BIO 001 - Access Biology

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First published 2004

ISBN 978 058 384 X

Published by Folubee Prints for National Open University of Nigeria

Course Guide

Programme:	B.Sc Science and Technology
Course:	Access Biology
Duration:	First Semester
Programme Leader:	Dr. M. A. Wasagu

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1.0 Introduction

Biology is a science that deals with the living world. Its methods of inquiry are similar to those employed in all natural sciences. It is a fascinating study that ranges from microscopic cellular molecules to the multicellular macro forms of life, encompassing the earth's surface and its living organisms. The unit examines the characteristics of living things which distinguish them from non-living things, plant and animal cells, cell division and the exchange of materials within a cell.

2.0 Objectives

By the end of this unit, you should be able to:

(a) define what Biology is;
(b) distiguish between living things and non-living things;
(c) show diagrammatically plant and animal cell;
(d) describe the two types of cell division;
(e) describe the process involved in the exchange of materials within a cell.

3.0 Definition of Biology

Biology is the branch of science that involve the study of living things (Plant and animals)

3.1 Characteristics of Living Things

Living things can be distinguished from non-living things by a number of characteristics.

(a) **Movement:-** All living things move. Movement means a change in position which could be total (from one location to another) as in the case of animals or limited to one part of the body as in plants.
(b) **Nutrition:-** A Living organism needs food to supply the energy and materials for life processes. Nutrition involves the total process of taking in, and the utilisation of foods in animals; as well as taking in of mineral substances and their utilisation in plants.
(c) **Respiration:-** This is the break down of food substances taken in by the organism to release energy.
(d) **Irritability (Sensitivity):-** This is the ability of a living organism to receive an external stimulus and respond to it.
(e) **Excretion:-** This is the removal of waste products of metabolism from the body of a living organism.
(f) **Reproduction:-** This is the process of giving rise to new individuals of the same kind for the continuation of life. Reproduction may be sexual or asexual in nature.
(g) **Growth:-** A living organism grows. This is an increase in size which is usually accompanied by development (a change in form and abilities). The materials used for growthar derived from the food taken in by the organism.
(i) **Adaptation:-** This is the posession of features (structures or functions) which enable organisms to live successfully and to survive in their respective environments.

3.2 Differences between Plants and Animals

There are notable differences between plants and animals. These are shown in Table 1.1

Table 1.1

	FEATURES	PLANT	ANIMALS
1.	Nutrition	Autotrophic nutrition, i.e. makes own food by Photosynthesis, since it is green and has clorophyll.	Heretotrophic Nutrition, obtain complex organic food already made.
2.	Support	Depends on tugor and lignifield tissues.	Many Possess an endoskeleton or an exoskeleton.
3.	Movement	Rooted on one spot. Movement is generally slow since usually is as a result of growth.	The whole animal can move about quickly.
4.	Sensitivity	Responds slowly to stimulus by means of hormones.	Sensory system allows rapid responses.
5.	Growth	May grow large with branching body. Growth which is mostly at meristems, is indefinite.	Body is compact, growth stops at maturity in higher animals.
6.	Cell Structure	Cellulose cell wall and vacuoles containing cell sap are present, may contain Chloroplasts.	Cell wall is absent. Vacuole and chloroplast, are absent.

Source: **Federal Government School Practical Book**

3.3 Microscope

Microscopes are instruments which magnify the size of objects. There are various types. Simple, Compound and Electron microscope. The diagram below (Fig. 1) shows a simple type.

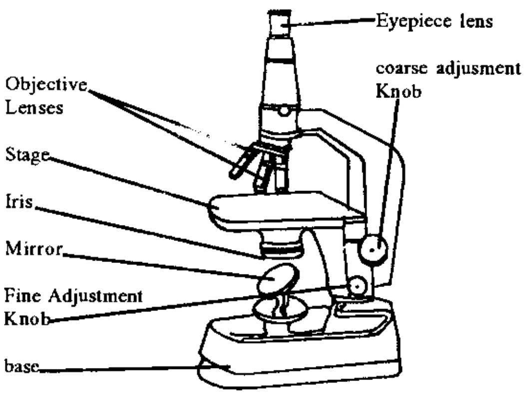


Fig 1.1 a. A compound light Microscope

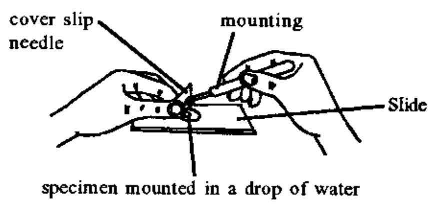


Fig 1.1 b. Making a wet-mount of a specimen

3.4 Plant and Animal Cells

3.4.1 Plant Cell

Under the light microscope, the plant cell has two principal parts. These are the protoplasm and the cell wall. The protoplasm is a term used to describe all the constituents of a living cell. Protoplasmic materials in the nucleus are called *nucleoplasm* and those outside the nucleus are called *cytoplasm*. The generalised plant cell (Fig. 1.2) shows the cell wall enclosing a nucleus which is surrounded by cytoplasm. Within the cytoplasm, there are a variety of sub-cellular parts called *organelles*.
The organelles include the following:

(a) **Cell wall:** This encloses the outer surface of the cell membrane in plants. It is rigid, made up of cellulose. It provides support in plants.

(b) **Plastids:** These are spherical organelles in the cytoplasm of plants. The three types of plastids common in plants cells are leucoplasts, chromoplast and chloroplast. The chloroplasts contain the green pigment called chlolophyll used in the manufacture of organic food. Each chloroplast is surrounded by a membrane. Leucoplasts are colourless plastids and they form sites for the storage of starch and lipids. Chromoplasts contain different colours, and the colour of flower petals is due to these plastids.

(c) **Nucleus:** Spherical or disc-shaped body located in the centre of the cell. It controls all the activities of the cell.

(d) **Endoplasmic reticulum (E.R.):** It is a network of channels which traverses the cytoplasm and also connects to the cell membrane and the nuclear membrane.
Its functions are:
(i) Transport of substances within the cytoplasm and across the cell to the nucleus and cell membrance
(ii) It also helps in the formation of enzymes and proteins.
(iii) It provides a surface for the atachment of ribosomes.

(e) **Mitochrondria:** These are small bodies which are barely visible under the light microscope. Mitochrondria are the sites of cellular respiration for the production of energy.

(f) **Lysosomes:** These bodies are similar in size to mitochrondria. They contain the hydrolytic enzymes which break down macro-molecules into smaller molecules. Found in animal cells.

(g) **Centrioles:** These are a pair of small cylindrical bodies which lie close to the nucleus. They play a vital role in cell division.

(h) **Vacuole:** These are cavities or spaces bounded by a definite membrane called tonoplast. They are not empty but usually contain water and a variety of substances in solution. They function as osmo-regulatory organelles. They are large in plant cells but small in animal cells.

(i) **Golgi Bodies:** These are assemblies of vessicles and folded membranes present within the cytoplasm of animal and plants cells. They assist in the transport of new layers of synthesised lipids and proteins. They help in the manufacture of lysosomes of the endoplasm and in the formation of the membranes reticulum and production of the cellulose of the cell walls of plants.

A Typical Plant Cell

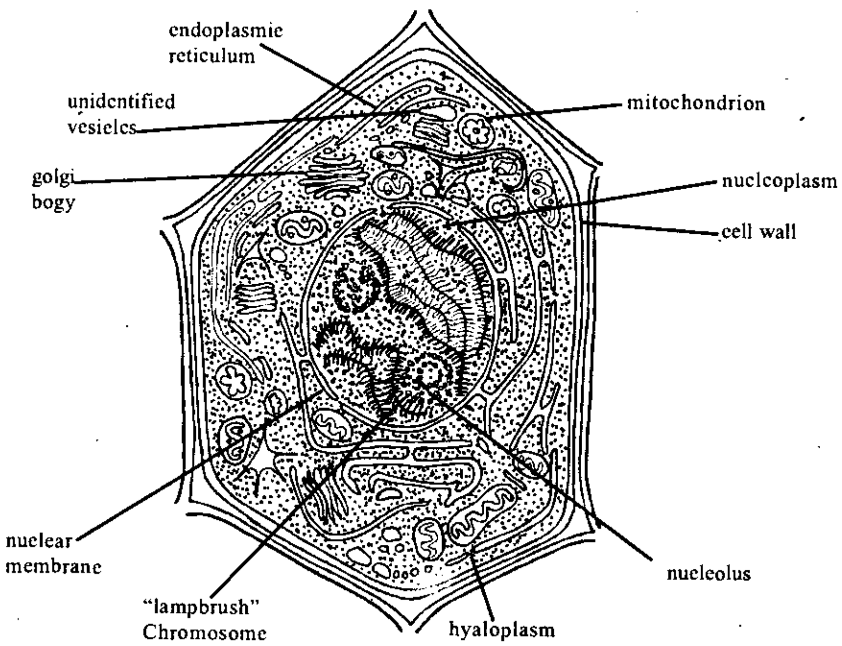


Figure 1.2

***Source: Senior Secondary Biology Book 2 by F.O.C. Ndu et al* – page 3**

3.4.2 A Typical Animal Cell

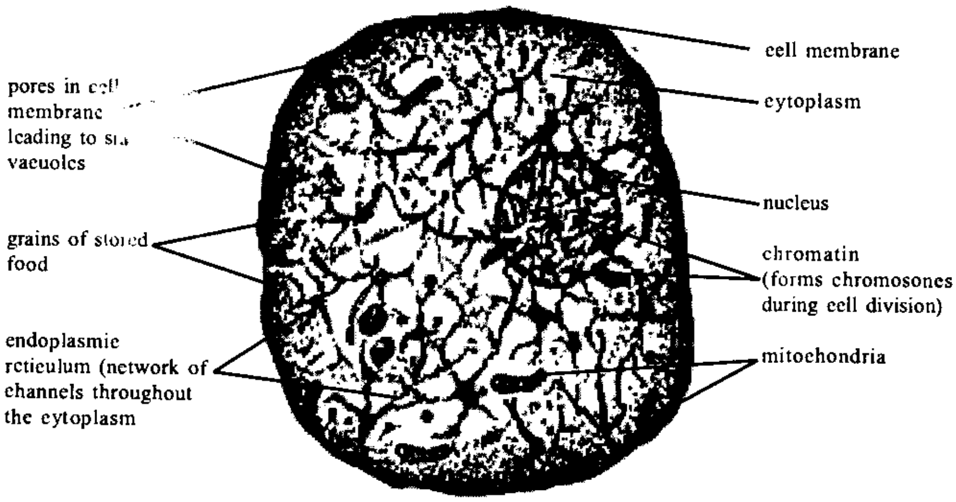


Figure 1.3

Source: Federal Govt. Book Programme Practical Biology for Senior Secondary Schools - page 2

3.5 Differences Between Plant and Animal Cells

There are notable differences between plant and animal cells see Table 1.2

Table 1.2

Part	Plant	Animal
1. Shape and covering	1. Exhibition definite shape because of presence of rigid cellulose cell wall.	No definite shape since no cell wall.
2. Cytoplasm (a) Locations (b) Inclusions	2. Cytoplasm pushed towards edge of wall. 3. Large fluid filled central vacuole. 4. Green Plastids (chloroplasts present). 5. Starch grains present.	Cytoplasm spread through the cell. Few, small vacuoles. Absent. Glycogen granules found.
3. Nucleus	6. Centrosome absent.	Present.

Source: Federal Govt. Book Programme Practical Biology

3.6 Similarities between Plant and Animal Cells

Plant and animal cells are also similar. They both contain cell membrane, cytoplasm, nucleus, nucleus and vacuoles.

Activity A

1. Listen very carefully to the interactive audio tape on "Biology as a Science".
2. Now list 6 characteristics of living things.
3. Also list the main differences between plant and animal cell.
4. With the aid of the video recording on "The use of the microscope", Look more closely at the diagrams of (a) plant cell and (b) animal cell. Draw and label each of them in detail.

3.7 Cell Division

All living organism are composed of cells in multicellular organism, the number of cells increases greatly as the organism grows. Since new cells develop from pre-existing ones, some means must exist for an individual cell to form more cells. This process is called cell division. Cell division includes two distinct processes. These are meiosis and mitosis.

3.7.1 Meiosis

Meiosis (Reduction division) The process of cell division which leads to the production of reproductive cells (gametes) having half the chromosome number of the parent cell. Cell formed by meiosis produces gametes and the diploid number of chromosomes is restored during fertilisation. Meiosis involves two successive cell divisions, *first meiotic division,* when the parent splits into two, and *second meiotic division* when the products divide again, giving a total of four daughter cells. Like mitosis, the process is divided into a series of stages; Prophase I and II, Metaphase I and II, Anaphase I and II, and Telophase I and II.

Prophase I: Two homologous chromosomes attract each other and get lined up beside each other, a condition known as *synapsis,* forming *bivalents.* The chromatids of two homologous chromosomes remain in contact at points called *chiasmata*. An exchange of chromatid material occurs between the pairs of homologous chromosomes. This is known as *crossing over.*

Metaphase I: The nuclear membrane breaks down, spindle is formed, and bivalents align themselves along the spindle equator.

Anaphase I: The homologous of each pair moves towards opposite poles of the spindle.

Telophase I: The haploid number of chromosomes gathers at either end of the spindle, the cell constricts across the middle, and divides as in mitosis. The daughter cells go into interphase and prepare for the next division.

Prophase II: The centrioles replicate as new spindle apparatus is formed

Metaphase II: The chromosomes, each now present as two chromatids, arrange themselves on the equator spindle.

Anaphase II: The centromeres divide and the chromatids separate and move apart from each other to opposite poles of the cell. The chromatids become the chromosomes of the daughter cells.

Telophase II: A nuclear membrane is formed around each group of daughter chromosomes to form four haploid nuclei. The cytoplasm constricts at the middle forming four gametes and the cells go into *interphase*

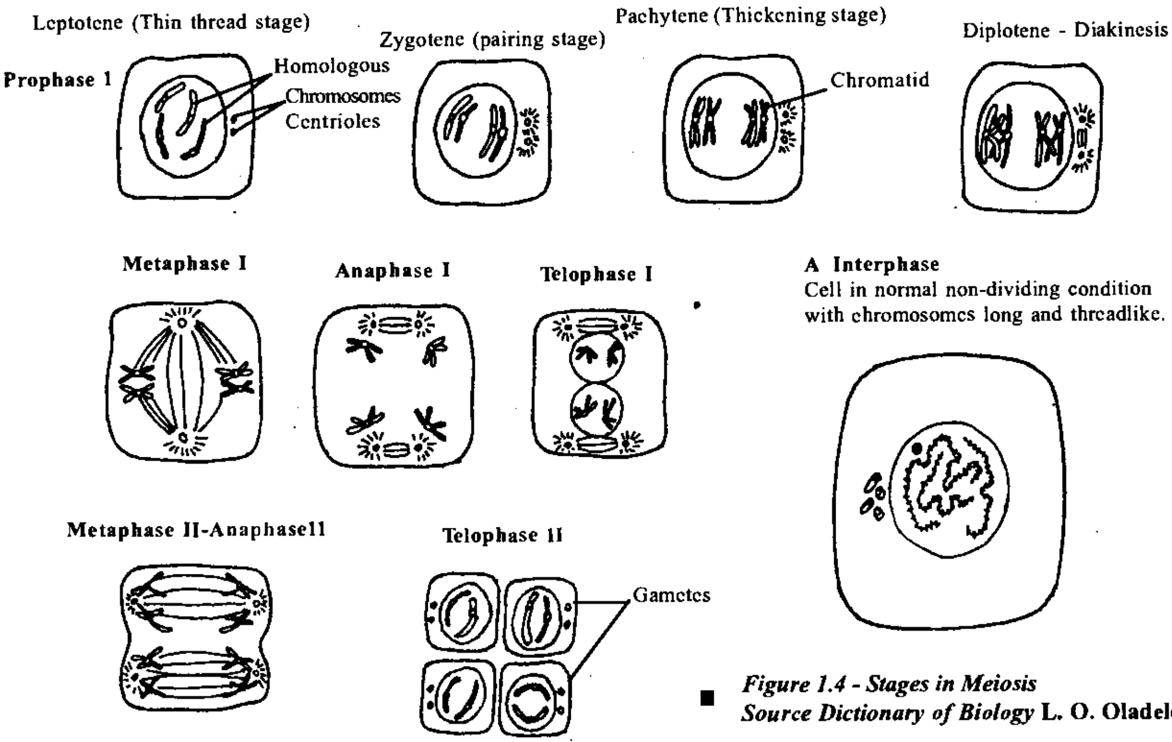


Figure 1.4 - Stages in Meiosis
Source Dictionary of Biology **L. O. Oladele**

Significance of Meiosis

During meiosis, the nucleus divides twice, while the chromosomes have doubled only once. In the first division, the homologous pairs of chromosomes separate. The chromatis separate in the second division. The products are quite different from the original cell when the many different kinds of haploid gametes recombine during fertilisation, the resultant diploid cells may vary greatly from each other and from the originals. This is one of the most important feartures of sexual reproduction - the production of variants as a result of exchange of chromatid materials at the chiasmata during crossing over.

3.7.2 Mitosis

Mitosis is the ordered process by which the cell nucleus and cytoplasm divide into two each having a nucleus containing the same number and kind of chromosomes as the parent cell. The process is divided into four successive stages: *Prophase, Metaphase, Anaphase, Telophase*. The four stages are preceded by a resting stage, called *interphase* during which chromosomes undergo a process of self-duplication.

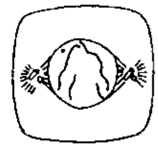
Prophase - The centriole duplicates itself and divides, and the two new centrioles move to opposite ends of the poles. Spindle fibres are formed. Chromosomes shorten and thicken, each seen to consist of a pair of *chromatids* held together at the centre by the *centromere*. The nucleolus and nuclear membrane break down

Metaphase - The chromosome pairs arrange themselves on the equator of the spindle, and each centromere becomes attached to one spindle fibre from each pole.

Anaphase - Chromosomes split at the centromere and the daughter chromosomes move apart from each other and migrate to opposite poles of the spindle and the spindle fibres shorten.

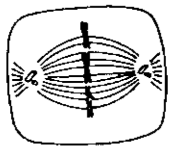
Telophase - The cell constricts across the middle. The spindle fibres disappear and a nuclear membrane forms around each new group of chromosomes and the cell returns to resting condition (interphase).

A. Interphase
Cell has normal appearance of non-dividing cell condition: chromosomes too threadlike for clear visibility.

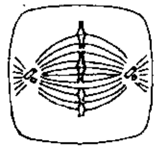


B. Early prophase
Chromosomes become visible as they contract, and nucleolus shrinks. Centrioles at opposite sides of the nucleus. Spindle fibres start to form.

C. Late prophase
Chromosomes become shorter and fatter-each seem to consist of a pair of chromatids joined at the centromere. Nucleolus disappears. Prosphase ends with breakdown of nuclear membrane.

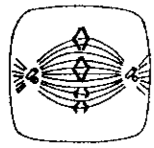


D. Early metaphase
Chromosomes arrange themselves on equator of spindle. Note that homologous chromosomes do not associate.

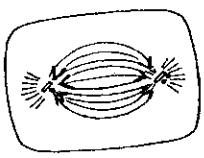


E. Late metaphase
Chromatides draw apart at the centromere region. Note that the daughter centromeres are oriented toward opposite poles of the spindle.

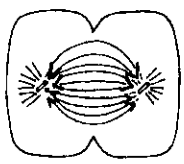
F. Early anaphase
Chromatids part company and migrate to opposite poles of cell, the centromeres leading.

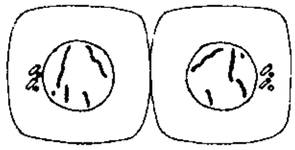


G. Late anaphase
Chromosomes reach their destination



H. Early telophase
The cell starts to constrict across the middle.





I. Late telophase
Constriction continues. Nuclear membrane and nucleolus reformed in each daughter cell. Spindle apparatus degenerates. Chromosomes eventually regain their threadlike form and the cells return to resting condition (interphase).

Significance of Mitosis

As a result of the doubling of chromosomes and the subsequent separation of chromatids, each daughter cell contains the same **number** and the same **kind** of chromosomes as did the original (parent) cell. Since genes, which determine hereditary characteristics, are located within the chromosomes, each daughter cell has the same potentialities as the parent cell. The daughter cells enlarge to a mature size, at which time they also may undergo cell division. Enormous numbers of cell divisions occur during the development of the large multicellular organisms found on this earth, and each of such division occurs basically as just discussed.

Similarities between Mitosis and Meiosis

1. Interphase is the same in mitosis and first division of meiosis, but there is however no interphase between telophase I and prophase II of meiosis.
2. Centrioles divide in both mitosis and meiosis at interphase. Doubling of chromosomes takes place in interphase stage in both mitosis and meiosis.
3. Nucleolus gets dissolved in the nuclear materials at prophase in both mitosis and meiosis.
4. Spindle is laid down in the cytoplasm by the centrioles which divide in interphase.
5. Both mitosis and meiosis form new cells from pre-existing cells through cell division.

Table 1.3 Differences between Mitosis and Meiosis

Mitosis	Meiosis
1. It takes place in somatic cells.	It takes place in reproductive cells.
2. It produces two diploid cells from one parent diploid cell.	It produces four haploid cells from one parent diploid cell.
3. No pairing of chromosomes.	There is pairing of homologous chromosomes.
4. Only one nuclear division occurs	Two nuclear divisions occur.
5. Short prophase stage.	Long prophase stage.
6. No chiasmata occur.	Chiasmata occur.
7. There is no exchange of genes.	There is an exchange of genes.

Mitosis in a generalised animal cell. The sequence of events is almost exactly the same in plant cells. Two pairs of chromosomes are shown: a long pair and a short pair. In **A** the black dot in the nucleus is the nucleolus and the rods outside the nuclear membrane are the centrioles.

3.8 The Cell and Exchange of Materials

The exchange of materials between an organism and its environments is necessary for the life of the organism. In multicellular organisms, there is exchange of materials between different parts in one cell, betweeen cells, and their neighbouring cells, between cells and tissue fluid that surround them as well as between cells and their external environments. The processes that bring about exchange of materials are:

3.8.1 Diffusion

This is the movement of the molecules of fluids (i.e. gases and liquids) from a region of higher concentration to a region of lower concentration. Diffusion plays a very important role in the physiology of protoplasm. When molecules are unevenly distributed in the cell, diffusion tends to equalise the distribution.

3.8.2 Osmosis

This is the net movement of water through a differentially permeable membrane from a region of high diffusion (or high water potential) to a region of lower diffusion pressure (or lower water potential) of water. The movement of water into and out of cells of organisms is brought about, principally, by osmosis. This makes osmosis very vital to many biological processes. Osmosis occurs in living organisms. It helps to prevent certain cells from drying out which may result in wilting in plant. The pressure which must be applied to a solution in order just to stop movement of solvent into it through a membrane is called the osmotic pressure. Osmotic pressure is a mechanism of osmo-regulation to stop the cells from bursting or shrinking.

3.8.3 Plasmolysis

If a cell is placed in a highly concentrated sugar or salt solution, water diffuses out of the cell and the protoplast shrinks away from (collapses away from) the cell wall as turgor pressure is lost. The vacuoles, which contain most of the water of the cell, shrink and may even disappear completely. Since the cell wall is freely permeable, the space between the protoplast and the cell wall will contain the bathing solution. This condition is called plasmolysis, and the cell will die if left in that solution. The effect of plasmolysis on living cells is utilised in the salting of meat and fish. The excess salt prevents the growth of decay organisms by plasmolysing the cells of such moulds and bacteria.

Activity B

Briefly explain the following terms:
(a) Osmosis (b) Diffusion (c) Plasmolysis

4.0 Conclusion

Living things therefore are composed of cell(s) and the life processes within the cell play a vital role in the survival of the organism.

5.0 Summary

In this unit we have learnt that:

i. Biology is a study of living things.
ii. Living things can be distinguished from non-living by a number of characteristics, and these characteristics include movement, respiration, growth, excretion, reproduction, sensitivity and adaptation.
iii. There are notable differences between plants and animals e.g. plants undergo autotropic nutrition while animals undergo heterotropic nutrition.
iv. Cells of living organisms can divide and give rise to new ones, through the processes of mitosis and meiosis.
v. The processes that bring about the exchange of materials within a cell are diffusion, osmosis and plasmolysis.

6.0 Tutor Marked Assignment

1a. Make a large, labelled diagram of a plant cell
 b. State *one* function each of the following organelles
 i. Mitochondrion
 ii. Golgi body
 iii. Vacuole
 iv. Ribosome
 v. (Cellulose) cell wall
2. List the main differences between plant and animal cells.

7.0 Further Reading and other Resources

F.O.C. Ndu, P. Asun and J. O. Aina (1991) - *Senior Secondary Biology, Book 1-3*
Idodo - Umeh (1996) - *College Biology*
Sarojini T. Ramalingam (1993) - *Modern Biology*
Walter H. Multer (1974) - *Botany, A functional approach, third edition*

An interactive Audio recording on "Biology as a Science". *(A Noun Production)*
A video recording on "The use of the Microscope" *(A Noun Production).*

Unit 2: Classification of Living Organisms

Page

1.0 Introduction

A casual observation of living organisms around you anywhere will reveal a wide variety of different plants and animals. These may vary in sizes, shape, colour, speed of locomotion, etc. A closer observation also will reveal that these varieties of forms also exhibit some similarities of features or behaviour. We must, therefore have a meaningful way of classifying, identifying and naming them. The study of the general principles of classification is known as taxonomy or systematics. This unit will discuss the various methods of classification and the characteristics of each group by which it can easily be identified.

2.0 Objectives

By the end of this unit you should be able to:
(a) produce a brief summary of the different groups of living organisms.
(b) explain the various method of classification.
(c) list the characteristics of the major groups of plants and animals.

3.0 Method of Classification

To classify organisms into main groups, biologists look for important features that are shared by a large variety of organisms. These features should have a similar origin, structure and position. Organisms with certain important features in common are then put together into one group. Divisions and subdivisions within a main group are based on progressively less important features.

3.1 Hierarchy of Living Organism

The largest group of organisms is the *kingdom*. Each kingdom is split into smaller groups, and these groups into even smaller groups, and so on. The arrangement of living organisms in this hierachy from the highest level to the lowest is as follows:

Kingdom
Phylum or Division (plants)
Class
Order
Family
Genus
Species

Sometimes intermediate levels are added. These are usually identified by prefixes such as *sub-* and *super, e.g. subphylum* and *superclass*.

As we go down the levels, the variety of organisms decreases. The kingdom, of course, has the largest variety of organisms. They have certain important features in common but show many differences. Organisms in a *genus*, however, are very similar. The *species* is the smallest unit of classification. The individuals within a species are identical in general appearance. They can mate with one another and produce fertile offspring. Thus, organisms within a species are very closely related.

This system of classifying living organisms is very useful to biologists for the following reasons:
* It provides a set of rules that can be used to identify an organism (table 2.1);
* It shows that organisms within groups are related, i.e. they have a common ancestral history or background. This fact enables biologists to trace how simple primitve organisms may have developed or *evolved* into complex advanced ones.

3.2 Binomal Nomenclature

We are familiar with the common names of living organisms such as cow, cat, mango and maize. Biologists, however, use a standard system to name living organisms. Each kind of organism is given two names, hence the term *binomial nomenclature*.

* The first name is the name of the genus to which the organism belongs
* The second name is the name of the species to which it belongs.

Both names are printed in italics with only the genus name having an initial capital letter. Hence, the scientific name of the maize plant is *Zea mays,* that of the African elephant is *Loxodonta africana.* Our name is *Homo sapiens*. An extinct member of our genus is *Homo erectus*. This method of naming organisms is used because it avoids the ambiguity present in the use of common names.

3.3 Kingdoms

Linaeus placed all living organisms into two kingdoms: *plants and animals.* In this scheme, many one-celled organisms could not fit in properly. Now, most biologists favour the placing of all living organisms into five kingdoms (Table 2.1.)

* *Monera*
* *Protista*
* *Fungi*
* *Plantae and Animalia.*

The monerans are composed of very simple cells which do not have true nuclei. Such organisms are known as *procaryotes.* The majority of organisms, i.e. the protists, fungi, plants and animals, are known as *eucaryotes* as their cells are highly organised with definite or true nuclei.

The five-kingdom way of classifying organisms still presents problems. For example a lichen is made up of a fungus and a protist so where does it fit in?

Viruses are not included in any of the five kingdoms. This is because biologists are still debating over their status as a living organism. Currently, viruses are considered as non-living.

Table 2.1

LIVING ORGANISMS

Kingdom Monera (Procaryotes)
Single-celled, motile or non-motile organisms. Organisms are microscopic. Cell structure is simple with no definite nucleus. Bacteria and blue-green algae make up this kingdom.

Kingdom Protista (Eucaryotes)
Single-celled, motile or non-motile organisms. Organisms are much larger than the monerans. Cell structure is complex with a definite nucleus. Members include *Chlamydomonas and Amoeba.*

Kingdom Plantae (Eucaryotes)
Many celled, non-motile organisms which contain the green pigment chlorophyll that enables them to make their own food by photosynthesis. Members mosses, ferns, pines, oil palms and yam bean plants.

Kingdom Animalia (Eucaryotes)
Many celled, motile organisms that feed on other organisms. Members include corals, worms, insects, snails, fishes, frogs, snakes and cows.

3.3.1 Kingdom Animalia

All animals belong to this kingdom. They are motile multicellular organisms whose cells have no cell wall or chloroplasts. They take in ready made food from their surroundings mostly in solid forms, and digest it in their bodies.

Animals are put into two main sub-groups (sub-phylla)

i. Sub-phyllum: Invertebrata *(Invertebrates)* animals with no backbone.

ii. Sub-phyllum: Vertebrata *(Vertebrates)* Animals with backbones. The divisions and subdivisions of animals are based on several important features including body symmetry, body design and body cavity.

Sub-Phyllum: Invertebrates. (Invertebrata)

See **Table 2.2.** for the characteristics features of the invertebrates.

Table 2.2

Phylum	Cellular organization	Coelum	Body symmetry	Reproduction	Distinguishing features
Porifera or sponges	No tissues	None	Asymmetrical	Sexual and asexual; usually hermaphrodites.	Aquatic, adults non-motile, filter feeders; possess pore and collar cells.
Coelenterates e.g. *jellyfish, Hydra, corals*	Tissues	None	Radial	Budding and sexual; individuals are hermaphrodites.	Polyp and medusa forms; stinging cells on tentacles.
Platyhelminthes e.g. flukes, tapeworms	Organs	None	Bilateral	Sexual; individuals are hermaphrodites.	Flat body with definite head and tail end.
Nematodes e.g. Ascaris, hookworm	Organs	Pseudo-coelum	Bilateral	Sexual; separate male and female individuals	Cylindrical unseg-mented body
Annelids or e.g. earthworms, leeches	Organ system	Coelom	Bilateral	Sexual; male, female or hermaphroditic individuals.	Cylindrical segm-ented body
Molluscs e.g. snails, clams, oysters	Organ system	Coelom	Bilateral	Sexual; separate male and female individuals	Unsegmented body, muscular foot, mantle cavity shells present in most
Arthropods e.g. crustaceans, snails, insects, spiders, millipedes	Organ systems	Coelom	Bilateral	Sexual, separate male and female individuals	Jointed appendages, chitinuous exoskeleton; specialized, segments and sensory system
Echinoderms	Organ systems	Coelom	Radial (adult); bilateral (larva)	Sexual, separate male and female individuals	Spiny skeleton; system of water canals; tube feet

Source: Modern Biology by S. T. Ramalingam pg. 39

Vetebrates

The General Characteristics Features of Vertebrates are Shown in **Table 2.3.**

Class	Cold/warm	Skin blooded	Limbs	Gaseous Exchange	Reproduction/ Parental Care
Fishes *(Pisces)*	Cold blooded	Covered with scales	Limbs modified and slime	Through gills	Fertilisation is external; eggs are laid into fins in water, young look like adults; parental care rare.
Amphibians *(Amphibia)*	Cold blooded	Soft and moist	Two forelegs and two hindlegs	Through gills in young; skin and lungs in adults	Fertilisation is external, eggs are laid in water, complicated life cycle where young look like adults; no parental care.
Reptiles *(Reptilia)*	Cold blooded	Covered with dry scales.	Two forelegs and two hindlegs with toes ending in claws	Through lungs.	Fertilisation is internal; eggs with shells are laid on land and hatch into young which look like adults; no parental care
Birds *(Aves)*	Warm blooded	Covered with feathers (scales on feet)	Forelimbs modified into wings; hindlegs with toes ending in claws	Through lungs.	Fertilisation is internal; eggs with shells are laid on land and hatch into young which look like adults; parental care present in most.
Mammals *(Mammalia)*	Warm blooded	Covered with hair (fur).	Two forelegs and two hindlegs ending in claws.	Through lungs.	Fertilization is internal, young develop in mother's body and are born alive; parental care with young feeding on milk secreted by the mother's mammary glands.

Source: Modern Biology by* S. T. Ramalingam *(pg. 40).

3.3.2 Kingdom Plantae

The familiar green plants belong to this kingdom. Plants are non-motile multicellular organisms whose cells have cellulose cell walls and chloroplast. The chlorophyll in the chloroplasts enable plants to make their own food by photosynthesis.

The plant kingdom include:

1. *Thallophyta*
2. *Bryophyta*
3. *Tracheophyta*

Thallophyta

Thallophytes or algae are simple green plants that are all aquatic. They have thread like *(filamentous)* or flat *(thallus)* bodies that do not have roots, stems or leaves.

Bryophyta

The Bryophytes include the liverworts and mosses. They grow in damp places on land. Bryophytes show a distinct alternation of generations. The sporophyte is always attached and dependent on the gametophyte.

The gametophyte produces:

i. Motile male gametes known as spermatozoa
ii Non-motile female gametes known as ova or eggs, in special sex organs. Water is essential for fertilisation. The fertilised egg or zygote grows on the gametophyte into a sporophyte which produces spores. These spores are dispersed, and when they fall on a suitable moist environment, they develop into gametophytes.

Tracheophyta

Trachophytes are known as vascular plants since they have vessels *(vascular tissues)* for conducting water and food, this is the largest group of plants and includes seed plants like the familiar *flowering plants*, as well as some spore-bearing, non-flowering plants like *ferns.*

3.3.3 Kingdom Protista

Protists are single-celled or *unicellular* organisms. They are made up of *eucaryotic cells in* which the cell structure is complex with a well-defined nucleus. Many structures called *organelles* are present. Each organelle carries out a certain type of work. A eucaryotic cell is not only complex and highly organised but also very much bigger (more bigger than 10 to 100 times) than a procaryotic cell. (See fig. 2.5).

Most protists live in water - in rivers, seas, moist places and body fluids of living organisms. Many of them can move about by using hair-like structures called flagella and *cilia* (singular, cilium), or by forming *pseudopodia* (singular pseudopodium) often known as 'false feet'.

Protophyta: Some protists are 'plant-like' and are known as *protophyta.* They have *cellulose* cell walls and organelles called *chloroplasts.* The chloroplasts contain chlorophyll, which enable them to make their own food. Some examples include *Chlamydomonas* and *Chlorella*, found in freshwater and in the sea. Diatoms have hard silica coats.

3.3.4 Kingdom Fungi

Fungi (singular: fungus) include mushrooms, toadstools, bread moulds and slime moulds,.

All fungi except slime moulds are non-motile. They do not possess chlorophyll and so cannot make their own food by photosynthesis. Instead, most fungi are saprophtes which make use of the food present in the dead parts of plants and animals.

Activities

1. Look more closely at the wall chart on "The classification of living organisms". How many kingdoms can you identify? Attempt a further breakdown of each kingdom (i.e. produce your own chart).
2. Explain the method used in classifying living organisms
3. List the major characteristic features of the following
   a. Vertebrates
   b. Invertebrates
   c. Kingdom plantae

4.0 Conclusion

The general principles of classification is very important in the study of Biology. Classification makes identification and naming of living organisms easier.

5.0 Summary

In this unit, you have learned that:

i. Biologists classify organisms in the hierarchy of groups.

ii. The Binomial name that identifies each type of organism is made up of its generic and specific names.

iii. Most biologists currently favour the classification of living organisms into five kingdoms: monera, protista, fungi, plantae and animalia.

iv. Monerans are unicellular procaryotes. Protists are unicellular eucaryotes. Fungi are mostly non-motile, unicellular organisms which are either saprophytes or parasites.

v. Plants are non-motile, multicellular autotrophs. Plants include thallophytes, bryophytes and racheophytes.

vi. Animals are mobile, multicellular heterotrophs. They include invertebrates and vertebrates.

vii. Invertebrates are animals without backbones.

viii. Vertebrates are animals with backbones.

6.0 Tutor - Marked Assignment

1. State one difference between members of each of the following pairs of organisms
   a. Fish and Reptile
   b. Flatworm and Annelid
   c. Birds and Mammals
   d. Sponges and Nematodes
2. Briefly describe the principles of the binomial system of nomenclature.

7.0 Further Reading and other Resources

F.O.C. Ndu, P. Asun and J. O. Aina (1999); *Senior Secondary School Biology 1. pg. 6-8.*

Sarojini T. Ramalingam (1993); *Modern Biology. Senior Secondary Science Series. pgs. 9-40.*

G Idodo-Umeh (1996); *College Biology* , Idodo-Umeh Publishers Ltd., Benin City.

A Wall Chart on "The classification of Living organisms"; *A Noun Production*

Unit 3: Viruses

Page

1.0 Introduction

The position of viruses relative to living organisms has been the topic of interesting debates among many scientists over the years. The basic question has been concerned with whether they are living or not living. We now know that viruses do not fit into the classification of living organisms. They are not cells, but particles. They differ from the five kingdoms in that they lack a nucleus, cytoplasm or cell membrane which characteristics cells of their own and cannot produce ATP.

Some viruses can be crystallised like non-living chemicals. Viruses are capable of parasiting living cells and cannot replicate (reproduce) thermselves outside a living host cell. Every virus is made up of the basic genetic material contained in living things. (i.e. DNA or RNA) surrounded by a protein coat. Viruses are obligate intracellular parasites that are host specific.

2.0 Objectives

By the end of this unit, you will be able to explain:

i. what viruses are.
ii. characteristics of viruses.
iii. the structures of viruses.
iv. mode of nutrition of viruses.
v. culturing of viruses.
vi. viral diseases and their control.

3.0 Characteristics of Viruses

The major characteristics of viruses are given below.

1. They are smaller than bacteria so they pass through bacterial filters.
2. They are crystallisable.
3. They lack structural sites for protein synthesis. No Ribosomes, ATP and Mitochondria except in Arenoviruses.
4. They lack metabolic enzymes so they cannot generate their own energy. They depend on host's A.T.P. - generating system for their energy.
5. They are made up of an outer coat of protein capsid enclosing the genetic material (no nucleus)
6. The genetic material is either RNA or DNA, never both, except the pox and retro viruses (AIDS virus).
7. All viruses contain carbohydrates.
8. They are intracellular obligate parasites requiring living cells for survival; hence they can reproduce only in other living cells by multiplication (also called replication).
9. They cannot grow on artificial media like bacteria.
10. They are highly specific, not only to host, but to a particular tissue within a specific host.
11. They do not have a cellular structure.

3.1 Structure of Viruses

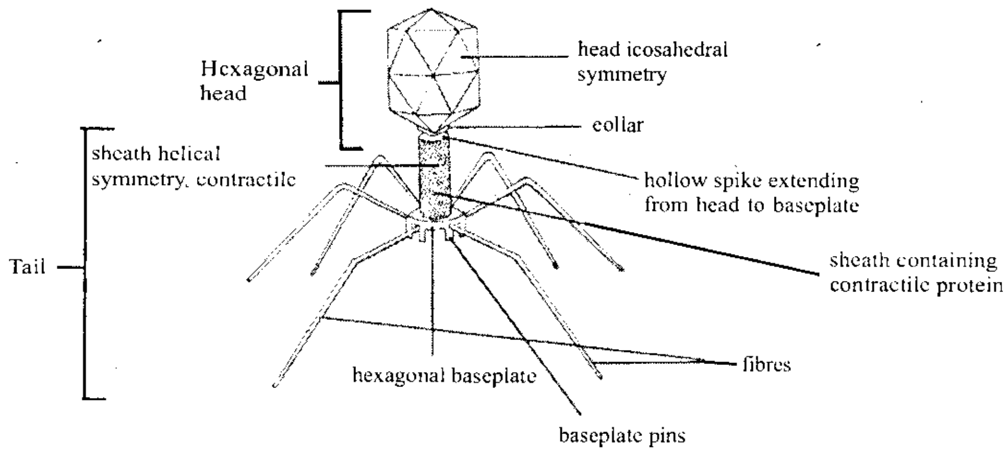
Viruses consist of two components, nucleic acid and protein coat (fig. 3.1). The nucleic acid is the genetic material, which may be single-stranded or double-stranded ribonucleic acid. The protein material or coat capsule protects the genetic material.

Four morphological groups have been identified, on the basis of their symmetry, namely;

i. **Icosahedral** e.g. Herpes and polio viruses
ii. **Helical** e.g. Tobacco mosaic virus and rabies virus
iii. **Binal** e.g. Bacteriophage
iv. **Complex** e.g. small pox and influenza viruses.

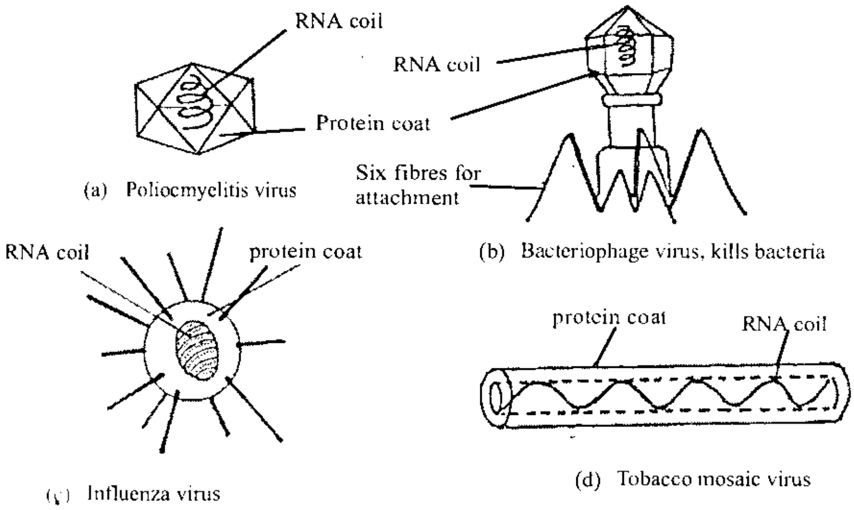
3.2 Size

Viruses are much smaller than bacterial cells. They can only be seen with the aid of an electron microscope. The particles range in size from about 20- 30nm – about 50 times smaller than bacteria and can pass through filters, which retain bacteria.



Structure of a T2 bacteriophage

The structure of various viruses (not to scale)



3.3 Mode of Nutrition

Nutrition

Viruses are parasites in living tissues of plants and animals and bacteria.

3.4 Nature of Viruses (Invation of a Bacterial Cell by a Bacteriophage)

A virus invades or infects a host or bacterial cell by attaching itself to specific receptor sites on the cell. Once secured to the cell, the virus penetrates the cell wall or cell membrane. Once inside the host cell, the viral nucleic acid takes over the metabolism and genetic machinery of the host cell to produce new virus particles in their thousands.

A free bacteriophage particle comes into contact with a bacterial cell by random collision. The phage attaches itself to a specific site on the bacterial cell wall by means of the tail fibres and end plate. The tail sheath contracts to force the DNA from the head core into the host (bacterial) cell. This event causes the bacterial DNA to be disorganized and the bacterial cell metabolism now comes under the control of the viral DNA.

The bacterial synthetic machinery is now used to make enzymes, which replicate viral DNA and viral structural proteins. Subsequently new viral heads and tails are formed in large numbers, and the component protein parts come together, forming complete new viruses. The process continues until the bacterial cell undergoes lysis releasing copious amounts of new virus particles into the infected host cells.

3.5 Culturing of Viruses

Because viruses cannot grow on artificial, they can only be cultured in living tissue. Living tissue cultures used in the laboratory include mice and incubated chicken eggs, and plant leaves/tissues.

3.6 Viral Diseases and their Control

- All viruses are intra-cellular parasites.
- Their reproduction within the host cells is rapid and results in the destruction of the cells. This explains why they are so harmful.
- The most serious diseases caused by viruses include measles, poliomyelitis, small pox, chicken pox, hepatitis, Acquired immune deficiency syndrome (AIDS) (Table 3.1).
- Other viral diseases of man are influenza, mumps, common cold, cowpox, shingles and dengue.
- Plant diseases due to virus infection include swollen shoot of cocoa and mosaic disease of cassava, tobacco mosaic disease, Bean mosaic disease, Tulip yellows (Table 3.2).

Table 3.1 Viral Diseases of Humans

Disease	Method of Transmission	Symptoms	Control/prevention and treatment
Measles	Air, by droplet infection.	Fever.	Isolation of patient.
One of the six killer diseases in children		Runny nose and cough.	Avoidance of overcrowding in schools.
7-14 days incubation period		Red, sore eyes.	
Especially dangerous in children		Rash inside the mouth (Koplik's spots).	Vaccination of children 8-14 months of age.
		Rash behind ears, then the face and later the rest of the body.	

Disease	Method of Transmission	Symptoms	Control/prevention and treatment
Poliomyelitis (Polio, paralysis)	Contaminated water and food Droplet infection	Sometimes only a cold with fever and sore muscles	Clean water supplies. Infantile
One of the six killer diseases in children 5-30 days incubation period, usually 10 days Most common in children under 2 years		Sometimes muscles and nerves are attached; a leg or both legs become paralysed and grow thin and the child may be crippled.	Hygienic food preparation. Vaccination - (mouth vaccine, polio drop's now available).
Hepatitis (infectious hepatitis) Affects normal functions of the liver	Contaminated water and food.	Fever Marked loss of appetite Nausa and vomiting.	Drinking water to be boiled Hygienic disposal of feaces Strict control of sanitation Globulins from plasma have been used.
Mild in small children, more serious in older people	injection with unsterilized needles.	Jaundice (yellowing of tissues e.g. the eyes) Dark yellow urine.	
AIDS (Acquired Immune Deficiency Syndrome)	Sexual contact-vaginal or anal intercourse.	Various infections which cannot be fought off.	Avoidance of casual sex Avoidance of anal intercourse.
Caused by Human Immunodeficiency Virus (HIV)	Sharing hypodermic needles for injection. Transfusion with contaminated blood Mother to child in the womb or in breast milk.	Common diseases are *Kaposis sarcoma*, a cancer of the skin and *pneumocystis carini* a type of pneumonia.	Avoidance of oral sex Sex with only one partner Treatment with AZT. No cure available as yet.

Table 3.2 Viral diseases of other organisms

Disease and Organism affected	Method of Transmission	Symptoms	Control/prevention and treatment
Rinderpest (cattle plague) Cattle (fig. 10.17)	Direct contact with sick animal	High fever and dullness Severe diarrhoea and bloodstained faeces Tear production and nasal discharged	Slaughter of affected animals Quarantine measure of avoid spread Vaccination of all cattle No treatment
Foot and mouth. Severe in cattle and pigs. Mild to sheep and goats	Direct contact with a sick animals.	Fever. Weakness. Heavy salivation. Sores on many body parts. Severe in cattle and pigs. Mild in sheep and goats.	Immediate slaughter of affected animals. Improved sanitation. Preventive vaccination. No treatment.
Newcastle. (Poultry)	Highly infectious Direct contact with infected bird.	Paralysis-drooping wings and sudden jerking of neck Blindness, Muscles tumors (swellings) Yellowish-white diarrohoea	Culling (killing) and removing of all infected birds Vaccination No treatment and thigh bone
Swollen shoot. Cocoa.	Mealy bugs.	Distorted leaves. Swelling at basal part of trees. Very few or no pods are produced.	Destruction (cutting and burning) of trees and using insecticides to control the black ants which carry mealy bugs
Cassava mosaic Cassava	White fly *Bemisia nigeriensis*	Leaves developed white mosaic patches, become wrinkled and lose chlorophyll.	Uprooting and burning of affected plants. Using insecticides to destroy white flies. Planting disease resistant varieties.

Activity

1. In addition to all you have studied so far, try to participate in the activity as you listen to the audio interview and /or watch the video presentation on "The Viruses: Are they living or non-living?
2. List six Characteristics of Viruses.
3. Briefly Describe the structure of a bacteriophage.

4.0 Conclusion

The study of Viruses is very important because of its signaficant, and importance to man in terms of human health and agriculture.

5.0 Summary

In this Unit, You have learned that:

1. viruses are visible only under the electron microscope.
2. viruses are classified into four morphological groups according to their symmetry, namely: icosahedral, Helical, Binal and Complex.
3. all viruses are intracellular parasites.
4. they cause diseases in humans, animals and plant.

6.0 Tutor - Marked Assignment

1. List 3 diseases caused by viruses in humans
2. (a) Draw and label the T_2 bacteriophage
   (b) Describe how viruses can be cultured.

7.0 Further Reading and other Resources

G Idodo – Umeh – *College Biology*, Idodo – Umeh Publishers Ltd., Benin city.
Tailor, D. J; N. P. O. Green and G W. Stout (1997). *Biological and Science* (R. Sopeed) Cambridge Low Price Editions, Cambridge University Press, UK.
B. V. M. Roberts, *Biology A Functional Approach*: ELBS
S.T. Ramalingam (2001) *Modern Biology*; Africana Fep Publishers, Nigeria.

(i) An audio recorded interview of renowned professors of Biology
(ii) A video demonstration with back-up current research findings by renowned professors of Biology on "The viruses: Are they living or non-living organisms?" A NOUN Production.

Volume 1: Basic Concepts in Biology

Unit 4: Bacteria

1.0 Introduction

Anton Von Leeuwenhoek discovered bacteria between 1653 - 1673 with the help of a crude microscope. This was later established by Louis Pasteur (1822 - 1895). Bacteria are unicellular, procaryotic, a-chlorophyllous organisms, of microscopic size. The largest bacteria are about 12 microns in diameter and cannot be seen without the aid of a microscope.

They are ubiquitous - occuring in every natural environment - in the air, water, soil and in and on the bodies of other organisms. Bacteria even colonise the buccal cavity and alimentary canal of humans and ruminants.

Over 2000 species of bacteria have been classified and named of these only a few cause discases in humans, animals and plants. The vast majority of bacteria are saprophytic or free-living. They are extremely important because of their effects on the human systems.

2.0 Objectives

By the end of this unit, you should be able to:

i. list at least six of the general characteristics of bacteria.
ii. describe the structure of bacteria.
iii. describe reproduction and nutrition in bacteria.
iv. explain the Economic importance of bacteria.

3.0 Characteristics of Bacteria

Do you remember that living organisms have features that are peculiar to them? Bacteria do have theirs.

You will recall that there are over 2,000 species of bacteria. They are:

* generally microscopic in nature, they are single celled.
* they may be spherical, rod-like or spiral in shape.
* they may be motile or non-motile.
* aerobic or anaerobic.
* they have no definite nucleus but chromatin granules.
* the Cell wall is made up of chitin.
* some are equipped with one or more flagella.
* they lack chlorophyll.
* spherical ones are about 0.5mm wide while the rod like are about 2mm - 10mm long.
* they inhabit a wide range of natural habitats.

Activity A

i. Go, back and read through the above features (characteristics) 5 - 10 times
ii. Now close your text and list any six of the characteristics of bacteria.

3.1 Occurrence

We need to also consider the occurrence of bacteria as living organisms;

* They exist everywhere i.e. in water, air, soil and body of other organisms living or non-living
* They float in air or dust particles.
* Abundant in water bodies and soil to a depth of 30cm.
* Surplus in sewage.
* Occur in the intestine of all animals.
* One gram of fertile soil is estimated to contain 2.5 thousand million while 1cms of fresh milk may contain more than 3000 million bacteria.

3.2 Structure of Bacterial Cell

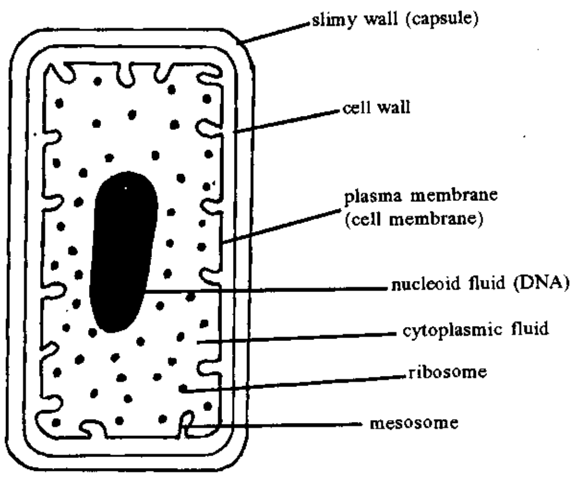
With the aid of diagram (Fig. 4.1) let us look at the structure of bacteria

* Bacteria are made up of complex cell wall made up of proteins and carbohydrate, sometimes impregnated with chitin.
* No cellulose.
* Covering the cell wall is a slime layer called the **capsule or sheath**. In this form they are resistant to drugs and adverse conditions.
* There is a definite cytoplasm.
* No clearly defined nucleus, but DNA is the nuclear material that is not bounded by a nuclear membrane.
* Contains no membrane bound organelles.

3.3 Different Shapes of Bacteria

Again, let us consider different shapes of bacteria. They have four different forms (Fig. 4.2). These are;

1. **Cocci {Singular = Coccus}.** The cells are spherical or rounded. Depending on how they cling together after cell division the cocci can further be classified as *diplococci, staphylococci and streptococci.*
2. **Bacilli {Singular = bacillus}.** The cells are rod-shaped. Some have flagella. Rod-shaped bacteria may also remain attached end-to-end as in the genus *Lactobacillus.*
3. **Spirilla {Singular = spirillum}.** The cells are spirally twisted or corksrew like. Some have flagella. Example is *Treponema.*
4. **Vibrio:** The cells are comma-shaped Example is *Vibrio cholerae*



Source: College Biology by Idodo-Umeh

Figure 4.1: The Structure of a bacterial cell

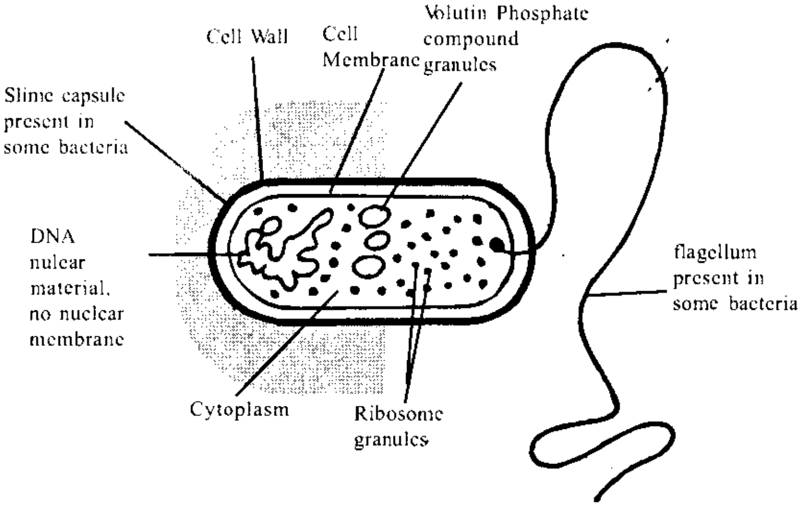


Figure 4.2 Schematic diagram showing the internal structure of a bacterial cell

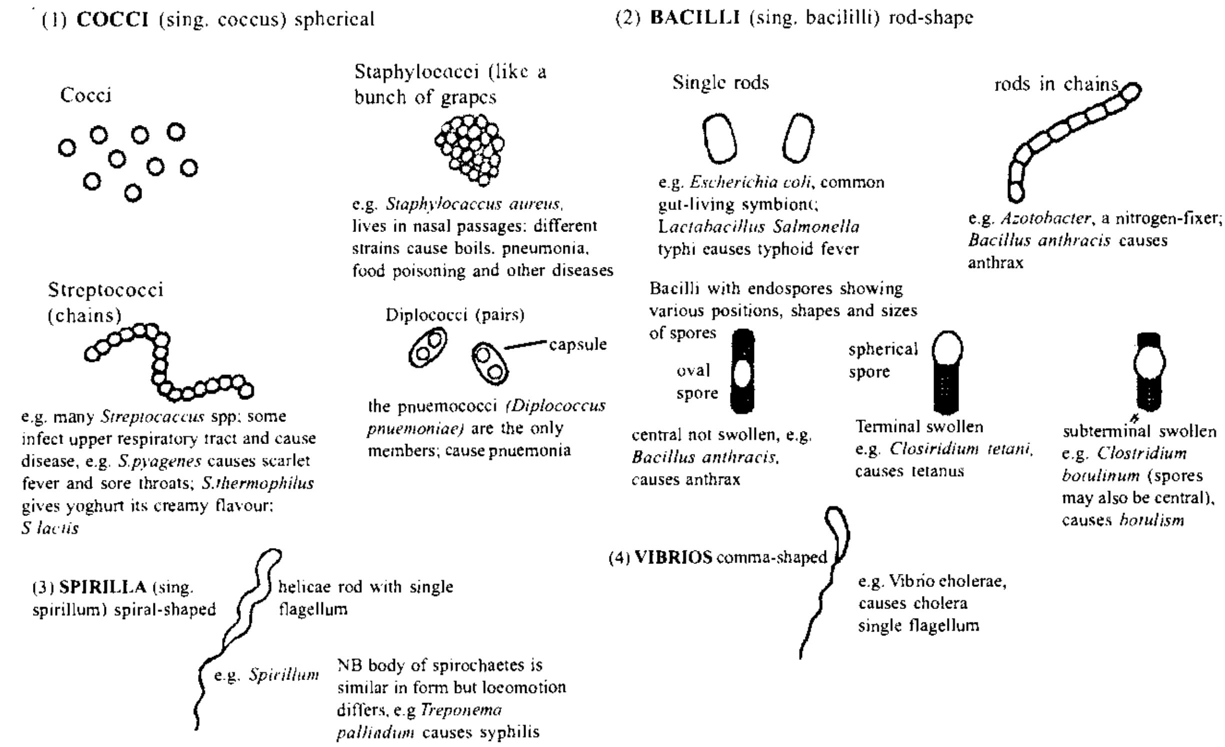


Figure 4.3: Forms of bacteria, illustrated by some common useful and harmful types

Activity B

1. Describe to your study group/mate ... various shapes of bacteria
2. With a well labelled diagram describe the structure of a bacterial cell.

3.4 Reproduction

You will find the process of reproduction in bacteria very interesting. Let us now consider the details.

Reproduction in Bacteria:

* Mainly by binary fission, no sexual reproduction.
* Binary fission occurs under favourable conditions.
* The chromatin material divides mitotically.
* Cytoplasm divides along with its content.
* Two daughter bacterial cells are formed.
* *Bacillus subtilis* divides 2 - 3 times in an hour.
* A single cell may give rise to about 16 million cells in 12 hours.

3.4.1 Sporulation

We now consider this as an occurence that leads to the multiplication in the number of bacteria. Sporulation goes on as follows:

* Rod-shaped bacteria form spores as resting spores.
* Mass of protoplasm condenses with thick membrane (endospore).
* Mother cell dissolves; endospore remains dormant resisting adverse conditions e.g. freezing, dryness, high temperature etc.
* Under favourable conditions, new bacterial cells emerge.

Activity C

You can now describe the process of reproduction in bacteria.

3.5 Gram Reaction

The gram reaction/test developed in 1884 by Danish Biologist (Christian Gram) revealed that bacteria can be divided into two natural groups based on their reaction to the **Gram's Stain**.

Those bacteria which stain with gram's stain are called **Gram Positive**, others that do not are called **Gram Negative**.

Gram positive bacteria such as *Staphylococcus, Bacillus* and *Lactobacillus,* develop thick walls impregnated with polysaccharides and proteins. The walls of Gram negative bacteria such as *Salmonella, E coli* and *Azotobacter* are thinner but more complex. Gram positive bacteria are purple or violet after staining with Gram's stain while Gram negative bacteria are pink in colour after the staining reaction.

Activity D

1. With the aid of the video clip on "Gram reaction/Test"

   (a) State the colour of a bacterial cell if it is

   i Gram negative

   ii. Gram positive

   (b) Name two examples each of;

   i. Gram positive bacteria

   ii. Gram negative bacteria

3.6 Nutrition

* Bacteria require energy for activities.
* Some are autotropic, others are heterotrophic.
* Autotrophic ones possess chlorophyll-like pigment.
* Manufacture complex compounds from oxidation of sulphur, iron and nitrogen compounds.
* Heterotrophic ones are either saprophytic or parasitic.
* Saprophytes live in water, soil and material containing decaying plants and animals.
* They produce enzymes for extra-cellular digestion of complex compounds.
* Parasites depend directly on the living host (plants and animals) for food.
* They secrete enzymes which digest the food into simpler forms
* Toxins produced by bacteria result in disease conditions in the host.

3.7 Economic Importances of Bacteria

Some bacteria cause food spoilage, diseases and yet some are very beneficial.

Food Spoilage

Bacteria are man's competitors for food. This competition leads to the spoilage of food. Protein foods are caused to decay due to the action of bacteria. Carbohydrates are fermented by bacteria, while fats and oil are destroyed by causing them to have bad smells, by bacteria.

3.7.1 Harmful Bacteria

* Parasitic or pathogenic bacteria infects plants and animals causing various diseases.
* They infect host through water, food and wounds.

The following bacterial disease occur in man:

Bacterium	Disease
Bacillus anthracis	anthrax
Bacillus typhosus	typhoid
Clostridium tetani	tetanus
Clostridium botulinus	botulism (food poisoning)
Corynebacterium diphtheriae	diphteria
Mycobacterium tuberculosis	tuberculosis
Mycobacterium leprae	Leprosy
Bacillus dysenteriae	dysentary
Diplococcus pneumoniae	pneumonia
Vibrio cholerae	cholera

In plants, bacteria cause the blight disease of apple, pear, potato, tomato etc. They also cause the soft rot and decay of fruits and vegetables, as well as the scab of potato

Table 3.1 - Some other Diseases caused by Bacteria

Disease	Causative Organism	Mode of transmission	Symptoms	Control
1. Tetanus *(Lock jaw)*	Bacteria *(Clostridium tetani)*	Through a cut on the skin. Through a hole on the body by dirty sharp objects, such as nails or broken bottle	Paralysis of muscles (inability of the muscles to contract) especially the muscles of the jaw.	1. Avoid cuts on body. 2. Broken bottles, nails or any sharp objects must not be thrown to the floor, compound and streets, but buried. 3. Immunise yourself.
2. Leprosy.	Bacteria. *(Mycobacterium leprae)*	Long contact with a sufferer of leprosy.	1. Swelling of the limbs. 2. Fingers and toes are gradually being eaten up by the germs. 3. Blotches on the skin. 4. Skin becomes insensitive to pain.	1. Infected person should be isolated. 2. See medical doctor.
3. Whooping cough.	Bacteria. *(Haemophilus pertusis)*	By inhaling droplets from an infected person.	Cold, high fever, cough with prolong sound and vomiting. Pneumonia may result.	1. Isolation of infected person. 2. Babies should be immunised early in life. 3. Sputum of an infected person must be burnt or buried.

Source: College Biology by - Idodo - Umeh 1996

3.7.2 Beneficial Activities of Bacteria

Bacteria play vital roles in agriculture, industry and medicine as shown below;

Agriculture

A. Decay

- Most active in the decay of dead organic matter. The complex organic compounds are reduced to nitrates, sulphates and phosphates in the soil, for plant use. CO_2, H_2O and oxides of nitrogen formed in the process are equally used in the synthesis of food.
- Similarly, during the process of decaying, chemical substances locked up in the dead organisms are released into the soil; making the soil fertile.

B. Nitrification

- Proteins in dead plants and animals are reduced by bacteria to ammonium compounds (ammonification) - these are oxidized into nitrites and nitrates (nitrification), and are then absorbed by green plants.

C. *Nitrogen Fixation*

Free nitrogen of the air is fixed by soil bacteria e.g. *Azotobacter, Clostridium*. Fixation occurs in their body but *Rhizobium* does it through the agency of root nodules in leguminous plants.

D. *Fertilisers*

Conversion of cow dung and animal faeces into manure and humus is by bacterial activity. Other activities in conjuction with other soil organisms increase soil fertility.

E. *Plant Disease Control*

Some antibiotics are obtained from bacteria and used to control various plant diseases.

Industrial

Industrially, curing and ripening of tobacco leaves, fermentation of tea leaves, ripening of cheese and butter making for flavouring are carried out by bacteria.

Other uses include:

* Degradation of sewage; In sewage, solid matter is acted upon by bacteria converting it into material which can be used as fertilizers.
* Retting of fibres: In the retting of flax, bacteria decompose the pectin that holds the fibres together. The free fibres are then processed into linen.
* Formation of vinegar from alcohol.
* Fermentation of glucose to alcohol by yeast and bacteria.
* Curdling of milk
* Conversion of hide to leather by tanning.
* Silage preparation for cattle.
* Fermentation of milk to yoghurt: Yoghurt is made by fermenting milk using lactic acid bacteria e.g. *Lactobacillus bulgaricus*. This fermentation process yields lactic acid and ethanol that give yoghurt its characteristic flavour.

Medical

A number of antibiotics have been obtained from bacterial e.g.

i. Streptomycin from *streptomyces grisesus*
ii. Chloromycetin from *Streptomyces venezuelae*

These antibiotics are used to cure deadly deseases.

Other bacteria are found in both human and herbivore intestine. In man they are known to control growth of putrefactive and pathogenic bacteria. In ruminants, they produce cellulose enzymes for digestion of cellulose to simple sugars.

Other uses include

Synthesis of vitamin B complex and vitamin K in man: Some bacteria present in the intestine of man manufacture vitamin B and vitamin K. These vitamins are useful to man.

Activity E

Briefly explain to a friend/parent/mate the importance of bacteria in agricultural, industrial and medical development in Nigeria.

4.0 Conclusion

The importance of bacteria to man cannot be overemphasised. In the light of this the study and application of bacteria should be intensified.

5.0 Summary

In this unit, we have learnt that:

i. Bacteria are unicellular organisms of microscopic size.
ii. Bacteria can be seen with light microscope.
iii. Bacteria possess the following characteristics, they lack chlorophyll; have no definite nucleus; cell wall is made up of chitin, may be spherical, rod-like or spiral in shape.
iv. Bacteria have different shapes.
v. Bacteria play vital roles in agriculture, industry, and in medicine, while some are harmful to man and his crops.
vi. Bacteria may be categorised as Gram positive or Gram negative based on their reaction to the Gram stain.

6.0 Tutor-Marked Assignment

1. Briefly describe the following
(a) Sporulation.
(b) Nutrition in bacteria.
2. List six bacterial diseases which occur in man and bacterial diseases of plants.

7.0 Further Reading and other Resources

F.O.C. Ndu, P. Asun and J. O. Aina (1991) - *Senior Secondary School Biology, Books 1 & 3*
Idodo - Umeh (1996) *College Biology;* Idodo - Umeh Publishers Ltd, Benin City
Sarojini T. Ramalingam (2001). *Modern Biology* Africana - Feb Publishers. Benin City
A video clip of the bacterial Gram reaction / test. A Noun Production.

Unit 5: Protozoa

Page

1.0 Introduction

The Protozoa are microscopic and unicellular animals found in both marine and fresh water environment and in damp soil.

- They belong to the kingdom, protista (Refer to Unit 2 Vol 1)
- Some are free-living (e.g. *Amoeba proteus, paramecium, entamoeba histolytica* and *Trypanosoma).*
- *Amoeba* and *Paramecium* are typical examples of protozoans.
- *Euglena viridis* is a protist that shows both 'plant-like and animal-like features.

2.0 Objectives

By the end of this unit, you should be able to;

1. List at least five of the characteristics of protozoans.
2. Give two examples and describe the structures of protozoans.
3. Explain the process of feeding, respiration, excretion and reproduction in protozoans.

3.0 Characteristics of Protozoans

Do you remember that living organisms have features that are peculiar to them? Protozoans do have their own.

In this lesson, we will consider a few organisms that are too tiny to be studied with the unaided eye and for which we will need a microscope.

They inhabit fresh and salt water, damp and dry soils, while others are parasites of animals.
They are unicellular organisms.
Usually microscopic in size
They may be spherical, oval, elongated, colonial or irregularly shaped
Possess a single nucleus or multiple nuclei.
Locomotion is by means of cilia, flagella, pseudopodia, or movement of cell itself by contraction and extension.
They form spores or cysts during dry, adverse conditions.
Asexual reproduction is by binary fission, while sexual reproduction is by gamete fusion and conjugation.
The animal body is protected either by a cell membrane or by a pellicle.
The protoplasm performs all the processes of living things, as there are no organs or tissues, while reproduction is controlled by the nucleus.
Examples of protozoans include *Amoeba, Euglena, Paramecium* and *Plasmodium.*
They may be commensals or symbiotic.

The different classes are characterised by locomotory organelles, e.g. *Amoeba* moves by Pseudopodia, *Paramecium* moves by cilia, *Zooflagellates* move by flagella, sporozoa have no organelles for movement.

3.1 *Amoeba Proteus*

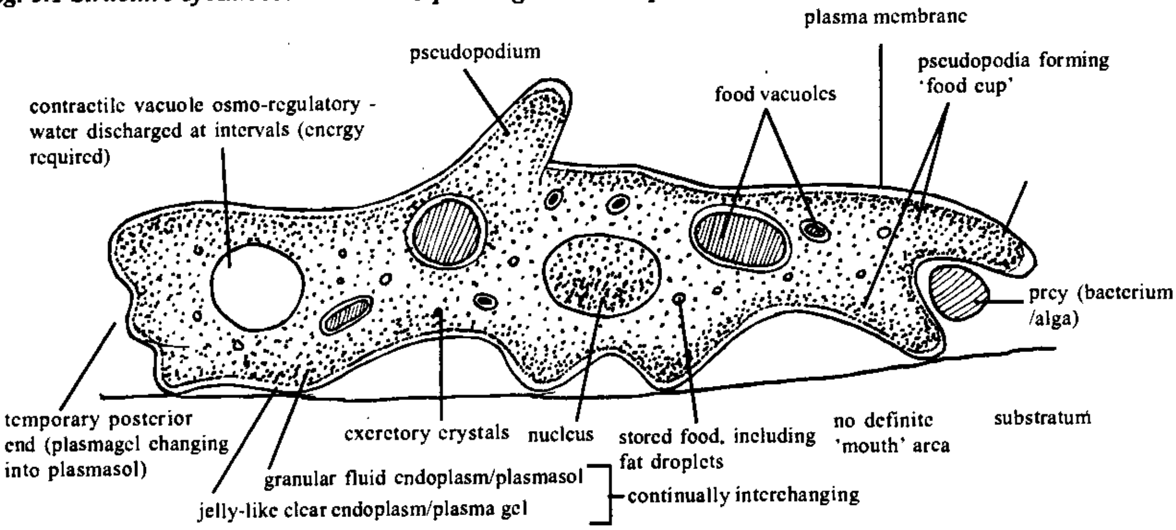
* It belongs in the class *Rhizopoda (Sarcodina)*
* It lives in the bottom of fresh water ponds.
* It cannot be seen with naked eye, except with a microscope, though very large ones can be seen as white specks when viewed with the naked eye or hand lens.
* It has no mouth or alimentary canal

3.1.1 Structure of *Amoeba Proteus*

With the aid of the diagram in fig. 5.1, let us look at the structure of *Amoeba.* You also need to either look at a live specimen under the microscopic or look at the video clip on *Amoeba*. Using all these we can see that;

* The body is covered by a delicate cell membrane called plasmalemma or plasma membrane.
* This plasma membrane prevents the animal from sticking to surfaces.
* Inside the plasmalemma, lies the protoplasm, which divides into two portions namely the ectoplasm and endoplasm.
* The ectoplasm is the outer clear portion while the endoplasm is the dense inner portion.
* The endoplasm is dense because it contains the food vacuoles, contractile vacuole, the nucleus and other inclusions.
* The nucleus controls the metabolic activities of the organism and takes part in reproduction.
* Contractile vacuole helps in osmoregulation and excretion.
* The pseudopodia help in movement and feeding.
* Food vacuoles are involved in feeding and digestion.

Fig. 5.1 Structure of Amoeba Class Rhizopoda e.g. Amoeba Sp.

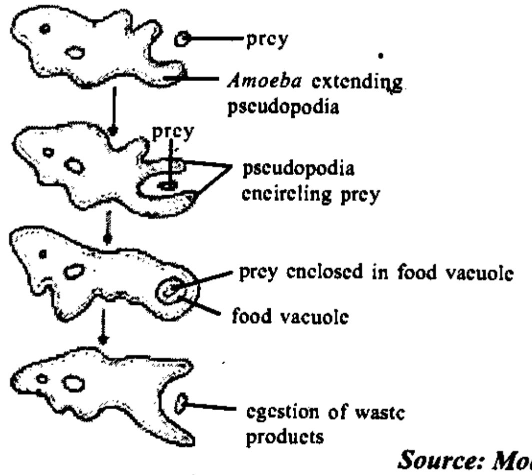


Gross Morphology of Amoeba

3.1.2 Feeding in *Amoeba*

Now let us consider how Amoeba feeds.

* Amoeba feeds on minute particles (microorganisms) such as *Chlamydomonas*, bacteria, diatoms, and desmids etc. that float around it.
* When it comes in contact with the food, it sends out its pseudopodia that surround the food, engulfing it with a drop of water, thus forming a food vacuole. This process is termed ingestion.
* Immediately the food is engulfed, digestive juice from the cytoplasm is secreted into the vacuole and this breaks it down into diffusible molecules.
* These molecules are then absorbed for metabolic purposes.
* Undigested material is left behind and egested as waste.



Source: Modern Biology

Figure 5.2 Feeding in Amoeba

3.1.3 Respiration in *Amoeba*

Do you know how oxygen gets into the body of *Amoeba* and carbondioxide gets out of the body of Amoeba? read this:

* Amoeba has no respiratory structures (organelles); respiration is by simple diffusion
* Oxygen from the surrounding water diffuses through the plasmalemma into the protoplasm while carbon dioxide from inside diffuses out into the water.

- This interchange of gases correponds to the internal respiration of cells in higher animals. That oxygen is necessary for life of the *Amoeba* can be demonstrated by replacing the oxygen with hydrogen. Movement ceases after 24 hours; if air (oxygen) is introduced movement begins again.

3.1.4 Reproduction in *Amoeba*

You remember that all living organisms increase in number. Let us consider how *Amoeba* does it ordinarily the *Amoeba* builds up protoplasm more rapidly than it breaks it down; and when full size is attained, it reproduces by a simple process of division called Binary fission. The young *Amoeba* grows until it reaches its maximum size. Then it reproduces to give rise to young individuals.

At the onset of division, *Amoeba* stops moving and rounds off. The nucleus constricts and becomes dumbbell shaped. Then it divides into two identical parts. Then the cytoplasm of the *Amoeba* cell divides into two identical daughter *amoeb*

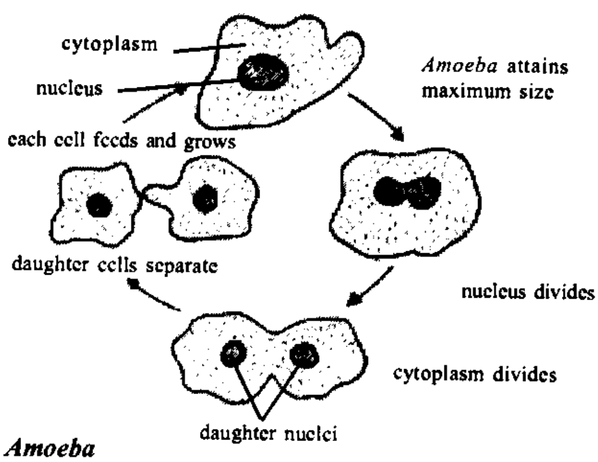


Figure 5.3 Binary Fussion in Amoeba

3.1.5 Excretion and Osmoregulation in *Amoeba*

The process of osmoregulation in *Amoeba* is very interesting. You will like it.

- The Amoeba lives in freshwater which is hypotonic to the content of its cells.
- Water constantly enters the amoebic cell through its selectively permeable membrane by osmosis.
- This water will dilute the cell content unless the *Amoeba* secretes it.
- The contractile vacuole expands as it is filled with water and then empties its contents to the exterior (Fig. 5.4)
- The vacuole acts as a kind of water pump for getting rid of excess water.
- This water has almost no salt in it.
- For the contractile vacuole to work energy is needed and mitochondria that lie close to the vacuole supply the energy.
- The frequency of the filling and discharging processes of the contractile vacuoles decreases as the salinity of the aquatic medium increases.
- The contractile vacuole is known as an **osmoregulator** as it regulates the water content of the cell.
- Excretory products, like ammonia and carbondioxide, leave the *Amoeba* by diffusion across the selectively permeable cell membrane to the exterior.
- This is an adequate mechanism for excretion of metabolic waste since the surface area to volume ratio of the *Amoeba* is large.

* Osmoregulation is the maintenance of water balance in the body.

A. How a contractile vacuole works

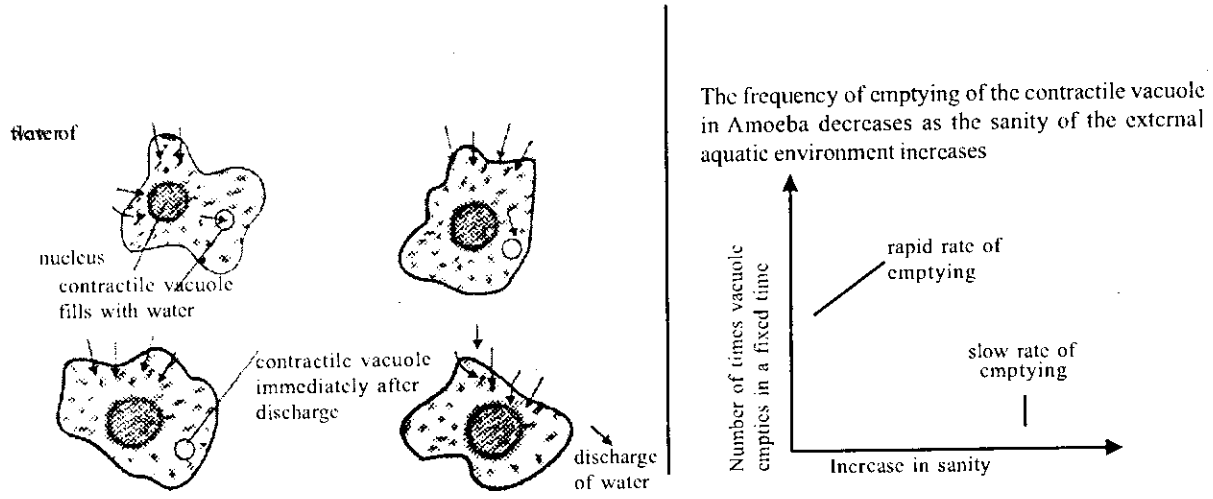


Figure 5.4 Osmoregulation in Amoeba

3.1.6 Movement in *Amoeba* (Amoebiod Movement)

* *Amoeba* moves be means of pseudopodia.

* During amoeboid movement, the ectoplasm and the flexible plasmalemma form a temporary projection into which the endoplasm flows. This results in the formation of a pseudopodium

* Thus *Amoeba* moves by continual formation of pseudopodia in the direction it wants to go.

N.B: Some people say that the *Amoeba* is shapeless. This is not true. The *Amoeba* is only *irregular* in shape because by its movement, it is continually forming pseudopodia in the forward direction and withdrawing those behind.

Activity A

1. List 6 characteristics of the protozoans.
2. With a well labelled diagram, list four features of Amoeba proteus.

3.2 Euglena Viridis

This is another unicellular organism. Its peculiarity is that it has some characteristics of a typical plant cell and some of a typical animal cell. You will appreciate these facts as you study *Euglena viridis*

Euglena viridis

Euglena is found in muddy water of slow-running streams, stagnant pools and ditches, which are polluted with urine and faeces. It has both plant and animal features. It is a unicellular flagellated organism. It is characterised by the following features;

Presence of photosynthetic pigments that contain chlorophylls a and b and also carotenoids.

Cell has no cellulose cell wall, but possesses a cell membrane or pellicle

Presence of one, two or three flagella at the anterior end of the cell

Presence of the polysaccharide, paramylum as food reserve.

Euglena belongs to the class Mastigophora (Flagellata); it is a green spindle-shaped unicellular organism. The botanist regards it as a plant, while the zoologist calls it an animal. This is because it has the features of both plants and animals.

3.2.1 Plant-like Characteristics of *Euglena*

* It possesses chloroplasts and feeds like a plant.
* The food reserve is starch in form of paramylum granules.

3.2.2 Animal-like Characteristics of *Euglena*

* It possesses a flagellum and it is motile.
* It has photoreceptors (eye spots).
* Possesses contractile vacuole for osmoregulation, and, a gullet.
* It is protected by an elastic covering called the pellicle.
* It has no cellular cell wall, but has a plasma membrane called pellicle, an animal feature.
* It has myonemes, i.e. contractile fibres, which permit contraction and elongation of the organism during movement.

3.2.3 Structure of Euglena

There is no cellulose wall. The cell is bounded by a cell membrane called a pellicle or periplast. The pellicle is flexible and elastic and this enables the cell shape to change 'euglenoid movement'.

Gullet and Contractile Vacuole

The organism has a flask-shaped invaginatoin at the anterior region known as the gullet. The gullet consists of an enlarged reservior and a narrow cytopharynx which is concemed with ingestion of solid food particles.

A contractile vacuole is located near the reservior. The vacuole empties into the reservoir and a new contractile vacuole is formed from smaller vacuoles. The contractile vacuoles have an osmoregulatory functions.

Flagellum

It is a whip-like structure located at the posterior end of the reservoir and passes through the cytopharynx.

It is used for locomotion.

Stigma or eyespot

It is a light-sensitive spot situated near the base of the flagellum, which enables the organism to sense and move towards light needed for photosynthesis. When it encounters an unfavourable stimulus, it moves quickly away from it.

Chloroplast

Euglena contains the photosynthesis pigment of coloured euglenoids. The colour of *Euglena* is due to the presence of chlorophyll in its stellate chloroplasts which absorb energy from sun light.

Nucleus

The nucleus is oval and found either in the centre or at one side of the endoplasm (plasmasol). It is used for reproduction (longitudinal binary fission).

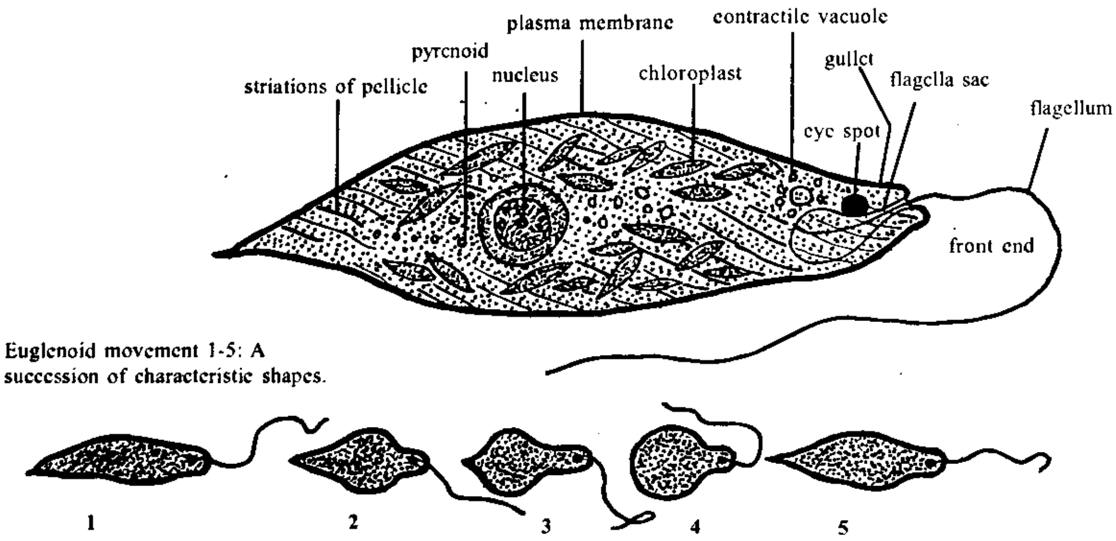


Figure 5.5: Structure of Euglena

Activity B

1a. Make a large, labelled diagram of the Euglena

b. State one function each of the following organelles found in an Euglena cell:

   i. chloroplast

   ii. Eyespot

   iii. Flagellum

3.2.4 Nutrition in *Euglena*

Nutrition in *Euglena* is very interesting. Let us now go through the details of how *Euglena* obtains its food.

* The mode of nutrition is similar to what obtains in green plants due to the presence of chloroplasts with which *Euglena* manufactures its food.
* By means of chloroplyll contained within chloroplasts, *Euglena* makes use of its surrounding water, sunlight and dissolved carbon dioxide to manufacture carbohydrates

* Oxygen is given out as by product.
* Although *Euglena* is capable of photosynthesis, all species of *Euglena* require some organic materials from the water in which they live, i.e. they are heterotrophic. A few species can live saprophytically in darkness e.g. *Euglena gracidis*. Generally, however, starch is stored in the paramylum granules and in pyrenoids.

3.2.5 Movement in *Euglena (Euglenoid movements)*

- *Euglena* can creep over surfaces as well as swim with the aid of its flagellum.
- Creeping involves marked changes in shape, known as (***euglenoid movements***).
- Swimming is achieved by the undulations of thc flagellum.
- The beating of the flagellum is intrinsic (it will continue lashing when removed from the organism, as long as ATP is available).
- It is usually held in front or at the side of the swimming cells, causing the cell to rotate and describe a spiral path as it is pulled forward through the water.

3.2.6 Reproduction in *Euglena*

The only form of reproduction in *Euglena* is asexual.
This is by longitudinal divison of the whole animal.
The nucleus and the cytoplasm divide into two longitudinal unequal halves
One of the halves goes with the flagellum.
The other half grows a new flagellum.
Under unfavourable conditions *Euglena* may form cysts.
The protoplasmic contents contrast and are enclosed in a thick cyst to resist adverse conditions.
The contents of the cysts divide to form numerous young *Euglena*, which are liberated and they grow to be adults.

Activity C

List 8 processes involved in the reproduction of Euglena.

4.0 Conclusion

In the two organisms discussed, there are no organs or tissues to carry out the activity of life. However, there is some degree of specialisation and differentiation of the cell protoplasm into organelles to carry out different functions in the two organisms and in the members of the group that they represent. Their study therefore, help us to know the evolutionary trend of the organisms.

5.0 Summary

In this unit, you have learned that;

1. Protozoans are microscopic and unicellular in nature
2. They belong to the kingdom protista.
3. Some are free-living (e.g. *Amoeba proteus*) while others are parasitic (e.g. *Plasmodium, Entamoeba histolytica* and *Trypanosoma*).
4. Typical examples include *Amoeba, Paramecium, Euglena,* and *Plasmodium.*
5. Asexual reproduction is by Binary fission and sexual reproduction is by gametic fusion and conjugation.
6. Amoeba belongs to the class Rhizopoda.
7. *Euglena* possesses both plant and animal features. The features of plants include the presence of chloroplasts and pyrenoids while those of animals include the presence of eyespot and pellicle.

6.0 Tutor - Marked Assignment

1a. Make a large, labelled diagram of the *Euglena.*

b. State one plant like and one animal-like characteristics of *Euglena*.

2. Describe the process of movement in *Amoeba*.

7.0 Further Reading and other Resources

Idodo - Umeh (1996) *College Biology; Idodo* - Umeh Publishers Ltd., Benin City

Sarojini T. Ramalingam (1993). *Modern Biology* Africana-Feb Publishers, Benin City.

A video clip of *Amoeba* demonstrating its structure, movement and feeding. A NOUN Production

Volume 1: Basic Concepts in Biology

Unit 6: Paramecium, Biological and Economic Importances of Protozoa

Page

1.0 Introduction

Paramecium belongs to the class ciliophora (ciliata) in the Phylum Protozoa.
It is found in pond water and streams containing decaying matter.
It is a unicellular organism, however, its body is more complex than that of the*Amoeba*.

2.0 Objectives

By the end of this unit, you should be able to;

i. describe *Paramecium* and its structure.
ii. explain the type of feeding in *Paramecium.*
iii. discuss respiration in *Paramecium* in comparison with Amoeba.
iv. summarise excretion, movement and reproduction in *Paramecium.*
v. state the economic and biological importance of protozoans.

3.0 Structure of Paramecium

Lets have a run down of the distinguishing features of a *Paramecium* using (Fig. 6.1)

* It is slipper-shaped, with pointed and blunt ends.
* The blunt end is the anterior end while the pointed end is the posterior end.
* The whole body is protected by stiff and firm covering called the pellicle, which gives it shape
* The entire body is covered with cilia, which are used for locomotion, selection of food materials and also for wafting food into the gullet.
* The inside of the pellicle is lined with thread-like structures called trichocysts.
* Trichocysts are very sensitive. They serve as a means of defense as well as for anchorage.
* The protoplasm, found underneath the pellicle is divided into two, the dense thick ectoplasm and a more fluid endoplasm.
* The endoplasm contains the two nuclei, the contractile vacuoles and many food vacuoles.
* The large meganucleus controls digestion and excretion while the small micronucleus controls reproduction.
* The two contractile vacuoles have radial canals that collects fluid and discharge same into the vacuole. From the vacuole, the fluid is discharged through the surface to the surrounding water.
* There is a wide shallow opening called the oral groove (mouth) on the ventral surface of the organism. The groove leads into a tube called the gullet, at the base of which is a cytostome. These structures help in feeding.
* Food enters through the oral groove, passes through the gullet and forms an oval food vacuole at the end of the gullet.
* The food vacuoles serve as food reservoir.
* The cilia are delicate extension of the ectoplasm. Each contains fibrils.

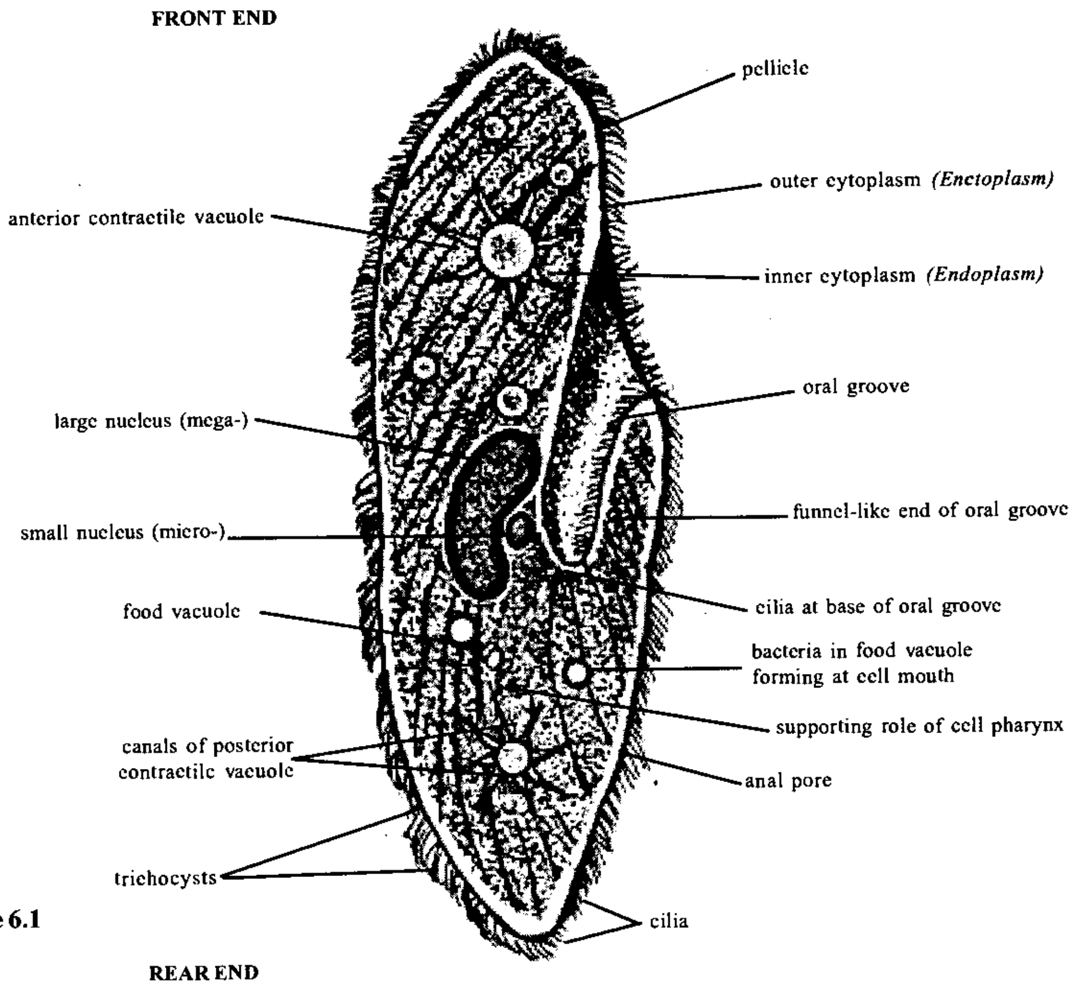


Figure 6.1

3.1 Feeding in *Paramecium*

This organism whose structure you are now familiar with moves by means of its numerous cilia which line the entire body and which also closely line a small passage into its body called the gullet.

It feeds mainly on bacteria and organic particles.

The food is taken through the oral groove and sent down through the gullet by the help of cilia that line the oral groove.

In the gullet, the cilia strain or select the food particles and send them down into the food vacuole, which then moves to the posterior part of the body following a definite path in the endoplasm (cyclosis).

The endoplasm secretes enzymes, which help in the digestion of food and it also absorbs the digested food.

The undigested particles are removed through the anal pore at the posterior end of the oral groove.

3.2 Respiration in *Paramecium*

Just as you saw in *Amoeba*, there are no special respiratiory organs. We therefore have respiration in Paramecium as follows;

Oxygen diffuses in, while carbondioxide diffuses out through the entire body surface.
The concentration of dissolved oxygen in the water is higher than that inside the cell, while the concentration of carbondioxide inside the cell is higher than that in the water. Oxygen therefore diffuses into the cell while carbondioxide diffuses out of it.
Oxygen which diffuses into the cell can reach all parts of the cell by diffusion, while carbondioxide in any part of the cell can diffuse out.

Activity A

a. Watch a video clip on Paramecium. Now look again at Figure 6.1 in detail.
b. Make a large, labelled diagram of Paramecium and describe the structure.

Activity B

You are also now familiar with feeding in Paramecium. Highlight the importance of cilia as you explain this process to a friend.

Activity C

a. Refer to unit 5 again. Look at respiration in Amoeba
b. Using a Table, compare respiration in Paramecium and Amoeba

3.3 Excretion and Osmoregulation in *Paramecium*

You will see below how *Paramecium* as a living organism, removes the waste products of its activites. Can you make short notes as you read on?
Nitrogenous waste materials are removed through the body surface through the contractile vacuoles.
The contractile vacuoles carry out the function of osmoregulation. Their radial canals gather excess fluid from the cytoplasm for discharge into the surrounding water.
Most of the excretion in *Paramecium* is by diffusion through the cell membrane.
Paramecium which is permanently bathed in water, simply excretes its wastes from its body surface.
Contractile vacuoles are used to regulate the amount of water in the cell water enters the cell by osmosis and excess of this water is removed by the contractile vacuoles to prevent the cell from increasing in size and bursting.
Excretion of carbondioxide and ammonia occurs by diffusion over the entire surface of the cell.

3.4 Movement in *Paramecium*

We need to consider movement as another important activity in *paramecium*. You do remember that it needs to move in order to take in food.

* Movement is carried out using cilia.
* When the cilia beat backwards (backstroke), the animal is pushed forward and when the cilia beat forwards, the animal returns to former position.
* The cilia stops beating when the animal stops or changes direction of movement.
* The structures called myonemes are used for changing shape or squeezing the body of the animal during locomotion.
* The propulsion of the food vacuole, along a more-or-less definite pathway around the protoplasm of a protozoan is peculiar to *paramecium*.
* Movement can be rapid by ciliary action either swimming or gliding over surfaces.

Activity D

Now make short notes describing movement in Paramecium

3.5 Reproduction in *Paramecium*

The next activity we shall consider in *Paramecium* is reproduction. You need to follow it step by step. Try and make short notes as you do so.

Paramecium reproduces both sexually and asexually.

