals

The cell membrane of animal cells is semi-permeable just like the visking tubing, dialysis tubing or cellophane. The cytoplasm contains dissolved salts and sugars in solution form. If an animal cell, for example a red blood cell, is placed in distilled water or hypotonic solution, there would be a net flow of water into the cell by osmosis.

The cell would swell up and eventually burst. The cell membrane is weak and is not as strong and as firm as the additional cellulose cell wall found in plant cells. The cellulose cell wall in plants prevents the outward pressure and eventually prevents the cell from bursting. The bursting of the red blood cell is

known as **haemolysis**. If a similar red blood cell is placed in a hypertonic solution then water would be drawn out of the cell by osmosis. The cells would shrink by a process called **crenation.** See figure 4.8(a) and (b).

This behaviour of red blood cells placed in various concentrations of solution indicates that body fluids and the blood plasma surrounding the cells must be kept at the same concentration (i.e. isotonic) as that which is found inside the cells. If this is not done, the cells will either gain water and burst or lose water and shrink and their functions will be impaired. The body has a mechanism of keeping these concentrations constant within a narrow range.

4.3 (c) Water Relations in Plants

A plant cell has both a cellulose cell wall and cell membrane. The centre of the cell contains a vacuole with sap. The sap is a solution of salts and sugar and is bound by a membrane called **tonoplast**. The cell membrane and tonoplast are semi-permeable while the cellulose cell wall is fully permeable thus allowing solutes and water to pass through freely. If a plant cell is placed in water or hypotonic solution, the water will move into the cell by osmosis and cause the cell to distend. The cellulose cell wall is rigid and does not allow cells to burst as in animal cells. As the cell gains more water, its vacuole enlarges and exerts an outward pressure on the cell wall called **turgor pressure**. This pressure increases as more water is taken into the vacuole which pushes the cytoplasm against the cell wall until the cell wall cannot stretch any more. The cell becomes firm or rigid and is said to be **turgid**. When the cell wall is being stretched towards the outside, it develops a resistant pressure to stretching that is equal and opposite to turgor pressure called **wall pressure**. These processes are illustrated in figure 4.9.

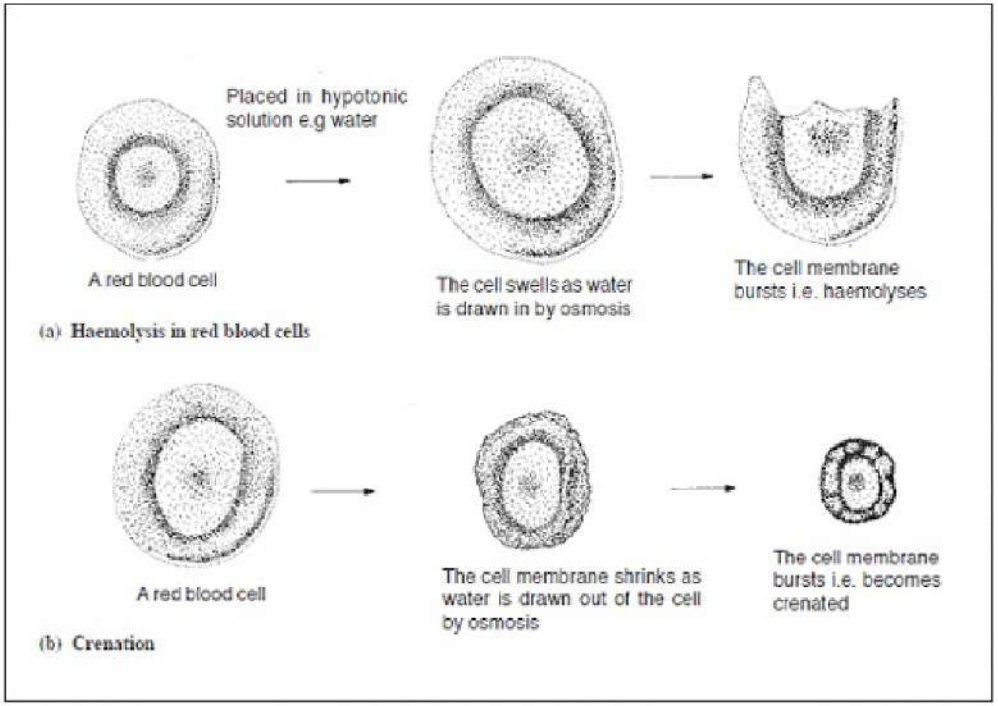


Fig. 4.8: Haemolysis and crenation in a red blood cell

When a plant cell is placed in a hypertonic solution, water molecules move out of the cell into the solution by osmosis. As the water moves out of the cell, the cell starts to shrink, becomes less rigid or flabby and is said to be **flaccid**. If the cell continues to lose more water, its contents reduce in size and the plasma membrane pulls away from the cell wall towards the centre. The process by which plant cells lose water, shrink and become flaccid is called **plasmolysis**. Plasmolysis can be reversed when a flaccid cell is placed in distilled water and this process is called **deplasmolysis.**

Study Question 5

A student at Kondele Secondary School observed that when sodium chloride was poured onto grass, the grass dried up. Explain this observation in relation to osmosis.

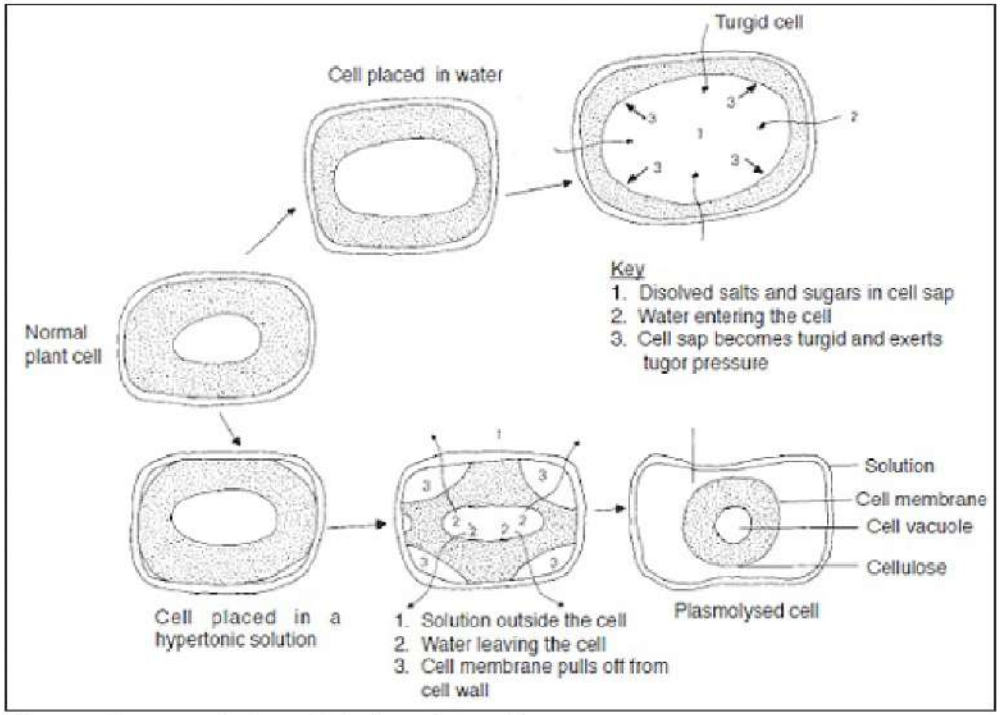


Fig. 4.9: Turgor and plasmolysis in a plant cell

Practical Activity 4

To examine the effects of osmosis on living cells

Requirements

Microscope, microscope slides, coverslips, dropper, pair of forceps, blotting paper, common salt solution and onion bulb.

Procedure

1. Put two drops of water on a clean microscope slide using a dropper.
2. Using a pair of forceps, carefully remove a piece of onion epidermis and place it on the drop of water on the slide. Cover with a coverslip.
3. Using a blotting paper, drain the excess water from the slide.
4. Observe under low and medium power objective lenses and make a large clear drawing of one of the cells.
5. Add three drops of salt solution to the left-hand side edge of the coverslip.
6. Hold a piece of blotting paper on the other side of the cover slip to draw the salt solution under the coverslip.
7. Observe the cells under the microscope after some time for about three minutes. Make another drawing of the observation.
8. Explain your observation of the epidermal cells observed in water and salt solution.

Wilting

Plants lose water to the atmosphere through transpiration and evaporation. The cells in the plants lose water and draw more from the soil. It reaches a time when the rate of water loss to the atmosphere is more than that of absorption from the soil. Turgor in cells is reduced while cells shrink and the plant **droops**. This phenomenon is observed in plants on hot and dry days and is called **wilting**. At night, plants recover from wilting because their stomata are closed and rates of both evaporation and transpiration are reduced. However, if water supply from the soil is inadequate, the plants do not recover from wilting and are said to have undergone **permanent wilting**.

Study Question 6

(a) Distinguish between plasmolysis and wilting.
(b) Explain how wilting assists plants to reduce excessive water loss to the atmosphere.

Role of Osmosis in Organisms

(a) Absorption of water from the soil

Root hair cells of a plant absorb water from the soil by osmosis. This same process (osmosis) also helps in water distribution from cell to cell in the body.

(b) Support

Water taken into cells increases cell turgor hence, cells become firm or rigid and therefore gain support. This type of support is important in seedlings, leaves and herbaceous plants which are less woody.

(c) Opening and closing of stomata

The guard cells synthesise glucose through the process of photosynthesis in the presence of light. As glucose accumulates in the guard cells, their osmotic pressure increases and this enables them to draw water from adjacent cells by osmosis. This action results in the guard cells becoming turgid causing the opening of stomata. The opening of the stomata allows gaseous exchange to take place. At night the guard cells do not photosynthesise and therefore, glucose level goes down leading to lowering of osmotic pressure. The guard cells lose turgidity and therefore, the stomata closes.

(d) Feeding in Insectivorous Plants

These are plants that trap insects using special structures that suddenly change their turgor pressure when disturbed. The change in turgor pressure enables the special structures such as leaves to close trapping insects which are digested to provide amino acids.

(e) Osmoregulation

In kidney tubules of animals, water is withdrawn from the tubules through the tubular walls through osmosis. The water finds its way into the surrounding blood capillaries. This helps the animal to regulate its body osmotic pressure.

Factors affecting Osmosis

(a) Concentration of Solutions and Concentration Gradient

Osmosis is greater in solutions that have greater differences in osmotic pressure. The greater the concentration gradient between two points, the greater the speed of osmosis.

(b) Certain factors that increase rate of diffusion also increase rate of osmosis provided they do not destroy the semi-permeable membrane. Such includes temperature.

4.3 (d) Active Transport

Diffusion and osmosis do not account for the transport of all substances across cell membranes. Substances such as amino acids, sugar and many ions do not easily diffuse across cell membranes even if their concentration on one side is greater than on the other side. Other substances, although able to diffuse across cell membranes, do not meet the requirement of the cells. **Active transport** is a process that moves these substances across the cell membranes and **against a concentration gradient**. The process **requires energy** to move these substances across the cell membrane.

It is suggested that there are **carriers** on cell membranes which combine with substances being transported, and then move them from one side of the membrane to the other. It is by active transport that sea-weeds take up large quantities of iodine from their surrounding sea water and accumulate it in their tissues at a higher concentration than the sea water. It is important to note that cellular intake of solutes is largely dependent on active transport.

Role of Active Transport

(a) Reabsorption of sugars and some salts by the kidney. Useful substances are reabsorbed back into the blood stream from the kidney tubules by active transport.
(b) Absorption of some mineral salts from the soil by roots.
(c) Absorption of digested food from alimentary canal of animals into the blood stream.
(d) Accumulation of substances into the body to offset osmotic imbalance in arid and saline environments.
(e) Excretion of waste products from body cells.

Study Question 7

(a) What is the significance of active transport in plants?
(b) Distinguish between osmosis and active transport.

Factors Affecting Active Transport

Any factor that affects energy production influences the rate of active transport. Such factors include oxygen concentration, change in pH, glucose concentration, enzyme inhibitors and temperature.

Revision Questions

1. (a) What type of membrane is the visking tubing?
   (a) How does a visking tubing differ from a cell membrane?
2. Explain the following terms:
   (a) diffusion
   (b) osmosis
   (c) active transport
   (d) plasmolysis.
3. How would you make a flaccid cell turgid?
4. In what ways are the properties of the cell membrane affected by:
   (a) temperature?
   (b) strong acid?
5. Name the method by which molecules like amino acids and glucose enter a cell.
6. Explain the differences between:
   (a) turgor pressure and wall pressure.
   (b) osmotic pressure and osmotic potential.
7. How would you demonstrate the process of diffusion using a bottle containing perfume?

8. Name two plant and two animal processes in which diffusion plays an important role.
9. How is the rate of diffusion affected by:
   (a) temperature?
   (b) concentration?
   (c) surface area to volume ratio?
10. The following experiment was set up to demonstrate the water relations of plant cells. Two tubes x and y made of visking tubing were filled with different liquids and placed in a beaker containing a certain liquid, see fig. 4.10.
    It was found that after 20 minutes, visking tubing x felt hard and the amount of liquid in it had increased. Visking tubing y was soft and contained less liquid as shown in figure 4.10.

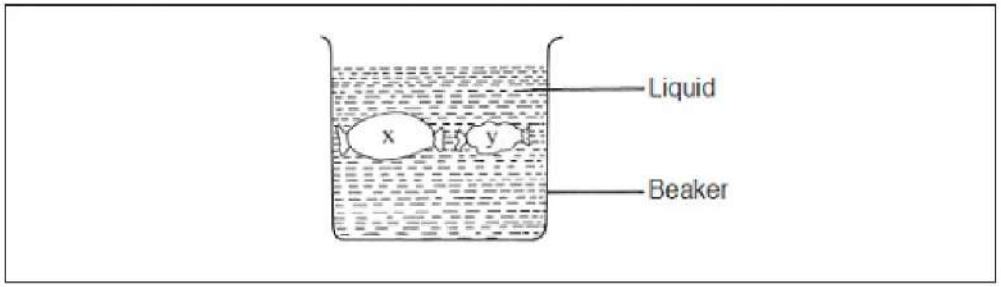


Fig. 4.10

   (a) Explain what took place in visking tubings x and y.
   (b) (i) Identify which liquid is hypotonic to the liquid in the beaker.
       (ii) Use (b) above to explain the meaning of hypotonic and hypertonic solutions.
11. Four equal strips A, B, C and D were cut from a potato whose cell was 28.5% of sugar. The strips were placed in sugar solutions of different concentrations as follows: A 10%, B 15%, C 25% and D 35%
    (i) What changes would you expect in strips A and D?
    (ii) Account for the changes in A and D above.
12. An experiment was set up in a laboratory as shown in figure 4.11

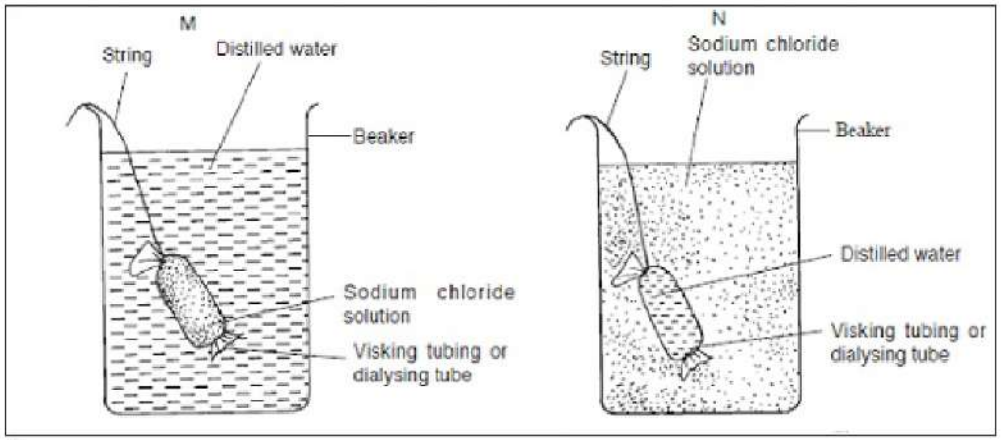


Fig. 4.11

    (i) What will happen to the visking tubing in M and N after two hours?
    (ii) Explain the observation made in M.
    (iii) What does a visking tubing correspond to in a living organism?
13. A group of students set up an experiment to investigate a certain physiological process. The set-up was as shown in the figure 4.12.

