Senior Secondary

Biology

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Contents

Preface

This is the first of a three-book course, specially written to adequately cover the new NERDC Biology curriculum for Senior Secondary Schools. Books 1, 2 and 3 are designed to cover the schemes of work in Biology for Senior Secondary School Classes 1, 2 and 3 respectively.

Like the curriculum, this series of books is based on the conceptual approach and covers the concept of living, basic ecological concepts, plant and animal nutrition, conservation of matter and energy, variations and variability, evolution and genetics. These major concepts are presented in spiral sequence running through the three-year course and moving from basic to complex ideas as the course develops from Senior Secondary School Class 1 to Class 3. This approach, no doubt, aids learning.

In this third edition, up-to-date and relevant knowledge in Biology is presented in this series of books in a simple and effective manner. The contents of the books have been enlarged to include the requirements of WAEC, NECO and UTME Syllabuses. Suitable investigation activities for the students and demonstration activities for the teachers are also provided. Students are helped to learn Biology as a science through guided discovery.

We believe that the books in this series satisfy the aims and objectives of the new NERDC Biology curriculum for Senior Secondary Schools and we recommend them to all students and teachers of Biology at the Senior Secondary School level.

12 April 2013

Theme 1
Organisation of life

Chapter 1 Recognising living things

The theme for the first four chapters of this book is organisation of life. An organisation, such as a bank, a school, a factory, a company or a political party contains members who work together for a united goal. In the same way, organisation of life means that the body of a living thing has many parts, but all, while doing their individual duties have a united goal. In the next four chapters, you will learn how living things are organised.

Introduction

At a critical point in time, a farmer will painfully decide if his farm animals would live or die. A medical doctor will decide if his patient would live. Students of biology have no painful decisions of this kind to take. Since biology is the study of living things, it is appropriate to begin the study of this subject by identifying what living things do that constitute being alive, and the special way in which their bodies are made up. This chapter is concerned with these issues. In addition, you will learn how living things are arranged in groups to facilitate their study.

Living and non-living things

Everything in the world can be classified as either ***living*** or ***non-living***. Living things are distinguished from non-living things by a number of characteristics.

Living things

Look outside the classroom or laboratory. Make a list of any five things which you regard as living. Then, make a list of five things which you regard as non-living. Now, take a second look at your lists and write down what characters are common within each group. What are these characteristics? Biologists have identified some of them which, taken together, distinguish the living from the non-living things. Study them and see which of them feature in your lists.

1 **Movement:** All living things move. Movement means a change in position, which could be total, as in animals that move from place to place, or limited, as in plants which carry out bending movements under certain conditions.

2 **Nutrition:** This is the taking in and use of food by animals, as well as the taking in of mineral substances and their use by plants.

3 **Respiration:** This is the breaking down of food substances taken in by the organism to release energy. There are two types of respiration. They are;

a) *Aerobic respiration*, in which oxygen is needed to release energy; and

b) *Anaerobic respiration*, in which energy is released without the use of oxygen.

Many organisms have special body parts for taking in oxygen for respiration. For instance, human beings use their lungs; fishes use their gills, while plants use openings in their leaves (stomata) or stems (lenticels).

4 **Growth:** Growth is a permanent increase in size. With good feeding comes increase in the mass and height (or length) of an organism. At birth, human babies weigh an average of 3.5 kilograms (kg). How does body mass increase as a baby grows up?

5 **Excretion:** This is the removal of the waste products of metabolism. Metabolism is the sum total of all the chemical processes which take place within the cells of the body, for the continuous activities of building the cells of the body. From the continuous activities of building up and using up energy, waste accumulates. Such waste is not useful to the body. It may indeed be removed. The process of such removal is known as **excretion**.

6 **Reproduction:** This is the process by which adult organisms give rise to new individuals of the same kind. The adult housefly will lay eggs which, on hatching, develop into adult houseflies. A maize plant germinates into a maize seedling, which grows into a maize plant. A sheep gives birth to a lamb, which grows into a sheep. Reproduction is the only means by which a living thing is kept in existence from one generation to another. If there were no means of reproducing oneself, every given type of living thing would soon disappear from the face of the earth.

7 **Irritability:** This is the ability of a living thing to receive an external stimulus and respond to it. If you touched a hot plate by mistake, you would quickly withdraw your hand. Your skin receives the sensation of heat, which goes to the brain. The brain orders the muscles to contract in an action which translates as the withdrawal of your hand from the heat or other harmful stimulus.

Anything which shows all the foregoing seven characteristics is a living thing. As we shall see, a crystal can increase in size. This increase is by addition to the crystal surface from the outside. The increase in size which takes place in living things is from within.

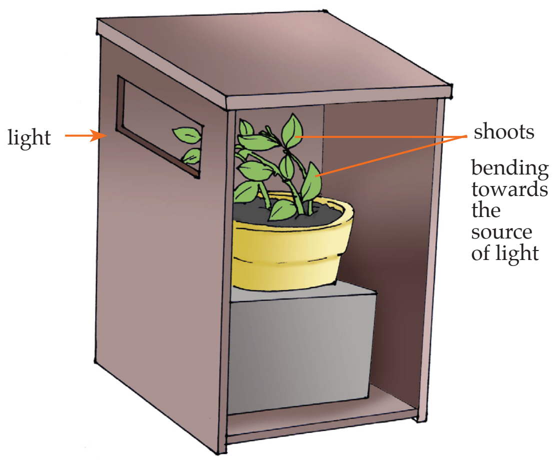


Fig. 1.1 Seedlings responding to the stimulus of light received from a particular direction.

Activity 1.1 Observing growth in living things

a) ***Materials required***

Potassium trioxonitrate (V) (potassium nitrate), glass rod, distilled water, evaporating basin, boiling tube, Bunsen burner, and stopwatch.

Procedure

To about 2 cm^3 of distilled water in a boiling tube, add potassium trioxonitrate (V). Shake the boiling tube. When the potassium trioxonitrate (V) has dissolved, add another small amount and shake the boiling tube. Repeat the process until some of the potassium trioxonitrate (V) no longer dissolves and there is undissolved solid potassium trioxonitrate (V) in the solution.

Warm the boiling tube on a Bunsen burner and add more potassium trioxonitrate (V) until it no longer dissolves. The warm solution is now saturated.

Pour the warm, saturated solution into an evaporating basin and allow it to cool slowly on the table. Observe it every two minutes for twenty minutes.

Dip the glass rod into the saturated solution. Pull it out and hold it in the air. Observe it.

You should see crystals forming as the saturated solution cools. The crystals in the basin grow bigger as the solution cools. They increase in size, but is this growth the same as the growth of a living thing?

b) ***Materials required***

A few seeds or grains (e.g. beans, maize, okro), tins, garden soil, water and ruler.

Procedure

Fill the tins with garden soil and wet the soil, ready to sow the seeds or grains. Sow two or three seeds in each tin. After a few days, the seeds will germinate.

Your teacher will assign you one tin. Ensure that the seedlings are kept in a well-lit location. Water the soil daily, without flooding it. Measure the height of each seedling and count the number of leaves on it. Keep your records in the form of a table as shown in Table 1.1. Is there an increase in height with time? Does the number of leaves increase or decrease with time?

Continue your observation for two weeks after the germination of the seeds. Has there been growth? Is this the same kind of growth observed in the crystals of potassium trioxonitrate (V)? What is the difference?

Seed ....

Date sown ....

Date it germinated ....

Table 1.1 Record of growth of a seedling

Date	Height (cm)	Number of leaves

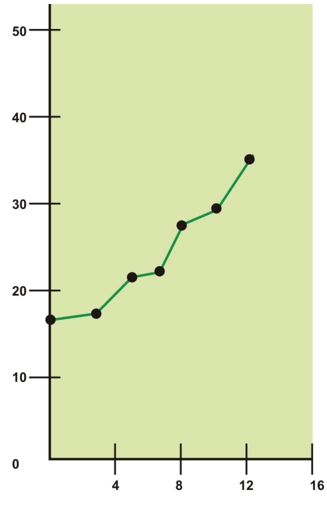


Fig 1.2a) Graph of number of duckweeds against time (days)

Activity 1.2 Observing how living things reproduce

Materials required

Duckweed (*Lemna sp.*), water trough, graph sheets and water from the stream.

Your teacher will provide you with a small quantity of a water plant called duckweed. You will also be given water from the stream where the duckweed was collected. Your teacher may give you what is called a water culture solution in place of the stream water.

Place a few individual strands of duckweed in the water or culture solution inside a water trough. Record the number of strands. Place the water trough containing the duckweed in a well-aerated and lit location, but not directly under sunlight. A window still will be suitable, provided that the sun is not shining directly on it. Observe every day, but count the number of strands of duckweed every other day. Record your observation each time your count is taken. Continue for two or three weeks.

At the end of the experiment, how many strands of duckweeds are there? Plot graphs, such as those in Figs 1.2a) and (b), to show your findings. Your teacher, who should have maintained a large population of Lemna, will give you his result. Plot that too. Compare the two sets of graphs. Discuss your findings and write a clear conclusion to the experiment.

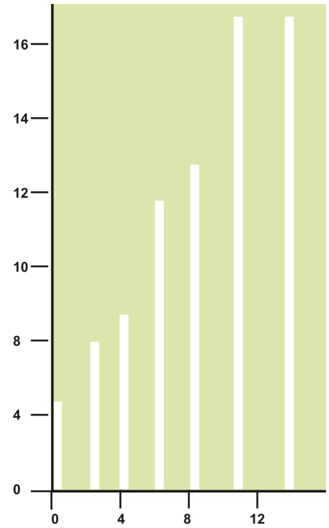


Fig 1.2b) A histogram of number of duckweeds against time (days)

Non-living things

Non-living things do not show all the characteristics of living things.

Note also that growth in living things requires food. Non-livings things, on the other hand, do not feed. Growth in living things is usually irreversible, whereas the 'growth' of a crystal can be reversed.

How would you group non-living things? What properties would you use for this? The answer is quite straightforward. Non-living things are solids, liquids or gases. Solid non-living things may be metals or non-metals. Some non-living things are soluble in water (or in some specific solvent), while others are not. Some metals are magnetic, others are not.

Living things and non-living things interrelate very much. For instance, all living things derive their nutrients from non-living things. All the raw materials which green plants require to manufacture their food are non-living things. Plants and animals use air for respiration and take in water. Similar interrelationship exists between the following living and non-living things: water, soil, air, crops, man, fish and algae.

Can you describe these?

Differences between plants and animals

The differences between plants and animals are shown in Table 1.2 below.

Table 1.2

	Animals	Plants
1	Animals move from place to place (they exhibit locomotion).	Plants do not move from place to place; they carry out only bending movements.
2	Animals do not make their own food; they feed on plants and/or other animals. They are heterotrophic.	Plants make their own food from simple inorganic substances (carbon dioxide and water) using energy of sunlight. They are autotrophic.
3	Animals grow all over their bodies.	Plants grow only at the meristems (groups of cells capable of dividing). Growth in length occurs only at the tips of stems and roots, while growth in girth occurs at the cambium.
4	Animals have specific organs for respiration, excretion and co-ordination.	Plants do not have specialised organs for respiration, excretion and co-ordination.
5	An animal cell has no cell wall. It is bounded by cell membrane.	A plant cell has a cell wall containing cellulose. A cell membrane is on the inside of the cell wall.
6	An animal cell has no cell vacuoles with cell sap. It may have food vacuoles.	A mature plant cell usually has some cell vacuoles with cell sap.
7	An animal cell has plentiful cytoplasm which fills the cell.	A plant cell has moderate amount of cytoplasm which does not fill the cell.
8	An animal cell contains no chlorophyll.	A plant cell contains chlorophyll, present in chloroplasts within green cells.

Organisation of life

The cell is the structural and functional unit of life. Each organism is made up of one or more cells. If an organism is made up of one cell, it is said to be **unicellular** while an organism not divided into cells is known as **non-cellular**. If an organism is made up of many cells, it is said to be **multicellular**.

In a multicellular organism, cells become specialised and rearranged to form **tissues**. A tissue is a group of cells which are similar in structure and are specialised to perform a particular function. Examples of tissues in animals include muscular, nervous, epithelial, skeletal and connective tissues. Examples of tissues in plants include epidermal, collenchyma, parenchyma, xylem, phloem and cork tissues.

A group of tissues form an **organ**. An organ consists of a number of different tissues which are organised, and work together to perform a special function in an organism. Examples of organs include an eye, or a leaf. The leaf is a plant organ which contains epidermal, parenchyma, phloem and xylem tissues. Other examples of organs include heart, lungs, kidney, and liver in animals, and flower, rhizome, and root in plants.

A group of organs which work together to perform a function is called a **system**. Examples of systems in animals are circulatory, excretory, respiratory, digestive and nervous systems. In plants, examples of systems are transport, root and shoot systems. All the organ systems in one organism make up the organism. The organisation of cells in an organism is shown below:

Cell → tissues → organs → organ system → organism

Levels of organisation of life

The bodies of living organisms are at different levels of organisation.

1 **Cell level of organisation**
Organisms made up of one cell only (unicellular organisms) are said to be at the cell level of organisation. Specific parts of the cell, known as **organelles**, perform specific functions, e.g. cilia for movement. All life processes are performed in the unicellular organism by the single cell. Examples of organisms at the cell level of organisation include amoeba, paramecium. euglena, and chlamydomonsa.

2 **Tissue level of organisation**
The organisms in this group have only tissues in them. They do not have organs. The activities of their bodies are performed by cells in tissues. A good example in the animal kingdom is hydra, in which the body cells are differentiated into two layers of tissues, known as **ectoderm** and **endoderm**. Cells of the endoderm carry out the function of digestion of food.

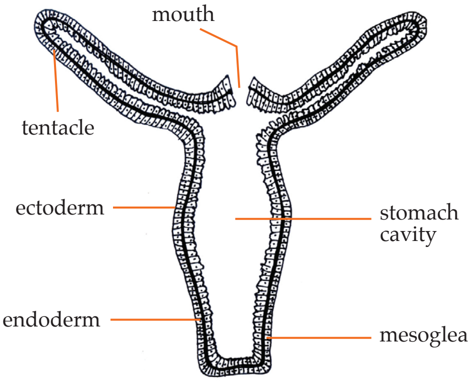


Fig. 1.3 Vertical section of hydra

3 **Organ level of organisation**
A living thing may be an organ. For instance, an onion bulb, a rhizome, a corm and a tuber are organs. Such a living thing is at the organ level of organisation.

4 **System level of organisation**
Some organisms are organised at the systems level. Such organisms are more advanced and complex than those at the other levels of organisation. In the animal kingdom, all animals from platyhelminthes to mammals are organised on this level. Man, for example, has many systems in his body. Higher plants also have systems, such as transport and root systems.

Complexity of organisation in higher organisms

Biologists believe that all organisms that live today have not always existed, but that over a long time, some organisms have evolved from others. This is the concept of evolution.

In this process of evolution, unicellular organisms evolved into multicellular, simple into complex, and aquatic into terrestrial organisms. Higher organisms are those which are considered to be more recent than lower organisms in coming into existence. For instance, vertebrates are considered to be higher animals than invertebrates, while flowering plants are considered to be higher than nonflowering plants, such as algae and mosses.

Higher organisms are more complex than lower ones. For instance, in amoeba or paramecium, gaseous exchange is by diffusion only. In insects, there are tracheae and spiracles for breathing. In man, there is a respiratory system consisting of larynx, bronchi and lungs. The same progression in complexity of organisation can be traced in many other systems, such as transport, excretory and skeletal systems.

Advantages of complexity of organisation

1. In organisms with complex organisation, the organism can attain a large body size.
2. It makes it possible to have a division of labour among cells, organs and systems.
3. It makes the organs and organ systems more efficient than in a simple organisation.
4. It enables an organism to adapt itself to a large number of various habitats.

Disadvantages of complexity of organisation

1. As the size of an organism increases, the surface area to volume ratio decreases.
2. Diffusion alone is not sufficient to move materials from one part of the organism to all other areas. A transport system is necessary.
3. A system of co-ordination is necessary in a complex organism. A simple organism, such as amoeba can do without a nervous system but a complex one, such as man cannot.

Classification of living things

If books in a library or goods in a large shop are left in disarray, it would be difficult to find the book or article which one wants. The books or goods have to be arranged in some kind of order. Books in a library may be arranged according to their sizes or colours, but this would not be very useful. They are usually arranged by subject matter and by authors.

There are about one and a half million distinct types of plants and animals. It would be difficult to study these plants and animals without arranging them in some kind of order. Just as books on the same subject are arranged together, similar plants and similar animals are grouped together. This makes the study of each group of plants or animals easier, as the members of each group have certain features in common.

The grouping of living things into their kinds is called classification or **taxonomy**. Classifications are not limited to living things. Books or goods may be classified. Classification may be described in general terms as sorting, ordering and grouping things into sets.

The principal reason for classification is for the convenience of the user. The classification of books makes it easier to use the library, that of goods makes it easier to use a shop, and that of living things makes it easier to study them. The feature which is used as a basis for classification, such as the subject matter of a book, is called the **criterion** of the classification.

Man has tried over the ages to classify the confusing variety of living things found in the world. The earliest classifications of living things were artificial. For instance, if one used the ability to fly as a criterion for classifying animals, then one would put in one group, such animals as insects, bat (a mammal), flying squirrel (a mammal) and a pigeon (a bird) which we know are more dissimilar than similar.

In present day classification of plants and animals, all the characters of the plants and animals are used. Such a classification aims at reflecting the natural or evolutionary relationships among the living things. In practice, organisms which have the largest number of characters in common are considered to be most closely related by evolutionary descent.

The system of classification of living things used today is based on that introduced by a Swedish naturalist, **Carl Von Linne** (1707-1778). He was better known by the Latinised form of his name, **Carolus Linnaeus**. He published a classification of plants in 1753, and of animals in 1758.

Taxonomic groups

In the classification of plants and animals, individual organisms are arranged in small groups based on their common features. Then the small groups are arranged into progressively larger groups. The basic unit of classification of things is the **species**. This is the smallest unit containing members which have the largest number of features in common and usually interbreed among themselves. For instance, all maize plants belong to one species and all human beings belong to one species.

Species which have many features in common are placed in one **genus**. For instance, the horse belongs to one species, the donkey to another and the Zebra to yet another species. These three species have so much in common that they are placed in one genus. In the same vein, genera which have many things in common, are placed in one **family**; families are placed in an **order**. Orders are placed in a **class**, and classes in a **phylum** or **division**, and phyla or divisions are placed in a **kingdom** (see Fig. 1.4). In this arrangement, each smaller group belongs to a larger group that includes it, and every organism belongs to a species, genus, family, order, class, phylum and kingdom.

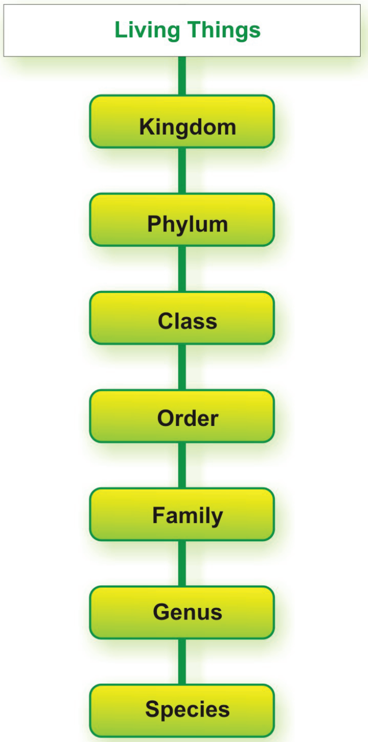


Fig. 1.4 Hierarchy of groups used in classification of living things

Nomenclature

It is necessary to name things before classifying them; otherwise it would be difficult to refer to them by name. If a book had no title, for instance, it would be difficult to classify it precisely. It would have to be referred to by some vague description, such as 'the book with the red cover'.

Linnaeus also introduced a system of naming living things which biologists use today. It is called the **binomial system of nomenclature**. In this system, each species is given two names. The first name is the genus or generic name. It is usually started with a capital letter. It can be abbreviated (if it occurs in a context in which the full name is clear) and can also stand alone e.g. the scientific name of water leaf is *Talinum triangulare* or *T. triangulare* or *Talinum*. *Talinum* is the generic name of water leaf. The second name is the species or specific name. The specific name starts with a small letter e.g. *triangulara* is the specific name of water leaf. Both the generic and the specific names are underlined separately when written or typed. When printed, they are italicised. The scientific name of man is *Homo sapiens*.

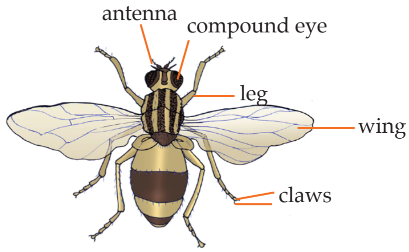


Fig. 1.5 The housefly, Musca domestica

The classification of the housefly is summarised below:

Kingdom:	*Animalia* – all non-plant living things.
Phylum:	*Artropoda* – animals with jointed legs, appendages.
Class:	*Insecta* – animals with bodies divided into head, thorax and abdomen, as well as three pairs of jointed legs.
Order:	*Diptera* – insects with only two wings.
Family:	*Muscidae* – the flies.
Genus:	*Musca* – a fly-type.
Species:	*Domestica* – the housefly.

The housefly is, therefore, named scientifically as *Musca domestica*. The first of this pair of names is the generic name and the second, the specific name. In the same way, the mango tree is named as *Mangifera indica*, the domestic dog as *Canis domestica* and the potato plant as *Ipomea batata*.

Systems of classification of organisms

The two-kingdom classification

In the two-kingdom system of classification, organisms are grouped into two kingdoms: the plant kingdom and the animal kingdom.

The plant kingdom is further divided into these phyla or divisions: *thallophyta* (including bacteria, algae, and fungi); *Bryophyta* (including liverworts and mosses); *pteridophyta* (ferns); and *permatophyta* (seed-bearing plants, which are subdivided into gymnospermae (gymnosperms) and angiospermae (flowering plants).

The animal kingdom is further divided into the following phyla: *protozoa*, *porifera*, *coelentrerata*, *platyhelminthes*, *nematoda*, *annelida*, *mollusca*, *echinodermata*, *chordata*.

The five-kingdom classification

This modern classification replaced the old two-kingdom classification in 1969. The criteria taken into consideration for this classification include:

1 The complexity of cell structure (i.e. whether it is prokaryotic or eukaryotic).

2 The complexity of the organism's body structure (whether it is unicellular and simple or multicellular and complex).

5 *Animalia* (includes various multicellular animals)

The viruses were not included because they have some characteristics of living things and some of non-living things.

Kingdom: *Monera*

The organisms in this kingdom include the bacteria and the blue-green algae. They have the following characteristics:

Table 1.3 Classification of living things into two kingdoms

Kingdom	Phylum	Class
Plantae	*Schizophyta* *Thallophyta* *Bryophyta* *Pteridophyta* *Spermatophyta*	Gymnosperm Angiosperm
Living things *Animalia*	*Protozoa* *Porifera* *Coelenterata* *Platyhelminthes* *Nematoda* *Annelida* *Mollusca* *Arthropoda* *Echinodermata* *Chordata*	Pisces Amphibia Reptilia Aves Mammalia

3 Mode of nutrition (i.e. whether autotrophic or heterotrophic).

Almost all the examining bodies in Europe and America have adopted this system. The New York State Biology Regents syllabus adopted it in 1982.

The five kingdoms are:

1 *Monera* (includes bacteria and blue-green algae)

2 *Protista* (includes mainly aquatic, primarily unicellular organisms, photosynthetic or heterotrophic ones and some decomposers)

3 *Fungi* (includes moulds, mushrooms)

4 *Plantae* (includes multicellular photosynthetic plants)

a) They are unicellular, though some form filaments of cells.

b) The cells are prokaryotic.

c) The cells have no organised nucleus, with nuclear envelope.

d) They do not have complex chromosomes.

e) The cells have no mitochondria, no endoplasmic reticulum, no chloroplasts, but polysaccharides and amino acids.

f) There is no sexual reproduction.

g) They may be autotrophic or heterotrophic.

Phylum: *Schizophyta* (bacteria)
Characteristics:

i) They are microscopic.

ii) They consist of one cell only.
iii) The cell is prokaryotic (lacks a true nucleus and a nuclear envelope).
iv) Organelles, such as mitochondria are absent.
v) Contain one strand of DNA, not bound by nuclear membrane.
vi) The cell has a rigid cell wall, which is complex. It lacks cellulose, but consists of polysaccharides and amino acids.
vii) Reproduction is by binary fission.

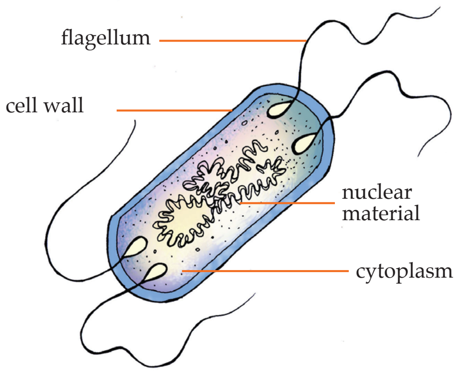


Fig. 1.6 A bacterium cell

viii) Some are autotrophic (photosynthetic or chemosynthetic) and some are heterotrophic (parasitic or saprophytic).

Bacteria are divided into classes according to their shapes.

Phylum: ***Cyanophyta*** **(blue-green algae)**
Characteristics:
i) They are microscopic.
ii) Some are unicellular, others are filamentous with individual cells joined end to end; few form branched filaments, very few form colonies, and none is truly multicellular.
iii) Cells contain chlorophyll, but not in chloroplasts. They also contain accessory pigment, such as carotenoids. Some contain a blue pigment, phycocyanin, and some a red pigment, phycoerythrin.
iv) Cell wall does not contain cellulose, but some sort of polysaccharides and amino acids as in bacteria.
v) The cells lack cilia, flagella or other locomotory organelles, but some filamentous blue-green algae move by gliding.
vi) Reproduction is by cell division.

Kingdom: *Protista*
Characteristics:
a) The organisms are all eukaryotic and unicellular.
b) Some of the protista are heterotrophic (including parasitic forms) while some are photosynthetic autotrophs, and some are both heterotrophic and photosynthetic.
c) Reproduction is usually asexual by mitosis but some also have sexual reproduction by fusion of gametes.
d) Movement may be by cilia, flagella or may be amoeboid.

This kingdom is divided into the following phyla: *protozoa*, *euglenophyta*, *chrysophyta* and *pyrrophyta*:

Phylum: ***Protozoa***
Characteristicss:
i) They are simple and microscopic.
ii) They are unicellular.
iii) The different classes are characterised by their locomotory organelles: the *rhizopoda* or *sarcodina* move by means of pseudopodia, e.g. *amoeba*, the ciliate move by means of cilia (e.g. paramecium), the *mastigophora* move by means of flagella (e.g. zooflagellates) while the *sporozoa* have no organelles for movement and are all parasites.
iv) They may be commensals or symbiotic.
v) Mode of nutrition is variable; it may be holophytic, holozoic, saprozoic or parasitic.
vi) Reproduction occurs asexually by binary fission, multiple fission, budding, and spore formation, and sexually by conjugation.

Class: ***Mastigophora (zooflagellates)***
Characteristics:
i) Each organism has one or two flagella for locomotion.
ii) The cells have generally no outer wall.
iii) Most members are free-living, some are parasitic, e.g. *Trypanosoma gambiense*, which causes sleeping sickness. *Trichonympha*, another member of this class, lives as a symbiotic in the digestive tract of termites, where it digests wood ingested by the termite.

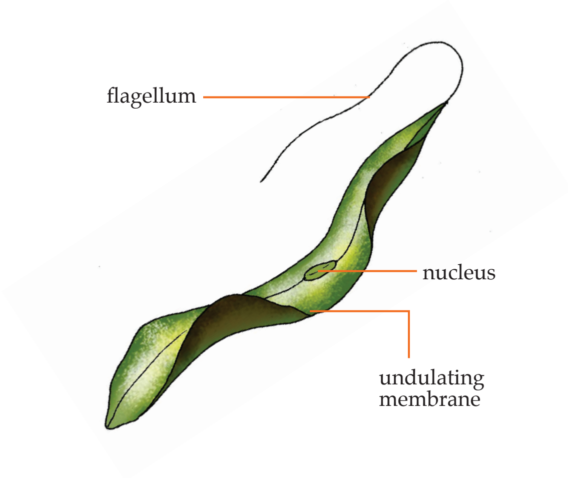


Fig. 1.7 Trypanosoma

Class: ***Sarcodina***

Characteristics:

i) The organisms are unicellular.

ii) Temporary pseudopods are used for locomotion and food capture, e.g. *amoeba*.

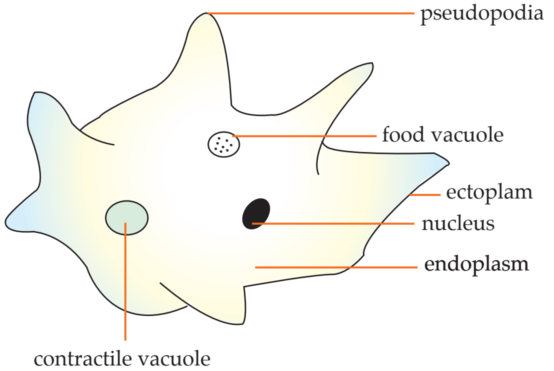


Fig. 1.8 Amoeba

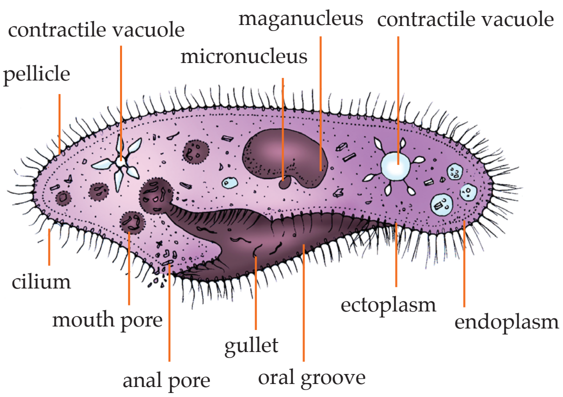


Fig. 1.9 Paramecium

Class: ***Ciliophora***

Characteristics:

i) The organisms are unicellular.

ii) Each organism has cilia for locomotion and food gathering.

iii) The organisms have macronuclei and micronuclei, e.g. paramecium.

Class: ***Sporozoa***

Characteristics:

i) All the members of this class are parasitic.

ii) They have no cilia or flagella.

iii) Each organism has a complex life cycle, e.g. Plasmodium, which causes malaria.

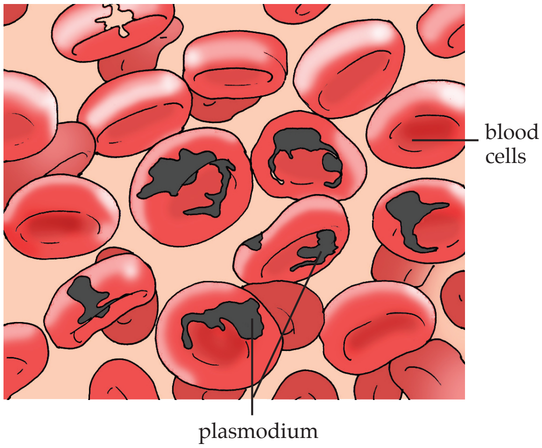


Fig. 1.10 Plasmodium

Phylum: ***Euglenophyta***

Characteristics:

i) The organisms are unicellular.

ii) Each organism has one or two flagella.

iii) The organism stores carbohydrates as paramylum.

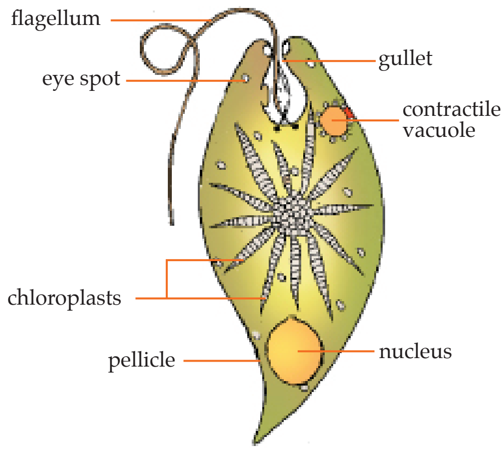


Fig. 1.11 Euglena

iv) The cell lacks a cell wall but has a pellicle, made of protein, inside the cell membrane.
v) Chloroplasts are present in the cells and contain chlorophylls a and b as in higher plants.
vi) Reproduction is asexual by longitudinal division, e.g. *euglena*.

Phylum: *Chrysophyta* (Diatoms)
These are the golden algae, which are the main components of phytoplankton in inland and oceanic waters. Most of the golden algae are diatoms.

Characteristics:
i) The photosynthetic pigments are chlorophylls a and c.
ii) They contain a yellow carotenoid called fucoxanthin, which gives the algae their characteristic colour.
iii) The cell walls contain no cellulose, and are often impregnated with silicon compounds. Each species has characteristic markings on the cell walls.
iv) The cells store food in the form of oil, not starch.
v) A diatom has two halves of its shell, which fit together, one on top of the other.

Phylum: *Pyrophyta (Dinoflagellates)*
The *dinoflagellates* are single-celled algae, which are almost all marine. They are important components of phytoplankton.

Characteristics:
i) Each *dinoflagellate* has two flagella, which beat within grooves. One flagellum encircles the body like a belt; the other is perpendicular to it. The effect of the beating of the two flagella is that the cell spins as it moves through the water.
ii) The cell has a stiff cellulose wall.

Kingdom: *Fungi*
The *fungi* were for a long time classified with the plants. They, however, differ from plants in the position of their cell walls. In most groups of *fungi*, the cell walls are composed primarily of chitin, a polysaccharide that is not found in the plant kingdom but which is the principal component of the exoskeleton of insects.

Characteristics:
a) Some *fungi* are unicellular, e.g. yeast, while many are multicellular, e.g. rhizopus, mushroom.
b) The body of a fungus is composed basically of filaments, each called a *hypha*.
c) All the hyphae of a single organism are collectively called a *mycelium*.
d) The mycelium may be a loose mass of hyphae on the surface of the material the fungus is growing, e.g. rhizopus, or it may be made up of tightly packed hyphae as in a mushroom.
e) In a fungus, there are many nuclei in a cell.
f) All fungi are heterotrophic. They lack chlorophyll. Some are saprophytic, some are parasitic, and some others are symbiotic.

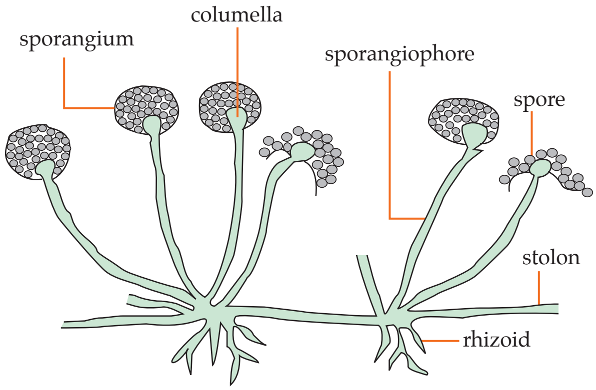


Fig. 1.12 Rhizopus

g) The fungi, together with the bacteria, are the principal decomposers in the biosphere.
h) Fungi reproduce by asexual and sexual methods.

Kingdom: *Plantae*
Division (phylum): *phaeophyta* (brown algae)
The brown algae are the principal seaweeds of the temperate and polar areas. They dominate rocky shores throughout the cooler areas of the world. *Sargassum nitans*, a brown algae occurs in the Sargasso Sea, which lies between the West Indies and the Azores.

Characteristics:
a) The plants are multicellular, and some are large in size.
b) The cells contain chlorophylls a and c, and a yellow pigment, fucoxanthin.
c) They differ from all other plants in storing food as an unusual polysaccharide called *laminarin*, and sometimes as oil, never as starch.
d) The plant body is differentiated into a holdfast (for attachment), a stripe (or stalk) and a blade.
e) The sperms and spore cells are often flagellated.

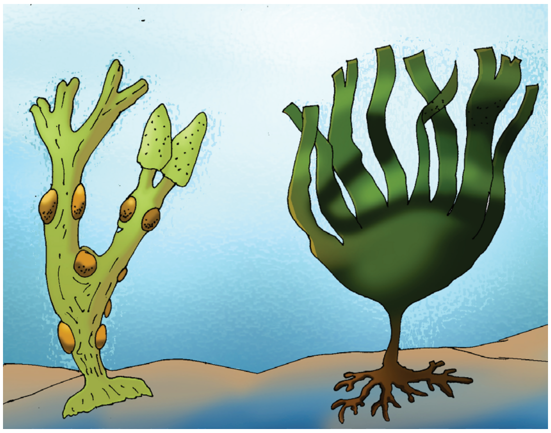


Fig. 1.13 Bladderwrack and Kelp(brown sea weeds)

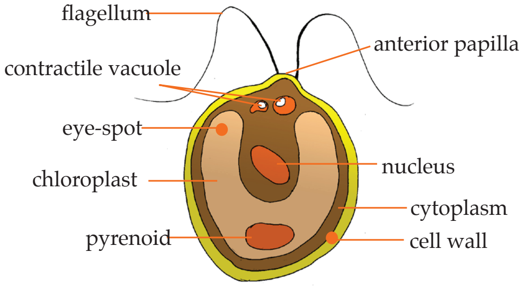


Fig. 1.14 a) Chlamydomonas

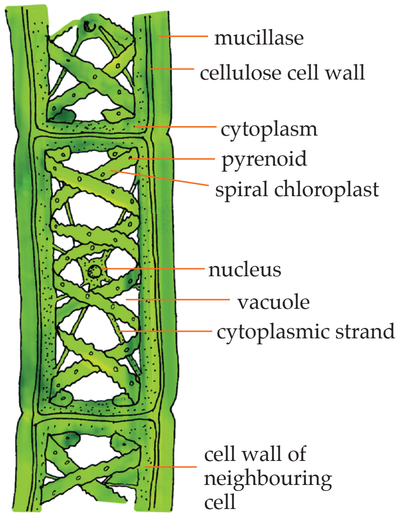


Fig. 1.14 b) Spirogyra

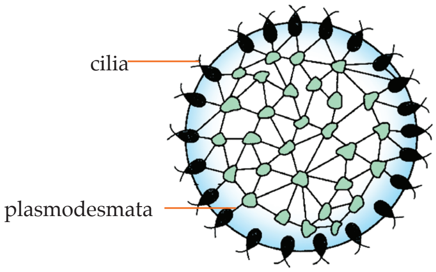


Fig. 1.14 c) Volvox

Division (Phylum): *Rhodophyta* (red algae)
The red algae are most commonly found in warm marine waters, usually at some depth below the surface.

Characteristics:

i) The cells contain chlorophylls a and d, carotenoids, and also certain phycobilins which give them their distinctive colour.
ii) They usually grow at greater depths than other algae.
iii) They do not normally grow as large as brown algae.
iv) The gametes are not mobile. The male gamete is carried to the female gamete by the water.

Division (phylum): *Chlorophyta*
Most of the *chlorophyta* are aquatic, but some live in wet places, such as tree trunks, some live as symbionts in invertebrates, and lichens. The majority live in fresh water, few are marine.

Characteristics:

a) Some are microscopic and unicellular, e.g. *chlamydomonas*.
b) The chlorophyta show a wide variety of forms. Some are filamentous, e.g. *spirogyra*, some are colonial, e.g. *volvox*.
c) They resemble higher plants in the following ways:
    i) They contain chlorophylls a and b and carotenoid pigments.
    ii) They store food as starch.
    iii) They have cell walls of cellulose.

Division (phylum): *Bryophyta*
The bryophytes are found in moist habitats, such as tree trunks, damp places, walls of open drains, and sides of ponds. Bryophytes are made up of two classes: *hepaticae* (liverworts) and *musci* (mosses).

Characteristics:

a) The vegetative body of the plant is made up of
    i) Rhizoids, which absorb water and mineral

salts from, and attach the plant to the substratum;
ii) The 'shoot', which may or may not be differentiated into stem and leaves.

b) Chloroplasts are present, as in higher plants.

c) The plant undergoes an alternation of generations. This means that there are two forms of the same plant, which regularly follow each other in the life cycle. The form that produces spores is called the **sporophyte generation**, while the form that produces gametes is called **gametophyte generation**.

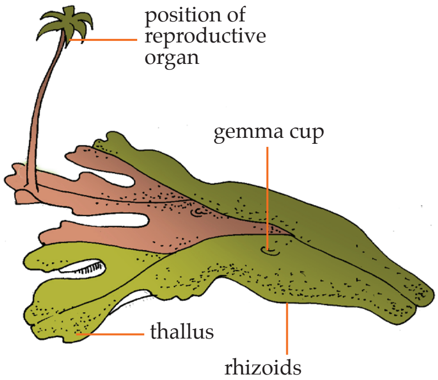


Fig. 1.15 a) Marchantia: a liverwort

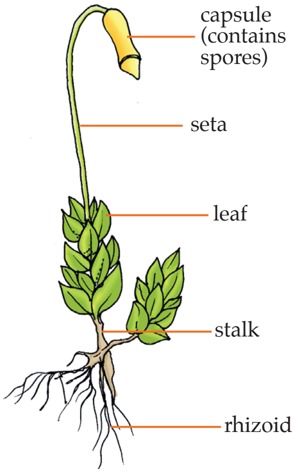


Fig. 1.15 b) Brachymenium: a moss plant

d) The dominant plant is the gametophyte plant. Examples of bryophytes are: *marchantia*, a liverwort, and *funaria*, a moss.

Division (phylum): *Tracheophyta*

The *tracheophyta* includes plants with well-developed conducting tissues. The majority of land plants belong to this phylum.

Characteristics:

i) There is tissue specialisation.
ii) Egg cells develop in the body of the parent plant inside a specialised organ.
iii) There is alternation of generations.
iv) Most members are differentiated into roots, stem and leaves.

Class: *Filicinae* (Ferns)

The ferns are found in moist places in both tropical and temperate areas.

Characteristics:

i) The leaves are large and feathery.
ii) The stems are usually underground rhizomes.
iii) Spores are borne in sporangia which occur at the under-surface of leaves or sometimes on specialised leaves.
iv) The sperms are coiled, multiflagellated and require free water to swim to the female gamete for fertilisation.

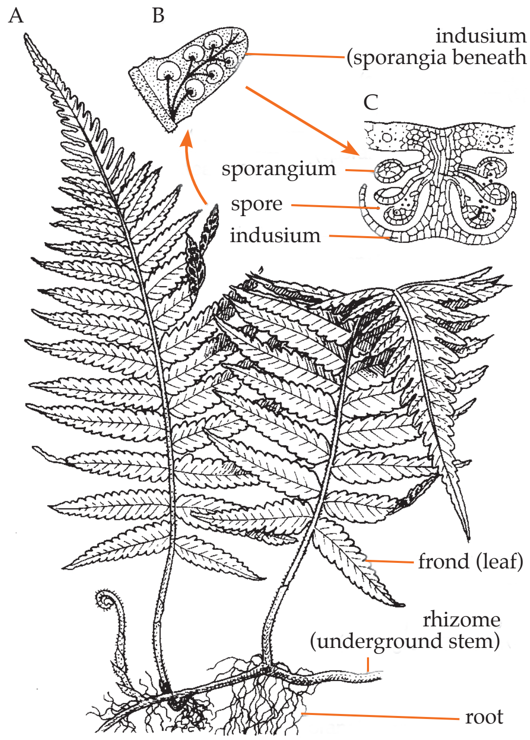


Fig. 1.16 Arthropteris, an example of a fern

Class: *Coniferinae* (Conifers)

The conifers occur mainly in temperate regions. The leaves are needle-shaped. The seeds are naked and borne in cones. The plants are usually ever-green. Example: Pinas

Class: ***Cycadinae*** **(Cycads)**
The leaves are large and fan-like, and the seeds are naked. Example: *cycas*.

Class: ***Ginkgoidae***
The leaves are large and fan-like, and the seeds are naked. Example: *ginkgo*.

Class: ***Gnetinae***
The leaves are often scale-like, while the seeds are naked. (The four classes above are all gymnosperms).

Class: ***Angiospermae*** **(Flowering plants)**
The flowering plants constitute the majority of the land plants. They bear flowers, and their seeds are enclosed in the mature ovary or fruit. They have well-developed conducting sytems.

Kingdom: *Animalia*

Phylum: ***Porifera*** **(Sponges)**
Multicellular, sessile, aquatic (largely marine) organisms, with a single body cavity, called gastric cavity. The body has two layers of cells, an outer pinacoderm and an inner choanoderm. The choanoderm consists mainly of collared flagellated cells.

The body has many holes through which water carrying food particles enters the gastric cavity. A skeleton of calcareous or siliceous spicules or horny fibers of sponging may be present. There is no nervous system. Asexual reproduction is by budding.

Phylum: ***Coelenterata***
Coelenterates are mostly marine but few are found in fresh water habitats. Examples include hydra and obelia.

Characteristics:

i) The organisms are simple multicellular invertebrates.

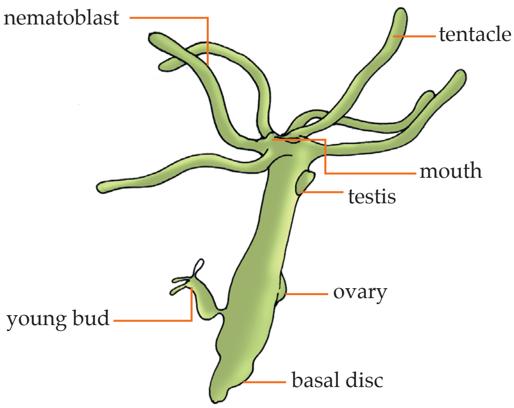


Fig. 1.17 Hydra

ii) They have two body layers called ectoderm and endoderm, with a structureless mesogloea lying between them, i.e. they are diploblastic.
iii) The body cavity or coelenteron has only one opening to the exterior called the mouth.
iv) Organs are absent; the body has two layers of cells which are organised as tissues.
v) The nerves are in the form of a primitive nerve net.
vi) They have stinging cells called nematocysts for offence and defence.
vii) The organism is radially symmetrical.
viii) Asexual reproduction is by budding while sexual reproduction is by the fusion of gametes.

Phylum: ***Platyhelminthes*** **(The flat worms)**
They are mostly endoparasites of animal hosts while few are free living in water. Examples include flukes, tapeworm, and *planaria*.

Characteristics:

i) The organisms are bilaterally symmetrical.
ii) They are triploblastic (i.e. they have three body

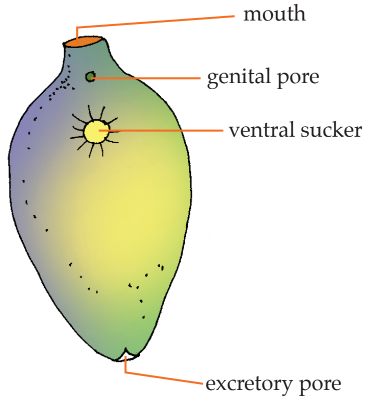


Fig.1.18 a) Liver fluke

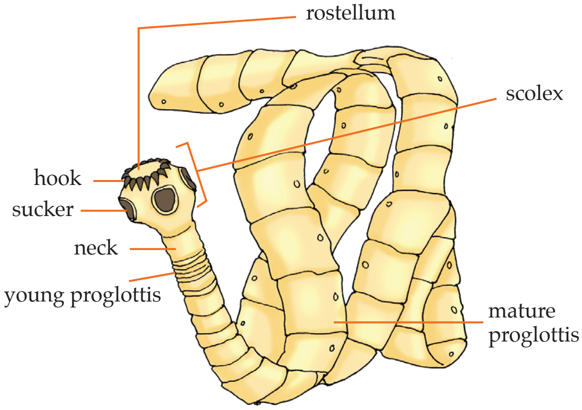


Fig. 1.18 (b) Tapeworm

layers: ectoderm, mesoderm, and endoderm)
iii) They are animals without coelom.
iv) They are dorso-ventrally flattered, and unsegmented.
v) The body has a single opening (the mouth) into the alimentary canal.
vi) Circulatory or respiratory systems are absent.
vii) Excretion is by flame cells.
viii) They are usually hermaphrodites, with a complex life cycle.

Phylum: ***Nematoda***

Some are free living while others are parasitic. Examples include ascaris and hookworm.

Characteristics:

i) They are bilaterally symmetrical.
ii) They are triploblastic.
iii) The body is elongated and pointed at both ends.
iv) They have no coelom.
v) The body has a thick covering of cuticle.
vi) The sexes are separate.

Phylum: Annelid (Segmented worms)

Some of these worms are aquatic (e.g. *nereis*) while some are terrestrial (e.g. earthworm).

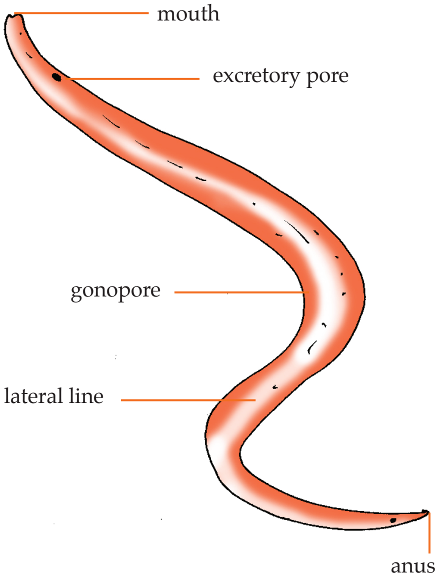


Fig. 1.19 Ascaris

Characteristics:

i) They are bilaterally symmetrical.
ii) The body is elongated and cylindrical.
iii) The body has a coelom.
iv) The organisms are triploblastic.
v) The alimentary cannal has two openings: mouth and anus.
vi) They are metamerically segmented (i.e. the body is made up of repeating units or segments).
vii) The body has a segmentally arranged chaetae.
viii) The excretory organs are called nephridia.
ix) The body is covered with a thin cuticle.
x) The organism may be unisexual or hermaphrodite.

Phylum: ***Arthropoda***

Characteristics:

i) They are metamerically segmented.
ii) They are bilaterally symmetrical.
iii) They are coelomate.

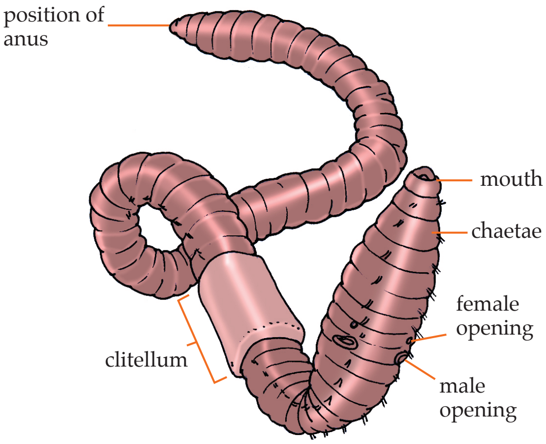


Fig. 1.20 Earthworm

iv) They have an exoskeleton of chitin.
v) They have jointed appendages.
vi) Fertilisation is internal.

The members of this phylum are widely distributed and very successful. The phylum consists of four classes: *inseta*, *arachnida*, *crustacean*, and *myriapoda*.

Class: ***Insecta***

This class contains the insects, such as cockroach, housefly, grasshopper, and butterfly. They are mainly terrestrial.

Characteristics:

i) An insect has a pair of jointed antennae.
ii) It has a pair of compound eyes.
iii) It has three distinct regions of the body: head, thorax and abdomen.
iv) It has three thoracic segments: prothorax, mesothorax and metathorax.
v) Each segment of the thorax has a pair of jointed walking legs.
vi) An insect may have wings.

vii) An insect respires by means of tracheae.
viii) An insect undergoes metamorphosis.

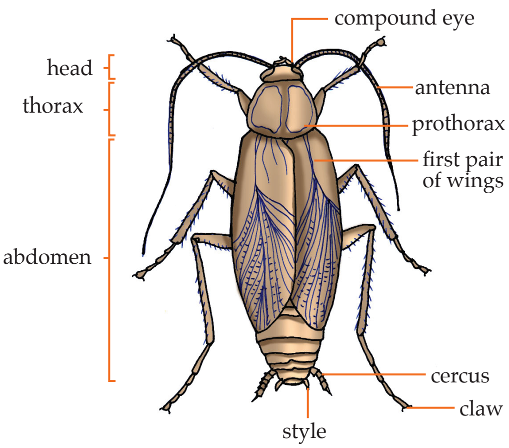


Fig. 1.21 a) Cockroach

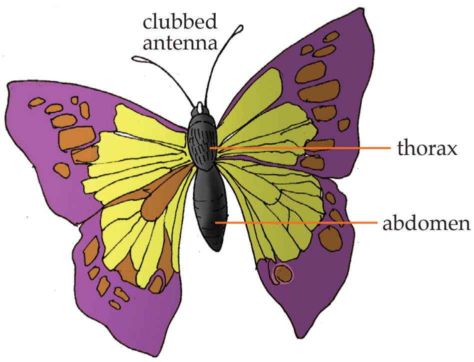


Fig. 1.21 b) Butterfly

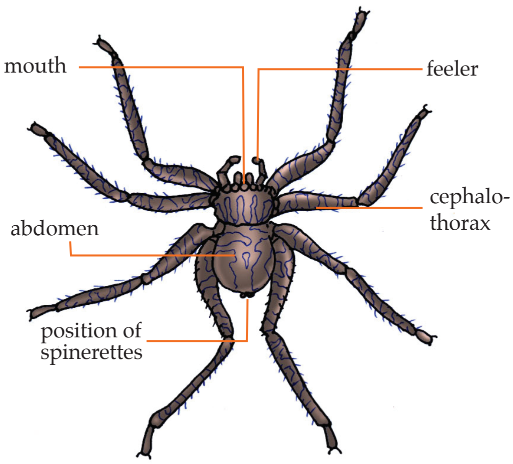


Fig. 1.22 a) Spider

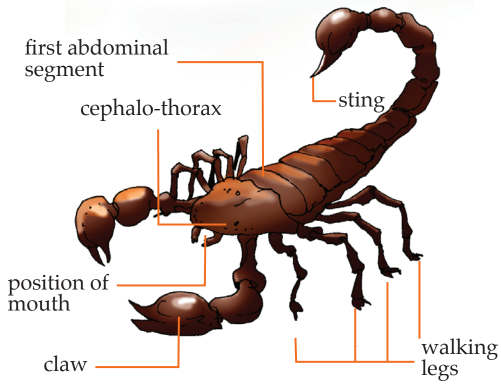


Fig. 1.22 b) Scorpion

Class: *Arachnida* (Spiders and scorpions)
Characteristics:

i) Arachnids have two body divisions: prosoma and opisthosoma (or abdomen).
ii) They have chelicerae and pedipalps.
iii) They have eight simple eyes.
iv) They have eight walking legs.
v) They respire by means of lung hooks.

Class: Crustacea
The members live in water, or both in water and on land. Examples include prawns, shrimps, crabs, water flea and barnacle.

Characteristics:

i) Crustaceans have two body regions: cephalothorax and abdomen.
ii) They have one pair of antennae for feelers and a pair of antennules for smelling.
iii) Some have five pairs of walking legs.
iv) Each has a pair of compound eyes.
v) They breathe by means of gills.

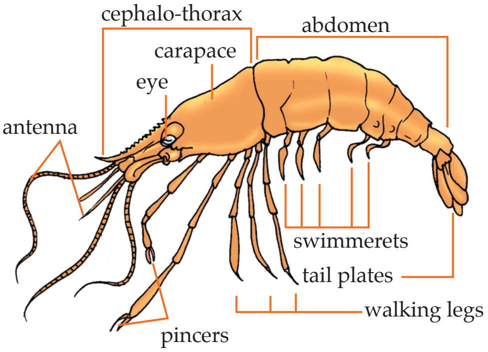


Fig. 1.23 a) Prawn

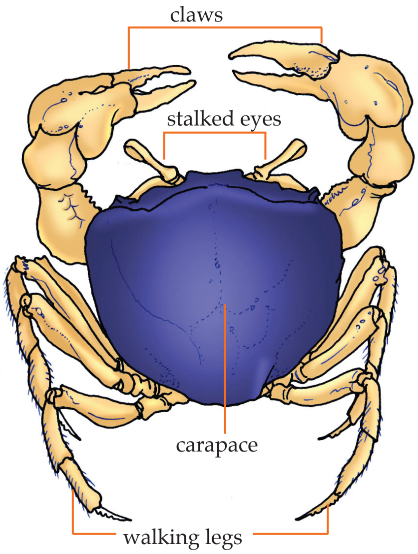


Fig. 1.23 b) Crab

Class: *Myriapoda* (Centipedes and millipedes)
These are terrestrial arthropods.

Characteristics:

i) They have two body regions: head and fused trunk and abdomen.
ii) The abdomen consists of many limb-bearing segments.
iii) The head bears a pair of simple eyes, a pair of jaws and a pair of short antennae.
iv) They breathe by means of tracheae.
The class myriapoda has two subclasses:

a) **Subclass: *Chilopoda* (Centipedes)**

Characteristics:

i) Centipedes have a pair of appendages on each body segment.
ii) They are carnivorous.

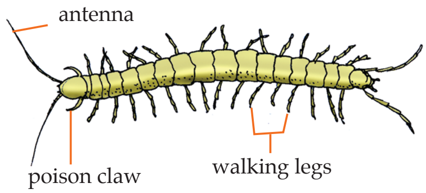


Fig. 1.24 Centipede

b) **Subclass: *Diplopoda* (Millipedes)**

Characteristics:

i) Millipedes have two pairs of appendages on each body segment.
ii) They are herbivorous.

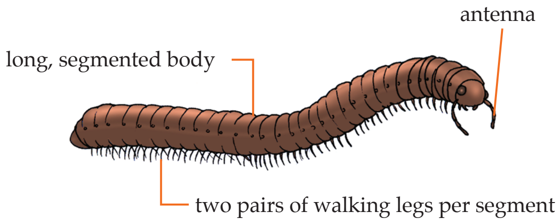


Fig. 1.25 Millipede

Phylum: *Mollusca* (Snails, bivalves)
Some members are aquatic, while some are terrestrial.

Characteristics:

i) Molluscs are bilaterally symmetrical.
ii) They are triploblastic.
iii) The organism has a coelom.
iv) The body is unsegmented.
v) The body consists of head, foot and visceral mass.
vi) The body has no cuticle; it is soft.
vii) The skin covering the visceral mass extends to form the mantle, which secretes the shell.
viii) It breathes by means of the mantle cavity.
ix) Molluscs are hermaphrodite.

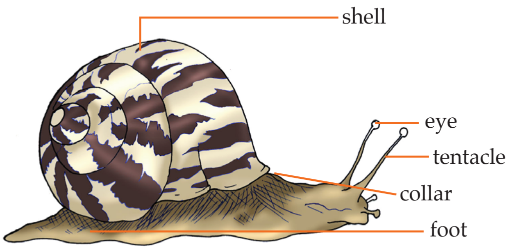


Fig. 1.26 Land snail

Phylum: ***Echinodermata*** **(Star fish)**
Echinoderms are all aquatic and live in or near water.

Characteristics:

i) They are radially symmetrical.
ii) They are triploblastic.
iii) They have a coelom.
iv) They have exoskeleton of calcareous ossicles and spines.
v) The organs for locomotion are suckers or tube feet.
vi) The sexes are separate.

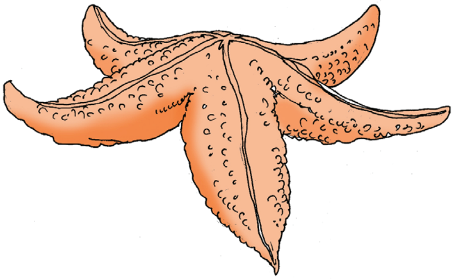


Fig. 1.27 Star fish

Phylum: ***Chordate***
Characteristics:

i) A notochord is present, at least in the early stage of the life history.
ii) The pharynx has visceral clefts.
iii) There is a dorsal, tubular, central nervous system.
iv) Three is a post-anal, metamerically segmented tail.
v) Limbs, where present, are formed from more than one body segment.
vi) There is a closed body circulatory system.

Subphylum: ***Acrania***
These are chordates which have no true skull, brain, heart or kidneys.

Class: ***Hemichordata***
Characteristics:

i) The notochord is represented by a short portion in the proboscis.
ii) The body is divided into three parts: a pre-oral proboscis, a collar and a trunk.
Example: *Balano-gloussus*

Class: ***Urochordata***
Characteristics:

i) Chordate features are most obvious in the larval stage. During metamorphosis, the notochord is lost, nerve cord degenerates, and gill slits multiply to form a large perforated pharynx which becomes a ciliary feeding organ.
ii) There is no coelom.
iii) Sexes are separate or combined. Asexual reproduction is by budding. Colony formation is common.
Example: *Ciona*.

Class: ***Cephalochordata***
Characteristics:

i) The organisms are fish-like but small.
ii) They do not possess specialised head, limbs or heart.
iii) The notochord extends along the whole length of the body.
iv) The pharynx is large, with gill slits between gill bars which open into an atrium.
v) Excretion is by nephridia.
Example: *Amphioxus*.

Subphylum: ***Craniata*** **or** ***vertebrata***
Characteristics:

i) The vertebrates are chordates with well-developed heads and brains.
ii) The internal skeleton is of bone or cartilage.
iii) Excretion is through the kidney.
iv) The heart is ventral.
v) Visceral clefts are few and are lost in the adult.

The vertebrates are divided into five classes.

Class: ***Pisces*** **(Fishes)**
Characteristics:

i) The visceral clefts persist in the adult as gill clefts.
ii) The paired limbs are the pectoral and pelvic fins.
iii) A lateral line system is well developed.
iv) There is an endoskeleton of placoid or cycloid scales.
v) Fertilisation is external.
Example: *Tilapia*

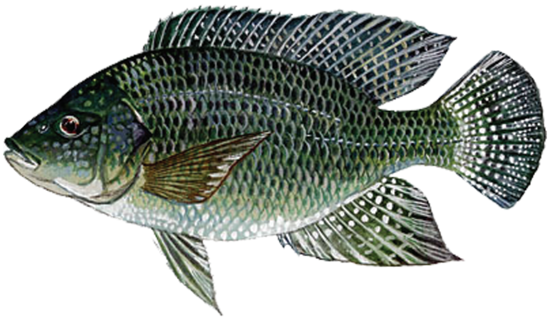


Fig. 1.28 Tilapia fish

Class: *Amphibia* (Amphibians)

Characteristics:

i) The amphibians have pentadactyl limbs.
ii) The skin is soft and has no scales.
iii) Gills are present in the tadpole larva, but lungs are present in the adult.
iv) There is no external ear, but there is a middle ear.
Examples: Toad and frog.

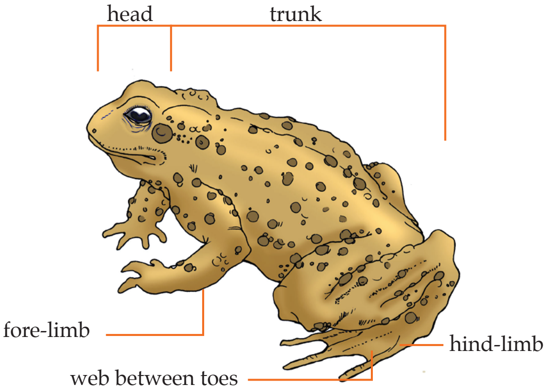


Fig. 1.29 Toad

Class: *Reptilia* (Reptiles)

Characteristics:

i) Reptiles have pentadactyl limbs.
ii) The skin is dry, with scales.
iii) The respiratory organs are lungs.
iv) They lay eggs with much yolk, and there is no larval stage.
v) Fertilisation is internal.
Examples: lizards, snakes, crocodiles, and tortoise.

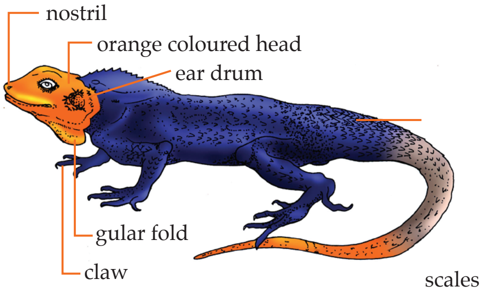


Fig. 1.30 Agama lizard

Class: *Aves* (Birds)

Characteristics:

i) The birds have pentadactyl limbs; the first pair of limbs are modified into wings for flight.
ii) They are warm-blooded animals.
iii) They have feathers on their skins.
iv) They have beaks; teeth are absent.
v) They have scales on their legs and feet.
vi) The respiratory organs are lungs.
vii) They lay eggs with much yolk.
viii) There are no larval stages.
ix) Fertilisation is internal.
Examples: Domestic chicken, and pigeon.

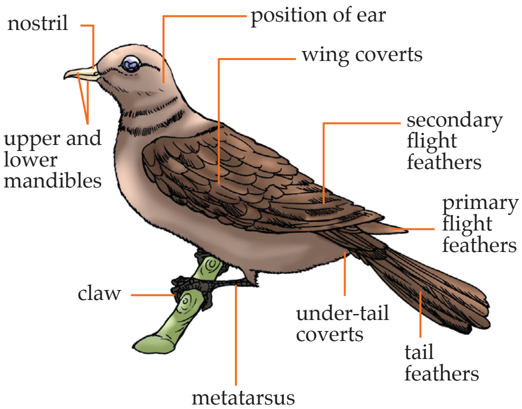


Fig. 1.31 A weaver bird

Class: *Mammalia* (Mammals)

Characteristics:

i) Mammals have pentadactyl limbs.
ii) They are warm-blooded animals.
iii) They have hair and sweat glands in their skin.
iv) They have mammary glands; young ones suck their mother's milk.
v) They have four-chambered hearts.
vi) The eggs are small, and the young ones develop within their mothers.
vii) Fertilisation is internal.
viii) They are viviparous.

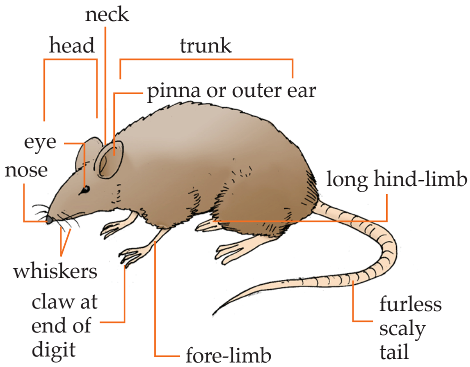


Fig. 1.32 A rat

Summary

This chapter has taught the following:

- Living things have:
  - Physiological characteristics: They feed, respire, excrete, grow, perceive and respond to stimuli, move and reproduce.
  - Ecological characteristics: They adapt to their environments.
  - Genetic characteristics: They transmit their characteristics to their offspring.
  - Evolutionary characteristics: They change with time.
  - Structural characteristics: They all contain the living substance protoplasm, and consist of one or more cells.
- Cells are organised into tissues, tissues into organs, organs into organ systems, and organ systems into organisms. There are some organisms at the cell, tissue, organ and organ system levels of organisation.
  Complexity of organisation of living things has both advantages and disadvantages.
- Living things are classified in such a way that organisms with the largest number of similarities and which interbreed form a specie. From this species, there is a hierarchy of groups of increasing size, namely, genus, family, order, class and phylum.

Revision questions

1 Which of the following is true of a living thing?
   A It breathes.
   B It transmits its characteristics to its offspring.
   C It adapts to its environment.
   D It consists of one or more cells.
   E It does all of the above.

2 The lowest level of organisation of life is the ____________.
   A cell
   B tissue
   C organ
   D organ system
   E heart

3 Which of the following is present in both plant cell and animal cell?
   A Cell membrane
   B Cell wall
   C Cell vacuole
   D Chloroplast
   E Cell sap

4 Which is the correct arrangement of groups used in classification of organisms in order of increasing size?
   A Genus, family, species, order, phylum, class
   B Species, genus, family, order, class, phylum
   C Family, order, genus, species, class, phylum
   D Phylum, order, family, class, species, genus
   E Class, family, phylum, species, order, genus

5 Describe the characteristics of living things.

6 State the levels of organisation of life with one named example for each level.

7 Describe the differences between plants and animals.

8 a) What is classification?
   b) Why is it necessary to classify organisms?
   c) List the characteristics of one named phylum.

Chapter 2 The cell

Introduction

The dictionary gives the meaning of cell as 'a small room in a prison for one or more persons' or as 'a small number of people.' A person suspected of committing a crime may be put by the police in a 'cell' while investigation is going on.

In 1665, **Robert Hooke**, an English scientist, who discovered Hooke's law, used a crude microscope to observe thin slices of cork from an oak tree. What Robert Hooke saw were cell walls of dead cells. Since then, more efficient microscopes have been developed and more people have used them to look at living cells. It is now realised that the spaces which Robert Hooke saw contain living matter, in living cells.

This living matter, which Robert Hooke did not see, is the most important part of the cell. The living matter carries out the life processes in the cell. The living matter, and the walls surrounding it form a unit, the cell.

In biology, a cell is defined as the structural and functional unit of which organisms are composed. A living thing is made up of cells in more or less the same way as a building is made up of blocks or bricks.

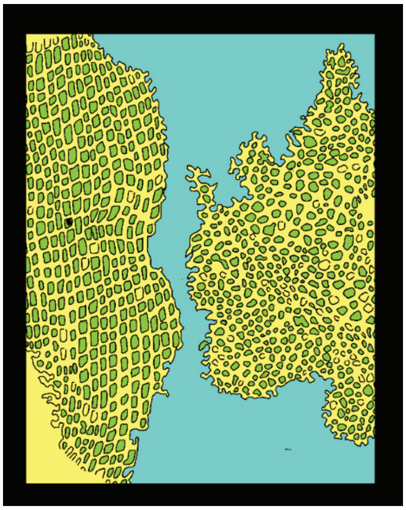


Fig. 2.1 Hooke's cork cells

The cell as a living unit

A cell is a living unit because it displays the characteristics of living things. The cell is the smallest unit that shows the characteristics of life.

Characteristics of living things

1 All living things have one common quality in their structure. Each is made up of one or more cells. A cell has this quality.

2 All living things show seven functional characteristics: nutrition, respiration, movement, growth, excretion, sensitivity and reproduction, A cell does all these.

Forms in which cells exist

Living cells exist in different forms. Some exist as independent organisms, some as colonies, some as filaments and some as parts of living organisms.

The cell as an independent organism

In some microscopic organisms, such as *amoeba, paramecium, euglena,* and *chlamydomonas*, the body consists of one cell only. An organism that consists of one cell only is said to be **unicellular**. Unicellular organisms are also described as **acellular** or **non-cellular** because their bodies are not divided into cells.

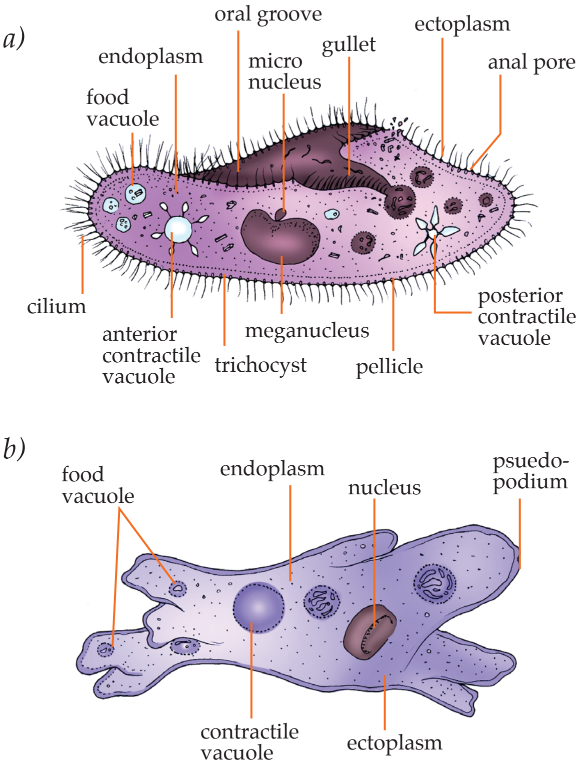


Fig. 2.2 Unicellular organisms: (a) Paramecium (b) Amoeba.

Activity 2.1 Observing unicellular organisms

Materials required
Microscope; microscope slides containing stained specimens of *paramecium, euglena and chlamydomonas*

Procedure
1. Your teacher will mount (for you under a microscope,) stained specimens of paramecium, euglena and chlamydomonas.
2. Your teacher will also mount (for you, under a different microscope,) living specimens of *paramecium*, *euglena* and *chlamydomonas*, one after the other.
3. Draw and label each organism in your book. Note the size, shape and main features of each.
4. Observe the characteristics of living things shown by a living specimen of each of the organisms.

Unicellular organisms exist as independent living things in nature. Their activities show that cells are living units.

Paramecium

Habitat
Paramecium is found in muddy ponds and stagnant or sluggish fresh water containing decaying organic matter.

Structure
Paramecium is a unicellular organism, just visible to the naked eyes. It is between 0.15mm and 0.3mm long. The shape resembles that of the human foot or a slipper.

Locomotion
Paramecium moves by means of *cilia,* which occur on the surface of the body. The cilia beat obliquely backwards, causing the organism to rotate on its axis as it moves forward, with the blunt end leading.

Feeding
It feeds on microscopic organisms, such as bacteria, protozoa and algae. As the cilia in the oral groove beat, food particles are carried toward the gullet. Cilia in the gullet move in such a way that the food particles are carried to the bottom of the gullet. There, at the mouth pore, food particles, from time to time, enter the endoplasm to form food vacuoles.

As a food vacuole circulates, the endoplasm secretes digestive enzymes into it. The food is digested and absorbed. The undigested or unabsorbed remains of the food are removed at a definite spot: the anal pore.

Respiration
Oxygen dissolved in the water in the habitat diffuses through the entire body surface into the *paramecium.* The *paramecium* uses the oxygen for respiration.

Excretion
Carbon dioxide and nitrogenous waste products are passed out by diffusion through the entire body surface of the *paramecium* into the surrounding water.

Osmoregulation
The protoplasm of *paramecium* contains a higher concentration of salts than the surrounding water in the habitat. Water, therefore, passes from the surroundings into the organism by osmosis. *Paramecium* has two contractile vacuoles, one at each end. These act alternately. Each slowly enlarges, reaches its maximum size and then bursts, removing excess water from the protoplasm to the outside. This control of the water content of the protoplasm is called **osmoregulation**.

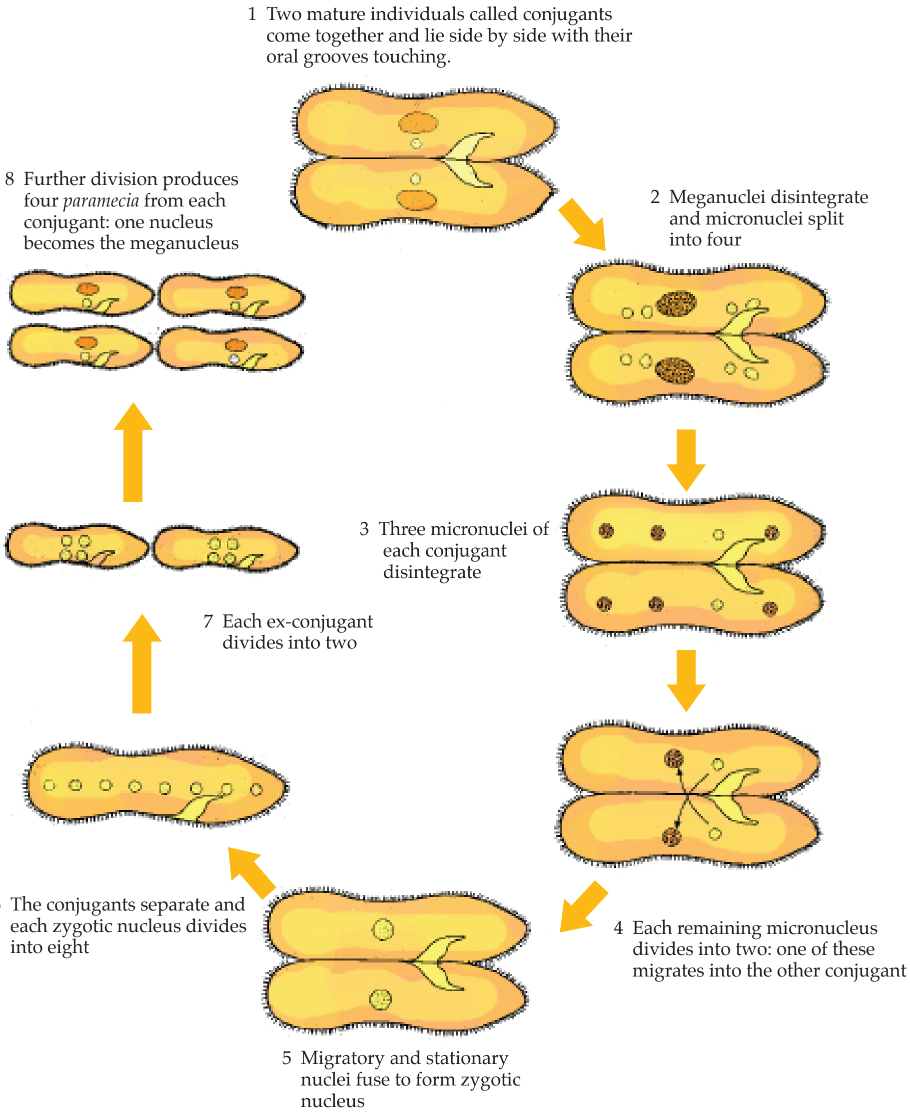


Fig. 2.3 Conjugation in paramecium

Sensitivity

Paramecium perceives changes in its environment and responds to them. It defends itself against its enemies by shooting out its trichocysts which may hurt or kill them. If it meets an obstacle while in motion, the cilia temporarily stop beating. Then it reverses the ciliary beat and moves back at a different angle. Then it resumes the forward motion in a new direction. This is called **avoiding reaction**.

Reproduction

There are two methods of reproduction: **asexual** and **sexual.** Asexual reproduction in *paramecium* is by a mature individual dividing into two. This is called binary fission. During the binary fission, the meganucleus and micronucleus, each divides into two. The cytoplasm also divides transversely into two, each half containing one meganucleus and one micronucleus.

Asexual reproduction by binary fission is rapid, and gives rise to a large number of individuals called **clones.** However, it leads to a gradual weakening of the offspring. When this weakening goes on to a certain degree, sexual reproduction takes place to make the young ones strong again.

Sexual reproduction in *paramecium* takes place by a complicated process known as **conjugation**. Conjugation starts *w*hen two fully developed individuals, called **conjugatants,** come together and lie side by side. The two attach themselves together along their oral grooves. The meganucleus of each individual breaks down. The micronucleus of each individual divides into four parts. Three of the four pieces in each breaks down. The remaining piece of the micronucleus divides into two. One of the two pieces of the micronucleus in each individual migrates into the other individual and fuses with the stationary piece of micronucleus to form the zygotic nucleus (or fusion nucleus). The conjugants now separate. The fusion nucleus in each ex-conjugant divides into eight parts. The cytoplasm divides into four parts by binary fission to form four young *paramecia* each with meganucleus and micronucleus (see Fig. 2.3).

Euglena

Euglena is a minute organism which has the characteristics of both plants and animals.

Habitat

Euglena lives in stagnant fresh water, such as pools and ponds which contain decaying organic matter.

Structure

Euglena is a microscopic organism about 0.125 mm long. It has a definite shape, which is slender, and tapers towards each end. The front end is blunt, while the hind end is pointed.

Euglena is green because it contains green chloroplasts. In some species, these chloroplasts are rod-shaped and are arranged in the form of a star in the middle portion of the body. In other species, the chloroplasts may be spherical and are scattered in the cytoplasm. The body surface is covered with a thin, tough material called **pellicle**, which is flexible and allows the organism to alter its shape for short periods of time during a form of movement known as **euglenoid motion**.

At the anterior end is a flask-shaped structure called **gullet**. From the bottom of this gullet arises a long filament known as **flagellum**. On one side of the gullet is a red spot, which is sensitive to light, and known as the **eye spot**. Near the gullet is a contractile vacuole. The cytoplasm is differentiated into an outer thick cytoplasm called **ectoplasm** and an inner liquid cytoplasm known as **endoplasm**. In the endoplasm, there are granules of paramylum, a type of carbohydrate stored by this organism. The nucleus is located in the endoplasm.

Locomotion

Euglena moves by the whip-like action of a single flagellum. Waves pass along the flagellum from the base to the tip. The organism rotates as it moves. Euglena can also move by the contractions of fibrils in its body called **myonemes**. These contractions bring about a sequence of changes in the shape, and cause euglenoid movement.

Nutrition

Euglena viridis is a green and photo-autotrophic organism. With carbon dioxide obtained from the water in which it lives, and energy from sunlight, it photosynthesises. It makes up its nitrogen requirement by absorbing nitrogenous substances, such as amino acids from the water. In some species of euglena, the flagellum sets up a whirl pool, which carries small organisms into the gullet. The small organisms are engulfed through the gullet, which in these species, has no pellicle, and digested in the cytoplasm.

Some species of *euglena* lack chlorophyll and are colourless. They nourish themselves by extracellular digestion, then absorption of organic materials. When kept in the dark, green species of euglena lose chlorophyll. They continue to live if supplied with organic food materials.

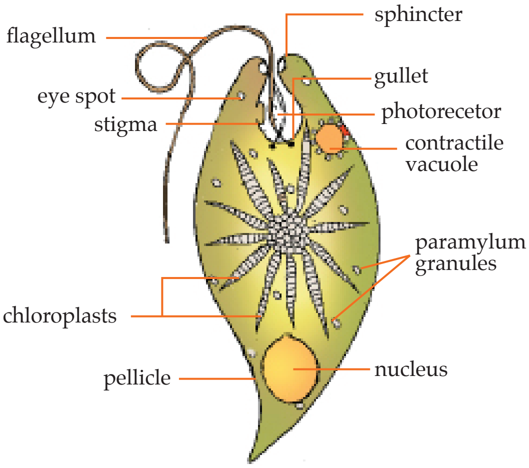


Fig. 2.4 Euglena

Respiration

Euglena absorbs oxygen from the water through its entire body surface and uses it for respiration.

Excretion

Carbon dioxide and nitrogenous waste materials are removed from the body by diffusion through the external body surface.

Osmoregulation
There is one contractile vacuole, with tributary canals, which collects excess water from the cytoplasm and discharges it into the gullet.

Sensitivity
Euglena viridis moves towards a source of light. It reacts to harmful chemicals by turning and moving away.

Reproduction
Euglena reproduces asexually only by binary fission. A fully grown individual divides lengthwise beginning from the anterior to the posterior end.

Chlamydomonas

Chlamydomonas is a microscopic, unicellular, green alga, which lives in fresh water ponds and ditches. Its structure is shown in Fig. 2.5. *Chlamydomonas* has a constant, oval shape, it has a cell wall which encloses the cytoplasm and nucleus. There are two flagella at the anterior end. Within the cytoplasm, in the anterior part, is one cup-shaped chloroplast, with a pyrenoid embedded in it. The pyrenoid is a centre for the storage of food.

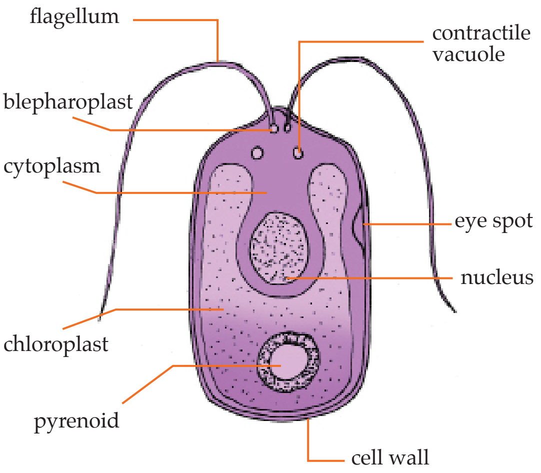
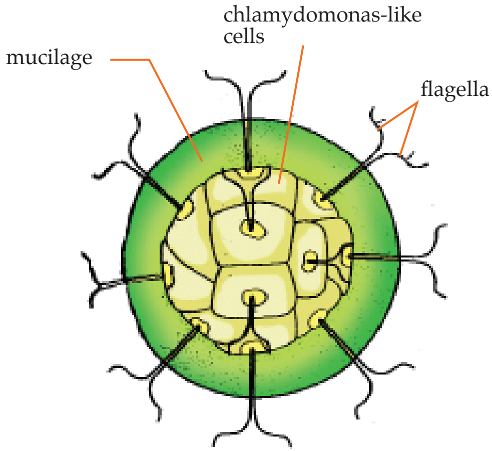


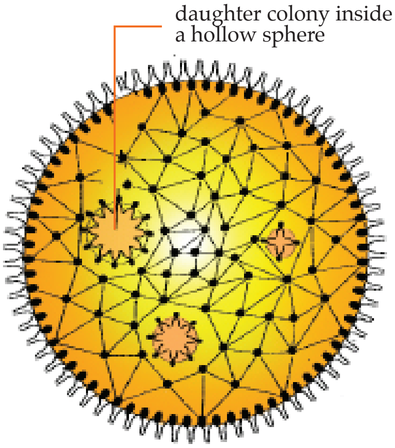
Fig. 2.5 Chlamydomonas

Living cells as a colony

The body of an organism may consist of separate living cells held together by mucilage. All the cells move together as a unit. The individual cells carry out some activities independently. A group of cells is called a **colony.**



(a) *Colony of pandorina*



(b) *Colony of volvox*

Fig. 2.6

Pandorina, eudorina and volvox

Pandorina, *eudorina* and *volvox* are colonial algae, which are made up of cells, each similar to *chlamydomonas*. Each *pandorina* consists of a colony of 16 cells; each eudorina is a colony of 32 cells, while each volvox contains hundreds or even thousands of cells in a colony.