Asexual reproduction is by binary fission. When conditions are favourable, *Paramecium* undergoes a tranverse division, giving rise to two new individuals.

The mega and micro-nuclei each divide into two. This is followed by division of the cytoplasm surrounding them, thus forming two new cells that separate into two new individuals *(see Fig. 6.2)*.

Asexual reproduction is achieved by transverse binary fission. The micro-nucleus divides mitotically, but the meganucleus divides amitotically (i.e. by simple constriction).

Sexual reproduction involves conjugation between differing mating strains of which there are several types. During conjugation the nuclei undergo complicated changes:

Sexual reproduction in Paramecium (Diagrammatic)

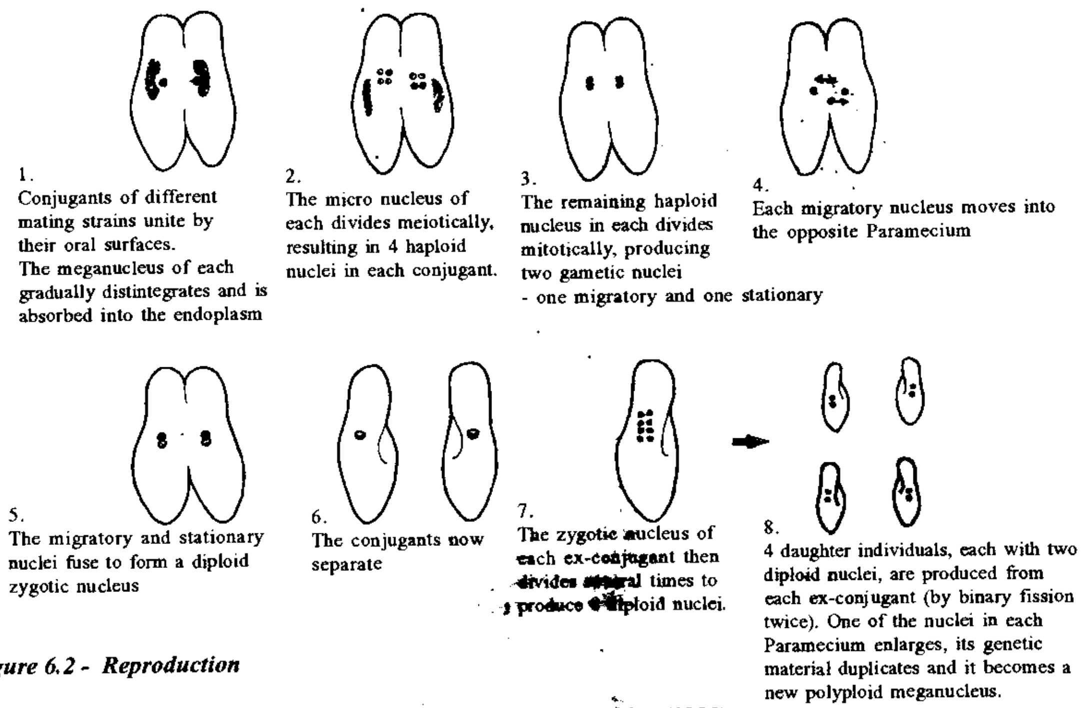


Figure 6.2 - Reproduction

Source: *Kathleen Cratchley (1980)*

Notes:

1. *Autogamy* may also occur. This is a sexual process, but the gametic nuclei fuse within the *same* individual.

2. Both conjugation and autogamy restore the correct chromosomal balance to the meganucleus. The repeated amitotic divisions of the meganucleus during binary fission result in a culture of paramecium becoming 'senescent' if neither conjugation nor autogamy takes place.

Activity E

Now with the a well labelled diagram describe the process of reproduction in Paramecium.

3.6 Hydra

External and Internal Structure

Hydra is cylindrical in shape of the phylum coelentrata. It is about 5mm in length. It has only one opening (mouth) that leads to a large cavity called enteron and to the outside world. The mouth is located in a cone-like structure called hypostome. The hypostome is surrounded by 6 to 10 long hollow tentacles containing cells called nematocysts. The lower end is sealed off to form the basal disc (foot) equipped with gland cells that secrete adhesive substances that help to fasten it to substratum. In some cases, ovary and testes may develop as rounded knobs from the body. Usually one ovary develops near the basal disc while one or more testes develop below the tentacles. A bud with mouth and tentacles may grow from the body.

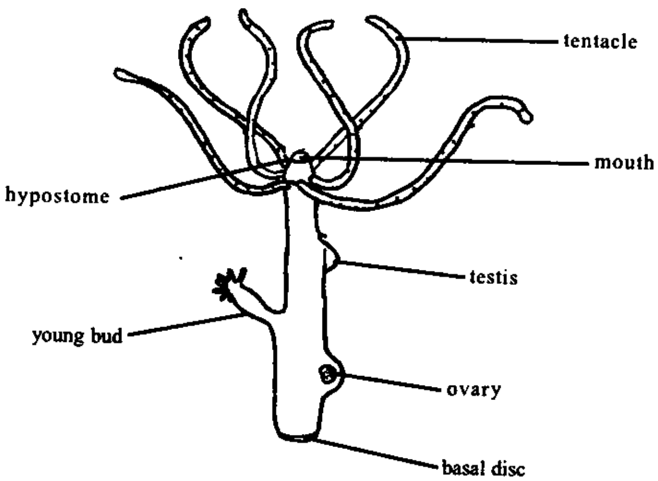


Figure 6.3 - External Features of Hydra

The longitudinal section of the body of *Hydra* reveals that it consists of two layers of cells surrounding the enteron, the outer layer called ectoderm (epidermis) and inner layer called endoderm (gastrodermis).

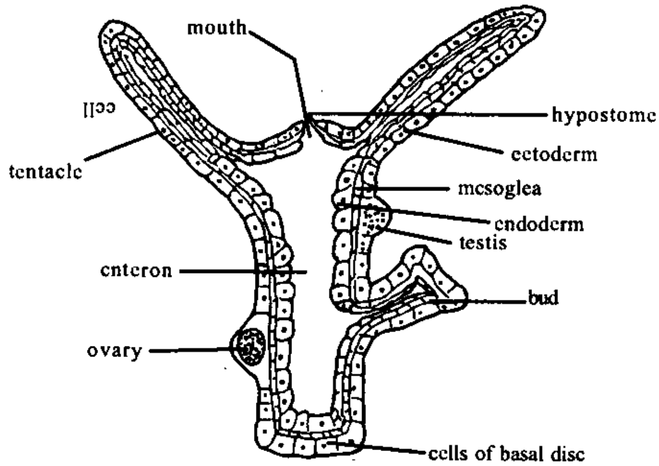
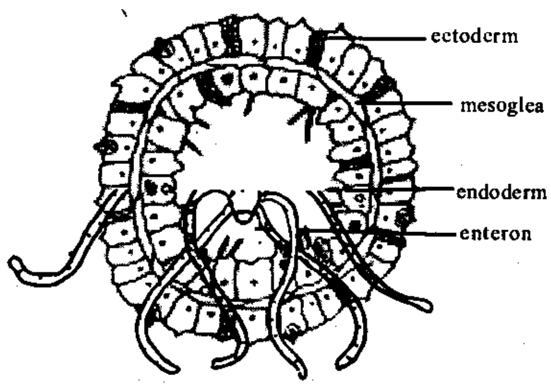


Figure 6.4 -
Longitudinal section of Hydra

Figure 6.5: Cross Section through the body wall of Hydra



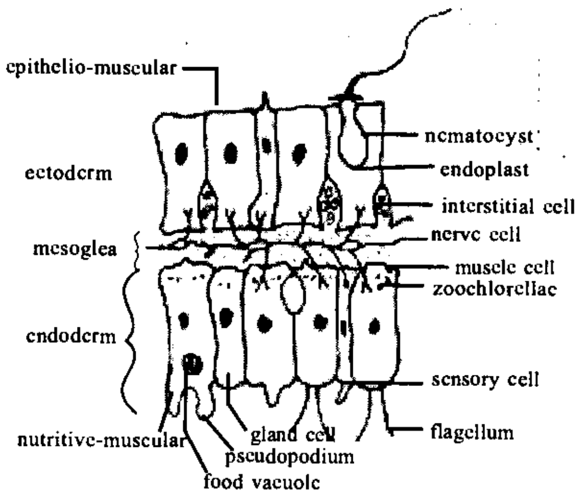


Fig. 6.6 Longitudinal section of a portion of the body of Hydra to show different types of cells

The ectoderm is separated from the endoderm by a jelly-like material called mesogloea.

Ectoderm: The ectoderm is made up of epithelio-muscular cells, interstitial cells, epidermal gland cells, sensory cells and cnidoblasts (nematocysts).

1. **Epithelio-muscular cells:** The bulk of the ectoderm is made up of epithelio-muscular cells. The outer portions of the inner bases of the cell is modified into muscle tails (muscle fibres).

Functions
Epithelio-muscular cells cover and protect the body. The muscle tails cause the muscular contraction of the body thus controlling the shape and length of the body.

2. **Interstitial cells:** These are small and oval shaped cells that lie between the bases of the epithelio-muscular cells.

Functions
They replace used up or damaged cells.
They can transform into endoblasts.
They can give rise to sex cells or buds.

3. **Epidermal gland cells:** Epidermal gland cells are found on the basal disc. Their secretion helps to fasten the animal to a substratum.
4. **Cnidoblasts (Nematoblasts):** These nucleated cells are oval in shape and contain stinging cells called **nematocysts**. A nematocyst contains a **cnidocil** and **thread** or **coiled tube**.

When the cnidocil is touched by a prey, a nematocyst thread is ejected. Cnidoblasts are found on the ectoderm but far more common on the tentacles. There are three types of cnidoblasts namely **penetrant, volvent** and **glutinant.**

The **penetrant** is long and thread-like with thorns and spines. When discharged, it pierces the body of its prey that touches the cnidocil of the tentacle and poisonous substances are injected that paralyse the prey.
The volvent has a short thread which when ejected coils around the prey.
The **glutinant** is a long thread either barbed or unbarbed. It may be coiled or straight. It produces an **adhesive** material used for locomotion and attachment.

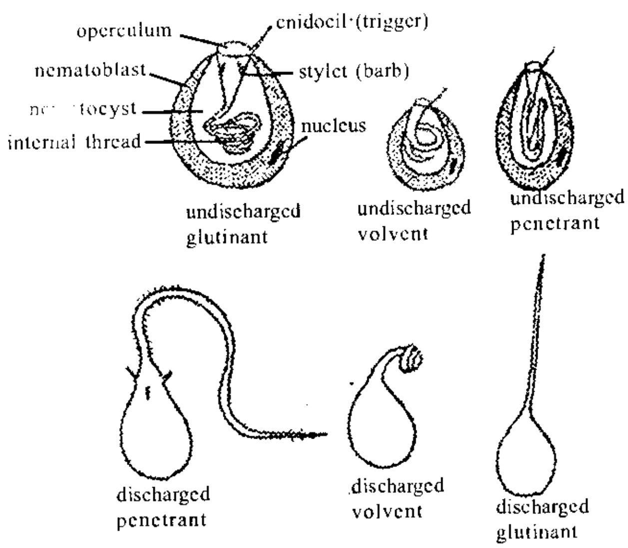


Fig. 6.7 Three kinds of nematoblasts of Hydra

Sensory cells: These long and slender cells are scattered among the ectodermal and endodermal cells. They are more common in the mouth, tentacles and basal disc areas.
They are connected to nerve cells.
They are sensitive to temperature, touch and chemicals.
Endodermis: The endodermis is made up of nutritive-muscular cells, interstitial cells, gland cells and sensory cells.

i. **Nutritive-muscular cells:** They are similar to epithelio-muscular cells. Their bases are modified into circular muscles that run around the body and tentacles. When these muscles contract, the animal becomes thin and the body is lengthened. The free ends of the nutritive-muscular cells end up with two flagella. Nutritive-muscular cells contain food vacuoles and they secrete digestive enzymes into the enteron for food digestion.

Biological Importance of Protozoan

i. Sleeping sickness: This disease is caused by a protozoan blood parasite (Trypanosoma) which is transmitted by the bite of an infected tsetsefly. Symptoms include fever, headache, weakness, dosing and sleeping all the time, loss of weight, diarrhoea, restlessness, swelling of lymph glands, oedema and anaemia
ii. Dysentery (amoebic dysentery). Dysentery is a disease caused by a protozoan. Dysentery is charcterized by severe diarrhoea with blood and mucus in faeces. It is causd by *Entamoeba histolytica.* Control is by keeping our environment clean and drinking clean water.
iii. Other diseases include River blindness, Bilharziasis.

Activity F

Repeat in your own words the biological and economic importance of protozoans. Remember to highlight the specific protozoans that are involved.

4.0 Conclusion

Protozoans are of biological and economic importance to man. They cause a lot of diseases such as malaria, sleeping sickness, dysentery etc to man. Control of these diseases can only be possible by knowing the biological life cycle and physiological activites of these protozoans.

5.0 Summary

In this unit, you have learned that;

i. Paramecium belong to the class ciliophora.
ii. Paramecium is also a unicellular orgnism like the Amoeba, but its (Paramecium) cell body is more complex than that of Amoeba.
iii. Structurally, the paramecium cell is covered with cilia which are used for locomotion, selection of food material and also for wafting food into the gullet.
iv. Paramecium like Amoeba, has no special respiratory organs. Oxygen diffuses in the body surface carbondioxide diffuses out through the entire body surface.
v. Nitrogenous waste materials are removed through the body surface using contractile vacuoles
vi. Reproduction is both asexual and sexual.
vii. Asexual reproduction is by binary fission, while sexual reproduction is by conjugation.

viii. Protozoans have a lot of biological and economic importance. They cause disease like malaria dysentry, trypanosomiasis etc.

6.0 Tutor-Marked Assignment

1. List five diseases caused by protozoans.
2. Explain two of these diseases.

7.0 Further Reading and other Resources

F.O.C. Ndu, P. Asun and J. O. Aina (1995) - *Senior Secondary School Biology 2*

Idodo - Umeh (1996) - *College Biology*

Sarojini T. Ramalingam (1993) *Modern Biology*

Kathleen Cratchley (1980) *Systematic Biology - Handbook of Animal types.*

Volume 1: Basic Concepts in Biology

Page

1.0 Introduction

Fungi (singular: fungus) is a kingdom of its own. They are mainly non-motile organisms composed usually of thread-like structures called hyphae containing many nucleic members include moulds, mushrooms, toadstools, and slime moulds. All fungi except slime moulds are non-motile. They do not possess chlorophyll and so cannot make their own food by photosynthesis. Instead, most fungi are saprophytes which make use of the food present in the dead parts of plants and animals. They break down this food into smaller substances which they absorb and use, bringing about the decomposition of the dead organisms. Thus, fungi, together with bacteria are important decomposers. We find them growing on logs, dead leaves, fruits, bread and leather. Some fungi are parasites, living and feeding on living organisms. These fungi cause diseases especially in plants.

The kingdom fungi too presents problems to biologists as they exhibit both plants and animal charateristics. In another modern classification, the fungi are divided into two kingdoms. One containing the slime moulds (showing more animal-like features) and the rest of the fungi (showing more plant-like features). The kingdom has been divided into five classes These are:

Class one - *Myxomycetes* or slime fungi
Class two - *Phycomycetes* e.g. *pythium*
Class three - *Ascomycetes* or sac fungi e.g. *yeast*
Class four - *Basidiomycetes* or club fungi e.g. *Ustilago*
Class five - *Deuteromycetes* or fungi imperfecti e.g.*Helminthosporium & Fusarium*

2.0 Objectives

By the end of this unit, you should be able to;

1. list at least six of the general characterisitcs of fungi
2. list at least seven general characteristics of fungi
3. state ten processes involved in the reproduction of fungi
4. explain the importance of fungi in industry, agriculture and medicine.

3.0 General Characteristics of Fungi

Let us consider these features that have made fungi to be in a kingdom of its own.

1. They are non-green plants.
2. They are simple multicellular plants.
3. Their body is not differentiated into root, stem and leaves.
4. The vegetative body (hyphae) is collectively known as **mycelium.**
5. Reproduction is by means of spores.
6. The cell wall is composed of cellulose and chitin.
7. Carbohydrate is stored in form of glycogen (and not starch) just as in animals.
8. They are either saprophytic or parasitic. Examples include *Mucor, Rhizopus, Penicillium,*
9. Some fungi form association with algae (as in lichens)

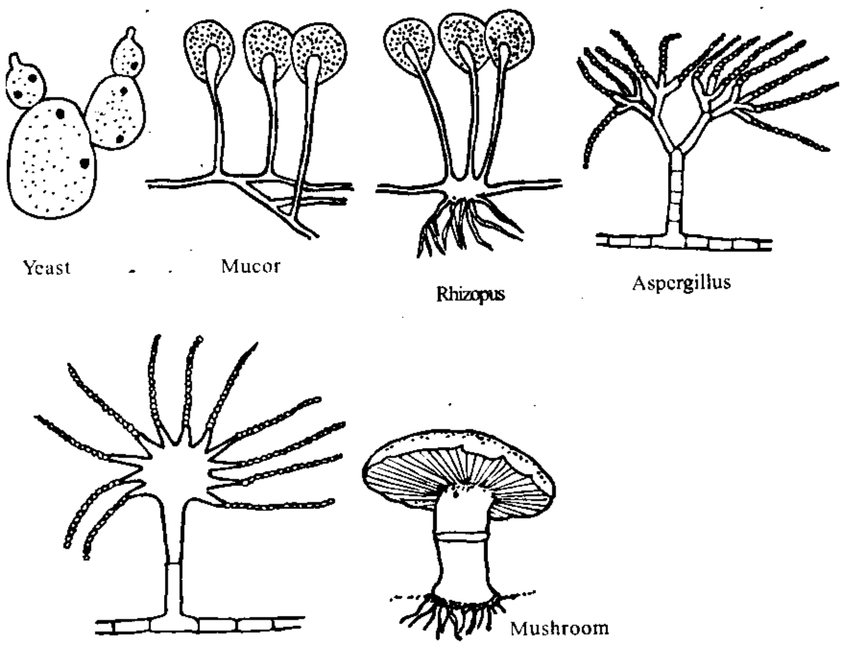


Fig. 7.1 Different forms of Fungi

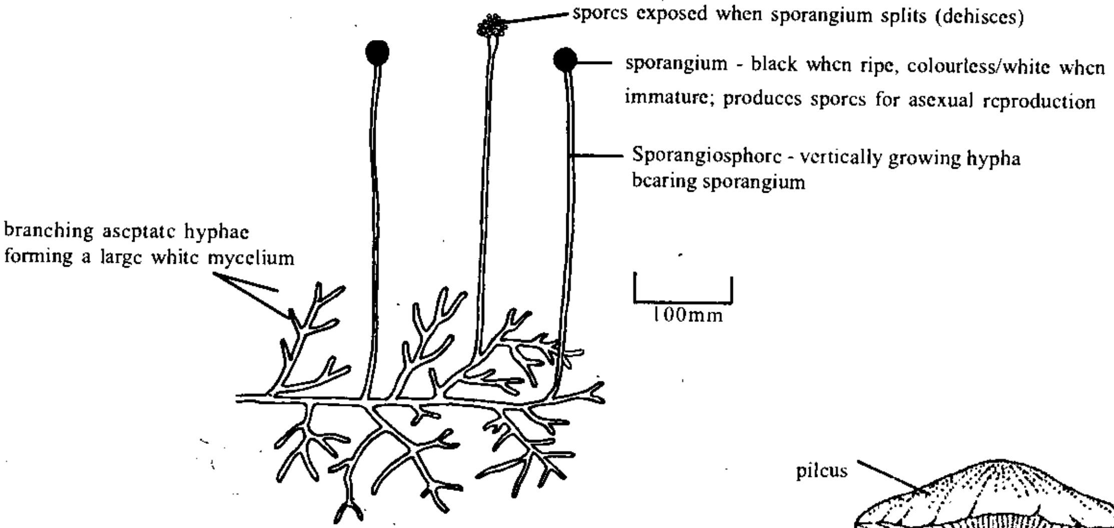
3.1 *Mucor Mucedo* (Black Mould) - Structure

Can you recall the black thread-like growth you have ever noticed on your exposed moist bread (food)? That is the black mould (*Mucor mucedo*). It is a fungi that is saprophytic on animal dung, wet shoes, moist bread, rotten fruits and other organic matter.
With the aid of the diagram (Fig. 7.2), let us look at the structure of a fungus.

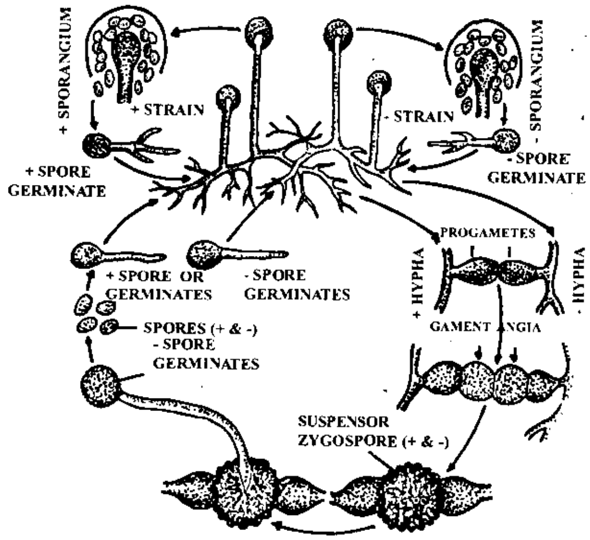
Composed of a mass of white, delicate threads called mycelium (pl. mycelia).
It is **coenocytic**, non-septate and multinucleate.
Each thread in the mass is called the hypha.
There are three types of hyhae: horizontally growing, vertically upward-growing and vertically downward -growing.
Horizontally hypha is called the stolon.
Vertically upward growing hypha is the sporangiosphore.
Vertically downward growing hypha is rhizoid.

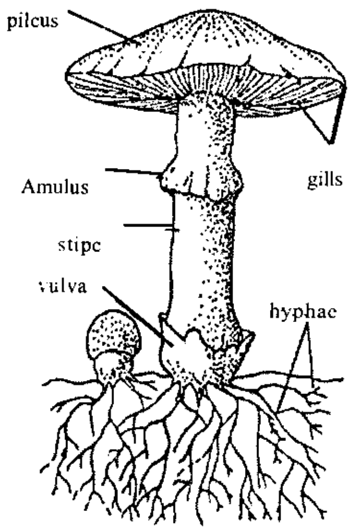
Activity A

If you have never observed the black mould, grow some using moist bread. Observe the detailed structure as shown in Fig. 7.2 but if you have, grow another for same observation.



Mycelium of Mucor as seen with low power of a light microscope





Mushroom

Figure 7.2 - Life cycle of Mucor

Have you paused for a while to think of how fungi obtains its nutrients? Now, let us consider the following

3.2 Nutrition in Fungi

Unlike, green plants, fungi have no green (chlorophyll) pigments in their cells. They also do not have specialised structures like mouth or hypostome for capturing food. So, fungi cannot manufacture their own food.

However, fungi display two modes of nutrition. Some fungi live in, or on the tissues of other living organisms and from their they derive their nutrients directly by absorbing such through their hyphae that **ramify** the host tissue or substrate. This mode of nutrition is said to be **parasitic**. The host does not benefit from this association, and in fact, may eventually be killed.

In some other fungi, as the hyphae grow on some dead or decomposing matter, copious amounts of **enzymes** are secreted unto such matter. The complex food in the decomposing matter is digested into **simpler and readily absorbable** forms. In this way, the hyphae of the fungus now absorbs the soluble food. This mode of nutrition is said to be **saprophytic**. the digestion of food that takes place outside the cells of the fungi is said to be **extra-cellular**.

3.3 Structure of a Mushroom

The macroscopic part of fungi is usually called the "fruiting body: A typical fruiting body of a mushroom fungus consists of an expanded umbrella-shaped structure called a **pileus**. This is usually attached to the stripe (or stalk) by an **annulus**. The under part of the pileus bears gills which bear the reproductive structures (the basidiospores). The mushroom is anchored on the substrate by rhizoids which are specialised hyphae that absorb nutrients from the substrate. see fig. 7.2.

Activity B.

1. List six characteristics that are peculiar to fungi
2. Try to find the meaning of the following terms; (i) coenocytic (ii) septate (iii) sporangiosphore (iv) rhizoids.
3. What are the function of the following structures; (i) pileus, (ii) stipe (iii) gills (iv) annulus

3.4 Reproduction in Fungi

You will find the process of reproduction in fungi very interesting. Now let see the details of the reproduction process.

Reproduction is by asexual and sexual methods;

Asexual reproduction (fig. 7.3)

- This is by spores.
- Developed in a container called sporangium.
- Occurs under good conditions of moisture and temperature.
- Mycelium develops into sporangiosphore.
- The tip of the sporangiosphore develops the sporangium.
- Vertical hypha swells at the tip.
- Protoplasm migrates to tip.
- Central portion becomes dome-shaped and sterile; this is the columella.
- Peripheral protoplasm gives rise to small, mutinucleate masses by cleavage.
- Each mass becomes the spore.
- Spore wall thickens and darkens.
- Sporangium wall becomes thin and brittle.
- Columella swells due to fluid accumulation.
- It bursts open to liberate spores.
- Spores are dispersed by wind and
- They germinate into slender mycelium, under a favourable condition.
- Hyphae sometime develop from the columella when the sporangiosphore happens to fall over and these hyphae then bear the sporangia.

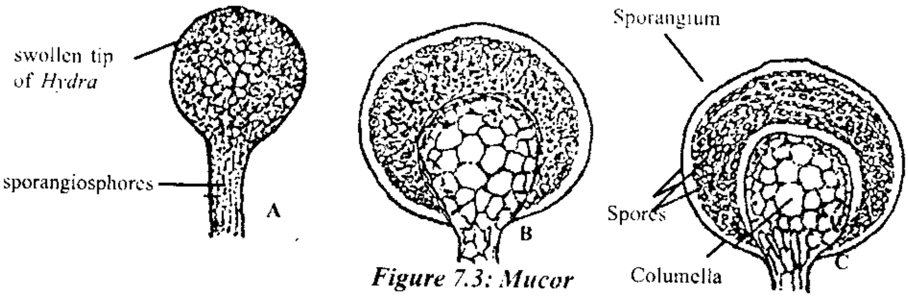


Figure 7.3: Mucor

Mucor: *Fig. 7.3* Development of sporangium, spore and columella. A, the end of the hypha swells; B, two regions - dense and light - are apparent with a layer of vacuoles between them; and C, mature sporangium (or gonidangium) with spores (or gonidia) and dome-shaped columella.

Sexual Reproduction in Fungi

Takes place by conjugation.

Occurs when food is exhausted.

Occurs through fusion of two similar gametes (isogametes).

Two hyphae of different plants of opposite strain (+ and -) lie side by side.

Protuberances are produced by each plant to form programetes.

Each progamete enlarges to form club-shaped structure (progametangium).

Each is held by a suspensor.

Apex becomes gametangium (gamete store).

Gametes are multinucleate (coeno gametes).

Walls of gametangia in contact dissolve and gametes fuse to form zygospore.

The zygospore swells into a rounded body and its wall thickness, turns black in colour and becomes warted.

It contains an abundance of food, particularly fat globules.

The zygospore undergoes a period of rest and then germinates. The outer wall bursts and the innter wall grows out into a tube called the sporangiosphore or promycellium which ends in a single sporangium.

The sporangiosphore may be branched, each branch bearing a sporangium

The sporangium contains numerous small spores but no columella.

The spore germinates, giving rise to the mucor plant see fig. 7.4

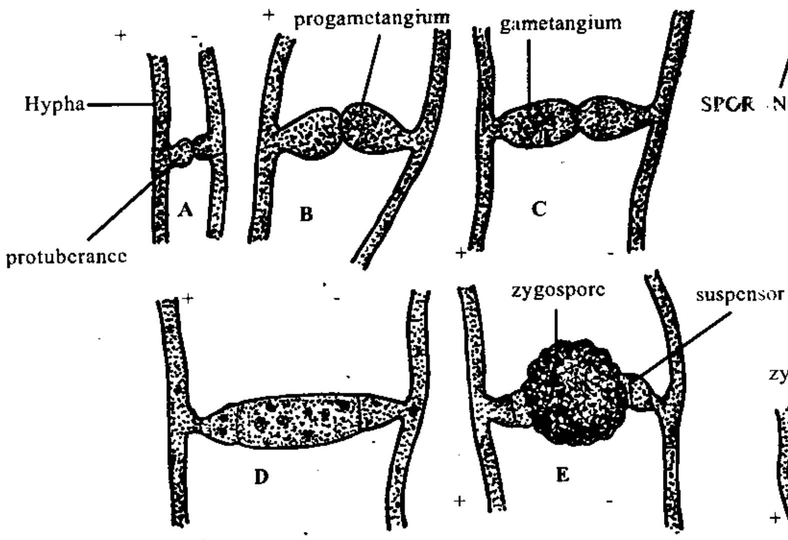


Figure 7.4

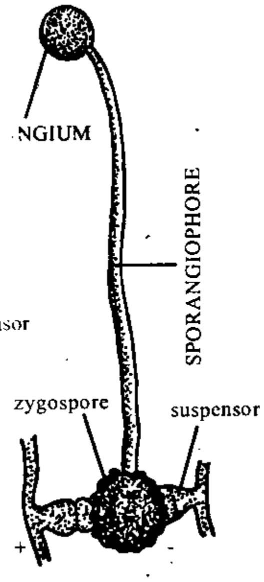


Figure 7.5

Figure 7.5: Mucor: Conjugation: A -E are stages in the process; note the thick-walled Zygospore at E. Germination of zygospore

Activity B

a. Try to remind yourself of the various processes that go on during the asexual reproduction in Mucor

b. Why is asexual reproduction important?

3.5 Importances of Fungi

Do you know that Fungi play vital roles in the development of agriculture, medicine and industries?

Diseases caused by Fungi

Plant diseases caused by fungi:

a. ***Late blight of Potato*** - The disease is caused by *Phytophthora infestans*. The symptom includes black patches on the under surface of leaves, less often on the upper, indicating diseased conditions of the plants. The diseases may spread to the entire leaf and to all parts of the plant body including the tubers. The fungus finally causes wilting of leaves and rotting of tubers.

Control: (i) Spraying the young plant with Bordeaux mixture (fungicide)

(ii) Selection of seed tubers from non-infected areas

(iii) Storage of seed tubers as a low temperature - 4.5^{oC}

b. ***Smuts***: This is a serious disease of wheat, barley, maize, oats and sugarcane caused by different species of *ustilago*.

- the fungus mainly attacks the stems, flower and often inflorescence.
- the infected parts turn black and all the grain are totally destroyed.

Control: (a) varieties of wheat or barley or maize already immune and resistant to smut should be cultivated.

(b) cross-breeding with types immune or resistant to smut is possibly the best method.
(c) hot water treatment of wheat grains and then drying them under strong sun may reduce the intensity of the disease.

c. ***Rusts***: This is a disease of wheat, maize, - caused by different species of *Puccinia*
- The stem become yellowish or black depending on the species of ***Puccinia***

Control: (a) Eradication of the barberry bush (alternate host) near a wheat field is a good established practice
(b) By cross-breeding with rust resist ant varieties
(c) Elimination of cultivation of wheat during summer may reduce the spread of the disease
(d) Cultivation of rust-resistant varieties.

d. ***Mildews***: These diseases appear as whitish, yellowish or brownish sports on the leaves and also on other parts.
- There are two kinds of mildews: downy and powdery
- downy mildews are caused by *cystopus, plasmopara* and *peropospora spp*
- powdery mildews are caused by *Erysiphe* and *Uncinula spp.*

Control: the disease is not a serious one, as such no control measures are taken.

Animal Diseases caused by Fungi

a. ***Ringworm*** - caused by *Epidermophyton* - located between outer and inner layers of the skin

Symptoms: Circular red patch formed on the part of the skin infected. Later outer circular patch turns dark red. Small scales fall from the outer skin. Intense itching, disturbing sleep and general discomfort. - Ringworm of hairs causes hair to fall off.

Control: Good personal hygiene
- Avoid wearing wet shoes and clothes.
- Avoid contact with an infected person and his belongings.
- Spray infected materials with fungicides.
- See a medical doctor for medical advice and treatment.

b. ***Athlete's Foot*** - also called *Tinia pedis* is located between skin and toes.

Symptoms - skin between toes becomes whitish.
- at advanced stage, pains, and itchings, result. Offensive odour is produced.

Control: - keep feet clean and dry all the time after bathing.
- rub dusting powder in between toes.
- Wear open sandals or loose shoes.

Benefits of Fungi to Man

1. **In Medicine:** Antibiotics (in form of capsules, syrup and injection) have been manufactured from saprophytic fungi for the cure of bacterial diseases, such as gonorrhoea, cholera, tuberculosis and dysentery.

   Penicilin is made from *Penicillium notatum*; Streptomycin is made from *Streptomyces* and Aureomycin from *Aureomyces*.

* Production of Antibiotics e.g.

Penicilin from *Penicillium notatum*

Streptomycin from *Streptomyces grisesus* (bacterium with fungi)

Chloromycetin from *Streptomyces venezuelae*

Aureomycin from *S. aureofaciens*

Ferramycin from *S. rimosus*
Erythromycin from *S. erythreus*
Jaweharene from *Aspergillus sp.*

2. In Industry

a. Alcoholic industry

Yeast is very important in the production of industrial spirit and bev   ıges. Yeast breaks down sugar to **alcohol** and **carbon (IV) oxide**. This is called **fermentation.**

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 28Kcal.$

b. Bread Industry

In bread baking, yeast is used. Yeast produces carbon (IV) oxide which causes the dough to rise, making the bread spongy and easy to digest.

c. **Fungi** are used to ferment tobacco, in the curing of tobacco the carbohydrates in fresh leaves of tobacco are fermented by fungi to produce the special aromatic flavour. and also for the retting of flax to obtain linen fibres.

The fungi break down the pectin that holds the fibres of flax together free for processing into linen.

* Fermentation: basis of industrial production of alcohol.
* Source of food e.g. *Agaricus, volvariella, lepiata, Pleurotus spp* and vitamin B.
* As saprophytes they help to decompose dead plants and enrich the soil.
* They cause superficial skin diseases of man e.g. ringworm and athlete's foot;
* Internal diseases of man and other animals such as fungal tuberculosis and meningitis have been traced to fungi e.g. *Aspergillus*, thrush, moniliasis, etc.
* Cause decay and spoilage of valuable food.
* Yeast is an important source of vitamins and enzymes; it is used to make dough rise in bakery for making bread, etc.
* Useful for research work in cell biology, genetics and biochemistry.

In agriculture - soil inhabiting fungi play a major role in the decomposition of organic matter and in releasing minerals into the soil for plant growth and nutrition.

Activity C

1. List six characteristics of fungi.
2. With a well labelled diagram describe the process of sexual reproduction in Mucor.

4.0 Conclusion

The study of fungi is very important because of it's significant importance to man in terms of human health, agriculture, and medicine

5.0 Summary

In this unit, you have learned that

i. fungi are non-green plants.

ii. their vegetative body is collectively called mycellium.

iii. reproduction is both asexual and sexual.

iv. fungi cause diseases like smut, rust etc to man.

v. fungi causes diseases in man and animals e.g. ringworm.

vi. fungi are highly important in medicine, industries and in agriculture.

6.0 Tutor-Marked Assignment

i. Briefly explain the economic importance of fungi to man.

ii. List three differences between asexual and sexual reproduction in *Mucor*

iii. How do fungi obtain nutrients from their substrates?

7.0 Futher Reading and other Resources

Dutta A.C., *Botany for degree students*

Idodo - Umeh (1996) *College Biology* - Idodo - Umeh Publishers, Benin City.

Volume 1: Basic Concepts in Biology

Page

1.0 Introduction

There are several distinct divisions of the plant kingdom, which although they are not really closely related, are conveniently discussed together because they have certain features in common. Even though some of these basically simple plants appear to have bodies that have true roots, stems or leaves because they lack the vascular tissues and other characteristics of such structure in higher plants. The sex organs and sporangia are usually one celled, or if multicellular, the gametes and spores are not enclosed within a wall formed by a layer of sterile (non reproductive cells).

The members of these groups are generally called cryptogams.

Algae are Cryptogams. Cryptogams are flowerless, seedless plants. They form three main groups.

1. Thallophyta: algae, fungi and lichens.
2. Bryophyta: Liver worts e.g. marchantia and mosses e.g. *funaria* (*polyrichum*).
3. Pteridrophyta: ferns e.g. Dryopteris.

There are various kinds of algae base on their morphology and the pigment they contain.

On the basis of their pigments, the following groups have been identified

* Blue green algae e.g. *Nostoc, Oscillatoria*
* Green algae e.g. *Spiroygra*
* Brown algae e.g. *Fucus, sargassum*
* Red algae e.g. *Bartrachospermum*

On the basis of morphology

* Euglenoid algae e.g. *Euglena*
* Bacillairophytes e.g. diatoms e.g. *Pinnularia, Diatoma*

2.0 Objectives

By the end of this unit, you should be able to:

i. Explain what algae are.
ii. List the characteristics of algae.
iii. Describe the structure of algae.
iv. Explain the reproduction of algae.
v. State the importance of algae.
vi. List the differences between algae and fungi.

Now let us commence our study of algae by examining the general characteristics of this group

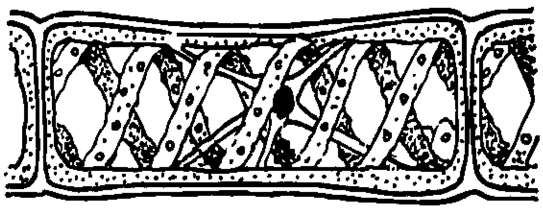
3.0 Characteristics Features of Algae

1. They are simple plants without roots, stems and leaves.
2. All algae have chlorophyll. Some have blue, yellow, brown and red pigments which mask the chlorophyll.
3. Majority are non-cellular while few are multicellular. Some, such as sea weeds are large.
4. They are mainly aquatic, with a few on damp soils and shady places.
   Examples are *Spirogyra*, *Anabaena* and *Sargassum* see fig. 8.1
5. The body of an alga in composed of a true parenchymatous tissue.
6. The cell wall of an alga is composed of a true cellulose.
7. Reserve carbohydrate is usually starch, and not glycogen as in fungi.

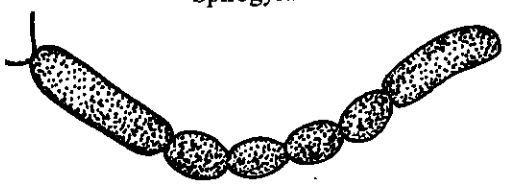
8. Algae are classified into six classes. These are:

* Class 1 - *Mycophyceae or cynophyceae or blue green algae* e.g. include *Nostoc, Anabeana, Oscillatoria*.
* Class 2 - *Euglenophyceae* e.g. *Euglena*
* Class 3 - *Chlorophyceae* or green algae *e.g. volvox, spirogyra, witella, Zygnema*
* Class 4 - *Bacillariophyceae* or *diatoms.*
* Class 5 - *Phaeophyceae* or brown algae, e.g. *Fucus*
* Class 6 - *Rhodophyceae* or red algae e.g. *Batrachospermum*

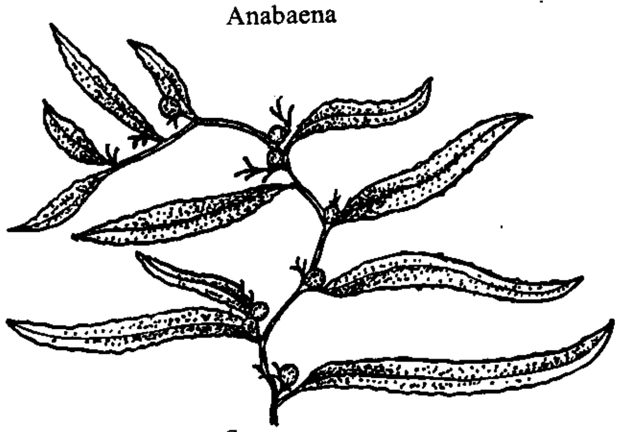
Conjugation in Sypirogyra



Spirogyra



Anabaena



Sargassum

Closterium (diatom)

Figure 8.1 - ***Different forms of Algae***

3.1 Spirogyra *(Chlorophyceae)*

Occurence: ***Spirogyra*** belongs to the family chlorophyceae and the order conjugales or zygnematales. It is a cosmopolitan plant which forms a tangled mass of filaments floating on stagnant fresh water, especially in ponds, ditches, springs and streams. Some species grow in running water. Such species produce a short unicellular organ of attachment, called **hapteron**, for anchorage on sea weeds.

Spirogyra is commonly found as bright green masses of thread-like or filamentous structures on the surfaces of waters, and is often referred to as a "pond scum".

3.1.1 Structure of a Spirogyra

- Mature filament is unbranched and consists of single row of identical cylindrical cells joined end to end.
- Cell wall is made of cellulose and pectin.
- External cell wall is covered by mucilage, making it slimy.
- Cytoplasm is a thin layer with spiral bands of chloroplast.
- Nucleus is suspended at the centre by strands of cytoplasm.
- Chloroplast contains small nodular protoplasmic bodies called the pyrenoids.
- Starch grains are deposited around each pyrenoid.
- Gametes are without cilia and are called aplanogametes.
- Gametes are morphologically isogamous (identical in structure) but physiologically anisogamous (ie. gametes are different in terms of appearance and behaviour).

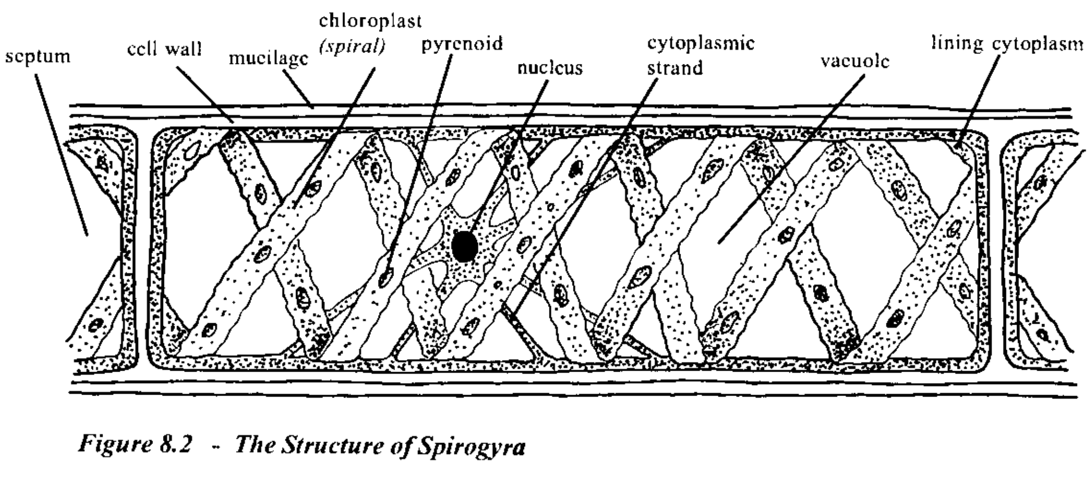


Figure 8.2 - The Structure of Spirogyra

Activity A

List five characteristic features of algae.

3.2 Reproduction in *Spirogyra*

Reproduction in spirogyra occurs in two ways.

1. Asexual reproduction.
2. Sexual reproduction.

Asexual Reproduction: Asexual reproduction is in the form of vegetative fragmentation. The filament breaks into pieces by wave action against solid objects. Each piece grows into mature filament.

Sexual Reproduction: Sexual reproduction is by the process of **conjugation** or fussion of two similar reproductive units or gametes i.e. isogametes. Conjugation usually takes place between the cells of two filaments or even three; this is called **scalariform (or ladder-like) conjugation**. When conjugation takes place between the gametes of the same filament, this is called **LATERAL CONJUGATION**.

Do you know how the process of conjugation occurs? During conjugation, two *spirogyra* filaments come to lie side by side. Conjugation tubes are formed between them as shown in fig. 8.3. The cells in one filament act as male gametes, while those in the other act as female gametes. The male gamete migrates into and fuses with the female gamete in the opposite cell to form thick-walled zygospores.

Now what happens to the zygospores that are formed?

Germination of Zygospores

The zygospore is provided with a thick cellulose wall, composed of three layers, of which the middle one contains chitin. With the rapid decay of the parent filament all the zygospores are set free and they sink to the bottom of the pool of water. (fig. 8.4). They undergo a period of rest till the next favourable season and then they germinate. The protoplast of each zygospore at first increase in size, then its outer layers burst and the inner one with the protoplast grows out in the form of a short tube which ultimately forms a new filament. The filament escapes and floats on the surface of water. The cell divides and the filament increase in length, soon the floating filament takes to conjugation again, and the life-cycle begins again (see fig. 8.5. and 8.6)

What happens when conjugation does not take place?

The gametangia becomes converted into thick-walled bodies identical with zygospores, these bodies which are thus formed parthenogenetically are called a zygospores or parthenospores. They germinate like the zygospores.

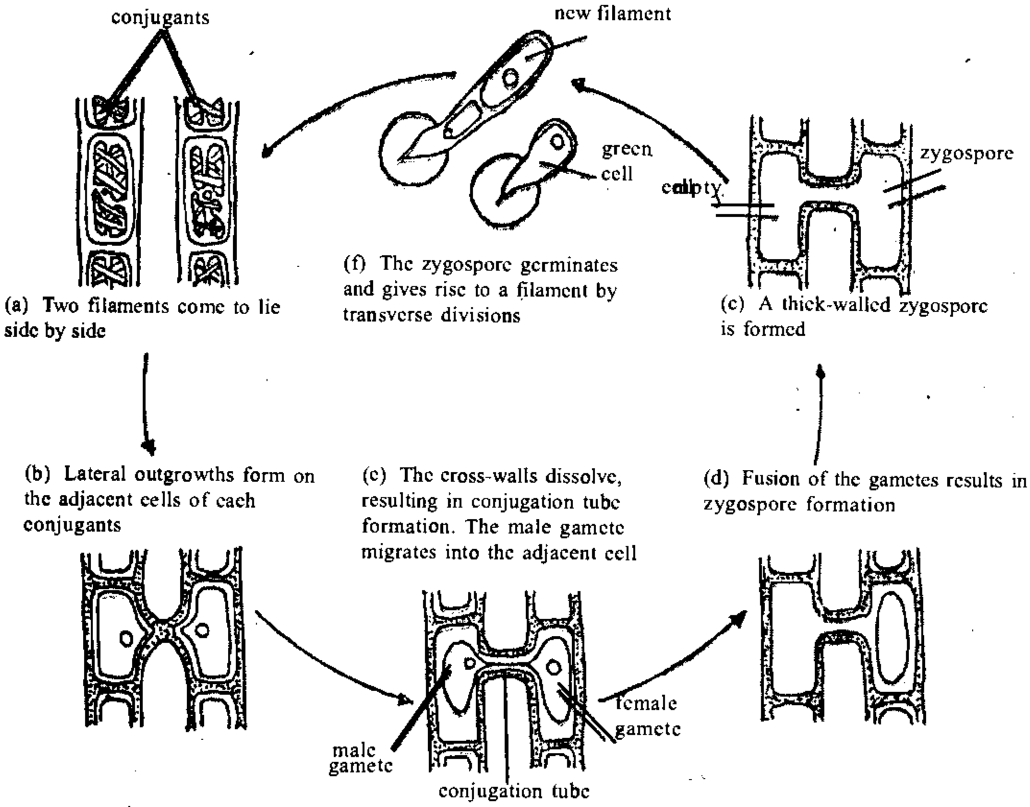


Fig. 8.3

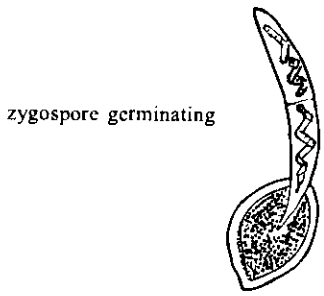


Figure 8.4

Activity 4

You can now describe the process of sexual reproduction in spirogyra. Share your experiences with your study group/mate.

3.3 Importance of Algae

- The green algae probably evolved from motile unicells similar to *Chlamydomonas*. It exhibits a variety of forms and it has different reproduction.
- This group presents a clear example of radiating evolutionary development. The evolution of sexuality has been emphasised because of the great importance of this type of reproduction in the production of variation whicb is significant in the survival of any group.
- Green algae are also thought to have given rise to all of the higber green plants by evolution.
- The chloroplast in both fresh and salt water comprise food supplies for animals.
- Algae (e.g. ulva) are utilised by man as food
- The photosynthetic process of algae supplies the oxygen that is necessary for life in water.
- Green algae along with other algae, occassionally cause problems wben they become abundant in water. They impart obnoxious odours and flavours to the water, and make water treatment difficult.

4.0 Conclusion

Algae have a lot of significant importance to man and his environment. Therefore, tbeir study should be intensified

5.0 Summary

In this unit, you have learned that;

i. Algae are cryptogams.
ii. They are simple plants without roots, stems and leaves.
iii. The cell wall of algae is composed of cellulose.
iv. The reserve carbohydrate is usually starch and not glycogen as in fungi.
v. Algae can undergo both sexual and asexual reproduction.
vi. Algae are important to man and his environment.

6.0 Tutor-Marked Assignment

i. Briefly explain the importance of algae to man and his environment
ii. List five attributes which show that both *Amoeba* and *Spirogyra* are living organisms.

7.0 Further Reading and other Resources

Dutta A. C. (1979) *Botany for Degree Students* - Oxford University Press, Dehli Bombay, Madras
Sarojini T. Ramalingam (1993) *Modern Biology* - Africana - Feb Publishers, Onitsha.
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Page

1.0 Introduction

Mosses belong to the division Bryophyta and the class, *musci*. Mosses are land plants which grow on moist ground under the shade of big trees as epiphytes; on packed wet blocks, and or old block walls and rocks. *Funaria* (a common moss species) grows in turfs to form a green carpet. Sometimes, relatively extensive areas may be completely covered by it, particularly the sites of old bonfires in woodlands. The moss is often able to colonise such burnt patches remarkably quickly. This is an indication of its measure of success as a land plant. Mosses lack true roots, stems and leaves; they are parenchymatous (i.e. they have parenchyma tissues), they lack vascular tissue. The gametophyte (the haploid, gamete producing phase of the plant) is dominant and nutritionally independent, whereas the sporophyte (the diploid, spore-producing phase of the plant) is permanently attached to the gametophyte.

The mature gametophyte is usually erect and radially arranged. The spores are released from the sporophyte by a tranverse splitting of the sporangium or capsule.

Mosses play an important role in nature as we shall see....

2.0 Objectives

By the end of this unit, you should be able to;

i. List at least ten of the general characteristics of mosses.
ii. Describe the process of reproduction in *Funaria* (moss).
iii. List at least five differences between Fungi and Mosses.
iv. Trace the link between simpler plants (unicellular forms) and complex, more advanced plants (multicellular forms).

3.0 Characteristics of Mosses

Do you remember that living organisms have some characteristics or features that are peculiar to them? Mosses as living organism have their peculiar characteristics. See the following characteristic features of mosses below;

The plant is small and erect.
Persisting vegetative body is attached to subsratum.
Body consists of attaching and absorbing rhizoids and, aerial part for photosynthesis.
Dichotomous branching.
Growth is from a single cell or row of cells.
Low degree of tissue differentiation.
Well defined sexual reproduction.
Sex organs are the antheridia and archegonia.
Fertilisation is with biflagellate male gametes.
Plant body is one haploid gametophyte.
Diploid sporophyte (sporogonium) is partially or wholly dependent upon the gametophyte.
Spores are of one type (homosporous)
Spores usually germinate into an intermediate structure (protonema).
Mainly terrestrial but in wet environment.
Commonly found on old damp walls, tree trunks and wet ground.
They are gregarous, forming green carpet.
Small in size measuring a little more than one centimeter in height.
Axis is short with spiral, minute green leaves.
True roots are absent but rhizoids are present for absorption and anchorage.
Rhizoids are made of cells not differentiated into tissues and organs.
The stem (no conducting tissues) is short, slender and often with a branching stem, covered by

simple leaves spirally arranged along the stem and its branch.
The two branches of stem are differentiated into male and female branches.
The sporogonium consists of a long seta (stalk) and a pear-shaped capsule.
The rhizoid, stem and leaves all together form the **gametophyte**. The gametophyte alternates with the **sporophyte** during the life cycle. This is called **alternation of generations.**

Now, you may wish to know the structure of a moss plant. See below.

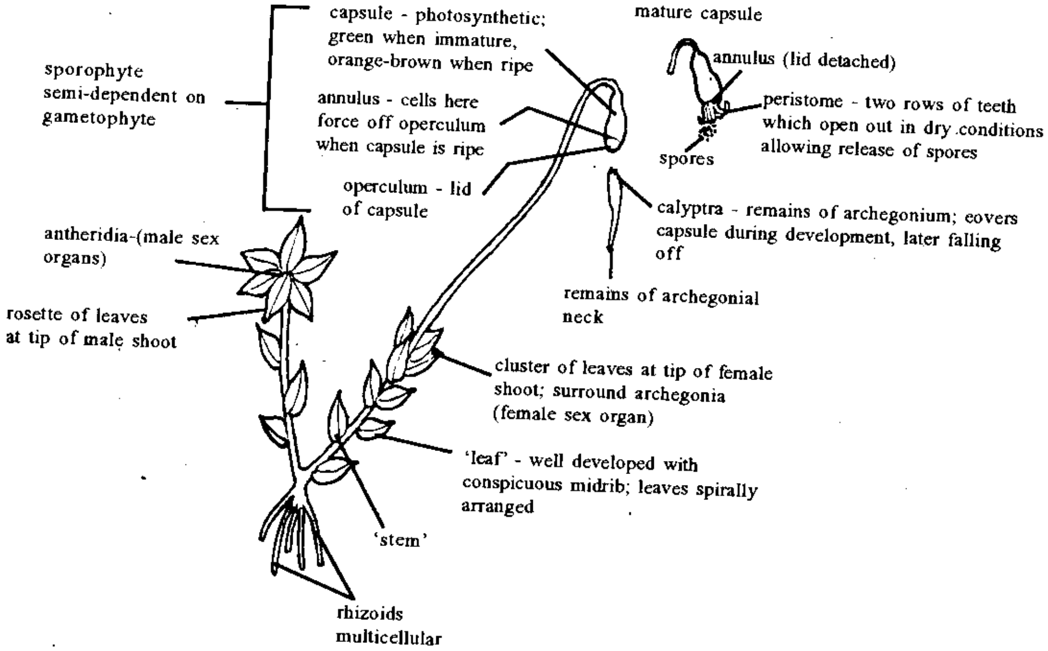
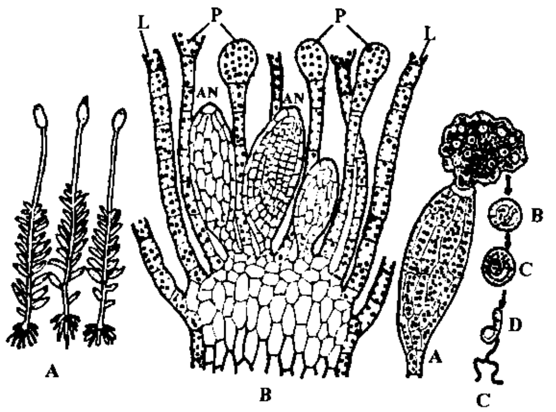


Figure 9.1: Features of a Moss Plant



MOSS. A, Three moss plants with capsule; B, Apex of the male shoot in L.S. showing antheridia (AN), paraphyses (P) and leaves (L); C, a mature antheridium discharging antherozoid mother cells in a mass of mucilage (A), antherozoid mother cell (B), wall of the same getting dissolved (C), and biciliate antherozoid (D).

Activity A

Study the diagram illustrated in fig. 9.1 and use it to list six features of a moss

3.1 Reproduction in Moss

You will find reproduction in moss very interesting. Would you like to know how reproduction occurs in moss plant?

The moss plant (e.g. *Funaria*) bears separate male and female parts at maturity, biciliate spermatozoa (*antherozoids*) and large ovoid eggs are formed at the top of the plants. Reproduction takes place in the rainy season as male gametes swim in water into the *archegonium* (***multicellular structure in which an egg is produced, a female gametangium***).

Male gametes (antherozoids) are released by the male plants after rainfall when water covers the top of the plants growing in turfts. Male gametes (antherozoids) swim in water into the archegonium on the female plant within the tufts. One antherozoid fuses with one egg in the archegonium of the top of a female plant. A zygote is formed on the top of the female plant. The, zygote develops into a sporogonium which constitutes the sporophytic generation. This is the spore-producing structure which is partly dependent on the gamete producing structure for its nourishment. The bryophytes (moss and liverworts) have two phases in their life history;

1. The gametophyte phase which reproduces sexually by means of gametes and
2. The sporophyte phase which reproduces asexually by means of spores

This phenomenon is known as the Altemation of Generations.

It is very necessary for you to know more about the Antheridium, Archegonium, gametophyte, sporophyte and Alternation of generations and the roles they play in the development of a new moss plant.

3.1.1 The Antheridium

It is club-shaped.

Inside are antherozoid mother cells (or androcytes) a mass of small cells surrounded by a simple layer of cells that form the wall or jacket.

Each develops into a single antherizoid.

Antheridium lid opens to liberate antherizoids.

Antherizoids are minute, spirally coiled and bicilliate.

They swim in films of water to the archegonium.

3.1.2 The Archegonium

It is flask-shaped.

Consists of swollen portion (venter) and upper tube-like neck.

Neck canal secretes mucilage and malic acid to attract antherizoids

Fertilisation occurs in the venter to form zygote

Zygote secretes thick walls to become **oospore.**

Oospore germinates through the apex to form the sporogonium (sporophyte).

3.1.3 The Gametophyte

Bears reproductive organs.

Male organs: the antheridium produces antherizoids.

The female organ, the archegonium, borne on separate shoots/branches produces egg cell or ova.

Both are protected by **hair-like** structures called **paraphyses.**

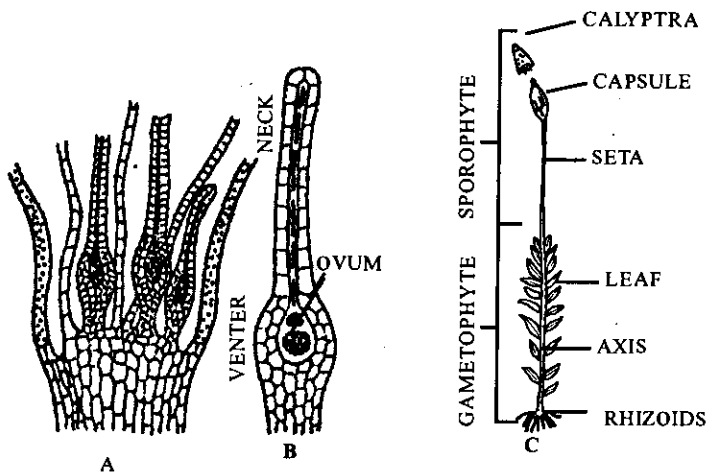
3.1.4 Sporophyte - Inside the capsule (see fig. 9.2)

* The sporophyte produces spores.
* Consists of foot, seta and capsule.
* Capsule dehisces, spores are liberated and dispersed.
* Spores germinate.
* Under favourable conditions, spores germinate into short tube which forms a green much-branched filament called protonema.
* Develop slender-brown rhizoids and small lateral buds.
* Buds develop into new moss plants.

3.1.5 Alternation of Generations

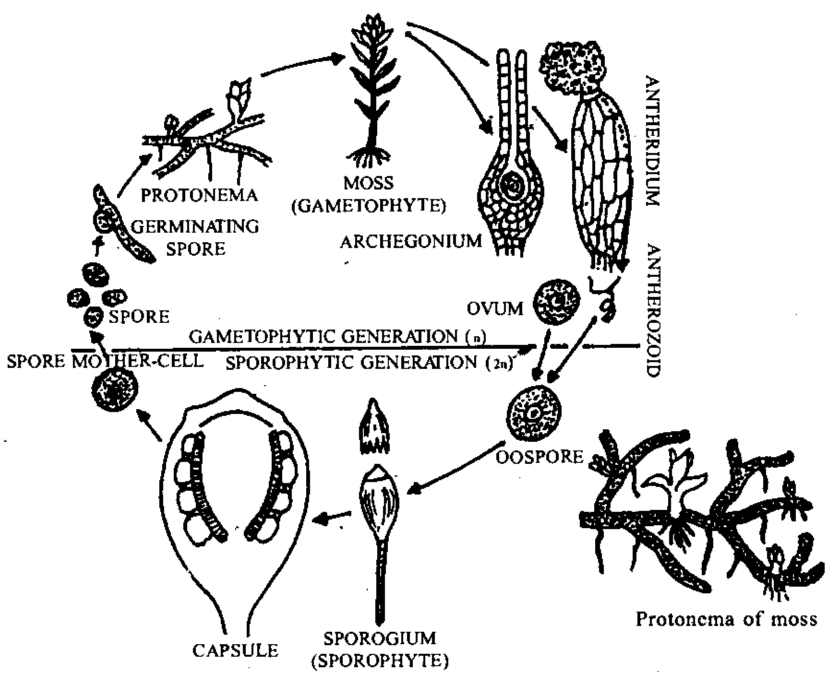
* *Funaria* shows two stages in its life cycle.
* The growing plant is the gametophyte.
* *Sporogonium* is the *sporophyte.*
* Fertilization leads to formation of sporophyte.
* By asexual production of spores, gametophyte germinates.
* Chromosomes are reduced to haploid number during spore formation.
* There is thus an altemation between the gametophyte and sporophyte phases.

Figure 9.2



A, apex of a female shoot in longi-section showing three archegonia, three paraphyses and two leaves; B, an archegonium; C, a moss plant showing the sporophyte growing on the gametophyte.

Figure 9.3



Life Cycle of Moss showing Alternation of Generations

Activity B

i. Describe the process of reproduction in the moss plant.

ii. Try to see how the green leafy gamete-producing plant (gametophyte) alternates within the asexual, spore-bearing structure (sporophyte) during the life cycle of the moss plants.

3.2 Economic Importance of Mosses

Let us now consider the economic importance of mosses

1. Mosses grow and reproduce rapidly on a favourable substrate and under favourable environmental conditions. As they die and decompose, they form suitable humus on which other higher plants can grow. They, therefore, form a necessary step in the natural process of ecological succession that may lead to a climax vegetation.

2. The bog or peat moss (sphagnum) actually consists of a mixture of plants of which the *sphagnum* form the dominant vegetation. This plant colonises an acid environment. The plant, itself, has antiseptic properties for which reason it does not decay fast. Thus, the plant debris accumulates as "peat"

Peat is often dried and used as fuel. It is also useful in agriculture because of its water-holding capacity for which it is frequently mixed with sandy or humus-poor soils.

There are reports that sphagnum has been sterilised and used for wound- dressing because of it's water-holding characteristics.

3.3 Differences between Fungi and Mosses

	Fungi	Mosses
1.	Have rhizoids but no stem and leaves.	Also have rhizoids but have stem and leaves.
2.	Have no chlorophyll.	Have chlorophyll.
3.	Heterotrophic and saprophytic/parasitic.	Autotrophic.
4.	Have mycelia and hyphal threads.	None.
5.	No peristomal teeth.	Have peristomal teeth and seta.

3.4 Similarities between Fungi and Mosses

Both fungi and mosses possess the following features

i. Spores

ii. Rhizoids.

Activity C

List at least five differences between fungi and mosses

Conclusion

Mosses especially the peat moss (sphagnum) are of a lot of importance to a Horticulturist because of its water-holding capacity, thereby it is frequently mixed with sandy or humus-poor soil to improve the water holding capacity of the soil. Mosses can also be of medical importance.

More importantly, from the point of view of evolution, mosses form the link between the simpler aquatic plants and the more complex terrestrial plants.

Summary

In this unit, you have leamt that;

1. Moss belong to division Bryophyta and the class musci.
2. Mosses lack vascular tissues.
3. The gametophyte phase is nutritionally independent and structurally more complex than the sporophyte phase.
4. The plants has a well developed altemation of generatons and is basically a land plant
5. The antheridia may be found on the same or on different gametophytes
6. The sperms are flagellated and swim to the archegonium, where fertilisation occurs
7. The zygote developes into an embryo.
8. Mosses have chlorophyll while fungi have no chloropyll. Mosses can, therefore, shynthesise their own food by the process of photosynthesis.

[illegible]

i. In your own words, describe the economic importance of mosses to man

ii. Discuss the terms;

   i. Gametophyte

   ii. Sporophyte

[illegible]

Dutta A. C. (1979). *Botany for Degree Students*

Idodo - Umeh (1989) *College Biology*

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Volume 1: Basic Concepts in Biology

Unit 10 Ferns

Page

1.0 Introduction

Ferns are a group of highly developed cryptogams and are widely distributed all over the world. They are shade and moisture-loving plants and, therefore, grow abundantly in cool shaded, moist places both in the hills and in the plains. They belong to the division called *Pteridophyta*. Some live as epiphytes, growing on other trees, for example *Platycerium* on the palm trees. A common and widely distributed fern is *Dryopteris*. Dryopteris s a land plant that grows in wet soil and under the shade of trees. It consists of roots, stems, and leaves.· The Pteridophyta (ferns) are the most advanced of the cryptogamic plants.
Ferns are mostly perennial herbs with stems often in the form of a rhizome, by which they commonly reproduce vegetatively. The stem is stout, erect and aerial. Roots are adventitous (fibrous) growing in clusters, from the rhizomes. Leaves are commonly pinnately compound and consist of two parts. The frond (leafy portion) and the stipe (stalk). The life-cycle of a fern is complete in two phases sporophytic and gametophytic. The fern plant is the sporophyte and this is followed by another small green flat structure called the **prothallus**, which is the gametophyte.

2.0 Objectives

By the end of this unit, you should be able to;

i. draw and label the sporophyte of a fern.

ii. list at least ten characteristics of ferns.

iii. describe the structural features of a fern leaf (frond).

iv. summarise the process of reproduction in Ferns.

v. list the biological and economic importance of fems.

vi. list at least six differences between mosses and ferns.

3.0 Characteristics of Ferns

Persistent vegetative plant body is the sporophyte, which is differentiated into stem, roots and leaves
The stem, roots and leaves all have conducting tissues making up the vascular system
The conducting system is made up of xylem, tracheids and phloem which transport water, mineral salts and food.
The leaves are called **fronds.**
Fronds are large and compound pinnate. They vary greatly in size and the life-cycle shows alternation of generations with the sporophyte being dominant over the gametophyte generation.
The sporophyte generation is diploid (2n) producing spores and is independent of the gametophyte generation at maturity.
The gametophyte generation is haploid (n) and produces the gametes that are generally smaller and different in shape from the sporophyte generation.
It is called the prothallus.
The male reproductive structure is the antheridium, while the female structure is the archegonium.
Water is required to transport the antherozoids to the archegonium for fertilisation.
The sporophyte reproduces asexually while the gametophyte reproduces sexually e.g. of ferns include *Nephrolepis, Adiantum, Polypodium, Dryopteris, Pteris.*
The stem is a rhizome, which bears numerous adventitous roots on the lower surface in contact with the soil.
The stem is covered with numerous small brown scales called **ramenta.**
The stem is non-branching
Mature leaves bear groups of sporangia (abaxial) surface of the frond (leaf).
Each sorus encloses many sporangia that bear numerous spores.

3.1 Vegetative Structure of Ferns

Has a true stem called a rhizome that lies horizontally underground and is covered with brown scale-like structures called **ramenta**.

Leaves and roots arise from buds on the rhizome.

It has *adventitious* roots with conducting tissue, which carry water from the ground to the leaves.

They also help to hold the plant firmly to the ground.

Young leaves arising from the rhizome are covered with ramenta and are rolled into tight spirals.

They have circinate venation.

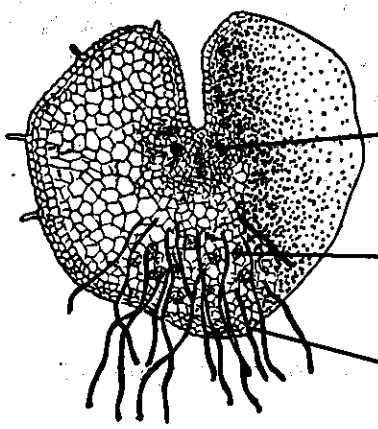
Mature leaves (fronds) are large and conspicuous. They are divided into the leafy frond and stalk or stipe.

The stipe is covered with ramenta and attaches the frond to the rhizome.

The leafy frond has a main axis called rachis. The rachis bears leaflets called pinnae, which may at times be subdivided into pinnules.

Fertile fronds are called sporophylls. These bear sori (sin. sorus), which are packets of spores occuring on the underside of the fronds.

Fronds are green and photosynthetic.



Prothallus of fern

Fig. 10.1

3.2 Nutrition in Ferns

Ferns obtain their food through the process of photosynthesis as in other higher plants. This is so because their leaves contain chlorophyll which is required for photosynthesis. Besides the roots of the plant absorb water and mineral salts from the soil.

Activity A

List at least ten characteristics of ferns

3.3 Reproduction in Ferns

Spores develop within the sporangia; when they mature they are released and dispersed when sporangia dehisce.

The indusium dries up and shrinks;

The walls of the sporangium dries out and tension builds up in the annulus, which curls back, flinging the spores out of the sporangium.

Under favourable conditions of moisture and temperature each spore germinates into a very small, thin, heart-shaped green structure, called the **Prothallus.**

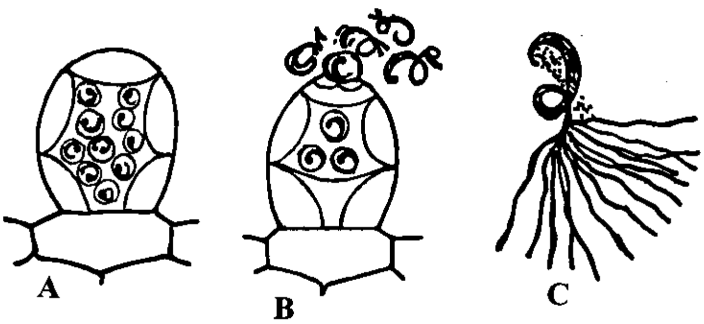
The margin of the prothallus is very thin and single-layered while the central part is comparatively thick and

many layered.
Unicellular hairy **Rhizoids** grow out from the under surface of the prothallus and anchor the prothallus to the soil;
The prothallus is delicate and lacks a cuticle and is prone to dessication, so it survives only in damp conditions.

3.3.1 The Antheridium

The antheridium is a spherical or oval body consisting of a wall/jacket with 1 or 2 cap cells at the apex, It also consists of a number of antherozoid mother cells (20 - 50) which develop into antherozoids. Antherozoids are spirally coiled multinucleated and ciliated (fig. 10.4).

Fig. 10.2



Antheridium. A, a young one with antherozoid mother cells; B, a mature one after bursting; and C, an antherozoid

3.3.2 The Archegonium

Both archegonia and antheridia are bome on the lower surface of the **prothallus** (gametophyte).
The archegonium is a flask-shaped organ.
It is the female reproductive organ.
The swollen basal portion is called the **venter** while the slender upper tube-like portion is the neck.
The venter enclose a single large egg cell or ovum (the female gamete) when mature.
The venter is linked to the neck through a canal (ventral canal) which extends into the neck canal fig. 10.4

3.4 Fertilisation

At maturity the archegonium **secretes malic acid** and **mucilage** to attract antherozoids.
In the presence of a film of water the antheridium bursts to release the ciliated antherozoids.
Antherozoid swims through the venter to fertilise (fuse) the egg forming a **DIPLOID** zygote.
The diploid zygote is called an **Oospores.**
The oospore divides rapidly to form an **embryo.**
Which later develops into the **sporophytic generation**.
This sporophyte is initially depended on the prothallus until it develops roots.

Activity B

Describe the process of reproduction in ferns.

3.5 Alternation of Generations

The fern plant during its life history passes through **two stages or GENERATIONS**
The plant itself which is dominant is the **sporophyte.**
The leaves of the sporophyte bears the spores and are called the **sporophylls.**
The spores themselves are **Haploid** and are produced through **reduction division (meiosis)**.
When the spores disperse and germinate they give rise to the **Gametophyte** or the prothallus
This gametophyte produces the sex organs (archegonia and antheridia) which contain the gametes (Ovum and antheroids).
The fertilisation of the ovum by the antherozoid produces a zygote which becomes the oospore that gives rise to the sporophyte or the fern plant.
The fern plant is now DIPLOID as a result of fertilisation of the ovum by antherozoid.
Thus, the two generations (sporophyte and gametophyte) alternate regularly with each other
This phenomenon is referred as **Alternation of Generations** (fig. 10.5).

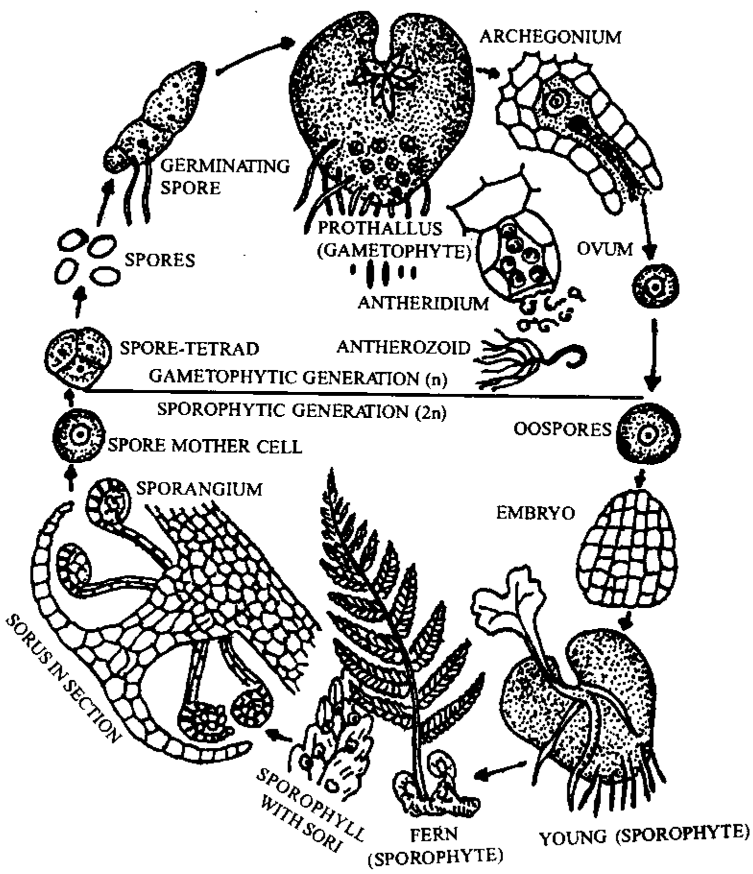


Fig. 10.3 - Life cycle of Fern showing alternation of generations

Activity B

Describe the process of reproduction in Ferns.

3.6 Biological and Economic Importance of Ferns

They are sometimes used for decoration as omamental plants

They are also of evolutionary importance and form links between mosses and gymnosperms. They are the first land plants with true roots.

They are eaten by animals

Fossil ferns contribute to the formation of coalbeds, petroleum products and natural gas.

3.7 Differences between Mosses and Ferns

	Mosses (e.g. *Polytrichum; Funaria*)	Ferns (i.e. *Dryopteris*)
1.	Rhizoids.	True roots.
2.	No underground stem.	Underground stem called rhizome.
3.	No ramenta (scale leaves).	Ramenta/scale leaves present.
4.	Simple leaves.	Fronds and leaves more advanced.
5.	No sori, no indusium.	Sori on fronds and protective indusium.
6.	Elaters, or peristomal teeth present	No elaters or peristomal teeth.
7.	Capsule has chlorophyll.	Capsule has no chlorophyll.
8.	There are stomata on capsule.	No stomata on capsule.
9.	Dominant generation is the haploid gametophyte.	Dominant generation is the diploid sporophyte.

[redacted]

List at least six differences between Mosses and Fems

[redacted]

Fems are of biological and economic importance to man. Therefore, their study should be intensified.

[redacted]

In this unit, you have learnt that:

- Fems are highly developed cryptograms.
- The gametophyte is haploid while the sporophyte is diploid.
- Leaves and roots arise from buds on rhizomes.
- They are of biological and economic importance.

[redacted]

1. List at least six differences between mosses and fems.
2. With well labelled diagrams, describe the process of reproduction in fems.

[redacted]

A. C. Dutta (1979). *Botany for Degree Students*

Idodo - Umeh (1993). *College Biology*

Volume 2: Flowering Plants

1.0 Introduction

Flowering plants are also called spermatophyta or spermatophytes. They are members of the seed-producing vascular plants. They have well-developed roots, stems and leaves. The seeds containing the embryo develops from a fertilised egg of a very small gametophyte which is completely dependent on the sporophyte, the plant form that we see around us. The efficient seed dispersal of seed plants account for their continued existence and widespread occurrence. The fertilisation of the egg is by the male gamete which is brought about by the pollination, followed by the growth of the pollen tube which carries the male gamete to the egg. Water is not needed in this process. Hence, the seed plants are true land plants. This is an advance over non-vascular plants and ferns which need water for fertilisation. The seed plants are divided into ***gymnosperms and angiosperms***.

[illegible]

By the end of this unit, you should be able to;

i. describe the structure of a typical flowering plant
ii. list at least six characteristics of flowering plants
iii. list at least five differences between Gymnosperms and Angiosperms

[illegible] Plant

A typical flowering plant consist of a shoot system and a root system (fig. 1.1). The roots, stems and leaves are the growing or vegetative part of the plant. The flowers which give rise to fruits and seeds are the reproductive part of the plant.

Plants have three main tissue systems that run throughout their roots, stems, leaves and flowers. These are:

i. dermal tissue system or epidermis
ii. vascular tissue system of conducting cells (xylem and phloem) to transport food, water and minerals throughout the plant;
iii. ground tissue system which consists of all the tissues other than the epidermal and vascular tissues.

3.1 Characteristics of Flowering Plants

Do you remember that living things have features that are peculiar to them? Flowering plants too have their own.

1. The plant body is well organised and highly differentiated into special parts and they perform particular functions.
2. There is a distinct division into root, stem, branches, leaves and flowers. The roots from the root system, while the stem and other parts form the shoot system. The conducting tissues consists of xylem and phloem making up the vascular system; these plants are also called tracheophyta or vascular plants.
3. The flowers are developed for reproduction
4. Pollen grains form 'pollen' tubes, which carry male gametes.
5. Fusion of male and female gametes occurs in the ovary giving rise to the embryo sac that later forms the seed.
6. The seed is the new sporophyte. It depends on the parent plants.

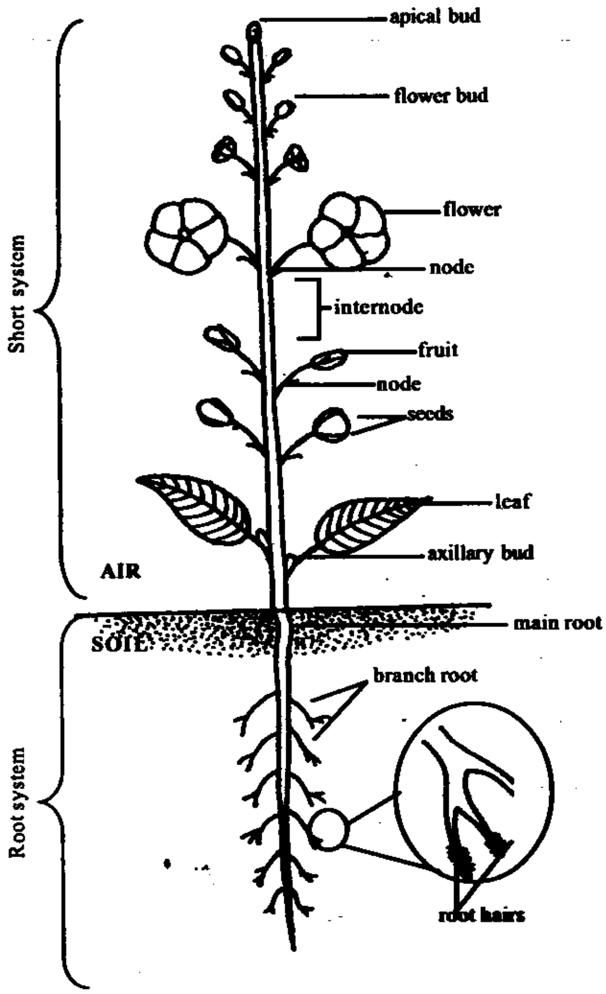


Figure 1.1 Structure of a Typical Flowering Plant

7. The seed contain the embryo.
8. The embryo develops from a fertilised egg of a very small gametophyte which is completely depen on the sporophyte, the plant that we see around us.
9. The fertilisation of the egg by the male gamete is brought about by pollination, followed by the growth of the pollen tube which carry the male gamete to the egg. Water is not needed in this process.
10. Seeds are formed enclosed in the carpels which become the fruits.
11. Both fruits and seeds are variously adapted for their effective dispersal.

1. Briefly describe the structure of a typical flowering plant.
2. List at least six characteristics of flowering plant.

3.2 Gymnosperms And Angiosperms

Can you remember that seed plant/flowering plants are divided into Gymnosperms and Angiosperms? It will interest you to know more about Gymnosperms and Angiosperms.

3.2.1 Gymnosperms

Gymnosperms (gymnos = naked) means plants with naked seeds. They do not have well developed flowers. They are trees or shrubs, mostly evergreen, with needle-like leaves, although, a few have scale-like leaves or broad leaves. The seeds are borne in special structures called ***Cones.***

Gymnosperms include the cycads, gingkos and conifers. Of these the conifers are the most important as they make up the world's temperate region forests. They produce 'soft wood' which is used for timber and wood pulp (Paper making). They also yield resins and turpentine. Pine, fir and sypruce are examples of conifers.

3.2.2 Angiosperms

Angiosperms (angion = case) means plants with covered seeds. Angiosperms are the flowering plants. They form the largest group in the plant kingdom. There are over 25,000 species of angiosperms which differ greatly in size and form. They have adapted to almost every kind of habitat.

The angiosperms are more highly evolved than the gymnosperms because they have an abundance of water-conducting vessels and bear seeds which are protected within fruits. Fruits developed from the ovaries of flowers, the female reproductive organs of the angiosperms. The angiosperms are grouped into **dicotyledons** and **monocotyledons**.

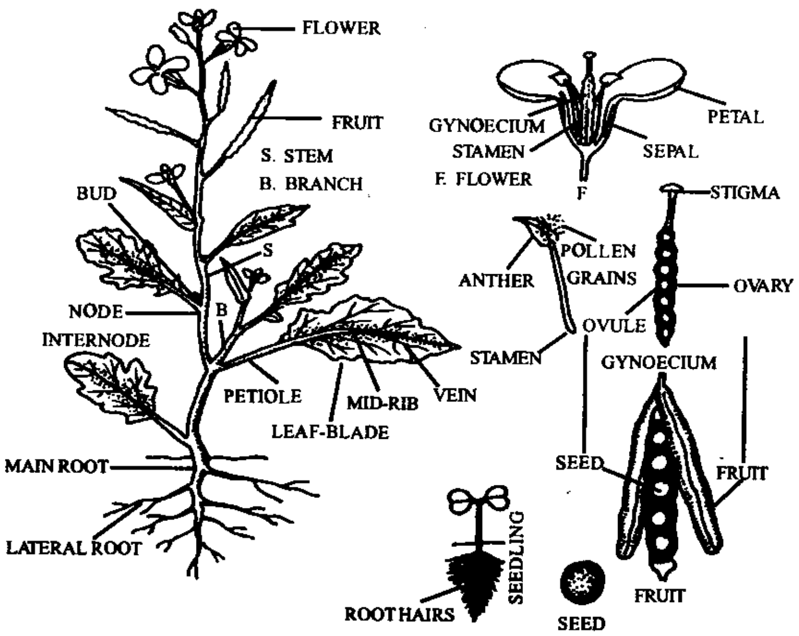


Fig. 1.2 Parts of an Angiospermic Plant (Mustard Plant)

3.3 Differences Between Gymnosperms And Angiosperms

Gymnosperms	Angiosperms
- Do not have well developed flowers	Have well developed flowers.
- Flowers lack calyx and corolla, they are called strobili	Flower have perianth, calyx and corolla. No strobili
- Have naked seeds	Have covered seeds
- All seeds have endosperms, no cotyledons	Have both endospermous and cotyledonous seeds.
- Xylem tissues have tracheids only, no vessels	Xylem tissues have vessels, no tracheids
- They are terrestrial in habitat eg. whistling pine, cycas	They are terrestrial but few are aquatic
- They have cones where naked seeds are formed. Fruits are not formed	Seeds and fruits are produced after fertilisation
- The leaves are green in colour, small, scaly and needle-like	Well developed true roots, stems and leaves are present
- Seed endosperm is haploid	Seed endosperm is triploid
- Phloem tissue has no companion cells	Phloem tissue has companion cells

Activity 3

In tabular form, list six differences between Gymnosperms and Angiosperms

3.4 Advancement Of Flowering Plants Over Ferns

Flowering Plants	Ferns
Plant body differentiated into distinct root and shoot system	Plant body not divided into root and shoot system
Vascular bundles well developed comprising xylem and phloem.	Vascular bundles less developed consists of tracheids
Form pollen grains and pollen tubes that carry male gametes to the ovum.	No pollen grains and pollen tube, male gametes consist of motile antherozoids
Produce seeds with cotyledons or endosperms	No seeds, have sori
Have megasporangium that is protected by a coat at maturity	Megasporangium absent, instead, archegonium present
Have cambium that leads to secondary thickening	Cambium is absent, no secondary growth.

The possession of seeds, well developed vascular bundle, root, shoot and presence of cambium among other features has made flowering plants or seed plants more advanced than non-seeded and flowerless plants.

In this unit, you have learnt that;

i. Flowering plants are also called spermatophytes

ii. They are members of seed plants

iii. Flowering plants are highly differentiated into roots, stems, branches and flowers

iv. The conducting tissues of flowering plant are more advanced compared to seedless plants

v. The seed of flowering plants is the new sporophyte and it depends on the parent plant
vi. Seed plants are classified into Gymnosperms and Angiosperms
vii. Gymnosperms has naked seeds while Angiosperms have covered seeds
viii. Gymnosperms seeds has endosperms and no cotyledons while Angiosperms seeds have both endosperms and cotyledons.

[redacted]

1. In tabular form, list five reasons why flowering plants are more advanced than ferns. (10 marks)
2. List five differences between Gymnosperms and Angiosperms (5 marks)

[redacted]

Idodo - Umeh (1996) *College Biology*
Sarojini T. Ramalingam (1993) *Modern Biology.*

Flowering Plants

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In its earliest usage, when coined in 1960, the term ***angiosperm*** had not its correct modern taxonomic significance. In 1827, Robert Brown gave it its present taxonomic distinction of meaning from gymnosperms, when he established the truly naked characters of the seeds of cycads and conifers. Even then, there was no plant classification which separated the gymnosperms from the angiosperms on this characteristics. This was because the life cycle of neither the cryptogams nor seed-bearing plants had the nature of a seed. When Hofmeister correctly interpreted the life history of Fern and in 1851 discovered the nature of the occurences in seed formation, he was able to see that the two series of events paralleled one another and to establish the significance of the origin and form of the seed as a criterion in classification. From that time gymnosperms were clearly separated from angiosperms, whereas they had previously been grouped together as dicotyledonous plants to distinguish them from the monocotyledonous plants. The term angiosperm now includes all the flowering plants other than gymnosperms and comprises therefore all the monocotyledonous as well as the dicotyledonous higher flowering plants.

In this text, we will discuss the differences between monocotyledonous and dicotyledonous plants, root system of angiosperms.

[redacted]

By the end of this unit, you should be able to;

i. list at least six differences between dicotyledonous and monocotyledonous plants
ii. list at least five characteristics of roots
iii. list at least four functions of roots.

Dicotyledons and Monocotyledons

Do you remember that living organisms have features that are peculiar to them? Dicotyledons and monocotyledons do have theirs. The different features possessed by dicotyledonous and monocotyledonous plants.

Dicotyledons: These are the more primitive angiosperms. They may be trees, shrubs or herbs. Most large trees with spreading branches are dicotyledons.
Dicotyledons have these features:

* They bear seeds which have two seed leaves or *cotyledons* each
* The vascular bundles of their stems and roots are arranged in a regular pattern
* Their floral parts - sepals, petals, pistils and stamens - exist in groups of four or five
* Their leaves have veins arranged in a branched network
* They have a tap root system
* Dicotyledons usually undergo secondary growth; because of the presence of cambium cell.

Some examples of dicotyledons are *Hibiscus, Ipomea batatas* (sweet potato), *Carica papaya* (pawpaw), *Dioscorea sp.* (yam), and *Vigna unguiculata (*cowpea*).*

* In dicotyledonous roots the number of xylem bundles varies from 2 to 6.

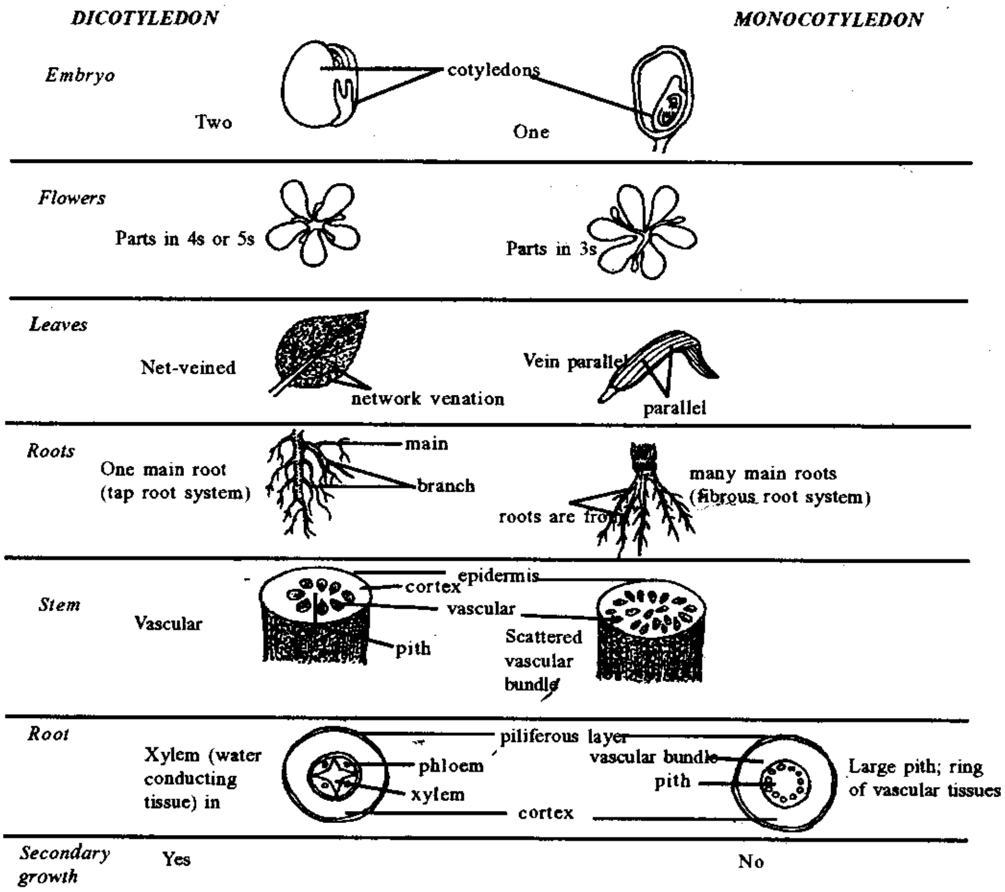
Monocotyledons: These are the most advanced plants. They tend to be more efficient and specialised because they have fewer parts. As such they show a very high degree of adaptation to their environment. They are generally herbs.
Monocotyledons have these features:

* They bear seeds with one cotyledon each
* The vascular bundles of the stem are scattered
* Their floral parts exist in groups of three or multiples of three
* Their leaves have veins running parallel to one another
* They have a fibrous root system
* Monocotyledons do not undergo secondary growth because of the absence of cambium.

Some examples of monocotyledons are *Zea mays* (maize), *Elaeis guineensis* (oil palm), *Axonopus compressus* (carpet grass), *Panicum maximum* (Guinea grass) and *Oryza sp.* (rice).

* In monocotyledonous roots, the number of xylem bundles are numerous.

Table 2.1 Comparing Dicotyledons and Monocotyledons



Note: All cereal plants are monocotyledons

Activity

List at least five differences between Dicot and Monocot

3.1 Morphology of Angiosperms

It will interest you to know the morphology of angiosperms.
The dicot plant is made up of a single axis consisting of the root system (below the ground) and shoot system (above the ground) see fig. 2.1

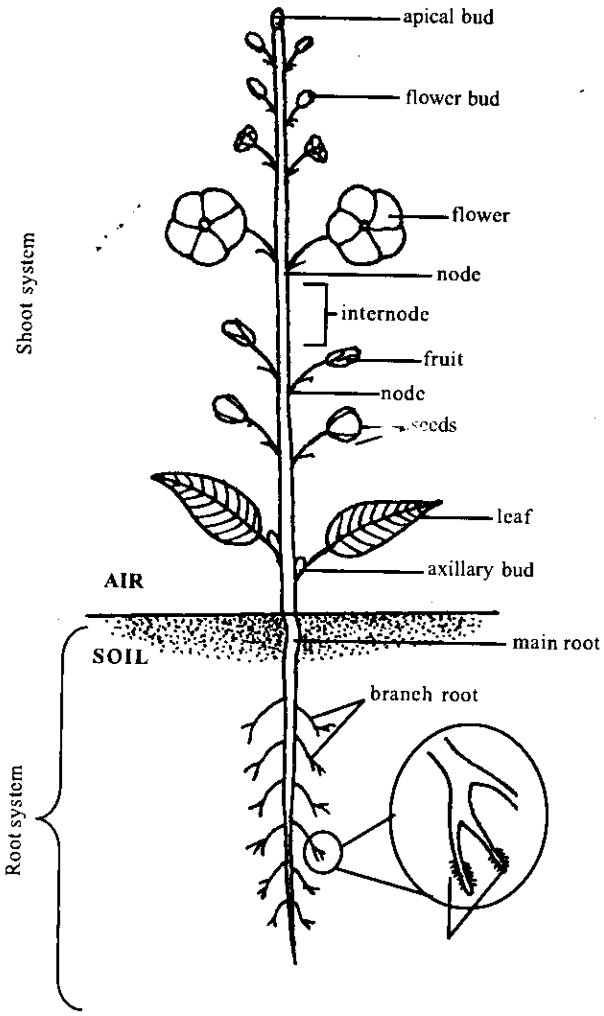


Figure 2.1 Structure of a typical flowering plants.

3.2 Root System

The root system is the part of the plant growing in the soil. This excludes the underground stems which are **organs of perennation** (survival from year to year by vegetative means). There are two kinds of root systems, namely: **tap root** and **fibrous root system**. The root system develops from radicle of embryo which normally stays below the ground, and because it never bears leaves or flowers is not divisible into nodes and internodes.

Tap Root System: This system is characteristic of the dicotyledonous plants. There is just one main root known as the **tap root** growing deep down and giving rise to smaller branches, the **lateral roots**.
Tap roots are firm, if the primary radicle establishes itself to become a permanent and clearly defined organ, then together with its lateral branches it forms a tap root system and the primary radicle become the tap root.

The Fibrous Root System: This is characteristic of monocotyledonous plants. In this system, there is a mass of roots arising from the base of the stem. The mass consists of several main roots of approximately the same size. These give off numerous branch roots which in turn give off other branch roots of smaller size. The roots are slender in appearance.

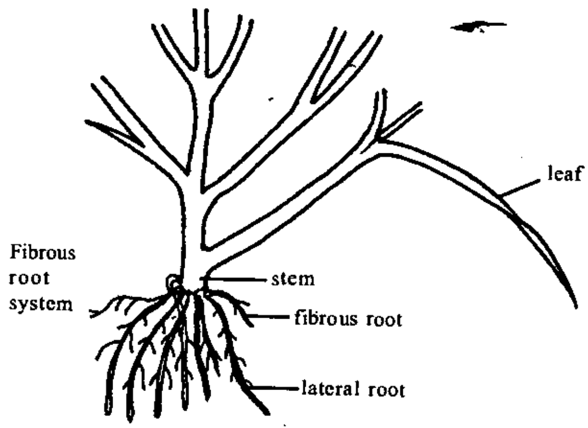


Figure 2.2. The Fibrous Root of Grass, Eleusine indica

Both the main and branch roots bear a root cap at their tips. The root cap protects the soft growing regions of the root tips. Here the cells are actively dividing to add new cells to the root. A little above the root tips are some unicellular root hairs used for absorption of water and mineral salts from the soil into the plant body. The root hairs are very numerous and tiny and should not be confused with the very small branch roots seen after an intact plant has been uprooted from the soil. One may need a microscope to observe the root hairs if they have not been damaged by uprooting . The root begins to thicken above the root hair region. Root produced from parts other than the radicle of a seed are known as**adventitious roots.** For example, the prop roots of maize which grow from the lower nodes of the stem into the soil. The roots seen in stem tubers, rhizomes, bulbs and corms are all adventitious roots.