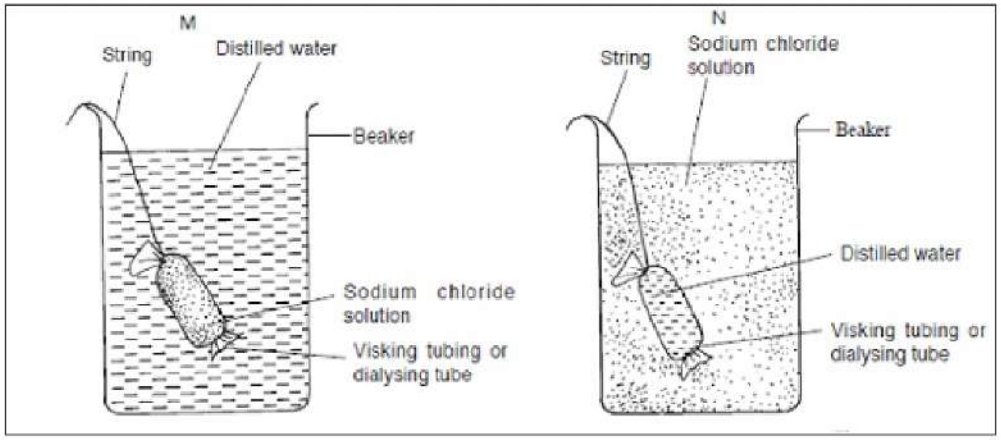


Fig. 4.12

After some time, the students observed that the level of the sugar solution had risen.
   (a) What physiological process was being investigated?
   (b) Account for the rise in the level of sugar solution in the experiment.
   (c) Suggest the results that the students would obtain if they repeated the experiment using a piece of boiled pawpaw.

CHAPTER FIVE

Nutrition in Plants and Animals

5.1 Introduction

All living organisms require food to sustain life. Food is also required for carrying out metabolic activities such as respiration and growth and repair of worn out tissues in living organisms. The process by which organisms **obtain nutrients** and **assimilate** them is referred to as **nutrition**. The modes of nutrition differ depending on the type of organism. Both **Autotrophism** and **Heterotrophism** are modes of nutrition that have been identified among the organisms.

Autotrophism is a mode of nutrition in which the living organism manufactures its own complex food substances from simple substances. These simple substances are carbon (IV) oxide (carbon dioxide), water, light or chemical energy. The simple substances are obtained from the immediate environment. Living orga-nisms that make their own food are known as **autotrophs.**

Heterotrophism is a mode of nutrition that involves taking complex food materials such as carbohydrates, proteins and fats obtained from bodies of plants and animals. Organisms that feed on these already synthesised foods are called **heterotrophs.**

5.2 Autotrophism

(a) Autotrophism is a process by which some plants manufacture food substances such as carbohydrates from simple substances such as carbon (IV) oxide and water. Where sunlight is used as a source of energy, the process is referred to as **photosynthesis. Photo** means light while **synthesis** means to make. Some non-green plants obtain energy for making food from oxidation of chemicals. Their process of making food is therefore, known as **chemosynthesis.**

As a result of photosynthesis, food substances such as carbohydrates, proteins and fats are formed. Plants are therefore, the **primary producers** and animals directly or indirectly depend on them as a source of food. Therefore, it can be concluded that the process of photosynthesis involves the conversion of light energy into a form that can be utilised by all living organisms.

During the process of photosynthesis, carbon (IV) oxide from the atmospheric air is used. Oxygen is given out and released in to the atmospheric air as a by-product. Animals and plants use oxygen from the atmosphere for respiration. They release carbon (IV) oxide as one of the products of respiration. This way, photosynthesis helps to maintain the level of these two gases fairly constant in the atmosphere.

The process of photosynthesis occurs in green plants, mainly in the leaves. In order to understand the process of photosynthesis, it is necessary to study the external and internal structure of the leaf.

(a) External Structure of a Leaf

A leaf is a thin flattened organ which is attached to the stem or a branch of green plants. A typical simple leaf consists of a flattened surface called **lamina**. The lamina is green in colour and contains the photosynthetic tissue. In dicotyledonous plants, simple leaves have a thick **midrib** which runs in the middle. From the midrib arises small veins that run into the lamina forming an extensive network of **veins**. In monocotyledonous plants, the midrib is absent but small veins run parallel to each other.

In some plants, the leaf is attached to the stem or branch by a petiole while in others the leaf is attached directly. In some monocotyledons, some leaves are attached to the stem by the leaf sheath. See figure 5.1.

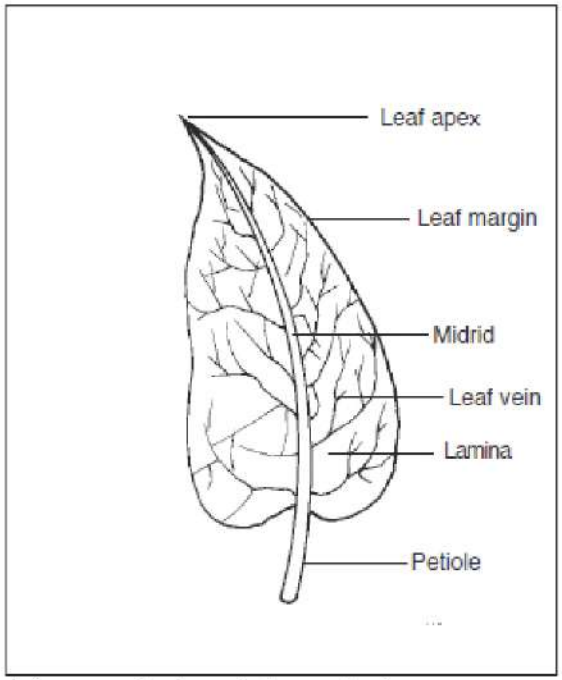


Fig. 5.1 (a): External features of a dicotyledonous leaf, e.g., Bean

Practical Activity 1

To examine the external features of a dicotyledonous and monocoty-ledonous leaf

Requirements

A hand lens, dictoyledonous leaf e.g. bean, hibiscus, monocotyledonous leaf e.g. maize, napier grass or tradescantia.

Procedure

1. Take one dicotyledonous leaf. Notice the smooth shiny upper surface due to the waxy cuticle layer covering it. Compare the upper and lower surface. Which one is less shiny? What is the reason for this?
2. Study the venation (arrangement of veins) of the leaf. Observe the thick mid-rib and the finer veins branching off from it.

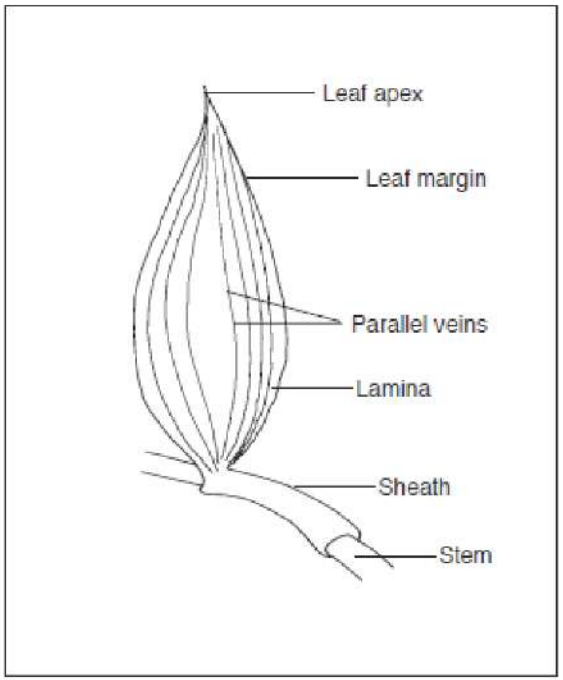


Fig. 5.1 (b): External features of a monocotyledonous leaf, e.g., Zebrina

3. Repeat the same observations using the monocotyledonous leaf. What differences do you notice in leaf surfaces and venation?

Study Question 1

(a) What can you say about the surface area of the lamina in practical activity 1 above? Give a reason for your answer.

(b) Why is the leaf thin?

(c) Make a drawing of the two types of leaves and label the lamina, petiole, veins, leaf sheath and leaf margin.

(b) Internal Structure of a Leaf

A transverse section of the leaf, examined under a light microscope reveals the internal structures shown in figure 5.2. The following is a description of the structure and functions of the parts labelled below.

Cuticle

This is a thin non-cellular, waxy, waterproof and transparent layer that coats the upper and lower surfaces of the leaf. It reduces excessive loss of water and protects the inner tissues of the leaf from mechanical damage. It also prevents entry of disease-causing micro-organisms. The cuticle is transparent. It allows penetration of light for photosynthesis.

Epidermis

This is a thin tissue, usually one cell thick, on the upper and lower surfaces of the leaf. The epidermal cells have no chloroplasts except the guard cells. Chloroplasts are the organelles that contain the photosynthetic material known as **chlorophyll**. The epidermis secretes the cuticle and also protects the inner tissues from mechanical damage and entry of disease-causing microorganisms.

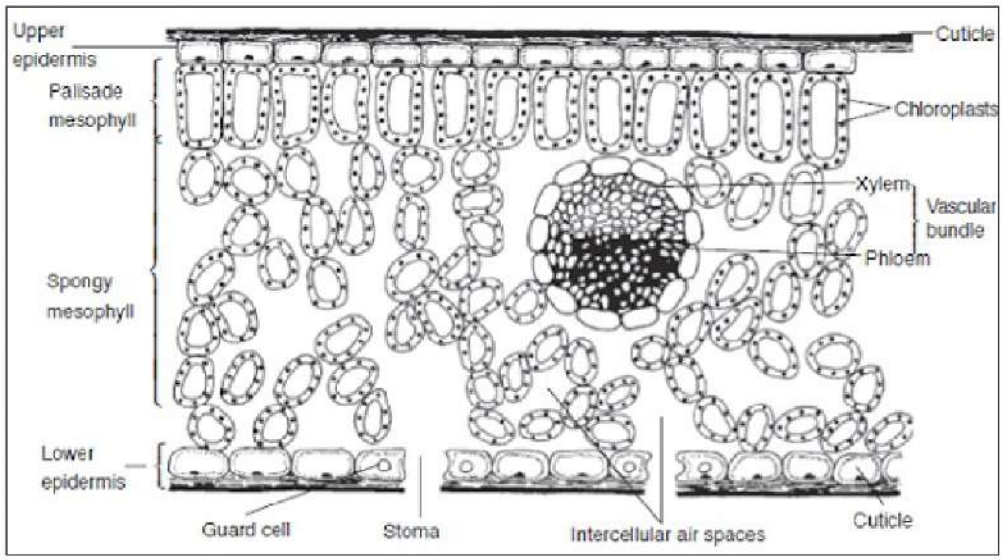


Fig. 5.2: Transverse section of a leaf

The **guard cells** are special bean-shaped epidermal cells, mostly found on the lower surface of the leaf. Unlike the adjacent epidermal cells, guard cells contain chloroplasts and are able to carry out the process of photosynthesis.

They control the opening and closing of the stoma. They also control water loss. Through the stomata, air moves in and out of the leaf.

Palisade Layer

This is a layer of cells located beneath the upper epidermis. It consists of cylindrical shaped cells closely packed together and with the long axis perpendicular to the surface. They have numerous chloroplasts containing chlorophyll which is necessary for photosynthesis. Their position and arrangement enables them to receive maximum sunlight.

Spongy Mesophyll Layer

This is a layer of cells between the palisade and the lower epidermis. The cells are irregularly shaped and loosely arranged creating large air spaces in between them. The air spaces provide communication pathways through which gases diffuse in between the cells. Unlike the palisade cells, these cells contain fewer chloroplasts. This explains why the lower surface of the leaf is lighter in colour than the upper surface.

Leaf Veins

The leaf has an extensive system of veins which ensures that every cell is close to the supply of materials. Each vein is a vascular bundle which consists of xylem and phloem tissues. Through the xylem, water and mineral salts are conducted from the roots to the leaf cells while manufactured food is translocated through the phloem from the leaf cells to the rest of the plant.

Study Question 2

Name three cells in a leaf which contain chloroplasts.

Summary of the Adaptations of the leaf to its Photosynthetic function

Leaves posses special structural features which enable them to carry out the process of photosynthesis efficiently. The structural features include the following:

(i) Broad flat lamina provides a large surface area for the absorption of carbon (IV) oxide and sunlight.
(ii) The thinness of the leaf allows light and carbon (IV) oxide to pass through a short distance to reach the photosynthetic cells.
(iii) The presence of stomata ensures efficient diffusion of carbon (IV) oxide into the leaf.
(iv) The cuticle and epidermis are transparent enough to allow penetration of light to the palisade cells.
(v) The palisade cells contain large numbers of chloroplasts, and their arrangement and location next to the upper epidermis enables them to receive maximum sunlight.
(vi) The existence of extensive veins which conduct water and mineral salts to the photosynthetic cells and removes the products of photosynthesis.

Plate 5.1: Photograph of leaf mosaic

(vii) The air spaces in the spongy mesophyll layer are large enough to allow gases to circulate easily.
(viii) The regular arrangement of leaves on the stem minimises overlapping and overshadowing. This is called **leaf mosaic**. See Plate 5.1.

(c) The Chloroplasts

These are disc-shaped organelles found in the cytoplasm of some plant cells. Each chloroplast is bound by a double unit membrane: the outer and inner membranes. Internally, the chloroplast consist of layers of membranes known as **lamellae** suspended in an aqueous matrix called **stroma**. The lamellae may at certain intervals form several layers of membranes grouped together to make a **granum** (plural – grana). See figure 5.3.

Chlorophyll molecules and other photosynthetic pigments are located in the granum which provides a large surface area to accommodate a large number of chlorophyll molecules. Chlorophyll molecules absorb light energy which is necessary for photosynthesis to take place. The stroma contain enzymes that speeds up the process of photosynthesis.

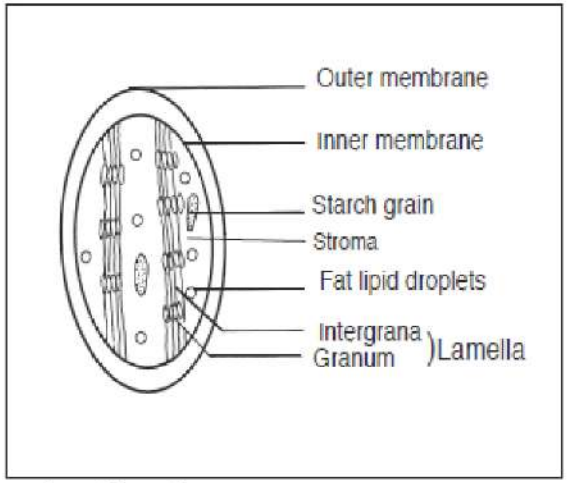


Fig. 5.3: Section through a chloroplast

Practical Activity 2

To observe distribution of stomata

Requirements

Leaves of zebrina, Tradescantia or kales (*sukuma wiki*) microscope, microscope slides, a pair of forceps, water, a dropper and coverslip.

$$\text{Carbon (IV) oxide} + \text{Water} \xrightarrow{\text{Light energy and chlorophyll}} \text{Glucose (simple carbohydrate)} + \text{Oxygen}$$

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Procedure

1. Obtain a leaf of the plant and cut the leaf across.
2. Using the pair of forceps, obtain a thin epidermis from the lower surface of the leaf.
3. Mount this on the microscope slide, add a drop of water and then place a coverslip.
4. Place the slide on the stage and observe under low power and medium power objective lenses.
5. Identify the guard cells and the normal epidermal cells.
6. Identify the stoma in between the guard cells. Count the number of stomata observed in the field of view.
7. Repeat the procedure for the upper surface of the leaf.

Study Question 3

(a) Explain how chloroplasts are adapted to their photosynthetic functions.
(b) List three adaptations of leaves that maximise efficiency in trapping sunlight for photosynthesis.

(d) The process of Photosynthesis

The raw materials for photosynthesis are water and carbon (IV) oxide gas. For the process to take place, it requires the presence of light and chlorophyll pigment. As mentioned earlier, the process of photosynthesis occurs in the chloroplasts. Water and carbon (IV) oxide molecules undergo several chemical processes in the presence of sunlight to form carbohydrates and oxygen is given out as a by-product. The process can be summarised using a general equation represented below in the boxed text above.

This process is however, more complex than what is represented in the simple series of equations given above. It involves chemical reactions that can be outlined in two general stages. These are the light stage and the dark stage.

The Light stage (Light Dependent Stage)

This is the initial stage in the process of photosynthesis. It occurs in the **grana** of the chloroplasts. The chlorophyll molecule absorbs light energy which is used to split water molecules into oxygen and hydrogen atoms. This process is called **photolysis** of water and is shown below.

$$2H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} 4H + O_2$$

$$\text{Water} \longrightarrow \text{Hydrogen atom} + \text{Oxygen}$$

The hydrogen atoms that are produced by the splitting of water enter the dark stage while oxygen is released to the atmosphere or used by the plant for respiration. Some of the solar energy absorbed by chlorophyll molecules is used in the formation of energy-rich **Adenosine Triphosphate** (ATP) which is later used in the dark stage. This reaction involves conversion of light energy to chemical energy.

The Dark Stage (Light Independent Stage)

This is the second stage of the process of photosynthesis. It proceeds whether light is present or not. This process involves combination of carbon (IV) oxide with hydrogen atoms to form simple sugar such as glucose. This process is

known as **carbon (IV) oxide fixation** which involves a series of enzyme controlled reactions in the box. The equation below is a summary of Carbon (IV) oxide fixation. The energy required for this reaction is provided by ATP from light stage reaction.

The intermediate product $(CH_2O)_n$ undergoes further reactions to form simple sugars such as glucose. Some of the glucose formed is directly utilised by the plant cells while the rest is converted to starch and stored in the plant. In addition to glucose, fatty acids and amino acids are also formed in the dark stage of photosynthesis.