When a colonial organism consists of a constant number of cells, and the cells are specifically arranged into a definite form and integrated, the colony is called a **coenobium**.

Volvox will be described below as an example of an organism in which living cells form a colony.

Habitat
Volvox lives in fresh water ponds and ditches. Under favourable conditions, the organism is present in large numbers, causing the habitat to be green.

Structure
Volvox *is a* colonial green alga. The colony or coenobium is a hollow sphere of cells arranged in a single layer near the outer surface. The cells are separated from one another by mucilage which also envelopes all the cells. The mucilage is soft at the centre of the sphere and firm near the external surface.

The number of cells in a colony varies from one species to another. It ranges from about 1 000 to 20 000. A colony is readily visible to the naked eye. Each cell has a chloroplast with pyrenoid, eye spot, two flagella, contractile vacuoles and nucleus. The flagella protrude through the mucilage.

There are protoplasmic processes connecting the cells. The cells in one coenobium are similar in structure, and the entire colony has definite anterior and posterior ends.

Nutrition
Volvox moves by means of flagella, with the front end leading. The coenobium rotates about the anterior- posterior axis in an anticlockwise manner as it moves.

Sensitivity
The organism moves towards light.

Reproduction
It reproduces by both asexual and sexual methods.

Asexual reproduction
Most of the cells in a colony are body cells which do not reproduce. A few cells in the posterior part reproduce asexually. Each asexually reproductive cell enlarges in comparison with other cells, and then divides many times to produce a plate of cells.

By further division and rearrangement, the cells form a hollow sphere of cells, which is a young coenobium. Young coenobia lie in the interior of the parent until the parent eventually dies and disintegrates, and then they are released.

Sexual reproduction
Sexual reproduction is marked by the formation of gametes and the occurrence of fertilisation. In some species, such as *Volvox globator*, one individual forms both male and female gametes. In other species, such as *Volvox aureus,* there are male or female gametes only.

A cell that will form male gametes or **antherozoids** divides to form many male gametes which are released into the water. A cell that will form female gametes forms only one large female gamete. The male gametes swim to the female gamete. One male gamete fertilises the female gamete to form a resting **oospore**, which remains in the parent coenobium for some time. Eventually, it is released, and it divides many times to form a new coenobium.

Activity 2.2 Observing volvox

Materials required
Pond water containing volvox, microscope, microscope slide

Procedure
1 Your teacher will mount a sample of water containing *volvox* under a microscope.
2 Observe the organism, noting its structure and movement.
3 Make a drawing of *volvox* in your notebook.

Living cells as a filament

Living cells may also exist as a filament.
Spirogyra, a common green filamentous alga, is a good example.

Habitat
Spirogyra is found in slow-flowing fresh water streams and ponds as floating green masses, near the surface of the water.

Structure
Many *spirogyra* filaments are held together by slimy mucilage. When a small sample of spirogyra is examined under the microscope, the filament is seen to be made up of individual cells joined end to end.

Activity 2.3 Observing spirogyra cells

Materials required
Sample of stream or pond water containing *spirogyra*, microscope, microscope slide, watch glass

Procedure
1 Your teacher will mount under a microscope a specimen of *spirogyra,* stained with iodine solution.
2 Observe the specimen through the microscope.
3 Draw one filament and one cell in your notebook.

Each *spirogyra* cell is cylindrical in shape. It has a cell wall, outside which is a layer of mucilage. Inside the cell are a nucleus and cytoplasm. The cytoplasm does not fill the cell but leaves cell vacuoles filled with cell sap. Within the cytoplasm is a spirally-shaped chloroplast which goes from one end of the cell to the other. The cells in a filament are alike, but independent.

When the filament is broken by wind or by water movement, separate pieces reproduce vegetatively to form new filaments. This type of reproduction is called **fragmentation**.

The cell as a part of a living tissue

A unicellular organism consists of one cell only. Organisms that consist of many cells, such as man or *iroko* tree, are said to be multicellular. In a multicellular organism, there is usually specialisation of cells and division of labour. All the cells are not of the same kind. Different kinds of cells perform different functions. Each kind has a structure that enables it to perform its own function.

In the human body, white blood cells defend the body against infection, red blood cells transport oxygen, nerve cells conduct impulses, spermatozoa fertilise ova in reproduction, muscle cells bring about movement. All the cells of the body benefit from the different actions of different cells. In a multicellular organism, therefore, the cells are interdependent.

The cells which perform the same function may occur as a group. A group of cells which are similar in structure and perform the same function is called **tissue**. Cells in a tissue differ from a colony or filament of cells. Cells in a tissue do not carry out all functions of life in the organism, but only one or few functions. Each cell in a colony or filament carries out functions of cells in that organism. Cells in a filament are independent in many functions- nutrition, respiration and excretion. Cells in such a colony are also independent in many functions. They cooperate in movement. Cells in a tissue are clearly interdependent with other cells in the organism, because if a tissue carries out one function, such as support by xylem tissue, that tissue depends on other tissues for nutrition, sensitivity, reproduction and so on.

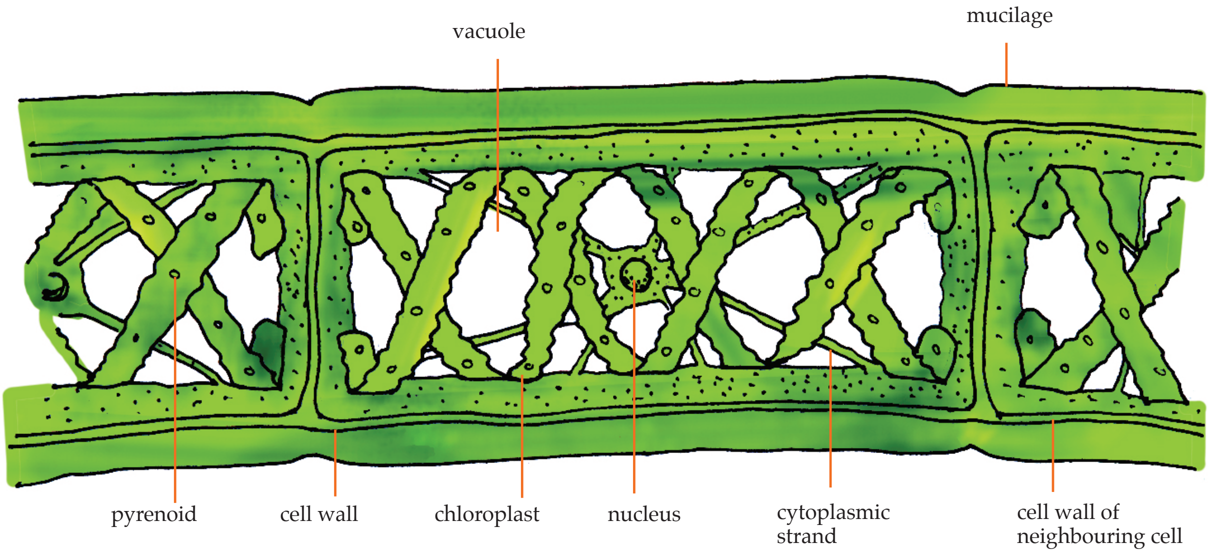


Fig. 2.7 A spirogyra cell

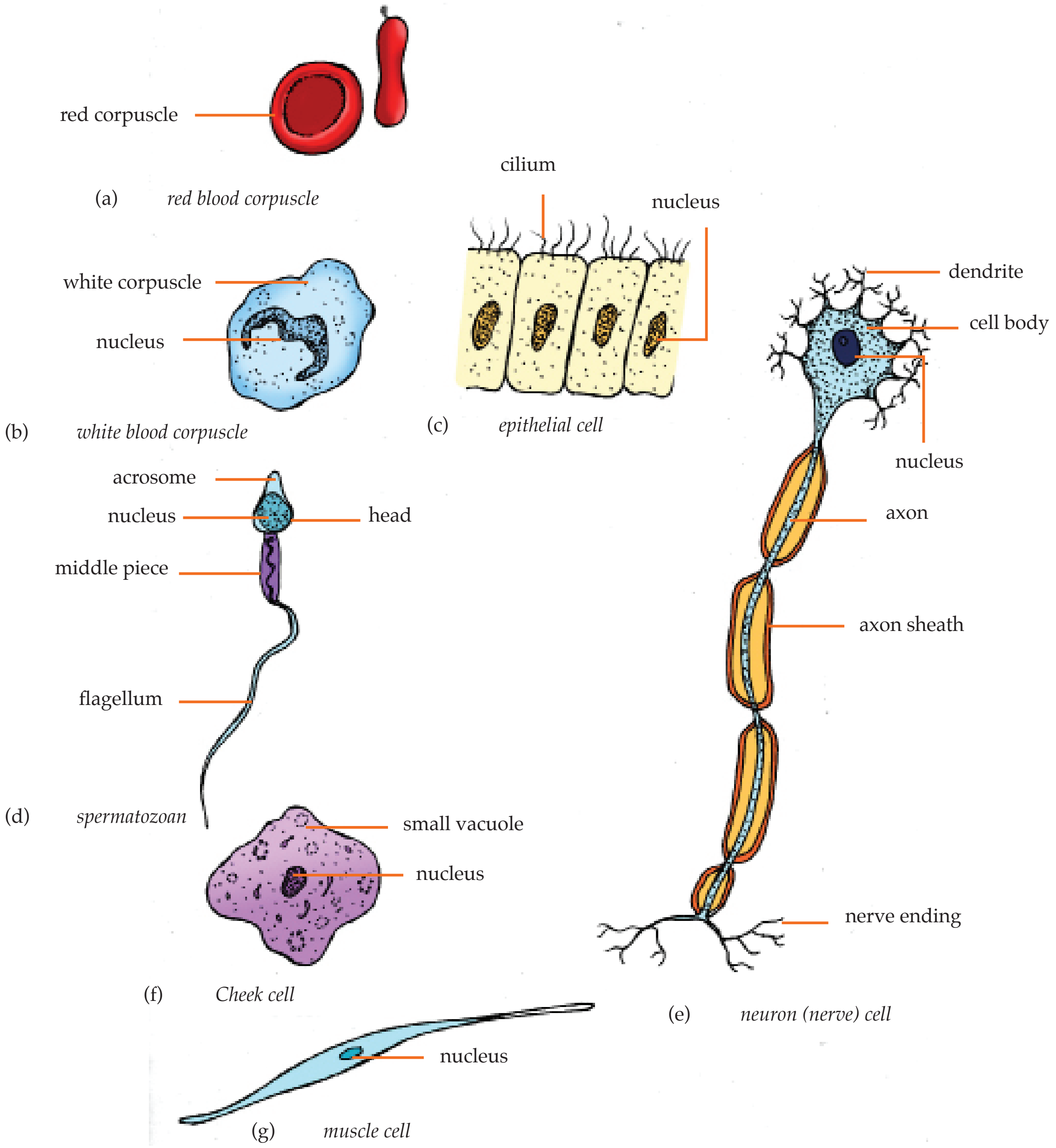
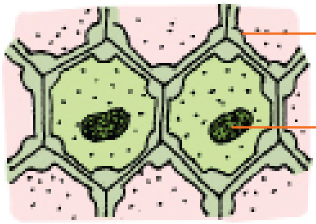
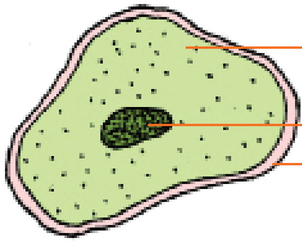


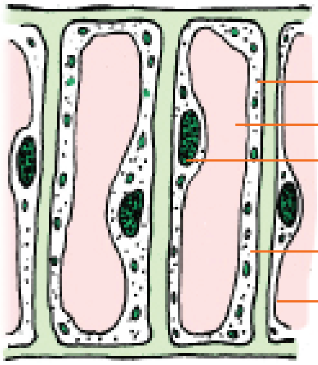
Fig. 2.8 A variety of cells in man



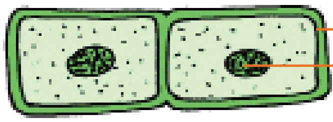
(a) *collenchyma cells*



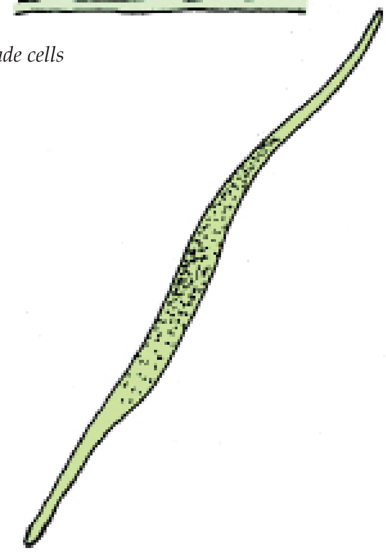
(b) parenchyma cell in pith



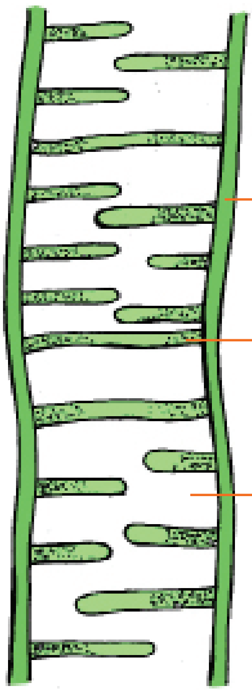
(c) *palisade cells*



(d) *epidermal cells of leaf (side view)*



(e) *pericycle cells*



(f) *xylem vessel in stem*

Fig. 2.9 A variety of plant cells

Cell theory

As you learnt earlier in this chapter, Robert Hooke was the first, in 1665, to observe dead cork cells with a microscope. In 1834, a French biologist, **Dujardin** discovered the living part of the cell. He called it sarcode. This is known as protoplasm. In 1838 **Matthias Schleidon**, a German botanist discovered that all plants are made up of cells. In 1839 **Theodor Schwann**, a German zoologist discovered that all animals are made up of cells.

In 1839, **Matthias Schleidon** and **Theodor Schwann** jointly stated what is now known as the cell theory, namely, that all living things are made up of cells. After the statement of the cell theory, in 1846, **Hugo Von Mohl** first applied the term protoplasm to the living substance in the cell, the name by which it is still known. In 1858, **Rudolf Virchow** stated that cells come from pre-existing cells.

Other scientists made contributions to our knowledge of the cell.

In summary, the cell theory is stated as follows:

1 All living things are composed of cells.
2 Cells are the basic units of structure and functions of living things.
3 All cells arise from pre-existing cells by cell division.

Cell structure

Cells differ in structure, from one type to another. Each type has a structure that fits it for its particular function. Cells vary in size. Only a few kinds are visible to the unaided human eye. The majority of cells are microscopic, ranging from about 0.025 mm to about 0.25 mm in diameter. However, there are exceptions. Eggs are cells, and the largest cell is the egg of an ostrich.

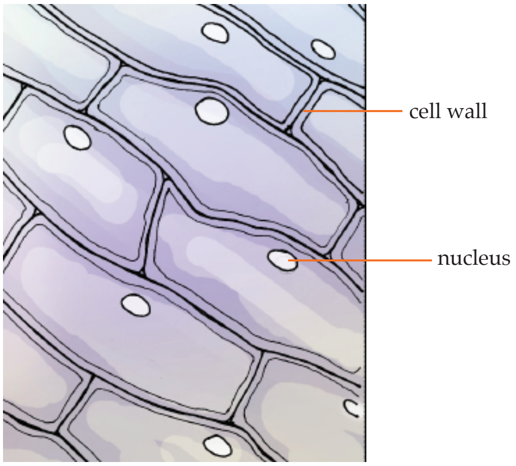


Fig. 2.10 Epidermal cells of onion

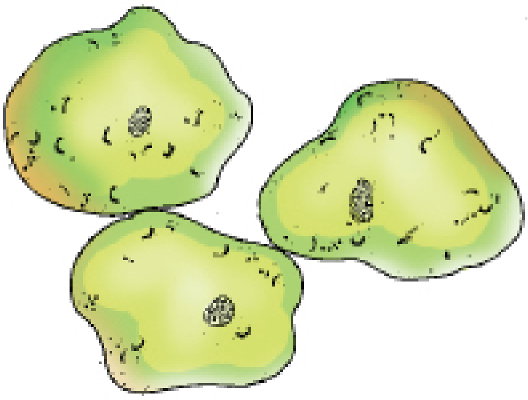


Fig. 2.11 Human cheek cells

Cells differ in shape. Cells of the human skin are flat, cells lining the intestine are cylindrical, liver cells are circular, nerve cells are elongated ending in fine processes, white blood cells are amoeboid while red blood cells are disc shaped and biconcave. All cells have some structural properties in common. They are as follows:

1 Most cells are microscopic.
2 Every living cell has a cell membrane, cytoplasm and nucleus. The protoplasm in the nucleus is known as **nucleoplasm.**

Activity 2.4 Observing a plant cell

Materials required

Onion bulb, razor blade, mounted needle, microscope, microscope slide, water

Procedure

1 Strip the epidermis from the inner side of the fleshy leaf of an onion bulb. You can use a razor blade or a mounted needle to start the process.
2 Cut a small piece of the epidermal strip.
3 Stain the epidermal strip with iodine solution.
4 Examine the specimen under the low power of a microscope.
5 Draw the cells as you see them.

Activity 2.5 Observing an animal cell

Materials required

Mounted needle, microscope, microscope slide

Procedure

1 Use a mounted needle to clean out a finger nail.
2 Run the clean finger nail lightly over the inside of your cheek.

3 Clean out the cheek cells scraped out by your finger nail unto a clean slide.
4 Mount the cheek cells in a little saliva. Cover with slip, and examine the cheek cells under the low power and high power of a microscope.
5 Draw the cells as you see them.

The structure of a generalised plant cell

Since plant cells differ in structure from one type to another, a generalised plant cell will be described. When seen through a compound light microscope, a plant cell consists of the following major parts: cell wall, cell membrane, cytoplasm and nucleus.

The outermost part of the plant cell is the cell wall. In a young cell, this cell wall is made of cellulose and is thin. As the cell grows older, the cell wall is thickened with cellulose. In addition, in some tissues, other chemicals may be deposited on the cellulose wall. For instance, **lignin** is deposited on cell walls in xylem and pericycle tissues, while **suberin** is deposited on cellulose cell walls in cork tissue. The deposition of lignin and suberin on the cell walls causes the protoplasm in these cells to die. Cellulose cell walls are permeable to water and oxygen. Suberin is not permeable; hence in cork tissue, water and air diffuse through the lenticels.

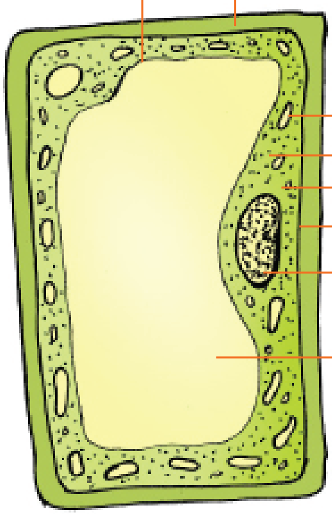


Fig. 2.12 A generalised plant cell

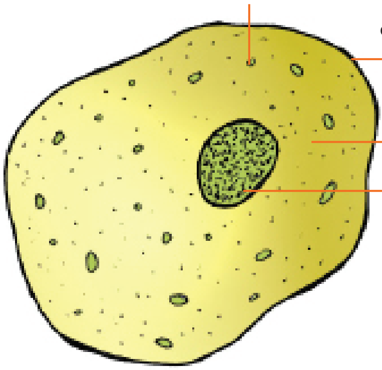


Fig. 2.13 A generalised animal cell

The cell membrane lies immediately below the cell walls. It is seen through a light microscope as a line. It is semipermeable, that is, it is selective in allowing small molecules, but not large molecules to pass through. The cell membrane encloses the cytoplasm. The cytoplasm is a complex colourless, granular, colloidal liquid which contains water, mineral salts, enzymes, proteins and other organic molecules. Sometimes, reserve food particles are present. A young plant cell is filled with cytoplasm. As the cell grows, the growth of the cytoplasm is slower than the growth of the cell. As a result, spaces occur in the cytoplasm called cell vacuoles, which are filled with cell sap. The membrane that separates the cell vacuoles from the cytoplasm is called **tonoplast**. In the cytoplasm also there are **chloroplasts**. In higher plants, each cell in the green parts of the plants contains many small, spherical chloroplasts. Chloroplasts contain chlorophyll, and are the centres for photosynthesis.

The nucleus is roughly spherical in shape and is denser than the cytoplasm in which it is embedded. It is surrounded by a double membrane, which together make up the nuclear envelope. At certain points, the two membranes come together, creating spaces, called **nuclear pores**, through which the nucleus communicates with the cytoplasm. In the nucleus, there are numerous very fine threads which form a network of material called **chromatin**. Normally, these threads are not visible when a cell is not dividing. In a dividing cell, the chromatin network condenses into chromosomes, whose number is constant in each species. Chromosomes are visible through the compound light microscope but only in dividing cells. The chromosomes carry hereditary factors called **genes**. The nucleus is the body that controls all the functional activities of a cell, and also contains the chromosomes that transmit inheritable characters.

The structure of an animal cell as seen through a light microscope

A cheek cell is taken as an example. The animal cell is similar in some respects to a plant cell. However, it lacks a cell wall, chloroplasts and cell vacuoles. The cheek cell is roughly irregular in shape. The outermost layer is the cell membrane which encloses the granular cytoplasm. The nucleus is embedded in the cytoplasm.

The compound light microscope is commonly used in schools. It is compound because it uses a combination of lenses. It is a light microscope because light rays pass through a thin specimen, then through the lenses that produce a magnified image. A compound light microscope gives a maximum magnification of about 2 000 times.

In the last several decades, the electron microscope was invented. Instead of light, a beam of electrons passes through the specimen. The image is not seen with the naked eye, but is produced on a sensitive screen. The electron microscope can magnify up to 500 000 times. With this instrument, the structures of cell organelles which had been seen with the light microscope are now better understood, and organelles too small to be seen with the compound light microscope have been seen. Cell organelles which are seen through electron microscope but not with light microscope include endoplasmic reticulum, golgi body, mitochondria and ribosomes.

Endoplasmic reticulum

This is a system of membrane-bound spaces which form an extensive network in the cytoplasm. It extends from the nuclear envelope to the cell membrane and provides channels of communication within the cell. It is considered that some materials may also pass through these channels from the nucleus to the cell membrane or the other way round.

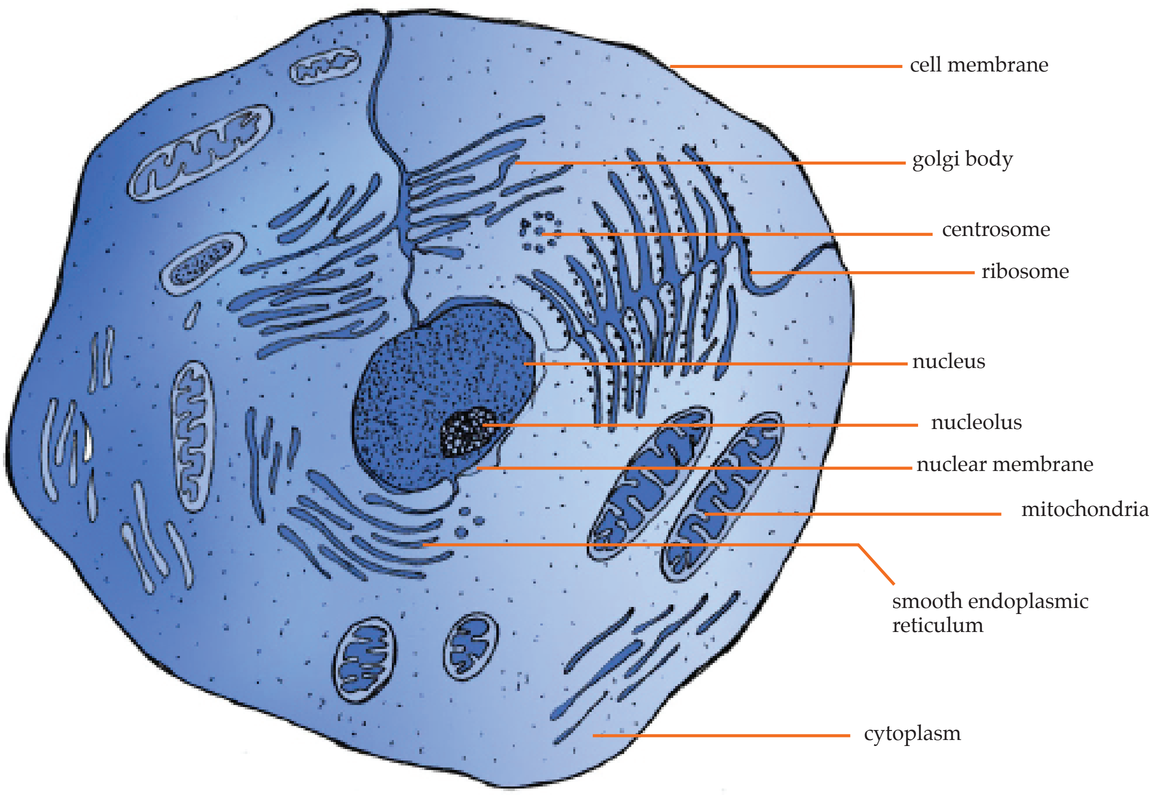


Fig. 2.14 A cell as seen through the electron microscope

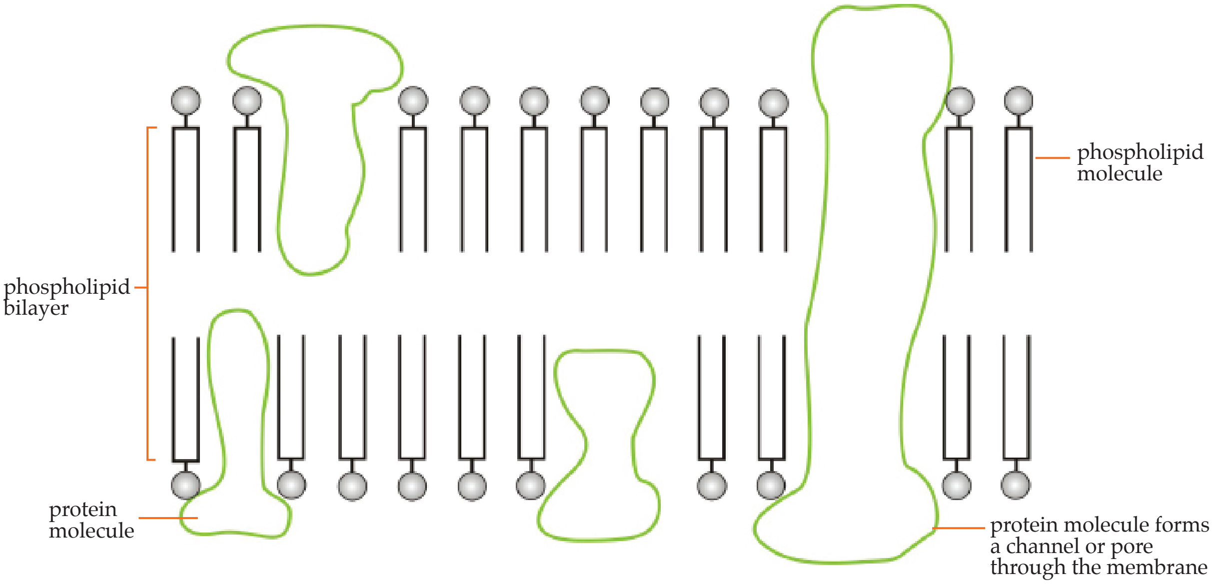
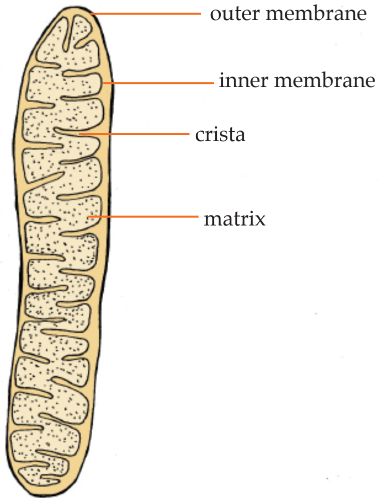


Fig. 2.15 Singer and Nicholson's model of the cell membrane

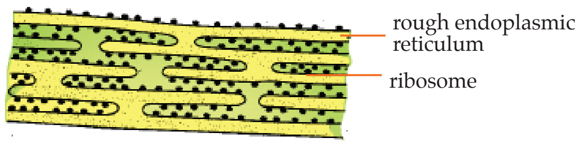
Golgi body
A Golgi body is a system of membrane-bound sacs, packed together. Several Golgi bodies occur in the cytoplasm of a cell. The Golgi body is concerned with the packaging of materials for removal out of the cell.

Mitochondrion
A mitochondrion is rod-like or spherical in shape. Several mitochondria (plural) are found in each cell. They are the centres for respiration. They secrete the enzymes that bring about respiration. They are more numerous in metabolically active cells than in other cells.

Ribosomes
Ribosomes are very tiny particles, which may be attached to the endoplasmic reticulum or may occur free in the cell. They synthesise proteins.

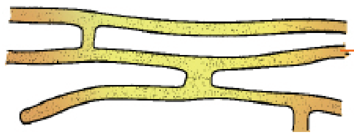


(a) Mitochondrion

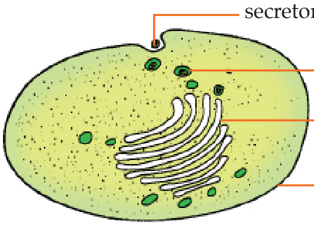


(b) Rough endoplasmic reticulum

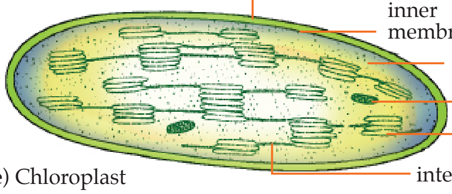
Fig. 2.16 Structures of cell organelles



(c) Smooth endoplasmic reticulum



(d) Golgi body



(e) Chloroplast

Cell components and their functions

Table 2.1 Functions of cell organelles

Cell organelle	Function
1 Cell wall (plant cell)	It gives shape and firmness to the cell; allows gases and water to pass through (except where substances, such as lignin or suberin are deposited on the cell wall).
2 Cell membrane	It forms the outer boundary of the protoplasm, being semipermeable; it allows some substances to pass in and out of the cell and prevents others from doing so.
3 Cytoplasm	It contains cell organelles, such as chloroplasts, endoplasmic reticulum, Golgi bodies, and mitochondria. It contains organic molecules, such as enzymes, food substances which are used by the cell. Many metabolic activities are carried out in it.
4 Cell vacuole (plant cell)	It contains cell sap which helps to make the cell turgid. Some excretory substances are stored in the cell sap.
5 Food vacuole (animal cell)	It contains food in the process of being digested.
6 Chloroplast (plant cell)	It is the site for the synthesis of sugar.
7 Nucleus	It controls the shape, size and functions of the cell; it contains chromosomes by which hereditary characters are transmitted.
8 Mitochondrion	It is the organelle in which reactions in respiration take place.

Comparison of plant and animal cells

The differences between plant and animal cells are shown in Table 2.2

Table 2.2 Differences between plant and animal cells

Plants cells	Animal cells
1 Chloroplasts are present in green plant cells.	1 Chloroplasts are absent in animal cells.
2 Cell wall of cellulose is present.	2 Cell wall is absent.
3 A few large cell vacuoles are present in mature cells.	3 Cell vacuoles are usually absent. Food or contractile vacuoles may be present.
4 Mature plant cells are not filled with cytoplasm.	4 Mature animal cells contain plentiful cytoplasm, denser than in plant cells.

The similarities between plant and animal cells include the following:

1 Both have cell membranes.
2 Both have cytoplasm.
3 Both have nucleus.
4 Both have cell organelles.

Summary

This chapter has taught the following:

- A cell is the structural and functional unit of which living things are made up.
- Each living thing is made up of one or more living cells.
- A cell shows the seven functional characteristics of all living things: nutrition, respiration, movement, growth, excretion, sensitivity and reproduction.
- A cell may exist as an independent organism, a part of a colony, a part of a filament of cells or a part of a multicellular organism.
- A cell has organelles which carry out specific functions.
- A plant cell resembles an animal cell in some respects but differs from it in other respects.
- An electron microscope makes the detailed study of cells possible.

Revision questions

1 The statement that all living things are made of cells was first made by
   A Dujardin.
   B Robert Hooke.
   C Mathias Schleiden and Theodor Schwann.
   D Von-Mohl.
   E Rudolf Virchow.
2 The part of a cell that is responsible for protein synthesis is called
   A endoplasmic reticulum.
   B nuclear envelope.
   C ribosome.
   D mitochondria.
   E Golgi body.
3 Which one of these is present in both plant cells and animal cells?
   A Cell membrane
   B Chloroplasts
   C Cellulose
   D Large cell vacuoles
   E Cell sap
4 Which of the following statements about cells is true?
   A All cells are alike in structure.
   B Cells in a tissue perform different functions.

C In a multicellular organism, each cell is independent.

D A part of a cell is called an organ.

E A cell can exist as an independent organism.

5 Differentiate between a colony of cells and a filament of cells, using named examples. What is the relationship between the cells in each type of organism?

6 a) Describe the structure of a plant cell.

State

b) three similarities between plant and animal cells.

c) three differences between plant and animal cells.

7 Describe the functions of the following:

a) The cell membrane

b) The nucleus

c) The mitochondrion

d) The Golgi body in a cell.

Chapter 3 The cell and its environment

Introduction

In a living organism, there is constant movement of materials. Within a cell, materials, such as oxygen, food, enzymes, and carbon dioxide move from one part to another. Between a cell and its external environment, there is exchange of materials. The exchange of materials between an organism and its external environment is necessary for the life of the organism.

A simple organism, such as spirogyra, that lives in water, obtains water, mineral salts, oxygen and carbon dioxide from the environment for its vital activities. In multicellular organisms, there is exchange of materials between different parts of one cell, between cells and the tissue fluids that surround them, and between cells and their external environments.

In this chapter, you will learn about some biophysical processes that bring about this exchange of materials. These include diffusion, imbibition and osmosis.

Diffusion

The molecules that make up matter are continually in motion. The speed with which they move varies. If you were to open a bottle of petrol or ethanol for a few seconds in one corner of the laboratory or classroom, everyone in the room would soon smell it. The petrol or ethanol evaporates and the molecules somehow spread from the bottle in your hand to other parts of the room. This spread of molecules happens much faster in gases and vapours than in liquids. It is so slow as to be almost non-existent in solids.

The movement of molecules from a region where they are in higher concentration to a region where they are in lower concentration is called **diffusion**. This movement (or flow or spread) continues until the molecules are evenly dispersed throughout the space available to them. Individual molecules are too small for the human eye to see. It is, however, possible to do experiments that demonstrate the diffusion of many molecules from an area where they are in high concentration to an area where they are in lower concentration.

Activity 3.1 Observing diffusion in liquids

Materials required

Measuring cylinder (minimum capacity 500 cm^3), distilled water, pipette, concentrated copper (II) tetraoxosulphate (VI) (copper sulphate) solution

Procedure

1 Locate a spot in the laboratory where you can have the measuring cylinder standing undisturbed for weeks (a shaded window would be quite suitable).

2 Pour into the measuring cylinder 200 cm^3 of the distilled water. Draw up copper sulphate solution into the pipette. Carefully lower the tip of the pipette to the bottom of the measuring cylinder and very slowly run in 100 cm^3 of the copper sulphate solution. If this is done correctly, there should be a distinct 'line' between the clear distilled water above and the blue copper sulphate solution below. Withdraw the empty pipette slowly, after delivery.

3 Cover and leave the measuring cylinder to stand undisturbed for about two weeks. Observe daily and record your observations in your notebook. Pay particular attention to the boundary or face between the water and copper sulphate solution.

4 After a few days, you should observe a mixing up or shading-off in the colouring at the face, with the blue colour below and the clear, colourless water above. If you leave the cylinder long enough, the colour will eventually become mixed all through the liquid.

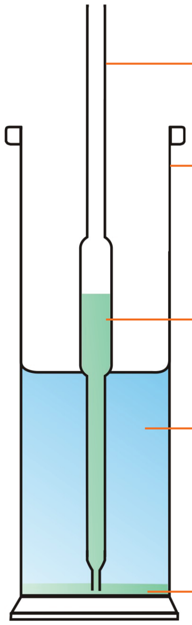


Fig. 3.1 Demonstrating diffusion in liquids

The molecules of the copper (II) tetraoxo sulphate (VI) (copper sulphate) have diffused evenly, all through the water. The water molecules will also have moved into the copper sulphate solution.

Activity 3.2 Observing diffusion in gases

Materials required

Litmus solution, test tube, dilute hydrochloric acid, bottle of ammonia solution, filter or tissue paper, rubber band

Procedure

1 Put water in the test tube to make it about three-quarters full. Add a few drops of litmus solution. To this mixture, add one to two drops of dilute hydrochloric acid, just enough to turn the contents of the test tube red.

2 Ensure that the test tube is completely full by adding more water. Place a filter paper or a piece of tissue paper over the mouth of the test tube. Secure the paper tightly over the test tube with a rubber band.

3 Now invert the test tube, (the contents are now slightly acidic) over an open bottle of ammonia solution. Hold the test tube in this position for a few minutes.

Caution

Keep your face away from the ammonia bottle and avoid breathing in the ammonia fumes. What do you observe in the test tube? How soon after placing the test tube over the bottle of ammonia solution did you notice a change? Account for this observation.

You will have seen the contents of the test tube change colour gradually from red to blue. The change started at the mouth of the inverted test tube and progressed upwards all through the test tube. Molecules of ammonia gas had diffused through the liquid mixture and turned the original acid mixture alkaline. The litmus solution indicated this by its colour change from red to blue. The movement of molecules from one region to another region within a space, depends on the relative concentrations of the molecules in different parts of the space. Diffusion is responsible for much of the transport of substances from area to area within the cell.

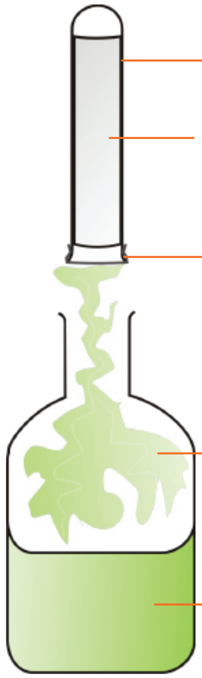


Fig. 3.2 Demonstrating diffusion in gases

Activity 3.3 Observing diffusion of a perfume in air

Material required

A bottle of cheap perfume

Procedure

1. A student releases a puff of the cheap perfume at the back of the class.
2. Students are instructed to stand up and observe the time when each perceives the smell of the perfume.

Observation

One by one, the students stand up and also observe the time as each perceives the smell of the perfume. The distance diffused by the perfume can be plotted on a graph paper against the time taken to do so.

The rate of diffusion is controlled by these factors:

1. *State of matter:* The diffusion of gases is much faster than that of liquids. This is explained by the fact that gas molecules are much less tightly bound to each other and can, therefore, move much faster than liquid molecules.
2. *Temperature:* Generally, a higher temperature increases the speed at which molecules move. Thus, the higher the temperature, the faster the diffusion.
3. *Molecular size:* The size of the molecules that make up a liquid or gas influences the rate of its diffusion. In general, larger molecules diffuse more slowly than smaller molecules.
4. *Differential concentration:* The relative concentration of the molecules of a substance in different parts of a space, that is the concentration gradient, will influence the rate of diffusion of the molecules. The greater this gradient, the greater will be the rate of diffusion. This factor has been expressed as a generalisation called **Fick's law**. It states that the amount of solute diffusing through a unit cross-section of area is directly proportional to the concentration gradient across this section.
5. *The nature of the medium:* Molecules diffuse faster in a gaseous medium than in a liquid medium, and faster in a liquid medium than in a solid medium.

Imbibition and diffusion

In a solid or a dense colloid, the molecules are very close together, and their movement is very limited indeed. However, when a thin piece of dry gelatin is placed in water, it swells, because water pushes apart the molecules of the gelatin and diffuses into spaces between them. Thus, the gelatin swells up, becoming bigger than the original, dry gelatin. This movement of water molecules into substances that swell or increase in volume as a result of the interaction between them and water molecules is called imbibition, which means 'drinking in'.

Imbibition is the explanation for wooden doors becoming difficult to shut or open in wet weather. Imbibition makes the bean seed swell up when left in water for some time. Imbibition leads to a tremendous building of pressure. There have been accounts of rice-laden ships which split when water got into the rice and was imbibed by the grains.

The biological significance of diffusion

Diffusion plays a very important part in the activities of a cell. When molecules are unevenly distributed in a cell, diffusion tends to equalise the distribution. Exchange of substances between the cell and its environment may also be due to diffusion.

Processes in which diffusion occurs in plants

1. Movement of carbon dioxide, for photosynthesis, from the atmosphere, into the leaves through the stomata
2. Movement of oxygen, produced during photosynthesis from the leaves to the atmosphere through the stomata
3. Movement of oxygen for respiration from the atmosphere into the plant through the stomata or lenticels
4. Movement of carbon dioxide produced during respiration from the plant to the atmosphere through the stomata or lenticels
5. Movement of manufactured food from the leaves to other parts of the plant

Processes in which diffusion occurs in animals

1. Gaseous exchanges in amoeba, skin of toad, alveoli of the lungs, and gills of fish
2. Exchange of nutrients between a foetus and the mother through the placenta
3. Absorption of food from the small intestine through the villi into the blood stream

Osmosis

In Activity 3.1, you observed that the molecules of copper sulphate diffused evenly throughout the solution while in Activity 3.2, you observed the diffusion of molecules of ammonia through water containing one or two drops of hydrochloric acid.

In organisms, diffusion generally takes place across membranes. For example, the diffusion of water molecules from the soil into the cells of the root hairs takes place across their cell membranes, the diffusion of carbon dioxide from the cytoplasm of amoeba occurs through its cell membrane into the water in its external environment, the diffusion of water from one cell into a neighbouring cell in the body of a person takes place across cell membranes:

When there is a membrane in the path of diffusion of molecules, one of three possible results will occur depending on the type of membrane and the type of molecules diffusing:

1. Some membranes will not allow the passage of the molecules at all. For instance, a rubber membrane will not allow the passage of the water molecules or copper sulphate molecules. Membranes that will not allow the passage of either solute or solvent molecules through them are said to be **impermeable**.
2. Some membranes, such as filter paper, will allow the passage of all molecules. Such membranes are said to be **fully permeable**.
3. Some membranes will allow the passage of water molecules but not of solute molecules, such as copper sulphate molecules. Such membranes, which allow the passage of one type of molecules but not other types, are called **semi-permeable** membranes.

   Examples of non-living semi-permeable membranes (which are permeable to water but not to solutes like copper sulphate) include cellophane, parchment and visking tube. Living semi-permeable membranes include pig or sheep bladder, unripe pawpaw, Irish potato, yam tuber, cell membrane and tonoplast.

   The passage of water molecules (or solvent molecules) from pure water (or pure solvent) or from a dilute solution into a more concentrated solution, through a semi-permeable membrane, is called **osmosis**. Osmosis is a special type of diffusion: the diffusion of molecules of water (or molecules of other solvents) through a semi-permeable membrane.

The osmotic process

Osmosis involves diffusion of molecules through a semi-permeable membrane. The semi-permeable membrane is very much more permeable to the water (or solvent) molecules than to the solute molecules. A living cell is usually surrounded by a medium which can be described in three ways:

1. If the medium is more concentrated than the cellular fluid, it is described as **hypertonic**. In this case, water molecules move out of the cell into the surrounding medium. The movement of water molecules out of a living cell is called **exosmosis**.
2. If the medium is less concentrated than fluid in the cell, it is described as **hypotonic**. In this case, water molecules move into the living cell. The movement of water molecules into the living cell is called **endosmosis**.
3. If the surrounding medium has the same concentration as the fluid in the cell, it is described as **isotonic**. There is no net movement of water molecules to either side.

Osmosis can also be defined as the movement of water molecules from a hypotonic solution to a hypertonic solution through a semi-permeable membrane.

Activity 3.4 Demonstrating osmosis

Materials required

4 beakers of the same size, 4 thistle funnels, pieces of cellophane materials, rubber bands, candles, granulated sugar (or crushed sugar cubes), stirring rod, pipette, three retort stands

Procedure

1. Prepare in one of the beakers a concentrated sugar solution in the following way. To about 200 cm^3 of water, add the granulated or crushed sugar gradually and stir. On dissolving, add more sugar and stir. Repeat until no more sugar will dissolve.
2. Secure a piece of cellophane material over the end of each of three thistle funnels. To make it airtight, seal the edge with wax from the candle. This may not be necessary if the rubber band holding the cellophane material to the thistle funnel is made very tight.
3. Now, set up the apparatus as in Fig. 3.3. Label the beakers **A**, **B** and **C**. Into beakers **A** and **B**, pour water, and into beaker **C,** pour some of the concentrated solution.
4. With the aid of the pipette, deliver into one of the thistle funnels a quantity of the same water held in beakers **A** and **B**. Stand this thistle funnel in beaker **A**, held up by the retort stand.
5. Set up the other two funnels similarly, but in beakers B and C, in place of water, deliver the concentrated sugar solution into the funnels. Ensure that the three thistle funnels are dipped into the liquid in the beaker to the same level. The level of liquid in each of the three thistle funnels should be the same.
6. Mark the position of the liquid in each funnel. Allow the three beakers and funnels to stand for one hour. Then observe and record your observations.

7 Can you explain your observations in terms of osmosis? Why were experiments A and C included?

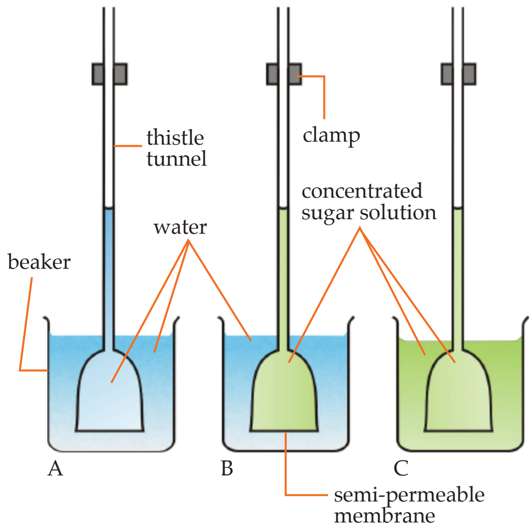


Fig. 3.3 Demonstrating osmosis

Osmotic pressure

When a solution is separated from water (or solvent) by a semi-permeable membrane, osmosis occurs. Osmosis is brought about in this way: on one side of the semi-permeable membrane, there are water molecules only. On the other side of the semi-permeable membrane, there are both water and solute molecules. Since there are more water molecules in the water than in the solution, more water molecules will diffuse from water through the semi-permeable membrane into the solution than from the solution into the water in unit time. As a result, there will be a net movement of water molecules into the solution. You observed in Activity 3.4 that the level of the solution rose in thistle funnel B owing to the net movement of water molecules into the solution.

The pressure which causes osmosis to take place is called **osmotic pressure**. Osmotic pressure is a property of the solution. The effect of the solute in the solution is to increase the concentration of water molecules compared with pure water. Osmotic pressure increases with the concentration of the solution. A 30% solution for example, has higher osmotic pressure than a 10% solution of the same substance.

A solution of sugar in a beaker has the capacity to bring about osmosis, if and when it is separated from water by a semi-permeable membrane. While in the beaker, and while it is not separated from water by a semi-permeable membrane, the solution is said to have an **osmotic potential**. This means it is capable of bringing about osmosis, but it is not yet doing so.

You will recall that the diffusion of petrol from one corner of a room continues until the petrol molecules are equally distributed in all parts of the room. So, one might expect that osmosis would continue until water molecules are equally distributed on both sides of the semi-permeable membrane. In fact this does not happen. As the level of the solution in the thistle funnel in Activity 3.4 rises, the column of the solution in the thistle funnel becomes a pressure pressing down on the solution. This pressure on the solution increases the speed of water molecules in the solution and their rate of diffusion from the solution through the semi-permeable membrane into the water. When equal numbers of water molecules move in both directions in unit time, the rise in the column of the solution will stop. The excess pressure, represented by the column of the solution in the thistle funnel, over the solution in the beaker, is a measure of the osmotic pressure of the solution.

Following from the above, osmotic pressure is defined as that amount of pressure which would need to be applied to just prevent the passage of water into a solution when separated from it by a semi-permeable membrane.

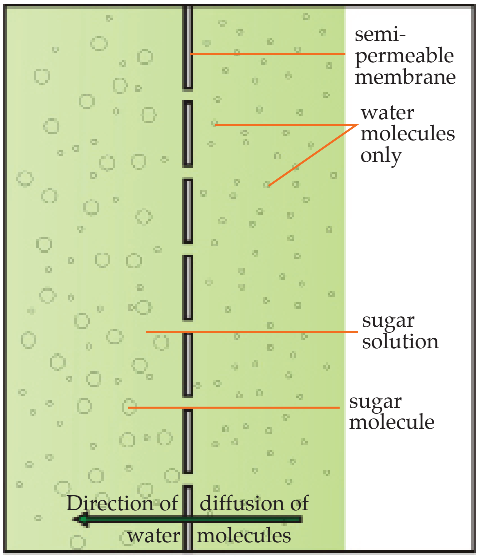


Fig. 3.4 How osmosis takes place

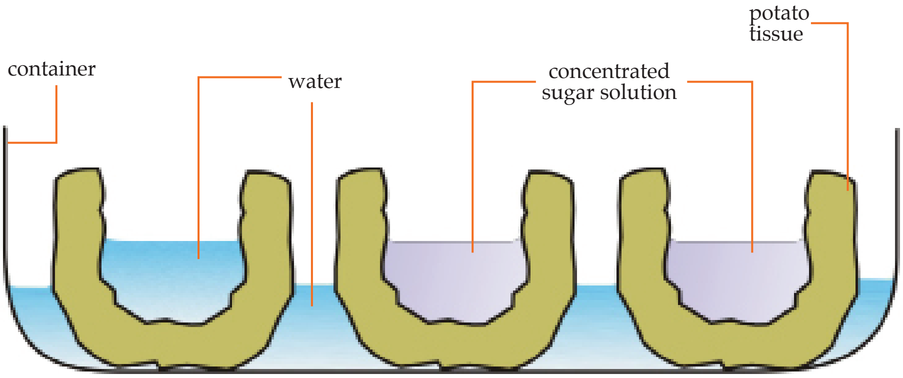


Fig. 3.5 Demonstrating osmosis in living tissue

Activity 3.5 Demonstrating osmosis in living tissues

Materials required

Two young, unripe, pawpaw fruits or four Irish potato tubers, a knife, concentrated sugar solution, three beakers, boiling water

Procedure

1 Prepare a concentrated sugar solution, as in Activity 3.4.
2 Cut each pawpaw fruit into two to produce four halves, of which only three will be used. If you are using Irish potatoes (not sweet potatoes), scoop out a hole in each tuber, then peel the tuber and slice the bottom so that it can sit in the beaker. A piece of yam tuber may be used as substitute.
3 Peel the pawpaw fruit and slice the bottom off so that it will sit in the beaker.
4 Into one pawpaw half (or scooped-out potato tuber), **A**, pour some water. Mark its level and set aside. Into another half **B**, pour some of the concentrated sugar solution, and similarly mark the level and set aside.
5 Place the third pawpaw half in the boiling water for one to two minutes (if using potato, treat the tuber similarly). This treatment kills the cells of the pawpaw or potato. Then cool the pawpaw or potato.
6 Pour some of the concentrated sugar solution into this treated pawpaw or potato tuber, which now becomes specimen **C**. Mark the level of liquid in specimen **C.** then place each specimen in a beaker of water, as in Fig. 3.5. Let them stand for two or three hours. What do you observe? Account for the differences between your observations in **A** and **B**, as well as in **B** and **C.**

There should be a rise of liquid level only in **B** and not in **A** or **C**. In this experiment, the cells of the raw Irish potato or pawpaw act together as a semi-permeable membrane allowing the passage of water but not sugar, the solute. In B, water diffuses through the potato cell down a concentration gradient of water molecules into the sugar solution. The level in B, therefore, rises. In **C,** you killed the potato or pawpaw cells by boiling them. Boiling made the cells fully permeable to both water and sugar allowing the concentration gradient to be removed by the movement of water molecules in and sugar molecules out. As a result, no rise in level is seen in **C.**

Turgidity, plasmolysis and the living cell

The movement of water into and out of cells of an organism is brought about principally by osmosis. This makes osmosis very vital to many biological processes.

Dissolved substances are present in the cytoplasm of living animal cells, and in both the cytoplasm and cell sap of living plant cells. These dissolved substances often inside the vacuoles make the osmotic potential of the cell normally higher than that of the surrounding water medium. For instance, for amoeba and spirogyra, the surrounding medium is normally water in fresh water ponds, while for the red blood corpuscle or erythrocyte, the surrounding medium is the plasma.

When the osmotic potential of a cell is higher than that of the surrounding water medium, water molecules pass into the cell by osmosis. As a plant cell absorbs water by osmosis, the vacuole and the protoplasm increase in volume. The cell is said to be **turgid.** The outward pressure acting on the cell wall as a result of the entry of water molecules by osmosis is known as **turgor pressure.** Similarly, when an animal cell absorbs water by osmosis, it becomes turgid, and the cell membrane becomes firmer.

However, when the osmotic potential of the surrounding water medium is higher than that of the cell, water diffuses out of the cell, the cell loses its turgidity and becomes **flaccid.** A cell that is flaccid is not rigid or firm. In a living plant, when the cells become flaccid, the plant wilts. If living cells (e.g. spirogyra) are put into concentrated salt solution, the series of changes in the cell go beyond merely becoming flaccid. The vacuoles collapse and the cytoplasm shrinks away from the cell-wall. In this state, the cells are said to be **plasmolysed**. If the outflow of water from the cell continues, plasmolysis reaches its last stage in which the protoplasm shrivels into a mass inside the cells. Mild plasmolysis is reversible if the cell is again placed in water. Severe plasmolysis damages the cell and may be irreversible. Since water is the largest component of the protoplasm of the cell, plasmolysis is bound to have a great effect on all the life activities of the cell.

Activity 3.6 Plasmolysis in plant cells

Materials required

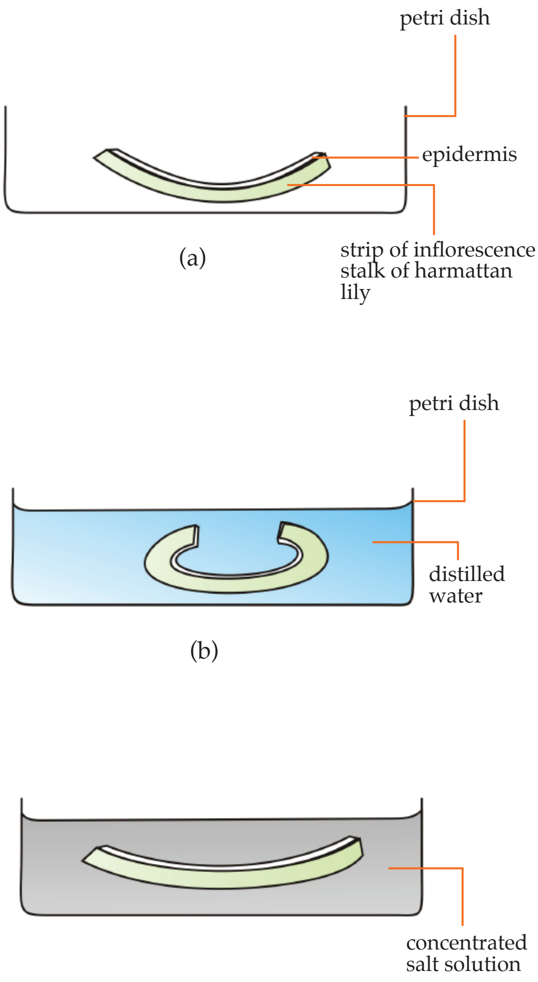
Fresh, healthy filaments of spirogyra in its own pond water, common salt solution, microscope, glass slide, water

Procedure

1. Mount two filaments of fresh spirogyra on a glass slide in a drop of the pond water from which they were collected.
2. Observe the cells under the microscope. What is the state of the turgidity of the cells?
3. Prepare a fairly concentrated common salt solution and replace the pond water in your preparation with a drop of this. This is done by sucking away the pond water from one end of the glass slide, using a filter paper, whilst introducing the common salt solution from the opposite side with a dropping pipette.
4. Again, observe the cells of the filaments and describe your observation in your notebook.
5. Now, replace the common salt solution with the pond water, making sure that the preparation is well flooded with the pond water. View again.

You will observe a 'recovery' as osmosis takes places now, after the plasmolysis observed at (4) above. With the pond water surrounding the cell, water flows back into the cell, as they have osmotic potential than the water.

The stems of non-woody plants are kept upright principally by the turgor pressure exerted by individual cells. On hot or dry days, the cells lose water more rapidly than the roots can take and transport the water to the shoot. There is, therefore, a 'net' loss of water, and so there is partial plasmolysis in the cells and the result is that the plant wilts or droops.



(a)

(b)

(c)

Fig. 3.6 Demonstrating turgor pressure in plant tissues

Activity 3.7 Observing turgor pressure in plant tissues

Materials required

Inflorescence stalk of harmattan lily, distilled water, pen knife, concentrated common salt solution, troughs

Procedure

1 Cut the lily stalk length wise into strips. Place one strip in a dry trough. Observe that the strip tends to curl outwards. This is caused by the turgor pressure in its cortical cells, i.e. cells of the inner layer of the stalk.
2 Place another strip in a trough of distilled water. How does this strip behave?
3 Transfer the strip in the distilled water very quickly, but carefully, into a concentrated common salt solution. What, do you observe? Why? In distilled water, the strip should have curled even further outwards, because more water had gone into the cortical cells by osmosis and so there would have been an increase in turgor pressure in the cortical cells. Placed in the salt solution, the cells lost water to the salt solution and underwent plasmolysis. Turgidity in the cells was lost and so the strip straightened out. This would have been seen as a drooping effect in the full plant.

So far, our demonstration of osmosis has been with plant cells only. The phenomenon can also be shown to take place in animal cells.

Activity 3.8 Observing osmosis and plasmolysis in animal cells

Materials required

Methylated spirit, mounted needle (or sterile lancet), Bunsen burner, microscope slides, cover clips, distilled water, cotton wool, concentrated salt solution, fine sterile pipette, two drops of blood (from your own thumb)

Note

You must only handle your own blood. Your teacher will provide you with special containers into which you can place needles and lancets after the experiment.

Procedure

1 To obtain the blood, first sterilise the skin on the inside surface of your left thumb (if you are right-handed) just below the nail, using a piece of cotton wool moistened with methylated spirit. Do not touch this area until the blood sample has been taken.
2 Sterilise a mounted needle by passing it several times through the hot part of a Bunsen flame. A sterile lancet may be used in place of the sterilised mounted needle.
3 Swing your arms around two or three times to increase the blood flow into your fingers. Now bend the top joint of the sterilised thumb upwards and jab the sterilised needle or lancet firmly into the skin of the thumb.
4 Take a couple of drops of blood from the needle prick with the sterilised pipette. Wash the thumb in water and sterilise with alcohol. A little cotton wool over the needle prick point will stop further bleeding.
5 From the pipette, place a drop of blood on each of two glass slides. Mix the blood on the first glass slide with a drop of concentrated salt solution. Using the edge of a free glass slide, make a thin smear of the blood solution. Place a cover slip over the top.
6 View the preparation under the microscope both under the low and high-power magnification, identify and draw the red blood cells.
7 To the second drop of blood, add a drop of distilled water. Make a thin smear also of this blood solution. View under the microscope and draw the red blood cells. You should have observed that while the red blood cells in the first preparation became plasmolysed, those in the second preparation gained water (by osmosis), swelled up and, in some cases, actually burst. Such bursting of blood cells is called **haemolysis.**

The implication of the result of our observation in Activity 3.8 is clear. If there is any change in the osmotic potential of plasma in which the blood cells float, harm may come to the blood and to the organism. Indeed, in the healthy body, both the fluid and the red cells maintain a constant osmotic potential. The human body, by osmo-regulation, keeps the osmotic potential of the body cells and fluids constant.

Processes in which osmosis is involved in plants

The following are ways by which osmosis occurs in plants:

1 Absorption of water from the soil by root hairs.
2 Movement of water from one living cell into another.

3 Movement of water into and out of guard cells of stomata, leading to opening and closing of the stomata.
4 Maintenance of turgor.

Processes in which osmosis is involved in animals

The following are ways by which osmosis occurs in animals:

1 Reabsorption of water from glomerular filtrate in the kidney tubules.
2 Absorption of water by the colon.
3 Movement of water from one living cell into another.
4 Maintenance of turgor in animal cells.
5 Loss of water through sweating.

Active transport

There are instances during which the general laws governing the directions of flow of materials, as discussed so far in this chapter, may not be obeyed. In certain processes, solute may pass through a membrane from a region of lower concentration to a region of higher concentration, i.e. against the concentration gradient. Such a movement is described as **active transport**.

Active transport is not simply a physical process. Rather, it seems that there are molecules or groups of molecules which actively carry other specific molecules across the membrane i.e. into or out of the cell, using up energy in the process. Active transport of sodium ions, potassium ions and calcium ions in particular is an essential part of the process by which nerves and impulses are propagated along the length of a nerve and by which muscles are induced to contract. Experiments have shown, for example, that cells and tissues contain much less sodium than there is in the extra-cellular fluid. This means that there must be a kind of sodium pump or mechanism by which the plasma membrane selectively drives ions from inside the cell to the outside.

If there were no such selective mechanism, the physical process of diffusion would cause sodium ions to enter the cells through the cell membrane until the sodium concentration was the same inside and outside the cells. It seems that there are other selective ion-pumps in some cells, which are specific for potassium, hydrogen and chloride ions.

The transportation of sodium and potassium ions across the red cell membrane has been observed and found to involve the expenditure of energy. Cells also have a mechanism for the active transport of amino acids, such as its movement through the intestinal epithelium and the kidney tubules. It has been found that there are distinct systems of transport for at least four different amino acids.

The selective re-absorption of substances back into the blood stream during the excretory process in the kidney is another example of active transport. The cells lining the tubules expend energy, to move this substance, by active transport, back into the blood from the urine. This is usually against a concentration gradient. It has been found that a given amount of kidney tissue consumes more oxygen per hour than an equivalent weight of heart muscle, indicating how 'hard-working' the kidneys are. When deprived of oxygen, re-absorption is the first function to cease in the kidney. The substance reabsorbed in greatest amount by the kidney is sodium chloride. Sodium ions are actively reabsorbed by sodium pump in the kidney tubules. Glucose and amino acids are also reabsorbed by the selective active transport of the membranes.

Examples of active absorption in plants and animals

1 Absorption of high concentration of salt or ions in some plants.
2 Reabsorption of glucose, amino acids, and sodium ions in the kidney tubules.
3 Movement of sodium ions out of the axon during the transmission of nerve impulse.

Summary

This chapter has taught the following:

- There is exchange of materials between cells and their environments.
- Diffusion is a movement of materials from a region of higher to a region of lower concentration of the molecules.
- Diffusion occurs in a number of processes in plants and animals; it accounts for exchange of gases and materials between unicellular organisms and their environments.
- Osmosis is the movement of solvent or water molecules from a dilute solution (or pure water) into a more concentrated solution through a semi-permeable membrane.
- Osmosis is involved in the absorption of water by plants.
- Osmotic processes are involved in animals, such as in absorption of water by the colon, reabsorption of water by the kidney tubules and so on.

- Elements, such as sodium, and potassium may be taken up against the concentration gradient by active transport.

Revision questions

1 The diffusion rates of gases are generally higher than those of liquids because ______________.
   A atmospheric air is much lighter than water.
   B gas molecules move faster than those of liquids.
   C the proportion of the atmosphere which is gaseous is very high.
   D liquids tend to cool down more quickly than gases do.
   E of none of the above.
2 Haemolysis is an example of ______________.
   A osmosis.
   B plasmolysis.
   C active transport.
   D hydrolysis.
   E absorption.
3 The toad does not normally drink water. Placed in a dish of salt water, however, a toad may drink the water. This is because the toad ___________.
   A is absorbing molecules of salt through its skin.
   B is losing salt too rapidly to its salty surrounding.
   C requires salt from its surroundings for its bone formation.
   D is losing water from its body to its salty surroundings.
   E requires water from the surroundings for a balanced diet as an amphibian.
4 Under what conditions is it essential to water your vegetable or flower bed? Give reasons for your answer.
5 Leave a leaf of lettuce (or any such common, soft vegetable) in a dish of concentrated salt solution for three to five minutes. Lift it up, observe it and note your observation. Then, quickly drop it into a dish of tap (or well) water. Leave for four to five minutes, then take it out and observe. What has happened? Explain your observations.

Chapter 4 Properties and functions of the cell

Introduction

So far in this book, we have attempted to show the cell as the unit of life. Thus, the cell, as the unit of life, ought to be capable of showing the seven characteristics of living things. First, we studied the unicellular organism, and then we learned that physical laws are in control of the exchange of materials between cells.

In this chapter, our attention will remain focused on the cell, as both a whole organism and part of the body of a multicellular organism. We will also investigate how cells demonstrate the characteristics of living things, such as feeding, respiration, excretion, growth, response to the environment and reproduction.

Feeding

This is the process by which an organism obtains the nourishment which provides it with the energy for life activities as well as materials for growth and maintenance of good health. The food needed by the plant is manufactured by the plant itself from raw materials extracted from its environment. Fungi extract their food from the decaying organic matter on which they grow. Animals are unable to manufacture their own food; they feed on substances made by other organisms.

What does a unicellular organism like *amoeba* feed on? It does not have a mouth, so how does it feed? Answers to these questions will be found in the demonstration which your teacher will set up for you. *Amoeba,* as you will find out, feeds on both animal and plant materials. The method of feeding in amoeba is described as **engulfing**. The animal sends out fingers of its cytoplasm (called **pseudopodia**) to engulf the particles of food. The pseudopodia flow round the food particle and gradually enclose (engulf) the food, along with a drop of water, into the body of the animal. In this way, a food vacuole is formed, inside which digestion takes place, with the aid of digestive enzymes produced by the protozoan.

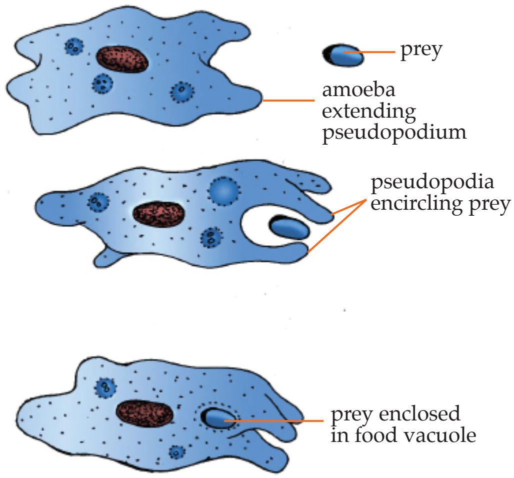


Fig. 4.1 Engulfing feeding action in amoeba

The digested food is diffusible, and is absorbed into the surrounding protoplasm. Undigested and indigestible portions of the food are left behind by the cell, which simply 'flow' away from it. This is a reverse of the engulfing action. Amoeba has no definite mouth or anus, and its mode of feeding is typical of animals with a very simple cell organisation.

The food of *paramecium,* another protozoan, consists mainly of bacteria. It will, however, ingest any small organic particle. *Paramecium* has an oral groove which is lined with fine beating hairs called cilia. Food from the surrounding water is drawn in a cone of water into the gullet by the beating of the cilia.

Large particles are prevented from going into the gullet by a crossed arrangement of cilia at the base of the gullet. The food particle enters the cytoplasm at the cytostome and a food vacuole begins to move along a characteristic path round the body. Digestion and absorption in *paramecium* are continuous and similar to that in *amoeba*. However, undigested food is expelled from the cell at a specific point, the anal pore.

The content of the food vacuole initially is acidic (about pH^7) but becomes alkaline (over pH^4) in the course of digestion. *Paramecium* can store up excess carbohydrate in the form of glycogen. In a class demonstration, you will observe *paramecium* feeding.

The term **nutrient** in biology means a substance which the cell (and by implication, the organism) requires for normal growth and development.

Recall that nutrients are required by organisms for providing energy, as well as providing materials needed for growth and repair. In chemical terms, the main nutrients needed by plants are made up of the elements carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium and magnesium. These are required in relatively substantial quantities by the cell. They are known as macronutrients. Some other nutrients, e.g. manganese, zinc, copper, boron and molybdenum, are required in much smaller quantities. They are the micronutrients. Iron is an essential element for plants. The quantity of iron taken up by a plant is less than that of a macronutrient, but more than that of a micronutrient.

A unicellular organism in an aquatic environment obtains all its nutrients from the water which surrounds it. Higher plants obtain their nutrients, except the gaseous ones, from soil in the form of mineral salts.

Activity 4.1 Effects of different nutrients on spirogyra (whole class project)

Materials required

10 beakers, a fresh supply of spirogyra in pond water, glass slide, hand lens, complete culture. Sach's solution.

Procedure

1 Make a complete Sach's culture solution, by dissolving the following in 1000 cm^3 of distilled water:

Calcium tetraoxosulphate (VI)
(Calcium sulphate) 0.24 g
Calcium tetraoxophosphate (V)
(Calcium phosphate) 0.25 g
Magnesium tetraoxosulphate (VI)
(Magnesium sulphate) 0.25 g
Potassium trioxonitrate (V)
(Potassium nitrate) 0.7 g
Iron (III) chloride 0.005 g
Enough trace elements are usually present as impurities in these compounds and supply the needs of plants.

2 Place a few filamemnts of spirogyra in a beaker of the complete culture solution and label the beaker. In another beaker, place a few filaments of the spirogyra and add the pond water from which the alga was collected. A third beaker of spirogyra will contain only distilled water. Seven other beakers will contain the culture solution but with each lacking only one element. No two beakers should lack the same element. Follow Table 4.1 in the preparation of the culture solution. This experiment has one control, namely, spirogyra in a beakers of complete culture solution.

3 Label each beaker properly, so as to be able to tell exactly what element it lacks. Place a few filaments of spirogyra in each beaker. Observe the beakers for about 4 to 6 weeks. Ensure that none dries up. Record your observations accurately. Compare the results in each of the ten beakers. In which culture solution are the filaments most healthy? In which culture solution have the spirogyra filaments lost most of their colour?

Precautions

1 The beakers must be washed thoroughly, and rinsed several times with distilled water, so as to keep out impurities which may supply elements that can affect the results of the experiment.

2 The outside of each beaker should be covered with black paper to cut off sunlight that will encourage the growth of other photosynthetic algae in the culture solution.

3 Air should be blown into the culture solution from time to time to provide adequate supply of oxygen for the plant. An organism only requires a certain quantity of each nutrient. Too much of a particular nutrient may be harmful to the organism. In agriculture, for example, great care must be taken not to apply too much fertilizer to a crop.

Table 4.1 Recommendation for the preparation of a culture solution

Element lacking	Preparation
Magnesium	Substitute potassium tetraoxosulphate (VI) for magnesium tetraoxosulphate (VI)
Sulphur	Substitute calcium chloride for calcium tetraoxosulphate (VI) and magnesium chloride for magnesium tetraoxosulphate (VI)
Potassium	Substitute calcium trioxonitrate (V) for potassium trioxonitrate (V)
Phosphorus	Substitute calcium trioxonitrate (V) for calcium tetraoxophosphate (V)
Nitrogen	Substitute potassium chloride for potassium trioxonitrate (V)
Calcium	Substitute potassium tetraoxosulphate (VI) for calcium tetraoxosulphate (V) and sodium tetraoxophosphate (V) for calcium tetraoxophosphate (V)
Iron	Leave out iron (III) chloride (ferric chloride).

Activity 4.2 Observing the effect of a high concentration of fertiliser on vegetables

Materials required

Hoes, maize grains or the seeds of any vegetable, e.g. okro, fertiliser

Procedure

1 Prepare three vegetable beds. Let each be about 1m wide and 3 m long. The beds should be at least 15 cm high. Pick a good garden soil for this project.

2 Sow the seeds singly in two rows, along the length of each bed, 50 cm apart, between the rows, and 50 cm apart, each row. Water the beds as necessary. Label the beds **A**, **B**, **C**.

3 12 to 14 days after germination, apply 15 g of mixed fertiliser to each seedling in bed **A**, by making a shallow round furrow, with 15 cm radius away from the seedling putting the fertiliser in the furrow and covering it up. In the same manner, apply 5 g of mixed fertiliser to each seedling in bed **B**. The seedlings in bed **C** are the control.

4 Make a close and regular observation of the three vegetable beds. Record the growth and state the conditions of the plants on the two experimental beds and control bed.

Which treatment gave the better result? What is the effect of high concentration of fertiliser on the plant? We can thus conclude that there is an optimum, i.e. best quantity of fertiliser for optimum growth of the plant experimented with. The same is true for any other plant.

Anabolism

Anabolism is the synthesis, by living things, of complex compounds from simple substances. Living things require food (carbohydrates, lipids, proteins, mineral salts, vitamins and water) for:

1 the production of new protoplasm,

2 growth,

3 repair, and

4 production of energy for life activities,

Types of feeding

There are two main types of feeding or nutrition: **autotrophic** and **heterotrophic** nutrition.

Autotrophic nutrition or feeding

Autotrophic nutrition or feeding is one in which the organism makes its own complex organic food molecules from simple inorganic substances. Autotrophic organisms are 'self-feeding'. Some autotrophic organisms are **photosynthetic** while others are **chemosynthetic**. Autotrophic organisms are also called **autotrophs**.

Photosynthetic autotrophs

Photosynthetic autotrophs are organisms which use chlorophyll to absorb the energy of sunlight. With carbon dioxide and water as raw materials, they make glucose. From glucose, they can synthesise starch and other carbohydrates, lipids, proteins and other compounds.

Photosynthetic autotrophs include green plants, blue-green algae and bacteria that contain chlorophylls.

Chemosynthetic autotrophs

Chemosynthesis is the synthesis of complex organic food molecules from simple inorganic substances, using energy obtained from exergonic inorganic oxidation reactions. Examples of chemosynthetic autotrophs include:

1 Nitrosomonas - a nitrifying bacterium that converts ammonium compounds to nitrates. This reaction releases energy which the bacterium uses for making its food.

2 Nitrobacteria - a nitrifying bacterium that converts nitrites to nitrates. This reaction releases energy used for synthesis of food.

3 A group of chemosynthetic sulphur bacteria oxidise sulphur to tetraoxosulphate (VI) acid
$2S + 2H_2O + 3O_2 \rightarrow 2H_2SO_4 + \text{Energy}$

4 Another group of sulphur bacteria obtains energy by oxidising hydrogen sulphide.

Heterotrophic nutrition or feeding

Animals and non-green plants cannot make their own food. They depend on plants or other animals for their food. Organisms which obtain complex food molecules from plants or animals are said to show heterotrophic nutrition. They take these complex food materials and the foods are digested, that is, they are converted to simple sugars, glycerol and fatty acids and amino acids. These are then absorbed and utilised to provide energy, or to synthesise new prototoplasm for growth or repair of worn-out cells and tissues.

There are different types of heterotrophic feeding, such as holozoic, saprophytic, parasitic and symbiotic feeding.

Methods of collecting and taking in food

Some of the methods by which heterotrophic animals collect and take in food include filter feeding, sucking as well as biting and chewing.

1 **Filter feeding**
A filter feeder strains small particles of food from the water in which it lives. For example, some fish are filter feeders, e.g. herring. Such a fish takes in water through the mouth and passes it out through the gill slits. This process used for breathing is also used for feeding. As the water passes through the gill slits, structures known as gill rackers strain out particles of food from the water, and the animal feeds on these particles. Some whales are filter feeders.

2 **Sucking method of feeding**
Some animals suck liquid food. For instance, aphids suck the juices of plants, while mosquitoes suck the blood of man and other vertebrates.

3 **Chewing and biting methods of feeding**
Locusts, grasshoppers, rats, goats, sheep and cattle bite and chew their food.

The role of enzymes in digestion

An enzyme is an organic catalyst produced in living tissues, which speeds up and controls the rate of metabolic reactions. Food substances eaten by animals are usually complex organic substances. The breakdown of these complex molecules, which can be absorbed by the organisms is **digestion**.

Digestion is brought about by enzymes. The enzymes split the bonds in complex molecules and this changes starch to glucose, lipids to glycerol and fatty acids, and proteins to amino acids.

Activity 4.3 Demonstrate the action of ptyalin in saliva on cooked starch

Materials required

Two test tubes, iodine solution, Benedict's solutions, white tile, a beaker of water, 1% cooked starch solution, 2 glass rods

Procedure

1 Label the test tubes **A**, and **B**.
2 Put about 1cm³ of saliva in each test tube.
3 Boil the saliva in test tube **B** to destroy the enzyme ptyalin in it. This set-up will serve as control.
4 Add 3 cm³ of 1% cooked starch to each test tube, after warming the saliva in it to about 37⁰C in a water bath.
5 Immediately after mixing the saliva and the 1% starch solution in each test tube, use a separate glass rod to take a drop from each test tube. Place the drop on a white tile. Add a drop of iodine solution.
6 Repeat this at intervals of about 5 minutes for 30 minutes. What colour changes did you observe?

Give an explanation for your observations.

Respiration

Respiration is the process by which complex food substances are broken down in a stepwise series of reactions, in cells to produce energy with carbon dioxide and water as waste products. Respiration occurs in all living cells.

The energy produced during respiration is used by the organism for such activities as synthesis of proteins, lipids and protoplasm; germination; cell division and enlargement leading to growth; movement; transmission of nerve impulses; active transport and maintenance of body temperature.

Organisms vary in the amounts of energy they use. A very active organism, such as the horse, uses much more energy than a sluggish one, such as the snail.

Types of respiration

There are two types of respiration. Respiration that occurs in the absence of oxygen is described as **anaerobic** while that which occurs in the presence of oxygen is **aerobic**. Respiration occurs in cells, and for that reason, it is called cellular or tissue respiration.

Chemical process in cellular respiration

The reactions that occur in cellular or tissue respiration are usually represented by the following equation:

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{Energy}$$

This equation represents only a summary of the raw materials and the end products of tissue respiration. The details of respiration are far more complicated than the equation indicates. The pathway for the breakdown of glucose in tissue respiration is shown in Fig. 4.2.

Tissue respiration is divided into two main parts. The first is known as **glycolysis**. Glycolysis is the step - wise series of reactions which leads to the breakdown of glucose to pyruvic acid. The process occurs in the cytoplasm inside cells. It consists of step-wise reactions, each brought about by a specific enzyme. Glycolysis is common to, and occurs in, the same general manner in all organisms.

Oxygen is not required for glycolysis, that is, the process is anaerobic. In this series of reactions, glycogen (in animals) or starch (in plants) is converted to glucose. Then glucose, is converted through ten steps to pyruvic acid. The steps in glycolysis are shown in Fig. 4.3.

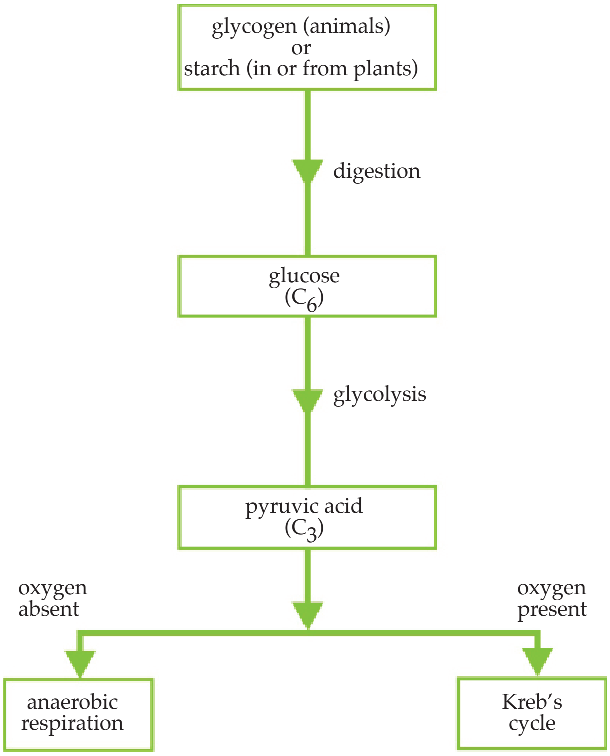


Fig. 4.2 Pathway of glucose breakdown in tissue respiration

Examples of specific enzymes in glycolysis are given below.

1 The conversion of glucose to glucose -6- phosphate is catalysed by the enzyme **hexokinase**.

$$\text{Glucose} + \text{ATP} \xrightarrow{\text{Lexokinase}} \text{Glucose -6- Suiphate} + \text{ADP}$$

2 Glucose -6- phosphate is converted to fructose -6- phosphate by the action of the enzyme **glucose phosphate isomerase**.

In the series of reactions involved in glycolysis, 2 molecules of ATP are used to convert glucose into glucose -6- phosphate, and fructose -6- phosphate into fructose -1-6- diphosphate. In other reactions in glycolysis, 4 molecules of ATP are formed, resulting in a net gain of 2 molecules of ATP.

After the formation of pyruvic acid, the path of further reaction depends on whether the respiration is aerobic or anaerobic.

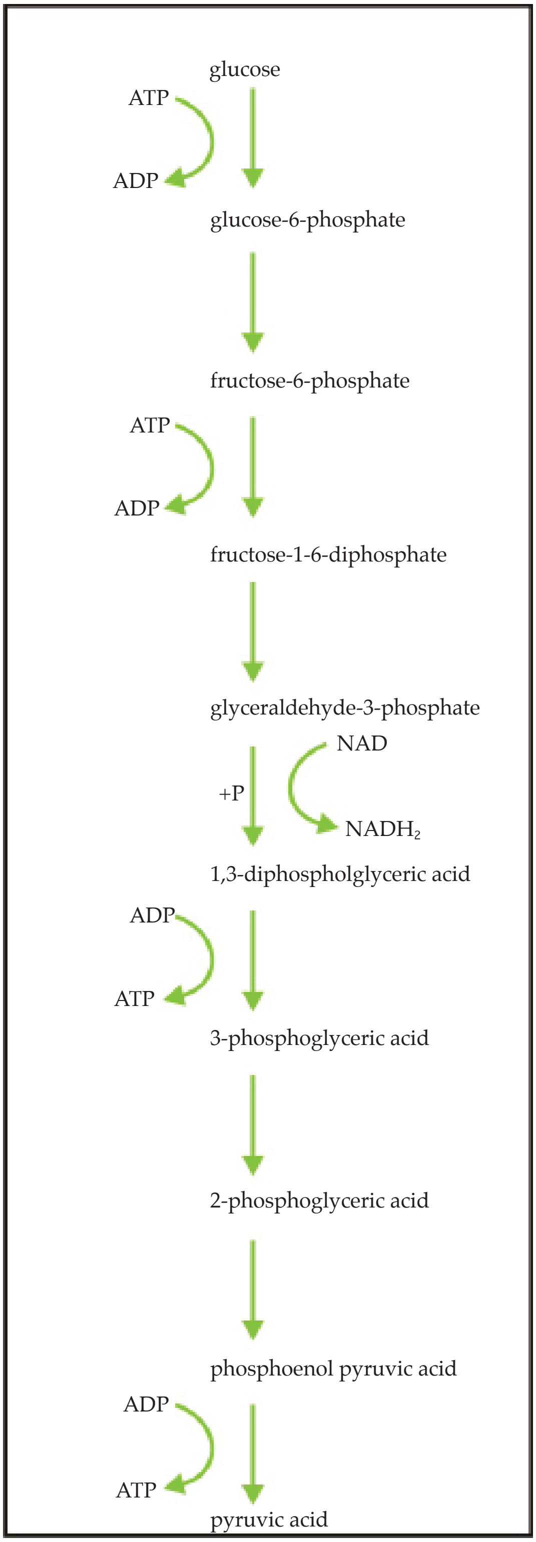


Fig. 4.3 Glycosis

Aerobic tissue respiration

Aerobic respiration is one that occurs in the presence of oxygen. Under aerobic conditions, pyruvic acid is converted into acetyl-coenzyme **A**, which is fed into a cyclic series of enzyme-controlled oxidation reactions known as the **Kreb's cycle** (after the discoverer) or the tricarboxylic acid cycle (TCA). These reactions take place in the mitochondria within the cells. The Kreb's cycle is shown in Fig. 4.4.

Oxygen is not actually involved in the Kreb's cycle. The oxidation reactions that occur in the Kreb's cycle involve the removal of hydrogen ions. These hydrogen ions are accepted by compounds known as hydrogen ion acceptors, such as nicotinamide adenine dinucleotide (NAD) to form reduced nicotinamide adenine dinucleotide ($NADH_2$). The hydrogen ions are passed through a series of reactions in what is called **electron transport chain**. In these reactions, hydrogen is oxidised to water. Energy is released in the form of ATP. This is how oxygen taken in for respiration is used at the tail end of the reactions.