3.3 Characteristics of Roots

The general characteristics of roots are as follows;

1. Roots grow inside the ground except for some modified aerial roots
2. Roots lack buds
3. Roots end in caps (stems end in buds)
4. Roots do not bear green pigments or chlorophyll
5. Roots possess unicellular hairs known as root hairs. (Hairs found in some stems and leaves are multicellular)
6. Nodes and internodes are absent in roots.

3.4 Functions Of Roots

The main functions of roots are:

1. For absorption of water and dissolved mineral salts from the soil into the plant body through the root hairs.
2. For anchoring the whole plant firmly to the soil
3. Certain roots become modified to perform some special functions such as food storage, vegetative reproduction, climbing, breathing in water-logged soil and for extra support to the plant.

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1. List at least six characteristics of roots
2. List four functions of roots

3.5 Modification of Roots

These will be summarised with reference to the particular function the modification serves. Both tap and fibrous roots may be modified for support, food storage or climbing.

Types of Modified Roots

3.5.1 Root-Tubers

These are roots which become swollen with food reserves. Hence they are called storage organs. Examples are seen in the tap roots of carrot, (*Boerhaavia diffusa*) and lateral roots of cassava (fig. 2.3).

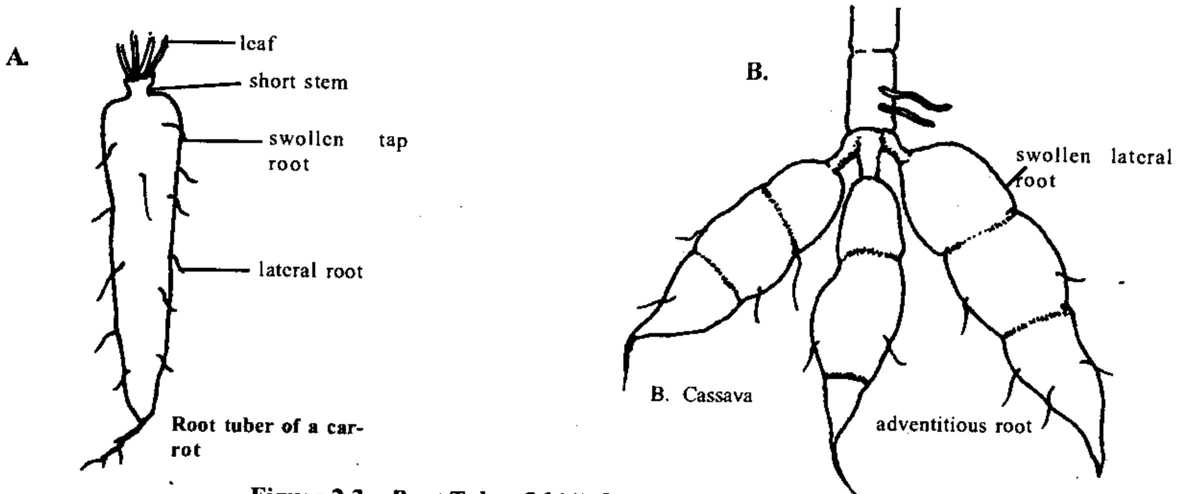


Figure 2.3. ***Root Tuber Of (A) Carrot, (B) Cassava***

3.5.2 Climbing Roots

They are also known as **clasping** or **adhering** roots. These are aerial roots growing into cracks, walls, or barks of host plants. By clasping the host for support they are able to climb high. In *Ficus pumila*, the aerial roots appear in clusters at the nodes.

In *Scindapus sp.*, the clasping roots grow downwards and on getting to the soil they develop lateral roots. In **black pepper**, the small roots of the plant produce sticky substance that helps to gum it to the host tree or wall.

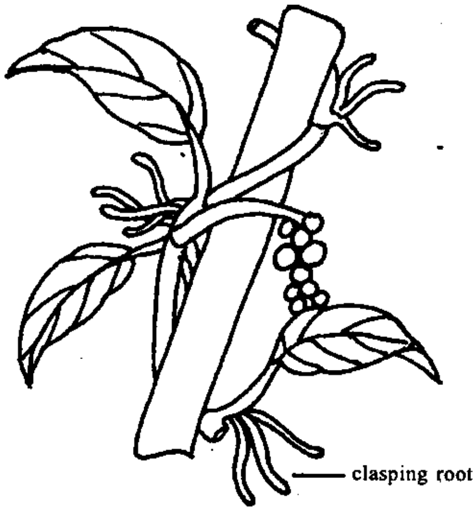


Figure 2.4 Climbing Roots Of Black Pepper

3.5.3 Breathing Roots

These are special roots possessed by some plants in the swamps for breathing in the air. These **breathing roots** or **pneumatophores,** are lateral branches growing above the soil which is often water logged. Good examples are seen in raphia and the white mangrove (fig. 2.5).

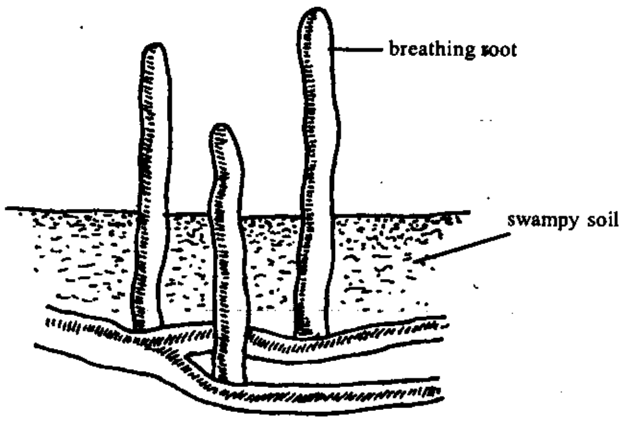


Figure 2.5 Breathing Root of White Mangrove

3.5.4 Prop Roots

These are clusters of roots growing from the nodes of a stem straight into the soil for extra support to the plant. Prop roots occur in maize.

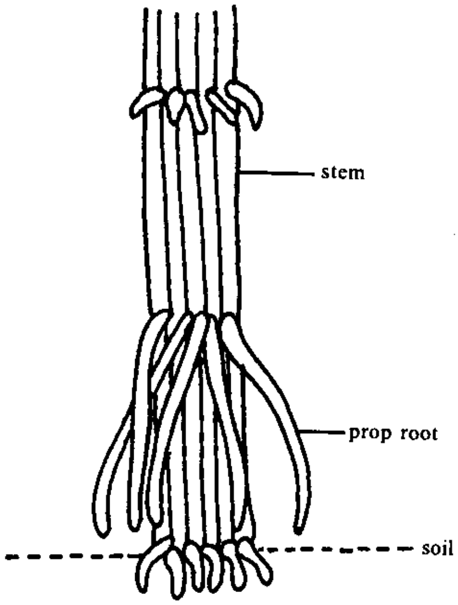


Figure 2.6 Prop Root of Maize

3.5.5 Stilt Roots

These are branches from the base of certain trees which grow in muddy places and they help in the support of the plant. In the umbrella tree, for example, (fig. 2.7) the trunk narrows at the base from where the stilt roots develop to provide the necessary support. Stilt roots are also seen in the red mangrove.

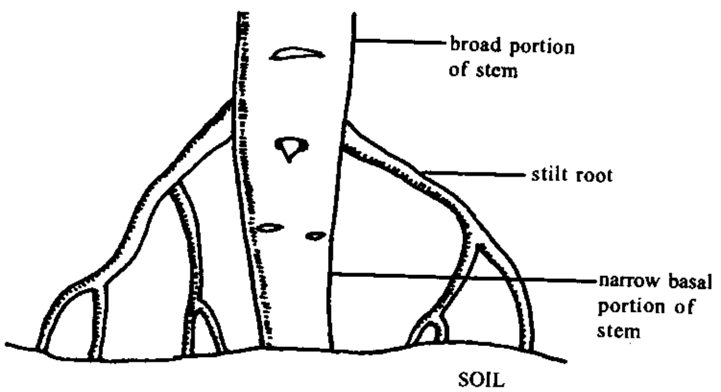


Figure 2.7 Stilt Root Of Umbrella Tree (Musanga cecropeoides)

3.5.6 Buttress Roots

These are enlarged growths on the upper edges of normal lateral roots of some huge trees such as silk cotton tree. Buttress roots also act as support to the plant as well as providing good hiding places for some forest animals (fig. 2.8).

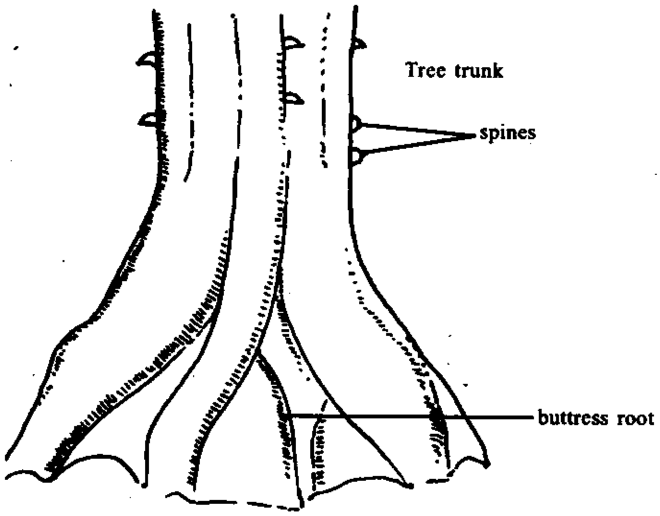


Figure 2.8 Buttress Roots Of Terminalia Superba

3.5.7 Ephiphytic Roots

These are produced by plants growing on another plant with special aerial roots eg. epiphytic orchid. The plants with such roots are not parasitic (fig. 2.9).

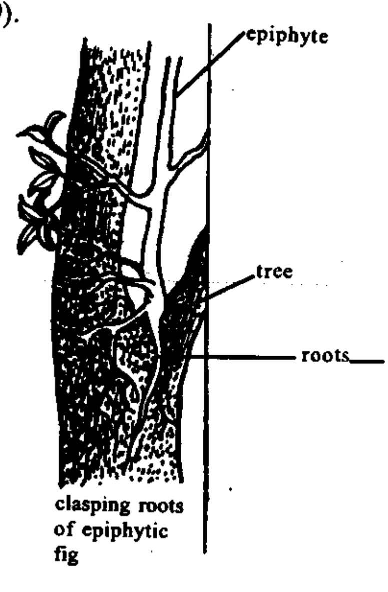
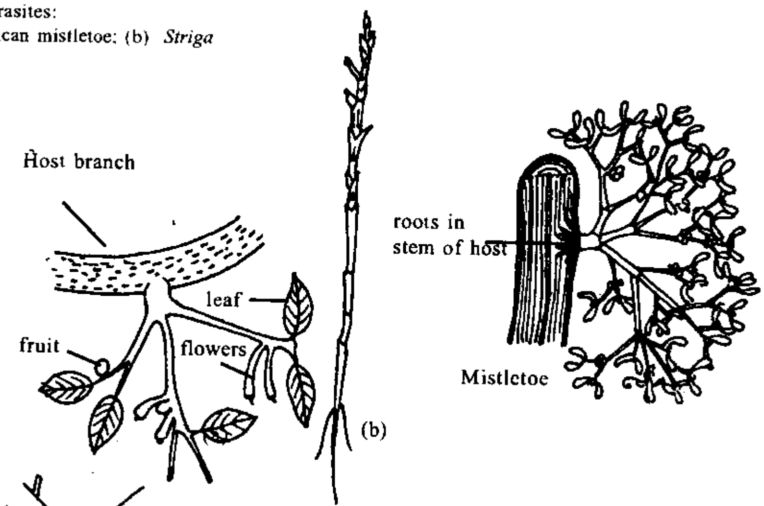


Figure 2.9

3.5.8 Sucking Roots

These are developed by parasitic plants. Such roots are called **haustoria** e.g. dodder (*cuscuta sp*) and mistletoe

semi-parasites:
(a) African mistletoe; (b) *Striga*



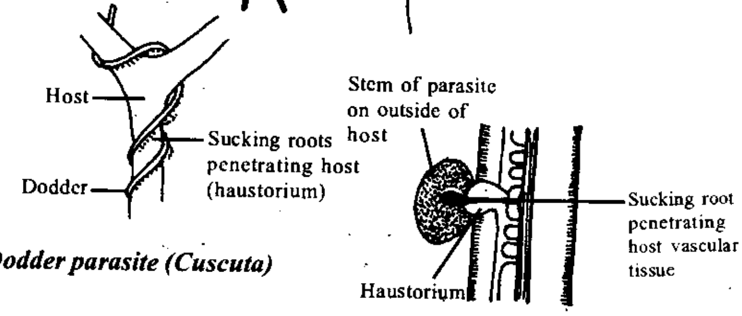


Figure 2.10: ***Dodder parasite (Cuscuta)***

Activity C

Briefly describe the following types of roots;

i. Prop roots
ii. Sucking roots
iii. Epiphytic roots

3.6 Internal Structure of the Root

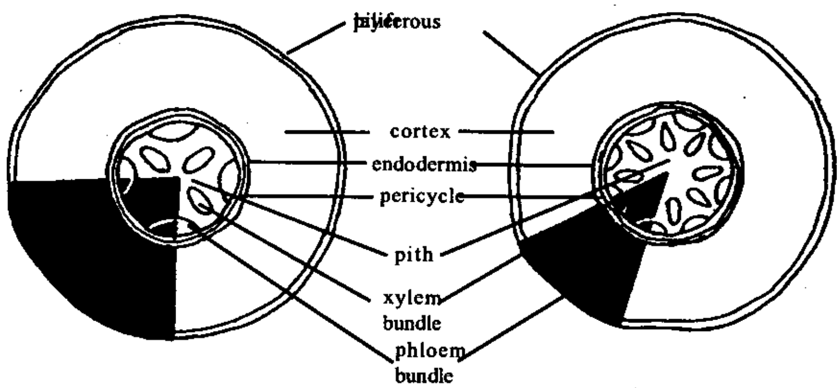
Internally, a root consist of an outer cylinder and an inner central cylinder or stele. A transverse section of a root (fig. 2.11) shows the following arrangement of tissues from the circumference to the centre.

* Piliferous layer
* Cortex, includes the endodermis — Outer Cylinder
* Pericycle
* Vascular tissue and pith — Inner Cylinder or Stele

The outer cylinder consists of a wide zone of loosely packed, thin-walled parenchyma bound on the outside by a single-cell thick piliferous layer. Roots hairs arise from young cells of the piliferous layer. The endodermis is the innermost layer of the cortex. It is made up of a single-cell thick layer of barrel-shaped cells. Each cell is encircled by a thick waxy band.

The stele consists of vascular tissue made up of alternate phloem and xylem bundles arranged in a ring. Usually, there are more vascular bundles in a monocotyledonous root than a dicotyledonous one. The pericycle which bounds the vascular tissue on the outer side is a one- or two cell thick layer of thin-walled cells. The pith which is large in monocotyledonous roots is composed of thin-walled parenchyma. In most dicotyledonous roots, the xylem fills up the centre of the stele, forming a centrally supporting column.
The main supporting tissues in roots are xylem and the turgid parenchyma which makes up the cortex
Note: Cambium, a meristematic tissue which gives rise to secondary growth, appears in older dicotyledonous roots but is completely absent in monocotyledonous roots (Fig. 2.11).

Figure 2.11



Transverse section of a dicotyledonous root (diagrammatic)

Transverse section of a monocotyledonous root (diagrammatic)

Briefly describe the internal structure of a root.

Angiosperms as a group of plants has a lot of biological and economic importance to man. Angiosperms which comprises of dicotyledonous and monocotyledonous plants can be sources of food, raw materials, for industries and sources of income to the farmer. Therefore their study should be intensified.

In this unit, we have learnt that;

i. Angiosperms comprises of monocotyledonous and dicotyledonous plants
ii. Monocotyledons bear seeds with one cotyledon each, while dicotyledons have two cotyledons
iii. The vascular bundles of the stem of monocotyledons are scattered, while that of dicotyledons are in a regular pattern.
iv. Monocotyledons do not undergo secondary growth because of the absence of cambium cells, while dicotyledons usually undergo secondary growth because of the presence of cambium cells.
v. Roots can be modified for support, storage and for climbing.

6.0 Tutor - Marked Assignment

Write short notes on the following;

a. Monocotyledon (2 marks)

b. Dicotyledon (2 marks)

c. Prop roots (2 marks)

d. Breathing roots (2 marks)

7.0 Further Reading and other Resources

Id-do - Umeh (1996) *College Biology* - Publisher, Ltd., Benin City.

rojini T. Ramalingam (2001). *Modern Biology* - Africana - Feb Publisher, Benin City.

Volume 2: Flowering Plants

Unit 3: Shoot System-Stems, Leaves, Flower and Fruits

1.0 Introduction

Shoot system is the part of the plant which grows above the soil except the modified aerials roots. Shoot system can also be defined as that part of the plant which develops from the plumule of the embryo, normally appears above ground (at least at some stage in development) and bears the leaves, buds, flowers and possibly other appendages. There seems to be no other way to distinguish morphology between a root system and a shoot system except by reference to appendages such as leaves and flowers, which are never borne by roots.

The shoot system consists of two main organs:- (1) **stem** and (2) the **leaves**. During the reproductive stage, flowers and fruits may be seen on different branches of the stem.

2.0 Objectives

By the end of this unit, you should be able to;

i. explain the types of stems
ii. explain the various types and purposes of stem modification
iii. list the functions of stems
iv. explain the internal anatomy of a stem
v. explain the various forms of leaves
vi. list the functions of leaves
vii. list the four floral leaves of a flower
viii. explain the types of fruits.

3.0 Stems

The stem is the ascending portion of the axis of the plant, developing directly from the plumule, and bears leaves, branches and flowers. When young, it is normally green in colour.

A stem consists of nodes and internodes alternating throughout its length. It is more or less cylindrical in appearance and ends in a terminal bud. Nodes are the slightly enlarged portion of the stem from which leaves and buds arise. The buds occur on the axis of leaves and sometimes develop into branches and flowers. An internode is the portion between two successive nodes. The terminal bud consists of actively dividing cells (meristematic cells). All the young tissues of the shoot system develop from these meristematic cells. Newly formed leaves can be seen covering the terminal buds.

- Stems are either erect, decumbent, procumbent, prostrate or creeping.
- Stem can be smooth, hairy or rough
- They can bear roots or not.

3.1 Types Of Stems

There is a variety of stem structures adapted to perform diverse functions. They may be aerial or underground. Aerial stems may be erect, rigid and strong, holding themselves in an upright position; while there are some too weak to support themselves in such a position. They either trail the ground or climb neighbouring plants and other objects. Some stems remain permanently underground and from there periodically give off aerial shoots under favourable conditions; such stems are for food storage and perennation.

There are different types of stems in flowering plants. With regard to their external characteristics and internal structures, stems can be grouped into the following.

3.1.1 Woody Stems

These are the stems of trees and shrubs. In this group the xylem tissue is highly developed into wood which occupies a very large area of the stem, hence the stem cannot easily be bent.

3.1.2 Herbaceous Stems

In this group the stems are thin. Wood is absent or present in very small amount, hence the stems can easily be bent. Woody and herbaceous stems belong to the dicot plants.

3.1.3 Monocotyledonous Stems (Monocot Stems)

These are type of stems found in grasses, maize, lily and palms. Their vascular bundles are scattered and there is no secondary growth.

3.1.4 Other Types of Stems

Other types found within the dicot and the monocot plants are:

3.1.5 Leaning Stems (Twiners)

These are tender stems with no means of support. They therefore grow by twisting round other plants for support. An example is the aerial stem of yam.

3.1.6 Creeping Stems

These are stems growing on the soil surface. They spread in all directions, producing roots at their nodes and leaves which cover the ground. A good example is seen in sweet potato.

3.1.7 Modified Stems

The normal or unmodified stems grow upright above the ground. Some stems are however modified for different purposes and functions. These are:

(a) Tendrils

These are thin leafless and spirally curled branches with which certain plants get attached to neighbouring objects. Tendrils are therefore modified for climbing. They occur in passion flower, *Curcubita* and melon (fig. 3.1).

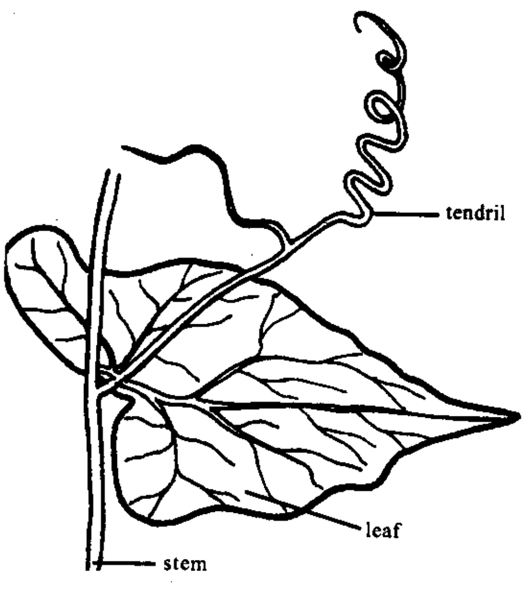


Figure 3.1. A Stem Tendril

(b) Thorns and Spines

These are outgrowths of the stem. Thorns are from auxillary buds hence they are borne on the axis of leaves. Thorns are seen in orange trees (fig. 3.2). Spines appear on the stem body. Thorns and spines are stems modified for protection against animals.

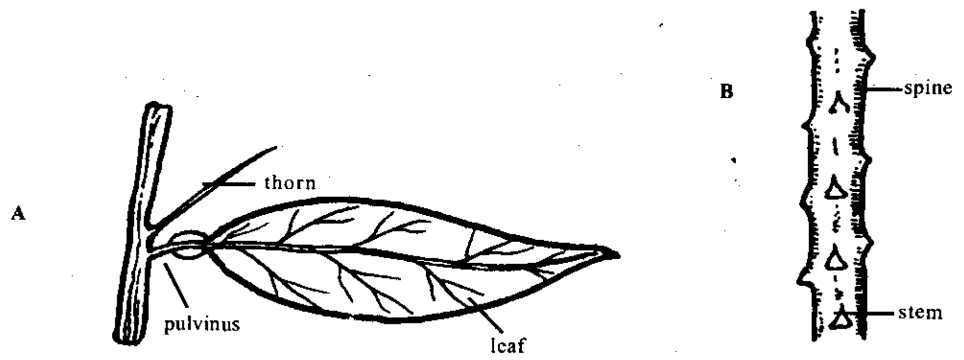


Figure 3.2 (A) Thorn, (B) Spine Of Orange Tree

(c) Underground Stems

These are the stem tubers, such as rhizomes, corms and bulbs modified for food storage and vegetative reproduction.

i. ***Rhizomes:*** Rhizomes are prostrate, thickened stems, creeping horizontally under the surface of the soil. It is provided with distinct nodes and long or short internodes; it bears some scaly leaves at the nodes; it possess a bud in the axil of the scaly leaf; and it ends in a terminal bud. The rhizome may be unbranched or sometimes the auxillary buds grow out into short, stout branches. Examples of rhizome are seen in ginger, canna (see fig. 3.3).

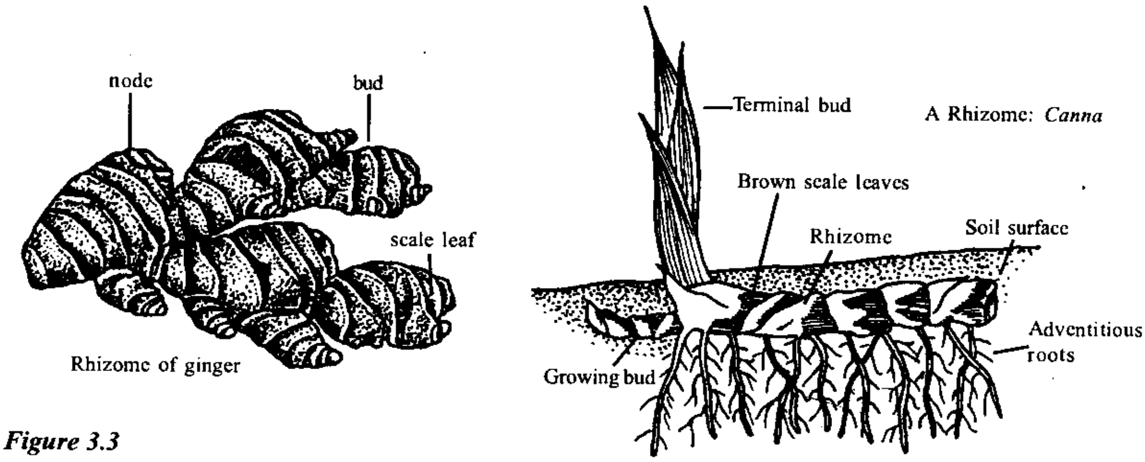


Figure 3.3

ii. ***Tuber:*** This is the swollen end of a special underground branch (tubers means a swelling). The underground branch arises from the axil of a lower leaf, grows horizontally outwards and ultimately swells up at the apex. It has on its surface a number of "eye" or buds which grow up into new plants. A tuber is often very much swollen owing to a heavy deposit of food material, becoming atmost spherical e.g. potato, irish potato, yam (see fig. 3.4).

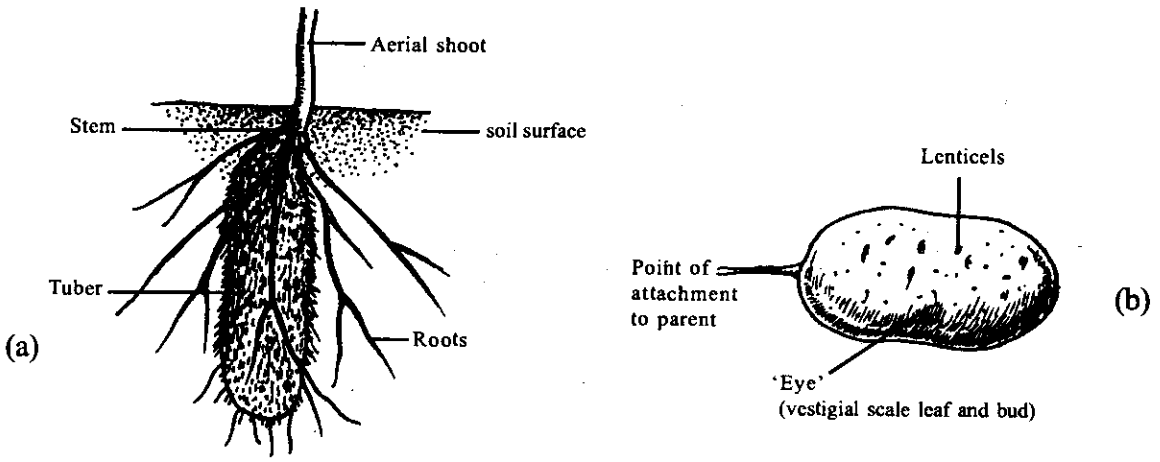


Figure 3.4 ***(a) Yam (b) Irish potato***

iii. ***Bulb:*** This is an underground modified shoot, consisting of a shortened convex or slightly conical stem, a terminal bud and numerous scale leaves. The inner scales are commonly fleshy, the outer ones dry. The fleshy scale store food (sugar in onion and mostly starch in others), while the dry scales gives protection. Example of bulbs are Onion, Garlic, Leek. see fig. 3.5.

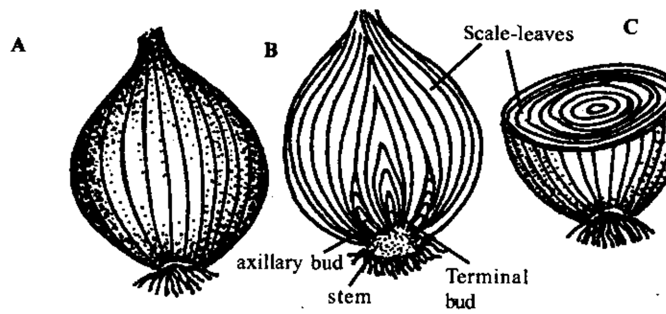


Figure 3.5

Onion Bulb: a) Whole, b) In longitudinal section, c) In transverse section

iv. ***Corm:*** This is a condensed form of rhizome consisting of a stout, solid, fleshy, underground stem growing in the vertical direction. It is more or less rounded in shape or often somewhat flattened from top to bottom. It contains a heavy deposit of food material and often grows to a considerable size. It bears buds and adventitious roots normally developed from the sides (Example Cocoyam, *Gladiolus, Amorphallus*).

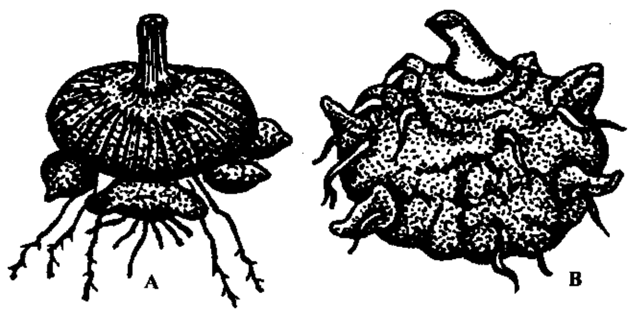


Figure 3.6 ***A, Corm of Gladiolus: B, Corm of Amorphallus***

(d) Others

Runners, offsets, suckers and stolons are various types of stems also modified for vegetative reproduction.

i. ***Runner:*** This is a slender, prostrate branch with long or short internodes, creeping on the ground and rooting at the node. The runner arises as an auxillary bud and creeps some distance away from the mother plant, then strikes roots and grows into a new plant. The runner may break off from the mother plant and grow up as independent daughter plants.

Examples are seen in wood-sorrel (*oxalis*). see fig. 3.7.

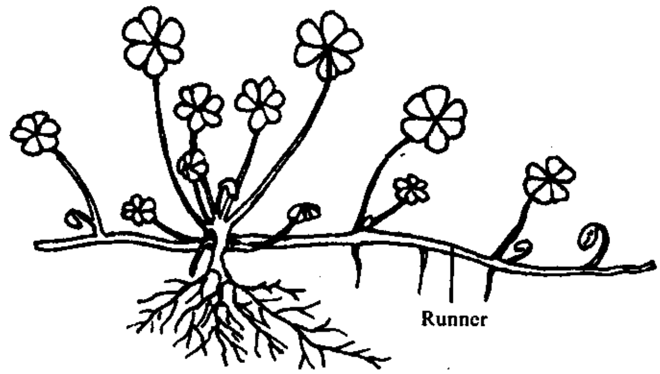


Figure 3.7 Runner of Wood-sorrel (Oxalis)

ii. ***Offset:*** Like runners, this originates in the axil of a leaf as a short, more or less thickened, horizontal branch. The offset often breaks away from the mother plant and then the daughter plant grows into a new plant. Common examples are water lettuce *(pistia)* and water hyacinth.

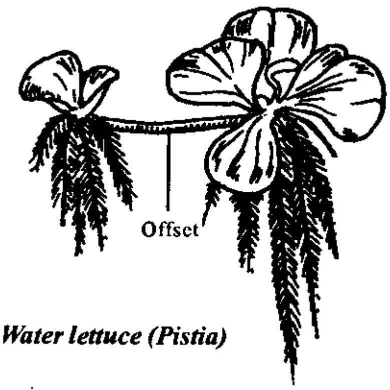


Figure 3.8 Offset of Water lettuce (Pistia)

iii. ***Sucker:*** Sucker is a lateral branch developing from the underground part of the stem at its node. But it grows obliquely upwards and directly gives rise to a leafy shoot or a new plant. Examples of suckers are seen in chrysanthemum, banana, pineapple. see fig. 3.9.

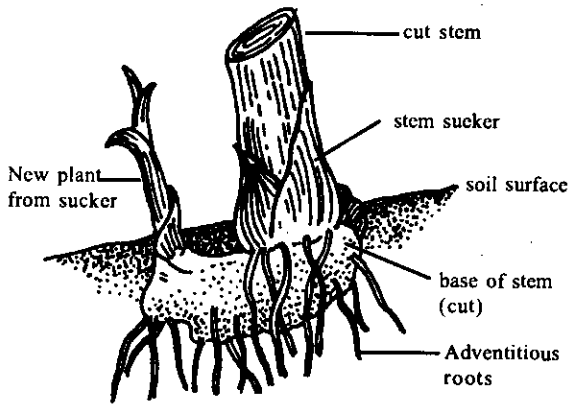


Figure 3.9: A Sucker of Banana Shoot

iv. ***Stolon:*** Like the runner this is also a slender lateral branch originating from the base of the stem. Many stolons are provided with long or short internodes which may grow out as a mother plant and spread out in different direction. see 3.10.

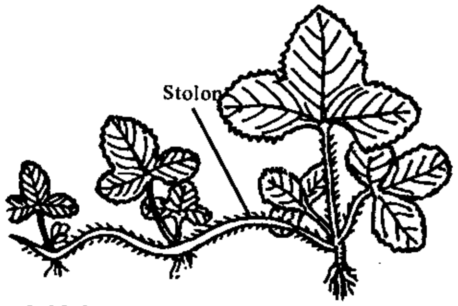


Figure 3.10 Stolon of wild strawberry (Fragaria indica)

Activity A

Briefly explain the following types of stems

i. Leaning stems
ii. Creeping stems
iii. Modified stems

3.2 The Internal Anatomy Of The Stem

A transverse section (T.S) of a dicot stem under the low power or electronic microscope shows three major regions- the epidermis (on the outside), the cortex (the middle) and the endodermis (on the inside). The cortex is further sub-divided into collenchyma and parenchyma. A ring of vascular bundles is arranged inside the endodermis or starch sheath. The vascular bundle consists of phloem (outside), a layer of cambium (middle) and xylem tissue (inside) (figure 3.11). In monocots however, the T.S. of the stem shows that vascular bundles are scattered without cambium, hence, no increase in thickness in monocots. Also there is no central pith and the cortex is thin (fig. 3.11).

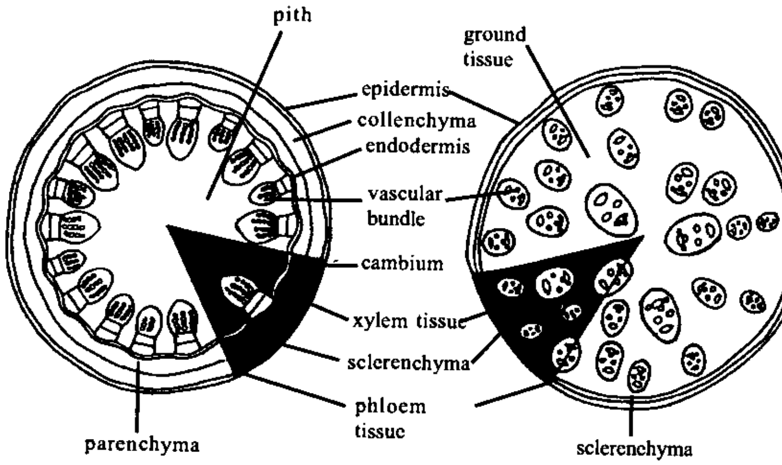


Figure 3.11

Transverse section of a dicotyledonous stem (diagrammatic)

Transverse section of a monocotyledonous stem (diagrammatic)

3.3 Functions Of Stems

1. They hold the leaves in the best position for light which is used in photosynthesis
2. They hold the flowers and fruits in the best position for pollination and dispersal respectively
3. They conduct water and mineral salts from the roots to the leaves and manufactured food from the leaves to the roots, growing regions and storage organs of the plant.
4. Some stems are modified for special functions such as climbing, protection, food storage, water storage and vegetable reproduction
5. Young parts of stems contain chlorophyll, hence they take part in photosynthesis.

With a well labelled diagrams describe the internal structure of the stem of an angiosperm.

3.4 Leaves

A leaf is the flattened outgrowth from the nodes of stems and their branches. A complete leaf bears a bud on its axil. A leaf is usually greenish in colour, in many dicot plants, the leaves are attached to the stem or branch by a stalk or petiole which continues in the **lamina** as mid-rib, branching into veins. A dicot leaf has **a net-work** or **reticulate venation.** Many monocot leaves have no petioles. The leaves are attached to the stem by sheathing **leaf-base** almost encycling the entire stem. Monocot leaves have **parallel venation** along the sides of the mid-rib (Fig.3.12). Yam is however an exception. Yam has reticulate venation like dicot leaves.

In banana (a monocot) the veins branch from the mid-rib almost at right angles to it, but are parallel to each other.

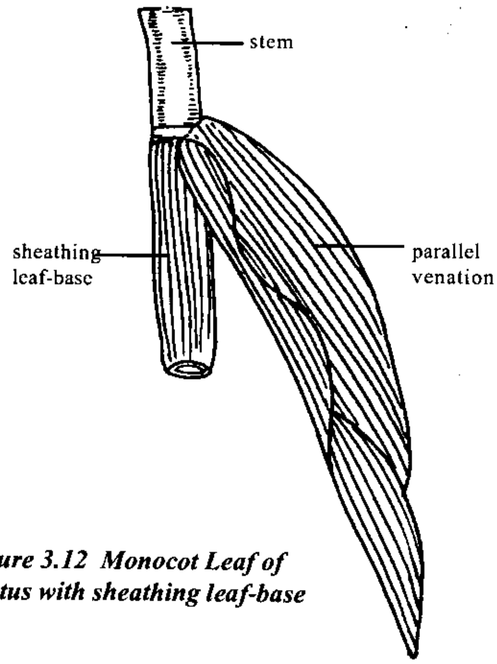


Figure 3.12 Monocot Leaf of Costus with sheathing leaf-base

3.4.1 Leaf Shape

There are a lot of variations in the overall shape of the leaves. These variations appear in the leaf-blade or lamina, the apex, the margin and the base. The margin for example may be smooth or entire, serrated or lobed. The familiar leaf shapes are shown in figure 3.13.

A. Sagittate or arrow-shaped as in arrowhead
B. Linear as in grass
C. Oval as in *Ixora*
D. Ovate as in *Hibiscus*
E. Oblong as in banana
F. Cordate or heart-shaped as in yam

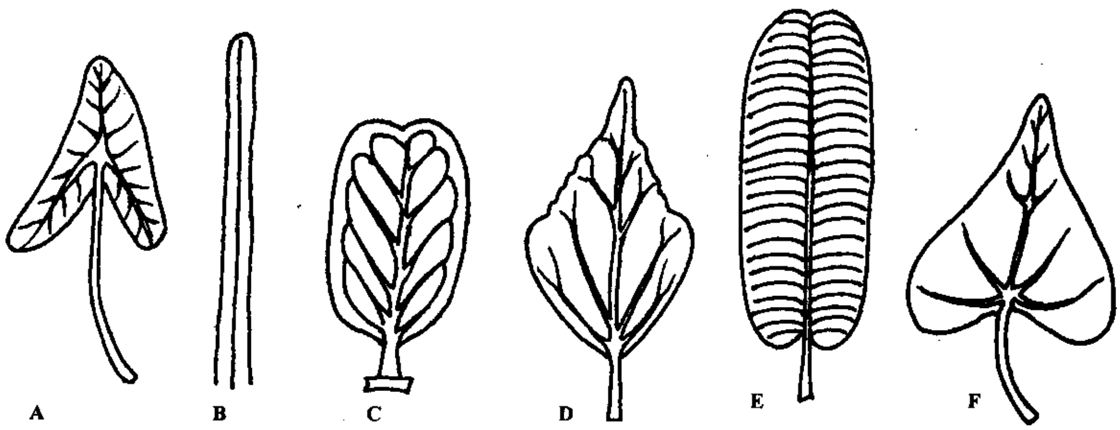


Figure 3.13 A - F Shapes of leaves

3.4.2 Forms of Leaves

There are two forms of leaves. These are **simple** and **compound** leaves

1. **Simple Leaves:** A leaf is said to be simple if it consists of only one **leaf-blade.** The leaf-blade may however become deeply lobed, but this does not extend to the mid-rib or petiole. Sometimes the mid-rib of a deeply lobed simple leaf could be divided at the base where it joins the petiole, to form a **simple palmate** leaf as in pawpaw and cassava (fig. 3.14).

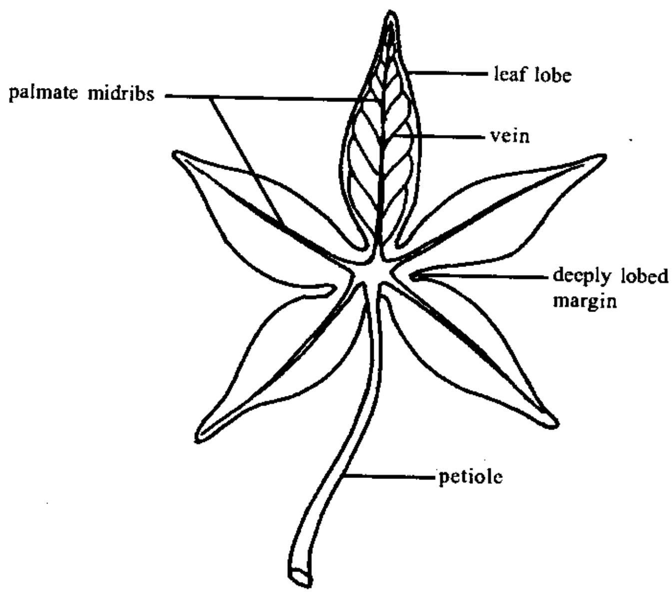


Figure 3.14 Simple palmate leaf of cassava

(Note: that the lobing does not extend to the midribs). Every complete leaf has on its axil, an axillary bud which sometimes develops into a branch shoot (axillary shoot).

2. **Compound leaves:** A compound leaf is a leaf divided into separate laminated units known as leafless. A leafless has its own leafbase and is either attached to a mid-rib (rachis) or directly to the petiole head. Leaflets have no axillary buds.

3.4.3 Types of Compound Leaves

1. **Pinnate leaf:** The leaflets are arranged on both sides of the midrib or rachis.There are two forms of pinnate leaves;
   (a) **Imparipinnate:** The apex of the leaf terminates in a single leaflet. An imparipinnate leaf made up of only three leaflets is trifoliate (fig. 3.6)
   (b) **Paripinnate:** The apex of the leaf terminates in two leaflets.

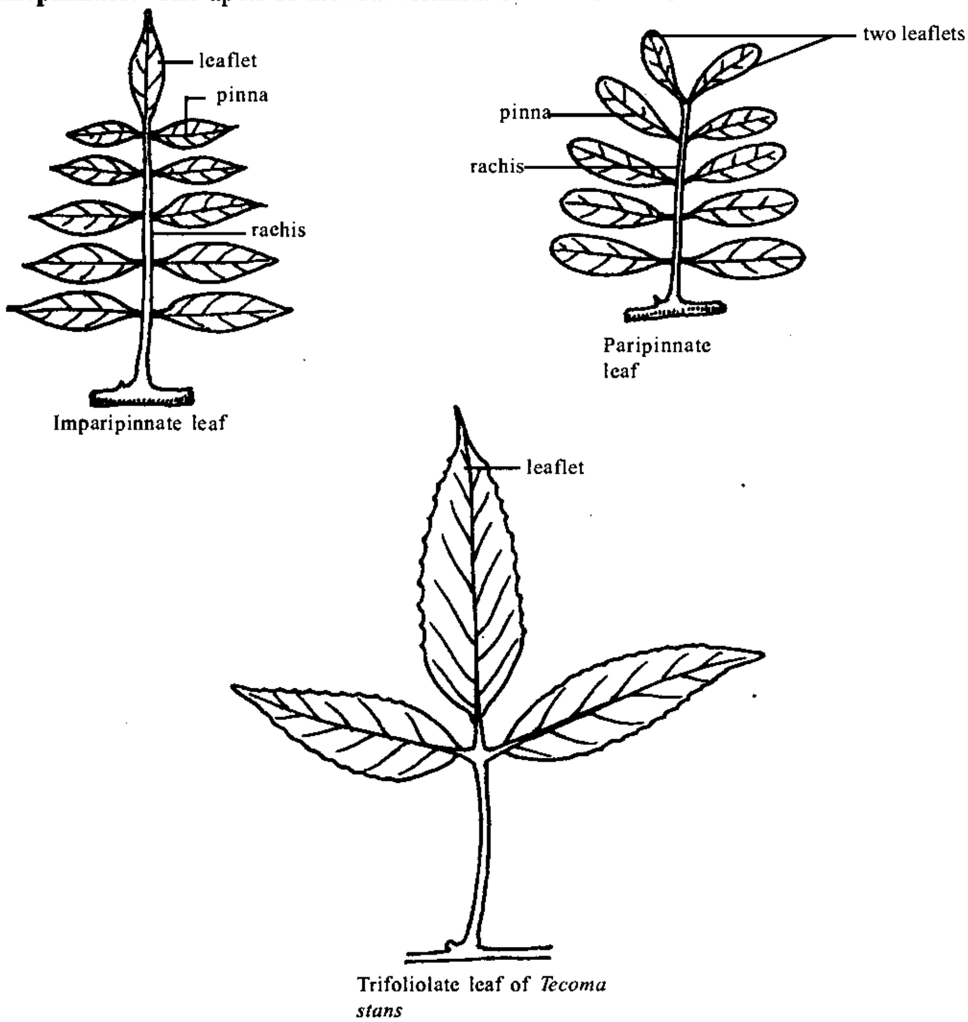


Figure 3.15 Types of compound pinnate leaves

2. **Bipinnate leaf:** This is a compound leaf in which the rachis gives off opposite branches of pinnae which bear oppositely arranged leaflets. (Fig. 3.16). In other words the pinnate is branched twice, as in **Pride of Barbados, sensitive plant** and *Delonix regia*. A major difference between pinnate and bipinnate leaves is that in a pinnate leaf the leaflets are attached to the rachis or midrib, whereas in a bipinnate leaf the leaflets are attached to the pinnae which are branches on the rachis.

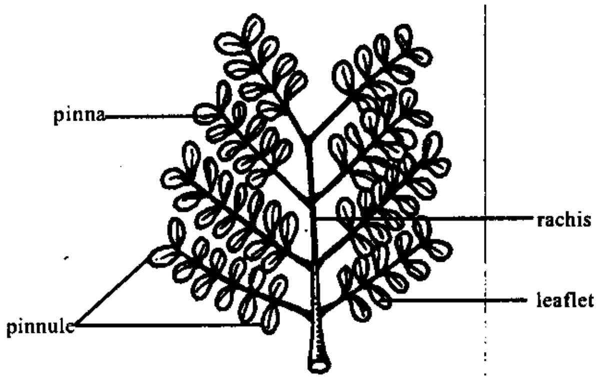


Figure 3.16 A Bipinnate leaf

3. **Digitate (compound palmate) leaf**: In this type the leaflets radiate from the head of the petiole as in silk cotton, and umbrella tree (*Mussanga cecropoides*). see fig. 3.17.

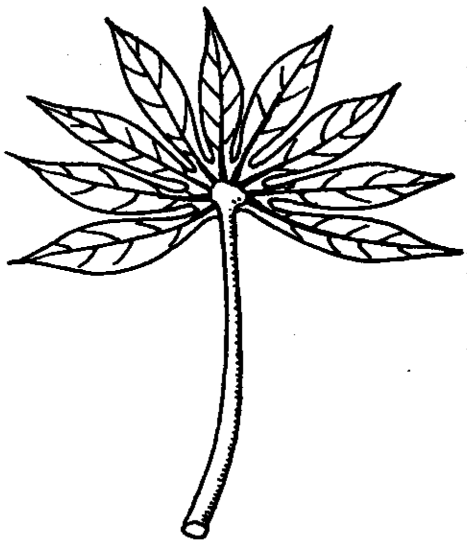


Figure 3.17 Digitate leaf of umbrella tree

3.5 Arrangement of Leaves

These are the various forms in which leaves are attached to the stems. The usefulness of leaf arrangement is to prevent one leaf from shading another so that each leaf receives maximum amount of sunlight for photosynthesis. The arrangement of leaves is also very useful in the classification of plants.

* **Alternate arrangement:** When the leaves appear singly on each node on either side of the stem (left and right), the arrangement is **alternate** as in *Crotalaria* and **sour sop**.
* **Opposite arrangement:** In some plants, two leaves appear from each node on the opposite sides of the stem, this is **opposite arrangement** as in guava see 3.18.

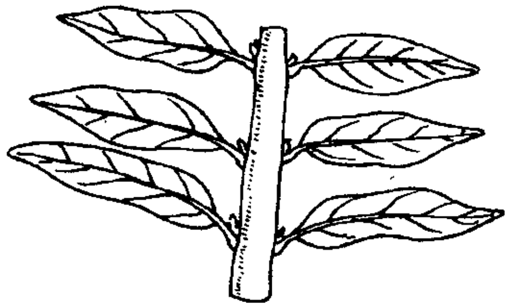


Figure 3.18 Alternative and opposite arrangement of leaves

When the leaves appear singly on each node but from any part of the stem, it gives a spiral arrangement as in **pawpaw, cassava,** and **palms.**

* **Decussate arrangement:** Sometimes opposite arrangement may be modified into decussate, in which case the opposite set of leaves below them. Examples are seen in *Aspilia* and independence plant *(Chromolaena odorata)*. *Ixora* is another good example of decussate arrangement see 3.19.

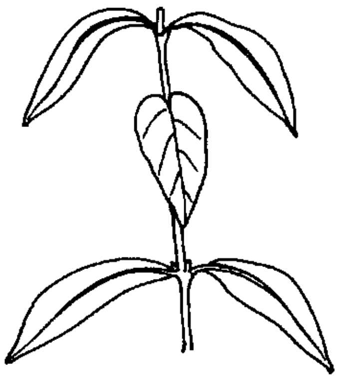


Figure 3.19 Decussate arrangement of leaves

* **Whorled arrangement:** In another form of arrangement more than two leaves occur at each node as in *Allamanda* and *Alstonis*. This is whorled arrangement (Fig. 3.20).

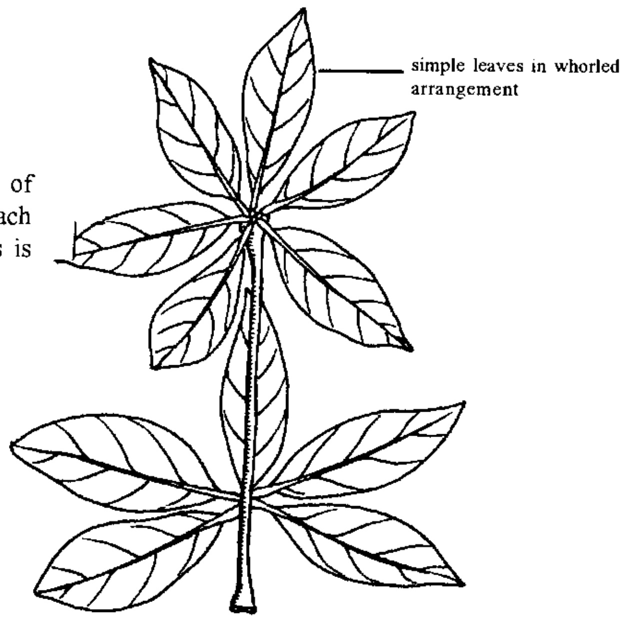


Figure 3.20 Whorled arrangement of leaves

3.6 The Internal Anatomy of a Leaf

The transverse section of a dicot leaf under the low power of a microscope shows the following tissues:

The outer upper and lower epidermis, the middle mesophyll and the vascular bundles are at the core. The upper epidermis has thin layer of *cuticle* for protection while the lower epidermis has *pores* or stomata. The mesophyll is made up of two types of tissue - the palisade tissue above and the spongy tissue below. Each contains chlorophyll but there is more in the palisade than in the spongy tissue. The mid-rib contains the vascular bundles responsible for water transport (fig. 3.21).

3.7 Functions of Leaves

The normal functions of leaves are:

1. Photosynthesis
2. Transpiration
3. Respiration (gaseous exchange)
4. Transportation of water and food

Other special functions of leaves include:

1. Protection, such as the spines in palm fronds
2. Climbing, as in *Gloriossa superba* where the apex is modified into tendril.
3. Vegetable reproduction as in life plant *(Bryophylum pinnatum).*
4. Floating or supporting organ in water as in *Nymphaea* and water lettuce.
5. Food storage as in onion bulbs.
6. The leaves of some plants such as sun dew and venus fly trap are modified for trapping insects for food.

Activity C

With a well labelled diagram, describe the internal anatomy of a leaf.

3.8 Flowers

A *flower is that part of shoot modified for sexual reproduction*. Flowers are usually produced in groups on a special branch of the shoot known as **inflorescence**. Some flowers however occur singly on the axil of a leaf on the stem. Such flowers are said to be solitary. Example is seen in the common *Hibiscus or China rose and pepper.*

A flower consists of four main parts known as **floral leaves.** These floral leaves are arranged on a receptacle in form of rings called **whorls**. The flower is attached to the stem branch by a stalk called the **pedicel**. Some flowers like *Aspilia* and **sunflower** have no pedicel. Such flowers are said to be **sessile**.

The four floral leaves consist of:

1. Sepals or *Calyx*
2. Petals or *Corolla*
3. Stamens or *Androecium*
4. Carpels or *Gynoecium* or *Pistil*

Calyx

The calyx consists of all the sepals which make up the outermost whorl. Sepals are usually greenish in colour and vary in number and arrangement. In many dicots, sepals range from four to five in number. In monocots however, they occur in multiples of three, say 3,6, or 9. In flowers like the **Pride of Barbados**, the sepals are said to be ***Petaloid***. When the sepals are free from one another the flower is **Polysepalous** as in Allamanda. But when they are all united, the flower is **gamosepalous**, as in *Hibiscus* species.

Functions of Calyx

1. The major function of the calyx is to protect the inner floral leaves when the flower is still in the bud stage.
2. Because sepals are greenish in colour, they contain chlorophylls and can therefore carry out photosynthesis.
3. When sepals are petaloid, they help in attraction of animal pollinating agents, such as insects, birds and man.

Epicalyx and bract

It is not usual to find in some flowers, some structures which look very much like the calyx. These are:

1. **Epicalyx:** They are additional floral leaves occuring below the calyx as in *Hibiscus rosasinesis*. In *Crotalaria*, the epicalyx is reduced to two tiny hair-like structures.
2. **Bract:** A bract is a foliage leaf on the axil which occurs on a flower or a group of flowers as in sweet potato and other *Ipomea* species. In sunflower and related members, there is a collection of bracts known as **involucre**. In *Bougainvillea* the flower is more or less hidden inside three brightly coloured bracts, which attract animals for pollination.

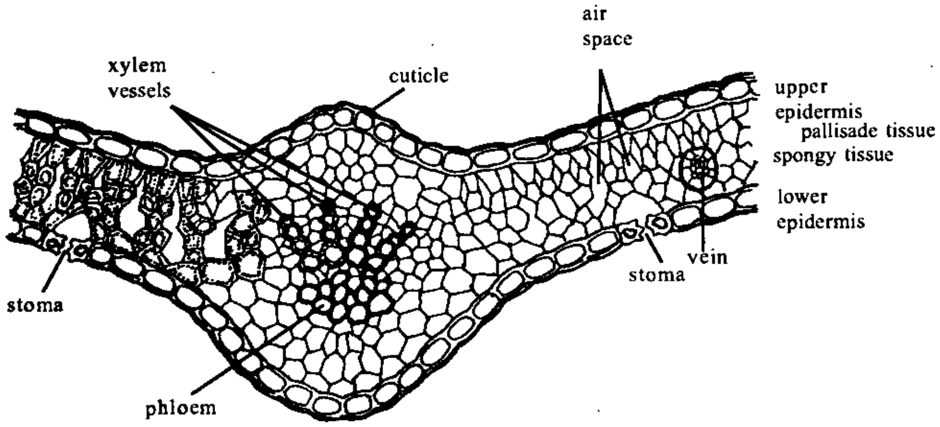


Figure 3.21 Transverse section through a leaf

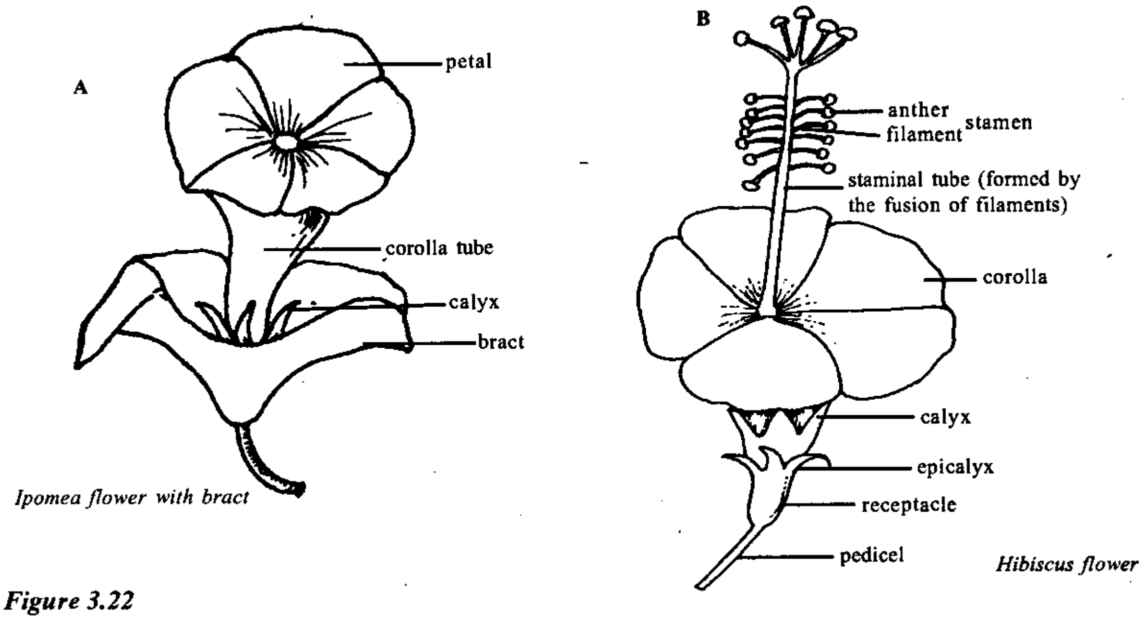


Figure 3.22

A = *Ipomea flower;* B = *Hibiscus flower*

Corolla

The petals of a flower make up the corolla which is the next inner whorl to the calyx. Petals are the most conspicous part of a flower. They are often brightly coloured and scented, especially in those flowers pollinated by insects and birds. Petals also vary in number in different plants. They range from four to five and sometimes up to eight in number. Like the sepals, petals may be free or united. When they are free the flower is polypetalous as in *Hibiscus.*

But when they are united to form a **corolla tube** as in *Allamanda,* the flower is **gamopetalous.**

Functions of Corolla

1. Brightly coloured and scented petals attract the animal pollinating agents such as insects and birds.
2. Petals retain pollen grains in the corolla tubes and keels.
3. Petals also offer protection to stamens.

Perianth and Perianth Segments

Perianth is the word commonly used to describe the unidentified calyx and corolla of a flower together. In many monocot flowers, the petals and sepals are so alike in number, size and colour that it is often not easy to distinguish between them. In such flowers the calyx and corolla are together referred to as perianth segments. The individual parts are called *tepals.*

The calyx and corolla are also known as the **non-essential** organs of a flower. This is because they do not produce the gametes required for sexual production.

Androecium

The androecium is made up of all stamens which are the male reproductive organs of a flower. A stamen (figure 3.23) consists of an anther and a **filament** which is attached either to the receptable as **in Pride of Barbados** or to the petals as in *Allamanda.*

In a good number of flowers the filaments are free from each other, but in flowers like the *Hibiscus* and *Crotalaria* all the filaments unite to form a **staminal tube** completely enclosing the ovary and style (figure 3.23b).

Anthers are of different shapes. Some are elongated as in grasses, some are rounded as in *Delonix regia,* others are arrow shaped as in *Allamanda.* Whatever the shape, each **anther** consists of two lobes and each lobe contains two **pollen sacs**. The pollen sacs contain **pollen grains** from which are the male gametes are produced. When the anther is mature, it dehisces to liberate the pollen grains which are seen as yellowish powdery substances at the surface.

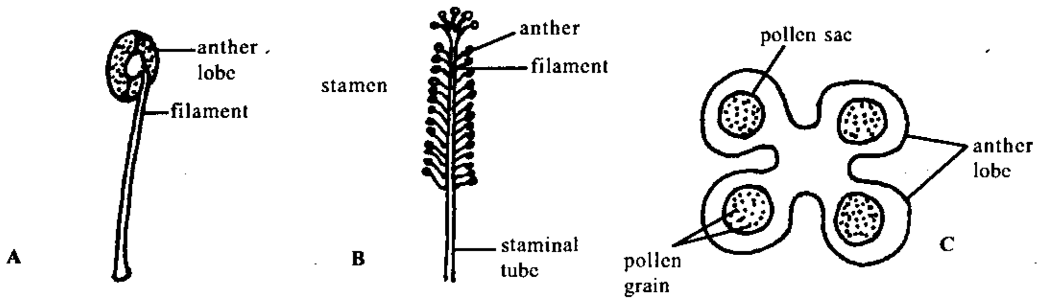


Figure 3.23
A = A Stamen; B = Staminal tube of Hibiscus; C = Transverse section through an anther showing the pollen sacs in the anther lobes

The Gynoecium

This is the female reproductive organ consisting of an ovary, a style and a stigma (fig. 3.25). The gynoecium is also known as pistil or carpel and forms the innermost whorl of a flower.

The ovary contains the ovules from which the female gametes are produced. The stigma receives the pollen grains. The style is a narrow tube connecting the stigma to the ovary. After pollination, a pollen tube grows through the style to carry the male gamete to the ovary.

An ovary may be monocarpous, apocarpous or syncarpous. An ovary is monocarpouus if it consists of only one chamber as in *Cassia, Crotalaria, Pride of Barbados* and *Delonix regia.*

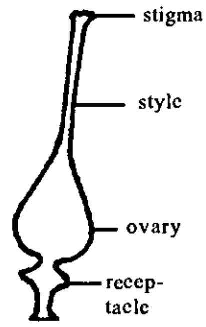


Figure 3.24 The Female reproductive organs in a flower

Briefly explain the functions of the following

i. Calyx

ii. Corolla

3.9 Seeds and Fruits

Seeds

A seed is a structure which develops from the ovule after fertilisation. A seed consists of an embryo and one or two **cotyledons**. It may contain an endosperm or food reserve. The embryo is made up of **a radicle** or future root system and **a plumule** or future shoot system. The seed is therefore a potential young plant awaiting certain favourable conditions for germination. Flowering plants have been classified into two major groups according to the number of seed leaves contained in their seeds. Hence plants whose seeds contain two seed leaves are called **dicotyledonous** plants and those whose seed contain only one seed leaf are called **monocotyledonous** plant (mono = one, di = two).

During the development of a seed certain changes take place in the ovule. These are;

1. The **endosperm nucleus** develops into an endosperm which stores food for the developing embryo.
2. The **antipodal** and guard cells degenerate.
3. The **integuments** become the testa or **seed coats.**
4. The **micropyle** remains as a **tiny hole** for absorption of water and diffusion of air during germination.

After the embryo has grown to maturity, the food reserve in the endosperm may or may not have been completely used up. Seeds in which the endosperm is completely used up during development are called non-endospermic seeds. Such seeds have no endosperm in their structure. Food used during germination is stored in their cotyledons. Many dicotyledonous seeds are non endospermic. Examples are cowpea, **groundnut, Okra, Pride of Barbados** and **balsam**. Seeds in which the food reserve in the endosperm is not completely used up during development are called endospermic seeds. Such seeds have an endosperm in their structure which contains the food required for germination. There is no food reserve in their cotyledons. Most monocotyledonous seeds are endospermic. Examples are **coconut, palmnut, maize, rice** and **guinea corn**. Seeds whether endospermic or non endospermic are important source of food for man and other animals. The food is stored as proteins, fats or carbohydrates.

Fruits

A fruit is the structure which develops from the ovary after fertilisation. Immediately after fertilisation the ovary begins to increase in size as a result of accumulation of food substances. This is followed by gradual changes in colour. The wall of the fruit develops into a **pericarp or fruits coat**. At maturity the pericarp is either hard and dry or soft and fleshy. A fruit can therefore be regarded as a mature ovary, containing one or more seeds.

Sometimes a fruit may be so small that it may be mistaken for a seed. Size is not an identification mark. Fruits and seeds can be identified by the number of scars they possess. A fruit has **two scars**. These are: the remains of style at one end and the point of attachment to the receptacle at the opposite end. A seed has only one scar or **hilum** representing **the point of attachment** of the seed **to the placenta** of the ovary.

Classification of fruits

There are many criteria employed in the classification of fruits, but the most popular is according to the nature of the ovary from which the fruit develops. Using this criterion, fruits can be divided into three main groups. These are:

1. ***Simple fruits:*** These are fruits formed from a single flower in which the gynoecium is made up of either a single carpel or many united carpel (that is, a syncarpous ovary). Majority of fruits belong to this group.
2. ***Aggregate fruits:*** These are fruits formed from a single flower in which the gynoecium consists of many free carpels (that is, apocarpous ovary).

3. ***Multiple fruits:*** These are fruits formed from many flowers whose ovaries unite together, with other parts of the flower after fertilisation.

True and False fruits

Fruits can be **true** or **false** according to what part of the flower ripens after fertilisation. A true fruit is a fruit formed from the ovary alone.

A **false fruit** is a fruit formed from the ovary as well as any other part of the flower or inflorescence. For example, the inflorescence stalk of pineapple, the pedicel and receptable of cashew nut, or the calyx of *Tridax and Emilia*, all are parts ripening along with their ovaries.

Simple fruits

There are three types of simple fruits grouped according to the nature of the fruit-walls at maturity and the manner in which the seeds are released from the fruits.

i. ***Dry indehiscent fruits:***

   These are one-seeded fruits whose walls become hard and dry at maturity, but the fruit walls or pericarps do not split on their own to liberate the seeds.

ii. ***Dry dehiscent fruits:***

   These are one or many-seeded fruits whose walls are **hard** and **dry** at maturity and have **definite lines** through which they split to liberate the seeds.

iii. ***Succulent fruits:***

   These are fruits whose walls become soft and **fleshy** at maturity. In most cases these soft fleshy walls are edible. Succulent fruits are indehiscent.

Dry Indehiscent fruits

There are five types of dry indehiscent fruits classified according to the type of pericarp they possess.

1. ***Achenes:*** An achene is a one-seeded dry indehiscent fruit with a very simple wall. Examples are the fruits of sunflowers and four o'clock plant. The other types of dry indehiscent fruits are achenes with a kind of modification on their pericarps.

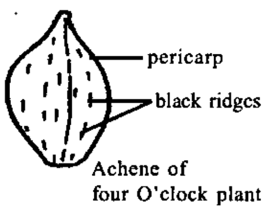


Figure 3.25 External structures of The fruit of the Four O'clock Plant

2. ***Nut:*** Nut is an achene with tough woody pericarp. Example is cashew nut. Most fruits and seeds commonly referred to as "nuts" are not true nuts. For example, groundnut, colanut, coconut and palmnut are not nuts.

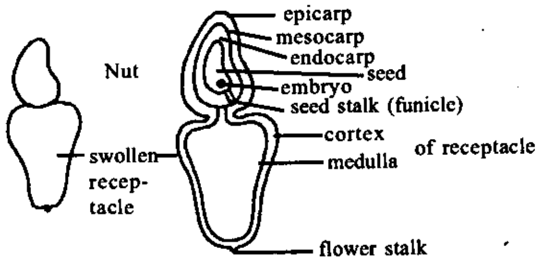


Figure 3.26 Structures of cashew, a false fruit

3. *Cypsela:* This is an achene developed from a flower with an inferior ovary with a persistent calyx which becomes modified into hairy pappus. The pappus acts as a parachute during the dispersal of the fruit by wind. Examples are *Tridax, Emilia*, *Eupatorium* and goat weed etc.

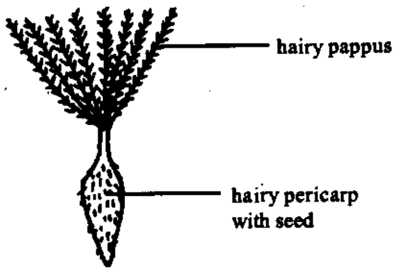


Figure 3.27 Mature fruit of Tridax

4. *Caryopsis:* This is an achene in which the pericarp becomes fused with the testa. The seed cannot be separated from the fruit. Examples are maize, rice, millet, guinea corn and most of the cereal crops commonly referred to as grains.

5. *Samara:* This is an achene in which the pericarp becomes extended into flat membranous wings for dispersal by wind.
   Examples are the fruits of *Combretum* and Obeche tree.

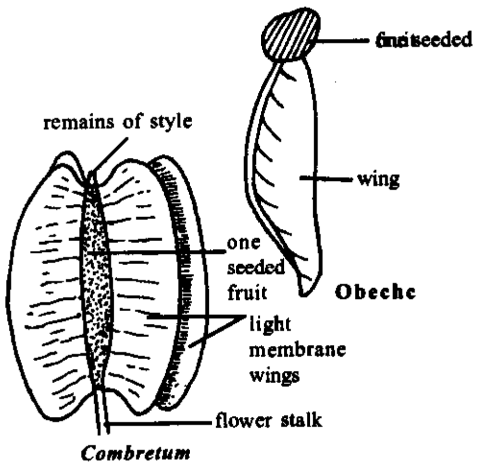


Figure 3.28 Winged fruits of Combretum and Obeche

1. Dry Dehiscent fruits

These are fruits which can split to release their seeds. There are four types of dry dehiscent fruits classified according to the number of lines through which the walls break open at maturity.

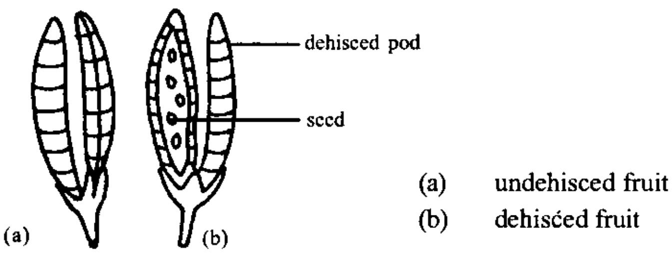


Figure 3.30 Follicles of Rose periwinkle

2. Legumes

Legumes are simple dry dehiscent fruits splitting by two longitudinal lines into two halves at maturity. The fruits of many leguminous plants belong to this group. Examples are **Pride of Barbados, oil bean tree,** *Crotalaria, Delonix regia* and cowpea. Sometimes when the walls split, they become twisted.

3. Capsules

A capsule is a simple dry dehiscent fruit opening by three or more lines. For example castor oil and water leaf open by three lines. Queen of flowers opens by six and sometimes seven lines. Okra opens by manylines into separate parts, each part containing many seeds.

4. Schizocarp

This is a many-seeded fruit which breaks up into one-seeded parts at maturity. The one-seeded parts is called a mericarp. Examples are *Urena lobata, Sida species* and a few leguminous fruits such as *Cassia* and *Desmodium.*

Succulent fruits

There are two types of succulent fruits. These are **drupes** and **berries**.

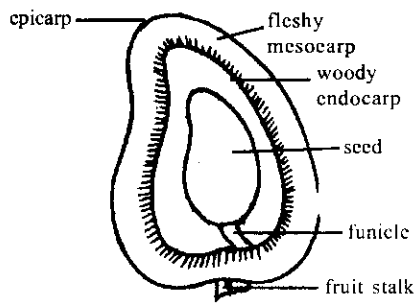
Drupe: A drupe is a one-seeded succulent fruit in which the pericarp consists of three layers. These arc;

1. an outer skin known as **epicarp**
2. a middle layer or **mesocarp**
3. an inner layer or **endocarp**

A

In a drupe, only the **epicarp** and **mesocarp** are fleshy. The endocarp which encloses the seeds is **hard** and woody and is often called the **"stone layer"**. Examples are mango, coconut and oil palm fruit.

In coconut and oil palm fruit, the mesocarp is fibrous in nature.



Longitudinal section of a mango fruit

Figure 3.31 Drupe

Berry: A berry is a many-seeded succulent fruit. Like the drupe the pericarp of a berry consists of an outer epicarp, a middle mesocarp and an inner endocarp. There layers are not as distinct as in the drupe. But unlike the drupe, the endocarp of a berry is edible. Examples are tomato, guava, and garden egg and banana seeds are absent in banana.

B

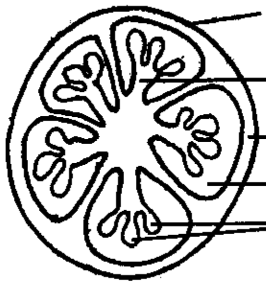


Figure 3.32 Transverse section of Berry of tomato

Aggregate fruits

As has earlier been mentioned, aggregate fruits are formed from an ovary with many free carpels. Each carpel may develop into a folicle, drupe or a berry. Hence there exists an aggregate of folicles as in cola and rose periwinkle; an aggregate of drupes as in soursop and an aggregate of berries as in custard apple. Soursop and custard apple are false fruits in which the receptacles ripen with the free carpels where a seed or many seeds occur.

Multiple fruits

Multiple fruits develop from flowers which are very close together in an inflorescence. Their ovaries unite and ripen along with the inflorescence stalk and sometimes the receptacle and pedicel. Multiple fruits are false fruits. Examples are pineapple, whistling pine and bread fruits. see fig. 3.34.

C

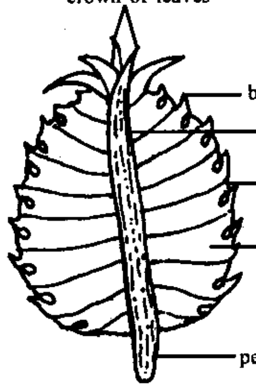


Figure 3.33 Multiple fruit of pineapple, C = Longitudinal section

Dispersal of Fruits and seeds

After the maturation of fruits, an abscission layer is formed at the point of attachment of the fruits to the stems. This layer later dries up and the fruits drop from the plant. Some times the fruits split up to release the seeds before the fruit walls finally drop. The pericaps of indehiscent fruits have to decay off before their seeds are exposed to conditions necessary for germination. Supposing that all the fruits and seeds formed in a plant dropped to the ground just below the parent plant, and that all the seeds germinated, the area would easily become overcrowded. Very serious competition will set in between the young plants and their parents. The plants compete for **nutrients, water, light and space**. The young plants are likely to die soon after. To avoid such adverse situations, the fruits and the seeds of many plants have got certain means by which they can be carried to different directions, some distance from the parent plants. The scattering of fruits and seeds to different directions from the parent plants is known as dispersal.

Advantages of Dispersal of fruits and seeds

Fruits and seeds are dispersed:

1. To prevent overcrowding of plants
2. To reduce the degree of unhealthy competitions between plants
3. To introduce the plant species into new environments where they may be better adapted.

Agents of Dispersal

Fruits and seeds can be dispersed:

1. By wind
2. By animals (including man)
3. By water
4. By explosive mechanism or explosion.

Fruits and seeds are especially adapted to suit their dispersal by any of these agents. It is either the fruits which are dispersed while the seeds are still enclosed in them, or for the dehiscent fruits, the fruits break up to liberate the seeds which are dispersed along. Their various structural adaptations are designed to carry them over a short or long distance from the parent plants.

[illegible]

Briefly explain the following types of fruits

i. aggregate fruits
ii. succulent fruits
iii. multiple fruits.

4.0 Conclusion

The study of a shoot system is of great important to Biologist and to the Agriculturists because of the roles the stem, leaves and flowers play to the survival of man, his animal and to the environment generally. The stems and leaves can be modified for food storage and for vegetable reproduction. Leaves play an imporant roles in photosynthesis, transpiration etc. The flowers are organs of sexual reproduction in flowering plant. Their study therefore should be intensified.

5.0 Summary

In this unit, we have learnt that;

i. Shoot system consists of stems, leaves, flowers and fruits
ii. A stem is the ascending portion of the axis of the plant, developing directly from the plumule, and bears leaves, branches and flowers.
iii. Stems can be modified for climbing (tendrils), protection (spines and thorn), food storage (tubers, corms, rhizome) and for vegetative reproduction.
iv. A leaf is the flattened outgrowth from the nodes of stems and their branches
v. Leaves can be modified for food storage (onion) trapping insects as in venus etc.
vi. Leaves have the following functions, photosynthesis, transpiration, respiration, transportation, protection, vegetative reproduction.
vii. A flower is that part of the shoot modified for sexual reproduction
viii. A flower consists of four main parts known as floral leaves

ix. The floral leaves consist of sepals, (calyx), petals (calyx), stamen (androecium) and carpels (gynoecium).

x. A fruit is the sturcture which develops from the ovary after fertilisation

xi. Fruits can be classified as simple, aggregates and multiple fruits.

6.0 Tutor - Marked Assignment

List at least four functions each of the following

i. Stems (2 marks)

ii. Leaves (2 marks)

iii. Calyx (2 marks)

iv. Corolla (2 marks)

7.0 Further Reading and Other Resources

Idodo - Umeh (1996), *College Biology*

Sarojini T. Ramalingam (2001) *Modern Biology*

Volume 2: Flowering Plants

Important Definitions - Herbs, Shrubs, Trees, Ephemeral, Annual, Biennial, Perennial Plants

Page

1.0 Introduction

The level of development and advancement varies within the plant kingdom. Some plants within the kingdom have more advanced roots, stem and leaves than other; some complete their life cycle within one year, some in two years and some in more than two years. The vascular tissue also varies in terms of arrangement, structure and functions. Some plants have soft stem while others have woody stem.
In this unit, we shall learn about the various important definitions that are commonly used in the plant kingdom.

2.0 Objectives

By the end of this unit, you should be able to:

i. Explain what herbs, shrubs, trees, emphemerals, annual, biennial and perennial trees are;

ii. Give examples of each

3.0 Herbs

These are plants that do not produce permanent shoot systems but die at the end of one growing season. They do not grow tall and their shoots are soft and greenish and have very little or no tough woody tissue. There is little growth in diameter and the plants are usually short-lived. The outer surface consists of a thin epidermis in which stomata are present. The green colour of the stem is caused by the presence of chlorophyll and indicates the food manufacturing ability of such stems. The supports of the leaves depends upon collenchyma, sclerenchyma, and the turgid condition of individual cells. Examples of herbs include sunflower, beans, pepper, tomato etc. Herbs may be annuals or perennials. Herbaceous stems are divided into monocotyledonous and dicotyledonous.

3.1 Herbaceous Monocotyledonous Stem

The vascular tissue of herbaceous monocotyledon stem exists as scattereed bundle of xylem and phloem, although the bundles may be more numerous at the periphery of the stem. Except for the palm trees and certain other monocots, which have an anomalous cambium, no cambium, and thus no secondary tissue is present; the little growth in diameter is dependent upon enlargement of the cells of primary tissues. Even though no definite arrangement of vascular bundles exists - the xylem and phloem never form continuous cylinders of tissues, the xylem is always located on the inner side of a bundle and the phloem to the outer side.

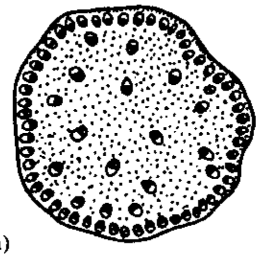
The greater part of the stem consists of parenchyma tissue. The sclerenchyma and collenchyma cells surround the vascular bundles and give strength and support the stem.

3.2 Herbaceous Dicotyledonous Stem

In these stems (fig. 4.1b) the vascular tissue is also arranged in discrete bundles, but the bundles themselves are arranged in an orderly ring and not scattered. The cambium, which is visible between the xylem and phloem, may be restricted to the individual bundles or may be continuous from bundle to bundle.

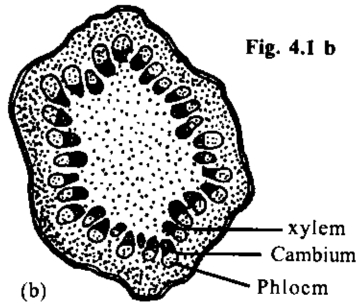
Whatever the arrangement, secondary tissues are poorly developed and the stem remain non woody. Frequently the cortex may contain many collenchyma cells and the vascular tissue may contain fibers, both of which aid in the support of these stems. The parenchyma cells, between vascular bundles, are continuous with those of the pith and cortex.

Fig. 4.1 a



(a)

Fig. 4.1 b



(b)

a) ***Herbaceous monocotyledonous stem***

b) ***Herbaceous dicotyledonous stem***

Briefly explain what herbs are.

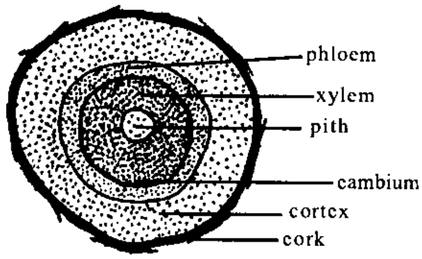
3.3 Shrubs

These have hard woody shoot system and grow larger than herbs and do not die at the end of the season. Their stems form many branches which grow close to the ground. The outer surfaces of the older stems is rough and covered with cork e.g. the bark of trees and shrubs. In this rough surface are lenticels which are really openings beneath which the cells are loosely arranged with many intercellular spaces. Gaseous exchange can take place through these openings. A young woody stem may contain chlorophyll and carry on photosynthesis for a short period, but as the diameter increases and the cork form, this ability is lost. Infact, young stems are all herbaceous in appearance at first, and the woody characteristics develop as the stems become older. The increase in diameter of such stems results mainly from the production of wood and cork. Examples include *Hibiscus, Tecoma, Oleander, Pride of Barbados.*

3.3.1 Woody Dicotyledonous Stems of Shrubs

In woody dicotyledonous stem, the young stem has vascular bundles, the conducting of mature woody stems are in the form of concentric cylinders, in which the great development of secondary xylem results in the characteristic woody condition. The stems usually have much less pith than the herbaceous dicotyledonous stems. see fig. 4.2

Figure 4.2



3.4 Trees

Trees grow greater in size than shrubs and have a single main trunk. Trees have hard woody ·· :ms, which do not die at the end of each growing season. Some trees shed leaves annually and are known a**deciduous** plants while some others retain green leaves all through the seasons(**evergreen plants**). The difference between a tree and a shrub is merely one of growth-form rather than any intrinsic difference. In a tree, the stem (or trunk) grows erect above the ground before branching occurs, while in shrubs, several stems of rather equal size usually arise at or close to ground level. Examples of trees include silk cotton, Iroko etc.

Activity B

Write short note on the following

i. Shrubs

ii. Trees

3.5 Ephemerals

Ephemerals are plants with very short life cycles e.g. seasonal plants such as grasses.

3.6 Annual Plants

Once a seed has germinated, the growth and development of the plant are influenced by both the environment and the inherited characteristics of that particular type of plant. Factors of the environment would include:

1. Water supply
2. Temperature
3. Supply of minerals in the soil,
4. Light
5. Oxygen and carbondioxide
6. Parasites or herbivores.

However, even if all these factors are conducive to growth, not all plants will grow indefinitely. The length of the life-span will depend upon the type of plant:

Annuals - are plants that complete their life-cycle and die in one growing season. The seed germinates, grows and produces fruits and seeds within the period of one season. Examples include rice, wheat, maize, bean etc.

3.7 Biennial Plants

There are plants that pass through two different stages in their lifecycle. They have a longer life span of two years. The biennials grow vegetatively in the first season and store food. The food is utilised in the second season at the flowering and fruiting stage. Recent investigation have demonstrated that temperature influences flowering in biennial plants. Most biennials will flower only after exposure to relatively low temperature, the condition that exists between their two seasons of growth. During the first season, growth is normally vegetative. During the second season plants produce flower stalks and eventually seeds. For example, Celery (*Apicium graveolus*) remain vegetative at 16°C to 21°C. If the plants are exposed to temperature of 5°C to 16°C for 10 to 15 days, flowers and seeds will be produced. Thus, this biennial can be converted to an annual by manipulating the environment. Such induction of flowering by low-temperature of seeds or plants is called **Vernalisation**.

3.8 Perennial Plants

They may be trees, shrubs or herbs. They grow year to year. They are either herbaceous or woody perennials. In herbaceous perennias the aerial part dies at the end of every year. Examples are plants with corm, bulbs, tubers and rhizomes (ginger). Herbaceous perennials, sprout again at the beginning of the next growing season. Woody perennial are mainly trees, shrubs, and vines.

[illegible]

Briefly explain the following

i. Biennial
ii. Perennial

4.0 Conclusion

The level of development and advancement varies within the plant kingdom, and these variations help in classifying plants.

5.0 Summary

In this unit, we have learnt that:

i. Herbs are plants that do not produce permanent shoot system, but die at the end of one growing season.
ii. The vascular tissues of herbaceous monocotyledonous stem exist as scattered bundle of xylem and phloem while that of herbaceous dicotyledonous stem are arranged in discrete undles, but the bundles themselves are arranged in an orderly ring and not scattered.
iii. Shrubs have had woody shoot system and grow longer than herbs and do not die at the end of the growing season.
iv. Trees grow greater in size than shrubs and have a single main trunk.
v. Emphemerals are plants with very short life cycles e.g. seasonal plants such as grasses
vi. Annual plants are plants that complete their life-cycle and die in one growing season.
vii. Biennial plants are plants that complete their life cycle in two growing season.
viii. Perennial grow for several to very many years, producing a new crop of seeds each year after the first few years.

6.0 Tutor Marked Assignment

Briefly define the following terms

i. Herbs
ii. Shrubs
iii. Annual plant
iv. Biennial plant

7.0 Further Reading and Other Resources

Idodo - Umeh (1999). *College Biology*

Walter H. Muller (1969). *Botany A. Functional Approach.* Third Edition Macmillian Publishing Co. Inc. New York

Volume 2: Flowering Plants

Unit 5: Nutrition in Plants

Page

1.0 Introduction

One of the main characteristics of living things is their ability to feed. This is called nutrition. Both plants and animals feed. While some organisms called autotrophs can manufacture their own food through a process called photosynthesis other organisms called heterotrophs cannot. Both plants and animals need food for energy supply.

2.0 Objectives

By the end of this unit, you should be able to;

i. define what photosynthesis is
ii. describe the mechanism of phtosynthesis
iii. explain the conditions necessary for photosynthesis
iv. explain the importance of photosynthesis
v. list the mineral elements, their functions and deficiency symptoms
vi. explain the nitrogen cycle.

3.0 Photosynthesis

Photosynthesis is defined as the process by which green plants manufacture their food (organic compounds) making use of carbon dioxide and water in the presence of sunlight. Photosynthesis can be represented by chemical equation as:

$$\underset{\text{(Carbon dioxide)}}{6CO_2} + \underset{\text{(water)}}{6H_2O} \xrightarrow[\text{chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$$

From the chemical equation above, water combines with carbon dioxide in the presence of sunlight within the chlorophyll of leaves to manufacture food (glucose) and oxygen is liberated as a by-product. Photosynthesis occurs in all green parts of plants.

Mechanism of Photosynthesis

Photosynthesis is an endothermic reaction and it consists of a series of complex reactions. These reactions during photosynthesis is grouped into two stages called **Light reaction** and **Dark reaction** (fig. 5.1).

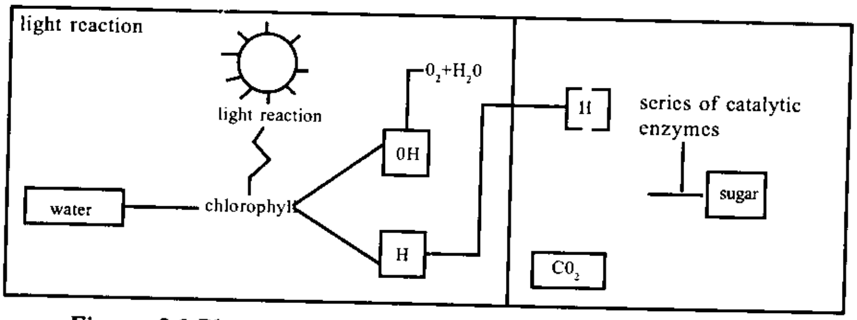


Figure 5.1 Photosynthesis - The light and dark reactions

Light Reaction Stage

Light reaction stage occurs during the day or in the presence of sunlight. The light energy or solar energy is captured by the chlorophyll and electrons are excited. The energy so trapped is used to split water into hydrogen ion (H) and hydroxyl ion (OH). This splitting of water into hyrogen ion (H) and hyroxyl ion (OH) is called **photolysis of water.** Photolysis of water is represented by the equation;

$$\underset{\text{(water)}}{4H_2O} \xrightarrow[\text{chloroplast}]{\text{Light}} \underset{\text{(Hydrogen ion)}}{4H} + \underset{\text{(Hydroxyl ion)}}{4(OH)}$$

The hydroxyl (OH) is converted to water

$$\underset{\text{(Hydroxyl ion)}}{4(OH)} \longrightarrow \underset{\text{(Water)}}{2H_2O} + \underset{\text{(Oxygen)}}{O_2}$$

During this process, oxygen is given out as by-product as shown in the chemical equation above. At the same time, a compound, co-enzyme or NADP is reduced by hydrogen ion to NADPH and ATP (Adenosine Triphosphate) is formed.

Dark Reaction Stage

Dark reaction occurs at night or in the absence of light. Together with the energy provided by ATP, the reduced compound Nicotinamide Adenine Dinucleotide (NADP) then lead to the assimilation of carbon dioxide. Through a series of steps, each controlled by a specific enzyme, a three carbon compound (CH_2O) or sugar is formed. The formation of this three carbon compound can be represented by a chemical equation as follows:

$$\underset{\text{(Hydrogen ion)}}{4H^+} + \underset{\text{(carbon (iv) oxide)}}{CO_2} \xrightarrow{\text{enzyme}} \underset{\text{(sugar)}}{CH_2O} + \underset{\text{(water)}}{H_2O}$$

CH_2O is the carbon structure from which simple sugar, fat and oil, protein etc are formed during the dark reaction.

Activity A

i. Define photosynthesis

ii. Briefly describe the mechanism of photosynthesis.

3.1 Materials and Conditions Necessary for Photosynthesis

For photosynthesis to take place, certain materials or conditions must be available. These are carbondioxide (carbon (IV) oxide), water, chlorophyll, sunlight, mineral salt, suitable temperature and enzymes these factors are external except for chlorophyll and enzymes which are internal factors necessary for photosynthesis to take place.

1. **Carbon(IV)oxide:** Carbon(IV)oxide is derived from the atmosphere and it diffuses into the intercellular spaces through the stomata of the leaves. From the intercellular spaces, carbon(IV)oxide diffuses further into the mesophyll cells containing chloroplast.

2. **Water and Mineral salts:** Water and mineral salts are derived from the soil. They pass into the roots of plants through the root hairs by a process called **Osmosis**. Water and dissolved mineral salts are conducted by xylem from the roots through the stem and finally to the mesophyll cells containing chlorophyll of the leaves.
3. **Sunlight:** Sunlight is obtained from solar energy. The light from the sun is trapped by the chlorophyll of the leaves. The sunlight is used to split water into hydrogen ion and hydroxyl ion in a process called **Photolysis**.
4. **Optimum Temperature:** Temperature is derived partly from the solar energy and partly from chemical reactions within the leaves druing which heat is generated. Suitable temperature is important for enzymes to enable them function properly during photosynthesis.
5. **Chlorophyll:** Chlorophyll is the green colouring pigment found in the pallisade and spongy mesophyll of the leaves. The chloroplyll represents sites where food can be synthesized and it helps to trap solar energy and convert it to chemical energy.

3.2 Importance of Photosynthesis

Photosynthesis is very important both to plants and animals for the following reasons.

(i) **Production of Food:** Photosynthesis provides food for both plants and animals. All green plants are able to manufacture their food through the process of photosynthesis while animals depend directly or indirectly on the green plant for their food.

(ii) **Purification of the Atmosphere:** Waste products like carbon(IV)oxide released during respiration by both plants and animals is removed from the atmosphere by plants for use during photosynthesis.

(iii) **Release of Oxygen to the Environment:** Oxygen needed for respiration by plants and animals is released into the environment during photosynthesis.

(iv) **It serves as building blocks for other substance:** Photosynthesis provides the building block or carbon skeleton on which other food substances such as proteins, fats, oil etc are built.

Activity B

1. Explain the conditions necessary for photosynthesis
2. Explain the importance of photosynthesis

3.3 Mineral Requirements of Plants

Plants require mineral nutrients or element obtained from the soil in form of solution for good growth and healthy development. The soil is the main source of the mineral salts while gaseous elements such as oxygen, hydrogen and carbon are mainly derived from the atmosphere. These elements or plants nutrients are grouped into two classes, depending on the quantity that is required by plants. They are as follows:

(a) **Macro-nutrients or Major elements:** Macro-nutrients are mineral elements or nutrients required in large quantities for healthy growth of plants. Examples of macro-elements are nitrogen, phosphorus, potassium, magensium, calcium, oxygen, hydrogen, carbon, sulphur and iron. These macro-nutrients are sometimes called **essential elements**.

(b) **Micro-elements or Trace elements:** Micro-nutrients are mineral elements or nutrients required in small quantities for healthy growth of plants. Examples of micro-nutrients are zinc, copper, boron, molybdenum, cobalt, chlorine and manganese. When a plant lacks any of these elements, it shows certain signs and these signs are called **deficiency symptoms**. These micro-nutrients are sometimes called non-essential elements. See table 5.1 for the functions and deficiency symptoms of each of the elements mentioned above.

The functions and deficiency symptoms of these elements are stated in the table below:

Table 5.1

ELEMENT	FUNCTION	DEFICIENCY SYMPTOMS
(1) Nitrogen	(i) Aids protein synthesis (ii) Formation of nucleic acid (iii) Formation of chlorophyll (iv) Constituents of all enzymes and protoplasm	(i) Stunted growth (ii) yellow leaves (iii) Small or reduced leaves
(2) Phosphorus	(i) Aids protein fonnation (ii) Formation of co-enzymes (iii) Controls nuclear division (iv) Fruit formation and maturity	(i) Poor growth (ii) Leaves and stem turn reddish brown (iii) Poor root development resulting in logging
(3) Potassium	(i) It aids cell formation (ii) It aids synthesis of carbonhydrate (iii) It activates various plant enzymes	(i) Weak slender plants (ii) Poor Delayed growth (iii) Brown colour at margin of leaves
(4) Calcium	(i) Cell membrane formation (ii) Formation of cell walls (iii) Activate certain enzymes (iv) Normal growth of root tips	(i) Weak slender plants (ii) Poor root development (iii) Stunted growth
(5) Magnesium	(i) Chlorophyll formation	(i) Yellowing of leaves (ii) Poor growth
(6) Sulphur	(i) Protein synthesis	(i) Stunted growth and slender stem, yellowing of leaves (chlorosis)
(7) Iron	(i) Chlorophyll formation	(i) Yellowing of leaves (chlorosis and stunted growth
(8) Manganese	(i) Activation of some enzymes	(i) Die-back of shoots
(9) Copper	(i) Constituent of respiratory enzymes	(i) Poor growth (ii) Pale green colour of leaves
(10) Zinc	(i) Activation of enzymes	(i) Poor leaf fonnation
(11) Boron	(i) Transport of calcium and sugar	(i) Shoot turns brown
(12) Molybdenum	(i) Aids nitrogen fixation (ii) Metabolism of nitrate	(i) Retarded growth (ii) Necrosis of leaf tissue
(13) Silicon	(i) Cell wall formation	(i) Poor growth

3.4 Culture Solution

A culture solution is a solution containing all the major elements required by plants for their normal growth and development. Examples of culture solutions usually prepared in the laboratory are: **Knops culture solution** (see table 5.2) and **Sach's culture solution** (see table 5.3). Both culture solutions are called complete culture solution, because they contain all the major elements necessary for plant growth.