Study Question 4

(a) What is the importance of light dependent reaction in the process of photosynthesis?
(b) What are the products of the light independent stage in photosynthesis?

Practical Activity 3

To investigate the presence of starch in a leaf

This activity aims at investigating the presence or absence of starch in a leaf. If a positive result is desired, then the leaf must be exposed to light for sometime in order to allow the process of photosynthesis to proceed.

The test-leaf must be killed by dipping it in boiling water. The dead leaf should then be decolourised by boiling it in methylated spirit. A water bath should be used to avoid igniting the highly flammable methylated spirit. The leaf is softened by dipping it in warm water.

Requirements

Water, dropper, beaker, source of heat, boiling tube, a leaf and petri dish or white tile.

Carbon IV oxide + Hydrogen ⟶ Simple carbohydrate + Water

$$CO_2 + 4(H) \longrightarrow (CH_2O)_n + H_2O$$

Procedure

1. Obtain a leaf that has been exposed to light for at least 5 hours.
2. Boil water in a beaker.
3. Dip the leaf in the boiling water for 3 to 4 minutes.
4. Put the leaf in a boiling tube containing methylated spirit and stand the tube in the beaker containing boiling water (water bath) for about 10 minutes to decolourise the leaf.

   CAUTION: Methylated spirit is highly flammable, avoid direct heating.
5. Remove the leaf from the test-tube and wash it in hot water in the beaker.
6. Spread the leaf in a petri-dish and add drops of dilute iodine solution. Observe and record the colour changes.

   Note. A blue-black colour indicates presence of starch.

Study Question 5

Explain why:
(a) it was necessary to use a leaf that had been exposed to light for a few hours.
(b) the fresh leaf was dipped in boiling water.
(c) the leaf was decolourised.
(d) the methylated spirit was boiled indirectly.

(e) Factors Affecting the Rate of Photosynthesis

The main factors which affect the rate of photosynthesis are light intensity, carbon (IV) oxide concentration, temperature and water. Each of these factors are discussed below.

Light Intensity

Light intensity varies from day-to-day and from place to place. On a bright sunny day, plants photosynthesise faster than on a dull cloudy day. The rate of photosynthesis increases linearly as the light intensity increases, up to a certain level when it slows down and finally levels off. Very bright sunshine may actually damage plants because of high amount of ultra-violet light.

It is important to note that the quality of light also affects the rate of photosynthesis. Most of the plants require red and blue wave-lengths of light for photosynthesis. Plants growing in the shade receive low quantities and poor qualities of light which slows the process of photosynthesis. See figure 5.4.

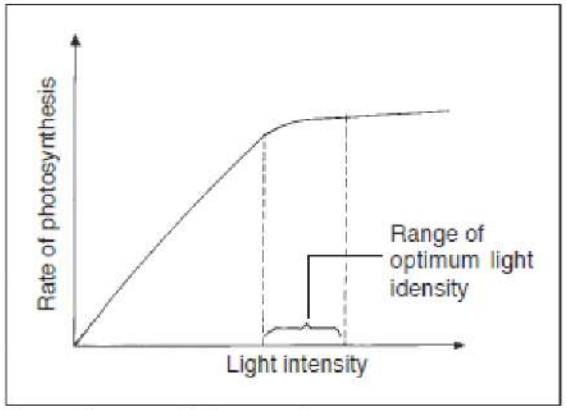


Fig. 5.4: Effect of light on the rate of photosynthesis

Carbon (IV) oxide Concentration

The amount of carbon (IV) oxide in the atmosphere is about 0.03% and does not vary very much. Under controlled conditions like a green house, an increase in carbon (IV) oxide concentration results in a linear increase in the rate of photosynthesis up to a certain level when it slows down and finally levels off as shown in figure 5.5.

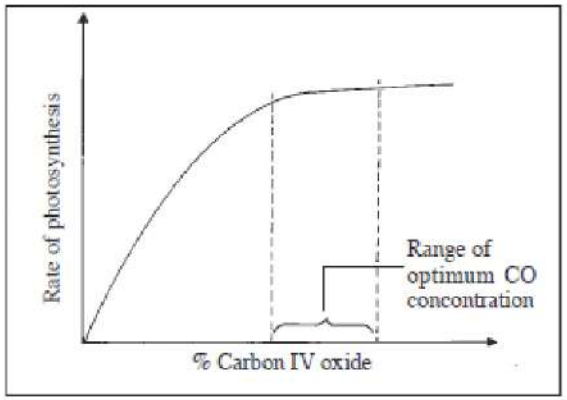


Fig. 5.5: Effect of carbon (IV) oxide on the rate of photosynthesis

Temperature

Photosynthesis is a process controlled by enzymes. Enzyme-controlled reactions are affected by temperature changes. At low temperature, the rate of photosynthesis is low. A rise in temperature by 10°C results in the doubling of the rate of photosynthesis up to about 40°C. Further increase of temperature decreases the rate sharply and finally stops. This is because the excess heat destroys the enzymes which are responsible for the chemical reactions. Figure 5.6 graphically summarises this information.

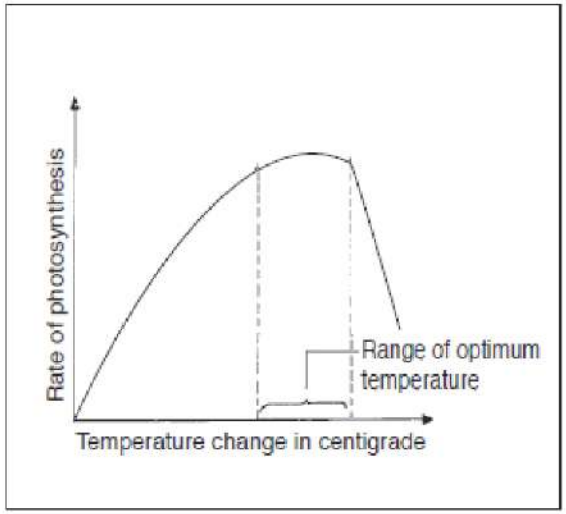


Fig. 5.6: Effect of temperature on photosynthesis

For each factor considered, the rate of photosynthesis increases up to the point where it levels off. At this point, there is a limiting factor. For example, where the graph levels off for carbon (IV) oxide, the limiting factor may be light intensity. If this were increased, the rate of photosynthesis would increase beyond the plateau.

Water

Plants need water for photosynthesis. A plant whose leaves are withering due to lack of water may photosynthesis at a lower rate. However, water is needed for many other purposes besides photosynthesis and the effect of water shortage on photosynthesis may be indirect.

To maximise the rate of photosynthesis optimum temperature conditions with adequate rainfall and sufficient carbon (IV) oxide are necessary.

Study Question 6

Name the factors that affect photosynthesis in plants.

Practical Activity 4

To investigate the factors which are necessary for photosynthesis.

(a) Light

Requirements

Methylated spirit, iodine solution, water, white tile, droppers, beaker, source of heat, boiling tube, light proof material (e.g., aluminium foil), potted plant and clips.

Procedure

1. Cover two or more leaves of a potted plant with a light-proof material as shown in figure 5.7.
2. Place the plant in a dark place for 48 hours.
3. Transfer the potted plant to light for 2–3 hours.
4. Detach and uncover the leaves and immediately carry out the test for starch as in practical ativity 2. Observe and record the observations.

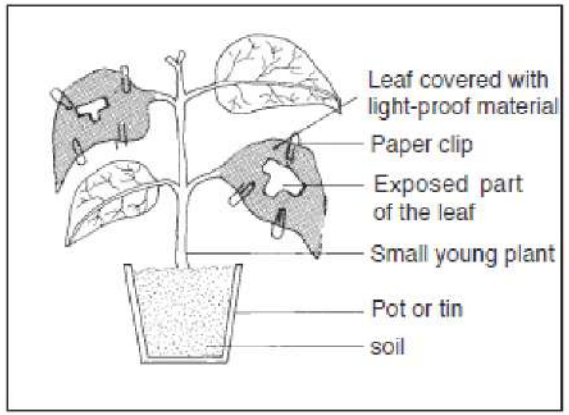


Fig. 5.7: Necessity for light in photosynthesis

Study Question 7

(a) Why was the plant kept in the dark for 48 hours?
(b) Why was it necessary to transfer the plant to light?
(c) What was the role of the light proof paper?

The plant is kept in the dark for about 48 hours to ensure that all the starch in it is used up. This is also called **destarching**. Once destarched, the experimental plant would be ideal for investigating whether starch would be formed in the presence of light.

(b) Carbon (IV) oxide

In this experiment, sodium hydroxide pellets are used to absorb carbon (IV) oxide. Sodium hydroxide is deliquescent and absorbs water to form a solution. The solution formed absorbs carbon (IV) oxide readily.

The leaves outside the flask act as a control. They have access to all requirements of photosynthesis. The leaf under test lacks carbon (IV) oxide.

Requirements

Conical flasks/polythene bags, potted plants, sodium hydroxide pellets, cork or plasticine or clay, cork borers, blades, petroleum jelly, iodine solution, methylated spirit, water, beakers, droppers, white tiles, boiling tubes, source of heat and wooden support.

Procedure

1. Keep the potted plant in a dark place for 48 hours.
2. Place a few pellets of sodium hydroxide in the flask.
3. Bore a hole in the cork of the same size as the petiole of the leaf being used.
4. Cut the cork lengthwise.

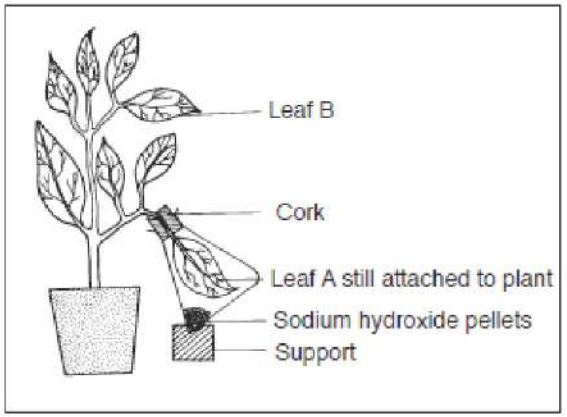


Fig. 5.8: Necessity for carbon (IV) oxide

5. Remove the plant from the dark and immediately fit the petiole of a leaf A in the groove and cork the flask as shown in figure 5.8.
6. Seal the mouth of the conical flask with petroleum jelly to make it airtight.
7. Keep the set up in the light for two to three hours.
8. Detach and test for the presence of starch in both leaves A and B.
9. Record your observations.

Study Question 8

(a) What is the function of the sodium hydroxide pellets?
(b) Why was the leaf outside the flask also tested for starch?

(c) Chlorophyll

A variegated leaf is one that has some patches that lack chlorophyll. These patches have other colours for example, yellow. These parts lack chlorophyll and therefore photosynthetic activity does not take place in them.

Requirements

Variegated leaves, iodine solution, methylated spirit, white tile, water, boiling tubes, beakers, droppers and source of heat.

Procedure

1. Detach or remove variegated leaf from a plant that has been exposed to light for at least 3 hours.
2. Draw a large labelled diagram of the leaf to show the distribution of the chlorophyll pigment in the leaf. See figure 5.9.
3. Test the leaf for starch in the usual way as described in activity 2.
4. Record your observations in form of a diagram.

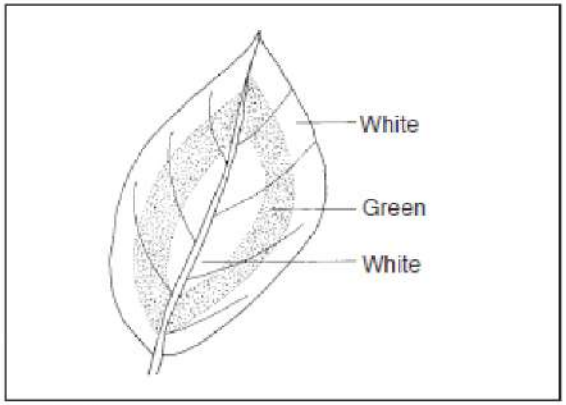


Fig. 5.9: The variegated leaf

Study Question 9

Comment on the distribution of starch in the leaf.

Study Question 10

Compare the distribution of stomata on the upper and lower surfaces of the leaf.

Practical Activity 5

To investigate the gas produced during photosynthesis

As you are already aware, oxygen gas is a by-product of photosynthesis. This activity makes use of plants that are submerged in water to find out the gas released during photosynthesis. Other plants that are not adapted to this environment may not work well since the set-up provides an aquatic environment.

As you may notice, the amount of carbon (IV) oxide dissolved in water may be low. Addition of sodium hydrogen carbonate boosts this amount and accelerates the rate of photosynthesis.

Requirements

Water plant, e.g., *Elodea* spp., Spirogyra or Nymphea (water lily), glass funnels, beakers, small wooden blocks, test tubes, wooden splints and sodium hydrogen carbonate.

Procedure

1. Setup the experiment as shown in figure 5.10.
2. Place the set-up in the sunlight to allow photosynthesis to take place.
3. Leave the set-up in the sun until sufficient gas has collected in the test-tube.
4. Test the gas collected with a glowing splint.
5. Record your observations.

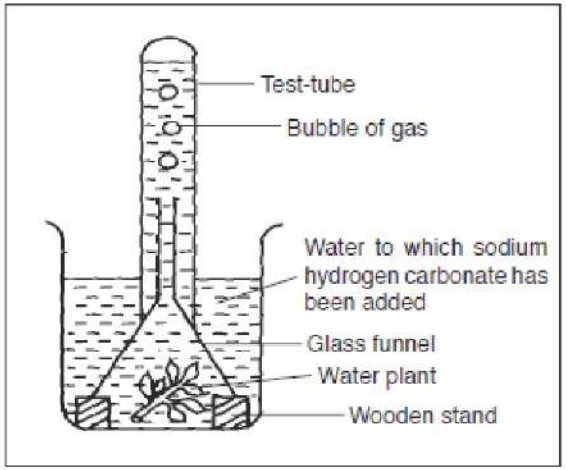


Fig. 5.10: Gas released in photosynthesis

This experiment can be used to investigate various factors on the rate of photosynthesis such as:

- Temperature
- Light intensity
- Carbon (VI) oxide concentration

With advice from your teacher, attempt these experiments.

Study Questions 11

(a) What gas is produced during photosynthesis?
(b) Why was sodium hydrogen carbonate used during the experiment?

(c) Explain why only submerged water plants are used instead of terrestrial plants in the experiment.

5.3 Chemical Compounds Which Constitute Living Organisms

Cells, tissues and organs are composed of chemicals which are referred to as **chemicals of life** and are obtained from the environment. The study of chemical compounds found in living organisms and reactions in which they take part is known as **biochemistry**. This study attempts to review the chemical composition of living systems. Many of these chemicals are identical to those found in nonliving organic matter. However, we shall consider carbohydrates, lipids and proteins.

5.3 (a) Carbohydrates

Carbohydrates are compounds of carbon, hydrogen and oxygen. The elements are in the ratio of 1 carbon: 2 hydrogen: 1 oxygen. This gives the carbohydrates a general formula $(CH_2O)_n$ where "n" represents the number of carbon atoms a molecule of a carbohydrate has. Carbohydrates can be divided into the following types: **monosaccharides, disaccharides** and **polysaccharides.**

(i) Monosaccharides

These are the simplest carbohydrates and have a general chemical formula of $(CH_2O)_n$ where n = 6. Hence their chemical formula is $C_6H_{12}O_6$. For example, glucose, fructose and galactose are simple carbohydrates which have the formula $C_6H_{12}O_6$.

Properties of Monosaccharides

Monosaccharides are soluble in water and form sweet tasting solutions. Sweet tasting fruits owe this property to the abundant content of monosaccharides in them. When monosaccharides are mixed with Benedict's solution and heated, the copper sulphate is reduced to red copper (I) oxide. Thus, they are described as **reducing sugars**. They are crystallisable. Molecules of monosaccharides link together to form complex carbohydrate molecules. This process is called **condensation**. In this reaction, water molecules are also formed. For example, two glucose molecules can be condensed and linked together to form one molecule of disaccharide.

Functions

(a) Monosaccharides are oxidised during respiration to **release energy.** Glucose is the common respiratory substrate and the most common monosaccharide.

(b) When condensed together, they form polysaccharides such as starch and cellulose in plants. Glucose can be converted into glycogen which is stored in animal tissues.

(ii) Disaccharides

They are formed by linking two monosaccharide molecules through the process of condensation. Therefore, they are more complex than monosaccharides. Their formation from two monosaccharides results to loss of water molecules.

For example:

$$\text{Monosaccharide} + \text{Monosaccharide} \xrightarrow{\text{Condensation}} \text{Disaccharide} + \text{Water}$$

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

$$\text{Glucose} + \text{Glucose} \xrightarrow{\text{Condensation}} \text{Maltose} + \text{Water}$$

$$\text{Glucose} + \text{Fructose} \xrightarrow{\text{Condensation}} \text{Sucrose} + \text{Water}$$

$$\text{Glucose} + \text{Galactose} \xrightarrow{\text{Condensation}} \text{Lactose} + \text{Water}$$

From the above equations, it can be concluded that the type of disaccharide formed depends on the monosaccharide units that enter into its composition.