A simple outline description of the Kreb's cycle is this:

1 Pyruvic acid (a 3-carbon carboxylic acid) is decarboxylated (i.e. carbon dioxide is removed). The remaining 2–carbon fragment is combined with a compound called co-enzyme A to form acety co-enzyme A.

2 Oxaloacetic acid, (a 4-carbon acid,) combines with acetyl co-enzyme A(a 2-carbon compound) to form citric acid (a 6-carbon acid).

3 Citric acid loses carbon dioxide and hydrogen ions to form α-ketoglutaric acid (a 5-carbon acid). The hydrogen ions are oxidised in the electron transport system to produce ATP.

4 α-ketoglutaric acid loses carbon dioxide and hydrogen ions to become oxaloacetic acid (a 4-carbon acid).

The cycle of reactions starts all over again.

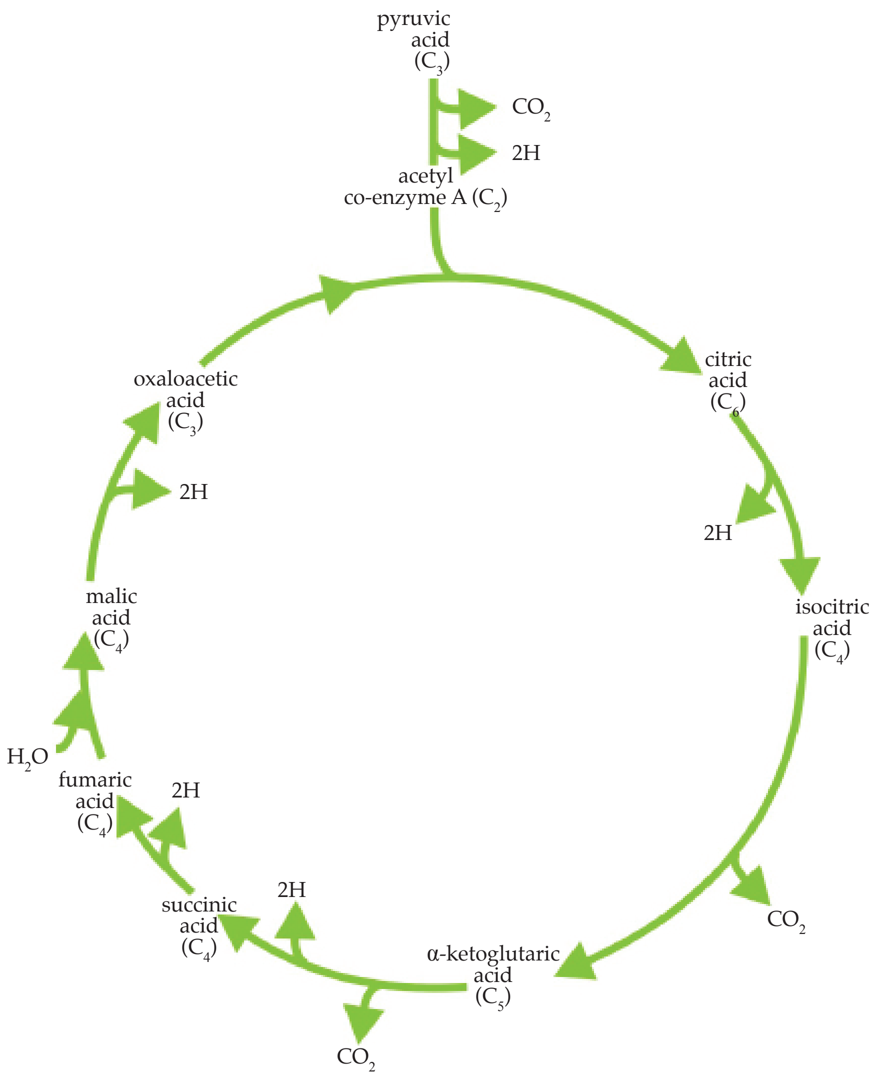


Fig. 4.4 Kreb's cycle

Anaerobic respiration

When oxygen is not present, the path of reactions depends on whether respiration is in a plant or an animal cell (see Fig. 4.5).

In an animal cell or bacterium, lactic acid is formed by anaerobic respiration. The formation of lactic acid occurs for instance, in the skeletal muscles of athletes, when the rate of use of oxygen during a race exceeds the rate of oxygen supply. The vigorous exercise creates an anaerobic condition in which lactate accumulates. The athlete may experience muscle pain. The body is said to have an **oxygen debt**. At the end of the exercise, the individual continues to breathe rapidly for some time, supplying much oxygen to the muscles until the lactic acid is oxidised to carbon dioxide and water. Lactic acid formation is represented by the equation

$$\underset{\text{glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{lactic acid}}{2C_3H_6O_3} + \text{Energy}$$

In a plant cell, the products of anaerobic respiration are ethanol and carbon dioxide. Formation of alcohol is represented by the equation:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{ethanol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2} + \text{Energy}$$

Fermentation is a special case of anaerobic respiration by micro-organisms such as yeast. Yeast fermentation results in the formation of ethanol with production of bubbles of carbon dioxide. Lactic acid bacteria ferment glucose and lactose to lactic acid.

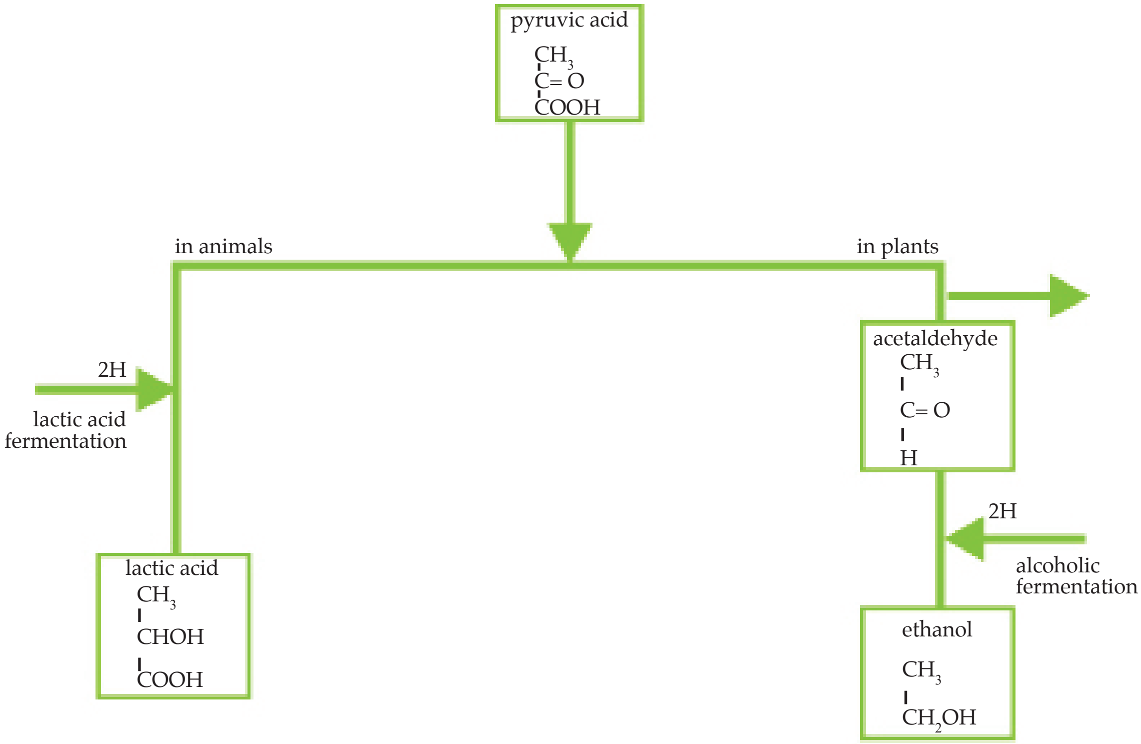


Fig. 4.5 Pathways of anaerobic respiration in animal and plant cells

Energy release during respiration

In aerobic respiration, one molecule of glucose yields 38 molecules of ATP which represent a large amount of energy. In alcoholic fermentation, only 2 molecules of glucose ferment. This represents a small amount of energy compared to that of aerobic respiration.

Activity 4.4 Demonstrating that energy is produced during respiration

Materials required

Soaked cowpea seeds, cotton wool, two vacuum flasks, two thermometers, two clamps and two retort stands per group

Procedure

1 Set up the apparatus as shown in Fig. 4.6. The cowpea seeds in flask A were soaked in water for 2 hours beforehand. Equal number of cowpea seeds in flask B (control) were boiled, cooled and sterilised in dilute formalin solution beforehand, to prevent decay or growth of microorganisms.

2 Leave to stand for 24 hours. The advantages of turning the vaccum flasks upside down are;

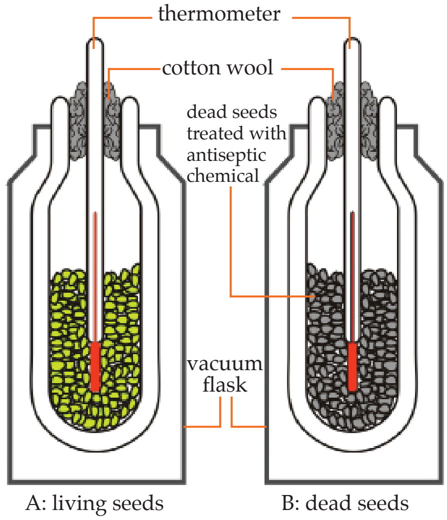


Fig. 4.6 Demonstration of heat production by respiring seeds

a) The thermometer records the temperature of the seeds, not that of the air in the flask.
b) Carbon dioxide is heavier than air, so when the flask is upside down, it diffuses out easily through the cotton wool. If the flask is upright, carbon dioxide accumulates around the seeds and reduces availability of oxygen to the seeds.

3 Read the temperature shown by the thermometer in each flask.

It is normally observed that the thermometer in flask A gives a higher reading than that in flask B. This shows that live, respiring seeds in flask A produce heat energy, while the boiled, non-respiring seeds in flask B do not.

Activity 4.5 Demonstrating fermentation by yeast

Materials required

Two test tubes, cork carrying bent delivery tube, active yeast, lime water, 5% sucrose solution

Procedure

1 Put 5 cm^3 of 5% sucrose solution in a test tube and add half a teaspoonful of active baker's yeast.
2 Quickly place the tube in the apparatus as shown in Fig. 4.6. Set up control without yeast in the other test tube.
3 Observe for 30 minutes.

It is usually observed that the lime water in the apparatus with active yeast turns milky. The residue in flask A has a smell of ethanol. Lime water in control does not turn milky. This leads to the inference that yeast breaks down sucrose solution to produce carbon dioxide and ethanol.

Activity 4.6 Demonstrating respiration by a rat

Materials required

Four containers, rat, lime water, caustic soda solution, tap

Procedure

1 Set up the apparatus as shown in Fig. 4.7. Set up a control experiment without the rat.
2 Start the tap running, so that air will be drawn through the apparatus in the direction indicated by the arrows.

Note that carbon dioxide in incoming air will be absorbed by the caustic soda solution. This is confirmed by the lime water in the next vessel remaining clear.

What do you observe? Does the lime water in container **D** turn milky? What is your inference? What do you observe in the control experiment? You may have observed that the lime water in container **D** turned milky. This indicates that the rat produced carbon dioxide which turned lime water milky. The rat, therefore, respired.

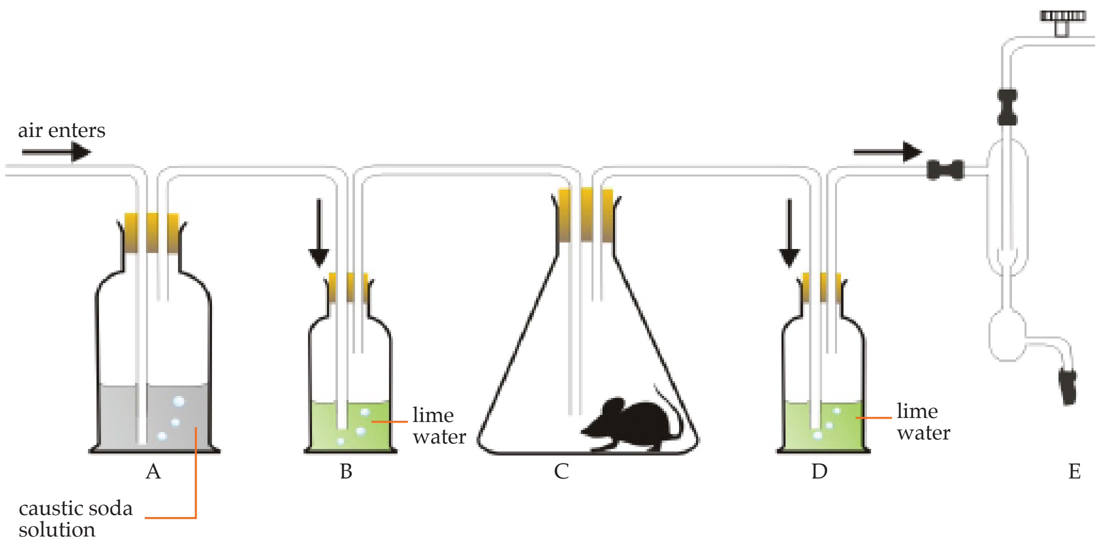


Fig. 4.7 Apparatus for demostrating that a rat respires

Excretion

Excretion is the process by which an organism gets rid of the waste products of metabolism in its cells. Note that the undigested food remaining in the food vacuole of the protozoan is not excretory waste, and the process of getting rid of it is not excretion, but rather, **egestion**. Undigested food egested by higher animals is referred to as **faeces.**

Organisms, no matter how primitive or simple, must get rid of their metabolic waste, otherwise these will accumulate and interfere with normal body metabolism. These waste are actually harmful to the body. In protists, excretion occurs mainly by diffusion. The waste materials simply pass out of the cell by diffusion through the entire cell membrane. Some unicellular organisms have a contractile vacuole in addition as a specialised organelle of excretion.

You should have observed the contractile vacuole of amoeba in earlier lessons. Paramecium has a pair of contractile vacuoles which are both easy to observe.

Activity 4.7 Observing excretion by means of contractile vacuole

Materials required

Fresh water sample or culture rich in paramecium, microscope, glass slide, cover slips, dropping pipette, boiled starch solution

Procedure

1. Viewed under the microscope, protozoans tend to be very mobile. You can slow them down so that they can be more carefully observed. To do this, put a few drops of boiled starch solution on the glass slide. On this, place a drop of your culture.
2. Locate some protozoans. View each, first under the low power, then under higher power magnification. Locate a paramecium and bring its contractile vacuoles into focus. Patiently observe both of them.

The contractile vacuole is basically a structure for osmoregulation. It removes extra water that enters the unicellular aquatic organism either by osmosis or with food. As the contractile vacuole removes the extra water, some soluble metabolic waste may also be collected by it and passed out. In this way, the contractile vacuole functions also as an excretory organelle.

Much of the excretion in paramecium occurs by diffusion through the cell membrane. It is interesting that, among most animals, the excretory organ is generally the organ of osmoregulation as well.

Later on in our study of biology, we will learn that excretion in many organisms can be very complex. In marine fishes, excess salt is excreted through the gills, even against the direction of osmotic pressure. What process do you think these fishes must be using?

By osmosis, water flows into the bodies of the freshwater fishes because there is a concentration gradient between the fishes' body fluids and the surrounding water. To control the water content of the body, freshwater fishes drink little or no water, but excrete a great quantity of urine, thereby getting rid of much water.

Mammals have a very complicated excretory system which involves various organs- lungs for gaseous excretion of carbon dioxide, the kidney: for getting rid of urine, and the skin for excreting water and salts in the form of sweat.

Forms of excretory waste

Carbon dioxide produced by tissue respiration is one of the major excretory products. It is eliminated by diffusion through the whole body surface or via specialised respiratory organs such as gills or lungs.

Nitrogenous waste constitutes another major group of excretory substances. These arise from the metabolism of nitrogenous compounds, such as proteins, the breakdown of protoplasm, the conversion of amino acids to carbohydrates for storage (deamination) or the use of amino acids in tissue respiration. Nitrogenous waste substances are excreted in various forms which have some relationship with the environment of the organisms. Almost all aquatic organisms excrete nitrogenous waste in the form of ammonia, a poisonous gas, which is readily soluble in water, and is readily excreted by aquatic organisms. Terrestrial organisms which have limited access to water, and indeed need to conserve water, excrete nitrogenous waste in other forms.

Birds, reptiles and insects excrete nitrogenous waste as uric acid, which is almost insoluble in water and leaves the body as solid crystals. Uric acid can be stored for a long time without being absorbed into the body to cause harm. Mammals excrete nitrogenous waste as urea, which is soluble in water in the urine.

Growth

Growth is an irreversible increase in size and or dry mass. Cell division by mitosis, cell enlargement and cell differentiation form the basis for growth. Growth in an organism may be recognised in several ways. In a unicellular organism, growth is recognised by an increase in size and mass of the cell. Further, when the unicellular organism reproduces, such as by binary fission, there is an increase in the number of individuals. This is an evidence of growth.

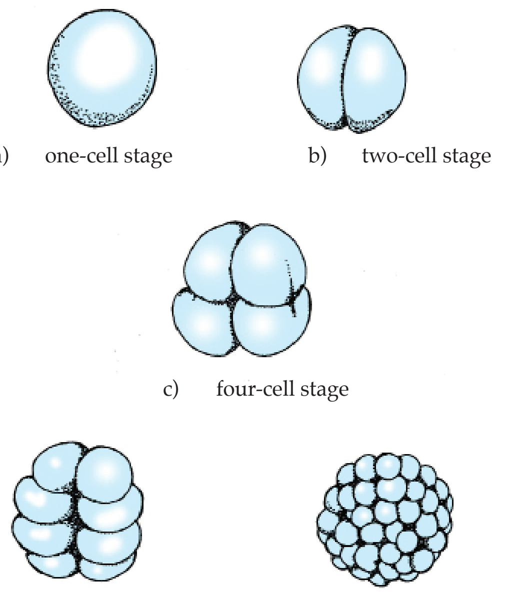
In a multicellular organism, growth is recognised by an increase in the number of cells. When the cells assimilate nutrients, enlarge and differentiate into issues, there is increase in size, length and mass as evidence of growth.

True growth is usually not reversible. Increase in size or mass due to uptake of water is not true growth. A good way of telling whether the in size or mass of organism is true growth or simply due to uptake of water is to compare the dry weight of representative samples of the organisms over a period of time. If the number of cells making up an organism increase without there being any accompanying increase in size or mass, this is still true growth. An example of this is shown in Fig. 4.8 below.

In the early development of the fertilised frog egg, numerous cell divisions or cleavages by mitosis result in more and more cells, but there is, at least initially, no increase in the size or mass of the embryo.

Aspects of growth include:

1 Increase in number of cells
2 Increase in number in size (height, length, breath, girth)
3 Increase in dry mass
4 Differentiation of cells into tissues and organs
5 Synthesis of new body material



a) one-cell stage
b) two-cell stage
c) four-cell stage
d) eight-cell stage
e) many-cell stage

Fig. 4.8 Early cleavage stages in the frog embryo

Mitosis

Mitosis is the division of a **somatic** cell (i.e. a body cell as distinct from a reproductive cell) into two daughter cells. This type of cell division may occur in connection with growth, or in connection with repair of wear and tear. In unicellular organisms usually, each cell can divide. In multicellular organisms all cells cannot divide. In plants, mitosis occurs normally only in cells located at the tips of shoots and roots in the cambium or in the other specific parts.

These cells which can divide are said to be **meristematics,** and a group of meristematic cells, such as that found at the tip of a stem is called a **meristem**. Mature plant cells do not normally divide but a wound may cause mature plant cells to become meristematic, such as when a hedge is cut. In animals, cells which can divide are not located at the tips of the body, but are in various tissues all over the body.

Mitosis consists of a division of the nucleus followed by a division of the cytoplasm. The division of the nucleus is a continuous process, but for convenience of description, it is considered to be made up of steps called **prophase**, **metaphase**, **anaphase**, and **telophase**. The process of mitosis in an animal cell will now be described.

Prophase

In early prophase, fine threads known as chromosomes appear in the nucleus. These chromosomes can now be stained and seen under the microscope, whereas in an undividing cell, they cannot be seen. The number of chromosomes is constant in each cell of a species. For example, in the maize plant, the number of chromosomes in the nucleus of a body cell is 20, while in the body cell of a human being, the number of chromosomes is 46.

Early in prophase, the two centrosomes, located just outside the nucleus of the cell, separate. Each moves to one of the two opposite poles. When the centrosomes arrive at the opposite poles, fine filaments called **aster** fibers form around them. Meanwhile changes continue in the nucleus. The nucleolus disappears. The nuclear membrane disintegrates and the chromosomes lie free in the cytoplasm. Filaments are formed which run from the middle of each cell to the poles. These filaments join with the aster fibres to form a structure known as the spindle.

In late prophase, the chromosomes are seen to be composed of two strands each. The two strands, called **chromatids**, are held together at a point called the **centromere**.

Metaphase

In the next stage called the metaphase, the chromosomes, each made of two chromatids, come to lie at the equator of the cell. Each chromosome is attached to a spindle fibre at the centromere.

Anaphase

The two chromatids in each chromosome separate at the centromere and begin to move toward opposite poles attached to spindle fibres.

Telophase

The chromatids arrive at the poles. At each pole, a new daughter nucleus is reconstituted containing the number of chromatids equal to the number of chromosomes in the parent cell. A new nucleus is formed. While this is going on, the spindle gradually breaks down.

Summary of mitosis

1 **Interphase**

- Cell is not dividing.
- No chromosomes is visible.

2 **Early prophase**

- Centriole pairs separate and move to opposite poles.
- Aster rays form around centriole pairs.
- Spindle fibres develop between the centriole pairs to form a spindle.
- Chromosomes become visible in nucleus, then

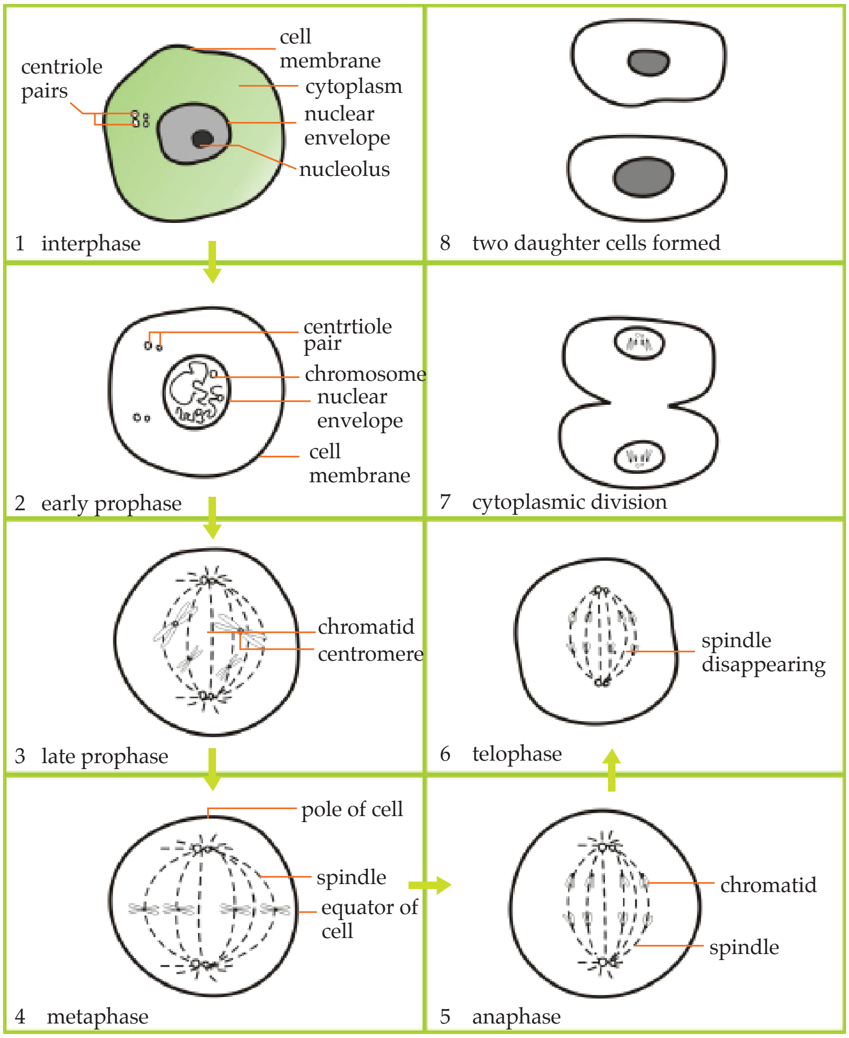


Fig. 4.9 Stages of mitosis

shorten and thicken. Each chromosome can be seen to be made up of two chromatids joined at the contromere.

3 **Late prophase**
- Nucleus membrane disappears.
- Choromosomes lie free in the cytoplasm.

4 **Metaphase**
- Choromosomes come to lie around the equator of the cell.

5 **Anaphase**
- The two chromatids in each choromosome separate at the centrome, and are moved towards opposite poles, along the spindle fibres.

6 **Telophase**
- Chromatids arrive at the poles.
- Spindle gradually disappears.
- A nuclear membrane forms around each set of chromatids
- Chromatids gradually become invisible.

This is the end of nuclear division (mitosis) proper. It is followed by the division of the cytoplasm.

Cytoplasmic division

After the division of the nucleus into two daughter nuclei, the cytoplasm now divides into two, along the equator of the cell. In an animal's cell, the cytoplasmic division starts by a constriction forming around the middle of the cell. This constriction continues to deepen until the division is complete. Two daughter cells are formed, each with the same number of chromatids as the number of chromosomes in the parent cell.

Interphase

The interphase follows the completion of one cell division. The interphase was formerly thought to be a resting period for the cell, but it is now known to be a period of synthesis of body materials and preparation for the next division.

During the interphase, each chromatid synthesises its opposite half to make a chromosome. New protoplasm is synthesised and endoplasmic reticulum, mitochondria, centrosomes and other cell organelles which broke down during mitosis are formed. The cell grows to a suitable size so that it can divide again.

The stages of mitosis in a plant cell are similar to those in an animal cell except that, in a plant cell,

1 there are no centrosomes, and the formation of spindle fibres goes ahead without the movement of centrosomes of the poles;

2 cytoplasmic division is not by constriction of the cytoplasmic but by the lying down of a cell wall between the two daughter nuclei.

Cell enlargement and differentiation

Cell division is usually followed by cell enlargement and cell differentiation. For instance, of the cells formed by the cambium in a plant, some specialise into xylem, and some into phloem cells. Again, all the cells in human body come from one original cell: the zygote. However, as cell division continues, some cells differentiate into nerve cells, others into bone cells, others into skin cells, muscle cells and so on.

Activity 4.8 Observing cell division

Materials required

A variety of prepared slides of root tips, microscope

Procedure

1 Examine under the microscope, each of the slides provided.

2 Make a high power magnification drawing of as many of the cells as you require to give you a complete story of the process of cell division or mitosis.

Growth curves

There is a pattern to growth which, by and large, is shared by both plants and animals. Perennial plants have more open growth than animals. They grow for relatively much longer periods. Even after what is called maturation, the pattern of growth is still very similar to that in animals.

Activity 4.9 Growth curves of height of plants

Materials required

Seedlings of common fast growing annuals (e.g. balsam, sunflower, Okro plant) in pots, metre rules, graph paper

Procedure

1 Maintain the pot of seedlings assigned to you by watering it and ensuring that it obtains adequate air and sunlight. Record the height of two or three seedlings at weekly intervals. Record the heights in centimetres.

2 Plot the average height of the plants over 8 to 10

weeks on a height/time graph. If you now continue for long enough, you will obtain a graph not too different from Fig. 4.10. A growth curve is a graph which shows the patten of growth of an organism or a part of it, with time. Calculate from your average height figures how much the plants grew each week. Do this by subtracting from each week's average height, the average height of the plants the week before.

This is the weekly increment in height. Plot the weekly increment against time. What shape of curve do you get? Discuss the shape of curve with your teacher.

You have observed and recorded the growth of a plant by way of its height. Growth of guinea pigs may also be measured by an increase in body weight.

Table 4.2 Heights of seedlings over eight weeks

Height (cm) seedlings	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**
A								
B								
C								
Average height								

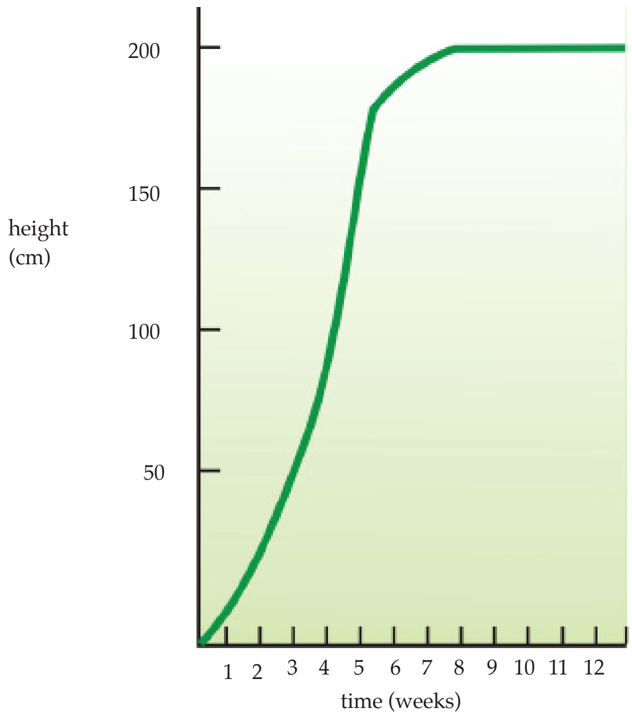


Fig. 4.10 Growth curve of plant stem

Activity 4.10 Measuring increase in mass of guinea pigs

Materials required

Guinea pigs (about 1 week old), suitable animal feed, weighing scale, labels, suitable bag for weighing the guinea pigs

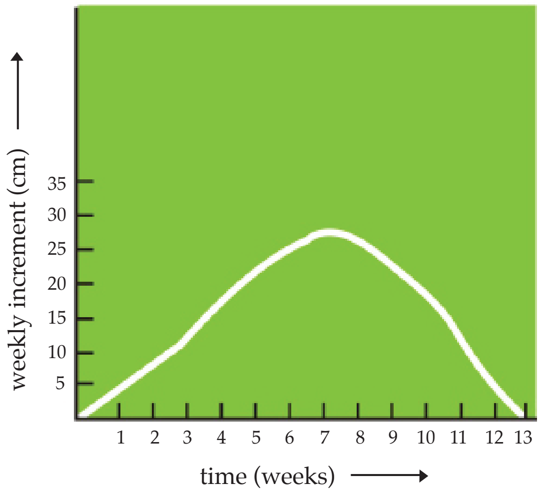


Fig. 4.11 Graph of weekly increment in length of stem

Procedure

1 Mark the animal assigned to your group for easy identification.

2 Feed the animal and provide it with regular and adequate water supply as your teacher will direct. Use the weighing balance provided to weigh the guinea pig. Record this weight and repeat every week. After 8 to 10 weeks, plot the weights (in kg) against time (in weeks).

3 Describe the shape of your graph and compare your graphs for Activity 4.9 and Activity 4.10. When the weekly increment in growth is plotted against time, it is observed that increase in mass is rather slow initially, and then becomes rapid. With increasing age, the increase tapers off. In most healthy humans, increases in height and weight usually stop in the early 20s. Cessation of growth is a characteristic of mammals and birds.

Generally, in other vertebrates, most invertebrates and many plants, growth may continue throughout life. In these living things, growth tends to become very slow with age. The growth rate is highest at the beginning of the life of the organism, and then steadily falls until growth stops or the organism dies.

The increase in growth, expressed as a percentage of the existing mass or size, is a better index of growth than the absolute growth. The 10 kg baby who gains 2 kg in a year is growing faster than the 50 kg man who gains 5 kg in one year. The baby's increase in growth is a 20 percent gain whereas the 5kg increase in growth of the man is only 10 per cent.

Growth in insects is especially interesting, because insects' bodies are protected and supported by a hard outer shell called an exoskeleton. The exoskeleton of the insect limits its growth and confines the body tissues.

Growth is, therefore, in spurts, and is accompanied by the moulting of the old exoskeleton and the growth of a new and larger one. Growth ceases after the last moulting, when the insect is considered to have achieved adult-hood. For this reason, it is safe (and scientific) to talk of the 'adult size' of an insect, as this size is more or less fixed for each given insect.

Regions of fastest growth

Do the different parts of a root or stem grow at the same pace? You will now find out by yourself through a practical investigation.

Activity 4.11 Determining the region of fastest growth in a root

Materials required

Five cowpea seeds, blotting paper, water, gas jar, marking ink, pen

Procedure

1 Place five cowpea seeds between the wall of a gas jar and a layer of blotting paper that lines the inner surface of the gas jar.

2 Put some water into the gas jar to a level well below the cowpea seeds, so that the blotting paper draws the water up to the seeds.

3 In about four days, the cowpea seeds germinate. Select three seedlings with straight radicles. Bring out the seedlings and lay them flat on wet blotting paper.

4 Mark the last 2 cm of each radicle with marking ink into 2 mm portions.

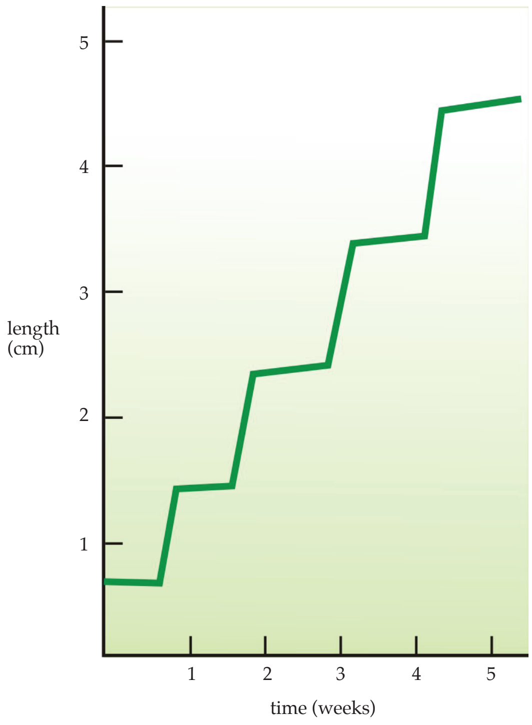


Fig. 4.12 Growth curve of insects

5 Replace the seedlings in the gas jar wall. Place the gas jar in the dark for 48 hours.
6 Observe the division on the radicle which were initially equal. Are some divisions longer than the other after 48 hours? In which part of the radicle are the divisions longer than before?

It is normally observed that some spaces have elongated more than others. The region of greater elongation is a few mm behind the apex of the root. This region is the region of cell elongation.

Activity 4.12 Determining the region of fastest growth in length of stems

Materials required

Five cowpea seeds, a small plastic pot for planting, seeds, water, garden soil, marking ink, pen

Procedure

1 Plant five cowpea seeds in garden soil in a plastic pot. Water the soil to keep it moist. Leave the pot in a secure place, with adequate sunlight.
2 When the seedlings grow up to about 4 cm, use marking ink to mark the shoot apex of two cowpea seedlings into 1 mm spaces. Leave the seedlings for 48 hours.
3 Observe the marks. Are the divisions still equal in length? In which part of the stem are the divisions longer than in other parts?

You should have observed that the greatest elongation occurred within a few mm behind the shoot apex.

Environmental factors that affect growth

Several environmental factors affect growth. You may have observed that many plants grow faster in rainy season when water is available in adequate amounts than in the dry seasons, e.g. mango plant. In the dry season the shoot of some plants die, and the plants survive the dry season by means of seeds e.g. cowpea and maize, or underground part, e.g. yam and cocoyam.

Growth requires synthesis of new protoplasm and other body materials, such as cellulose (in plants). Food is necessary for synthesis of protoplasm and body materials. Energy obtained through respiration is also necessary for synthesis of body materials. Warmth is necessary for reactions that are brought about by enzymes during respiration or synthesis of body materials.

Therefore, the environmental factors necessary for the growth of plants include the following:

1 *Adequate sunlight, water and carbon dioxide* (for photosynthesis)
2 *Mineral salts* (for synthesis of proteins, enzymes and other essential substances in the body)
3 *Warm temperature* (for enzymes to catalyse reactions at a suitable speed), e.g. optimum temperature for man is 37^{o}C
4 *Oxygen* for respiration

Environmental factors necessary for the growth of animals include the following:

1 *Balanced diet* (adequate amounts of carbohydrates, lipids, proteins, mineral salts, vitamins and water)
2 *Oxygen*
3 *Warmth* (or suitable temperature)

Regulation of growth by hormones

Regulation of growth means co-ordination and control of growth, so that different parts of an organism grow in proportion and in a balanced manner to one another.

For instance, in a plant, as the shoot system grows, the root system grows to match it.

Growth is regulated by hormones. In animals, a hormone is a substance secreted by an endocrine gland or a tissue, which is transported by the blood stream to other parts of the body, and which causes a response in a specific organ or tissue. In plants, a hormone is a chemical substance produced in one part of a plant, in small quantities, which is capable of producing effect in other parts of the plant. In plants and animals, there are hormones that regulate growth.

Hormones that regulate growth in plants

Hormones that regulate growth in plants include **auxins, cytokinins, gibberelins, abscissic acid** and **ethylene**. These hormones influence different aspects of growth as described below:

Auxins

Our knowledge about auxins has been built up gradually over many years. In plants of the grass family, e.g. wheat, oat and maize, there is a sheath called the **celeoptile**, which covers and protects the plumule as the seed germinates. The celeoptile pushes through the soil and then the plumule bursts through the celeoptile. Growth in celeoptile is mainly by cell elongation. Seedlings bend towards light coming from one side. **Charles Darwin** studied this response of seedlings to light in 1880, using celeoptile, and found that if the tip of the celeoptile was cut off or covered with metal foil, the bending did not occur. This showed that the tip received the stimulus of light coming from one side, but the response occurred at a little distance behind the tip.

In 1928, **F. W. Went** found that if the tip of oat celeoptile was cut off and removed, growth of the celeoptile stopped. If the cut tip was later replaced, growth started again. If the cut tip was placed with the cut surface in contact with a small block of agar for some time, then the agar block was placed on the cut celeoptile, the agar stimulated growth. This indicated that the tip of the celeoptile produced a substance, which diffused downwards in the stem and stimulated that aspect of growth represented by cell elongation.

This natural chemical substance has been isolated and named auxin. Its scientific name is **indole acetic acid** (IAA). Several other substances with similar action are now known, such as **indole butyric acid.** Some of these have been synthesised artificially. All of such substances are called auxins. Auxin has several actions in plants, including the following:

1 **Stem elongation**
Auxin produced by cells at the shoot tip diffuses downwards in the stem and brings about that aspect of growth represented by cell elongation. This elongation of cells behind the stem tip makes the stem increase in length.

2 **Suppression of lateral buds**
The auxin, which is produced by cells at the shoot tip, and which diffuses downwards in the stem, inhibits the development of lateral buds. This is because different concentrations of auxin stimulate the stem, root or lateral buds. Auxin concentration which stimulates cell elongation in the stem is too high for, and inhibits the growth of lateral buds. In this way, the apical bud continues to grow while the lateral buds are suppressed. This is called **apical dominance.** When a hedge is cut, the apical buds are cut, then apical dominance is removed, and lateral buds grow.

3 **Root elongation**
Auxin produced by cells at the root tip stimulates cell elongation behind the root tip, and brings about growth in length of the root. The concentration of auxin that stimulates cell elongation in the root is smaller than the concentration of auxin which stimulates cell elongation in the stem.

4 **Root initiation**
Auxin stimulates root initiation. When a stem cutting is planted, such as the stem cutting of a cassava, buds appear on the stem. The buds on the stem produce auxin, which diffuses downwards in the stem, and stimulates root formation.

5 **Phototropic response**
Auxin makes stem bend towards light that comes to a plant from one side. When light rays reach a stem from one side, the unilateral light causes unequal concentration of auxin on different sides of the stem. The shaded side has a higher concentration of auxin and grows than the lit side, hence the bending towards the source of light.

6 **Geotropic response**
When a root is placed horizontally, more auxin accumulates on the lower side than on the upper side. In the root, the high concentration of auxin on the lower side inhibits cell elongation, while the low concentration of auxin on the upper side promotes cell elongation. Hence the root bends towards gravity.

7 **Leaf fall**
Auxin formed by young leaves diffuses downwards through the petioles into the stem, and prevents the leaves from falling off. When a leaf grows olds and its ability to produce auxin drops or stops, the leaf falls off. Leaf fall is preceded by the death of a layer of cells at the base of the petiole called the **abscision layer.** This is a layer of parenchyma cells. When the leaf becomes old, auxin production stops, the parenchyma cells in the abscission layer die and dry up. The leaf can then fall.

8 **Renewal of cambium activity**
In the dry season, many trees become dormant and shed their leaves. At the beginning of the rainy season, new shoot buds are formed. These produce auxin which diffuses into the stem and stimulates cambium cells to become active.

Cytokinins
Cytokinins are a kind of plant hormones that are produced in actively growing tissues, such as embryos, developing roots and fruits.

Functions of cytokinins
1 Cytokinins stimulate cell division.
2 They stimulate the development of shoot buds.
3 They promote the growth of lateral buds.
4 They retard ageing of plant organs.
5 They break dormancy in some seeds.
6 They include flowering in some plants.
7 They stimulate growth in leaves.
8 Cytokinins and auxins interact to produce cell division and cell enlargement. In cells growing in the laboratory in tissue culture, an auxin with a low concentration of cytokinin produces rapid cell enlargement leading to the formation of a few large cells. On the other hand, a cytokinin with a low concentration of auxin, results in rapid cell division forming a large umber of small cells. Nor mal growth depends on a balance between the two hormones.

Gibberellins
Gibberellins are plant hormones which stimulate both cell division and cell elongation. Some of the observed effects of gibberellins on growth of plants are as follows:
1 When gibberellins are applied to genetic dwarf plants, they grow to normal size.
2 Gibberellins cause stem elongation in normal non-dwarf plants.
3 Some plants, such as cabbage form leaf rosettes before flowering. In a rosette, the leaves develop and remain clustered together because the stem does not elongate. These plants can be induced to flower by exposure to long days or a period of cold (in the temperate countries). Application of gibberellins causes the plants to grow tall (bolt) and flower.
4 In germinating grass seeds, the embryo secretes gibberellin, which stimulates the aleuron layer to produce enzymes, such as alphamylase, which hydrolises the starch in the endosperm.

Abscissic acid or dormin
Abscissic acid is produced in many parts of the plant, such as stem, leaf, seed and fruit.

Functions of abscissic acid
1 Abscissic acid inhibits bud development and growth.
2 It inhibits mitosis in meristematic cells, such as vascular cambium.
3 It causes dormancy of seeds.
4 It stimulates the formation of the abscission layer which leads to fruit, leaf and flower fall.

Ethylene (ethene)
Ethylene is a gaseous growth regulator produced by various parts of plants.

Functions of ethylene
1 Ethene (ethylene) inhibits stem elongation.
2 It accelerates the abscission of leaves, flowers and fruits.
3 It causes the changes that take place during ripening of fruits.
4 It hastens the ripening of fruits.
5 It is associated with the process of ageing of plant organs.

Hormones that regulate growth in animals

Pituitary gland
The pituitary gland has a very important effect on growth. If the pituitary gland is removed from a young animal, it ceases to grow, and fails to develop sexually.

Thyroid gland
The thyroid gland also has a strong effect on growth, some of which are as follows:
1 If an animal does not produce enough thyroxin, it

does not grow to a normal size.
2 Thyroxin stimulates mental growth and development.
3 In frogs, if tadpoles do not produce enough thyroxine, they will not metamorphose into adult frogs. If they produce too much thyroxine, metamorphosis is quicker than normal.
4 Too much thyroxin causes hyperactivity. The individual eats too much, is too active and loses weight.

Cell reactions to its environment

One of the characteristics of living things is that they can respond to stimuli. A **stimulus** is an environmental change which induces or brings about a response in a cell or organism.

If you mistakenly place your hand on a hot object, you will quickly withdraw your hand. The heat of the object is a stimulus, to which you respond by withdrawing your hand. If someone pricks your body with pin, you will withdraw from the pin. The prick of the pin is a stimulus to which you respond by withdrawing your body. Examples of stimuli include light intensity, temperature, hydrogen ion concentration, presence of chemicals and concentration of oxygen or carbon dioxide.

The ability of a living organism to respond to stimuli is called **irritability.** Organisms show irritability or sensitivity in variety of ways. In this chapter, you will learn about three types of responses to stimuli, namely **taxism, tropism** and **nastism.** Responses of organisms to stimuli are usually advantageous to them.

Taxism

If you step on a cat's foot by chance, the cat will quickly withdraw the foot and move away from you. If you present food to the cat, the cat will move towards the food. In each case, the cat is responding to a stimulus of pain or gain. In one case, the response is a movement away from the stimulus (this is described as a negative response) while in the other case, response is a movement towards the stimulus (this is described as a positive response).

Taxism is the movement of a whole organism or a freely moving part of it, towards or away from a stimulus. A **tactic movement** bears a relationship with the direction of the stimulus, i.e. it is a directional movement.

Taxis in prostista

In the prostista, an organism consists of only one cell. Even these organisms display sensitivity which clearly shows that sensitivity is a property of protoplasm.

Chlamydomonas

Chlamydomonas relies on photosynthesis to make its food. It has an eye spot with which it locates areas of suitable light intensity. The organism swims with its flagella to such areas. *Chlamydomonas*, therefore, shows positive phototaxis. Phototaxis is defined as the movement of a whole organism in response to an external stimulus of light.

Euglena viridis

Euglena viridis is a protista which makes its own food by photosynthesis. It responds to the stimulus of light by swimming parallel to light rays towards the source of light. *Euglena* is positively phototactic.

Amoeba

Amoeba prefers dim diffuse light to bright light. It, therefore, shows negative phototaxis to bright light. *Amoeba* also displays other kinds of taxis. When it comes in contact with a strong chemical, such as an acid, it stops and reverses its movement. This is a negative taxis. When an *amoeba* is given an electric shock, it withdraws all its pseudopodia and assumes a spherical shape.

Paramecium

Paramecium is sensitive to dissolved chemicals, oxygen, and carbon dioxide concentrations, light, touch and temperature all over the body surface. Apart from a few long tactile cilia at the posterior end, it has no special sense organelles.

Paramecium has cilia in the oral groove which beat strongly, drawing water towards the organism. This helps the organism to sample water that lies ahead of it. It reacts to unfavourable conditions by stopping the beat of the cilia for a few seconds, then the cilia beat in the reverse direction causing the organism to move back, and the organism resumes forward movement at a different angle. This behaviour has been called 'avoiding reaction' or **avoidance behaviour.** It enables the *paramecium* to avoid the unfavourable stimulus. *Paramecium* also avoids obstacles through the avoiding reaction.

In plants and animals, motile gametes show taxism. Usually, the male gamete moves towards the female gamete in a liquid medium.

Tropism

Most plants are fixed in their positions. They do not move from place to place. Nevertheless, parts of plants can carry out limited movements. For instance, when

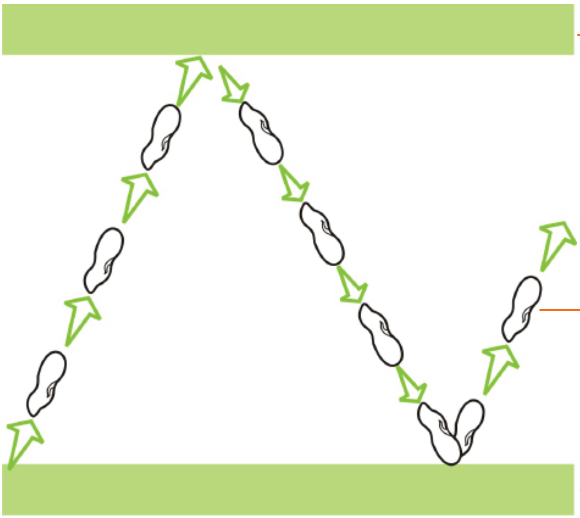


Fig. 4.13 Avoiding reaction by paramecium

a pot containing seedlings of maize, beans or other plants, is placed near a window, the seedlings bend towards light coming in through the window. Such bending of seedlings occurs because one side of the stem grows faster than the other side. The bending of seedlings towards light coming from one direction is an example of a tropism.

Tropism is a bending growth movement, by a plant organ, in response to a stimulus from one direction, by which the plant organ assumes a particular posture or orientation, which bears a relationship to the direction from which the stimulus is received. The stimuli to which plants respond in this way include light, gravity, touch, water and chemical substances. **A tropic movement** is described as positive or negative depending on whether the bending movement is towards or away from the direction of the stimulus respectively. Various tropic responses made by plants are shown in Table 4.3.

Table 4.3 Tropic responses made by plants

Stimulus	Name of tropic movement
1 Gravitational force	Geotropism
2 Unidirectional light	Phototropism
3 Concentration of chemicals	Chemotropism
4 Water	Hydrotropism
5 Heat	Thermotropism
6 Water current	Rheotropism
7 Electric current	Galvanotropism

Activity 4.13 Observing the response of the stem to the force of gravity

Materials required

Seeds of common plants, e.g. beans or balsam, two pots, a dark cupboard (large enough to take the two pots)

Procedure

1 Allow the seeds to germinate in the pots which are filled with good garden soil. You need only two seedlings in each pot. Ensure that the shoots of the seedlings are upright and straight as they grow by regularly turning the pots around.

2 When the shoots are about 3 cm tall, place both pots in the dark cupboard, one on its side and the other upright.

3 After two days, observe both pots of seedlings. Note what has happened. Which seedling shows a curve on their stems? In what direction is the curve? Compare this to the seedlings in the pot that was kept standing upright.

You should have found that the stems of the plants in the pot laid on its side grew upwards. The force of gravity pulls downwards so the stems may be said to show negative **geotropism** because they are bending away from the stimulus. Stems are nearly always negatively geotropic.

Activity 4.14 Observing the response of the roots to the force of gravity

Materials required

A large beaker (500 cm^3), black paper (or sheets of carbon paper), blotting papers, cellotape, two petridishes, cotton wool, seeds (e.g. beans, balsam), a cupboard, wooden blocks. (or plasticine) to support petridishes. For this experiment you need seedlings with straight roots. These can be obtained by proper germination of the seeds

Procedure

1. Select three seeds. Position them on the bottom of a petridish so that the radicles lie flat and are at right angles to each other.
2. Hold them in place with moist cotton wool and cover with a second petridish.
3. Mark an arrow on the top dish pointing in the same direction as any one of the three radicles. Tape the two dishes together.
4. Stand your taped-together petridishes on their edges in the cupboard so that the arrow marked on the top dish points vertically downwards. Hold the dishes in place with wooden blocks or plasticine. Cover the standing dishes with the beaker you covered in black paper.

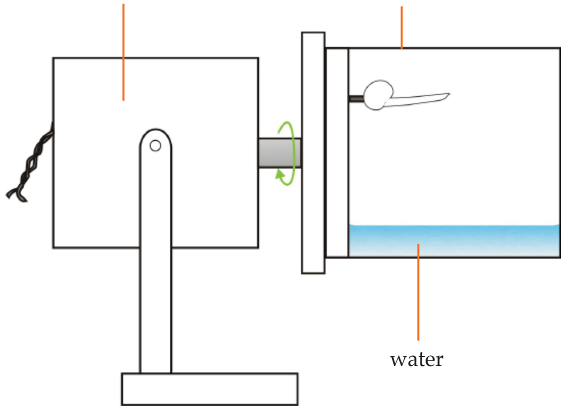


Fig. 4.14 A klinostat

After two days take out the petridishes, with the indicator arrow pointing downward. Where does each radicle now point? Which of the radicles is now bent? In what direction is this radicle bent?

You should have found out that no matter in what direction the radicles were pointing at the start of the experiment, by the end, all were pointing downwards. Your radicles are showing positive geotropism. You should not be surprised by this finding as roots of plants always grow downwards no matter in what position the seeds are planted.

Study your teacher's demonstration very carefully. The teacher has fixed the seedlings to an instrument called a **klinostat**. This instrument keeps the seedlings with their roots in continuous rotation. This way, the force of gravity acts equally on all sides of the roots of the seedlings. This is kept going for a couple of days. You will observe that the radicles continue to grow and elongate, without bending either way – up or down. This shows clearly that when the force of gravity is eliminated or neutralised; the root does not grow downwards.

Activity 4.15 Observing the response of stems to light that comes from one side

To observe this response clearly, more light rays must strike the plant from one direction than any other.

Materials required

Two pots of growing seedlings, a large cardboard box

Procedure

1. Place one of the pots, with its growing seedlings, near a window in the laboratory. Ensure that more light comes in from the window than from the opposite direction. In about two or three days, the shoots bend. In what direction do they bend? Turn the pot round through 180^0 so that the bent shoots now point away from the window. In another few days, what do you observe? Towards what direction do the shoots now bend? You should find that the shoots bend again towards the brighter light from the window.
2. Now, cut a hole about 10 cm by 10 cm from one side of the cardboard box. Place the box at a window such that the cut surface is away from the window. Place the second pot with its growing seedlings in the box. Ensure that the only light available to the seedlings is that from the cut on the box. Leave it to stand for two or three days. Examine the seedlings. Are the stems bent? In which direction are they bent? Phototropism is more marked here compared to what you saw in (1). Why is this?

Your shoots are thus positively phototropic and this is generally true of shoots.

Activity 4.16 Observing the response of roots to water

Materials required
Two porous pots (i.e. clay pots), two large troughs, a small quantity of garden soil, some healthy seeds, such as beans or balsam

Procedure
1 Set up two sets of apparatus, such that in each, the porous pot is held in the middle of the trough of garden soil.
2 Moisten the soil. Sow four to six of the seeds, each about 5 cm away from the clay pot. As soon as the plumule appears above the soil, stop wetting the soil. Now fill up the pot in one set of apparatus with water. Leave the porous pot in the other set-up dry, i.e. without water.

Table 4.4

Plant part	Stimulus	Response	Inference
1 Root	Force of gravity	Grows/bends towards force of gravity	Roots are positively geotropic
2 Root			
3 Stem/shoot			
4 Stem/shoot			

3 Leave both to stand for two or three days. Then very carefully uncover the roots of the seedlings in each trough. In which trough have the roots begun to bend? What is the direction of the bending of the roots? Carefully compare your observations of the roots of the seedlings in the two troughs.

The roots of the seedlings in the trough with a pot of water will have bent towards the porous pot. In the second trough, the roots grow straight down. Roots are sensitive to water and will bend towards it. Roots are thus positively hydrotropic.

Make a summary of your findings from Activities 4.13 to 4.16. Complete Table 4.4 by following the example.

Movement

Movement is an activity which results in a change of shape, form or position. It is one of the characteristics of living things. There are several kinds of movement and methods of bringing about movement.

Protoplasmic streaming or cyclosis

In some living cells, such as the cells of the plant elodea, or the protist paramecium, it is possible to observe under the microscope cytoplasm flowing from one part of the cell to othe other. This is known as protoplasmic streaming or cyclosis. Protoplasmic streaming helps to circulate materials within a cell. The circulation of a food vacuole in *paramecium* through a definite path is thought to be brought about by protoplasmic streaming.

Protoplasmic streaming is brought about by two actions.

1 Cytoplasm can exist in a fairly liquid form, called **plasmasol**, or in a fairly solid form, called **plasmagel**. The first action in protoplasmic streaming is that cytoplasm changes from plasmagel to plasmasol progressively, from the anterior end to the posterior end of the stream.

2 The cytoplasm exerts pressure at the posterior end on the plasmasol as it is formed, causing it to flow forward. At the anterior end of the streaming, plasmasol is again converted to plasmagel.

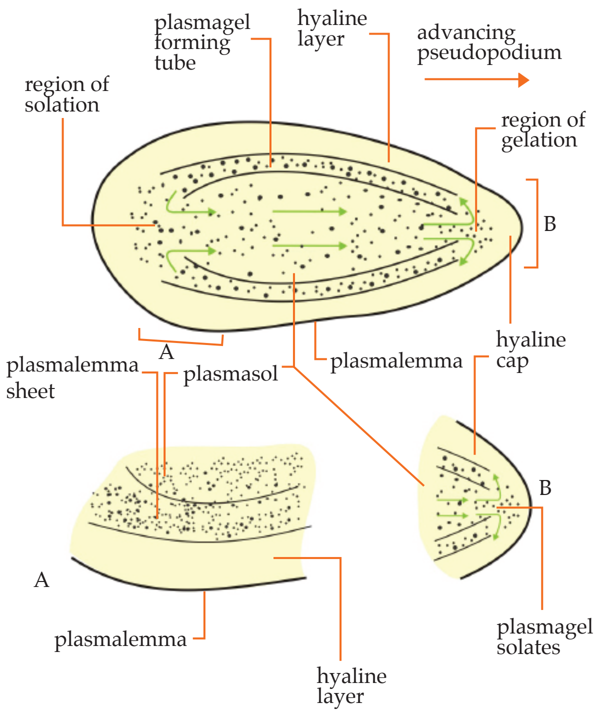


Fig. 4.15 Amoeboid movement

Amoeboid movement

The manner in which *amoeba* moves is called **amoeboid movement**. This type of movement occurs also in white blood corpuscles of man.

Amoeboid movement is related to protoplasmic streaming. It involves the change of state of the cytoplasm from gel to sol, and back again to the gel state. At the point where a new pseudopodium is to be formed, the plasmagel softens. Plasmasol flows towards this point from the rest of the cytoplasm where plasmagel is being changed to plasmasol. This flow is maintained by pressure at the posterior end relative to where the pseudopodium is forming. As the plasmasol flows into the forming pseudopodium, the pseudopodium steadily elongates. Near the tip of the pseudopodium, the plasmasol fans out in all directions and changes to plasmagel which forms a tube in which there is a core of streaming plasmasol.

Movement of cilia and flagella

You already know from the activities earlier in this chapter that unicellular organisms move, often very quickly. The movements you observed involved movements of the whole body. Unicellular organisms may have specialised organelles to help them move, such as cilia or flagella.

Cilia and flagella are long, thin structures which extend from the surfaces of many kinds of cells. They occur widely in living things. Flagella occur in such organisms as *euglena, chlamydomonas* and *volvox*. Cilia occur in ciliates, including *paramecium* and some invertebrates. Cells that line the respiratory tract of man have cilia. However, the cilia do not bring about movement of the cells. They lash in such a way that they cause the movement of particles (such as dust and soot) towards the back of the mouth where they are removed by spitting out or swallowing. Spermatozoa in man and in some other animals move by means of flagella.

Cilia and flagella are similar in structure. They differ only in length, the flagellum being longer than the cilium. The cilium or flagellum is made up of nine pairs of microtubules arranged in a circle. These surround two solitary microtubules in the centre of the cilium or flagellum. A flagellum or cilium arises from a basal body which has the same diameter as the cilium or flagellum. The basal body consists of microtubules arranged in nine triplets around the periphery, and unlike the cilium or flagellum, has no microtubules in the centre.

Cilia and flagella move in definite ways. A cilium beats downwards from an upright position. Then it returns in a relaxed condition to the upright position. It then beats again. The cilia in an organism do not beat all at the same time. They beat in a coordinated manner from one end of the body to the other. In doing so, they continuously provide the force that moves the organism, such as paramecium, through the water.

Growth movement

You have already learnt that plants carry out growth movements in response to stimuli, such as light, gravity, water and touch. These movements called tropisms, do not result in movement from one place to another, but in bending or curvature of plant organs (stem, root, etc). The bending bears a relationship with the direction from which the stimulus is received.

Reproduction

Reproduction is the process by which living organisms give rise to new individuals of the same species. This process leads to an increase in the population of the species, and ensures the continued existence of the species. Without reproduction, every species would sooner or later die out and become extinct.

Forms of reproduction

There are two forms of reproduction, known as **asexual** and **sexual** reproduction. Sexual reproduction is characterised by the fusion of sex cells of gametes, while in asexual reproduction, no gametes are formed. The differences between sexual and asexual reproduction are summarised in Table 4.5:

Table 4.5 Differences between sexual and asexual reproduction

Sexual reproduction	Asexual reproduction
1 Gametes are formed	No gametes are formed
2 Involves fusion of male and female gametes	No fusion of gametes occurs
3 Zygote is formed	No zygote is formed
4 Usually involves two individuals, male and female, but occasionally one hermaphrodite (an organism with both male and female organs)	Involves one individual

Asexual reproduction

In asexual reproduction, one or more cells of a single parent give rise to a new organism. Method of asexual reproduction includes binary fission, budding, spore formation and vegetative reproduction.

Binary fission

This is a form of asexual reproduction in which the parent organism divides by mitosis into two halves. Each half develops into a new individual. Binary fission is common in unicellular organisms, such as bacteria, amoeba, paramecium, and chlamydomonas.

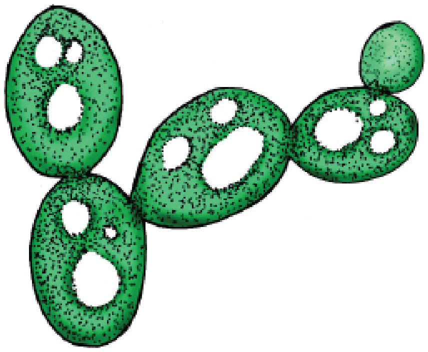


Fig. 4.16 Budding in yeast

Budding

Budding is a form of asexual reproduction in which the parent organism forms outgrowth (bud), which then grows into a new organism and separates from the parent. This occurs commonly in yeast and hydra.

Spore formation

Spores are asexual reproductive bodies formed by certain lower organisms, such as fungi. The bread mould, rhizopus, produces numerous spores in structure called **sporangia** which are borne at the ends of upright hyphae called **sporangiophores**. When the sporangia become mature, they burst and the spores are dispersed by the wind. If a spore falls on a suitable substance, it germinates and gives rise to a new mycelium.

Sometimes, under adverse conditions, amoeba encysts (surrounds itself with a tough coat). Within the cyst, the protoplasm divides into many parts, each surrounded by a resistant coat to form a spore. When conditions become suitable again, the cyst bursts and each spore develops into a new individual.

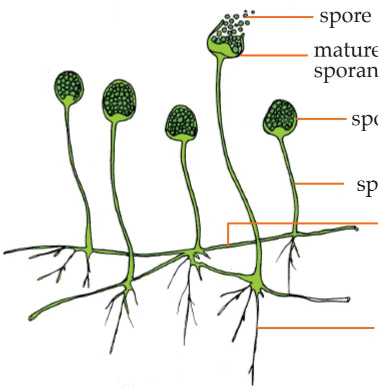


Fig. 4.17 Rhizopus: asexual reproduction

Activity 4.17 Observing asexual reproduction in unicellular organisms

Materials required

A tin of baker's yeast, dilute sugar solution, prepared slides of binary fission in amoeba, microscope, glass slide, palm wine, dropping pipette

Procedure

1 Heat the dilute sugar solution provided until it is just warm to touch. Turn off the flame, suspend a little quantity of baker's yeast in this warm solution for two hours. Place a drop of the resulting milky liquid on a glass slide. Examine under the microscope. Make drawings of the cells that you observe. (note that budding in yeast can be so fast that a bud on a parent cell can itself begin to bud before it is fully detached from the parent cell).

2 Examine under the microscope a drop of the palm wine provided. You should find yeast cells in it if you look carefully. Record your observation. Are the cells budding?

3 Examine the prepared slides under the microscope. Make large, clear drawings of what you see. What process in the life of amoeba do you observe? How is this different from sporulation?

Activity 4.18 Observing spores of rhizopus

Materials required

Microscope, temporary mounts of sporangia of rizophus showing spores

Procedure

Look at the slide mounted by the teacher under a microscope. Make clear drawings of what you see.

Vegetative reproduction

The production of new individuals from the vegetative parts of plants is known as vegetative reproduction. The vegetative parts are stems, roots and leaves, which are not normally concerned with reproduction as opposed to the flowers that are normally concerned with reproduction.

Vegetative reproduction may be classified as either **natural vegetative reproduction or artificial vegetable reproduction**.

Natural vegetative reproduction

1 **Underground stems**

Underground stems, such as rhizomes, suckers, corms, bulbs and tubers reproduce vegetatively in nature.

Buds formed at the nodes of the stems give rise to new shoots which may become separated from the parent plants (by death of the parent underground stem) and develop into new individuals.

2 **Runners**

Runners are creeping stems which grow on the surface of the soil. Examples of runners include bahama grass and sweet potato. Runners produce adventitious roots wherever their nodes touch the ground. If the internodes die, the buds develop into new independent plants.

3 **Roots**

The roots of some plants, such as the ice plant and allamanda spread just below the surface of the soil and give rise to new shoots which grow up at intervals around the parent plant. If the root that connects the parent shoot to the daughter shoot is cut by any agent, an independent shoot results.

4 **Leaves**

The leaf of the live plant, bryophyllum can reproduce vegetatively. If a healthy leaf is broken off, it produces one or more buds, each with roots. If the roots come in contact with good soil, the buds can develop into new plants. Vegetative reproduction by means of leaves, as in bryophyllum, is said to be by **adventitious buds**.

5 **Bulbils**

Bulbils are detachable buds. They grow on parts of some plants, such as the inflorescence of sisal, the stems of some wild yams and the leaves of kalanchoe. When mature, the bulbils drop to the ground, take root and grow into new plants.

Artificial vegetative reproduction

Man propagates plants artificially by vegetative methods. Some artifical methods of vegetative propagation include cutting, grafting, budding and layering.

1 **Cutting**

A cutting is a short piece of the parent plant which, when planted, gives rise to a new plant. Cassava is normally planted in the form of cuttings.

2 **Grafting**

Grafting involves bringing together the piece of young shoot known as the **scion** and the rooted stump of a mature individual of a related species known as the **stock**, so that both of them grow and develop into one plant.

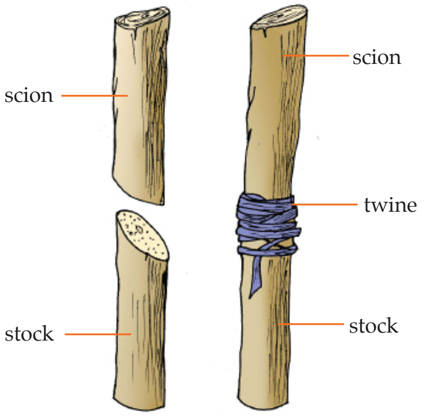


Fig. 4.18 Grafting

Grafting is a way of combining the good qualities of two related species or of two varieties of one species into one plant. For instance, the sweet orange produces sweet fruit but is not very resistant to citrus diseases. The rough lemon is resistant to citrus diseases, but the fruit has unpleasant taste. If the scion of a sweet orange is grafted on to the stock of a rough lemon, the resulting plant produces sweet fruit (derived from the scion), and at the same time, the plant has the disease resistance of the rough lemon stock.

3 **Budding**
In this procedure, a bud is obtained from a desired species or variety of plant, and is inserted in a t-shaped cut in the bark of a plant of a closely related species. The bud is tied securely in place with a thread. For instance, the bud from a grapefruit plant may be budded on to a rough lemon stock. When the bud becomes established, the stem of the stock is cut immediately above the bud. The bud now grows into the main shoot. The fruits of resulting plant are, therefore, characteristic of the species of variety from which the bud was obtained.

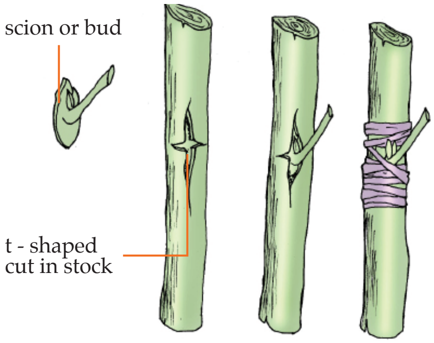


Fig. 4.19 Budding

4 **Layering**
Layering involves bending a branch of an established plant so that it touches the soil; then the branch is held in that position with pegs and covered with soil. After some time, the portion of the stem that has been covered with soil develops roots. When this happens, the portion of the branch connecting the parent plant to the rooted part is cut. The rooted branch then becomes an independent plant. This process is readily carried out with tomatoes or bougainvillea.

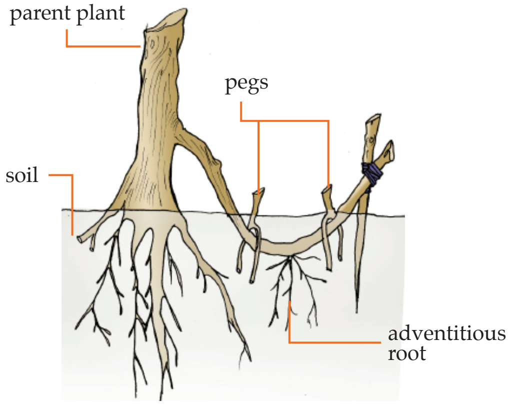


Fig. 4.20 Layering

Advantages of vegetative reproduction

1 Vegetative reproduction is fast. A hedge planted from cutting grows quicker than one planted from seeds. Budded fruit trees, such as oranges, may produce fruits in three years or less, while those grown from seeds take a longer time to fruit.
2 While becoming established, plants grown vegetatively require less care than seedlings.
3 Vegetative reproduction is independent of agents of pollination.
4 Plants formed by vegetative reproduction are similar to the parents. This is an advantage where it is desired to retain specific qualities of the parent, such as large or sweet fruits.
5 Some plants have no seeds and can only reproduce vegetatively, e.g. banana.
6 In natural vegetative reproduction, offspring obtain food from their parents.
7 New plants are produced when conditions are already favourable to the parents.

Disadvantages of vegetative reproduction

1 Natural vegetative reproduction may lead to overcrowding of plants, e.g. allamanda.
2 At fertilisation, the characteristics of two individuals are brought together. Good qualities in the two

individuals may come together in the offspring. In vegetative reproduction, there is no opportunity for variation and introduction of new desirable qualities.

3 Plants that grow from seeds after cross-fertilisation have what is called hybrid **vigour**. The plants are healthy and strong. There is no hybrid vigour in plants reproduced vegetatively.

4 Any defects in the parent plant are passed on to the offspring unaltered in vegetative reproduction.

Sexual reproduction

The distinctive feature of sexual reproduction is the fussion of two gametes. Generally, one is the male gamete, which is motile, while the other is the female gamete, which is not motile. When the two gametes come together, their nuclei fuse, and this is called fertilisation. The fusion of the nuclei is followed by the fusion of their cytoplasms. Then a zygote is formed, which develops into an embryo.

Conjugation

The process in protozoans, certain algae and fungi, by which nuclear material is passed from one cell to another, is called conjugation. It is a form of sexual reproduction.

In spirogyra, for instance, conjugation starts with two filaments lying side by side. Projections start to develop opposite each other from opposite cells in the two filaments. The projections meet, and the separating walls dissolve so that a continuous channel or conjugation tube is formed. Meanwhile, the cytoplasm of each shrinks away from the cell walls and rounds up to form a gamete.

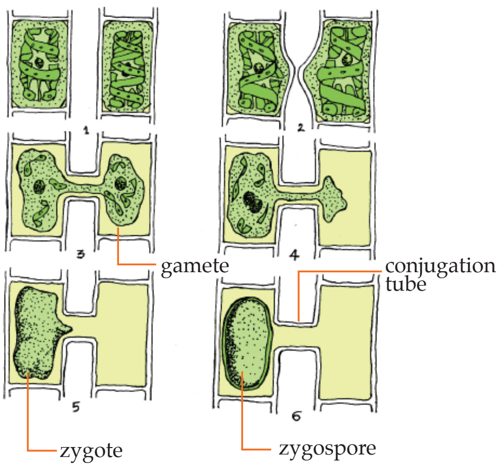


Fig. 4.21 Conjugation in spirogyra

One of the two gametes, regarded as the male, migrates through the conjugation tube into the other cell. The cytoplasms of the two cells fuse, the nuclei also fuse and a zygote is formed.

In rhizopus, a fungus, the process of conjugation is comparable to that of spirogyra but conjugation normally takes place between two different kinds of hyphae known as + and – strains. That is, conjugation never occurs between hyphae of the same strain.

Conjugation in paramecium involves two individuals, the conjugants, which come to lie side by side with their oral grooves touching. The meganuclenus of each organism disintegrates. The micronucleus of each organism divides into four micronuclei, three of which disintegrate. The remaining micronucleus of each organism again divides into two. One micronucleus from each individual migrates into the other paramecium. In this way, there is exchange of nuclear material. The micronucleus that migrates (migratory nucleus) fuses with the one that stayed (stationary nucleus) to form the fusion nucleus. The two individuals separate; they are now exconjugants. The fusion nucleus in each individual then divides into eight, while the cytoplasm divides into four, so that four individuals are produced, each with a new meganucleus and a new micronucleus.

Activity 4.19 Observing conjugation in paramecium and spirogyra

Materials required

Microscopes, microscope slides showing conjugation in paramecium and in spirogyra

Procedure

1 The teacher sets up two microscopes. One microscope shows conjugation in paramecium and the other shows conjugation in spirogyra. Observe the two slides through the eyepiece of the microscope.

2 Make drawings of your observations in your notebook. In higher plants and animals, sexual reproduction normally occurs by the fusion of gametes. The process of gamete formation is called **gametogenesis**. Gametes differ from somatic or body cells in one important respect: gametes are haploid, that is, each gamete has half the number of chromosomes in a somatic or body cell of the animal or plant so that when two gametes fuse, the diploid number of chromosomes, which exists in the somatic cell, is restored. A special cell division occurs during gametogenesis, and this results in the

halving of chromosomes in the gametes. This cell division is called **reduction division** or **meiosis**.

Cell division is a continuous process but for convenience may be considered to consist of stages called **prophase**, **metaphase, anaphase**, and **telophase**. A cell that is not dividing is said to be in the interphase.

A cell in the interphase, however, is not dormant. It is growing and synthesising protoplasm preparatory to another cell division.

Meiosis

Meiosis may be thought of as consisting of two divisions of cell. The first halves the number of chromosomes per nucleus, and is a **reduction division**. The second is similar to mitosis, and the two chromatids of each chromosome separate. The main events of meiosis are summarised as follows:

First meiotic prophase

The chromosomes become visible in the nucleus as long threads. Homologous chromosomes come to lie side by side. Each chromosome divides into two chromatids, joined at the centromere. The centrosome which consists of paired centrioles, split with one centriole pair migrating towards a different end or pole of the cell. Centrioles produce a system of **spindle fibres** which radiate from the two poles towards the middle or **equator** of the cell.

As the homologous chromosomes lie close together the chromatids may become joined at points called **chiasmata**. When they separate again, portions of chromatids may have been swapped. The exchange of genetic materials is called **crossing over**. The nuclear membrane breaks down.

First meiotic metaphase

The chromosomes line up in homologous pairs at the equator of the cell in such a way that the centromeres of homologous pairs of chromosomes lie on opposite sides of the equator. The centromeres are attached to the spindle equator.

First meiotic anaphase

The spindle fibres attaching the chromosomes begin to shorten, dragging each member of each pair of homologous chromosomes towards opposite poles of the cell.

First meiotic telophase

The chromosomes arrive at the two poles of the dividing cell. The cytoplasm divides so that two daughter cells are formed, each with half the number of chromosomes in the cell that divided. New nuclear membrane may or may not reform in each daughter cell, and the chromosomes do not disappear from view by the time the daughter cells are already in the prophase of the second meiotic division.

Second meiotic prophase

The chromosomes are visible, each consisting of two chromatids joined at the centromere. The single centriole divides into two, and as before, each migrates to a different pole of the cell, laying down the spindle fibres for the second meiotic division as they go.

Second meiotic metaphase

The chromosomes arrange themselves at the equator of the cell with their centromeres attached to spindle fibres. Each centromere divides into two.

Second meiotic anaphase

The chromatids separate and are pulled by the spindle fibres towards opposite poles of the cell.

Second meiotic telophase

The chromatids arrive at the two poles of the cells. A nuclear envelope surrounds each group of chromatids, and the spindle disappears. The cytoplasm divides into two; each daughter cell now contains a number of chromatids equal to the number of chromosomes in the cell as it was at the end of the first division.

At the end of meiosis, four cells are formed from the original one cell. The number of chromosomes in the original cell is described as **diploid** or **2n**, while the number of chromosomes in each of the four cells formed at the end of meiosis is described as **haploid** or **n**. This is the way nature keeps the number of chromosomes in the cells of a species of organism constant from generation to generation.

If meiosis did not occur, then the gametes would have the same number of chromosomes as the somatic cells. When two gametes fuse, the number of chromosomes would become 4n; in other words, the chromosomes number would double in each generation. This would have serious implications.

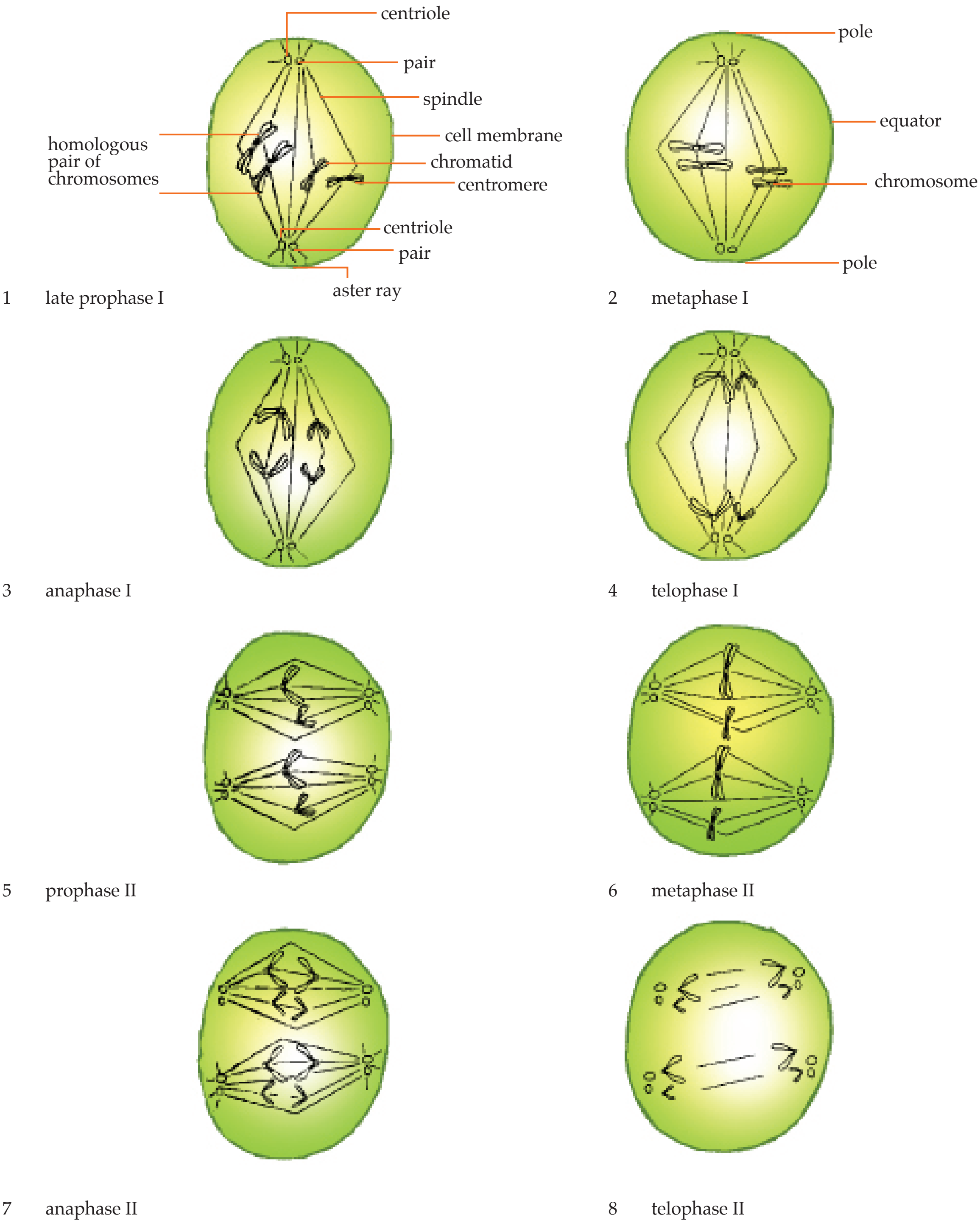


Fig.4.22 Stages of meiosis

Activity 4.20 Identifying the parts of a flower

Materials required
Several flowers of hibiscus or any other large flower, such as flame of the forest, razor blade
Procedure
1 The teacher will cut each flower longitudinally into two halves.
2 Look at the longitudinal section of one flower. Identify the sepals, petals, filament, anther, pollen grains, ovary, ovule, style, stigma, pistil, stamen.

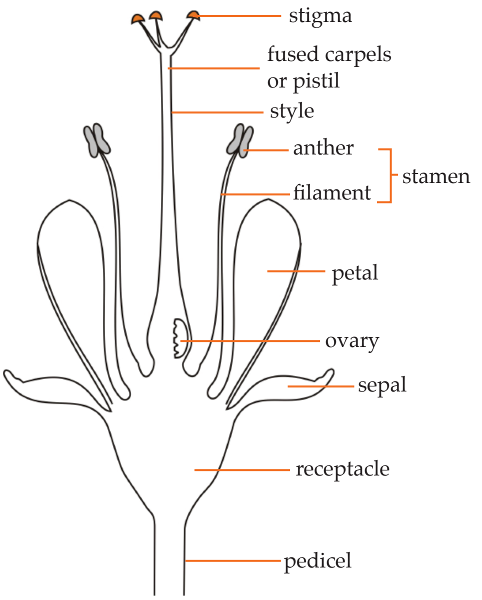


Fig.4.23 Longitudinal section of a flower

3 Make a large labelled drawing of the longitudinal section of the flower.
The essential parts of the flower for the purposes of pollination and fertilisation are:
1 The **androecium** or male part of the flower which consists of stamens. Each stamen is made up of
   a) a filament
   b) an anther which bears the pollen grains
2 The **gynoecium** (pistil) or female part of the flower which consists of
   a) the stigma
   b) the ovary which contains the ovules
   c) the ovary style which connects the stigma to the ovary
The pistil may be made up of units which are called carpels.

Pollination

The flower is said to be pollinated when a pollen grain lands on the mature stigma of a flower of the same species. The pollen grain absorbs liquid from the stigma and germinates. It produces a pollen tube which grows down through the style towards the ovule in the ovary. The nucleus of the pollen grain moves into the pollen tube and divides into two, forming the **tube nucleus** and the **generative nucleus**. The tube nucleus is at the tip of the pollen tube. Later, the generative nucleus divides into two male nuclei, which are the male gametes.

The pollen tube grows into an ovule through an opening in the ovule known as the micropyle. Inside the ovule, the pollen tube bursts. One male nucleus fuses with the female nucleus to form a zygote. The zygote develops into an embryo and later into a plant. The ovule develops into a seed, while the ovary develops into a fruit. As the fruit develops, the sepals, petals, stamens, style and stigma wither away.

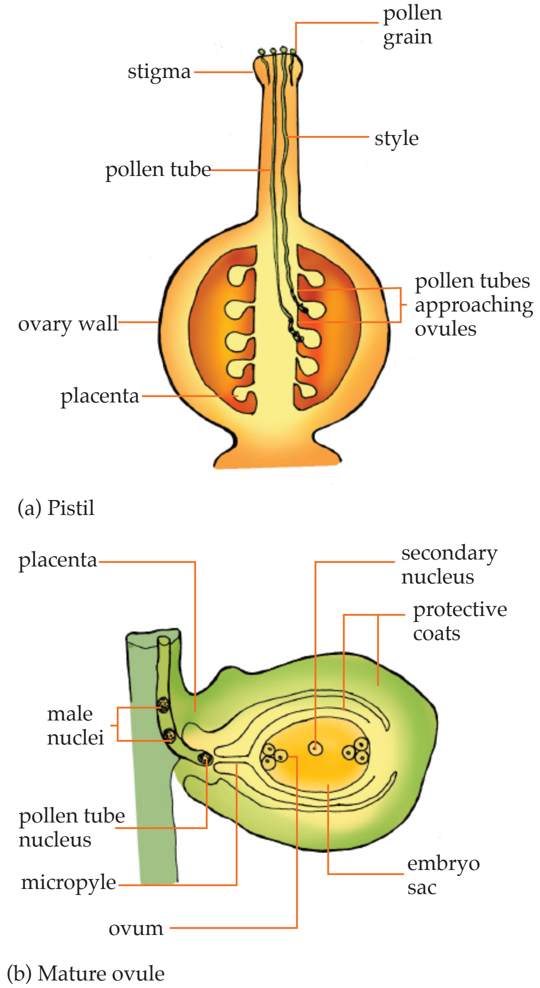


Fig. 4.24 Fertilisation in a flower

The structure and functions of male and female gonads

Gonads are the male and female reproductive organs in animals. The gonads in male and female human being will now be described.

Human male reproductive organs

The human male gonads are two spherical organs called **testes**, enclosed in a sac, known as **scrotum**, which is attached to the pubic region. Each testis (singular) contains many tubules known as **seminiferous tubules** in which sperms are formed by cells that line the inside of the tubules.

From the testis on each side, a coiled tube, the **epidydimis**, leads into the sperm duct or vas deferens, which carries sperm to the seminal vesicle where sperms are stored until ejaculated. The prostate gland secretes a liquid in which sperms are suspended. The sperms pass to the outside through the urethra. An individual sperm is microscopic about 0.5 mm long, with a pointed 'head' and a 'tail'.