Culture 1: Knop's culture solution (Table 5.2)

Salt	Chemical formula	Quantity (gm/litre)
Calcium nitrate	$Ca(NO_3)_2 4H_2O$	0.8
Potassium nitrate	KNO_3	0.2
Potassium dihydrogen phosphate	KH_2PO_4	0.2
Magnesium sulphate	$MgSO_4 7H_2O$	0.2
Iron (III) phosphate	$FePO_4$	Trace

Culture II: Sach's culture solution (Table 5.3)

Salt	Chemical formula	Quantity (gm/litre)
Calcium sulphate	$CaSO_4$	0.5
Calcium phosphate	$Ca_3(PO_4)_2$	0.5
Magnesium sulphate	$MgSO_4 7H_2O$	0.5
Sodium chloride	Nacl	0.5
Potassium nitrate	KNO_3	1.0
Iron (III) chloride	$FeCl_3$	Trace

Activity C

Write short notes on two of the macro-elements you know

3.5 Nutrient Cycles

Nutrient cycles refer to the circulation of certain nutrients like nitrogen, carbon, sulphur and water in nature.

3.5.1 Nitrogen Cycle

Nitrogen cycle involves the complex process by which nitrogen is naturally added and removed from the soil. It is a sequence of reaction indicating the various means by which nitrogen is added to and removed from the atmosphere and the soil. Nitrogen cycle is shown in (figure 2.8).

Nitrogen fixation process involves soil organisms which add reasonable amount of nitrogen to the soil.

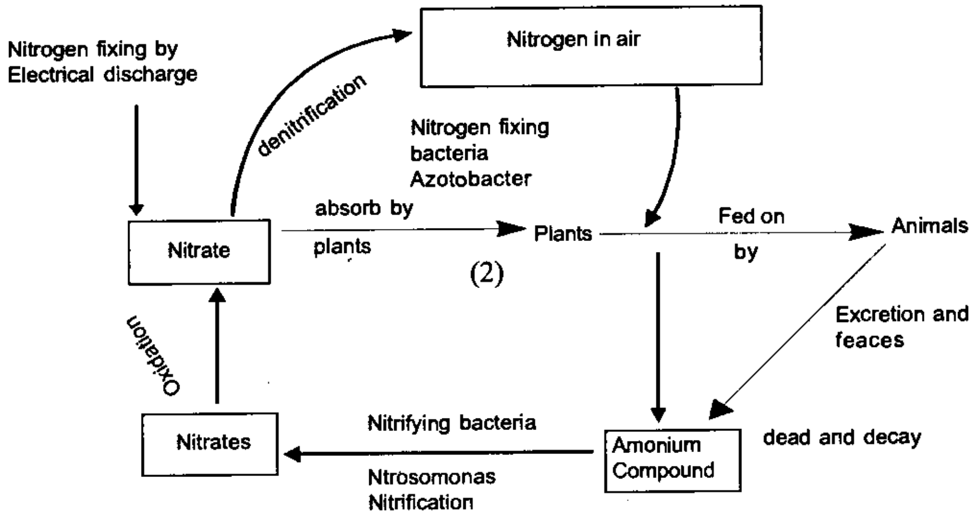


Figure 5.2 Nitrogen Cycle

Nitrogen cycle involves the following stages

(1) **Symbiotic nitrogen fixation:** Some bacteria such as **rhizobium leguminosarlum** which live in the root nodules of leguminous plants can fix atmospheric nitrogen directly into the plant. The plant supplies carbohydrate for use by the bacteria while the bacteria supply the plant with combined nitrogen.

Electrical discharge: Nitrogen can also be fixed into the soil during lightening and thunderstorm. Nitrogen in the air combines with oxygen to form nitric oxide or nitrogen (II) oxide which further undergo oxidation to form nitrogen dioxide or nitrogen (IV) oxide.

The nitrogen (iv) oxide formed will dissolve in rain water to form nitrous (HNO_2) and nitric acid (HNO_3) which later dissociates to form nirate in the soil.

(3) **Non-symbiotic nitrogen fixation:** Some bacteria such as *Azotobacter* and *Clostridium* also live freely in the soil and can fix atmospheric nitrogen into the soil either aerobically or anaerobically.

(4) **Ammonification and nitrification:** The process involving the formation of ammonium compounds from the dead and decaying of plants and animals and their waste products like urine and feaces is called **ammonification**. A further reaction known as **nitrification** involves the convertion of ammonium compounds first into nitrate by nitrifying bacteria called **nitrosomonas**. These nitrites are converted by oxidation to nitrates by another bacteria called **nitrobacter**. Plants can only absorb nitrates from the soil.

(5) **Denitrification:** This is the process which involves the conversion of nitrate to nitrogen gas by certain bacteria. The nitrogen gas so formed can escape into the air.

Note: Denitrification is the only major stage in which nitrogen can be lost from the soil while other stages involve the fixing of nitrogen into the soil.

Briefly describe Nitrogen cycle

3.6 Differences Between Respiration And Photosynthesis. (Table 5.4)

Respiration	Photosynthesis
1. It is a catabolic process associated with the break down of organic matter $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$	It is an anabolic process associated with synthesis of organic matter $6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$
2. Energy in the form of ATP is released	Energy in form of heat is absorbed and stored as chemical energy
3. Oxygen is absorbed and used up	Carbon (IV) oxide is absorbed and used up
4. Carbon (IV) oxide is liberated	Oxygen is liberated
5. Water is liberated	Water is used up
6. It takes place in mitochondria	It takes place in the chloroplasts only
7. It takes place in all living organisms	It is restricted to green plants only
8. It takes place both day and night	It takes place only in the day time

3.7 Similarities Between Respiration and Photosynthesis

1. Both respiration and photosynthesis convert energy from one form to another.
2. Both require mechanism for exchange of gases (oxygen and carbon (IV) oxide)
3. Both require special organelles. Mitochondria in case of respiration and chloroplast in case of photosynthesis
4. Both involve cycles of reaction, kreb cycle in respiration and calvin cycle in photosynthesis
5. Electron carriers (NAD) are involved in both processes.
6. The light reactions of photosynthesis is similar to respiration in that both expend energy in the form of ATP

4.0 Conclusion

Photosynthesis plays a vital role to the survival of man and animals. Man and his animals depend on plants for food which is the basic requirement for survival on earth. Therefore, the studyof plants and the process of photosynthesis should be intensified.

5.0 Summary

In this unit, we have learnt that:

1. Photosynthesis is the process whereby green plants manufacture their own food in the presence of carbondioxide, sunlight and water.

ii. There are two stages in photosynthesis – light reaction and dark reaction.

iii. Light reaction occurs during the day or in the presence of sunlight, while dark reaction occur at night or in the absence of light.

iv. For photosynthesis to take place, certain material or conditions like carbondioxide, water, chlorophyll, sunlight, mineral salts, suitable temperature and enzymes must be available.

v. Photosynthesis is very important both to plants and animals for the following reasons – prodution of food, purification of the atmosphere, release of oxygen to the environment, it serves as building block for other substances.

vi. Plants require mineral nutrient or element for good growth and healthy development.

vii. Nutrient cycles refer to the circulation of certain nutrients like nitrogen, carbon, sulphur and water in nature.

viii. Nitrogen cycle involves the complex process by which nitrogen is naturally added and removed from the soil.

6.0 Tutor - Marked Assignment

List the functions and deficiency symptoms of the following elements

(a) Nitrogen } 4 marks
(b) Phosphorus } 4 marks
(c) Potassium } 4 marks
(d) Calcium } 4 marks

7.0 Further Reading and other Resources

Essential Biology

Idodo-Umeh (1996). College Biology

Volume 2: Flowering Plants

Unit 6: Co-ordination and Control in Plants

Page

1.0 Introduction

Co-ordination in plants is simpler than in animals. It is done by a chemical known as **plant hormones**. They are similar to animal hormones in that they are only needed in small amount to bring about their effects. Therefore produced in one part of the body and transported to another part where they exert their effects (positively or negatively). Animal hormones are produced in specific glands and bring about very specific responses in specific target organs. In plants, hormones are not produced in tissues specialised only for their production, their effects are also more general, varying with concentration and types of target organ. Chemically too, plant hormones are not related to animal hormones, although they are organic compounds.

Plant hormones almost always stimulates or inhibit growth in the target tissues in responses to external stimuli such as light, temperature, day length, gravity and touch. As a result, they are also known as plant growth substances, though they affect other activities such as fruit formation, root development and leaf fall. Combination of plant hormones bring about responses that are different from what each hormone would produce alone. The responses of plant hormones are usually much slower than those of animals hormones. This is because responses in plants are mainly brought about by growth.

In this unit, we shall discuss the various type of plant hormones and their functions.

2.0 Objectives

By the end of this unit, you should be able to:

i. explain what plant hormones are.

ii. explain the roles/functions of the hormones.

3.0 Plant Hormones

The growth of plants to a great extent is regulated by hormones. These chemical substances (hormones) influence the plants internally while factors such as light, temperature, water and gravity influence the plant externally. Hormones are needed in small quantities. They are manufactured in some areas (apical meristems of shoots and roots, young growing leaves, developing seeds or fruits) and diffuse to other parts to produce some special effects.

The major or well known plant hormones are auxins, gibberelins, cytokinins, floregens, abscissic acid, ethene (ethylene), traumatin, dormin, formin etc.

3.1 Auxins

The most important naturally occuring auxin is indole acetic acid (IAA). It is produced at the apices of shoots and is transportaed in one direction away from the tip. It moves across short distances by diffusion and longer distances via the phloem.

3.2 Functions or Effects of Auxin on Plant

The functions or effects of auxin on plant include the following:

a. **Fast growth of shoot:** Auxin is known to cause the shoots of plants to grow fast.

b. **It causes apical dorminance:** Auxin is known to cause the growth of plants at the apices.

c. **Prevention of Lateral growth:** Auxins produced in the terminal bud stimulates the growth or elongation of the main stem, while at the same time move down to the shoot to inhibit (prevent) the growth of lateral buds. Thus, the terminal bud dominates the rest of the shoot so as to ensure that energy for the growth of the main stem is not wasted thereby producing a tall plant with short lateral branches.

d. **It induces flowering:** Auxin is known to induce or initiate flowering in plants.

e. **It stimulates the vascular cambium** to divide to increase the production of secondary vascular tissues (increase in width of stem).

f. **Auxin and fruit development:** Once a flower is fertilised, auxins are produced and sent to the ovary causing rapid development of the ovary as it develops into fruits. The presence of auxins also prevent the formation of abscission layer at the base of the flower stalk. This will help the fruits to reach ripening stage. When the fruits are ripe, auxin supply to the flower stalk is reduced and abscission layer is formed leading to the dropping of the fruit.

g. **It induces root formation:** Auxin is known to induce the formation of roots in plants.

h. **Delay abscission or leaf fall:** Auxin in petiole of fruits and leaves delays abscission or leaf fall.

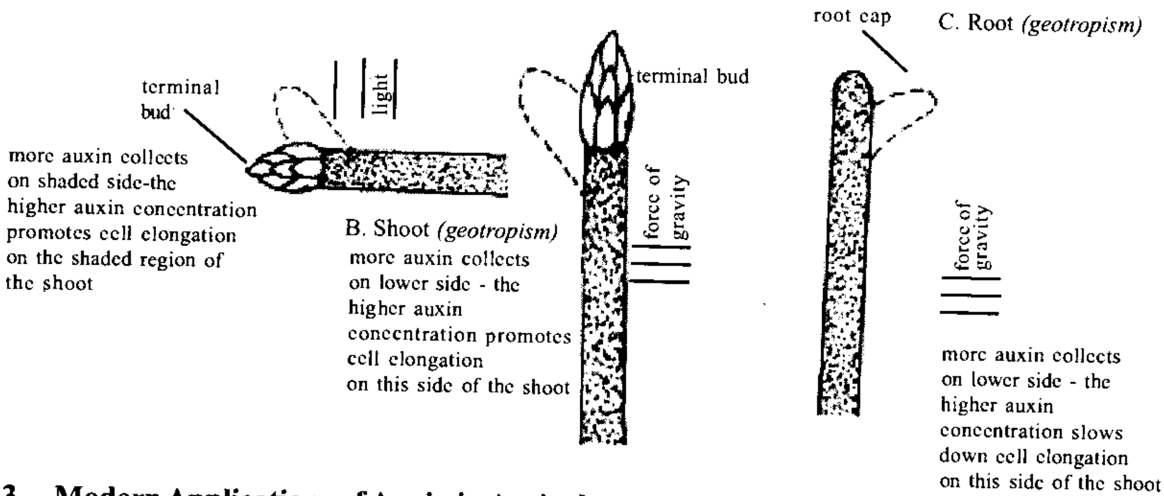
i. **It breaks dormancy in seed:** Auxin equally promotes or help to break dormancy in seed thus ensuring their early germination.

j. **It induces pathenocarpy:** Auxins induces pathenocarpy or fruiting without fertilisation in plants.

k. Auxin influences the growth of stems toward light (phototropism) and away from the force of gravity (geotropism). Similarly, it also cause the growth of roots towards the force of gravity (see fig. 6.1).

Figure 6.1 How auxin brings about photoropism and geotropism

A. Shoot *(phototropism)*



3.3 Modern Applications of Auxin in Agriculture

Auxins, both natural and synthetic, are widely used in agriculture and horticulture. Some of the uses are:

1. **Weed Control:** Synthetic auxin called 2,4 - dichloropheno acetic acid - (2,4-D) at high concentration is used in killing weeds. When applied to lawn, it kills the weeds having broad leaves without killing grasses.

2. **Development of Seedless fruits:** Synthetic auxin, naphthalene acetic acid (NAA) can be sprayed on certain crops to induce the formation of fruits without fertilization. The causing of flowers to develop into fruits without fertilization is called **PARTHENOCARP**. Seedless water cucumber, watermelon and tomatoes have been produced in this way.

3. **Harvesting:** If a farmer has a storage problem or the market price of his fruits is low due to surplus supply by other farmers, he can apply auxins to the plants to make the fruits stay longer on the plants. Reduced amount of auxins stimulates the formation of abscission layer and when auxins are applied to plants, abscission layers will not be formed hence a longer stay of fruits on the plant. Tomato, orange and mango fruits have been prolonged on plants in this way.

4. **Preservation:** If stored products like yam, cocoyam, potatoes are sprayed with auxin, the auxin

controls the dormancy of the "eye" which remain dormant. Sprouting is prevented, thus prolonging the storage life of these products.

5. **Root Initiation:** Stem cutting which are dipped in auxin solution of appropriate concentration are capable of initiating roots.
6. **Ripening of Fruits:** Fruits like tomatoes are picked unripe and stored in an atmosphere of carbon dioxide (which prevents ripening). Auxin can be applied to ripen them artificially and uniformly when needed.

Activity A

Briefly explain the functions/roles of auxin.

3.4 Gibberellins

Gibberellins are produced in young foliage leaves and roots, apices of roots and stems as well as in embryo.

3.4.1 Functions or Effects of Gibberellins

1. Gibberellins stimulate rapid stem elongation in dwarf plants and other plants that undergo little stem elongation.
2. It induces the production of fruits without fertilisation.
3. Dormancy in seeds and buds are broken when gibberellins are released to them.
4. It stimulate the growth of roots.
5. Stimulate some biennial plants to flower during their fruit year of growth.
6. Stimulate the embryos in germinating seeds to produce\ enzymes that hydrolyse starch reserves in the seeds.

Activity B

Explain the main functions of Gibberellins

3.5 Cytokinins (Kinins)

Cytokinins are produced in roots, embryos and fruits that are actively undergoing growth. Cytokinins are also growth promoting hormones like auxins, and gibberellins.

3.5.1 Functions or Effects of Cytokinins

1. It controls cell division.
2. It can stimulate the development of roots.
3. Help in breaking dormancy in some seeds.
4. Promote flowering in some plants.
5. Promote fruits development in some plants.
6. Help to retard the onset of ageing in leaves by maintaining protein and nucleic acid synthesis.
7. It stimulates mitosis in meristems and in embryos during germination.
8. It increases resistance of some plant to harmful effects such as viral infections, radiation and low temperature.
9. It promotes auxilliary bud growth in plants.

10. Cytokinins and auxins act together in promoting the replication of DNA.

Activity C

In your own words, explain **six** function of cytokinins.

3.6 Abscisic Acid

The abscisic acid is a hormone produced in mature green leaves, fruits and root caps. It is a growth inhibitor whose effects generally oppose those of auxins, gibberellins and cytokinins.

3.6.1 Functions or Effects of Abscisic Acid

1. It suppresses the growth of buds.
2. It induces dormancy (especially when environmental conditions are unfavourable).
3. It brings about ageing in leaves.
4. It may play certain roles in abscission.
5. It controls the opening and closing of stomata.
6. It inhibits mitosis in vascular cambium.

3.7 Ethene (Ethylene) Gas

Ethene gas is a simple hydrocarbon produced in leaves, stems and young fruits.

3.7.1 Functions or Effects of Ethene

1. It retards lateral bud development.
2. It hastens the ripening of fruits.
3. It inhibits stem elongation.
4. It accelerates abscission of leaves, flowers and fruits.
5. It accelerates ageing of plant organs.

3.8 Floregens

Floregen is found in flowers and fruits of plants - most botanists are convinced that flower initiation is a result of a hormonal influence and the tentative name floregen has been assigned to this kingdom material.

3.8.1 Functions or Effects of Floregens

It controls initiation of flowers in plants

Activity D

Explain the importance of abscisic acid to your study mate.

4.0 Conclusion

Plant hormones play significant roles in the development of agriculture. For increase in food production, the use of plant hormones especially auxins should be encouraged.

5.0 Summary

In this unit, we have learnt that;

1. Co-ordination in plants is done by a chemical known as plant hormones
2. This hormones are produced in one part of the plant and transported to another part where they exert their effects (positively or negatively).
3. The major or well known plant hormones are auxin, gibberellins, cytokinins, abscisic acid, ethene, traumatin, dormin, formin.
4. Auxins, both natural and synthetic ones, are widely used in agriculture and horticulture for weed control, harvesting crops, root initiation, formation of fruits, preservation of stored products.
5. Gibberellins control growth in plants, induces production of fruits without fertilisation, help to break dormancy in seeds, stimulate stem elongation, promote development of flowers and stimulates dwarf bean plant to grow into large plants.
6. Cytokinins are produced in roots, embryos and fruits that are actively undergoing growth.
7. Cytokinins help to slow down ageing of plant part, it stimulates mitosis in meristems and in embryo during germination, increases resistance of some plants to harmful effects such as viral infection, radiation and low temperature.
8. Abscisic Acid are hormone produced in mature green leaves, fruits and root caps. It suppresses the growth of bud, induces dormancy, bring about ageing in leaves and controls the opening and closing of stomata.
9. Ethene gas is a simle hydrocarbon produced in leaves, stems and young fruits. It retards lateral bud development, hastens the ripening of fruits, accelerates ageing of plant organs.
10. Floregen is found in flower and fruits of plants. It controls initiation of flowers in plants.

6.0 Tutor - Marked Assignment

i. List the importance of auxin in the agricultural development of Nigeria.

ii. Give four functions each of the following hormones

   * Gibberellin
   * Cytokinins

7.0 Further Reading and Other Resources

Essential Biology
Idodo - Umeh (1996) *College Biology*
Sarojini T. Ramalingam (2001). *Modern Biology*

Volume 2: Flowering Plants

Unit 7: Transportation and Transpiration in Plants

Page

Have you ever imagined how water, mineral salt get to the roots, stem and leaves of the plants? Similarly, do you know how manufactured food from the leaves get to the shoot/stem, roots of the plants. Have you ever stayed under the shade during hot and dry time?, What was the condition surrounding the shade?, cool or hot?. You will get answers to all these questions in this unit.

1.0 Introduction

In a country, the transport system includes land transport by trains, motor vehicles, bicycles and beasts of burden, water transport by ships and boats, and air transport by aeroplanes. The function of the transport system is to carry persons, goods, and materials from one place to another. Normally, various agricultural products are obtained in larger quantities in certain parts of a country than in others. Various manufactured goods are produced in some towns but not in others. Imports enter the country through the ports. Yet all parts of the country require the agricultural products, manufactured goods or imports.

In plants and animals, there are transport systems. They carry materials from various parts of the organisms where they are produced or obtained to the parts where they are used or removed from the body. This unit deals with the materials that are transported, the routes along which they are transported, the process/ mechanisms by which they are transported in flowering plants and the process of transpiration.

2.0 Objectives

By the end of this unit, you should be able to:

i. list the materials that are transported
ii. explain the media for transportation
iii. describe the structure of transport system in higher plants
iv. describe the process/mechanism of transportation in highter plants
v. define what transportation is.
vi. explain the factors/condition that are affecting the rate of transpiration
vii. list the importance or advantages of transpiration.

3.0 Transport in Plants

In a simple plant like an alga, materials enter or leave the cells in its body by diffusion. Within the cell itself, materials are distributed by the circular streaming movement of the cytoplasm. In higher plants, special conducting tissues, known as vascular tissues, carry out transport. These vascular plants include all flowering plants and non-flowering plants such as **ferns** and gymnosperms.

3.1 Materials For Transportation

The major materials transported within plants are water, mineral salts, manufactured food, oxygen and carbondioxide, gases and essential chemicals such as hormones and pigments.

a. Water absorbed from the soil is transported to the leaves and other parts of the body for photosynthesis and other functions.
b. Mineral salts absorbed from the soil are transported to all cells of the body where they are used in synthesis of food, protoplasm or other body substances.
c. Manufactured food is transported from the leaves to all living cells of the body for tissue respiration or to storage tissues for storage.
d. Excretory products such as carbondioxide and water are transported from all the living cells to where they are excreted.

3.2 Media For Transportation

Plant saps, cell saps and cytoplasm are the main transport media. Plant sap is a general term which includes the fluids in the vascular tissues and latex tubes. The sap in vascular tissues is composed mainly of water (98%) and a complex mixture of organic and inorganic solutes. These solutes include the following substances.

i. Nutrients, sugars, proteins, amino acids, inulin, mineral salts.

ii. Organic acids, citric, tartaric acid, pigment, anthocyanins, flavones.

Unlike the blood in animals, plants saps tend to be acidic. Latex, a milky substance rich in plant food, is found in latex tubes. Mature plant cells often have large, centrally placed vacuoles filled with cell sap, a watery fluid containing a complex mixture of solutes. The cell saps help in the uptake of water from the soil by the root hairs and its transport to the vascular tissues in the root. It also help in the diffusion of gasses within the plant body.

Activity A

i. List the major materials that are transported within a plant.

ii. Explain the media of transportation in higher plants.

3.3 Mechanism of Transportation in Plants

Plants generally require sufficient quantities of several minerals and other substances which are transported in them. As discussed earlier, materials transported in plants include manufactured food, carbon dioxide, water, oxygen, nitrogenous waste products, latex, amino acids, glucose, auxins and mineral salts. The medium of transport in plants is the **latex** or **cell sap**.

In aquatic, unicellular and simple multicellular plants, gases enter and leave the cells by simple **diffusion.** Water enters the cells of these plants by **osmosis** while manufactured food and waste products are transported by diffusion.

In multicellular plants like flowering plants, the gases are mainly absorbed through the stomata in the leaves and lenticels in the stem while mineral salts and water are absorbed through the root system. Inside the plants, gases moved by diffusion. They dissolved in the water of the moist cells before entrying the cells. Water, mineral salts and soluble food are transported in the vascular tissues of the plant. The vascular tissues of plants are made up of a network of long tubes called **vascular bundles**. A vascular bundles consists mainly of the xylem and the phloem tissues. But in the roots and stems of dicotyledonous plants, a layer called **cambium** exists between the xylem and the phloem tissues. Hence the vascular bundles are found in the roots, stems and leaves of flowering plants (fig. 7.1).

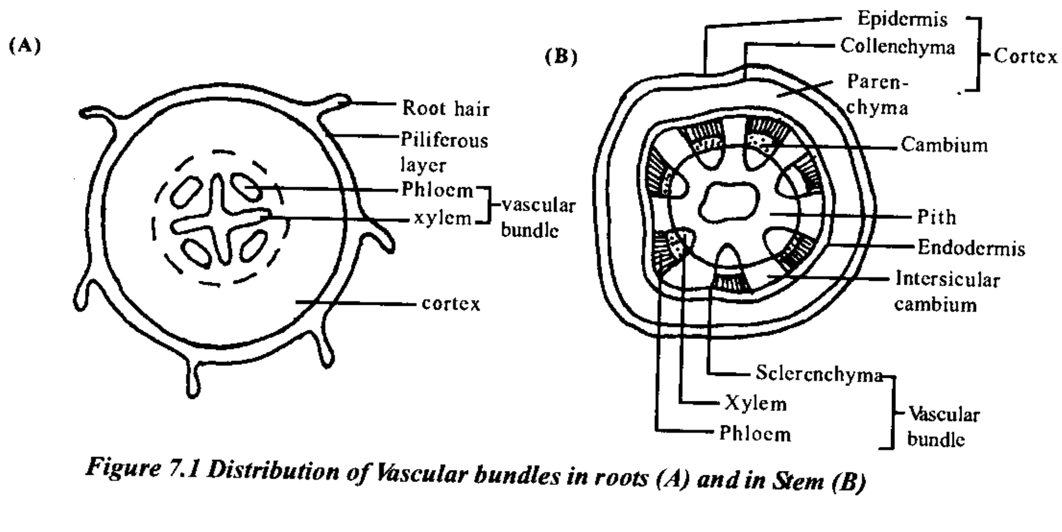


Figure 7.1 Distribution of Vascular bundles in roots (A) and in Stem (B)

1. **The Cambium tissues:** The cambium tissues are made up of narrow living cells with thin walls and dense cytoplasm

   Functions: They are capable of dividing and multiplying thereby enabling the plants to produce secondary xylem and phloem. this then results in the growth in width or girth of the stems called **secondary thickening.**

2. **The xylem tissues:** The xylem tissues consist mainly of dead cells with lignified cell walls.

   Functions: The xylem tissues transport water and dissolved mineral salts from the roots to other parts of the plants. It also gives support and rigidity to plants.

3. **The phloem tissues:** The phloem tissues consist of thin-walled living cells with dense cytoplasm which have perforated cross walls.

   Functions: The phloem tissues transport manufactured food from the leaves mainly to other parts of the plant either for use or storage.

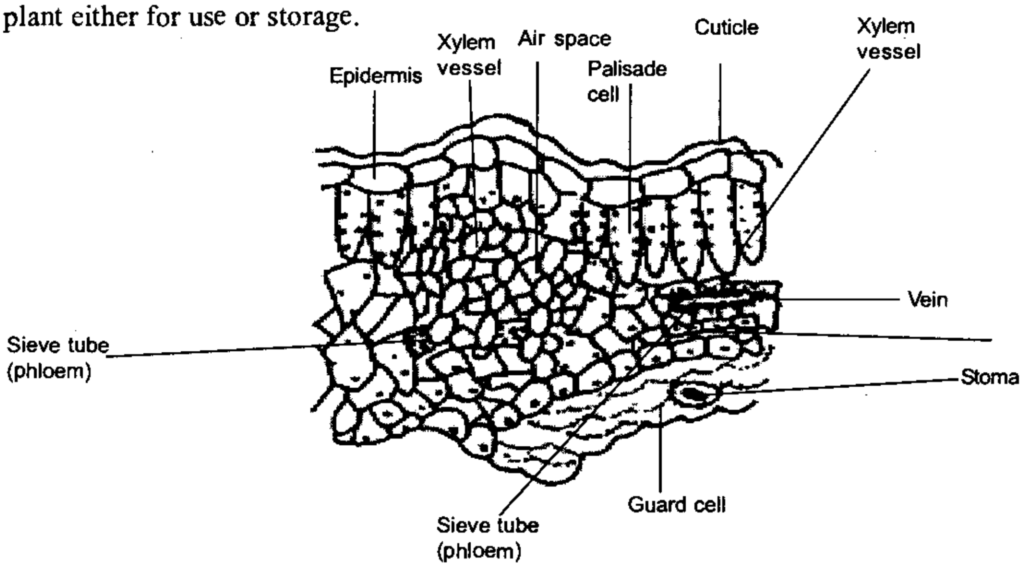


Figure 7.2 Distribution of Vascular bundles in leaf

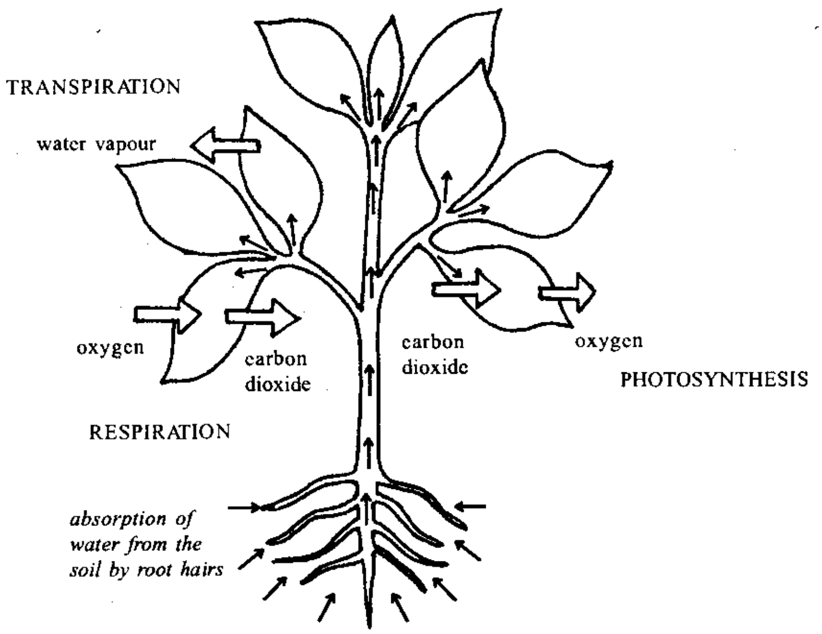
Activity B

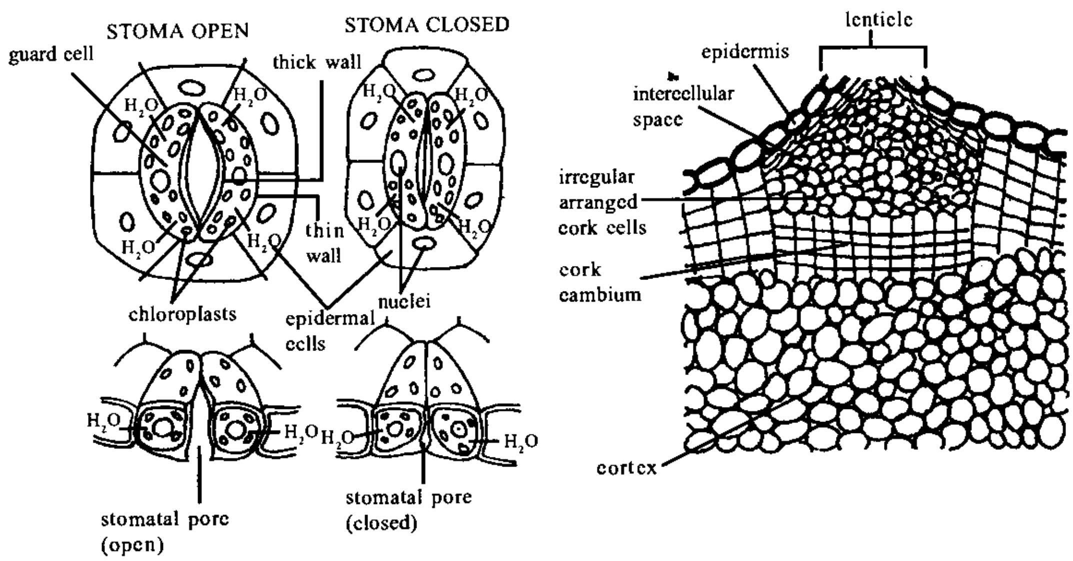
Briefly describe the structure of transport system in higher plants.

3.3.1 Transport of Gases

In plants, water vapour diffuses to the exterior, while carbondioxide and oxygen diffuse in both directions between the plant and the external environment. These gases enter and leave the plant through openings called stomata (singular: stoma) on leaves, and lenticels on stems and roots (see fig. 7.3 a &b).

Figure 7.3a. Diffusion of gases in a plant





A. Stoma: how the guard cells open and close a stoma ***B. A Lenticle***

Figure 7.3b: Opening and closing of stomata. The opening and closing of stomata control the flow of gases

3.3.2 Absorption of Water by Roots of Plants

The young roots hairs of flowering plants have direct contact with water in the soil (fig. 7.4). The cell sap in the root hairs is more concentrated than the soil water, hence water is able to pass from the soil into the root hairs by osmosis. The water passes through the thin layer of cytoplasm or cell membrane which is selectively permeable into the vacuole of root hairs. The extra water raises the tugor pressure of the vacuole or reduces the osmotic pressure and forces water out into the cell walls towards the cortex. The cell next to the root hair cell on the inside has a lower tugor or higher osmotic pressure, hence water will pass into it by osmosis. In this way, the water absorbed will get to the xylem vessels. see fig.7 .4.

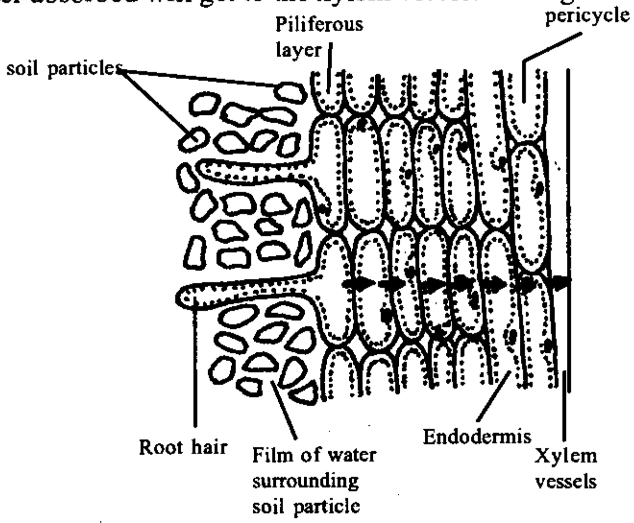


Figure 7.4 Diagram showing path of water from soil to xylem vessels in a root

3.3.3 Transport of Water in The Xylem Tissues

We can easily show that xylem tissue conducts water by placing a herbaceous plant in a beaker containing Eosin solution and examining sections of the root, stem and leaf (fig. 7.5). The xylem vessels will be stained red by the dye showing that water has moved through them.

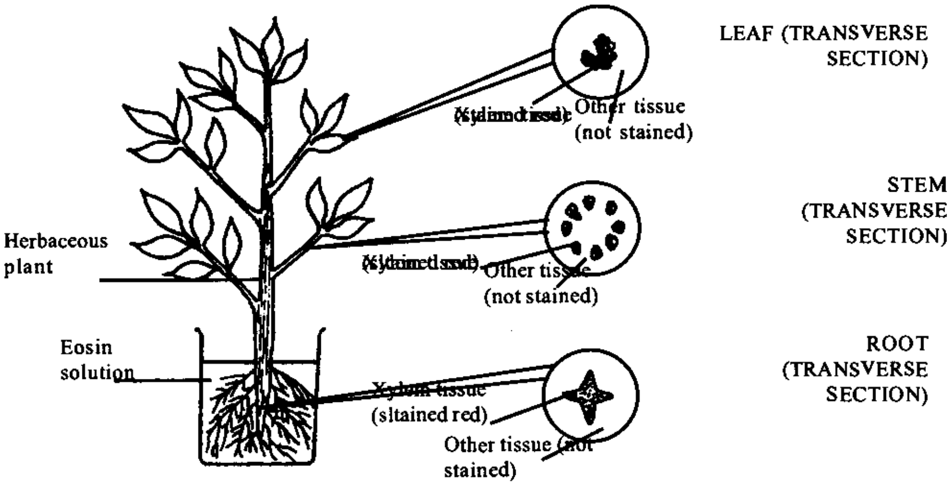


Figure 7.5 To show that xylem tissue conducts water upwards from the roots to leaves

Transport of water in Xylem tissue is due to:

i. root pressure
ii. capillary action and
iii. transpiration pull.

(i) Root pressure and suction pressure: Root pressure is usually created as a result of differences in osmotic pressure between the cell sap and the concentration of soil nutrients. The cell sap being more concentrated, tends to draw up the nutrients. On the other hand, **suction pressure** is the total force by which the cell absorbs water from its surroundings. The suction pressure is normally created when water is lost in form of transpiration through the stomata of the leaves. By these pressure, the movement of water from the soil to the xylem tissues through the root hairs is achcived.

(ii) Capillary action: The upward movement of water through the xylem is mainly achieved through capillary action. The xylem vessels that extend from the roots to the leaves form very fine capillary tubes. Water then rises up such tubes as a result of capillary action.

Capillary action is due to the attraction between the water molecules and the wall of the xylem vessels.

(iii) Transpiration pull: The continuous flow of water from the roots to the leaves forms the transpiration stream. As water evaporate from the leaf cells and as photosynthesis produces more sugar, the osmotic pressure in the leaf cells increases with respect to that in the xylem cells. This causes more water to flow into the leaf cells from the xylem vessels. So, there is a pull on the water columns in the xylem vessels and water is drawn up in the plant.

Activity C

Briefly describe the mechanism of transportatoin in higher plants.

3.4 Processes Which Aid Transportation in Plant

Transportation in plants is aided by the following processes;

i. Translocation
ii. Transpiration
iii. Absorption of water and mineral salt
iv. Transport of water in the xylem tissue.

The last two has been discussed. Let us now discuss the first two.

3.4.1 Translocation

Translocation is the process by which manufactured food substances are tranpsported from where they are needed or stored. Translocation normally beings from the leaves to other parts of the plant. Phloem is the tissue through which these manufactured food substances are translocated.

Substances or materials commonly translocated in plants include sugar, glucose or carbohydrates, oil, resins, proteins or amino acids, alkaloids and hormones.

The functions of these translocated substances include:

(i) Proteins or amino acids which are used for building up new tissues.
(ii) Sugar, glucose or carbohydrate which provide energy for synthetic process.
(iii) Oil provides energy.
(iv) Alkaloids, resins and steroids are protective in function and prevent herbivores from eating the plants as they are all waste products in plants.

3.4.2 Transpiration

Is defined as the removal of excess water from plants into the atmosphere in form of water vapour. Plants are capable of loosing excess water through:

(i) the stomata in the leaves and this is called stomata **transpiration.**
(ii) through the lenticels in the stem and this is called **lenticular transpiration.**
(iii) through the cuticle of the leaf surface in what is called **cuticular transpiration.**

Conditions affecting the Rate of Transpiration

The rate at which water vapour is lost by a plant depends on a number of factors which include:

(1) ***The size of the stomata pores:*** When stomata opens due to turgidity of the guard cells, transpiration takes place while flaccidity of the cells causes the guard cells to close and prevent transpiration from taking place.
(2) ***Humidity:*** The higher the humidity of the atmosphere the slower the rate of transpiration while the lower the humidity the higher the rate of transpiration.
(3) ***Temperature:*** Increase in temperature gives rise to high rate of transpiration while low temperature gives rise to low rate of transpiration.
(4) ***Light:*** High light intensity results in high rate of photosynthesis and consequently leads to increase in temperature, thereby giving rise to high rate of transpiration and vice versa.
(5) ***Wind:*** The higher the rate or speed of wind the higher the rate of transpiration and vice versa.
(6) ***Soil water:*** The higher the level of soil water the higher the rate of absorption and consequently the higher the rate of transpiration and vice versa.

Importance or Advantages of transpiration to Plants

Transpiration has the following importance or advantages to plants:

(i) It enables plants to absorb water and mineral salts from the soil.
(ii) It facilitates the movement of soil water.
(iii) The evaporation of water due to transpiration from the plants cools the plants.
(iv) It helps to remove excess water from the plants.

3.5 Measurement of Transpiration

There are various ways by which the rate of transpiration can be measured.

i. By the weighing method
ii. By the use of a potometer
iii. By the use of cobalt chloride paper

3.5.1 The Weighing Method

This method involves the use of an intact living potted plant. The plant is well watered in the morning. The pot and the soil are covered to prevent evaporation of water from the soil. The initial weight of the potted plant is taken with a sensitive balance at about 8.00 a.m. The pot is kept in an open place, where the plant can receive maximum sunlight. Weighing is repeated at one hour interval until 7.00 p.m. Atmospheric temperature may be taken at each time of weighing and related to the amount of water loss. The amount of water transpired at various time interval is calculated from the differences in weight. see example in Table 7.1

Table 7.1 - Water loss by Transpiration of a single Indian Spinach plant (vegetable)

Time of Day	Weight of potted plant (in gramme)	Atmospheric temp. in °C	Amount of water transpired (in gm)
8.00 am	1489.2	27.0 °C	0
9.00 am	1487.0	28.2 °C	2.2
10.00 am	1483.0	30.0 °C	4.0
11.00 am	1477.6	32.5 °C	5.4
12.00 noon	1467.8	35.5 °C	9.8
1.00 pm	1455.5	36.8 °C	12.3
2.00 pm	1441.2	38.2 °C	14.3
3.00 pm	1426.7	38.6 °C	14.5
4.00 pm	1412.6	38.0 °C	14.1
5.00 pm	1404.8	32.8 °C	7.8
6.00 pm	1400.6	30.5 °C	4.2
7.00 pm	1398.9	28.4 °C	1.7

3.5.2 The Potometer Method

A potometer is an instrument for measuring the rate of transpiration of a plant shoot at a very short interval and under different environmental conditions. As a matter of fact, the potometer measures the rate of water absorption rather than the rate of transpiration. It works on the assumption that the rate of transpiration is very nearly equal to the rate of water absorption.

3.5.3 The Cobalt Chloride Paper Method

The method is used to estimate the relative rate of transpiration of different plants or different leaves on the same plant. It can also be used to estimate the relative rate of transpiration through the upper and lower epidermis of the same leaf.

Cobalt chloride paper is blue when dry. The colour changes to pink when it is wet. Cobalt chloride paper can therefore be used to measure the rate of transpiration based on the time it takes the dry blue paper to change to pink when brought in contact with a transpiring leaf.

3.6 Similarities Between Transport in Plants and Animals

(i) Tabular or cylindrical vessels are necessary in plants and animals.

(ii) Liquid medium is required for transportation in plants and animals.

(iii) Materials or food nutrients and hormones are transported in dissolved or fluid form.

(iv) Diffusion plays a major role in transportation in both plants and animals.

3.7 Differences between Transport in Plants and in Animals

Plant	Animal
(i) Cell sap is the medium of transportation	Blood is the medium of transportation
(ii) Root pressure or transpiration generates force for pull	Heart generates forces for transport of nutrients
(iii) Water/mineral salt manufactured and food are transported through different vessels (Xylem and phloem)	Water, food substances and mineral nutrients are transported in the same vessels.
(iv) The transport medium is not tissue	The transport medium is made up of cells or different types or tissues

Activity D

1. Briefly define what transpiration is
2. List three factors that affect the rate of transpiration
3. List four importance of transpiration.

4.0 Conclusion

Water, mineral salts, manufactured food are essential materials needed for the growth and development of a plant. Water and mineral salts are absorbed by the roots and the manufactured food are synthesised in the leaves and in other green parts of the plant. The water and mineral salts absorbed by the roots can get to the stem, leaves and other parts of the plant through the process of transportation, similarly, manufactured food from the leaves can get to the stem, roots through the process of transportation. Therefore transportation in plants play a vital role for the survival of the plant. Transpiration aid the process of transportation, it removes excess water from the plant and facilitates the movement of soil water into the roots and to all parts of the plant thereby helping the survival of the plant.

5.0 Summary

In this unit, we have learnt that:

i. Plants has transport system and these systems carry materials from various parts of the plant where they are produced or obtained to the parts where they are used or removed from the body of the plant.

ii. The major materials transported within the plants are water, mineral salts, manufactured food, oxygen and carbondioxide, gases and essentials chemicals such as hormones and pigments.

iii. Plant saps, cells saps and cytoplasm are the main transport media of a plant.

iv. Xylem tissues transport water,and dissolved mineral salt from the roots to other parts of the plants.

v. Phloem tissues transport manufactured food from the leaves mainly to other parts of the plant either for use or storage.

vi. Transport of water in xylem tissue is due to (i) root pressure, (ii) capillary action and (iii) transpiration pull.

vii. Transportation in plants is aided by these processes - translocation, transpiration, absorption of water and mineral salt, transport of water in the xylem tissue.

viii. Translocation is the process by which manufactured food susbtances are transported from where they are manufactured to tissues where they are needed or stored.

ix. Transpiration is the removal of excess water from plants into the atmosphere in form of water vapour.

x. Factors such as size of the stomata pores, humidity, temperature, light, wind and soil water affects the rate of transpiration.

xi. Transpiration can be measured by the following methods - weighing method, use of potometer and through the use of cobalt chloride paper.

xii. Transpiration enable plants to absorb water and mineral salts from the soil, it help to remove excess water from the plant, help to cool the plant as a result of evaporation.

[illegible] Assignment

1. Briefly explain five factors that affects the rate of transpiration
2. (a) List the major materials transported within the plant

   (b) List four advantages of transpiration.

[illegible] and Other Resources

Idodo - Umeh (1996) *College Biology*

Sarojini T. Ramalingam (2001) *Modern Biology*

Essential Biology

Volume 2: Flowering Plants

Unit 8: Respiration in Plants

Page

1.0 Introduction

Respiration is essentially a process of oxidation and decomposition of organic compounds, particularly simple carbohydrate such as glucose, in the living cells with the release of energy. The most important feature of respiration is that the potential energy stored in the organic compounds in living cells is released in a stepwise manner in the form of active or kinetic energy under the influence of a series of enzymes and is made available, to the protoplasm for its manifold vital activities such as manufacture of food, growth, movement, reproduction etc.

The reserve food materials that undergo oxidation are mostly simple carbohydrate particularly glucose and sometimes also, other substances such as complex carbohydrates, protein and fats, these are of course first hydrolysed and then oxidised. The main facts associated with respiration are: (i) Consumption of atmospheric oxygen (II) Oxidation and decomposition of a portion of the stored food (iii) liberation of carbondioxide and small quantity of water, (IV) release of energy by the breakdown of organic food.

The overall chemical reaction may be stated thus:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6O_2 + 6H_2O + \text{Energy.}$$

All the living cells of plant must respire day and night in order to live. If the supply of air is cut off by growing the plant in an atmosphere devoid of oxygen, it soon dies. Growing organs such as floral and vegetative buds, germinating seeds, stem and root tips respire actively, while adult organs do so comparatively slowly.

2.0 Objectives

By the end of this unit, you should be able to:

i. Describe the respiratory system in plants.
ii. Explain the mechanism of gaseous exchange in plants.
iii. Explain cellular respiration.
iv. List at least five similarities and differences between aerobic and anaerobic respiration.
v. List the factors that affect respiration.

3.0 Respiration in Plants

All plants respire at all times, like any other living things. The green plants respire along with photosynthesis during day light. During respiration plants take in air from their surrounding, use the oxygen of the air to break down stored food for the purpose of energy production and release of carbondioxide and water. The green plants use the carbondioxide from respiration for photosynthesis during the day.

3.1 Respiratory System in Plants

Plants do not have special respiratory organs for gaseous exchange. However gases move in and out of the plants through the stomata lenticels and root hairs in young roots.

3.1.1 Stomata

Stomata (singular: stoma) are very thin openings found in the epidermis of leaves and stems of seedlings. Each stoma (fig. 8.1 and fig. 8.2) is surrounded by two bean-shaped cells called **guard cells.** Stomata are more abundant in the lower epidermis of leaves and the very few in the upper epidermis. The closing and opening of the stomata are controlled by the guard cells.

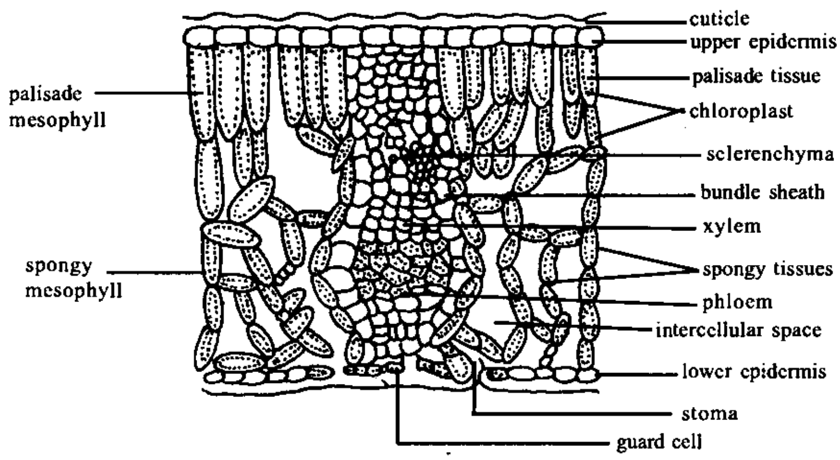


Figure 8.1 Transverse section through a dicot leaf

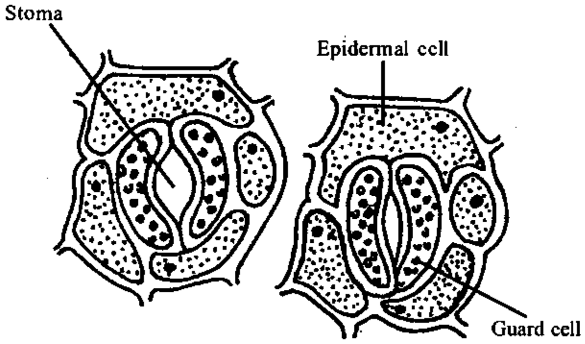


Figure 8.2 Opening and closing stoma

3.1.2 Mechanism of Opening and Closing of Stomatal Pore

The opening and closing of the stomatal pore (stoma) depends on the turgidity of the guard cells. Variation in turgor pressure change the shapes of the guard cells.

1. Opening of the stomatal pore (stoma):

The chloroplasts of the guard cells carry out photosynthesis during the day. Sugar manufactured during photosynthesis increases the concentration of the cell sap. Water moves from adjacent epidermal cells into the guard cells by osmosis. The guard cell become turgid. The pressure resulting from the turgidity causes the bulging of the thinner cell wall to press into the adjacent epidermal cells. This causes the thicker inner cells walls to assume crescent shape and thus open the stomatal pore.

2. Closing of the stomatal pore:

At night when photosynthesis has ceased, the sugar in the guard cells is converted into starch .The concentration of the cell sap of the guard cells is now lower than the adjacent epidermal cells. Water moves by osmosis from the guard cells to adjacent epidermal cells. This makes guard cells to shrink and become flaccid due to loss of water, causing the inner cell walls to straighten and close the stomatal pore.

3.1.3 Factors That Lead to The Opening and Closing of Stomata

1. **Concentration of Carbondioxide:** When the concentration of carbondioxide is more than 0.04%,

stomata close and open when less than 0.04%.

2. **Dry Weather:** When the weather is dry and hot, the rate of transpiration is high. Stomatal pore has to close to conserve water for the plant.
3. **Acidity:** High acidity in the guard cells prevent or inhibit the action of enzymes that digest starch to sugar. However, starch in the guard cells, make the guard cells to lose water and become flaccid. Stomata therefore close up. Low acidity stimulates the action of enzymes to convert starch to sugar. Increase in sugar content increases water volume of the guard cells by osmosis. Guard cells swell and stomatal pores open.

3.2 Lenticels (Breathing Pores)

Lenticels are breathing pores or tiny openings found in the bark of older stems. A lenticel (fig. 8.3) consists of a loose mass of small thin-walled cells which permit easy diffusion of gases in and out of the plant.

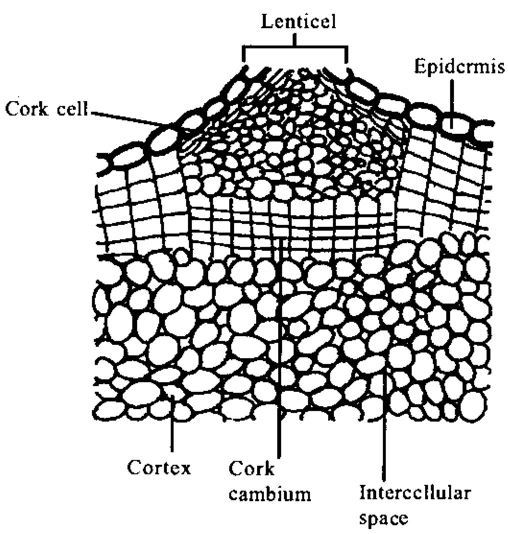


Figure 8.3

3.3 Root Hairs

These provide a large surface area for the absorption of water, mineral salts and oxygen. Oxygen present in the soil air, dissolve in the soil moisture and diffuses into root hairs. From there, it diffuses into the other root cells. The carbondioxide produced by the cells diffuses out of the root into the soil via the root hairs.

Activity A

Briefly describe the respiratory system in plants.

3.4 Mechanism of Gaseous Exchange in Plants

The shoot system of flowering plants obtains oxygen from the atmosphere and gives out carbon dioxide and water vapour to the atmosphere through the stomata of the leaves and lenticels in the stem through the process of **diffusion**. Due to differences in concentration gradient, oxygen is taken in through the stomata and lenticels especially during the night and carbon dioxide and water vapour are given out.

But during the day, when photosynthesis is going on, oxgyen and water vapour from photosynthesis diffuse out to the exterior through the stomata and lenticels. It will be recalled that the closing and opening of the stomata are controlled by the guard cells. Turgidity of the guard cells quicken the opening of the stomata

1. Budding

This is the bringing together of the **bud** and **stock**. The bud is taken from a tree already producing or matured. This forms the bud stock or slip. The stock is a young plant of about a year old.

During budding, a T-shaped cut or inverted T is made at about 45 cm from the ground on the stem of the stock plant. The cut shape is slightly raised to expose the **cambium**. The bud is carefully slopped into the raised bark and pressed firmly to ensure that the **cambia** of both bud and stock unite togetber. It is tied with plastic material, or any device to hold it in place. This should be done quickly to prevent the bud from drying. Air and water should be prevented from the cut until the bud has **"taken"** or healed togetber with the stock. This will show when the bud remains green. The bud then shoots out after some days. When it becomes well established, the part of the stock above the bud should be cut-off. The cut surface should be painted to avoid fungal or bacterial infection. It is commonly used in **citrus** to select desired species. see fig. 9.1.

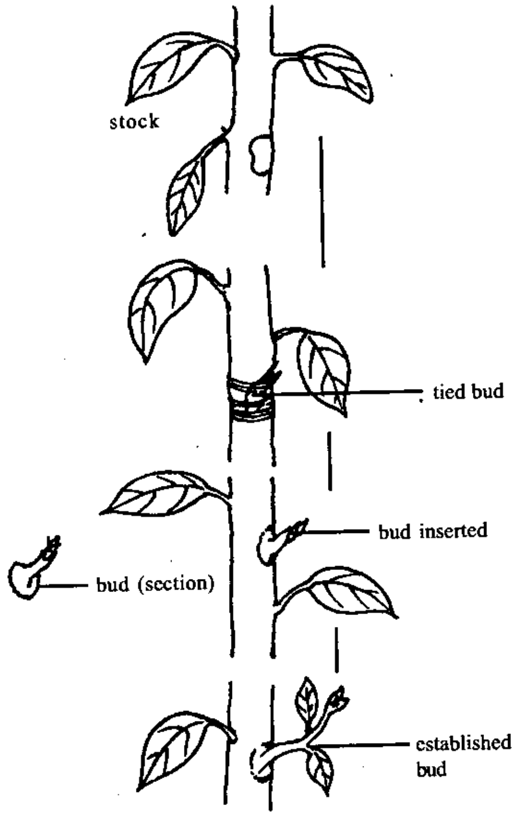


Figure 9.1 Stages in budding

2. Grafting

This is the union of the **stock** and **scion**. The part of the plant whose root is in the ground is called the stock while the shoot removed from other plant is called **scion**. The scion is normally attached to the stock for grafting to take place. The two plants must be of the **same species** or closely **related species**. The plant should be of the same age and size for grafting to be possible. Both plants are cut in a **slant** or **V-shaped** to provide good surfaces for contact. They are tben tied together with plastic tape or any device to keep them in place. The junction is rubbed with **grafting wax** to prevent the entrance of air, water and pathogens. It is advisable to water until when the wrapping may be removed after two weeks.

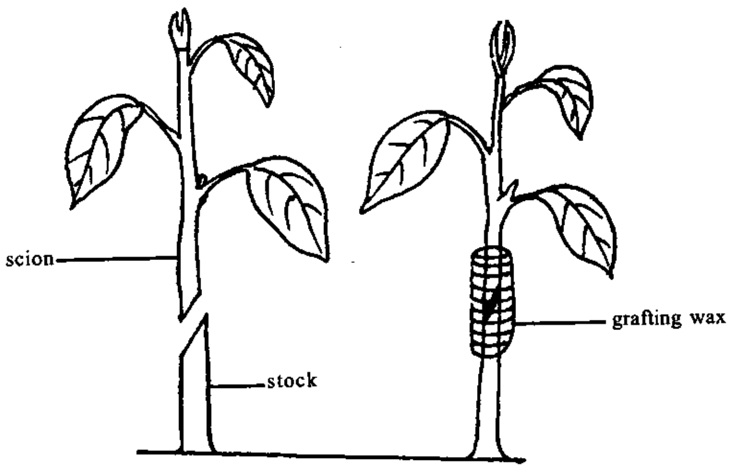


Figure 9.2 Grafting stages

Advantages of Budding and Grafting

a. They are used to bring good qualities in two crop species together. Examples are high yield, taste and resistance to diseases.

b. They are used in perpetuating **clones**.

c. Budded plants mature very early. This is because the bud tends to assume the age of the parent plants.

d. They produce plants with uniform qualities.

e. They take the advantages of the roots of a more resistant stock to thrive.

f. Destroyed parts of a plant could be replaced by grafting.

3. Layering

This involves bending a shoot or branch of a plant to the ground so that the nodes can make contact with the soil. It is then pegged below the ground and covered with rich soil to provide good medium for root development. When roots have emerged the branch is cut from the parent plant. This can be transplanted after a time as rooted cutting. Layering can be used in coffee, cocoa and kola production.

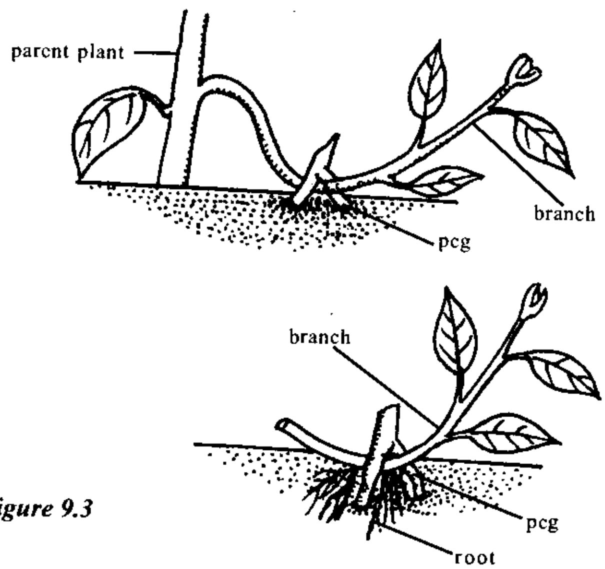


Figure 9.3

4. Cutting

This involves the use of mature stem or branch stem to propagate plants. This is a very common method of asexual propagation in many crops such as **cassava, Ixora, croton** and **sugar-cane**. The plants produced have the same characteristics as the original plant from which the cuttings were obtained. Cuttings can be obtained from soft wood as in sweet potato, semi hard wood as in cassava and hard wood as in Hibiscus plant. They should be cut from stems that have started to harden.

The cuttings should be above 20cm long or convenient length, with two or three nodes or buds. It should be put into the ground to enable it have contact with the soil. It should be watered after planting or raised in shade during dry periods or planted during the rains.

5. Marcotting

Marcotting is a practical vegetative propagation method. In this practice, the bark of a branch is peeled off with a knife, up to a considerable length. This should not be more than 5cm long. Soil rich in organic manure is tied to the peeled portion by means of coconut husks or any suitable device. It is watered to keep it moist always.

After a time, roots will grow out of the peeled portion. As the roots become strong enough, the branch is cut off the plant. The rooted branch is planted into the soil to give rise to a new plant. It is used for plants whose cuttings do not produce roots easily. It is employed in fruit crops such as lemon and mango as well as apple.

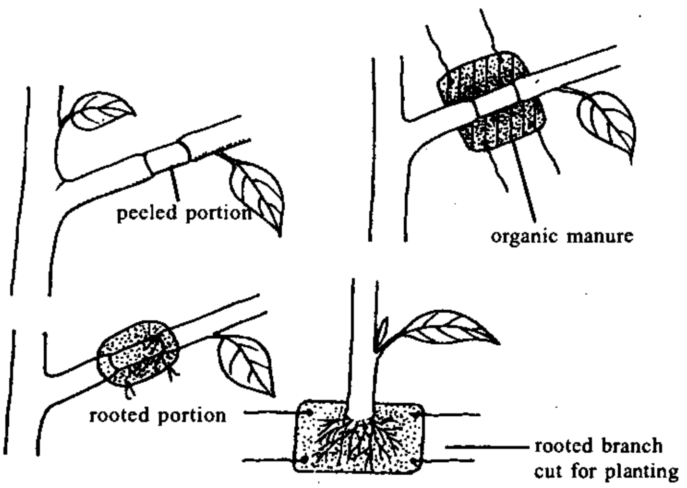


Figure 9.4 stages in marcotting rooted branch cut for planting

Advantages of Asexual Reproduction

1. The offspring are genetically similar to their parents. This is a great advantage if the organisms are well adapted to their environment.
2. Agents of pollination are not needed.
3. Agents of dispersal are not needed.
4. Greater nourishment is obtained from the parents therefore they can withstand adverse conditions.
5. Since food is ready at hand, the offspring grow and mature quickly.
6. They can colonise the locality easily.
7. It is easy to obtain planting materials.

Disadvantages of Asexual Reproduction

1. No variation since parents and offspring are similar from generation to generation.
2. Bad adaptation of the parents and offspring can lead to their death since they are similar genetically.
3. Since there are no means of dispersal, overcrowding, competition for food, space and light may result. This will lead to stunted growth.
4. There is less chance of evolution.

[redacted]

i. Briefly explain artificial vegetative reproduction in flowering plants

ii. List at least three advantages and disadvantages of asexual reproduction

3.2 Sexual Reproduction in Flowering Plants

Sexual reproduction is the fusion of two different sex cells which usually come from two different parents. The sex cells are known as gametes. In flowering plants, the male gamete is the pollen grain, while the female gamete is the ovule. The fusion of these haploid gametes (pollen grain and ovule) is known as **fertilisation**. It results in the formation of a single-celled zygote which has a diploid number (2n) of chromosome. The zygote then divides and develops to produce the offspring whose somatic cells are all diploid.
In flowering plants, the flowers is the reproductive organ. It bears the stamen that produce the pollen grains and the pistil which contain the ovule in the ovary.

3.2.1 Reproductive System in Flowering Plants

The flower is the reproductive structure of flowering plants. It contains the male and the female sex organs which enable them to exhibit sexual reproduction. Fertilization inside the flower often leads to the production of seeds which are capable of germinating into new plants.

The Structure of a Flower

A flower is a cluster of modified leaves which is borne on a shortened stem, the flower **stalk** or **pedicel**. The flower is made up of four floral parts. These are (i) the calyx (ii) the corolla, (iii) the androecium (iv) the gynoecium. These floral parts are usually arranged in concentric rings, one above the other, on the **receptacle or thalamus**. The swollen tip of the pedicel is shown in fig. 9.5. and fig. 9.6.

(i) **The Calyx:** The calyx consists of sepals which are usually small and green. This protects the flower which is in the bud. The outer most whorl of a flower is made up of three to five sepals. They may be separated (**polysepalous**) or joined to form a cup (**gamosepalous**). There may be an **epicalyx** of bract below the calyx as in Hibiscus flower.

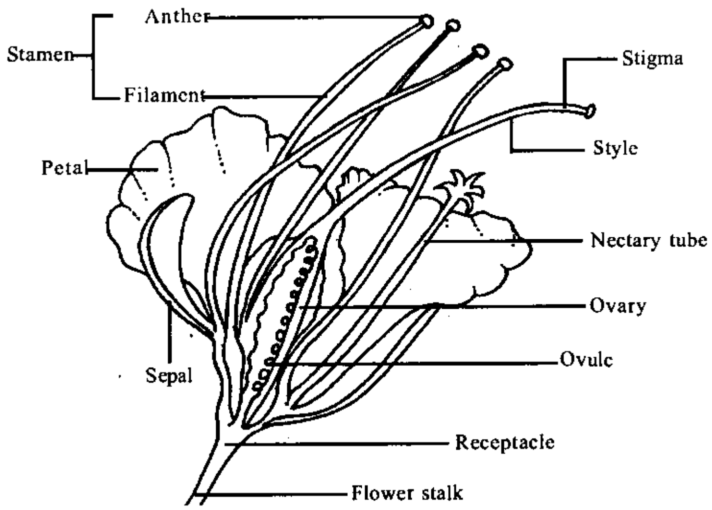


Figure 9.5 Longitudinal section of pride of Barbados

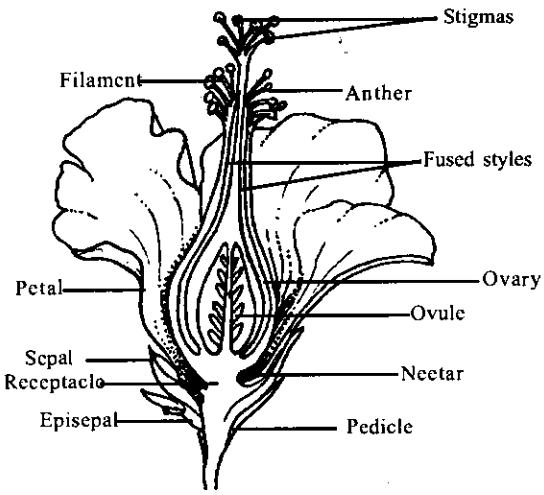


Figure 9.6 Longitudinal section of Hibiscus flower

(ii) **The Corolla:** The petals collectively known as the corolla form the second whorl or floral part inside the sepals. In many plants, they are the eye-catching part of the flower. Most flowers have four to ten petals which may be separated (**polypetalous**) or joined to form a tube (**gamopetalous**). Generally, petals are brightly coloured and scented (**pollinators**). When both the petals and sepals look alike, e.g. lilies, they are collectively known as the **perianth**.

(iii) **Androecium:** The androecium are the male reproductive organs of a flower. The whorl inside the petals is a group of stamens collectively known as the **androecium**. Most **stamens** have:

* a long slender stalk called the **filament**
* a swollen end called the **anther**

Flowers may have three to numerous stamens which may be free or united. In some flowers, the filaments are united while the anthers are free. In the Hibiscus, the fused filaments from a **staminal tube**. In the sunflower, the anthers are fused while the filaments are free. Sometimes, the filaments of stamens are attached to petals **(epipetalous)**.

Anther and Pollen Grains

The anther is a 2-4 lobed structure. Pollen grains are produced in these lobes within the region called **pollen sacs**. When the pollen grains mature, the anther lobes split to release them;
Pollen grains are fine yellowish particles. Each pollen grain is made of;

i. Two coats - a tough protective outer coat called **exine** and a thin inner coat called **intine** of cellulose.
ii. A haploid **generative nucleus** which gives rise to two male gametes.
iii. haploid **tube nucleus**

When a pollen grain lands on the mature stigma of the same type of flower, it germinates to form a pollen tube.

(iv) **Gynoecium:** The gynoecium are the female reproductive organs of a flower. It is the innermost whorl of the floral parts of the flower. The gynoecium consists of **carpels.** It may consist of one, a few or many carpels. **A** separate **carpel** or a single structure of several fused carpels is called a **pistil.**

A pistil with a single carpel is described as **monocarpous,** e.g. flamboyant, while one with two or more carpels is known as **polycarpous,** e.g. Hibiscus. When the carpels are free from one another, the pistil is said to be **apocarpous,** e.g. rose flower, but when they are fused together, it is described as **syncarpous**, e.g. lilies.

Pistils have the following (i) ovary (ii) style and (iii) stigma. The ovary contains one or more ovoid structures called **ovules**, Each ovule houses a female gamete or egg cell.
After fertilization, the ovary develops into a **fruit** while the ovules develop into **seeds.**

Table 9.1 - Summary of Parts of a Flower and their functions

Parts of a flower	Function
(i) Pedicel	Attaches the flower to the stem
(ii) Receptacle	Carries and holds together the other parts of the flower
(iii) Sepals (calyx)	Enclose and protect the other floral parts when the flower is in the bud stage. If brightly coloured, they also attract insects, if green, they make plant food (photosynthesis).
(iv) Petals (corolla)	attract insects which pollinate flower
(v) Filament	holds or carries the anther.
(vi) Anther	contains the pollen grains
(vii) Pollen grains	produce the male gametes that fertilise the ovules
(viii) Stigma	receives pollen grains at pollination
(ix) Style	connects the stigma to the ovary and it is the passage for the pollen tube to reach the ovules
(x) Ovary	contains the ovules, develops into fruit
(xi) Ovules	produce the female games, develop into seeds

Types of Ovary

The position of an ovary in the receptacle dictates how it is classified. An ovary can be described as superior, inferior and half-inferior (fig. 9.7).

(i) **Supreme ovary:** An ovary is described as superior when it is placed above the other floral parts, namely the calyx, corolla and stamens on the receptacle e.g. Hibiscus. The flower having this type of superior ovary is described as **hypogynous** flower.

(ii) **Half inferior ovary:** An ovary is described as half inferior when the ovary lies inside a cup-shaped receptacle and other floral parts appear to be attached slightly above it or almost at the same level. e.g. rose flower. The flower having this type of half inferior ovary is described as **perigynous flowers**.

(iii) **Inferior ovary:** An ovary is described as inferior when it is placed below the other floral parts, namely the calyx, corolla and stamens on the receptacle. That is, other floral parts are:

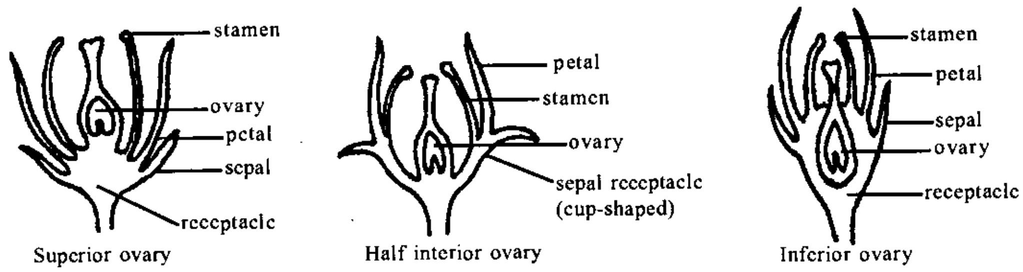


Figure 9.7 Types of ovary

above it on the receptacle, e.g. cana lily, sunflower. The flower having this type of inferior ovary is described as **epigynous flower**.

Terms Used in Describing Flowers

(i) **Inflorescence:** Inflorescence is a group of flowers which attached themselves to a common stalk or axis, e.g. Pride of Barbados.

(ii) **Solitary flower:** A solitary flower is one that is attached singly either to the leaf axis or to the tip of a branch e.g. Hibiscus and pawpaw flower.

(iii) **Perfect flower:** A perfect flower is one that has both carpels and stamens in it, e.g. pride of Barbados.

(iv) **Imperfect flower:** An imperfect flower is one in which either stamens or carpels are naturally missing, e.g. maize flowers.

(v) **Complete flower:** A complete flower is the type that has naturally all the four floral parts namely, calyx, corolla, androecium and gynoecium, e.g. Hibiscus, pride of Barbados.

(vi) **Incomplete flower:** An incomplete flower is the type which lacks one or more of the floral parts, e.g. maize and pawpaw flowers.

(vii) **Regular flower:** A flower is regular if it has all members of a whorl on it, i.e. petals identical in shape and in size and are evenly arranged on the receptacle. Such a flower can be cut vertically into two similar halves through any one of several vertical places (radial symmetry) and is described as ***actinomorphic flower,*** e.g. Hibiscus.

(viii) **Irregular flower:** An irregular flower is one in which the members of a whorl, e.g. petals are not similar either because some parts are fused, some are smaller than others or because one or more parts are missing. The flower can be cut vertically into two similar halves through only one plane (bilateral symmetry) and is described as **zygomorphic flower** e.g. pride of Barbados and Delonix.

(ix) **Axillary flower:** Axillary flowers are the those which are borne in the axils of leaves.

(x) **Terminal flowers:** Terminal flowers are borne at the end of stems or branches.

(xi) **Bisexual flower:** A bisexual flower also called a **hermaphrodite** has both the carpels (female) and tamens (male) on it, e.g. pride of Barbados, Hibiscus.

(xii) **Unisexual flower:** A unisexual flower is the type that has either stamens or carpels at its sexual parts. A flower that has only carpels is a female flower and such flower is described as **pistillate**, e.g. maize, pawpaw. On the other hand, any flower that has only stamens is a male flower hence it is described as staminate, e.g. pawpaw, maize.

(xiii) **Monoecious flower:** When male and female flowers are found on the same plants, the plant is said to be monoecious e.g. oil palm, maize.

(xiv) **Dioecious flower:** When male and female flowers are found on different plants, the plant is said to be dioecious plants, the plant is said to be dioecious, e.g. pawpaw.

(xv) **Essential parts of a flower:** The stamens and carpels are regarded as the essential parts of the flower because they produce the gametes required for fertilisation to take place resulting in the formation of seeds or fruits.

(xvi) **Non-essential parts of a flower:** The petals and the sepals are regarded as the non-essential parts of a flower because they are not required for gamete production in flowers.

Placentation in Flowering Plants

Placentation is defined as the arrangement of the ovules within the ovary. There are various ways in which ovules are attached to the ridges of the ovary. These ovules are attached to the ovary by fleshy structures called **placentae** (singular: **placenta**) through short stalks called **funicles**.

Kinds of Placentation

The various kinds of placentation (fig. 9.8).

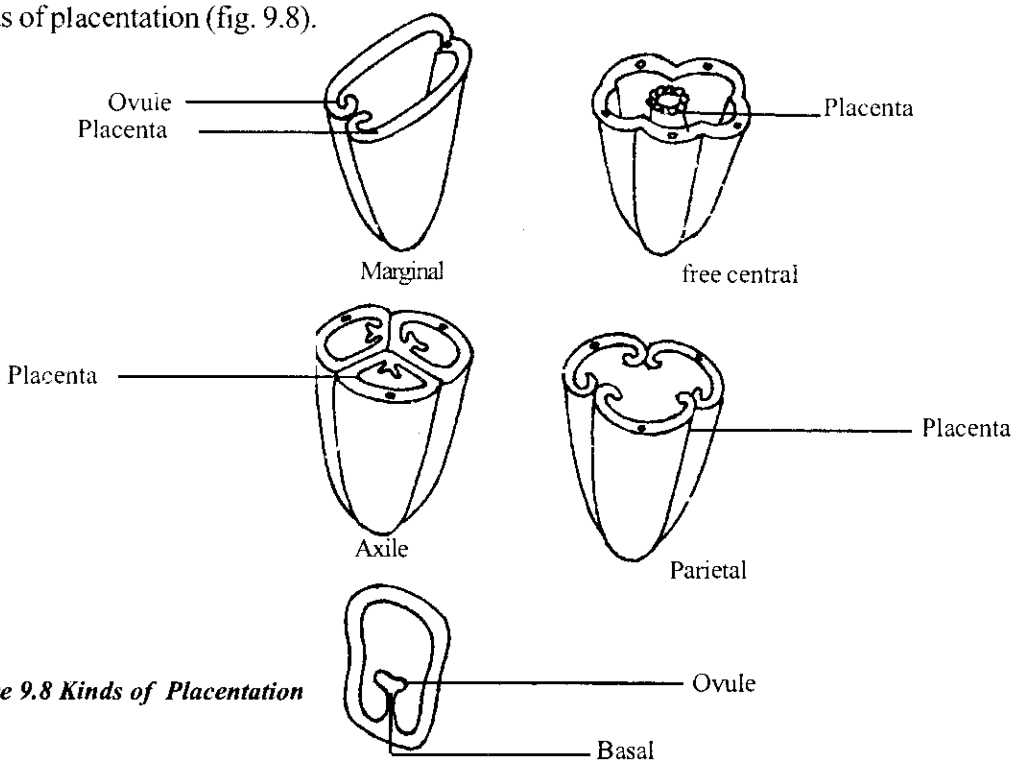


Figure 9.8 Kinds of Placentation

1. **Marginal placentation:** In marginal placentation, the ovules are attached to the placenta along one margin of the ovary. Examples are beans, cowpea, pride of Barbados, flamboyant, cassia, crotalaria and Delonix.
2. **Parietal placentation:** In this arrangement, the ovules are attached to the sides of a syncarpous ovary havng a single chamber, e.g. pawpaw.
3. **Free-central placentation:** In this type of arrangement, the ovules are bome on a knob which projects from the base of the ovary, e.g. cana lily.
4. **Axile placentation:** In an axile placentation, the carpels of a syncarpous ovary meet in the centre to form the placenta to which the ovules are attached e.g. tomato.

while flaccidity of the guard cells causes the closing of the guard cells. Gaseous exchange, especially through the stomata, is made possible when the stomata open. see fig. 8.6.

A. Stoma: how the guard cells open and close a stoma

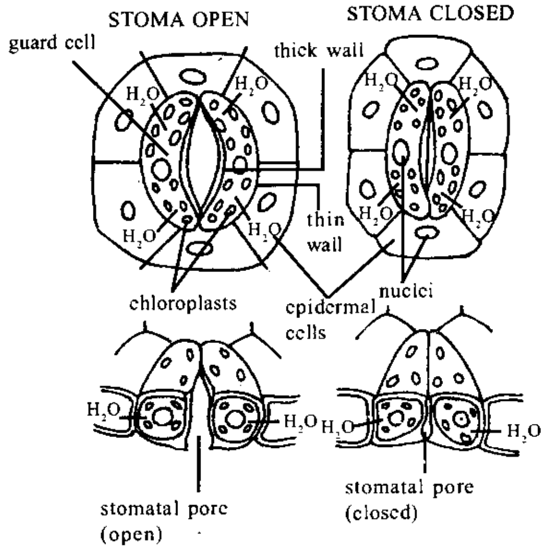


Figure 8.4 Gaseous exchange structures and mechanisms in plants

3.4.1 Factors or Conditions Affecting Respiration

1. **Oxygen:** Presence of oxygen is essential for respiration (Kreb cycle only). The rate of respiration under varying concentration of oxygen varies. If the concentration of oxygen falls below 5%, the rate of respiration rapidly drops. Under this condition more carbondioxide is evolved than oxygen absorbed. With gradual increase in oxygen concentration, there is a corresponding steady increase in the rate of respiration.
2. **Temperature:** The minimum rate of respiration is reached at 0oC or even at 10oC. With the rise in temperature, the rate of respiration increases. Beyond 40% or 45% which is the maximum, protoplasm is injured, particularly affecting enzyme activity, and thus the rate of respiration decreases. The optimum temperature however lies between 30oC and 35oC.
3. **Light:** The effect of light is only indirect; in bright sunlight, the respiratory activity is greater than in subdued light. This may be due to the fact that in bright light stomata remain wide open and oxygen is easily and quickly absorbed.
4. **Supply of Water:** Protoplasm saturated with water respires more vigorously than that in a desiccated condition, as in dry seed. Thus with the supply of water the rate of respiration increases.
5. **Vitality of Cells:** Respiration in young active cells is more rapid than in old cells. Vegetative buds, floral buds and germinating seeds respire more vigorously than older parts of the plant.
6. **Carbondioxide Concentration:** If as a result of respiration carbondioxide be allowed to accumulate inside the plant as a result of stomata closure, or the plant, surroundings respiration rate decreases and gradually ceases. If this carbondioxide is removed however respiration rate increases. Carbondioxide has a depressing effect on respiration.
7. **Nutritive Materials:** Food materials, more particularly soluble carbohydrates, affect respiration to a considerable extent. With the supply of oxygen these materials become quickly broken down.

3.5 Differences Between Respiration and Photosynthesis

	Respiration	Photosynthesis
(i)	Respiration occurs in every living cells	Photosynthesis occurs only in autotrophs
(ii)	It takes place at all times	It takes place only in the presence of sunlight
(iii)	Food substances are broken down (i.e. catabolism)	Food substances are built up (i.e. anabolism)
(iv)	High energy containing food, e.g. oxygen and carbohydrate are used.	Low energy substances like carbon dioxide and water are used
(v)	Carbon dioxide and water are the by-products	Oxygen is the by-product
(vi)	Respiration releases energy	Photosynthesis makes use of energy
(vii)	Respiration results in a decrease in weight	It results in an increase in weight.

3.6 Cellular Respiration

Cellular respiration involves the chemical activities of the cells in which glucose is broken down by a series of reaction controlled by enzymes to release energy. The energy so released is stored in adenosine triphosphate (ATP). ATP is the form in which energy is carried, stored and used by all living cells for the various metabolic processes. The entire purpose of cellular respiration is to generate energy for various metabolic processes in all organisms.

Type of Cellular Respiration

There are two main types of cellular respiration. These are **aerobic** and **anaerobic respiration.**

3.6.1 Aerobic Respiration

Aerobic respiration is the type of respiration which requires oxygen to break down glucose (substrates) into water, carbon dioxide and energy (ATP).

Aerobic respiration can be represented by the chemical equation below:

$$\underset{\text{(Glucose)}}{C_6H_{12}O_6} + \underset{\text{(Oxygen)}}{6O_2} \longrightarrow \underset{\text{(Carbon dioxide)}}{6CO_2} + \underset{\text{(Water)}}{6H_2O} + \underset{\text{(ATP)}}{\text{Energy}}$$

The breaking down of glucose in the body passes through several pathways before it can produce energy. These pathways are Glycolysis and Kreb's cycle.

Glycolysis

Glycolysis is a series of chemical reaction which involves the breaking down of glucose to a 3-carbon molecule called pyruvic acid. During glycolysis, no oxygen is required and it takes place in the cytoplasm of the cells. Very little energy is produced or generated during glycolysis. A net formation of 2 ATPs are produced from complete oxidation of one glucose molecule during glycolysis.

The process of glycolysis begins with the phosphorylation of glucose to glucose - 6 - phosphate and so on till pyruvic acid is produced as shown in figure 13.1. What happens to the pyruvic acid depends on whether oxygen is present or not. Therefore, one can conclude that glycolysis takes place in both aerobic and anaerobic organisms yielding only a net gain of 2 ATPs.

In anaerobes (absence of oxygen), the pyruvic acid is converted to alcohol in plants and lactic acid in animals. If oxygen is present (aerobes), the pyruvic acid will enter the mitochondria where it is converted to acetyl co-enzyme A (acetyl CoA) which is an important intermediate in the breaking down of sugar. It links glycolysis to the Kreb cycle. It is also formed in the breaking-down of fats and proteins.

Kreb's Cycle

The Kreb's cycle also known as **Citric Acid Cycle** or **Tricarboxylic Acid Cycle (TAC)** involves a series of cyclic reactions which begin with the pyruvic acid formed from glycolysis which combined with acetyl co-enzyme A to form citric acid. The reaction continues in a cyclic form as shown in figure 8.7 and it repeats itself continuously. Kreb's cycle takes place in the presence of oxygen and in the mitochondria (power house) of all cells. At various stages of the Kreb's cycle. carbon dioxide and hydrogen are produced. The hydrogen released combines with oxygen to produce water.

During the entire process, large number of energy in the form of adenosine triphosphates (ATPs) are released to the cell for use. Unlike glycolysis, which yields a net ATPs of two, Kreb's cycle along produces a total net ATPs of 36. Therefore, the entire breaking down of a glucose molecule from glycolysis to Kreb's cycle provides a total net formation of 38 ATPs.

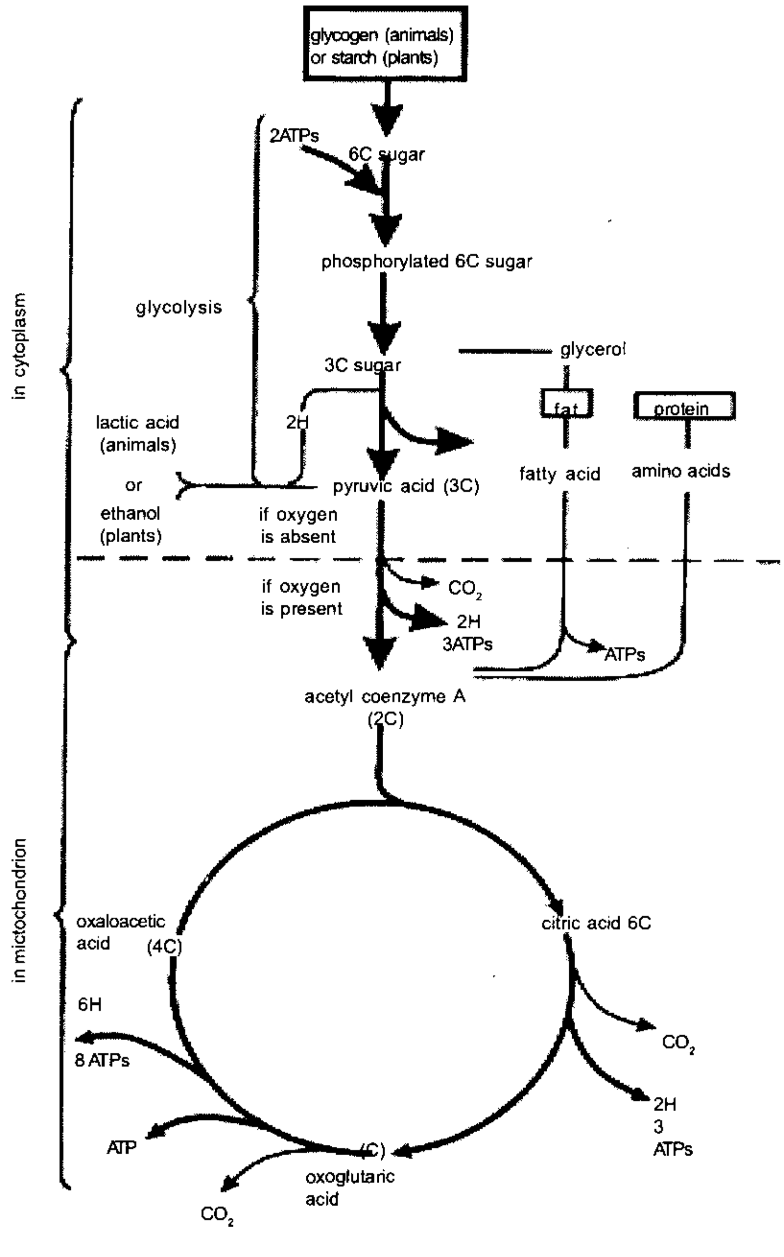


Figure 8.5 Glycolysis and Kreb's Cycle

3.6.2 Anaerobic Respiration

Anaerobic respiration is the type of respiration which does not require the presence of oxygen to provide energy. During anaerobic respiration, glucose is broken down to yield carbon dioxide, alcohol (ethanol) and energy.

The anaerobic respiration can be represented by a chemical equation below:

$$C_6H_{12}O_6 + \xrightarrow[O_2]{No} 2CO_2 + 2C_2H_5OH + \text{Energy}$$

(Glucose) (Carbon dioxide) (Alcohol) (ATP)

The process by which glucose is broken down to alcohol in the absence of oxygen is called **fermentation.** Yeasts exhibit anaerobic respiration and contain some enzymes called zymase which can break down sugar or glucose into carbon dioxide and alcohol (ethanol) to release energy for metabolism.

3.7 Similarities Between Aerobic and Anaerobic Respiration

(i) Both aerobic and anaerobic respiration lead to the release of energy.

(ii) Both occur in plant and animal cells.

(iii) Both processes require enzymes to speed up the reactions.

(iv) Both processes lead to the generaton of heat.

(v) Both give off carbon dioxide as by-product.

3.7.1 Differences Between Aerobic and Anaerobic Respiration

Aerobic Respiration	Anaerobic Respiration
(i) Oxygen is required for oxidation	Oxygen is not required for oxidation
(ii) By-products are water and carbon dioxide	By-products are alcohol and lactic acid
(iii) More energy is released	Less energy is released
(iv) It takes place in mitochondria	It takes place in cytoplasm
(v) Water is given off as by-product	Alcohol is given off as by-product

Activity B

i. Briefly explain the two types of cellular respiration

ii. Give at least four differences between aerobic and anaerobic respiration.

4.0 Conclusion

Respiration is a vital life process in plants. The energy released during the process of respiration is therefore used for growth, movement, reproduction and manufacturing of food. Therefore it can be concluded here that survival of plants is directly or indirectly dependent on the process of respiration.

5.0 Summary

In this unit, we have learnt that;

1. All plants respire at all times.
2. Respiration is the breakdown of organic compound like glucose in order to release energy.
3. This energy is used for vital activities such as manufacture of food, growth, movement, reproductions etc.

4. Gases move in and out of the plant through the stomata, lenticels and root hairs.
5. Factors like concentration of carbondioxide, dry weather, acidity affect the opening and closing of stomata.
6. Factors like oxygen, temperature, light, supply of water, vitality of cells, carbon dioxide and nutritive material affect the rate of respiration.
7. There are two types of cellular respiration aerobic and anaerobic respiration.
8. Aerobic respiration require oxygen to break down glucose into water, carbondioxide and energy (ATP). While anaerobic respiration does not require the presence of oxygen to provide energy.

6.0 Tutor- Marked Assignment

Briefly explain how the following factors affect the rate of respiration in plants.

i. Vitality of cells
ii. Supply of water
iii. Light
iv. Temperature

7.0 Further Reading and Other Resources

Idodo - Umeh (1996) *College Biology*
Sarojini T. Ramalingam (2001) *Modern Biology*
Essential Biology

Volume 2: Flowering Plants

Unit 9: Reproduction in Plants

Page

1.0 Introduction

Reproduction is the ability of living organisms to produce offspring, i.e. new individuals of their types. This is an important feature of all living organisms. It is the only way in which each kind of organism can continue to live on forever, although the individual must eventually die.

Organisms have developed many methods of reproducing. These can either be asexual or sexual. Asexual reproduction is a type of reproduction in which only one parent is involved. No gamete is formed. Asexual reproduction occurs in both plants and animals. Sexual reproduction is the reproduction that involves the sex cells - the sperm and the egg resulting to the formation of zygote. In this unit, we shall discuss reproduction in flowering plants.

2.0 Objectives

By the end of this unit, you should be able to;

i. Explain the various types of asexual reproduction
ii. List the advantages and disadvantages of asexual reproduction
iii. Describe reproduction system in flowering plants.
iv. Explain the various types of pollination
v. Describe the process of fertilisation in flowering plants
vi. Explain the two types of germinations in seeds.

3.0 Reproduction in Flowering Plants

Reproduction in flowering plants can either be asexually or sexually.

3.1 Asexual Reproduction

Asexual reproduction is the type of reproduction which only one parent is involved. No gamete is formed. Vegetative propagation is an example of asexually reprodution in flowering plants.

3.1.1 Vegetative Propagation

Vegetative propagation involves the use of parts of plants in multiplying the plant or when a new plant grows out of a parent plant, without the use of seeds. Vegetative propagation involves two methods - natural vegetative and artificial vegetative propagation.

3.1.2 Natural Vegetative Propagation

Natural vegetative propagation is carried out by the plants themselves by means of leaves, stems and buds. Tiny plants growing from the leaf can later on break off to form new plants, examples are seen in *Bryophyllum* and *Begonia*. Some stems are modified as runners, rhizomes, corms and tubers. All these has been discussed in volume two unit 3.

3.1.3 Artificial Vegetative Propagation

Artificial propagation is the use of parts of the parent plant to multiply the plant. Budding, grafting, cutting, layering and marcotting are some ways of artificial vegetative propagation.

5. **Basal placentation:** In basal placentation, the ovules are attached to the base of syncarpous ovary, e.g. sunflower.

Activity B

Give one function each of the following flower parts.

i. Anther

ii. Stigma

iii. Ovary

iv. Petals.

3.3 Pollination

Pollination is defined as the transfer of mature pollen grains from the anthers of one flower to the mature stigma of the same flower or another flower of the same plant or closely related species. Pollination is the first step which leads to the eventual coming together of the male and female gametes for the sake of fertilisation.

Types of Pollination

There are two types of pollination. These are self pollination and cross pollination.

Self Pollination

Self pollination is the transfer of mature pollen grains from the anther of a flower to the stigma of the same flower or to that of another flower of the same plant, e.g. pea, cotton, tomato. For self pollination, only one parent plant is involved.

Cross Pollination

Cross pollination is the transfer of mature pollen grains from the anther of a flower to the stigma of a flower of another plant of the same or closely related species, e.g. morning glory, Hibiscus, pride of Barbados. For cross pollination to occur, two parent plants are involved.

Agents of Pollination

Agents of pollination also called **pollinators** are organisms and other means by which pollen grains are transferred from the anthers to the stigma of flowers. Agents of pollination include insects, winds, water and other animals like snails, birds, bats and man. Common insects involved in pollination are butterfly, moth and bees.

Conditions or Devices which Aid Self Pollination

Some plants have conditions or devices which aid self pollination to take place. These conditions are **homogamy** and **cleistogamy**.

Homogamy

Refers to the ripening of the anthers and stigmas of a bisexual flower at the same time. Under this condition, self pollination may occur in the following ways;

i) A gentle breeze may blow the mature pollen grains which may be shed on mature stigma that are situated below.

ii) A visiting insect may transfer the mature pollen grains to the stigma of the same flower.

iii) Self pollination may also occur when mature stigmas push their way out of the corolla tube during which they are brushed against the anthers and in the process pollen grains are collected.

iv) In a situation where the filaments are longer than the stigma, the filaments may recoil to touch the stigmas.

v) In like manner, self pollination may occur where the styles are longer than the filaments, the styles may also bend or recoil to make the stigmas touch the anther.

Cleistogamy

Cleistogamy is defined as a condition in which ripe pollen grains are deposited on the stigma which becomes ripened at the same time.

This situation usually occurs among closed flowers, that is, bisexual flowers which never open at all.

Advantages of Self Pollination

i.) It is a sure way to ensuring pollination, especially in bisexual flowers.

ii.) It may not waste pollen grains.

Disadvantages of Self Pollination

i.) It leads to the production of weak offspring as a result of continuous or repeated self pollination.

ii.) The offspring or individuals produced are less adapted to the environment.

Conditions or Devices which Aids Cross Pollination

Some plants may have conditions or devices which may aid cross pollination to take place. These are dichogamy, unisexuality and self-sterility.

Dichogamy

Dichogamy refers to the ripening of the anthers and stigmas of a bisexual flower at different times. Dichogamy occurs in two ways. These are protandry and protogyny.

(a) ***Protandry***

Protandry refers to the condition in which the anthers of a flower mature earlier than the stigmas of that flower or other flowers of the same plant so that the mature pollen grains are only useful to flowers of other plants which have mature stigmas to receive them.

(b) ***Protogyny***

Meaning: Protogyny refers to the condition in which the stigma of a flower matures earlier than its own pollen grains or those of other flowers of the same plant so that it can only receive pollen grains from flowers of other plants.

Unisexuality

Unisexuality is a situation in which some plants bear only male or female flowers and not both on the same plant, e.g. pawpaw. Such plants are said to be **dioecious plants**. Cross pollintion may occur under this condition.

On the other hand, in a **monoecious plant** the male and female flowers are bome by the same plant, the female flowers are usually situated higher than the male flowers so that pollen grains may not reach the stigma of the female flowers. Hence, they will be received only by stigmas of female flowers of other plants.

Self-sterility

Self-sterility refers to situation in which some plants make themselves sterile. The presence of pollen on their stigmas is injurious to further development of the plant. For example, they may wither and die. However, when pollen grians come from other plants, fertilisation can take place in such plants. Examples are found in passion flowers and tea.

Advantages of Cross Pollination

i.) Cross pollination leads to the production of healthier offspring than self pollination.
ii.) It also produces viable seeds.
iii.) Offspring or individuals produced are more adapted to the environmental conditions.
iv.) It also leads to the formation of new varieties with good characteristics.

Disadvantages of Self Pollination

i.) It relies on external agents such as wind and insects whose presence at the right time cannot be guaranted.
ii.) It may lead to wastage of pollen grains especially pollination by wind.

Differences between Self Pollination and Cross pollination

Self Pollination	Cross Pollination
(i) Self pollination takes place only in bisexual plants.	Cross pollination takes places in both unisexual and bisexual plants
(ii) Only one parent is involved.	Two parents are involved .
(iii) Pollination may occur without an external agent.	This requires external agents. e.g insects and wind.
(iv) It does not ensure new varieties.	It results in the formation of new varieties
(v) Pollen grains are effectively utilised.	Much of the pollen grains are wasted.

Major Agents of Pollination

Two major agents of pollination are wind and insects.