Properties of Disaccharides

Like the monosaccharides, disaccharides are soluble in water to produce sweet tasting solutions. The sugar cane juice is rich in sucrose. This juice is processed to make ordinary sugar. Some disaccharides such as sucrose cannot reduce copper sulphate in the Benedict's solution unless they are first broken down to their constituent monosaccharides. They are therefore known as **non-reducing**

sugars. However, some dissaccharides such as maltose reduce copper sulphate in Benedict's solution when heated together. They are known as **complex reducing sugars**. Disaccharides can readily be broken into their constituent monosaccharide molecules in a process known as **hydrolysis.** The process involves splitting of complex molecules in the presence of water. For example:

Hydrolysis

Disaccharide + water $\longrightarrow$ 2 Monosacharides

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6$$

Hydrolysis

Sucrose + water $\longrightarrow$ Glucose + Fructose

Hydrolysis

Lactose + water $\longrightarrow$ Glucose + Galactose

Hydrolysis

Maltose + water $\longrightarrow$ Glucose + Glucose

In nature, disaccharides are hydrolysed by enzymes. In the laboratory, hydrolysis can be carried out by heating them with an acid such as dilute hydrochloric acid.

Functions

Disaccharides are hydrolysed by enzymes into monosaccharides which are then oxidised to release energy.

(iii) Polysaccharides

Polysaccharides are made up of many monosaccharide molecules. Thus, their molecules are long and more complex. They have a general formula $(C_6H_{10}O_5)$ n where the value of n is very large. The polysaccharides commonly found are starch and cellulose in plants while glycogen is found in animal tissues.

Starch

Starch is present as stored food in plant tissues. It is formed by condensation of a large number of monosaccharides. Plants that are rich in starch include maize, wheat, potato and rice. These plants are grown as sources of food.

Cellulose

It exists as a component of the cell wall in plants. It is made up of more molecules of monosaccharides than starch. Cellulose gives the plant cells their definite shape.

Glycogen

It is present as stored carbohydrates in animal tissues. Glycogen is synthesised from excess glucose.

Properties of Polysaccharides

All polysaccharides are insoluble in water and do not have a sweet taste. Therefore, they are referred to as non-sugars.

Study Question 12

(a) Name the carbohydrate that is:
  (i) stored in plant seeds.
  (ii) stored in mammalian muscles.
  (iii) most abundant in human blood.

(b) Summarise the main functions of carbohydrates in living organisms.

Practical Activity 6

To carry out food tests for carbohydrates

(a) Test for starch

Requirements

Starch powder, test-tubes, 10 cm^3 measuring cylinder, dropper, iodine solution, distilled water, spatula and means of heating.

Procedure

1. Put a spatula endful of starch in a test-tube, add some warm water and shake.
2. Add three to four drops of iodine solution using a dropper and shake.
3. Observe the colour change and record your observations.

Note: A colour change to blue-black indicates presence of starch.

(b) Test for a reducing sugar

Requirements

Glucose solution, Benedict's solution, test-tube, beaker, hot water bath, test-tube holders and 10 cm^3 measuring cylinder.

Procedure

1. Put 2 cm^3 of glucose solution in a test-tube.
2. Add an equal amount of Benedict's solution into the test-tube.
3. Note the colour of the mixture.
4. Place the test-tube in a hot water bath.
5. Observe and note the colour changes.

Note: If colour changes to;

(i) Green – very little reducing sugar is present in the solution.
(ii) Yellow – average amount of reducing sugar is present.
(iii) Red, orange, brown – a lot of reducing sugar is present.

(c) Test for a non-reducing sugar

Non-reducing sugars do not react directly with Benedict's reagent. They are first hydrolysed into monosaccharides.

Requirements

Sucrose, test-tubes, Benedict's solution, dilute hydrochloric acid, sodium hydrogen carbonate solution, hot water bath, dropper and 10 cm^3 measuring cylinder.

Procedure

1. Put 2 cm^3 of sucrose solution in a test-tube.
2. Add a few drops of dilute hydrochloric acid.
3. Place the test-tube into a hot water bath for three minutes.
4. Remove the test-tube and cool it in cold water.
5. Add sodium hydrogen carbonate solution drop by drop until fizzing stops.
6. Add 2 cm^3 of Benedict's solution to the mixture.
7. Place the test-tube in the hot water bath.
8. Observe and record the final colour of the solution.

Note: Dilute hydrochloric acid hydrolyses or breaks down non-reducing sugars to reducing sugars. Sodium hydrogen carbonate is used to neutralise the acid. The final colour can be yellow, orange or red which indicates presence of reducing sugars after **hydrolysis.**

5.3 (b) Lipids

These are fats and oils. Fats are found in animals while oils are found in plant leaves, fruits and seeds. However, a few animals such as whales contain oil. Fats and oils are similar except that oils are liquid while fats are solid at room temperature. Like carbohydrates, they are compounds of carbon, hydrogen and oxygen. However, the number of oxygen atoms are fewer in lipids than in carbohydrates. The building units of lipids are fatty acids and glycerol. Synthesis of lipid molecules requires three fatty acid molecules condensing with one molecule of glycerol. See figure 5.11.

Fatty acids are of different types. Therefore, the nature of a lipid depends on the fatty acids it contains even though the glycerol is the same in all lipids. Like carbohydrates, complex lipids are also formed by a condensation process. Examples of complex lipids include phospholipids, waxes, steroids and cholesterol.

Properties of Lipids

When fats are heated, they readily change into liquid, while oils solidify if subjected to low temperatures. Both fats and oils are insoluble in water. However, they will readily dissolve in organic solvents such as alcohol, ether and chloroform. When fat and oils dissolve in these organic solvents, they form emulsions and suspensions. Lipids are quite inert, a property which enables them to be stored in the tissues of organisms.

The presence of fats or oils in a substance can be easily detected by using Sudan III dye, grease spot test and emulsion test.

Functions of Lipids

(i) Lipids as Source of Energy

Lipids are sources of energy just like monosaccharides. A given weight of a lipid will liberate almost twice as much energy as an equivalent weight of a monosaccharide.

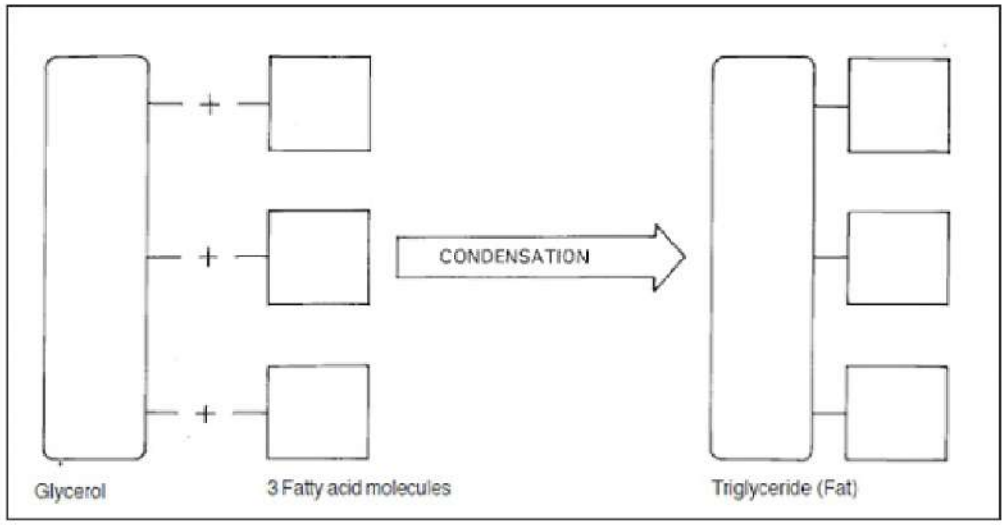


Fig. 5.11: Diagrammatic representation of fat formation

(ii) As a Source of Metabolic Water

When oxidised lipids, release more water and energy than monosaccharides. Such water is known as **metabolic water**, which supplements the requirements in the body. This explains why some animals such as camels accumulate large quantities of fat reserves in their body. They metabolise these fats to obtain the metabolic water in addition to the energy released.

(iii) As Structural Compounds

Lipids are constituents of plasma membrane and protoplasm. Oils are storage materials in some seeds e.g. groundnuts, castor seed, maize grain.

(iv) Heat Insulation

In animals, fat is deposited under the skin where it forms the adipose tissue which acts as a heat insulator. In this way, fats assist to reduce heat loss from the bodies of mammals. Mammals living in temperate regions have thick adipose tissue which greatly reduces heat loss. In addition, the thick adipose tissue in some acquatic mammals helps them to be buoyant in water.

(v) Protection

Fat is deposited around the major organs such as the kidney, heart and at the back of the eyeball where it acts as a shock absorber. On the other hand, the wax in plant cuticles reduces excessive water loss.

Study question 13

(a) If glycerol is the same in all lipids, why is corn oil different from coconut oil?

(b) Outline three properties of lipids.

Practical Activity 7

Testing for the presence of lipids

(a) The grease spot test

Requirements

Fat or oil, filter paper (or white paper) and Bunsen burner.

Procedure

1. Rub a little fat or oil on a filter paper.
2. Remove any excess fat from the paper.
3. Hold the paper above the flame taking care not to burn it.
4. Hold the paper against light. Observe and record what happens to the spot on which the fat was rubbed.
5. Repeat this procedure with a drop of water and note the difference between the fat and the water spot.

Note: If permanent translucent spot is formed it indicates the presence of lipids.

(b) Emulsion test

Requirements

Fat or oil, ethanol (alcohol), test-tubes, 10 cm^3 measuring cylinder.

Procedure

1. Put a little oil or melted fat in a test-tube.
2. Add 4 cm^3 of alcohol into the melted fat or oil and shake thoroughly.
3. Transfer the contents of the test-tube into another test-tube about half-full of water.

Note: Formation of white emulsion confirms presence of fats or oils.

5.3 (c) Proteins

Proteins, like carbohydrates and lipids, are compounds of carbon, hydrogen and oxygen. However, unlike carbohydrates and lipids, they contain nitrogen and sometimes phosphorus or sulphur or both. Some proteins such as haemoglobin also contain other elements such as iron. Haemoglobin is a protein containing iron. Proteins are made up of small units called amino acids. There are about 20 different types of amino acids occurring naturally. All amino acids

contain amino group ($-NH_2$) which consists of hydrogen and nitrogen but the number of carbon atoms differ from one amino acid to the other. Proteins are referred to as nitrogenous compounds because of the presence of nitrogen in their structure.

A single molecule of protein can have hundreds or even thousands of amino acid units which are joined together. Like carbohydrates, proteins are also formed by condensation. The process involves combination of two amino acids to form a **dipeptide** molecule. The bond between the two amino acids is called a **peptide bond**. During this process, a water molecule is formed. Continued condensation leads to the addition of more amino acids to a protein chain. A long protein chain known as polypeptide results. Figure 5.12 is a diagrammatic representation of a polypeptide formation.

The uniqueness of a particular protein is determined by the **type** and **sequence of amino** acids that it contains. Theoretically, the possible number of ways in which amino acids could combine may lead to an infinite number of proteins. However, this is not the case since organisms possess mechanisms which control the synthesis of specific proteins. Hence, the number of proteins in life is much lower than is expected.

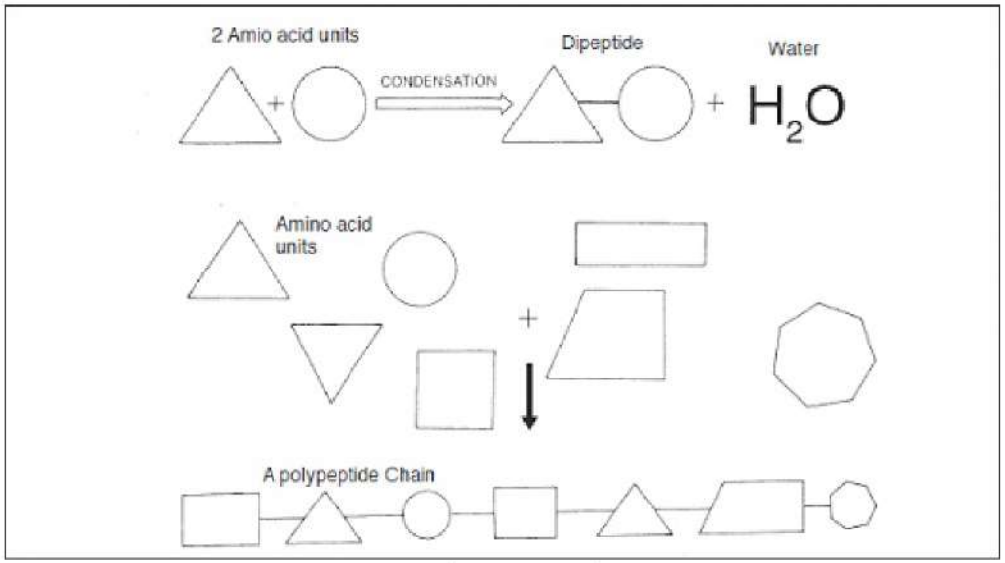


Fig. 5.12: Diagramatic representation of protein synthesis

Properties of Proteins

Most proteins dissolve in water but do not form true solutions. They form **colloidal suspensions** where particles remain suspended in water. Collectively, the colloidal particles have a very large surface area and since they have a strong capacity to absorb water and other substances, they are important in holding molecules in position within the cell.

Most proteins are **denatured** at temperatures above 40°C. The heat alters the structure of the protein molecule. This changes chemical and physical properties of proteins and hence, their physiological activity. Denaturing can also be caused by chemicals such as acids, bases, detergents and organic solvents. Denaturing is irreversible hence it permanently damages the protein in the tissues.

Proteins have both acidic and basic properties. Due to these properties, proteins are described as **amphoteric.** They therefore, react with acids and bases. This property enables the proteins to combine with non-protein compounds to form **conjugated proteins**. For example, in mucus, the non-protein compound is a carbohydrate while in haemoglobin; the non-protein compound is iron.

Functions of Proteins

(i) Structural Functions

Plants synthesise amino acids which build up the proteins. Animals obtain proteins from the plants and then break them up during digestion and use the amino acids to form animal proteins. In both plants and animals, proteins are used to make the framework of living systems. For example the plasma membranes, connective tissues, muscle fibres, hair, hooves, nails and skeletal materials.

(ii) As Metabolic Regulators

Enzymes and some hormones are protein in nature. Enzymes are organic **catalysts** which speed up metabolic reactions. Thus, they control the rate at which metabolism takes place. **Hormones** are **chemical messengers** which act as regulators of many body processes for example growth, reproduction and regulation of chemical substances such as salt, water and sugar.

(iii) As Sources of Energy

Like carbohydrates and lipids, proteins can be broken down to release energy. However, amino acids cannot be stored in the body like carbohydrates and fats. Proteins are normally used as a source of energy in conditions of starvation.

Study Question 14

(a) Name the building blocks of proteins.
(b) Differentiate between a dipeptide and a polypeptide.

(c) List three properties of proteins.

Practical Activity 8

To test for proteins

Requirements

10% sodium hydroxide solution, egg albumen in solution or milk, 1% copper sulphate, test-tubes, droppers and measuring cylinder.

Procedure

1. Put 2 cm^3 albumen solution (or milk) in a test tube.
2. Into the test-tube, add an equal amount of the 10% sodium hydroxide solution and shake.
3. Into the mixture in (2) above, add a few drops of 1% copper sulphate solution drop by drop, shaking well after each addition.
4. Observe and record the colour change.

Note: Purple colour indicates the presence of protein.

5.3 (d) Enzymes

These are **organic catalysts** which are protein in nature. They are produced in living cells. As catalysts, they speed up or slow down the rate of chemical reactions in the body without themselves being used up. There are two types of enzymes: **intracellular** and **extracellular** enzymes. Intracellular enzymes are secreted and used within the cells which produce them for example respiratory enzymes. Extracellular enzymes are produced within the cells but used outside the cells which produced them for example digestive enzymes.

Naming of Enzymes

(i) Trivial naming: The method involves names given to the enzymes by the people who discovered them. The names end in-**in**, for example: pepsin, trypsin, and ptyalin. Some of these names have been retained to date.

(ii) Use of Suffix-**ase**

This is the modern method of naming enzymes. The suffix **–ase** is added to the substrate (type of food) or the reaction which the enzyme catalyses. The following are examples of enzymes that act on certain substrates:

Substrate		**Enzyme**
Carbohydrate	–	carbohydra**se**
Starch e.g. amylose	–	amyla**se**
Sucrose	–	sucra**se**
Maltose	–	malta**se**
Protein	–	protea**se**
Lipids	–	lipa**se**

Similarly, the following are some of the examples of enzymes which catalyse certain reactions.

Reaction	**Enzyme**
Hydrolysis	hydrolase
Oxidation	oxidase
Reduction	reductase

Properties of Enzymes

1. Enzymes are protein in nature. They are therefore affected by temperature and pH.
2. Enzymes are substrate-specific.
3. They are efficient in small amounts since they are not affected by the reactions they catalyse. They can be used again and again.
4. They are catalysts that speed up the rate of cellular reactions. They are not used up in the reactions they catalyse.
5. Many of these enzyme catalysed reactions are reversible.