Functions of the male gonads

The testes produce sperms which are the male gametes. Some endocrine glands in men secrete the hormone, **testosterone**, which makes the testes develop and descend to a position below the abdomen where the temperature is lower than the body temperature.

Testes only function properly under a temperature lower than the body temperature. Testosterone produces the effects recognised as **secondary sexual characteristics** (e.g. pubic hair; broken voice; hair or face; masculine muscular development) and stimulates sperm production.

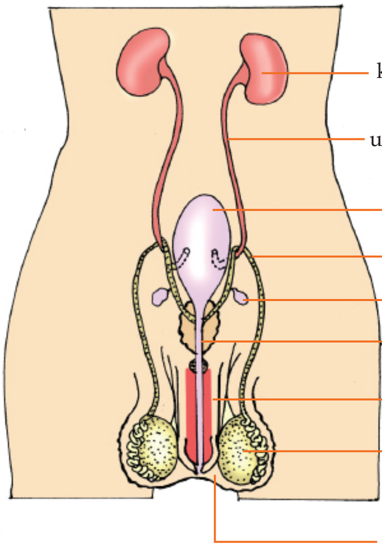


Fig. 4.25 Human male reproductive system

Human female reproductive system

The human female gonads are the two **ovaries** which are located on the dorsal surface of the abdominal cavity, one on each side of the vertebral column. In human beings, each ovary produces one egg every alternate month. The eggs released by the ovary pass into the oviducts or fallopian tubes, which are two tubes that lead from near the ovary to the **uterus.**

Each fallopian tube has a funnel-shaped opening close to its ovary in the abdominal cavity.

Functions of the human female gonads

The female gonads produce eggs, which pass down into the uterus through the fallopian tubes. The eggs are usually fertilised in the fallopian tube. The ovaries are also endocrine glands which secrete the female sex hormones known as **oestrogens** and **progesterone**.
The oestrogens produce and maintain female sex characteristics, such as development of breasts, pubic hair and deposition of fat around the hips. They also stimulate the growth of the lining of the uterus.

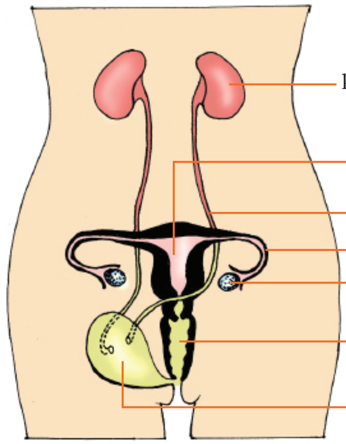


Fig. 4.26 Human female reproductive system

Cyclical increases in levels of progesterone cause growth of the lining of the uterus in preparation for implantation of an embryo. If fertilisation does not happen, the thick lining of the uterus breaks down, producing the monthly **menstruation**.

Summary

This chapter has taught the following:

- A cell as a living thing can show all the characteristics of living things.
- Some unicellular organisms which cannot manufacture their own food feed by engulfing food.
- Plants require specific nutrients for optimum growth.
- Metabolic waste must be removed from the body or else the organism will be harmed. A variety of ways exist by which this removal is done.
- Growth is an irreversible increase in size or dry mass accompanied by differentiation of cells.
- A number of factors control growth.
- Cells are sensitive to stimuli and will respond to them.
- Organisms move from place to place by means of some special organelles or organs.
- Energy is released through tissue respiration. More energy is released from aerobic than from anaerobic respiration.
- Organisms give rise to young ones of their respective types in various ways.

Revision questions

1 Excretion is that process by which all organisms ___________________________.
   A remove undigested food from the body.
   B collect all the metabolic waste.
   C get rid of metabolic wastes.
   D get rid of unwanted water.
   E produce and collect sweat.
2 Increase in the height of a plant is _____________.
   A greatest at the flowering stage.
   B greater when it is young than when it is old.
   C easier to measure when it is well nourished.
   D an indication that it has potassium ions.
   E only obvious between the nodes.
3 The cell division which is responsible for growth is ____________________.
   A meiosis.
   B binary fission.
   C reduction division.
   D mitosis.
   E fragmentation.
4 The shoot of a plant bends towards the source of light because ______________________________.
   A the shoot is positively phototropic.
   B the shoot is negatively phototropic.
   C it responds to the higher temperature.
   D light reduces growth of plant cells.
   E light is essential for photosynthesis.
5 The three end products of anaerobic respiration in mammals are __________________________.
   A water, energy and carbon dioxide.
   B ethyl alcohol, energy and carbon dioxide.
   C glucose, ethyl alcohol and energy.
   D carbon dioxide, glucose and ethyl alcohol.
   E ethyl alcohol, glucose and water.
6 Compare the methods of reproduction in amoeba and spirogyra.
7 Describe in detail how you would measure the growth of a common animal.

Theme 2
The organism at work

Chapter 5 Tissue and supporting systems

All living things exhibit seven life processes namely movement, nutrition, respiration, excretion, growth, sensitivity or irritability and reproduction. These are the seven physiological (functional) characteristics of living things.

The various things a living thing does are all forms of work. This theme highlights the fact that keeping alive involves work. Different areas of work will be examined in this theme.

Introduction

Have you ever thought of what you would look like or what you would not be able to do without the support of your bones and cartilage? You would not be able to sit or stand upright; you would not be able to move your limbs or any part of your body; a mistaken pressure on your head would squeeze out your brain tissue; walking, crawling or sprawling would be impossible and there could be no way of playing football or tennis! Nearly all organisms have some form of support system.

What is a skeleton?

Every organism has a peculiar shape of its own. This shape often depends on the shape of the supporting system of the organism. The body of an organism may be supported by a frame on the inside or outside. This frame is called a skeleton. A skeleton can, therefore, be defined as a rigid framework which gives support and shape to an organism.

Activity 5.1 Demonstrating the use of a skeleton

Materials required
Plasticine or clay, a ruler, pieces of straight stick, weights, or stones

Procedure

1. Divide your plasticine into four pieces and shape each one into a tall cone. Flatten the wider base so that each will stand on its own.
2. Use one of your cones to support each end of the ruler.
3. One by one, place weights or stones on top of the ruler. How many stones or weights does it take before the cones collapse?
4. Now, push a piece of straight stick, from top to bottom, into the remaining two cones, cut off any visible part of the sticks and then balance a ruler on them as in (2) above. How many small weights or stones would you put on the ruler before the cones give way?

The sticks make the cones stronger. The skeleton of an organism acts in a similar way. Your experiment illustrates one of the important functions of skeletons of animals or the supporting tissues in plants. You should, however, note that some organisms, like bacteria, viruses and some protozoa, are so small in size that they do not require such support.

Are you aware that you have a skeleton? Try to find it in your arms, for instance. The skeleton forms the central core of the human body, and is covered up by muscles, blood vessels, nerves and skin. It is internal, and is, therefore, described as an **endoskeleton** (endo = within). In contrast, animals, such as crabs, millipedes, spiders and insects, have their skeletons on the outside of their skin. Such skeletons are called

exoskeletons. In an insect, the skeleton is a hard cuticle containing mainly chitin and some hardening mineral salts like phosphates and carbonates of calcium. Its outermost layer is covered with a thin layer of wax which makes it waterproof. It performs the same functions as the endoskeleton.

The greater part is made up of non-living materials. It, therefore, cannot grow, and must be shed occasionally, during moulting or **ecdysis,** to enable the animal to grow. The shells of molluscs, e.g. that of the giant land snail are protective exoskeletons.

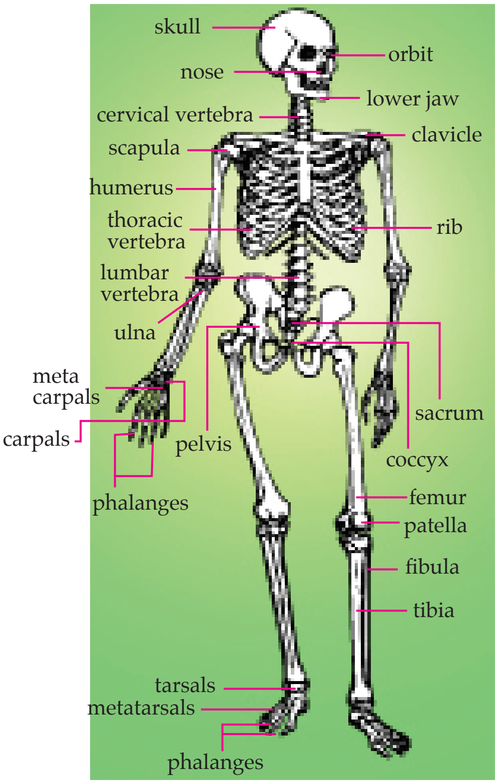


Fig. 5.1 The human skeleton

Location and arrangement of skeletal tissues in animals

The skeletons of vertebrate animals like fishes, frogs, toads, snakes, lizards, birds and mammals are internal, and are made up of bones and cartilage. You can think of the mammalian skeleton as divided into two. The bones lying along the length of the body, namely the skull and the spinal column make up the **axial skeleton**. The bones joined to the axial skeleton, for example the bone of the limbs and the pelvic and pectoral girdles make up the **appendicular skeleton**.

Look at Fig. 5.1, taking particular note of the following important parts:

1 The skull, which covers the most important and most delicate organ of the body, the brain, together, with other very vulnerable sense organs like the eyes and ears.
2 The girdle of the forelimbs called **pectoral girdle** consists of two halves, each of which is made up of the shoulder blade or **scapula** fused with the **coracoid**, and a separate bone, called the **clavicle**, or collar bone which connects the scapula with the sternum in the middle of the thorax.
3 The forelimb attached to the pectoral girdle. This is made up of the long, strong bone of the upper arm called the **humerus**; the two bones of the forearm, the **radius** and **ulna**, the multiple bones of the wrist and palm called the **carpals** and the **metacarpals** respectively, and finally the finger bones, the **phalanges**.
4 The hindlimb girdle or **pelvic girdle** is also made up of two halves, each of which is made up of three bones: the **ilium**, **ischium** and **pubis**, all three contributing to the socket or **acetabulum** in which the round head of the thigh bone or **femur** fits.
5 The hindlimb is similar to the forelimb in components and structure. The single, strong bone of the lower limb is the femur, followed by the **tibia** and **fibula** of the foreleg. The **tarsals**, **metatarsals** and **phalanges** occupy similar positions on the hindlimb bones as the carpals, metacarpals and phalanges of the forelimb.

The fore and hind limbs are described as **pentadactyl limbs** (**penta** meaning five and **dactylus** meaning digits); both limbs end in five digits.

The vertebral column

The vertebral column forms the backbone of vertebrate animals, and its main function is to protect the spinal cord. It is, however, made up of very many individual bones or vertebrae which are held one to the other by strong ligaments, with compressible cartilage pads, called **intervertebral discs**, between consecutive vertebrae.

In mammals, five different types of vertebrae are known. These are the:

1 **cervical** vertebrae, in the neck region;
2 **thoracic** vertebrae, in the chest;
3 **lumbar** vertebrae, in the upper abdominal region;
4 **sacral** vertebrae, in the lower abdominal region; and
5 **caudal** vertebrae, in the tail region.

The number of vertebrae in these various regions of the vertebral column vary in different mammals as shown in Table 5.1.

Table 5.1 Distribution of vertebrae in man, rabbit and rat.

	Man	Rabbit	Rat
Cervical	7	7	7
Thoracic	12	12	13
Lumbar	5	7	6
Sacral	5	3-4	4
Caudal	4	16	27-30
Total	**33**	**45 - 46**	**57 - 60**

Typical vertebra

Every bone in the vertebral column is built on a basic plan which we may describe as the typical vertebra. A prominent part is the piece of solid bone in the middle of each vertebra called the **centrum**. The centre of the entire column forms a strong supporting body along the longitudinal axis of the animal.

Above the centrum is the **neural canal**, which is a space for the spinal cord. It is surrounded by the **neural arch**. The **neural spine** arises centrally and points upward from the arch and a pair of **transverse processes** extend sideways from the arch. Both transverse processes provide surfaces for muscle attachments.

Each individual vertebra touches the one on its anterior side by a pair of articulatory surfaces called the **prezygapophyses**. These surfaces face inward and upwards, while the articulatory surfaces at the back, called the **postzygapophyses**, face outwards and downwards.

Cervical vertebra

By virtue of the position of the cervical vertebra in the body (i.e. the neck region), it possesses a (very) short neural spine, but two other characteristics distinguish it further:

1 There is a pair of canals through its neural arch. These are known as **vertebraterial canals**, and are spaces through which the blood vessels of the neck pass;

2 There is an additional transverse process on each side, termed a **cervical rib**.

The first two cervical vertebrae are, however, different because of their nearness to the skull. The vertebra immediately next to the skull is called the **atlas**. It is a ring of bone with a large neural canal and a very small centrum, having lost its centrum to the vertebra behind it. Its neural spine is greatly reduced, but its cervical ribs or transverse processes are prominent. Its anterior surface bears two prezygapophyses with which the nodding or 'yes' movement, of the head is made. Its posterior surface also bears two postzygapophyses for the axis behind it.

The second neck vertebra, the **axis** has a peculiar shape.

1 It has acquired the centrum of the atlas during development and so has, protruding into the atlas, what is known as the **odontoid process**. This and its two broad prezygapophyses allow for rotatory movement, or shaking of the head, possible in man.

2 Vertebraterial canals are present.

3 Its cervical ribs are flat.

4 Its neural spine is more prominent than that of the atlas.

Thoracic vertebra

Thoracic vertebrae can be distinguished by a number of characteristics, most prominent among which are the following:

1 Its long neural spine which points upwards and backwards;

2 A large neural canal surrounded by a large neural arch, and also

3 A large centrum;

4 It also has a pair each of zygopophyses of the front and back, for articulating with other vertebrae.

5 Each thoracic vertebra supports two ribs, one on either side. Each rib articulates with a vertebra at two points, the upper one being the tubercular facet on the ventral surface of the transverse process, and the other the capitular facet which touches two adjacent centra together, thus anterior of one centrum and the other on the posterior of the centrum of the vertebra in front.

Lumbar vertebra

Each lumbar vertebra can be recognised by the following:

1 Its stout centrum;

2 Its large neural canal;
3 Its long neural spine which projects upward and forward, and
4 Its transverse processes which point forward.

It has, however, some unique processes:

a) One pair of these, called the **metapophyses**, arise above the prezygapophyses and neural arch, while
b) Another pair, known as **anapophyses**, also arise below the postzygapophyses.
c) In certain mammals, a centrally-placed process, called **hypapophysis**, may arise on the lower side of centrum.

Sacral vertebra

Each sacral vertebra has a large centrum but a narrow neural canal. The neural spine is reduced to a small notch and its transverse processes serve for the attachment of the hip muscles. Sacral vertebrae are generally few in most mammals, numbering three to five, and are all fused into a single, rigid sacrum which supports the pelvic girdle.

Caudal vertebra

The caudal vertebrae nearest the sacrum have small transverse processes, neural spines and articulating processes, but all these become progressively reduced, until they disappear in the more distal ones where they occur as small rods of solid bone.

Man has only four fused caudal vertebrae, called the **coccyx**, which does not protrude as a tail, whereas the rat has as many as thirty caudal vertebrae, the number depending on the length of the tail and on the individual rat species.

Activity 5.2 Studying the skeleton of a mammal

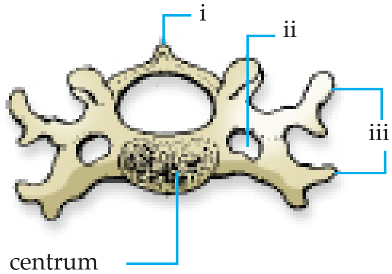
Your teacher will supply you with either the entire skeleton of a rabbit, guinea-pig, or rat, or a model of the entire human skeleton. It is important in the study of bones to note how the size, shape and thickness of each bone is related to its function.

Procedure

1 Learn the names of the two bones of the upper jaw, and the only bone of the lower jaw in which the teeth are inserted. Note also the bones of the skull that articulate with the atlas of the vertebral column and see practically how these joints allow the skull to be moved from side to side, as well as forward and backward.
2 Learn the names of the vertebrae of the following parts of the body:
   a) neck,
   b) thorax,
   c) trunk or lumbar,
   d) hip, and
   e) tail.
3 Look at individual bones of the first three regions and compare their centra, transverse processes, spines, articular surfaces and the sizes of their neural canals. Note the attachments to ribs and other special characteristics that distinguish each one.
4 Also note the shape, length and position of the vertebral column in the body, Compare the fore and hind girdles.
   a) Learn the names of the three bones in each and how one half of each is attached to the other half.
   b) Learn how and by which bones, the front and hindlimbs are attached to their girdles and look at, how they form ball-and-socket joints.
   c) Note the relative sizes of the two girdles and relate these to their function of support for the limbs and muscles.
5 Compare the corresponding bones of the fore and hind limbs and learn their names. Which bones of the hindlimb are not at all represented in the forelimb?
6 From the real bones, carefully make large labelled drawings of:
   a) anterior/posterior view of a cervical vertebra
   b) laterial view of a thoracic vertebra
   c) anterior/ posterior view of a lumbar vertebra.
   Label each drawing fully.

   i) Your teacher will also give you some or all of the following: millipede (preferably the *lulus species)* crab, and cockroach.
   Note the protective function of the exoskeleton.
   ii) Confirm that every part of the body, including the eye, is covered by exoskeleton.
   iii) Open up the exoskeleton of the cockroach, longitudinally, to prove that:
   a) there is no endoskeleton, and
   b) muscles are attached to the insides of the exoskeleton (look at the thoracic part of cock roach in particular). Use a hand lens to see better.

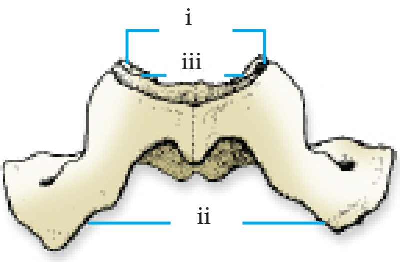
a) Cervical (nos. 3 to 7)



i) The neural spine is short.
ii) Each transverse process is pierced by a hole which forms part of the vertebraterial canal (the canals carry the vertebral arteries).
iii) The outer part of each transverse process is divided into two.

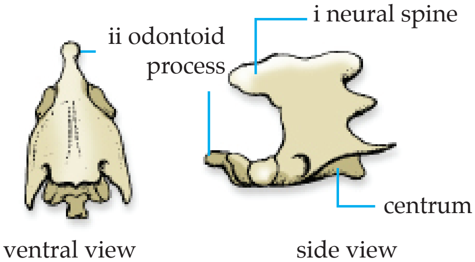
The first two cervical vertebrae, called the atlas and axis respectively differ from the rest. They are specially shaped to allow the skull to move freely on the vertebral column.

b) Atlas



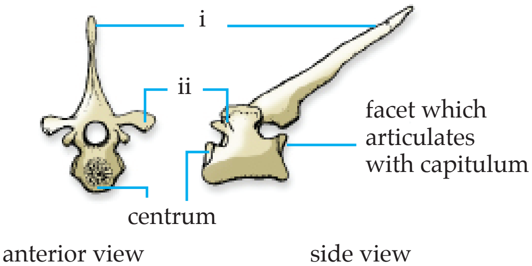
i) The neural canal is very large.
ii) The transverse processes are broad and flat.
iii) Two large facets at the front articulate with knobs on the base of the skull. The joint thus formed is used in nodding movements.

c) Axis



i) The neural spine is prominent and projects forward.
ii) The centrum projects in front as the odontoid process. This fits into the ventral part of the neutral canal of the atlas. The joint thus formed is used in twisting movements.

d) Thoracic



i) The neural spine is prominent and of a distinctive shape.
ii) The transverse processes are well developed. They articulate with the ribs.

e) Lumbar

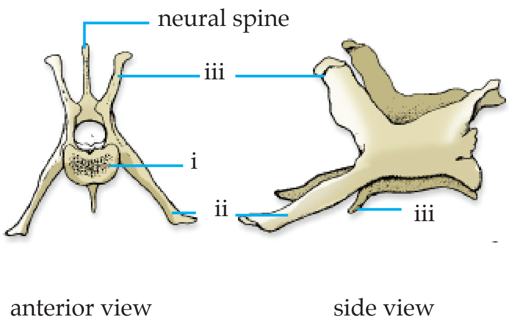


Fig 5.2 Types of vertebrae

i) The centrum is large and thick.
ii) The transverse processes are well developed.
iii) A number of projections from the centrum provide attachments for muscles of the abdominal region.

Joints

A joint is the point where two or more bones meet.

Structure of a joint

The surfaces of bones which touch at a joint are called **articular surfaces**. Such surfaces are covered by a layer of articular cartilage which prevents the wear and tear of the bone surfaces. The bone ends are held together by tough, slightly elastic tissue called **ligaments**. A membrane called **synovial membrane** lines the inside of the joint space and secretes a viscous **synovial fluid** which lubricates the joints and acts as shock absorber.

Types of joints

Joints all over the body are either **moveable or immoveable**. There are four types of moveable joints.

1 **Ball and socket joints** in which the rounded head of one bone fits into a hollow cavity or socket of another or other bones.

This device allows free movements in almost all directions. Such is found between the head of the upper arm bone and the pectoral girdle, and between the head of the thigh bone and the pelvic girdle.

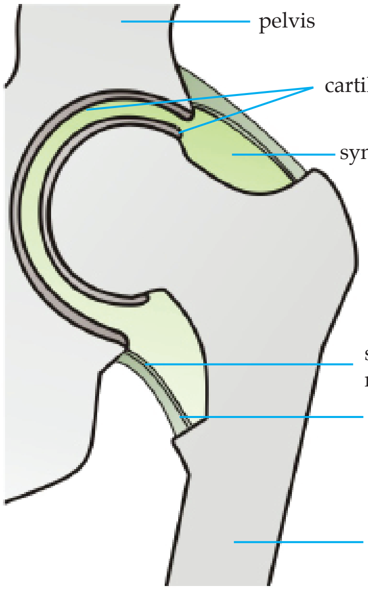


Fig. 5.3 Ball and socket joint of human hip

2 **Hinge joint** allows movement in only one plane. Examples are found in the elbows and knees in particular, but also at the fingers.

3 **Pivot joint** allows a rotating movement as is found between the atlas and axis in the neck where the odontoid process of the axis fits into the ventral part of the neural canal of the atlas.

4 **Gliding joint** allows the rubbing of two or more bones against each other as we have in the wrist or ankle.

The immovable joints are of three types. They are:

1 **Sutured joints** of the skull whose serrated edges fit perfectly together.

2 **Fused joints** as in the sacral vertebrae.

3 **Bones bound** tightly by ligaments as in the two halves of the pubic symphysis.

Movement of a joint

Movement of a joint is brought about by the muscles attached to its bones. Muscles are attached to bones by the very strong, narrow tendons at their ends. A pair or more of muscles bring about the movements of a joint. They work in opposing or antagonistic pairs, e.g. the biceps which bends the elbow when it contracts and the triceps which straightens or unbends the elbow again when it contracts.

As one contracts, the other relaxes. The one that causes a limb to bend like the biceps is called a **flexor**, while the one that causes the limb to straighten out like the triceps, is called an **extensor**.

And so, in order to make the fore limb bend, the biceps whose upper ends are attached to the scapula and lower end to the radius contracts while the triceps relaxes and in so doing, the radius is raised, i.e. the arm is bent; while in order to straighten the arm, the triceps whose upper ends are also attached to the scapula and lower end to the radius, contracts while the biceps relaxes.

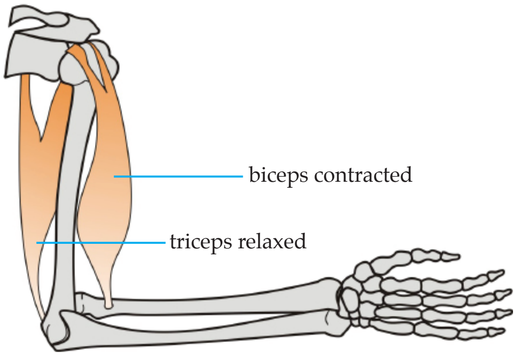


Fig. 5.4 Upper arm muscles of human showing biceps and triceps

Supporting tissues in plants

Plants also need support, particularly trees and shrubs which may stand metres high.

1 Immediately below the epidermis is the **cortex**, the outermost layer of which is called the **hypodermis**, containing **collenchyma** cells. This layer may be four to five cells thick in dicotyledonous stems. All the cells which are living cells are clearly thickened at their corners. Collenchyma is, therefore, a

strengthening tissue, which enables plants to withstand bending and twisting when affected by wind, water, etc.

2 Another type of strengthening tissue is found on the outer edge of the vascular bundles of flowering plants. These cells make up the **sclerenchyma**. There are two types of sclerenchyma cells: the **stone cells**, which are short and irregular in shape, and the sclerenchyma **fibres**, which are long and thickwalled. Stone cells give stiffness to the cortex and, when they form a continuous layer, sometimes replace the epidermis. Each sclerenchymatous cell is thickened by the deposition of lignin, the main component of wood.

The lignified cells provide the strength and rigidity of stems. In old stems, sclerenchymatous cells lose their protoplasm and are, therefore, dead.

3 Further strengthening tissue is found amongst the dead water-conducting cells of the **xylem**. Xylem vessels are themselves thickened by lignin, the main component of wood, but in addition, extra woody fibres are present in xylem, giving the stem further strength.

4 When the unthickened cells of the **parenchyma** are turgid, the outward pressure of their protoplasm also helps strengthen the plant. All the cells are living and have thin cellulose walls.

Activity 5.3 Studying the cells of the supporting tissues in a plant

Your teacher will supply prepared slides of the transverse sections of sunflower, or any other dicotyledonous stem.

Procedure

1 Mount it under the low power of a microscope. Make a large diagram of the plan of the stem and label the following parts: epidermis, cortex, vascular bundle, pith.

2 Now take a look at this section under the higher power of your microscope. Take particular note of the cells immediately next to the epidermis.

3 Comment on the
   a) size
   b) shape
   c) thickness of the walls, and
   d) thickness of the corners of each cell.

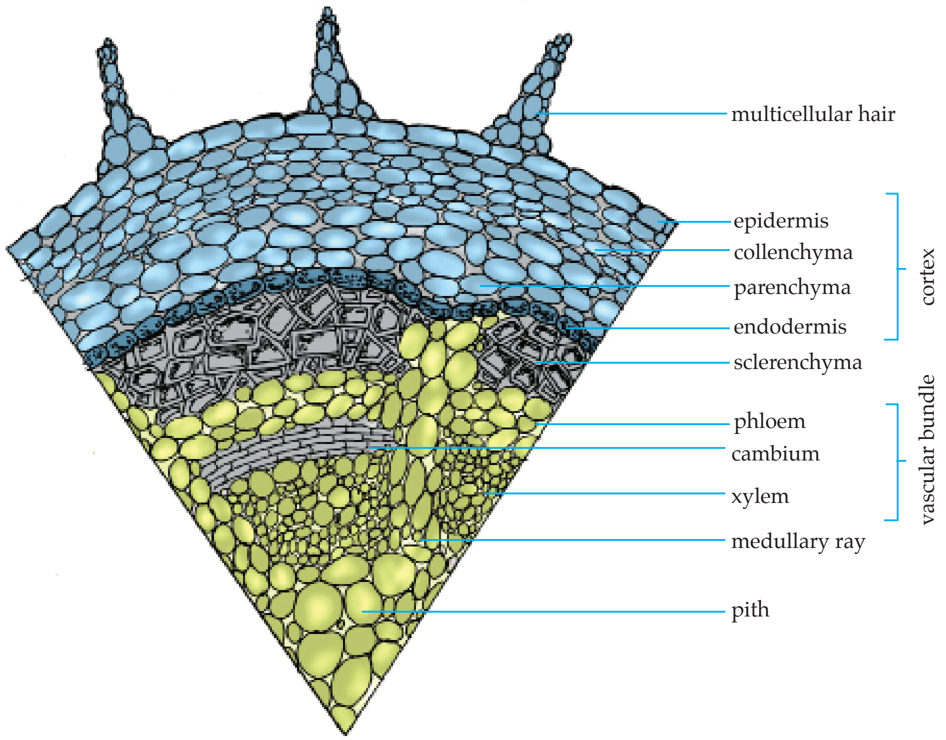


Fig. 5.5 Parts of a dicotyledonous stem

4 Draw two or three of these collenchyma cells,
5 Now see if you can identify some sclerenchyma and xylem cells. Draw these two. Make sure you note their thickened walls.

Mechanism of support in plants

How would you go about breaking the trunk of a tree in your school compound? Would it be easy? What tools would you need? Some trees, like the iroko or mahogany, have trunks almost as hard as stone. This hardness is the result of possessing such supporting tissues as sclerenchyma, xylem (wood) vessels, tracheids and fibres as well as phloem fibres.

Plants are often able to resist strong winds, such that when the wind bends them, they still do not break. Water plants are able to resist water movement in a similar way. These capabilities are due to the effects of the various supporting tissues of plants.

Uses of fibres to plants

Fibres provide flexibility and strengthening - two of the special functions of the supporting tissues in plants. They are thus major contributors to the mechanism of support and the characteristic hardiness of plants in which they abound. Plants, such as *Hibiscus spp,* jute and sisal contain some of the strongest plant fibres.

Functions of the skeleton in animals

The following are the reasons why animals have skeletons:

1 **Support**

The skeleton of an animal forms a framework for the shape of the animal's body. The total weight of the animal is also borne by the skeleton of the animal. Notably, the pectoral girdle supports the shoulder and the forelimbs, while the pelvic girdle supports the back and hindlimbs of the animal. Both girdles and ribs are also supported by the vertebral column along the longitudinal axis of the body.

The skeleton is also the frame upon which the internal organs are hung. Without the skeleton to support them, the soft internal organs would pile up on top of each other and be unable to function.

2 **Protection**

The skull forms the strong protective box for the soft tissues of the brain and such sense organs as the eyeballs and inner ear. In the same way, the vertebral column protects the spinal cord. Many vital organs like the heart, the blood vessels close to it, as well as the lungs are all hidden within the rib cage of the thoracic region. The pelvic girdle protects important organs in the lower trunk, such as the urinary bladder and reproductive organs, especially those of the female.

3 **Movement**

All movements, including locomotive movements in animals are the results of muscle contractions moving the bones to which they are attached. The skeleton is, therefore, very important for body movement. The skeleton consists of very many bones joined to one another, in such a way as to allow the muscles to pull on them to produce controlled movement. Joints may act as hinges, for example, the knee or elbow joints, or may allow a larger range of movements, for example the ball and socket joint of the shoulder.

4 **Respiration**

The rib cage of the thoracic region contributes significantly to the breathing mechanism of mammals by intermittently moving out and in, thus increasing and decreasing the volume of the thoracic cavity for the intake or output of air.

5 **Production of red blood cells**

The bone marrow is a site for the production of red blood cells which are of vital importance in respiration. Red blood cells are produced in the marrows of long bones.

Functions of supporting tissues in plants

The following are functions of supporting tissues in plants.

1 **Strengthening**

Four kinds of plant tissues have been named as supporting tissues in stems (and roots) of plants, namely:

a) turgid parenchyma cells (in herbaceous plants),
b) collenchyma cells,

c) sclerenchyma cells, and
d) xylem vessels, tracheids and fibres.

The walls of collenchyma cells are relatively thickened, but in particular, their walls have thickened corners which provide strength (rigidity) to the stem. The walls of sclerenchyma cells are thickened and lignified. Lignin is the main constituent of wood. The lignified cells, therefore, provide support to stems and roots. When cells are lignified, the protoplasm dies as the cell grows leaving walls which remain to give strength to the stem. Some sclerencyma cells, the sclerenchyma fibres make stems and roots flexible. Short sclerenchyma (stone) cells make stems rigid.

Xylem tissue contains xylem vessels, xylem tracheids, xylem fibres and xylem parenchyma. Xylem vessels, tracheids and fibres have walls thickened with lignin, and the protoplasm dies as the cells are thickened with this substance. Xylem vessels are long tubes concerned with conduction of water and with strengthening. Xylem tracheids are concerned mainly with strengthening. Xylem parenchyma has strengthening function. Xylem parenchyma are living cells which transport food, water, and oxygen within the plant. The fact that trees are able to stand very many metres high without collapsing, and resist winds and objects that strike them can readily be attributed to the strength of the supporting tissues.

2 **Rigidity**

It is essential that the stem of a plant be rigid enough to hold the leaves up, and to provide support for the flowers and fruits. It is also important that plants be able to withstand blows from things in the environment, for example, passing animals. The supporting tissues give plants the rigidity they need.

3 **Resilience and flexibility**

Plants on land must constantly sway in the direction of breezes and winds, and then, regain their former positions. Those in seas and rivers are also carried in directions dictated by the water flow. The positioning of most of the supporting tissues of the stem in bundles around the edge means that the stem can bend without snapping; it is flexible. When the wind dies down, the plant will unbend and return to its original straight position. The ability to regain its original position after being bent by wind or water is called the resilience of the plant. Resilience is also due to the strengthening tissues.

Activity 5.4 Observing the use of a snail's shell

Your teacher will bring a live snail to the class. Give the snail a few minutes to stretch out its head, foot and tentacles, and crawl along the top of your desk.

Procedure

1 Attempt to disturb its movement by touching its tentacles or head with the tip of your finger. How does it react?
2 Hold it by its shell and lift its foot off the desk. What do you observe?
3 Allow it to settle and crawl on your desk again; then merely touch its shell. What is its reaction this time?

Can you tell how this animal preserves itself throughout the dry season, when it would find it difficult to live comfortably? Ask your teacher to show you how important its shell is for this purpose.

Activity 5.5 Showing how bones aid movement in a toad

Your teacher will show you the hindlimb of a toad whose skin has been removed, to demonstrate the attachment of muscles to bones. Take particular note of:

1 the various bone joints that make the leg movement possible;
2 the total size of the calf muscle and its bulk in the middle;
3 the tendons that attach the muscle to bone on either side, noting to which bone each tendon is attached;

What joint is flexed when the calf muscle contracts and what happens when it is brought back to its earlier position? Can you represent this set-up in a diagram?

Note that the muscle which makes the leg bend is the flexor and the one which makes it stretch is the extensor. They are called opposing muscles because they have opposite effects on the same joint.

Activity 5.6 Demonstrating limb movements, using a wooden model

Your teacher will supply you with some pieces of wood to represent the bones of the arm and some cords to represent the muscles. Try to construct a model of an arm of man, to show how alternately one muscle makes the arm bend and the other makes it stretch.

Summary

This chapter has taught the following:

- Both plants and animals need supporting tissues.
- In animals, support is provided by the skeleton.
- The skeleton of an animal may be made up of bone, cartilage or chitin or other materials.
- The skeleton of an animal may be internal or external.
- The skeleton of an animal provides support and protection for delicate parts; it helps in movement.
- The axial skeleton of a mammal contains vertebrae.
- The vertebrae of different parts of the body have special features.
- Joints make movement possible.
- Supporting tissues of plants include collenchyma, xylem and parenchyma.
- The arrangement of supporting tissues in plants provides both rigidity and resilience.

Revision questions

1 The mammalian cervical vertebrae invariably number __________.
   A 4
   B 7
   C 12
   D 5
   E 16

2 The various processes arising out of the centrum of a vertebra are designed to ____________________.
   A protect the animal from its enemies.
   B protect the spinal cord from dangers.
   C provide points for muscle attachment.
   D provide facets for articulation to other bones.
   E provide enough room for the vertebra.

3 One of the functions of supporting tissues in plants is to ______________________________.
   A lengthen the life span of the plant.
   B allow it to provide homes for birds and other animals.
   C make it capable of secondary thickening.
   D give it strength and rigidity against the attack of enemies.
   E make it possible to have more vascular bun dles.

4 The supporting tissue for plants that is found in the hypodermis of the cortex is the ____________.
   A collenchyma.
   B wood fibre.
   C parenchyma.
   D sclerenchyma.
   E reticulate vessels.

5 One of the distinguishing characteristics of a thoracic vertebra is __________________________.
   A a broad and short neural spine projecting forward.
   B a hypapophysis projecting ventrally from the centrum.
   C an odontoid process acquired from an anterior vertebra.
   D a vertebrarterial canal for blood vessels.
   E a long neural spine projecting upwards and backwards.

6 One of the advantages of rigidity in plants is that
   A they can no more bend to winds.
   B no physical force is able to uproot them.
   C it enables them to carry their leaves, flowers and fruits.
   D they would rather be hewn down than bend when touched by animals.
   E it loses its flexibility and resilience once it is made rigid.

7 a) Make a low power diagram of the transverse section of the stem of a dicotyledonous herbaceous plant, and label the tissues that provide support to the plant.
   b) Make a high power diagram of the cells of any two of the supporting tissues and briefly describe the supporting features of both cells.

8 a) What are the uses of the skeleton to mammals?
   b) Make a large diagram of a typical mammalian vertebra and label it fully.
   c) What are the differences between a cervical vertebra and a lumbar vertebra?

9 Explain how flexibility and resilience are achieved by plants. How do animals achieve movement and support by means of their skeletons?

10 Describe an experiment to show that the skeleton strengthens the animal body. Name five different vertebrae in a mammal's body. Describe two functions of the mammalian vertebrae.

Chapter 6 Nutrition in animals

Introduction

You will recall that nutrition is one of the seven functional characteristics of living things. All living things feed; they require nutrients. Green plants make their own food from simple inorganic materials, namely carbon dioxide, water and mineral salts. The process by which green plants manufacture their food is called **photosynthesis**.

In contrast, animals cannot make their own food. They, therefore, depend directly or indirectly on plants for their food. Some bacteria too are known to manufacture their food from simple inorganic raw materials.

Animal nutrition

Nutrition in animals means the sum total of the processes involved in intake, digestion, absorption and utilisation of food.

Nutrition in animals differs from that in plants. The differences are shown in Table 6.1.

Food

Food is any substance which, when eaten, serves as a source of energy, or is used to build the body for growth or in repair of body tissues.

Uses of food to animals

1 Food is oxidised in the body during respiration to produce energy for physiological processes, for maintaining body temperature and for doing work.

Table 6.1 Difference between nutrition in plants and animals

Nutrition in green plants	Nutrition in animals
1 Green plants make their own food. They are, therefore, said to be autotrophic.	1 Animals do not make their own food but feed on plant and animal material. They, are therefore, said to be heterotrophic.
2 Plants use simple inorganic molecules to make organic molecules as food.	2 Animals use complex organic molecules as food.
3 Plants have no mouths.	3 Animals have mouths (though there are exceptions).
4 Plants absorb raw materials (water, carbon dioxide, mineral salts), for making food either in solution or as gas.	4 Many animals take in solid food which they then digest, absorb, and remove undigested matter.

2 Food substances are used to make new protoplasm, new body materials and new cells for growth.
3 Food substances are used to make new body materials for the repair of damaged parts of the body, that is, replacement of wear or tear.

Food substances or classes of food

On the basis of chemical composition, food is classified into several kinds of chemical substances which are called food substances. These are carbohydrates, lipids (fats and oils), proteins, vitamins, mineral salts and water. These are described in detail below.

Carbohydrates

Carbohydrates are made up of carbon, hydrogen and oxygen atoms only. The ratio of the number of atoms of hydrogen to the number of atoms of oxygen in a molecule is 2:1 (e.g. $C_6H_{12}O_6$, a molecule of glucose).

There are several kinds of carbohydrates which include sugars, starch, cellulose and glycogen.

Sugar

There are several kinds of sugars, however. They are all soluble in water, and have a sweet taste.

Simple sugars or monasaccharides

The general formula for simple sugar is $\mathbf{C_6H_{12}O_6}$, e.g. glucose (grape sugar), fructose (fruit sugar) and galactose. Food sources of simple sugars are fruits, such as oranges, grapes, bananas, and pineapples.

Disaccharides

The general formula for disaccharides is $\mathbf{C_{11}H_{22}O_{11}}$. The disaccharides include sucrose (cane sugar), maltose (malt sugar) and lactose (milk sugar).

Starch

The formula for starch is $\mathbf{(C_6H_{10}O_5)_n}$. One molecule of starch consists of a number of glucose molecules joined together with loss of water.

Starch is white, and insoluble in water. When heated in hot water, it forms a colloidal liquid. Starch can be hydrolysed to simple sugar by boiling with dilute hydrochloric acid. Sources of starch include cassava, rice, yam, maize, millet, potato, bread and plantain.

Cellulose

Cellulose, like starch, is a complex carbohydrate. One molecule of cellulose is formed from many molecules of glucose joined together with loss of water (a polymer). The general formula for cellulose is $\mathbf{(C_6H_{10}O_5)_n}$. but *n* in the general formula for cellulose is larger than *n* in the general formular for starch. Cellulose is a structural material in plant cell walls. It is a major component of cotton or paper.

Glycogen

One molecule of glycogen is formed from many molecules of glucose. Glycogen is called **animal starch**, and is the form in which starch is stored in the liver or muscles of man.

Uses of carbohydrates to animals

The uses of carbohydrates to animals are as follows:
1 During digestion, complex carbohydrates are broken down to simple sugars, such as glucose. The simple sugars are oxidised during respiration to produce energy for physiological activities and heat for maintaining body temperature.
2 Excess sugars, not immediately required for the production of energy, are stored as glycogen.
3 Sugars are used to synthesise lipids and proteins.

Lipids (Fats and oils)

Fats and oils consist of carbon, hydrogen and oxygen atoms only, but the proportion of oxygen to hydrogen atoms in lipid molecules is less than that in a carbohydrate molecules. Consequently, fats and oils require more oxygen for oxidation, and yield more energy per unit mass oxidised than carbohydrates.

Fats and oils are similar in composition, but fats are solid while oils are liquid at room temperature. Food sources of oils include palm oil, groundnut oil, cod liver oil, corn oil, soya beans oil, and melon oil.

Food sources of fats include butter, margarine, animal fat, cocoa fats, milk.

Uses of fats to animals

Fats are useful to animals. Some of these uses are as follows:
1 Fat is oxidised during respiration to produce energy and heat.
2 Fat is stored under the skin and around organs, such as kidneys.
3 Fat stored under the skin acts as a heat insulator, which reduces heat loss from the skin.

Proteins

A molecule of protein contains carbon, hydrogen, oxygen, nitrogen atoms, sometimes sulphur and rarely phosphorus atoms as well. Proteins are complex substances formed by combinations of amino acid molecules.

There are about 20 amino acids which combine in a large variety of ways to form different proteins. Food sources of proteins include meat, fish, eggs, milk, butter, cheese, beans, groundnut and soya beans.

Uses of proteins to animals

The uses of proteins to animals are explained below:

1. Proteins are body-building food substances. They are used to synthesise protoplasm for growth and repair of wear and tear.
2. Proteins may be oxidised during respiration to produce energy for vital activities and heat to maintain body temperature.
3. Excess proteins in the body cannot be stored, as such. They are broken down in the liver to amino acids, which are further broken down to carbohydrates and stored as glycogen. The conversion of amino acids to carbohydrates involves the removal of the amino group in the amino acid molecule (deamination). This results in the formation of ammonium waste compounds, which are converted by the liver into urea and excreted through urine.

Vitamins

Vitamins are food substances which are required by the body in very small amounts. They are obtained from foods, and certain foods are rich in specific vitamins, The functions of vitamins in animals are as follows:

1. Some vitamins are parts of compounds called co-enzymes, which help enzymes to bring about chemical reactions in the body.
2. Vitamins protect the body from diseases, and when a particular vitamin is deficient, a particular deficiency disease results.

Table 6.2 Vitamins and their roles

Vitamin	Function	Sources	Deficiency diseases/ symptoms
A A_1 and A_2	Normal growth, smooth and healthy skin, healthy eyes, good night vision and strong resistance to diseases.	Cod liver oil, lettuce, spinach, peas, carrot, butter, cheese, egg yolk, liver, milk and palm oil.	Eye defects (e.g. night blindness),reduced resistance to diseases, dry skin, and nerve degeneration.
B_1 Aneurin or Thiamine	Carbohydrate metabolism, cell respiration, normal functioning of heart and nervous system.	Yeast, palm wine, whole grain, lean meat, egg white, spinach, potato, groundnuts, beans.	Beri-beri, slow heart beat, gastro-intestinal disorder
B_2 Riboflavin	As for B_1 and healthy mucous membrane and skin.	As for B_1 and yeast extract.	Scaly flaking skin, cracking of corners of lips, abnormal redness of lips and lesions of the eye.
B_6 Pyridoxine	Metabolism	Yeast, whole grain, liver and milk.	As for B_2.
B_{12} Cobalamin	Important in red blood cell formation (treatment of pernicious anaemia medically).	As for B_6.	As for B_6.

$B_{3,}$ Niacin (Nicotinic acid)	Carbohydrate reduction	Liver, kidney, yeast, milk, whole grain, egg.	Pellagra (rough skin), inflammation of tongues and intestine, nervous disorder, which may lead to putalysis dermatitis and thickening of skin.
C Ascorbic acid	Concerned in oxido-reduction reaction, wound repairs, production of collagen fibres and protein metabolism.	Blackcurrant, fruits, green leaves, liver and milk.	Scurvy, dental disorder and slow inefficient healing of wounds.
Citrin	Cures capillary haemorrhage.	In many fruits, e.g. lemon, orange.	
D	Regulation of calcium and phosphate absorption from the intestine.	Ultra-violet radiation, liver oils of fishes, butter, egg yolk and seed fat, e.g. of cocoa.	Rickets – incomplete calcification of bones, dental caries.
E	Needed for fertility.	Lettuce, oil, wheat, embryo and whole grain.	Interference with placental functions in females and gametogenessis in males; sterility and abortion.
H Biotin	Enzyme system in metabolism of pyruvic acid.	Yeast and seeds	Dermatitis, lassitude and loss of appetite.
K and K_2	Production of pro-thrombin in blood coagulation.	Green vegetables, tomatoes.	Anaemia, increased haemorrhage and failure of blood clotting.

Mineral Salts

Mineral salts are present in food. They enter plants through mineral salts absorbed by the plants for their nutrition. From plants, the mineral salts enter the bodies of animals that feed on the plant materials. Animals also obtain mineral salts through drinking water which usually contains small amounts of mineral salts. Sodium chloride is deliberately added to food because it is required by the body in large amounts. Some times edible common salt contains iodine, deliberately added.

Table 6.3 Functions of mineral elements in the human body

Element	Source	Function
Calcium	Bones, milk, cheese, green vegetables, fish, grains and fruits.	Constituent of bones and teeth, helps maintain correct acid-base balance of blood fluid and helps in blood clotting and normal functioning of cell membranes.
Potassium	In general diet.	Plays a part in conduction of nerve impulses.
Sodium	Common salt	Maintains osmotic pressure of blood plasma and plays a part in condition of nerve impulses.
Magnesium	Vegetables	Present in teeth and bones and co-factor to some enzymatic reactions.
Iron	Various foods e.g. plantain.	Constituent of haemoglobin while deficiency of iron causes anaemia.
Copper	In general diet.	Catalyses use of iron.
Cobalt	In general diet.	Catalyses use of copper and iron, constituent of vitamin B_{12}.
Manganese	In general diet.	Activates some enzymes.
Molybdenum	In general diet	Activates some enzymes.
Zinc	In general diet.	Necessary for proper growth of hair, and proper functioning of some enzymes and insulin.
Nitrogen	Meat, milk, egg and vegetables.	Component of amino acids, proteins and protoplasm, enzymes.

Phosphorus	Bones, fruits and seeds.	Constituent of bones and teeth, and of ATP; necessary for respiration in which glucose is changed into various compounds as phosphates.
Sulphur	In general diet.	Constituent of some proteins, amino acids, vitamin B.
Iodine	General diet water and common salt.	Constituent of thyroxine, a hormone that controls metabolic rate and growth. Deficiency may lead to cretinism and other growth defects.
Chlorine	Common salt and water	Maintains osmotic pressure of blood plasma and tissue fluid.
Fluorine	Common salt and water	Necessary for healthy teeth.

Water

A man can live for about five minutes without oxygen, about one week without water and a few weeks without food. Water is considered as a food substances. While it does not by itself produce energy, it is a body-building material, and many physiological and biochemical processes in the body cannot go on without water.

Use of water to animals

1 Water constitutes about 90 per cent of protoplasm, and is, therefore, essential for body building and growth.
2 Water makes up 50 per cent of the blood, and about 90 per cent of plasma.
3 Water is essential for digestion. It mixes with the food, and enables enzymes to hydrolyse complex food substances.
4 Water helps in the absorption of digested food substances. It acts as a solvent for sugars, amino acids, mineral salts and water-soluble vitamins, which then diffuse into the blood vessels in the wall of the alimentary canal.
5 Glands secrete their products in aqueous medium, e.g. tears, sweat, enzymes, and bile.
6 Excretion of some waste products such as sweat, urine, is made possible when they are in aqueous solution. Water is a major component of these solutions.
7 Water is a major component of the liquids in the eye (aqueous and vitreous humours).
8 Evaporation of sweat (containing water) from the skin cools the skin and helps to regulate body temperature.
9 Water in the blood enables the blood to flow, to dissolve and carry carbon dioxide and excretory substances such as salts.

Diet

Diet is a collective name for all the foods that a person normally eats. All human beings do not have the same diet. If you write down what you have eaten in the morning, afternoon and night for one week or two, that may give an idea of what your diet is.

Activity 6.1 Preparing a table of food eaten in a week

Procedure

Fill in the table provided, the kinds of food you ate at breakfast, lunch and supper for the last week.

Diet varies with factors such as:

1 The foods available in the part of the world where you live,
2 The foods you can afford,
3 The foods you like to eat.

Day of the week	Breakfast	Lunch	Supper
Sunday			
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			

Table 6.4 Effects of unbalanced diet

Deficiency	Effects
1 Carbohydrates	Weakness, low capacity for work
2 Lipids	Weakness, low capacity for work
3 Proteins	Low energy, stunted growth, leanness, in extreme cases kwashiorkor, serious protein deficiency in children impairs both physical and mental development.
4 Vitamins	Deficiency diseases such as night blindness, scurvy, beri-beri.
5 Mineral salts	Deficiency diseases such as poor bone and teeth formation, anaemia, stunted growth.
6 Water	Thirst, failure of metabolic processes, in serious cases of deficiency, death.

Balanced diet

You have learnt, that each class of food has its functions in the body. If one eats mainly some classes of food, but not enough of others, then those functions of the deficient foods will not be performed well in one's body.

A balanced diet is one that contains adequate amounts of all classes of food (carbohydrates, lipids, proteins, vitamins, mineral salts and water) as well as roughage, in correct proportions. Roughage is coarse material such as cellulose from vegetables. It helps the passage of food, under digestion, through the alimentary canal. Roughage also prevents constipation.

The advantages of a balanced diet are that:

1 It provides energy,
2 It builds the body for growth,
3 It repairs wear and tear,
4 It protects the body from diseases,
5 It prevents constipation.

Activity 6.2 Discussion of balanced diet

Procedure

1 Students organise themselves in groups of four.
2 Each group discusses the common diet of people in the area and how to make it balanced.

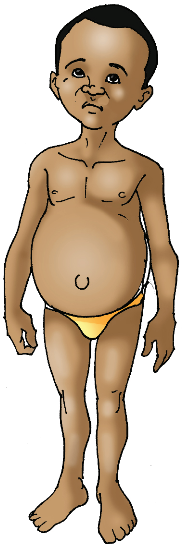


Fig. 6.1 A Kwashiorkor patient

Food tests

Each class of food has one or more characteristic reactions by which that class of food may be identified. A physical or chemical reaction, that is characteristic of a particular class of food, which can be used to identify that class of food, is called a **food test.**

Food tests for sugars

Physical tests for sugars

Sugars are soluble in cold water and also have sweet taste.

Chemical tests for sugars

Glucose, fructose, maltose and lactose are called reducing sugars because they reduce copper (II) ions in **Benedict's** or **Fehling's** solution to copper (I) ions.

Activity 6.3 Testing for a reducing sugar using Benedict's solution

Procedure

1 Mix $1cm^3$ of Benedict's solution with $1cm^3$ of glucose solution in a test tube.

2 Place the test tube in a boiling water bath for three minutes.

Observation

The solution changes from blue to green. Then a yellow, orange or reddish brown precipitate of copper (I) oxide is formed, according to whether the sugar solution is very dilute or fairly concentrated.

Fehling's test

Procedure

1 Mix equal volumes of Fehling's solutions **A** and **B** just before use.

2 To $1cm^3$ of glucose solution in a test tube, add $1cm^3$ of a mixture of Fehling's solutions **A** and **B**.

3 Place the test tube in a boiling water bath or heat to boiling for 2 or 3 minutes.

Observation

A reddish brown precipitate of copper (I) oxide is formed.

Substances that give positive results with Fehling's or Benedict's tests are reducing sugars.

Activity 6.4 Test for starch

Procedure

1 Make a dilute starch solution by making a starch suspension in cold water, and pouring the required quantity of boiling water into it.

2 Allow the starch solution to cool.

3 Put $2cm^3$ of the dilute starch solution in a test tube.

4 Add one drop of iodine solution to the starch solution.

Observation

The starch solution turns blue-black. (A positive result may be obtained by adding a drop of iodine to solid starch.)

Activity 6.5 Test for lipids

1 Grease spot test

Procedure

Place a drop of palm oil or groundnut oil on paper and allow it to dry. Raise it up and look at it.

Observation

The drop of oil forms a translucent grease spot.

2 Emulsion tests

Procedure

Dissolve a little fat or oil in 2 cm^3 of ethanol in a test tube. Add 2 cm^3 of water and shake.

Observation
A milk-like emulsion is formed.

3 Sudan III test
Procedure
Add 2 drops of oil to 3 cm^3 of Sudan III solution in a test tube and shake.

Observation
A red coloured liquid is formed. (This test is no longer popular because Sudan III is red to start with.)

Activity 6.6 Test for proteins

1 Millon's test
Procedure
Put a small quantity of egg albumen in a test tube. Add 0.5 cm^3 Millon's reagent to it and shake.

Observation
A white precipitate is formed, which on heating turns red.

2 Biuret test
Procedure
a) Add about 1 cm^3 of dilute sodium hydroxide solution to about 2 cm^3 of egg albumen or aqueous extract of bean seeds in a test tube and shake.
b) Add 1 to 2 drops of dilute copper (II) tetraoxo sulphate (VI) (copper sulphate) solution and shake.
c) For control, add the same amounts of these reagents to 2 cm^3 distilled water in a different test tube.

Observation
A purple colour indicates protein.

3 Xanthoproteic test

Procedure
a) Place about 3 cm^3 of egg albumen in a test tube.
b) Add 1cm^3 of concentrated HNO_3 (trioxo nitrate (V)) acid).
c) Heat. A yellow precipitate is formed.
d) Cool. Add 1cm^3 of dilute ammonia solution.

Observation
The yellow precipitate turns orange.

Activity 6.7 Identifying food substances using food tests

Materials required
Two food substances in powder form.

Procedure
1 Decide what food substance you suspect each substance to be.
2 Carry out food tests using the procedures described above.
3 Report your observations and inferences.

Modes of nutrition

Modes of nutrition can be divided into two main kinds, namely, **autotrophic** and **heterotrophic** nutrition. Each main type of nutrition has sub-types.

Autotrophic nutrition

Autotrophic nutrition is one in which an organism manufactures its own complex organic food substance from simple inorganic substances. There are two groups of autotrophic organisms: **photosynthetic** and **chemosynthetic autotrophs**.

Photo-autotrophic organism
Green plants can make their own food. You have learnt that photosynthesis is the process of synthesising simple sugar, with radiant energy of sunlight, using carbon dioxide and water, with the aid of chlorophyll, organisms such as green sulphur bacteria, can also synthesise simple sugar by photosynthesis. From simple sugar and other elements, plants and green bacteria can synthesise more complex food substances such as lipids and proteins.

Chemo-autotrophic organisms
Chemosynthetic organisms are those that derive energy from energy-releasing (exergonic) reactions carried out by them. The organisms use this energy to synthesise organic food substances from carbon dioxide.

Chemosynthesis occurs in bacteria. They carry out various inorganic oxidation reactions that release energy. Some examples are given below:
a) Nitrifying bacteria that convert ammonium compounds to nitrate:

$$2NH_3 + 3O_2 \xrightarrow[\text{Bacteria (aerobic)}]{\text{Nitrosomonas}} 2HNO_2 + 2H_2O + \text{Energy}$$

(b) Nitrifying bacteria that convert nitrites to nitrate:

$$HNO_2 + O_2 \xrightarrow[\text{Bacteria (aerobic)}]{\text{Nitrobacter}} 2HNO_3 + \text{Energy}$$

(c) Colourless sulphur bacteria oxidise hydrogen sulphide to sulphur.

$$2H_2S + O_2 \xrightarrow[\text{Bacteria}]{\text{Colourless sulphur}} 2S + 2H_2O + \text{Energy}$$

(d) When hydrogen sulphide is not available, colourless sulphur bacteria oxidise sulphur to sulphate:

$$2S + 2H_2O + 3O_2 \xrightarrow[\text{Bacteria}]{\text{Colourless sulphur}} 2H_2SO_4 + \text{Energy}$$

Beggiatoa, *thiothrix*, *thiospirillopsis* and *thiobacillus thiooxidans* are examples of sulphur bacteria that oxidise hydrogen sulphide to sulphur or sulphur to sulphate.

Heterotrophic nutrition

Heterotrophic nutrition is one in which the organism cannot make its own food from simple inorganic substances. There are different forms of heterotrophic nutrition. They include holozoic, saprophytic, parasitic, and symbiotic nutrition.

Holozoic nutrition

Holozoic nutrition means that an organism feeds on complex organic materials, often in solid form, which require ingestion, digestion and absorption before utilisation. Animals that practice holozoic nutrition include **herbivores** (which feed on plant materials, e.g. sheep), **carnivores** (which eat flesh, e.g. leopard, praying mantis, toad), and **omnivores** (which feed on both plant and animal materials, e.g. man, chicken).

Herbivores include rabbits, guinea-pigs, rats, sheep, goats and cows. They have adaptations that fit them to their food. For example:

1 Herbivores have longer alimentary canals than carnivores, so as to complete the digestion of complex plant materials such as cellulose;
2 Those that chew the cud (**ruminants**), have a four-chambered stomach, e.g. cow, sheep;
3 Some have a gap in the teeth, between incisors and premolars called **diastema**;
4 Premolars are similar to molars;
5 Premolars and molars have surfaces with cusps for chewing grass;
6 Teeth grow throughout life;
7 They have symbiotic bacteria in the alimentary canal, which secrete enzyme that digests cellulose in the food.

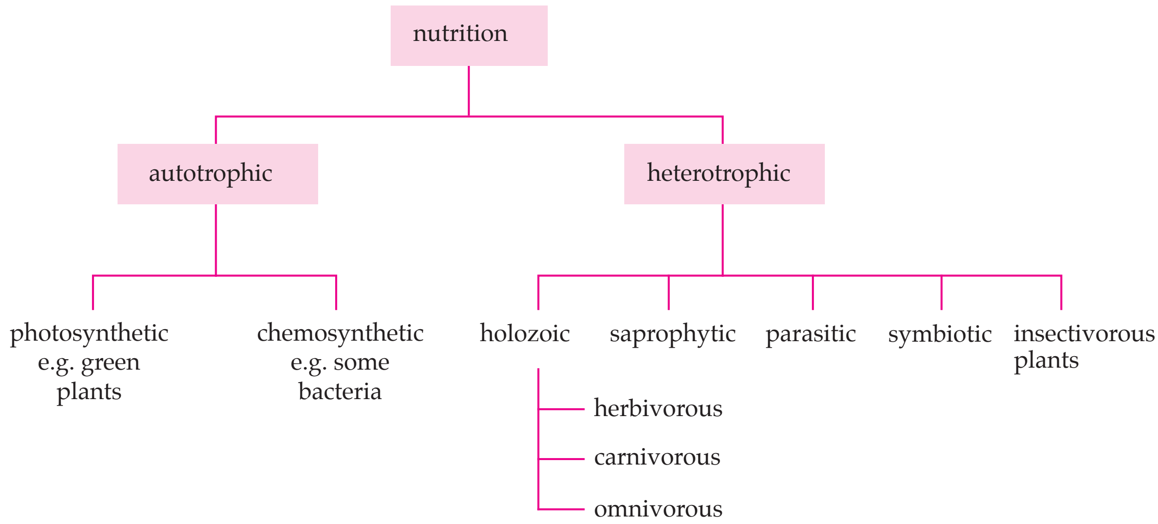


Fig. 6.2 Modes of nutrition and their inter-relationship

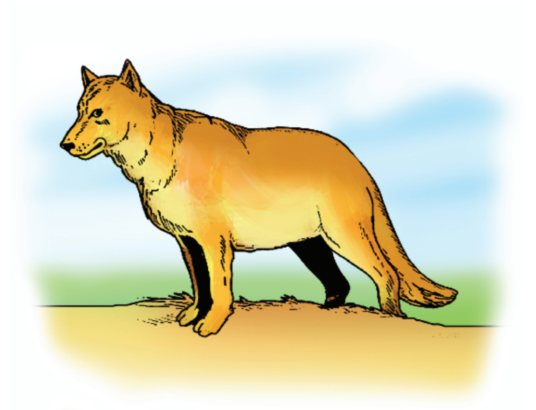


Fig. 6.3 A dog

Carnivores include lion, leopard, hawk, kite and toad. The adaptations to the carnivorous mode of feeding are:

1 Fast movement, to overtake their prey;
2 Keen eyesight, to see the prey;
3 Sharp retractable claws and sharp teeth or beak, to grasp the prey;
4 Sharp pointed canines to tear flesh;
5 Carnassial teeth (last upper premolar and the first lower molar on each side) operate in a scissor-like fashion; and are used for tearing flesh from bone;
6 Keen sense of smell to identify prey.

Omnivores include man, chicken and pig. Their teeth are adapted for general diet. They have incisors for cutting food. Canines are not very prominent or sharp as in carnivores, while premolars and molars have flat surfaces for grinding.

Activity 6.8 Observing what animals eat and how

Procedure

1 Identify five animals of your choice.
2 Observe what they eat and how they feed.
3 Record your observations in your notebook.

Saprophytic nutrition

Saprophytes are organisms that feed on dead organic matter. The organism secretes enzymes on the dead organic matter, digests it extracellularly, and absorbs the product of the digestion. Several kinds of fungi are saprophytes, such as the moulds that grow on bread, orange peels, overripe fruits and the fungi that bring about the decay of organic matter in the formation of humus.

Activity 6.9 Examining saprophytes

Materials required

Mushroom, toad-stool, shelf- fungi, mould on bread.

Procedure

1 Collect samples of mushrooms, toadstool and shelf fungi from the locality. Note where you collected each type, and what material it is growing on.
2 With a hand lens, observe the structure of **rhizopus** growing on stale bread provided by your teacher. Record what you see in your notebook.

Parasitic nutrition

Parasitism is an association between two organisms, known as the **host** and the **parasite**. The parasite feeds on or at the expense of the host. The parasite is usually smaller than the host. The parasite benefits while the host suffers. Parasites that live on the hosts are called **ectoparasites**, while those that live inside the hosts are called **endoparasites**.

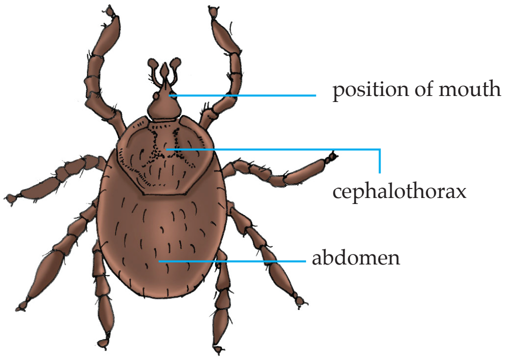


Fig. 6.4a) Tick

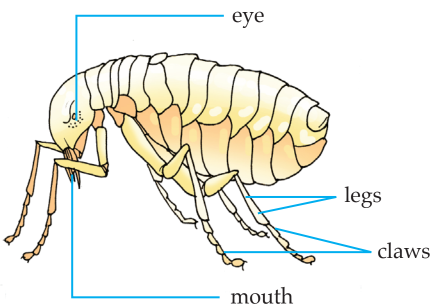


Fig. 6.4b) Flea

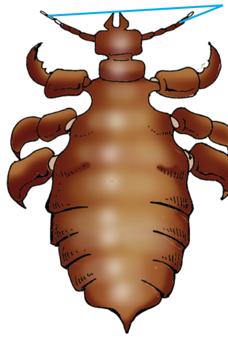


Fig. 6.4c) Louse

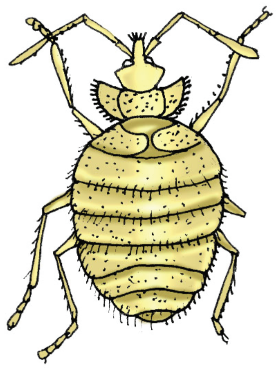


Fig. 6.4d) Bed-bug

Ectoparasites include ticks found on cows or dogs, fleas found on dogs or rats, lice found on chickens and man, bed-bugs which bite and suck the blood of man. Endoparasites include the roundworm (*Ascaris*) and the tape worm (*taenia solium*) both of which live in the small intestine of man where they feed on digested food.

Endoparasites are also found in human and animal blood, muscles and organs. The liver fluke, *Fasciola hepatica* is found in the liver of sheep. The human tape worm, *Taenia solium*, is found also in the muscle of pig, the alternative host. A similar tapeworm in cattle, called *Taenia saginata*, may also infect man. The filarial worm, *Wucheraria bancrofti*, is a round worm which is found in the lymphatic system of man, and causes elephantiasis. The guinea-worm, *Dracunculus medinensis* is found in the subcutaneous tissue of man from where it pushes out its head through a wound caused by it on the foot or leg of the host.

Some **nematodes** are also parasites which live in parts of certain plants such as the roots of tomatoes and bananas. They inhibit the growth and hence, the yield of the plants.

Some **protozoans** are endoparasites. Two very important diseases in West Africa are caused by endoparasitic protozoa. Malaria is caused by **plasmodium** while sleeping sickness is caused by **trypanosoma**.

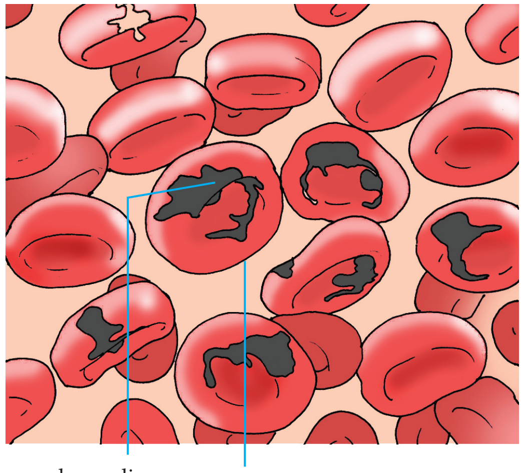


Fig. 6.5a) Plasmoduim

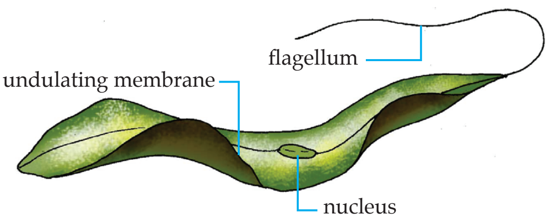


Fig. 6.5b) Trypanosoma

Activity 6.10 Looking for parasites in animals

Materials required

Dissected toad, rat or lizard, infected liver, infected flesh of pig, fresh fish, forceps, saline solution, and hand lens.

Procedure

1. Your teacher will provide you with a dissected toad, rat, or lizard. Look for parasitic worms in the alimentary canal. Keep a record of the number and kinds of worms seen.
2. Put each of infected animal liver and flesh in saline solution to make the parasites come out. Use a pair of forceps to bring out the parasites in the liver or meat given to you. Examine the parasites with a hand lens. Record where the parasites are found and describe their characteristics.

3 Cut open the fresh fish and cut open its alimentary canal along its length. Examine the alimentary canal for parasites. Examine also the gills. Sort the parasites. Draw and describe each kind.

Activity 6.11 Looking for parasites on animals

Procedure

1 Visit a place where cattle are kept (cattle pen) or fowls-sellers' stalls at the local market.
2 Look for parasites on these animals.
3 For each parasite, use a hand lens to observe carefully the shape of its body, how many legs it has, and the structure of its mouth parts.
4 Record your findings.

Adaptations to parasitic mode of life

Parasites have special adaptations which fit them to their modes of life and enable them to achieve success.

Adaptations of animal's ectoparasites

1 Animal ectoparasites have shapes adapted to their respective habitats. The body louse and the tick are flattened, so that they are not easily shaken or brushed off. The flea is laterally compressed, so that it can move easily between body hairs.
2 Animal ectoparasites usually have no wings because they do not fly about. The flea has legs that enable it to jump short distances on the host.
3 Animal ectoparasites have mouth parts adapted for feeding on the host. Many of them bite and suck blood.
4 They rely on contact between hosts to move from one host to the other. The bedbug stays on the bed, rarely on the host. It bites whoever comes to lie on the bed.

Adaptations of endoparasites

1 Some endoparasites have organs for attachment to avoid being pushed out of the host, e.g. the tape worm; an intestinal parasite of man attaches itself by four suckers and by hooks, so that it will not be flushed out with the contents of the intestine.

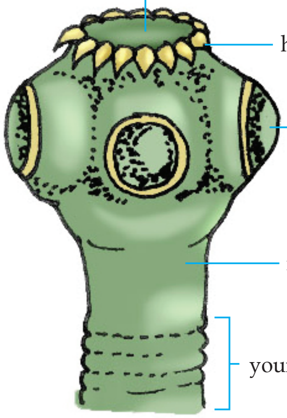


Fig. 6.6 Head of tape worm, Taenia solium

2 Endoparasites have a simple structure, because they do not have to search for their food. The tape worm is surrounded by digested food in the human intestine. It absorbs food through its entire body surface. It has no digestive system, no sense organs, and no organ of movement. The round worm *Ascaris lumbricodes*, which also lives in the human intestine, has a simple structure, without eyes, and organs for movement.
3 Endoparasites in the alimentary canal can tolerate low oxygen concentration in the system.
4 Endoparasites in the alimentary canal secrete anti-enzymes which prevent them from being digested by human digestive enzymes.
5 The biggest problem of endoparasites is how to infect new hosts. One of the ways of solving this problem is that they produce many eggs or offspring so that the chances of infecting new hosts are increased. The tape worm, *Taenia solium*, produces millions of eggs. It achieves this by having a complex reproductive system, and by formation of many *strobili*, each carrying numerous eggs. One round worm, *Taenia solium*, produces up to 200,000 eggs.

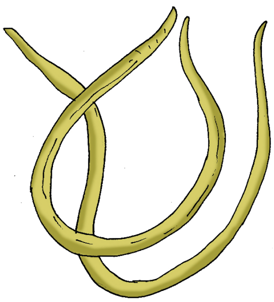


Fig. 6.7 Roundworm, Ascaris

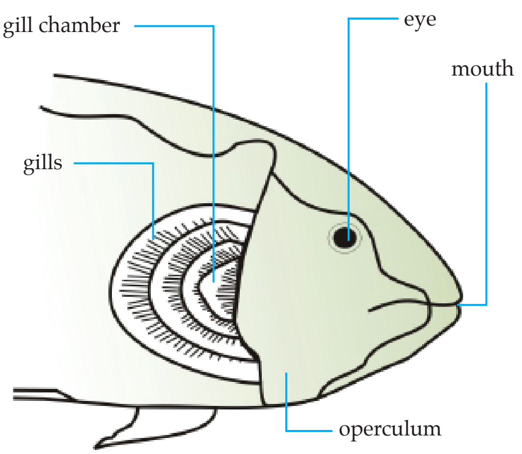
6 The eggs of endoparasites are resistant to weather conditions, and can remain viable for a long time.
7 Endoparasites have complex life histories, which help to improve chances of infecting new host. Some endoparasites have intermediates hosts, e.g. the mosquito is the intermediate host for the malaria parasite that attack man; the tse-tse-fly is the intermediate host for *Trypanosoma* that attacks man
8 Parasites are host-specific, that is, a parasite attacks one or a limited number of hosts, but not others. *Taenia saginata* attacks cattle, though sometimes it attacks man too. It does not attack all other animals. In this way the parasites avoid undue competition among themselves for hosts.

Feeding mechanisms in holozoic organisms

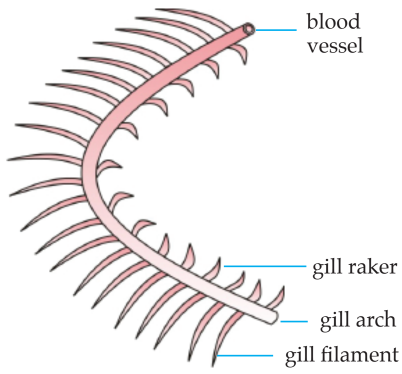
Holozoic organisms adopt various methods in taking in food. Some of these methods are described below.

1 **Filter feeding**

A filter feeder feeds on very tiny particles or organisms that cannot be picked up fast enough, one by one to provide sufficient food. Filter feeders are aquatic animals. they make water flow through a sieve-like structure in their body in order to collect a reasonable quantity of their food. They are therefore sometimes called **microphagous feeders**. Water is generally drawn to the body of the animal, either by the movement of appendages, as in a number of crustaceans or by action of cilia. The water then passes through some kind of sieve which filters off the particles. Then the water flows out through an outgoing passage.



(a)



(b)

Fig. 6.8 A gill arch, with gill rakers and gill filaments

For instance, the marine fish, herrings and sardines are filter feeders. They take in water through the mouth, and pass it out through the gill slits. This process used for breathing, is also used for feeding.

A gill consists of a gill arch, which carries gill rakers on the inner side, and gill filaments on the outer side. As the water passes through the gill slits, the gill rakers strain out particles of food from the water, and the fish feeds on these particles.

Blue whales, the largest kind of whales, are filter feeders.

2 **Deposit feeding**

Deposit feeding is by moving through, sifting and swallowing soil or sediment at the bottom of bodies of water. The soil or sediment they swallow is a mixture of both useful food, in form of small particles of living or dead organic matter, and inert matter, such as silt or clay or sand, of little food value. Earthworms, polychaete worms, fiddler crabs, insects and insect larvae are examples of deposit feeders. Beetles and other organisms that live inside heaps of compost or animal dung are also deposit feeders.

3 **Fluid feeding**

Fluid feeding is taking in food in liquid form. Animals which are fluid feeders may be divided into two groups. The first group consists of animals that lie within or wallow in their food, such as the tapeworm in the human intestine. Such an animal can be called a **wallower**. The second group consists of **suckers** which feed by sucking fluid from plants, animals or dead organic matter. Examples are bugs (e.g. aphids), butterflies, mosquitoes and house flies.

Animals that practise fluid feeding:

a) *Tapeworm*

Tapeworm is an internal parasite, which lives in the human small intestine. There, the food eaten by the host is already digested and is in liquid form. The tapeworm lies or wallows in this liquid, digested food and absorbs that food through its entire body surface.

b) *Bugs*

Insects such as aphids, cicads or cotton-stainer, suck juices from the leaves and stems of plants for which they require strong, piercing mouth parts. Their major mouthpart, a rostrum is formed mainly from the labium. It is comparatively short and strong, and has a groove on the dorsal side from inside of which both the mandibles and the maxillae can be brought out. The mandibles have cutting edge for cutting into stems, while the maxillae, when placed against each other form two holes, a smaller one for the passing out of saliva and a larger one for sucking juice.

c) *Mosquito*

The female anopheles mosquito feeds on human blood, while the male feeds on plant and fruit juices. All female mouth parts, with the exception of the labium are modified into piercing stylets and sucking tubes. The stylets have a sharp cutting edge. When the female anopheles mosquito bites its victim, it first pours out its saliva into the victim. This saliva is able to prevent the blood of the victim from clotting while mosquito is sucking it. In this way, the clotting of the blood and blocking of the sucking tube is avoided.

d) *Butterfly*

The butterfly feeds only on nectar, secreted by nectaries located at the bases of ovaries of flowers. In butterflies, the maxillae are modified into long proboscis for reaching down to the nectaries. When not in use, the proboscis is rolled into a coil under the head.

e) *Housefly*

The mouthparts of the housefly are modified into a strong proboscis formed from the labium. Other mouth parts are reduced. The end of the labium is expanded into labella, with many food channels and testing hairs, in order to equip it for juice sucking. When a housefly comes to rest on its food, which may be uncovered human food, open faeces, decaying plant or animal matter, dirty decaying food materials in dustbins or gutters, it first pours out saliva on the food materials. The saliva partly digests the food and converts it into fluid form. Then the housefly sucks the liquid food.

Mammalian teeth

Different types of teeth

The word **dentition** refers to the development, number, arrangement and types of teeth in an animal.

Milk and permanent dentition

In a child, the first set of teeth is called the **milk dentition**. At the age of about six, the milk teeth fall off, and are replaced by the **permanent teeth**, which remain till old age.

Homodont and heterodont dentition

In a fish, an amphibian or a reptile, all the teeth are similar in size and shape. These animals are said to have **homodont dentition**. In a mammal, however, there are four different kinds of teeth, which differ in structure and function. These different kinds of teeth are:

1 *Incisors*

This kind of tooth is located in the front part of the upper and lower jaws. It is chisel shaped, with a broad and sharp edge. It is used for cutting pieces of food and in certain cases for apprehending prey.

2 *Canines*

The canines are located next behind the incisors, in the upper and lower jaws. They are large, pointed, sharp and are used for seizing prey and tearing flesh.

3 *Premolars*

The premolars follow behind after the canines, in the upper and lower jaws. They are large. In some mammals, premolars have flat surfaces (for grinding food) while in others they have surfaces with two or more ridges called cusps used to tear flesh from bone.

4 *Molars*

Premolars and molars are called cheek teeth because they are located in the cheeks. Molars are the last set of teeth in the upper and lower jaws. Molars only occur in the permanent dentition like premolars, they are large in size, and their surfaces may be flat or have cusps.

Structure of a mammalian tooth

Externally, a tooth has three parts: a **crown** which projects above the jaw bone, the **root**, which is embedded in the jaw bone, and the **neck**, which lies where the crown and the root meet, and is covered by the **gum**. The tooth is fixed inside a hole in the jaw bone known as the **alveolus**.

All incisors and canines have one root each. Some premolars have one root each while others have two. The molars have two or three roots each.

The internal structure of a tooth is seen in a longitudinal section of the tooth. It has a **central pulp cavity** in which there are connective tissue, blood vessels and nerves. The pulp cavity is surrounded by a hard material called **dentine**, which makes up a major part of the body of a tooth. In the crown and neck, the dentine is covered by another hard substance called **enamel** which is white and contains calcium compounds. The enamel protects the dentine. In the root, the dentine is covered by a substance called **cement**, which is surrounded by a fibrous, vascular tissue called the **periodontal membrane**. This membrane holds the tooth in the alveolus. There is a hole at the lower end of the root of each tooth through which blood vessels and nerves pass into the pulp cavity to keep the living cells there alive and sensitive. In some mammals such as the rabbit, this hole is large, and remains open throughout the life of the organism. Hence the teeth grow continuously throughout the organism's life. In some mammals such as humans, this hole is small. Hence, in old age the tissues in the pulp cavity may die, and the teeth fall out.

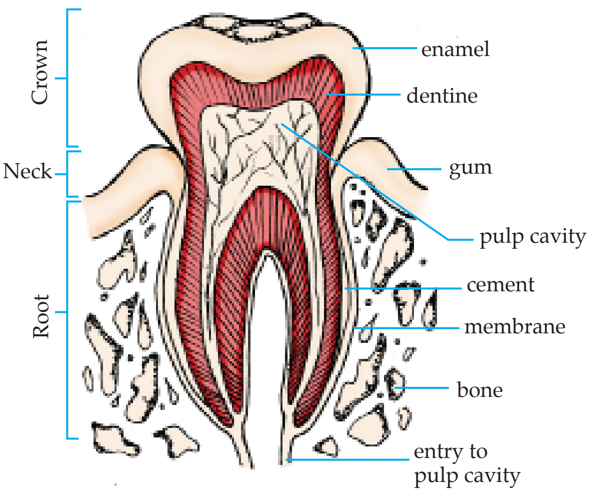


Fig. 6.9 Vertical section of a human molar tooth

Dental formula

The dental formula of an organism is a short way of writing the numbers of different kinds of teeth in one half of the upper and lower jaws.

Examples:

Man	$i\,\frac{2}{2},\ c\,\frac{3}{2},\ pr\,\frac{2}{1},\ m\,\frac{3}{3} = 32$
Dog	$i\,\frac{3}{3},\ c\,\frac{3}{2},\ pr\,\frac{3}{2},\ m\,\frac{3}{2} = 42$
Sheep	$i\,\frac{3}{3},\ c\,\frac{3}{2},\ pr\,\frac{3}{3},\ m\,\frac{3}{3} = 32$
Rabbit	$i\,\frac{2}{1},\ c\,\frac{3}{2},\ pr\,\frac{3}{2},\ m\,\frac{3}{3} = 28$

Adaptation of dentition to mode of nutrition

Animals have teeth that are adapted to their modes of nutrition.

Characteristics of the teeth of herbivores (example: rabbit)

1. Incisors are sharp, and are used for cutting grass. They grow continuously throughout the life of the animal.
2. Canines may be absent, leaving a space called the diastema.
3. Molars and premolars have broad surfaces with transverse ridges, and are used for grinding grass.
4. Molars and premolars look alike.

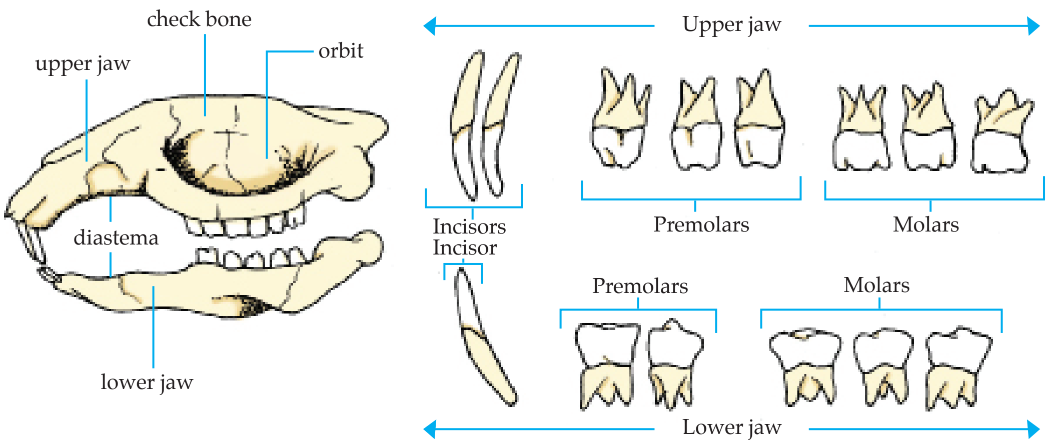
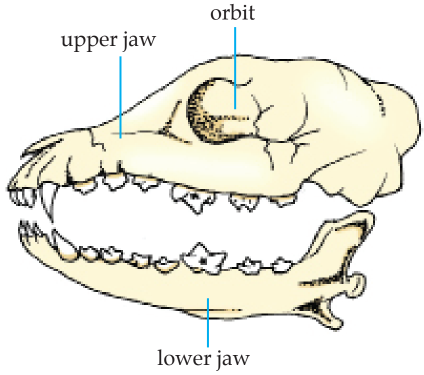


Fig. 6.10a) Dentition of a herbivore (a rabbit)



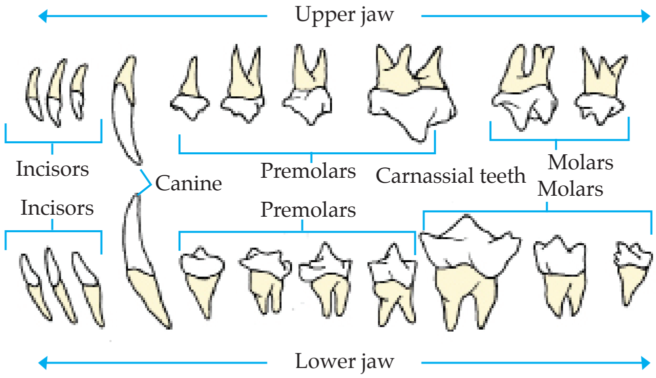


Fig. 6.10b) Dentition of a dog

Characteristics of the teeth of a carnivore (example: dog)

1 The incisors are sharp and are used for catching and holding prey.
2 Canine are long, curved and pointed for attack, defence and for holding prey.
3 Last upper premolar and first lower molar on each side are called carnassial teeth. They are large, with pointed projections and are used for tearing flesh from bone.
4 Molars have cusps for crushing bones.

Characteristics of the teeth of an omnivore (example: human)

1 The teeth of an omnivore such as a human, do not show much specialisation. They can be used for eating various kinds of food.
2 The incisors are fairly sharp, and are used for cutting or biting off pieces of food.

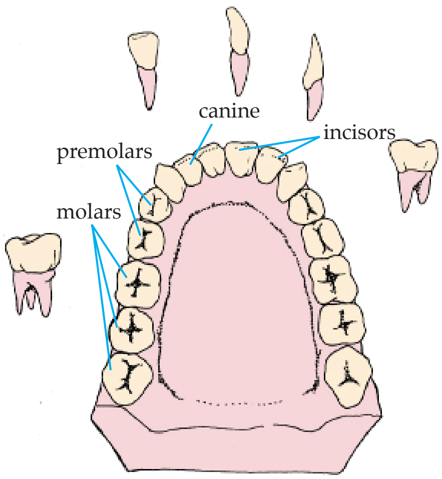


Fig. 6.10c) Dentition of a man

3 The canines are not very different from the incisors.
4 The premolars and molars have flat surfaces with cusps for grinding food.