Characteristics of Insect Pollinated Flowers

Insect pollinated flowers also called **entomophilous flowers** have the following characteristics.
i.) They have large conspicous petals/sepals.
ii.) Flowers are usually brightly coloured.
iii.) They possess scent.
iv.) Nectar is also present.
v.) Pollen grains are rough, sticky and relatively few.
i.) The stigma is flat with sticky surface to enable it receive pollen grain.

vii.) Petals are shaped and arranged to enable visiting insects become dusted with pollen grains.

Example of insect pollinated flowers include Hibiscus, Delonix, cowpea, crotolaria, Pride of Barbados.

Characteristics of Wind Pollinated Flowers

Wind pollinated flowers also called **anemophilous flowers** have the following characteristics.

i.) They have small, inconspicoús petals/sepals.
ii.) Flowers are usually dull coloured.
iii.) There is absence of scent.
iv.) There is absence of nectar.
v.) Large quantity of pollen grains are produced.
vi.) Pollen grains are small, smooth, light and not sticky.
vii.) Stigma is elongated and sticky with large surface area.
viii.) Anthers are attached to the flower in such away that they readily swing in the air and released the pollen grains.

Examples of wind pollinated flowers are maize, guinea grass, rice, millet and wheat.

Differences Between insect Pollinated Flower and Wind Pollinated Flower
Table 9.3

Insect pollinated flower	Wind pollinated flower
(i.) Flowers are usually large and conspicous.	Flowers are usually small and inconspicous
(ii.) Flowers are usually brightly coloured.	Flower are usually small and dull coloured.
(iii.) There is presence of scent.	There is abscence of scent
(iv) Nectars are present	Nectars are absent
(v) Pollen grains are rough, sticky and relatively few.	Pollen grains are light, smooth and very numerous.
(vi) Anthers may or may not be enclosed by the leaves.	Filament are long so that anther hang outside the flower.
(vii) Flower may or may not be held above leaves.	Flowers are carried above the leaves where they are exposed to the wind.
(viii) Stigma is flat or lobed sticky surfaces or pollen grains. adherence of pollen grains.	Stigma is large and feathery hanging outside the flower providing large surfaces area for easy trapping of pollen grains.
(ix) The shape and floral pairs are such that they enable insects get dusted with pollen grains during visiting.	There is particular adaptive shape as flowers are small and exposed.

In your own words, explain the following type of pollination

i.) self pollination

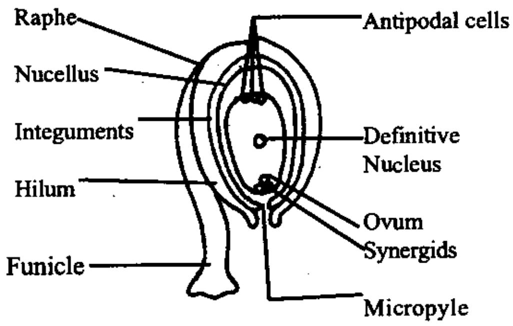
ii.) cross pollination

3.4 Fertilisation

Immediately after pollination, fertilisation follows. Fertilisation is the union of male and female gametes to form a zygote. In a flower, the male gametes develop from the pollen grains while the female gametes develop from the ovules which are retained in the ovary.

Figure 9.9 Structure of a Mature Ovule

A mature ovule (fig. 9.9) has the following parts;



(i) **Hilum:** Hilum is the point of attachment of the ovule to the placenta

(ii) **Integuments:** These are two coverings of the ovule.

(iii) **Embryo sac:** This is the tissue that produces the female gamete.

(iv) **Nucellus:** This tissue is enclosed by the integument. It is nutritive in function

(v) **Micropyle:** Micropyle is an opening into the ovule left by the integuments.

Fertilisation in Flowering Plants

In flowering plants, the zygote is formed through the following processes.

i.) After pollination, the pollen absorbs a sugary liquid on the stigma, swells and germinate.

ii.) The outer coat of the pollen grain, the exine, splits. The pollen tube grows out and down inside the style.

iii.) At the initial stage, the pollen grain has only one nucleus. Later, this nucleus divides into two- a larger **tube nucleus** and a smaller **generative nucleus**.

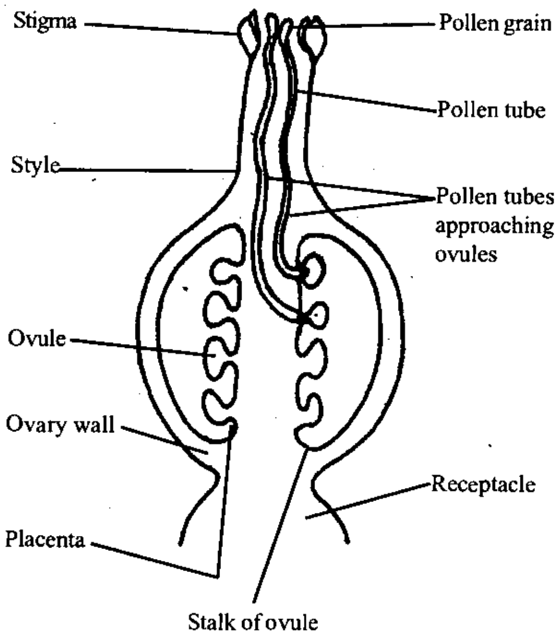
iv.) The generative nucleus divides into two **male nuclei**. The male nucleus is the **male gamete**.

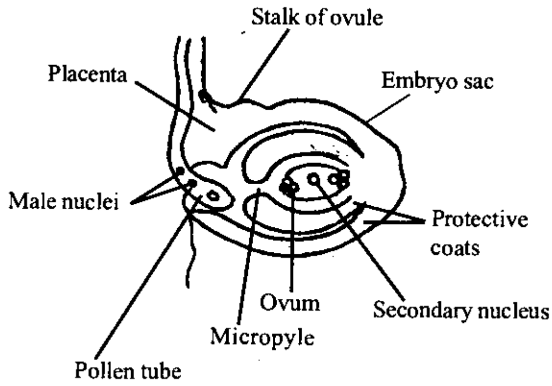
v.) The pollen tube grows into the ovule through the micropyle, and the end of the pollen tube bursts. The two male nuclei are released inside the embryo sac.

vi.) One male nucleus fuses with the ovum to the embryo. This is the first fertilisation.

vii.) The second male nucleus fuses with the secondary nucleus to form a triploid cell (endosperm nucleus) that produces the endosperm. This is referred to as the second fertilisation which takes place in plants.

Figure 9. 10 Fertilisation in an ovule of a flower





Development of the Embryo

The zygote divides by mitosis to form many cells which differentiate and become organised into an embryo. The embryo is made up of the following parts:

i.) The plumule or embryonic shoot

ii.) The radicle or embryonic root,

iii.) one or two cotyledons

iv.) sometimes, an endosperm

As the embryo develops, the nucellus degenerates. The endosperm may be used up by the embryo or may persist. The ovule now develops into a **seed**. Its inner and outer integuments develop into the inner and outer seed coats respectively.

The ovary undergoes changes after fertilisation and becomes the**fruit** while the ovary wall develops into the fruit wall. The sepals, petals, style and stigma wither away, although in some plants such as guava, sepals may remain and in some like pride of Barbados, the style may remain.

3.4.1 Seed

A seed is defined as a ripened fertilised and developed ovule.

Structure of a seed

The seed generally has the following parts.

i.) **Seed coat or testa:** A typical seed has a seed coat which covers an inner embryo. In most seeds, the seed coat is made up of an outer testa and an inner tegma. The testa is thin, transparent and membranous. Both structures protect the seed.

ii.) **Hilum:** On one side of the seed lies a scar known as hilum. the hilum is the point of attachment of the seed to the seed stalk or funicle.

iii.) **Micropyle:** Very close to the hilum is a tiny hole called the micropyle. This hole permits air and water into the embryo of the seed.

iv.) **Embryo:** The embryo consists of a plumule (the embryonic shoot), a radicle (the embryonic root) and one or two cotyledons (seed leaves). Around the radicle is the coleorhiza which is the sheath that protects the radicle while around the plumule is the coleoptile which is the structure that protects the plumule.

A seed which has only one cotyledon (one seed leaf) is called ***monocotyledonous seed***, e.g. rice, maize, wheat, sorghum etc while those that have two cotyledons (seed leaves) are called ***dicotyledonous seeds***, e.g. beans, mango etc.

Some seeds, e.g. maize, rice, wheat etc have area for the storage of food called ***endosperm***. Such seeds are described as ***endospermic seeds***.

3.4.2 Germination

Germination is defined as the process which involves the gradual development of the embryo of the seed into a seedling or a young plant. In other words germination is the series of changes by which an embryo in a seed grows into a seedling.

The embryo of developed seeds usually pass through a period of rest called ***dormancy***. During this period, there is very little cell activity. The seeds can remain in this condition as long as they are dry and the condition for germination is not favourable. When conditions become favourable, the seeds undergo several changes to develop into seedlings.

Type of Germination

There are two types of germination. These are **epigeal germination** and **hypogeal germination**.

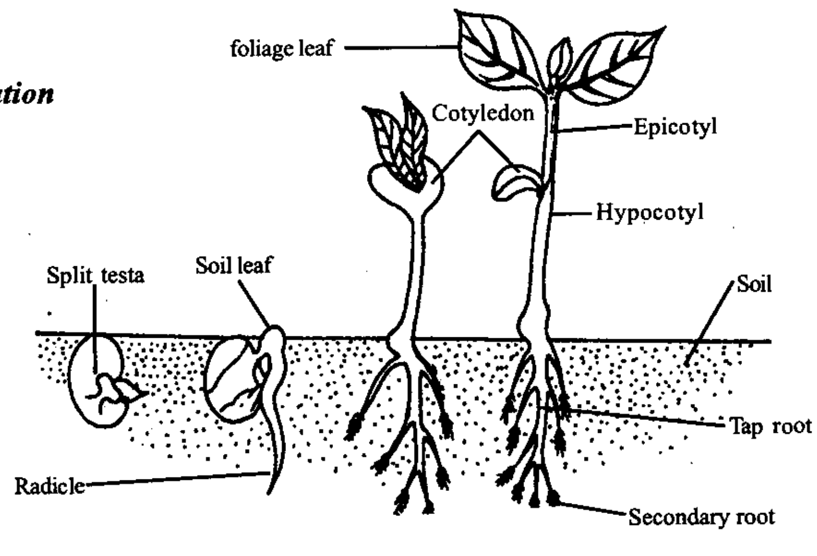
Epigeal germination

Epigeal germination is defined as the type of germination in which the cotyledons or seed leaves are carried above the soil surface (fig. 9.11). Epigeal germination is associated with dicotyledonous plants, e.g. germination of cowpea, groundnut, melon, mango etc.

Hypogeal germination

Hypogeal germination is defined as the type of germination in which the cotyledons, seed leaves or endosperm remain below the soil surface (fig. 9.12).
Hypogeal germination is associated with monocotyledonous plants, e.g. germination of maize, oil palm, guinea corn, millet, wheat etc.

Figure 9.11 Stages of germination in cowpea seed



3.4.3 Process of Germination

a) **Germination in cowpea:** Cowpea exhibits *epigeal germination,* i.e., during germination the cotyledonons (seed leaves) are carried above the soil.

When the seed is placed in the soil,

i.) It absorbs water and swells up.

ii.) The testa or seed coat splits.

iii.) The radicle appears and grows downwards into the soil.

iv.) The plumule (seed leaves) appears and grows upwards above the soil.

As the seedling grows, the food stored in the cotyledon is used up and the seed leaves eventually dry up and wither off. As the seed absorbs water, enzymes become active and the rate of respiration will increase and the seedling growth is sped up.

b) **Germination in maize:** Maize grain exhibits hypogeal germination, i.e., during germination, the cotyledon (seed leaves or endosperm) remains under the soil (fig. 9.12).

When maize seed is placed in the soil;

i.) It absorbs water and swells up.

ii.) The testa or seed coat splits.

iii.) The radicle appears and grows downwards into the soil.

iv.) The seed leaf (endosperm) remains below the soil.

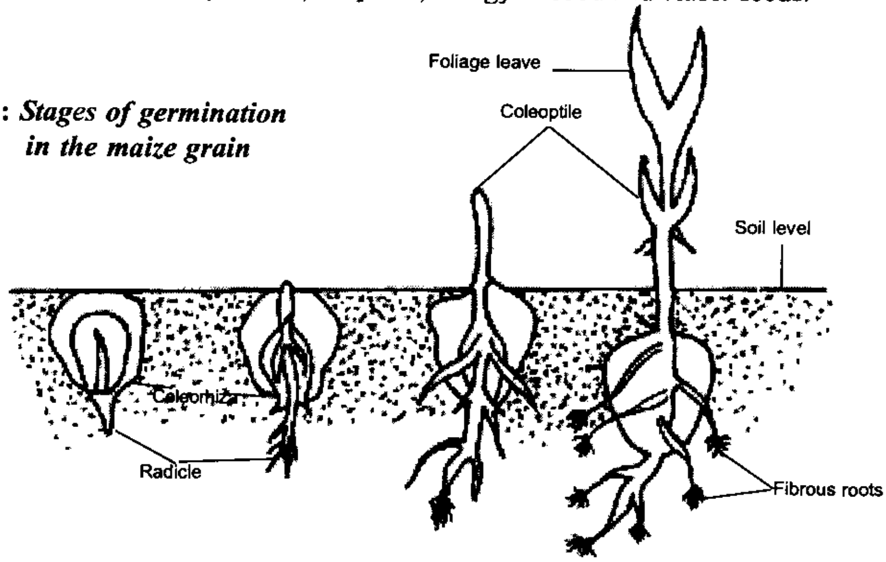
v.) The plumule (ordinary leaves) appear and grow upward above the soil.

As the seedling grows, the food stored in the endosperm below the soil is used up and it eventually withers off. The seed absorbs water, the enzymes become active, rate of respiration increases and the seedling growth rate is increased.

3.4.4 Conditions Necessary for Germination

The conditions which are necessary for the germination of the seed include; water for moisture, air or oxygen, warmth or suitable temperature, enzymes, energy or food and viable seeds.

Figure 9.12: ***Stages of germination in the maize grain***



(i) **Water or moisure**: The seed needs water to activate the cell. It is also needed to soften the testa or seed coat so that the radicle and plumaule can come out ofthe seed with ease.

(ii) **Air or oxygen**: The seed is a living organ. It needs oxygen to carry out respiration. During respiration, energy is released and it is used by the seed to grow.

(iii) **Warmth or suitable temperature**: Some seeds require certain range of temperature to germinate. This range in temperature is called **optimum temperature**. Below or above this temperature, the seed may or will not germinate and may even die.

(iv) **Enzymes**: Enzymes are organic catalyst which speed up the rate of reaction with the cells in the seed. Enzymes are required in the breaking down of food to release energy.

(v) **Energy or food**: There must be food within the seed from which it feeds. In dicotyledonous seed, the food is stored in the cotyledons or seed leaves while in a monocotyledonous seed, the food or energy source is stored in the endosperm.

(vi) **Viable seeds**: For a seed to germinate, it must be viable or alive. Damage seeds by insects, birds or man cannot germinate hence such seeds are not viable.

3.4.5 Fruits

We have discussed fruits in detail in volume 2 unit 3. Therefore you can see unit 3 of volume 2

Activity D

1. With well labelled diagram, describe the process of fertilisation in flowering plants
2. Briefly describe the two types of seed germinations

4.0 Conclusion

All organisms die sooner or later. Before doing so, most of them reproduce, i.e produce new organisms similar to themselves. This is how species survives without becoming extinct although individuals die. Therefore it can be concluded herethat reproduction is one of the most vital characteristics of living things, since it is very necessary for increase in memberand perpetuation of life here on earth

5.0 Summary

In this unit, we have learnt that:

1. Reproduction is the ability of living organism to produce offspring i.e new individual of their types
2. Reproduction in flowering plants can either be asexually or sexually.
3. Asexual reproduction is the type of reproduction whereby only one of parent is involved.
4. Vegetative propagation is an example of asexual reproduction.
5. Artificial propagation is the use of parts of the parent plant to multiply the plant. Budding, grafting, cutting, layering and marcotting are example of artificial vegetative propagation.
6. Sexual reproduction isthe fusion of male and female gametes to form zygote.
7. In flowering plants, the flower is the reproductive organ. A flower is made up of four floral parts – corolla, calyx, androcium and gynoecium
8. Pollination is transfer of flower to the mature stigma ofthe same flower or another flower ofthe smae or clsely related species.
9. Immediately after pollination, fertilisation follows, and that fertilisationisthe unionofmale and female gametes to form a zygote.

10. The ovule develops into a seed while the ovary develop into a fruit.

6.0 Tutor- Marked Assignment

1. In your own words, explain the following types of artificial vegetative reproduction (no diagram is required).
   a. Layering } 5 marks
   b. Grafting } 5 marks
   c. Cutting } 5 marks
2. List at least five advantages of budding and grafting } 5 marks

7.0 Further Reading and other Resources

Idodo Umeh (1986), *College Biology*
Sarojimi T. Ramalingam (2001), *Modern Biology*
Essential Biology
Dutta A.C., *Botany for Degree Students*

Volume 2: Flowering Plants

Unit 10: Growth and Development in Plants

1.0 Introduction

The term growth refers to two basic factors of a plant's development; (1) an increase in the number of cells as a result of cell division and (2) an enlargement and differentiation of existing cells accompanied by an increase of cellular components.

Growth is one of the characteristics of Living organisms. Growth in living things is an irreversible increase in size following the utilisation of food to make new or additional protoplasm within the body of an organism. Cell theory among other things states that new cells are formed from the pre-existing ones by division. When one cell divides by mitosis, two new cells result. The two cells put together are equal in volume to the one that gives rise to them. No growth has taken place in volume or mass of the cells even though growth has taken place in the number of cells. It is when the new cells grow to the maximum size of the parent cell that growth in volume is achieved. If these two cells are arranged linearly there will be an increase in length. Growth should therefore be traced in positive difference in volume, number of parts, length and weight of an organism. Growth therefore is the irreversible increase in volume (size), number of parts, length and weight of an organism. Growth is sometimes considered on the basic of an increased length and diameter of the plant which occur as a result of tissue development.

All living things have a pattern of growth inherited from their parent. As long as food is available in sufficient amounts, this pattern is maintained. Another point worthy of note is that growth is not an automatic or a short-term event. It is a relatively slow organic process which takes some time to accomplish. Growth, however, occurs faster in the young organisms than in the older ones.

2.0 Objectives

By the end of this unit, you should be able to;

i. explain the basic of growth
ii. explain the various types of growth
iii. explain how growth can be measured
iv. explain the factors that affect plant growth
v. describe growth movement in plants.

3.0 Growth in Plants

The growth in plant is a complex phenomenon associated with numerous physciological processes both constructive and destructive. The constructive process lead to the formation of various nutritive substances and the protoplasm. While the destructive process lead to the breaking down of the nutritive substances and the protoplasm. The protoplasm assimilates the protein food and increases in bulk, while the carbohydrate are mainly utilised in respiration and in the formation of the cell wall substance. The cell divide and numerous new cells are formed, these increase in size and become fully turgid and the plant grows as a whole. Growth is thus a complex vital phenomenon brought about by the protoplasm. It may be defined as a permanent and irreversible increase in size and form attended by an increase in weight, sometimes at the early stage of growth a loss in weight is noticed, as for example, when a potato tuber sprouts it shows a loss of weight in the beginning due to transpiration and respiration. But that is soon made good as new materials begin to form by the sprouting shoot.

Although growth in plants is very slow, certain plants show rapid rate of growth. For example some climbers like morning glory and wood-rose grow at the rate of about 20 cm per day, young shoots of giant bamboo show a growth of over 40 cm per day, while tendrils of some cucurbita show an extraordinary growth of 6 cm per hour. The growth of a plant, however slow it may be can be accurately measured with the help of an instrument called **auxanometer**.

3.1 Basis of Growth in Plants

Basis of growth involves three major processess namely (i) **cell division,** (ii) **cell enlargment** and (iii) **cell differentiation**.

3.2 Mitosis

All cells are derived from other living cells. Virchow wrote in 1848 when contributing to the cell theory that it is by cell division that all cells are derived from pre-existing cells. Cell division by which cells increase in number and achieve growth is called **mitosis**. This accounts for the bulk of the body of plants and animals. The cells do not just divide as a matter of splitting or cutting into two, but rather there is the synthesis of **protoplasm** leading to the doubling of the chromosomes number (this is known as **replication**) before the cell divides into two, with each daughter cell having the **same number** of chromosomes that is characteristic of the parent cell. Mitosis occurs in five stages namely **interphase, prophase, metaphase, anaphase** and **telophase**. (Note, the interphase in actual fact is not a part of mitosis as the nucleus is still controlling the activities of the cell. It is a preparatory stage).

Mitosis is therefore a division of a cell to produce two identical cells with the same number of chromosomes and characteristics as those of the parent cell. Mitosis occurs in somatic (body) cells such as skin, bone marrow, lymph nodes and injured place and meristematic tissues in plants.

Interphase

Chromosomes become elongated and from a network of fine threads called **chromatids.** The nuclear membrane is clearly visible.

The DNA duplicates (doubles) itself and chromosomes become double threads.

Two centrioles are formed just outside the nuclear membrane.

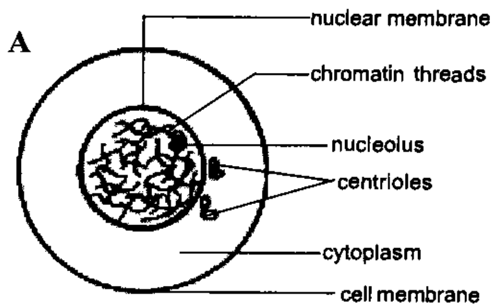


Figure 10.1a: *Interphase*

Prophase

There are two stages in prophase, namely early and late prophase.

Early prophase

1. Chromosomes become visible as **chromatin threads** condense.
2. Chromosomes are long and thin.
3. Nucleolus starts shrinking.
4. Centrioles start moving away from each other and forming asters.
5. The formation of spindle fibres starts.

Late prophase

1. Chromosomes become shorter, thicker and very visible.
2. Each chromosome now forms two distinct chromatids joined by a centromere.
3. Nucleolus disappears entirely.

4. Nuclear membrane disappears allowing the mixing up of cytoplasmic and nuclear materials freely.

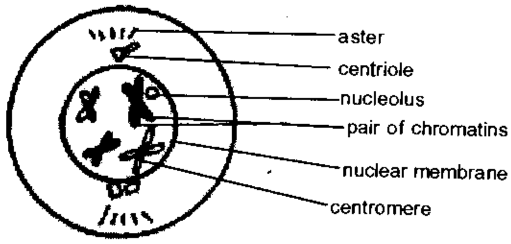


Figure 10.1b: *Prophase stage*

Metaphase

1. The chromosomes (now paired chromatids) arrange themselves along the equator of the spindle
2. The chromatids are attached to the spindle by the **centromeres**.

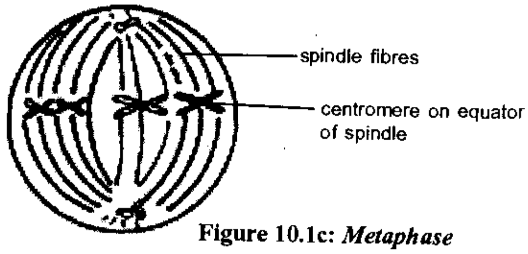


Figure 10.1c: *Metaphase*

Anaphase

1. The chromatids of each chromosome separate
2. The chromatids start migrating to the poles by the elongation of the spindle axis
3. The chromatids eventually reach the poles.

D

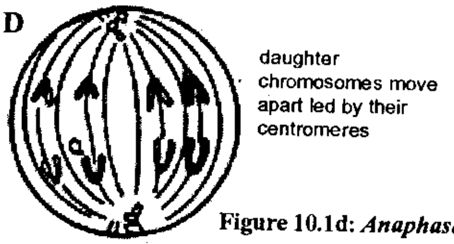


Figure 10.1d: *Anaphase*

Telophase

1. The cell starts dividing into two by constricting at the equator.
2. The chromosomes now lose their thick appearance.
3. The nuclear material and nucleolus reform, bounded by nuclear membrane.
4. The spindle structure disappears.
5. Constriction is completed and two daughter cells are formed and the interphase condition is restored.

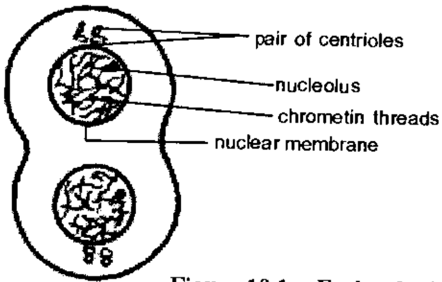


Figure 10.1e: *Early telophase*

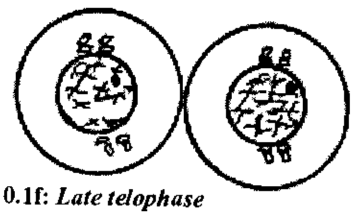


Figure 10.1f: *Late telophase*

Importance of Mitosis

1. It ensures that the **diploid** condition of the cells is retained from generation to generation.
2. **Growth:** Multicellular organisms grow from a fertilised egg to an adult stage having many cells through mitotic division. A man for example has billion of cells all resulting from mitotic division. As cells, divide, growth occurs.
3. **Asexual reproduction:** The binary or multiple fission in protozoans is as a result of mitotic division. Budding in Hydra results from mitosis. Formation of vegetative organs from parent plants such as bulbs and corms is by mitosis.

3.2.1 Cell Enlargment and Differentiation

After mitosis in animals the daughter cells absorb nutrients from their surroundings. A part of these nutrients is used for respiration to generate energy while the remaining part is assimilated resulting in the enlargement of the cells. As the cells enlarge, differentiation results leading to the development of specialized cells.

In plants the cell walls at this young stage are flexible (plastic) therefore tugor pressure from inside the cell presses them outwards, leading to the expansion of their walls and consequently vacuoles are formed.

3.3 Apical and Intercalary Growth

Growth does not occur any how in parts of the plant. It takes place in certain tissues and places or parts in a plant body. Certain tissues in which growth takes place are called *meristems* (meristematic tissues). Meristems have restricted distribution in plants. They are found in the root apex, stem or shoot apex, bases of internodes and vascular cambium. A **meristem** is a tissue that retains the ability to divide by mitosis and turn out new cells. Under favourable conditions, new cells are continually being formed as a result of repeated mitotic cell divisions of all its cells. The subsequent enlargement and structural differentation of cells originating in a meristem, enable various tissues to be developed according to a pattern peculiar to each species. Growth which is initiated in the apical-stem and apical-root meristems is called *apical* growth (fig 10.2).

A

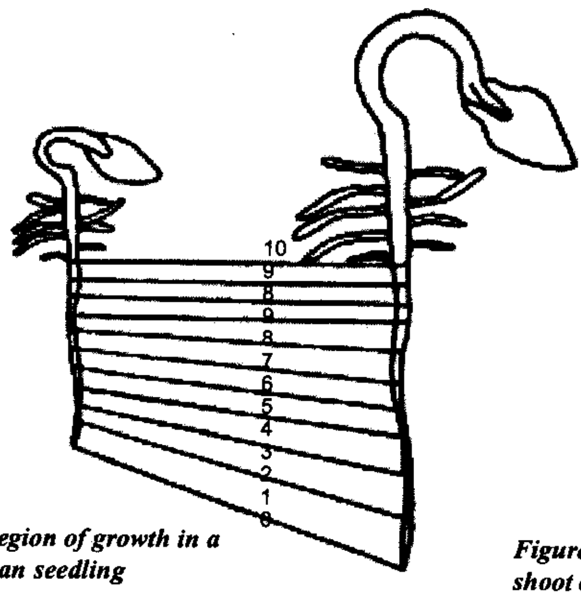


Figure 10.2a: Region of growth in a root of broad bean seedling

B

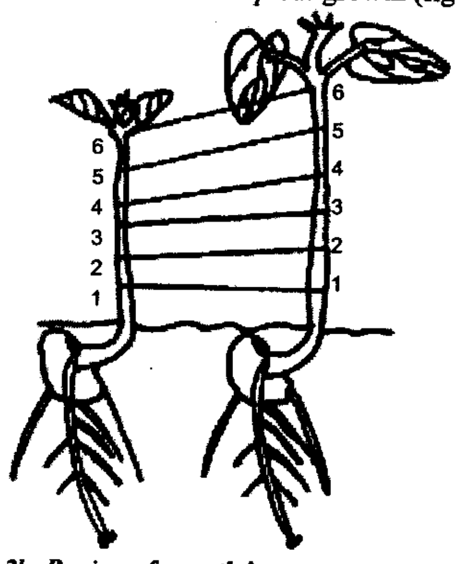


Figure 10.2b: Region of growth in a shoot of African yam bean

It is still the primary growth in plant since it results in the construction of primary tissues in a plant. Apical growth accounts for all increase in length of the plant main axis at both roots and stem tips or apices. Growth which occurs at the meristems of the base of internodes is called*intercalary* growth.

It is responsible for the development of the branching system of the stems and roots. The formation of lateral appendages such as roots hairs, leaves and floral parts is linked to intercalary growth. The activities of the intercalary meristem explain why hedge plants and grass shoots regenerate rapidly after being severely damaged in trimming, prunning, lawn mowing and animal grazing. In gymnosperms and most dicotyledons, growth does not only take place by the activities of the apical-root, apical-stem and intercalary meristems but also by the activities of the vascular cambium and cork cambium to bring about increase in the diameter of the roots and stem. This is called **secondary growth** as explained earlier. Tissues formed as a result of the growth activity of vascular cambium and cork cambium are called **secondary tissues**. Plants which have no vascular cambium and cork cambium (most monocotyledons and a few dicotyledons) achieve increase in diameter of their stems and roots by the activities of intercalary meristems and primary growth, since primary tissues constitute their entire body.

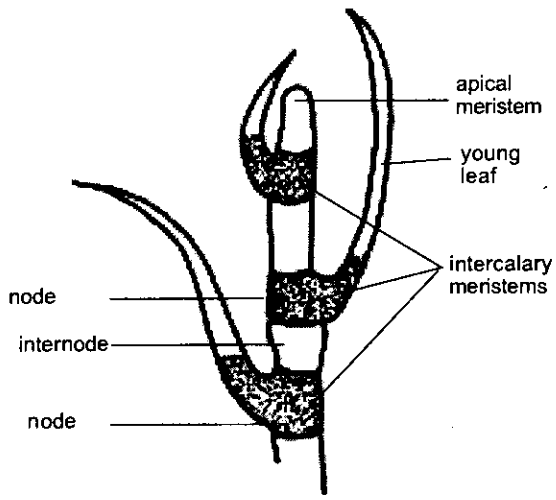


Figure 10.3: ***Intercalary growth at the nodes of stem***

3.3.1 Limited and Unlimited Growths

It is generally stated and accepted that growth is limited in animals while it is unlimited in plants. It has been discovered in human beings that growth in height stops in female at about 17 years and about 20 years in males. This is the instance of a limited growth in animals. Most plants continue to grow year in year out after sexual maturity had been achieved. This is why most plants are seen to achieved. This is why most plants are seen to achieve very great heights and large stem widths. In most plants and animals studied, growth is known to be very fast at the early stages of their life up to sexual maturity after which the rate of starts to diminish. In most plants, growth continues and increase in size and development of new stem and root branches, leaves, flowers and fruits containig seeds are recorded from time to time throughout their life history.

3.3.2 Definite and Indefinite Growths

Most animals show definite **growth** while most plants on the other hand show indefinite growth. In segmented animals, the number of body segments is fixed and pre-determined in the embryo. The animal grows that number according to its genetical constitution and never more no matter its longevity or improved living condition. In animals generally body parts are numbered. In tapeworm, however, there is an exc ion to this rule for the number of proglottides is not fixed or pre-determined in its embryo. It produces proglottides throughout its life cycle as most plants produce leaves. In most plants the number of nodes and internodes, roots and stem branches, leaves, flowers and fruits containing seeds are not fixed nor pre-determined in the embryo. They are simply being produced from time to time throughout life cycle of the plants. This is an instance of indefinite growth in most plants.

3.4 Growth and Development

So far from the discussion, we can now sum up that growth is a quantitative matter. That means that there is a positive increase in the solid or dry weight and in the amount of protoplasm such that it is measurable with

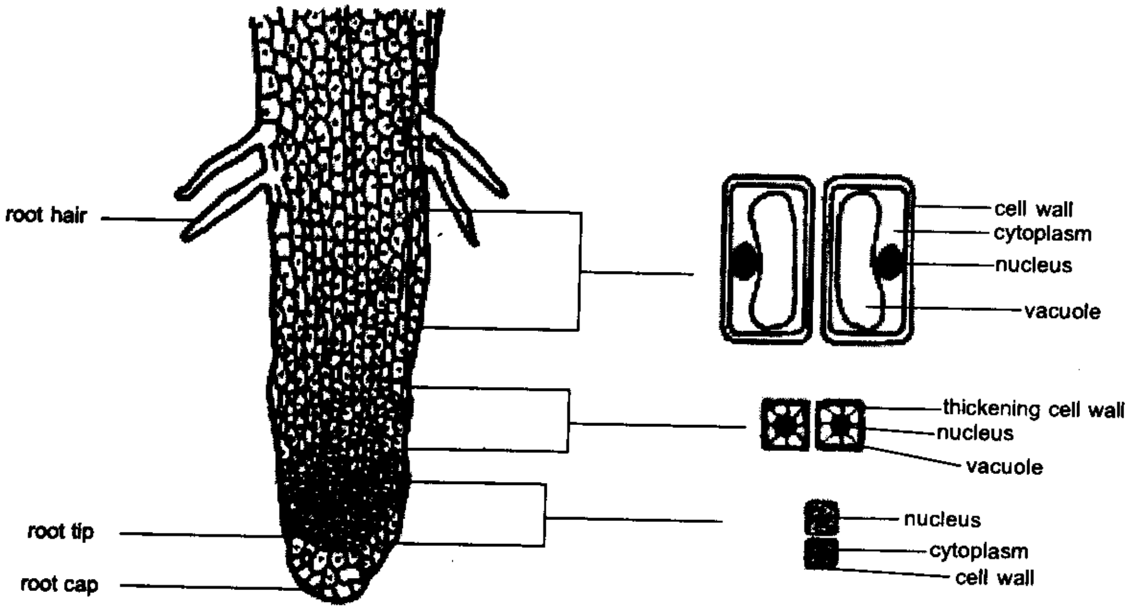


Figure 10.4: A longitudinal section through a root tip area of cell division (meristem) cell enlargement and cell maturation

There is no sharp distinction between the regions of elongation and differentiation. Some of the cells could undergo the two processes at the same time. The cells of the region of elongation have stopped dividing but continue to enlarge, and elongate until they are fully matured.

In the region of maturation, the cells grow by strengthening the walls and differentiating into different plant cells. The differentiated cells form the permanent tissues, such as the parenchyma, some of which form the epidermis of the stems and piliferous layer of roots. The majority of other parenchymatous cells form the cortex of the stems and roots in dicotyledonae while in the monocotyledonae they form the ground tissue of the stems and roots since monocots have no cortex. Some other cells become elongated and taper at both ends and they form the collenchyma and sclerenchyma found among parenchymatous cells in the cortex of dicot stems. From the innermost cells arise the central stele (cylinder) of dicot stems and roots made up of endodermis, pericycle, phloem, cambium and xylem. Some parenchymatous cells form the pith at the centre. Primary growth is restricted to the repetition of the formation of these tissues resulting in the elongation of the roots and stems. This primary growth does not bring about increase in girth or width of roots and stems in dicots because no new tissues are added. The new tissues that are produced, form lateral branches, flowers and inflorescences and are responsible for the elongation of roots and shoots. **Primary growth** is the type of growth in the annuals, biennials, non-woody perennials and monocotyledonae.

Secondary Growth

Secondary growth does not occur in herbaceous annual or biennial plants. It is growth in thickness due to the division of the lateral meristematic cells which are found between the xylem and phloem. They include the cambium which retains the ability to divide mitotically like the apical cells.

In a young woody plant, the cambium is found between the *xylem* and *phloem* of the vascular bundle. As secondary growth occurs, the cambium cells in the vascular bundles will grow radially to link up with the other cambium cells to form a ring of cambium cells within the stem in between the xylem and phloem of each bundle. The cells of the cambium ring can divide to produce xylem cells **inward** and phloem cells a ruler or balance. Most multicellular organisms become more and more complex as growth proceeds. Thus, there is a marked change in shape, form, degree of differentiation and functions.

The qualitative changes in structure and functions that go on side by side with growth in an organism is called development. A maize seedling that had grown for two weeks should have got enough fibrous roots to fix it firmly to the soil, enough leaves to carry out photosynthesis and a height of about twenty centimetres. The measurable aspects of this seedling include the height and number of leaves and roots referred to as the amount of growth while the qualitative changes in the seedling such as the shape and colour of the leaves constitute development. **Growth** is thus **quantitative,** measurable in the increase in the amount of protoplasm while **development** is **qualitative** observable in the changes in nature of growth and function of the organism. For example, good growth and development of a two week old tadpole larva of toad should have attained a length of about 3cm, respire with internal gills and swim with a well formed tail and tail fin. If it still has external gills with such a large body at that age, it will be said to have grown **without development.** So that **growth** and **development** go on hand in hand. Similarly growth and development cannot be separated, they are two processes that have to go side by side at the same time in living organisms.

Isometric growth (equal growth) and allometric growth (unequal growth)

Growth which is the positive and permanent increase in the bulk or size of the organism strictly follows various patterns in different organisms. A germinating seed or stem cutting first develops long root or roots into the soil or any other suitable substratum before producing the shoot or aerial portion of the plant body. While in the stem cutting of yam tuber, a long aerial shoot can be developed before any roots are produced. This is due to the large stored food and mineral salts in the yam tuber. In both plants and animals the *vegetative* and *somatic parts* are first developed before the *reproductive structure*. It is clear that all parts of the living organisms do not grow at the same time. All the parts of the body that grow side by side at the same time show **isometric** growth. The organs or structures in which rate of growth is different from the rest of the parts of the organism are said to show **allometric growth**. The organs or structures concerned with sexual reproduction are the last to develop. At this time the growth rate of the rest parts of the body has been completed. Thus the main body structures of body plants and animals show **isometric growth** while their sexual reproductive organs shows **allometric growth**.

3.4.1 Aspects of Growth

Primary Growth

Primary growth starts from the development of the embryo into the seedling. This is the growth that forms the main ground tissue of the plant body. It is also the growth that gives rise to the **primary root** and shoot which continues in the root and shoot apices to develop the main tissues of the plant. It consists of the mitotic cell divisions of the meristematic cells of the root and shoot tips in apical growth and the lateral buds in the intercalary growth.

The growth of plants is restricted to special regions known as **meristems** which may be **apical, lateral** or **intercalary**. The cells at the apex of roots and stems are meristematic cells which are constantly dividing and producing more cells. Behind these cells, are cells which are in a state of **elongation** and **maturation** and are differentiating into **vascular tissues, epidermis, parenchyma** and **sclerenchyma cells**.

Thus, the tip or a growing point of a stem or root can be divided into three regions; a region of mitotic cell division followed by **a region of cell elongation** and then a **region of cell maturation** and **differentiation**. This is the same for roots and stems. see fig. 10.4

outside. During secondary growth, the cambium grows to form a ring, connecting all the vascular bundles together. The cambium ring then begins to produce both secondary xylem and secondary phloem tissues.

Outcome of Secondary Growth

Secondary growth gives rise to new xylem tissues on the inner side of the cambium and new phloem tissues are added to the tissues formed during primary growth in the first year. The new xylem is pressed against the older xylem towards the pith. Thus the cells of the older xylem (protoxylem) look crushed. Their lumens are greatly reduced as a result. The new phloem tissue formed is pushed outwards exerting pressure on the older phloem towards the periphery of the stem. At this time a cork cambium is formed just below the epidermis from some cells of the cortex in stems of dicot. The **cork cambium** becomes meristematic, dividing to form **secondary cortex** to the inside and **cork cells** to the outside. The cork cells become dead and impermeable to water to form the **bark** of the stem. In some areas of the bark, openings called **lenticels** are formed, through which respiratory gases are exchanged.

Primary growth is the main growth in the first year in the tropics and first growing season in the temperate regions of the world. Secondary growth starts in the second year. In each growing season cambium produces **a ring of xylem** towards the inside of the stem and **a ring of phloem** towards the outside of the stem. This is referred to as an *annual ring* to **growth ring**. Annual rings or growth rings can be counted to determine the age of the plant since a ring of growth is formed every year. Annual rings are very conspicuous in temperate trees because of the distinct summer and winter.

Activity A

1. In your own words, briefly explain the three major basis of growth
2. Write short notes on the following types of growth
   i. Intercalary growth
   ii. Limited and unlimited growth
   iii. Definite and indefinite growth

3.5 Measuring Growth

Growth is quantitative and measurable so that the amount of growth achieved by plant can be expressed. The known and widely used measures or indices of growth include;

1. Height or length increase of the stem, root and any other organs of the plant.
2. Increase in the girth or circumstances of the stem
3. Increase in the area of leaves
4. Increase in weight and
5. Increase in number of stem branches.

The foresters and timber collectors are interested in the increase in height and circumference of the stems of forest trees. The practical farmers are interested in the increase in the volume of fruits and increase in the fresh weight of vegetable leaves, stem and root tubers. The practical teacher and research students are interested in the increase in length of root and shoot of young seedlings and increase in number of individuals in a population. **The amount of growth achieved by a seedling at 24 hours interval over a known period of time represent the rate of growth.** The increase in height (mm) can be plotted on a graph over time intervals (days). The rate of elongation or height growth is seen to vary from individual to individual and from species to species. The graphs are the same. In all cases, the rate of growth is at first slow, then rises up to a point and continues at this rapid rate until maturity, when it declines. The graph shows a typical **S-shaped** curve called *sigmoid* growth curve. The sigmoid growth curve is characteristic of all living organisms.

It is the typical growth curve for the whole plant as well as for its individual organs.

3.5.1 Measurement of Length Increase in a Root

Measurement of length increase in a root can be carried out using germinated bean seeds. Bean seeds germinated on wet cotton wool in test tubes are ideal for this exercise. Seedlings that have straight roots are selected and those that are with 3cm long roots are used for the experiment. The roots are marked with black Indian ink 1cm away from the cotyledons to the tips at equal distance of 2mm intervals. The seedlings are carefully returned to the moist cotton wool in the test tubes for them to continue their growth. Rolls of filter papers should be used to hold the seedlings up in vertical position to keep the roots straight up. Each day for 10 days, the following measurements should be recorded and their curves plotted.

1. Daily length increase of whole roots
2. Daily length increase of the individual zone
3. Average growth rate of each zone. Another important aspect of this experiment is the distribution of growth over the whole root.

Length Increase of Roots of Germinating Bean

About 4 to 5 zones away from the cotyledons remain unstretched while 4 zones towards the root tip widened and the ink marks move further away from each other. In addition to length increase the distribution of growth in the root is revealed. The growing region is in the portion few **millimeters away from the root tip**. Growth is fastest in the zone next to the root tip. At the end of the experiment all the seedlings should be assembled for comparision of length increase and distribution of growing areas.

3.5.2 Measurement of Height Increase of a Whole Stem

The height increase of a whole stem from germination to death of certain annual food crops can be measured using maize, peas, okro and rice. A suitable apparatus for this exercise should be a specially constructed metre rule of about 2m long and clearly marked in water-proof black ink on a white background. This can be conveniently handled by students and their teachers as measurement are obtained directly without mathematical interpretation. An experimental ground is prepared and maize, peas, okro and rice are sown at their real planting season on different plots marked out for them. Measurement of height growth of their stems starts as soon as they emerge from the soil and hence forth, daily measurement is taken until growth diminishes or stops when the plant dies.

3.5.3 Measurement of Growth of Organism by Dry Weight Method

The dry-weigth or solid weight of organisms is the measurement of the amount of living substances (protoplasm) formed during growth in the organisms. The dry-weight is all that is left after the organisms have been dried in the oven until all the water in them has been removed. The inevitable disadvantage of this method is that the organisms are killed in the process. It is the most accurate and reliable method of measuring the amount of growth achieved by living organisms. In this method, the organisms are collected, killed by method, and placed in the oven to dry. They are weighed at short intervals and recorded. When the weight becomes constant over many intervals, the dry weight is got and the drying is stopped. The moisture or water contained in the organisms is driven out because it is not considered as growth achieved by the organisms. The total weight, the amount of protoplasm formed and the water in it constitute fresh weight. Fresh weight is not reliable because it changes freely but growth is an irreversible increase in size, volume and weight.

Activity B

Explain two growth parameters (indices) that are used to measure the growth of a plant.

3.5.4 Factors Influencing Growth

Organisms are derived from other organisms through the processes of asexual or sexual reproduction with sets of genes inherited from their parents. The pattern and rate of growth, quantitative and qualitative, depend partly on these inherited genes and partly on the conditions of the dynamic external world. The living organisms are always the products of heredity and environment. Environmental factors usually influence growth and growth rates in a number of ways. Such factors of the external environment include; temperature, light, water, and mineral salts (nutrients).

Temperature

Temperature has a profound effect on growth. Enzymes act best at a particlar range of temperature. At an optimum temperature the metabolic activities are increased leading to a faster growth. Above and below optimum temperature, enzymatic activities are reduced leading to reduced growth. And in extreme cases death may result.

Light

Light is important for photosynthesis in green plants. Together with water, carbon (IV) oxide plant food is manufactured. With the availability of food from photosynthesis, growth occurs in plants.

Food

Green plant manufactrue their own food through the process of photosynthesis. Directly or indirectly animals and non-green plants depend on the food manufactured by the green plants. In all cases when anabolism (building up process), exceeds catabolism (breaking down process) growth occurs.

Oxygen

Most plants and animals are aerobes meaning that they require molecular oxygen to carry out aerobic repsiration to release sufficient energy for growth and other vital functions. Seeds and fruits require oxygen among other conditions to germinate. Eggs require oxygen for the growth of the embryo leading to hatching hence the provision of air cavity or space in eggs.

Carbon (IV) oxide

Carbon (IV) oxide is required by green plants to carryout photosynthesis. The Carbon compounds formed during photosynthesis are used for respiration, growth and food supply to embryos in seeds, fruits, buds, and roots. Animals depend on plant food for growth and other metabolic activities.

Water

Seeds and fruits require certain amount of water to germinate. Water in cell sap, protoplasm, blood and interstitial fluid forms the medium in which mineral salts, organic compounds, digested foods, hormones essential for growth are absorbed and transported inside plants and animals. All enzymes controlled activities including the synthesis of new, protoplasm, an esential feature of growth are influenced by water availability. Cell enlargement and elongation during growth in roots and shoots is achieved by water filling the newly divided cells. Vacuolation and maintenance of turgidity in young growing organs is dependent on water availability. Scarcity of water leads to drooping of leaves and when prolonged, wilting and finally death of plants result. Water availability is essential for fresh weight increase in plants and animals and this is of interest to farmers. The availability of water is directly responsible for the seasonal growth in plants and in animal populations. Dead body of plants and animal decay faster in the wet season than in the dry season. It is by decay of **organic matter** that **humus** essential for plant growth is returned to the soil. It is interesting to note that water builds life and water destroys life.

Internal Factors

1. Genetic constitution

Every species has its own peculiar genetic constitution which determines the rate and pattern of growth, size (quantity) and quality of growth of its members. There is a particular size, height, girth and number of parts that can be developed by a growing plant, beyond which it cannot grow no matter the other suitable environmental factors that may be provided. Genetic constitution sets the limit of quantitative and qualitative growth in plants and animals, and environment may only influence it in some ways. The maize plant cannot grow as tall and as big as an oil palm tree, nor can the rat grow as big as a deer no matter the favourable environmental conditions available to them. Every individual organism is the product of genetic constitution and environmental condition.

Hormones

Plants and animals have been known to produce susbtances that are capable of promoting and inhibiting their growth and development. These substances are called **plant hormones** in the plants and animal hormones in the animal. Their under secretion and over-secretions have been known to result in abnormal growth. In the plants, **plant hormones** or **phytohormones** are produced in the root tips and shoot apices from where they are transported to areas where they control growth. Some of the known plant hormones are **auxins, gibberellins, cytokinins** and **ascorbic acids**.

Auxins bring about their growth effects by promoting or inhibiting cell elongation in stems and roots. They also stimulate cell division.

The main effect of gibberellins is to promote cell elongation and bring about growth in stem. They also affect cell division and cell differentiaion to a certain extent.

Activity C

Explain three factors that affect plant growth.

3.6 Growth Movement

Growth movements may be spontaneous and self-controlled (autonomic) or they may be induced by external stimuli (paratonic). Paratonic are further classified as tropism or nastism (or nastic movements).

3.6.1 Nastism or Nastic Movement

Nastism is a type of response in which a part of a plant moves in response to non-directional stimuli such as changes in light intensity, temperature or humidity.

The response movements are also non-directional. Examples of nastic movements are;

i.) Closing of the morning glory flower when the light intensity is low.

ii.) The petals of sunflower which open in the light and close in the dark.

iii.) The folding of the leaflets of the mimiosa plant when it is touched.

iv.) The closing of the leaflets of the flamboyant tree i.e. sleeping movements due to low light intensity.

3.6.2 Tropism or Tropic Movement

Tropism is a type of response in which a part of a plant moves in response to a directional stimulus. The direction of the response is related to that of the stimulus and is **positive** if the plant part grows towards the stimulus, and **negative** if the part grows away from it.

Tropism are very slow growth movements. They are named according to the stimuli, e.g. phototropism is a response to light while hyrotropism is a response to water.

Examples of Tropic Responses

Stimulus	Names of response	Examples
(i) Light	Phototropism	Shoots of green plants bend towards light (positively phototropic) while roots bend away from it (negatively phototripic)
(ii) Gravity	Geotropism	Shoots of green plants bend away from gravity (negatively geotropic) while roots bend towards it (positively) geotropic).
(iii) Water	Hydrotropism	Roots bend towards moisture (positively hydrotropic), while shoot bend away from it (negatively hydrotropic)
(iv) Touch	Thigmotropism	Tendrils of a climbing plant twine around a support (as a positive response totouch), while root tips grow away from it (as a negative response to touch).

Activity D

Briefly give the nature of response and examples of the following stimulus

i. Light
ii. Water
iii. Gravity

3.7 Similarities of Growth in Plants and Animals

1. Both multicellular plants and animals grow by mitotic cell division of pre-existing cells to form new cells.
2. Both achieve a certain amount of vegetative or body growth before reproductive growth sets in.
3. Both show sigmoid growth curve in which the rate of growth is slow at first, becomes faster later until the maximum is reached, then growth rate starts to decline.
4. Both plants and animals require food for growth.
5. Both secrete growth hormones for growth.
6. Growth is irreversible in both plants and animals.

Table 10.2: Differences between growth in plants and animals

Plant	Animal
1. Growth in plants is restricted to special areas as the meristemic tissue at the root tip and shoot apices.	Growth in animals is not restricted to specific areas instead it takes place all over the body.
2. Growth is continuous throughout life in the growing regions.	Growth is not continous throughout life in most animals. However, animals such as lobsters and fishgrow throughout life even though growth reduces at old age.
3. Growth in plants is directly influenced by such external factors as sunlight, temperature, humidity, gravity etc.	Growth in animal is usually not directly influenced by such external factors.

Conclusion

Development of a plant cannot occur without growth. Growth being an important characteristic of living organisms, help the organisms to increase in size and to fully utilise the available food in order to make new cells. It can be concluded here that reproductive growth of any living organism can only set in after that organism may have achieved a certain amount of vegetative or body growth.

Summary

In this unit, we have learnt that;

1. Growth is one of the characteristics of living organisms and that it is an irreversible increase in size following the utilisatoin of food to make new or additional protoplasm within the body of an organism.
2. The basis of growth involves three major processes namely; (i) cell division (ii) cell enlargement (iii) cell differentiation.
3. A meristem is a tissue that retain the ability to divide by mitosis and turn out new cells.
4. Growth which occur at the meristem of the base of internodes is called intercalary growth.
5. Most animals show definite growth while most plants show indefinite growth.
6. Primary growth start from the development of embryo into the seedling.
7. Secondary growth does not occur in herbaceous annual or biennial plants.
8. The growth parameters that are used to measure growth in plants are; mass, length, height or width and area or volume.
9. The external environmental factors that affect plant growth are temperature, light, water and mineral salts (nutrients). While the internal factors include genetic constitution and hormones.
10. Tropic movements include phototropism, Geotropism, hydrotropism.

Tutor - Marked Assignment

- Briefly explain external factors that affect plants growth.
- List at least three similarities and differences each between growth in plants and animals.

7.0 Further Reading and Other Resources

Idodo - Umeh (1996) *College Biology*
Sarojini T. Ramalingam (2001) *Modern Biology*
A. C. Dutta (1979). Degree for Degree Students
Essentials Biology

Volume 3: Regulatory Systems and Mechanisms

Unit 1: Regulatory Processes

1.0 Introduction

Organisms are made up of cells which are embedded in body fluids. Body fluids include blood, lymph and tissue (intercellular) fluids. These fluids form the internal environment of organisms, which must be kept fairly constant if proper growth, health and efficient performance of the cells are to be achieved. Maintenance of constant internal environment is called **Homeostasis.**

2.0 Objectives

At the end of this unit you should be able to;

a. Explain homeostasis and homeostatic process

b. Describe the regulation of body temperature

c. Explain regulation of Muscular movement and

d. Regulation of hormone production.

3.0 Homeostasis

The environment of an organism is an aggregate of all the physical, chemical and biotic conditions, under which it exists. The internal environment is made up of conditions created by the inside of an organism, by virtue of its metabolism and reactions to external changes and behaviour. The organism is faced with the problem of fluctuation, and for this reason, the inside of an organism has to be in a state of homeostasis or constant condition, maintained by specific regulatory processes. These processes include the maintenance of a constant body temperature and osmoregulation in animals. Thus, the maintenance of a constant internal environment in spite of changing external conditions is homeostasis.

The conditions in which body cells function properly are narrow.

Changes in osmotic pressure, temperature and amount of chemical substances can disrupt the biochemical activities in cells and kill them.

The internal environment is the immediate surrounding of cells, which is filled with fluid called**tissue, intercellular or interstitial fluid.**

Tissue fluid is formed by ultra-filtration of small molecules and ions from larger molecules and cells.

Pressure from the heart forces the fluid out of capillary walls into the spaces and finally drained into lymph vessels.

Materials which need to be kept constant include glucose, ions (Na^+, K^+, Cl^-, $0H^-$ etc)

Osmotic pressure through amount of water,

Level of $C0_2$ and Temperature

The process of keeping these constant is known as homeostasis.

[illegible]

i. What is homeostasis?

ii. Why is homeostasis important to organisms?

iii. List the materials to be kept constant by the body.

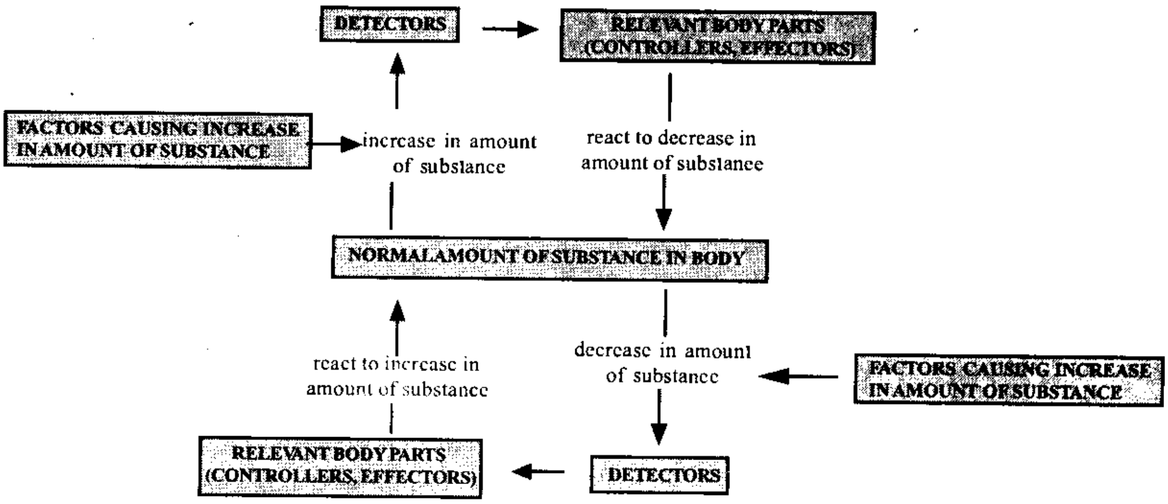
Homeostatic Processes

Regulatory processes are used to [illegible] and adjust changes in internal [illegible] of organisms.

It involves a ***sensory detector*** which [illegible], therefore, stimulates the [illegible] of the body that is responsible for controlling the change.

The parts stimulated receive the signals, interpret them and send out instructions to the exact *effector organs or glands* to react and return the body to normal state. These types of control processes are called homeostatic processes (fig. 1.1).

Fig. 1.1 Control processes of Internal environment



Source: Modern Biology, Pp. 374

Activity B

i. Briefly explain the term homeostatic process?

ii. Study fig. 1.1 carefully, noting the direction of the arrows, and most importantly factors causing increase or decrease in amount of substances and how the detectors and effectors normalise the amount of substances in the body. Now attempt to reproduce the above diagram without copying!

3.1 Regulation of Body Temperature

Birds and mammals regulate body temperature and are therefore, thermostatically said to be **homoiothermic** (warm-blooded) while other animal groups have their body temperature varying with that of environment and are said to be **poikilothermic** (cold blooded).

Homoiothermic animals control temperature in two ways, firstly, through regulation of amount of heat produced in the body and control of heat loss from the body. Secondly, through changes in environmental temperature-sensitive centre of the brain, which subsequently triggers mechanisms of homeostasis. Heat released in the body is through respiratory activities. Respiratory activity in the presence of sufficient substrate and oxygen is controlled by hormones such as thyroxin, adrenalin glucocorticoids, insulin, glucagon and somatotrophin. These hormones control heat generation under different conditions.

Activity C

i. Explain the following words - Homoiothermic and poikilothermic.

ii. How is temperature controlled by mammals?

3.2 Regulation of Muscular Movement

There are three types of muscles; these are cardiac, voluntary (striated/skeletal) and involuntary (unstraited/ visceral). Voluntary or skeletal muscles, except the tongue, are attached to skeleton by tendons.
Among muscle fibres are sensory organs whose nerve endings are sensitive to the degrec of contraction of fibres. Sensory organs send impulses to the brain. In the brain, impulses are coordinated and responses are relayed through motor nerves to muscles fibres. At end plates, acetylcholine is released to depolarize the membrane of muscle fibres. This increases permeability to ions. An action potential is initiated and the muscle fibre contracts.

i. Watch video clips on Types of muscles/ muscles in action.
ii. List the types of muscles that you know and give examples
iii. Explain how the brain receives and sends impulses to the muscle.

3.3 Regulation of Hormone Production

The hypothalamus of the brain controls most of the endocrine system. It has nervous connections to all parts of the brain and therefore, receives all information of internal and external origin. Hypothalamus acts by sending long autonomic nerves to target regions by secretion of hormones into pituitary body (Neurosecretion) and by sending releasing factors, which stimulate the pituitary to secrete hormones.

Neurosecretion occurs through neurons whose axons pass through the pituitary stalk into the pars nervosa and end in small swellings. Droplets of hormones pass along the axon. Important hormones secreted this way include vasopressin and oxytocin. Vasopressin causes rise in blood pressure and has an antidiurctic effect as well. Oxytocin causes contraction of the uterine wall during child birth and contraction of mammary alveoli to force milk out of the nipple.
Pars anterior produces about six hormones, which are transported to the pituitary body through the **hypothalamus hypophygial portal system.**
Other hormones from the pituitary include somatotropin, which is a growth hormone; thyrotropic hormone that stimulates the thyroid to release thyroxin; the adrenocorticotropic hormonc that stimulates the release of corticoid hormones and the gonadotropic hormone from pars anterior, which stimulates sex organs to release the appropriate sex hormones.

Activity E

i. Where is the hypothalamus situated?
ii. What does it do to the pituitary gland?
iii. List the functions of vasopressin and oxytocin
iv. Give the names and functions of hormones produced by the pituitary.

In this unit, you have learned the regulatory processes in animal. You should be able to explain Homeostasis and Homeostatic process, and suggest reasons why maintenance of internal environment is important. You should be able to explain regulations of body temperature, muscular movement and hormone production.

* Homeostasis is the process of keeping the internal environment constant. Homeostatic process involves detection (by sensory detectors) and adjustment (by effector organs or hormones) to changes in internal environment.

* Birds and mammals are homoiothermic while other animal groups are poikilothermic. Warm-blooded animals control body temperature in two ways. Heat released in the body is through respiratory activity, which is controlled by various hormones.
* In mammals, three types of muscles are involved in muscular movements these are cardiac, voluntary and involuntary muscles.
* Hormone production is regulated by the hypothalamus of the brain, which secretes hormones into the pituitary body.

The pituitary secretes and controls several hormones such as vasopressin, oxytocin, thyrotropic, adrenocorticotropic, and gonadotropic.

6.0 Tutor - Marked Assignment

i. Define homeostasis?
ii. Why is it important in birds?
iii. Briefly explain how mammals regulate their hormone production.

7.0 Further Reading and Other Resources

S. T. Ramalingam 2001. *Modern Biology* edition published by Africana - Feb. Publishers Ltd.,
M. B. V. Roberts Biology - *A Functional Approach*, ELBS Edition.
G. Idodo-Umeh *College Biology* 2nd edition, Idodo - Umeh Publishers, Ltd., Benin City
Video clips on "Types of Muscles/Muscles in action" A NOUN Production.

Unit 2: The Mammalian Liver

Page

1.0 Introduction

The liver is a large reddish-brown organ which lies on the right side of the body just below the diaphragm, partly overlapping the stomach. It is about 3-4% of total body weight. Blood supply to the liver is excellent and it is the body's metabolic centre.

The liver performs several functions including homeostasis. It screens the food present in the blood which is transported from the small intestine; it adjusts its content to satisfy the body's immediate requirement, before releasing it into the circulatory system. Inspite of the functions of the liver, there are several diseases associated with it.

2.0 Objectives

By the time you complete studying this unit, you must be able to;

a. Discuss the structure of the liver,

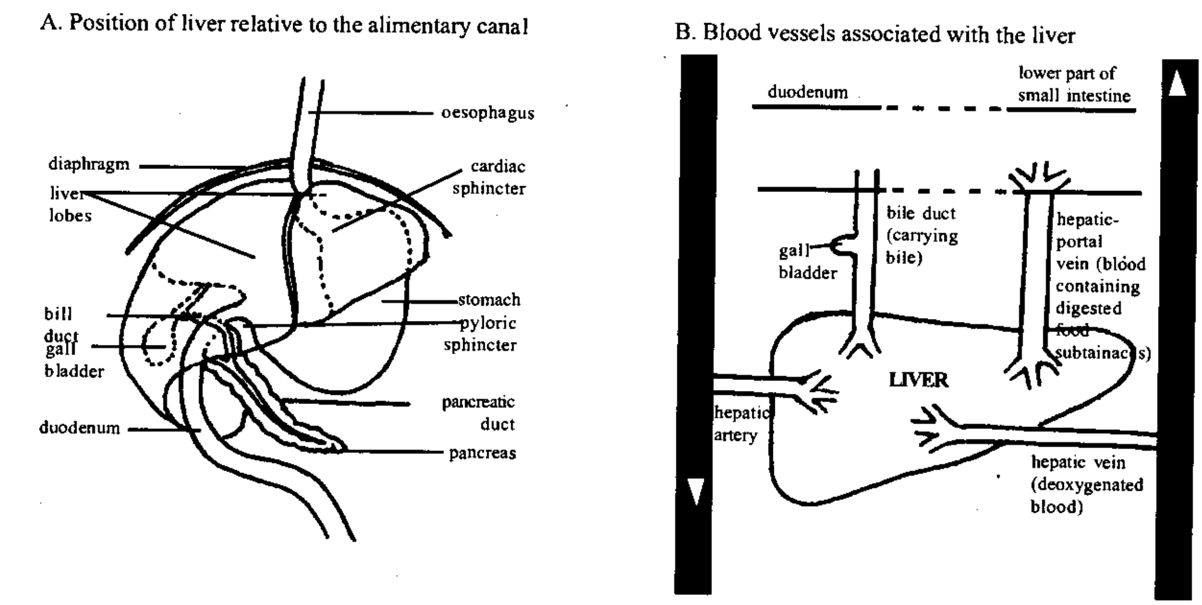
b. Summarize the functions of the liver and

c. Explain the disease of the liver.

3.0 The Mammalian Liver

The liver is a reddish-brown organ which partly overlaps the stomach. The cells of the liver secret an alkaline greenish fluid called bile, which is stored in the gall bladder, attached to the right lobe of the liver (fig. 2.1). The bile stored in the gall bladder is passed into the duodenum (for emulsification of fat) through the bile duct (see unit 9).

(Fig. 2.1) Liver: it's position in the body and it's blood supply.



Blood supply to the liver is through two major blood vessels:

a. The **hepatic artery**, which brings oxygenated blood from **dorsal aorta**

b. The **hepatic portal** vein, which brings blood from the **gut**.

The liver distributes products through veins. Its functions are carried out by liver cells, which have numerous mitochondria and prominent golgi apparatus. Microsocopic examination of the liver shows a close association between liver cells, blood vessels and bile channels. It contains lobules, which are roughly hexagonal in shape; each lobule is filled with liver cells arranged in rows radiating from the centre toward the periphery. On the sides of lobules are branches of the hepatic artery, portal vein and bile duct (fig. 2.2). The branches of the hepatic and portal veins are called **interlobular blood vessels**.

The whole of this lobule is filled with radiating rows of liver cells, canaliculi and sinusoids as shown in B

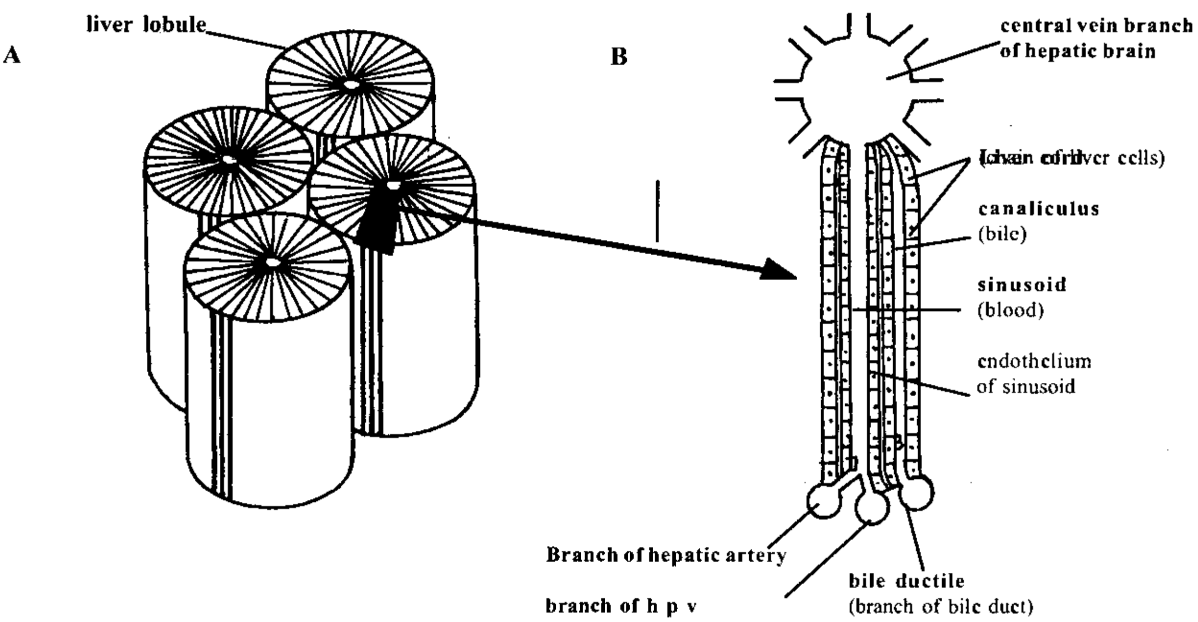


Figure. 2.2. Structure of a liver lobule. The liver is made up of numerous lobules, cylindrical in shape and approximately 1mm in diameter. There is an intimate relationship between the liver cells, sinusoids and canaliculi. In (B) the arrows indicate the flow of materials to and from the liver cells. What precisely do arrows 1, 2 and 3 represent? ***hpv*** *stands for hepatic portal vein.*

Source: Biology - A functional Approach by M.B.V. Roberts PP 209

Activity A

i. Watch the video display of (a) preserved (b) live specimen of the liver with the associated blood vessels
ii. Briefly describe the location of the liver
iii. Give the names of the two most important blood vessels associated with the liver and state their functions.

3.1 Functions of the Liver

1. Regulation of Sugar

Through the agency of insulin, the liver removes or adds glucose to the blood. In the liver cell glucose is converted to glycogen for storage or broken down to produce CO_2, water and energy. Excess glucose is converted to lipids.

2. **Regulation of Lipids**
The liver cells remove lipids from the blood and either break them down or modify them and send them to the fat depots.

3. **Regulation of Amino acids**
The body does not store excess protein or amino acids; excess is destroyed by the liver in a process called **deamination.** In the process, the amino (NH_2) group is removed and ammonia is formed. This is very toxic in small concentrations so it enters into reactions called **ornithine cycle** in which it reacts with $C0_2$ to form urea. This is finally removed from the blood by the kidneys.

4. **Heat Production**
Because of the numerous reaction occuring in the liver, much heat is produced. The liver therefore regulates body temperature by its blood network conveying heat to other parts of the body.

5. **Bile Production**
Liver cells produce bile by the destruction of red blood cells; it is stored in the gall bladder. Bile is conveyed through the bile duct to the duodenum. Bile salts play an important role in the**emulsification** of **fat**.

6. **Cholesterol regulation**
Cholesterol is a fat derivative of cell membranes especially nerve cells. Excess is excreted in bile and therefore, crystallizes as gall stones. The bile duct is blocked by bile stones leading to obstructive jaundice and skin becomes pale due to **bilirubin** accumulation in blood. Excess in blood blocks arteries leading to intra-vascular clot. If it occurs in the coronary vessels it leads to coronary thrombosis or heart attack. Cholesterol removal therefore, is an important function of liver.

7. **Elimination of Sex Hormones**
The liver converts sex hormones into other substances which are later removed by the kidney in renal excretion or through bile.

8. **Red Blood Cell Formation**
Red blood cells of the foetus are produced by the liver. In adults, the liver produces **Haematinic principle** needed for the formation of the blood cells in the bone marrow. The liver produces the principle under the agency of vitamin B_{12}. Deficiency of the principle leads to **pernicious anaemia** characterised by reduced haemoglobin level.

9. **Blood Storage**
Since veins in the liver have a high power of expansion, they store blood up to 1500cm^3, the liver, therefore, acts as a reservior for blood.

10. **Plasma Protein Formation**
The liver produces plasma protein including fibrinogen, albumin and globulin.

11. **Storage of Vitamins A, D and B_{12}**, as well as potassium, iron, and copper

12. **Detoxification**
This involves conversion of foreign substances into harmless forms such susbtances may be drugs, alcohol, food addictives and atmospheric pollutants.

By all these functions, the liver regulates both the physical and chemical conditions of the internal environment. It is therefore, a homeostatic organ.

Activity B

(i) list eight functions of the liver

3.2 Some Diseases of the Liver

a. **Jaundice:** This is caused by an increase in the blood bilirubin level, leading to paleness of the skin and whites of the eyes. Jaundice is due to three reasons.

i. Breakdown of large number of red blood cells, which leads to the formation of large amount of bilirubin. This may occur during a malarial bout (especially in new born babies) and in the disease called sickle-cell anaemia (which is inherited defects of the red blood cells).

ii. Blocking of bile ducts by gall stones. The stones prevent the bile from emptying into the intestines, thus leading to increase in blood level of bilirubin.

iii. Damage of the liver cells reduces their ability to extract bilirubin from blood to form bile. This raises the blood bilirubin level.

b. **Gall Stones:** These are formed in the gall bladder or bile ducts, and are made up of cholesterol. Gall stones obstruct the flow of bile and increase infections of the gall bladder, bile ducts and liver. This lead to enlargement of the gall bladder.

c. **Viral Hepatitis:** It causes enlargement and destruction of liver cells. Viral hepatits is caused by two types of viruses by (i) an infective hepatitis caused by virus type A and (ii) serum hepatitis caused by virus type B.

d. **Amoebic liver abscess:** This is cause by a parasitic amoeba called *Entamoeba histolitica*, which also causes dysentry. This parasite invades the liver from large intestine through the hepatic portal vein. The parasite produces an enzyme that damages liver tissues and causes formation of an abscess.

e. **Cirrhosis:**
In this case, the damaged liver cells are replaced by useless fibrous tissue which makes the liver to be firm and irregular. This disease is associated with excessive consumption of alcohol over a long period, and by hepatitis.

Activity C

i. Write short notes on the following; Jaundice, Gall stones, viral hepatitis, liver abscess and Cirrhosis

ii. If your blood level of bilirubin is found to be high, what reasons would you associate with this?

4.0 Conclusion

In this unit, you have studied the liver, its functions and diseases. Therefore, you should be able to describe the position of the liver in the body relative to the intestine, the important blood vessels of the liver and their functions, and various diseases that affect the liver.

5.0 Summary

The liver is a homeostatic organ, its functions include regulating nutrient level in blood. Other specific functions include regulation of sugar, lipids, proteins, heat production, bile production, elimination of sex hormones, red blood cell formation, blood storage, plasma protein formation, storage of vitamins and detoxification.

6.0 Tutor - Marked Assignment

i. Draw an annotated diagram showing the association of the blood vessels with the liver (15 mks).
ii. List five functions and five diseases of the liver (10 mks).

7.0 Further Reading and Other Resources

M.B.V. Robert. *Biology - A Functional Approach ELBS edition*
S. T. Ramalingam 2001. *Modern Biology*, edition published by Africana - Feb. Publisher Ltd.
G Idodo - Umeh. *College Biology* 2nd edition; Idodo - Umeh publisher, Ltd., Benin city.
A video display of the mammalian organs (e.g. Liver) with the associated blood vessels.
A NOUN production

Unit 3: The Mammalian Kidney

1.0 Introduction

Kidneys are two reddish brown; bean-shaped organs located in the dorsal part of the abdominal cavity on either side of the vertebral column.
The kidneys (like the liver) have several functions including homeostasis! It is responsible for the removal of nitrogeneous waste, control of amount of water, salts (sodium, potassium and chloride ions), acids and osmoregulatory functions. Irrespective of these functions, the kidneys can be damaged by diseases, poisons and physical injuries.

2.0 Objectives

At the end of this unit, you should be able to:
a. Describe the structure of the kidney
b. Discuss the functions of the kidney and
c. Summarize the diseases of the kidneys.

3.0 Structure of Mammalian Kidney

There are two bean-shaped kidneys, one on each side of abdomen. Each contains 1-2 million nephrones. The kidneys are on the body wall of the lumbar (upper) region of the abdomen and are held by fatty tissue. Above each kidney is the adrenal gland. Kidneys are connected to the urinary bladder by the ureters. Blood supply is through the renal artery. The reddish brown kidneys are covered by a tough, transparent membrane called the capsule. The ureters arise from the depression of the kidneys called the **hilum** (fig. 3.1). A longitudinal section shows the outer cortex, inner medulla and triangular-shaped tissue called pyramid, which opens into a broad cavity called the **pelvis** (fig. 3.2).

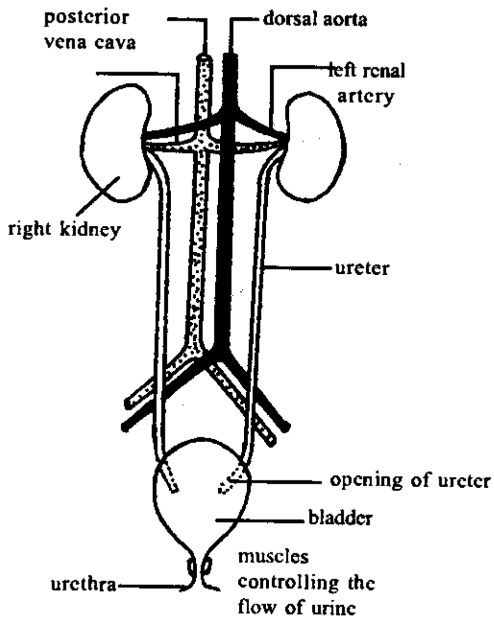


Figure. 3.1 Kidneys of mammal: Human

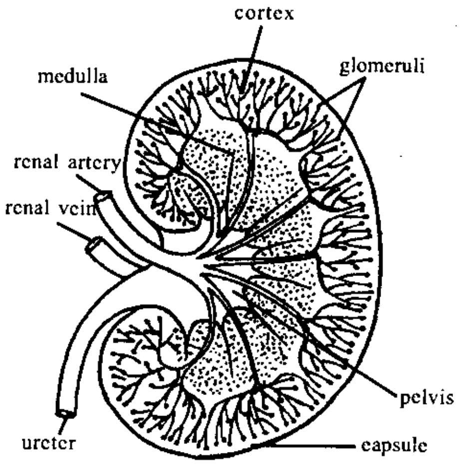


Figure 3.2: Longitudinal section through Kidney

Excretion is carried out in the **Malpighian body** (fig. 3.3) which is found in the **cortex** and consists of **Bowman's** capsule and the **glomerulus**. Blood that is brought into the glomerulus contains water, urea, nitrogenous waste, mineral salts, sugar and plasma solutes. The diameter of the renal artery entering the glomerulus decreases thereby increasing pressure within the glomerulus. The pressure forces out urea, other nitrogenous material and water; salts are filtered out into capsular as glomerular filtrate except the blood cells and proteins, whose diameters are too large to filter through. This process of filtration under pressure is known as **ultra-filtration**.

The filtrate moves through the proximal convoluted tubule where glucose and water are reabsorbed, while only water is reabsorbed in the loop of Henle. The filtrate becomes more concentrated as salts are reabsorbed by the distal convoluted tubule.

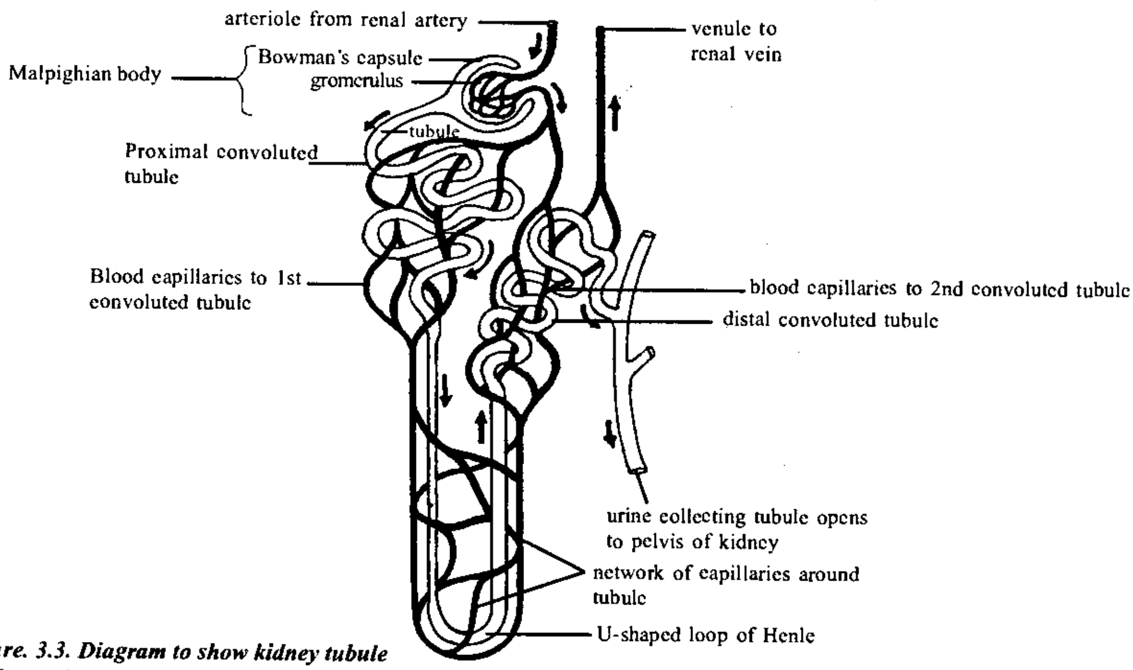


Figure. 3.3. Diagram to show kidney tubule (or the nephron)

Apart from their function as excretory organs; the kidneys also carry out the function of osmoregulation. They regulate the osmotic concentration of the blood plasma and in doing this, keep the environment around each cell fairly contant. This is very important because fluctuations in osmotic concentration will lead to serious consequences. When the concentration of salts in the blood is higher than that of the cells, water is drawn from the latter, leading to shrinkage, which may result in irreversible damage. On the other hand, when the osmotic concentration of the cells is higher, water is withdrawn from the blood leading to abnormal swelling of the cells. The osmotic concentration of the blood is determined by the quantities of sugar, sodium chloride, mineral salts, amino acids and some other solutes it may contain. When the concentration of these solutes is high, the kidneys reduce their amount by removing some of them (fig. 3.4). When the concentrations are low, the kidneys would remove more water from the cells thereby raising the concentration of the solutes to their normal levels.

The kidneys also maintain the acid-base balance of the body. They excrete acid to prevent loss of base.

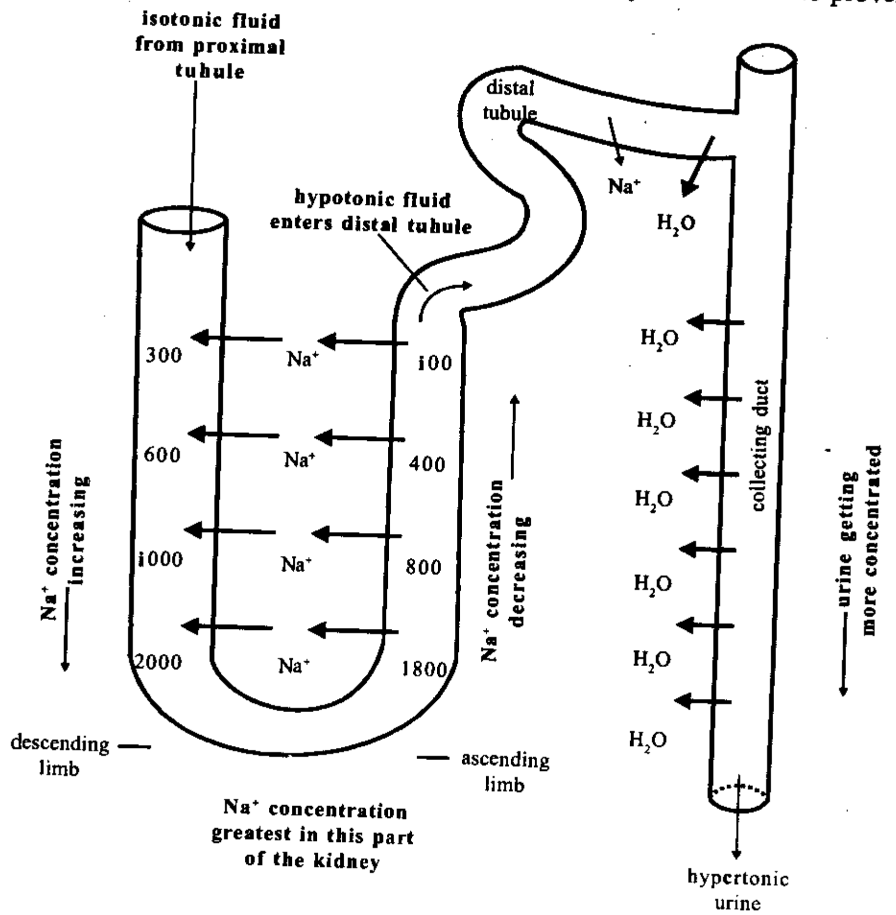


Figure 3.4 Reabsorption in the loop of Henle. The figures in the descending and ascending limb refer to the Na+ concentration in milliosmoles per kilogramme of water. At each level sodium ions are actively transferred from the ascending limb to the surrounding tissue, whence they diffuse into the descending limb. The ascending limb, thicker walled than the descending limb, is impermeable to the outward movement of water, so water does not move with the salt, as happens in the proximal convoluted tube. The result of this continual movement of sodium ions is to build up a high salt concentration in the medullary tissue of the kidney. The salt concentration is highest towards the apex of the loop, i.e. in the deepest part of the medulla close to where the collecting ducts open into the pelvis. In moving from the ascending to the descending limb the salt passes through the medullary tissues, including the blood vessels. This, together with their U-shaped arrangement, ensures that the high salt concentration in the medulla is not rapidly dissipated. [illegible] high salt concentration in the medullary tissue results in water being drawn out of the collecting ducts by osmosis. Recent [illegible] suggests that urea-retention may also play a part in building up a high osmotic pressure in the deeper part of the medulla.

Source: Biology-A functional Approach by M.B.V. Roberts

Activity A

i. Take your reference Text book(s) and/or watch the video recordings on "The mammalian organs. With the aid of these materials draw:

a. The kidneys of a mammal and associated blood vessels, Ureter, bladder etc.

b. The longitudinal section through the kidney

ii. The functional unit of the kidney is called the nephron. Describe how it carries out its excretory and osmoregulatory functions.

3.1 Functions of the Kidney

* Excretion by filtering out waste products such as urea, water and salt whose excess would be poisonous to cells.
* Osmoregulation is carried out by the kidneys through the reabsorption of glucose, water and salts, depending on the body requirement for them.
* Production of adrenaline through the agency of the adrenal glands
* Regulation of the composition of the blood, which depends on the blood solute concentration; which in turn affects the reabsorptive activities of the kidney through hormones.
* Keeping the pH of the blood fluid constant
* Production of heat on a cold day by increasing its activity
* Elimination of toxins, drugs and other harmful susbtances.

Activity B

i. Summarize the functions of the kidney

ii, In your opinion, which of the functions are (or is) not important?

3.4 Diseases of the Kidney

i. **Glomerular Nephritis:** This conditions is caused by bacterial (streptococcal) infection of the kidney, whereby the gromeruli become inflamed and the porosity of its membranes increases. When this occurs proteins and red blood cells leak into the glomerullar filtrate. White blood cells and dead tissue cells aggregate in the inflamed glomeruli, in some cases, it blocks the blood flow and even fill the Bowman's capsule, thereby preventing the tubules from receiving sufficient nourishment from the already reduced blood supply. In some extreme cases the glomeruli may become permanently blocked and some tubules damaged. Finally, the kidney may become completely damaged leading to kidney failure.

ii. **Kidney Stones:** There are crystalysed mineral salts and organic matter in urine. Kidney stones are formed when salt intake is high or due to low water intake; or when urine is acidic or alkaline. The salts crystalize is form the store. The size of kidney stores vary from tiny sand - like grains to large ones which may block the flow of urine.
When urine flow is blocked, pressure builds up causing severe pain and damage of the kidney tubules.

iii. **Diuresis:** This condition involves the production of large quantity of dilute urine after drinking large quantity of water. This is called water diuresis, and may last for two to three hours.
In *diabetes insipidus*, the production of anti-diuretic hormone (ADH) becomes reduced or stops, resulting in diuresis, increasing daily urine production to an abnormal level of 5 to 20 litres! This also results to drinking of plenty water by such patient.
In diabetes mellitus excretion of glucose in urine is accompanied by excretion of water, due to osmosis.

iv. **Oedema:** Also called dropsy, is caused by accumulation of intercellular fluid in tissues, causing the

affected part of the body to increase in volume. Outward sign of oedema include puffy or swollen face, swollen ankles and elbows.
Reduced plasma osmotic pressure in some kidneys may also cause oedema, which is basically associated with excretion of high protein in urine.

Activity C

i. Summarize the kidney diseases that you know
ii. Give adequate reasons that are responsible for the various kidney diseases.

4.0 Conclusion

In this unit, you have studied the kidney, its structure function and diseases. You should be able to describe the location of the kidneys in the mammalian body, the functional unit of the kidney and how it carries out its functions. Various diseases are associated with the kidneys, and you are expected to be able to list them.

5.0 Summary

Kidneys are homeostatic organs because they regulate the composition of the blood that flow through them, by eliminating nitrogenous wastes and carrying out osmoregulation. These responsibilities are carried out by the functional unit of the kidney called nephron.
Disease of the kidney include kidney stones, diuresis and Oedema.

6.0 Tutor - Marked Assignment

i. Draw and label the nephron
ii. Describe the process of urine formation in the nephrone.

7.0 Further Reading and Other Resources

S. A. Odunfa. *Essentials of Biology*
S. T. Ramalingam. *Modern Biology*
M.B.V. Roberts. *Biology- A functional Approach*
G Idodo - Umeh (1996). *College Biology* by Idodo - Umeh publishers, Ltd, Benin City.
A video recording of the (i) live (in vitrio) (ii) preserved (in situ) specimens as well as an annotated diagram of the mammalian kidney demonstrating the structure and functions. A NOUN Production

Comments

The description of the kidney diseases is rather too elaborate without losing the facts of the information, the description of glomerular nephritis, kidney stones, diuresis and oedema should be reduced. By the time the diseases are typed, the number of lines would be reduced considerably.

* The network of capillaries around the proximal and distal convoluted tubules should be labelled
* In fig. 3.2, the label cortex should actually be capsule (i.e. the membrane covering the kidney). The cortex is further inside the kidney.

Volume 3: Regulatory Systems and Mechanisms in Animals

Unit 4: The Mammalian Skin

Page

1.0 Introduction

In man the entire surface of the body is covered by the skin which has sparce growth of hair. The skin is 1 to 2mm thick. The skin of the palm of the hand and soles of the feet are about 6mm thick. The mammalian skin consist of an outer layer (epidermis) and an inner layer (dermis).
The skin, being an outer covering of the body surface, requires constant care to ward off microorganisms which can penetrate it to cause infection.

2.0 Objectives

At the end of this unit, you should be able to;

i. Describe the structure of the mammalian skin
ii. Summarize the functions of the skin and
iii. Discuss the care of the human skin

3.0 Structure of the Mammalian Skin

The skin is made up of two layers, an outer epidermis and an inner dermis. The dermis is much thicker than the epidermis. The epidermis consists of three layers, (i)the outer most cornified layer or stratum corneum, (ii) the middle granular layer or stratum granulosum and (iii) an innermost pigmented Malphighian layer or stratum malpighii (fig. 4.1).

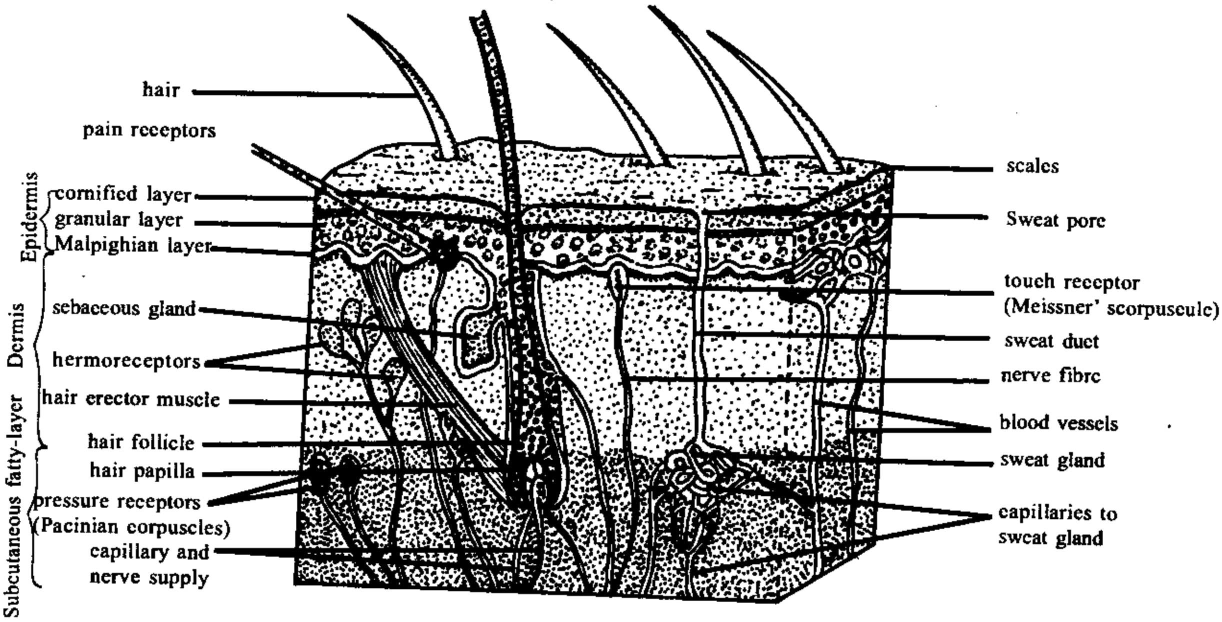


Figure. 4.4 Section of the human skin
Source: Modern Biology by S.T. Ramatingam P382

The malpighian layer (the innermost layer) has actively dividing cells which produce new epidermal cells. The Malpighian layer contains the pigment **melanin** for skin colour; it protectss the skin from ultra-violet rays penetration. The layer also contains **keratin** (protein) that imparts toughness and flexibility to skin.
The granular layer (the middle layer) also consist of living cells that are constantly pushed upwards from the malpighian layer. In this process they become flattened, accumulate keratin and eventually die.
The cornified layer (the outermost/surface layer) consist of dead cells impregnated with keratin. This layer is a tough water-proof layer that protects the skin from damage and infection. The cells of the cornified layer are continuously being worn-out and replaced by cells from the layer below.

The dermis contains blood vessels, lymphatic vessels, muscles, fat cells, nerves and hair follicles, and glands such as sweat and sebaceous glands. Hair consists of the hair root and hair shafts. Hair follicles in the dermis are associated with erector muscle or pili. The sebaceous gland produces an oily substance called **sebum,** for keeping the hair waterproof.
Sweat glands are coiled tubes embedded in the dermis. Each gland is surrounded by blood capillaries; therefore waste products such as water, urea and salts are absorbed and excreted through the pore. The skin therefore, acts as an excretory organ.
The subcutaneous (fatty) layer is below the dermis. It contains fat cells, it stores food and it ácts as an insulating layer that prevents the loss of heat from the body.

Activity A

ai. Draw a longitudinal a section of the mammalian skin and label it fully.
ii. Describe the epidermal layer of the skin and state its functions.
b. With the aid of video recorded support material, identify the major layers of the skin and briefly describe their functions.

3.1 Functions of the Skin

The main functions of the skin include;
i. Protection: Dead cells of the cornified layer (outer layer of the skin surfacc) protect the body from infectious substances Melanin (body pigment) protects the body from ultra-violet radiation of the skin.
ii. Sensitivity: There are several nerve endings and touch receptors (Meissner's corpuscles) on the skin that are sensitive to touch, pressure, heat, cold and pain; as such, the skin is a sense organ.
iii. Temperature regulation:
* Fur or hair on the surface of the skin traps warm air close to the body surfacc for the purpose of conserving body heat.
* On hot days, the sweat glands produced sweat. Evaporation of the sweat causes cooling
* On hot days, the blood vessels of the skin dilate, a process which allows more heat loss from the body. Whereas on cold days, blood vessels constrict to conserve heat loss.
* Fat stored in the subcutaneous layer prevents heat loss from the body i.e. acts as an insulator.
iv. Excretion: Water and salts are excreted by the sweat glands of the skin.
v. Production of Vitamin D: Ultra-violet radiation helps in converting fat derivatives in the skin to vitamin D.
vi. The mammary glands (breasts) are modifications of the sebaceous glands of the skin.They help to produce milk for feeding the young
vii. Nails, claws and scales, and horns are modified out growth of the cornified layer of the skin. They serve for protection of the inner organs, as well as weapons of offence and defence.

Activity B

i. List the functions of the skin
ii. Briefly summarize the processes involved in temperature regulation in mammal.

3.2 Care of the Skin

Our skin is in direct contact with the surroundings and gets dirty easily. Therefore, we should take proper care of it by observing the following;
1. Bathe with soap to remove natural oils, sweat and dirts from skin. This will prevent blocking of the sweat pores, reduce stale unpleasant smells and limit bacterial activity on the skin.
2. After bathing, dry the body with clean towel.
3. Feet must be washed regularly. Cut toe nails regularly. Wear clean stockings to absorb sweat from

clefts of toes. Sweat in toes encourages the growth of bacteria and fungi causing stawful ench resulting from "athlete's foot". Wear appropriate shoes out doors to prevent hookworms and tetanus infection.