Factors Which Affect Enzyme Controlled Reactions

The following factors affect enzyme controlled reactions:

Temperature

Enzymes are protein in nature hence they are sensitive to changes in temperature. They work best only within a narrow range of temperature. As the temperature increases, the optimum temperature is attained where the rate of enzyme reaction reaches its maximum.

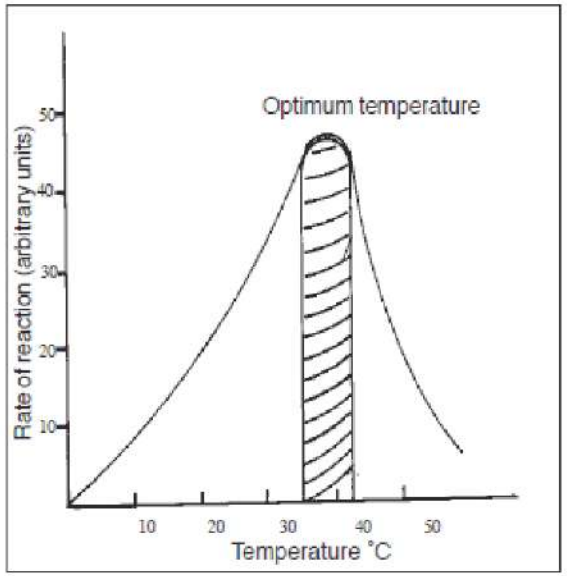


Fig. 5.13: Effect of temperature on the rate of enzyme activity

Above the optimum temperature, reaction decreases sharply due to destruction of enzyme structure. That is, the enzyme is denatured. This makes the enzyme ineffective. Most enzymes have optimum temperature between 35-40°C. Figure 5.13 shows the effect of temperature on the rate of an enzyme reaction. When the temperature decreases, rate of enzyme reaction decreases due to inactivation of the enzyme. However, low temperature does not destroy the enzyme because when temperature is increased, the enzyme becomes active again.

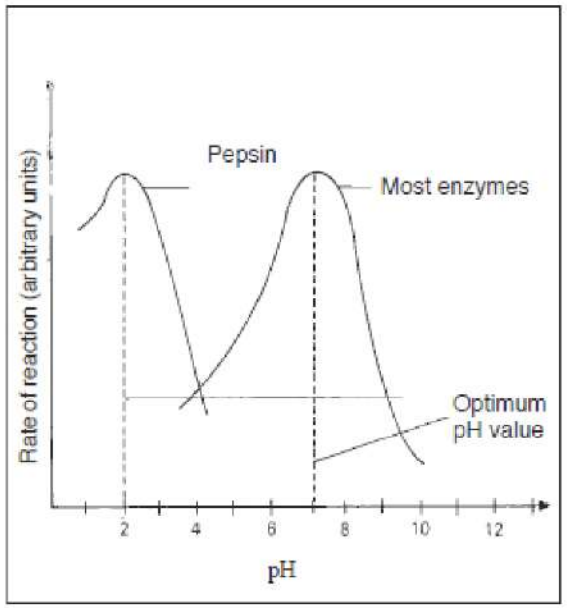


Fig. 5.14: Effect of pH on the rate of an enzyme controlled reaction

pH

pH refers to acidity or alkalinity of a substance. Most enzymes have optimum pH close to 7 which is the intra-cellular pH. However, some enzymes work best in acidic conditions while others work best in alkaline conditions. As pH changes from optimum, the enzyme activity decreases. Extreme acidity or alkalinity denatures most enzymes. See figure 5.14.

Specificity

Enzymes are specific in nature. A particular enzyme will only act on a particular substrate. For example, salivary amylase will only speed up the break down of starch to maltose. In other words, two different enzymes cannot act on the same substrate to bring about similar products.

Substrate Concentration and Enzyme Concentration

When the substrate concentration is increased, the rate of enzyme reaction also increases up to a certain level. However, further increase in substrate concentration does not increase the rate of enzyme reaction. This can be explained in terms of **active sites** of enzyme. When the substrate concentration is increased, all active sites of an enzyme are occupied. This condition makes the number of enzyme molecules to be the limiting factor. When the enzyme molecules are increased, there is a proportional increase in maximum rate of enzyme action as shown in figure 5.15.

However, the nzymes are required in small amounts. They speed up the rate of enzyme reaction but do not alter the equilibrium.

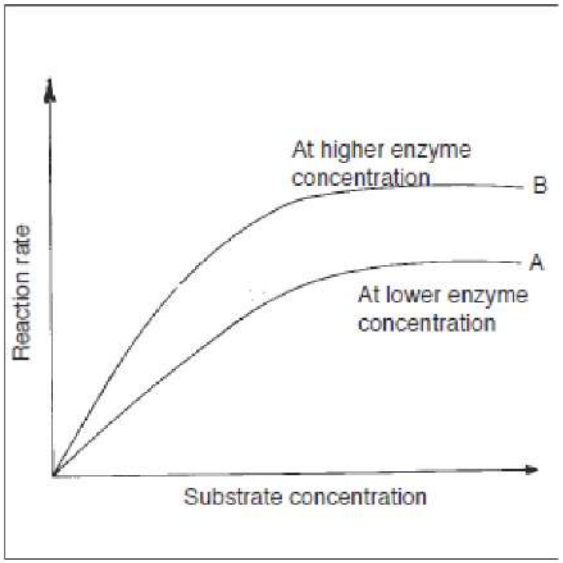


Fig. 5.15:

Graph A – shows the effect of increasing substrate concentration on the rate of an enzyme-controlled reaction.

Graph B–shows effect of increased enzyme concentration on the rate of an enzyme-controlled reaction.

Enzyme Co-Factors and Co-enzymes

Co-factors are non-proteinous substances which activate the enzymes. Most of the enzymes will not work without them. Some of the co-factors are metallic ions such as those of iron, magnesium, zinc, copper while others are vitamins. Co-factors are required in small quantities. Like enzymes, co-factors are substances that can be used again and again. Co-enzymes are other substances that affect enzyme controlled reactions. These are organic non-protein molecules that work in association with particular enzymes. Many Co-enzymes are derived from vitamins.

Enzyme Inhibitors

Inhibition occurs when action of an enzyme is slowed down by another substance. The inhibitor competes with the normal substrate for the active sites. In other cases the inhibitor takes up the active site of the enzyme permanently.

(i) Competitive Inhibitors

These are chemicals closely related to normal substrate and their shapes are very similar. When both substrate and inhibitor molecules are present, they compete for active sites so that the action of the enzyme is slowed down. The inhibitor is not normally affected by the enzyme so it stays in the active site longer than the substrate. This type of inhibition has no permanent effect on the enzyme action. The inhibition they cause can be overcome either by increasing the substrate concentration or reducing the concentration of the inhibitor.

(ii) Non-competitive Inhibitors

They are called non-competitive because they do not compete with the substrate. They combine permanently with enzyme molecules thus blocking the active site. This prevents the enzyme from interacting with the substrate. Such inhibitors include poisons such as cyanides, mercury and silver-arsenic compounds. The list is long.

Study Question 15

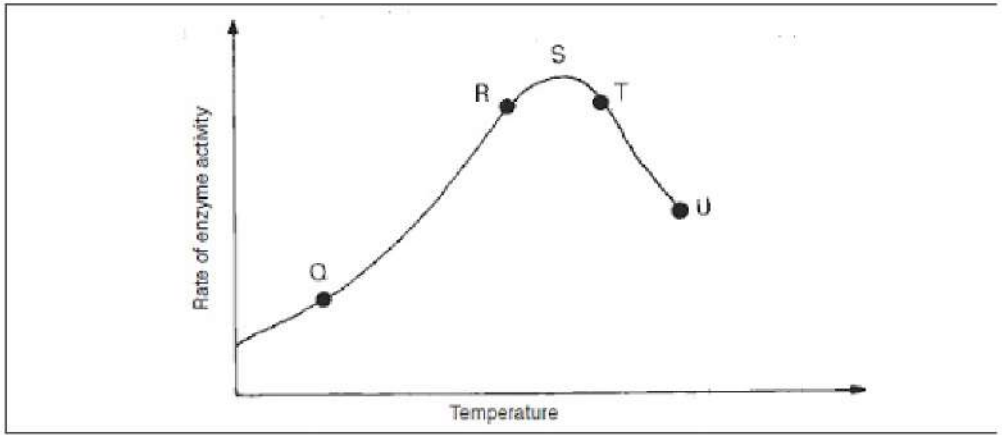


Fig. 5.16

Importance of Enzymes

Enzymes speed up cellular reactions so that they proceed at a pace that is appropriate for sustaining life. Enzymes not only speed up cellular reactions but also control them. This prevents violent incidents in the cell.

Figure 5.16 shows the rate of enzyme action in relation to changes in temperature.

Use it to answer the following questions:

(a) Explain, giving reasons, the rate of enzyme action:
  (i) between Q and R.
  (ii) at S.
  (iii) between T and U.

(b) Other than the property investigated above, state three properties of enzymes.

(c) State the collective name of the enzymes which work on:
   (i) Carbohydrates
   (ii) Proteins
   (iii) Lipids.

Practical Activity 9

To Investigate the factors affecting enzyme activities

(a) Effect of temperature on enzyme activities

Requirements

Six clean test-tubes, white tile, test-tube holder, a dropper, distilled water, Benedict's solution, iodine solution, water bath maintained at $37^{O}C$ and $50^{O}C$ source of heat, thermometer, measuring cylinders, labels, 6 cm^3 of amylase solution and soluble starch powder.

Procedure

1. Label three test-tubes A, B and C.
2. Into test-tube A and B, add 3 cm^3 of starch solution.
3. Into test-tube A, B and C add 2 cm^3 of amylase solution.
4. Place test-tube B in the water bath maintained at 50° C for 30 minutes.
5. Place the remaining test tubes A and C in the water bath maintained at $30^{O}C$ for 30 minutes.
6. After the 30 mins, test for starch and reducing sugars on the contents of each test tube. Record your results.
7. After the 30 minutes, test for starch and reducing sugars on the contents of each test-tube. Record your results.

Study Question 16

Which of the test tubes showed:

(i) presence of starch?

(ii) presence of reducing sugars? Explain your results.

(iii) What was the reason for maintaining the test tubes at $37^{O}C$?

(iv) treating test-tube C to a temperature of 50°C?

(b) Effect of pH on enzyme activity:

Requirements

Water bath kept at $37^{O}C$, egg albumen suspension, 2M of hydrochloric acid, 2M sodium hydroxide three test-tubes, 5 cm^3 of 1% pepsin solution, means of heating and measuring cylinder.

Procedure

1. Stir the white of an egg (the albumen) with 500 cm^3 tap water. The mixture is boiled and filtered through glass wool to remove large particles.
2. Using a measuring cylinder, place 2 cm^3 of the cloudy suspension of egg albumen into each of the two test-tubes labelled A, B and C.
3. Add 1 cm^3 of the 1% pepsin solution to each of the three test tubes A, B, C.
4. To the contents of test-tube A, add three drops of the 2M hydrochloric acid, to B add three drops of distilled water and to C add three drops of the 2M sodium hydroxide solution.
5. Incubate the test tubes for 10 minutes in a water bath kept at $37^{O}C$.
6. Examine the test-tubes every two minutes, noting the cloudiness of the contents. After the 10 minutes remove the test tubes and place them in a test-tube rack.
7. Tabulate your results in the following format.

	Observation of cloudiness					
Test-tube	0 mins	2 mins	4 mins	6 mins	8 mins	10 mins
A						
B						

Study Question 17

(a) Name the tube whose content has different appearance after ten minutes. Explain the change.

(b) Which aspect of the enzyme properties does the experiment investigate?

Practical Activity 10

To investigate the presence of catalase in living tissues

Catalase is an enzyme present in living tissues of plants and animals. Its role in living tissues is to break down hydrogen peroxide (H_2O_2) produced during cellular metabolism. Hydrogen peroxide is a highly toxic chemical substance which should not be allowed to accumulate in the tissues. If it were to accu-

mulate in the tissues, it would interfere with cellular metabolism. Enzyme catalase breaks it down into water and oxygen which are non-toxic substances.

Requirements

Fresh liver, fresh kidney, fresh muscle, potato, hair, seeds, leaves, hydrogen peroxide, four test-tubes, wooden splints, means of heating, scalpel blade, measuring cylinder (10 cm^3) and labels.

Procedure

1. Label four test-tubes A, B, C, D and E.
2. Measure 2 cm^3 of hydrogen peroxide and put in test-tube A. Repeat the same procedure for test-tubes B, C, D and E
3. Cut a small piece of the liver and place it in test-tube A. Record your observations.
4. Immediately, introduce a glowing splint into the mouth of the test tube. Record your observations.
5. Repeat step 3 using muscle tissue, kidney, potato and finally a small amount of hair.
6. Record your observations noting any differences. Explain your observations.
7. Repeat step 3 using boiled liver. Make sure that the liver is thoroughly boiled for about 5 minutes. Record your observations and account for the differences with unboiled liver.

5.4 Nutrition in Animals Heterotrophism

Heterotrophism is a mode of nutrition that involves taking in complex food materials such as carbohydrates, proteins and fats obtained from bodies of other plants and animals. The organisms that feed on these already synthesised foods are called **heterotrophs**. The heterotrophs break down or digest these foods into simple soluble molecules which can pass through the cell membrane during absorption. Heterotrophs obtain their foods using the following heterotrophic modes of nutrition.

(i) Holozoic – This is a type of nutrition characteristic of animals where solid complex substances are ingested, digested and assimilated in the body.

(ii) Saprophytism – This is a type of nutrition where organisms obtain nutrients from dead organic matter causing decomposition.

(iii) Parasitism – This is an association where one organism, the parasite, feeds on or obtains nutrients from the tissues of another living organism, the host.

(iv) Symbiosis – It is an association where two organisms live together and mutually benefit from each other.

Heterotrophs are dependent on autotrophic organisms as a source of preformed organic materials. The following sub-topic considers specifically the main aspect of nutrition in humans and other animals. Many big-sized animals take in large particles of food of different types and are, therefore, grouped into three categories namely: herbivores, carnivores and omnivores. These animals have four different types of teeth i.e. **incisors, canines, pre-molars** and **molars** and are thus referred to as **heterodonts**. Other vertebrates have teeth of the same sizes and shapes and are therefore called **homodonts**. The description of types of teeth, their arrangement and specialisation is known as **dentition**.

Teeth are arranged in groups to occupy specific positions in the jaws. Incisors are flat, chisel-shaped with sharp ridged edges for cutting and biting food. They have one root. Canines are conical with sharp pointed tips especially modified in carnivores for seizing prey and tearing flesh. They normally have one root. Premolars have two roots while molars have two or three roots. Both have broad surfaces and may be ridged with **cusps** on their crown for crushing and grinding of food. Figure 5.17 shows the four types of teeth in a human being.

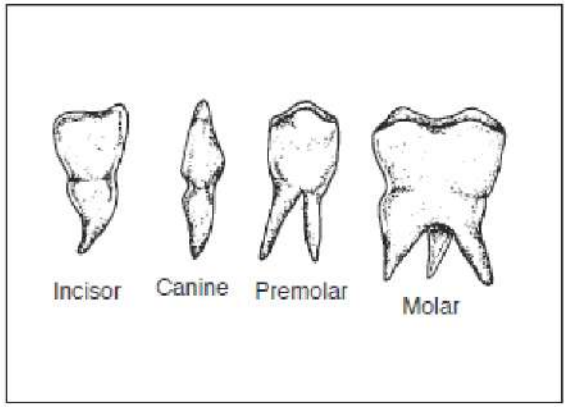


Fig. 5.17: Human teeth

Study Question 18

1. Define the following terms:
   (i) symbiosis
   (ii) saprophytism

(iii) parasitism.

2. How are the four types of heterodont teeth adapted to their functions?

Dental Formula

This describes the number, type and position of teeth in the jaws of mammals. The numbers of teeth recorded represent half the total teeth in the upper and lower jaws. The names of types of teeth are abbreviated as follows: incisors as *i*, canine as *c*, premolar as *pm* and molar as *m*.

The dentition determines the mode of feeding that is whether herbivores, carnivores or omnivores.

Herbivores

These are animals which feed exclusively on vegetation. They are grouped as **grazers** and **browsers**. Grazers for example cows, donkeys and zebras feed on grasses while browsers such as giraffes, goats and antelopes feed on shrubs and herbs.

Herbivores have several adaptations on their dentition that suit them to the kind of food they take in. Most herbivores do not have upper incisors but instead have a horny pad against which grass is pressed and cut by the lower incisors. The long tongue assists in the cutting and turning of grass and also moving the food during grinding. These functions are made possible by the **diastema**. This is a gap in the lower jaw separating the canines from premolars. The jaws move side by side to enable premolars and molars to grind the food.

There are four different types of herbivore teeth namely incisors, canines, premolars and molars. These teeth have open enamel in the crown, a condition which allows continuous growth to replace worn out surfaces due to grinding. Figure 5.18 (a) and (b) show the dental formula of two herbivores.

Study Question 19

Identify with reasons the mode of feeding of the animal whose dental formula is given below.