Enzymes

Enzymes are biochemical catalysts which speed up the rates of metabolic reactions but remain unchanged or unused up at the end of the reactions.

Characteristics of enzymes

1 Enzymes are proteins.
2 They speed up reactions but remain unchanged at the end of the reactions.
3 They catalyse reversible reactions in both directions.
4 A small quantity of enzyme acts on a large amount of substrate.
5 Enzymes are destroyed by heat.
6 Each enzyme acts optimally at a specific pH.
7 Each enzyme acts best within a narrow range of temperature.
8 An enzyme is specific in reaction; it can speed up one reaction, but not others.

Digestive enzymes

Digestion is the process by which complex organic food substances are broken down into simple, diffusible molecules, which can be absorbed through the walls of the intestine into the body. This digestion is brought about by digestive enzymes. In many cases, the digestive enzymes bring about hydrolysis of complex molecules.

Classes of digestive enzymes

Digestive enzymes are classified into three groups according to the classes of food they act on.

Table 6.5 Classes of digestive enzymes

Class of enzyme	Class of food digested	Example
Amylases	Carbohydrates	Amylase
Lipases	Lipids	Steapsin
Proteases	Proteins	Pepsin, trypsin

Enzyme precursors and activators

Some digestive enzymes are formed by two secretions from two different parts of the digestive system. One secretion is an **active precursor**, while the other is the **activator**. When the two secretions mix, one active enzyme is formed. For instance, **tripsinogen** is an active precursor secreted by the **islets of Langerhans** in the pancreas. The duodenum secretes the activator, **enterokinase**. The secretions form the active enzyme **trypsin** which acts in the intestine.

Functions of digestive enzymes

Digestion involves physical and chemical changes. Physical changes include chewing of food by teeth in the mouth and physical mixing of food with digestive secretions in the stomach and intestines. This mixing is called **churning**. Enzymes bring about chemical changes as shown in Table 6.6.

Table 6.6 Function of digestive enzymes

Enzyme	Source	Location	Food digested	Action
Ptyalin	Salivary glands	Mouth	Starch	Starch $\rightarrow$ maltose
Rennin	Glands in wall of stomach	Stomach	Milk	Curdles milk
Pepsin	Glands in wall of stomach	Stomach	Proteins	Proteins $\rightarrow$ peptides
Trypsin	Pancreas	Duodenum	Proteins	Proteins $\rightarrow$ peptides
Lipase	Pancreas	Duodenum	Lipids	Lipids $\rightarrow$ fatty acids and glycerol
Amylase	Pancreas	Duodenum	Starch	Starch $\rightarrow$ maltose
Amylase	Intestinal wall	Intestine	Starch	Starch $\rightarrow$ maltose
Aminopeptidase	Intestinal wall	Intestine	Tripeptides	Tripeptides $\rightarrow$ dipeptides

Dipeptidases	Intestinal wall	Intestine	Dipeptides	Dipeptides → amino acids
Maltase	Intestinal wall	Intestine	Maltose	Maltose → glucose
Sucrase	Intestinal wall	Intestine	Sucrose	Sucrose → glucose + fructose
Lactase	Intestinal wall	Intestine	Lactose	Lactose → glucose + galactose

Importance of enzymes

The purpose of digestion is to convert complex, insoluble food molecules (such as starch) into simple soluble food molecules such as glucose, which can be absorbed from the intestine into the body, where it is utilised for producing energy, or growth and repair or other functions. Enzymes are the chemicals that convert complex molecules into simple ones. Without enzymes, chemical digestion cannot take place, and animals cannot benefit from the complex food substances they eat.

Summary

This chapter has taught the following:

- All living things feed.
- All animals are heterotrophic because they cannot make their own food.
- For optimal growth and health, animals require food substances, each in adequate amount. Deficiency of any of these soon becomes evident through impaired health and growth of the animal.
- Animals feed in diverse ways.
- Teeth are used in feeding, such as for catching prey, biting off pieces of food, shearing bone from flesh and chewing food.
- The teeth of a mammal are adapted to its mode of nutrition.
- Enzymes digest food. This means that they convert large insoluble, organic food molecules into small, organic, soluble, absorbable food molecules.
- Different enzymes digest different food substances.

Revision questions

1 Which of these are described as micronutrients?
   A Fats and oils
   B Mineral salts and vitamins
   C Proteins and lipids
   D Zinc, boron and molybdenum
   E Water and rice.

2 Which of the following is food used for?
   A Synthesis of protoplasm
   B Growth
   C Repair of the body
   D Production of energy
   E All of the above.

3 Which of the following is not a holozoic form of nutrition?
   A Filter feeding
   B Deposit feeding
   C Chemosynthesis
   D Parasitic feeding
   E Fluid feeding.

4 An enzyme is a biochemical catalyst because it is ____________________.
   A alive
   B a catalyst
   C specific in action
   D studied in biology
   E produced by a living thing

5 Distinguish between autotrophic and heterotrophic nutrition naming two examples of each.

6 Describe the structure of a mammalian tooth. State the characteristics of the dentition of a carnivore.

7 State the characteristics of an enzyme.

8 Describe one chemical test for glucose and one chemical test for proteins.

Theme 3
The organism and its environment

Chapter 7 Basic ecological principles

The concept of ecosystem highlights the fact that an organism and its environment are closely related. An organism obtains its requirements for life from the environment. In the case of plants, this includes sunlight, water, mineral salts, carbon dioxide and oxygen. In the case of animals, the requirements for life obtained from the environment include water, food, oxygen, warmth and shelter.

Without the environment, an organism cannot survive. Through adaptation, an organism is made fit for its environment.

Introduction

The whole universe, with living and non-living things constitutes nature. The portion of the earth inhabited by living organisms, including the land masses, oceans and atmosphere is called the **biosphere**. In the biosphere, the rocky crust of the earth is called the **lithosphere**, the oceans, seas, lakes, rivers, streams, ponds and all other bodies of water make up the **hydrosphere**, while the envelope of gases surrounding the earth is called the **atmosphere**.

Countless interactions take place in the biosphere every second and all the time. Interactions take place between non-living things, between living things, as well as between living and non-living things. When two winds clash, thunder and lightning may result as well as other consequences. As the sun rises in the morning, sleeping animals stir themselves from slumber and green parts of plants become active in making sugar. If a hungry mosquito bites you, you will feel pain, and later you may become ill.

Many interactions in the biosphere affect man directly or indirectly. **Ecology** is concerned with the study of interactions in the biosphere.

Ecological concepts

Consider a maize plant on a farm. It is surrounded by the atmosphere. It is growing on the soil. It receives sunshine which enables it to make its food. The wind may break its stem. If the rainfall fails, it may die. Insects may eat its leaves and fruits.

The total surrounding of an organism is called its **environment**. The environment includes the physical surroundings, non-living factors and living organisms which influence an organism in its surroundings. For instance, the environment of a maize plant in the farm includes:

1 The soil and the surrounding atmosphere,
2 The climatic elements, such as rainfall, temperature, sunlight, relative humidity and wind,
3 Living organisms within or above the soil, such as ants and grasshoppers.

The environment of an organism is essential for its survival. In fact, an organism depends partly on its non-living environment for life. The soil supports the growing maize plant and supplies it with mineral salts and water. It absorbs carbon dioxide and oxygen from the atmosphere for photosynthesis and respiration respectively. Without the soil and the surrounding atmosphere, the maize plant in the farm cannot remain alive.

An organism constantly interacts with living and non-living things within its environment. A fish in a stream constantly obtains oxygen from and gives out carbon dioxide to the water. It obtains food from, and passes out waste products into the environment. It may be eaten by predators and if the stream dries up, it migrates; hide in the interesting range of interrelationships with its environment.

Ecology is the branch of Biology concerned with the study of interrelationships between living organisms and their external environment. Ecology is divided into two main sub-branches, **autecology** and **synecology**. Autecology is concerned with the study of an individual organism or a single species of organism and its environment. The study of the interrelationships between a single palm tree and its environment is an example of autecology. The study of the interrelationships between groups of organisms or species of an organism living together in an area (such as organisms in a salt-water marsh, or an abandoned farmland, or a stream) and their environment is an example of synecology.

If you wished to collect an earthworm, you would probably look for it in moist soil in a garden. If you wanted to catch a Tilapia fish, you would probably look for it in a stream or river. Similarly, to catch a cockroach, you would probably have to look in a dark corner of a home, possibly containing some remains of human food. The kind of place where an organism normally lives in nature is called its **habitat**. An organism normally lives in a specific part of a habitat. For instance, spirogyra lives at the surface of slow-flowing fresh water stream, Tilapia swims in the water, and tadpoles are found at the stream bottom. In these locations, each organism does something in relation to other organisms. Spirogyra is an **autotroph** (i.e. it does not depend on the environment for a source of organic substance as nutrients. It manufactures complex organic substances from simple inorganic substances such as water, carbon dioxide, and nitrate ions). Tilapia is a consumer of small plants and animals in the water; the tadpole is a primary consumer of small water plants.

The specific place occupied by an organism, and the activity it engages in, with reference to other organisms is its **niche**. Accordingly, the niche of the tadpole is that it lives at the bottom of slow fresh water streams and is a primary consumer.

Living and non-living things in a natural area collectively form what is called an **ecological system** or **ecosystem**. This term highlights the fact that in nature, there is constant interaction between the living and non-living components. For instance, in an area of forest, the trees absorb water and mineral salts from the soil. The water is used by the plant, while the excess is transpired into the atmosphere. The trees shed their old leaves, which earthworms, ants, beetles and fungi feed on and cause them to decay on the soil. As they decay, some nutrients originally absorbed from the soil by the trees are returned to the soil, for possible absorption by the trees again. So there is recycling of materials between the living components (trees) and the non-living components (soil and atmosphere). In the same way, forest animals may eat leaves and fruits of trees then pass out their droppings on the soil, thus recycling nutrients in the forest.

An **ecosystem or ecological system** is defined as a natural unit of living and non-living things which interact to form a stable system in which a cyclic interchange of materials takes place between the living and the non-living components. Examples of ecosystems are a lake, a forest, a fallow farmland, a stream or large pond.

Components of an ecosystem can be divided into two: living (**biotic**) and non-living (**abiotic)** components.

All the living things in an ecosystem constitute a biotic community or community in a community; all the living things that belong to one species form a population.

Habitats

There are two main kinds of habitats: **aquatic** (water) and **terrestrial** (land) **habitats**.

Aquatic habitats

Aquatic habitats are divided into:

1. **Marine habitats**, which contain saltwater and include the open sea, sea-shore and saltwater lakes.
2. **Freshwater habitats,** which contain salt-free water and include springs, streams, rivers, freshwater ponds and rice fields flooded by freshwater.
3. **Brackish water habitats,** which contain a mixture of saltwater and freshwater. Brackish water habitats occur in estuaries and lagoons where freshwater flowing down rivers mixes with seawater brought in by tides.

Activity 7.1 Naming habitats

Complete the following table by filling in, as precisely as possible, the habitat of each of the organisms.

Table 7.1 Some organisms and their habitats

Organism	Precise habitat
1 Spirogyra	
2 Moss	
3 Rhizopus	
4 Tadpole	
5 Housefly	

Terrestrial habitats
Terrestrial or land habitats are divided into:
1 **Arboreal habitats** (on, in or among trees),
2 **Ground habitats,** and
3 **Underground habitats**.

Ecological or habitat factors

An organism will live in a particular kind of habitat that provides it with its requirements for life, including oxygen, food, water, shelter and facilities for reproduction. For instance, Tilapia fish can obtain these requirements in freshwater, but not on land. Apart from providing the requirements for life, the habitat also provides a suitable environment for the organism.

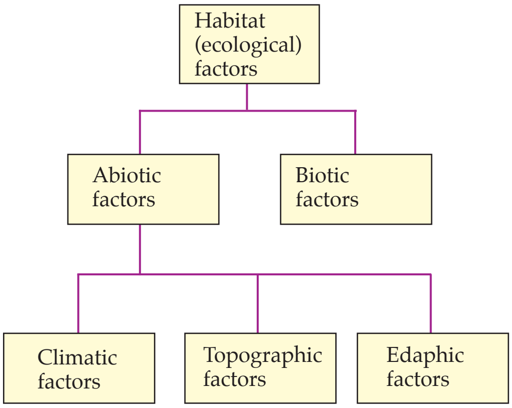


Fig. 7.1 Schematic classification of ecological factors

The factors which influence living organisms in a habitat and control their survival and distribution are called **habitat factors**. Habitat factors are also called **ecological** factors or **environmental factors**. These factors are also grouped into **abiotic** or **physical** factors which relate to non-living aspects and **biotic** factors which relate to other living things.

Physical factors
These can be sub-classified into climatic, topographic and edaphic factors which relate to climate, physical features of the land and soil respectively.

1 Climatic factors
The average weather conditions of a place or region, throughout the seasons, make up the climate. The factors which determine the climate include rainfall, temperature, relative humidity, sunlight, pressure and wind.

a) Rainfall
In Nigeria, both the total annual rainfall and the distribution of rainfall throughout the year vary from place to place. The main causes of variation in total annual rainfall are:
i) The distance from the Atlantic coast and
ii) The elevation.

The rain-bearing wind in Nigeria and throughout West Africa is the south-west wind. As this blows over the Atlantic ocean towards West Africa, it becomes laden with moisture. On reaching the land, this moisture-laden wind rises and cools, then the water vapour in it condenses and falls as rain. The annual rainfall is highest near the coast and decreases progressively inland. The effect of elevation is observed on the Jos Plateau and other high lands. There, the elevation of the land causes the rain-bearing wind to rise. In so doing, the wind is cooled and the moisture in it condenses and falls as rain. The windward sides of Jos Plateau and other highlands therefore have more rain than would have been the case if the highlands were not there.

The length of the rainy season is greatest near the coast and diminishes progressively inland. While Calabar, Lagos and Port Harcourt have some rain in each of the twelve months of the year, Jos has rainfall for eight months of the year, and Sokoto has rain for only six months (April to September) of the year.

In Nigeria, rainfall is the most important climatic factor. It determines the seasons, which are the **rainy season** and the **dry season**. The main vegetation belts, or **biomes**, are determined mainly by the annual rainfall in each belt.

Rainfall affects living things in several ways. It soaks and softens the soil, making it easy for plant roots to penetrate. It provides water for the germination of seeds and for plant growth. Where rainfall is low, plant growth is poor and animals which feed on the plants are few. Where rainfall is very high, on the other hand, the soil may become waterlogged, usually leading to the extensive erosion and leaching of the soil. Plant growth is also usually poor and animals are few. Moderate levels (of about 500 to 2000 mm) make for healthy plant growth and the successful rearing of many animals. Both the total rainfall per annum and the pattern of distribution of rainfall throughout the year are important. Zaria and Ibadan have a roughly equal mean annual rainfall of about 1300 mm. At Ibadan, however, there are three months with less than 25 mm of rainfall while Zaria has five such months. The vegetation at Ibadan is tropical rain forest while that of Zaria is savannah.

Rainfall is measured with a **rain gauge**. If the earth's surface were perfectly flat and water could not sink into the ground nor run off from it, rain water would settle down in a uniform thickness over the earth whenever it rained. The height of the water, in millimetres, would be exactly the amount of rain that had fallen. However, the situation is not so in real life, hence the need for an instrument with which rainfall can be accurately measured.

Any vessel with vertical side walls may be used as a rain gauge. It should be stood on an elevated stool, at least 0.8 m high from the ground, so that rain drops which strike the ground do not splash up into it. After each rainfall, a millimetre rule is used to measure the height of the water in the vessel. Such a makeshift gauge would have one major source of error, namely that water would evaporate from it.

A normal rain gauge has three main parts. These are a funnel which collects the water, a graduated cylinder into which the water collected by the funnel runs, and a container which encloses the graduated cylinder.

Table 7.2 Mean monthly rain (mm) (1964-1984) at Ibadan and Zaria: data from Federal Meteorological Service, Lagos

Month	Ibadan (mm)	Zaria (mm)
Jan	4.27	0.00
Feb	21.80	0.30
Mar	80.30	3.48
April	144.61	43.15
May	163.70	84.36
June	165.93	143.90
July	155.14	250.50
Aug	129.24	246.78
Sept	178.87	159.78
Oct	157.33	42.15
Nov	28.46	1.07
Dec	9.52	0.00
Total	1 239.17	975.47

If the mouth of the funnel, and the mouth of the graduated cylinder of the rain gauge are of equal surface areas, then the height of the water in the graduated cylinder in millimetres would be taken as the measure of rainfall. However, the mouth of the graduated cylinder usually has a smaller area than the mouth of the funnel. The height of the water in the cylinder is therefore greater than the depth of the rainfall (if it had formed a layer over the ground surface). The height of the water in the measuring cylinder has to be multiplied by a conversion factor, obtained as the value derived when the area of the mouth of the graduated cylinder is divided by the area of the mouth of the funnel.

Mathematically,

$$\frac{\text{Area of mouth of graduated cylinder}}{\text{Area of mouth of funnel}} = \text{Conversion factor}$$

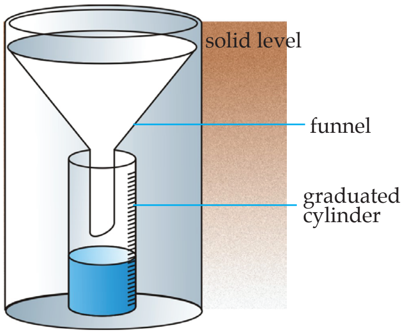


Fig. 7.2 A rain guage

Activity 7.2 Measurement of rainfall in the school compound

Procedure

1 Use rain gauge to measure the rainfall in your school compound, during the rainy season, over a period of one week. After each rain, measure the rainfall and record your data. Pour away the water in the measuring cylinder and set up the rain gauge again.

2 Place a large tin cylinder, such as a *Bournvita* tin, on a high stool and use it to collect rain water in your school compound over the same period of one week. Measure the rainfall after each rain using a ruler. Record your measurements and pour away the water.

Compare your results from the two methods.

Activity 7.3 Representing a rainfall data in a histogram

Use a sheet of graph paper to draw a histogram showing the mean monthly rainfall distribution for Zaria (see Table 7.2).

b) Temperature

Plants do not grow well at very low temperature close to 0^0C, or at high temperature above 35^0C. Temperatures of 20^0C - 30^0C are suitable for the healthy growth of plants and animals which feed on the plants. Temperature influences the rate of metabolism of plants and animals (proceed normally). At very high or very low temperature, the life-processes may cease. Temperature also affects organisms through its effect on relative humidity. As temperature rises, relative humidity increases the rate of transpiration by plants and loss of water by animals. Excessive transportation retards plants' growth.

Temperature is measured with a thermometer. A special thermometer is used for measuring soil temperatures. To measure the water temperature at various depths, it is necessary to lower the thermometer to the desired depths after tying it with a rubber band to a metre rule or graduated pole. The metre rule or graduated pole helps in determining the depth at which the reading is taken.

The temperature taken at a point in habitat does not give an accurate indication of the temperature in the place throughout the year, nor of the range of variation of temperature. For this reason, many readings taken throughout the year are more useful than a single or a few readings. At least, mean monthly temperatures are necessary. The mean monthly temperature is the average of temperature readings taken at a specific time (say 9.00 a.m) every day, throughout a month.

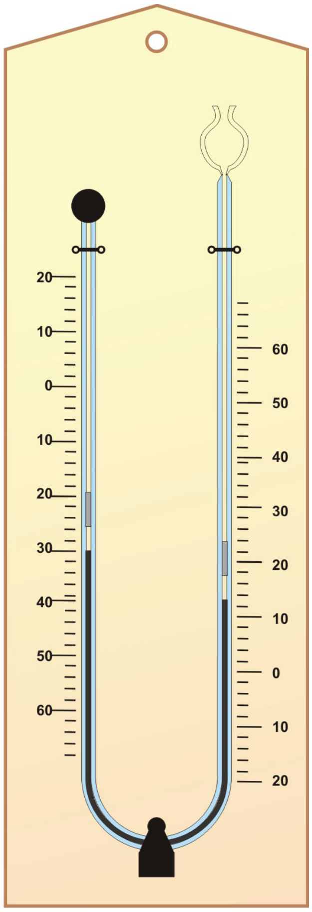


Fig. 7.3 Thermometer (maximum and minimum ^0C)

Activity 7.4 Representing temperature data on a graph

Use a sheet of paper to draw a graph showing the mean monthly temperatures provided for Jos.

Jan	21.3	Jul	20.9
Feb	22.3	Aug	20.5
Mar	25.7	Sep	21.9
Apr	25.5	Oct	24.3
May	24.0	Nov	24.1
June	22.5	Dec	22.5

Mean monthly temperature for Jos (1951-1975).
Data from Federal Meteorological Service, Lagos.

c) **Relative humidity**

The relative humidity of the atmosphere at a particular time is given by:

$$\frac{\text{the amount of water vapour in the air}}{\text{the amount of water required to stimulate air at that temperature}}$$

Relative humidity is expressed as a percentage, e.g. RH = 60%.

When relative humidity is high, the rate of transpiration of plants and evaporation of water from animals is low. The reverse is the case when relative humidity is low.

High relative humidity promotes the growth of forest species, while low relative humidity can be tolerated by savannah and scrubland plants. Relative humidity decreases progressively northwards, from the rain forest belt to the savannah and desert belts.

Measurement of relative humidity

Relative humidity is measured with a **hygrometer**. There are some direct-reading hygrometers which directly give the relative humidity of the atmosphere. The wet and dry bulb hygrometer, is commonly used in place of a direct-reading hygrometer. It consists of two thermometers. The bulb of one of these, known as the dry bulb thermometer, is exposed to and measures the temperature of the air. The bulb of the other thermometer, known as the wet bulb thermometer, has a wick tied to it, which dips into water in a container. The wick soaks up water which keeps the wet bulb continuously moist. As the water evaporates from the surface of the wet bulb, it absorbs heat from it, causing the wet bulb thermometer to give a lower reading than the dry thermometer.

The difference between the wet bulb and the dry bulb is related to the humidity of the air. When the air is very humid, the water evaporates only slowly from wet bulb, hence there is a small difference between the wet and the dry bulb readings. On the other hand, when the air is dry, water evaporates fast from the wet bulb; hence there is a big difference between the wet and dry bulb readings. In order to determine the relative humidity of the atmosphere using the wet and dry bulb thermometers, the difference between the readings of the two is taken. Then from an already prepared chart, the relative humidity, which corresponds to that difference at that temperature, is read.

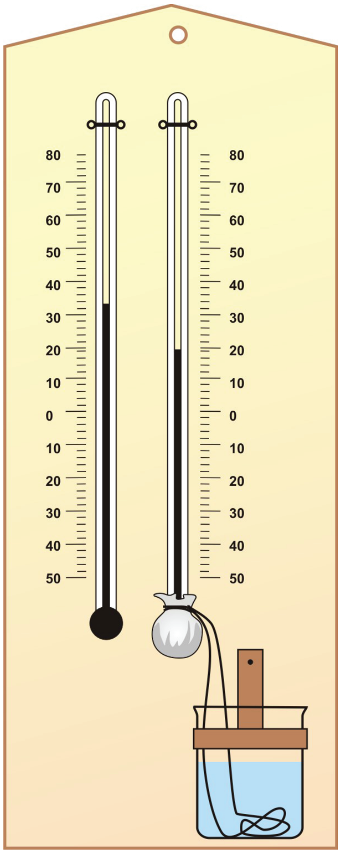


Fig. 7.4 Wet and dry bulb hygrometer (^0C)

Activity 7.5 Determining the relative humidity in the classroom

Use the wet and dry bulb thermometer (maximum and minimum (^0C)) to determine the relative humidity of your classroom.

Record your readings as follows:

Reading of the dry bulb thermometer = ^0C

Reading of the wet bulb thermometer = ^0C

Difference between the dry bulb and the wet bulb thermometer readings = ^0C

Relative humidity read from a chart = ^0C

d) **Wind**

Wind affects plants and animals in many ways. It increases the temperature rate in plants. Strong wind may break branches or cause trees to fall. In very windy situations, plants are few and those that survive tend to be stunted. Animals that live in windy places need to have protective features, such as means of attachment to supports. Wind causes the erosion of exposed soil surfaces, thus reducing soil-thickness. It may however bring rain, which is beneficial to plants and animal. Wind-direction is determined with a wind **vane**, while wind speed is determined with **an anemometer**.

e) Light

Plants require light for photosynthesis, hence where sunlight is abundant (other factors being favourable), many plants grow. Relatively few species of plants live successfully in the shade.

Light is also associated with heat. Sunlight brings with it warmth, which is favourable to living things. When sunlight is very intense and the temperature very high, plants tend to wilt, while animals seek shade.

Apart from light intensity, the number of hours of daylight in a day, known as **day length**, affects living things. The day length varies throughout the year. In Nigeria, it is observed that in January, it is still dark at 6 a.m. and already dark again by 6.30 p.m. At this time of the year, the day length is short. The day length in Nigeria is shortest in December and longest in July. On summer's day in Europe or North America, there could be daylight from 5.30 a.m. to 8 p.m. Although the actual difference between the longest day and shortest day in Nigeria is comparatively small, plants nonetheless respond to these changes in day length. For instance, day length affects the flowering of plants.

Some plants such as some varieties of dry-season Okro flower only when the day length is short (usually around September). Other plants flower when the day length is long, while a few do so at any time.

Light intensity is measured with a **light meter**.

Some light meters give readings in **candela units**, while others are graduated into divisions without naming the units. The latter type is only useful in comparing the intensities of light in two places or two parts of the same locality.

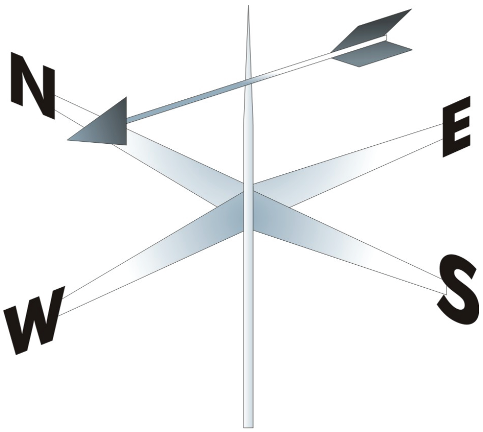


Fig. 7.5a) Wind vane

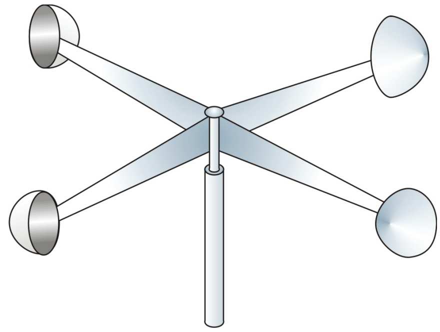


Fig. 7.5b) Anemometer

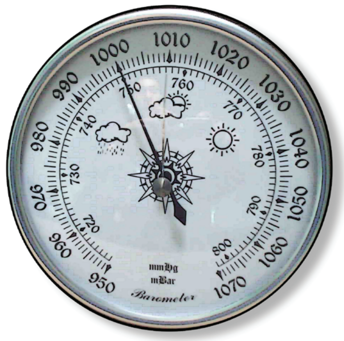


Fig. 7.6 Aneroid barometer

Fig. 7.7 Light meter

2 Topographic factors

Topographic factors are those which relate to the physical features of the earth's surface. Hills, valleys, rivers, ravines, water courses and other features affect the living conditions of organisms. Some topographic factors are described as follows.

a) Elevation

The height of a place above sea-level is described as its elevation. As the elevation increases, wind speed and wind strength increase while the temperature, atmospheric pressure and amount of oxygen in the air decrease. Plants and animals of high altitudes have to possess features which fit them to function well there. Clear vegetation changes can be observed as one ascends a mountain.

Elevation is measured with a **barometer**, such as the **aneroid barometer**. The barometer in fact measures air pressure, but this is related to elevation, hence the elevation can be worked out from barometer readings.

b) Slope

When the slope of the ground is steep, rainwater runs off fast, allowing little water to soak into the soil. At the same time, soil erosion may be strong so that the soil tends to be shallow. Plants in such locations tend to be herbs, shrubs, and stunted trees. Where a land has a gentle slope or is flat, conditions are more favourable for the growth of plants. Rainwater flows on the soil surface slowly, and much of it sinks into the soil. The soil is not strongly eroded and will usually be deep. Numerous species of plants will also live in such a place, together with the animals associated with them.

The slope of a piece of land can be determined by measuring the drop in height at one metre intervals along a line, and then plotting the height drops on a graph.

Activity 7.6 Determining the degree of slope of a piece of land

Procedure

(Two students work together in one group).

1 Place one metre rule vertically upright at a point **A** and another vertically upright at a point **B**, so that **A** and **B** are exactly one metre apart.

2 Place the third metre rule horizontally across the other two. Use a spirit level to ensure that this metre rule is truly horizontal.

3 Note the readings on the two vertical metre rules at the point where the horzontal metre touches them. Work out the difference between the readings of the two vertical metre rules.
Example: Suppose that at point **A**, the horizontal metre rule touches the vertical rule at the 10 cm mark, while at point **B**, the horizontal rule touches the other at the 8 cm mark. This shows that point **B** is 2 cm lower than point **A**. Record this observation in your notebook in a short form which you can understand, such as **A** (0), **B** (2 cm).

4 Repeat this procedure at 1 m intervals, along a straight line down the slope, beginning at point **A**.

5 Use the data to plot a graph of the slope on the sheet of graph paper.

c) Exposure

Plants and animals living on a hilltop are more open to the influence of climatic and other factors than those living in a valley. An animal that lives in a hole in the ground is not exposed. Exposure is the degree to which organisms are left open to climatic and other factors. In exposed habitats, light intensity is high, wind may be strong but relative humidity may be low. Light-loving plants live in exposed places. Where the exposure is low, light intensity is low, wind may be mild, but relative humidity is high.

3 Edaphic factors

a) Soil texture

The feel of a soil to the touch is its **texture**. Sandy soil is coarse; clay soil is very fine while loamy soil is neither coarse nor very fine. Soil texture is determined by the relative proportions of sand, silt and clay in it. Sand, silt and clay differ in particle size (Table 7.3).

Table 7.3 Size ranges of mineral particles of soil

Particle	Size range (diameter in mm)
Stone	Greater than 200
Gravel	02-200
Fine gravel	2-20
Coarse sand	0.2-2
Fine sand	0.02-0.2
Silt	0.002-0.02
Clay	Less than 0.002

Soil texture affects drainage and capillarity and hence the water-retaining capacity of soil. The water-retaining capacity of soil affects plant growth. Sandy soil is porous, retains little water and consequently supports only a few small plants. Clayey soil retains too much water and easily becomes waterlogged. Such soil supports a few plants, such as mangroves which are adapted to waterlogged conditions. Loamy soil, with good water-retaining capacity, supports healthy plant growth and many species thrive on it.

Soil texture also affects soil air. Sandy soil contains much air, whereas clayey, waterlogged soil contains little air. Both conditions are unfavourable to plants.

b) Soil structure

Soil structure relates to how the soil particles are arranged. In a soil with good structure, the soil particles are in crumbs. Good crumb structure helps the soil to retain water and the air content is good. These promote plant growth.

c) Soil depth

Shallow soil can sustain only small plants such as grasses and hence few animals. Causes of shallow soil include strong erosion or an underlying rock layer very close to the surface. Deep soil can sustain many species of plants and the animals associated with them.

d) Soil organic matter

Dead plant and animal matter at various stages of decay in the soil constitute soil organic matter which is useful in several ways.

i) It helps to retain water in the soil.

ii) It provides food for soil microorganisms some of which have useful roles in promoting soil fertility.

iii) It releases nutrients for plants as it decays, hence soil that is rich in organic matter supports the healthy growth of plants and rich vegetations.

Activity 7.7 Determining the amount of humus or organic matter in a soil sample

Materials required

Air- dried soil, crucible, stove or Bunsen burner, balance.

Procedure

1. Weigh a dry crucible.
2. Put a small amount of air-dried soil (soil from which water has evaporated through exposure to air) into the crucible and weigh.
3. Heat the crucible containing the soil on stove or burner until the soil is red-hot. Continue to heat the soil until no more smoke is produced. Then allow cooling.
4. Weigh the heated and cooled soil. The loss in weight is due to organic matter which has burned off.
5. Calculate the percentage of humus organic matter in the soil as foolws:

   Let the weight of empty dry crucible be **a** g,

   The weight of crucible and air-dry soil be **b** g.

   Then the weight of air-dry soil is (**b** - **a**) g = **c g**.

   Let the weight of crucible and heated soil be **x g**.

   Then loss in weight owing to burning off of organic matter is (**b** - **x**) **g** = **d g**.

   Percentage of organic matter in the soil

$$= \frac{\text{weight of organic matter}}{\text{weight of air - dry soil}} \times \frac{100}{1}\% = \frac{\mathbf{d}}{\mathbf{c}} \times 100\%$$

Note

Loss in weight may also be due to the decomposition of calcium trioxocarbonate (IV) (calcium carbonate) in the soil into lime and carbon dioxide. The loss from decomposition of calcium trioxocarbonate (IV) can be ignored. To find out if a soil sample contains much calcium trioxocarbonate (IV), dilute hydrochloric acid may be added to a small quantity of the soil sample in a test tube. Bubbles of gas (carbon dioxide) from the ensuring reaction indicates the presence of carbonate in the soil sample.

e) Soil pH

Certain plants, such as tea, grow best where the soil is acid, while some, such as maize, can grow reasonably well where the soil is slightly acid or alkaline. Soil pH, therefore, helps to determine the plant species that can grow in a habitat and how well they will grow there.

The pH of a soil is commonly measured by using a soil indicator. This is a chemical in solution, whose colour changes in accordance with the pH of the material mixed with it. An example of a soil indicator is the **BDH soil indicator** made by the British Drug House. This company produces a soil testing kit which includes the soil indicator, test tubes, a spatula, a chart of pH colours, barium tetraoxo-sulphate (IV) (barium sulphate) and an instruction sheet for use with the kit. The procedure for determining the pH of a soil sample is as follows:

– Place about 10 mm of soil in a clean test tube.

– Add about 10 mm of barium tetraoxo sulphate (VI) powder (this is to flocculate and precipitate the clay particles).

– Add 10 cm^3 of distilled water with a pipette.

– Add 2 cm^3 of soil indicator to the test tube.

– Close the mouth of the test tube with a thumb and shake the test tube thoroughly.

– Allow the test tube to stand so that a clear coloured liquid appears above the soil in the test tube.

– Hold the clear coloured liquid in the test tube against the chart of colours that corresponds to that obtained from the soil sample. Each colour on the chart represents a different pH. From your observation, deduce the pH of the soil sample.

f) Soil water

Water is very important to plants. Mineral salts are absorbed in solution from the soil. The salts are transported in the plant, also in solution. Water keeps the living cells of the plant turgid. Loss of water vapour from the leaves keeps the plant cool.

Many biological reactions in the plant take place in aqueous solutions. Water is necessary for germination and is a raw material for photosynthesis.

The water that the plant needs is absorbed from the soil. The quantity of available water in the soil is therefore a very important ecological factor.

Activity 7.8 Determining the amounts of water retained by different soil-types

Materials required

Three filter funnels, filter paper, sandy soil, loamy soil and clayey soil.

Procedure

1. Obtain samples of sandy soil, loamy soil and clayey soil and dry them in the air to constant weight.
2. Place three funnels in the necks of three 10 cm^3 measuring cylinders.
3. Place a folded filter paper inside each filter funnel.
4. Put 20 g of air-dried sandy soil into the filter paper in the first filter funnel and the same quantity of air-dried loamy and clayey soils into the filter papers in the second and third filters respectively.
5. Pour 50 cm^3 of water into each soil sample. Leave the water to drain through into the measuring cylinder until no more drops of water pass through.
6. Measure the volume of water collected in each measuring cylinder.
7. Calculate the amount of water retained in each soil sample. This is obtained by subtracting the volume of water collected in each measuring cylinder from 50 cm^3.

Tabulate your results as follows:

Type of soil	Volume of water collected in measuring cylinder	Volume of water retained in the soil
Sandy soil		
Loamy soil		
Clayey soil		

It should be observed that clayey soil retains more water than loamy soil and loamy soil more water than sandy soil.

Activity 7.9 Determining percentage of water in a soil-sample

Materials required

Freshly collected soil, evaporating dish, steam bath or beaker, water, balance.

Procedure

1. Weigh a dry evaporating dish.
2. Weigh the dry evaporating dish with some soil.
3. Place the evaporating dish with soil on a steam bath. A beaker of water, heated with a stove or Bunsen burner may be used as a steam bath.
4. Cool and weigh the evaporating dish with soil from time to time until two consecutive weighings give a constant weight.
5. Calculate the loss in weight. This represents the amount of water in the soil which was driven off by heating.
6. Calculate the percentage of water in the fresh soil.

Factors which affect the ability of soils to retain water

The capacity of the soil to retain water depends on several factors including the following:

1 Temperature

When the weather is warm, more water will evaporate from the soil than when the weather is cool.

2 Relative humidity

If relative humidity is high, the rate of evaporation of water from the soil surface will be low and more water retained in the soil. The reverse is the case with low relative humidity.

3 Exposure

Evaporation of water from exposed soil, such as on a hilltop or hillside, is greater than evaporation from sheltered soil in a valley.

4 Humus content

Humus absorbs and retains water; hence soil that is rich in humus can retain much water.

5 Clay content

Clay retains much water for the following reasons:

a) Clay particles are very small and therefore have a very large total surface area. Each clay particle is surrounded by a film of water. The films of water surrounding all the particles add up to a large amount of water.

b) Clay particles are colloidal and therefore absorb and hold water.

Soil types and their effects on vegetation

The soil affects the vegetation that grows on it and helps to determine the type of vegetation that will develop. Different soil types have different properties as described below.

1 Sandy soil

Sandy soil contains mainly silica, which is low in nutrient elements. It is made up of large particles and is porous. It retains little water. As the water flows downwards between the sand particles, it washes off some mineral elements from the sand particles. This process is known as leaching. With their low content of mineral nutrients and low water retention, sandy soil supports only scanty vegetation, such as grasses.

2 Loamy soil

Loamy soil is a mixture of sand, silt and clay in about equal proportions. It also contains humus. This kind of soil has good crumb structure and an adequate capacity of retaining air and water. Loamy soil is, therefore, fertile and if well supplied with air water, supports healthy vegetation.

3 Clayey soil

Clay consists of silicates, sulphates and phosphates of sodium, potassium, calcium, magnesium, aluminium and iron. The presence of these elements makes clay soil fertile. Clay retains much water but can become waterlogged, thus reducing the amount of air that the soil can hold. Clay particles hold films of water around them strongly, so that at the point when plants growing on a clayey soil begin to wilt, some water may still be present. Plants growing on clay soil are quite often those that can withstand drought.

4 Laterites

Laterites are soils formed by the chemical weathering of granite rocks. The compounds in the rocks may become oxidised, causing the rocks to crumble. Rainwater, which flows downwards through the soil, leaches most of the alkaline metallic elements such as sodium, potassium, calcium and magnesium, leaving mostly aluminum and iron oxides. Laterites are usually acid and yellow or reddish brown in colour (though not all yellow or reddish brown soils are laterites). They are not fertile and can only support little vegetation. Prolonged fallowing may improve such soil through the addition of organic matter from leaf litter. Laterites may thus, over many years, support rain forest vegetations.

Biotic factors

Biotic factors are those factors which relate to living things. Living things influence other living things in many ways, such as feeding, parasitism, shading from light and fires, pollination and dispersal of seeds and competition. Some of these factors are favourable to some organisms.

1 Feeding

a) Green plants make their own food, using sunlight, water, carbon dioxide and mineral substances. Such food, made by plants, is the source of food for many grazing animals, other animals that feed on the gazing animals and eventually those organisms that feed on dead plant and animal materials.

b) While grazing, cattle and other heavy-grazing animals trample on some herbs and grasses and may kill them or inhibit their growth.

Overgrazing may expose the soil to erosion.

2 Shading from light

Plants shade other plants that grow beneath them. If the amount of light reaching the plants below the tall plants is insufficient, growth of the plants below is inhibited and only shade-tolerant plants may thrive, e.g. the cashew tree shades plants below it.

3 Fires

Some bush fires are caused by lightning, but most are caused by man, deliberately or accidentally. An example of an accidental fire is one caused by a cigarette stub, dropped by a smoker on dry grass near a bush. Bush fires destroy vegetation, including valuable resources such as timber, firewood and medicinal plants. When fire removes the vegetation cover, the soil is exposed to agents of erosion. Bush fires destroy organic matter on the soil as well as microorganisms, some of which promote soil fertility. For these reasons, bush fires are undesirable and should be prevented.

4 Competition

Members of the same or different plant species, which grow together in the same area, compete for space, mineral nutrients and sunlight. In this way, the individuals hinder one another's growth.

5 Pollination

Bees, butterflies, ants and other insects pollinate many flowers, including those of crop plants, and by so doing, help the plants to reproduce and continue the species. By pollinating flowers, insects prove helpful to plants and man.

6 Dispersal of fruits and seeds

Bats, rats, birds, goat, sheep, cattle and other animals help to disperse fruits and seeds. The methods by which this is done are many, but dispersal generally helps to spread the plant species concerned and to prevent overcrowding around the parent plant.

7 Parasites

A parasitic organism gains from its relationship with its host, but makes the host suffer harm in one way or another. Some parasites ultimately kill their hosts while many hosts suffer, at least, a reduction in growth and an impairment of health.

8 Support

One of the ways in which some organisms influence others is through physical support. Bigger plants support certain kinds of smaller ones, such as epiphytes and climbing plants. By so doing, the epiphytes or climbers are helped to obtain light which they may not have had otherwise.

9 Cover

Plants are useful to animals which live on or around them. Apart from providing food for such animals, the vegetation provides protective cover as well as resting and nesting sites for the animals.

Ecological factors in aquatic habitats

Ecological factors which are peculiar to aquatic habitats include salinity, speed of flow, turbidity, depth of water and nature of the bottom and pH.

1 Salinity

The degree of salinity is one of the factors which determine the species that will occur in an aquatic habitat. A freshwater organism cannot live in saltwater and vice versa. Those organisms that live in brackish water do not normally live in seawater or freshwater. Salinity of water is measured in parts per thousand. If 1000 g of the water is evaporated and 5 g of salt recovered, then the salinity of the water can be expressed as 5 parts per thousand. The salinity of sea water is around 35 parts per thousand.

2 Speed of flow

Some organisms live in fast-flowing water. The larvae of the blackfly thrive in fast flowing streams. As the water of the fast-flowing streams runs over pebbles and rocks, it acquires more dissolved oxygen than would have been obtainable from slow-flowing water. Organisms that live in fast-flowing water, however, have to be strong swimmers, in order to move against the direction of water flow, when necessary. Some organisms live only in slow-flowing or stagnant water. Such organisms usually have only moderate powers of movement.

The speed of flow of water in a stream is determined by measuring the time it takes a light object, such as a cork, to be carried by the water, from one fixed point to another along the stream.

Activity 7.10 Measuring the speed of flow of water in a stream

Materials required

A piece of cork, two poles, stopwatch.

Procedure

1 Fix two poles, 20 metres apart along the bank of a stream.
2 Drop the cork into the water.
3 Start the stopwatch exactly when the cork reaches the first pole and stop it exactly when the cork reaches the second pole. Repeat the activity three times and find the average time it has taken the cork to be carried from one pole to the other. The speed of flow of the water is obtained by dividing the distance (20 m) by the average time.

3 Turbidity

Turbid water allows less light to pass through it than does clear water. Plants can, therefore, live at a greater depth in clear water than in turbid water.

The turbidity of water can be determined by putting down into the water a white object, known as a **Secchi disc**, and measuring the depth at which the disc just fails to be seen. The Secchi disc is attached to a metre rule or graduated pole to facilitate the reading.

4 Depth of water

Sunlight can penetrate down to the bottom of shallow body water in a stream or pond. Green plants can, therefore, grow throughout the depth of the water, together with animals that feed on them.

Sunlight also helps to keep the water warm. In deep water, only the surface layers receive sunlight and green plants are restricted to these. Again, oxygen dissolves in the water only at the surface, where the water is in contact with the atmosphere. The concentration of oxygen in the water, therefore, decreases from the surface to the deeper layers. There is little oxygen in very deep layers of the oceans. As depth increases, the pressure also increases. Organisms that live in deep water must be able to withstand this pressure.

5 Nature of bottom

The bottom of a river or stream or sea may be rocky, muddy or rich in organic matter. Each type of bottom attracts certain animals. Animals that dig holes prefer a sandy or muddy bottom while those that need to attach themselves prefer a rocky bottom.

6 pH

Organisms are affected by the pH of their habitats. In aquatic habitats, the pH depends on the kinds and amounts of dissolved substances in the water. Carbonates neutralise acidic substances present, so that the pH assumes a neutrality value of approximately 7.0. If basic ions are in excess, the water is alkaline and the pH is higher than 7.0. If, however, acidic ions are in excess, the water is acidic and the pH value is less than 7.0. The pH of seawater tends to be alkaline, with values of 8.0 to 8.5 in surface waters. Aquatic organisms usually tolerate small pH variations that occur naturally in the habitat. If, however, through the addition of large amounts of waste substances (such as effluents from factories) there occurs a significant change in the pH of the habitat, the usual plant and animal inhabitants of the water may migrate or die out, while new and tolerant organisms take over the habitat. For instance, fresh water molluscs tend to be absent in acidic waters with a pH value of less than 6.0.

Ecological factors common to both aquatic and terrestrial habitats

The ecological factors which are common to both aquatic and terrestrial habitats include:

1 climatic factors namely rainfall, temperature, sunshine, relative humidity, wind and pressure;
2 topographic factors such as slope, exposure and elevation;
3 pH; and
4 biotic factors (influence of other living things).

Population studies

In ecology, the word **population** does not refer only to human beings. A **population** is defined as a group of living things of the same species which inhabit the same defined area or locality. Thus, it is possible to have a population of weevils, palm trees or human beings.

In a green ecosystem, there may be many populations making up a community. In a freshwater stream, one may find populations of diatoms, tilapia, water lilies, dragon flies and water batsmen.

The total number of individuals of a population per unit in a defined area is known as the **population number** or population size. The number of individuals of a population per unit area or volume is known as the **population density**.

Hence population density = $\dfrac{\text{population size}}{\text{area or volume of habitat}}$

Changes in population size

The number of individuals in a population changes and is affected by various factors, such as the weather, availability of food, disease, rates of reproduction and death, emigration and immigration.

The size of population of mosquitoes changes with the weather. In the rainy season, the numbers increase, owing to the abundance of reproductive sites. In the dry season, the number is reduced. A population of maize weevils increases in size when there is abundant food. If the food eventually runs out, the weevils die, unless they succeed in finding an alternative source of food.

Reproduction is the means by which a population increases in number. The rate of reproduction, therefore, strongly influences the rate of increases of the population.

In an ecosystem, however, the populations of different species eventually achieve a kind of stability and the population numbers of the different species remain more or less constant. Consider this food chain.

Carpet grass → grasshoppers → toad → snake → hawk

If the number of grasshoppers suddenly increases, they will very likely consume more grass than usual and may soon run short of food. Some grasshoppers may die of hunger. Again, if grasshoppers increase in number, the toads which feed on them may also increase in number and help to reduce the number of grasshoppers. Either way, the population of grasshoppers tends towards a number at which a balance is maintained with either populations in the food chain or community.

Suppose all the toads in the ecosystem should die. The population of snakes would face a shortage of food and some of the snakes would die. Factors which tend to keep populations more or less constant are said to **regulate** the populations.

Determination of population size

The proper technique to be adopted for determination of the population size depends on the species and habitat.

1 Complete census

If the area covered by the species is small, and the individuals are few in number and large in size, a complete census may be used. In this case, all the individuals can be counted, e.g. palm trees in a palm plantation.

2 Sampling

If the individuals in the population are small in size, many in number, or covers a large area, it may not be practicable to count them one by one. In such a case, only part of the population is taken and counted. On the basis of the part counted, an estimate of the total population is worked out. The study of the whole population by looking closely at certain parts of it is known as **sampling**. Each part chosen for study is called a **sample**. Three sampling methods are often used.

a) *Quadrat method:* A quadrat is a square wooden or metal frame. The size of the quadrat to be used depends on the population to be studied and the size of the individuals. For savannah, a one metre square ($1m^2$) quadrat is commonly used. For a population of mosses, a quadrat of size 0.1 m^2 may be suitable.

Activity 7.11 Determination of the number of crotalaria plants on a plot of fallow farmland

Materials required

1 m^2 quadrat, record book.

Procedure

1 Throw the quadrat in a random manner onto a piece of fallow farmland.
2 Count the number of **crotalaria** plants inside the quadrat frame. Record this number in your notebook.
3 Repeat the throw ten times, counting and recording the number of **crotalaria** plants inside the quadrat each time.
4 Find the average number of **crotalaria** plants per square metre.
5 Determine the area of the whole plot of farmland.
6 Using the area of the plot, calculate the population size of **crotalaria** plants in the entire plot.
7 What does the average you calculated in 4 above represent?

b) *Volume sample method:* The number of mosquito larvae in stagnant water inside a tin can may be estimated using this method. This is done by counting the number in 1 cm^3 of the water. The water should first be stirred, then 1 cm^3 taken out with a suitable pipette and the number of mosquito larvae in the 1 cm^3 counted. After counting, the water with the larvae is returned to the can and allowed to mix. The procedure is then repeated several times. The average number of larvae per 1 cm^3 is determined and used to calculate the total number of larvae in the entire volume of water in the tin can.

c) *Transect sample method:* The transect method is used to find out what percentage of the total number of organisms in an area belong to a particular species. **A transect is a line that runs through a plot**. A rope tied to pegs at each end is a convenient line. Only those plants which actually touch the rope are counted. The number of each kind of species of plant that touches the rope is recorded. From a fallow farmland, the figures obtained might be as follows:

Guinea-grass	20
Ipomea	2
Commelina	5
Aspilia	25
Croatalaria	3
Total	**55**

The percentage of each species or population can be calculated. In any given habitat, one species will often have a larger population size than other species. Such a species is said to be dominant.

d) *Capture-recapture method:* This method is used to estimate the number of mobile animals in a habitat. Such animals include fish, insects and snails.

Activity 7.12 Estimating the population of moths in an area

Procedure

1. Use a standard technique to catch the moths on one occasion. For instance, use an electric bulb to attract the moths to settle on a white sheet of cloth at night. (Use a particular fish net, in a particular way to catch the fish in a river or stream, or use a suitable food to attract cockroaches or snails).
2. Use an indelible ink to mark all the animals caught in a readily recognisable part of the body.
3. Count the number of animals caught and marked in first catch. Let this number be **x**.
4. Release all the animals caught and marked in the first catch.
5. Allow a period of about two weeks so that the animals caught and marked in the first catch will mix thoroughly with the rest of the population.
6. Carry out a second catch using the same standard technique. This time;
   - Count all the animals in the second catch, let this number be **y**;
   - Count all the animals in the second catch that were caught and marked in the first catch, let this number be **z**.

Calculation of population size

Let the number of animals in the population be **N**.

Let the number caught and marked in the first catch be x.

Let the number caught in the second catch be y.

Let the number found in the second catch be marked **z**.

Then, $$\frac{z}{y} = \frac{x}{N}$$

$$N = \frac{yx}{z}$$

3 Dominance

The most frequently occurring species in a community is said to be **dominant**. For instance, in an abandoned farmland, *Eupatorium oderata* may constitute 70 out of 100 plants in the area. The *Eupatorium* species is said to be dominant to the other species. When one species outnumbers other species in a community, the most commonly occurring species is said to have dominance over the other species.

Two species or more may be co-dominant. In a Savannah biome, grass species are dominant over tree species. In a tropical rainforest, tree species are dominant.

Communities

Organisms do not generally live apart from one another in nature; they live together. On a grass lawn, many individuals of the same species of grass or different species of grass co-exist, with different species of grasshoppers, butterflies, ants, earthworms and other animals. All the individuals of one species, living in an area, such as the grass lawn, form a population. For instance, in the grass lawn, there might be a population of carpet grass, a population of swallowtail butterflies and so on. Each species has its population. All the populations of living things in the grass lawn form a **community**. A community or **biotic community** is a group of organisms living together and interacting with one another in an area. The community and the non-living things with which it interacts (such as air, soil) form an ecological system or ecosystem. An ecosystem is defined as a natural unit, consisting of living (biotic) and non-living (abiotic) components, in which the living and non-living components interact, and there is exchange of material between the living and non-living components. An ecosystem may be terrestrial, such as the grass lawn, or aquatic, such as a pond.

Communities vary in size. Several species of moulds and bacteria on a piece of bread, form a community. This community is small. A strip of forest is a community. Large biotic communities which correspond to vegetation belts or zones are called **biomes**.

Local biomes

Local biomes in Nigeria can be divided into two kinds, forest and savannah. The most important factors that determine the distribution of forest and savannah are climatic. They are:

1. The mean annual rainfall,
2. The length and severity of the dry season,
3. The minimum relative humidity in the driest months.

The annual rainfall decreases progressively from the south to the north of Nigeria and the vegetation changes accordingly.

Saltwater swamp forest

The saltwater swamp forest forms a belt along the coast of Nigeria, from Lagos State across Ondo, Edo, Delta, Rivers, Cross River and Akwa Ibom States.

In this belt, the mean annual rainfall is very heavy; sometimes over 2 000 mm. The mouths of several rivers are located here. During the rainy season, the river water brings down large amounts of sand and silt which are deposited at the delta. The land is low-lying and swampy and there are many creeks and lagoons. During the dry season, the flow of the rivers subsides and seawater brought in by tides makes the water in the estuaries and creeks brackish. Saltwater also floods the alluvial deposits, making them salty.

Mangrove swamp forests develop on the bare, water-logged salt mud deposits, where few other species grow. The red mangrove (*Rhizophora racemosa*) is the mangrove species that first colonises bare, shifting mud banks. The seed of the red mangrove germinates on the parent plant. The seedling falls into the water and floats at an angle, with the root pointing downwards. The movement of the water by wind tide may push the root of the seedling into the mud. The root does not grow root hairs but numerous **rootlets**, which absorb water and mineral salts. The rootlets, in turn, form a mat of smaller roolets.

These hold the shifting particles of mud together. As stem grows upwards, it puts out **stilt roots**. Each stilt root grows downwards to the mud where it produces a mass of rootlets. The stilt roots grow bigger as the tree grows. All the rootlets help to support the plant and to stabilise the soil. As the red mangrove grows, it produces also from the stem, another kind of roots, known as **drop roots**. Drop roots do not grow big but remain thin. They contain air spaces and are used for obtaining air.

As new alluvial deposits are formed, the red mangrove advances to colonise new ground. The vegetation grows best at the edge of the creeks and waterways. In the areas colonised earlier, the ground level continues to rise as more and more mud is deposited around the roots of established plants. In this area, the growth of the red mangrove vegetation begins to decline. Further behind still, in the area that is flooded by the highest tides only, grows the white mangrove, *Avicenia nitida*. This plant has breathing roots which project upwards from the ground and are used obtaining oxygen in this environment where the soil may still be waterlogged.

Coconuts and reeds grow on sandy beaches along the sea shores. Animals found in the mangrove swamp vegetation include tilapia species, angel-fish, bloody clam (*Arca*), oysters, barnacles, mangrove crab, lagoon crab, hermit crab, mudskipper fish, mosquitoes and birds, e.g. heron.

Freshwater swamp forest

The freshwater swamp forest occurs beyond the range of the tides. The rainfall in this biome is very heavy, relative humidity is high and evaporation from river is low. Rivers overflow their banks during the rainy season and flood the land, making the soil marshy and waterlogged.

The forest vegetation is irregular and broken. The canopy is open in places. Shrub and climbing plants form clumps of thick bush. Patches of open water are present even in the dry season. In standing water, floating plant species include water lettuce, *Lemma* and *Salvina*. At or near the edges of the bodies of water are arums, several species of grass, such as sword grass, ferns and raffia palm. Trees that occur on land near the water include *Alstonia* and *spondiathus*.

Tropical rain forest

The tropical rain forest occurs where the mean annual rainfall is at least 1250 mm and sometimes up to 2000 mm. The temperature is high, the relative humidity is at least 70%, the rainy season is long, i.e. from 8 to 10 months, while the dry season is short and not very severe.

Forest is a form of vegetation dominated by trees and shrubs which form a more or less continuous overhead canopy that does not permit the growth of grasses at the ground level. One of the characteristics of tropical rain forest is its structure. It is possible to identify five layers of which the three top layers are trees, the fourth is the shrub layer while the fifth is the ground vegetation.

Upper tree layer

The upper tree layer, or **storey**, consist of the tallest trees, which are over 40 m tall. These trees, called **emergents** have straight, slender trunks and do not branch till they reach high up on the air. Some emergents are evergreen, others are deciduous, i.e. shed their leaves in the dry season. They have small flower and spreading crown which do not touch and do not form a continuous canopy. These include many valuable timber trees, such as mahogany (*Khaya sp.*), African walnut (*Lovoa*), African cedar (*Guaria*), ironwood (*Lophira procera*), opepe (*Sarocephalus*) and iroko (*Chlorophora excelsa*).

The middle tree layer

The trees in this layer, range from 16 m to 34 m tall. They have small crowns which, in a mature forest, touch and form a continuous upper canopy.

The lower tree layer

The shrub layer contains shrubs and also young plants of the tree layers. Many of the plants in this layer have straight, unbranched, thin stems.

The ground vegetation

Since little light reaches the forest floor, the ground vegetation consists of shade-tolerant species such as ginger, ferns and mosses. Here also are found seedlings of the tree species. Most of the tree seedlings die. Only a few survive in the spaces created by large trees which have died and fallen down, creating openings in the forest roof for light to shine through.

The forest floor is normally open, having only a few plants. The herb layer is densest at the forest edge where the plants in this layer can obtain light.

A characteristic of the tropical forest is the presence of many climbing plants. Some of these have long, wiry stems which twine round large trees and are called **lianas**. At different heights, epiphytes may be found growing on the trees, depending on their light requirements. These include orchids and ferns. Many of the animals of the tropical rain forest are arboreal. These include monkeys, squirrels, lizards, birds, frogs and insects.

Southern Guinea Savannah

Savannah is grassland vegetation in tropical and subtropical areas. It contains scattered trees and shrubs.

In the southern Guinea savannah biome, the mean annual rainfall is above 500 mm, but less than 1250 mm. the dry season is shorter and less intense than in the Northern Guinea savannah and there are not more than six months in the year with less than 25 mm of rainfall. The lowest monthly relative humidity is above 28%.

The vegetation is an open savannah woodland type, with tall grass up to 3 m high. The trees have short boles, with broad leaves. They are usually up to 17 m but rarely up to 30 m high.

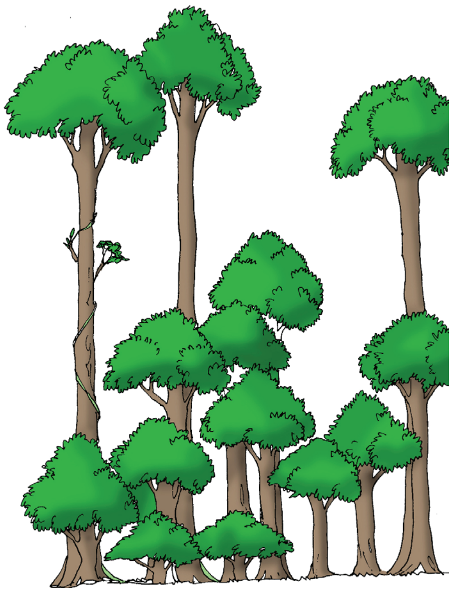


Fig 7.8 Profile of a tropical rain forest

One major characteristic of the savannah is the cyclic change of the vegetation, from the rainy to the dry season. In the rainy season, the vegetation is green and luxuriant. Many of the herbs and grasses flower. In the dry season, the trees shed their leave and the vegetation turn dry and brown.

Another major characteristic of the savannah is the common occurrence of fires in the dry season. The fires burn the grass which is dry at this time, leaving behind standing clumps of burnt grass stems and black ash on the ground. Several of the trees are adapted to fire by possessing thick, fire- resistant barks. They also produce new sucker growths soon after each fire. Many of the trees have crooked trunks as a result of their exposure to fire. The grasses also have remarkable powers of producing new suckers from the bases of old shoots, soon after fires.

The savannah tree species include *Daniellia oliveri, Hypmemocardia acida, Vitex doniana and Afzelia africana.* Others are *Butyrospermam (*shea butter tree*) and Parkia* (locust beans). The grass species include *Andropogon, Hyarrenia and Pennisetum.*

Many animals are found in this biome and they include guinea fowls, deer, rats, grass cutters and snakes. Termites are also plentiful.

Northern Guinea Savannah

In this vegetation zone, the mean annual rainfall is above 600 mm, as in the Southern Guinea Savannah, but the dry season is longer. The vegetation is dominated by grass. There are also scattered trees and shrubs. The tree species are also shorter and thornier, while the number of tree species is fewer than in the Southern Guinea Savannah zone. A common tree species of the zone is *Isoberlina doka;* others include *Uapaca somon* and *Monotes kerstingii.* The grasses in this zone are shorter than those in the Southern Guinea zone. The vegetation of the Northern Guinea savannah resembles that of East and Central Africa known as **miombo.** The Northern Guinea savannah zone is very thickly populated and has been so for several centuries. The natural Northern Guinea savannah has, therefore, been disturbed by long periods of habitation, cultivation and grazing and may now be seen only far away from villages.

Sahel savannah

Sahel savannah extends across West Africa from Senegal in the west to Chad in the east, and from the Sahara in northern to the Northern Guinea savannah belt in the south. In Nigeria, it occurs only at the north east corner, in Borno State, near Lake Chad.

Rainfall is very variable in this zone. The mean annual rainfall in Maiduguri is 629 mm, but rainfall sometimes fails in the Sahel, resulting in drought. The zone is arid.

The typical vegetation is an open thorn savannah, with trees up to 10 m tall, having small leaves and thorns. The grasses are short and sparse. Common plant species include *Acacia,* gum Arabic, *Leptadenia* and date palms. A common grass in this region is *Aristida stipioides.*

World biomes

Several tropical biomes have already been described as local Nigerian biomes. Temperate biomes differ from tropical biomes in two important respects:

1. In tropical biomes, the most important ecological factor is the rainfall, while in temperate biomes it is the temperature.
2. In tropical biomes, there are two seasons, wet and dry, while in temperate biomes there are four seasons with marked temperature differences, namely spring, summer, autumn and winter. Some world biomes are described in the following section.

Fig. 7.9 Tundra in the summer

Tundra

The tundra occurs in the northernmost parts of the North America and Euroasia, extending to the North Pole. The tundra region is intensely cold and the ground is almost permanently frozen and covered with ice. The summer is short summer; the top layer of the ground thaws a depth of a few centimetres.

Lichens form the principal plant cover. One of these, called the **reindeer moss,** is a major producer in the food webs. The growing season is short and limited to the short summer. Tundra animals include the caribou (or reindeer), lemmings, shrews, arctic foxes, wolves and polar bears. Birds migrate into this area in summer. Mosquitoes and black flies are plentiful.

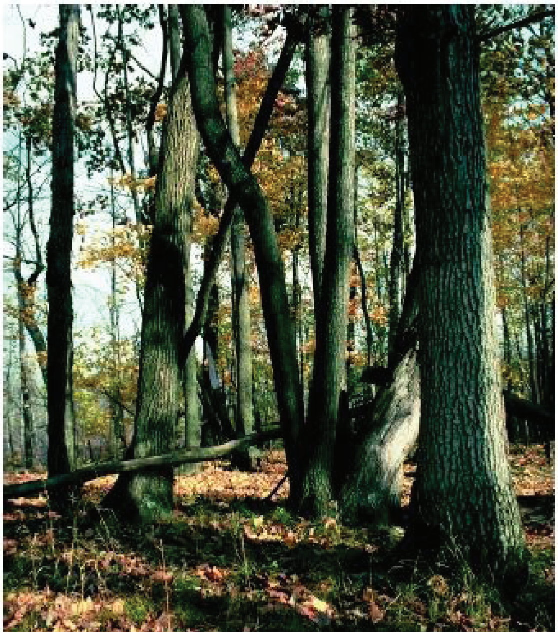


Fig. 7.10 Temperate forest

Temperate deciduous forest

Temperate deciduous forest occurs in temperate regions of Europe, Asia and North America, especially in eastern USA. Most of the areas formerly occupied by this vegetation have been altered by urbanisation and agriculture.

The trees are broad- leaved and include the maple, beech, oak, hickory, poplar, walnut and others. They shed their leaves in autumn and grow new leaves in spring. There are also many herbs and shrubs.

Animals of this zone include the black bear, deer, red fox, racoon and various rodents. Many birds, reptiles and insects are also present.

Fig. 7.11 Desert vegetation

Desert

Deserts occur between latitudes $15^0$and 30^0 north and south of the equator. In most cases, they are found on the western side of land masses, except the Sahara desert, which extends right across Africa. Other deserts include the Arabian (covering parts of Iraq and Syria), Negev (between Israel and Egypt), and Australian, Namibian (covering parts of South- west Africa), Atacama (in parts of Peru and Chile) and Californian deserts.

The mean annual rainfall in desert vegetation is less than 25 mm. Daily temperature fluctuation is great, varying from near 0^0C at night to over 30^0C by day. There is more evaporation of water from the soil.

The dry conditions permit only few adapted species of plant to thrive. The annuals flower during the short, rainy period, produce seeds and then die. Succulent plants store water which enables them to survive.

Woody species have tiny, reduced leaves, thorns in the place of leaves, as well as other devices to reduce transpiration. In some plants, the branches are green and carry out photosynthesis, while the leaves may be smaller or scaly. Common desert plants include the *cactus and acacia*. Date palms occur around oases.

Desert animals are especially adapted for the conservation of water. They tend to excrete solid urea instead of urine. The camel has feet adapted for walking on loose sand.

Afro – alpine vegetation

Afro- alpine vegetation occurs on highlands and mountains in Africa and is brought about by altitude and rainfall. The vegetation changes as one ascends the mountain. On the Kenyan highlands, the variation of vegetation is as follows:

600 m to 1600 m – savannah
1600 m to 2000 m – temperate forest
2000 m to 3000 m – bamboo forest
Above 3000 m – Alpine pasture

In West Africa, there are a few highlands with full mountain vegetation. On the highlands of Guinea and mountains of Fernando Po and Cameroun, rain forest on the lower slopes changes to mist forest between 900 and 1800 m. Above 1800 m, there is temperate forest and beyond the temperate forest, there is grass.

Activity 7.13 Observing charts and photographs of different world biomes

Materials required

Charts and photographs of different world biomes

Procedure

1. Observe the different charts and photographs of different world biomes.
2. Identify the characteristic features of each biome.
3. Make a list of the major characteristics of each biome.

Scrub land

Scrub land or thorn forest is a kind of forest vegetation consisting chiefly of shrubs and stunted trees. The shrubs have thorny leaves and other xerophytic features.

This type of vegetation is found in the temperate zone such as Meditteranean areas, and parts of the coast of California in the United states of America. Tropical scrubland occurs in Brazil, South America.

The climatic conditions that produce this vegetation include short rainy season and low unpredictable rainfall. Animals that can be found in this biome include birds, snakes, insects (e.g. butterflies, ants, locusts) and bats.

Summary

This chapter has taught the following:

- Concepts which are used in ecology include biosphere, lithosphere, hydrosphere, atmosphere, habitat, niche, ecosystem, population, community, biome.
- Ecological factors in an ecosystem affect the lives of organisms and their distribution and survival.
- All individuals of the same species in an ecosystem make up a population.
- All populations in an area of nature make up a community.
- Communities and ecosystems are of different sizes. The largest size of community, equivalent to a vegetation belt is a biome.
- There are local and world biomes.

Revision questions

1 All the parts of the earth where living things occur make up the ___________.
  A ecosystem
  B habitat
  C biosphere
  D community
  E biome
2 Which one of these habitat factors is common to aquatic and terrestial habitats?
  A Speed of flow of water

B Tide
C Currents
D Biotic factors
E Salinity

3 Population size is affected by the following: ________________________.
A availability of nutrients
B disease
C rate of reproduction
D immigration
E all of the above

4 A community whose size is up to that of a vegetation belt is _________________.
A a biome
B a community
C an ecosystem
D a habitat
E none of the above

5 Describe the influence of two named habitat factors on lives and distributions of organisms.

6 Describe one sample method for determining the population size of a named organism in a habitat.

7 Describe the characteristics of the tropical rain forest.

8 Describe the adaptations of plants for life in the savannah.

Chapter 8 Functioning ecosystem

Introduction

In freshwater, one may find green plants, such as *spirogyra* and animals such as fishes and tadpoles. These living things in the water interact with the non-living environment which includes the water itself, the atmosphere above and the soil beneath it. The living things in an environment, together with the non- living part of the environment, constitute an ecological system or **ecosystem.** The living part interacts with the non-living part of an ecosystem and there is an exchange of materials between them. For instance, a fish absorbs oxygen dissolved in the water through its gills and gives out carbon dioxide into the water.

Components of an ecosystem: autotrophs and heterotrophs

There are two major parts of an ecosystem, the biotic or living and abiotic or non- living.

From a functional point of view, the living things in an ecosystem may be classified into three kinds, known as **producers, consumers** and **decomposers.** Producers are green plants which can make their own food through the process of photosynthesis. These plants are autotrophic or self-feeding. Consumers are animals which feed on plants or on other animals. They are said to be heterotrophic.

Consumers are subdivided as follows:

1 Primary consumers are animals which feed directly on plants; e.g. grasshoppers, rats.
2 Secondary consumers are animals that feed on primary consumers, e.g. cats.
3 Tertiary consumers are animals that feed on secondary consumers, e.g. hawks, leopards.
4 Omnivores are animals that feed on both plants and animals, e.g. man, domestic fowl.

Decomposers are organisms which feed on the carcasses of dead producers and consumers and in the process bring about the decay of such carcasses. Large decomposers, such as insects, are called **macro decomposers,** whereas small decomposers, such as certain bacteria and fungi, are known as **micro decomposers.** The importance of decomposers is that they break down dead organic matter and release simple chemical compounds which plants can absorb and use again.

Products of decomposition
During decomposition, dead organic matter is broken down physically and chemically, in stages. The ultimate decomposition products are inorganic compounds, such as carbon dioxide, ammonia and ammonium compounds, as well as salts of elements present in the organic matter. Gaseous products, such as carbon dioxide, ammonia and hydrogen sulphide can be identified as organic matter decomposes. Intermediate products of decomposition include sugars, and complex organic compounds derived from protein.

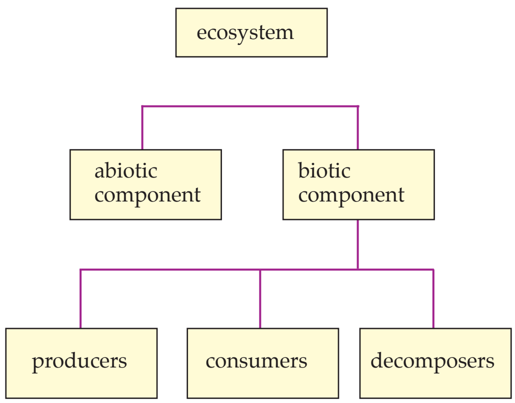


Fig. 8.1 Schematic representation of components of an ecosystem

Activity 8.1 To show that carbon dioxide is released during decomposition

Materials required

Two test tubes; delivery tube, decaying humus, lime water

Procedure

1. Set up the apparatus as shown in Fig. 8.2.
2. Set up a control experiment with no humus in test tube A.
3. Leave to stand for three hours.
4. Observe the lime water in test tube B in the experiment and in the control.
5. What inference can you make?

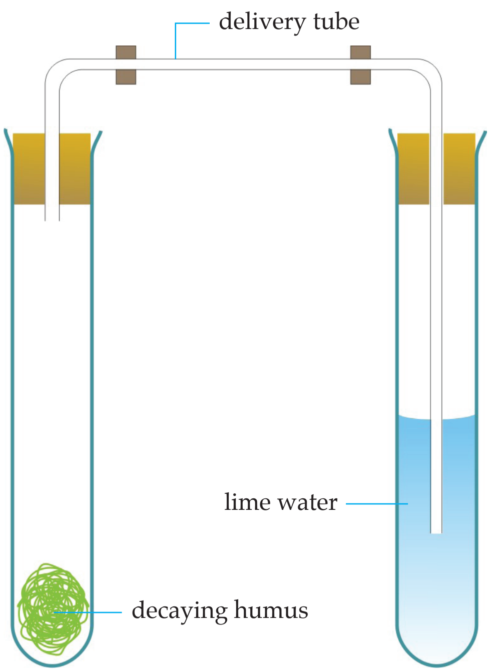


Fig.8.2 Release of carbon dioxide by decaying humus

Activity 8.2 To show that heat is released during decomposition

Materials required

Two vacuum flasks, moist humus, and thermometer.

Procedure

1. Place moist humus in a dry vacuum flask, A. Cover the mouth with cotton wool and insert a thermometer.
2. Cover the mouth of a similar vacuum flask B, with cotton wool and insert a thermometer. This is the control.
3. Leave the flasks for three hour. Read the thermometer. Record your observation in your notebook.

Food chains

On land that has been left fallow, there are various plants and animals, all of which find their food for survival there. The grasshopper feeds on plants, such as guinea grass. A toad eats the grasshopper. A snake eats the toad and a hawk eats the snake. The guinea grass, grasshopper, toad and hawk thus form a relationship, in which one eats the other in turn. A linear feeding relationship among organisms in the same community, in which each organism feeds on the one before it in the sequence, is called a **food chain**. The chain described above can be represented as follows:

Guinea grass → grasshopper → toad → snake → hawk

In a freshwater stream, a paramecium may eat a diatom, a water flea may eat the paramecium, a small fish may eat the water flea and a big fish may eat the small fish. This food chain can be represented as follows:

Diatom → paramecium → water flea → small fish → big fish

Each of the two food chains described above starts with a green plant, the producer. This is nearly always the case. However, some food chains begin with dead plants or animals. An example is as follows:

Humus → earth worm → domestic fowl → man

Food web

A food chain is a single line relationship and gives the impression that one organism feeds on only one other and may itself only be eaten by one other. For instance, our first example may suggest that only the grasshopper eats guinea- grass, and only the toad eats grasshoppers. In fact, the guinea-grass may be eaten by any of several insects or other animals. A grasshopper may be eaten by a toad, an agama lizard, a chicken or a chameleon. A toad may be eaten by a snake or a hawk, while a snake may be eaten by a hawk or some other animal. In nature, therefore, there are more complex feeding relationships than food chains show. A complex feeding relationship consisting of interrelated food chains is called a **food web**.

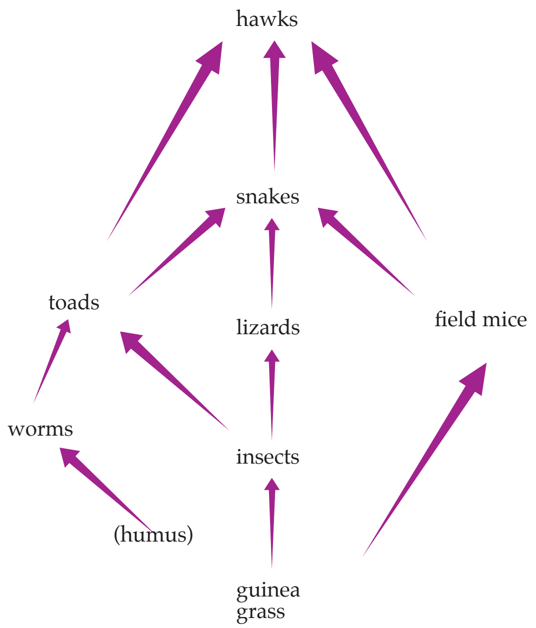


Fig.8.3 A food web

Trophic level

In a food chain or web, each stage in the chain or web is called a trophic (feeding) level. In the food chain:

guinea grass → grasshopper → toad → snake → hawk

there are five trophic levels.
Guinea grass is the first trophic level, grasshopper the second, toad the third, snake the fourth and hawk the fifth trophic level. Some food chains are short, having only a few trophic levels, e.g.

maize→ goat → man

Pyramid of numbers

One of the relationships observed in a food chain or web is that of the relative numbers of individuals at the different trophic levels. Normally, the number of individuals decreases progressively from the first to the last trophic level. Look at this food chain:

diatom → paramecium → water flea → small fish → big fish

The number of diatom eaten by paramecia is greater than the number of paramecia, while the number of paramecia eaten by water fleas is greater than the number of water fleas. Similarly, the number of small fish is greater than that of the big fish which eat them. The relationship among the numbers of individuals at various trophic levels in a food chain can be represented diagrammatically, as in Fig. 8.4.
The diagram which represents the decreasing number of individuals from one trophic level to another in a food chain is called a **pyramid of numbers.**

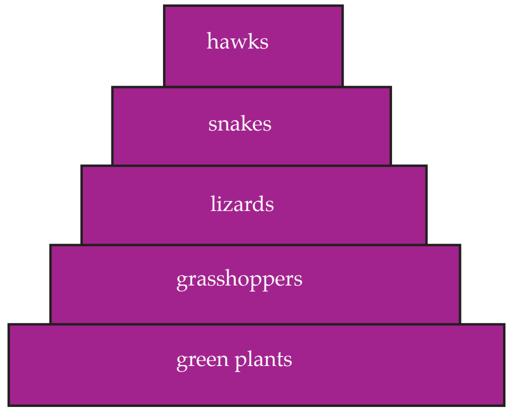


Fig.8.4 A pyramid of numbers

Energy-flow in an ecosystem

Organisms require energy for such vital activities as movement, growth, irritability and reproduction.

They obtain this energy from the food they eat. Human beings obtain energy from the carbohydrates, lipids and protein that are present in the various kinds of food they eat. How does such food, e.g. rice, obtain its energy?

As we saw, green plants use the radiant energy of the sun for the manufacture of sugar in a process known as photosynthesis. The radiant of sunlight is built into stored energy in the molecules of carbohydrates. Starting with simple carbohydrates, the plant makes more complex food substances, such as lipids and proteins.

Primary production

Photosynthesis is the process by which radiant energy from sunlight is built into the molecules of sugar. The energy thus built into plants during photosynthesis is the source of energy for consumers and decomposers. The conversion of the radiant energy of sunlight into energy in carbohydrates is known as **primary production**.

The rate at which radiant energy is converted into energy in carbohydrates, through photosynthesis, is called the **rate of primary productivity**. This rate can be determined in different ways, such as by:

1 Measuring the amount of plant material produced in a given time;
2 Measuring the amount of carbon dioxide absorbed in a given time,
3 Measuring the amount of oxygen evolved in a given time;
4 Measuring the amount of chlorophyll present to carry out photosynthesis.

Of these methods, the simplest is the first, i.e. measuring the amount of plant material formed. This is done by harvesting plant material in a unit area, e.g. one square meter ($1m^2$) of an ecosystem. The fresh weight of the plant material is obtained. The plant material is then dried in a suitable oven at a temperature of about 110^0C, cooled and weighed several times until a constant weight is recorded. Finally, the dry plant material is burnt in a calorimeter and the amount of energy in the plant material is determined in **kilojoules**.

Net production

The amount of vegetation found in one square metre of an ecosystem does not represent the total production. After a plant has converted radiant energy into energy in carbohydrates and other molecules in its body, the plant itself uses up some of this energy for its own vital activities, such as the synthesis of body materials as well as growth. Only what is left of this energy remains in the standing plant is described as the **net production**. When primary production is determined by harvesting the vegetation, drying it and burning it in a calorimeter, it is in fact the net production that is determined.

Energy transformations in nature

As energy flows in ecosystems, it is transformed from one form into another. In the process of photosynthesis, the radiant energy of the sun is converted into chemical energy stored in the sugar molecule. From the sugar molecules, the plant makes lipids, proteins and other body materials containing chemical energy. The plant needs energy for the absorption of mineral salts, as well as for movement, synthesis, growth, reproduction and other vital processes. It obtains this energy through respiration, during which some molecules of carbohydrates, lipids or proteins are broken down and the chemical energy in them released. Part of this energy is used by the plant and part converted into chemical energy, which is lost to the environment. The chemical energy in the organic molecules of the producer is the energy for the primary consumer.

Energy loss in ecosystem

A very large amount of radiant energy is given out by the sun. In the upper layers of the atmosphere, about half of the radiant energy is absorbed by the clouds and ozone layer. Of the radiant energy that reaches the biosphere, only a small part, estimated at about two per cent, is reflected, transmitted or radiated and much of this is converted into heat energy. Part of the heat energy also causes the water on the earth or in the soil to vaporise. This water vapour later condenses and falls as rain.

Of the radiant energy actually absorbed by green leaves, only a part is used in photosynthesis and converted into chemical energy in sugar molecules, while part is lost as heat energy to the environment.

The plant then uses some of the energy it has built into carbohydrates and other molecules for its own life activities and loses some as heat to its surroundings, through conduction, convention and radiation.

When a primary consumer eats a part of the body of a producer, the material eaten contains chemical energy in carbohydrates, lipids, proteins and other molecules. The primary consumer digests and absorbs some of the food, discarding the rest as solid or liquid waste. It uses the absorbed food to build its own body material and some of it for respiration, but not all absorbed molecules may be fully utilised. Some of the energy produced through respiration is used by the primary consumer to keep itself warm, while some is lost to the environment as heat. The same thing happens between the primary and secondary consumers. In all, there are many ways in which energy is lost, form one trophic level to another, resulting in a progressive diminution of the energy content in a food web or chain. It is estimated that only about ten percent, on the average, of the energy in one trophic level, is transferred to the next.

Laws of thermodynamics

The first law of thermodynamics states that **energy cannot be created or destroyed but can be converted from one form to another**.

The second law of thermodynamics states that **when energy is converted from one form to another, a fraction of it is converted to heat**.

These can be applied to ecological phenomena as follows:

In an ecosystem, there are producers, different orders of consumers and decomposers. The feeding relationship between these organisms in the ecosystem has led to the formation of food chains, food webs and ecological pyramids. The producers use light energy from the sun to make food in photosynthesis. During the process the light energy is converted to chemical energy (another form of energy) which is stored in the carbohydrate in plants, as potential energy.

When the primary consumer eats the plants, only a fraction of this energy is transferred to this trophic level. Part of the energy is released as heat in the body of the primary consumer. When a secondary consumer feeds on the primary consumer, the energy is transferred to this third trophic level. However, like in the first case, only a portion of the energy gets to the secondary consumer as part of it has been lost as heat to keep the animal warm. At every point of energy transfer in either a food chain, food web or ecological pyramid, only a fraction of the energy is transferred to the next trophic level, part of it is lost as heat. (This supports the second law of thermodynamics).

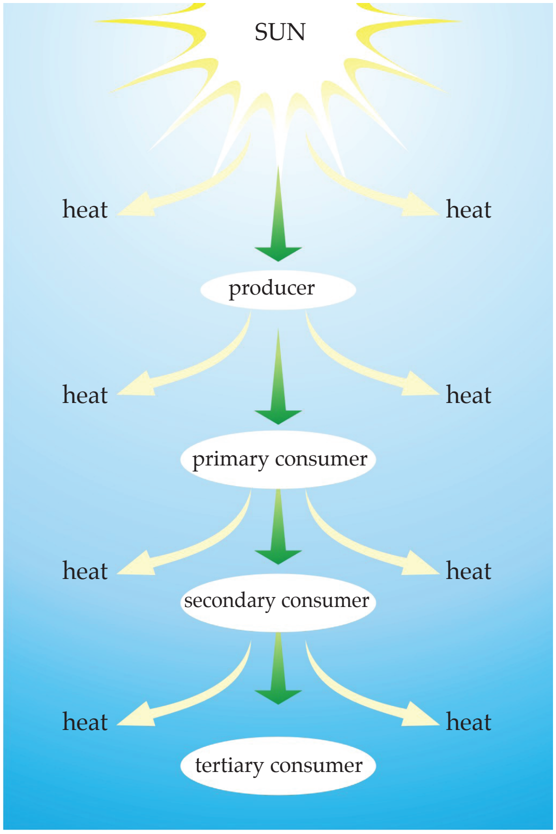


Fig.8.5 Energy flow diagram

Only about ten per cent of the total energy in a trophic level is transferred to the next trophic level. This shows that energy transfer is not efficient as part of the energy is lost as heat.

However, if all the energy involved in an energy transfer is put together, it would be seen that there is no net gain or loss of energy; this therefore supports the first law of thermodynamics.

Pyramid of energy

The amount of energy present in the living organism at the different trophic levels of a food chain can be represented in what is called the **pyramid of energy**.

In this pyramid, the energy contained in the producers is always more than that in the primary consumers, which is more than that in the secondary consumers, and so on. The ratio of the energy in one trophic level to that in the preceding one is about 1:10.

There are significant differences between the pyramid of energy and the pyramid of numbers. In the pyramid of numbers, only the number is counted. The size of the individuals is not reckoned with. For instance, plankton is counted as one unit, and the whale, which feeds on plankton, also as one unit, regardless of the difference in their sizes. A pyramid of energy is based on a common unit, i.e. the unit of energy (joule).