4. Cuts, wounds and sores on the skin should be cleaned with antiseptics and covered.
5. Report skin diseases such as scabies, ringworm, eczema and other fungal and parasitic infestations and infections to a medical doctor.
6. Keep your skin moist with appropriate lotion or cream during harmattan or dry seasons to protect the skin from cracking. Do not use bleaching creams. Bleached skin predisposes a person to skin infection and cancer!
7. Do not expose the skin to unnecessary ultraviolet radiation from the sun, more especially the albinos. Direct sunlight may cause skin burns (sunburns).
8. Effect special cleanliness of these parts of the body:

i. The hair and scalp,
ii. Eyes, ear and nose
iii. Armpits and groins
iv. Hands and fingernails
v. Feet and toe nails
vi. Teeth

Activity C

i. Write a letter to your primary school Headmaster stating your advice to the pupils on how to take care of their body.

ii. State (a) why you should not use bleaching cream
(b) reasons for avoiding direct sunlight.

4.0 Conclusion

In this unit, you have learned the structure of the skin, its functions and how to take good care of the skin. You should then be able to draw and label the sections of the skin, list the functions of the skin and discuss how to take care of the skin.

5.0 Summary

Mammalian skin consists of an outer layer (Epidermis) and inner layer (the dermis). Functions of the skin include protection, sensitivity, temperature regulation, excretion and production of vitamin D. The skin is in direct contact with the surroundings and as such requires special care.

6.0 Tutor - Marked Assignment

a. Draw and label the section of the mammalian skin (20marks).

b. i. State the functions of the various parts of the mammalian skin (10 marks).
   ii. List five functions of the skin and five ways of taking care of your skin (10 marks).

7.0 Further Reading and Other Resources

G Idodo - Umeh. *College Biology* 2nd edition Idodo - Umeh publishers Ltd., Benin City.
S. T. Ramalingam, 2001. *Modern Biology* edition. Publ. by Africana - Feb. publishers Ltd., Onitsha.
A video recorded demonstration of the learner's participatory annotation of the skin: A study guide on "The skin and its functions". A NOUN Production.

Volume 3: Regulatory Systems and Mechanisms in Animals

Unit 5: Hormones in Animals

Page

1.0 Introduction

Hormones are organic compounds produced in minute quantities by cells of one part of the body and transported to all or some other parts of the body by the blood system of animals to produce a response. Such response result in the promotion of good body growth, sexual maturity, response to fight, fear or flight. If a hormone is underproduced or overproduced, serious effects can arise.

2.0 Objectives

By the end of this unit you should be able to
a. List the endocrine glands in mammals
b. Discuss the important hormones, their functions
c. See the effects of over or under or normal secretion of hormones in animals.

3.0 Endocrine Glands and Hormones

Have you tried to imagine how saliva gets to be in your mouth? Now read this. The salivary gland releases saliva into the mouth via **ducts**; as such, they are called **exocrine glands**. On the other hand some glands do not have ducts because their secretions are released directly into the blood system and transported to where they are required. These glands are called **ductless glands** or **endocrine glands** and their secretions are called hormones.
The endocrine glands in the human body are:

i. The pituitary gland: found just below the hypothalamus, at the base of the brain (fig. 5.1).
ii. The thyroid and parathyroid glands: found in the neck, below the larynx.
iii. Adrenal glands: These are situated above the kidneys
iv. Pancreas: This is found below and behind the stomach
v. Gonads: These are the ovaries found in the pelvis, of the female reproductive organ and the testes located in the scrotum of the male organ.

Activity A

a. Write short sentences on exocrine and endocrine glands
i. You now have a clear picture of what goes on inside us.
ii. List the mammalian endocrine glands and state where they are found.

3.1 Important Hormones and Their Functions
Hormones (What they are)

Hormones are organic (chemical) compounds secreted by endocrine glands in response to internal and external stimuli. They are transported in the blood streams to target organs. They therefore act as chemical messengers. In the target organs, they (a) speed up (excite) the rate of reaction, (b) slow down (inhibit) the reactions or (c) alter the activities.
You can then define a hormone as a chemical messenger that is produced in one part of an organism transported to another part where it brings about a specific effect on the target organ(s).
Hormones are produced by endocrine glands. They also are involved in homeostatic processes.

Endocrine Glands, Their Functions, Secretions and Deficiencies

Now you can also describe the functions, secretions and deficiencies of the endocrine glands.
The hypothalamus and pituitary gland
a The **hypothalamus** is found at the base of the forebrain, above the pituitary gland. Although it is not

described as a gland, it regulates several activities in the body such as temperature, thirst, heart beat rate, blood pressure, ventilation rate, peristalsis, hunger and sleep.
The hypothalamus is connected to, and controls, the pituitary gland. This connection is important becuase it is the main link between the nervous system and the endocrine system and its hormones.
The hypothalamus passes information to the pituitary gland which then regulates the activity directly or indirectly to other glands (fig. 5.1).

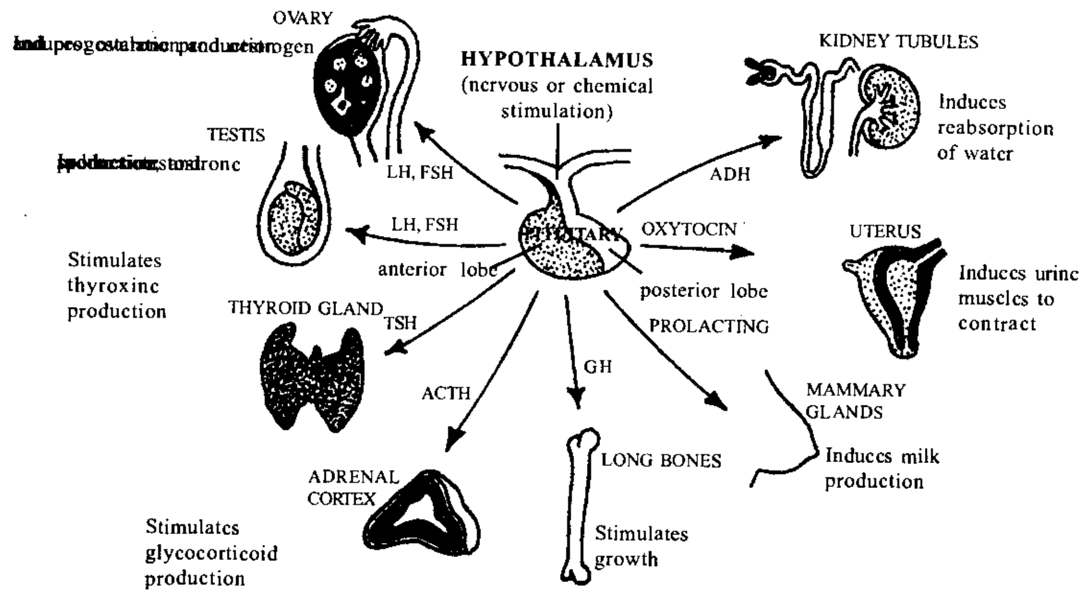
b. **The pituitary gland** consists of an anterior and posterior parts which secretes different hormones.

* Anterior pituitary hormones are;
  - tropic hormones that regulates the activities of other endocrine glands
  - the growth hormone and
  - prolactin

* Posterior pituitary hormones are;
  - Antidiuretic hormone (ADH) and
  - Oxytocin

The functions of the pituitary hormones are summarized in Table 5.1. and 5.2

5.1 Interactions between the hypothalamus, anterior and posterior lobes of the pituitary and the various organs of the human body



Source: Modern Biology by Ramalingam P.388

The pituitary gland is therefore, called the master gland because of its interaction with other glands and various organs of the body.

Table 5.1: Functions of Some Pituitary Hormones

Hormones	Functions
	Anterior Pituitary
Adrenocorticotropic hormone (ACTH)	Stimulates the adrenal cortex to produce its hormones, the *corticosteroids*
Thyroid-stimulating hormone (TSH)	Stimulates the thyroid glands to produce its hormone, e.g. *thyroxine*
Follicle -stimulating hormone (FSH)	* Causes follicles in the ovary to ripen and produce mature eggs * Initiates sperm formation in testis
Luteinizing hormone (LH)	* Causes ovulation (release of mature egg into the Fallopian tube) * Stimulates secretion of testosterone (male sex hormone) in testis
Growth hormone (GH)	* Stimulates growth of long bones * Promotes protein synthesis arid increases metabolic rate in cells
Prolactin	* Induces milk production in pregnant women
	Posterior Pituitary
Anti-diuretic hormone (ADH)	* Increases reabsorption of water by kidney tubules * Raises blood pressure by constricting arterioles
Oxytocin	* Induces birth by contractions of uterine muscles * Induces milk secretion from nipples
Note: FSH and LH are commonly known as *gonadotropins.*	

Source: Modern Biology by Ramalingam, P.389

Do you know that;
* Over secretion of growth hormone before maturity causes lengthening of the bones leading to gigantism
* Deficiency or undersecretion results in dwarfism. Dwarfs are fully developed mentally and sexually.

Activity B

i Define Hormones
ii. What are the basic functions of the hormones
iii. State four functions of the hypothalamus
iv. Give four functions of the pituitary hormones
v. Suppose three children (A, B, C) of an era have pituitary over-secretion, normal secretion and under secretion respectively. make a sketch of what their growths may likely turn out to be.

The Thyroid and Parathyroid Glands

a. Thyroid gland

The gland is situated in the neck. It secretes the hormone thyroxine, which contains iodine. Secretion of thyroxine is triggered by **thyrotropic hormone**, from the anterior lobe of the pituitary gland. Its secretion depends on the level of thyroxine in the thyroid gland. In the follicles of the thyroid gland is a precursor thyroglobulin (thyroxine and protein). A proteolytic enzyme from the follicle separates thyroxine from the protein before it passes into the blood stream.

Thyroxine controls basal metabolic rate and is therefore important in growth. Deficiency or underproduction (hypothyroidism) results in arrested physical and mental development (cretinism). However, in adults a condition called **myxoedema** occurs. Signs include decreased metabolic rate, increase in subcutaneous fat, coarsening of skin and physical, sexual and mental retardation. When there is deficiency of iodine in the diet, the thyroid gland enlarges to compensate for the deficiency. This results in **hyperplastic goitre**, that is seen as a swelling in the frontal part of the neck.

Over-production (hyperthyroidism) leads to exophthalmic goitre (swelling of thyroid and protrusion of eyes), increased metabolic rate, loss of weight, increased heart beat, and physical and mental restlessness, A person with such condition is hyperactive, irritable, nervous and thin with bulging eyes.

b. The parathyroid glands:

There are four tiny glands attached to the thyroid gland. They secrete parathyroid hormone. The thyroid and parathyroid glands secrete calcitonin, which regulates blood calcium levels. Parathyroid hormone raises level of calcium ions in blood by:

* releasing calcium from bones into the blood
* increasing calcium absorbtion in the intestines and
* reducing calcium excretion from the kidneys.

Activity C

i. What are the functions of the hormone called thyroxine?
ii. Describe the effects of under-production and over-production of thyroxine in humans
iii. Give the functions of the hormone called calcitonin.

Activity D

i. Give the names of;
   a. Two hormones produced by the adrenal gland
   b. State the functions of each of the hormones that you have listed.
ii. Where is insulin produced in the human body
b. List the funcitons of insulin.

The Gonads

The gonads are the reproductive organs of the male (i.e. testis) and the female (ovaries) animals. They produce hormones generally called gonadotropic hormones, which are sex hormones.

The interstitial cells of the testes and ovary produce sex hormones. The testes produce the male hormone testosterone, while the ovary produces the female hormones called estrogen and progesterone. They are produced at maturity and therefore, stimulate growth of sexual organs from the time of puberty. Gonadotrophic hormones in both sexes are responsible for secondary sexual appearance characters such as enlargement of the breasts, appearance of hair in the pubic region and armpits and onset of menstruation in females. In males, the organ increases in size, hair appears on the face, armpit and pubis, and the voice deepens.

Estrogen prepares the uterus for reception of fertilized egg; it also tums some animals on in heat period (oestrus). Progesterone produced by corpus luteum and placenta maintains pregnancy, inhibits ovulation and prevents the uterus from contracting.

Activity E

i. List the hormones produced by
   - the gonads and
   - give the functions of the hormones that you have listed.
ii. If a woman suddenly begins to grow vast amount of hair on her face, what hormone will you suggest is responsible
iii. If a 16 year old boy starts developing breasts what hormone will you suggest is deficient?

4.0 Conclusion

In this unit, you have studied the endocrine glads and the hormones they produce. Therefore, you should be able to list glands, state the hormones they produce and list their funcitons. In addition, you should be able to describe the effects of over secretion or undersecretion of these hormones.

5.0 Summary

Hormones are chemical messengers, produced by endocrine glands and transported via the blood stream to target organs where they bring about specific effects.

The endocrine glands produce hormones such as pituitary hormones, thyrotropic hormones, adrenalin, insulin and gonadotrophic hormones.

6.0 Tutor - Marked Assignment

i. In a tabular form list the endocrine glands and state the specific hormones they produce (20 marks)

ii. List the functions of thyroid and sex hormones (20 marks)

7.0 Further Reading and Other Resources

S. T. Ramalingam 2001. *Modern Biology* edition published by Africana-Feb Publisher Ltd.,

M.B.V. Roberts. *Biology - A Functional Approach* by ELBS

G Idodo - Umeh. *College Biology* 2nd edition Idodo - Umeh Publisher, Ltd., Benin City.

Volume 3: Regulatory Systems and Mechanisms in Animals

Unit 6: Nervous Coordination and Sense Organs in Animals

Page

1.0 Introduction

In animals, there are well-articulated systems for perception and transmission of stimuli. A stimulus (singular) is any change in the internal or external environment that can bring about a change in either a part of, or the whole of an organism. Response is the change in activity of an organism as a result of the stimulus.
In animals, activities such as locomotion, respiration, digestion and excretion, and response to external and internal environments are coordinated by the endocrine system and nervous system. The hypothalamus is the important link between these endocrine and nervous system.
You have studied the endocrine (hormonal) system in which messages are transmitted as chemical substances. In the nervous system, the messages are passed mainly as electrical impulses along the nerves, whereas the sense organs are specialised receptors that detect particular stimuli. Examples of sense organs include the skin, eye, ear, tongue and nasal (nose) cavity.

2.0 Objectives

By the end of this unit, you should be able to;

i. Tabulate the differences between the nervous and endocrine system
ii. Describe the structural unit (neurone) of the nervous system and types of neurones
iii. Discuss the central nervous system
iv. Describe the peripheral nervous system and
v. Explain the reflex actions
vi Describe some sense organs.

3.0 Differences Between the Nervous System and Endocrine System

Table 6.1

Nervous system	Endocrine system
* Messages are transmitted as electrical impulses along nerves	* Messages are transmitted as chemical substances (hormones) in bloodstream
* Transmission is via nerve fibres and is very fast	* Transmission is via circulatory system and is very slow
* Muscles and glands (effectors) receive the message	* Message is received by target organs
* Response is immediate, short-lived and very precise	* Response is slow, long-lasting and widespread throughout the body
* Effects are localized and temporary	* Effects are widespread and permanent

Source: Modern Biology by S. T. Ramalingam, P. 397

3.1 The Components and Organisation of the Nervous System

a. **The nerve cell or neurone:** The neurone is the basic structural unit of the nervous system. **It has** a cell body with at least two protoplasmic processes. The cell body has a large nucleus and dense granular cytoplasm (greyish in colour). It has branched processes called **dendrites** and a long axon (fig. 6.1). These are collectively the nerve fibres. The **axons** is divided into several fine, branched processes (dendrites) at the free end. It has a long nerve process called axis cylinder surrounded by a white fatty body called **myelin sheath**, in **myelinated neurons**. Enclosing the myelin sheath is a thin membrane called the **neurilemma** adjacent to which are sheath nuclei. The myelin sheath is interrupted by constrictions called **nodes of Ranvier.** Nerve fibres, which do not have the myelin sheath, are said to be non-myelinated. Neurons may be grouped according to their functions. There are sensory (afferent), motor (efferent) and relay neurones. Information is transferred as electrical impulses (nerve-impulses) along the neurone and the impluse is

undirectional. The nervous system has the following components;
i. The brain, which is regarded as the central processing region
ii. Nerves taking information to the brain from receptors
iii. Nerves carrying instructions from brain to effectors
Examples of receptors are skin, eye and ear which are sense organs. Effectors are muscles and glands that go into action when nerve impulses are received from the brain.

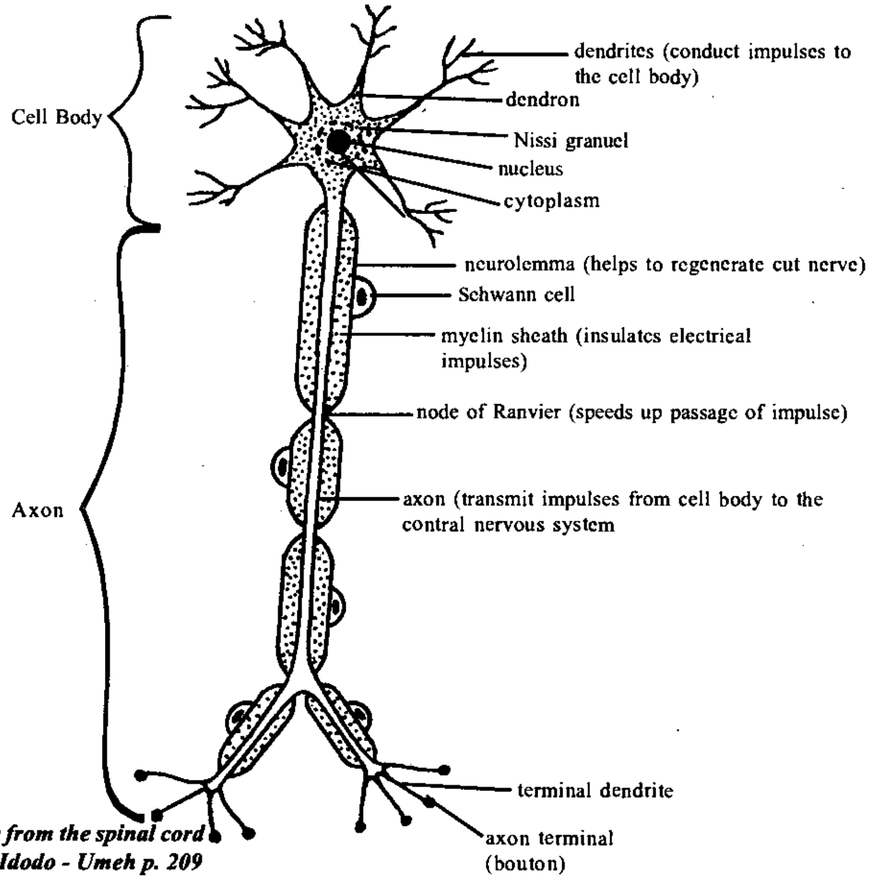


Figure. 6.1 A motor neurone from the spinal cord
Source: College BIology by Idodo - Umeh p. 209

b. Functions of the nervous system:
* It collects information on changes in the environment of the organism (internal and external)
* It processes the information received, and
* It acts on the information

c. Organization of the nervous system:
The nervous system of mammals is composed of two parts:
i. The central nervous system (brain and spinal cord);
ii. The peripheral nervous system, linking central nervous system (CNS) to body receptor and effector and it is made up of the following;
* sensory system - i.e. sensory receptors and sensory or afferent neurones which connect receptors to the CNS
* motor system - i.e. motor or efferent neurones have two parts; ***somatic nervous system*** that consists of motor neurones which carry instructions to voluntary muscles (those muscles that you can control); and ***autonomic nervous system*** which consists of motor neurones that carry instructions to involuntary

muscles (muscles that you cannot control) and various glands. Autonomic nervous system is further subdivided into two;

* parasymphathetic system: it operates when one is relaxed and
* symphathetic system: which operates when one is stressed and during emergency;

Activity A

i. Tabulate the differences between the Endocrine and Nervous system
ii. With the aid of a labelled diagram, describe the nerve cell.
iii. State the functions of the nervous system

3.2 The Central Nervous System (CNS)

In mammals the central nervous system is made up of the brain and the spinal cord.

a. The mammalian brain

The mammalian brain is divided into three main parts the **fore brain, mid brain and hindbrain** (fig. 6.2). The fore brain is the cerebrum (the largest part of the brain). It consists of right and left cerebral hemispheres separated by the median fissure but connected by fibres called **corpus callosum.** The grey matter of the cerebrum is the **cerebral cortex**.

The olfactory lobes, which receive the impulse of smell, are located anteriorly in the fore brain. Some other parts of the cerebrum receive and correlate impulses and coordinate responses. It controls all voluntary actions, ability to hear, intelligence, memory, will power, imagination, reasoning and judgement, impulses of touch, sight, taste and sound. On the hind part of the fore brain are two ovoid-shaped thalami (epithalamus and thalamus) which receive impulses from the spinal cord, hind brain and mid brain and transmit them to the cerebral cortex and vice-versa. It is the centre of consciousness in man. Below the thalami is the hypothalamus which controls the body temperature, appetite and sleepiness.

The mid brain connects the **pons varolii** and the cerebellum with the fore brain (fig. 6.3) *it controls reflexes connected with sight and hearing.*

The hindbrain consists of the **cerebellum, pons varolii** and **medulla oblongata.** The cerebellum is located in the rear part of the cranium (see figs. 6.2 and 6.3). The Cerebellum regulates and coordinates muscular movements particularly for body equilibrium. It is the unconscious coordinating centre.

Pons varolii, which lies on the ventral side of medulla oblongata, is the posterior part of the brain. The cerebellum has grey matter on the surface and white matter internally. Medulla oblongata is white externally and grey internally; it controls involuntary actions like heart beat, movement of the lungs and digestive system and controls the diameter of blood vessels. The CNS is hollow; the cavity (ventriole) of the brain is continuous with the central canal of the spinal cord. These cavities are filled with cerebro-spinal fluid.

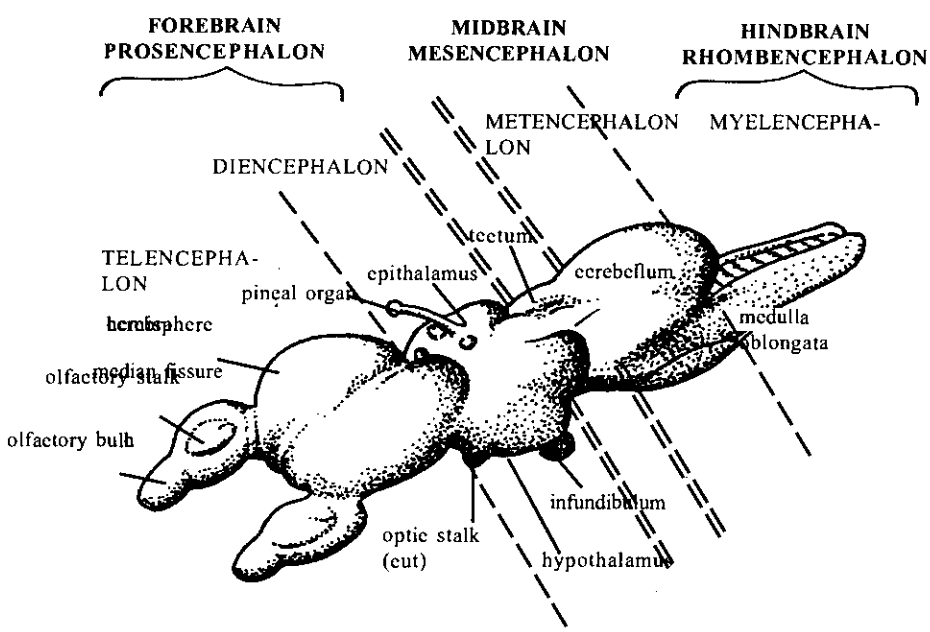


Figure. 6.2 A generalized vertebrate brain showing principal brain divisions and structures

B. Human brain (vertical section)

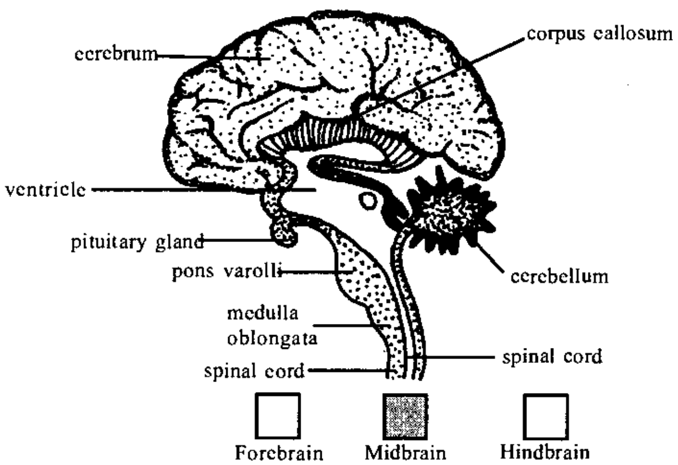


Figure. 6.3 Vertical section of Human brain
Source: Modern Biology by S. T Ramalingam p.401

b. The spinal cord

This is the extension of the brain into the neural canal of the vertebrae. It is made up of two similar halves fused with a canal at the centre (spinal canal), containing cerebro-spinal fluid. The central portion is made up of grey matter and outer portion white matter (fig. 6.4). There are two fissures, dorsal/anterior fissure and the ventral/posterior fissure.

The CNS is adequately nourished and protected. It is enveloped in membranes called **meninges**; the innermost is called **pia mater** (delicate) and the outermost is called **dura mater** (tough). The two are separated by the **arachnoid matter** which is thin and web-like, whose spaces are filled with cerebro-spinal fluid. It cushions and facilitates diffusion of oxygen and nutrients. The cranium and vertebral column are pierced by holes/**foramina,** which allow entry and exit of peripheral nerves.

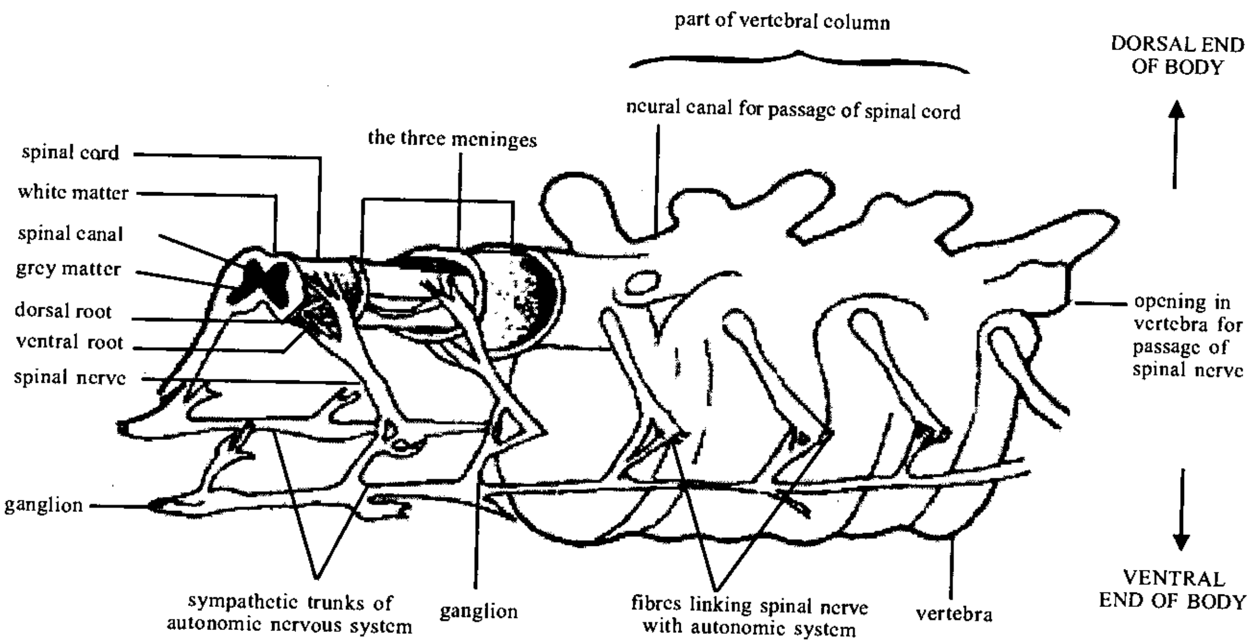


Figure. 6.4: The mammalian Spinal Cord, Spinal nerves
Source: Modern Biology by Ramalingam S. T.

Activity B

i. The functions of the mammalian brain are divided in this unit. Now, write out the functions of the;
   a) Cerebrum b) Thalami c) Mid brain
   d) Cerebellum e) Medulla oblongata

ii. Describe the CNS

3.3 The Peripheral Nervous System

The peripheral nervous system provide the bridge between the brain, spinal cord and the entire body. It consists of twelve parts of cranial nerves which arise from the brain and 31 pairs of spinal nerves which arise from spinal cord. They are mainly of the motor system and sensory system. The peripheral nervous system consists of somatic nervous system and the autonomic nervous system.

a. **Somatic Nervous System:** Consists of nerves that do not have synapses but which originate from the brain through the spinal cord to the skeletal muscles. These nerves transmit messages from external stimuli to the CNS to the skeletal muscles of the body to initiate movement such as clapping (a voluntary action) and to some extent knee jerk, which is beyond our control (involuntary), see fig. 6.5

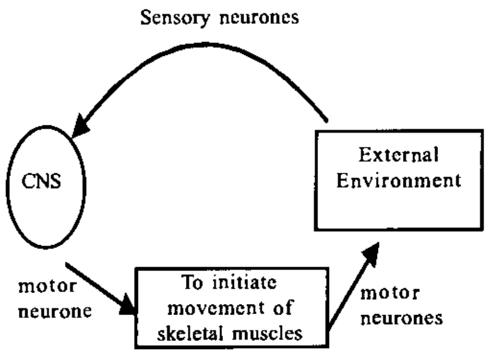


Figure 6. 5: The gap between the terminal end of motor neurone and muscle fibre is called neuromuscular junction

b. Autonomic Nervous System (ANS): The ANS connects the CNS with glands, smooth muscles, cardiac muscles, gut muscles which are all involuntary activities, i.e. they are not under conscious control. The ANS consists of two parts; that is sympathetic and parasympathetic nervous systems.

i. *Sympathetic Nervous system:* This system prepares the body for emergencies and stress. The sympathetic motor nerves fibre leaves the CNS through the spinal nerves. These synapse (functions between neighbouring neurones) with cell bodies in ganglia located near the spine. The motor nerve fibres are long, orginate from the cell bodies and extend to innovate the effectors. There is a chain of ganglia on each side of the spinal cord. The ganglia recieve nerves from the spinal cord and send nerves to the internal organs and blood vessels.

ii. *Parasympathetic Nervous system*: This system reverses the actions of symphathetic nervous system. For example it maintains normal heart beat, respiration, food digestion and conservation of energy.

The ganglia are in organs, resulting in long preganglionic and short post ganglionic nerve fibre. The nerve fibre leave the central nervous system in the cranial and sacral areas.

Functional Differences Between the Parasympathetic and Sympathetic Nervous System are summarized in Fig. 6.6 below

*** Parasympathetic** **Sympathetic**

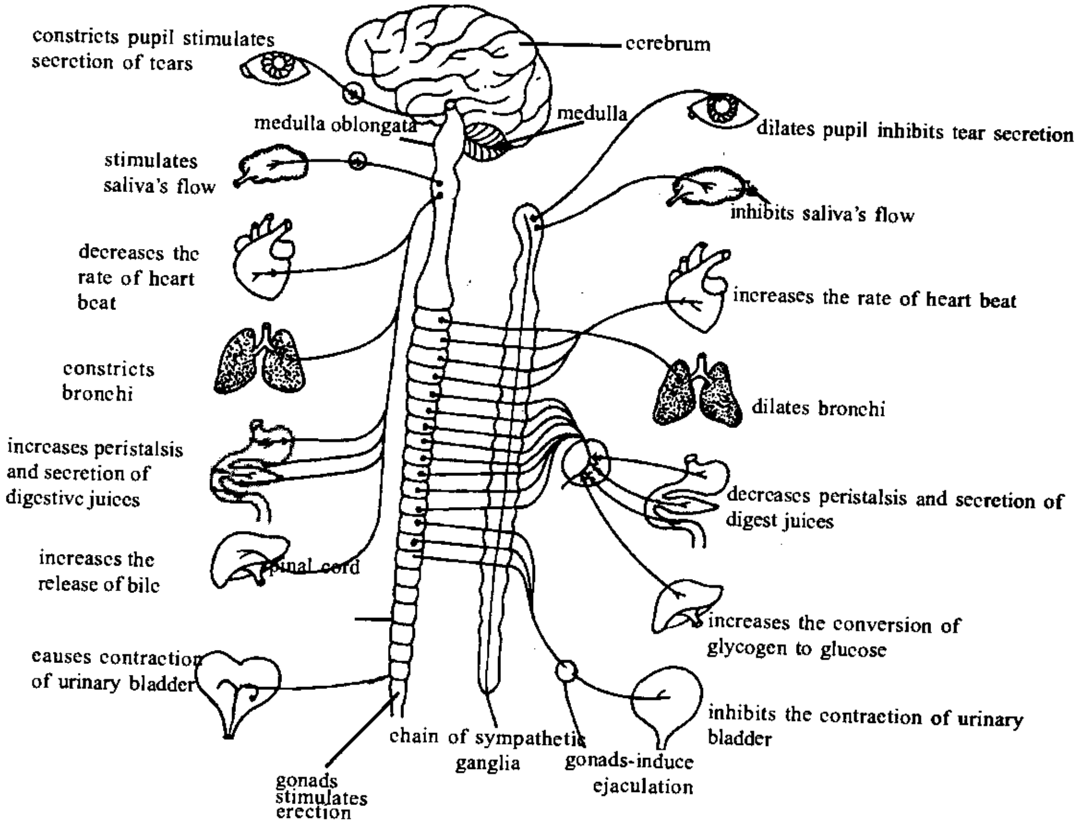


Figure 6.6

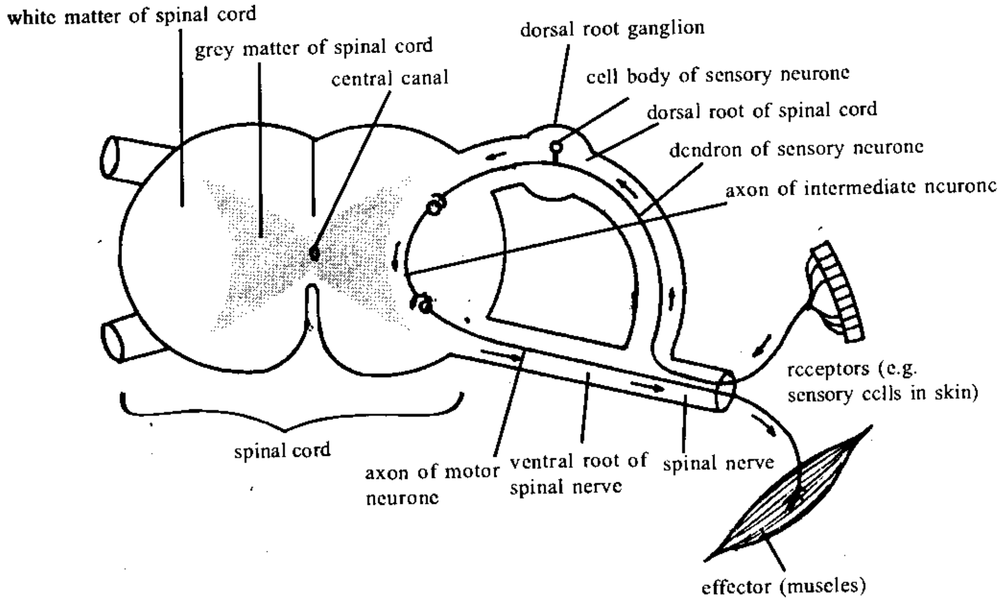
3.4 Reflex Actions

These are actions in reaction to stimuli without prior thought or planning (involuntary action). They are quick, automatic responses e.g. blinking of eyes, beating of the heart, jerking of leg on tapping the knee cap, etc. The path followed by impulses is called a reflex arc.

a. A Reflex Arc

Organs receiving external stimuli are called sensory/receptor organs e.g. eyes, nose, ear, tongue etc. Neurones carry messages from here to either the brain or spinal cord. Such neurones are called afferent or sensory neurones. In the brain or spinal cord, there are neurones that can receive, transmit and interpret message called intermediate or relay neurones. The interpreted message is then passed to the motor or effector organ through motor or efferent neurones. A simple arc contains three neurones, afferent intermediate and efferent neurones, but usually more than that. Knee jerk in man is made up of afferent neurones connected to efferent neurone.

Impulses from the receptor go to the afferent neurone then intermediate neurone by synapses; impulses get to brain through the spinal cord and are sent back to the motor neurone then effector organ (muscle) see fig. 6.7.



Some reflexes are present at birth e.g. blinking and knee jerk, these are innate or involuntary reflexes. Others are developed as a result of learning after birth, e.g. walking, driving speaking and riding. These are called conditioned or acquired reflexes.

b. Conditioned Reflex Action

Presence of food in the mouth produces chemical stimulus causing secretion of saliva (salivation). It is an automatic reflex action. There is a direct relationship between the stimulus and response. A period of training could evoke repsonse that is not related to a stimulus e.g. Pavlov, a Russian scientist, rang a bell each time dogs were given food. After a while, the ringing of the bell alone, without food, made the dogs to salivate. Pavlov called this behaviour conditioned reflex.

[redacted]

i. Describe the pathways of the somatic nervous system
ii. Compare the differences between the sympathetic and parasympathetic nervous systems
iii. With the help of a diagram, describe a simple reflex arc pathway.

3.5 Sense Organ

A sense organ includes specialized structures which function to protect the sensory cells to ensure that they receive the kind of stimulation to which they are adapted to respond. Sense organs enable an organism to be aware of the conditions of the environment e.g. heat and cold and any changes that may take place. Simple sense organs include the skin, ear, eyes, tongue and nasal cavity.

[redacted]

State what these organs detect in your body.

a. The Mammalian skin

You have studied the mammalian skin in unit 4. You should study the unit again. In addition, take note of the information given below;

* Different types of nerve endings are found in the dermis of the skin. These include touch/tactile corpuscles sensitive to pressure. The deep pressure receptors (**Pacinian corpuscles**) consist of a bare axon surrounded by a corpuscle consisting of lamellae interspersed with fluid. Other receptors in the skin include **Meissner's corpuscles** and **Merkel's** (touch) and **Ruffini's** organs and the **bulbs of Krause** (temperature).

Humans have especially high concentrations of receptors in sensitive regions such as the fingertips and lips. The free nerve-endings in the epidermis detect pain, while the specialized nerve-endings in the deeper epidermal layes and the dermis detect pressure, temperature and touch.

b. The Mammalian Eye

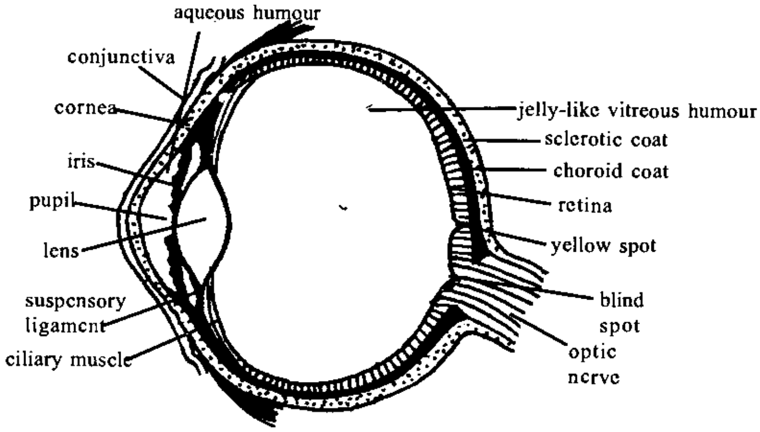
The eye is the sense organ of sight

The structure of the vertebrate Eye (see fig. 6.8)

- The eye of a vertebrate is a spherical structure enclosed in an orbit on either side of the brain case.
- It is connected to the brain by an optic nerve
- The conjuctiva is a transparent layer, which protects the cornea and is continuous with the epithelium of the eyelid.
- This cleanses the eyeball and moistens it.
- The tears also contain an enzymes that has bacteriocidal action
- Cornea is the transparent front part of the sclera; the curved surface acts as the main structure bending light towards the retina.

The eyeball has three layers

1. The **scleroid** layer (sclera) is tough and external. It preserves the shape of the eyeball and resists pressure.
2. The **choroid** layer is a soft tissue rich in blood vessels supplying the retina. This layer contains pigments, which prevent passage of light to the back of the eye.
3. The retina is the innermost layer and encloses most of the interior of the fluid-filled eyeball



- The retina ensures that light rays are properly brought in and focused for reception and transferred to the brain.
- There is an anterior chamber in front of the **lens** that is filled with **aqueous humour**.
- The **iris** regulates the size of the pupil and the amount of light allowed to pass through the lens to the retina.
- The lens is kept in position just behind the iris, by **suspensory ligaments** attached to the **ciliary body.**
- When the **ciliary muscles** relax, the perimeter of the lens is pulled outward and the lens is flattened and assumes a narrow form.

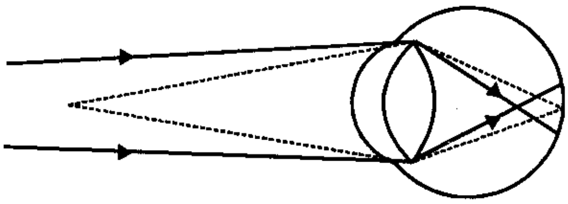
* With this, the eye focuses distant objects.
* The lens contracts and returns to a spherical shape to accommodate for near objects.

Eye Defects

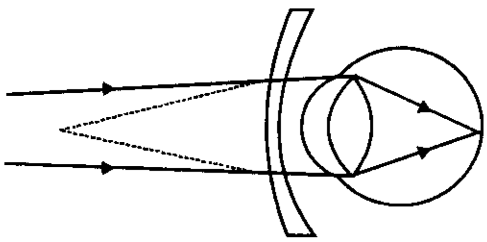
* Include **shortsightedness, long-sightedness and astigmatism**.

Shortsightedness *(myopia)*

* Occurs when parallel rays of light from a distant object focus in front of the retina, in the vitreous chamber.
* It is due to the eyeball being too long from front to back
* The eye cannot focus distant objects properly
* Images are focused in front of the retina.
* Can be corrected by use of concave lens. (see fig. 6.9).



In Short-sighted people the distance from cornea to retina is too long

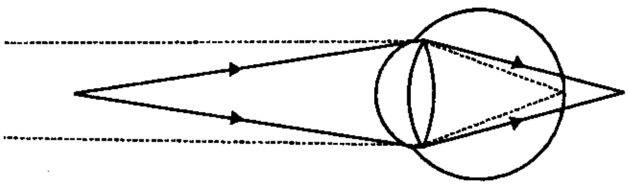


Short sight is corrected by wearing concave lenses

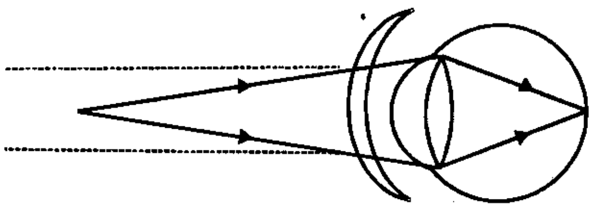
Fig. 6.9 Illustration of short sightedness and its correction

Long-sightedness (hypermetropia)

* May occur as a result of the eyeball being too short or due to loss of elasticity in the lens and ciliary muscles, due to ageing (**presbyopia**; far sightedness).
* Near objects are focused behind the retina
* Correction of long-sightedness is by use of convex lens. (see fig. 6.10)



In Long-sighted people the distance from cornea to retina is too short



Long-sighted is corrected by wearing convex lenses.

6.10 Illustration of long sightedness

Astigmatism

* Most common defect of the eye
* Occurs as a result of the cornea not being smooth or spherical
* Rays of light are not brought to sharp points on the retina
* Corrected by use of cylindrical lenses.

Activity D

i. Make a large labelled diagram of a vertical section through the mammalian eye
ii. State the functions of each of the parts that you have labelled
iii. Make two simple diagrams to show how defects of short sightedness or longsightedness can be corrected.
iv. List (a) types of nerve endings found in the dermis of the skin, (b) What are the listed nerve endings sensitive to?

The Mammalian Ear

* The ear is the sense organ for hearing and balance
* The mammalian ear has three chambers
* The outermost air-filled chamber
* The middle ear and
* A fluid-filled inner chamber
* The outer ear includes the **pinna** which is found only in mammals (see fig. 6.11)
* The **tympanic membrane** (ear drum) separates the middle ear from the outer ear.
* The **Eustachian tube** connects the middle ear with the pharynx and equalises air pressure on either side of the tympanic membrane
* The middle ear has three soft bones
* These are the **auditory ossicles** known as the **malleus** (hammer), **incus**, (anvil) and **stapes** (stirrup).

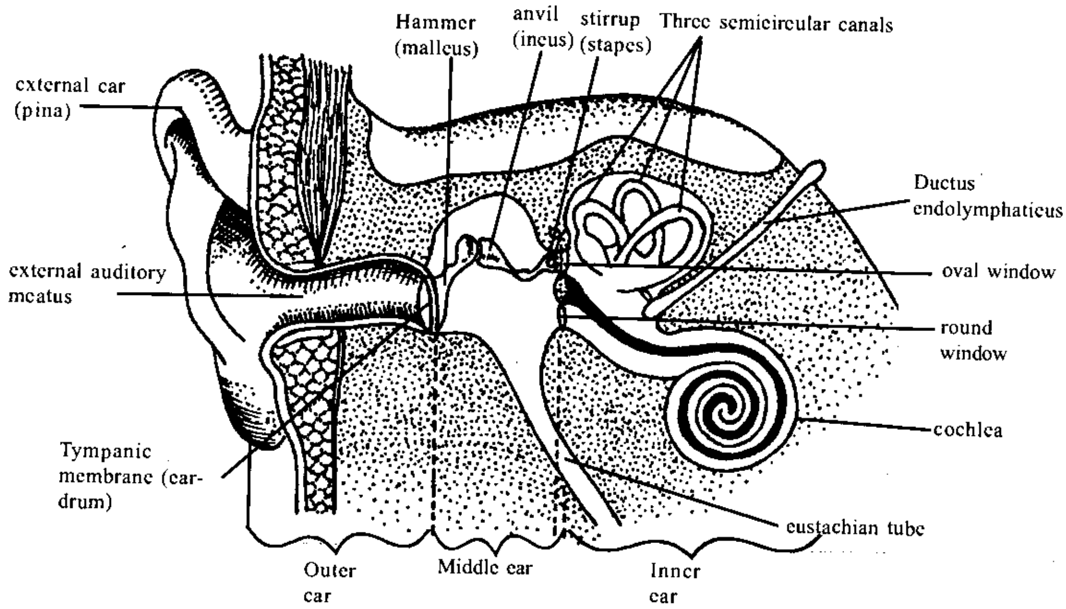


Fig. 6.11 Structure of the Mammalian (Human) ear

* The auditory ossicles are loosely connected to each other and the stapes lies against the **fenestra ovalis** (oval window)
* The ossicles transmit vibrations to the fenestra ovalis.
* The fenestra ovalis opens into the inner ear
* The inner ear consists of a membranes labyrinth which is made up of the vestibular apparatus and **cochlea**
* The functions of cochlea is for hearing.
* There are three **semi-circular canals,** which are attached to the **utriculus.**
* They are fluid-filled tubes.
* Each semi-circular canal has a swollen base at either end called the **ampulla** that is responsible for maintaning balance.

Hearing

* Sound waves are collected by the pinna and passed through the **external auditory meatus,** from where they impinge on the tympanic membrane causing it to vibrate.
* The ossicles, membranes and fluid-filled cavities transmit the vibrations to the basilar membrane.
* Sensory stimulation occurs in the inner ear
* Movement of basilar membrane distorts the sensory cells of the **organ of Corti,** resulting in impulses being passed to the auditory nerve and then to the brain, which translates impulses into perception of sound.

Balance

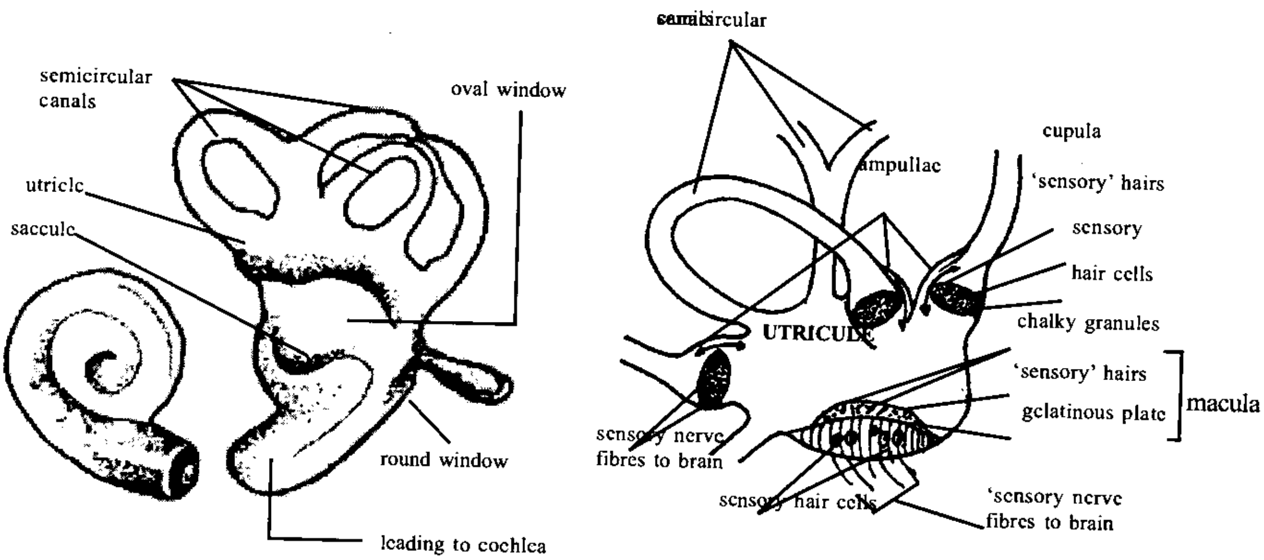
The hear functions in the detection of changes in the orientation of the body with respect to its surroundings and thus helps to maintain equilibrium. Balancing is primarily a function of the inner ear.

The structures in the inner ear concerned with balance consists of;

1. A complex of closed sacs and canals.
2. The membranous labyrinth filled with **endolymph** and surrounded by a protective liquid cushion, the

periplymph (fig. 6.12).

The equilibrium receptors are two sacs, the **sacculurs** and **utriculus,** which have sensory hairs, **saccular** and **utricular maculae**). The two sacs are filled with a gelatinous material containing ear stones or **otoliths,** which lie under gravity against particular sensory cells of the maculae. Movement of the head causes the otoliths to move and stimulate the hairs of different sensory cells; these impulses are carried to the brain by branches of the auditory nerve and are interpreted by the brain as a change in orientation. The semi-circular canals give information concerning turning movements of the head. Each canal lies in a plane at right angles to the others and is connected at each end to the utriculus. The ampullae have patches of sensory epithelium each consisting of hair cells. Movement of the head in any direction will move the fluid in at least one of the three semi-circular canals and stimulate the sensory hairs.



Indicates direction of movement

Activity E

i. Draw and label, the mammalian ear
ii. Describe the perception of sound by the ear.

4.0 Conclusion

In this unit you have learned the differences between the nervous system and endocrine glands, the nervous system including reflex actions and the sense organs.
You should be able to;

a. Tabulate the differences between nervous and endocrine systems
b. Draw and labelled the nerve cell (neurone) which is the structural unit of the nervous system
c. State the (i) functions of the nervous system
   (ii) the functions of the brain
   (iii) compare the differences between the parasympathetic and sympathetic nervous systems
   (iv) Discuss the simple reflex arc.
d. Draw, label and state the function of the major sense organs in this unit.

5.0 Summary

There are several differences between the Nervous and Endocrine systems, but the hypothalamus is the important link between the two systems. The basic structural unit of the nervous system is the neurone which collects, processes and acts on information.

The CNS consists of the brain and the spinal cord peripheral nervous system consists of the somatic and autonomic nervous systems. The autonomic nervous system is further subdivided into sympathetic and parasympathetic nervous systems, and their activities or functions are opposite to each other. A reflex arc is the pathway that impulses would pass in order to bring about a reflex action. Sense organs are specialized structures of the body that detects conditions of the environments

6.0 Tutor Marked Assignment

ai. How does hormonal action differ from a nervous action? Tabulate you answer (10 marks)
ii. Draw and label a motor neurone (5 marks
iii. Enumerate the functional differences between sympathetic and parasympathetic nervous systems. Tabulate your answer (5 marks)
bi. Draw and label a section of the mammalian eye (8 marks)
ii. List two other sense organs (2 marks
iii. Describe the eye defect called myopia (6 marks)
iv. Write short note on astigmatism (4 marks)

7.0 Further Reading and Other Resources

M.B.V. Robert. *Biology - A Functional Approach*
S. T. Ramalingam, 2001. *Modern Biology* edition
S. A. Odunfa, 2001. *Essentials of Biology* edition
G. Idodo - Umeh 1996. *College Biology* edition

Volume 3: Regulatory Systems and Mechanisms in Animals

Unit [illegible] Locomotion in Animals

[illegible]

There are different types of skeletons in animals. These are hydrostatic, exoskeleton and endoskeleton. The skeleton is the frame work or foundation on which the body is built. Some of the functions of the skeleton in animals include; protection, support and locomtion. The skeletal material in mammals is the bone the skeleton is divided into axial and appendicular skeletons, which also consists of specialised junctions called joints. The relationship between the skeleton and muscles brings about movement (locomotion) in mammals.

Objectives

By the end of this unit, you should be able to;

i. List the types of skeleton
ii. Summarize functions of the skeleton
iii. Describe types of joints and
iv. Discuss how movement is achieved in mammals.

Types of Skeleton – Bones

There are three types of skeleton;

i. Hydrostatic skeleton: found in invertebrates such as earthworm. It consists of body fluid secreted by the body wall into the coelom. This fluid, in combination with the circular and longitudinal muscles of the earthworm, functions as the hydrostatic skeleton. The functions of the hydrostatic skeleton include; support, protection and movement.

ii. Exoskeleton: It is located externally on the animal. It is mainly a protector against dryness. It may cover the entire body surface just like the shells of snails, tortoise and turtle. Insects and arthropods also have an exoskeleton.

iii. Endoskeleton: It is made up of hard structures, found inside the body of animals. The structures are mainly the bones. and the soft parts of the body are built on bones! presence of the endoskeleton is a major characteristics of the vertebrates.

B. Skeletal Materials

There are three major types of skeletal materials these are:

i. Chitin: This is a major component of the exoskeleton of arthropods. It is a protein - carbohydrate - mineral compound similar to cellulose; It is tough, light and flexible.

ii. Cartilage: It is a tough elastic tissue that has neither blood vessels nor nerves. Its main functions include;
   * preventing friction between two bones
   * absorbing shock
   * supporting the protruding parts of the nose and ear
   * forming major components of the trachea and bronchi

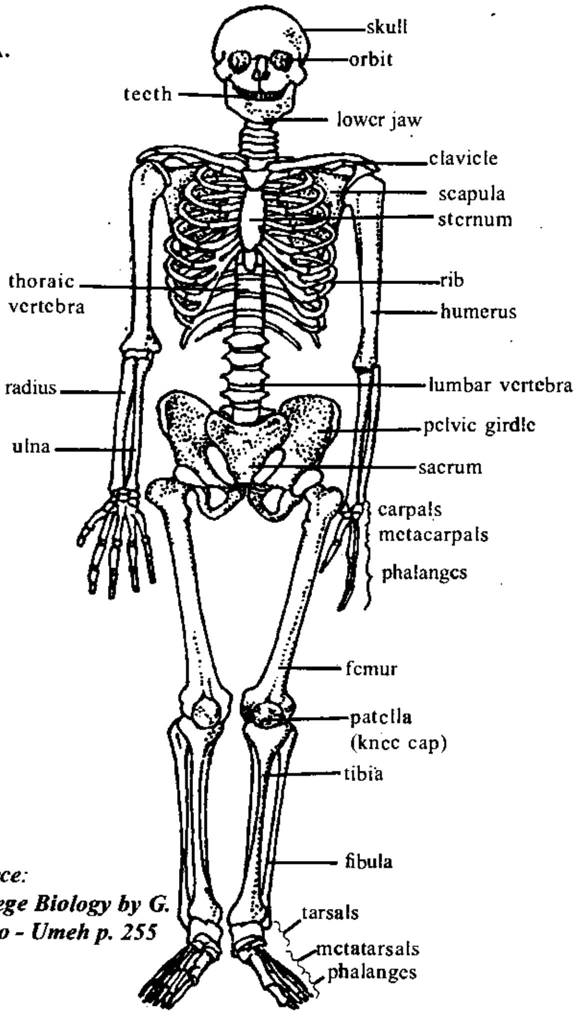
iii. Bone: It consists of organic (gelatinous) and inorganic (magnessium, phosphorus and calcium) materials. The bone is stronger and more rigid than cartilage. Shape and size of bone depends on its position and function. For example the bones of the limbs are long and big, while those of the ear (malleus, incus and stapes) are the smallest bones of the body.

3.1 The Mammalian Skeleton

The mammalian skeleton comprises of;

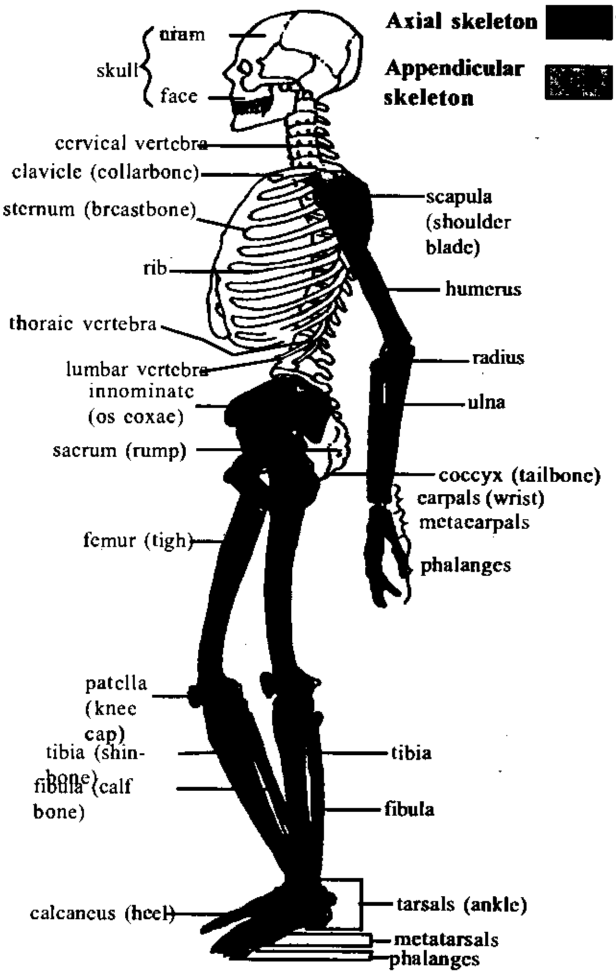
* The axial skeleton, which is made up of the skull, vetebral column, breast bones or sternum and ribs.
* The appendicular skeleton which is made up of the pectoral girdle, pelvic girdle, fore and hind limbs.

A.



***Source:* College Biology by G. Idodo - Umeh p. 255**

Human Skeleton



The Human Skeleton (Side view)
*Source: College Zoology by **R.A. Boolotian and K. A.** Stiles pp. 483*

a. The Axial Skeleton

ai. The Skull: It consists of two major parts;

* *Cranium* - it is the brain box, that protects the brain. It has flat and curved bones, fitted together at sutures. The brain joins the spinal cord at a large hole called foramen magnum.
* *Facial bones* - are the cheek, nasal and jaw bones. Between the upper and lower jaw bones is the mouth. The teeth are attached to the jaw bones.

aii. The Vertebral Column: It is called the backbone or vertebrae (singular: vertebra) or spinal cord. The vertebral column of man consists of the following vertebrae;

* Cervical vertebrae - they are seven (7) in number including atlas (first cervical bone) and axis (second cervical bone).
* Thoracic vertebrae - they are twelve (12) in number,
* Lumber vertebrae - are five (5) in number,
* Sacral vertebrae - they are also five (5) in number
* Caudal vertebrae - they are four (4) in number.

All the vertebrae have common features. They are all hollow and placed on each other to form a continous canal. Some of the common features of the vertebrae are;

- *Neural canal*: is a wide hole at the middle of the vertebrae through which the spinal cord passes
- *Neural arch*: it forms the roof of the neural canal, provides places for attachement of muscles and protects the spinal cord.
- *Transverse processes*: are found at the sides of the neural arch they form articulating facets with ribs in the thoracic region and provide areas for attachement of muscles.
- *Neural spine*: Part of neural arch that also provides areas for attachement of muscles.
- *Centrum*: it is situated below the neural canal, it is the thick base of the vertebra. It forms an articulatory surface with other vertebrae in the vertebral column. Between one centrum and another (or between the vertebrae), a disc is formed called intervertebral disc.
- *Prezygapophysis*: it is the smooth part on the neural arch at the anterior view of the vertebrae. There are two prezygapohyses on each vertebra through which they articulate with the vertebra in front of it.
- *Postzygapohysis*: It is the smooth part of the neural arch at the posterior view of the vertebra. There are two postzygapohyses on each vertebra through which they articulate with the vetebra behind.

aiii. Structures and Functions of the Different Vertebrae

***Cervical vertebrae*:** Their functions include giving support to the head and giving the neck its form. Atlas and axis allow the head to nod and rotate. They protect blood vessels and spinal cord by providing holes (canals) for them.

The cervical vertebrae are seven (7) in number.

They consists of Atlas vertebra (1), Axis vertebra (1) and five (5) other normal cervical vertebra.

- Atlas vertebra (see fig. 7.2)
    * It is the first vertebra of the cervical region
    * It has large neural canal
    * It has two large depressions on its anterior surface which fits two projections at the base of the skull, this allows nodding movement of the head.
    * It has no centrum nor zygaphophyses
    * Its spine is short or almost absent
    * It has transverse ligament

- Axis vertebra (see fig. 7.2)
    * It is the second vertebra of the cervical region
    * It has broad and flat centrum
    * It has an elongated odontiod process which fits into the neural canal of the atlas, thereby allowing rotation movement of the head.
    * It has large neural spine and small transverse processes
    * It has two (2) post-zygapophyses but no pre-zygapohyses

- Other cervical vertebrae
    * That is, vertebrae numbers 3, 4, 5, 6 and 7

* They all look alike
* They have a short bifurcate (divided) transverse processes
* All cervical vertebrae have vertebraterial canals (on either side) through which blood vessels and nerves pass.

Thoracic vertebrae: The twelve of them are attached to the ribs.

* They protect the lungs and heart
* They support ribs
* They have well developed transverse processes articulating with the ribs (fig. 7.2 and 7.3)
* The neural spine is long and backwordly directed
* There are articular facets on the centrum and transverse processes, which articulate with the head and tubercle of ribs respectively

Lumbar vertebrae: They are massive and support the body's weight.

* They maintain proper gait of body
* They support pregnancy in females
* They have well developed ventrally directed transverse processes (see fig. 7.2)
* They have two extra projections that are paired (anapophyses and metapophyses) which are meant for attachement and abdominal muscles.
* They have well developed pre-and-post-zygapophyses.
* They have large thick centra (singular: centrum).

Sacral vertebrae: They are fused to form a large bone called the sacrum

* The sacrum articulates with the pelvic girdle
* The sacrum protects the nerve fibres which save the lower body
* They have reduced centrum with several tiny holes meant for passage of blood vessel and nerves fibres (fig. 7.4)

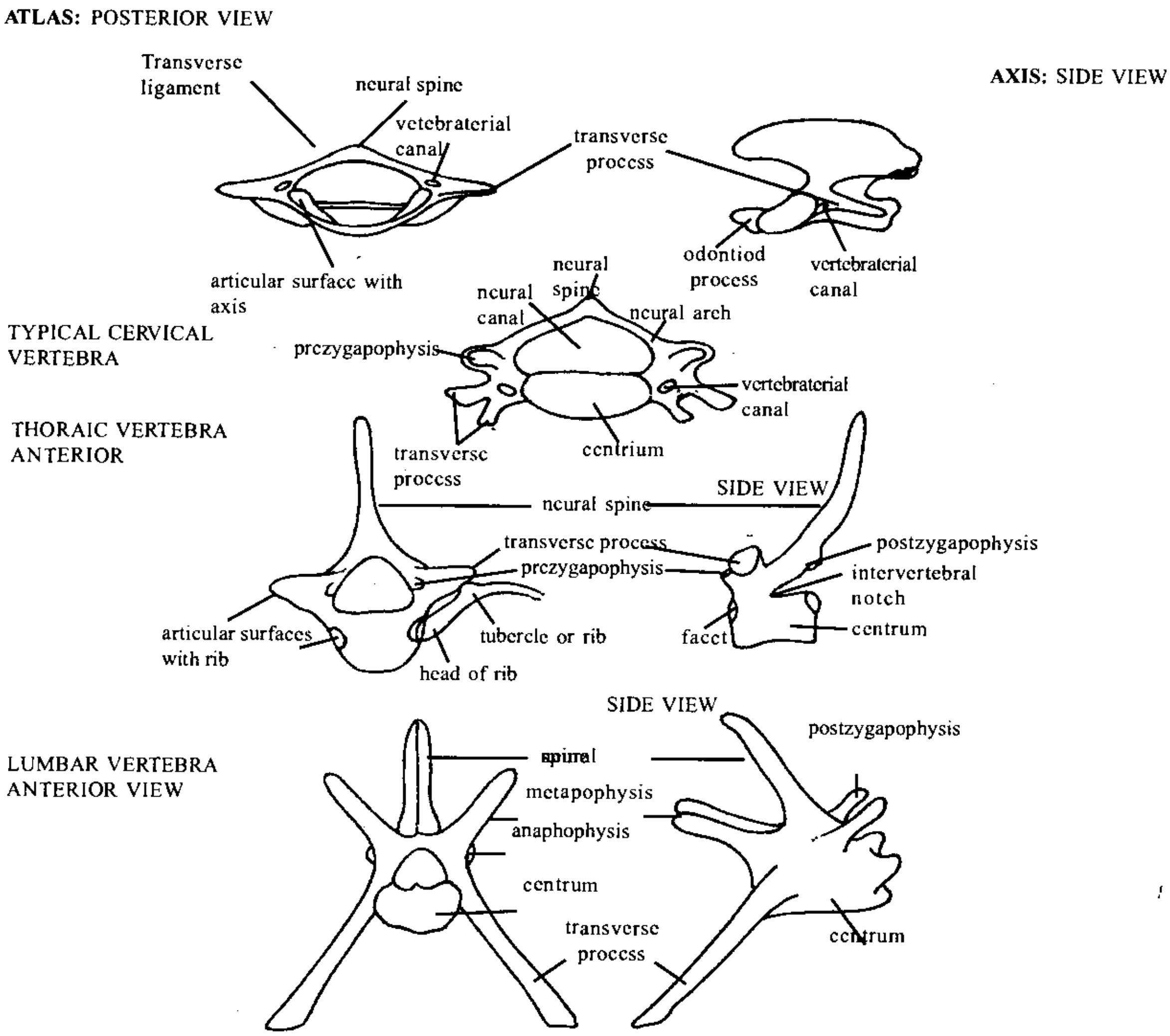


Fig. 7.2 Different types of vertebrae

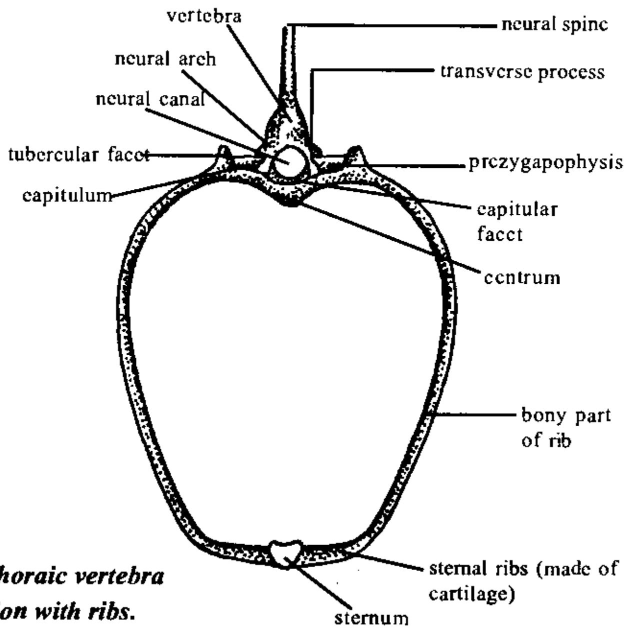


Fig. 7.3 Anterior view of thoraic vertebra showing articulation with ribs.

The Caudal vertebrae: There are four (4) in the vertebral colum of man (27 - 30 in rats, that forms the tail)

* They are fused together to form the coccyx (fig. 7.4) which stabilizes the rigid pelvic girdle.
* Greatly reduced to small centrum bones
* Coccyx houses and protects blood vessels and nerve fibres from the ischium

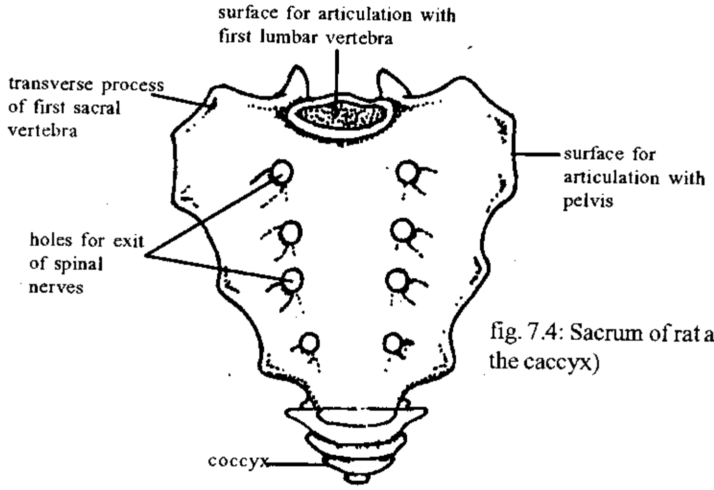


fig. 7.4: Sacrum of rat anterior view (note the caccyx)

Figure 7.4 Source: College Biology by G. Idodo - Umeh p. 261

iii. Ribs and Sternum

* In human, there are twelve pairs of ribs.
* The ribs articulate with thoracic vertebrae at the back
* The ribs and the sternum (which is a single bone in front of the chest) form the rib cage (fig. 7.5)
* The cage protects the heart and lungs
* In humans, only the first ten ribs are attached to the stemum directly.
* The last two pairs are not attached to the sternum and they are called floating ribs
* The posterior end of the sternum has cartilage called the xiphoid cartilage.

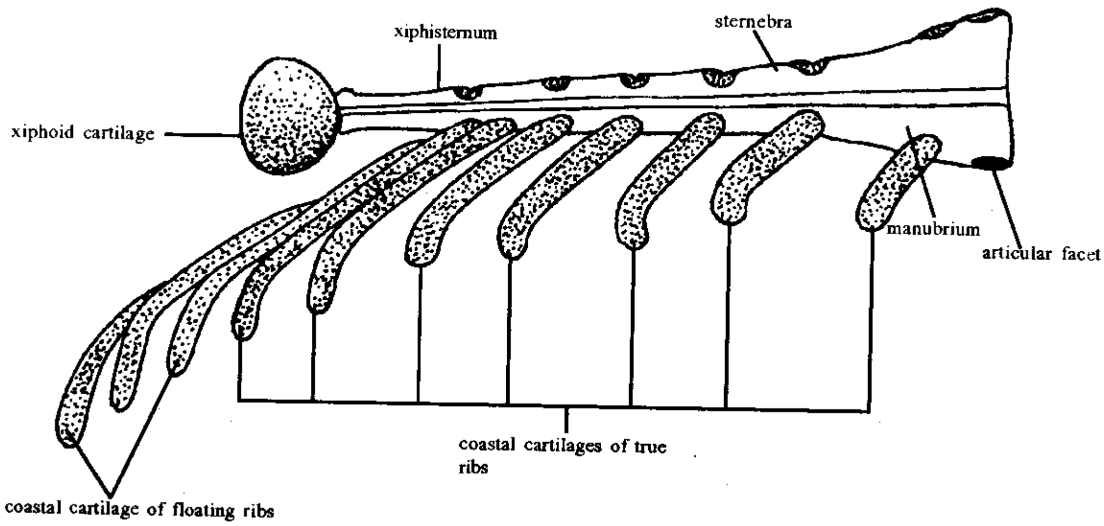


Figure. 7.5 The Sternum and rib

Activity A

ai. List the three types of skeleton you have studied.
ii. In a tabular form, list the common features of the vertebrae and state their functions.
bi. Describe the structure and functions of the different vertebrae
ii. Draw a thoracic vertebra and label it fully.

b. The Appendicular Skeleton

i. This is made up of the **pectoral girdle** two large **triangular blades** *(scapulae)* at the back and two small slender **collar bones** *(clavicle)* in front. The scapulae are attached to the vertebral column by muscles.

At one end of the scapulae (singular: scapula) there is a depression called **glenoid cavity** (fig. 7.6). The head of the upper arm bone (humerus) fits into the glenoid cavity to form the shoulder joint which is a ball and socket joint. The clavicles are attached to the scapula at one end and to the sternum (in front) at the other end (see fig. 7.1a).

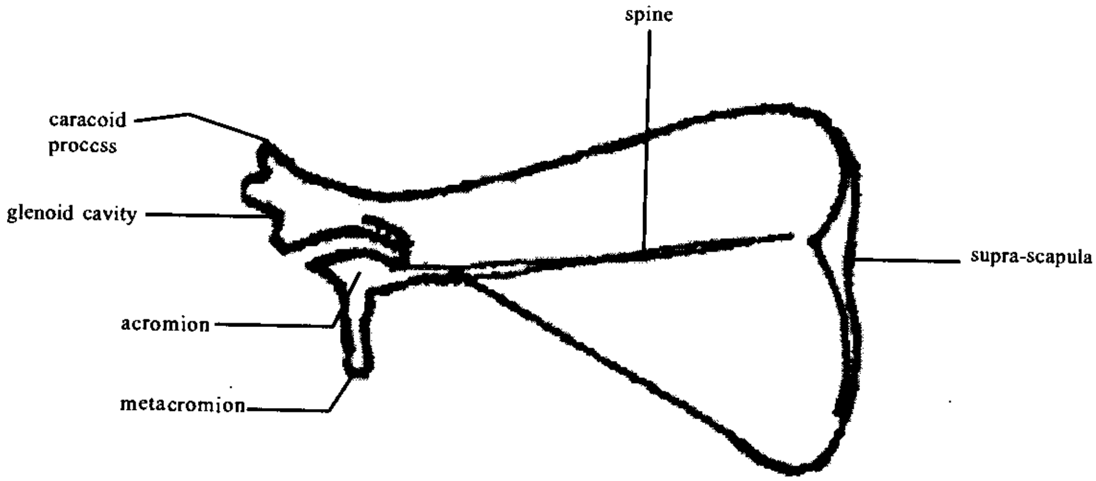


Figure 7.6 left scapula of a rabbit

bii. Pelvic Girdle or Hip: consists of two bones i.e. the right and left pelvis.

* Pelvis are joined at the back to the sacrum and held together by fibo-cartilage at the facets in front, to form the rigid girdle.

A cavity called **acetabulum** is on the outer edge of the girdle. The head of the femur (thigh bone) fits into the acetabulum to form the hip joint which is another example of a ball and a socket joint. Functions of the pelvic girdle include to receive weight of the upper body, to pass the weight to the legs (while standing) or to surface on (which you are sitting) fig. 7.7.

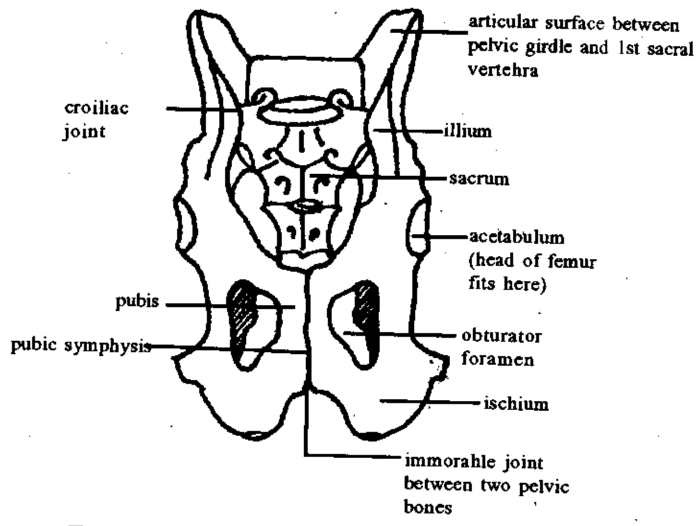


***Figure. 7.7:* Ventral view of pelvic girdle**
Source: College Biology by G. Idodo - Umeh

biii. The fore and hind limbs
These are limbs of the arms (upper) and legs (lower). They both have the same basic pattern called pentadactyl plan.
The upper limb has sixty (60) bones
The lower limb also has sixty (60) bones. The pentadactyl plan of the limbs are summarized in fig. 7.8

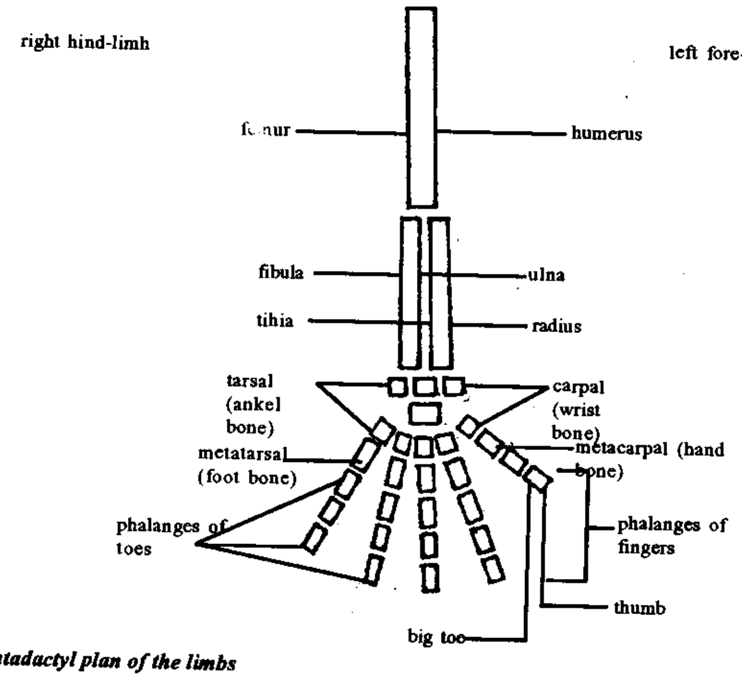


Figure 7.8 The pentadactyl plan of the limbs

Table 7.1 Summary of Total Bones in the Body and where they are located.

Site	No of Bones
Ear	6
Hyoid	1
Vertebrae	26
Ribs	24
Sternum	1
Shoulder girdle	4
Pelvic girdle (excluding pubis)	2
Upper limbs	60
Lower limbs	60
Total	206 Bones!!!

3.2 Functions of the Skeleton

* It gives **shape** to the body
* It **protects** organs of the body e.g. the skull protects the brain, eyes and tongue, vertebral column protects the spinal cord; the heart and lungs are protected by the ribs or thoracic bones and the sternum.
* It gives **support** to the body, e.g. cervical vertebrae support the head, the hindlimbs support the weight of the whole body
* It allows **movement** of parts of the body, because of the attachement of muscles to bone
* Skeleton **manufactures** white and red blood cells in the bone marrows of humerus and femur
* Thoracic bones aid **breathing** movements
* The three small bones of the ear (hammer, anvil and stirrups) vibrate and transmit sound waves.

3.3 Joints

The place or region where two or more bones meet is called a joint. Joints allow movement. Joints are held together by ligaments (fig. 7.9). A typical moveable joint has the following;

* bones - which provide frame of the joint
* cartilage - which is smooth and rigid, often present at the end of bone. Cartilage prevents bone from wearing out by reducing friction between two bones
* ligaments - a strong tissue that holds the bones together and prevents them from dislocating
* synovial membrane - found on the inner surface of joints, it secretes synovial fluid that lubricates joints.

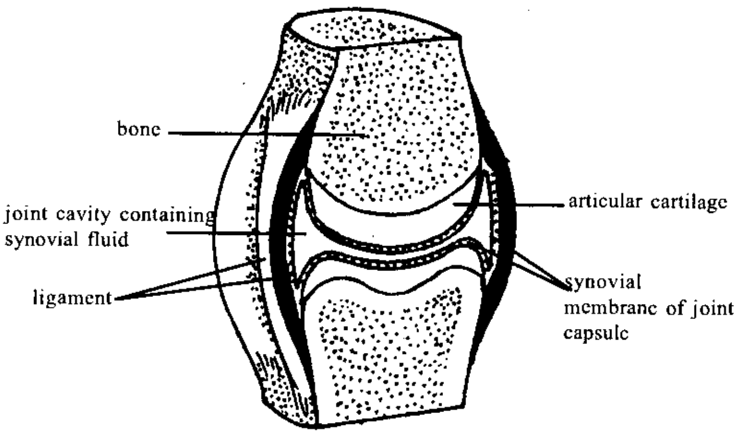
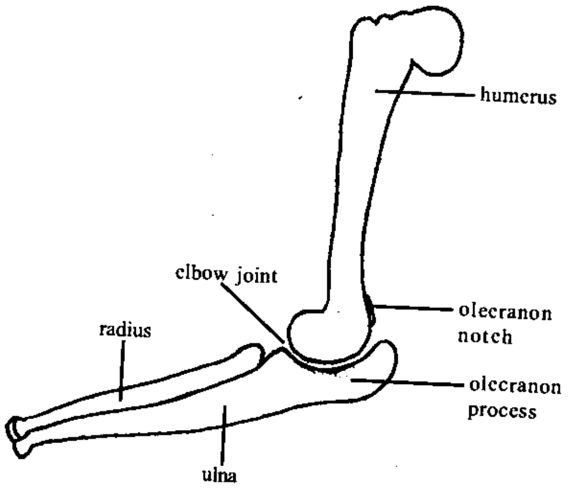


Figure. 7.9 A diagram of a joint surface (longitudinal section) showing some of its characteristics
Source: College Zoology by R. A. Boolootian and K. A. Stiles p. 484

3.3.1 Types of joints

a. **Hinge joint** - found at the elbow and knee (fig. 7:10)

* It permits angular movement in one direction



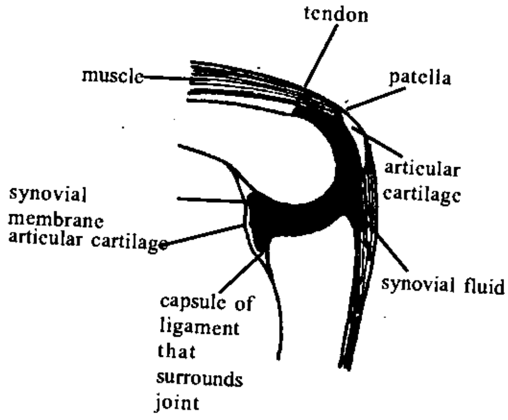


Fig. 7.10 Hinge joint of elbow and knee
Source: Modern Biology by S. T. Ramalingam P. 262

b. **Ball and socket joint** - found at the shoulder and hip (see fig. 7.11)

* it allows multidirectional movement

* at the shoulder, the head of the humerus (ball-like) fits into the glenoid cavity (socket) of the scapula.

* simialrly, at the hip, the head of the femur, fits into the acetabulum of pelvis

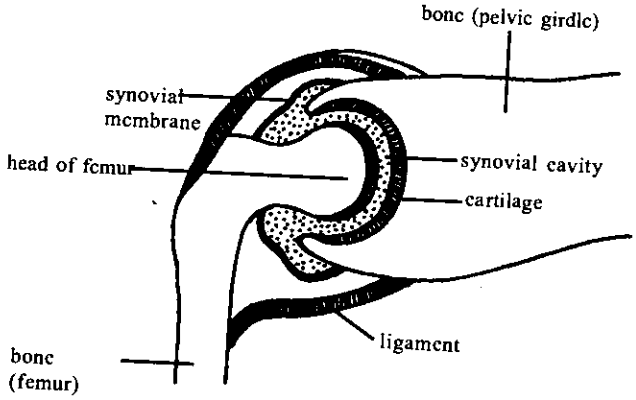


Fig. 7.11 Ball and Socket joint of hip
Source: College Biology by G. Idodo - Umeh p. 267

c. **Pivot joint** - found between the atlas and axis

* it allows only rotational movement

* it acts as pivot and allows head to rotate.

d. **Gliding and Sliding joint** - found at the wrist and ankle

* allows sliding of bones over each other

* allows movement of hand and foot up and down, and to rotate slightly

3.4 Movement at the Joints

* Movement or locomotion of bones at the joints is caused by muscles
* Muscles are involuntary e.g. smooth and cardiac muscles. Or voluntary such as the skeletal muscles
* It is the skeletal muscles that brings about movement
* Muscles are joined to bones by tendons
* Ligaments connects bones to bones
* Muscles are usually attached to two bones
* A pair of muscles are usually antagonistic at the joints
* When one contracts, the other relaxes
* For instance, when biceps muscles (flexer muscle) of the lower arm relax, the triceps muscle (extensor muscle) contracts and the lower arm is straightening.
* The reverse occurs when you are bending your arm! (see fig. 7.12a and b).

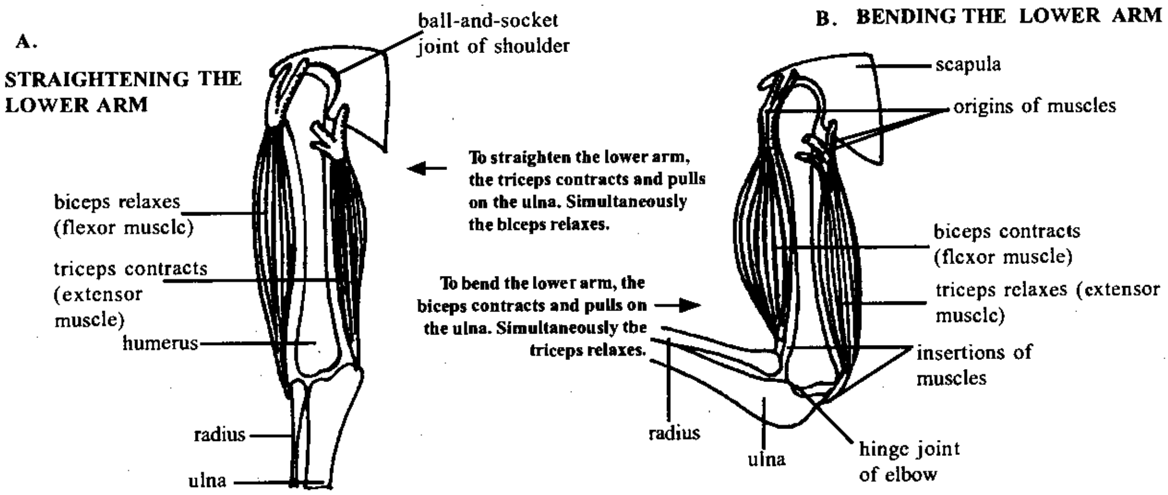


Fig 7.12 Movement of the fore limb

Activity B

ai. List the components of the appendicular skeleton
ii. State the functions of the skeleton
bi. Describe a typical movable joint
ii. How is movement achieved by the lower arm?

4.0 Conclusion

In this unit, you have learned that there are three major types of skeletons (hydrostatic, exo-and endo-skeletons). You have also realised that functions of the skeleton include; protection, support and locomotion, and the skeleton is divided into axial and appendicular skeleton. You should be able to list the different types of vertebrae and their functions. In addition you should be able to describe a typical joint and state how the joints assist in locomotion.

5.0 Summary

The hydrostatic, exoskeleton and endoskeleton are found in Earthworm, arthropods (insects) and mammals respectively. Skeletal materials are chitin, cartilage and bones.
The mammalian skeleton is comprised of the axial skeleton (skull, vertebral column, breast bones or sternum) and the appendicular skeleton (pelvic and pecteral girdles, and fore and hind limbs). The functions of skeleton

include to protect, support, give shape and allow easy movement of the body.
Joints are the meeting points of two or more bones. Joints include ball and socket joints, hind joint, pivot joint, sliding or gliding joint, movement or locomotion in mammals is assisted by muscles which are attached by the skeletal system.

6.0 Tutor Marked Assignment

ai. State the functions of the mammalian skeleton (8 marks)
ii. With the aid of a diagram, describe the thoracic vertebra of a mammal (8 marks)
iii. State the function(s) of each of its parts (4 marks)
bi. Make a large drawing of a typical movable joint and label it (6 marks)
ii. State the functions of the parts you have labelled
iii, Describe the basic movement of your arm

7.0 Further Reading and Other Resources

S. A., Odunfa. *Essential of Biology*
S. T. Ramalingam. *Modern Biology*
G. Idodo - Umeh. *College Biology*
M.B.V. Roberts. *Biology - A Functional Approach*
R. A. Boolootian and K. A. Stiles. *College Zoology*

Volume 3: Regulatory Systems and Mechanisms in Animals

Unit 8: Respiration (Gaseous Exchange) in Animals

Page

1.0 Introduction

When we breathe, we take in oxygen through our nostrils (nose) and give out carbon-dioxide as waste product. We can survive for weeks without food, but we will die within a few minutes without oxygen.
Oxygen is used to release energy stored in food that we consume in a process called respiration. Food contains carborhydrates, fats, proteins (Amino acids) minerals and water. These food must be broken down to release energy in living cells.
The use of oxygen to release energy as ATP (Adenosine triphosphate) in living cells is called cellular respiration. Cellular respiration involves aerobic (in presence of oxygen) and anaerboc (without oxygen) respiration, which you have studied in volume 2, and 8.
In this unit we will be concerned with intake of oxygen by various ventilating organs and the release of carbon dioxide and water (which are waste products). This system of respiration is called gaseous exchange system.

2.0 Objectives

At the end of this unit, you should be able to;

a. List the types of respiratory systems
b. Discuss diffusion and respiratory structures
c. Describe gaseous exchange in insects amphibians, fish and mammals.

3.0 Types of Respiratory Systems and Structures

There are four major types of respiratory systems in animals. These are;

a. Body surfaces: In most unicellular organisms e.g. amoeba and paramecium, gaseous exchange takes place through the plasma membrane by simple diffusion.
In flat worms, e.g. planaria the body surface has increased surface area to volume ration, and brings the innermost cells close to the body surface. These allows the worms to get its oxygen requirement by simple diffusion.
In frogs and toads (Amphibians), which live in water and on land; they have lungs, as well as moist skin for respiration. The respiration that takes place on the skin is called *cutaneous respiration*.
The skin of frog is highly supplied with blood capillaries and kept moist by mucus that is secreted by the mucus gland.

b. Gill: They are special respiratory organs used in aquatic environment to absorb oxygen.

- *Simple gills:* are external gills as found in tadpoles, sea slugs, aquatic snails and many fishes (see fig. 8.1). They are branched; this allows increased surface area to be exposed for gaseous exchange in water. They are richly supplied with blood capillaries.
- *Complex gills:* found in fishes. The gills are within the gill chambers (opercullar cavities), there are two gills chambers situated on each side of the head, just behind the mouth.

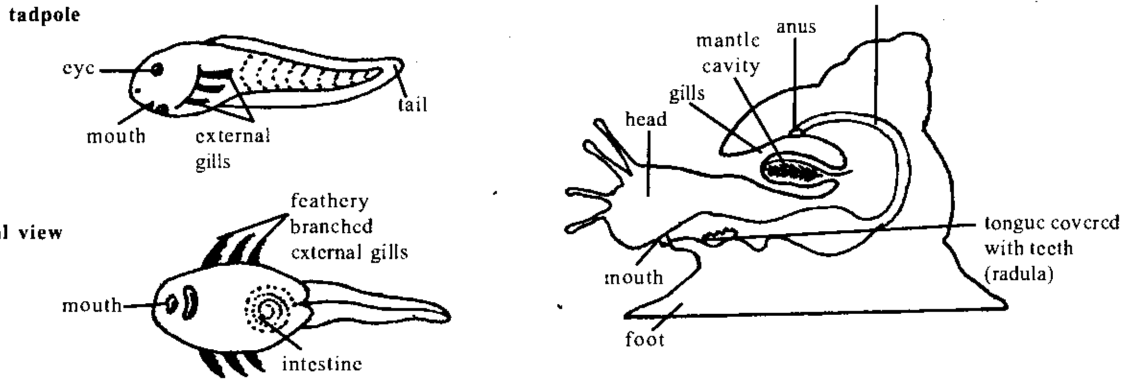
Gills are covered by operculum. Direction of water flow in fish is as follows;

water → mouth → pharynx → gill chambers → out from opercular.

There are four gills in each chamber. Each gill is made up of a gill arch, which has two rows of gill filaments on the outside and gill rakers on the inside (fig. 8.2)

Fig. 8.1 - Simple Gills

A. Young tadpole **B. Aquatic snail**

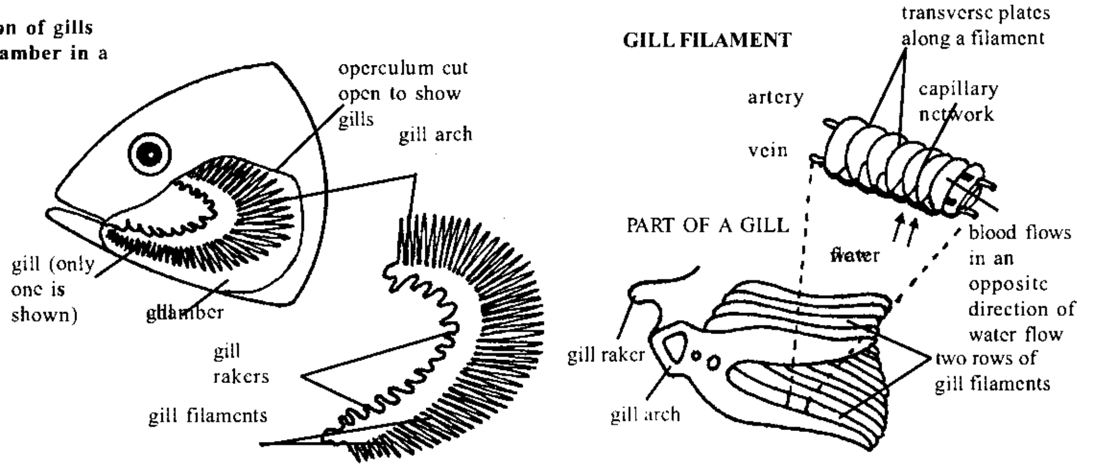


Source: Modern Biology by S. T Ramalingam, P 315

Fig. 8.2 Gills in bony fishes (complex gills)

A. Position of gills and gill chamber in a bony fish

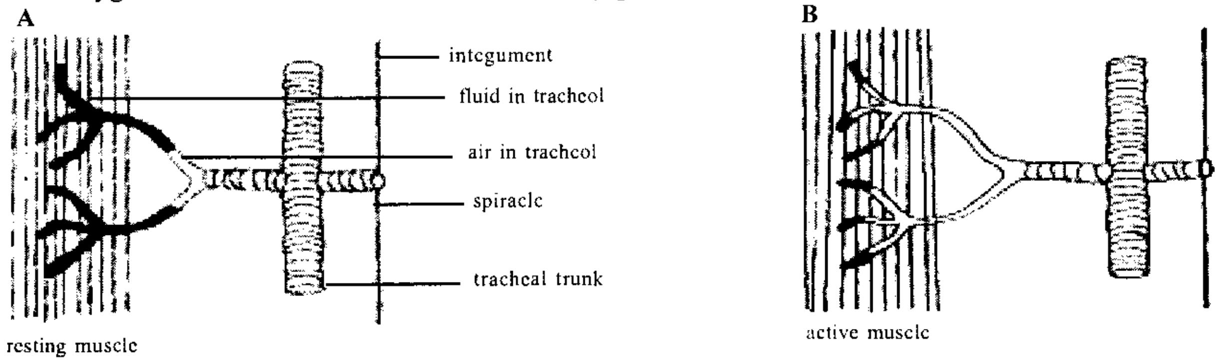
B. Structure of gill and gill filament



c. **Tracheae:** Tracheal system is found in land arthropods. Air enters the body through openings called spiracles found along the sides of the insect. In cockroach there are ten pairs of spiracles.