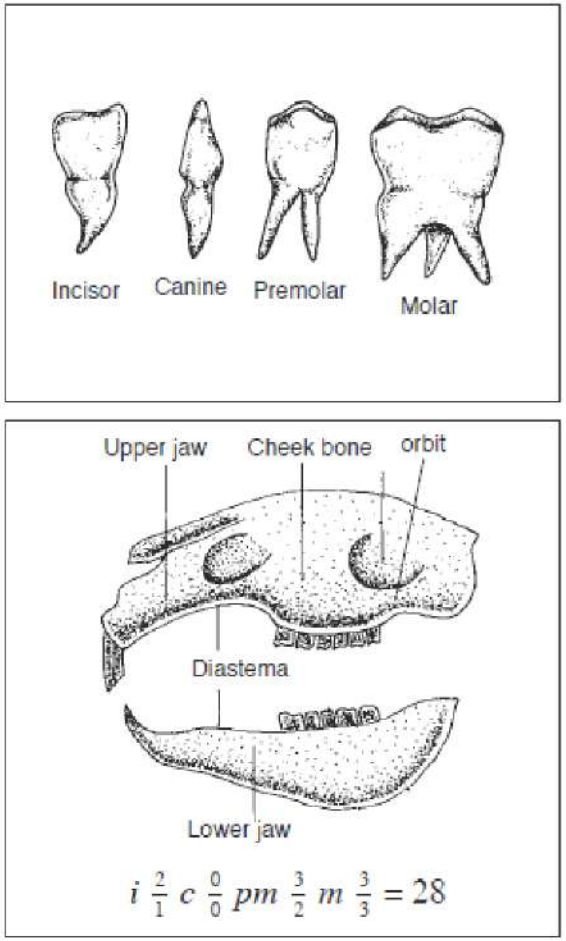


Fig. 5.18 (a): Dentition of the rabbit

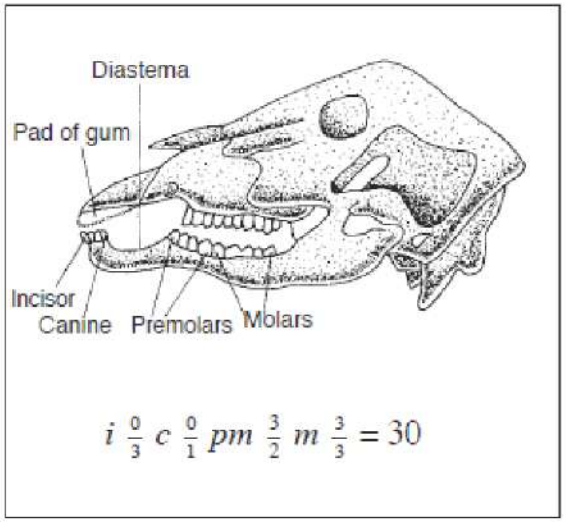


Fig. 5.18 (b): Dentition of the sheep

Carnivores

These are animals which feed exclusively on flesh. Most carnivores are hunters. Some are adapted to fast running and have well-developed leg muscles that facilitate this movement. The cheetah is one such animal that moves very fast. They also have strong jaws and sharp teeth to grasp their prey. They have four different types of teeth.

Incisors are chisel-shaped and closely fitting to seize the prey. They are used for gripping and stripping flesh from the bone. Canines are long conical and curved to hold, kill and tear the prey. Premolars and molars are small except for special premolars in the lower and upper jaws which are modified into **carnassial teeth**. The carnassial teeth have smooth sides and sharp edges to slice through flesh and crush bones. Jaws are attached to powerful muscles that move the jaws up and down by snapping. Figure 5.19 on page 75 shows the dentition of a dog.

Study Question 20

The dentition of a certain animal had the following characteristics: large curved and sharply pointed canines, small closely fitting incisors, narrow molars and premolars with cusps. Suggest the likely mode of feeding in this animal.

Omnivores

These are animals which feed on both vegetation and flesh. Omnivores are discussed in this topic with special reference to the human being in relation to dentition, dental formula and structure of teeth.

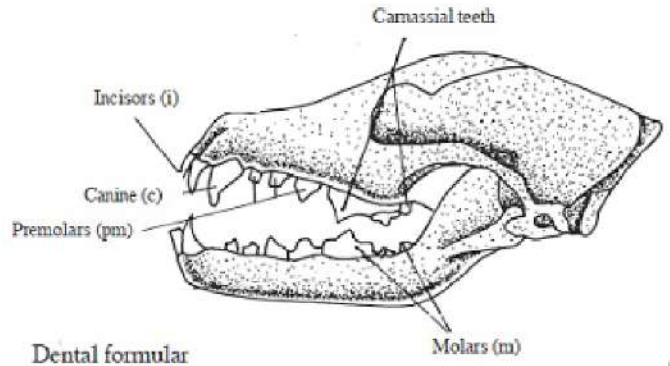
Mammals produce teeth in two sets, **milk teeth** and **permanent teeth.** Milk teeth are the first set of teeth to be produced and then lost between the age of 6 – 12 years. In human beings 20 milk teeth are produced. Permanent teeth replace the milk teeth lost. An adult person has 32 permanent teeth.

Practical Activity 11

To study the dentition of sheep

Requirements

Skulls of sheep



Dental formular

$$i\frac{3}{3}c\frac{1}{1}pm\frac{4}{4}m\frac{2}{3} = 42$$

Fig. 5.19: Dentition and dental formula of a dog

Procedure

1. Examine the lower and upper jaws.
2. List the types and numbers of teeth in the lower and upper jaws of each specimen.
3. Construct the dental formula.
4. Describe the shape and probable function of each type of teeth.
5. For the different types of teeth identified, extract at least one tooth of each type. Draw and label.

Structure of a Tooth

Externally, a tooth is made up of three regions. These are: the **crown** that projects above the gum; the **root**, the part that is embedded in the jaw and the **neck,** the region between the crown and root. The crown is covered with a hard nonliving layer called enamel that is made of calcium phosphate and carbonate. The enamel is a protective covering of the tooth that also forms a surface for biting and grinding of food. Internally, a root is mainly composed of dentine which is not as hard as enamel. The dentine extends to form the root and consists of living cells. Within the dentine is the pulp cavity containing nerves and blood vessels. The blood vessels provide nutrients to the living tissue in the dentine and remove waste products. Nerves detect heat, cold and pain. The root is fixed into the jaw bone by cement that is surrounded by supporting fibres. See figure 5.21 (a) and (b).

Study Question 21

Examine figures 5.20 (a) and (b).

Work out the dental formular of an adult human being.

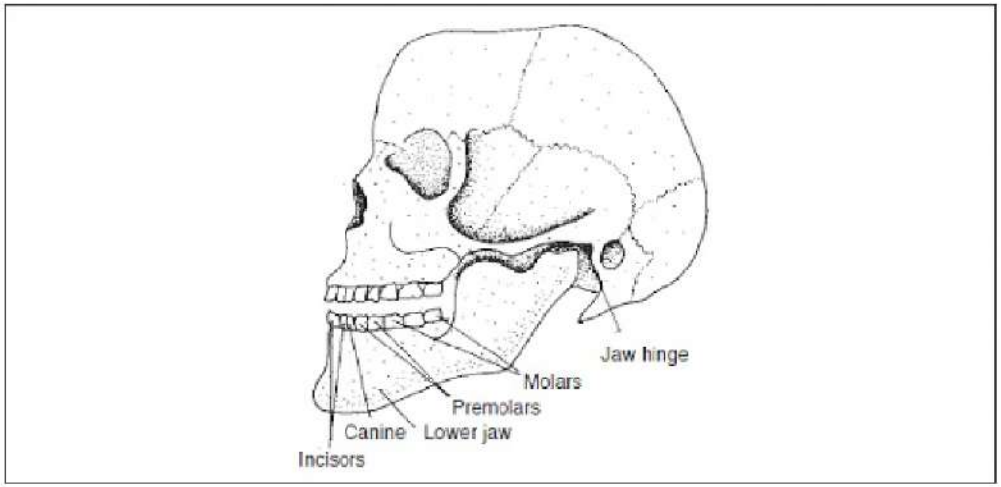


Fig. 5.20 (a): A human skull and dentition

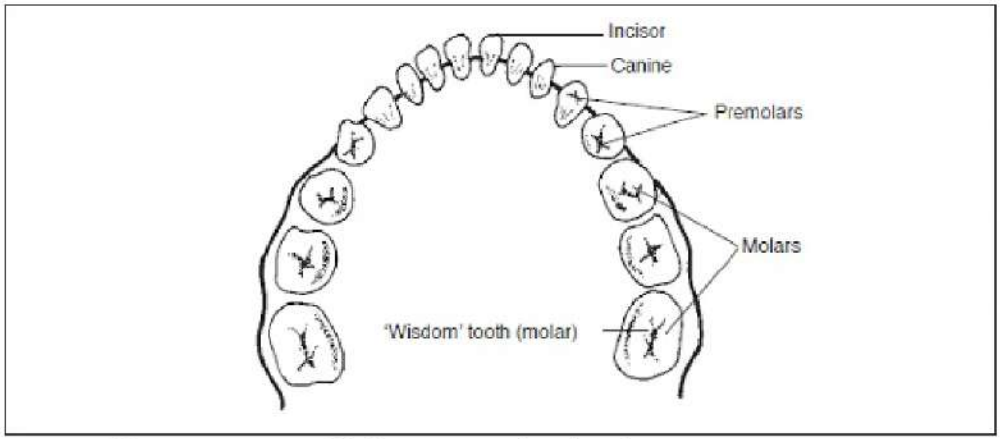


Fig. 5.20 (b): Arrangement of different types of teeth in human jaw

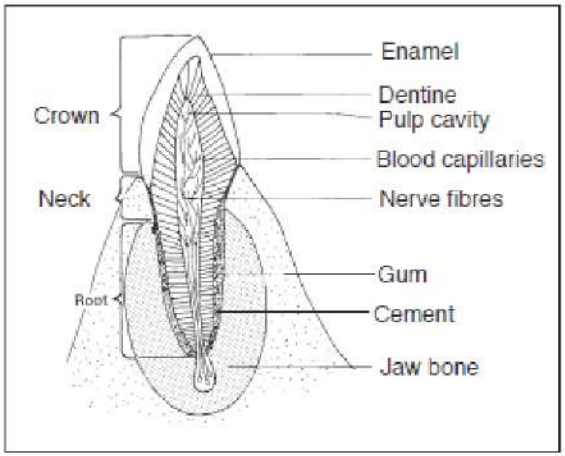


Fig. 5.21 (a): Vertical section through an incisor tooth

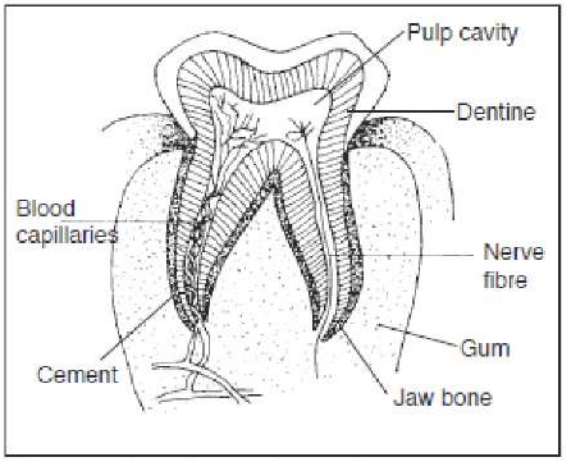


Fig. 5.21 (b): Vertical section through a molar tooth

Dental Diseases

Tooth decay is on the increase. Dentists have been trying to discover what causes this decay. There are several possible causes. One possible cause, supported by a great deal of evidence, is that the sugars and starch we eat become logged between the teeth and teeth cavities where they are broken down by microorganisms. The micro-organisms use up the sugars for their own food and produce acids as waste products. The acids react with the enamel and dentine of the teeth, causing them to dissolve. A hollow area of those decayed parts is formed. When the decaying process continues into the pulp cavity, the nerves are affected and therefore, a lot of pain is felt (toothache). In very serious cases, the pulp cavity may be destroyed and the infection spreads to the gums. There are two main dental diseases discussed below.

Dental carries and Periodontal diseases

(i) Dental carries is caused by lack of hard food, too much sweet or sugary foods, lack of calcium in the diet, lack of vitamin D, lack of cleaning teeth and general ill-health. These have the effect of causing gradual tooth decay as shown in figure 5.22.

(ii) Periodontal disease is caused by lack of vitamins A and C, lack of massage of the gums and lack of proper cleaning of gums. This disease causes the gums to become soft and flabby so that they do not support the teeth. It is more common in adults than in children. There are two types of periodontal disease **pyorrhoea** and **gingivitis**. Gingivitis is characterised by the reddening of the gums, bleeding and the presence of pus in the gums. Pyorrhoea is a condition where teeth become loose due to infection of the fibres holding the teeth in the sockets. The diseases can be avoided by eating a balanced diet, brushing the gum regularly to encourage blood circulation and removing food particles through observing dental hygiene.

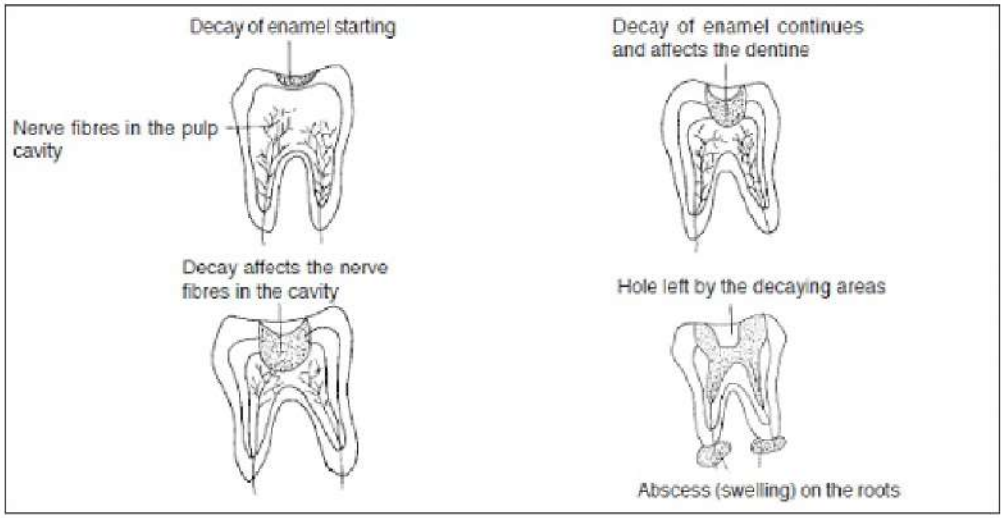


Fig. 5.22: Progressive stages in tooth decay

Dental Hygiene

Proper care of the teeth requires the following:

(i) Regular cleaning or brushing of teeth after every meal.
(ii) Avoid eating too much sugary foods.
(iii) Eating hard foods, for example raw carrots, cassava, yams and sugar cane. This helps to remove the soft materials from the gums and teeth. It also helps to exercise the teeth.
(iv) Eating diet rich in calcium, phosphate and vitamins A, C and D.
(v) Teeth should be used for their proper purpose. They should not be used to open beverage bottles or crack hard nuts.
(vi) A regular visit to the dentist is necessary.

Study Question 22

(a) State four ways of keeping teeth healthy.
(b) Draw a neat well-labelled diagram of the internal structure of an incisor tooth.

Digestive System in Animals

The digestive system is made up of the alimentary canal, and it is associated with organs such as the liver and pancreas. The main functions of the digestive system are digestion and absorption apart from others like ingestion and egestion.

The alimentary canal, also known as the digestive tract, is a tube leading from the mouth to anus. It consists of oesophagus, stomach, small intestines, (comprising duodenum and ileum) and the large intestines the caecum, appendix, colon and rectum. See figure 5.23.

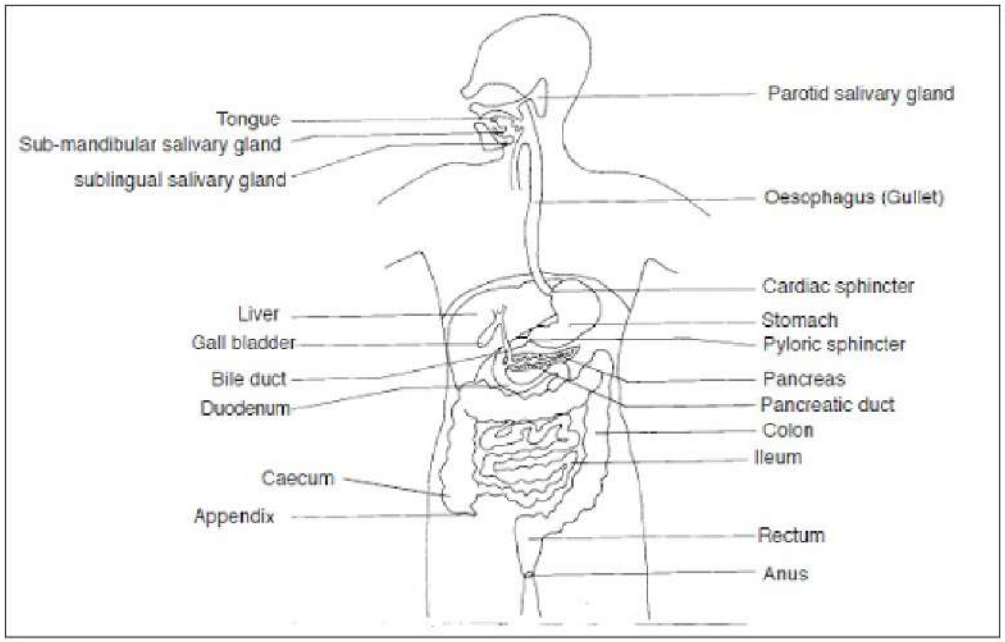


Fig. 5.23: The alimentary canal of a man

The alimentary canal is relatively long and greatly folded to increase the surface area for digestion and absorption of food. It is also wide and narrow in some parts and in others it is sac-like. Although each different portion of the mam-

malian digestive tract has its own adaptations in relation to function, all conform to a basic common structure as shown in figure 5.24.