Again, the shape of the pyramid of numbers is not constant. It depends on what an organism feeds on. If one grasshopper feeds on two large grasses, the ratio of number is 2:1. If the same grasshopper feeds on five small grasses, the ratio of the number of producers to the number of primary consumers is 5:1. If a hundred grasshoppers feed on one large tree, the ratio of the number of producers to the number of primary consumers is 1:100. (This is an example of what is referred to as an **inverted pyramid** of numbers). The shape of the pyramid of numbers will thus be inverted. The pyramid of energy cannot be inverted.

Nutrient cycling in nature

Through feeding and other relationships between organisms and their environments, it is possible for a single atom to pass from the environment into a plant, then through several animals and back into the environment. A nitrogen atom, for instance, may be a part of nitrate molecule in the soil. This molecule may be absorbed by a plant, where it may become part of a plant, protein molecule. If the plant is eaten by a guinea-pig, the nitrogen atom may become part of a protein molecule in the guinea-pig. If the guinea-pig is then eaten by man, the same nitrogen atom becomes part of man. If the man excretes urea in his urine, this nitrogen atom may pass out, as part of urea, into the environment, and may be absorbed again by a plant.

The movement of atoms of nutrient elements from environment into various organisms and back into the environment is known as **nutrient cycling**. The path along which the atoms of the elements pass is called a **cycle**. There are many such cycles. In fact, each element has its own cycle. However, the nitrogen, carbon and water cycles will now be considered in detail.

Nitrogen cycle

The nitrogen cycle is the pathway along which nitrogen moves through living and non-living components of the ecosystem, so that the same atoms of nitrogen are used over and over again.

Below are the different ways in which the nitrogen atoms may be recycled in nature.

1 The atmosphere is a large reservoir of nitrogen, which forms about 78% of air by volume. The nitrogen of the air may become part of a plant, an animal, or of soil, as will be seen presently.

2 When there is lightning, the electrical discharge in the air brings about the production of oxides of nitrogen. These oxides of nitrogen dissolve in rain water as it falls through the air, forming dilute nitric acid. On reaching the soil, the nitric acid forms nitrates of various metallic elements.

3 Free-living nitrogen-fixing bacteria in the soil convert the atmospheric nitrogen into various nitrogen compounds, within themselves or in the soil.

4 Nitrogen-fixing bacteria which live in root nodules of leguminous plants fix atmospheric nitrogen into various nitrogen compounds in the root nodules.

5 Plants absorb the nitrates in the soils, through their roots. In the plants, the nitrogen in the nitrates is used to synthesise protein and protoplasm.

6 The nitrogen in plant proteins and protoplasm passes into animals which feed on the plants. The nitrogen is built into the protein and protoplasm of the animals.

7 When the plants and animals die and decay, the nitrogen compounds in their proteins and protoplasm are converted by bacteria into ammonium compounds. The ammonium compounds are converted, first by bacteria of the genus *Nitrosomonas*, into nitrites, then by those of the genus *Nitrobac ter* into nitrates. These nitrates can again be absorbed by plants.

8 Nitrates in the soil can be converted directly into atmospheric nitrogen by denitrifying bacteria. Thus, atoms of atmospheric nitrogen can pass into plants, animal, soil and back to the atmosphere. In this cycle, the same atom may have been part of free atmospheric nitrogen, then a part of a plant protein, an animal protein, and a nitrate in the soil or part of a bacterium.

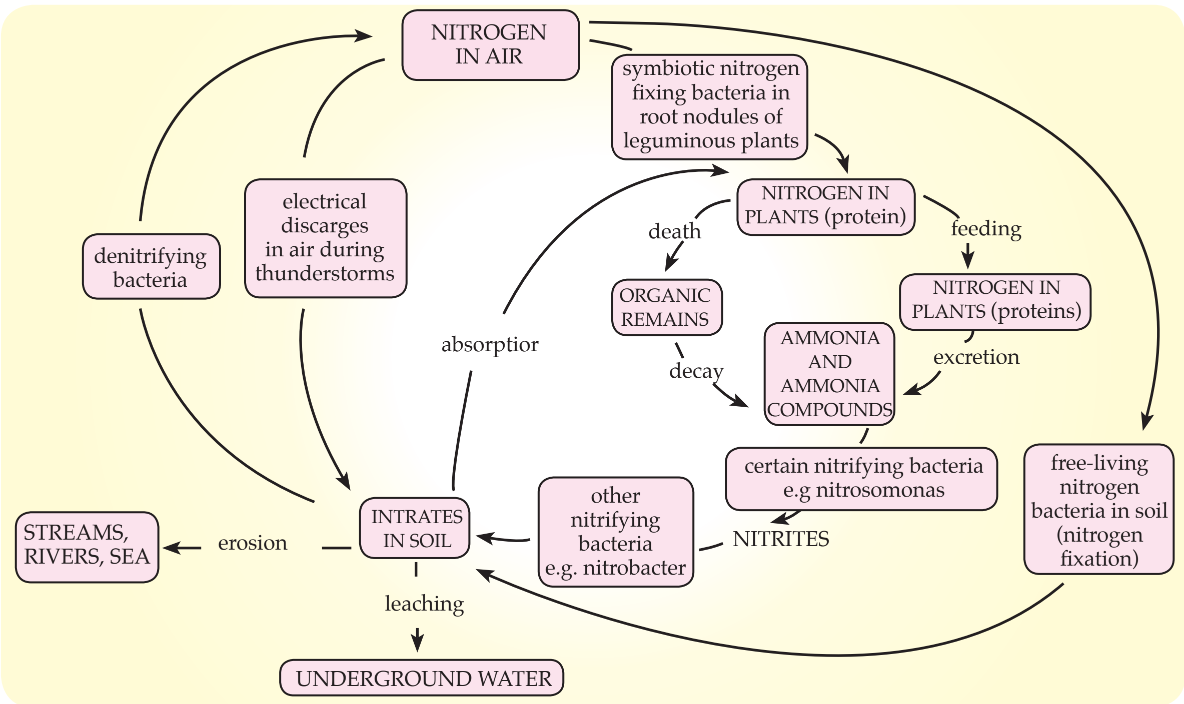


Fig.8.6 Nitrogen cycle in nature

Carbon cycle

Carbon dioxide forms about 0.03% of the atmosphere by volume. The proportion of the air that is carbon dioxide remains more or less constant because certain processes in nature use up carbon dioxide while others produce it. These are shown in Fig. 8.6.

Carbon atoms may be recycled in nature as follows:

1 Green plant, in sunlight, absorbs atmospheric carbon dioxide and uses it to take sugar by the process of photosynthesis. Starting with sugar, plants can make other compounds in their bodies, such as proteins, lipids or complex carbohydrates. The carbon in atmospheric carbon dioxide thus becomes part of carbohydrates, lipids, proteins and other compounds in plants.

2 When animals feed on plants, they take in the carbon compounds of the plants including carbohydrates, lipids and proteins and use these to make compounds in their own bodies. The carbon originally present in atmospheric carbon dioxide thus passes into animals through plants.

3 When plants and animals respire, they give out carbon dioxide. The carbon in carbon compounds of plants and animals, such as carbohydrates, lipids and proteins, is thus returned to the atmosphere in the form of carbon dioxide.

4 When plants and animals decay, some carbon compounds in their bodies break down and give off carbon dioxide to the atmosphere.

5 The burning of plant material (such as wood) and animal materials converts the carbon compounds in them to carbon dioxide.

6 Dead plant and animal material may be subjected to heat and pressure over a long time, to form coal. When coal burns, carbon dioxide is produced.

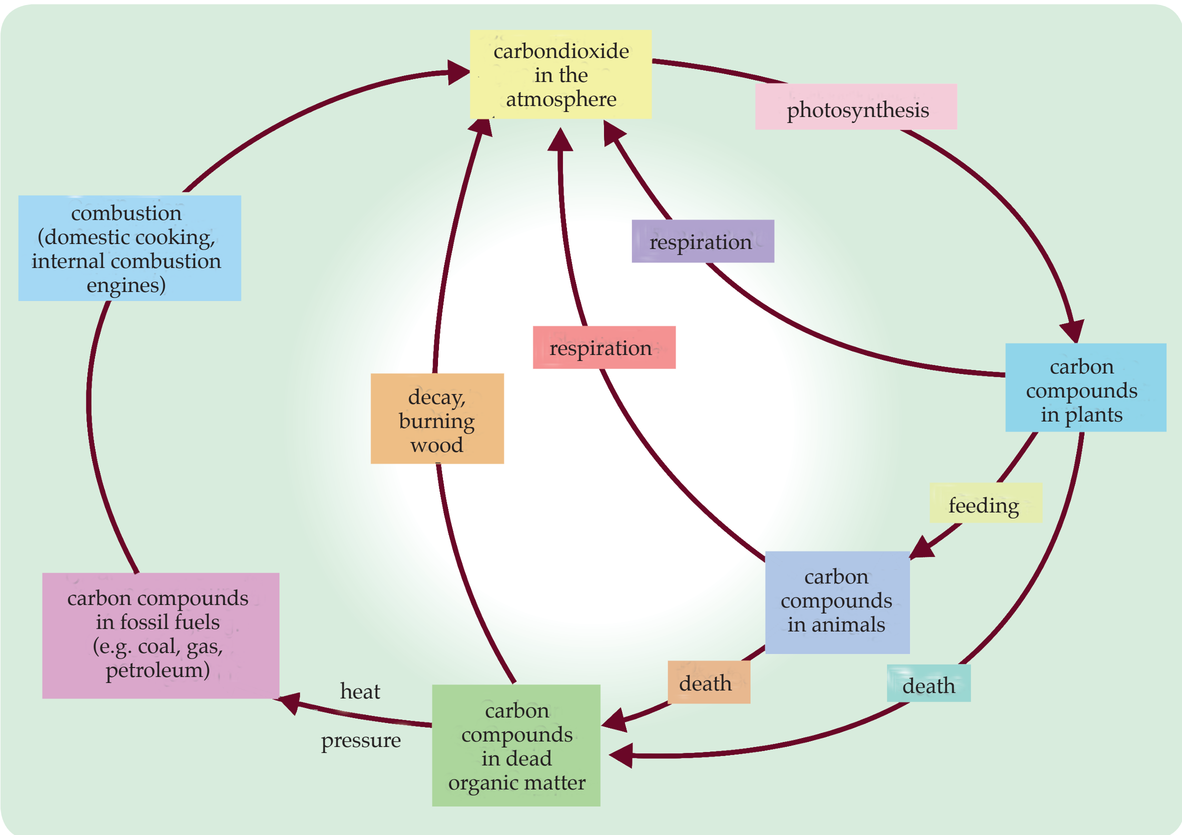


Fig.8.7 Carbon cycle in nature

Activity 8.3 To show that carbon dioxide is absorbed and oxygen released during photosynthesis

Materials required
Three beakers, test tube, funnels, water plants.

Procedure
1. Set up three sets of apparatus, as shown in Fig. 8.8. Distilled water is put in A. B and C are then filled with water saturated with carbon dioxide.
2. Place C in a dark cupboard and A and B in bright sunlight, until some gas has collected in one of the test tubes.
3. Test the gas in the test tube with a glowing splint, to find out if it is oxygen.

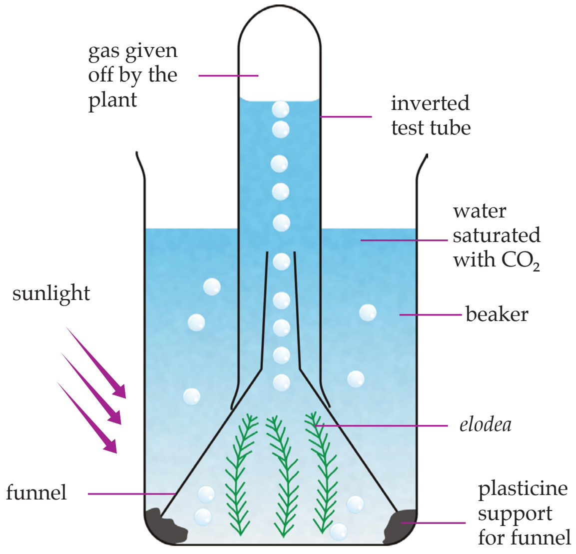


Fig.8.8 To show that carbon dioxide is absorbed and oxygen released during photosynthesis

Tabulate your results as shown:

Flask	Carbon dioxide present	Sunlight present	Oxygen present
A	No		Yes
B	Yes		Yes
C	Yes		No

What do your results say about the requirement for carbon dioxide in photosynthesis?

Water cycle

Water has a cycle in nature. The same water is used over and over again. When rain falls, some of the rain water runs off the ground into streams and rivers. Some of the rain water sinks into the ground until it reaches rocky layers through which it cannot flow. Then it moves sideways along the surface of the rocky layer until it breaks out, as a spring, at a point of low resistance. The spring may flow into a river and the river into an ocean.

Some of the rain water which has sunk into the soil is absorbed by plants. As plants transpire, they lose water vapour into the atmosphere. Evaporation of water takes place from all free water surfaces, including streams, rivers and oceans. The water vapour from vegetation, streams, rivers, and ocean rises into the atmosphere. The higher it rises into the atmosphere, the cooler it becomes, until it condenses into rain drops which fall again as rain.

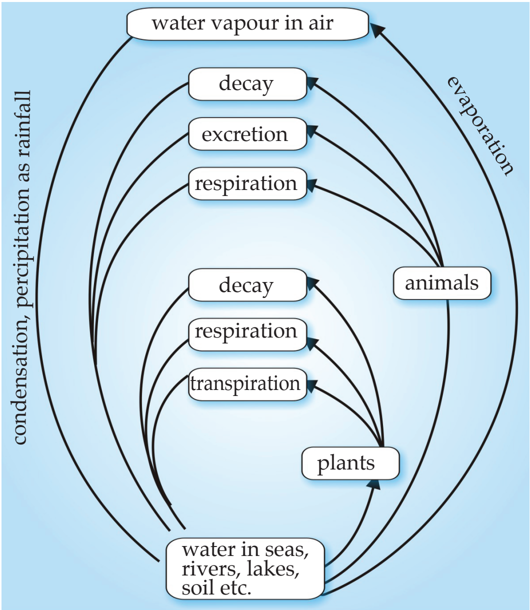


Fig.8.9 Water cycle

Activity 8.4 To show the presence of water in expired air

Materials required
Dry strips of cobalt chloride paper.

Procedure
1 Take two strips of dry cobalt chloride paper. (Cobalt chloride paper is blue when dry and pink when wet.)
2 Place one dry strip on a dry table in front of you.
3 Hold the second dry strip in front of your nose and breathe on it.
4 Observe the time it takes for each of the two strips of dry cobalt chloride paper to turn pink. What do you infer from this result?

Activity 8.5 To show that water is given off during transpiration

Materials required
Strips of dry cobalt chloride paper, glass slides.

Procedure
1 Take a strip of dry cobalt paper, which is blue, from its container. Place it quickly on the lower surface of a leaf attached to a plant (e.g. *panax, hibiscus*), growing in the school compound.
2 Quickly cover the dry cobalt chloride paper with a glass slide, to protect it from atmospheric moisture. Also place a glass slide on the upper surface of the leaf opposite the glass slide on the lower surface. Hold the two glass slides together firmly.
3 Does the cobalt chloride paper turn pink?
4 Explain your results and suggest a control experiment you might try.

Summary

This chapter has taught the following:

- An ecosystem or ecological system is a natural unit consisting of living and non-living things in which there is a cyclic interchange of materials between the living and the non-living components e.g. a pond, a forest.
- All the living things in an ecosystem form a community. The community is made up of producers, consumers and decomposers.
- A food chain is a linear feeding relationship among organisms in which one organism feeds on the one before it in the line. Interrelated food chains form a food web.
- The number of individuals in a food chain decreases from one trophic level to another. This gives rise to a pyramid of numbers.
- Organisms derive energy from the food they eat. A food chain is therefore a line along which energy flows in an ecosystem.
- Total energy in organisms decreases from one trophic level to another. This results in a pyramid of energy. Only about 10% of energy is transferred from one trophic level to another.
- In an ecosystem, there are transformations of energy and energy losses.
- Laws of thermodynamics apply to an ecosystem.

Revision questions

1 An ecosystem consists of ____________.
   A non-living materials
   B abiotic and biotic components
   C producers and consumers
   D producers, consumers and decomposers
   E air, water and soil
2 Which of the following is least likely to be involved in a food chain or food web?
   A Humus
   B Mineral salts in the soil
   C Trophic level
   D Pyramid of numbers
   E Energy flow
3 In the nitrogen cycle, nitrates in the soil can be converted into atmospheric nitrogen by ________ ________________.
   A denitrifying bacteria
   B nitrosomonas
   C nitrobacter
   D nitrogen fixing bacteria
   E thunderstorm
4 The amount of energy transferred from one trophic level to another is about ________ .
   A 1%
   B 10%
   C 20%
   D 5%
   E 50%
5 Describe one method of measuring primary productivity.
6 a) Distinguish between pyramid of energy and pyramid of numbers.
   b) Which of them has a consistent shape and why?
7 Discuss energy losses in the biosphere.
8 Explain the relevance of the laws of thermodynamics to ecological systems.

Chapter 9 Relevance of biology to agriculture

Introduction

Agriculture is the practice of farming, and it involves the cultivation of crops and the raising of livestock. It is the occupation of the majority of the Nigerian population.

When man first inhabited the earth, he was a wanderer, who went from place to place hunting animals, and gathering wild leaves and fruits for food. With time, man learnt to domesticate animals as well as to plant and tend crops. This was the beginning of agriculture. Farming helped man to live a settled life in communities. Most of the food eaten by man comes from farms. However, some human food items notably fish, crayfish, crabs and some snails, come from oceans, rivers and other bodies of water.

Today, the demand for food is high since there is a continuous increase in the world human population. The implication of this is that there are more and more people to feed, and less and less land for food production. As much food as possible should be produced on each piece of land.

Science and technology help man to increase the production, preservation and storage of food. For instance, tractors, which are products of technology, help man to cultivate large areas. Of all branches of science, however, biology is the closest to agriculture. Biological knowledge is applied in improving agriculture in many ways such as in providing adequate nutrients for crops and livestock, in controlling pests and diseases, in developing improved varieties of crops and livestock, in controlling pests and diseases, in developing improved varieties of crops and livestock, and in food preservation and storage.

In this chapter, we will study how plants are classified, the effects of agricultural activities on the environment, pests and diseases of agricultural importance, ways of improving crop yield, methods of preserving and storing food, as well as the problem of population growth and food supply.

Classification of plants

Scientists study plants. They obtain knowledge which a farmer may apply to improve production. In chapter 1, you learnt that classification of plants and animals helps us to study them. Here we shall learn how plants are classified in botany and in agriculture, in order to study them effectively.

Botanical classification

In a botanical classification, plants fall broadly into two groups, the **flowering plants** and the **non-flowering plants**. Each of these groups may be sub-divided into smaller groups.

Agricultural classification of plants

This is based on:

i) the product obtained from the plant;
ii) the part of the plant that is useful;
iii) the economic importance of the plant.

Plants are therefore classified into the following groups:

a) root crops
b) vegetable crops
c) cereal and grain crops
d) legumes
e) fibre crops
f) oil crops
g) latex crops
h) beverages and stimulants
i) fruit crops
j) spices
k) forage crops
l) cash crops

A crop is any plant that is cultivated by man for its usefulness.

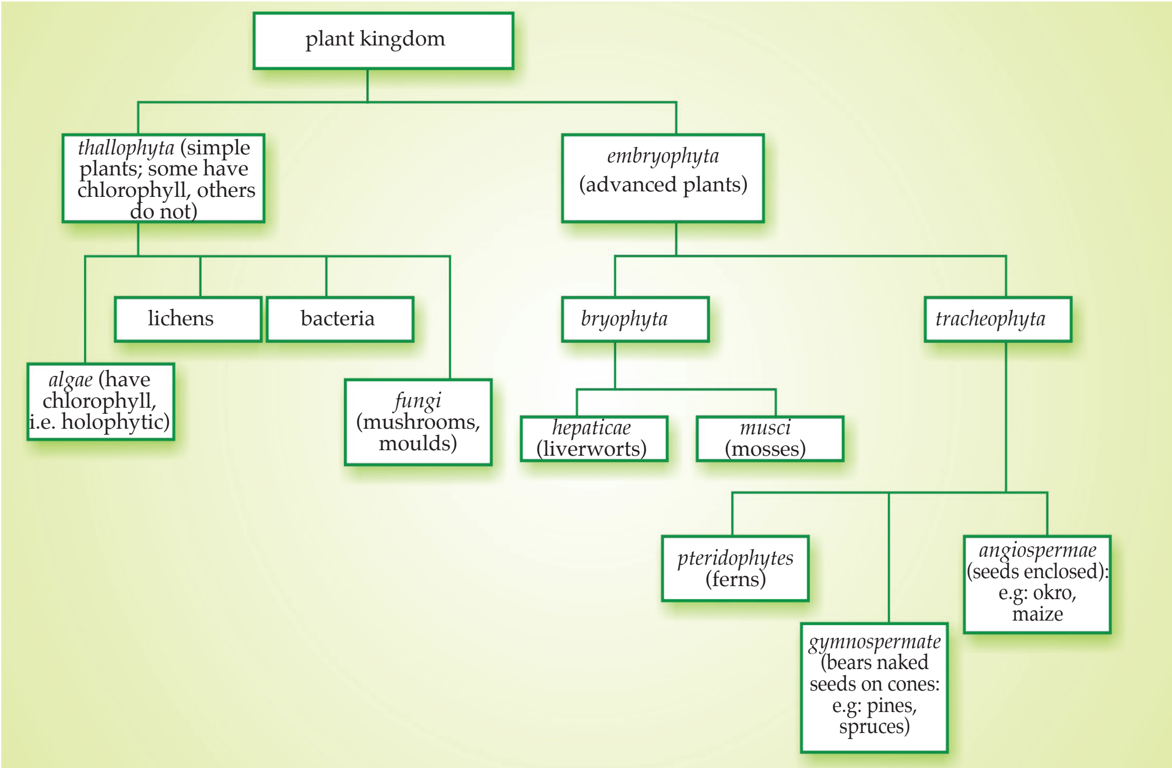


Fig.9.1 Early botanical classification of plants

Root crops
These are plants with underground organs modified for storing food. Some of them are annuals while others are biennials. They include cassava, sweet potato, yam, and Irish potato.

Vegetables crops
These are cultivated for the roots, stems and leaves which are useful either as food or economically. Common examples include okro, garden egg, pumpkin, water melon, cabbage, lettuce, amaranthus, carrots, onion and tomato.

Cereal and grain crops
They are cultivated for their seeds. These include rice, maize, guinea corn and millet.

Legumes
These are cultivated for their fruits and seeds which are rich in protein. They are cultivated for human consumption, as fodder crops for feeding livestock and to enrich the soil with nitrates. Examples include groundnuts, soya beans, cowpea and beans.

Fibre crops
These are produced for their economically important fibres which may be used as raw materials in local industries or exported to other countries for foreign exchange, e.g. cotton, sisal and jute for making fabrics, sacks, paper, and ropes.

Oil crops
These crops are cultivated for the oils stored in them. Such oils are used for making cooking oils, lubricants, varnishes, paints and soap. The oils may be used locally or exported. Examples of oil crops include groundnut, oil palm, shea butter and coconut.

Latex crops
These produce a lot of fluid called **latex** which is important as a raw material in making rubber and other synthetic products, e.g para rubber.

Beverages and stimulants
The vegetative parts, fruits or seeds of these crops serve as raw material for beverages and stimulants e.g. cocoa, tea, coffee, kola and tobacco.

Fruit crops
These are cultivated for their fruits that are edible. They include oranges and other citrus crops, pawpaw, mango, guava, cashew, avocado pears, pineapples, plantain and bananas.

Spices
These may have medicinal properties and some are also used as spices to add flavour to food, e.g. pepper, thyme, onions, curry leaves and ginger.

Forage crops
These are pasture and fodder crops on which farm animals graze. Farm animals derive carbohydrate, protein, mineral salt and vitamins from forage crops, e.g. grasses and legumes.

Cash crops
These are crops cultivated for export to earn foreign exchange. Local industries may also use them. They include cocoa, oil palm, benniseed, soya beans, cotton, kola, rubber and groundnuts.

Classification based on life cycle
Plants are classified on the basis of the duration of their life cycle into annuals, biennials and perennials.

1 **Annuals** are plants which complete their life cycles in one growing season within a year, e.g. maize, yam, melon, cowpea, tomato.
2 **Biennal plants:** In some regions of the world, there are biennial plants. The biennial plant completes its life cycle in two growing seasons; it produces vegetative parts such as roots, stems and leaves in the first season and in the second groowing season, it produces more vegetative parts, manufactures and stores food, produces flowers and fruits.
3 **Perennials** are plants that complete their life cycles in many years and live for many years, e.g. mango, orange, and oil palm.

Classifications of plants on the basis of size
Plants are classified on the basis of the size of the full grown plant, into **herbs, shrubs** and **trees**.

1 **Herbs** are small plants with fleshy stems, e.g. *Talinum triangulare.*
2 **Shrubs** are medium sized plants with woody stems e.g. croton, hibiscus plant.
3 **Trees** are big plants with woody trunks and branches, e.g. silk cotton, iroko, mahogany trees.

Under adverse conditions, a big plant may be medium sized, and a medium- sized plant may be small.

Activity 9.1 Classifying various plants using botanical and agricultural techniques

Materials required
About twelve different specimens of plants collected from the school garden and compound.

Procedure
Students will work in pairs.

1 Classify each plant specimen using the botanical classification (refer to Fig.9.1). Record your results.
2 Classify each plant specimen using the agricultural classification. Record your results.

Give one example of a plant which falls into two possible groups using the agricultural classification.

Effects of agricultural activities on ecological systems

Activities of man have effects on the environment. The effects of some agricultural activities on ecological system are examined below.

Bush clearing
Bush clearing has many adverse effects on ecological systems.

1 Clearing removes the plant cover over the soil.
2 It exposes the soil to direct sunshine, thus increasing the temperature of the soil.
3 Increasing temperature of the soil speeds up the rate of humus decay.
4 Removal of plant cover over the soil exposes the soil to erosion.
5 Mineral salts in exposed soils are subjected to leaching.
6 Useful soil organisms in exposed soil may be washed away or displaced to other places.
7 Prolonged exposure of soil surface may lead to desertification in areas of low rainfall.

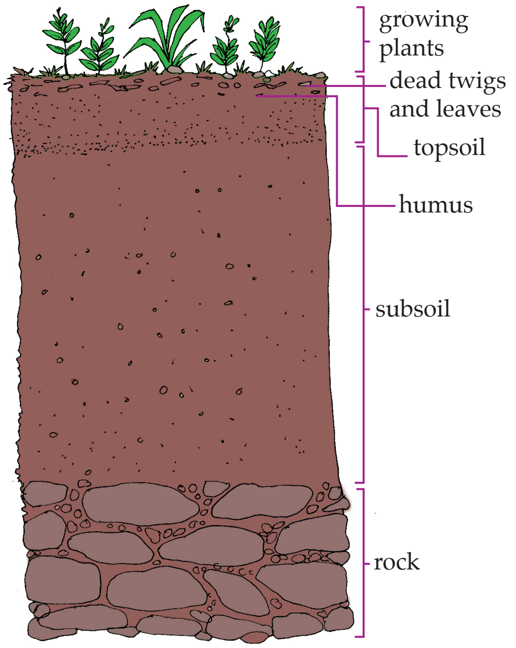


Fig.9.2 Soil profile

Bush burning

Bush burning is harmful to the ecological system for several reasons.

1 Bush burning causes humus on the soil surface to be burnt, thereby bringing about loss of soil fertility.
2 Useful organisms in the soil, such as putrefying bacteria, nitrifying and nitrogen-fixing bacteria, earth worms and fungi that bring about decay are burnt by bush fires, thus causing loss of fertility.
3 Bush burning makes the soils to be exposed, and promotes soil erosion.
4 Bush burning may cause useful crops in the area such as oil palm or orange trees to be burnt.

Tillage

Tillage has good and bad effects on the ecological system. Minimum tillage is good.

1 It breaks up the soil surface and loosens the soil for roots of young plants.
2 It makes water that rises up by capillarity through pores in the soil to accumulate at the tilled surface layer, where young planst absorb the water.
3 It mixes humus into the soil. However, tilling increases soil erosion, and removes plant cover over the soil.

Fig.9.3a) Early stage of gully erosion

Fig.9.3b) An erosion site

Fertilisers

Fertilises are chemical compounds that are artificially prepared for increasing soil fertility. A chemical fertiliser is usually described by its nitrogen, phosphorous and potassium (NPK) content, since these are the essential elements most often deficient in soil. Excessive use of fertilisers has adverse effects on the ecosystem.

1 It may kill useful soil organisms that come into direct contact with the fertiliser.
2 If washed into nearby rivers and streams, fertilisers pollute the water, lead to alga bloom, may kill aquatic organisms and make the water unfit for human use.
3 Use of chemical fertilisers over a long time may lead to development of poor soil structure.

Pesticides

These are chemicals used to control plant pests and diseases. They may be herbicides for controlling weeds, insecticides for controlling insect pests, mollusicides and fungicides for controlling molluscs and fungi respectively which destroy crops and animals.

Excessive use of such chemicals has adverse effects on the ecosystem as shown below.

1 Pesticides pollute the atmosphere because most of the chemicals are aerosols.
2 Insecticides may kill useful insects such as butterflies and bees that pollinate flowers.
3 Pesticides may pollute the soil, and cause the death of useful soil organisms like earthworms.
4 Plants including those eaten by man may absorb pesticides from the soil and become contaminated.
5 Herbicides may kill crops if they are not selective.

Effects of different kinds of farming on the ecological system

There are several kinds of farming, some of which have adverse effects, and some have favourable effects on the ecological system.

Types of farming with adverse effects

The types of farming with adverse effects on the ecological system include the following:

1 **Monoculture**

Monoculture is the practice of growing the same crop on the same piece of land from year to year. The crop may be an annual, such as yam, or a perennial, such as oil palm. The disadvantages are:

a) The same crop removes the same kind of nutrients, year by year leading to impoverishment of the soil.
b) The soil structure may be destroyed, leading to erosion.
c) Plant pests and diseases spread rapidly and easily in a monoculture.

2 **Continuous cropping**

Continuous cropping means cultivating the same piece of land from year to year This leads to exhaustion of the essential mineral salts in the soil, low productivity and erosion.

3 **Shifting cultivation/bush fallowing**

Shifting cultivation is a kind of farming in which a farmer cultivates a piece of land for a few years, then, as the yields become low, he abandons the land completely and moves to another place. This is possible where human population is small, and land is abundant.

In the bush fallowing system, a farmer cultivates a piece of land for a few years and leaves the land to fallow for 6 to 12 years. If the period of fallow is short (such as two years) essential elements in the farm become depleted, and harvests become poor. Frequent change to new pieces of land implies clearing of vegetation every two years and encouragement of erosion.

4 **Nomadic herding**

In this non-settled type of animal husbandry, a farmer keeps grazing animals only. This happens in arid areas with low rainfall and small natural pasture. The farmer leads his animals to wherever pasture is available. There is tendency for overgrazing to occur, which causes erosion.

Types of farming with favourable effects

The following are methods of farming that have favourable effects on the ecological system:

1 **Crop rotation**

Crop rotation is the practice of cultivating plots of land every year in such a way that the crops follow in a definite order. For instance, cassava, maize, yam and legumes follow in definite sequences. The advantages are that:

a) The same land is cultivated every year;
b) The nutrient level of the soil is maintained, because different crops absorb essential elements to different extents;
c) Nitrogen is added to the soil by legume;
d) The legume may be ploughed into the soil as green manure.

2 **Mixed cropping**

In mixed cropping, more than one type of crop is cultivated on the same land at the same time. This method, if well planned, makes good use of nutrients in the soil, for deep-rooted plants can be planted with shallow-rooted ones. Again pests and diseases of one crop do not spread very easily where there are crops of different kinds together.

3 **Mixed farming**

Mixed farming involves growing crops and keeping livestock. Product of the crop may be used to feed the animals, and the faeces of the animals may be used to manure the farm for the crops.

Activity 9.2 Discussing the effects of man's activities on ecological systems

Procedure

Students are organised to work in groups of four or five per group.

1. Each group discusses the effect of one human activity on natural ecosystem in the locality.
2. At the end of the discussion, all groups write respective findings in a tabular form on the board such as shown below.

Table 9.1 Effects of human activities on natural ecosystems

Human activity	Effects on natural ecosystems
1 Bush clearing	
2 Bush burning	
3 Tilling	
4 Cultivation of hill slopes	
5 Spraying insecticides on crops	

Pests and diseases of agricultural importance

Pests and diseases are important in agriculture because they hinder crops and livestock from attaining their optimum yield or production.

Pests

Pests are organisms that are troublesome or cause damages to man, livestock and crops. Types of pests of crops include mammals (especially rodents), some birds, insects, nematodes, snails and fungi.

Insect pests of crops

There are many insect pests which cause many kinds of serious damages to standing crops or stored agricultural products.

1. **Biting and chewing insects**
   Some insect pests have biting and chewing mouth parts, e.g. locusts, grasshoppers, mantids, termites. Some of the kinds of damage they cause to crops are described below.
   a) Some eat leaves of crop plants and reduce photosynthetic tissue and hence the yield, e.g. grasshoppers, locusts, and caterpillars eat leaves of maize, guinea corn, and yam.
   b) Some eat young stems and terminal buds causing the plants to have stunted growth, e.g. the variegated grasshopper eats young shoots of yam.
   c) Some pests eat stamens and pistils of flowers of crop plants, preventing pollination and seed formation, e.g. grasshoppers.
   d) Some pests eat the storage organs of crops, e.g. yam beetle eats yam tubers, and termites eat cassava tubers.
   e) Some insects tunnel into stems of crops and weaken the plants, e.g. bitter leaf beetle.

2. **Piercing and sucking insects**
   Some insect pests of crop plants have mouth parts adapted for piercing and sucking. These include capsids, shield insects, scale insects, aphids, cotton stainer and mealy bug. They cause damage to crops in the following ways:
   a) Some pierce into young stems and suck cell sap. This weakens the plant and reduces both the growth and the yield. Sometimes the stem or leaf becomes distorted, e.g. mealy bug sucks cell sap from cassava.

Table 9.2 Mammalian pests of crops

Pest	Crop affected	Effects	Control
Bush rat	eats groundnuts, yam, cassava	destroys the crops	clearing vegetation around the farm, weeding to remove hiding places
Grass cutter	eats shoots of rice, tubers of cassava	reduces farmers' harvest	shooting; weeding to remove hiding places
West African ground squirrel	eats tubers of yam and cassava in farms	consumes yam, cassava crops, causing losses to farmers	trapping, shooting
Monkey	eats maize in farms	reduces farmers' harvest	shooting, chasing away by man.

Table 9.3 Birds that are pests of crops

Bird	Crops affected	Effects	Control
Bush fowl	feeds on corn, groundnuts, cassava in early morning and evening	damages crops and causes loss of part of the yield	scare-crows, mechanical devices that make a noise
Guinea fowl	feeds on groundnuts	loss of part of yield	scare-crow, or loud noise made by knocking two sticks or cans
Village weaver bird	feeds on maize and rice grains in the field	damage to maize and rice, and loss of yield	use of explosives and spraying of poisonous chemicals from aircraft
Quelea bird	feeds on ripening grains of maize, rice, guinea corn and millet	colonies that number up to a million can wipe out all grains in farms in an area in a few days	spraying with chemicals from aircraft

b) The pests may pierce into young developing seeds or fruits and suck the contents, causing seed or fruits formation to fail, e.g. cotton stainer sucks materials for developing okro fruits.

c) Pests inject poisonous chemicals in their saliva into host plants, and harm the plants.

d) Piercing and sucking pests transmit disease-causing organisms, such as viruses, from one plant to another, and thus help to spread diseases.

3 **Pests of stored products**

The maize weevil (*Sitophilus zea*) is described as an example. This weevil belongs to the order of beetles (*Coleoptera*). It has mouth parts for boring. Infestation begins in the field before harvest, and continues in the store.

The adult female lays eggs singly in a cavity in grain which she makes with her boring mouthparts. She then seals up the egg in the cavity. The egg hatches into larva which feeds on the stored food in the grain. The larva changes into a pupa in the cavity and finally the adult emerges in about four weeks.

When the maize grains are harvested and stored, infestation continues. A new generation of adults emerges about every four weeks. From infested stores, the adults fly to fields where they cause new infestation. The adults can feed on maize or other grains, but the larvae feed on maize grains only.

The maize weevil causes considerable damage to the maize crop. Unless control measures are taken, more than 50% of the crop harvested may be lost to weevil damage.

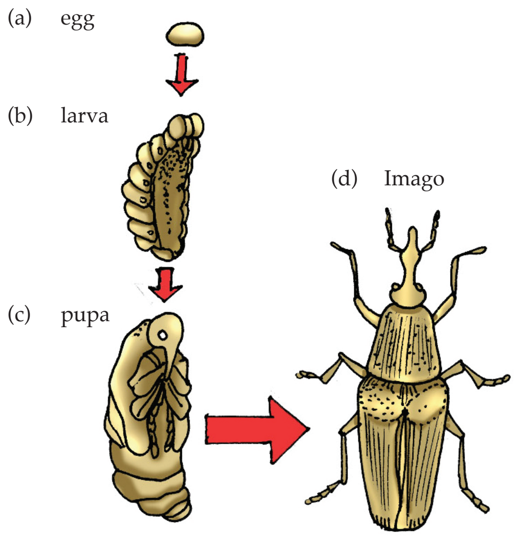


Fig.9.4 Life cycle of maize weevil

Life cycles of insect pests of plants

Knowledge of the modes of life and life cycles of insect pests helps in the control of the pest.

The life cycles of the grass-hopper (*Orthoptera*) and the aphid (*Hemiptera*) are described as representatives of their respective orders.

Life cycle of the grasshopper

Adult grasshoppers are found in areas with grass, in gardens and farms, where they feed on leaves with biting and chewing mouthparts. In the breeding season, the male mounts on the female, holds it firmly with the aid of styles and inserts sperms into the female reproductive system. The female stores the sperms in a special pouch, until she is ready to lay eggs.

When the female is ready to lay eggs, she digs a hole in the ground with the **ovipositor** and deposits about 30 eggs in the hole. The sperms in the sperm pouch fertilise the eggs as they pass out to be laid. After the eggs have been laid, the female secretes a liquid over the eggs, which hardens into a protective case.

After some time, the eggs hatch. Metamorphosis is complete. The eggs hatch into **nymphs**, which look like adults but are small. They moult about five times to become adults.

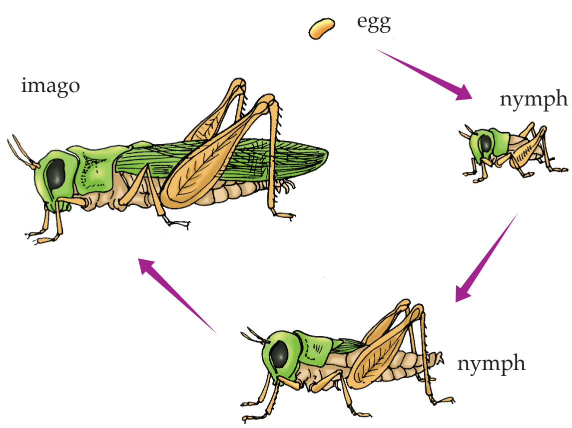


Fig.9.5 Life cycle of a grasshopper

Life cycle of an aphid

Aphids are small, usually green, sometimes black insects in the order *Hemiptera*. They live together in large numbers, on host plants such as orange, rose and bean plants.

The piercing and sucking mouths parts consist of four needle-like styles for piercing, a tubular labium for sucking, held in a labrum. It inserts the phloem tissue of plants and sucks juice rich in sugar.

The aphid reproduces by both unfertilised and by fertilised eggs. Under favourable whether and food conditions, the female lays unfertilised eggs, which hatch into mainly wingless females and few wingless males. Reproduction by unfertilised eggs is called **parthenogenesis**.

When conditions are unfavourable, some winged males and females are produced. These mate and the female lays fertilised eggs. The fertilised eggs withstand adverse conditions and hatch to produce winged males and females. Some of these move to fresh hosts. There, the females reproduce by parthenogenesis once more to produce wingless females.

Aphids do much harm to crops in the following ways.

1 They suck juice from the phloem tissue and thereby weaken the crops, and reduce their yield.
2 The piercing of the plant tissue causes physical damage.
3 As they suck juice from one plant to another, they transmit viruses that cause diseases, such as swollen shoot of cocoa.

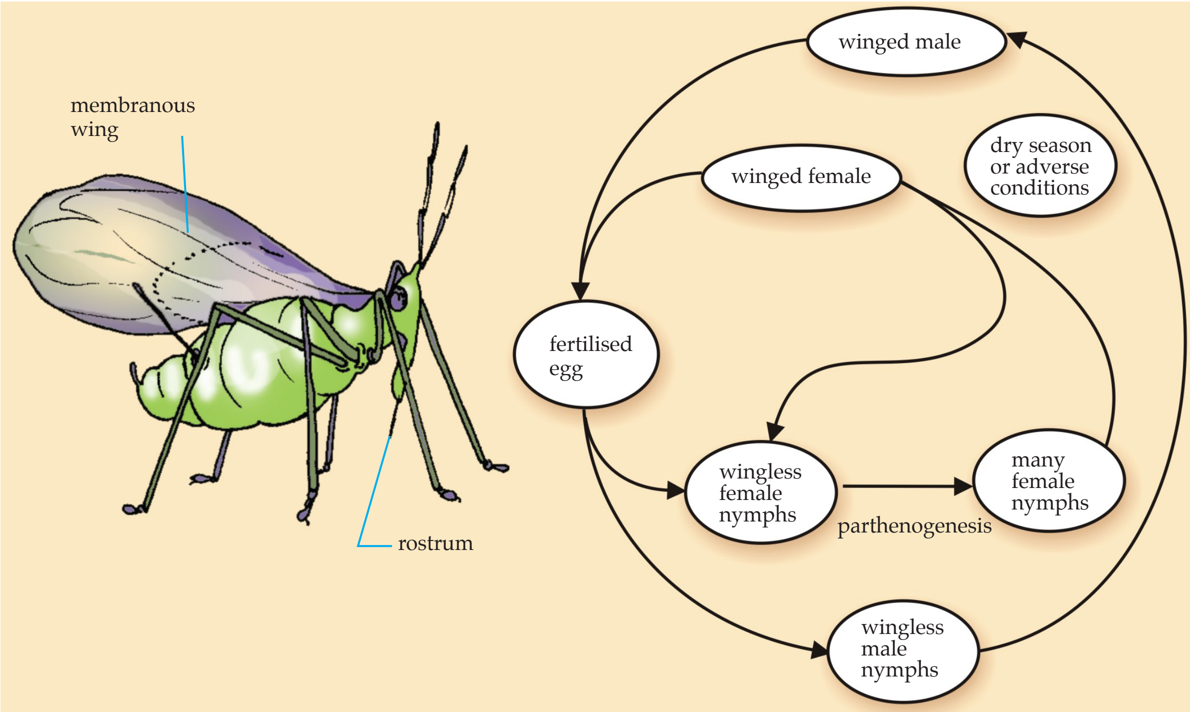


Fig.9.6 Life cycle of an Aphid

Methods of control of pests of plants

It is necessary to study the biology of a pest, including its feeding habits, life cycle and interactions with its host and environment in order to determine the stage at which it is best to control it. Control measures include those described below.

1 **Prohibitions (preventive measure)**
Prohibitions involve forbidding the introduction of materials, likely to carry pests or disease organisms into an area or country. It is normally done by legislation. For instance if the economy of a country depends on tomatoes, that country may prohibit the importation of tomatoes, so as to avoid introducing new pests or diseases.

Table 9.4 Common insect pests, their effects on crops and control

Pest	Mode of feeding	Nature of damage	Crops attacked	Control
Grasshopper	biting and chewing	eats leaves of garden flowers and crop plants	maize, beans, yam, guinea corn, millet, etc	application of insecticides
Yam beetle	biting and chewing	eats the yam tuber, reduces yield	yam	application of insecticide before planting
Termite	biting and chewing	eats the stem of cassava or tuber, reduces growth and yield	cassava, yam, flowers	application of insecticide before planting
Cotton stainer	piercing and sucking	weakens plants, damages developing fruits and seeds	okro, cotton	application of insecticide.
Aphids	piercing and sucking	weakens and may kill plants, causes distortion of parts, transmits disease virus	citrus plant, e.g. orange rose plant, beans plant	use of contact insecticide
Mealy bug	piercing and sucking	weakens the plants and reduces the yield	cassava, pepper	planting resistant varieties; use of insecticides.
Maize weevil	boring and chewing	eats and damages stored maize	stored maize	use of fumigants or other insecticides
Bean weevil	boring and chewing	eats and damages stored beans	stored beans	use of fumigants or other insecticides

2 **Quarantine (preventive measure)**
Quarantine is the practice of keeping an imported material in a closed apartment for a period of time for observation. The period of quarantine is long enough for any pest or disease in the material to be noticed. If such a pest or disease in the material is found, the material is returned to the country of origin or destroyed.

3 **Pest resistant varieties (preventive measure)**
Farmers are advised to plant pest or disease resistant varieties of crops, to minimise pest or disease attack. For instance some varieties of cassava are resistant to mealy-bug attack, while some varieties of maize (such as yellow hybrid maize) are more resistant to weevil attack than other varieties.

4 **Cultural practice (preventive measure)**
Some farming practices reduce pest attack. Such practices include:

a) Planting at the time pests are usually few;
b) Crop rotation so that the host crop is replaced by other crops for some years;
c) Correct spacing of crop stands, so as to discourage spread of pests;
d) Regular weeding to remove weeds that may act as hiding places or hosts for the pests;
e) Ploughing to bury seeds of pests inside the ground.

5 **Drying (preventive measure)**
Proper drying of some products before storage (e.g. beans, maize) reduces the water content of the stored product to such a low level that weevils cannot easily live on them.

6 **Biological control (treatment measure)**
Where pests have already attacked, one of the control measures is to use organisms that feed on the pests (natural enemies) to reduce pest numbers, e.g. ladybird beetles or wasp's larvae feed on aphids. Biological control has to be done with care so that the introduced organism does not itself become a worse problem than the pest it is to eliminate.

7 **Chemical control**
Chemicals used to control pests are called **pesticides**. They include **herbicides** for control of weeds, **insecticides** for insects, **fungicides** for fungi and **nematicides** for nematodes.

Some insecticides are solid (e.g. Aldrin, Vertox 85, Furadan), some are liquid or liquid suspension (e.g. Gammalin 20, Didimac 25). Some insecticides are applied as vapour, especially to stored products (e.g. carbon tetrachloride, dichloro ethane (ethylene dichloride). Chemicals may be applied to standing crops to prevent the attack of pests, or they may be applied to kill pests after an attack has started.

Pesticides must be applied with care, for reasons given below.

a) Application of pesticides in excess causes pollution of the environment.
b) Persistent pesticides must not be used.
c) Many herbicides are harmful to man and must be applied by trained people, with adequate protection.
d) Pesticides may kill useful species (e.g. bees that pollinate flowers) in addition to the pests.

Diseases of agricultural importance

Each type of crop or farm animal suffers from specific diseases which are agriculturally important because diseases cause reduction in yield of crops and livestock, or their death. Many diseases of agricultural importance are caused by fungi, viruses, bacteria, protozoa and nematodes. Some of these are shown in Tables 9.5, 9.6 and 9.7.

Table 9.5 Some diseases of plants and animals caused by fungi

Disease	How it spreads	Symptoms and effects	Prevention and control
'Rust' of maize, guinea corn, millet	spores of the fungus are scattered by the wind	yellow or brown patches on leaves, reduces yield	plant resistant varieties; crop rotation
Blackpod disease of cocoa	spores of the fungus are spread by the wind	brown spots on pods, pods are damaged and eventually turn black; yield is reduced	cut infected pods and bury or burn, spray plants with appropriate chemicals (e.g. 0.4% perenox or 1% Bordeaux mixture)
'Blast' of rice	spores of the fungus are spread by the wind	small grey brown spots or patches on leaves; there may be dark rings on nodes; severely attacked leaves shrivel and dry up	plant resistant species

Aspergillosis (fungal pneumonia or pulmonary mycosis) of poultry	inhalation from contaminated litter or feed; also a hatchery-borne disease	loss of appetite, thirstiness and fast breathing	sanitation (clean buildings, litter and equipment; use disinfectant); eliminate affected birds
Favus of poultry	contact with infected birds	yellowish white scaly lesions on the skin of the head and comb; loss of feathers or broken ones on the neck	disinfect litter and equipment; apply formaldehyde plus vaselin 1:20
Foot rot of sheep	contact with infected marshy pastures	sores on the skin of the feet between the hooves; difficulty in walking	dip feet of sheep in dilute copper(II) tetraoxosulphate(VI) (copper sulphate) solution

Table 9.6 Some diseases of plants and animals caused by viruses

Disease	How it spreads	Symptoms and effects	Prevention and control
'Mosaic' of cassava, tobacco, pepper, garden egg plant	transmitted from one plant to another by insects such as aphids and leaf hoopers or by wind	yellowing, mottling, distortion and curling of leaves; reduced leaf area and reduced amount of food synthesised; rosette formation (excessive branching, stunted growth)	plant resistant varieties
Swollen shoot disease of cocoa	transmitted by mealy bug	mottling, distortion of leaves, reduced yield of cocoa	cut down infected trees and burn; destroy vectors
Fowl pox	transmitted by some mosquitoes, i.e. Aedes, culex, stegomyia	high temperature, scrabs all over the head (comb, wattles, nostrils, eyes, ears); nasal discharge if lesion around nostrils, tear production and closing of eyelids if lesions appear on the eyelids	vaccinate when birds are 1 to 2 weeks old; remove sick birds

Newcastle's disease of chickens, turkeys, ducks, pigeons	direct contact with contaminated food, water, litter, faeces or other objects. Infected birds give out mouth, nasal, eye and faecal discharges which spread contamination	attacks respiratory and nervous systems, average incubation period is 5 days; difficult breathing, gasping, weakness; signs of nervous problems include trembling, partial or complete paralysis of wings and legs, twisting of neck	vaccination of birds usually twice (when birds are 1 day to 2 weeks and 5-6 weeks old); strict sanitation, e.g. clean equipment, dip feet in disinfectant before entering pen; eliminate infected poultry
Rinderpest of cattle	by inhalation, by direct contact with contaminated secretions and excretions of infected animals	high fever, inflamation of lining of mouth, nostrils and eyes; lesions inside the lower lip and lower surface of tongue; lesions on skin, diarrhea	vaccination
Foot and mouth disease of cattle	contact with contaminated saliva, food and other materials	vesicles filled with clear fluid in mouth mucosa; vesicles rupture leaving raw bleeding surfaces; lesion on skin between toes; lameness due to lesions and salivation due to mouth soreness	vaccination; in case of outbreak slaughter and bury infected animals; quarantine; invite veterinary officer for professional help

Table 9.7 Some diseases of plants and animals caused by bacteria

Disease	How it spreads	Symptoms	Prevention and control
'Soft rot' of vegetables, e.g. carrots, onions	infection occurs through wounds	reduces parenchymatous tissue of the storage organ to a watery, slimy mass	avoid bruising of plants harvest; destroy refuse dumps to prevent them from becoming sources of infection
Bacterial 'wilt' of tomato, potato	infection occurs mostly through wounds	vascular system becomes brown, adventitious roots may develop along the stem, leaves droop, wilt and die	crop rotation; plant resistant varieties
'Blight' off cowpea	infection occurs mostly through wounds	chlorotic areas appear in parts of leaves, general chlorosis of younger plants, kills the plant	disinfect seeds before planting

Fowl typhoid	contact with faeces of affected birds; may be transmitted through eggs	diarrhea with yellowish or greenish discharge, dehydration, loss of weight, reduced food intake, slightly bluish combs, drowsiness, ruffled feathers	keep pens clean, inoculate birds when 5 to 6 weeks old, in outbreak invite veterinary officer for proper curative treatment of birds, remove and destroy infected birds
Tuberculosis of cattle, poultry, swine	inhaling the bacteria in air-borne droplets; taking infected milk, food or water; repeated exposure to infected animals	coughing, damage to respiratory system, laboured breathing, weakness, weight loss	vaccination; remove and isolate infected animals; adopt hygiene measures – clean and disinfect feeding and drinking troughs; in case of outbreak invite veterinary officer to give curative treatment
Anthrax of cattle	ingestion or inhalation of contaminated food, soil, vegetables, grass, water	muscular tremors, high temperature, rapid pulse and respiration; diarrhea, marked depression, bloody exudates from nasal, rectal, vaginal and mouth openings; infects man; attendant should not allow any exudate from the animal to get into any wound or opening on his body	vaccination; good sanitation; in case of outbreak invite veterinary officer to give curative treatment; treat infected pasture; disinfect pen and equipment

Activity 9.3 Observing the effects of pests and diseases on plants and animals

Procedure

1. Observe the pests and diseases of common crop plants and farm animals, and their effects. Write them down in a table.
2. During the next lesson, write your results as it is in Table 9.8 below, on the board for a class discussion.

Table 9.8 Observed pests and diseases of common plants and farm animals

Crop	Pest	Effects
Cassava	(a) (b)	(a) (b)
Maize	(a) (b)	(a) (b)
Pepper	(a) (b)	(a) (b)
Beans	(a) (b)	(a) (b)

Livestock	Disease	Effects
Poultry	(a) (b)	(a) (b)
Pigs	(a) (b)	(a) (b)
Sheep	(a) (b)	(a) (b)
Cattle	(a) (b)	(a) (b)

Food production and storage

Adequate food production is very important in a country because:

1 food production keeps a major part of the population in our country employed;
2 adequate food keeps people well fed, healthy, contented and happy;
3 food may be exported to earn money.

Ways of improving crop yield

Factors that affect production of crops include soil fertility, availability of adequate water to crops, suitable temperature, areas of land under cultivation, correct timing of planting and good cultural practices (such as spacing of stands), protection of crops from weeds, pests and diseases and planting of high yielding varieties. Some ways of improving crop yield are described below.

1 Soil convservation

Soil conversation is using the soil in such a way as to maintain its fertility. This includes:

a) Preventing soil erosion, e.g. by terracing;
b) Mulching;
c) Crop rotation; and
d) Avoiding bush burning.

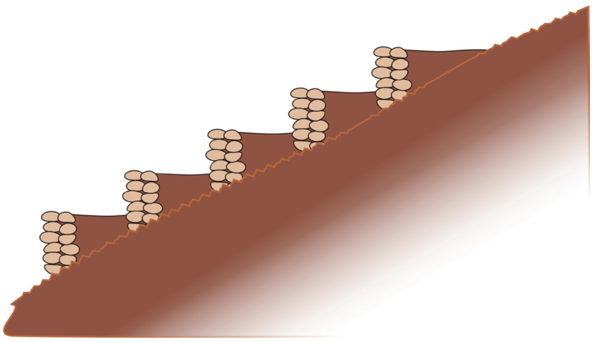


Fig.9.7 Terracing

2 Applying fertilisers

Chemical fertilisers may be added to the soil in recommended amounts to maintain adequate level of fertility. Organic manure may be used in place of or in addition to chemical fertilisers, for this improves soil structure in addition to providing plant nutrients.

3 Use of correct cultural practices

Some known cultural practices are:

a) Planting at the correct time;
b) Giving adequate spacing between crop stands;
c) Removing all weeds;
d) Crop rotation.

4 Plant-breeding to develop improved varieties of plants

Through plant breeding, improved varieties of plants with desirable qualities are developed. Improved varieties are usually disease resistant or high yielding or early yielding.

Examples include high yielding and disease resistant cassava; budded, early yielding oranges, and mangoes.

5 Plant protection

Protecting crops from pests and diseases increases their yield.

6 Putting more land under cultivation

Where land is available, more land can be cultivated to increase farm yield.

Causes of wastage

Every year, a part of the crop harvest is wasted and lost. After the labour that goes into food production, it is unfortunate that some of the food is wasted. Wastage is caused by several factors.

1 Incomplete harvesting

Rice, yams, cocoyams, groundnuts and other crops are usually not completely harvested. Some part of the potential harvest is left (through oversight or carelessness) in the field to waste.

2 Damage of harvest by weather

The weather may damage part of the harvest. In the rainy season, some maize grains mature, germinate and waste in the field before harvest. Fruit-bearing banana and plantain stems may be blown down by wind and some of the fruits are wasted. The wind may dislodge some rice stands in the field causing the grains to fall on the ground or into water on the ground and waste.

3 Late harvesting

Many fruits become overripe, fall off and are wasted if they are not harvested at the right time, e.g. mangoes, pawpaw, avocado pear. If some fruits, e.g. okro are not harvested in time, they become unsuitable for eating, and are wasted.

4 Pest damage

Pest damage may begin in the field and continue in storage. For example, maize, rice, beans are eaten by pests in the field and also in storage.

5 Poor preservation

Harvested crops need to be properly preserved, otherwise they rapidly deteriorate or decay. Tomatoes, carrots, vegetables, fresh maize, fresh fruits among others must be properly preserved or they depreciate and rot. Maize and rice must be well dried, or they become damp, hot and mould when stored.

6 Poor storage

Harvested crops must be properly stored, otherwise wastage will occur. Yam for instance, must be stored in cool, dry, airy barns, or else, it will decay.

Activity 94 To demonstrate how food can deteriorate in storage

Materials required

Slices of bread, petri dishes or watch-glasses, cupboard.

Procedure

1 Cut a slice of bread to a convenient size, and put it in a petri dish A.
2 Cut a similar size of the same bread, of the same size, put it in another petri dish, B.
3 Put petri dish A in a cupboard,in the laboratory.
4 Put petri dish B in a refrigerator.
5 Observe the appearance and smell of each of the two slices of bread daily for one week.

What have you observed? Record them in your notebook. Give reasons for your observations.

Methods of preserving food

These methods include heating, pasteurisation, freezing, drying, salting, smoking, irradiation, addition of chemicals and fumigation.

The following factors if present in food make the food a suitable breeding environment for micro- organisms of food spoilage. They include:

1 Water and moisture.
2 Warm and suitable temperature.
3 Food
4 Other suitable conditions such as P^H and osmotic pressure of surrounding liquid.

The principle of food preservation is to make the food unsuitable for the growth of microorganisms that spoil it. Some methods of preserving food are:

1 Heating

This is based on the principle that very high temperature kills microorganisms. Heating or boiling food regularly prevents food from spoiling. This is good for all cooked food.

2 Freezing

This is based on the principle that cold temperature chills food and inactivates microorganisms of food decay.

Refrigeration slows down the growth of microorganisms but does not kill the organisms. Foods preserved by freezing include meat, fish, and yoghurt while those preserved by refrigeration include fruit and vegetables.

3 Salting (and addition of sugar)

This is based on the principle that sugar or salt, if added in large quantities, would increase the osmotic potentials of the food. This would cause any microorganism already present in the food to lose fluid by exosmosis, become plasmolysed and eventually die. It would also prevent the entry of other microorganisms into the food. Food preserved by this method includes meat and fish.

4 Smoking

This dries up moisture in the food and covers the food with carbon, a protective chemical substance. This is good for fish and meat.

5 Drying

This is based on the principle that heat of the sun or fire causes water to evaporate from food thereby leaving the food to dry. Microorganisms which bring about spoilage of food cannot thrive in such dry food. This method is good for food such as pepper, melon, cocoa and beans.

6 Irradiation

In this case high–energy radiation is applied to the food to kill the microorganisms that are already present in it and to prevent the entry of new ones. The rays used are mainly ultra violet rays. This method is good for preserving meat, fish, and fresh juice and even for preserving containers used for storing water.

7 **Addition of chemicals**

These kill the microorganisms of spoilage thereby preventing the food from going bad. The chemicals used include vinegar ethanoic (acetic acid), sulphur dioxide and phenyl methanoic acid (benzoic acid). The method is good for preserving vegetables, fruits and fruit drinks.

8 **Fumigation**

This is chemical dusting or the spraying of chemicals or fumigants on stored grains or in the storage houses like silos where they are kept. This is good for preserving grains such as stored maize, millet, rice, sorghum and for preserving beans.

9 **Pasteurisation**

In this method, food is subjected to high temperature and pressure for some time to kill the micro organism in the food and to expel air from the food before sealing the container. If by chance new microorganisms gain entry into the container, they cannot get air for respiration. Canning and bottling are based on this method.

10 **Canning**

Some food materials are sealed in tins, heated to a specified temperature for each food, and then cooled. The heat kills putrefying organisms in the can. Suitable chemical preservatives may also be added to tinned food. Fish, tomato, peas, and baked beans are among commonly available tinned foods.

Some methods of storing food

After preservation, food may be stored for varying lengths of time. Methods of storing food include the following:

1. Keeping dried food materials in bags in a room, e.g. rice, maize;
2. Tying in a barn, e.g. yam;
3. Keeping in a cool moist shade, e.g. cocoyam;
4. Hanging over a wood fire or on a shelf over a fireplace, e.g. maize cobs, dried fish, dried meat (in a covered basket);
5. Keeping in tins, e.g. palm oil;
6. Keeping in a store at room temperature, e.g. tinned fish, tinned tomatoes;
7. Keeping in a refrigerator, e.g. fresh milk, fresh fish, meat, vegetables and fruits.

Population growth and food supply

A population is a group of organisms of the same species, living in a defined area. A population may grow or decline in number. Since the origin of man, human population on earth has been growing. However, the pattern of this growth is a cause for worry.

Estimates of human populations on earth have been made for various periods going back to thousands of years BC. From such estimates, it has been found that between 12 000 BC and AD 1650, the population grew slowly, and doubled, on the average, in the course of 2000 years. Between AD 1650 and 1850 human population took 200 years to double. Between AD 1850 and 1950 human population took 100 years to double. At the present rate of human population growth, it takes 35 years for population to double.

In 1970,the total world population was 3 631 million (3.6 billion). More people means more mouths to feed. Indeed, food production can increase, but there are constraints to indefinite increase in food production.

1. In some countries, there is not much land left for farming. Such land as is left may be rocky, hilly, sloppy or desert, not very suitable for agriculture.
2. Some countries are close to the upper limit of production of each crop per hectare.
3. In Nigeria, land for farming is available, but young people dislike farming.
4. Mechanisation has helped to increase agricultural output in industrialised countries. In Africa, mechanisation is difficult because tractors are too expensive for the farmers. In some cases land holding are small and mechanisation is unprofitable.
5. Peasant farmers have little capital to improve production.
6. In Africa, storage techniques and facilities are still poor.

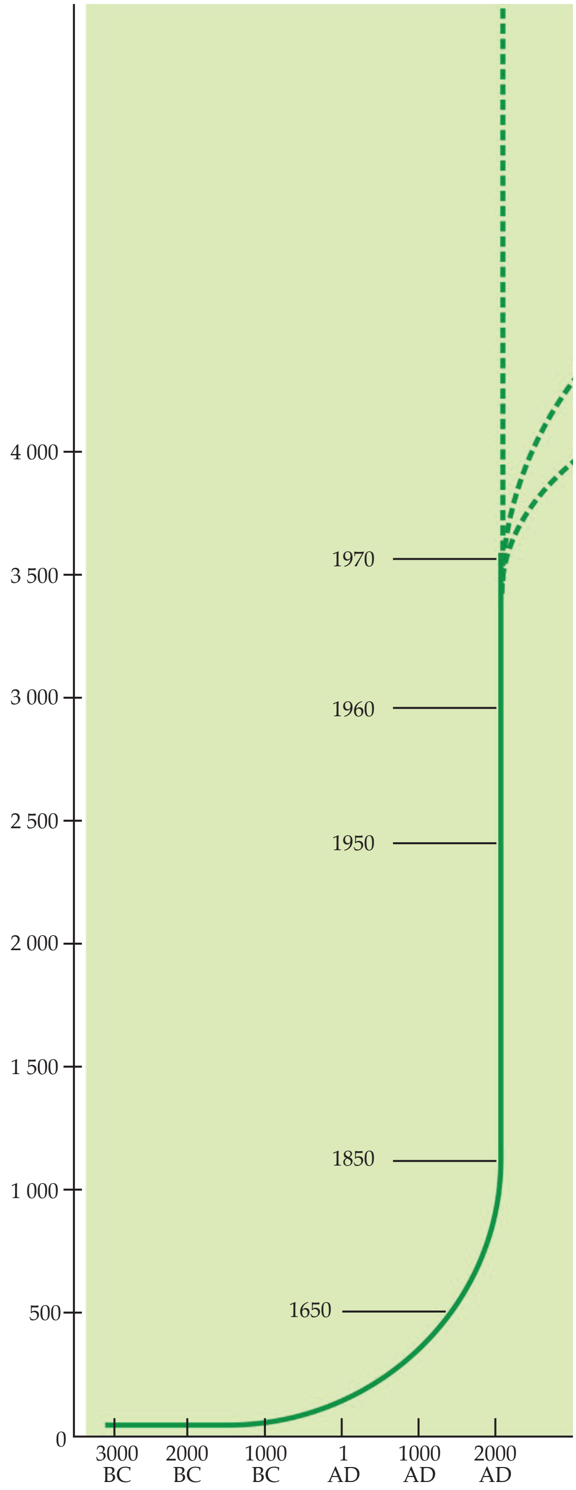


Fig.9.8 Graph showing human population growth since the 30th century BC

Reproduction and population growth

Population increases in two possible ways, namely:

1 By reproduction, to produce offspring.

2 By movement of human beings from other countries into a country (**migration**). Migration into a country is **immigration,** while migration out of it is **emigration.**

Of these two, by far, the more important is reproduction. In the world today, Africa and Latin America have the highest population growth rates.

If a father and mother have two children, when the parents die, the children will replace them. There will be zero population growth. In Nigeria, many families have children ranging from about 4 to about 5, though some families have two children or less. Nigeria's population, estimated at about 80 million in 1986 and 120 million by the year 2000 was expected to reach about 200 million by the year 2020.

If parents control the number of children they have, human population increase will be controlled. This is the reason for advocating family planning. Family planning means that parents decide to have just the number of children they can afford to feed well and educate.

Relationship between availability of food and human population

There is a close relationship between population and food supply. **Thomas Robert Malthus** (1776-1834), an English minister and social economist, first expressed this relationship in what is called the **Malthusian hypothesis.** He published a paper in 1798 entitled *An essay on the principle of population as it affects the future of mankind.* In it, he stated that human population grows up to the limit of possible food supply. He observed also that human population increases by geometrical progression while food supply increases by arithmetical progression. Hence, in time, population outstrips food supply. At that point, population growth stops, hunger, malnutrition, starvation and death follow, reducing the population to a level the food supply can support. Some called his hypothesis **the dismal theorem.** It sensitised people to the fact that a population is sustained by available food. It also started arguments and investigations which have continued till today.

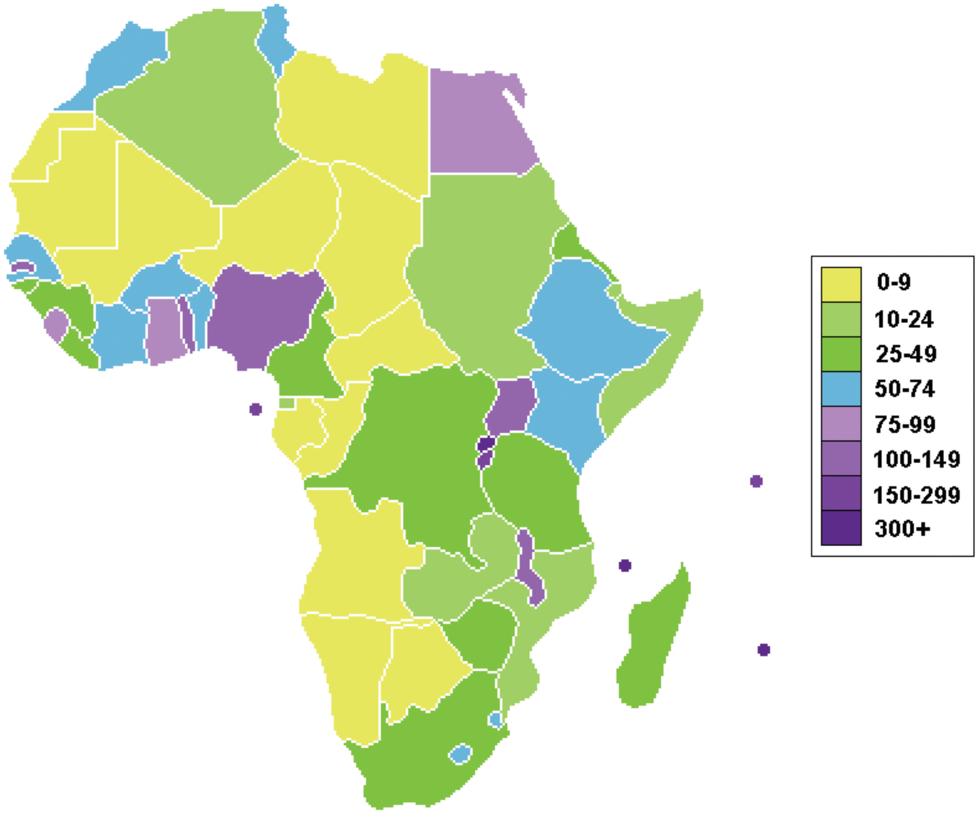


Fig.9.9 Distribution of human population in Africa

Activity 9.5 To demonstrate the effect of limited food on a rat population in a cage

Materials required

A large metal cage, two adult male and two adult female rats, rat food, water, container for rat food, container for water.

Procedure

1. In a large metal cage, put two adult male and two adult female rats.
2. In the cage put one container for food and one for water.
3. Fill the food container with rat food and the water container with water.
4. Replenish the food and water for six weeks.
5. Provide only half of the food and water for additional two weeks and stop providing food or water after that.
6. Observe the rats every week, count the number of rats in the cage and observe their condition and behaviour.
7. Describe any changes in the number of rats, and in the behaviour of the rats from the time food and water were plentiful to the time they were not enough or available at all.

What explanation would you give for what happened during each stage in the experiment?

Fig.9.10 Apparatus for demonstrating the effect of limited food on a rat population

Effects of food storage

Many countries have learnt, through experience, to store food against periods of scarcity. Each state in Nigeria has a Grains Board, a body set up by government and charged with the responsibility to store grains during periods of scarcity. In technologically advanced countries, individuals, states within a country, and national bodies store food for various reasons. The effects of food storage are summarised below.

1 **Prevention of hunger in off- harvest periods**
Food is normally plentiful during harvest time. If some of it is not stored, soon part of the harvest will be eaten up by man, and much of the remainder will be wasted through spoilage and pest damage. Then there will be hunger. Food storage prevents such hunger during off- harvest periods.

2 **Maintaining stable food prices throughout the year**
Food is cheap during harvest periods and tends to be expensive in off-harvest periods. Food storage improves availability of food throughout the year and help to maintain stable food prices all the year round.

3 **Preparation against natural disasters or war**
Drought, flood, earthquake, locust invasion or other natural disasters, as well as war, may cause crop failure or disrupt farming activity. Food stored in time of plenty will save people from starvation at such times of scarcity of food.

4 Food stored by one country can be used as aid to another country which is in need. Food may be donated on humanitarian grounds to refugees.

5 Storage of food helps workers in food processing industries to have employment throughout the year.

Summary

This chapter has taught the following:

- Our knowledge of biology is basic to practices and advancements in agriculture, especially in the effort to feed the world.
- Biology classifies plants in various ways; including a classification based on the agricultural characteristics of plants.
- Soils are also classified, each class by its special characteristics which indicate its suitability, or otherwise, for agriculture.
- Continuous cropping alters the character of the soil and may reduce its suitability for agriculture. Man continuously makes efforts to enrich the soil to support cropping.

- Man competes with pests of all types for his farm crops, on the field and in storage. There are many methods used in the control of pests. Such control methods must be safe for man, his animals and his environment.
- The population of the world is rising. This means that more food must be produced and well preserved. A safe and acceptable way of keeping a check on the growth of the human population will also reduce the problem of providing food.

Revision questions

1 The usually rich soil for agriculture has a mixture of sand, silt and clay in roughly equal amount together with humus. This type of soil is called the ____________.

A garden soil
B loamy soil
C impervious soil
D clay soil
E none of the above

2 The soil will lose its fertility most rapidly through ____________.

A erosion
B addition of lime
C use of compost
D grain farming
E root farming.

3 Biological control of pests depends on ____________________________.

A the predator-prey relationship in the ecological community
B how much biology the farmer knows
C the plant and animal relationship in biology
D the presence of poisonous organisms and animals on a farm
E the relative population of plants and animals on a farm.

4 What are pesticides? Describe the correct and safe use of any common pesticide in the home.

5 Briefly suggest ways by which the Nigerian peasant farmer may improve his agricultural yield.

6 Describe four different ways of preserving food.

Chapter 10 Microorganisms around us

Introduction

In this chapter, we shall learn about living organisms that are too small for us to see with our naked eyes, but which have far-reaching effects on the lives of man, other animals and many plants. These organisms are known as **microorganisms** (*micro* = very small) or **microbes**. Knowledge of these minute organisms came down to us through such scientists as **Antony Van Leeuwenhoek**, the Dutch man who invented the microscope and later discovered these microorganisms, which he then called 'little animals'. Other scientists like **Spallanzani, Pasteur, Robbert Koch, Lord Lister** and **Fleming** later carried out notable work on microorganisms, which considerably improved our knowledge of them.

Because these organisms are invisible to the naked eye, we do not notice how numerous they are around us. It is known that they are so many that their total weight on earth is more than twenty-five times the total weight of all visible animals (that is, vertebrates and invertebrates on land and in the sea) put together. It should therefore not surprise us that a number of them affect our lives in very different ways.

Classification of microorganisms

Microbes belong to one or another of the following groups of organisms 1) bacteria, (2) viruses, (3) fungi, (4) protozoa and (5) algae. From this list, we can see that microorganisms belong to various groups of living things. Of these, bacteria, viruses, protozoa and fungi are the most frequently discussed or studied.

The culture medium

For many of the activities in the next three chapters of this book, you will require a sterile growth medium on which microorganisms can germinate and grow.

Sterilising petri dishes, watch glasses and test tubes

The petri dishes, watch glasses and test tubes which are to be used in these experiments must not only be washed very clean, but must also be made microbe-free, to save the experiments from the interruptions of strange microorganisms. This is done by heating them, under pressure, in a pressure cooker or an **autoclave**.

Where none of these facilities is within easy reach, sterilisation can be achieved through ordinary boiling, in the following way:

Fill a large saucepan with water, up to about two-thirds or three-quarters full. Put all the clean petri dishes, watch glasses and test tubes into the water and **boil** for about fifteen minutes. Wipe each of the glassware dry, using a sterilised cloth, or simply let them drain dry and use them immediately.

Preparing a culture medium

Two of the usual media used in growing microorganisms are *malt agar* and *potato-dextrose agar*. Local food formulae, such as *Farex*, *Nutrend*, *custard* and cornflour, which are cheaper and more readily available, may also be used.

Malt agar medium

Malt agar can be prepared as follows:

1 Weigh 10 g of maltose or malt extract in a sterile watch glass.
2 Dissolve it in 500 cm^3 of distilled water in a sterile beaker.
3 Weigh 10 g of Agar-agar granules in a sterile watch glass and add these to the malt solution in the beaker.
4 Heat and stir all the while with a glass rod and with a thermometer standing in the solution. Continue until the temperature rises to about 90^0C and the solution becomes viscous and translucent.
5 Pour the hot agar into petri dishes, as required and cover up.

Food powder culture medium
The teacher might decide to use either *Nutrend* or *Farex*. These are tinned food formulae often used for weaning babies.
1 Boil 500 cm^3 of distilled water in a sterile beaker.
2 Remove from the burner and allow beaker to cool to about 70^0C.
3 Add about four tablespoonfuls of either *Farex* or *Nutrend* to the water and stir.
4 With a spatula, spread it on petri dishes and smoothen their surfaces.
5 Cover the petri dishes immediately and keep in a cupboard or oven.

Custard jelly culture medium
1 Dissolve four tablespoons of custard powder in 500 cm^3 of distilled water, inside a sterile beaker.
2 Break up all lumps and stir to a well-blended yellow suspension.
3 Heat suspension till it nearly boils, still stirring.
4 Pour into petri dishes and cover up.

Cornflour paste culture medium
1 Prepare a thin paste of cornflour with distilled water in a sterile beaker.
2 Heat the paste, stirring as it boils, to avoid lumps.
3 Put off flame when the paste thickens.
4 Spread the paste in sterilised petri dishes, with a spatula, and smoothen its surface.
5 Cover up each petri dish and leave in an oven.

Microorganisms in air

Caution on Activities 10.1 - 10.5 over students' safety
Fears have recently been expressed over the activities in Activity 10.1 to Activity 10.5. It is feared that students might inadvertently breed microorganisms that could hasten the speed of cholera, typhoid, paratyphoid, etc. These activities teach necessary lessons.

The following precautions might therefore be taken:
1 Do not open up any of the cultured petri dishes at all; rather, seal them with tape and label them 'BIOHAZARDS'.
2 Have a thorough look at such details as size of microorganisms, colours, growing patterns and general appearances with a good hand lens X8 or X10. Do not mount them under the power of a microscope for observation.
3 Teachers should dispose of culture plates at the end of experiments as follows: slit the tapes holding the petri dish and cover together in a strong bleach solution. Open them inside the bleach and leave for a couple of days. Then wash and re-use.

The following activity shows that microorganisms exist in air.

Activity 10.1 Growing microorganisms from air

This experiment may be carried out in six groups. Each group should attempt to grow microorganisms from a specified environment, in a sterilised petri dish. Six groups, A-F, will each work in one of the following places:
A inside a living room
B in the laboratory
C in an open field
D in a kitchen
E in the classroom, and
F in a lavatory.

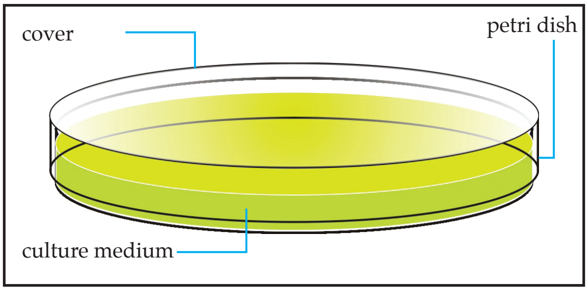


Fig.10.1 A covered petri dish containing a culture medium

Procedure
Your group will be provided with a sterilised and covered petri dish containing a culture medium.
1 Do not remove the lid of the petri dish until all members of the group have arrived at the particular location to be tested for the presence of microorganisms. Once there, one member of the group removes the lid and keeps the dish open for about five minutes, to allow the microorganisms in the surrounding air to alight on the medium, before closing it up again.
2 Label the petri dish using the test location number earlier allocated.
3 Return to the laboratory and leave the petri dish in a safe cupboard.
4 A covered, sterilised culture medium in a petri dish labeled 'G' should be used as control for the entire experiment. This dish is not to be opened up for microorganisms to alight on.
5 On the fourth day, observe each of the culture media in petri dishes A-C, for changes in colour, pattern of growth of microorganisms and general appearance. Also observe the differences between

the microorganisms in dishes A-F and the control dish G.
6 Observe, under low-power microscope, slides of materials from dishes A-G, prepared by your teacher. Note the structural details of each type of microorganism.
7 Record your observation in your notebook.

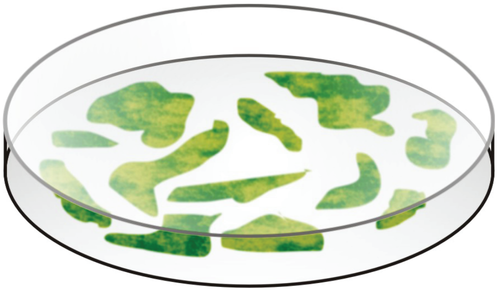


Fig.10.2 A colony of microorganisms on a culture medium

Microorganisms in water

Activity 10.2 Are there microorganisms in water?

We shall find an answer to this question through an activity similar to the previous one. The class will work in four groups trying to find out if there are microorganisms in: (A) a pond, (B) a river, (C) a stream, and (D) tap water. Each group is given a sterilised, covered petri dish with a culture medium in it. Water samples from sources A, B, C, and D are made available, in labelled bottles, in the laboratory.

Procedure

1 Use a pipette to take a few drops of water from the bottle assigned to your group.
2 Open one petri dish, containing the culture medium, just wide enough to take the trip of the pipette. Leave a drop or two of the water sample on the medium. Replace the lid of the petri dish instantly, to prevent microorganisms in the air from settling on the medium.
3 Label the petri dish A, B, C, or D, according to the source of water in it, and leave it in a safe cupboard in the laboratory for about three days.
4 Set up a control dish, to which no water drop is added. Label this E.
5 After three days, observe your set-up for changes in colour and pattern of growth of the microorganisms.
6 Write your observations in the form of a table, as follows.

Group	Source of water used	Observation
A		
B		
C		
D		
E	Control (no water)	

7 Compare the petri dishes A, B, C and D. What significant differences can you observe between the microorganisms in the various waters?
8 Is there any difference between the sizes of the microorganisms in tap water and stream water? Can you explain the difference?

From the last two activities, we have made the otherwise tiny, invisible organisms tangible. The process of growing microorganisms in a sterile growth medium is referred to as **culturing**.

We have found, from our activities, that these invisible organisms live in the air and water, but it is known that they are found in virtually all habitats, including soil, humus, decaying organisms, plants and animals, including man.

Activity 10.3 Microorganisms in our foods

You have probably seen a piece of bread that had turned greenish-black, or a piece of cooked yam that had, after a few days, turned orange. Did you ever find out what caused such colour changes? The following investigation should provide the answer.

Procedure

The teacher should split the class into six groups, A-F. Each group will carry out one of the following activities.

1 *Group A:* Put a small piece of boiled fresh maize cob (with the maize grains removed) in a petri dish and cover it. Label the petri dish A.
2 *Group B:* Put a small slice of cooked yam in a petri dish, cover it and label it B.
3 *Group C:* Moisten a slice of bread with some drops of water, enclose it in a watch glass or petri dish, cover it and label it C.
4 *Group D:* Slice a small portion of ripe pawpaw, place and cover it up in a petri dish labelled D.
5 *Group E:* Put a small morsel of 'eba' (garri paste) in a watch glass dish, cover it and label it E.
6 *Group F:* Break a coconut into pieces, leave a fleshy

piece in a petri dish, cover it and label it F.

7 All the set-ups should be kept in a clean drawer in the laboratory. After three days, inspect each of the dishes A to F. Note the general appearance and colours of the microorganisms growing on them. Also find out, by touch and sight, what has become of the substances on which they grow.

8 Draw the following table in your notebook and write down your observations.

Petri dish / watch glass	Food enclosed	Observation
A		
B		
C		
D		
E		
F		

Note where more than one species of microorganisms are thriving on any of the food substances in A-F.

Questions

1 What common change(s) can you observe on all the specimens?

2 What colour(s) and other general appearance(s) does each specimen exhibit?

3 What happens if we leave them a few days longer. It is likely that we often eat microorganisms with our food. Why do they not grow inside us?

You will notice that the usual culture medium has not been used for the growth of all the microorganisms that germinated on the various foods in this experiment. The culture medium is replaced by these foods. This confirms that the culture medium is a type of rich food medium for the germination of microorganisms.

All the food specimens used in Activity 10.3 had a considerable water content. Moisture is a condition for the germination and growth of microorganisms.

All exposed foods are open to the attack of microorganisms but those found on foods are mainly fungi and bacteria. Foods left under the influence of bacteria for a long time usually become unfit for human consumption, because they have been partly digested and their nutritive contents have therefore degenerated.

Activity 10.4 Microorganisms in our bodies

A number of microbes are harboured within and around us, in our mouths and alimentary tract, underneath our nails and even on our skin, when we fail to wash and scrub our body regularly.

For this, activity, the class should be divided into three groups and each group supplied with a culture medium in a sterilised petri dish.

Procedure

Group A

1 Use a tooth-pick or a short piece of washed broomstick to remove the remain of food around the gum of your teeth.

2 Open the petri dish containing the culture medium just wide enough to take your tooth-pick. Drop the food remains on the medium and cover it up immediately.

3 Label the petri dish A and leave it on a table or inside a cupboard.

Group B

1 Collect the dirt underneath your long nails with a sharpened matchstick, tooth-pick or pin.

2 Open your culture medium in a petri dish just wide enough to take the match-stick. Drop the nail-dirt on the medium and cover it up quickly.

3 Label the dish B and place it next to petri dish A.

Group C

1 Partially open the petri dish of culture medium. Slowly breathe out on it through the mouth, four to six times and close it up immediately.

2 Label the petri dish C and place it next to specimens A and B.

Control

Use the common culture medium in a petri dish which should not be opened at all. Label it D and place beside petri dishes A-C.

Results

After three days, inspect the petri dishes A-D and record your observations on a table like the one shown here.

Fig.10.3 A partially open petri dish

Petri dish	Content	Observation
A	Microbes in mouth	
B	Microbes under nails	
C	Microbes from expired breath	
D	Control	

Is there growth of microorganisms in all four petri dishes? Can you explain why if there is no growth in any of the dishes? Are the growths of microorganisms in petri dishes A, B, and C of equal vigour? Explain the difference in growths, with reference to the sources of the microorganisms.