Spiracles lead into tubes called tracheae, which branch into trachioles. Trachioles contains fluid in which oxygen dissolves before it gets to individuals cell of the body. In flying insects the trachae develops into air sacs. Oxygen diffuses into cells, tissues or muscle (fig. 8.3).

A **B**



A small part of the tracheal system of an insect. The spiracles open into a man longitudinal tracheal trunk on each side of the body. Branches of the tracheal trunks break up into numerous tracheoles which penetrate into the tissues.

B shows how the passage of oxygen to the tissues is accelerated by withdrawal of fluid from the tracheoles during muscular exertion.
(Based on Wigglesworth)

A small part of the tracheal system of an insect. The spiracles open into a main longitudinal tracheal trunk on each side of the body. Branches of the tranchea trunks breaks up into numerous tracheoles which penetrate into the tissues.

d. Lungs: Found in mammals. They are two, i.e. left lungs and right lungs, and are enclosed in the thorax. In humans, air enters the nostrils. The nostrils and mouth open into the pharynx, which branches into two; one leads to digestive tract while the other leads into the larynx (voice box). The entrance into the larynx is called glottis. The larynx lead to the trachea, which branches into bronchi (singular: bronchus) which is the air tube that enters the lungs. Smaller air tubes are called bronchioles which terminates in the air sacs or alveoli (fig. 8.4). The alveoli is rich in oxygen and poor in carbondioxide. The alveoli is also richly supplied with blood capillaries.

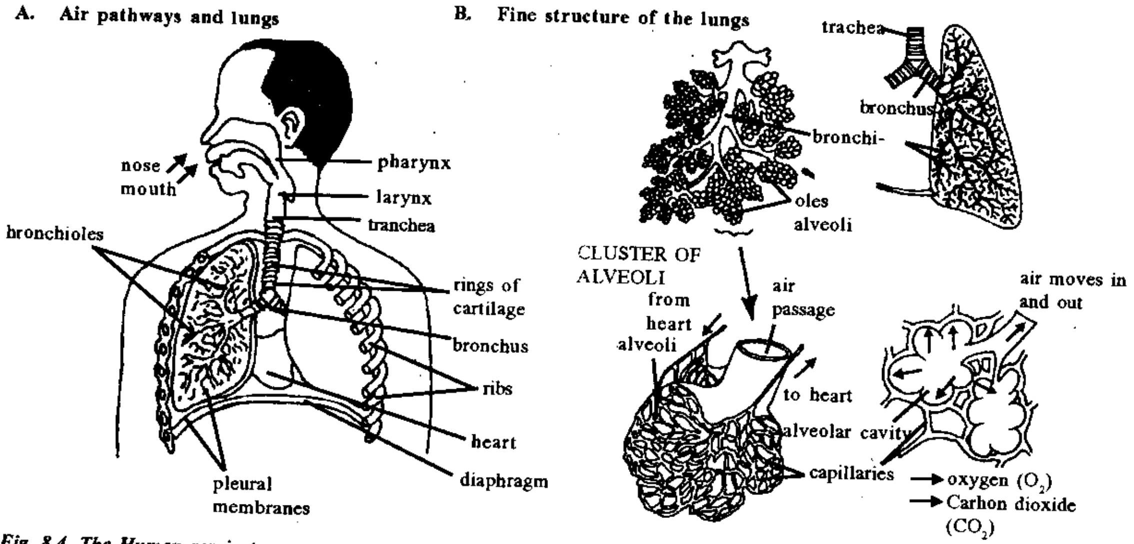


Fig. 8.4. The Human respiratory system

SECTION THROUGH ALVEOLI
Source: Modern Biology by S.T. Ramalingam, p. 315

3.3 Common Characteristic of Diffusion and Respiratory Structures

Gases enter and leave the cells by diffusion. Gases must be dissolve in water before they can diffuse across cell membranes. Therefore respiratory structures have certain properties which enables them to carry out their functions. Some of these include;

a. Respiratory structures must have large gaseous exchange surface;
b. The membrane which the gases diffuses through must be thin
c. They must have ventilation mechanisms that maintains difference in the concentrations of the gases across the membrane (to maintain a steep diffusion gradient) and
d. Gaseous exchange system must be linked to the transport (circulatory system)..

Activity A

i. List the respiratory structures
ii. Draw and label the respiratory strucutres used by insects and man
b. Describe briefly the common characteristics of diffusion and respiratory structures.

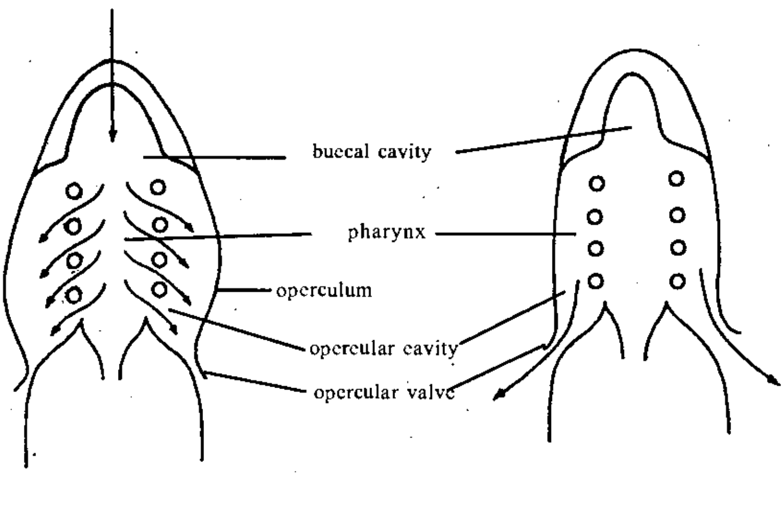
3.2 Cutaneous (Skin) Respiration

The skin of frog and toad is thin and well supplied with blood vessels. The skin is kept moist by mucus, secreted by mucus gland. Oxygen diffuses through the moist skin to the blood vessels. The oxygen then

combines with an oxygen carrying pigment called heamoglobin, which is present in the blood. When the oxygen combines with haemoglobin, it forms oxy-haemoglobin. Oxy-haemoglobin is transported to all parts of the body after internal respiration, the carbondioxide produced in the cells diffuses into the blood, and from the blood into the environment.
This type of respiration (cutaneous) takes place when the frog or toad is in water. So dissolved oxygen inwater diffuses through the skin into the blood capillaries and carbondioxide from blood diffuses into water. Cutaneous respiration can also take place on land provided the skin is moist.

3.3 Gaseous Exchange in Fish

The structure used for breathing in fish are the gills. The gills and its structure (fig. 8.2) are described in unit 3.1. In a fish like **Tilapia**, gaseous exchange occurs in the gill filaments. Breathing or ventilation movements brings about a one-way movement of water through the mouth to buccal cavity, to pharynx, to gill chambers and out of the fish.
Sucking in water from outside by the fish, involves the opening of the mouth and the closure of the opercula (singular : operculum) it is termed inspiration. As the mouth opens, the water is drawn in and mouth cavity is **lowered**. As water fills the mouth and pharynx, the fish expands its gills chamber to draw the water over the gills into the chamber (fig. 8.5a).
Expiration or expelling water involves the closure of the mouth, opening of the oesophagus, and the raising of the cavity. The water pressure in the mouth is then increased, and flows out of the body by pushing the opercular outwards (fig. 8.5b).
As water passes over the gill filament oxygen in water diffuses into the blood and carbon dioxide in the blood diffuses into the out going water. The exchange of these gases is assisted by the flow of blood
which is opposite to the water flow over the gill filament. Oxygenated blood that leaves the gills are taken to all parts of the body by the blood capillaries (fig. 8.6)



A. Inspiration
Water is sucked in through the mouth by expansion of the buccal cavity and thence into the opercular cavity by outward movement of the operculum accompanied by contraction of the buccal cavity.

B. Expiration
Water is exp elled through the opercular openings by inward movement of the operculum together with the continued contraction of the buccal cavity.

Fig. 8.5 Diagrams summarizing the ventilation of the gills in a teleost fish. Direction of water movements is shown by the fine arrows.

3.4 Gaseous Exchange in Mammals

The gaseous exchange structure in mammals are the lungs (see fig. 8.4 of unit 3.2) which are enclosed in the thorax. Ventilation of the lungs involves insipiration and expiration of air. The ribcage, intercostal muscles and diaphragm work together to bring about ventilation of the lungs.

* Inspiration: Air enters the lungs through the nostrils, leading to enlargement of the thoracic cavity and inflation of the lungs
  - then the external intercoastal muscles contract and the internal intercoastal muscles relaxes.
  - the ribs are moved upwards outwards
  - causing the sternum to move upwards and outwards
  - the position of the backbone remains fixed
  - the diaphragm contracts, flattening downwards and pushing out the ribs (see fig. 8.7a)

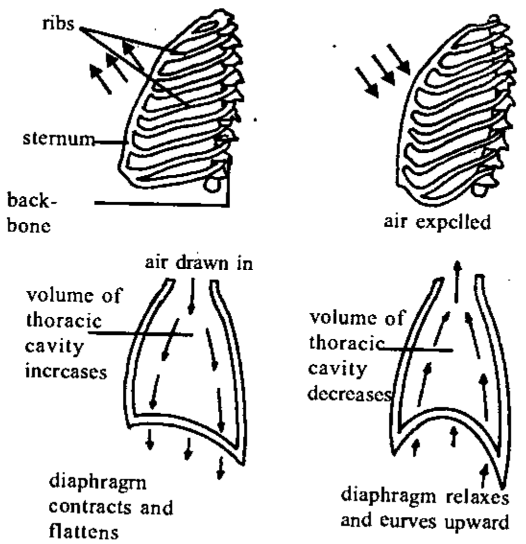
* Expiration: Air flows out of the lungs to the external environment and the thoracic cavity normalizes and deflates the lungs
  - the internal intercoastal muscles contract and the external intercoastal muscles relaxes
  - the ribs are moved downwards and inwards
  - the diaphragm relaxes and curves upwards to its normal shape (dome-like shape)
  - this eventually forces the air out of the lungs into the external environment (fig. 8.7b).

Fig. 8.6 Respiratory mechanisms in Humans

Ventilation Movement

A. Inspiration
Ribs move upwards and outwards when the external intercoastal muscles contract and the internal ones relax

B. Expiration
Ribs move downwards and inwards when the external intercostal muscles relax and the internal ones contract



3.4.1 Exchange of Gases in the Alveoli

- Air that is inhaled into the alveoli, is rich in oxygen and poor in carbondioxide
- Blood flowing in the blood capillaries to the alveoli is poor in oxygen and rich in carbondioxide
- These differences in concentrations of oxygen and carbondioxide in the alveoli air and blood, produces steep diffusion gradient thereby driving oxygen into blood stream and carbon dioxide into alveolar air space (fig. 8.8)
- There is little resistance to gaseous diffusion because the two layers of cells that separate the air in the alveolar space and blood in the capillaries are thin

- Oxygen dissolves in the fluid lining the alveolar wall before it diffuses in the blood
- The presence of haemoglobin in the red blood cells speeds the diffusion of oxygen and increases the oxygen carrying capacity of mammalian blood.
- The oxygen forms a complex with haemoglobin that is present in the red blood cells to form oxyhaemoglobin.

$$\underset{\text{haemoglobin (dark red)}}{Hb + 4O_2} \underset{\text{Low oxygen concentration in body cells}}{\overset{\text{High oxygen concentration in alveoli}}{\rightleftharpoons}} \underset{\text{Oxyhaemoglobin (bright red)}}{HbO_8}$$

- Oxyhaemoglobin lowers the concentration of free oxygen in the blood
- Thereby maintaining steep diffusion gradient
- Carbondioxide that must have diffused from body cells into blood stream is transported as hydrogen carbonate ions
- In the capillaries around the alveoli, the hydrogen carbonate ion dissociates into carbondioxide and water
- The carbondioxide diffuses into alveolar air space and escapes as gas.
- Water vapour is also released along with the carbondioxide

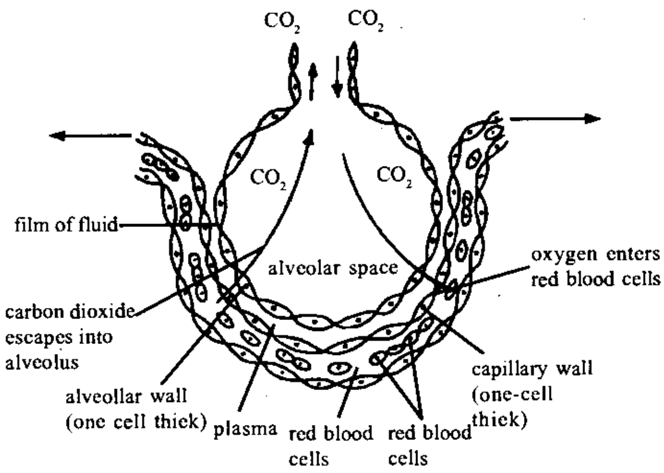


Fig. 8.7 Gaseous exchange in the alveolus by diffusion
Source: Modern Biology by S. T Ramalingam, p. 322

Activity B

i. Describe the cutaneous respiration
ii. How is expiration achieved in **Tilapia?**
iii. Describe the process called insipiration in a named mammal.
iv. Summarize the gaseous exchange between alveolus and blood capillaries

4.0 Conclusion

In this unit, you have studied respiratory systems, their structures and functions. You should be able to list respiratory structures in animals, draw these structures and label them fully. In addition you should be able to describe the mechanisms of gaseous exchange in insects, frog or toad, fish and mammal.

5.0 Summary

Respiratory systems are involved in gaseous exchange in multicellular organisms. There are four major types of respiratory structures in animals. These are body surfaces, gills, tracheae and lungs, found in toads, fish, grasshopper and man respectively.
Gaseous exchange takes place at respiratory surfaces, which have a large surface area, permeable, thin, moist and rich in blood supply. you should now summarize the mechanism of cutaneous respiration, gaseous respiration in fish (aquatic organism) and in terrestrial organisms (e.g. man).

6.0 Tutor - Marked Assignment

ai. Draw and label the respiratory structure used by a named mammal (10 marks)
ii. Describe the process of expiration in the above mammal (10 marks)
bi. With the aid of a well labelled diagram, describe the process of gaseous exchange between alveolus and blood capillaries (20 marks).

7.0 Further Reading and Other Resources

M.B.V. Roberts (1983). Biology, A functional Approach 3rd edition ELBS edition, publ. by Butler & Tanner Ltd., Frome and London.
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Volume 3: Regulatory Systems and Mechanisms in Animals

Unit 9: Nutrition and Transport System in Animals

Page

1.0 Introduction

The food that animals eat is composed of several substances which are generally grouped as carbohydrates, proteins, lipids, minerals, vitamins, roughage and water. These food substances must be eaten, digested by various enzymes and absorbed before it can be useful to the animal body. Animal nutrition involves the study of these food substances, balanced diet, digestive enzymes and abosorption of digested food by the villi. From the villi, the absorbed food will be taken to various parts of the body where they are required.
Various materials are transported in animals, these include digested food substances, water, oxygen, nutrients, excretory products such as urea, water, carbondioxide, and hormones. These materials are transported as an aqueous solution. In simple animals the cytoplasm and water acts as the transport media. In higher animals, blood is the medium of transportation. Intercellular fluid and lymph are also part of blood that are also important in transporting various materials. The blood has different components that flows in vessels (arteries, veins and capillaries) and are kept flowing by a vascularised pumping organ called the heart.

2.0 Objectives

By the end of this unit, you should be able to;

a. List the classes and sources of food substances
b. Define balanced diet
c. Describe dentition and alimentary systems of animals including various digestive enzymes
d. Describe the process of absorption of food
e. List the composition of blood and its function
f. Describe the circulatory systems in animals and
g. Enumerate the functions of the lymph.

3.0 Food Substances: Classes and Sources

Food substances consumed by an animal are carbohydrates, proteins, lipids (fats and oils), mineral salts, vitamins, water and roughage. Food is used to;

* to produce energy for the body's activities
* to build up the body for proper growth and development
* to replace worn out cells and tissues and
* to build special substances such as enzymes and hormones.

The classes of food, sources and functions are given below;

a. Carbohydrates: Made up of carbon (C), hydrogen (H) and oxygen (O). The H and O are in ration 2:1. Simple formular for carbohydrates is $C_x(H_2O)y$.

There are three types of carbohydrates, viz:

- Monosaccharides (simple sugars) e.g. Hexose, glucose, fructose with their formular as $C_6H_{12}O_6$ and ribose ($C_5H_{10}O_5$)
- Disaccharides (complex sugars) formed by condensation of two simple sugars; e.g. maltose, lactose, sucrose ($C_{12}H_{22}O_{11}$). Sucrose is found in sugarcane and ripe fruits. Lactose is found in milk of mammals and maltose is found in malted cereal and sprouting grains.
- Polysaccharides: such as starch and celluloses. Found in plants, formed by condensation of large number of simple sugars. e.g. Glycogen called animal starch, found in muscles. Cellulose is found in vegetables and fruits.

Functions of carbohydates

* Carbohydrates are food reserves as glycogen in muscles, liver, skin and starch in plants
* They are the main source of energy yielding food
* They form glycoprotein in mammalian skeletons

* Can you think of other functions of carbohydrates?

b. Proteins

They are made up of amino acids, which are joined by peptide bonds. They contain Carbon, Hydrogen, Oxygen and Nitrogen. Some amino acids have in addition to these sulphur, others have phosphorous.
There are twenty five types of amino acids.
Amino acids form polypeptides which are proteins. Sources of proteins include meat, fish, eggs, and beans.

Functions of proteins
* They are required for growth and repair of the body
* They are needed to manufacture enzymes and hormones
* They make antibodies that prevents diseases
* They provide energy

c. Lipids

These are fats (which are solid at room temperature) and oils (which are fluidish or liquid). Lipids are made up of fatty acids and glycerol. They also contain Carbon, Hydrogen, and Oxygen.
Sources of lipids include vegetable oils, butter, margarine, beef fat, and milk.

Functions of Lipids
* They give a great amount of energy
* They are stored under the skin, and around organs such as intestines, kidneys, heart and eyes
* They protect these delicate organs of the body
* They help to maintain body temperature
* They form an important structural material in nuclear and cell membranes

d. Mineral salts

These are calcium, phosphorous, sodium, potassium iodine etc, which are required for formation of bones and teeth, and to control several chemical reactions. The sources: functions and deficiencies of some minerals are summarized in table 9.1.

Table 9.1: Mineral salts, their sources, functions and deficiences

Mineral element	Source	Function	Deficiency
Iron	Leafy vegetable, liver, Kidney, plantain, meat, egg and salt	Formation of red blood cells and enzymes	Anaemia
Calcium	Milk, cheese, fish, meat, egg, green vegetables, shrimps, (seafood)	1. Formation of bones and teeth 2. Assist in the clotting of blood 3. Help in muscle contraction	1. Poor bone development 2. Poor growth 3. Causes decay of teeth
Phosphorus	Milk, meat, fish, snail, cheese, egg, yolk, green vegetables, beans, yam, bread	Formation of bones and teeth. Formation of ATP	Rickets and dental decay
Sodium	Table salt, fruits, fish, beef, chicken, yam, bacon	1. Proper functioning of muscles and nerves 2. Maintenance of salt concentration of the tissues	Muscle cramp
Potassium	Green vegetables, bananas, apples, chicken, potatoes, yam, milk, butter, beef	Proper functioning of muscle and nerves	Malfunctioning of muscles and nerves

Iodine	Fish, milk, drinking water, sea salt, iodised table salt	Proper functioning of thyroid gland	Goitre and cretinism in children
Fluoride	Drinking water, milk, green vegetables, some tooth paste bones from decay	Components of teeth and bones, protects teeth and	Decaying of teeth
Magnesium	Green vegetables, bread, apple and nerves	Proper functioning of muscles in children	May cause convulsion

Source: **College Biology by G. Idodo - Umeh, P. 97**

e. Vitamins

They are complex organic compounds that are required in small quantities for good health and good growth of the body. They do not give energy. The main vitamins are A, B, C, D, E and K. Vitamin B has many components (i.e. B complex). The sources, functions and deficiencies of the vitamins are summarized in table 9.2.

Fat solubule vitamins are;

Vitamin A, D, E, and K. Water solubule vitamins are; vitamins B_1, B_2, B_3, B_4, B_5, B_6, B_{12}, folic acid and C.

Table 9.2: Vitamins, their sources, importance and deficiencies

Vitamin	Sources	Function	Deficiency
Vitamin A (oil soluble)	Liver, red-palm oil, kidney, tomatoes, egg yolk, carrot, green vegetables, red pepper and sweat potatoes	1. Healthy growth 2. Healthy eyes and skin 3. High body resistance to disease 4. It enhances immunity 5. Protection against cold 6. Helps to slow down ageing process	1. Frequent colds 2. Retarded growth 3. Night blindness 4. Dry and scaly skin 5. Defective tooth formation 6. Reduced resistance
Vitamin B complex vitamin B_1 (Thiamin) (water soluble)	Yeast, milk, groundnuts, palm wine, beans, brown rice, wheat, liver, chicken, kidney, egg yolk and green vegetables.	1. Proper growth and normal appetite 2. Proper functioning of the heart, muscles, nerves and brain 3. Carbohydrate metabolism 4. It helps in the production of hydrochloric acid	1. Beri-beri 2. Retarded growth 3. Loss of appetite and weigth 4. Nervous disorder 5. Less resistance to fatigue 6. Constipation
Vitamin B_2 (Ribollavin) (Water soluble)	Meat, egg yolk, yeast, liver, fish, milk, mushrooms and green vegetables	1. Proper growth 2. Healthy skin 3. Proper functioning of eyes 4. Carbohydrates metabolism, fats and protein 5. Help in blood formation	1. Visual disturbances 2. Eye pain in bright light 3. Over flow of tears 4. Redness of eye 5. Wrinkling 6. A split or fissure of the skin at the corner (angle) of the mouth

Vitamin	Sources	Function	Deficiency
Vitamin B_3 (Niacin or ascorbic acid) Water soluble	Meat, fish, egg yolk, liver, yeast, rice, wheat, potatoes, green vegetable, cheese and carrots	1. Proper growth 2. Proper functioning of alimentary canal and nervous system 3. Gives healthy skin 4. Facilitates the metabolism of carbohydrates, fats and proteins 5. It helps to produce hydrochloric acid for digestive system	1. Skin eruptions 2. Disorder of the digestive system 3. Pellagra 4. Nervous disorder 5. Headache 6. Indigestion 7. Low blood sugar 8. Muscular weakness
Folic Acid (water soluble)	Yeast, egg yolk and green vegetables	Necessary for growth and formation of blood cells	Anaemia: Bones deformity in children. Bleeding for kidneys
Vitamin B_{12} (Cynocobalamin) (Water soluble)	Green vegetables, yeast, liver, milk, egg yolk, lean meat, kidney and seafoods.	1. It prevents nerve damage 2. Red blood cell formation 3. Helps in iron absorption 4. Helps in protein synthesis	1. Pernicious (fatal) anaemia 2. Poor growth 3. Nervousness 4. Liver enlargement 5. Drowsiness and dizziness memory loss, eye disorder, hallucinations, spinal cord degeneration
Vitamin C (ascorbic acid) (water solule)	Citrus fruits (oranges, grapes, lemons), tomatoes and leafy vegetables	1. Maintains the strength of the blood vessels 2. Essential for good development of the gum of the teeth 3. Healthy growth 4. Reduction of blood cholesterol 5. It is an anti-oxidant that helps to prevent cancer 6. It helps in the production of anti-stress	1. Scurvy (bleeding of the gums) 2. Loosening of teeth and sore gums 3. Delayed healing of wounds 4. Internal bleeding of tissues
Vitamin D (Calciferol)	Liver, fish liver, oil, eggs, milk, and sunshine	1. It helps in the production of anti-stress against the harmful effect of pollution 2. Regulate calcium and phosphorus absorption 3. Building and maintaining bone and teeth 4. It is necessary for normal blood cotting	Rickets (soft bones and poor development of teeth in children)
Vitamin E (Tocopherol (Oil soluble)	Green vegetables, butter, milk, meat and egg yolk	1. For normal functioning of the reproductive organs 2. It is an anti-oxidant that helps to prevent cancer 3. It improves blood circulation 4. Prevents cell damage by inhibiting the oxidation of fats	1. Destruction of nerves 2. Sterility in some animals, death of embryo 3. Destruction of liver cells and anaemia 4. weak muscles.

Vitamin	Sources	Function	Deficiency
Vitamin K (Oil soluble)	Green vegetables, egg yolk, liver and tomatoes	1. For normal clotting of blood 2. Normal liver function 3. It helps in the conversion of glucose to glycogen for storage in the liver thereby promoting health liver function	1. Failure of blood to clot 2. Bleeding

***Source:* College Biology by G. Idodo - Umeh, P. 96**

f. Water

Approximately, 70% of the body is water chemical reactions takes place in water and it is a means of transport. Substances such as excretory products hormones enzymes and digested food are transported in water it plays an important role in regulating body temperature. It is important in digestion of food and excretion of waste product.

g. Roughage

It is the fibrous material obtained from green vegetables, apples, fruits and maize it stimulates the muscles of the small and large intestines (bowels), thus pushing faeces along the intestines for easy defaecation.

3.1 Balanced Diet

This is a diet that contains sufficient quantities of carbohydrates, proteins, lipids, mineral salts, vitamins, water and roughage, to maintain proper body growth and development.
Breast milk is a balanced diet for infants because it contains most of the nutrients.

3.1.1 Food Tests

Remember that food substances are chemical compounds. Identifying individual food substances involve chemical tests. A summary of some chemical tests for carbohydrates, proteins and lipids are presented in Table below;

Table 9.3: Food tests

Substance	Test	Result
Carbohydrate	Add Anthrone solution to glucose solution, shake and allow to stand	Initial yellow colour turning brown on standing
Reducing sugars (glucose, fructose)	Add Fehling's solution to glucose solution, boil	Red precipitate formed
Non-reducing sugars (e.g. sucrose)	Boil with dilute HCl and then test as for reducing sugar	Red precipitate formed
Starch	Add iodine solution to starch suspension or piece of yam	Colour turns blue-black
Protein	(1) Add Million's reagent to egg albumen and warm (2) Add few drops of NaOH and copper sulphate to protein source (Biuret test)	Precipite formed and turns brick-red on warming Purple colour develops

Lipids	(1) Add Sudan III to groundnut oil in water and shake (2) Add fat source to white pepper	When oil separates, it is stained red Paper becomes translucent

Activity A

ai. List the classes of food substances
ii. State the functions of each class of food that you have written
bi. State the functions of mineral salts in your diet
ii. Write a short essay on fat soluble vitamins, stating their function, deficiency symptoms and sources.

3.2 The Mammalian Dentition

There are five types of teeth (fig. 9.1a) these are;

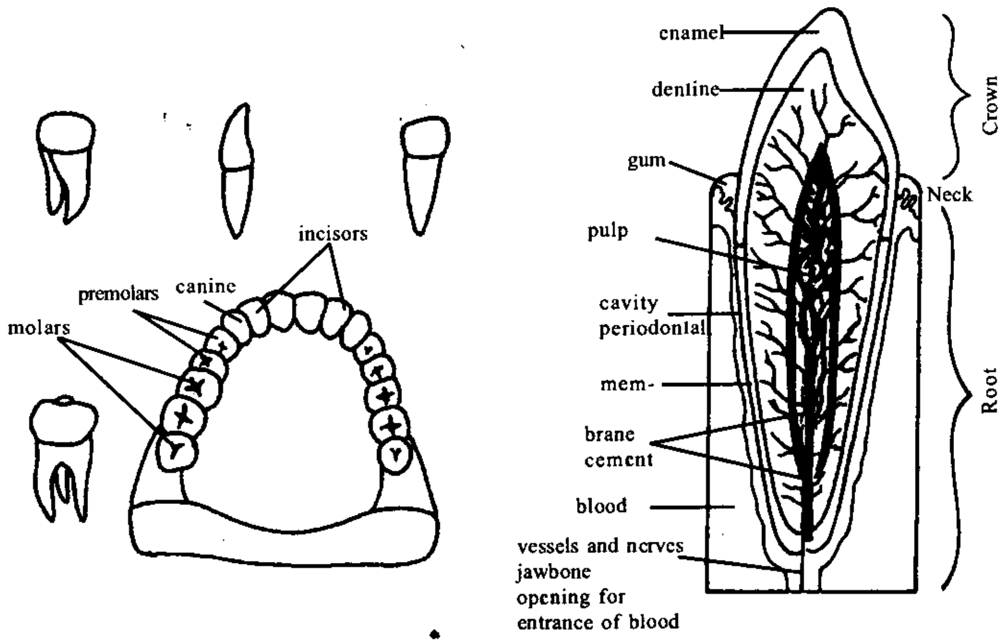
a. Incissors: found in front of jaw
   - it is flat and chisel shaped
   - it has one root
   - it is used for cutting and grabing

b. Canines: These are next to the incisors
   - their crown is pointed and conical (fig. 9.1b)
   - it has a single root
   - it is used for tearing food.

Fig. 9.1 **Teeth of Human Beings**

A. Types of Human Teeth

B. Longitudinal section of a tooth (Canine)



Source: Modern Biology by S.T. Ramalingam, P. 284

c. Carnassials: mainly found in canivorous animals like dogs, lions and hyenas
   - the upper and lower jaw carnassial teeth work like a pair of scissors by sliding over each other
   - they are used for cutting large pieces of meat and bones
   - used for breaking, grinding and chewing of bones

d. Premolar: next to canines
   - its crown has pointed ends and cusps
   - they have one or two roots
   - they are used for grinding and crushing

e. Molars: situated at the hind part of the mouth and jaw
   - next to premolars in human being
   - they have two or more roots
   - they are used for crushing and grinding. (Draw a premolar or molar and label it fully).

3.2.1 Structure of a Tooth

All teeth have the same basic structure (fig. 9.1b). The crown projects above the gum, the root is in the jaw bone, and the neck is between the root and the jaw.

* **Ename** - is the hard shinning covering of tooth, made of calcium
* **Dentine** - is the largest part of a tooth, made up of bone like structures and hardened by mineral salts
* **Pulp cavity** - is a hollow central core that contains nerve fibres and blood vessels which supply, food and oxygen to the tooth.
* Cement - is a bone like layer that fixes the tooth to its socket.

3.2.2 The Dental Formular of Mammals

Dentition refers to the number, arrangement and types of teeth in the jaw.

a. Dentition of an Omnivore: example of an omnivore is human being. The dentition has features of both herbivores and carnivores on a lesser scale (see fig. 9.1a).
The Dental formula of a man is:
$i\,^{2}/_{2},\ C^{1}/_{1},\ pm\,^{2}/_{2},\ m^{3}/_{3} = 16$ teeth.
where i = incisors, C = canine, pm = premolar and m = molar

This formular indicates half of upper jaw teeth and half of the teeth on the lower jaw. Therefore the complete dentition in man is 32.

b. Dentition of a Herbivores: e.g. sheep, goats, rabbit and cow. They feed mainly on grasses (vegetation or herbs) fig. 9.2 shows the dentition of a rabbit. Note the diastema, which is a toothless gap.
The dental formular of a rabbit is;

$i\,^{2}/_{1},\ C^{0}/_{0},\ pm\,^{3}/_{2},\ m^{3}/_{3} = {}^{8}/_{6},\ x\ {}^{2}/_{2} = {}^{16}/_{12} = 28$ teeth.
i.e. a total of 28 teeth are found on the upper and lower jaws of a rabbit.

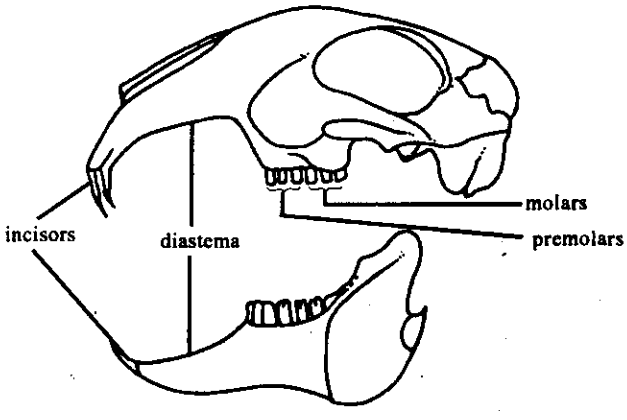


Fig. 9.2 Dentition of a rabbit
Source: College Biology by G Idodo - Umeh, P. 120

Dental formular of sheep and cow is;

$i\ ^0/_3,\ C^0/_1,\ pm\ ^3/_3,\ m^3/_3\ =\ ^6/_{10} \times\ ^2/_2\ =\ ^{12}/_{20}\ = 32$ teeth !

Can you sport the differences between the above formular and that of a rabbit?

c. Dentition of a Carnivore: e.g. lion, tiger, hyena and dog. They are meat or flesh eaters Their dental formular is;

$i\ ^3/_3,\ C^1/_1,\ pm\ ^4/_4,\ m^2/_3\ =\ ^{10}/_{11} \times\ ^2/_2\ =\ ^{20}/_{22}\ = 42$ teeth !

Fig. 9.3 shows the dentition of a dog.

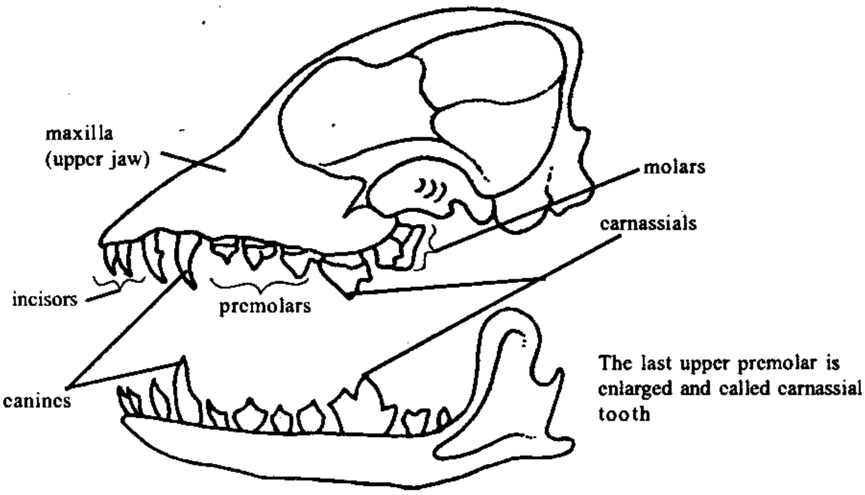


Fig. 9.3: Dentition of a dog
Source: College Biology by G Idodo - Umeh, p. 119

3.3 Alimentary Canal of Some Animals

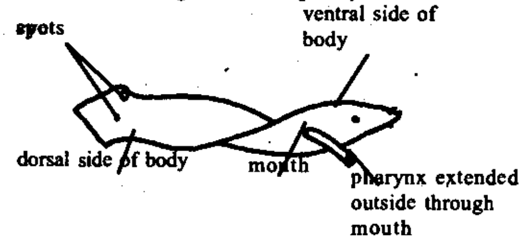
Mammals are the group of animals that have teeth to grind, chew or break food before swallowing, most other animals (e.g. the invertebrates) swallow their food. Therefore, the invertebrates must have other structures for softening and breaking their food, for efficient chemical digestion to occur. These structures are the crop and gizzard. Crop and gizzard are also found in vertebrates such as the bird. We shall not go into the details of the various types of alimentary canals. Fig. 9.4 shows some examples of alimentary canals of animals.

[redacted]

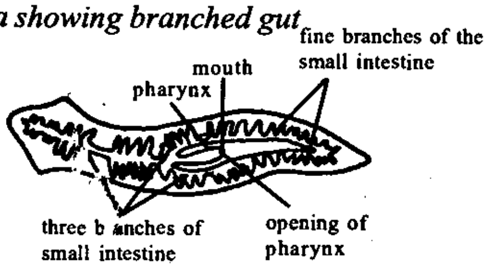
Write short notes on each of the alimentary canal in fig. 9.4. Use your reference text books

Fig. 9.4. Alimentary canals of some animals

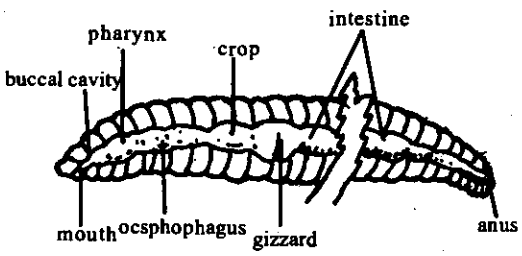
A. Panaria showing extended pharynx detalize



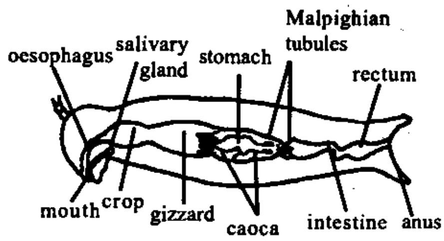
Panaria showing branched gut



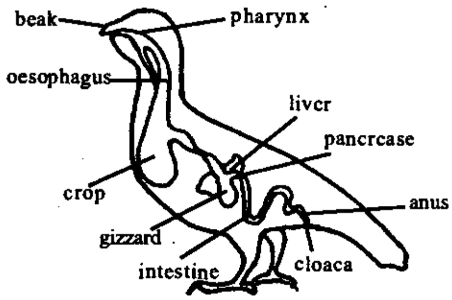
B. Earth worm



C. Grasshopper



D. Bird



Source: Modern Biology by S. T. Ramalingam, P. 291

3.3.1 Alimentary Canal and Digestion of Food in Humans

The alimentary canal starts from the mouth and ends at the anus. It is divided into the mouth, oesophagus, stomach and intestines. Fig. 9.5 shows the human alimentary canal.

a. Digestion in Mouth: Food taken into the mouth is chewed, cut and grinded by teeth. As these goes on, chemical digestion starts thus;
   - saliva secreted by salivary glands, contains the enzyme called **ptyalin**. Enzymes are organic catalyst that speeds up the rate of chemical reactions without being altered in the process.

List the properties of enzymes.

- **ptyalin** converts cooked starch into complex sugar like maltose.
- The tongue, found in the mouth rolls the food into a ball called bolus. The bolus is swallowed with the aid of the tongue
- The food goes into the oesophagus or gullet, through which food passes to the stomach
- The epiglottis prevents the food from going into the trachea during swallowing

- The wall of epiglottis has muscles which allow the food move to the stomach slowly by a process called peristalsis.

b. Digestion in the Stomach:
- food enters the stomach when the **sphincter** muscle at the entrance of the stomach relaxes
- food is churned in the stomach and mixes with mucus produced in the stomach
- **Gastric juices** that acts on food in the stomach are **pepsin** and **renin** (they are enzymes)
- **Hydrochloric acid**, present in the stomach also act on food (the stomach is acidic) by killing bacteria
- **pepsin (protease)** digest proteins to poly peptides
- **Renin** coagulates milk by turning into curds

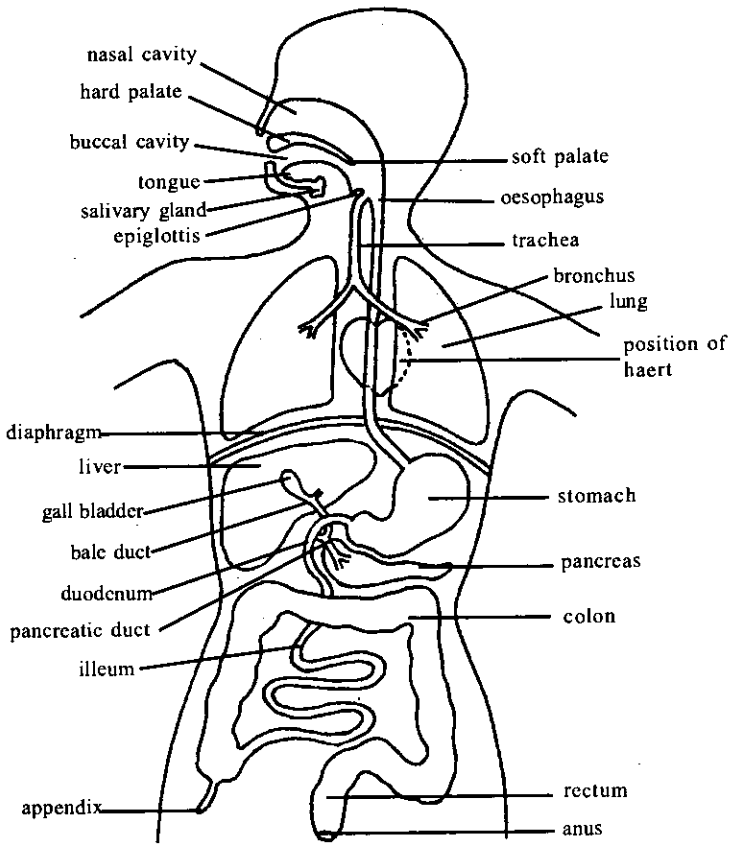


Fig. 9.5. Alimentary canal of man
Source: Essentials of Biology by S. A. Odunfa, p.75

- **renin** converts caseinogen (soluble milk protein) to casein (insoluble milk protein) mostly in infants
- casein is broken down by the enzyme **pepsin**
- food remains in the stomach for three to four hours and becomes fluidish, called chyme
- the food then moves out of the stomach via the **pyloric valve** to the duodenum (small intestine)

c. **Digestion in the small intestine**
- The duodenum is the beginning of the small intestine

- the ducts of the pancreas and gall bladder open into the duodenum
- pancrease produces *pancreactic juice* which is alkaline in nature
- the alkaline halts the action of stomach enzymes
- the liver produces *bile* which is stored in gall bladder
- the *bile* has no enzyme, but it is alkaline, which neutralises hydrochloric acid from stomach and also allows pancreatic juices to work.
- *bile* emusifies fat and reduces its surface tension
- *pancreatic juice* contains some enzymes

* *Amylopsin* which breaks down starch to maltose,
* *Trypsin* (a protease) converts proteins to polypeptides
* *Lipase* converts fats to carboxylic acids and glycerol.

- in the intestine proper, the chyme becomes more watery and becomes *chyle*
- Intestinal juice is alkaline and are produced by special glands in the small intestine
- There are five major intestinal enzymes (juice)

* *Maltose* changes maltose to glucose (simple sugar)
* *Lactose* changes lactose to glucose and galactose
* *Sucrase* changes sucrose to glucose and fructose
(these three enzymes completes digestion of carbohydrates).
* *erepsin* changes polypeptides (proteins) to amino acids which are the end products of protein digestion
* *Lipase* changes fats to carboxylic acids and glycerol which are the end products of fat digestion

Table 9.4 shows the summary of digestion in human alimentary canal.

Site of digestion	Secretion	Where produced	Enzymes present	Digestion
Mouth	Saliva (alkaline)	Salivary glands	Ptyalin	Cooked starch → maltose
Stomach	Gastric juice (acidic)	Gastric glands in stomach walls	(i) Renin (ii) Pepsin	(i) Caseinogen → casein (ii) Protein → polypeptides
Small intestine	Pancreatic juice (alkaline)	Pancreas	(i) Amylopsin (ii) Trypsin (iii) Lipase	(i) Starch → maltose (ii) Proteins → polypeptides (iii) Fats → carboxylic acids + glycerol
Small intestine	Bile (alkaline)	Liver	–	Emulsification of fats and oils
Small intestine	Intestinal juice (alkaline)	Glands in walls of small intestine (ileum)	(i) Maltase Lactase Sucrase (ii) Erepsin (iii) Lipase	(i) Maltose → glucose → glucose Lactose → glucose → galatose Sucrose → glucose → fructose (ii) Polypeptides → amino acids (iii) Fats → carboxylic acids + glycerol

Source: Modern Biology by S. T. Ramalingam, p. 287

3.4 Absortion of Digested Food

- Digested food substances are glucose amino acids, carboxylic acids and glycerol (from fats) as well as vitamins and mineral salts.
- They are absorbed by finger-like structures of the intestine called *villi* (fig. 9.10)
- The villi are covered by thin permeable epithelium
- The epithelium permits diffusion of solubule food substances
- Each villus (singular) is supplied with rich blood capillary and
- Lacteal vessel, which is a part of the lymphatic system transports carboxylic acid and glycerol,
* carboxylic acid and glycerol can recombine to form fats in the lacteal
* Lymphatic vessels empties their content into blood at intervals around the body, there are lymph nodes that produces leucocytes
* blood carries excess fat into storage organs such as adipose tissues under the skin and around organs.
- The blood cappillaries transport glucose (and other sugars) and amino acids away from the intestines
- Minerals salts and vitamins are also absorbed by blood capillaries
- These food substances are transported by the blood stream through the hepatic portal vein, from the intestine to the liver
- In the liver, the food substances are processed (can you recollect the functions of the liver?)
- The food is then carried by blood to other part of the body, where they are needed for assimilation (Absorption of digested food ends here) undigested food substances leaves the small intestine to the large intestine
- water is reabsorbed in the large intestine
- Then undigested food (waste or feaces) becomes concentrated and semi solid
- Feaces pass to the rectum and out of the body through the anus as semi solid
- Roughage facilitates movement of feaces.
- The journey of food from mouth to the anus takes about 24 - 36 hrs before the undigested food (feaces) are egested.

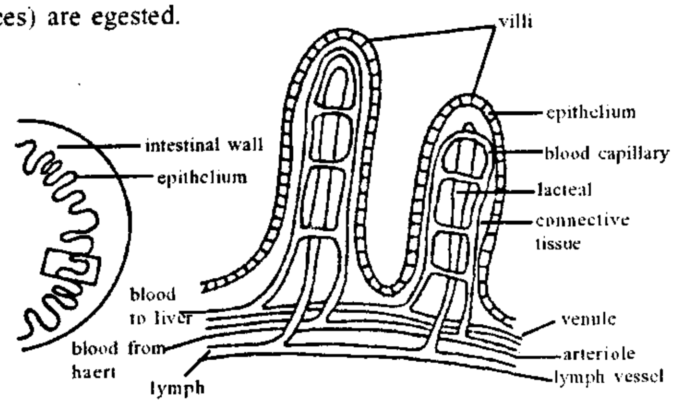


Fig. 9.10: Part of ileum wall showing villi
Source: Essentials of Biology by S. A. Odunfa, p. 77

Activity 2

ai. Draw and label the longitudinal section of a tooth
ii. Write the dental formular of an omnivore and herbivore
bi. Draw the digestive system of a man
ii. Describe the process of digestion and absorption of protein

3.5 Transport in Animals

Main materials to be transported in animals include

- digested food, water and nutrients
- oxygen
- excretory products such as carbondioxide, water and urea and
- hormones

These materials are transported in solution. In simple organisms like amoeba and paramecium, water and cytoplasm act as transport media. In animals, blood is the medium of transportation. Intercellular fluid and lymph are part of the blood

Transportation is required to;

* Regulate body temperature by distributing heat
* Maintain water balance in animals
* Carry hormones from ductless glands to target organs
* Send food substances to regions of active cell division, growth and development.

Transport system is also called circulatory system. Circulatory systems have the following features:

- The blood (which is a circulating fluid)
- The heart, which is a "pump" that send the fluid to all parts of the body
- Vessels or tubes that carries the fluid to different parts of the body.

3.5.1 Composition of Blood

Blood is made up of liquid plasma in which different types of blood cells floats. An average adult human has about 5.5 litres of blood

a. **Plasma:**

This is the fluid which contains red blood cells (Erythrocytes), white blood cells (leucocytes) and blood platelets (thrombocytes). It contains 90% of water, proteins and soluble food materials, mineral salts, hormones, gases, waste materials (Urea and $C0_2$), enzymes and antibodies. Its function is to transport all of the materials mentioned above and prevention of drastic changes in acidity or alkality in the body.

b. **Red blood cells (Erythrocytes)**

* They are red, non-nucleated, round, biconcave discs (fig. 9.1) They are produced in the bone marrow
  * They are destroyed in the liver at the age of about three months
  * Worn out cells are ingested by phagocytes in the spleen
  * The red colour is due to an iron pigment called hamoglobin which transports oxygen as oxyhaemoglobin from lungs to body cells

c. **White blood cells (Leucocytes):**

Less numerous and larger than red blood cells

* they are irregular in shape (fig. 9.11)
* they have nucleus which is round or lobbed
* they are produced in the bone marrow, lymph glands and spleen
* their life span is three weeks
* their main functions are to prevent infection and diseases
* their amoeboid movement allows them to move in and out of blood capillaries to engulf invading bacteria in the tissues.

d. **Blood Platelets (thrombocytes):**

They are minute irregular shaped bodies

* they are non-nucleated
* they are formed in large bone marrow cells

* they produce an important factor which initiates blood clotting process

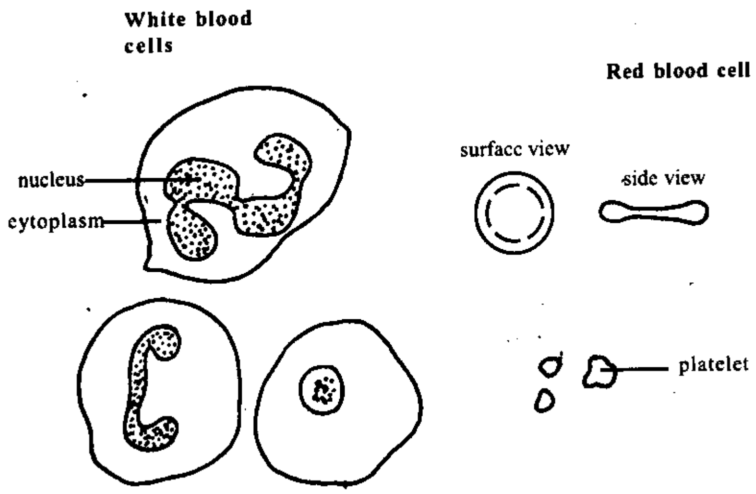


Fig. 9.11. Blood corpuscles and platelets
Source: Essentials of Biology by S. A. Odunfa, p.90

3.5.2 Functions of The Blood

a. Transportation of Materials

- oxygen combines with haemoglobin in the lungs to form oxyhaemoglobin which dissociates and released oxygen in tissues
- carbondioxide from tissues disolves in blood plasma and is released in the lungs
- digested food materials vitamins, salt and minerals are transported from villi to different parts of the body where they are required
- Hormones are carried from sites of production to target organs
- Urea formed in the liver is transported in the blood to the kidney
- Water is taken to cells and tissues, skin, kidney and other parts of the body through the blood

b. Defence of the body

- Leucocytes engulf invading bacteria or viruses of the body
- Some leucocytes produce antibodies that destroys foreign pathogens, thereby giving immunity against re-infection.
- Leucocytes also produce antitoxins to neutralise toxins produced by pathogens

c. Clot formation

- Blood clots when it is exposed to air
- Thereby preventing loss of blood
- Clot seals up wounds and prevent micro-organisms from getting into the body

d. Distribution of Temperature

- Heat can be absorbed from liver and muscles by distributing blood to body or skin (where heat is dissipated.

e. **The Blood Regulates** water, acidity, alkalinity and salt levels of cells.

3.6 Open Circulatory System

This is found in insects such as cocroaches and grasshoppers. The heart is dorsally, placed in a tabular chamber, which extends from the head to the thorax and to the abdomen. In the head, it forms the dorsal blood vessel (aorta). Blood that is pumped forward opens into the haemocoel. The blood is collected from the haemocoel (body cavity) through paired ostia and returned to the heart (fig. 9.12). The movement of the abdominal muscles assists the flow of blood into the heart.

Blood movement is slow, and its function is to transport food from gut to body cells. And to collect wastes from body cells to the malpighian tubules for excretion. The blood is colourless because it has no haemoglobin. Oxygen is not transported by the blood but by the network of air tubes.

Therefore, since blood is found in body cavity (haemocoel) and not transported in restricted vessels, it is called open circulation.

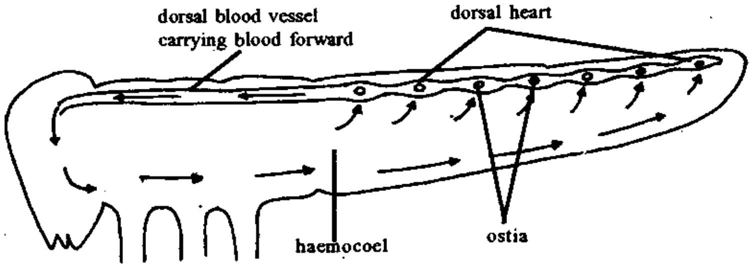


Fig. 9.12. Open blood circulatory system in an insect (arrows indicate the direction of blood flow)

Source: College Biology by G. Idodo - Umeh p,150

3.6.1 Closed Circulatory system

The closed circulatory system is found in all vertebrates. There are three main types of circulations in vertebrates,

a. **Single circulation:** this takes place in fish. The fish has a heart that is divided into two chambers an atrium and a ventricle. The blood passes through the heart only once in a complete circulation. This type of circulation is known as single circulation (fig. 9.13).

b. **Double circulation with partially divided heart:** This is found in amphibians. Their heart has two auricles and a ventricle that is not divided. So oxygenated and deoxygenated blood mixes before being pumped to the lungs and body (fig. 9.13) (In reptiles, the ventricle has a partially developed partition).

c. **Double circulation with completely divided heart:** This is found in mammals. Here, there are two ventricles and two auricles. Blood passes through the heart twice before it completes one circulation through the body. The oxygenated and deoxygenated bloods are completely separated (see fig. 9.13).

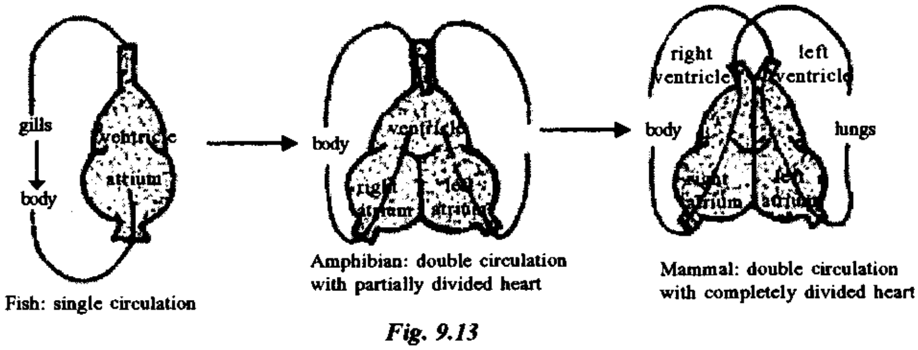


Fig. 9.13

Blood Vessels

There are three types of blood vessels, these are

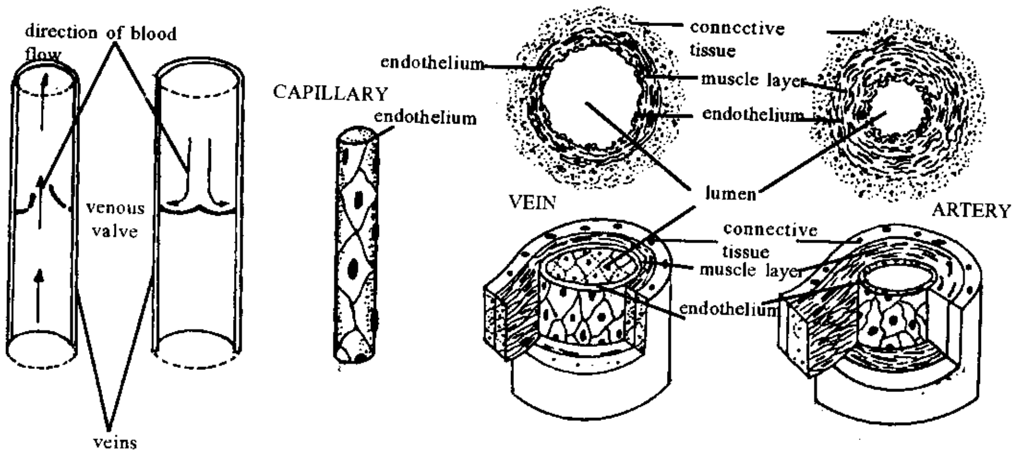
* Artery - which carries away blood from the heart to organs and tissues. Artery sub-divides to form smaller vessels called arterioles.
* Capillary - they are formed from arterioles. They are smaller finer vessels than arterioles.
* Veins - capillaries unite to form venules. Venules form veins. Veins transport blood from various parts of the body back to the heart. Summary of the structure and functions of the three types of blood vessels are given in table 9.5 below. fig. 9.4 shows the structure of the three vessels described above

Table 9.5 - Comparing the structure and function of the three types of blood vessels

Artery	Capillary	Vein
Carries blood away from heart	Links arterioles and venules	Carries blood to heart
Thick, muscular, elastic wall	One-cell thick wall	Fairly thick, slightly elastic wall
Blood is at high pressure and flows fast and in spurts (pulse waves)	Blood pressure is higher at arteriole end than at venule end of capillary network; flows smoothly	Blood pressure is low and flows slowly and smoothly (no pulse waves)
Valves absent (except for semi-lunar valves near the heart)	No valves	Valves present
Blood is oxygenated (except that in the pulmonary arteries)	Blood is oxygenated at arteriole end and deoxygenated at venule end (except that in the lung capillaries)	Blood is deoxygenated (except that in the pulmonary veins)

Source: Modern Biology by S. T. Ramalingam, p. 305

Fig. 9.14 Structure of Artery, veins and capillary.



Source: College Zoology by R. A. Boolootian and K. A. Stiles, p. 521

(Left) Venous valves, which allow blood to flow only toward the heart. (Right) Histology of blood vessels. The muscle layer of an artery is thicker than the muscle layer of vein of the same size. A vein usually has a lumen of greater diameter than its corresponding artery.

Structure of The Mammalian Heart

The mammalian heart has four chambers. Two upper thin walled auricles, and two lower thick walled ventricles. The auricles receives blood from vessels and pump it into the two lower ventricles (fig. 9.15). The left auricle and ventricle are separated from the right auricle and ventricle by septum.The ventricles pump blood to the body.

Pumping of blood occur in two phases;

(a) Diastole, during which the auricles contract and ventricles are relax and

(b) Systole, when the auricles relax and ventricles contract.

The right auricles receives deoxygenated blood from the body via the vena cava to the right ventricle. Tricuspid valves separates the right auricle from the right ventricle and prevents back flow of blood. The right ventricle pumps the deoxygenated blood to the lungs via the pulmonary artery (pulmonary circulation) for oxygenation. The semilunar valves of pulmonary artery also prevents back flow of blood from pulmonary artery into the right ventricle.

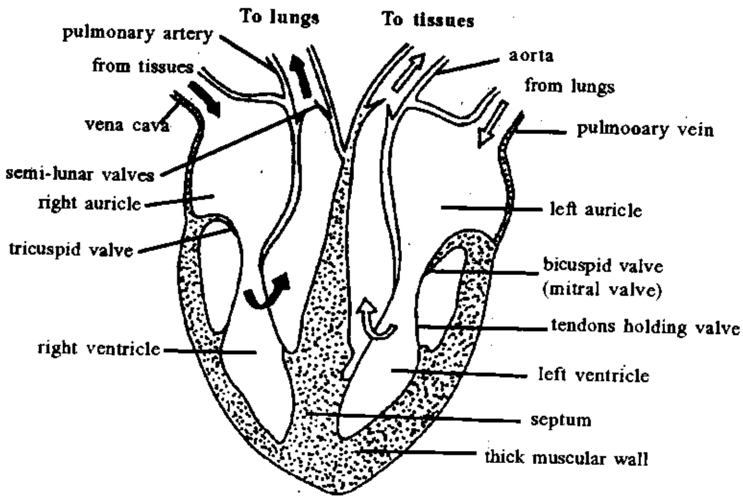


Fig. 9.15. Structure of the mammalian heart
Source: Essentials of Biology by S. A. Odunfa, p.91

The left auricle receives oxygenated blood from the lungs via the pulmonary vein and pumps it to the left ventricle. A valve called bicuspid valve separates the left auricle from the left ventricle and prevents back flow of blood. The left ventricle then pumps the oxygenated blood through the aorta to all parts of the body in the systematic circulation. The semi lunar valves of aorta prevents back flow of blood into the left ventricle. The wall of the left ventricle is very thickened this allows it pump adequate blood to all parts of the body.

3.6.2 Mammalian Double Circulation

In mammalian double circulation, oxygenated and deoxygenated blood are separated i.e. they do not mix when they pass the left and right side of the heart respectively. The liver is only organ that receives double blood supply from the heart; one from the hepatic artery, the other form hepatic portal vein which takes away blood that is rich in digested food from the stomach and intestines (fig. 9.16) summarises double circulation in human beings. The double circulation is divided into the venous and arterial systems (fig. 9.16).

VENOUS SYSTEM
All veins carry blood to the heart. Most veins contain deoxygenated blood - the exception include the pulmonary veins which contain oxygenated blood

ARRIAL SYSTEM
All arteries carry blood away from the heart, Most arteries contain oxygenated blood - the exceptions include the pulmonary arteries which contains deoxygenated blood

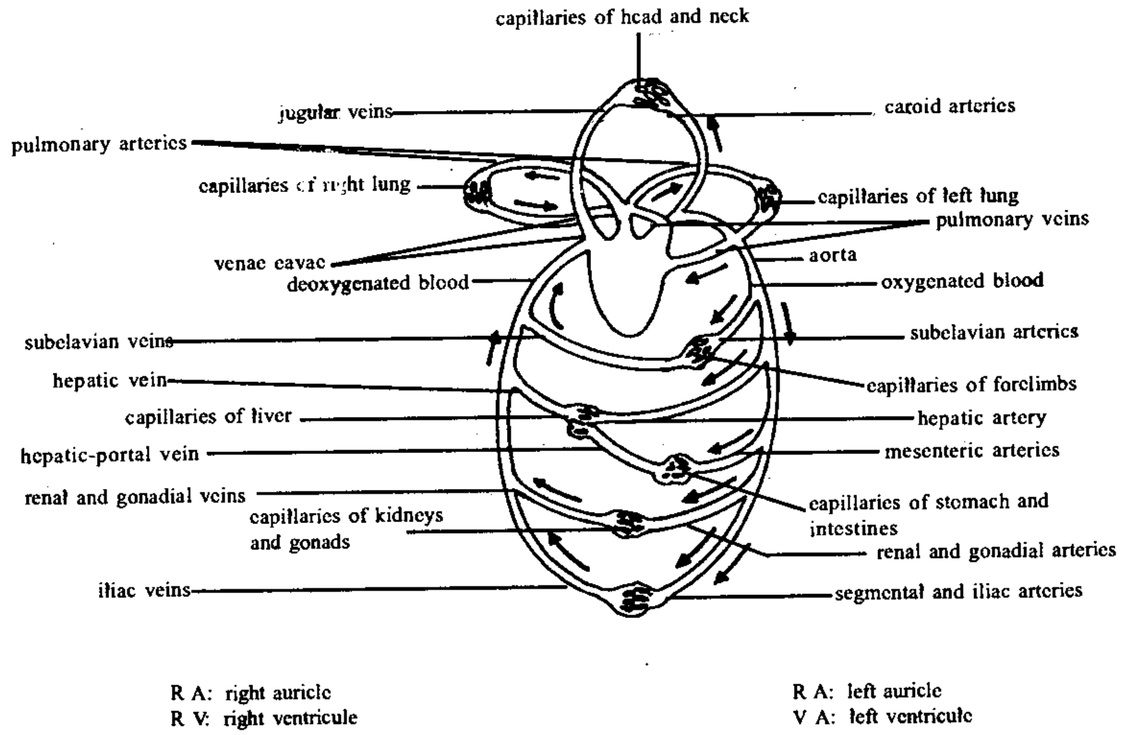


Figure 9.16 : Venous and Arterial Systems
Source: Modern Biology by S. T. Ramalingam, p. 305

3.7 The Lymphatic System and Its functions

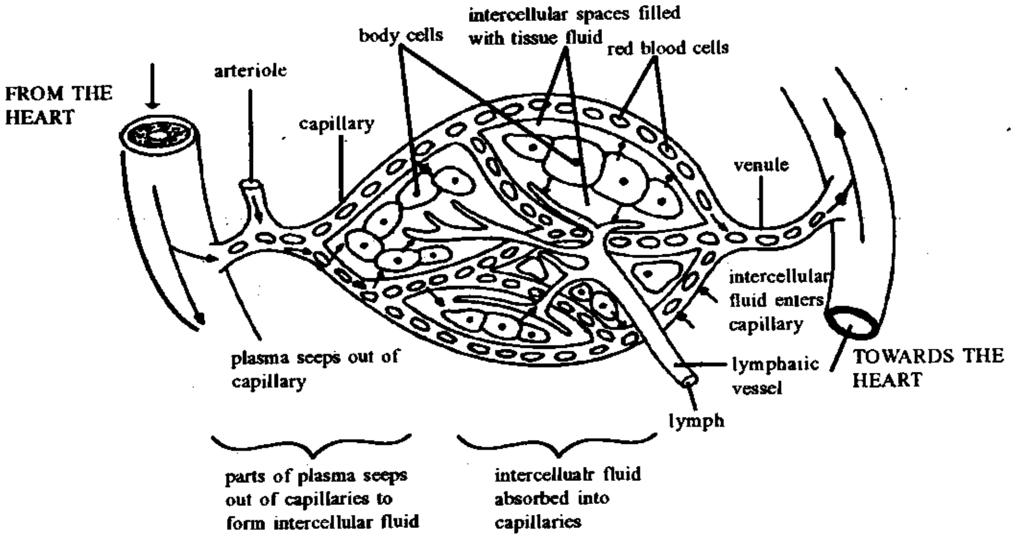
(a) The Lymph and Lymphatic system

Remember that capillaries unite to form venules (see unit 3.12.1). Blood in the capillaries contains mainly plasma proteins, minerals and little water, hence it is concentrated. The intercellular fluids around the capillaries near the ventricle is a weak solution because it has given up most of its dissolved materials to the body cells. This then allow some of the intercellular fluid to be absorbed into the blood in the capillaries.

Unabsorbed intercellular fluid move into the terminal endings of the lymphatic vessels near the capillaries (see fig. 9.17). This shows the continuous circulation of blood and lymph. The fluid in the lymphatic vessels is called lymph. Fine lymphatic vessels join to form large vessels and two large limphatic vessels that empty their content into blood veins in the neck and thoracic regions.

Lymph flows in Lymphatic vessels as a result of body muscular movement valves in the vessels also prevent back flows of lymph. At certain point within the lymphatic vessels, there are lymph nodes. Lymph nodes produces lymphocytes (white blood cells) which are phagocytes, that engulfs and digests micro-organisms.

Fig. 9.17. Formulation of intercellular fluid and lymph



Source: Modern Biology by S. T. Ramalinam, p. 302

b. **Functions of the Lymphatic System/Lymph.**

* Lymphatic system returns excess tissue fluid, fat, protein and minerals to the blood
* it transport fat from the intestinal villi
* it forms lymphocytes at the lymph nodes
* the lymphocytes formed at the nodes engulf cell fragments and invading bacteria
* the system cleans the tissues fluid before returning it to the blood by filtering particules and storing them at the nodes.

c. **Differences Between the Lymphatic System and the Blood Circulatory System**

These differences are summarised in Table 9.6

Table 9.6 Differences Between the Lymphatic System and the Blood Circulatory System

Lymphatic System	Blood Circulatory System
1. Mainly fluid plasma with white blood cells, no red blood cells.	Consists of plasma, white blood cells and red blood cells and others
2. Lymph flow is very sluggish	Blood flow is very fast
3. No respiratory pigment in lymph and so not efficient in the transport of oxygen	Has a respiratory pigment haemoglobin hence transport oxygen
4. Lymph flow is assisted by muscular activities	Blood flow is facilitated by pressure from heart
5. Collects tissue fluid and returns it into the blood stream	Circulates blood round the body and back to the heart

Source: College Biology by G. Idodo - Umeh, p. 153

Activity 3

ai. List the type of materials that are transported in animals
(ii) List the component of the blood
(iii) State hte functions of the blood
bi. Describe the open and closed circulatory system
(ii) Enumerate the functions of the lymphatic system.

4.0 Conclusion

In this unit you have studied food subtances, their classfication and sources. Therefore you should be able to define balanced diets, state the major composition, sources, functions and their deficiencies.
You should also be able to describe and draw the mammalian dentition, the alimentary canal and state the actions of various enzymes that are responsible for digestion. Absorption is an important part of the functions of the intestine, therefore you should also be able to draw and describe the villus.
You have also studied the circulatory system, composition of blood and its functions. Therefore, you should be able to describe the open and closed circulatory system, structure of the mammalian heart, the mammalian double circulation and the functions of the lymphatic system.

5.0 Summary

Food substances are carbohydrates proteins, lipids, vitamins, mineral salts, water and roughages, which must be digested in the alimentary canal of animals. Digestion of certain food substances starts in the mouth, through the oesophagus to the stomach, small intestine (where absorption takes place) then to large intestine, and finally the undigested food is excreted as faeces via the anus. In the stomach and small intestines, various enzymes help to break down the food substances into their respective components. Then absorption of the end-product of digestion takes place in the villi of the small intestine, from where the end-products are transported by the blood to various parts of the body.
The blood is responsible for transportation of digested food materials, oxygen, hormones and waste materials (such as carbondioxide and urea).
The blood has various components and functions. The blood circulates in vessels such as arteries, veins and capillaries, that are under the pumping influence of the heart. There are different types of circulations, these are open and closed blood circulations. The mammalian circulation which is closed is the highest form because the oxygenated blood and deoxygenated blood are separated. The lymphatic system is also a circulatory system that is closely associated with the blood system.

6.0 Tutor - Marked Assignment

ai. List the functions of carbohydrates, proteins and lipids (10 marks)
ii. Briefly describe the digestion of carbohydrates in a mammal (no diagram is required 10 marks)
bi. List the functions of the blood (10 marks)
ii. Draw and label the mammalian heart (7 heart)
iii. Give five major functions of the lymphatic system (5 marks)

7.0 Further Reading and Other Resources

S. T. Ramalingam. *Modern Biology*
G. Idodo - Umeh. *College Biology*
S. A. Odunfa. *Essentials of Biology*
M.B.V. Roberts. *Biology - A Functional Approach*
R. A. Boolootian and K. A. Stiles. *College Zoology*
Biology by Ann Fullick (1994) Publ. by Heinemann Advanced Science. Heinemann Educational Publisher, Halley Court, Jordan Hill Oxford, Ox2 8EJ.

Volume 3: Regulatory Systems and Mechanisms in Animals

Unit 10: Reproduction in Animals

1.0 Introduction

Reproduction is one of the vital functions or characteristics of living organisms. It is the ability to produce new generations of members of the same species. Genetic material is passed on from one generation to the next, ensuring the survival of species. Members of a species may die off due to a number of reasons e.g. predation, catastrophe etc; the survival of a species is therefore ensured if more offspring than the generation of the parents are produced.
You have treated reproduction in viruses, bacteria and protozoa in Volume 1, units 3, 4, 5 and 6.
In this unit, we will be concerned with the vertebrate reproductive systems, which is made up of gonads, reproductive ducts and glands. The gonads produce gametes, hormones which are necessary for reproduction. The gonads are the testes which produce sperms (spermatozoa) in males and the ovaries which produce eggs (ova) in females. Unification of the sperm with the ova leads to fertilization and subsequent production of new offsprings. The reproductive systems in mammals are similar, fairly different methods of reproduction are foun din amphibians, fishes and reptiles.

2.0 Objectives

At the end of this unit you should be able to;

a. List the types of reproductive systems in animals
b. Describe various forms of reproduction in vertebrates
c. Discuss in details reproduction in mammals and development of offsprings.

3.0 Types of Reproduction

There are two types of reproduction in animals. These are asexual and sexual reproduction. Both have their advantages and disadvantages.

ai. Asexual Reproduction:

This type of reproduction occurs in lower unicellular animals such as amoeba and involves a single individual and excludes the production of gametes. Genetically identical offspring are produced; genetic variation can only result from mutation.
In the animal kingdom, asexual reproduction occurs in very few groups. In the Phylum (Coelenterata)**budding** occurs, a new individual is produced as an outgrowth of the parent e.g. Hydra.
Another form of asexual reproduction is **fragmentation**. This occurs in groups that have very strong powers of **regeneration**. Here, the organism breaks into two or more parts, each of which grows to form a new individual. Examples: marine ribbon worms, which break up easily into several pieces with each piece developing into new individuals. Starfish can regenerate lost parts after accidental fragmentation. Planarians e.g. *Dugesia* and others (Class: Turbellaria) reproduce asexually by this method. To reproduce by fragmentation, *Dugesia* adheres to the substrate by its posterior end then pulls its anterior end forward until it divides transversely into two. Each of the fragments would then regenerate the missing half.
In protozoa asexual reproduction is by **binary fission** and **multiple fission**. Binary fission is the division of the nucleus and the cytoplasm to produce two identical cells, whereas, multiple fission is the repeated division of the parent nucleus into many daugher cells e.g. in *Plasmodium,* the malaria parasite. This is a reproductive/ survival strategy to compensate for the losses that occur in the successful transfer of the malaria parasite from one human host to the other via the mosquito, which is the vector.
Cloning is a method of asexual reproduction in which copies of genetically identical individuals are produced. This does not occur naturally in vertebrates.

ii. Advantages of Asexual Reproduction

* Only a single parent is required. This eliminates the problem of looking for a mate. This has been taken care of in a few animals that exhibit hermaphroditism.

* Offspring that are genetically identical to the parents are produced
* There is a rapid increase in numbers. This compensates for the losses at certain stages of the life cycles of some parasites.

iii. Disadvantages of Asexual Reproduction

* There is no genetic variation among offspring
* No hybrid vigour
* A great deal of energy is utilised/wasted
* Competition may result from overcrowding
* The new offspring, being genetically identical to the parent, would carry any undesirable traits of the parent.

bi. Sexual Reproduction

This is the type of reproduction in higher multicellular animals. Most of the species that have adopted sexual reproduction can be distinguished into male and female **sexes**. The sexes possess reproductive organs, which are the testes in the case of male animals and the **ovaries** in the case of the female. Sexual reproduction involves the fusion of **gametes** of male and female origin to form a **zygote**. The process of the fusion of gametes is known as **fertilisation**. Some individuals possess both male and female reproductive organs and are known as **hermaphrodites**. Unlike asexual reproduction, sexual reproduction leads to genetic variation, this leads to a phenomenon known as **hybrid vigor**. Over a period of time, variation leads to the formation of new species or **speciation**.

ii. Advantages of Sexual Reproduction

* There is genetic mixing which results in variation
* It brings about hybrid vigor
* Sexual reproduction provides the material which gives rise to major evolutionary changes.

iii. Disadvantages of Sexual Reproduction

* Because sexual reproduction requires that two gametes of two different individuals be brought together, this could be problematic if a mate is not readily available.
* Undesirable traits may also be carried from parents to offspring in sexual reproduction.

3.1 Reproduction in Vertebrates

As vertebrates evolved, there were gradual changes in their morphology and lifestyle, which served to adapt them to life in water and on land. One of the major challenges that the movement from water to land brought about was that of reproduction.

Unlike the Protozoa, vertebrates are **multicellular** and **triploblastic** and have a **vertebral column** and organs and organ-systems. It follows that their reproductive structures and the reproductive process are much more complex and elaborate than in the Protozoa. In the vertebrates, there are two individuals designated as **male** and **female**, each of which produce **gametes** of distinct types. The reproductive process is exclusively sexual and fertilisation may be internal or external.

Development may be **direct or indirect** and there are varying levels of parental care.

In this section, we shall draw reproduction in fish, amphibians reptiles and birds. Mammalian reproduction will be treated in unit 3.2

ai. Reproduction in Fish (e.g. Tilapia)

Most bony fish, e.g. *Tilapia*, shed their gametes directly into water, i.e. the eggs and the sperms to effect fertilisation. Fertilisation is therefore external. Fish eggs are **macrolecithal** (large quantity of yolk) and larval stages occur in some fish whereas, some hatch as soon as a fully formed individual develops. Parental care occurs to a greater or lesser extent in some species like *Tilapia* and *Clarias* but this is rare among fishes.

ii. Parental care in Tilapia

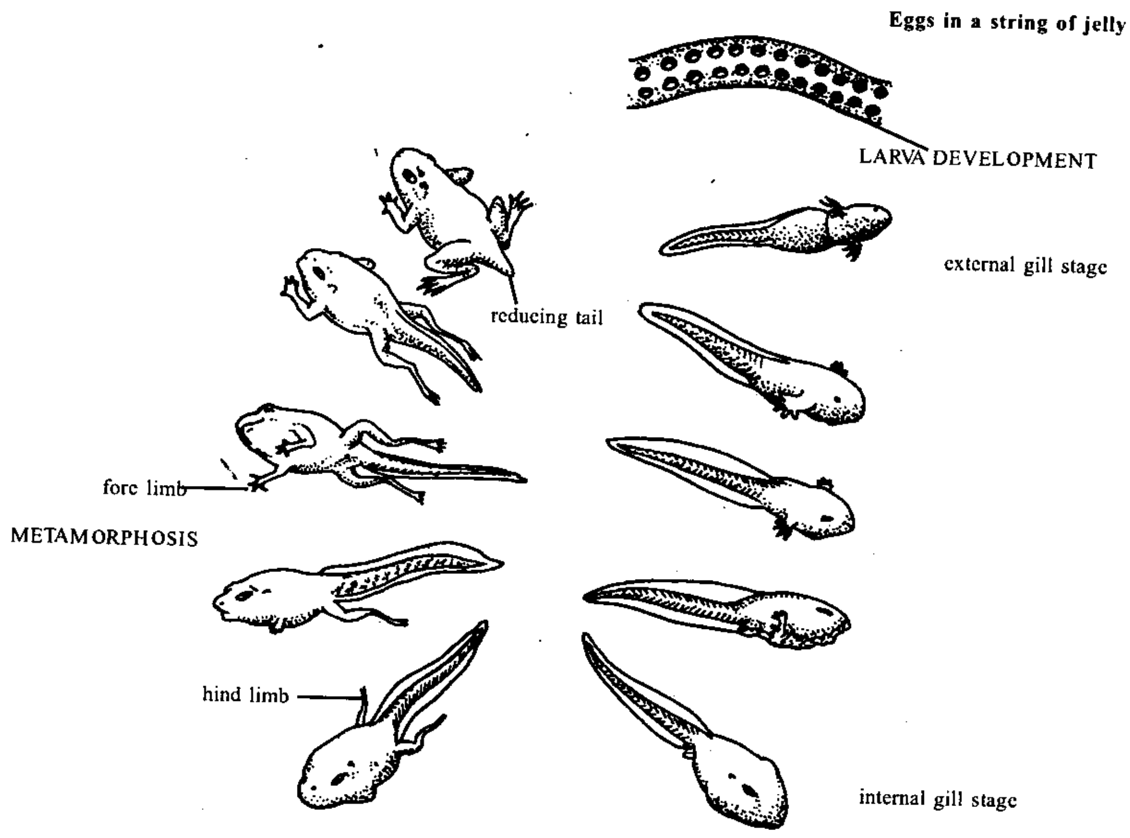
After the eggs of Tilapia are fertilised, the female takes them into her mouth, to keep them warm and protect them from predators. The eggs hatch in the mother's mouth in about two days but the newly hatched fish **(fry)** remain in her mouth for about ten days. The female does not feed while she is carrying the eggs and the fry in her mouth. After hatching, the fry still have a part of the egg, the yolk sac, attached to their belly. the yolk provides the fry with nourishment for a few days. By the time the yolk supply runs out, the mouths of the young fish would have developed to enable them feed by themselves. When the young fish are old enough, they are ejected from the mother's mouth to look around for food and fend for themselves. They still follow their mother around and she opens her mouth to allow them in whenever there is danger. After some time young fish become completely independent of their mother.
This method of producing and caring for the young in the mother's mouth is known as **mouth brooding.** In some species, the male is the **mouth-brooder.**

b. Reproduction in the Amphibia (e.g. *Bufo regularis*)

In the toad, breeding usually takes place during the rainly season. The male mounts the egg-laden female after he attracts her with his mating calls; he clasps her behind her fore limbs with the aid of **nuptial pads** (marriage pads) on the first digits of his forelimbs. Both toads go into water in this position. As the female lays her eggs in water, the male pours sperm over them, fertilising them externally. The jelly surrounding the eggs absorbs water and swells. The eggs stick together in floating masses called **spawns**.

The functions of the jelly are;
* To protect the eggs from mechanical damage
* To prevent the eggs from being eaten since it makes them slippery and difficult to grasp
* To protect the eggs from bacteria
* To keep the egg separate so that oxygen can circulate freely around each egg and so that there is enough room for the development of the embryo.

In the tropics the eggs develop very quickly because of the high temperature so that by the second day the eggs would have embryos within the jelly. Just after fertilisation, the eggs become black at the upper surface and yellowish at the lower surface. The black part of the egg soon grows over the yellow and eventually obscures it completely. The embryos emerge from the jelly on the second day as tiny tadpoles. The tadpole attach themselves to waterweeds by their V-shaped suckers.
At this stage, the positions of the eyes, ears and nostrils are marked out.
Further development (metamorphosis) brings the tadpole to the **external gill stage** (fig. 10.1). It uses the external gills to breathe for a short while and then they wither (by the fourth day) and become replaced by internal gills. By the end of seven days, the mouth, eyes and anus develop. At this stage, the tadpole has a long coiled intestine, which can be seen easily through the skin of its underside. The long, coiled intestine is an indicator of the tadpole's diet of plant material. An operculum forms over the gill slits and the tadpole breathes like a fish. By the time the tadpole is one month old, the hind limbs appear and then the forelimbs. The tadpole feeds and grows fast and changes from a vegetarian to a carnivorous diet. The internal gills wither to be replaced with lungs and the tail gets progressively shorter until it disappears completely. An adult toad form is then produced.



Larva development and metamorphosis in the toad (Note external changes)
Source: White paper on remedial Biology

Activity A

ai. List the various forms of asexual reproduction
ii. List the disadvantages and advantages of sexual reproduction
bi. Describe parental care in Tilapia.
ii. Discuss the larval development and metamorphosis in the toad.

c. Reproduction in Reptiles

Reptilia is a Class in the Sub-phylum Vertebrata. The class is made up of lizards, snakes, tortoises, turtles, crocodiles, alligators etc. The reptiles are the earliest group of vertebrates to become completely adapted to life on land, more so than the amphibians. They have successfully occupied a far wider range of habitats, as well as secondarily invading water. One of the most important reasons for their success is the development of an amniote egg that has freed them from the dependence on water for reproduction. This characteristics is an important distinction between the reptiles and the amphibia. They are also characterised by their dry, scaly skin, which adapts them to life on land better than the skin of the amphibians.

Agama lizards live in colonies made up of a single male, some adult females and several young lizards of both sexes. The resident male of the colony chases off any other adult male that happens to wonder into the colony or attempts to invade it. Copulation is normally preceded by courtship during which the female attracts the attention of the larger brightly coloured male. When the male chases and catches the female, he seizes

her by her flank and curves his body around hers and brings his cloaca to a position next to hers then copulates with her. The intromittent organ of the male is made up of two **hemipenises**, which are hollow, tubular cloacal sacs. The hemipenis can be turned inside out and everted through the cloacal aperture of the male into the cloacal aperture of the female. The hemipenis has a grooved surface that facilitates the transfer of sperm. After the eggs of the female are fertilised internally, they develop inside her, making her grow larger. The female digs a hole in the ground, into which she lays about six to seven eggs that are mainly made up of yolk and no albumen; she then covers the hole with soil. the eggs imbibe water from the soil, swell and hatch into fully formed miniature adults after about six to seven weeks. They find their way out of the soil and set about looking for food and fending for themselves. There is no parental care.
The lizards attain sexual maturity at the age of about **eighteen months**.
Some species of lizards are viviparous, 'giving birth' to young in their embryonic membranes from which they escape a few moments after 'birth'.

d. Reproduction in Birds (e.g. Pigeon)

Birds go through a period of **courtship** before they mate. the type of courtship varies from species to species. Courtship may be in the form of a dance, display of very attractively coloured plumage by the male, singing, bringing of bits of food to the female, bringing of nesting material, etc. Some of the display of the male is intended to frighten rival males away. After the period of courtship, the birds select their mates. In the case of the pigeon, which is **monogamous**, the mate is selected for life.
In pigeon, the act of mating involves the male and the female. The male mounts the female and the posterior parts of the cloacae of both birds are turned outwards and held together for the transfer of sperm. Fertilisation is therefore internal and takes place high up in the oviduct. The male and female pigeons builds a nest of interwoven twigs at the angle of two branches and where the nest is very well concealed. After the building of the nest, the female lays two eggs (some species lay a single egg). The male and female birds share the joy of incubating the eggs; the female sits on the eggs at night and the male during the day, this will help in the production of heat from the body of the pigeons, for incubating the eggs. During the process, the birds loose the feathers of their underbelly and the area becomes heavily supplied with blood capillaries. The eggs are incubated for about seventeen days. To aid the escape of the chicks from the eggs at hatching they have a small projection at the tip of the upper bill known as the **egg tooth**. The chicks would use its egg tooth to peck their way out of the shell. In addition to the egg tooth, a well-developed muscle occurs at the back of the neck and head to facilitate the movement of the upper bill. On hatching, the chick is at an advanced stage of development but it is naked, blind and helpless. The young pigeon becomes covered with soft yellow down feathers.
For about two weeks after they hatch, the chicks are fed and cared for by their parents. For the first few days after hatching, the chicks are fed on **'pigeon's milk'**, whose chemical constitution is similar to that of mammalian milk. This milk is produced in the crop of the male and female pigeons as a result of proliferation and sloughing off of the cells of the crop. After this, the chicks are fed on food regurgitated by the parents. In both means of feeding, the chicks stick their beaks into the **throats** of the parents to obtain their meal. Young pigeon feed and grow rapidly, their eyes open, feathers cover the body and they may become independent and fly out of the nest by the time that they are two weeks old.
In contrast to the reptiles, the majority of birds care for their young by first incubating the eggs and then caring for the young for varying periods after they hatch.
Though some birds display lack of care for their young ones.

a. Describe briefly, the reproductive process in a named reptile
b. Discuss the process involved from mating to hatching of eggs and parental care in pigeons.

3.2 Reproduction in Mammals

i. Mammalas belong to the most advanced group of vertebrates. Mammals have a highly developed brain, which makes them capable of very complex behaviour that is not seen in the other vertebrate groups. Their well-developed brain enables them to care for their young and this has resulted in the enhancement of their survival rate. The production of relatively few offspring, which is characteristic of mammals, enables them to care for their young effectively. Mammals are well adapted to life on land, trees, in burrows as well as in freshwater and marine habitats.

Mammals generally reproduce viviparously (giving birth to live young), however, a few exceptions exist, these are the monotremes, which are egg laying. Although these mammals lay eggs, they feed their young with milk produced by their mammary glands. Another group of mammals whose reproductive style does not conform to that of other mammals are the **marsupials**; these are the kangaroos, wombats, possums, wallabies and koalas. The marsupials, like the monotremes, are natives of Australia. The kangaroo gives birth to its young prematurely; the young attaches itself to a teat in the mother's pouch (**marsupium**) where it feeds and completes development.

Fertilization in all mammals is internal.

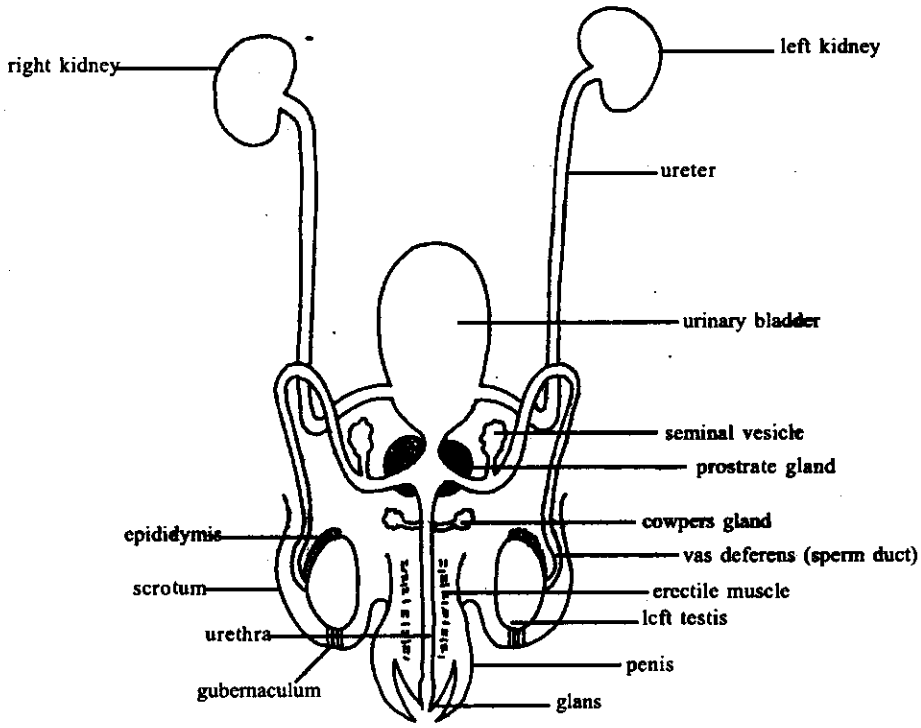


Figure 10.2a = Reproductive system of a human male (front view)

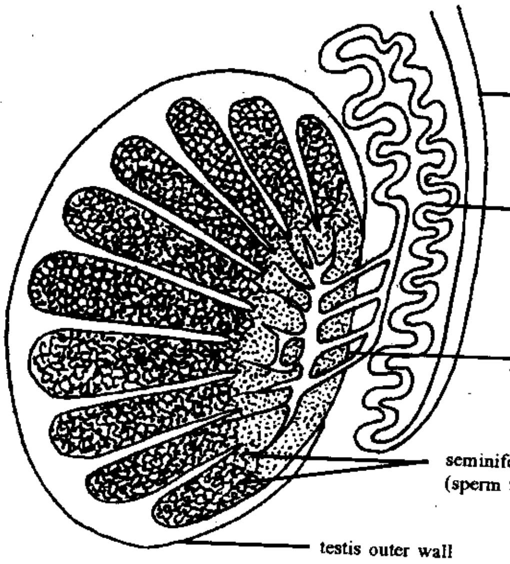


***Figure 10.2b** = Vertical section through testis*
***Source:** College Biology by G. Idodo - Umeh, p.355*

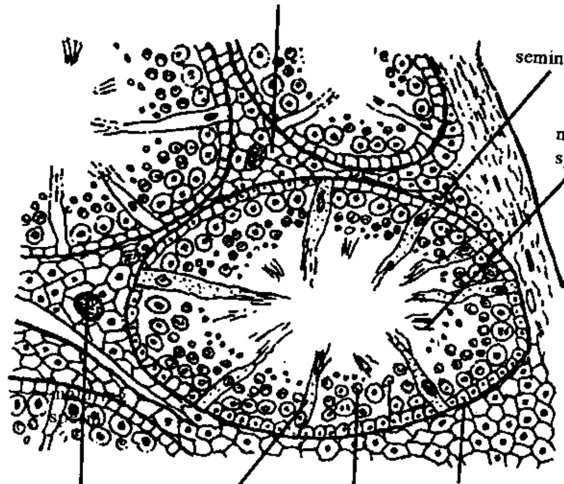


***Fig. 10.2c** A small section of mammalian testes showing developing sperm*
Source: White paper on remedial Biology

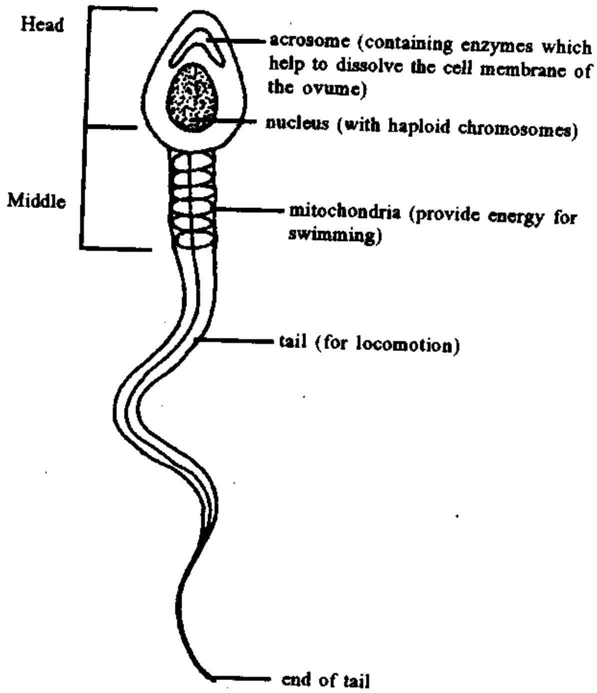


Fig. 10.2d The structure of Human spermatozoon (sperm)
Source: College Biology by G. Idodo Umeh, p.359

ii. The Female Reproductive System (fig. 10.3a)

The reproductive system of the female mammal consists of two **ovaries**, which are situated below each kidney on the dorsal wall of the abdomen. Each ovary is wrapped by connective tissue. In section the ovary contains connective tissue, blood capillaries and numerous **germ cells;** the germ cells give rise to the **ova** (singular: ovull) see the mammalian ovary (fig. 10.3b). Next to each ovary is the funnel shaped opening **(Fallopian funnel, oviducal funnel)** of the **Fallopian tu**be or oviduct, along which ripe ova that are released travel. Within the ovary, a fluid-filled cavity surrounds the ova and their surrounding nutritive cells; this structure is known as the **Graafian follicle**. A mature Graafian follicle bursts to release the ovum into the Fallopian funnel (which has finger-like projections at its mouth). The release of the ovum by the Graafian follicle is called **ovulation**. In humans, ovulation usually occurs every twenty-eight days (menstrual cycle). The fallopian tubes from each side unite to form the **uterus** (womb), whose walls are muscular and play an important role in the expulsion of the foetus at birth. The uterus opens to the outside via the **cervix, vagina** and **vulva** in humans. The urethra also opens into the vestibule; the vestibule therefore serves as a urinogenital tract.

The menstrual cycle is controlled by four hormones. They are follicles stimulating hormone (FSH), Luteinising hormone (LH), Oestrogen and progesterone, all are under the control of the pituitary gonadotropins. (Use your standard text book to formulate your note on menstrual cycle, noting the influences of the hormones.

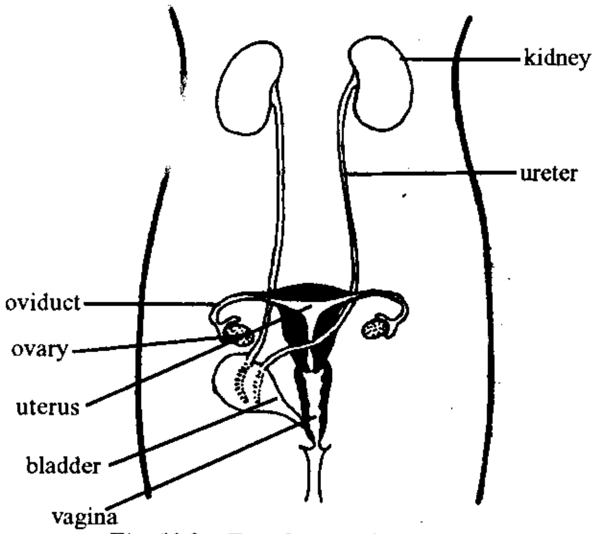
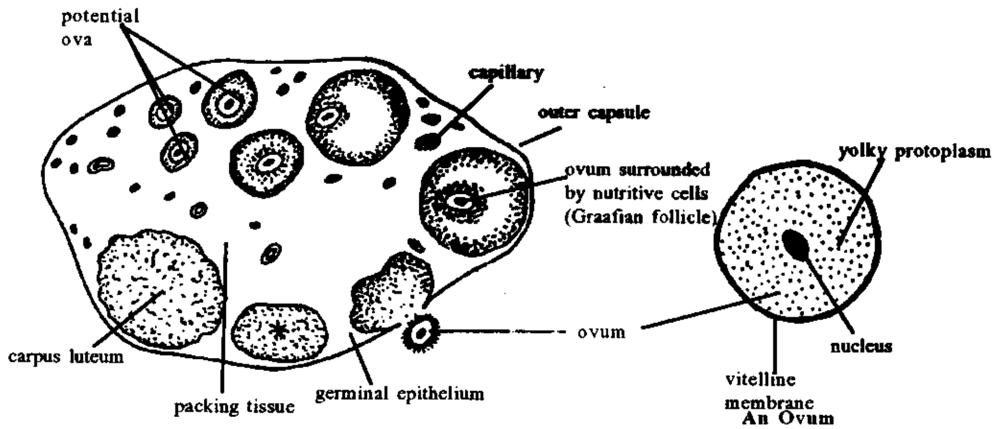


Fig. 10.3a. Female reproductive system
Source: White paper on Remedial Biology



(Corpus luteum produces the pregnancy hormone progesterone.
If fertilization does not take place it disintegrates and menstruation occurs.
Fig. 10.3b. The Mammalian Ovary and Ovum
Source: As in 10.3a above.