Also of interest to note is that although the digestive tracts of mammals show the basic fundamental plan, there exist slight variations which correlate to the kind of diet each animal eats, that is different eating habits. For example, carnivores have a relatively short digestive tract with very much reduced and functionless caecum and appendix. This is because the digestion of proteins which form the bulk of their diet is rapidly digested in the gut. However, some herbivores have a very long digestive tract with a single stomach and a large caecum and appendix particularly in non-ruminant ones such as the rat. But in ruminant herbivores such as cows, the stomach is four-chambered in order to increase the surface area for the digestion of cellulose which takes a long time.

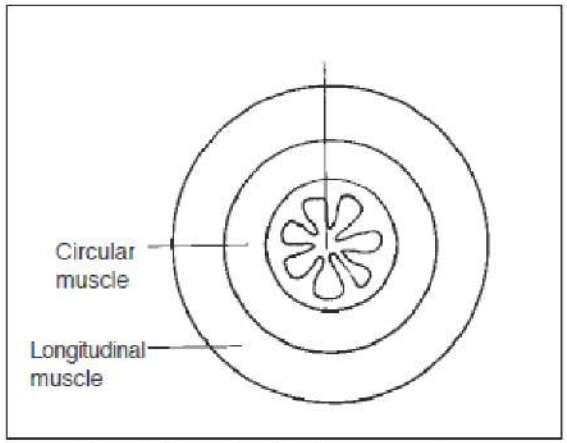


Fig. 5.24: A transverse section of the gut wall of a mammal

5.5 Food Processing along the Digestive Tract

This is the treatment which food undergoes as it passes along the tract so that food nutrients are availed to the body tissues. Since much of the food an animal takes in (ingests) is made up of large complex molecules (for example carbohydrates, proteins and fats), it is first broken down to simpler and soluble molecules before they can be absorbed. The process of food breakdown is called **digestion**.

However, small molecules like those of vitamins, mineral salts and water are directly absorbed into the blood stream without undergoing digestion.

Along the digestive tract, food digestion occurs in the following regions: mouth, the stomach, the duodenum and the ileum. Each region is adapted to its functions in a variety of ways.

Digestion in the Mouth

The introduction of food into the mouth is called **ingestion.** In the mouth, food is mechanically broken down by the teeth in the process of chewing and grinding. This is also known as **mastication. Mastication** reduces food to small particles and also increases the surface for enzymatic action. During this process, the food is moistened and mixed with saliva secreted from the salivary glands. The glands are located in various places around the mouth region. There are three pairs of salivary glands:

(i) Sublingual salivary glands are beneath the tongue.
(ii) Sub-mandibular salivary glands are under the jaw.
(iii) Parotid salivary glands are found in the cheeks in-front of the ears.

All these glands have ducts that open into the mouth and through which saliva flows into the mouth. Saliva is a mixture of water, mucus and an enzyme called **salivary amylase** or **ptyalin**. The mixture is slightly alkaline and this provides a suitable medium for the function of the salivary amylase. Water acts as a solvent while mucus lubricates the food and the lining of the mouth. The enzyme digests starch to maltose. The tongue rolls the food into small round masses called **boluses** (singular, bolus). The tongue then pushes the bolus into the pharynx (back of the mouth). This is the beginning of swallowing. The soft palate is raised to open the gullet and close the nasal cavity while the epiglottis relaxes to close the wind-pipe or trachea.

The food then passes down into the oesophagus or gullet. The gullet wall contains circular and longitudinal muscles. The passage of the bolus down the gullet is aided by a wave of muscle contractions known as **peristalsis**. This produces a series of constrictions that squeeze the bolus down the gullet and into the stomach as shown in figure 5.25.

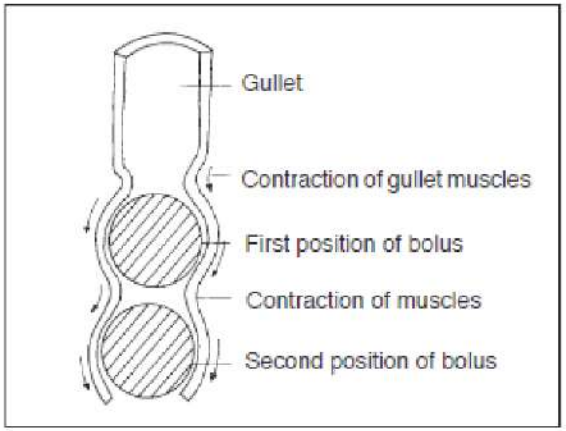


Fig. 5.25: Diagrammatic representation of peristalsis

Digestion in the stomach

The bolus enters the stomach through a muscular valve known as the **cardiac sphincter**. The stomach wall is made up of thick circular muscle and longitudinal muscle layers. These muscles contract and relax producing movements that mix the contents of the stomach. The mixing is known as **churning** and results in the formation of a fluid called **chyme**.

The presence of food in the stomach stimulates the secretion of the hormone **gastrin** which in turn stimulates the production of **gastric juice** from the gastric glands embedded in the glandular layer of the stomach wall.

Gastric juice contains:

(i) **Pepsinogen** which is activated to **pepsin** enzyme in the lumen of the stomach. Pepsin breaks down proteins into peptides.

(ii) **Renin** Enzyme which digests the protein caseinogen in milk to casein (curd). Renin is abundant in suckling young children.

(iii) **Hydrochloric acid** which provides an acidic medium for the optimum activities of these enzymes. The acid also kills some bacteria that may be present in the food.

(iv) **Mucus** which forms a protective barrier to the stomach wall against corrosions by the hydrochloric acid.

Digestion in the Duodenum

The chyme is let out into the duodenum through the pyloric sphincter. The sphincter muscle allows small quantities of chyme to pass through at a time. The duodenum is the first part of the small intestine where most of the digestion takes place. The duodenum receives secretions from the following organs:

(i) The liver has specific cells which secrete bile into the gall bladder to be stored. The gall bladder releases the **bile** into the duodenum through bile duct.

(ii) The pancreas lies just below the stomach. It is a thin flat and cream-coloured gland. It plays two major roles; secretion of hormones and the secretion of digestive juices.

The arrival of food into the duodenum stimulates secretion of the hormone **secretin** from the pancrease and **cholecystokinin** from the duodenal wall. Secretin stimulates the secretion of **pancreatic juice** into the duodenum whereas cholecystokinin stimulates the secretion of **bile** from the gall bladder. The pancreatic juice is alkaline and contains three digestive enzymes:

(i) **Pancreatic amylase** which speeds up the breakdown of the remaining starch into maltose.

(ii) **Trypsin** digests proteins into peptides. This enzyme is secreted in its inactive form trypsinogen.

(iii) **Pancreatic lipase** digests lipids into fatty acids and glycerol.

(iv) Also produced by the pancreas is the **sodium hydrogen carbonate** which neutralises the acidic chyme and creates a suitable alkaline medium for pancreatic and intestinal enzymes.

The bile contains bile salts that include **sodium glycocholate** and **sodium taurocholate**. These two salts aid in the breakdown of fats into tiny fat droplets to increase their surface area for digestion. This breakdown is known as **emulsification**. The salts also provide an alkaline medium in which the enzymes listed above work best. They also neutralise the acidic chyme from the stomach. Figure 5.26 illustrates emulsification.

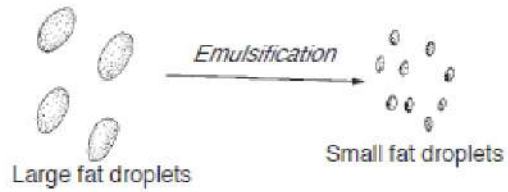


Fig. 5.26: Illustration of emulsification

Practical Activity 12

To demonstrate emulsification of fats

Requirements

Sodium hydrogen carbonate solution, cooking oil, water, test-tubes, ruler and measuring cylinder.

Procedure

1. Pour 2 cm^3 of cooking oil into the test tubes labelled A and B.
2. Add 2 cm^3 of sodium hydrogen carbonate solution into test tube A. Rinse the measuring cylinder.
3. Add 2 cm^3 of water into test tube B.
4. Shake the contents in both test tubes.
5. Write down your observations.

Digestion in the Ileum

The ileum is the lower part of the small intestine and the longest section of the alimentary canal. It is largely coiled to fit in the limited abdominal space. The inner walls of the ileum contain secretory cells, some of which secrete mucus

and others secrete an alkaline fluid known as intestinal juice or **succus entericus**. The arrival of chyme in the ileum stimulates the secretion of intestinal juice. The juice contains four enzymes that carry out digestive functions as follows:

(i) Maltase – speeds up breakdown of maltose to glucose.
(ii) Sucrase – speeds up breakdown of sucrose into glucose and fructose. Maltase and sucrase complete the digestion of the carbohydrates.
(iii) Peptidase – breaks down peptides into amino acids.
(iv) Lipase – breaks down lipids into fatty acids and glycerols.

Table 5.1: Summary of digestion

Part of the alimentary canal	*Gland*	*Secretion*	*Enzymes*	*Substrate (food acted upon)*	*Products*
Mouth	Salivary	Saliva	Ptyalin or salivary amylase	Starch	Maltose
Stomach	Gastric	Gastric juice	Pepsin Renin	Protein Milk protein	Peptides Clotted casein
Duodenum	Pancreas	Pancreatic juice	Pancreatic Amylase	Starch	Maltose
			Trypsin	Protein	Peptides
			Peptidase	Peptides	Amino acids
			Lipase	Lipids	Fatty acids and glycerol
	Liver	Bile	No enzymes	Fats	Small droplets
			(bile salts only)		
Ileum	Crypts of Leiberkuhn (secretory cells)	Succus entericus	Maltase	Maltose	Glucose
			Sucrase	Sucrose	Glucose and fructose
			Lactase	Lactose	Glucose and galactose
			Peptidase	Peptides	Amino acids
			Polypeptidase	Polypeptides	Amino acids
			Lipase	Fats	Fatty acids and glycerol

The process of digestion is thus completed in the ileum. The resulting watery emulsion of food is called **chyle** and contains soluble products of digestion ready to be absorbed. The entire canal is lined with an epithelial membrane that contains **goblet cells** which secrete mucus. The mucus allows smooth movement of food materials and also coats the wall of the alimentary canal, thus protecting it from being digested by the enzymes.

By the time food is fully digested, most of the enzymes on table 5.1 will have acted on the food and broken it to the end-products summarised as shown in the table 5.1.

Study Question 23

(a) List down the pH under which enzymes in each of the following parts of the alimentary canal work:
  (i) Mouth
  (ii) Stomach
  (iii) Duodenum
  (iv) Ileum.
(b) What are the final products of digestion for:
  (i) Carbohydrates?
  (ii) Proteins?
  (iii) Fats and Lipids?

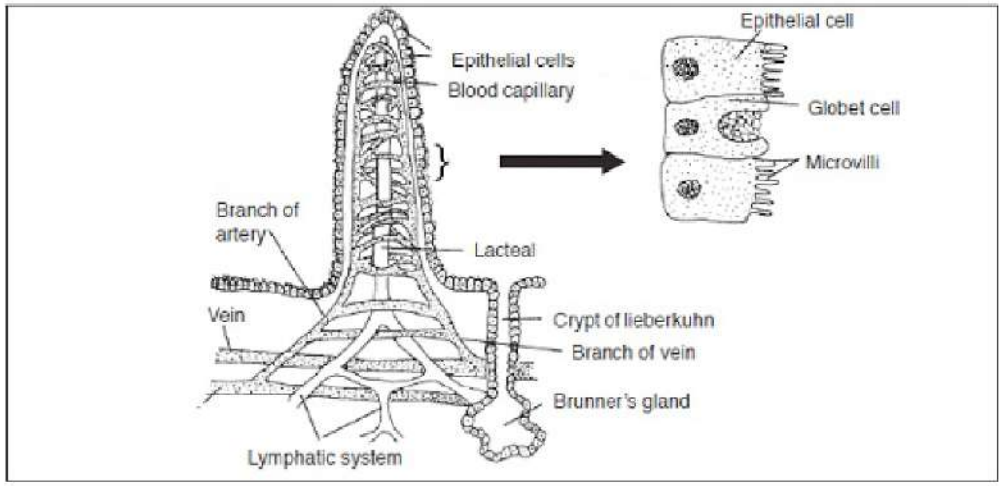


Fig. 5.27: A Villus

Absorption

This is the process by which the soluble products of digestion diffuse into the cellular lining of the **villi**. Diffusion of these products continues through the thin walls of the capillary network and into the bloodstream. Absorption of alcohol, some water, water soluble vitamins B and C and water soluble salts takes place in the stomach.

Most absorption of final products of digestion occurs in the small intestines. The ileum is where absorption of digested food substances occurs and it is adapted to its function in the following ways:

(i) It is **long** and therefore provide a **large surface area** for absorption in addition, it is narrow so as to bring digested food into **close contact** with the walls of the ileum for easier absorption.
(ii) The ileum is **highly coiled** in order to **slow down movement of food** and thus **allowing more time** for digestion and absorption to take place. It also **increases the surface** area for digestion and absorption.
(iii) The inner surface of the ileum has **large numbers of villi** and **microvilli** which **increases the surface area** for absorption of end-products of digestion. Figure 5.27 shows such a villus.
(iv) The presence of a **thin layer** of cells through which digested food diffuses.
(v) The presence of a **dense network** of **blood capillaries** in the villi into which amino acids, sugars, vitamins, mineral salts, some fatty acids and glycerol are absorbed. This helps to maintain a steep diffusion gradient.
(v) Presence of **lacteals** in the villi for the absorption of fatty acids and glycerol.

The molecules of amino acids and glucose pass through the epithelia of the villi and the capillary walls into the blood system by active transport. The capillaries drain into the hepatic portal vein where the amino acids and glucose are carried to the liver before being allowed to join general body circulation.

The fatty acids and glycerol are absorbed into lacteals of the villi which drain into the lymphatic vessels. The lacteal contents join the general lymphatic system which ultimately finds its way into the blood circulatory system. The fatty acids and glycerol are then distributed to all parts of the body.

Egestion

The undigested and indigestible food substances reach the large intestine by the process of peristalsis. As these materials pass through the colon, water is extensively absorbed. The remaining semi-solid waste material is then passed to the rectum where it is eventually eliminated from the body as feaces through the anus as the anal sphincter muscle relaxes.

The Caecum and Appendix

The caecum and the appendix have no function in humans. However, in herbivores, they contain a large number of bacteria which secrete **enzyme cellulase** that digests cellulose, breaking it down into glucose. The bacteria are in a symbiotic relationship with the herbivores. Some of the glucose is used by the bacteria but most of it is assimilated by the herbivores.

Assimilation

The absorbed products of digestion are carried in the blood stream to the rest of the body. From the blood, the body cells are able to obtain these substances and use them in their metabolism. The incorporation of these products of digestion into the cell metabolism is known as **assimilation**. The different food types are assimilated or utilised as follows:

(a) **Glucose** is oxidised to release chemical energy during respiration and the excess is stored in the body as fats underneath the skin or in the form of glycogen in liver or muscle cells.
(b) **Fatty acids** and **glycerol** are also oxidised to release energy but most of the fatty acids and glycerol combine into neutral fats which are stored underneath the skin to insulate the body against cold.
(c) **Amino acids** are used in the synthesis of proteins for general body growth and repair of worn out tissues. In absence of fats and glucose, they may be used to release energy through oxidation.

Study Question 24

Under which conditions will the body use proteins as a source of energy?