Microorganisms are responsible for human diseases like tooth decay, ringworm and athlete's foot. Dangerous microorganisms can be picked up from latrines and toilets when we use such rooms and microbes from under the nails are often eaten with food. For these reasons, the habit of washing the hands with water and soap after leaving the toilet must be cultivated. Nails should always be trimmed or cleaned, teeth well cleaned with a good tooth brush and our bodies regularly washed with soap and sponge. These measure help to remove from our body those materials on which microorganisms survive. The wearing of clean clothes also helps to keep microorganisms at bay.

Later in this chapter, we shall learn about microorganisms that are taken in with food and drink, those that could be breathed in with air and some that are directly injected into human blood by vectors like mosquitoes and tsetse flies. Meanwhile, it is useful to know that microorganisms are capable of living on human bodies, or of gaining entry into the body through openings like the mouth, nostril, cut on skin or by injection through the skin. Many microorganisms are harmful, causing several diseases, some of which are fatal, while some others in our bodies are useful in the various life processes.

Carriers of microorganisms

One other way in which microorganisms could be carried from place to place is by certain insects whose hairy or spine-packed bodies incidentally carry the microbes. Examples of such insects, which are called **carriers**, are houseflies and cockroaches. These live in latrines, food stores, kitchen, cupboard, dung hills and such other places where microbes, including disease-causing organisms, abound. The carriers pick up the microbes and bring them to exposed human foods on which they themselves normally feed. In the course of feeding, some of these dangerous microbes are dislodged from the body of the carrier onto the food and may be eaten by man.

Location of microorganisms in carriers

The carriers of microorganisms are called **vectors.** These microorganisms cause diseases in man**.** The diseases they cause do not affect the vectors that carry them. The vectors are usually the secondary hosts while man is regarded as the primary host. The microorganisms are found in the vectors because they need an environment (usually in the vector)for them to develop to a level that would be infectious to man. This phenomenon of disease causing organism having two hosts is known as **alternation of hosts**. Common vectors of microorganisms include mosquitoes, and the tsetse fly. The housefly is a carrier but not a vector because the microorganisms do not develop inside the housefly. When the housefly perches on rubbish, the microorganisms in the rubbish become attached to the hairs on its body. These microorganisms (bacteria) are shaken onto food left uncovered and on which such house-fly perches; this causes disease in man when the food is eaten. Anopheles mosquito transmits plasmodium (a protozoan) that causes malaria fever to man through biting and sucking blood from man.

Disease-causing microorganisms carried by vectors include the following:

1. Protozoa, e.g. plasmodium, trypanosoma, and entamoeba.
2. Viruses
3. Bacteria
4. Rickettsiae.

Beneficial effects of microorganisms

In nature

Microorganisms such as blue-green algae and bacteria living freely in the soil or symbiotically in the root nodules of legumes have the ability to fix atmospheric nitrogen to form nitrates which enrich the soil.

Fungi and bacteria are decomposers. They break down the dead remains of plants and animals respectively and by so doing help in the recycling of mineral elements. Bacteria also decompose the excretory waste products and faeces of animals.

In medicine

Penicillium is a fungus which is used to make the antibiotic penicillin. This drug is used to cure diseases caused by bacteria.

In industries

Yeast ferments sugar solution in anaerobic conditions, to form alcohol. This is applied in the baking and brewing industries. The carbon dioxide produced when yeast is mixed with dough, makes the dough rise when the dough is heated in the oven. While in breweries, the alcohol produced in alcoholic fermentation is distilled and processed to make beer and other alcoholic drinks.

and D, according to the parts named in (1) above.

3. Take a fifth petri dish of culture medium, but do not open it. Label it E and leave it as control.
4. Place the five petri dishes safely in a cupboard or on a table.
5. After three days, observe the changes in petri dishes A-E. Record your observations on a table like the one below.

Do microorganisms grow in all the petri dishes? What explanation can you give for the absence of microorganisms in any of dishes A-E? Describe the colour, general appearances and growth pattern of the microorganisms in dishes A to D.

Part	Colour	Pattern of growth	General appearances
A Proboscis			
B Legs			
C Abdomen			
D Wings			
E Control			

Activity 10.5 Carriers of micro-organisms

Procedure

1. Kill a housefly using a broom and with a pair of scissors or razor blade detach its (A) proboscis (B) legs, (C) wings, and (D) hairy abdomen.
2. With a pair of forceps, carefully place each of A-D on culture medium, in separate petri dishes. Immediately cover them and label them A, B, C,

Summary

This chapter has taught the following:

- Microorganisms exist in air, water, food and in and around us as animals.
- Microorganisms exist as bacteria, viruses and protozoa; some are algae while others are fungi.
- They are microscopic and can be seen with the aid of microscope as growing clumps on food or on culture media.

- Some microorganisms can live on our bodies, some on neglected food left in our mouths and others on our ordinary foods. They can also enter our bodies through our mouths, nostrils, cuts on the skin and by being injected into our bloods by vectors. Many of this cause us harm because we do not obey the rules of hygiene and some live in our bodies to help our living.
- Microorganisms can be transmitted from place to place by 'carriers'.

Revision questions

1 The presence of microorganisms was tested for in such locations as (i) inside a living room, (ii) in the laboratory, (iii) in an open field, (iv) in a kitchen, (v) in a classroom, etc. In what particular medium do these microbes exist? ____________________.
   A On the floor of these locations
   B In the air over these locations
   C In the dust over these locations
   D Within water in these locations
   E All of the above.

2 Which particular feature of a housefly helps it most to be a 'carrier' of microorganisms? It has ________________________.
   A wings
   B thin legs useful only in alighting
   C hairs all over its body
   D two compound eyes
   E three distinct body divisions

3 Which of the following habits is a means of keeping microorganisms from thriving on our bodies? ______________________________.
   A Trimming our nails regularly.
   B Taking three meals regularly.
   C Wearing beautiful dresses.
   D Walking with smart steps.
   E Working hard at one's job.

4 Prove, by experiments, that microorganisms exist in (a) the air, and (b) pond water.

5 Name five parts of the human body on which microorganisms can develop. For any **three** of these parts, state the name of the diseases, the type/group of microorganism(s) responsible, its source and two of its symptoms on the sufferer.

6 Make a list of at least ten foods and household materials of which you have observed microorganisms growing. Why do these organisms not grow on all other household good? Prove, by a simple experiment, that the housefly is a 'carrier' of microbes.

Chapter 11 Microorganisms in action

Introduction

In the last chapter, we found that microorganisms abound in air, soils water, plants and animals, including man. We also identified some of them by their growth patterns and colours. We will now study the activities of microorganisms, including their growth and how they affect man, for good or ill.

Growth of microorganisms

Microorganisms, like all living things, increase in size and multiply in number, using either the culture medium provided or any suitable surface, such as moist bread or a piece of ripe pawpaw, as surface of food. They can also increase in mass. Such an increase in size, mass or number, is regarded as growth.

Let us now carry out an experiment which will demonstrate growth in microorganisms.

Activity 11.1 Measuring growth in microorganisms

Materials required
A well covered petri dish of sterilised culture medium, any microorganism already growing on a medium, an inoculating loop, a transparent square paper, graph paper.

Procedure

1. Into the central portion of a sterilised culture medium, introduce any microorganisms already known to you.
2. Use an inoculating loop, (as in Fig. 11.1a). Put the looped end into blue flame for a few seconds, to sterilise it. Then allow it to cool.
3. With the culture medium partly open, use the loop to pick up a little bit of prepared culture. Place this in the middle of the petri dish and close it immediately. Label it and place it safely on a table or in a cupboard. Note the time of day when the experiment is set up.

Fig.11.1a) An inoculating loop

4. After twenty–four hours, examine the petri dish again. Measure the rate of the mass or colony of the microorganisms in the dish. This should be done as follows. Use cellophane or transparent paper marked in squares. Place the paper over the particular colony to be measured and count, underneath it, how many squares it has covered. Record your result. Repeat the count three times, find the average count and record it, for the first day.
5. Take the similar counts for each of the first seven days after planting the colony. Record your counts on a table.

6 Plot your count for the seven days on the vertical axis of a graph, against the age (in days) on the horizontal axis.
7 Complete the graph by drawing the curve or line described.

Questions

a) What do you notice about the number of squares counted from day to day? Interpret this observation.
b) Why do you think we placed the microorganism on a culture medium to start with?

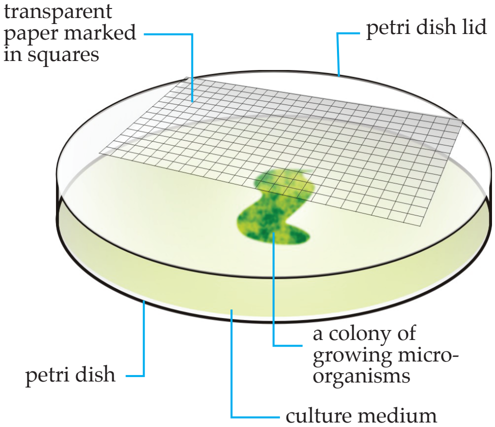


Fig.11.1b) Measuring growth in a microorganism

c) What type of curve does your graph show?
d) From your observations in respect of the daily counts, how can you describe growth?
e) Use the method used in this activity to determine the growth rate of another microorganism.

Are microorganisms beneficial to man?

It is common knowledge that microorganisms inflict diseases like tetanus, tuberculosis and syphilis on higher living organisms. However, many other microorganisms, including bacteria and fungi, are very useful to us in the production of such foods and drinks as butter, cheese, bread and alcoholic drinks. Besides, without these organisms, the soil would not be able to support any plant, for lack of nitrates. Let us confirm, by means of the following experiments, that some microorganisms are indeed useful to us.

Activity 11.2 Observing the behaviour of palm wine

Materials required

Two bottles of palm wine bought, one on day one and the other on the following day.

Procedure

On the first day of the experiment, purchase a bottle of fresh palm wine. Label it A. leave the bottle open and observe what goes on from the top of the bottle for some ten minutes. Attempt to cork the bottle and observe what happens after some time. Leave this bottle of palm wine open, on a table, until the following day. On the next day, obtain a similar bottle of palm wine. Label it B. Taste samples of the contents of bottles A and B, note how sweet each one is. Also take note of the foaming abilities of bottles A and B and the sediments at the base of bottle A.

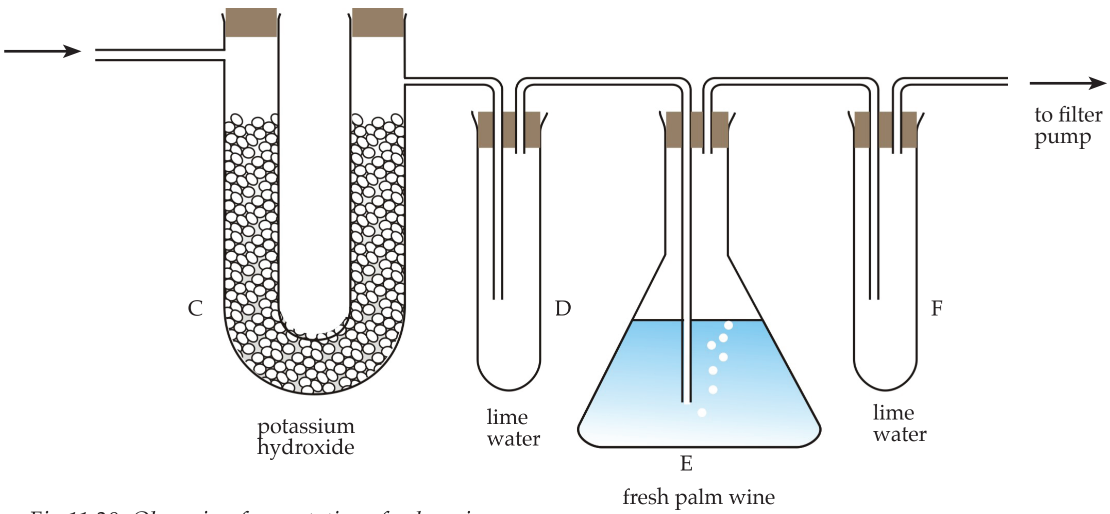
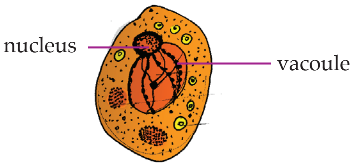
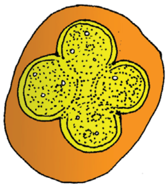


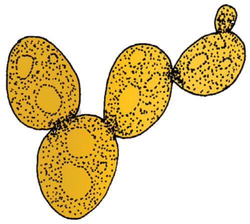
Fig.11.20 Observing fermentation of palm wine



(a) a yeast cell



(b) yeast cell after spore formation



(c) yeast multiplying by budding

Fig. 11.3 Yeast multiplying by budding.

1 Was there any difference in the sweetness of the samples of specimens A and B? What do you think is responsible for any changes between A and B?
2 What was noticeable in specimen A when observed for ten minutes on the first day? What do you think was happening to the palm wine?
3 Test the gas given off from the palm wine for carbon dioxide using the apparatus shown in Fig. 11.2.

If the limewater in tube F turns milky, it does so only because the gas escaping from flask E is carbon dioxide.

Put one or two drops of the contents at the base of bottle A on a slide and cover it up with a cover slip. Examine very carefully under the low power of a microscope. Can you find any microorganisms in the specimen? Are they living organisms? Why do you think so? The microorganism observed in the palm wine sample is **yeast.** Viewed under the microscope, some yeast cells can be seen multiplying by the process of budding. This microorganism is a fungus. It secretes an enzyme, zymase which acts as a catalyst in bringing about the fermentation of the sugar in the palm wine.

Thus, on the first day, the palm wine contained a lot of sugar and was, therefore, much sweeter than a sample which was preserved till the following day when much of its sugar had broken down into alcohol and carbon dioxide.

Palm wine kept for a day or two loses its sweetness while its alcohol content increases thereby making the wine stronger.

This process of fermentation is represented by the equation:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

From your microscope examination of yeast cells, it should now be clear why the yeast content of palm wine increases with time.

Activity 11.3 Production of alcohol from glucose

Materials required

A 400 cm^3 beaker, about 20 g of glucose, 180 cm^3 of distilled water, two small beakers, yeast.

Procedure

1 Weigh about 20 g of glucose. Mix thoroughly in a 400 cm^3 beaker with 1800 cm^3 of distilled water.
2 Pour the sugar solution into two small beakers, until each is about half-full. Label the beakers A and B. Add some yeast to beaker A while beaker B is used as control. After twenty-four hours, observe each beaker and smell the contents.
   a) Do you perceive any difference in smell between the contents of the two beakers?
   b) What does the content of beaker A smell like?
   c) Compare the smell of the content of beaker A with that of some ethyl alcohol in a beaker on the teacher's table.
   Are they similar? What conclusion can you draw from your observation?

The yeast added to glucose solution in the last activity merely acted as a catalyst in its fermentation. Alcohol is the main product of such fermentation.

Many other microorganisms are also useful to man. Fungi and bacteria are the main **agents of decay** of plants and animals. They are also important in the formation of *humus*, which returns useful nutrients into the soil for plant growth. Similarly, man depends on the activities of *saprophytic* bacteria and other microorganisms for the decomposition of faeces into soluble substances in septic tanks used in the modern sewage disposal.

Swelling on the root of leguminous plants like beans, peas and *crotalaria*, which are called **nodules**, are known to contain bacteria which are capable of converting ordinary nitrogen of the air into *nitrates*. As we saw earlier, nitrates are very useful nutritive substances for all plants.

A number of fungi and bacteria are used in the production of *antibiotics.* These are substances which have anti-microbial effects but are not harmful to man. They either kill bacteria outright, or stop them from growing and reproducing. *Penicillium* is a good ex-

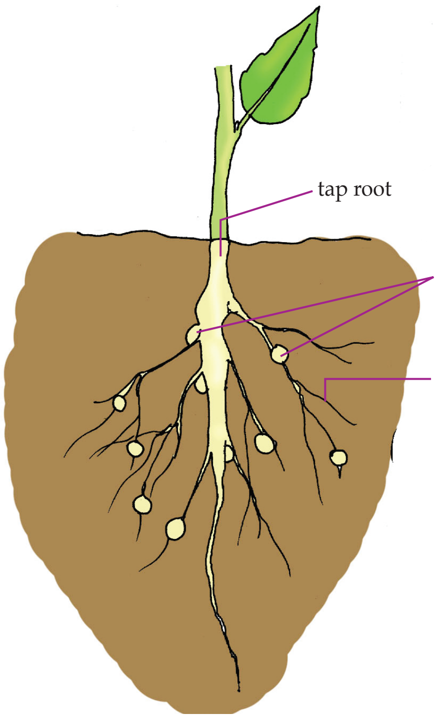


Fig. 11.4 Nodules of a bean plant

ample of a fungus used in producing the well known anti-microbial drug *penicillin*. *Streptomycin* and *Chloromycetin* are other examples of antibiotic drugs made from bacteria. All these are used to stop the growth of harmful bacteria in the human body. Some antibiotics are used in raising young animals and poultry. One of these, *aureomycin*, is used in increasing the growth rate in pigs, by controlling disease-causing microorganisms.

Yeast and bacteria are rich sources of enzymes like **amylase** and **invertase**. They are also rich sources of B vitamins.

Palm wine is used to make bread 'rise', because of the yeast it contains. Bread is made spongy and easily digestible because of the holes in it. These are created by the bubbles of carbon dioxide produced by yeast. Industrially produced yeast is often used for this purpose, in place of palm wine.

Some bacteria are used in butter and cheese making, while others are used in the manufacture of vinegar, lactic acid and citric acid, all of which are extremely useful in the food industry.

Harmful microorganisms

Very often in our society the death of people is blamed on the evil powers of their enemies. Very few people are ever believed to have died because they succumbed to the attack of a serious disease which they contracted by chance. Science, on the other hand, always gives an explanation for death, on the basis of cause-and-effect. Thus, illness may occur through direct infection by pathogenic microorganisms, or through indirect infection through a vector. Illness may also occur through heredity. All may lead to death.

Hereditary diseases are those which pass from parents to their children at birth. A common example of this kind of diseases is the sickle-cell disease or haemophilia.

Some diseases are caused by a deficient supply of vital food substances such as vitamins. Such diseases are known as *deficiency diseases*. Other diseases, such as asthma, are caused by substances in the air, to which our bodies react adversely. Various types of skin rash may be caused by foods which irritate our bodies. Such diseases are described as *allergies*. Some diseases are inadvertently contracted where people do their normal daily jobs. For instance asbestos factory workers or coalminers develop various lung diseases from the factories because they continuously breathe in dust. Diseases of this kind are described as **occupational**.

However, many human diseases are borne by microorganisms, through various media-air, food, drinking water, soil, vectors (insects, rats, fleas and dogs), or by direct contact with sufferers.

Cholera is a good example of a disease spread from person to person through the medium of food or water. It is transmitted by a bacterium. Cholera can become an **epidemic** disease, since it spreads fast within a human population. It principally affects those who do not keep simple rules of hygiene, such as the washing of hands after leaving a toilet or latrine, or those who defecate in open places from where water can wash the stool into nearby streams that are used for drinking. Careless exposure of food to flies, drinking unboiled or unfiltered water, or depositing garbage from homes on dung hills, open roads, gutters or such other open places, can also cause the spread of epidemic diseases.

Cholera patients develop a light to severe diarrhoea, which causes frequent stooling and vomiting. Their bodies are soon dehydrated and such patients may die within a day or two if not properly attended to.

Poliomyelitis is a microbial disease caused by a type of virus. If the virus escapes into water, those who drink such water will soon be infected with a disease that causes the paralysis of the body muscles, often affecting one half of the body. The patient loses control over his muscles and therefore cannot use such muscles as freely as before. Serious deformities of the limbs usually result from attacks of this disease.

Food and water-borne diseases

Microbes may be taken in with food or water. The diseases caused by them can, therefore, be avoided by strictly obeying the rules of hygiene. Some of these are as follows:

1 Do not drink impure water; water remains impure if it is not boiled or filtered. A chemical like alum may also be added to domestic drinking water, to make all the suspended particle settle. Clean drinking glasses or cups should always be used for drinking water.
2 Food should only be handled with clean hands and always put in clean utensils.
3 Hands should be thoroughly washed after getting out of toilet, as there are chances that several dangerous microbes may have settled on them.
4 Fruit and vegetables should be properly washed or boiled before consumption. Unwashed fruits are a ready source of contamination.
5 Food should be properly covered, to keep out flies, which may have earlier alighted on faeces, or decaying materials.
6 Meat should be obtained from healthy animals, hygienic sellers and a clean environment. It must also be thoroughly boiled to kill all germs.

Can you determine, from a study of Table 11.1a, which is the major causative organism of food or water – borne diseases? How common are those diseases caused by the other named pathogens in the area in which you live?

Air-borne diseases

Table 11.1b shows some diseases carried by microbes which are transmitted by air. It also provides some information about the pathogens, their hosts and the symptoms and effects of the diseases they cause.

The table shows that viruses are responsible for relatively more air- borne diseases than bacteria. Also observe, from the table, which of these two pathogens spreads its diseases to other groups of animals apart from man.

Smallpox, one of the air-borne diseases of microorganisms, used to be a very fatal disease. It could easily be contracted through contact with infected people. The pathogen could also be breathed in from infected air. One of the achievements of medical science is the eradication of this disease, achieved many years ago.

The viruses and bacteria which spread air- borne diseases are extremely light organisms. They are blown into air along with tiny drops of moisture from the mouth, nose, throat and lungs, when infected animals and humans breathe, sneeze, cough, or blow their noses. Healthy people within the reach of such microbes can then inhale or swallow them and become infected. Diseases such as influenza, measles, pneumonia, etc., which are contracted in this way, are described as *droplet infection diseases.* This is the reason why open and unchecked spitting, sneezing, coughing and blowing of noses are dangerous habits.

Vector-borne diseases

Certain diseases are carried to sufferers only through animals, known as *vectors*. Without the vectors, the diseases do not have a means of passing from one person to the other. Vectors are animals which carry disease pathogens from a sufferer to another person. A well known example of vector-spread diseases is malaria. The malaria vector is the anopheles mosquito, which transmits the pathogens from person to person, as it feeds on their blood. It should be understood that pathogen transmission is not a deliberate act. Mosquitoes may feed on human blood without ever bringing about malaria. However, whenever they feed on a malaria patient and suck up some of the protozoan pathogens, these develop in them and may later be transmitted to uninfected persons when the infected mosquitoes bite them.

Other vectors like the tsetse fly, body louse and dog also transmit various diseases, as shown in Table 11.1c.

All the vectors named in the table, except the dog, are arthropods. The first three are insects, with special adaptations of their mouth-parts for piercing and injecting pathogens into the bodies of animals.

Of the three types of pathogens named here, the Rickettsiae are the least known. These are tiny, rod-shaped microorganisms but are neither viruses nor bacteria.

Table 11.1a) Diseases of water and food-borne microorganisms

Disease	Microorganism causing it	Medium of transmission	Host and age range	Symptoms
Poliomyelitis	Virus	Water	Humans of all ages, mainly children	Loss of control of muscles/paralysis
Infective hepatitis	Virus	Food and water	Human children and young adults	Enlarged liver, fever, headache and jaundice
Amoebic dysentery	Protozoa	Food and water	Humans of all ages	Heavy vomiting and diarrhoea
Typhoid	Bacteria	Food, i.e. vegetables, milk, shellfish and water	Humans of all ages	High temperature with diarrhoea or constipation
Diphtheria	Bacteria	Food, milk and water	Humans of all ages	Pain in limbs
Paratyphoid	Bacteria	Food, vegetables and meat	Humans of all ages	High temperature but with less severe diarrhoea/constipation than for typhoid
Sore throat	Bacteria	Food, milk	Humans of all ages	Pain in the throat particularly while eating or drinking
Diarrhoea	Bacteria	Food, meat	Humans of all ages	Tiredness and frequent stools with blood
Tuberculosis	Bacteria	Food, meat	Cattle and humans of all ages	Persistent dry cough and sweating at night
Bacilli dysentery	Bacteria	Food, vegetables, shell fish	Humans of all ages	High temperature and frequent stools
Food poisoning	Bacteria	Food, milk, bread, ice-cream, pastry, salads	Humans of all ages	Headache, nausea, liquid stools with mucus
Cholera	Bacteria	Food, milk and water	Humans of all ages	Mild to very severe diarrhoea with vomiting

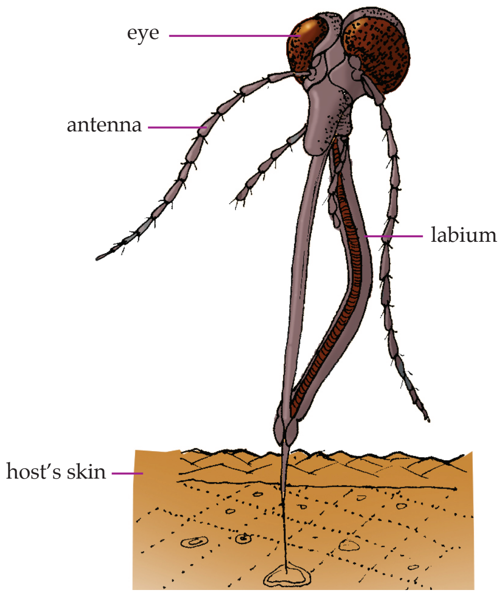
Table 11.1b) Diseases transmitted by air-borne microorganisms

Diseases	Microorganisms involved	Host and age range	Symptoms and effects
Pneumonia	Bacteria	Birds, cows, pigs and humans of all ages	Pain in the chest, breathlessness and cough
Tuberculosis	Bacteria	Cows and humans of all ages	Persistent dry cough and profuse sweating at night
Meningitis (cerebrospinal fever)	Bacteria	Children and young adults	Stiffness of the neck and joints, headache, and severe fever
Measles	Virus	Children	High constant temperature, skin rash, headache, cold and cough
Common cold	Virus	Humans of all ages	Fever, headache and running nose
German measles	Virus	Humans of all ages	Rashes on the face, swollen glands on the neck
Influenza	Virus	Humans of all ages	Headache, shivering, high temperature and general pains
Small pox	Virus	Humans of all ages	Skin rashes and small blisters. High fever, sometimes leading to death
Chicken pox	Virus	Humans of all ages	Itchy skin rash
Whooping cough	Bacteria	Humans of all ages	Cold, high fever, cough and vomiting

Table 11.1c) Diseases spread by vectors

Diseases	Microorganism causing it	Vector	Host	Symptoms and effects
Malaria	Plasmodium(protozoa)	Anopheles mosquito	Humans of all ages	Shivering, high fever, with irregular bouts of sweating.

Yellow fever	Virus	Aedes mosquito	Humans and monkeys	High temperature, headache, backache, vomiting and jaundice.
Sleeping sickness (trypanosomiasis)	Trypanosome (protozoa)	Tsetse fly	Humans	Persistent feeling of sleepiness, fever and headache.
Tick typhus	Rickettsia	Tick	Humans	Typhus fever,
Flea typhus	Rickettsia	Rat flea	Humans	fever, muscular pains, high temperatures and sudden splitting headaches.
Rabies	Virus	Dog	Humans and dogs	Swelling of lymphatics in region of dog's bite. Choking and breathlessness, fever, mental derangement, vomiting, secretion of sticky saliva and barking like a dog.



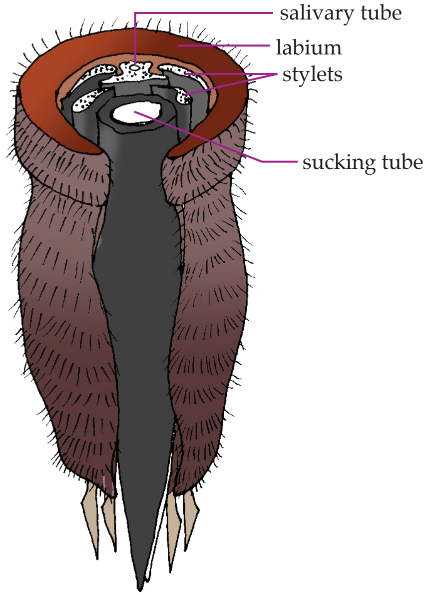


Fig. 11.5 *(a) Head of a female mosquito* *(b) Mouth parts of a female mosquito*

Summary

This chapter has taught the following:

- The growth activities of a microorganism shows that growth represents an increase in size, weight or number of body units.
- Microorganisms can be very useful to man in the food and drinks industries, in the manufacture of antibiotics and as sources of some enzymes and vitamins as well as for increasing the growth rate of some animals.
- Microorganisms may also be harmful to human beings and other higher animals. They cause various types of diseases which can be contracted from various media, including the air, our food and drink, as well as through vectors and by contact with infected persons.

Revision questions

1 Yeast is a microscopic organism because it ____________________.
   A ferments palm wine
   B moves at regular periods
   C can be carried by the air
   D lacks chlorophyll
   E is very tiny in size

2 Anopheles mosquito is a vector because ________________________.
   A it carries all diseases from person to person
   B it transmits malaria to non- sufferers with every bite
   C it transmits malaria when it carries the pathogen *plasmodium* to non-sufferers
   D it inflicts the disease malaria only on people it chooses to impart it to
   E it is the most notorious of all the animals that transmit malaria

3 Freshly tapped palm wine X, is sweeter than a day–old palmwine Y because ________________.
   A X has not yet undergone fermentation
   B Y contains far more yeast; sugar is formed inside fresh palm wine X
   C the alcoholic content of Y is not high
   D water content of Y is higher
   E more carbon dioxide has been lost from X

4 Describe an experiment to show that a known microorganism is capable of growing.

5 Which microorganism is involved in sugar fermentation? State the equation for sugar fermentation and the importance of the process to man.

6 a) State three different media through which microorganisms could reach animal hosts.
   b) For each medium, name (i) two diseases, (ii) the type of microorganisms causing each one, (iii) their respective hosts and (iv) the symptoms of the disease.

Chapter 12 Towards better health

Introduction

We have learnt that microorganisms are responsible for many diseases of man, other animals, as well as plants. In this chapter, we shall see how to control the spread of these microbes, either directly by applying conditions that would make it difficult for them to live and multiply within their hosts, or indirectly by attacking their vectors. We shall also discuss the importance of good health to individuals and communities and what can be done to maintain it.

Control of disease-causing microorganisms

Our present day knowledge of the control of microorganisms is due largely to the work of earlier scientists. **Louis Pasteur**, for instance, first demonstrated that microbes were killed or rendered inactive at certain temperatures. **Fleming** showed that the growth of bacteria was impeded when they shared a common substratum with the fungus *penicillium.*

Other means of stopping the growth or development of microorganisms are now known to include the use of dehydration or dryness, antiseptics, disinfectants and high salinity or saltiness. These can be shown experimentally.

Activity 12.1 Checking the growth of microorganisms

For this activity, the class should work in five groups, identified as A-E. Group A will use high temperature, group B antibiotics, group C antiseptics, group D dehydration, and group E high salinity.

Materials required

Each group will be supplied with two covered petri dishes containing a sterile culture medium.

Procedure

1 Using a sterile inoculation loop, transfer a known microorganism from an established culture to a number of points on the surface of petri dishes. One of the petri dishes should then be labelled A1, B1, C1… The other dish, to be used as control, should be labelled A2, B2, C2, etc., depending on the group.

2 *Group A:* Place culture A in an oven whose temperature is regulated to 150^0C. Alternately, put into a refrigerator with temperature regulated to 0^0C. Leave the culture A2 on a safe table.

3 *Group B:* Apply one or two tablets of penicillin on marked portion of B1 and leave it beside culture B2 safely on a table.

4 *Group C:* Add drops of *Dettol*, an antiseptic, on the surface of culture C1 and mark the the spots covered by it. Both C1 and C2 should then be left, side by side, on a table.

5 *Group D:* Place a culture D1 in a desiccator; put D2 on a safe table.

6 *Group E:* Use a pipette to place some drops of strong saline water on E1 and mark the extents covered by the drops. E1 should then be placed side by side with E2 on a table.

7 Commence observation two days after setting up the experiment and observe daily for five days. A daily record of observation should be entered on a table prepared for this purpose as follows:

	Observation in days			
	II	III	IV	V
High/low Temperature A1 A2	……….... ………....	……….... ………....	……….... ………....	……….... ………....
Penicillin (antibiotics) B1 B2	……….... ………....	……….... ………....	……….... ………....	……….... ………....
Dettol (antiseptics) C1 C2	……….... ………....	……….... ………....	……….... ………....	……….... ………....
Desiccator D1 D2	……….... ………....	……….... ………....	……….... ………....	……….... ………....
High Salinity E1 E2	……….... ………....	……….... ………....	……….... ………....	……….... ………....

Obtain results from the other groups and complete the table in your practical notebook.

Questions

1. In which of the cultures was there any growth of microorganisms?
2. What are the general effects of each of the treatments on the microorganisms contained in the respective petri dishes?
3. What conclusion can you draw after comparing dishes A1-E1 with their respective controls?

Control substances and methods

Based on the conclusions of the last experiments, we can discuss the control of disease-causing microorganisms.

Antibiotics

The use of antibiotics in our hospitals today is the final result of the work of the English scientist, **Alexander Fleming**, who incidentally observed that bacteria could not grow side by side with the fungus *penicillium*, another microorganism. *Penicillin* is the antibiotic prepared from *penicillium* and today there are several other antibiotics used to cure such diseases as dysentery, pneumonia, typhoid fever and tuberculosis, all of which are caused by bacteria infection. Some of these are *septrin, chloramphenicol, aureomycin.*

Antiseptics

Antiseptics destroy or inhibit the growth of bacteria and viruses on the body. They are often applied to wounds in hospitals, to prevent them from becoming septic. Examples of antiseptics are hydrogen peroxide, iodine tincture, potassium permanganate, common salt and camphor. They are so used because they do not damage human tissues, although they kill off pathogens. Antiseptic soaps also inhibit the growth of bacteria.

Disinfectants

These kill off microbes and are much stronger than antiseptics. They are so strong that they cannot be used on wounds in the same way as antiseptics are. Examples include solutions of formaldehyde, carbolic acid, *Izal* containing phenol, creolin, lysol and cresol. They are used for sterilising floors, clothing ,hospital instruments, sick rooms, etc. Thus they serve to prevent microorganisms from attacking our bodies.

Very high or very low temperature

A 19th century French scientist, Louis Pasteur, showed that very high temperatures of about 150^{0}C, could destroy microorganisms living in milk, wine or meat broth. This process of heating any mixture or solution to high temperature in order to kill off the microbes has since been known as **pasteurisation.** Very low temperature also has the same lethal effect on microorganisms. It renders them inactive, or freezes them to death, and so stops their pathogenic effects. Any substance kept in a freezer is therefore preserved from the attack of microorganisms.

Common salt

Common salt is sprinkled on some food items to preserve them. One example of this is the locust bean preparation (*ogiri or daudawa*) used in Nigerian soups. Salt is similarly used to preserve meat or fish over long periods. It does this by destroying all the microorganisms that could have caused decay.

Isolating patients with infectious diseases

Some diseases may be contracted merely by coming very close to, or touching people who are suffering from them, or by breathing in air that patients of these diseases have breathed, sneezed, or coughed out. Examples of such diseases are tuberculosis, chicken pox and measles. People suffering from these diseases should be *isolated*, i.e. kept away from other people or left in special hospitals for these diseases. In this way, uninfected people are protected.

Immunisation

Immunisation involves the introduction, into the blood, of some de-activated microbes of a given disease against which protection is desired. The presence of such microbes causes the blood to produce reasonable amount of antibodies specific to that disease. This ensures that the body is equipped to deal with any attack by organisms of the disease over a given period. In medical language, the recipient is said to become *immune* to the disease concerned, over the period. Anyone who wishes to travel to another country is first expected to be immunised against such diseases as cholera, chicken pox and yellow fever. This serves to reduce the likelihood of these diseases being carried to other countries by such a traveller. Yellow fever inoculation gives protection against the disease for about seven years, while cholera vaccination remains effective in the body for about six months only.

Personal hygiene

Personal hygiene is one of the means of keeping microorganisms off our bodies and environments. This is achieved through regular baths with soap and sponge, brushing the teeth with chewing sticks or tooth brushes, wearing clean clothes, washing or boiling fruits or vegetables before eating and washing the hands regularly.

Drugs

The use of drugs for the cure of diseases is a well-known medical practice. Prophylactic drugs are used in preventing diseases while curative drugs are used to destroy pathogens like bacteria, fungi and protozoans in the bodies of patients. Drugs for viral diseases are not yet widely known. Patients of diseases caused by microorganisms are therefore usually advised to immediately see a medical doctor in a hospital.

Importance of vectors

Two things really distinguish a disease vector from a mere carrier.

1 **The method of picking up the microbes**
This, in mosquito, for example, is by piercing with its mouthparts, the skin and muscles of a malaria patient and drawing his blood to feed itself. In this habit, the mosquito differs from the housefly, which merely passively transfers microbes from infected materials to the food of uninfected people.

2 **Active involvement in the development of the microorganism**
Part of the life-cycle of *plasmodium* takes place inside the mosquito. The mosquito sucks up, along with the sufferer's blood, male and female *gametocytes* of *plasmodium.* The sexual reproduction of *plasmodium* thus takes place inside the mosquito, and each *fertilised egg* transforms into many sporozoites, which find their way back into human blood when the mosquito feeds again. This arrangement ensures that at least some of the numerous sporozoites produced will find their way into fresh human hosts.

Vectors are usually not affected by the multiplication of microorganisms in them. They are thus both a breeding ground and a means of distribution of disease pathogens.

Control of vectors

The diseases carried by vectors have no means of infecting man except through vectors. If, therefore, vectors could be effectively controlled, the diseases that they carry would have been put in check.

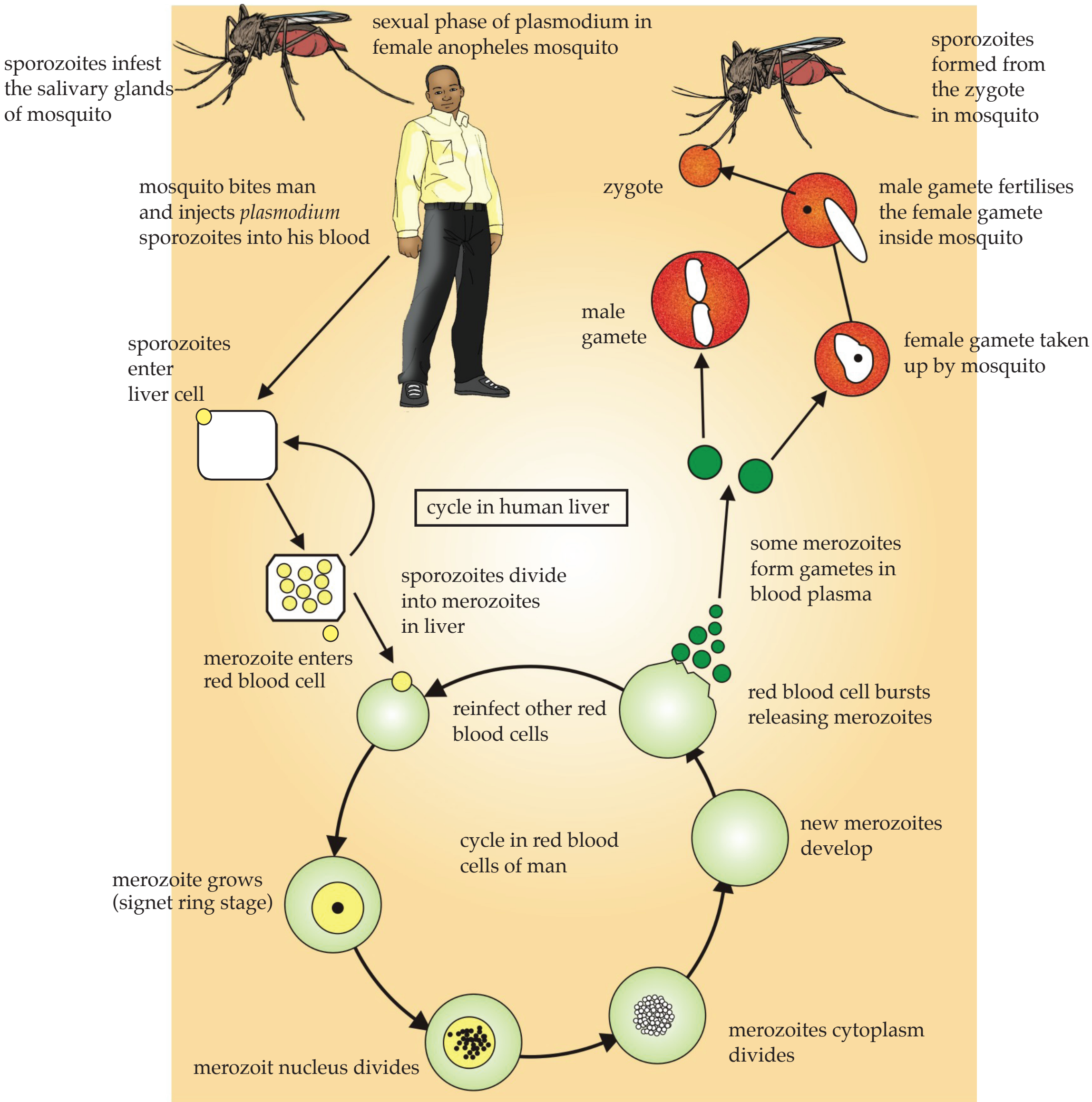
To effectively control a vector or pest of any kind, it is necessary to study its habit, behaviour and life history.

Mosquito

All these have been properly studied in mosquito. The adult anopheles mosquito hides itself against a dark background or in a dark corner during the day, emerging only at night for its blood meals. It lays eggs in standing water, wherever this occurs. These eggs hatch into larvae after one to three days. The larva is a worm-like creature which breathes atmospheric air over the water surface, by means of the breathing tube located on its tail region. It turns into a pupa after three or four days. The pupa also lives in water and tends to sink into the water whenever it does not swim. It is, however, active and frequently swims up to the water surface to breathe through short breathing trumpets on the head region. The pupa does not feed at this stage. It turns into an adult within two to seven days. The adult is a shy creature, which does not venture in for its bite unless its victim is virtually motionless, as in sleep.

Armed with this knowledge, let us now see how this vector can be controlled.

sexual reproductive phase of plasmodium in anopheles mosquito



Asexual reproductive phase of plasmodium in man

Fig. 12.1 Life cycle of plasmodium

Control of developmental stages

1 Kerosene may be poured on the surface of the water in which the larvae or pupae of mosquito live. Other oils may also be used. The oil lowers the surface tension of the water, so that tiny creatures can no longer hang onto the surface for breathing. The kerosene or oil also blocks the breathing tubes of larvae and breathing trumpets of pupae. Oil prevents atmospheric oxygen required by the larvae or pupae from dissolving in the water.

2 Since they develop only in water, all the water containers in which mosquitoes can develop around human dwellings should be removed or turned upside down to avoid standing water. Gutters should also be cleared, for the free-flow of water currents.

3 Whenever mosquito larvae or pupae are found in gutters they should be physically removed, along with the mud or sand at the bottom of the water, using a spade or hoe, and the sand dumped on dry land. All the larvae or pupae will die off or be eaten by ants.

4 Introduce fish or tadpoles into water where mosquito larvae or pupae are developing. They will be fed upon by these 'guests'.

Control of adult stage

1 Adult mosquitoes should be killed, either physically or by spraying with insecticides.

2 Adult mosquitoes may be prevented from biting by:
   a) using mosquito-proof nets around beds, or over windows and doors;
   b) burning mosquito coils which disturb their keen sense of smell. This can only be done in a well-aerated room;
   c) applying skin creams or lotions whose smell is repulsive to mosquitoes.

Preventing the development of pathogens

The malarial pathogens may be prevented from developing within the human body by:

1 Using medicines called **prophylactics** which prevent the development of pathogens in blood, e.g. *Daraprin.* Prophylactic drugs usually have to be taken regularly, e.g. *Daraprin* should be taken once a week;

2 Taking medicines which are capable of curing the malaria by destroying the pathogens in blood, e.g. *Chloroquine, Camoquine, Fansidar* and many others.

3 Applying the knowledge of the behaviour of adult mosquitoes.
   a) Any bush around a building should be cleared to remove the hiding places of mosquitoes, especially during the day.
   b) Walls of bedrooms should be painted with light-coloured paints, preferably white or cream, to expose the perched insect.

Tsetse fly

Another important vector in tropical Africa is the tsetse fly, which transmits *trypanosomiasis* or sleeping sickness through the causative microorganisms, *trypanosoma*. The tsetse fly belongs to the same insect group, the Order Diptera, as the common housefly. This suggests to us what its life history should be. The other disease transmitted by tsetse flies is **nagana**, a sleeping disease of cattle and horses, which could also be fatal if not given timely and adequate treatment.

Life history and mode of life

The tsetse fly does not lay its eggs. After mating, the female retains the single egg that is fertilised inside. It retains it for about eight days, after which the egg hatches into a larva, which is then 'born'. It is a white cylindrical larva, with two knobs which carry respiratory pores. This larva bores a tunnel inside which it sheds its skin several times.

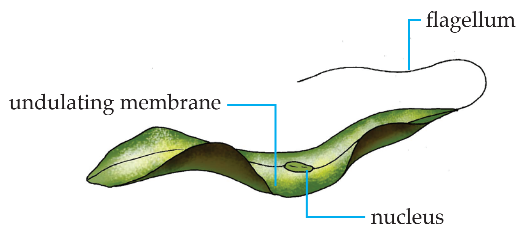


Fig. 12.2 Trypanosoma

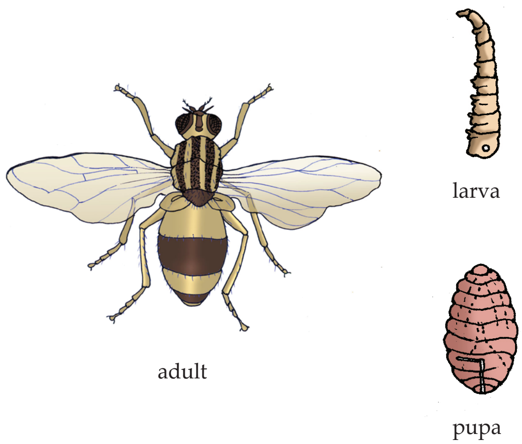


Fig. 12.3 Tsetse fly

The larva turns into a pupa some ten days later and undergoes several moults over a period of three weeks, after which it becomes a full grown adult or imago. This then climbs out to the soil surface, allows its wings to dry and flies away to a shady place. The tsetse fly cannot stand strong light and is usually found in the shady areas of forests, savannahs and river banks.

The fly feeds on the blood of mammals, birds and reptiles. Some of these animals, e.g. antelopes, do not suffer from trypanosomiasis. They merely serve as reservoir for the pathogen, from which the uninfected tsetse fly picks up the microorganisms. Like *plasmodium, trypanosomiasis* also undergoes its multiplication phase inside its vector. The numerous ineffective units thus produced then move, from the stomach wall of the fly into the salivary glands, for transmission into a new host.

Control measure

Knowledge of the life history, habitat and behaviour of the tsetse fly has led to the development of the following methods for the control of the fly.

1 **Preventive measures**
   a) Places where the tsetse fly could possibly rest and breed, such as shady areas near towns or beside river banks should be cleared.
   b) Farmers should be encouraged to breed cattle which are resistant to nagana.

2 **Curative measures**
   a) The tsetse fly can be brought into a country by moving objects such as cars and bicycles; such vehicles from suspected places should be sprayed with insecticides before entry into the country.
   b) Resting places of tsetse flies during the day should be sprayed with insecticides.
   c) Sleeping sickness should be promptly treated with appropriate drugs once its symptoms are diagnosed.

Public health

The well-being of every individual in a community cannot be maintained solely by personal effort. No matter how clean an individual is, if his neighbours and members of his household live unhygienic lives, he will himself soon fall victim of one microbial disease or another.

The maintenance of health should therefore be viewed as a matter of common concern among individuals, communities, nations and the world as a whole. Effective public health administration in a community is achieved in a number of ways. Some of these are as follows:

Importance of maintenance of good health to a community

1 Individuals in a community will work hard and improve their standard of living if they are healthy.
2 If individuals are healthy, they will spend less on medical bills; health and wealth are related.
3 Some diseases are communicable. If some individuals in a community suffer a disease, others may become infected; hence maintenance of good health is a common concern.

Ways in which communities maintain good health

1 Refuse disposal
2 Sewage disposal
3 Protection of water
4 Protection of food
5 Control of diseases

Disposal of refuse

Fig. 12.4 shows some ways of disposing of refuse. The **dustbin**, a large bucket with a lid, is used for collecting all the house refuse and is one item that every household should have. The modern usage of the dustbin involves placing of special black cellophane refuse paper or plastic bag inside the dustbin. At the end of each day, the contents of the dustbin are tied up in the large paper bag and left in a barrel on an agreed spot from where the refuse van carries it away for disposal.

When next you see a refuse van, take note of its size and its gadgets for collecting and compressing a large quantity of garbage into small size.

(a) A dust bin

(b) An incinerator

Fig. 12.4 Methods of waste disposal

The **incinerator** is a small building designed specially for the drying and burning of refuse. A fire is lit at the lowest opening and dry refuse is dumped in at the upper end, where some allowance has also been made for the escape of smoke. A well-kept incinerator may last for several years.

One other method, not in widespread use, is the burial of garbage and refuse. In spite of the heavy labour involved, it is an equally efficient method of disposing of garbage as the more popular methods earlier described.

Sewage disposal

Sewage includes faeces and urine, as well as waste water from kitchen and laundries. Not only is the mere sight of sewage quite offensive, it is also a source of serious microbial diseases affecting man. Efforts should therefore be made by every individual and every community to see that sewage is properly disposed of.

There are various methods for the disposal of sewage. Three usual methods are described:

Pit latrines are common in rural areas because of the lack of pipe-borne water. If pit latrines are well covered with lids and used hygienically; they can be a safe disposal method for human waste.

Bucket toilets, if regularly emptied, are also a safe way of disposing of human waste. They should be emptied into large, covered pits, dug far away from human habitation.

Modern toilets are the safest, most hygienic ways of disposing of sewage. Waste is deposited, first into water inside the toilet bowls and then flushed off into a large, underground septic tank. This system can work properly only where there is free-flow of pipe-borne water to fill the cistern. The septic tank is ultimately filled up, but this takes a considerable length of time, during which the sewage settles and the solid waste or **sludge** is acted upon by anaerobic bacteria. The products of this bacterial action may finally be collected, compressed into cakes and used as fertilisers. The liquid **effluent** above it is allowed to drain into a **soak-away** pit. In large cities with densely-populated areas, the septic tank is further modified. All sludge is directed into a central sludge plant which makes fertilisers from it, while the effluent is pumped into a system that makes the water harmless and empties it into a pond, lake or the seas.

Fig. 12.5a) Sewage disposal: A flush toilet

By using this method, man is saved from the bad smell and the danger of contamination by sewage, before it is disposed of or converted into useful materials.

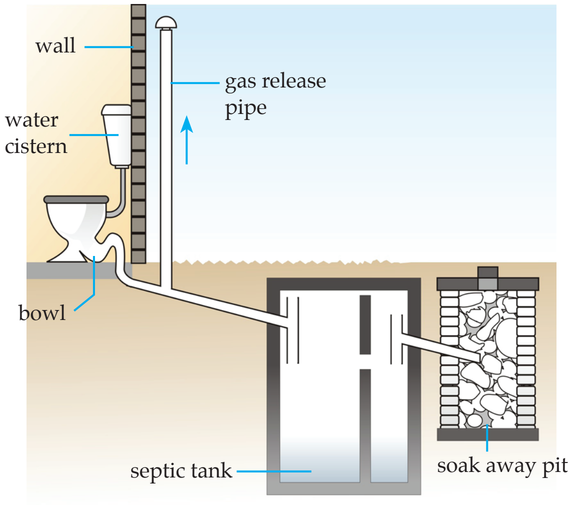


Fig. 12.5b) Working of flush toilet

Protection of water

Organisms that cause cholera, diphtheria, poliomyelitis, infective hepatitis, amoebic dysentery and typhus are all carried in impure water, as we saw in Chapter 8. These diseases can therefore be largely checked by the provision of treated water through a modern pipe-borne water system for the community.

One method of procuring the water for such a distribution is by the damming of a nearby river and channelling the water collected into a reservoir. From the reservoir, the water passes into large tanks, called **sedimentation chambers**, where all the large particules in the water settle and are removed. Clear water then moves on to filter chambers where much smaller particles still suspended in it are removed. The addition of a chemical like alum can hasten these two processes, as it can make very tiny and light dirt particles stick together, for easier sedimentation or filtration. The water is further treated with chlorine, to kill the organisms contained in it. Finally, the water is pumped through pipes from the reservoir to the various homes in the community.

By comparing the treatment and transport of pipe-borne water to what obtains where pipe-borne water is not available, it becomes evident that pipe-borne water is safer for drinking.

Protection of food

The community should also try to protect the foods of its members in order to prevent a spread of food transmitted diseases like diarrhoea, sore throat, food poisoning and cholera. Imported food, especially tinned or canned foods (e.g. tomato puree, fish, milk products), should be certified consumable before they are released into the market. Health officers from the Ministry of Health should also inspect cattle which are slaughtered for sale in various abattoirs, in order to declare those that are disease-ridden unfit for consumption. Health officers should also make sure that only hygienically maintained environs are approved as public eating places.

Control of diseases

Community efforts in respect of disease control are usually supervised by the Ministry of Health. The first duty of the ministry is to educate the public on the general rules of health, many of which are often overlooked or forgotten by our people. Some of such rules are as follows:

1 Maintenance of a clean domestic surrounding: environmental exercises are aimed at achieving this.
2 Discouragement of spitting or the blowing of noses, onto the street or into the public drains, etc.
3 Discouragement of urinating or stooling in open places.
4 Provision of child immunisation services, at the General Hospitals and local health centres, against measles, tetanus, whooping cough and poliomyelitis.
5 Encouragement of the burning of domestic and industrial waste in incinerators.

The Ministry of Health also takes special care about infectious diseases such as cholera and tuberculosis. The spread of these diseases is checked by isolating the patients in special infectious diseases hospitals where specially trained medical officers take care of them.

Health organisations

The Nigerian Medical Association (NMA) and the Nigerian Red Cross Society are two Nigerian organisations which have plans for the maintenance of good health among the Nigerian public. In addition to these are such international organisations as the World Health Organisation (WHO), the United Nations International Children's Emergency Fund (UNICEF), the International Red Cross and International Red Crescent Societies, all of which are specifically committed to the people's good health. These international bodies were founded at various times and for different purposes.

The World Health Organisation

The WHO is a special agency of the United Nations Organisation (UNO) and is therefore, financed by all member countries of the UNO. Its primary concern is the maintenance of world health and it works towards the achievement of this by:

1 keeping the health statistics of the world. This can help national health authorities to see whether a diseases (e.g. cholera) is spreading or receding at any time, so as to be prepared to apply emergency control measures, if necessary,
2 providing experts to train and advise the health personnel in member countries,
3 producing medical publications,
4 providing means for warning all member countries in the event of the outbreak of an epidemic.
5 providing drugs and vaccines in cases of emergency,
6 assisting national health organisations in the control of diseases and vectors,
7 helping in maternal and child health care,
8 setting and recommending safe standards for drugs,
9 setting international quarantine regulations.

One of the notable achievements of the WHO has been the eradication of small pox at the end of a mass vaccination campaign from 1967 to 1978, against the deadly viral disease.

The United Nations International Children's Emergency Fund

The UNICEF, another special agency of the United National Organisation, was also set up to deal with world health needs, especially those of children.
Among other things, the UNICEF seeks to:

1 provide for the emergency needs of children in devastated areas,
2 improve the nutrition of under-nourished children;
3 feed destitute children;
4 supply vaccines or equipment to prevent or control diseases that especially affect children, such as whooping cough, diphtheria, poliomyelitis and tuberculosis,
5 provide children's clothing and other needs,
6 assist in the improvement of the health of mothers and their children by providing training programmes and necessary equipment.

The recent campaign in Nigeria for the application of the Oral Rehydration Therapy (ORT) in the control of diarrhoea in children is an example of the useful work being done by the UNICEF.

The International Red Cross and International Red Crescent Societies

These are the two current arms of a voluntary international health organisation, first proposed by **Jean Henri Bunant**, a Swiss, in 1859. The organisation now has branches in over one hundred countries of the world.

In times of war, they concern themselves with the:

1 care of the injured,
2 provision of emergency aid to those in distress,
3 negotiation of the exchange of prisoners of war between countries,
4 provision of transport for the evacuation of refugees,
5 welfare of prisoners of war.

In peace time, they concern themselves with the:

1 provision of general first aid,
2 prevention of accidents,
3 training of nurses 'aides,
4 maintenance of maternal and child welfare clinics,
5 provision of help to victims of natural disasters (earthquakes, floods, etc) .

Branches of these international associations exist in our country and they pursue similar or identical goals.

The Nigerian Medical Association has the additional responsibility of caring for the needs of medical doctors in our country to provide adequate medical services in our hospitals.

Health organisations generally stress the need for the prevention of diseases, through improved public health services. They also provide aid for those afflicted by diseases or natural disasters.

Summary

This chapter has taught the following:

- Disease-carrying microbes can be controlled or killed by means of antibiotics, antiseptics, disinfectants, very high or low temperatures, common salt, isolation of sufferers, drugs, immunisation, and personal hygiene.
- By knowing what vectors are, their importance and nature of their habitats, life history and behaviour, the diseases that they transmit can be checked or controlled.
- Individual persons cannot, without the contributions of their communities (through the provision of good public health services), maintain a perfect health system.

- Health organisations nationally and internationally function in various ways to control diseases, and they have their common and various aims.

Revision Questions

1 The vector for the organism that causes sleeping sickness diseases is ______________.
   A *plasmodium*
   B *trypanosome*
   C tsetse fly
   D mosquito
   E trypanosomiasis
2 Setting international quarantine regulations is the exclusive function of the ___________________.
   A International Red Cross Organisation
   B UNICEF
   C Immigration Department
   D World Health Organisation
   E Nigerian Medical Association
3 Briefly describe the various ways in which you would protect yourself from malaria.
4 a) What is immunisation?
   b) State three diseases which are preventable by immunisation and name their causative organism.
   c) Describe five other ways in which diseases causing microorganisms may be controlled.
5 Why is it important for a community to cooperate in maintaining the health of its members? Describe four ways in which the community may maintain the health of its members.

Chapter 13 Aquatic habitats

Introduction

The habitat of an organism is that type of place in which it normally lives. Habitats may be classified into two main kinds, **aquatic** and **terrestrial**. Aquatic habitats are those which consist largely of water while terrestrial habitats relate to land.

Aquatic habitats are of three kinds:
1 Marine or saltwater habitats;
2 Estuarine or brackish-water habitats and
3 Freshwater habitats.

The marine habitat

Marine habitats contain saltwater and include oceans and saltwater lakes. The shore and the water of the open sea or lake together make up the marine habitat.

Characteristics of the marine habitat

The marine habitat has the following characteristics:

1 **Size**
The marine habitat is usually a large body of water. In West Africa, the available marine habitat is the Atlantic Ocean, which is very large.

2 **Chemical composition**
Seawater contains many kinds of dissolved ions, including sodium, potassium, magnesium, calcium, phosphate, iodine, bicarbonate, chloride, sulphate and nitrate ions. Of the salts present in sea water, sodium chloride occurs in the largest amount.

3 **Salinity**
The total salt concentration of water is known as its salinity. The salinity of seawater is high. The average salinity of seawater is 35 parts of salt per thousand (abbreviated as 3.5%).

4 **Density**
The density of seawater is about 1.028, while that of pure water is 1.00. The high density of seawater enables the eggs of some marine organisms and various organisms to float in it.

5 **Pressure**
Water pressure increases at the rate of one atmosphere for every ten metres or so increase in depth. At a depth of about 1000 m, the pressure would be about 100 atmospheres. Animals which live deep down in the ocean must therefore be adapted to resist such high pressures.

6 **Temperature**
The temperature of the sea changes less quickly than that of land. However, temperature falls with increase in the depth of the sea. In tropical waters, when the temperature of the surface of the sea is 30°C, the temperature at a depth of 15000 m is about 4°C.

7 **Oxygen concentration**
The concentration of oxygen in seawater is highest at the surface where the atmospheric oxygen dissolves in the water. As green plants carry out photosynthesis in surface waters where light is present, they release oxygen into the water. Oxygen-concentration decreases with depth and, in very deep parts of the oceans, oxygen concentration is low.

8 **Hydrogen-ion concentration**
Sea water tends to be alkaline, with pH of about 8.0 to 8.5 near the surface.

9 **Stability**
The marine habitat is stable when compared to most terrestrial habitats. The body of water is usually very large, and its chemical composition does not alter very much in spite of the addition of freshwater from rain or rivers. Its temperature does not fluctuate rapidly and the water does not dry out.

10 **Waves, ocean currents and tides**

Waves, ocean currents and tides are all movements of water. Waves are temporary movements of the surface waters of the sea, which can take place in any direction. Waves are caused by winds blowing against the surface of the water. They bring about the mixing of seawater, especially in the layers near the surface. Waves also beat against the shore and sometimes cause it to be eroded. An ocean current is a movement of the surface water of the ocean which has a dominant direction. Of the causes of ocean currents, the most important are the prevailing winds and the differences in density due to variations in temperature or salinity between areas of water. The rotation of the earth also causes some deflections in ocean currents. Ocean currents affect the distribution of marine organisms. For instance, the Gulf Stream is a warm current which flows up the eastern coast of North America, then it flows eastwards to Western Europe. It enables several warm-water living organisms to live beyond their normal limit of distribution.

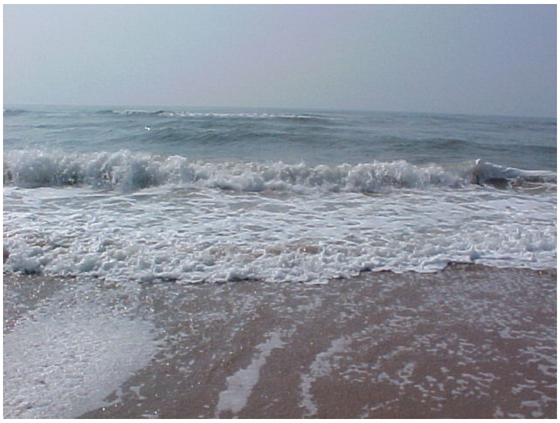


Fig. 13.1 Waves on the atlantic ocean

Along the sea coast, it is readily observed that the level of the sea is not constant. If the physical level of the sea is marked at a particular time, it will be observed, after three hours, that the water level will have risen above, or fallen below the marked level due to tidal action.

Tides are the alternate rise and fall of the surface of the sea, approximately twice a day. They are caused by water distortions resulting from the combined gravitational pull on the earth and on the water at the surface of the earth, by the sun and moon (the latter to a greater extent, because of its relative nearness). Water being a fluid is readily pulled out of shape, causing bulges in its level. This distortion is actually caused by the net result of the mutual attraction of the sun, moon, and the earth, along with the centrifugal force between the earth and moon, caused by their spins.

Generally, there are two high tides and two low tides per tidal day. The moon travels in its orbit round the earth in the same direction as the earth rotates. As a result, it takes 24 hours 52 minutes, or one lunar day, for the sequence of two high tides and two low tides to be completed, or 6 hours 13 minutes between one high tide and succeeding low tide. The time, either 12 hours 26 minutes or 24 hours 52 minutes, between high and low tides are known as the **tidal period**. In few cases, for example parts of the Gulf of Mexico, there is only one high tide and low tide per day. These are called daily tides or *diurnal* tides.

The highest level reached by a high tide is called the **high tide level** while the lowest level reached by a low tide is called the **low tide level**. The difference between the high and the low tide levels is the **tidal range** or **amplitude**. In the open sea, the amplitude is about 0.3m. The rise of the level of seawater at high tide causes the water to flow into lagoons and estuaries. In the Lagos lagoon, the amplitude varies from about 0.3m to about 1m. In a narrow estuary, the rise level of water may be as much as 16m.

The maximum gravitational pulls of the moon and the sun on the earth are exerted when the moon and the sun are both pulling on the earth along the same line. This happens at new moon and full moon. The highest tides are recorded at these times and are called **spring tides**. (Please note that there is no connection between the spring tide and spring which is a climatic season in the temperate zone).

When the positions of the moon and the sun form a right angle at the position of the earth, then the gravitational pulls of the moon and the sun do not add up, but detract from each other. The tides that occur at this time are called **neap tides**. These have the lowest high tides and low tides. In all other locations of the moon relative to the earth, the heights of the tides lie between the neap and the spring tides.

Tides affect those organisms that live at the edge of the sea by alternately flooding them and exposing them to dry air. They also affect life in lagoons and estuaries by both raising and lowering the level of the water and by making the water in these habitats brackish. Brackish water lies between fresh water and salt water in its salinity, which itself varies with the tides.

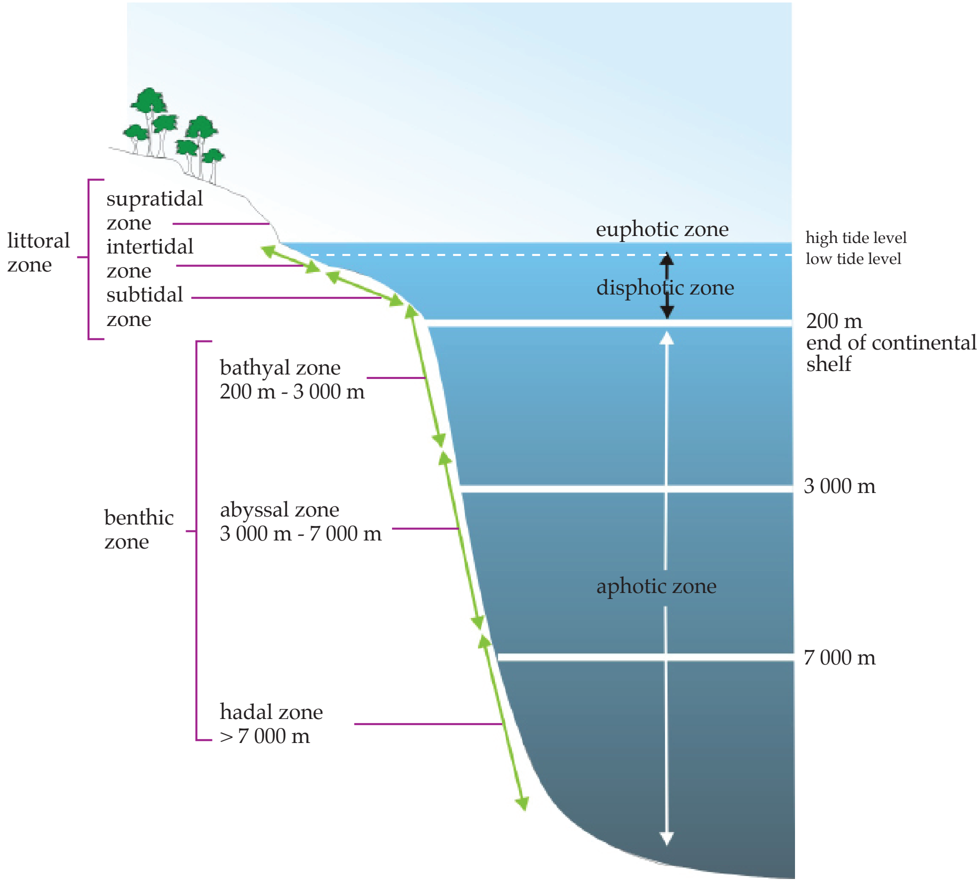


Fig. 13.2 Major ecological zones of the marine habitat

Major ecological zones of the marine habitat

It is convenient to consider first the ecological zones of the substratum or land at the bottom of the body of waters, and then the ecological zones of the open sea.

Land at the bottom of the body of waters

The substratum or land at the bottom of the body of waters is made up of the shore and the sea bed. The substratum can be subdivided into two big zones. They are:

1 The **littoral** zone or land near the coast is made up of the following zones:

a) The **supratidal or splash zone:** The supratidal or splash zone is really not part of the marine habitat, but of the terrestrial habitat. It is the area where water splashes when the waves break at the shore.

b) **Intertidal zone:** This is the zone along the substratum between the high tide mark and the low tide mark. It is submerged and exposed twice daily, and is subject to much wave action.

c) **Subtidal zone:** This is the zone along the substratum from the low tide mark to the end of the continental shelf where the sea is about 200m deep. This zone is never exposed.

2 The **benthic** zone (the deep sea bed) is made up of the following zones:

d) **Bathyal zone:** This zone extends from the end of the continental shelf down to a depth of about 3000m.

e) **Abyssal zone:** The abyssal zone extends from the end of the bathyal zone to a depth of around 7000m.

f) **Hadal zone:** This zone is the substratum of very deep water, beyond 7000m.

The open sea water

The open sea water covering the substratum is made up of the following zones:

1 **Neritic zone:** The neritic zone is the water above the continental shelf. It is generally shallow, warm, penetrated by light, and rich in dissolved gases especially oxygen.

2 **Oceanic zone:** The oceanic zone is the water beyond the continental shelf. The oceanic zone is also divided horizontally into three zones based on the extent to which light penetrates into water.

3 **The euphotic zone:** This is the zone that is illuminated by light. It starts from the surface of the water and extends to a maximum depth of 200m. The depth to which light penetrates is affected by the turbidity of the water. Waves cause reflections of light which reduce the penetration of light into the water. In the euphotic zone, photosynthetic phyloplankton abound, so do zooplankton and nekton that form food chains.

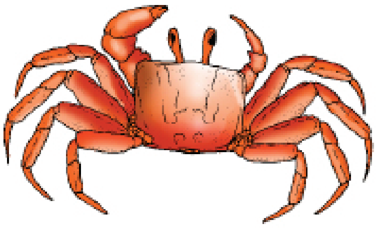
4 **Disphotic zone:** This is a zone, of dim light. In this zone brown algae, red algae, fish crustacean and other animals occur.

5 **Aphotic zone:** This is a zone of no light. No photosynthetic organisms occur in this zone. Animals in this zone do not depend on sense of sight. Some of the animals have fluorescent organs that emit light. Many of the animals are carnivorous.

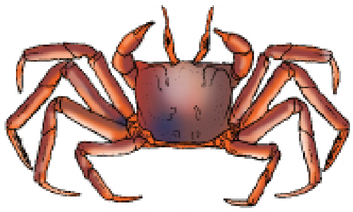
Distribution of organisms in the marine habitat

The different ecological zones in the marine habitat present a wide variation in ecological factors. For instance, waves are stronger in the surface water of the sea than in deep water. Light intensity generally decreases with depth to about 200m. Deep sea water is totally dark.

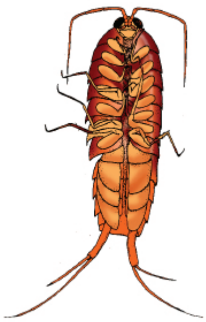
Each ecological zone of the marine habitat has its own peculiar features and problems of life. In view of these variations in ecological conditions, different organisms live in specific zones of the marine habitat to which they are adapted.



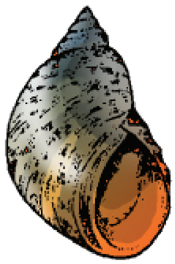
a) Sand crab



b) Ghost crab



c) Shore slater



d) Periwinkle (*Littorina punctata*)

Fig. 13.3 Some organisms of the marine spratidal zone

Organisms of the splash zone

Plants and animals which live in the supratidal or splash zone are in fact terrestrial organisms. Occasionally, they receive sprays of water when waves break against the shore. Organisms in this zone are adapted primarily for life on land, but appear to require occasional sprays of water to avoid desiccation. Plants of the splash zone include some grasses, and *Ipomea*.

Some of the animals are amphibious, such as the sand crab and the ghost-crab. They live in burrows which go down to the water level. The sand crab and ghost crab have gills for gaseous exchange in water, and also some spongy tissue which can be used for gaseous exchange on land. On rocky shores along the West Africa coast, animals of the splash zone include *Littorina angulifera* and *Ligavena gracilipes.*

Organisms of the intertidal zone

Living organisms in the intertidal zone are faced with some problems, some of which are the following:

1 **Displacement by moving water**
The organisms in this zone are liable to be dislodged and carried away by tidal water or beating waves. Special features are needed to protect them from being carried away.

2 **Desiccation**
At high tide, organisms in the intertidal zone are covered by sea water. At low tide, they are exposed to air and sun's heat. They are liable to dry out.

3 **Respiration**
Organisms of the intertidal zone need to continue respiration, both at high tide, when they are covered by water, and at low tide, when they are exposed to air.

4 **Flooding by fresh water**
Organisms of the intertidal zone are subject to flooding by fresh water when it rains.

5 **Predators**
At low tide, organisms of the intertidal zone need to be protected from predators. In the intertidal zone, there is a *zoning* of organisms. Those organisms which are most adapted to exposure occur high up in the zone, near the high tide mark. In this location, they are not covered by water for long periods per day. Those organisms which are least adapted to exposure occur low down in the zone, close to the low tide mark. In this location they are exposed only for short periods each day. Other organisms occur between these two extremes depending on their respective degrees of adaptation to exposure.

Most of the seashore along West Africa is sandy. The seashore in Nigeria is an example of a sandy shore. In building the Lagos harbour, large stones were piled up in two long lines, which are called the **east mole** and the **west mole**. The function of the moles is to break sea waves and provide calm water in the harbour. These moles or harbour breakwaters are artificial rocky shores. Ghana and Cameroon have natural rocky shores. Rocky shores and sandy shores have different organisms that live on them.

Organisms of the sandy intertidal zone

Some organisms that live on sandy intertidal zones and their adaptations are described below.

1 Plants
There are few plants on a sandy intertidal zone because they cannot secure a firm hold.

2 Astropecten (starfish)
This organism is an echinoderm which is common in sandy sea shores. It has the following adaptations.

a) At low tide, when the shore is exposed, the starfish quickly digs into the sand with its numerous tube feet. This enables it to escape from predators and avoid desiccation.
b) The starfish has a protective colouration, as it is coloured like the sand in which it digs in at the shore.
c) It is able to continue gaseous exchange when it is submerged as when the tide is out.

3 Donax pulcherimus (a bivalve mollusc)
The adaptations of this organism to life on a sandy shore are:

a) It is protectively coloured like the sand; this helps it to avoid the notice of predators;
b) It digs into the sand when exposed at low tide, which helps it to avoid desiccation;
c) It encloses itself in its shell after digging into the sand to avoid desiccation.
d) It continues to carry out gaseous exchange when not covered by water.

4 Terebra micans (a mollusc)

Adaptations

a) It quickly digs into the sand at low tide to escape from predators and avoid desiccation;

b) It encloses itself in its shell for protection from desiccation.

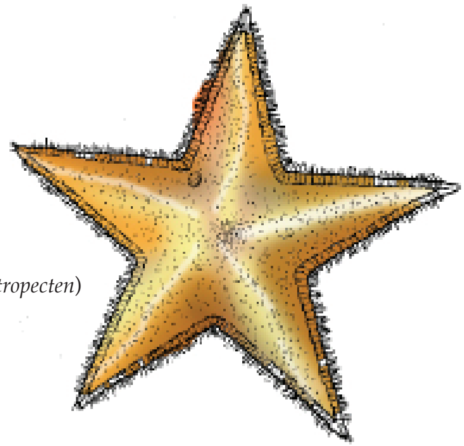
5 Hippa cubensis (mole crab, a crustacean)

Adaptations

a) It quickly digs into the sand at low tide to escape from predators and avoid desiccation;

b) It has exoskeleton, which limits loss of water from the body;

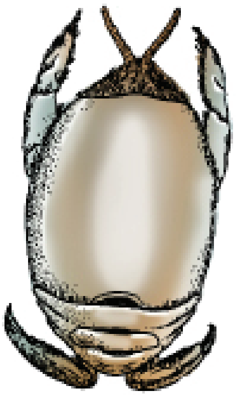
c) It can carry out gaseous exchange both when submerged under water and when exposed to air.



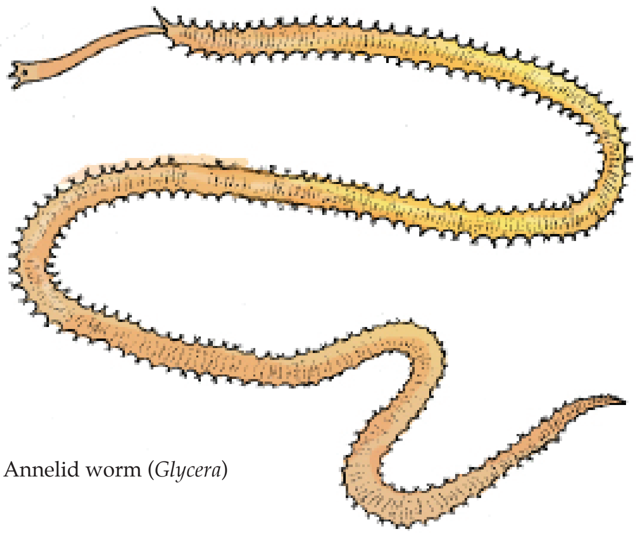
(a) Starfish (*Astropecten*)

(b) Bivaive (*Donnax Pulcherrimus*)

(b) Snail (*Terebra micans*)



(b) Mole crab (*Hippa cubensis*)



(b) Annelid worm (*Glycera*)

Fig. 13.4 Some animals of the sandy intertidal zone

6 **Glycera (Annelid)**

a) At low tide, it withdraws into its burrow in the sand, to avoid predators, and to protect itself from desiccation.

b) In the burrow it continues gaseous exchange through its moist body surface.

Organisms of the rocky intertidal zone

Organisms of the rocky intertidal zones include plants and animals. The adaptations of some of the most common of them are described below.

1 **Plants**

a) Plants in rocky intertidal zone are usually attached by means of a **holdfast**. Such plants include the green sea lettuce, *ulva,* and *dictyopteris,* a brown alga. The attachment protects the plant from being carried away.

b) Reproduction of the brown algae involves the production of motile male gametes, for which water is necessary. The thallus of a brown alga has an adaptation for floating. For example, the *thallus of Sargassum*, a brown alga has air bladders which make it float.

2 **Limpet, a mollusc (Siphonaria grisea)**

a) The limpet attaches itself firmly to rocks by its foot, and by suction.

b) It wears away its shell to fit exactly to the contour of the rock surface.

c) It pulls its shell to fit closely to the rock surface so as to offer minimal resistance between it and water, as the water flows over it.

d) It encloses water in the shell as the tide flows out, to avoid desiccation.

e) The water enclosed in the shell enables the limpet to continue normal aquatic gaseous exchange at low tide.

f) It stops feeding at low tide.

g) It may move around when submerged, but at low tide it returns to its 'home'.

3 **Barnacles (Balanus tintinabulum or Chthamalus dentatus)**

a) A barnacle is firmly cemented to a rock or other support so that it is not carried away by tides.

b) It has a protective shell to prevent desiccation.

c) The barnacle encloses water in its shell to avoid desiccation.

d) The water enclosed in the shell enables the barnacle to continue gaseous exchange as it does when submerged.

4 **Sea anemones**

Sea anemones occur in low positions in the intertidal zone. They have the following adaptations.

a) They are attached to rocks by their lower ends.

b) At low tide, they withdraw their tentacles and maintain a near spherical shape.

5 **Sea urchin (Arbacia lixula)**

It is very firmly attached to rock by its adhesive tube feet, so that it is not carried away by tidal water.

6 **Crabs**

a) Crabs move into cracks in rocks.

b) They hold on tightly to the rocks at low tide with their claws.

c) They have gills for breathing when submerged and spongy tissue for gaseous exchange when exposed to air.

7 **Worms**

These burrow into pockets of sand or debris in the rocks.

8 **Shore fishes**

These are small fishes which move into spaces between rocks at low tide. They have:

a) Flattened shape to be able to crawl into cracks in rocks,

b) Adhesive devices or modified fins for holding on to rocks.

Organisms of the subtidal zone

The organisms of the subtidal zone are always covered by water. There is no sharp division between the organisms of the intertidal and the subtidal zones. Several of the organisms found in the intertidal zone are also found in the subtidal zone such as astropecten (starfish), *Donax rugosus* (a snail) and *Terebra micans*.

The major factor that affects the distribution of organisms in this zone is the nature of the bottom which may be fine silt, or sandy silt, or silty sand or coarse sand. Other animals of this zone include the large snail, *Semifusus morio*, the cowrie snail, *Cypraea stercoania*, polychaete worms and the amphioxus, *Branchiostoma nigeriense.*

Brown algae, such as *Sargassium* are attached to the substratum by their holdfasts. Red algae occur at greater depths than the brown algae.

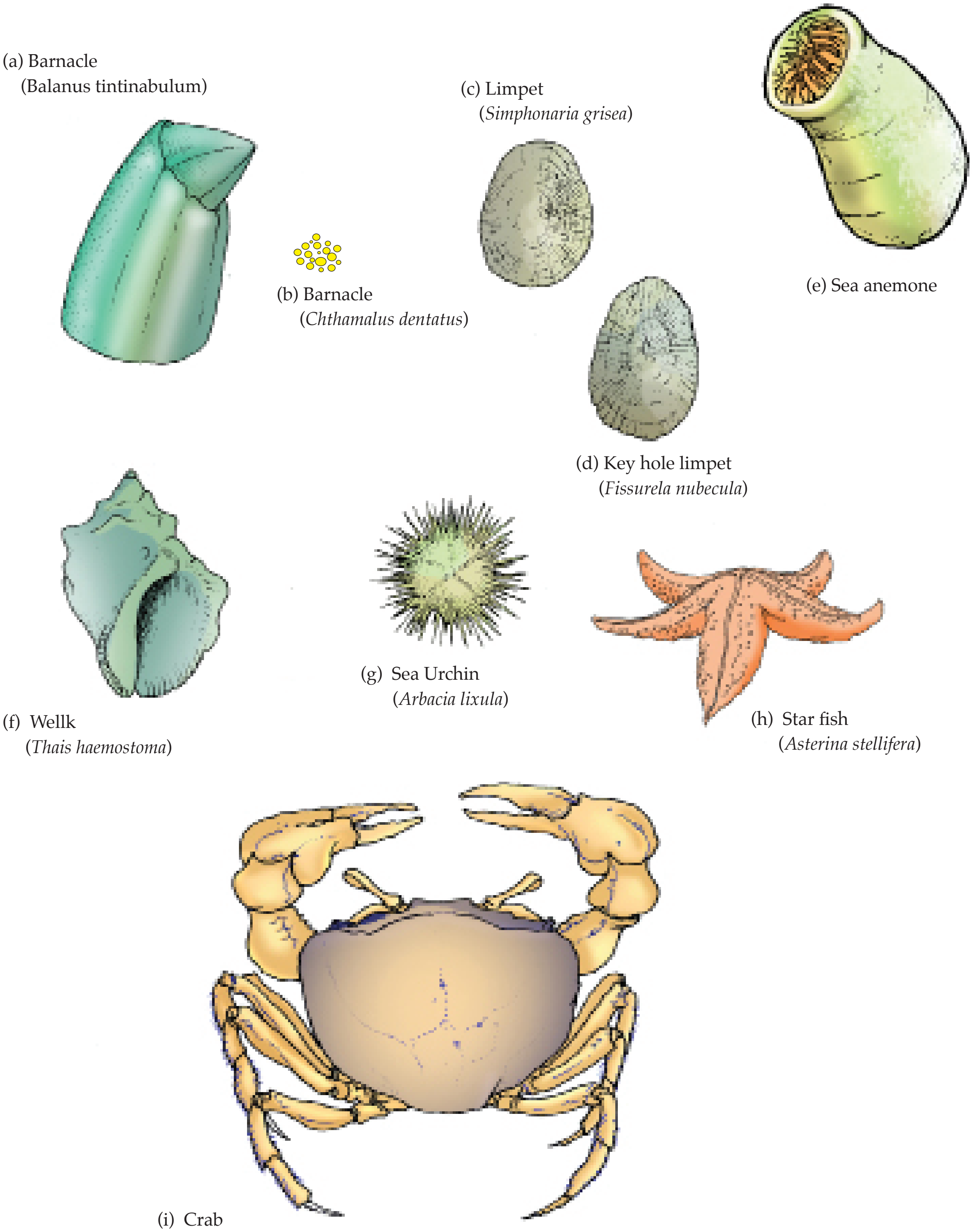


Fig. 13.5 Some animals of the rocky intertidal zone

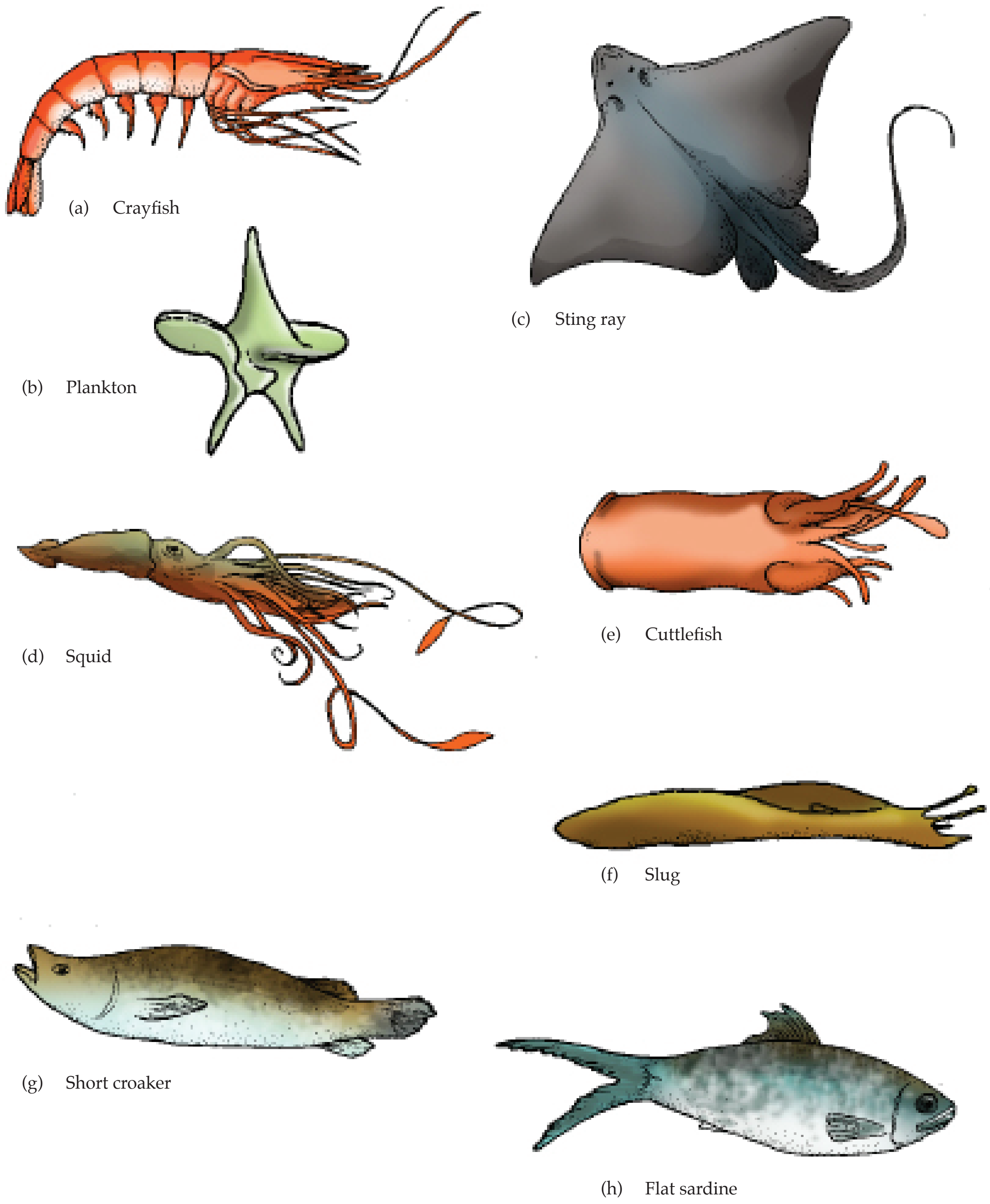


Fig. 13.6 Some animals of the neritic zone (Not drawn to scale)

Organisms of the neritic zone

In the neritic zone, the water is comparatively shallow, with a maximum depth of about 200m. This is the limit of the depth of water which light can penetrate. Sunlight and mineral salts are available and phytoplankton flourishes in this zone. The phytoplankton constitutes the first trophic level in various food chains. The neritic zones are rich in animal life and fish. Much commercial fishing takes place in this zone.

The adaptations of some organisms in the neritic zone are now described.

1 Phytoplankton e.g. diatoms, dinoflagellates

Phytoplankton are plants which are carried passively by water movements. Their adaptations for floating include the following:

a) They are small in size.
b) Some reduce their density by having mucilage around the cells e.g. diatoms.
c) Some have oil droplets in the cells to reduce density.
d) They pump out heavy K^+, Ca^{++} ions from vacuolar sap and replace them with lighter Na^+ ions.
e) Some achieve increased surface area by having projections from the cell wall e.g. Ceratium;
f) Expanded shape helps them to be supported by water.

2 Zooplankton (animal plankton)

These include protozoa such as flagellates, small crustaceans, larvae of various organisms such as annelid worms, molluscs, crustaceans, echinoderms. Most feed on phytoplankton. They are small in size, and have flattened or expanded shapes, with light density to enable them float.

3 Prawns and shrimps

Adaptations:

a) They have gills for gaseous exchange.
b) They have appendages for locomotion in water.
c) The exoskeleton prevents loss of water.

4 Bony fish

The bony fish caught in the Atlantic waters in West Africa include sardine, barracuda, lady fish, mackerel, and croaker among others.

a) A bony fish has a streamline shape.
b) It has a tail for movement, and fins for steering.
c) It has gills for gaseous exchange in water.
d) It has scales, which prevent loss of water from the body.
e) The body fluid of the bony fish is hypotonic to sea water. To prevent loss of water from the body to sea water by osmosis, a bony fish drinks sea water.
f) It excretes excess salt out of the body through the gills.
g) It passes out large amounts of hypotonic urine.
h) It has an air bladder for changing its position, up and down in water. When it secretes gas into the bladder its density decreases, and it rises up in water. When it reabsorbs gas from the bladder, it sinks.

5 Cartilaginous fish

Cartilaginous fish caught in West African Continental shelf waters include *Scoliodon* and sting ray.

Adaptations:

a) A cartilaginous fish has a streamlined shape.
b) It has gills for gaseous exchange.
c) It has a tail for locomotion and fins for steering.
d) The osmotic pressure of its body fluid is approximately equal to that of sea water. This is achieved through the dissolving of urea produced by the fish in its body fluid. There is then little tendency to gain water from or lose water to, the sea.
e) Scales on the skin prevent loss or entry of water into the fish.
f) The cartilaginous fish has a large liver which contains a large amount of low density oil called squalene. This oil helps the fish to have a low density that enables it to float.

6 Squid (Loligo)

The squid belongs to a group of molluscs called *cephalopods*. The adaptations of this organism include the following:

a) It moves very fast by pushing out water in a jet.
b) It hides from its enemies by producing an ink which colours the water.

Organisms of the oceanic zone

In the oceanic zone, plankton abound in the upper region of the water where light is present. Such plankton forms an important starting point for aquatic food chains. The major species of fish caught by trawlers in the Atlantic Ocean around Lagos include shark, ray, sea catfish, thread fin, big eye and croaker.

Organisms of the benthic zone

In deep water, the environment is stable. It is dark, oxygen concentration is low but not completely used up because cold surface water from the arctic region which contains oxygen flows under warmer water, to bring oxygen to benthic organisms.

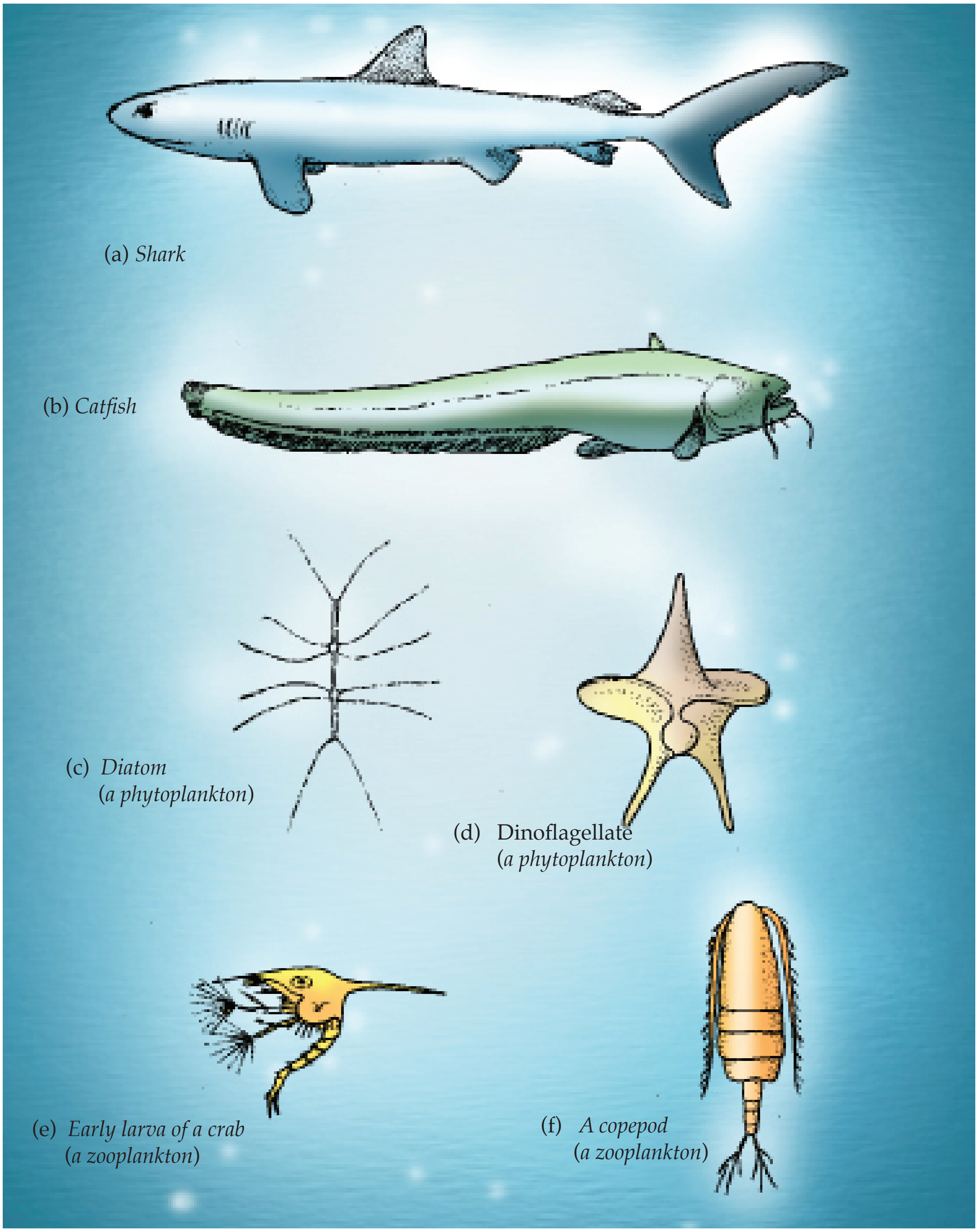


Fig. 13.7 Some organisms of the oceanic zone

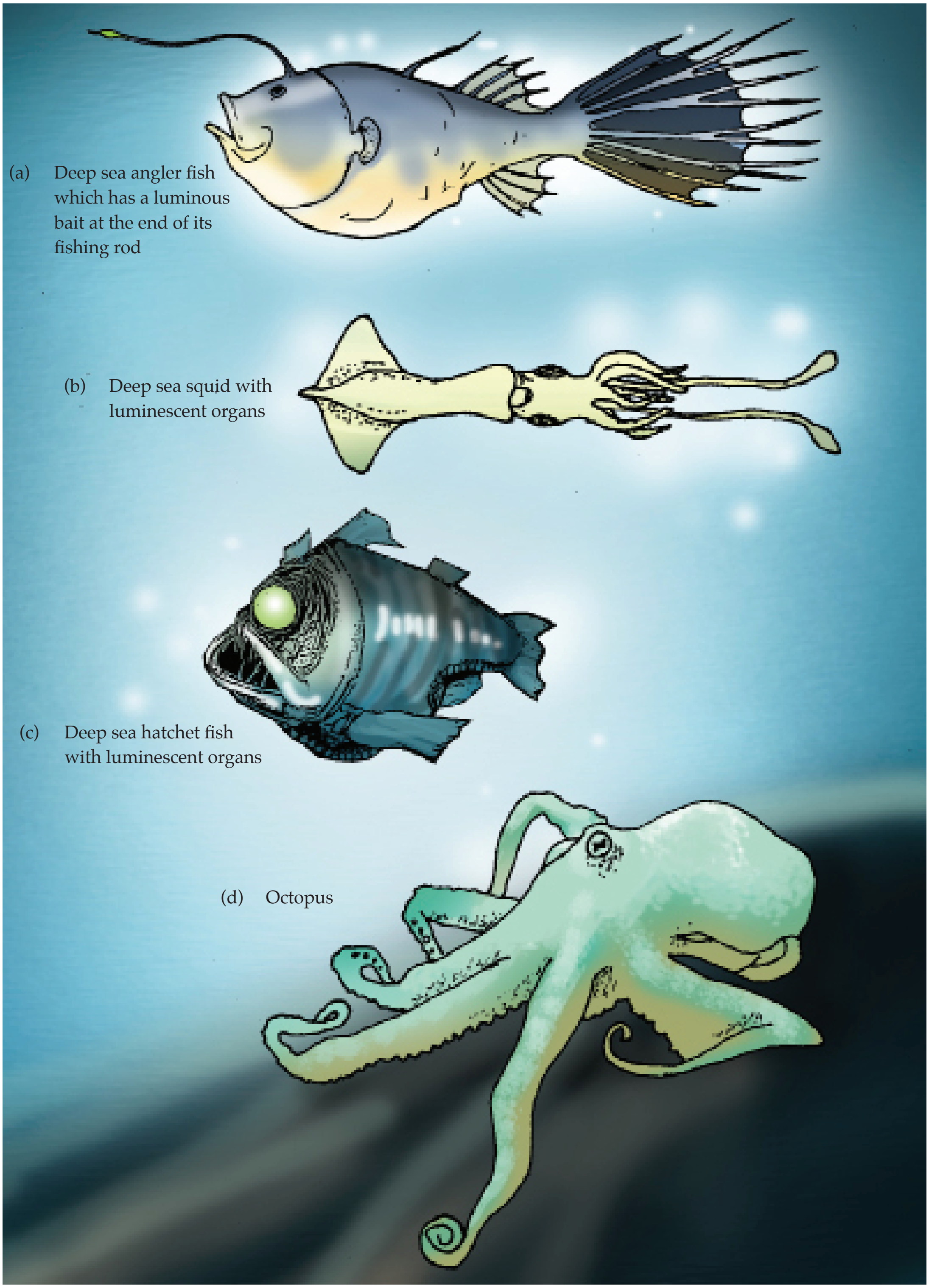


Fig. 13.8 Some deep sea organisms

Temperature and salinity are stable. Water currents are mild.

There are no benthic plants. Animals in this zone such as fish have the following characteristics:

1. They have curious shapes.
2. They have large mouths.
3. They often have fluorescent organs believed to attract their prey.
4. They can withstand high pressures.
5. They can withstand low oxygen concentration.

Practical study of a specific marine habitat

The intertidal zone is recommended for a practical study of the marine habitat because this zone can be studied without the use of boats or other special equipment.

Activity 13.1 Making a drawing of an intertidal zone

Materials required

Measuring tape about 100 m long, and drawing paper.

Procedure

1. Visit the shore at low tide.
2. Measure out a portion of an intertidal zone about 20 m long at low tide.
3. Make a plan of the habitat, indicating the low tide level and high-tide-level.
4. Indicate in the drawing any features of biological importance, e.g. hollows in the shore, containing water at low tide.

Activity 13.2 Identifying biotic components

Materials required

Plastic bags and bottles for collecting samples.

Procedure

1. Look around in the habitat. Observe and identify plant and animal species present.
2. Note the exact kind of place in which each was found, and mark it in your plan.

Activity 13.3 Measurement of habitat factors

Materials required

Thermometer, hygrometer, light meter, anemometer and pH meter.

Procedure

Measure the following:

1. Temperature
2. Relative humidity
3. Light intensity
4. Wind speed and direction
5. pH of the water.

Activity 13.4 Observing the distribution of organisms

Materials required

Students work in groups of five students per group. One long rope and two pegs per group, pencil and drawing paper. Use the transect-line method to study the distribution of organisms in this zone.

Procedure

1. Use a rope and two pegs to set up a line at right angles to the shore.
2. Begin from the high-tide mark and work carefully to the low-tide mark. Observe the distribution of organisms along this transect-line. Identify and record each species the line touches.
3. Each group should compare its result with those of other groups.

Activity 13.5 Observing the adaptations of plants and animals

Procedure

Observe and record the adaptations of plants and animals found in this zone.

The estuarine habitat

An estuary is the mouth of a river where seawater mixes with freshwater to produce brackish water. Tides occur in estuaries because they are close to the sea.

There are different kinds of estuaries.

1 The mouth of the river may be an open estuary; or
2 A delta may be formed by the deposit of sand or mud at the mouth of a river;
3 The estuary may be a lagoon.

Some rivers in southern Nigeria, such as the Ogun, Osun and Osse have open mouths. River Niger has a delta, and there is an extensive lagoon system in Lagos State. The conditions in open river mouths, deltas and lagoons are similar in many ways.

Characteristics of the estuarine habitat

a) The land is low lying.
b) The land is flat or has a small gradient towards the sea.
c) The valley of the river is usually shallow at the estuary.
d) Freshwater flowing downstream in the river mixes with tidal seawater.
e) The salinity in the estuary is intermediate between sea water and freshwater.
f) Salinity of water in the estuary varies in the following ways:
   i) Each day, there are two high tides. When the tide flows into the estuary, the salinity increases. When tide flows out to the sea, the salinity falls.
   ii) During the rainy season, much water flows down the river. Salinity in the estuary is reduced compared to the dry season. In the dry season, river water subsides, the salinity of estuarine water rises relative to that of the rainy season.
   iii) The salinity of estuarine water decreases from the sea end of the estuary towards the source of the river.
g) The flatness or small gradient of the land at the estuary causes the deposition of sand, silt or mud forming sand banks or mud flats.
h) Temperature changes in estuarine water are small because of frequent outflow and inflow of water.
i) Depending on the degree of turbidity, sunlight may reach the bottom of water in an estuary.
j) An estuary may overflow its banks causing the adjacent lands to be flooded frequently.
k) The soil at the bottom of, or close to an estuary is water logged and deficient in oxygen.
l) Waves and current are mild compared with the sea.
m) Estuarine water has lower specific gravity than sea water hence marine animals which float in sea water may sink and not do well in estuarine water.
n) An estuary is a disturbed area owing to the tidal flow in and out of it.

Distribution of organisms in an estuary

The organisms found in an estuary include:

a) Marine organisms which can tolerate low salinities;
b) Fresh water organisms which can tolerate moderate salinities;
c) Brackish water organisms which do not normally live in fresh water or sea water.

The principal factors that influence the distribution of animals in estuaries are the salinity levels and the tolerance of the various species to them. In the lagoons around Lagos, a zonation of organisms with salinity gradient has been observed. Where the salinity remains high all the time, polychaete worm, *Mercierella*, was found to be dominant among the species living in the stilt roots of red mangrove plants. Where the water was less saline, the oyster, *Gryphaea*, was dominant on the stilt roots of red mangrove, whereas where the salinity varied to very low levels, the barnacle, *Balanus*, was the dominant species.

Typical estuarine or lagoon animals are those which physiologically are tolerant to variation in salinity. These include the hermit crab, fiddler crab, hairy mangrove crab, common lagoon crab, mud skipper, the bloody clam, and the lagoon tulip.

On account of the tidal movements of water, estuarine contain few plankton including diatoms and algae. Zooplankton and bacteria are also present. Some of the common species of plant and animals found in estuaries are described below.

The red mangrove(*Rhizophora racemosa*)

The red mangrove is the main plant that grows on new mud banks. Its adaptations are:

1 The seeds germinate on the tree and the radicle grows down to about 30 cm. Then the seedling falls down, floats in water at an angle, alive for a long time, and is carried by tides, currents and wind until it reaches a mud bank. The rippling action of water pushes the root into the mud.
2 The seedling has large cotyledons with stored food.
3 The young seedling has no root hairs, but gives out numerous rootlets which absorb water and mineral salts. They also act as anchors in soft shifting mud.
4 The seedling grows fast. The stem grows up and soon produces branches. The stem produces *prop roots* below the first branches. These prop roots on reaching the mud, put out many spongy roots which in their turn produce numerous rootlets.

The rootlets help the plants to stand in soft mud. The rootlets help also to stabilise the mud.

5 From higher branches, the plant grows out *drop roots*. These do not thicken. The drop roots contain spongy tissue with many air spaces. They are used for obtaining air.

6 The plants have thick leathery leaves to reduce loss of water by transpiration.

7 It is physiologically tolerant to saltwater. On account of the above, the red mangrove is the first coloniser of mud flats in estuaries.

The white mangrove (*Avicenia nitida*)

The white mangrove occurs on salty, water- logged, oxygen deficient soil, close to the estuary. It has special adaptation of survival in its habitat.

1 The white mangrove has breathing roots (or pneumatophores) which grow upwards to about 15cm above the soil. The breathing roots contain spongy tissue, used for obtaining air.

2 The plant excretes excess salt through the leaves.

3 The leaves are thick, and have thick cuticle to reduce transpiration.

4 The cotyledons are fleshy and contain stored food.

5 The plant has a wide variety of pollinators.

Paspalum vaginatum

Plants that live in or near sea or brackish water often show features of plant of dry areas. This is because the high osmotic pressure of the soil water makes it difficult for them to absorb water.

Paspalum is a grass that occurs in estuarine habitats.

1 The leaves are short and thick, to reduce transpiration.

2 It colonises mud by vegetative reproduction.

Bulrush *(Cyperus anticulatus)*

This plant has green leafless stems up to 1.3m high, used for making mats.

Mudskipper *(Periophthalmus)*

The mudskipper is a fish which has various adaptations to the estuarine habitat.

1 It has several methods of locomotion. It can swim in water; it can crawl and hop on land with the aid of its modified pectoral fins. It can flap over the surface of shallow water or wriggle over soft mud or up stilt roots of the red mangrove in search of food.

2 It has gills for gaseous exchange in water. It has accessory respiratory organ for gaseous exchange when out of water.

3 It can crawl into spaces between rocks for protection.

4 It has physiological tolerance to changes in salinity.

Barnacles

Barnacles live in the brackish water in estuarine habitats. They show a zonation on the stilt roots of the red mangrove trees.

1 The animal is attached to stilt roots so that it is not carried away by incoming or outflowing tidal water.

2 It has a shell that covers and protects it from desiccation when exposed.

3 It encloses water in its shell, so that it continues with respiration with gills even when exposed at low tide.

4 It has tolerance to changes in salinity which occur in the estuary.

Hermit crab (*Clibernarius Africana*)

It is adapted to this habitat in the following ways:

1 It lives in the empty shell of a snail in the habitat.

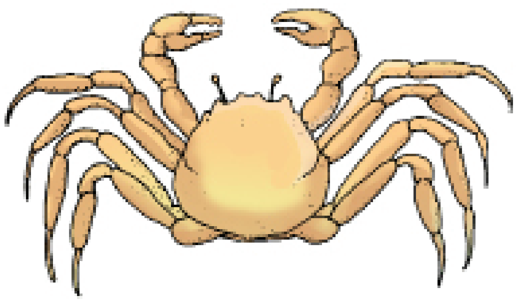
2 Its body remains in the shell for protection but its legs can emerge for a short distance.

3 It has specially modified legs for holding tightly to the shell.

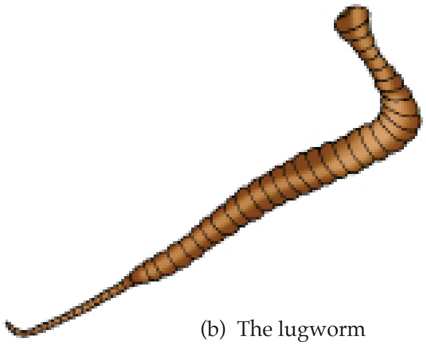
4 It has physiological tolerance to variations in salinity in its habitat.

Practical study of an estuary

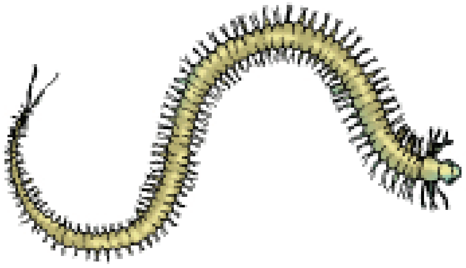
A convenient part of an estuary should be selected, such as a shallow part of the open estuary, or a portion of the intertidal zone.



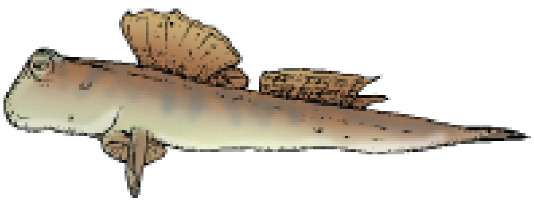
(a) Sand crab



(b) The lugworm
Arenicola



(c) The ragworm
Nereis



(d) Mudskipper

Fig. 13.9 Some typical estuarine organisms

Activity 13.6 Making a drawing of an estuarine habitat

Materials required
A long measuring tape, a pencil and drawing paper

Procedure
1. Measure out a convenient portion of an estuarine habitat.
2. Make a drawing of the habitat.
3. Indicate in the drawing any feature of biological importance.

Activity 13.7 Identifying biotic components

Procedure
Look around in the habitat, observe and identify plant and animal species present.

Activity 13.8 Measurement of habitat factors

Materials required
Metre rule, hydrometer, secchi disc, thermometer, light object such as table tennis ball, two pegs, stopwatch, measuring tape and pH meter

Procedure
Measure and record the following habitat factors:
1. Height of water at the time of the study
2. Density of the water
3. Degree of clarity of the water
4. Temperature
5. Speed of flow of the water
6. pH
7. Relative humidity of the air

Activity 13.9 Observing the distribution of the organisms

Procedure
1. Study the distribution of the organisms.
2. Find out, as much as possible, about the factors influencing the distribution of the organisms.

Activity 13.10 Observing the adaptation of the plants and animals

Observe the adaptation of the plants and animals, including means of attachment and means of surviving changes in salinity.

Activity 13.11 Constructing food chains

Construct some food chains based on the organisms present in the estuary.

The freshwater habitat

Freshwater habitats are very often selected for ecological study because they are conveniently close to a number of schools, which is hardly the case with marine or estuarine habitats. The characteristics of freshwater habitats are different from those of marine and estuarine habitats. The organisms are also different.

Characteristics of freshwater habitats

1. Freshwater habitats contain no significant amount of salt.
2. The body of water is relatively small, compared to oceans.
3. There is significant seasonal variation in freshwater habitats. For instance, some rivers and streams dry up in the dry season. Those that do not dry up completely have very much reduced volume. In the rainy season, the volume increases again. There is also seasonal variation in the degree of turbidity and speed of flow of the water. In the rainy season the water tends to be more turbid than in the dry season, owing to the addition of debris to it by surface floods. The speed of flow is greater in the rainy season than in the dry season.

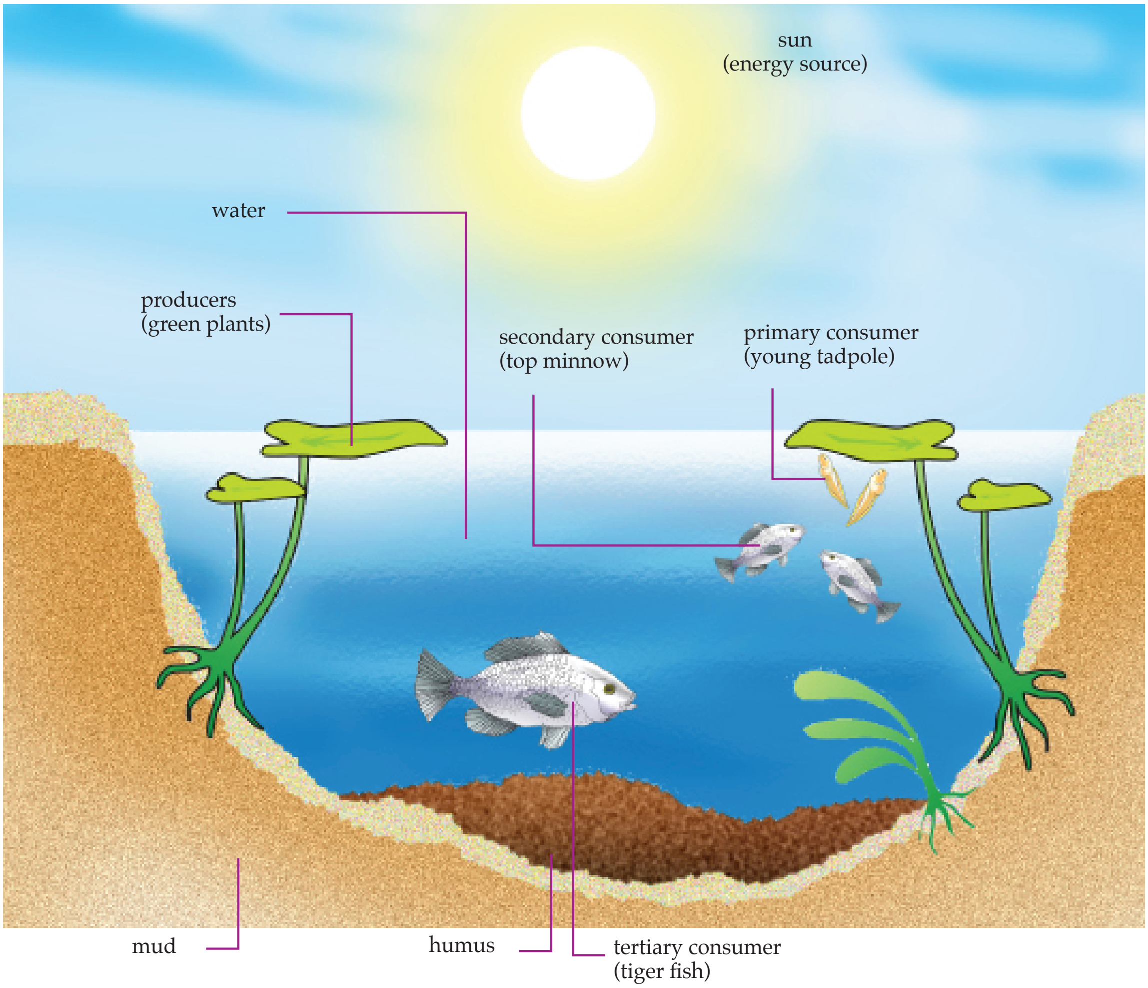


Fig. 13.10 Organisms in a freshwater habitat

4 Freshwater habitats are usually shallow, or relatively so, and light often penetrates through the water to the bottom.

5 The temperature of a body of freshwater varies with depth and season. Since the body of water is not usually large, the difference between surface and bottom temperatures is not as great as that obtainable in the sea.

6 Oxygen is usually available in all parts of the water, although moreso in the surface layers.

Types of freshwater habitats

Freshwater habitats may be divided into two main kinds, namely **lentic** water, which does not flow and calm and **lotic** water, which is flowing. **Lentic** freshwater habitats includes pools, ponds, lakes, while lotic freshwater includes springs, streams, and rivers. The dividing line between **lentic** and **lotic water** is not often sharp, as parts of a stream or river may be very slow- flowing.

Ecological zones of freshwater habitats

The zone of lentic freshwater habitats is similar to those of the marine habitats, but there are no supratidal or intertidal zones. The shallow part of the bottom is the littoral zone while the deeper part constitutes the benthic zone. The littoral zone may be distinguished from the benthic zone by the fact that the littoral zone has rooted vegetation at its base while the benthic zone does not, although flowering plants may float at the surface.

In lotic freshwater habitats, there are two zones, the pool zone, where the water is relatively slow and calm, and the rapid zone where the flow is fast.

Distribution of organisms in freshwater habitat

Many kinds of plants and animals live in freshwater and each species usually occurs in a particular zone of the freshwater. The following are some examples:

1 Plants at the waters edge

Reeds and sedges grow at the edge of freshwater, rooted in the soil.

2 Plants that are rooted in the mud in shallow water

Plants which grow in shallow water, with well-developed root systems in the mud, include *nymphaea* (water lily) *cytosperma senegalense* (water arum), crinum lily, ferns (e.g *naphrolepis*), commelina grasses and sedges, *costus sp* and *lpomea aquatica*.

3 Floating plants

Plants which float on the surface of the water include *pistia straliotes* (water lettuce), water ferns, such as *azolla* and *salvinia*, *lemma* and *wolffia* (duckweeds), diatoms, chlamydomonas, and bluegreen algae. Plants which float submerged in the water include spirogyra, *ceratophyllun* (hotnwort) and *utricularia* (bladderwort).

4 Zooplankton

Zooplankton is abundant in lentic freshwater, such as ponds and lakes. The animal's species frequently comprising the zooplankton include copepods, such as Cyclops and Daphnia (water flea).

5 Active animals found on the water surface

Active animals found on the water surface include the water skater, and the whirling beetle.

6 Animals that live in the main body of the water

Actively-swimming organisms, such as fishes, live in the main body of water. Some freshwater fishes are *Tilapia*, *Clarias* (mudfish), *Labeo coubia* (African carp), *Synodontis filamentosa* (cat fish) and *Al-estes longispini* (characin). Active animals which can swim against water currents are collectively called *nekton*.

7 Animals found at the bottom

The animals that live at, or close to, the bottom of the water include leeches, caddis fly larvae, larvae and pupae of mosquitoes, water snails, water spiders, crustaceans such as crayfish, water scorpions, and water boatmen. Bottom dwelling organisms are collectively called the *benthos.*

8 Amphibians

Toads and frogs live both on land and in freshwater. Toads may spend more time on land than in water, but they still return to the water for reproduction.

9 Reptiles

There are snakes which live in water. Crocodiles live both in water and on land, but they breathe atmospheric air.

10 Birds

Birds that wade in water in search of food include the heron and stork. Ducks swim in water in search of annelids, molluscs and other small animals as food, while birds such as the king fisher dive into water to catch fish.

11 Mammals

The hippopotamus is a large mammal that lives in water. Other mammals that can swim include the waterduck and giraffe.

Adaptive features of freshwater organisms

Freshwater organisms share many adaptations with marine and estuarine organisms relating to locomotion, respiration, production and protection. Some special cases are mentioned below.

Floating plants

They have various devices for keeping afloat such as presence of air bladders, expanded shape and light weight.

Locomotion

Many freshwater animals have organs of locomotion. For instance, the pond skater, Geris, has long legs with which it skates on the water surface.

Respiration

Generally, freshwater animals obtain oxygen through gills. The water bug and the water boatman carry bubbles of air with them as they go below the water surface to the bottom and use these as their air supply under water. The bloodworm is a larva of a dipteran fly, which is red in colour. Its red colour is due to the presence of a high concentration of heamoglobin which enables it to adapt to the low oxygen at the muddy bottom where it lives.

Lung fishes, such as *protopterus*, obtain oxygen through gills, but when the water dries out in the dry season, they dig into the mud and breathe air with lungs until the rains come and the river or stream water covers them again.

Practical study of a stream

Activity 13.12 Making a plan of a fresh water habitat

Materials required

A long measurement tape, pencil and drawing paper

Procedure

1 Mark out a portion of a stream, about 20m long for class study.
2 Make a drawing of the stream.

Activity 13.13 Identifying the biotic components

Materials required

Metre rule, Secchi disc, thermometer, light object such as a table tennis ball, stopwatch, two pegs, a measuring tape and a pH metre.

Procedure

Measure and record the following habitat factors:

1 Height of water
2 Degree of turbidity, using a Secchi disc
3 Temperature of the water
4 Speed of flow of the water
5 pH.

Activity 13.14 Observing the distribution of the organisms

Materials required

A long rope, measurement tape, pencil and drawing paper

Procedure

1 Place a rope across the stream and tie each end of the rope to a peg.
2 Record each plant that occurs along the rope and its exact distance from your starting.
3 Make a drawing to show the cross-section of the stream and the locations of the plants along the line represented by the rope.
4 Observe and record where different animals are found in the stream.

Activity 13.15 Observing the adaptations of the plants and animals

Observe and record the adaptations of a selected number of plants and animals such as water lettuce, water lily, *Utricularia, Lemna*, mosquito larva, water boatman, and *Tilapia*.

Activity 13.16 Constructing food chains

Construct some possible food chains based on the organisms present in the stream.

Summary

This chapter has taught the following:
- Aquatic habitats are subclassified into marine, estuarine and freshwater habitats on the basis of the salt content of the water.
- Marine habitats are the oceans and seas which contain much salt.
- Freshwater habitats are streams, rivers, ponds and lakes which do not contain significant amount of salt.
- Estuaries contain moderate amounts of salt.
- The major ecological zones of the marine habitat include the supratidal, intertidal, subtidal, bathyal, abyssal, hadal, neritic and oceanic zones. The organisms in each zone are adapted to life in that zone.
- Estuaries are characterised by changes brought about by the tidal activity and the amount of fresh water flowing down the river into the estuary. Organisms in this habitat have to withstand variations, in water salinity, density and depth.
- Freshwater habitats are relatively small in size and experience significant seasonal variations. Some freshwater organisms live at the edge of the water, some float on the water, others live in the water while some are attached to the bottom. All are suitably adapted to the places in which they live, within their respective habitats.

Revision questions

1 Freshwater is a body of water which ________________________.
   A contains no suspended matter
   B is good for drinking
   C contains no significant amount of salt
   D has no colour or taste
   E has not been stored for a long time

2 Contractile vacuoles are present in freshwater microorganisms such as *paramecium* and *amoeba,* but usually not in marine microorganisms. The reason for this is that ________________________ ________________________.
   A freshwater organisms obtain oxygen mainly through their contractile vacuoles.
   B the concentration of salts in seawater is higher than that in the body of the marine organisms.
   C the concentration of salts in freshwater is lower than that in the body fluids of the freshwater organisms.
   D freshwater organisms need to store water inside their bodies because the freshwater may dry up.
   E more water evaporates into the atmosphere from freshwater than from sea water.

3 Which of the following factors affects organisms in all aquatic habitats?
   A Salinity
   B Tides
   C Shape of habitat
   D Noise
   E Altitude

4 Of the following, the one that aquatic plants are least likely to require is ______________________.
   A water storage tissue
   B air storage tissue
   C stomata
   D chlorophyll
   E carbon dioxide

5 With the aid of a large labelled diagram, describe the major ecological zones of the marine habitat.

6 The estuarine habitat is in several respects intermediate between the marine and the freshwater habitat. Illustrate this fact with reference to named features.

7 Describe the effects of the following factors on the distribution of organisms in freshwater habitats:
   A Clarity of water
   B Depth of water
   C Speed of flow of water
   D Nature of the bottom.

8 Give an account of the adaptations of either plankton or organisms which live in the intertidal zone.

Chapter 14 Terrestrial habitats

Introduction

Terrestrial habitats are land habitats. Habitats of different kinds present different problems to living things. Life is believed to have started in water, and in due course, organisms that were suitably adapted moved on to land.

In general, land habitats present more problems to living organisms than aquatic habitats. Water, which is essential for life, is readily available in aquatic habitats. On land, water may be scarce, unpredictable or even unavailable, as in arid areas. Desiccation is a constant threat to organisms on land. Gaseous exchange, support of the body, excretion movement and reproduction present more problems on land than in water. Ecological factors such as temperature, wind and low relative humidity can be more harsh on land than in water.

In this chapter, you will study four kinds of terrestrial habitats: marsh, forest, savannah and arid lands. You will learn about the ecological factors that operate in them, the organisms that live in them and how they are distributed and adapted to live successfully in these habitats.

Marsh

A marsh is a lowland habitat which is flooded at all times, and in which grasses and shrubs grow. While a marsh is a terrestrial habitat, it represents, in many ways, a transitional habitat between the aquatic and terrestrial.

Characteristics of a marsh

1. The habitat is a lowland.
2. The ground is flooded most of the time.
3. The soil is wet, soft and water-logged.
4. Sometimes there are pools of standing water here and there in the habitat.
5. The relative humidity in the atmosphere over the habitat is usually high.
6. The bodies of water usually contain much decaying organic matter.
7. The decay of organic matter takes place on a large scale in a marsh and this causes a decrease in the oxygen content of the water. Under the mainly anaerobic conditions in the water or soil, foul-smelling gases may be produced in which hydrogen sulphide and methane may be present. The products of this decomposition change the chemical properties of the marsh. For instance, some marshes are very strongly acidic.

Formation of marshes

Marshes are usually formed near rivers or other bodies of water, such as lagoons. The land is low lying and its elevation is a little, if any, above the level of the river or lagoon water. During the rainy season, the river overflows its banks and its waters may flood the adjoining land. The flooded land receives additional water from rainfall. The land absorbs some or all of such water until it becomes saturated, leaving a layer of water lying on the surface. In the dry season, some of the water covering the marsh evaporates, leaving pools of water, separated from one another by patches of land.

The water in a lagoon may also flood the adjoining lowland, causing the formation of a marsh. At high tide, when seawater flows into the lagoon, the lagoon may be filled to overflowing, thus flooding the adjoining lowland. Again, during the rainy season, the rivers flowing into the lagoon bring in a lot of river water to overflow into the marsh.

A marsh may also be formed when debris partially fills up a lake.

Types of marshes

Marshes maybe either saltwater or freshwater marshes. In Nigeria, saltwater marshes are found in a belt along the Atlantic coast, which is influenced by the tides. Usually, freshwater flowing down the rivers, which empty into the sea, mixes with tidal seawater in the estuaries, creeks and lagoon. In the dry season, the volume of river water is relatively small, but in the rainy season, it is large. This large volume of river water mixes together with tidal seawater in estuaries, creeks and lagoons, filling them up and causing them to overflow their banks.

The water that floods the land near the estuaries, creeks and lagoons is a mix of fresh and saltwater, hence the marshes are called saltwater marshes.

Freshwater marshes occur inland, just beyond the limits of the saltwater marshes and beyond the areas influenced by tides. In this zone, only the fresh-water of the rivers overflows the river banks to flood the adjoining lowland, forming freshwater marshes.

Plants and animals that live in marshes

Plants found in saltwater marshes include various grasses and also algae that float on the water surface. The most common animals of saltwater marshes include the mangrove-crab, lagoon crab, hermit crab, mudskipper fish, bloody clam (*Arca senillis*) oysters, barnacles and angel-fish.

In fresh water marshes, the floating plants in standing water include algae, water lettuce, *Lemna* and *Salvinia*. Near the edge of the water may be found *Cyrtosperma* (water arum), various ferns and varieties of sword grass. The animals include frogs and toads, as well as fishes and birds that wade into the water to feed on fish for example, the heron.

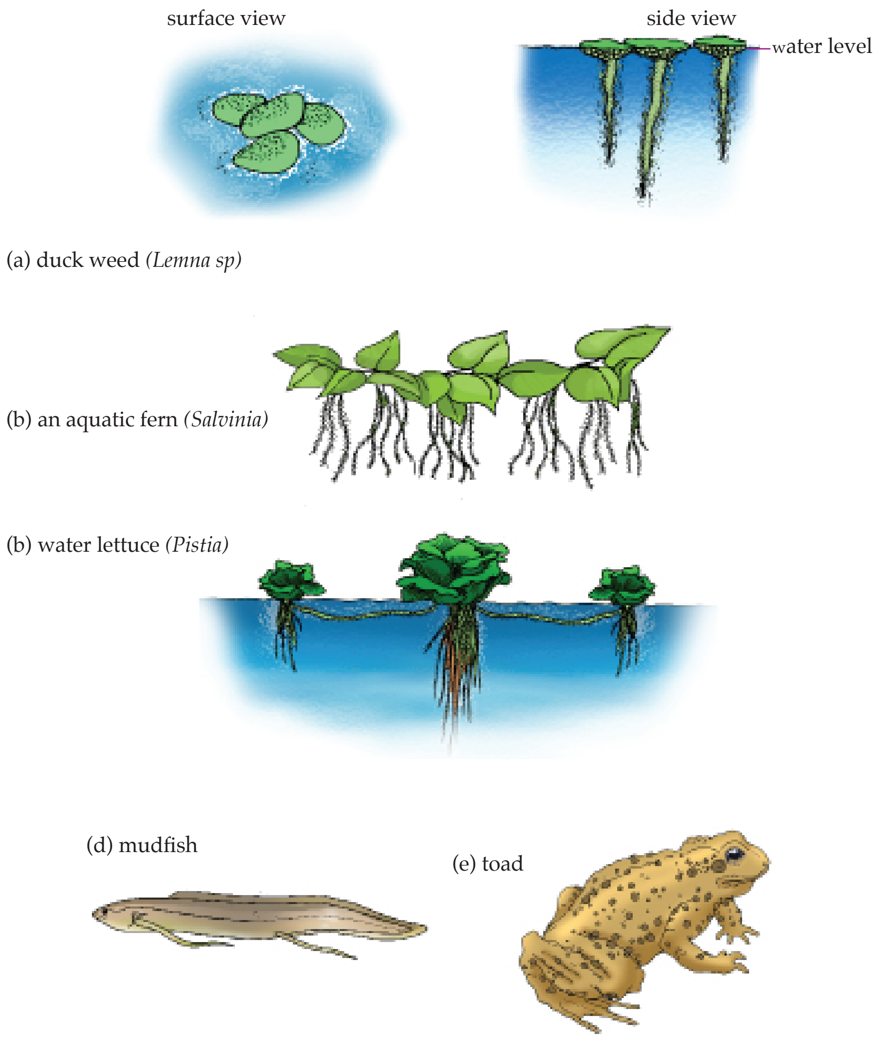


Fig. 14.1 Plants and animals that live in marshes

Adaptive features of plants and animals in marshes

In saltwater marshes, all the organisms have to be able to tolerate the salinity of the soil or water. They also have to tolerate the low oxygen concentration in the soil and water.

In freshwater marshes, the plants show adaptations similar to those of freshwater plants. Saprophytic organisms such as bacteria, which live on the dead organic matters in marshes, have to adapt to the mainly anaerobic conditions here.

Practical study of a marsh

Activity 14.1 Making a plan of a marsh

Materials required
Measuring tape, pencil and drawing paper
Procedure
1 Mark out an area of the marsh.
2 Make a drawing of the area marked out for study.

Activity 14.2 Measuring of physical ecological factors

Materials required
Thermometer, pH meter, light meter, and a hygrometer

Procedure
Measure the physical ecological factors in the habitat, such as soil temperature, air temperature, pH, light intensity, relative humidity.

Activity 14.3 Identification of plants and animals

Materials required
Plastic bags and bottles for collecting specimens

Procedure
1 Identify the plants and the animals in the habitat.
2 Collect and preserve some of these.

Activity 14.4 Observation of the distribution of organisms

Procedure
Use the techniques you used to study aquatic habitats to observe the pattern of distribution of organisms in the area.

Activity 14.5 Observation of adaptive features

Procedure
Observe the adaptive features of selected organisms in the habitat.

Activity 14.6 Construction of food chains

Procedure
Construct some food chains based on the organisms found in the habitat.

Forest

A forest is a plant community in which tree species are dominant. There are different kinds of forests, whose distribution is determined mainly by climate (particularly rainfall and temperature), but sometimes by elevation, soil factors and the activities of man, such as farming, lumbering, cutting of firewood, bush burning, road construction and building construction. Forest used to cover most of southern Nigeria but the area covered by forest has been reduced by human activity. The rain forest is the major type of forest in Nigeria.

Characteristics of the rain forest

1 The rainfall is high.
2 The tree species are usually mesophytes, with broad leaves. Mesophytes are plants adapted to life in an area with neither an excess nor a shortage of water.
3 Stems of trees have thin bark.
4 Tall trees have buttress roots which give additional support to them and prevent falling caused by strong wind.

5 Many reinforced trees produce flowers on the main stem, as the cocoa tree does. This is called cauliflory. This is considered to facilitate pollination, because the flowers are not easily blown down by wind.
6 Leaves of all trees have long drip tips to facilitate dripping off of water.
7 The vegetation has a pattern of arrangement in storeys or layers.
8 The topmost layer of leaves or canopy cuts off most of the light reaching the lower levels of vegetation so that there is only dim light at the forest floor.
9 The forest floor is usually open with little vegetation.
10 There is usually a large amount of leaf litter on the forest floor.
11 The rain forest usually has many climbing plants such as wild yam, and epiphytes such as ferns.

Strata in a rain forest

The plants in a forest may be classified into five storeys or layers which are briefly described as follows:

1 The top layer or storey is made up of the tallest trees, over 40m tall, called *emergents.* The crowns of the emergents do not normally touch one another.
2 The second storey or layer is made up of tall trees, between 16m and 40m tall. Their crowns touch, forming a continuous canopy below the emergents.
3 The third layer is made up of small trees, less than 16m tall, which also form a continuous canopy below the second or middle storey.
4 Below the third layer of trees is the shrub layer.
5 At the forest floor is the ground layer which consists of shade-tolerant plants, including mosses and ferns.

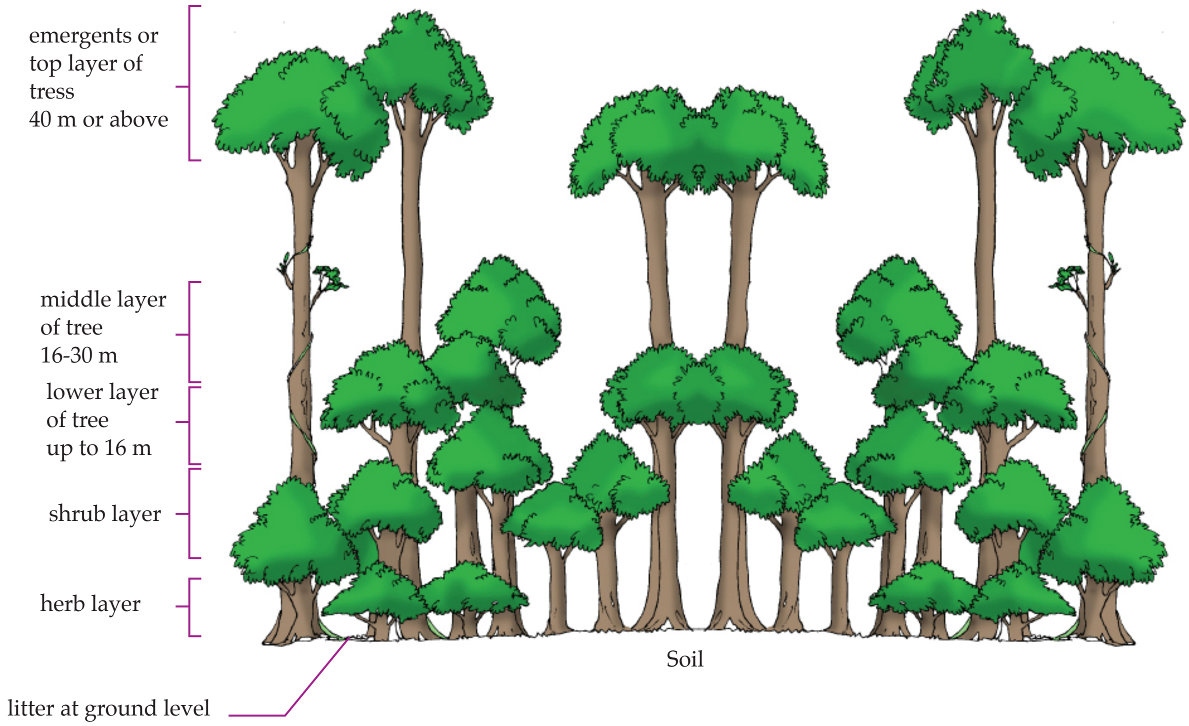


Fig. 14.2 Profile of a tropical rainforest

Distribution of organisms in a forest

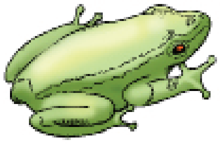
In a forest, there is a vertical distribution of plants according to their respective needs for light and their respective abilities to withstand exposure. On the forest floor, there are shade-tolerant plants, such as ferns, which can do with little light, and prefer the protected, humid environment of the forest floor to the exposed conditions higher up. At various levels, epiphytic orchids, ferns and herbs are found on the trunks and branches of trees where they are able to establish themselves in holes, the barks of trees or meeting points of two or more branches. The mistle toe is one of the most light-demanding epiphytes and is usually found high up in the trees, among the topmost smaller branches, where much light is available.

The fig is another epiphyte found on forest trees. Fig fruits are eaten by birds. The seeds are covered by a sticky thick juice by which they stick to the birds' beaks. The birds may then wipe their beaks against tree trunks or branches and the fig seeds may stick to such trees or drop from the birds' beaks into cracks on the barks of the trees, where they germinate. The young fig trees grow roots which attach it to the tree. The roots continue to grow downwards until they reach the ground and attach the plant to the soil. Thereafter, the fig tree continues to grow bigger and bigger, and produce more and more roots which clasp the tree on which it started life. Eventually, the fig tree may strangle the tree that helped it grow.

Climbers found on forest trees use their climbing habit to reach the sunlight at the top of the forest. There are many kinds of saprophytic fungi and bacteria which feed on the leaf litter on the forest floor.

Many forest animals live on the tree. They include monkeys, squirrels, snakes, bats, birds, lizards, tree frogs and chameleons. Some forest animals, such as earthworms and beetles, live in the soil. Others, such as millipedes, ants and snails, live amongst the leaf litter on the surface of the soil.

(a) Fruit bat

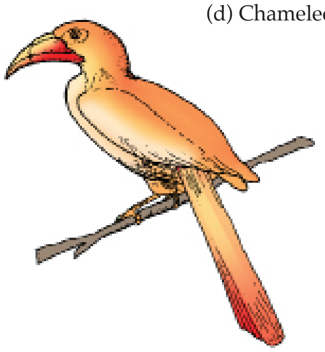


(b) Tree frog

(c) Flying squirrel

(d) Chameleon

(e) Wood owl



(f) Allied hornbill

Fig. 14.3 Some arboreal forest animals

Adaptations of forest plants

Forest trees have adaptive features for life in their environment. These include the following:

1 They have well-developed root system to hold them in the soil and to absorb water.
2 They have large amounts of strengthening tissues such as xylem, for support.
3 They have stomata and lenticels for gaseous exchange.
4 They have broad leaves, since water conservation is not a serious problem.
5 They have thin barks.
6 The leaves have long drip tips to facilitate drying of the leaf surfaces after rains.
7 The trees have buttresses for additional mechanical support.
8 Plants growing in the shade have broad leaves, which are thin, with few layers of mesophyll cells for photosynthesis.
9 Cauliflory improves chances of pollination and fruit production.

Climbing plants in the forest are adapted for climbing by the use of hooks and roots. Many are thigmotropic and respond to touch of the support plant by twining around it. Shade plants are adapted for carrying out photosynthesis in dim light conditions.

Adaptations of forest animals

Animals that live on trees in forests have many kinds of adaptations for arboreal or tree life. These include:

1 The ability to fly, e.g. birds, bats, flying squirrels.
2 Adaptations of climbing, such as:
   a) Presence of opposable fingers, e.g. monkeys.
   b) Prehensile tails, e.g. chameleons.
   c) Sticky discs on fingers, e.g. geckos.
   d) Grasping scales, e.g. snakes.
   e) Ability to jump from branch to branch, e.g. monkeys
   f) Grasping pads, e.g. tree frogs.

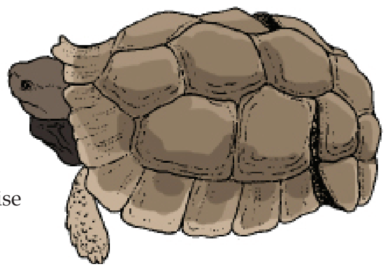
Food chains in a forest

Numerous food chains and food webs exist in a forest. The producers are the herbs, shrubs and trees. Herbivores include insects, rats, squirrels and monkeys which eat the plants. Civet cats, toads, snakes and chameleons are some of the carnivores which eat the herbivores. Leopards and other higher carnivores eat the lower carnivores.

Effects of soil on forest

Soil factors such as depth of soil, chemical composition, pH and texture influence the nature of a forest and the tree species present. If a soil is fertile and deep, with a good water-holding capacity, the rainfall is high enough and other factors are favourable, the vegetation can be a dense forest. If however, the soil is chalky, highly eroded, shallow, or very rocky, the forest may be poor even if rainfall and other climate factors are favourable. Where soil conditions are peculiar, such as where the soil is very acidic, only specially adapted plants can thrive.

(a) Black cobra



(b) Common hinged tortoise

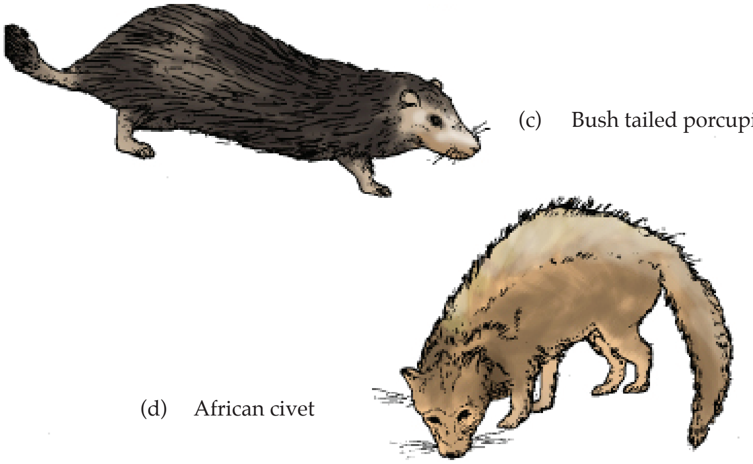


Fig. 14.4 Some ground dwelling forest animals

Practical study of a rain forest

Activity 14.7 Drawing a forest habitat

Materials required
A long measuring tape, pencil and drawing paper

Procedure
Mark out and draw an area of the forest selected for study.

Activity 14.8 Measuring ecological factors

Materials required
Thermometer, hygrometer and light meter

Procedure
Measure ecological factors such as temperature, relative humidity and light intensity in the study area.

Activity 14.9 Identification of biotic components

Procedure
Identify the plants and animals found in the habitat.

Activity 14.10 Observing the distribution of plants and animals

Procedure
Observe and record how the plants and animals in the habitat are distributed, as you have done before.

Activity 14.11 Observation of adaptation

Procedure
Observe and note down the adaptations of some selected plants and animals to their forest habitat.

Activity 14.12 Construction of food chains

Procedure
Construct some food chains based on plants and animals you identified in the habitat.

Grassland

Grassland is a plant community in which grass species are dominant, but trees and shrubs may also be present.

Characteristics of grassland

1. The rainfall is from moderate to low.
2. The distribution of rainfall throughout the year is often such that several months are without rain.
3. Sunshine is intense.
4. Bush fires are common in the dry season.
5. The soil is usually sandy.
6. The moderate rainfall and high temperature make water conservation very necessary for plants and animals.

Types of grassland

Grasslands are classified into tropical and temperate, depending on whether they occur in tropical or temperate zones respectively. Temperate grasslands are given different names in different countries, such as the *prairies* in United States of America, the *steppes* in Russia and Asia, the *pampas* of Argentina, the *veldt* of South Africa and the *downs* of Australia. Tropical grasslands are called *savannah*, such as in West Africa.

In Nigeria there are different types of savannah:

1 Southern Guinea savannah

This is characterised by very tall grass, with scattered trees and shrubs. It occurs where the rainfall is fairly high (250mm to 500mm per annum). In the rainy season, the vegetation is very rich and green, while in the dry season it is dry and brown. Bush fires are common in the dry season. The common tree species are fire-resistant.

2 Northern Guinea savannah

This type of savannah is characterised by the presence of short grasses and some characteristic trees, such as *Isoberlina doka*. The rainfall is low (500mm to 300mm per annum). The vegetation is shorter and more sparse than in the southern guinea savannah. The trees species present also tend to be smaller in size and fewer in number than in the southern guinea zone. Much of this zone in Nigeria is thickly populated, and the vegetation has been very much affected by farming, housing and other human activities, as well as by grazing of domestic animals.

3 Sahel savannah

This type of savannah occurs in Nigeria only on the eastern tip of Borno State, around Lake Chad. It is characterised by a poor vegetation of short grass and small trees; rainfall is low and spread over only a few months of the year.

4 Derived savannah

Owing to such human activities as farming, house construction and bush burning, grasslands now exist in certain parts of Nigeria where the climate could support a rain forest vegetation. This type of grassland, which is maintained by human activity, is called **derived savannah**. In appearance, derived savannah resembles southern guinea savannah but in essence it is artificial, for when human influence is withdrawn for many years, the derived savannah reverts to a rain forest.

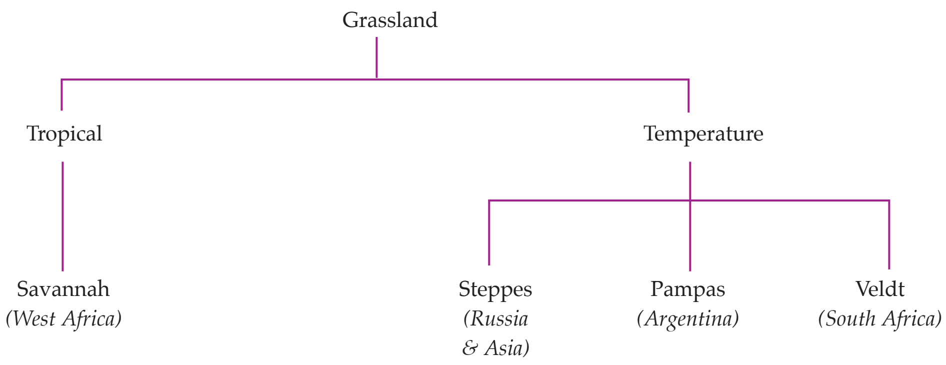


Fig. 14.5 Types of grassland

Distribution of plants and animals in the savannah

In savannah vegetation, grass species are dominant. Trees and shrubs are much less numerous than in forests and are scattered thinly across the land. Grasses occur in the spaces between the trees.

The savannah is very rich in animal population. In the soil, there are many animals such as termites whose termite mounds dot the landscape. On the land, there are many herbivores, such as rats, squirrels, deer, porcupines, gazelles, grass cutters and antelopes. Carnivores include snails, cheetahs and leopards.

Adaptations of plants and animals in the savannah

Plants in the savannah have adaptive features for the conservation of water and for protection against bush fires. These adaptive features include the following:

1. Presence of a thick bark, to reduce water loss by transpiration and protect the plant from bush fires;
2. Shedding of leaves in the dry season to reduce transpiration;
3. Presence of underground stems, such as in grasses, to help them survive the dry season and bush fires;
4. Physiological adaptation of the protoplasm to allow it to recover after desiccation (drying out).
5. Ability to regenerate new shoots immediately after bush fires.
6. Habit of plants completing their life cycles and forming seeds before the onset of the dry season e.g. cereals, grasses.
7. Presence of long tap root system for absorption of water from deep layers of the soil.

Animals of the savannah also have various adaptive features. For instance, some savannah animals burrow into the ground to avoid the high temperature at the ground surface and also to escape from their enemies. Termites build nests whose design ensures that they remain cool all the time.

Practical study of a savannah habitat

Activity 14.13 Mapping an area of savannah

Materials required
A long measuring tape, pencil and drawing paper

Procedure
Mark out and draw an area of the savannah selected for study.

Activity 14.14 Measurement of physical ecological factors

Materials required
Thermometer, hygrometer and light meter.

Procedure
Measure and record ecological factors in the habitat including temperature, relative humidity and light intensity.

Activity 14.15 Identification of plants and animals

Procedure
Identify the plants and animals present in the habitat.

Activity 14.16 Observation and distribution of plants and animals

Procedure
Observe and record how the plants and animals in the habitat are distributed.

Activity 14.17 Observation of adaptations

Procedure
Observe and record the adaptations of selected plants and animals to their habitat.

Activity 14.18 Observation of soil-texture

Materials required
A small hoe or a machete for collecting sample

Procedure
1. Take a sample of the soil and observe its texture.

2 Make an inference about its porosity and capacity to retain water.
3 Record your observations.

Arid lands

Arid lands are those in which water is very difficult to obtain, either because it is scarce or because it is frozen.

Types of arid lands
There are two main types of arid lands, namely:
1 Hot arid lands, which are hot deserts and semi-deserts; and
2 The cold arid lands, which are cold deserts or *tundra.*
These two kinds of arid lands have very different characteristics.

Characteristics of tropical arid lands
1 Water is very scarce because rainfall is very low (below 250mm per annum) and falls irregularly.
2 Temperatures are very high by day and very low by night.
3 The soils are sandy or rocky.
4 Sunshine is very intense, since there is little vegetation to provide cover.
5 The vegetation is very poor.
6 Winds are usually quite strong.
In contrast, the tundra is very cold and the ground surface is covered with ice throughout the year, except during the short summer. In discussing arid lands in this section, the emphasis will be on hot arid lands.

Distribution of organisms in hot arid lands

Only a limited number of plant species can live in arid lands. These include some spcies of grasses, thorny shrubs and plants of the cactus family. Date palms occur around oases (areas where there is a local source of water).

Few animals live in arid lands. These often live in burrows to avoid the harsh weather.

Adaptations of organisms in arid lands

Some of the principal adaptations of organisms in arid lands are those designed to conserve water. Examples of adaptation for water conservation by plants in arid lands include the following:
1 Some plants have underground stems which remain alive when the aerial parts die.
2 Cacti and other plants have little or no leaves, so as to check transpiration. The leaves are modified into scales or thorns, or are entirely absent. The stems are green and carry out photosynthesis.
3 Some plants, such as cacti, store water in their fleshy stems.
4 Some plants of arid lands have very long roots which can absorb water from deep down in the soil.
5 Some plants have sunken stomata or hairs on leaves to reduce transpiration e.g. Eucalyptus.
6 Some plants can complete their entire life cycle in the very short period when rains occur, and then they die and survive the long dry season in the form of seeds.

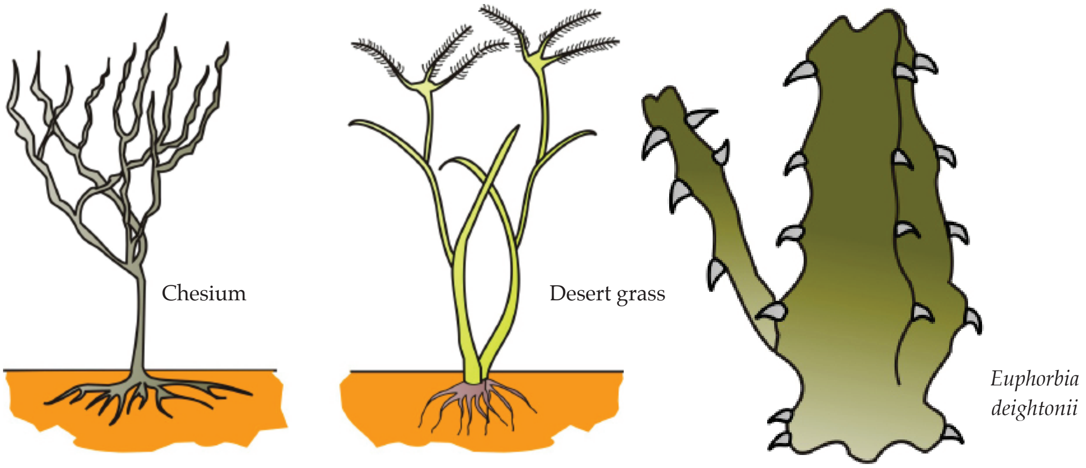


Fig. 14.6 Organisms of the hot arid land

The adaptations of animals of arid lands for water conservation include the following:

1 The camel can go a long distance and for several days with one drink of water.
2 Many desert animals excrete solid waste substances and hence avoid losing water as urine.
3 Desert rats use very little water and in fact depend largely on water present in the food they eat. They can feed on dry seeds almost indefinitely without needing to drink.
4 Living in burrows and coming out to feed at night when it is cool helps desert animals to minimise water-loss.
5 Sweat glands of desert animals are not very active and this is a check against water-loss.
6 Reptiles in arid lands have scales which limit their water-loss.

Another major kind of adaptations found in animals of arid lands is the adaptation for the regulation of body temperature. For instance, many animals of arid lands avoid the very high day temperatures by living in burrows.

Practical study of an arid habitat

Activity 14.19 Mapping an arid habitat

Materials required
A long measuring tape, pencil and drawing paper

Procedure
Mark out and draw a plan of the area of habitat to be studied.

Activity 14.20 Measuring physical habitat factors

Materials required
Thermometer, hygrometer and a light meter.

Procedure
Measure and record habitat factors such as temperature, relative humidity and light intensity.

Activity 14.21 Identification of plants and animals

Procedure
Identify the plants and animals present in the area of habitat chosen for study.

Activity 14.22 Observing the distribution of plants and animals

Procedure
Observe the distribution of the plants and animals in the area you have chosen for study.

Activity 14.23 Observing the adaptations of plants and animals

Procedure
Observe and note down the adaptations of the plants and animals in the habitat.

Summary

This chapter has taught the following:

- Terrestrial habitats include marsh, forest, grasslands and arid lands.
- A marsh is a low land which is flooded from time to time and in which grasses and shrubs, but no trees, grow. Marshes are of two kinds, saltwater and freshwater. Marsh plants and animals are adapted to withstand a waterlogged soil with low oxygen content.
- The tropical rain forest occurs where the rainfall, relative humidity and temperature are high. In forest vegetation, trees are dominant; the rain forest vegetations are characterised by the existence of layers or strata. The vertical distribution of plants is controlled by their respective requirement of light. Rainforest plants are mostly mesophytes. Many of the animals are arboreal (i.e. live on or in trees) and have suitable adaptations for doing so. Soil conditions may change the nature of the tropical rain forest from one place to another.
- Savannah is tropical grassland found in West Africa. It contains scattered trees but grass species

are dominant between the trees. The type of savannah found in Nigeria includes Southern Guinea savannah, Northern Guinea savannah and Sahel. Southern Guinea savannah is characterised by tall grasses, with marked seasonal variation in appearance, green in the rainy season and brown in the dry season. Northern Guinea savannah has a lower rainfall and shorter grasses than the Southern Guinea savannah. The Sahel has shorter rainy seasons, lower rainfall and shorter grasses than the Northern Guinea savannah.

- Arid lands are characterised by scarcity of water and include hot arid lands, which are deserts or semi-deserts and cold arid lands, which are the tundra regions.

Revision questions

1 Which of the following is the most important characteristics of an arid land? ___________________
 A High temperature during the day
 B Few animals
 C Low relative humidity
 D Scarcity of water
 E Poor vegetation.

2 Which of the following is an adaptation of savannah plants for protection against bush fire? _____
____
 A Production of flowers, fruits and seeds.
 B Gradual shedding of leaves throughout the year.
 C Possession of sunken stomata.
 D Rolling of leaves during hot days.
 E Possession of a thick bark.

3 Which of the following is **not** associated with the tropical rain forest? ___________________________
 A Epiphytes
 B Emergent
 C Littoral zone
 D Arboreal habitat
 E Canopy

4 State **three** characteristics of a marsh, how does a marsh differ from
 a) an aquatic habitat.
 b) a terrestrial habitat.

5 Describe the structure of the adaptations found in arboreal animals in the tropical rain forest.

6 What is savannah? Contrast savannah and tropical rain forest, with respect to
 a) habitat factors
 b) species present.

Theme 4
Continuity of life

Chapter 15 Reproduction in unicellular organisms and invertebrates

One of the major ideas in biology is that life continues from parent to offspring and from generation to generation. In the cell theory, you came across the idea that a cell comes from a pre-existing cell.

Life continues through reproduction. In this chapter, you will learn how reproduction occurs in unicellular organisms and invertebrates.

Introduction

In Chapter 4, you learnt that reproduction is the process by which an organism gives rise to new individuals of the same species. This process leads to an increase in the population and also a continuity of the species. While reproduction is a common characteristic of all living things, details of how it occurs varies from one species to another. In this chapter you will learn how reproduction occurs in selected unicellular organisms and invertebrates.

Reproduction in *amoeba*

In *amoeba*, reproduction occurs by asexual methods only (see chapter 4 for meaning of asexual reproduction).

Binary fission

Amoeba reproduces asexually by **binary fission**. The nucleus first divides into two, followed by a division of the cytoplasm. At the end of binary fission, two new individuals are formed from one parent individual.

Spore formation

Sometimes, under adverse conditions, such as the drying up of a habitat, *amoeba* forms a thick coat enclosing itself. The *amoeba* with its thick coat, is called a **cyst**. Within the cyst, by repeated division, the nucleus and cytoplasm become divided into many units. Each unit of nucleus and cytoplasm is surrounded by a resistant coat and is called a **spore**.

A spore is an asexual reproductive unit, formed by a parent individual, consisting of one or a few cells and which is capable of giving rise to a new individual. When habitat conditions improve, the cyst breaks, the spores are dispersed and each spore develops into a new individual.

Reproduction in *paramecium*

In *paramecium*, asexual reproduction by binary fission occurs. In addition, there is sexual reproduction by a process called **conjugation**.

Binary fission

In *paramecium*, binary fission occurs in this way. The micronucleus and the meganucleus divide into two to produce two micronuclei and two meganuclei. This is followed by a transverse division of the cytoplasm to form two new individuals, each containing one micronucleus and one meganucleus.

Sexual reproduction by conjugation

1 Two individuals called conjugants come together and lie side by side.
2 The meganucleus of each conjugant disintegrates.
3 The micronucleus of each conjugant divides into two parts twice, forming four micronuclei. Three of the four micro nuclei in each conjugant disintegrate. The remaining micronucleus again divides

into two.

4 One micronucleus from each conjugant migrates into the other conjugant. In other words, the conjugants exchange nuclear material.

5 The migratory nucleus of one conjugant and the stationary nucleus of the other conjugant fuse in each individual to form a fusion nucleus. The two conjugants separate. They are now called ex-conjugants.

6 The fusion nucleus in each ex-conjugant divides into eight parts, while the cytoplasm divides into four, to give four new individuals, each with a new meganucleus and a new micronucleus.

Reproduction in *spirogyra*

Spirogyra reproduces by both asexual and sexual methods.

Asexual reproduction

A *spirogyra* filament may break up into a number of pieces, each containing a few to several cells. This break may be caused by water current, or animals or other physical damage. The nucleus of each cell divides into two, followed by a division of the cytoplasm. As a result, each cell forms two new cells, still held together in the filament. At first, the new cells are small; as they enlarge, the filament becomes longer. This type of reproduction is also known as vegetative reproduction.

Sexual reproduction by conjugation

1 Two filaments come together side by side.

2 Projections arise opposite each other from opposite cells in two filaments. The projections meet and the separating walls dissolve, so that a continuous channel, called a **conjugation tube**, is formed.

3 Meanwhile, the cytoplasm of each cell shrinks away from the cell walls, and the contents of each of the two cells round up to form a mass of protoplasm, now called a gamete.

4 One of the gametes, regarded as the male, migrates through the conjugation tube into the other cell. The gametes of the two cells fuse (that is, the nucleus of one fuses, with the nucleus of the other, while the cytoplasm of one fuses with the cytoplasm of the other). The fused gametes form a zygote.

5 The zygote develops a thick wall and is now called a zygospore. The cell walls of the parent filaments break up and the zygospore drops to the bottom of the pond, where it may remain dormant and survive adverse conditions such as drying of the pond.

6 When habitat conditions improve, the zygospore germinates, by splitting. A filament grows out and divides by transverse cell walls into cells of a new filament.

7 This kind of sexual reproduction is called conjugation. Conjugation is characterised by:

a) Pairing and temporary union between two individuals.

b) Transfer of nuclear material from one individual or cell to the other.

c) Fusion of nuclear material from two individuals, or cells.

d) Production of new individuals from the zygote (fused nuclear material).

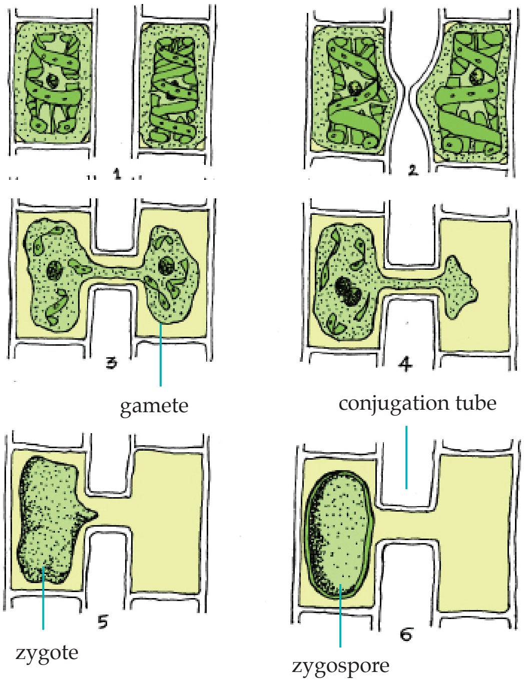


Fig. 15.1 Conjugation in spirogyra

Reproduction in earthworm

1 Each earthworm contains male and female reproductive organs inside the body near to the front end. The male and female reproductive organs have separate ducts that conduct sperm and eggs respectively to the surface of the body.

2 Although each earthworm is a hermaphrodite (has both male and female reproductive organs) sexual reproduction occurs normally between two worms, the sperm of one worm fertilising the eggs of the other worm.

3 When two earthworms mate, they lie close together

with their clitella (singular clitellum) touching. Each passes sperm into the other.

4 The egg cocoon is secreted by the clitellum. Each earthworm passes sperm from the other earth worm, and its own eggs into the cocoon. The cocoon slips over the body of the earthworm as it is dropped off at the front end of the body into the soil.

5 Fertilisation of sperm and eggs occurs externally in the cocoon.

6 Earthworm eggs hatch in the cocoon. Young earthworms come out from the cocoon into the soil.

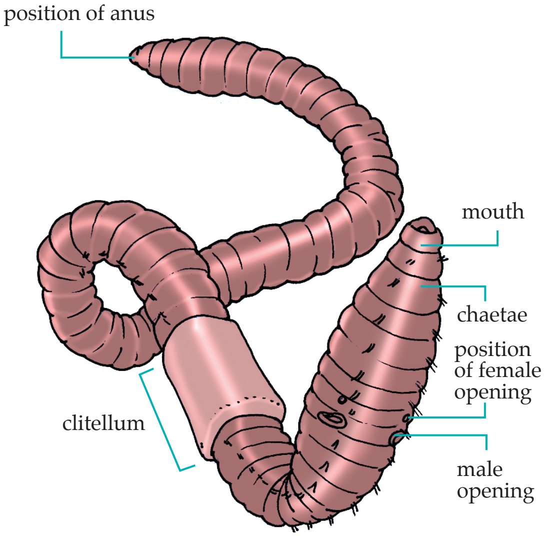


Fig. 15.2 Earthworm

Reproduction in cockroach

In cockroach, reproduction is only sexual.

1 Each individual is unisexual (either male or female).

2 Male and female cockroaches mate. Fertilisation is internal. The female lays eggs enclosed in a capsule. Each capsule is about 0.5cm long, and contains 16 eggs arranged in two rows of eight eggs per row. The female carries this capsule about for some time, and eventually drops it in a dark place, such as a cupboard.

3 After some days, the eggs hatch into light coloured nymphs, which look like adults but have no wings.

4 Nymphs grow and moult six or seven times. They gradually develop wings and become full grown.

5 The life cycle of the cockroach shows incomplete metamorphosis.

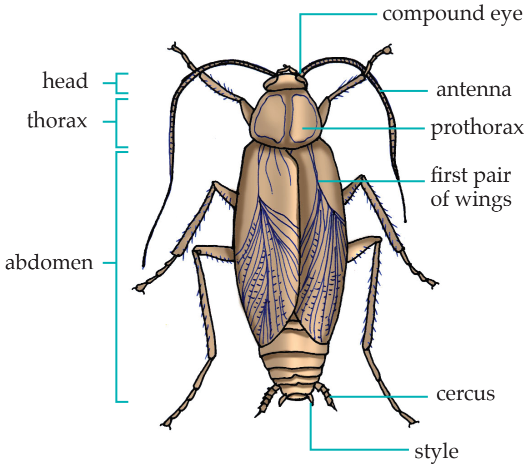


Fig. 15.3a) Cockroach

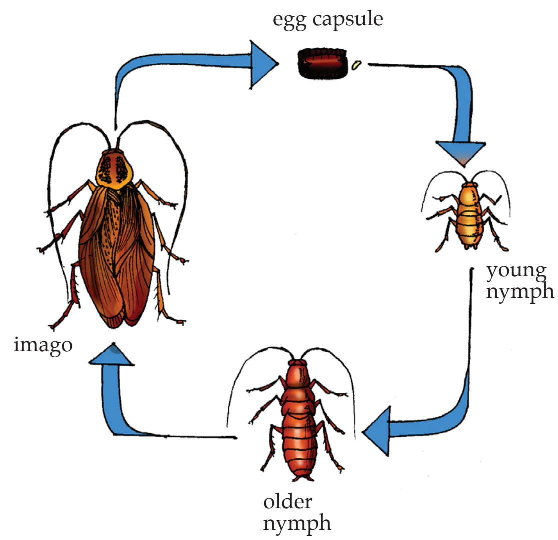


Fig. 15.3b) Life cycle of cockroach

Reproduction in housefly

Reproduction in housefly is sexual only.

1 The sexes are separate, that is, each housefly is either male or female.

2 The male and female mate.

3 The female pushes her abdomen into warm moist organic matter to lay eggs, so as to protect the eggs from desiccation. The eggs are laid in batches of 100 – 150. They are white, oval, about 1mm

long and have thick rib-like rings down each side. Depending on the temperature, they hatch within 24 hours or less.

4 The larva is white, and bigger at the hind than at the interior end. It has twelve visible segments, but no legs. It feeds on liquid food and small particles of organic matter. It has no eyes but apparently detects light for it moves away from light. It grows to about 1cm in four to five days, moults twice and migrates to a dry place where it changes into pupa.

5 The pupa is barrel shaped. As the larva changes to pupa, the skin darkens and hardens, forming the pupal case. The pupa is inactive. After 3 or 4 days, the imago (young adult) breaks through the pupal case and crawls out of the decaying organic matter. At first the wings are folded, but they expand within a few hours and the new adult can fly.

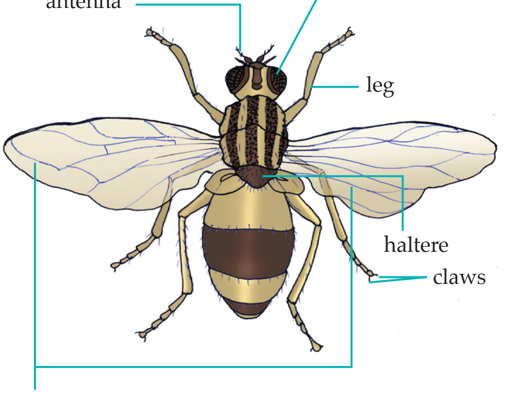


Fig. 15.4a) Housefly

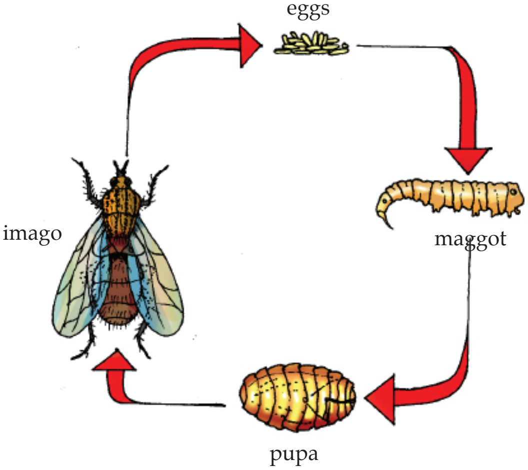


Fig. 15.4b) Life history of the housefly

Reproduction in garden snail

Reproduction in garden snail is sexual only.

1 Male and female organs are found in each individual, but a land snail does not fertilise its own eggs.

2 When the male and female mate, they exchange sperm.

3 Fertilisation occurs later, internally.

4 The snail passes out batches of eggs, on to the soil.

5 The young ones develop inside the eggs. When the eggs hatch, fully formed young snails come out, each with its own shell.

Fig. 15.5 Land snail

Summary

This chapter has taught the following:

- Reproduction leads to an increase in the population and continuity of species.
- In amoeba, reproduction occurs asexually by binary fission and spore formation.
- In paramecium, reproduction occurs asexually by binary fission and sexually by conjugation.
- Spirogyra reproduces by both asexual and sexual methods.
- Sexual reproduction occurs in earthworm.
- Cockroach reproduces by sexual method.
- Reproduction in housefly is sexual only.

Revision questions

1 In amoeba, asexual reproduction occurs by ____________________.

A vegetative reproduction and metamorphosis
B egg laying and multiple fusion
C fusion of gamete
D conjugation and budding
E binary fission and spore formation

2 Conjugation is characterised by _______________.
   A two individuals lying side by side
   B exchange of nuclear material
   C fusion of gametes or nuclear material
   D production of new individuals from the zygote
   E all of the above
3 Which of the following does *not* occur in the sexual reproduction of paramecium? _______________
   A Micronucleus
   B Meganucleus
   C Conjugation tube
   D Disintegration of nuclear material
   E Fusion of nuclear material
4 Which of these does not occur in asexual reproduction? _______________
   A Nucleus
   B Cell
   C Cell division
   D New individuals
   E Gametes
5 Compare and contrast asexual and sexual reproduction.
6 Describe the process of sexual reproduction in cockroach.
7 List the differences between conjugation in spirogyra and in paramecium.
8 Explain the following terms:
   a) Zygospore
   b) Cyst
   c) Spore
   d) Clitellum

Answers to revision questions

Chapter 1
1 E
2 A
3 A
4 B

Chapter 2
1 C
2 C
3 A
4 E

Chapter 3
1 B
2 A
3 D

Chapter 4
1 C
2 A
3 D
4 A
5 B

Chapter 5
1 B
2 C
3 D
4 A
5 E
6 C

Chapter 6
1 D
2 E
3 C
4 C

Chapter 7
1 C
2 D
3 E
4 A

Chapter 8
1 B
2 B
3 A
4 B

Chapter 9
1 B
2 A
3 A

Chapter 10
1 E
2 C
3 A

Chapter 11
1 E
2 C
3 A

Chapter 12
1 C
2 D

Chapter 13
1 C
2 C
3 C
4 A

Chapter 14
1 D
2 E
3 C

Chapter 15
1 E
2 E
3 C
4 E

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