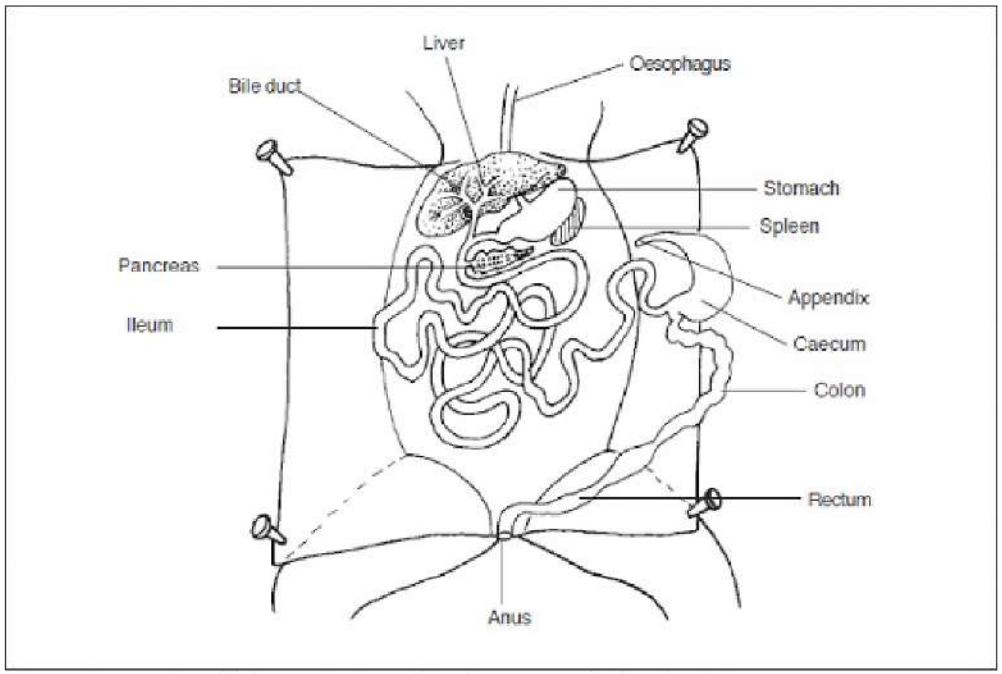


Fig. 5.28: Display of alimentary canal and associated glands of a rat

Practical Activity 13

Dissecting a mammal to display the digestive system and associated organs

Requirements

Small freshly killed mammals such as a rat, a guinea pig, a rabbit, a mouse or a hare, dissecting kit, dissecting basin or board, cotton wool and mounting pins.

Procedure

1. Dissect the mammal using the procedure in the dissection guide.
2. Display the alimentary canal and the associated glands as shown in figure 5.28.

5.6 Importance of vitamins and salts

Vitamins

Vitamins are organic chemical compounds that are essential for a healthy body. They are obtained from fresh fruits and vegetables. Some are synthesised in the body by the activity of micro-organisms present in the gut. An example of this is vitamin K.

Vitamins are destroyed when the food is excessively cooked. Although vitamins are required in small quantities, they play an important role in **metabolic reactions**. Some act as **co-enzymes** in enzyme activities while others **influence intakes** of certain substances into the body. For example, vitamin D influences absorption of calcium ions in the gut. Such vitamins are not affected by the reactions they influence hence they can be used repeatedly. Lack of vitamins in the diet results in a breakdown of normal body activities and produce deficiency diseases. The breakdown can be corrected by including the necessary vitamins in the diet. Table 5.2 gives some of those important vitamins, their major food sources and deficiency symptoms. which allows smooth movement of food in the alimentary canal. Lack of roughage in the diet leads to constipation.

Table 5.2: Vitamins; sources, uses and deficiency symptoms

Vitamin	*Main food source*	*Uses in the body*	*Deficiency disease symptoms*
VITAMIN A (Retinol)	Liver, milk, eggs, cod liver oil, carrots, fresh green vegetables, e.g., spinach and *sukuma wiki*, i.e., kale	For vision especially in the night. Protects skin and cornea from drying and becoming scaly.	Poor night vision and sore eyes, dry, scaly skin and cornea, reduced resistance to diseases, cold and bronchitis.
VITAMIN B_1 (Thiamine)	Groundnuts, beans, unpolished cereals, egg-yolk, milk, liver and kidney	For cell respiration and for proper growth in children	General weakness, retarded growth in children. The disease, Beri-beri, characterised by wasting of muscles and swelling of feet and legs.
VITAMIN B_2 (Riboflavine and nicotinic acid.)	As for B_1, plus green vegetables and yeast extract.	For normal skin health and function, for cell respiration.	Skin disorders, sores and bleeding in the mouth and gum. These are symptoms of the disease pellagra.
VITAMIN B_5 (Pantothenic acid)	Sources are those for B_1 and B_2, but especially in eggs.	For respiration, proper functioning of the nervous system and the alimentary canal.	Malfunctioning of the nervous system and digestive system.
VITAMIN B_{12} (Cobalamine)	Liver, beef and kidney.	For formation of blood cells.	Low red blood cell count due to pernicious anaemia.
VITAMIN C (Ascorbic acid)	Fresh citrus fruits such as lemons, oranges, grapes, green vegetables, mangoes, pawpaws and tomatoes.	For protection against infection.	Bleeding of mouth and gum, anaemia, swellings on the skin, poor healing of wounds, reduced resistance to infection. These are symptoms of the disease scurvy.
VITAMIN D (Calciferol)	Milk, fish, liver, egg-yolk, formed in skin in the presence of sunlight.	For formation and hardening of bones for strong teeth. For absorption of calcium and phosphorus.	Abnormal bone formation in children, soft and brittle bones in adults. These are symptoms of the disease rickets.
VITAMIN E (Tocopherol)	Milk, egg-yolk, green vegetables and vegetable oils.	Necessary for normal fertility in some animals, necessary for cell metabolism.	Sterility in some animals.
VITAMIN K (Quinone)	Liver, egg-yolk, green vegetables, e.g., cabbage and spinach, unpolished cereals.	Necessary for blood clotting.	Excessive bleeding

Practical Activity 14

Test for ascorbic acid (Vitamin C)

Requirements

0.1% solution of ascorbic acid, 0.1% of dichlorophenol indophenol (DCPIP), test-tube, dropper and 10 cm^3 measuring cylinder.

Procedure

1. Place 2 cm^3 of DCPIP into a test-tube.
2. Add ascorbic acid solution drop by drop into the DCPIP in the test-tube and shake well after each drop.
3. Observe the colour changes of DCPIP.

Note: Ascorbic acid decolourises DCPIP indicator.

Mineral Salts

Mineral salts are important inorganic compounds containing elements which are essential for normal body metabolism. Some of these elements are required in large quantities and are therefore called **macro-nutrients** while others are required in small quantities hence are called **micro-nutrients** or trace elements. Animals obtain these elements from the foods they take in. Table 5.3 gives a summary of the elements, their sources and importance in the body.

Table 5.3: A summary of the elements, their sources and importance in the body

Element	*Source*	*Function in the body*	*Disease caused by deficiency*
Nitrogen	Meat, milk, eggs, fish and other protein foods.	For synthesis of protein. For formation of cells, tissues and structures such as hair and nails.	–
Phosphorus	Protein foods.	Synthesis of proteins, formation of bones and teeth. Formation of ATP.	Rickets, disease characterised by poorly developed bones.
Calcium	Green vegetables, milk and cheese.	For blood clotting and muscle contraction. Formation of bones and teeth.	Muscle cramps and rickets.
Iodine	Iodised table salt, cheese, sea fish such as cod and salmon.	Formation of the hormone thyroxine.	Goitre characterised by a swelling of the thyroid glands in the neck region.
Potassium	Liver, beef, vegetables, milk and eggs.	Transmission of nerve impulses.	–
Iron	Liver, eggs, green vegetables, e.g., spinach and kale.	Formation of haemoglobin in red blood cells, role in respiration.	Anaemia.
Sodium	Table salt, green vegetables, fish, milk	Maintain osmotic balance of body fluids. Transmission of nerve impulses.	–
Chlorine	Table salt	Maintain osmotic balance of body fluids. Important in transmission of nerve impulses.	–
Sulphur	Protein foods	Protein synthesis. Formation of body tissues.	–

Roughage

It is composed of cellulose and plant fibres. Mammals do not produce any enzymes that can digest cellulose. Some mammals rely on micro-organisms which secrete cellulase that digests cellulose. The micro-organisms are present in their gut. In humans, these organisms are absent hence no digestion of roughage takes place. Roughage adds to the bulk of food and also promotes peristalsis,

Water

Water has a wide variety of functions in living cells. It is not therefore regarded simply as a nutrient. Water makes about 65-70% of the total body weight. The importance of water is clear from the fact that a human deprived of water will live for only a few days, whereas it is possible to survive for more than 60 days without food. The main functions of water are: activity as a solvent, cooling the organism, providing a media of transport and faciliting hydrolysis.

5.7 Factors determining energy requirements in human beings

Heat produced by the body comes from oxidation of food. This can be used to determine the energy content of foods. Heat energy is measured in units called kilojoules (kj). One gram of carbohydrates yields 17.1 kJ of energy. Fats release 31.8 kJ of energy while proteins release 22 kJ. These figures represent energy values of these foods.

The amount of energy required depends on the following factors:

(i) Basal Metabolic Rate (B.M.R.)

This is the energy required to maintain normal body functions such as breathing, heartbeat, circulation and other basic body reactions. It is also used to maintain constant body temperature. This requires about 760 kJ per day for a man at rest. This does not include any activity the man does for example walking, eating and bathing.

(ii) Occupation or Everyday Activity

This involves activities one does every day. It determines the energy requirement of the person. For example, a labourer pulling a cart or digging or mixing concrete in a construction site requires more energy than an office worker, a doctor or a teacher. Manual workers should take more energy-giving foods to sustain their high energy demand. See plate 5.2.

(iii) Age

Young children have many actively dividing cells and they are physically more active than adults. Therefore, their basal metabolic rate is higher than that of adults. As they grow older, they become less active physically and their energy requirements decrease.

(iv) Body Size

Small-bodied people have a small volume which leads to a large surface area to volume ratio. Therefore, their bodies lose more heat energy to the surrounding. Such people require more energy-giving foods. On the other hand-big-bodied people have a small surface area to volume ratio. They lose less heat to the surrounding as compared to thin people.

Plate 5.2: Manual workers require a lot of energy to carry out their daily chores

Therefore, their energy requirement is low. Some big-bodied people may, however, eat a lot to maintain the high energy demands of their large bodies.

(v) Sex

Many males are more muscular than females. That means their bodies have more muscles than fat while females have a lot of fat as compared to the males. Hence males normally use more energy. See table 5.4 for this comparative case study.

Table 5.4: Energy use per day (KJ)

Age (Years)	Male	Female
2	5 500	5 500
5	7 000	7 000
8	8 800	8 800
11	10 000	9 200
14	12 500	10 500
18	14 200	9 600
25	12 100	8 800

Study Question 25

From table 5.4, explain why after age 8, males require more energy than females.

Revision Questions

1. Define the term photosynthesis.
2. State four requirements and their sources for the process of photosynthesis to occur.
3. Discuss the role of each of the following structures of the leaf during photosynthesis:
   (i) Xylem vessels.
   (ii) Chlorophyll.
   (iii) Guard cells.
4. (a) Illustrate by means of a simple **labelled** diagram the structure of a chloroplast. (b) State the parts where (i) light reaction, (ii) dark reaction occurs.
5. Explain each of the following:
   (a) Variegated plants accumulate less food than non-variegated plants under similar conditions.
   (b) A leaf cannot be tested for starch by adding iodine solution directly.
   (c) Most leaves are thin with broad surface.
   (d) Plants will not photosynthesise in the dark.
6. (a) Name the elements that form:
   (i) Carbohydrates.
   (ii) Proteins.
   (b) (i) State two properties of polysaccharides.
   (ii) Write down three differences between polysaccharides and monosaccharides.

(c) What are the building blocks of proteins?

Carbon (IV) oxide concentration % by Vol. in air.	0	0.02	0.03	0.05	0.07	0.10	0.13	0.15	0.17	0.19	0.20
Rate of photosynthesis (Arbitrary Units)	0	21	25	29	38	40	44	46	46	46	46

7. (a) State two functions of lipids in the human body.
8. A particular food substance is suspected to contain vitamin C.
   (i) What chemical would you use to confirm the presence of the vitamin?
   (ii) What are the expected results if vitamin C is present?
9. An experiment was performed to find out how the concentration of an enzyme affected the rate of reaction of a chemical process. Three test-tubes were set up as described below:

Test-tube	*Substrate*	*Enzyme*	*Distilled water*
A	0.5 cm^3	0.5 cm^3	0.5 cm^3
B	0.5 cm^3	0.3 cm^3	0.7 cm^3
C	0.5 cm^3	0.1 cm^3	0.9 cm^3

The data obtained from the experiment was used to plot the graph figure 5.29.

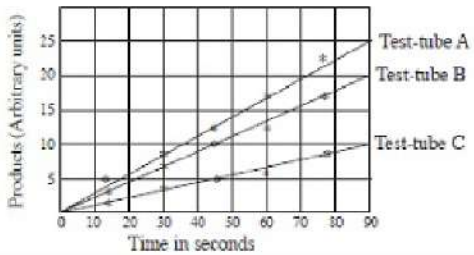


Fig. 5.8

(a) From the graph, explain how enzyme concentration affects the rate of reaction.
   (b) From the graph, what is the rate of reaction in test-tube B?
   (c) At what time interval were the readings taken?
   (d) Why are some of the points not on a straight line?
   (e) Why were different amounts of distilled water added to test-tubes A, B and C?
10. (a) What do you understand by the term heterotrophism?
   (b) State any four heterotrophic modes of nutrition.
11. State the factors that determine energy requirements in human beings?
12. Explain the following terms:
   (i) peristalsis
   (ii) emulsification
   (iii) assimilation.
13. Name two nutrients that do not require digestion before they are absorbed. Explain why this is so?
14. Figure 5.30 is a portion of human alimentary canal.

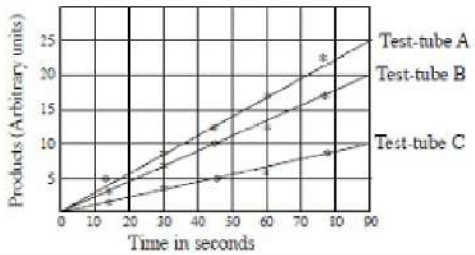


Fig. 5.29

(a) (i) Which part of the alimentary canal is represented by the portion above?
   (ii) Give one reason for your answer in (a) (i) above?
   (b) State two functions of the part of alimentary canal represented above.
   (c) State four adaptations of the part of alimentary canal represented above.
15. Explain why enzymes trypsin and pepsin are produced by glands along the alimentary canal as trypsinogen and pepsinogen respectively.
16. Figure 5.30, represents a longitudinal section of a human tooth.
   (i) What type of tooth is represented by figure 5.30. Give reasons.
   (ii) State the functions of the tooth.
   (iii) Using figure 5.30, name the structures labelled P, Q, R and state their functions.
   (iv) State four ways of keeping teeth healthy.

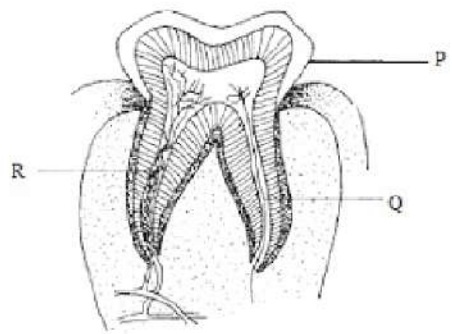


Fig. 5.30

17. In which region of the mammalian digestive tract does digestion of fats begin?
18. List four components of the pancreatic juice.
19. Give a reason why the digestion of starch started in the mouth with the help of salivary amylase is not continued in the stomach.
20. Explain the most likely effect on digestion if the small intestines of a human is reduced in an operation.
21. In an experiment to find out the action of pepsin on egg albumen, 5 cm^3 of egg albumen suspension was placed in each of four test-tubes Q, R, S and T. Three drops of hydrochloric acid were added to the test-tubes Q, R and T.

    1 cm^3 of 1% boiled pepsin was added to test-tubes R and T and 1 cm^3 of unboiled pepsin to test-tubes Q and S. The four test-tubes were then placed in a water bath at 37°C for 8 minutes.

    (a) Tabulate the results expected from this experiment.
    (b) State two conclusions that you would draw from the results of this experiment.
    (c) Why was it necessary to keep the test-tubes at 37°C?
    (d) Where is pepsin produced in the body?

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Secondary Biology Form One *Students" Book* is a well written biology book that aims at equipping students with knowledge, attitudes and skills that can enable them exploit the environment responsibly. It is the first book in the secondary biology series published by Kenya Literature Bureau.The book has been updated to match current trends in method of classification and other advances in the science. The system of naming chemical substances has also been standardized.

The content is in five broad topics namely: Introduction to Biology, Classification I, The Cell, Cell Physiology and Nutrition in Plants and Animals. Each topic is introduced in simple and precise language and is tied to the knowledge of basic science taught earlier in the primary cycle.

To enhance understanding of terminologies, each is explained before use. Emerging issues such as environmental conservation are also dealt with where they are relevant. Neat and precise illustrations have been widely used to enhance learning.

Practical activities are outlined at the end of each topic. These are designed to assist the learner conduct investigations on various discussion points and draw deductions.

Also, at the end of each topic there are revision questions that assist the learners to evaluate themselves. Answers to these questions are provided in the accompanying Teachers' Guide.The Teachers' Guide gives a logical approach to the teaching of each of the topics.

The Students' Book together with the Teachers' Guide provide an excellent interpretation of the current 8.4.4 syllabus.

Cover Photograph: Students learning to use a light microscope.
Courtesy of Kikuyu Secondary School.

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