Fertilisation takes place in the oviduct. The sperms introduced into the vagina during copulation swims through the cervix to the uterus and then to the fallopian tube. But only one sperm fertilises the ovum in the fallopian tube.

A fertilised ovum **(zygote)** starts to divide mitotically as it travels into and passes down the oviduct until it reaches the uterus, where it attaches itself to the wall **(implantation)** and begins to grow by absorption of fluid and rapid cell division (see fig. 10.3c). The length of time it takes an embryo to develop within the uterus varies from mammal to mammal, e.g. nine months in humans, three weeks in rabbits and about twenty months in the elephant. This period of development is known as the **gestation period**. The developing embryo obtains its food and oxygen supply from the mother's blood stream via the **placenta** (fig. 10.3d) which is an outgrowth of the embryo and its membranes; it has finger-like projections that are in close association with the uterine wall. The blood supply of the embryo and the mother are completely separate. At birth, a mammal is completely helpless and has to be cared for by the mother, who feeds it with milk produced by the **mammary glands.** The milk contains all the food nutrients that are required by the newborn. The young mammal is looked after and catered for until it is old enough to be independent.

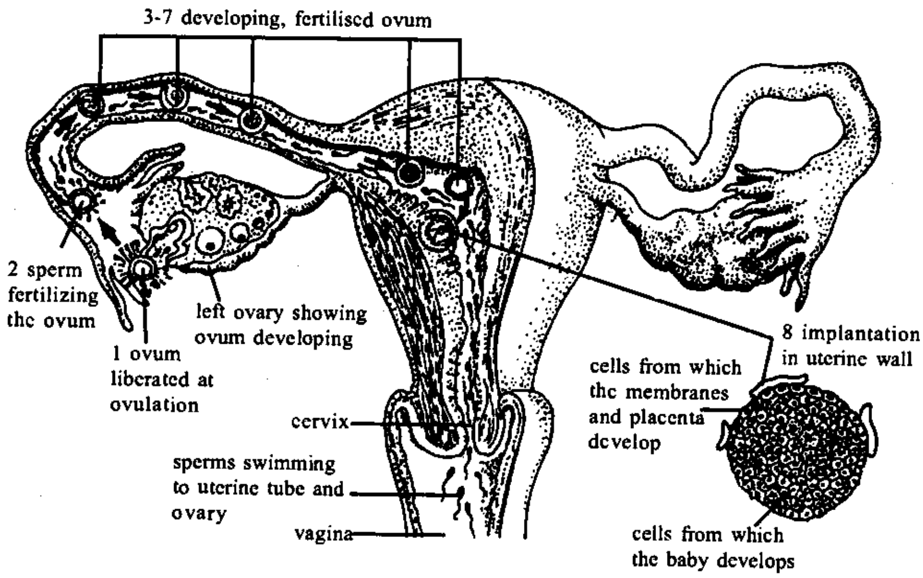


Fig. 10.3c Fertilization and development of the zygote in Human

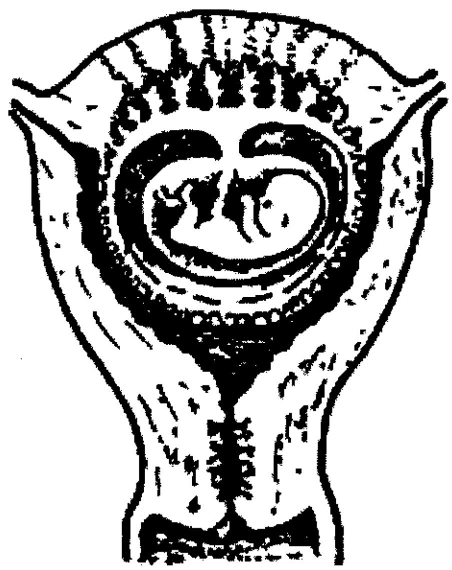


Fig. 10.3d

b. **Differences and similarities between the male and female reproductive organs.**

i. The differences between the male and female reproductive organs are summarised in Table 10.1

Table 10.1. Differences between male and female reproductive organs

Male reproductive organ	Female reproductive organ
1. Testes in scrotum hang outside the body	Ovaries are situated in the body
2. Sperms are manufactured by testes with outside temperature	Eggs are manufactured by ovaries with body temperature
3. Millions of sperms are produced every month	Only one egg or in some few cases two eggs are produced every month
4. Vasa efferentia present	Vasa efferentia absent
5. Epididymis present	Epididymis absent
6. Vas deferens (sperm duct) present	Eggs pass through the fallopian tubes into the uterus
7. Sperms pass through the urethra	Eggs pass through the fallopian tubes into the uterus
8. Seminal vesicle present	Seminal vesicle absent
9. Prostrate gland present	Prostrate gland absent
10. Cowper's glands present	Cowper's glands absent
11. Fallopian tube absent	Fallopian tube present
12. Uterus absent	Uterus present
13. Vagina with hymen absent	Vagina present, covered with hymen at young age
14. Cervix absent	Cervix present
15. Penis present	Penis absent
16. Scrotum housing testes present	Scrotum absent
17. Clitoris absent	Clitoris present
18. Labial majora and labial minora absent	Labial majora and labial minora present
19. Testes stop producing sperms at age of 70-80 years	Ovaries stop to produce eggs at age of 45 - 55 years
20. Produces male sexual hormone called testosterone	Produces female sexual hormones called oestrogen and progesterone

Source: College Biology by G. Idodo - Umeh, p. 360

- **Similarities between Male and Female reproductive organs.**

* Both possess sex organs (testes in male and ovaries in female)
* Haploid gametes are produced by both (haploid sperms by testes and haploid eggs by ovary)
* At certain age both stop producing gametes
* Both are influenced by sex hormones
* Both have external openings to the outside world

* Both have pubic hairs on their external surfaces at maturity
* Before puberty, both do not produce gametes.

3.3 Comparison of Reproduction Among Vertebrates

You have studied reproduction in five important vertebrates i.e. in fish, amphibians, reptiles, birds and mammal. It will be interesting to compare

* their breeding time
* number of eggs they laid
* site of fertilization
* site where embryo is developed
* and type of parental care

These are summarized in Table 10.2: Comparision of reproduction among vertebrates

Types of vertebrate	Breeding time	Number of eggs laid	Site of fertilization developed	Site where embryo is	Parental care. Type of Parental care
Fish	Seasonal	Millions	External (water)	Water	Protection by some fish e.g. *Oreochromis niloticus* (mouth brooder), and none for some fish
Amphibians	Seasonal	Hundreds	External (water)	Water	None
Reptiles	Seasonal	Few	Internal (oviduct)	Holes in earth covered with soil	Mostly none
Birds	Seasonal	Few	Internal (oviduct)	Nests	Incubation of eggs, protection, feeding and teaching of the young ones until flight is achieved
Mammal	Seasonal, exception being man	None, exception being the monotremes that lay few eggs			

Activity C

ai. Draw and label the human male reproductive system/organ

ii. Write short notes on the follwing;
  * ovulation
  * implantation and
  * placenta

b. Tabulate the differences between the male and female reproductive organs.

3.4 Development in Animals

The fertilized eggs of most animals develop into embryos. After hatching or birth it increase in size or grow

into adults with changes in their body form. Some animals such as amphibians and certain insects show considerable changes in body form between the fertilized egg and adult. This phenomenon is referred to as metamorphosis.
Metamorphosis include the changes that occur in the body form of a **larva** or immature organism until it develops into an adult. It is seen in insects e.g. from **caterpillar** to butterfly and in amphibians e.g. from tadpole to adult frog.

a. **Insect Metamorphosis**
Insects exhibit two types of metamorphosis, these are; **incomplete** and **complete** metamorphosis
i. ***Incomplete Metamorphosis***
Occur in the cockroach, locust and grasshopper. The fertilized egg hatches into a **nymph**, which is a miniature insect, looking exactly like the adult except that it lacks wings and is sexually immature. **The nymph** becomes an adult only after passing through several moults or **ecdysis** (fig. 10.4). This involves complete shedding of the exoskeleton. The stage between successive moults is called an **instar**.

EGG ⟶ **NYMPH** ⟶ **ADULT**

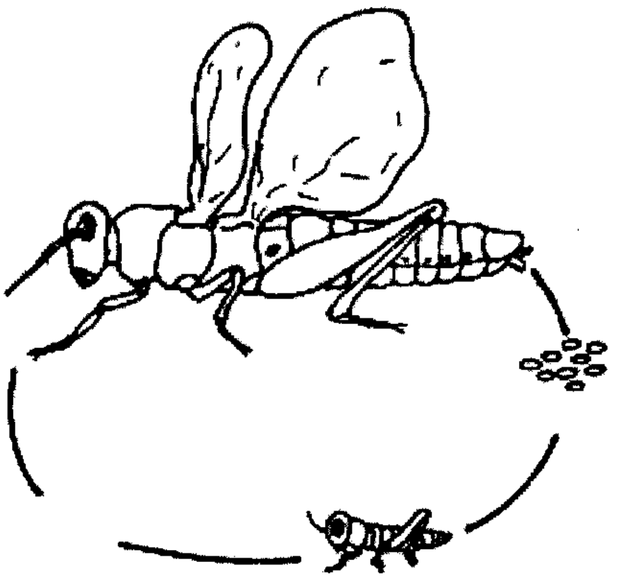


Figure 10.4

ii. ***Complete Metamorphosis***
E.g. Housefly, butterfly, moth, honey bee etc. Here, the stages of the life cycle are the egg, the larva, the pupa and the adult. The egg hatches into a very active larva different in form from the adult. The larva could be maggot, grub or caterpilla depending on the insect. The larva feed differently from the adult and passes

through ecdysis stages to become an inactive non-feeding pupa. Inside the pupa, tissue reorganisation occurs involving destruction of certain tissues. The sexually mature adult emerges from the pupa (fig. 10.5).

EGG → LARVA → PUPA → ADULT

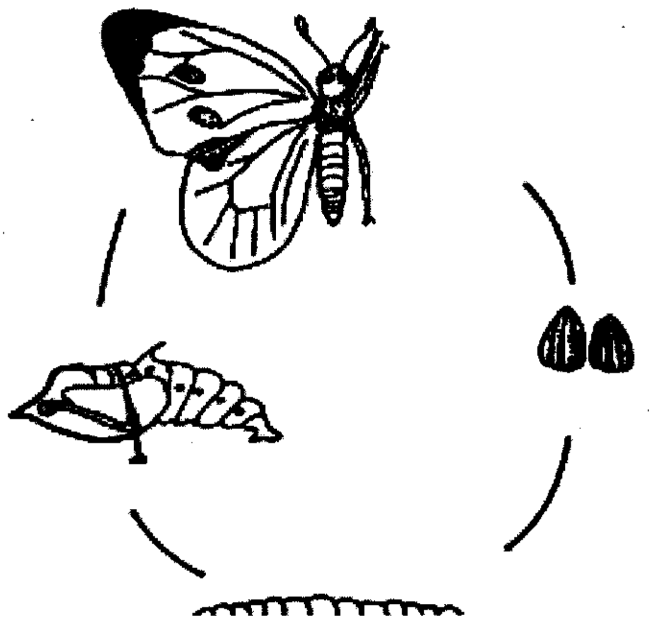


Figure 10.5

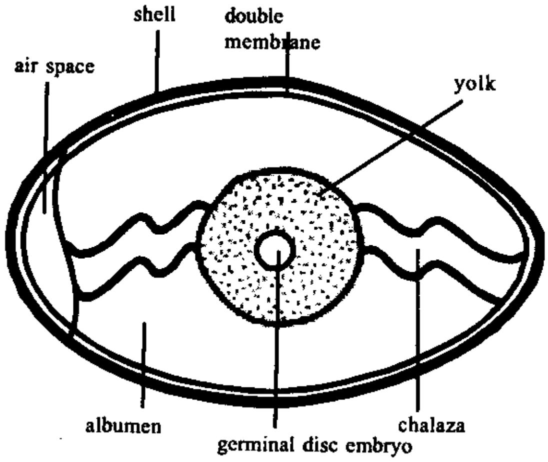
b. **Toad/Frog Metamorphosis** (see unit 3.1b) **"Reproduction in Amphibia"**

c. **Adaptive features in the Development of Animals**

A developing embryo requires food, water and oxygen. In eggs, food is provided in the form of yolk. Water comes from the albumen (the white of eggs). However, oxygen requirement is met by diffusion through the eggshell into the egg to the embryo. In some other cases, an air space exists in the egg from which oxygen is supplied.

Eggs with large amounts of yolk are referred to as **macrolecithal** egg e.g. eggs of reptiles and birds; eggs with little yolk are called **microlecithal** egg e.g. amphioxus and mammals.

The amount of yolk in the egg determine the pattern of development of the embryo. Birds and reptiles lay eggs with large amounts of yolk (see fig. 10.6). The embryo here uses this large yolk to develop to a considerable level, and a miniature adult emerges from the egg at the time it hatches.



[illegible]

ai. Define metamorphosis
ii. List two types of metamorphosis
iii. Draw and label a transverse section of an egg of a bird.

[illegible]

In this unit you have studied reproduction in animals. You should be able to list the types of reproductive systems and describe various forms of reproduction in animals. Furthermore, you should also be able to discuss reproduction in mammals and tabulate the differences and similarities between the mammalian male and female reproductive organs. Finally, you should be able to discuss the comparison of reproduction among vertebrates and development in animals.

[illegible]

Reproduction is one of the vital processes of living organisms. It is responsible for transmiting genetic material from parents to offsprings, and in continuity of species. Reproduction may be asexual (as in amoeba and paramecium) or sexual (as in amphibians reptiles, birds and mammals). Reproduction in vertebrates especially human being involves the testes in male and the ovaries in female. The reproduction processes are controlled by the pituitary gonadotropins. Basic differences and similarities exists between the male and female reproductive organs. The union of the egg and sperm is called fertilisation. Fertilised egg must grow and develop before adult hood is reached. This gradual developmental process is called metamorphosis, of which there are two types; in-complete and complete metamorphosis.

6.0 Tutor-Marked Assignment

ai. List the advantages and disadvantages of sexual reproduction (5 marks)
ii. Enumerate the functions of the jelly produced during fertilisation in amphibian (5 marks)
iii. Draw and label the egg of a bird (5 marks)
iv. Enumerate the similarities between the mammalian male and female reproductive organs (5 marks)
bi. Draw the male reproductive organ (5 marks)
ii. List ten (10) differences between the male and female reproductive organs (5 marks)
(Tabulate your answer)
iii. Write short note on complete metamorphosis. (5 marks)

[redacted]

S. T. Ramalingam. *Modern Biology*
Idodo - Umeh. *College Biology*
S. A. Odunfa. *Essentials of Biology*
M.B.V. Roberts. *Biology - A Functional Approach*
A.E. Vines and N.Rees (1982), *Plant and Animal Biology Volume 2*, Printed in Great Britain by The Pitman Press, Bath, U.K.

Volume 4: Evolution and Genetics

Unit 1: [illegible]

Page

1.0 Introduction

Plants and animals are believed to have under gone considerable changes over a prolonged period of time. These changs are seen in the great differences and similarities amongst the plants and animals existing on earth. New species of organisms continuously develop from earlier ancestral species by way of structural and behavioural modifcations to cope with changes in the environment. Several species of organisms also perish and become extinct in the continual process of change occuring in nature. The concept of evolution explains the overall gradual development which occurs in an orderly and sequential way in living organisms. Evolution is defined as the development of more complex organisms from an already existing simpler organism(s) over a long period of time; often million(s) of years. A number of scientists had made valuable contributions to the concept of evolution. Some of their hypotheses added together in form of theories are highlighted in this unit.

Also in this unit you will come across some of the evidence in support of evolution. These evidences are drawn from the distribution of animals in the continents, the fossilised remains of dead plants and animals, structural similarities in animals, development similarities in animals, biochemical similarities in organisms and molecular records of organisms. You should not fail to appreciate that evolution is an extremely slow process and a direct evidence in support of it is difficult.

2.0 Objectives

After going through this unit, you should be able to

a. Define evolution
b. List the major theories in support of evolution
c. Differentiate between Lamarck's and Darwin's theories of evolution
d. Explain the various evidence in support of evolution
e. Describe the concepts of gene and genetic mutation as they relate to the concept of evolution.

3.0 Pre-Darwinian Theories of Evolution

For a very long time, people had always speculated about the origin of life. These speculations are grouped into three major theories as follows:

a. **Theory of Eternity of the Present Condition**

This theory suggested that there is no beginning or end to the universe. According to this theory, the living organisms found on earth today have existed for several millions of years and would remain unchanged throughout eternity.

b. **Theory of Special Creation**

This theory was preached by religious bodies as a result of the account of the creation of plants, animals and everything in this world by God.

c. **Theory of catastrophism**

This theory recognised worldwide catastrophes which brought about the death of animals in the past. The death of these old animals on a massive scale gave rise to a new set of animals which occurred over millions of years due to changes in environment conditions.

3.1 Lamarck's Theory of Evolution

Lamarck was a French scientist who lived between 1744 and 1829. He put forward an evolutionary theory known as Lamarckism or the theory of use and disuse. The theory suggested that characteristics acquired by organisms due to environmental changes can be inherited. Explanation of Lamarckism is as follows;

- changes in the environment create some needs in organisms
- to satisfy these needs, organisms develop some organs
- continuous use of the organs develop them more in size
- organs that were not used degenerate
- the newly developed organs acquired by the organisms are inherited by their offsprings.

Lamarck explained that the long neck of the giraffe was caused by generations of neck stretching to browse the tops of shrubs and trees in the absence of lower grasses. The major objection to this theory of use and disuse is that acquired characters are not inheritable. Otherwise, a man that lost one of his hands in a major accident would continue to produce one-handed children!

3.2 Darwin's Theory of Evolution

This theory of evolution by natural selection was put forward by an English scientist, Charles Darwin (1809 - 1882) and it became the most widely accepted of the evolutionary theories. Charles Darwin not only supported the fact of evolution with powerful evidence, but also explained the mechanism of evolution. He sailed round the world in a ship known as H.M.S. Beagle between 1831 - 1836, observed and collected assorted types of living organisms. In 1835 while on the Galapagos Island (situated 900km west of Ecuador in South America), Darwin observed variations in some birds known as finches. The finches on the mainland, unlike those of the island, were all of one type having short straight beaks for crushing seeds. The finches on the Galapagos island were of thirteen species categorised into six main types, each with a beak specially adapted for dealing with a particular kind of food (fig. 1.1). Darwin thought that the Galapagos finches migrated from the mainland of South America. Whilst on the island, the birds became adapted to feeding on different types of food and this caused differences in the structure of their beaks. This is a good example of adaptive radiation. It was assumed that the ancestral stocks to the Galapagos finches migrated from the mainland and in the absence of competition, they evolve to fill all the empty ecological niches which was occupied on the mainland by other species of birds.

In 1859, Darwin published his theory of evolution by natural selection in a book entitled "on the origin of species by means of Natural Selection". The book gave documented evidence in support of evolution. Darwin postulated that individuals of a species differ from each other in the degree to which they are suited to their environment. The poorly adapted individuals perish whilst the well adapted ones survive. The surviving individuals pass on their beneficial characteristics to their offspring. This is the meaning of natural selection; when nature selects the fit and rejects the unfit.

The summary of the book published by Darwin on evolution is as follows;

- Organisms tend to reproduce far above the number that survives, thus maintaining the size of their populations at a fairly constant level.
- Members of a population continuously struggle for existence due to increased population size.
- The fittest individuals in a population will survive while the unfit are eliminated through death
- The fittest individuals pass on their favourable characteristics to the next generation
- There is a difference in the contribution of different members of a species to suceeding generations.
- Not all variation observed in members of a species are inheritable. The concept of natural selection put forward by Darwin is summarised thus:
- Variations occur in the individuals of a population
- The environment acted upon the variations

- Those individuals and organisms whose variations enable them to be better adapted to the environment are selected by nature.
- The selected organisms would have more offsprings in the next generation than the unfit individuals
- The increase in the proportion of selected individuals in relation to the unfit will standardise the characteristics of that variation for the species.

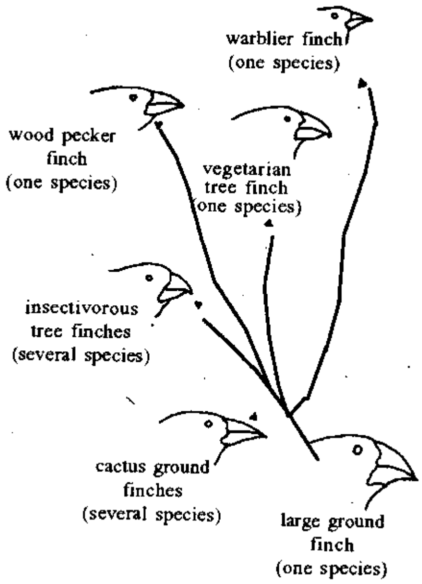


Figure 1.1 An evolutionary tree to indicate the relationship amongst the Galapagos finches. The beaks have evolved to suit different kinds of diet; an adaptation to fill a wide range of ecological niches. (Source: M.B.V. Roberts, Biology, A Functional approach. Pg. 568)

3.3 Contrast between Darwinism and Lamarckism

Table 1.1

Darwin's Theory	Lamarck's Theory
- Variations appear in a population by themselves	Variations appear in populations to satisfy needs in the environment
- Environment selects from a population only members with favourable variations or adaptations	Environment maintains variations in individuals as a way to satisfy the needs of the environment
- Only hereditary variations are transmitted from parents to offsprings	Variations (characters) acquired through use or disuse are transmitted from parents to offsprings
- The fittest species in any environment gives rise to the largest number of offspring in subsequent generation	Characters acquired by parents to satisfy needs of environment are inherited by offspring

Activities

i. What are the Pre-Darwinian theories of evolution
ii. Distinguish between Darwinism and Lamarckism

3.4 Evidence in Support of Evolution

Darwin postulated that evolutionary process was an extremely slow process that could not be directly observed. However, scientists from many areas of study have gathered a lot of indirect evidence to support the theory of evolution. Some of the evidence in support of evolution came from the following sources; fossil records, biochemical similarities, molecular records, Geographical distribution, comparative anatomy and embryology.

Evolution Evidence from Fossil Records

Fossils are the remains of plants and animals that are preserved either in the form of entire organisms, hard skeletal materials (bones, shells, teeth) in rocks or as mould cast. The study of fossils is known as**palaeontology**. When fossils are arranged according to their age, the oldest rocks contain very few fossilised organisms with simple structures whilst the younger and more modern rocks contain numerous fossilised organisms in great varieties with complex structures. This shows an evolutionary trend from very simple organisms in the distant past to a more complex and more recent forms. Fossil evidence alone is not sufficient to support evolutionary concepts. What it does is to prove a progressive increase in the complexity of organisms over time. It therefore disproves that species of organisms remain unaltered over time.

Most of the fossils discovered can be grouped with the living forms but it cannot be proved if they actually represent the ancestors of the living species. By using a series of fossils, scientists were able to trace the evolution of the modern horse named **Equus** from the 'dawnhorse' named **Eohippus** 60 million years ago (Fig. 1.2).

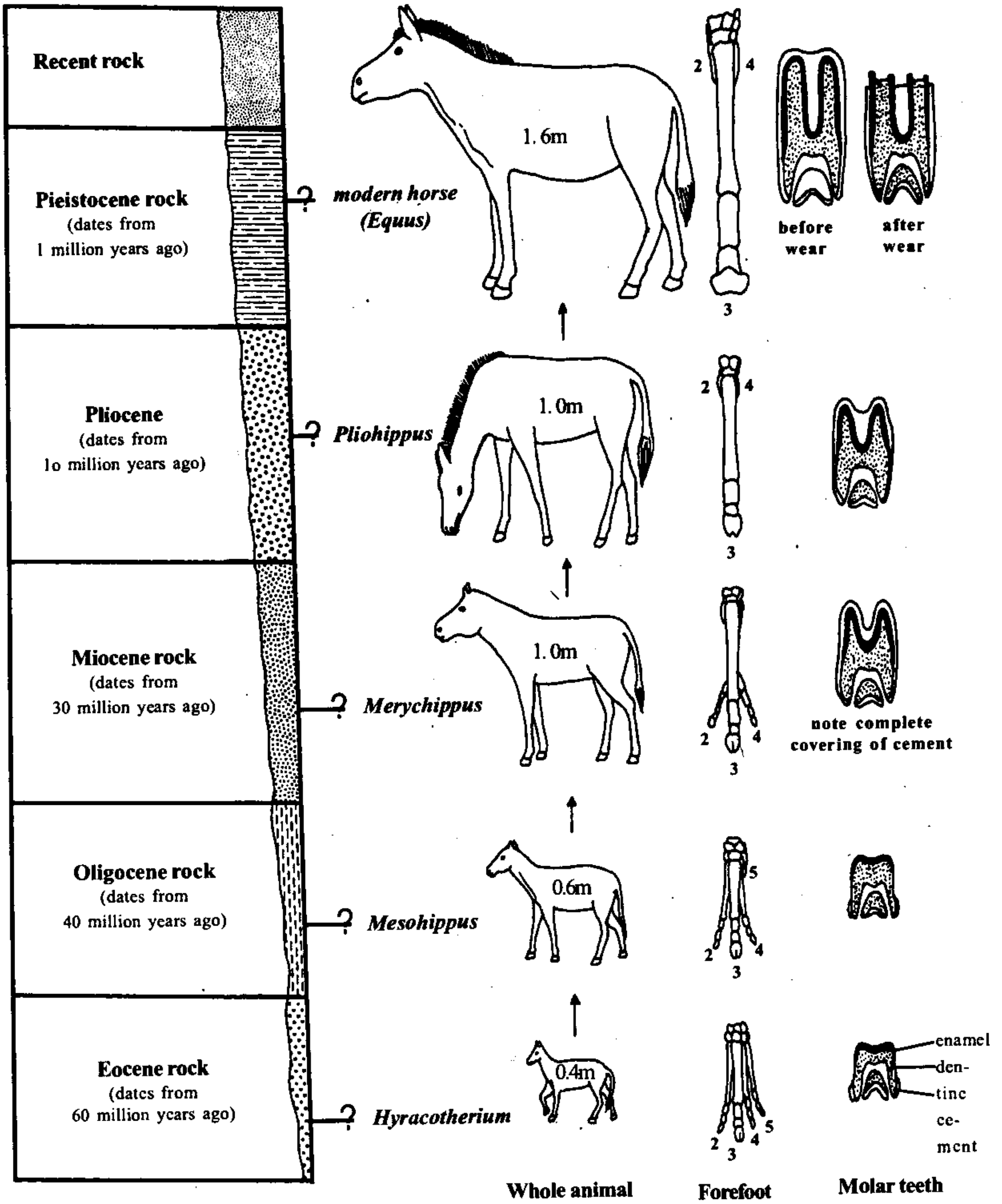


Figure 1.2: Evolution of the horse based on reconstructed fossil species obtained from successive rock strata. The front views of the left forefeet and longitudinal sections of the teeth are shown.
(Source: M. B.V. Roberts - Biology, A functional approach. Pg. 585).

Evolution Evidence from Biochemical Similarities

Similarities have been noticed in the chemical constitution and biochemical processes of all organisms. Every organism contains molecules of carbohydrates, lipids, proteins and nucleic acids. The source of energy for metabolic processes in the body of every living organism in ATP (Adenosine triphosphate). The storage, expression and transmission of genetic information in living organisms are basically of the same materials and processes. All these biochemical similarities point to a common ancestry for all organisms.

Evolution Evidence from Molecular Records

The DNA (Deoxyribonucleic acid) is the molecule of inheritance on which hereridary information are stored in virtually every organism. This DNA is located in the nucleus of cells found in the body. The present day idea of evolution centres on the alteration in the chemical structures of genes located on the DNA. It is expected that the DNA of closely related species should reveal greater similarities than those of unrelated species. It is known that the DNA of man and that of the chimpanzee are 98 per cent alike. This fact supports the idea of close evolutionary relationship between both organisms.

Evolution Evidence from Geographical Distribution of Animals

There are three continents located in the Southern Hemisphere namely Africa, South America and Australia. On the world map, three other continents namely Europe, Asia and North America are located in the Northern Hemisphere. Africa and South America are similar in terms of vegetation, relief and climate, but the two continents have different species of animals. Elephants, short-tailed monkey, illamas, panthers and jaguars. In Australia are found a completely different and unique set of animals, which include the marsupials (pouch mammals) e.g. Kangaroo, as well as the primitive monotremes (egg-laying mammals) e.g. spiny anteater and duckbilled platypus..

In the Northern Hemisphere, the indigenous animal types found in Asia, Europe and North America are very similar. These include bears, bisons, beavers, elks, reindeers and so on. Why are there similarities in animals of the Northern Hemisphere and differences in animals of the Southern Hemisphere? The answer lies partly in observing the world map (fig. 1.3). The three continents in the Southern Hemisphere (South America, Africa and Australia) are separated by large oceans but those in the Northern Hemisphere especially North America and Asia are separated by a shallow water body known as the Bering strait which is less than 100km wide. Geological evidence showed that the Bering strait was once occupied by a land bridge linking Europe with Africa, Asia with Australia, and North America with South America in geological past (Fig. 1.3). The differences and similarities observed in the continental distribution of animals was explained on the idea that the ancestral animals originated from the northern continents of Asia or North America and migrated to the three Southern continents by way of the natural land bridges. When the land bridges became submerged to form straits, the migration stopped and the animals evolved along their own lines. The animal types that succeded in getting into the various southern continents became isolated, underwent adaptive radiation (evolution of different forms to fill every habitat) independently to give rise to marked differences in their animal composition.

In conclusion, the distribution of animals and plants as well as their occurence in various forms in different locations depend, to a large extent, on migration and isolation. Both phenomena are hinged on the occurence of natural barriers which restrict free movement. Migration of terrestrial (land) organisms may be hindered by such barriers as water bodies, deserts, mountain ranges, extremes of temperatures and other climatic factors. Aquatic (water) organisms may be hindered from migrating by water currents, tides and or water salinity. Isolation may cause independent evolution of life forms.

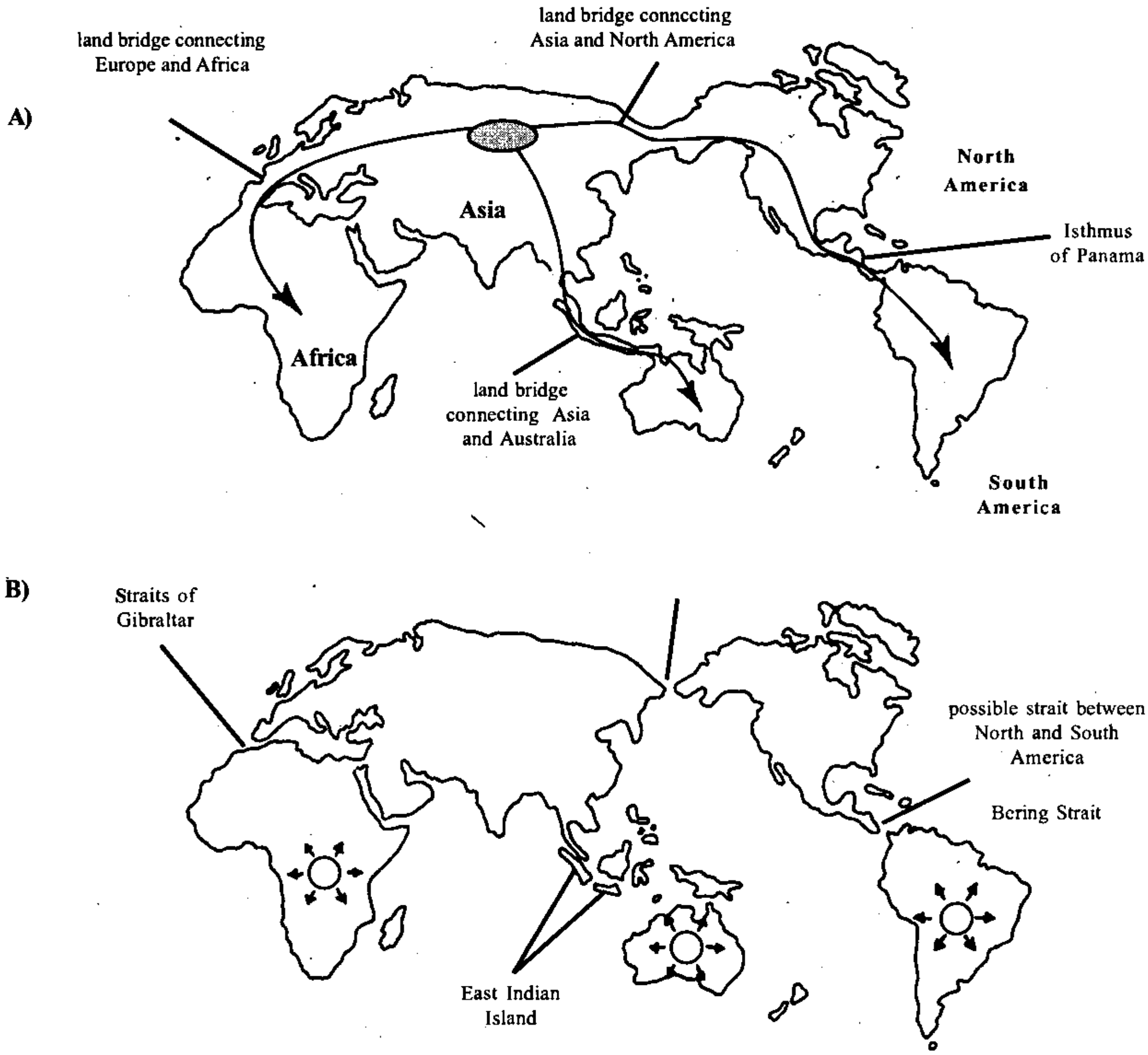


Figure 1.3: The World Map Showing continental connection by land bridges in A, and ocean-separated continents in B. Arrows show the movement of animals in the past. (Source: M.B.V Roberts - Biology, A functional approach. Pg. 563)

Evolution Evidence from Comparative Anatomy

You have just read that widely separated groups of animals share a common ancestor. These animals are expected to have similar structural features. The degree of structural resemblance between organisms should tell us how closely related or otherwise organisms are in evolutionary terms.

Groups of organisms with very little in common may be taken to have diverged from the ancestral stock much earlier in geological history than those sharing much structural similarities. Comparative anatomy seeks to establish evolutionary relationships between organisms on the basis of structural similarities and differences. Apart from allowing us to relate a group of diverse organisms to a common ancestor, comparative anatomy together with fossil data can also help us to work out evolutionary sequence or pathways for group of organisms.

Anatomical structures which may serve quite different functions in adult organisms but built on a similar pattern, thus suggestion a common origin are described as homologous structures. Examples of homologous structures are the pentadactyl (five digits) limbs of vertebrates (fig. 1.4). If you study fig. 1.5 you will appreciate the principle of homology. The variations in the pentadactyl limbs of mammals (fig. 1.5) show that numerous lines of evolution from an ancestral stock may lead to a modification of the basic pattern to serve different functions. This modification will allow the descendants to fill various ecological niches. This produces a form of divergent evolution which result in adaptive radiation. Adaptive radiation produces certain common structural features in several organisms which arose from an ancestral stock as found in the ancestor.

Similar structural features found in organisms having quite different ancestral origins are described as analogous structures. Examples of analogous structures are legs of mammal and insects; wings of birds and butterflies. Analogous structures are similar to each other not because of being derived from a common ancestor, but because there is no other way to build the structures to perform the functions they are used for. Analogous structures are produced from different lines of evolution as a form of convergent evolution.

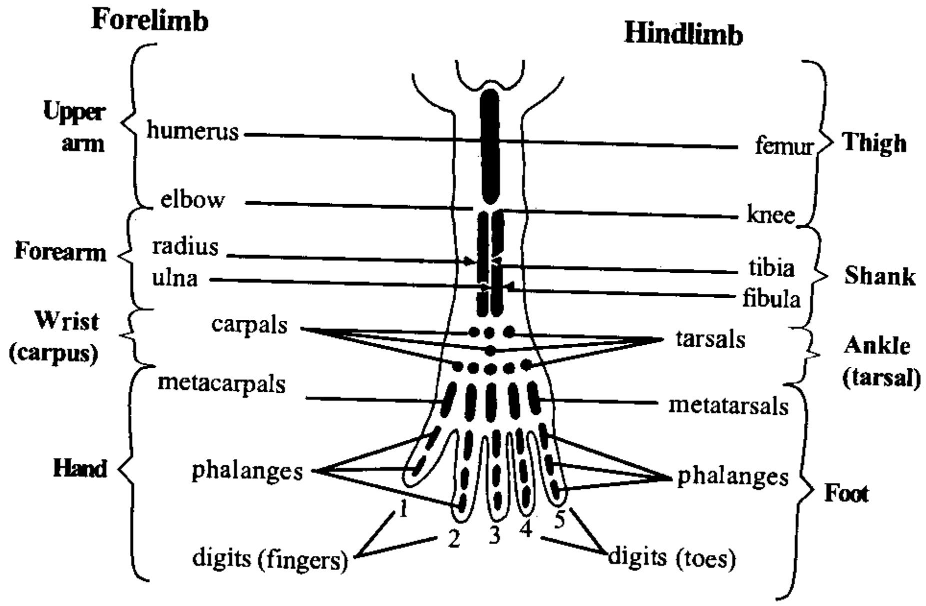


Figure. 1.4: ***A generalised pentadactyl limb possessed by all terrestrial vertebrates (Source: M.B.V. Roberts - Biology, A functional approach Pg. 569)***

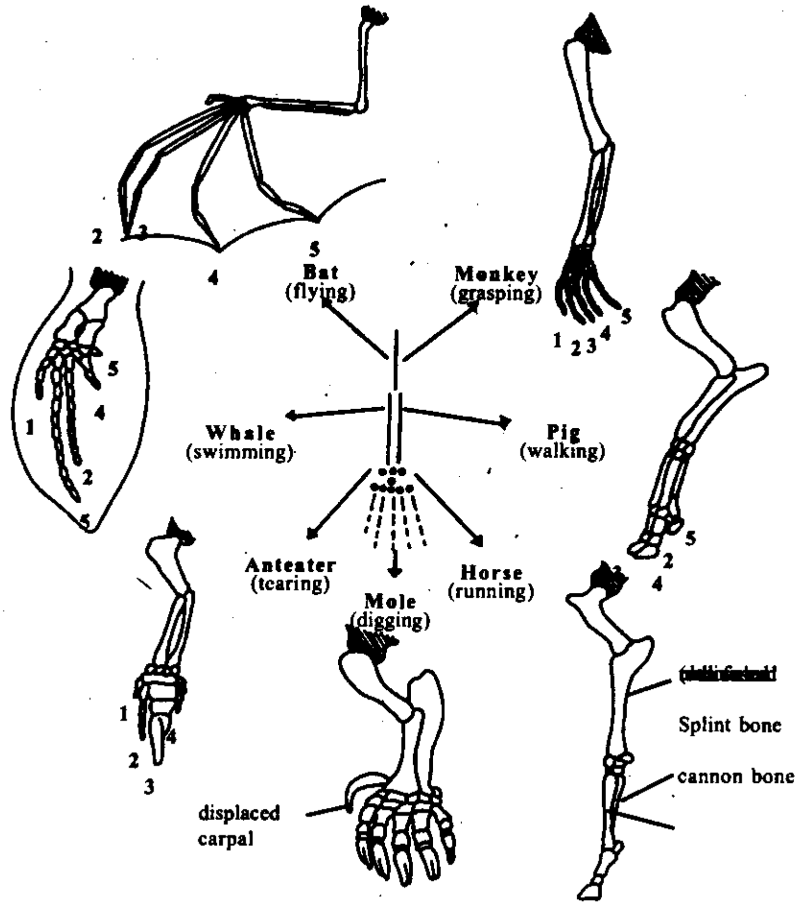


***Figure 1.5:** Illustration of adaptive radiation of the forelimb of mammals to demonstrate the principle of homology. All forelimbs conform to the basic pentadactyl pattern but modified for different usages.*
(Source: M.B.V. Roberts - Biology, A functional approach. Pg. 570.)

Evolution Evidence from Embryology

Embryology is the study of the formation and development of organism in its earliest stages of development. In many cases, the embryo of an organism looks like that of its ancestor at certain stages of development. The human embryo for instance, has gill slits at a stage as in fish, later it develops tail. The human embryo is very similar to the young embryo of other vertebrates which also pass through the gill-slit stage (fig. 1.6). This shows that all vertebrates share a common ancestry. Vertebrate development (human inclusive) has evolved by modifying and enlarging on existing genetic materials.

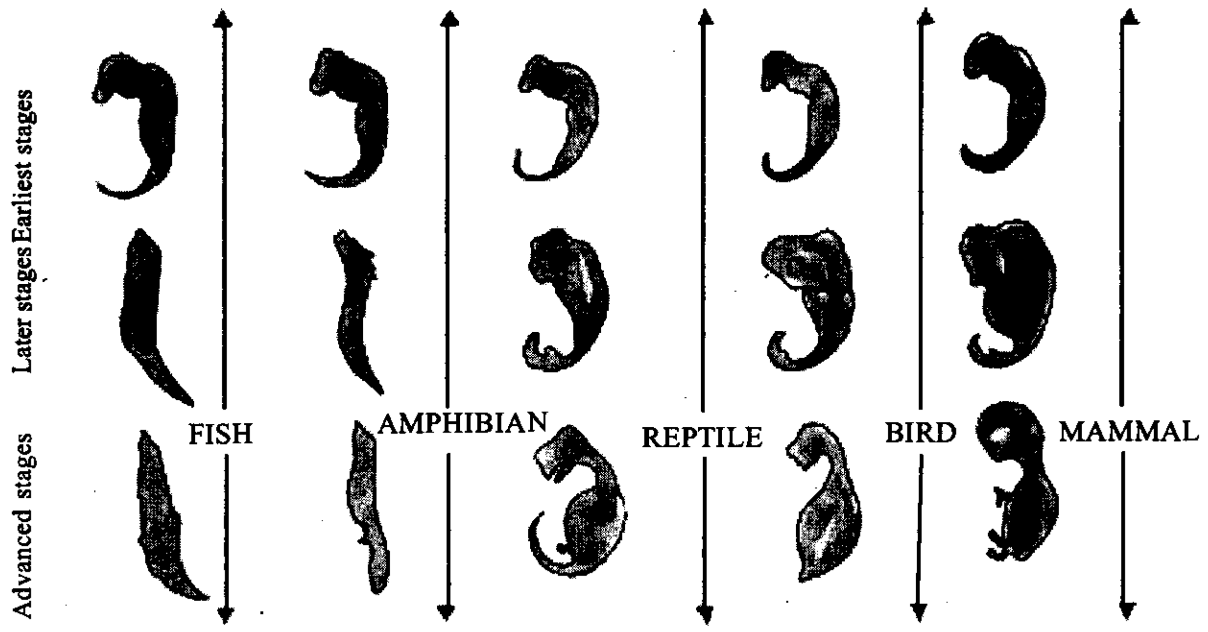


Fig. 1.6: Vertebrates embryos showing similarities
(Source: S. T Ramalingam, Modern Biology Pg. 531)

Activity [illegible]

i. List the theories of evolution
ii. Explain five of the theories that you have listed above

3.5 Modern views on Evolution

According to Darwin, evolutionary change is caused by natural selection acting through environmental pressures on individuals in a population. Darwin did not know how inheritance works and as such he could not explain the source of variation and how individual variations arise. The modern view of evolution which is referred to as Neo-Darwinism is a combination of Darwin's theory with the present-day knowledge of genetics and molecular biology. Currently, the process of evolution is described in line with the knowledge of genes and chromosomes, which accounts for genetic variation upon which natural selection acts. Apart from natural selection, scientists have come to identify mutation, gene flow and genetic drift as additional natural forces, acting either alone or in combination, to determine the rate and course of evolutionary change. Evolution is now seen in a different persepective from the survival or death of individuals but in the perpetuation or elimination of the genes which they carry. Individual organisms do not evolve as they retain the same genetic make-up throughout their lives and pass on their genes to the next generation. Evolution only occurs with populations of a species and this happens when the genetic content of the gene pool changes. Below is the explanation of the modern concepts relating to the occurence of evolution.

Genes

A gene is a segment of a DNA (Deoxyribonucleic acid) molecule that is responsible for the inheritance of characteristics. Genes are located on chromosomes which are found inside the nuclei of cells. All the information for the inheritable characteristic of an individual are contained in genes.

During cell division, genes are duplicated along with chromosomes to ensure that each of the daughter cells have identical set of genes as the parent cell. The genes of parents are passed into their offsprings through the gametes during sexual reproduction. Such transfer of genes occur in form of an encoded information in the sequence of bases in the DNA molecule. Genes act by controlling the synthesis of polypeptide chains that form proteins. These proteins are responsible for the formation of structures in organisms.

Mutations

These are uncontrolled changes occuring in DNA resulting in the alteration of genetic information in specific organisms. Though a very rare occurence, mutation is the only process that changes genes and once it occurs, it introduces new characteristics into the population of organisms. Mutation may occur in body cells in which case it is known as somatic mutation and cannot be inherited by the offsprings. Mutation may also occur during gametes (sex cells) formation, in which case it is known as germline mutation, which can be inherited. Such a germline mutation provides the raw material for evolution, since it leads to the inheritance of new characteristics which might or might not be manifested in the parental organism.

Gene Flow

The recombination and spreading of genes wihch occur when members of the same or different populations of the same species interbreed (sexual reproduction) is known as gene flow. Gene flow cannot occur between different species because they cannot interbreed. The total gene content of a speices is known as its gene pool. When big changes occur in the gene content of a gene pool, new species of organisms are produced. The genetic variations observed in individuals of a population are caused either largely by gene recombination or rarely by mutation. These variations are important because evolution acts through them.

Genetic Drift

When, in a small population by way of chance and not by intention, some genes spread more than other genes, then we say that there is a genetic drift. Genetic drift is important in the evolution of species in small islands.

Formation of New Species

New species of organisms can only be formed through the modification of existing species. This happens in two wys as follows;

- Transformation of one species into another species. In this case, the ancestral species becomes extinct and is replaced by a new species.
- New species evolve as branches from an existing species. This is the process of speciation and is responsible for the diversity of organisms.

Speciation normally follows the isolaton of the population of a given species to the extent that interbreeding is not possible. This causes a stoppage of gene flow between the population. Gene flow can be stopped by geographical barriers (mountains, seas) or by other barriers as differences in mating behaviour, genetic incompatibility, differences in structure of extemal genitals hindering mating, differences in breeding seasons etc.

Activity C

1. Write short notes on the following
   i. Genes
   ii. Mutations
   iii. Gene flows
   iv. Genetic drift
   v. Formation of new species.

[illegible]

In this unit, you have read about two interrelated subjects of evolution and genetics. Evolution as envisioned by pioneer scientist like Darwin recognised the continual changes occuring in the population of organisms. The definition of evolution should be clear to you now. You should also be able to highlight the thoughts of the early scientists especially Lamarck and Darwin as put together in their theories. How about the evidence put up to support the idea of evolution? These evidence were positive because the similarities and differences in organisms were linked to similar structural features in ancestral organisms. The explanation of fossil records, biochemical similarities, molecular records, geographical distribution, comparative anatomy and embryology as evidence of evolution should not be difficult for you now. The concept of gene, genetic mutation, genetic drift and gene flow make the fact of evolution evident. You should now know how new species are formed from preexisting species and the genetic basis of this formation.

[illegible]

The concept of evolution explain the adaptive changes that occured in populations of organisms over a long period of time. Evolutionary changes lead to the formation of new species from earlier ones. Although there are several theories on the origin of life, two theories stand out and they are known as Lamarckism and Darwinism. Lamarck based his theory on the inheritance of acquired characteristic of parents by offsprings whilst Darwin's theory is based on natural selection as the cause of evolution. Modern views of evolution recognise natural selection, mutation, gene flow, genetic drift as forces that regularly produce adaptive evolutionary changes.

Genes are units of inheritance of hereditary traits. New traits are introduced into a population as a result of mutation which causes changes in the genetic information of individuals. Inheritable mutations provide the raw materials for evolution. Recombination of genes which occur during sexual reproduction is mainly responsible for genetic variation.

Evidence in support of evolution comes from various sources including fossil records, biochemical similarities molecular similarities, distribution of animals in the continents, comparative anatomy and embryology.

[illegible]

1a. Tabulate the differences between Darwin's theory and Lamarck's theory (10marks)

b. List the evidence that showed that evolution occurred (10marks)

2. Write short notes on the following
   - i. Genes
   - ii. Mutation
   - iii. Gene flow
   - iv. Formation of New Species. } 20marks

[illegible]

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Unit 2: Modern Examples of Evolution (Microevolution); Classification and Evolution

1.0 Introduction

During the time of Darwin, natural selection was recognised as an evolutionary force on the basis of historical evidence (past happenings). It was then not possible to demonstrate direct evolutionary changes in populations of organism due to the enormous time span thought to be involved for such a change to be visible. However, with the advancement in technology, industrialisation and medicine, strong disruptive pressures have emerged that allow us to observe changes in both the genetic constitution (genotype) and physical nature (phenotype) of population of organism within days.

In this unit, you will learn a few examples of dramatic changes in population of organisms that support the idea of continuous evolution. Some of these examples bother on recent and contemporary issues of global health due to the development of mutant varieties of disease agents. On another dimension, some artifical practices like selective breeding programmes on useful plants and animals as well as genetic engineering are known to allow the observation of evolution occuring nowadays. The evolutionary basis of classification of organisms due to the possession of homologous structures and descent from a common ancestor is also treated.

2.0 Objectives

At the end of this unit, you should be able to;

a. explain some of the examples of present day evolution

b. describe the basis of natural classification of organisms as it relates to evolutionary concept

3.0 Sickle-Cell Anaemia

Sickle-cell anaemia is a genetic disorder (disease) in humans, caused by the inheritance in the homozygous recessive condition of the gene responsible for the formation of the blood haemoglobin. The variations available are people with AA (normal individual(s), AS (carriers of the trait but not sickler) and SS (sickle-cell anaemia patients). In sickle-cell anaemia the normal haemoglobin A found in the red blood cells is entirely replaced by abnormal haemoglobin S. When the oxygen concentration in the body falls, haemoglobin S begins to crystallise in the capillaries of the body tissues. This makes the red blood cells which is biconcave disc-shaped in normal individuals to become crescent or sickle-shaped. The sickled red blood cells are far less efficient in carrying oxygen and die easily. It results in severe anaemia (blood shortage) which causes the victim to suffer symptoms of extreme oxygen shortage including weakness, emanciation, kidney and heart failure ending in the death of the sufferer.

Sickle-cell anaemia disorder is being selected against, naturally by causing the death of its sufferer. And also artificial, by marriage of two carriers (heterozygous AS) individuals so as to halt or reduce the production of sicklers. This bad gene is being removed from the population of humans by both natural and artificial selection. From the evolutionary point, there is differential mortality of individuals with the sickle-cell because they usually die before they have a chance to reproduce and as such the unfavourable gene is eliminated from the population.

The gene that causes sickle-cell anaemia is known to confer an advantage in the heterozygous (AS) state by allowing people with AS haemoglobin type to be resistant to the most deadly form of malaria caused by ***plasmodium falciparum***.

3.1 Industrial Melanism

Another good example of evolutionary change is the response of the peppered moth (*Biston betularia*) to natural selection pressure caused by atmospheric pollution with sulphur dioxide and soot deposition on trees. Before 1848 in the United Kingdom, all forms of peppered moth appeared creamy - white with black dots and darkly shaded areas. By 1895, 98% of the moth appeared black due to recurring random mutation of a gene (melanic allele) which is responsible for colouration in the moth.

These moths fly by night and rest on the trunk of trees by the daytime. The creamy-white forms are well camouflaged with the colouration of lichens growing on the tree trunks (fig. 2.1) with much industrial development, sulphur dioxide pollution killed off the lichens growing on the trees in industrial areas; the bark of the trees also became darkened with soot deposits. Birds are known to feed massively on the creamy-white moths which became exposed against their new darkened background on the trees (fig. 2.1). This selective predation by birds reduces the population of the lighter moths whilst the population of the melanic (darkened) form of the moths increased especially in industrial areas. This is because the melanic forms are well blended with the darkened environment on the trees. Thus the melanic form of the moth had a selective advantage in industrial areas over the lighter form whereas the lighter form had selective advantage in non-polluted areas. Selective predation can therefore change the species composition of organisms, an aspect of evolution.

Figure 2.1: The light form (left) and dark form (right) of the peppered moth, Biston betularia. The light form is resting on soot-covered oak tree in polluted area while the dark form is on lichen-covered trunk in unpolluted area.
(Source: M.B.V. Roberts - Biology, A functional approach. Pg. 604)

3.2 Chloroquine - Resistance Malaria Parasite

Malaria disease is caused by a single-celled protozoan parasite called *Plasmodium*. The disease was at one time not curable and was responsible for the death of several million people worldwide. One of the drugs that was developed for the treatment of malaria infection is chloroquine. Initially chloroquine was very effective against *Plasmodium* species but soon after its introduction, a new strain of *Plasmodium* that is resistant to chloroquine has emerged. This resistance has been linked with patients not completing the prescribed dosage and adultration of chloroquine. The chloroquine - resistant strain of *Plasmodium* had undergone exposure to the drug. The resistance have been inherited by new generations of *Plasmodium* to the extent that it is being encountered in various parts of the world. We are now faced with a medical problem of chloroquine-resistant *Plasmodium* that can survive the normal dosage of the drug. This is a form of micro evolution in a microscopic organism.

Activity A

a. Explain the advantages and disadvantages of the sickle cell gene in human
b. Discuss the concept of industrial melanism.

3.3 Pesticide - Resistance Insects

Man has always seen insects as organisms that complete with him for valuable resources in the environment. Insects also cause annoyance and transmit certain diseases to man. A number of chemical substances have been developed to deal with the problems posed by insects. These substances are called pesticides (insecticides). As man continues to use insecticides to control insect pests, the insects have continued to react biochemically, physiologically and behaviorally to survive the pressures induced by exposure to pesticides. Some insects have also undergone genetic mutation and we now have insect populations that were once susceptible to pesticides and later became mutants resistant to the pesticides. The mutant gene is inherited by future generations of offsprings and the gene spread to new populations. These changes in populations of insects are forms of microevolution.

3.4 Human Immunodeficiency Virus (HIV)

The dreaded and incurable Acquired Immune Deficiency Syndrome (AIDS) is a disorder in humans due to infection with the Human Immunodeficiency Virus (HIV). The HIV shares an ancestor with a virus found in several species of African monkey.

The disease was first recognised in the United States of America in 1981 and have infected over 10 million people worldwide. The virus first appeared in Central Africa and its sudden appearance was associated with mutation which occurred in the stream of virus found in the monkeys. The virus was also thought to be a new species infective to humans from the ancestral monkey strains that were not infective to man. The rapid spread of the virus to all parts of the world and the disastrous consequence of it not being susceptive to known anti-viral drugs is a demonstration of a new problem caused by a new problem caused by a new species of virus that evolved from pre-existing species.

3.5 Severe Acute Respiratory Syndrome (SARS) Virus

Like HIV-AIDS, another viral disease that was widely reported in recent time (2003) is the Severe Acute Respiratory Syndrome (SARS). The virus that causes SARS was unknown until recently and it is said to be closely related to the myxovirus (DNA VIRUS) that causes influenza. Influenza virus affects the respiratory passages (epithelial lining of trachea and bronchi) causing symptoms similar to that of the common cold (running nose, cough and mild fever). The symptoms of SARS include fever, dry ecnough and pneumonia - like manifestations.

Unlike influenza which can self-cure even without taking any medicaments (medicine), SARS has the potential of killing its victim. The SARS virus also represents a new species that might have resulted from a mutant form of the influenza virus. It is a case of the evolution of a virus from an existing virus. SARS is reported to have a cure using one of the anti-retroviral agents.

3.6 Phylogenetic Classification of Organisms

There is a branch of biology known as taxonomy that deals with the classification of organisms into closely related groups. Organisms are classified either for convenience and or to facilitate their identification. Natural classification of organisms also known as phylogenetic classification shows the evolutionary relationship between the various groups of organism. Organisms classified in the same group are closely related whilst those in separate groups are more distantly related.

The basis of a natural classification is to reflect evolutionary or phylogenetic relationships based on the possession of homologous structures. The similarities observed in homologous structures demonstrate a common ancestry for the organisms that posses them. For example, the phylum chordata contains diverse groups of vertebrate and invertebrate animals lumped together solely on the fact that they all possess a notochord at some stage in their life history. The notochord is a flexible rod made up of tightly packed vacuolated cells located on the dorsal side of the body, beneath the neural tube. The phylogenetic importance of the notochord lies in the believe that all the chordates inherited it from a common ancestor. It is possible to arrange the various groups of organisms so as to show their possible evolutionary sequence from a common ancestor or a group of ancestors as in Fig. 2.2.

The figure helps to explain why certain groups of organisms are very similar while great differences are noticed in some other groups.

There are many units of classificatoin called taxon (plural is taxa). The size of a taxon shows the closeness of the organisms in it. For instance, a large taxon like a phylum may contain a wide range of organisms with very few features in common; a smaller unit like order or family will contain a much more closely - knit group of organisms with numerous similarities. Evolutionary, members of a phylum could be seen to have diverged from each other at a much earlier point in time than the members of a family or order.

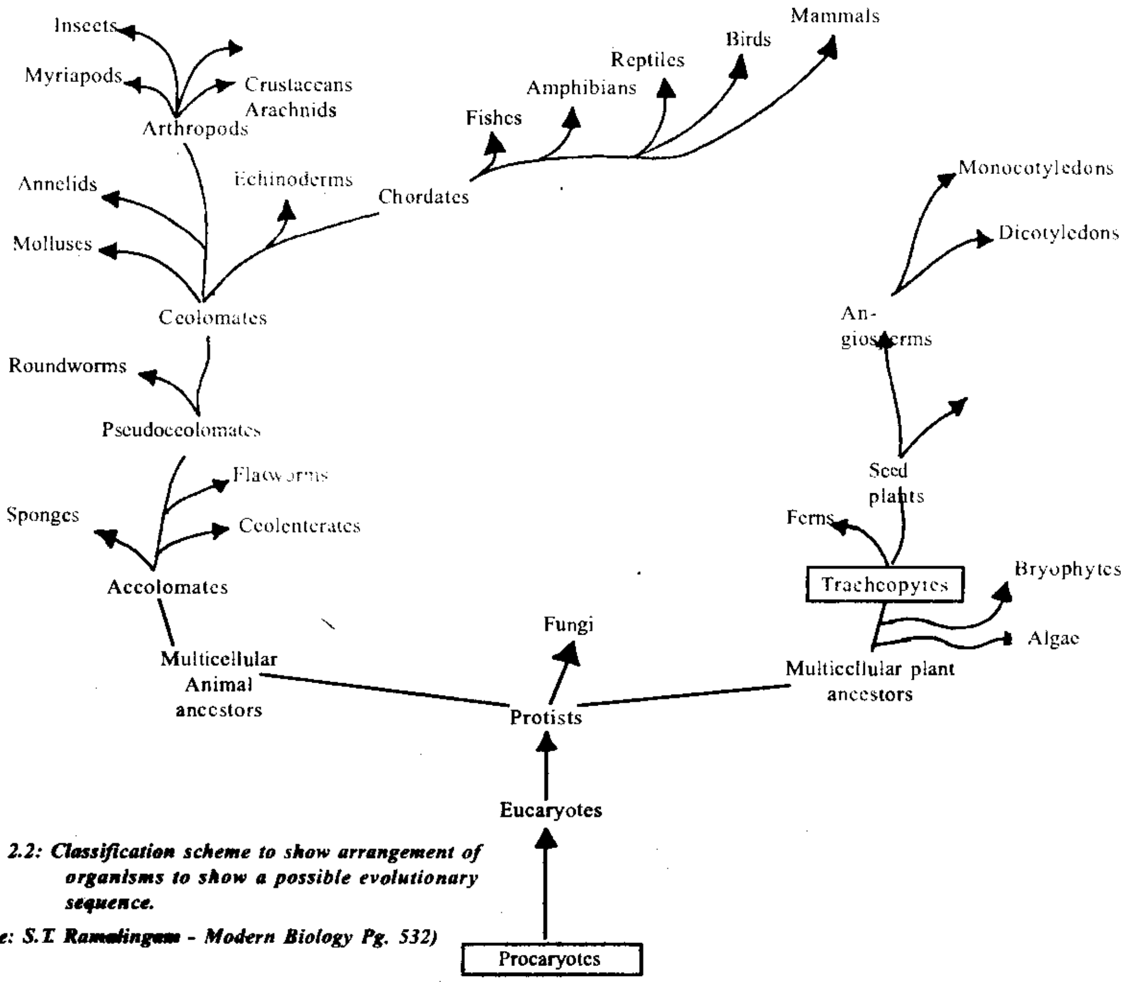

Figure 2.2: Classification scheme to show arrangement of organisms to show a possible evolutionary sequence.

(Source: S.T. Ramalingam - Modern Biology Pg. 532)

[redacted]

Write short notes on the following;

i. Micro evolution in Insects
ii. Human Immunodeficiency Virus
iii. Severe Acute Respiratory Syndrome

4.0 Conclusion

In this unit, you have studied some of the examples of evolution occuring in modern time leading to the production of new species or strains of organisms from pre-existing ones. The major emphasis is on genetic mutation at the driving force creating changes in populations of organisms. You should be able to explain the positive and negative consequences of sickle cell traits and sickle cell anaemia in humans, industrial melanism in moths, chloroquine-resistant *Plasmodium*, resistance of insects to pesticides, HIV and SARS Virus. These are changes in organisms which point to the occurrence of evolution. You have also learnt the evolutionary basis of the classification of organisms. Closely related organisms possess homologous structures which they inherited from a common ancestor. You should be able to relate natural classification to the concept of evolution.

5.0 Summary

In this unit, examples of microevolution in the modern time which was not considered by the earliest scientist was presented and studied. Sickle-cell anaemia is a deadly genetic disorder that causes selective mortality in its victim. This lowers the frequency of individuals with the disorder in human population. However, carriers of the trait with AS haemoglobin type are naturally protected, due to their resistance to infection with the deadly *Plasmodium falciparum* (it causes malaria fever). This has increased the population of carriers of the trait in malaria endemic regions of the world.

In industrial areas of the United Kingdom due to sulphur dioxide poisoning of lichens and deposition of soots on tree trunks, selective predation by birds have drastically reduced the population of the creamy - white forms of the peppered moth. The dark melanic forms of the moth that resulted from a mutation of the melanic genes are well camouflaged against the dark background on trees and are spared by the birds. This form of industrial melanism has increased the population of the dark moths.

Changes in population of organisms are also noticeable in the development of chloroquine - resistant *Plasmodium* from a chloroquine-susceptible strain. Insects have also yielded to the pressure created by continuous use of pesticides to develop mutant forms that are resistant to insecticides. The HIV and SARS Virus are examples of new mutant viruses that developed from pre-existing forms and are creating medical problems world wide.

Natural (phylogenetic) classification of organisms is based on the possession of similar homologous structures by the organisms grouped together. This is based on the believe that homologous structures are inherited from a common ancestor.

6.0 Tutor - MarkedAssignment

1. Show how the following support the theory of evolution
   i. Industrial melanism in moths (10 marks)
   ii. Inheritance of sickle-cell gene in humans (10 marks).

7.0 Further Reading and otherResources

Roberts, M.B.V., 1978, *Biology, A functional Approach*; ELBS & Nelson

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Unit 3: Common Terms in Genetics – Transmission and Expression of Characters – Hereditary Variation

Page

1.0 Introduction

It is a common knowledge that after sexual reproduction, the resulting offspring tends to look like their parents in one or more ways. This resemblance may be related to the immediate parents or even to a member in the lineage. This tendency of the offspring to look like their parents or a member of the lineage is a phenomenon which goes on from generation to generation. This is due to certain characters or traits which the offspring have inherited from their parents thus confirming one of the fundamental observations about heredity made by men several years ago, that is **"Like tends to beget like".**

Very often in our homes such questions are asked about inheritance of traits such as skin colour, hair colour or colour of eyes that a particular individual has. When questions of this nature are asked it affirms a genetic question frequently. Genetics, may them be described as the science that deals with questions and answer on inheritance. This is the inheritance of traits or characters, such as height and skin colour which are transmitted from parents to offspring during sexual reproduction. The ways and manners by which these characters are inherited from parents is known as **HEREDITY**.

The study of genetics dates back to several years in man out of curiosity to unravel the mechanism for the transmission of traits from parent to offspring. A breeder called Kilreuter worked with tobacco plants about 1770. He made crosses with different varieties of plants and produced hybrids. He also recognised that parental characters were transmitted by both the pollen and the ovule. However, studies on heredity before 1866 were not conclusive. The results obtained by earlier investigations offered little explanation of the way inheritance features were transmitted from one generation to the other. Work in genetics continued to draw the attention of natural scientists for many years, until when they realised that Mendel won the pioneer in these investigations and gave him full credit for his work by naming two of the fundamental principles of heredity **Mendel's Law**. All the work that has been done in genetics has made use of mendel's basic discovery and so, today, he is known as "the father of modern genetics". Great advances has been made in genetics, cytogenetics and related fields, but Mendels's two laws still remain the fundamental laws of heredity in genetics.

2.0 Objectives

By the end of this unit, you should be able to:

i. explain the common terms used in genetics
ii. list transmittable characters in human being and in plants
iii. define what variation is and explain at least two types of variation
iv. explain the importance of variation.

3.0 Some Important Terms used in Genetics

In order to understand better the language of genetics, it is very important that the following terms have to be explained.

i. **Gene:** Genes are hereditary units or basic units of inheritance. They are located in chromosomes and are responsible for the transmission of characters from parents to offspring.

ii. **Chromosomes:** Chromosomes are rod or thread-like bodies found in the nucleus of a cell. The chromosomes house or contain the genes.

iii. **Characters or traits:** These are the inheritable attributes or features possessed by an organism, e.g. seed colour, seed size, plant height etc. in plants.

iv. **Gamete:** Gamete is a matured sex cell which takes part in sexual reproduction. There are two types: male gamete or spermatozoan (in animals) and pollen grains (in plants) and female gamete, egg or ovum (in animals) and ovules (in plants). Gametes are usually haploid.

v. **Zygote:** Zygote is a single cell formed as a result of the union of a male gamete with a female gamete. Gamete is usually diploid.

vi. **Allelomorphs:** Allelomorphs are pairs of genes of the position of a chromosome (i.e. locus) that control contrasting characters. A pair of allelomorphs are called **allelic pair** while each member of the pair is the allele of the other.

vii. **Phenotype:** Phenotype is the sum total of all observable features of an organism, i.e., the physical, physiological and behavioural traits, e.g. height, weight, skin colour etc.

viii. **Genotype:** This term is used to describe those traits or sum total of the genes inherited from both parents. In other words, the genotype of an individual is his genetic make-up or constitution. Genotype includes both the dominant and the recessive traits that form the genetic make-up of an individual.

ix. **Dominant character:** This is a trait or character that is expressed in an offspring when two individuals with contrasting characters or traits are crossed. **Dominant genes** on the other hand are genes which control dominant characters. For instance, in a very tall plant, there may be the gene for shortness but the genes has no influence on the gene for tallness.

x. **Recessive character:** This is the character or trait from one parent which is masked or does not produce the effect in the presence of dominant character. From the illustration above, shortness is the recessive character while tallness is the dominant character. **Recessive gene** on the other hand are genes which control recessive characters.

xi. **Homozygous:** An individual is said to be homozygous if it has two similar genes for the same character, i.e. it has two identical alleles at the same position on a pair of chromosomes; the pair of genes controlling a given pair of contrasting characteristics are identical e.g. (TT) for tallness or (tt) for shortness.

xii. **Heterozygous:** An individual is said to be heterozygous if the two members of a pair of genes controlling a pair of contrasting characters are different, i.e. it has two different or contrasting alleles located on the same position on a pair of chromosomes, e.g. (Tt) for tallness or a plant with Rr genetic composition has a heterozygous red flower plant.

xiii. **Filial generation:** The offspring of parents make up the filial generation. The first, second and third generations of offspring are known as the first, second and third filial generation respectively, and are denoted by the symbols, F_1, F_2, F_3, respectively, too. F_1 generation gives rise to F_2 generation.

xiv. **Hybrid:** Hybrid is an offspring from a cross between parents that are genetically different but of the same species.

xv. **Hybridisation:** Hybridization is the crossing of plants with contrasting characters. **monohybridisation** involves the crossing of two pure traits while **Dihybridisation** involves the crossing of plants with two pairs of contrasting characters.

xvi. **Locus:** Locus is the site for location of a gene in a chromosome

xvii. **Haploid:** Haploid is when an organism has one set of chromosomes in the gamete. Gametes at certain stages in the life cycle of plants are haploid. It is represented by small letter (n).

xviii. **Diploid:** Diploid is when an organism has two sets of chromosomes in the body cell. The bodies of animals and plants are diploids. Diploid number is double the haploid number of chromosomes and is represented by (2n).

xix. **Mutation:** Mutation is a change in the genetic make-up of an organism resulting in a new characteristic that is inheritable.

* Genetic: Genetics is defined as the scientific study of heredity and variation in living things.
* Heredity: Heredity or inheritance is defined as the transmission and expression of characters or traits in an organism from parents to offspring

* Variation: Variation is defined as the differences which exist between parents and offspring as well as among the offspring.

Activity A

List ten common terms used in genetics and briefly explain five of them

3.1 Transmission and Expression of Characters in Organisms

The transmission of characters/factors from parents to offspring is known as heredity or inheritance. Different characters or traits are transmitted from parents to offspring or progeny and from generation to generation. Such as traits/characters are called transmitable characters.

Transmittable Characters in Human Beings

Transmittable characters in human beings include:

i. body stature or shape
ii Shape of head, nose and ear
iii. Size of nose, head and ear
iv. Colour of skin, hair and eye
v. Characteristic of voice or speech
vi. Intelligence
vii. Height of human
viii. Blood grouping
ix. Baldness
x. Tongue rolling
xi. Sickle cell anaemia
xii. Haemophilia
xiii. Colour blindness
xiv. Fingerprints
xv. Ability to taste (BTC)

Transmittable Characters in Plants

i. Height of plant
ii. size or weight of fruit
iii. size of leaf
iv. taste of fruit
v. food content of fruit
vi. colour of leaf, flower fruits or seeds
vii. resistance to environmental factors like diseases, pests of drought.
viii. shape of leaf, fruit and flower
ix. leaf texture
x. life span or habit of growth.

How Characters Get Transmitted and Behave from Generation to Generation

Only characters controlled by genes can be transmitted. In other words, inherited characters are determined by genes. A diploid organism has two sets of chromosomes referred to as **homologues**. Such an organism has two copies of each gene, with the copies occupying identical locations or **loci** on the homologous chromosomes.

Diploid organisms produce gametes by meiosis in their reproductive organs. A male individual produces sperms while a female produces egg cells or ova. During meiosis (fig. 3.1), the number of chromosomes in a cell is halved. The gametes are therefore **haploid**, containing one set of chromosomes, and hence only one copy of each gene.

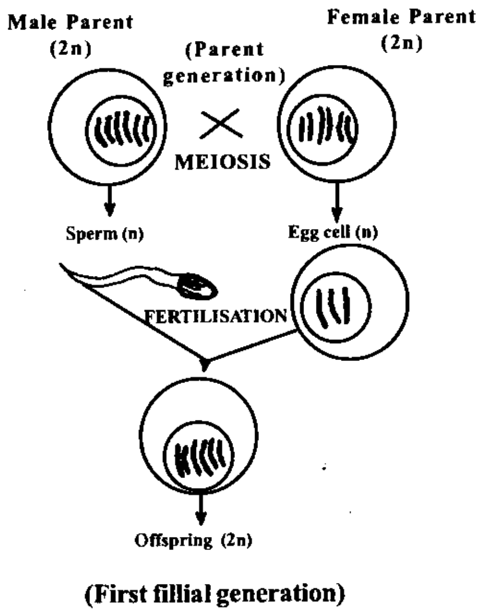

Fig. 3.1: How characters determined by genes are transmitted from parents to offspring through gametes

During sexual reproduction, the gametes of a male and a female individual or parent fuse to form **zygotes**. Each zygote is **diploid** as it gets one set of chromosomes, and hence one copy of each from the gamete of each parent. Characters determined by genes are thus transmitted from parents to offspring through gametes. The gene, an organism inherits during fertilization called **genotype** remains constant throughout life. The **phenotype** which is the physical appearance or features of an organism is determined by its genotype and the environment in which it lives. Hence, organisms with the same genotype may possess different phenotypes if they live in different environments.

Applications of Transmission of Factors/Characters

Transmission of factors can be applied in several ways

- **Sexual and Asexual Reproduction**
  * Sexual reproduction involves the fusion of male and female gametes. It results in the inheritance of factors from two parents. The offspring from sexual reproduction contain mainly variations.
  * Asexual reproduction results from inheritance from one parent. The offspring are exactly like the parents. The inherited characters/factors are desirable in certain cases but lead to weak offsprings which are a disadavantages.

- **Cross-fertilisation and Self-fertilisation**

  In cross-fertilization, new genes are recombined; offspring of cross-fertilisation are more virile. Self-fertilisation does not involve gene recombination and their offspring are not virile.

- **In-breeding and Out-breeding**

  In-breeding is reproduction with close relatives as parents while out-breeding is reproduction with unrelated members of the species as parents. In in-breeding, desirable characters such as speed and perseverance in racehorses and hunting and entertainment efficiency in dogs are perserved. In plants, inbreeding is used to maintain quality and quantities of fruit yields, but easily show signs of weakness. Out breeding introduces new recombination and hybrid vigour in offsprings.

- **Application of Genetic to Agriculture**

  Man selects and cultivates wild plants with desirable characters. Man also selects and domesticates wild animals that have desirable characters.

  * Through selective cross-breeding, new varieties of plants and domesticated animals have appeared.
  * New varieties of plants and animals appear naturally, man now selects and breeds by crossing varieties of plants and animals with certain desirable qualities by the process of plant breeding or animal breeding.
  * Improvement in quality of yield.
  * Development of disease-resistant varieties.

- **Application of Genetics to Medicine**

  * Diagnosis of disease
  * Counseling on inheritable diseases and genes e.g. haemophilia, sickle cell anaemia, the Rhesus factor and health of the unborn baby.

Activity B

List at least 10 transmittable, characters each in human being and in plants

3.2 Hereditary Variation

Hereditary variation refers to differences among individuals which can be passed from parents to their offspring (progeny). Hereditary variation arises because of the trasmission of varieties in character and in parents as in the case of identical twins, no two offspring inherit exactly the same set of characteristics from their parents. Each offspring inherits a different combination of characteristics from parents.

The differences between individuals of the same species are called **Variations.**

3.2.1 Types of Variation

There are different types of variation observed in populations.

1. **Morphological variation**

   is a result of group of differences, which relate to physical appearance e.g. Human beings vary in physical features such as;

   i. Height of the body
   ii. Sizes of various parts of the body including head, nose, jaw, eyes, ears, hands and chest.
   ii. Shapes of parts of the body such as head, forehead, mouth, nose, jaw
   iv. Colour of parts of the body such as skin, hair, and eyes
   v. Fingerprints.

2. **Physiological variation**

   Variation/differences that relate to the functioning of the body are called physiological variations. Examples include:

i. Rolling of the tongue
ii. Closing of one eye and leaving the other eye partly open
iii. Moving ears without moving the head
iv. Tasting the chemical substance called phenylthiocartamide (PTC)
v. These are four different blood groups in human beings, A, B, AB, and O. Each person has only one of these blood groups.

3. Genetic Variation

Sometimes in nature, certain changes suddenly occur in the chromosomes without necessarily destroying them. Such changes are known as mutation and may simply involve an alteration in position of certain genes or even entire chromosomes. When mutation occurs, it will lead to the production of offspring with marked differences in appearance from their members and such offspring are usually called variant or varieties.

4. Environmental variations

Perhaps the greatest factor producing variation is the effect of the environment on the individual. An individual may be potentially tall but remains short due to poor feeding. Such environmental factors as temperature, rainfall, sunlight can also bring about sharp variations among individual members of the same family. The appearance of an individual depend on the degree to which he has been affected by these environmental factors. Some of these factors are poverty, affluence, hardwork, laziness, thoughts, sorrows, food, restlessness, diseases and weather conditions among others.

Activity C

Briefly explain in your own words the following types of variation
i. Morphological variation
ii. Physiological variation

3.3 Application of Variation

3.3.1 Crime Detection

When a criminal is wanted, police detectives use the suspect's **morphological features** to mount a search. Such morphological features may include height, colour of skin, colour of hair, colour of eyes etc.

Fingerprints are also used in crime detection, e.g. when an object is found at the scene of the crime, fingerprints may be found on the object; these are compared with those of a suspect. Any individual whose fingerprint matches those found on the object at the scene of the crime may be arraigned in the court of law as an accused person. The use of fingerprints in crime detection is based on the fact that no two individuals have exactly the same fingerprints and that the fingerprints of an individual do not change throughout life.

3.3.2 Blood Transfusion

Blood groups are characterised by specific proteins in the red blood cells called antigens. Antigens are substances that can stimulate the production of antibodies. It is important that the blood of a donor matches the blood of a recipient; otherwise there could be serious consequences, including death.

Table 3.1 - Showing the Characterstics of Blood Groups

Blood group	Antigen in Red Blood Cells	Antibody in Blood plasma	Blood Recipient
A	A	Anti - B	A, O
B	B	Anti - A	B, O
AB Universal Recipient	A, B	None	A, B, AB, O
O Universal Donor	None	Anti - A & B	O

3.3.3 Determination of Paternity

Sometimes the paternity of a child becomes a source of dispute. One way of resolving the dispute is to determine the blood group of the child, the blood group of the disputing fathers and the blood group of the child's mother. From the result of the bood group test, it may be possible to determine the paternity of the child.

The following are blood groups of individuals involved in a paternity suite.

Child	Group **AB**
Mother	Group **A**
Contesting Father X	Group **B**
Contesting Father Y	Group **O**

By the law inheritance the father with blood group O and mother with blood group A can bear children with blood group A only. However, a father with blood group B and a mother with blood A can bear a child having blood group AB only. On this basis, father X whose blood is B, is the father of the child with blood group AB.

3.4 Variation Provides a Mark of Identity

Because variation is a common feature among living things, it provides a clear mark of identity between organisms of the same species. Among human beings, variation in finger prints is used to identify a person because of definite characters of the finger print. For example at Banks and during elections.

Activity D

In your own words, explain the importance of variation to man, share the knowledge with your study mate

4.0 Conclusion

In this unit, it can be concluded that genes determine the potentiality of an organism, but the environment influences the manner in which the genotype is expressed.

5.0 Summary

In this unit, we have learnt that;

1. Genetics is a science that deals with questions and answers on inheritance.
2. The transmission of characters from parents to offspring is known as heredity or inheritance.
3. The gene, an organism inherits during fertilisation is genotype which remain constant throughout life.

4. The physical appearance of an organism is called phenotype.
5. Transmission of characters/factor can apply in sexual and asexual reproduction, in-breeding and out-breeding, agriculture etc.
6. There are various types of variation morphological, physiological, Genetic and environmental variation.
7. Variations are useful in crime detection, blood transfusion determination of paternity and as a mark of identity.

6.0 Tutor-Marked Assignment

1. Define the following terms
    a. gene
    b. homozygous
    c. mutation
    d. recessive character
2. List three transmitable characters in
    a. human being
    b. plants

7.0 Further Reading and other Resources

Walter H. Muller (1974). *Botany A functional Approach*. Third Edition
Idodo - Umeh (1996) *College Biology*
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Volume 4: Evolution and Genetics

Unit 4: Mendel's Work in Genetics – Chromosomes as a Basis of Inheritance – Heredity and Environment – Probability in Genetics

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1.0 Introduction

Gregor Mendel (1822 - 1884) was an Augustinian Monk who had actually trained to be a biology teacher. He was interested in growing plants and seeing how inheritable characteristics were transmitted. His work include the studying of the inheritance of one character at a time. He ignored all the characters except the one in which he was interested. Mendel kept the record of how many times these characteristic appeared in the offspring of selected parents, and he was careful to maintain pollination under control so that all pollen came from one selected parent. Also he had allowed plants to self pollinate and observed that each produced offspring of its kind.

Although Mendel published his data in 1966, it's significance was only realised after 1900. By this time, improved microscopes and staining technique enabled scientists to observe the behaviour of chromosomes in gametes and zygotes. An American scientist Walter Sulton, saw striking similarities in the way Mendel factors were transmitted and chromosomes behaved during meiosis and fertilisation. In 1902, he proposed that chromosomes are the carriers of Mendel's factors (genes). This is called the chromosome theory of heredity. Later another American, Thomas Morgan (1866 - 1945), established clearly that Mendel's factors are indeed located on chromosomes. He used the fruitfly *Drosophia Melanogaster*, for his study. In this unit, we shall discuss some of Mendel's works, chromosomes as a basis of heredity and the probability of the characters appearing.

2.0 Objectives

By the end of this Unit, You should be able to;

i. List at least five reasons of Mendel's choice of pea plant for this experiment.
ii. Explain the methods used by Mendel in this experiment.
iii. State Mendelian laws of heredity.
iv. Explain with example what back cross is.
v. Describe the structure and functions of chromosome in genetical study.
vi. Define what probability is and its applications in genetical study.

3.0 Mendel's Work in Genetics

Gregor Mendel (1822 - 1884) was a monk in an Augustinian monastery in Brunn, Austria. He is often regarded as the father of genetics because his work formed the foundation of scientific study of heredity and variation.

Mendel's Experiments

Gregor Mendel carried out several experiments on how hereditary characters were transmitted from generation to generation. He worked with the garden pea ***(pisum sativum)***. His major aim was to find out the pattern of inheritance of different characteristics of the pea plant.

Reasons for Mendel's Choice of Pea Plant

Gregor Mendel decided to use the pea plant for his experiment because of the following reasons:

1. Peas are usually self-pollinating and he could pollinate them by himself
2. They have a very short life span because they are annual plants.
3. The pea plant was known to have several unique characteristics which exists in contrasting pairs such as:

i. some seeds were round while others were wrinkled.

ii. some plants were tall while others were short
iii. some seeds were yellow while others were green
iv. some flowers were axil while others were terminal
v. some pods were green while some were yellow
vi. some flowers were white while some were red.
vii. some pods were smooth while some were constricted.

Methods used by Mendel in His Experiment

Gregor Mendel used two major methods in conducting his experiments. These methods were grouped into monohybrid inheritance and dihybrid inheritance.

3.1 Monohybrid Inheritance

Mendel used artificial method to cross two different plants, at a time, which differed in one pair of contrasting characters e.g. tall and short plants. This procedure was called a monohybrid inheritance and it was an example of complete dominance.

He carried out the experiment in the following order;

i. He planted tall plants for several generations and discovered that the plants produced were all tall plants. In the same way, he planted short plants for several generations and discovered that the plants produced were all short.

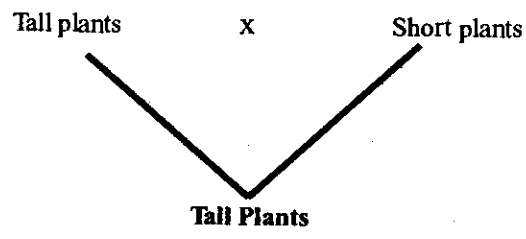
ii. He proceeded to plant tall plants and short plants. By the time the flowers were produced, he collected the pollen grains of the tall plants tagged the **male** and pollinated the stigma of the short plant tagged **the female**. He also collected the pollen grains of the short plant and place them on the stigma of the tall plant.

   Mendel then covered the artificial pollinated flowers with small paper bags to prevent the chance of natural pollination by insects.

iii. Mendel once again picked the seeds formed after the cross. When he planted the seeds, the plants obtained were all tall plants. These he referred to as the **first filial generation** or F_1 (fig. 4.1).

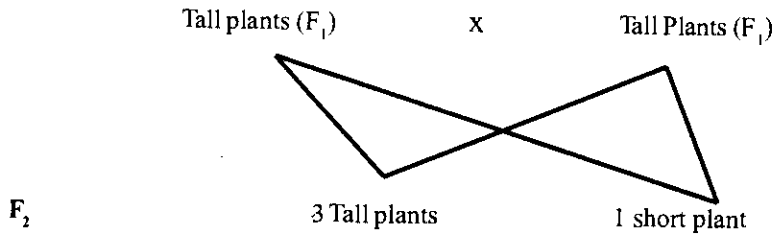
iv. Mendel then crossed the F_1 plants, collected their seeds and sowed them. The plants he got from these were tall and short plants in a ratio of 3:1 respectively. He then called these these stage the **second filial generation** or F_2

(i) Parents

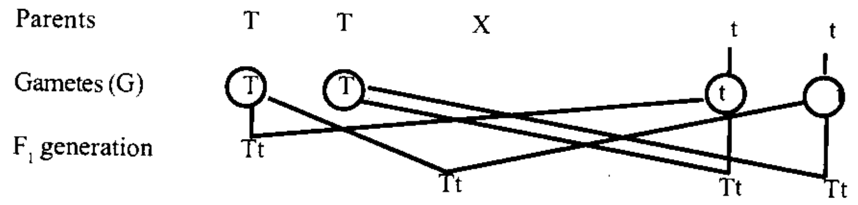


F_1

(ii) **Parents**

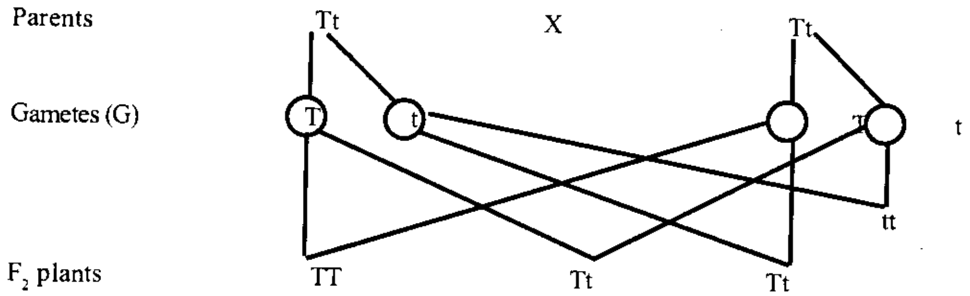


The outcome of this experiment led to Mendel's first law of inheritance.



* The genotype of all the F_1 plants is Tt.
* The phenotype is all tall plants, but they are heterozygous, i.e. they are not pure-breeding.

To obtain the second filial generation (F_2), the F_1 plants are self-pollinated. This can be illustrated as follows:



The genotype of the F_2 plants are

1 TT
2 Tt
1 tt

* The genotypic ratio is 1 : 2 : 1
* Their phenotypes are

3 tall plants
1 Dwarf plant

* Their phenotypic ratio is 3 : 1

Mendel's First Law of Inheritance

This first law is also called the **law of segregation of genes.** The law states that genes are responsible for the development of the individual and that they are independently transmitted from one generation to another without undergoing any alteration.

Explanation

As seen above and in fig. 4.1 all the offspring in the F_1 generation are tall. It shows that the genes for tallness (TT) is dominant over the recessive genes(tt).
In the F_2 generation, three of the offspring are tall while only one is short (tt).

From Mendel's first law of segregation of genes, the actual segregation occurs in F_2 generation. The phenotypic and genotypic ratios F_2 generation can be summarised as follows;

(i) Phenotypic ratio = 3:1 (i.e. 3 tall and 1 short)

(ii) Genotypic ratio = 1:2:1 (i.e. 1 TT, 2 Tt, 1 tt)

Note: Letters are used to represent the genotypes of the traits. In the case of complete dominance, the capital letter form of the first letter of the dominant trait is used to denote the dominant gene. The small letter form of it is used to represent the recessive gene.
Since tallness in the plant is dominant over shortness.

i. T represents gene for tallness

ii. TT represents genotype of the pure breeding tall plants. Such a plant is described as **homozygous** for tallness

iii. t represents gene for shortness

iv. tt represents genotype of the pure breeding short plant, **homozygous** for shortness.

v. A cross between two organisms is shown by a multiplication sign (x)

vi. Each gamete is represented by only one encircled letter, i.e. (T), or (t) depending on the trait being discussed. This is compliance with Mendel's law of segregation of germinal unit

vii. **A heterozygous** individual is represented by one dominant gene and one recessive gene, i.e. Tt. Such individuals are called **carriers of a trait.**

3.2 Dihybrid Inheritance

Gregor Mendel also carried out several experiments in which he crossed plants which differed in two pairs of contrasting characteristics such as seed shape (round and wrinkled seeds) and seed colour (yellow and green seeds).
Mendel therefore called the whole set up as dihybrid inheritance because two pairs of contrasting characters are involved.
When Mendel crossed plants which had round and yellow seeds with those which had wrinkled and green seeds, all the F_1 plants produced round and yellow seeds. However, when the F_1 plants were self pollinated, the F_2 plants were of four types;

i. plants that produced round and yellow seeds,

ii. wrinkled and yellow seeds

iii. round and green seeds,

iv. wrinkled and green seeds.

All these were in the ratio of approximately 9:3:3:1
Mendel then concluded that this could result if the contrasting characteristics of round and wrinkled seeds and the contrasting characteristics of yellow and green seeds were inherited independent of each other.
The outcome of this experiment led to Mendel's second law of inheritance.

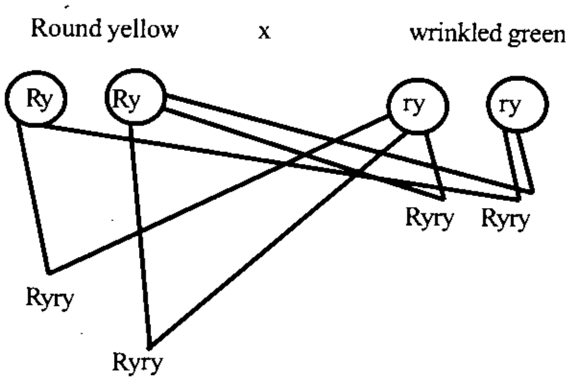
Mendel's Second Law of Inheritance

This second law is also called the **law of independent assortment of genes.** Mendel's second law of independent assortment of genes states that each character behaves as a separate unit and is inherited independently of any other character.

Mendel's work can be represented by letters and their explanations as below;

Parents

P. gen.



	RY	Ry	ry	ry
RY	(1) RYRY	(2) RYRy	(3) RYry	(4) RYry
Ry	(5) RyRY	(6) RyRy	(7) RyrY	(8) Ryry
ry	(9) ryRY	(10) rYRy	(11) rYrY	(12) rYry
ry	(13) ryRY	(14) ryRy	(15) ryrY	(16) ryry

Table 4.1 - Punnett table

The four phenotypes which appear in the ratio 9:3:3:1 are as follows;

1. 9 round yellow = 1, 2, 3, 4, 5, 7, 9, 10, 13
2. 3 round green = 6, 8, 14
3. 3 wrinkled yellow = 11, 12, 15
4. 1 wrinkled green = 16

The 9 genotypes which include the homozygous and 5 heterozygous conditions are;

1. 1 is homozygous for both round and yellow (1)
2. 1 is homozygous for both round and green (6)
3. 1 is homozygous for both wrinkled and green (16)

4. 1 is homozygous for both wrinkled and yellow (11)
5. 2 are homozygous for round and heterozygous for yellow (2, 5)
6. 2 are heterzygous for round and homozygous for yellow (3, 9)
7. 2 are heterozygous for round and homozygous for green (8, 14)
8. 2 are homozygous for wrinkled and heterozgyous for yellow (12, 15).

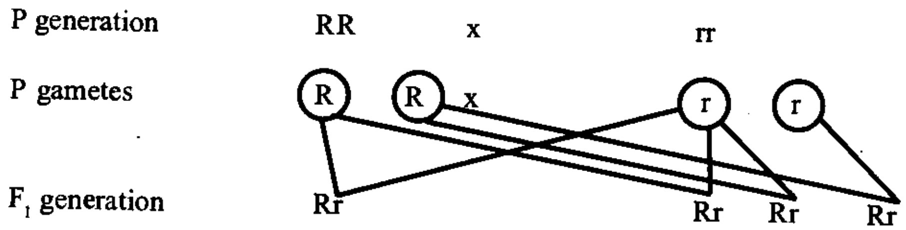
Activity A

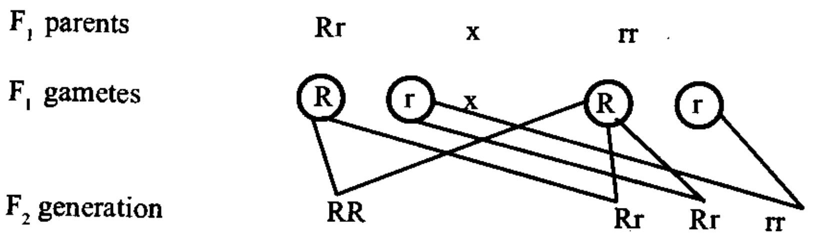
1. List at least five reasons why Mendel choose pea plant for his experiments
2. Write short notes on the following Mendel methods of experiment.
   a. monohybird inheritance
   b. dihybrid inheritance
3. Briefly explain in your own words, Mendel first and second laws of inheritance.

3.3 Back Cross and Test Cross

Meaning of test cross: Test cros is the crossing of an organism with the homozygous recessive organism.
Meaning of Back cross: Back cross is the crossing of an organism with the homozygous recessive organism from the original parental generation.

Test cross and back cross are used to determine the genotype of organisms showing dominant phenotype. To find out the genotype of a particular organism in the **F**$_2$ generation, this is done by mating the hybrid of pure homozygous **F** with parent homozygous recessive. For instance, in a situation in which the phenotype is the same in **F**$_2$ generation but the genotype are not known. For examples





Phenotypic ratio = 3 : 1, i.e. 3 red, 1 white

During the crossing, random gamete combinations can result only in the following three types of zygotes for flower colour;

i) Homozygous for red flower colour (RR)
ii) Heterozygous for red flower colour (Rr)
iii) Homozygous for white flower colour (rr)

Red flower pea plant may be homozygous (RR), pure stalk that breed true, heterozygous (Rr) hybrid that do not breed true. To find out their genotype, we have to do a recessive test cross. We back cross the red flower plant (genotype RR, Rr) with its recessive white flower parent plant (genotype rr). This will give offspring that are all;

(i) red flowered, if the red flowered parent plant is homozygous parents (RR)

(ii) half red flowered offspring with half white flowered, if the red flowered parent plant is heterozygous (Rr).

P parent RR x rr (back crossing process)

P gametes R R x r r

Offspring F_1 Rr Rr Rr Rr (All red)

P parent R r x r r (back crossing process)

P gametes R r x r r

Offspring F_1 Rr Rr rr rr (Half red, half white)

3.4 The Principles of Incomplete Dominance

Meaning: Incomplete dominance is the ability of two contrasting alleles to interact and produce a heterozgyous phenotype that is different from the two homozygous phenotypes.
Examples of organisms which exhibit incomplete dominance are the *Mirabilis Jalapa*, Four 'O' clock plant, Andlausian fowl etc.

Example: A pure breeding red flower *Mirabilis Jalapa* plant when crossed with a pure breeding white flowered plant produced F_1 plants that bear pink flowers.

The diagram in figure 4.2 illustrates incomplete dominance. A cross is made up of F_2 generation. The outcome of the F_1 and F_2 plants does not agree with Mendel's principles.

Let R represent the red flower expressing gene; r represent the white flower expressing gene.

Parent R R x r r (white)
Red Gametes

R R x r r

F_1 Rr Rr Rr Rr (all pink flower)

Parent (Pink) R r x R r (Pink)

R r x R r

F_2 RR Rr Rr rr
1 red 2 pink 1 white

Phenotypic ratio = 1:2:1
Genotypic ratio = 1:2:1

Reasons

According to the principles of Mendel, genes are either dominant or recessive; the dominant expressing itself in homozygous or heterozygous state, i.e., the F_1 flowers should have been all red while the F_2 plants should have been three (3) red and one (1) white. But in the case of incomplete dominance, the F_1 flowers are pink and the F_2 plants are one (1) red, two (2) pink and one (1) white.

Activity 2

With a well labelled diagrams, briefly explain what back cross is.

3.5 Determination of Sex in Human Beings

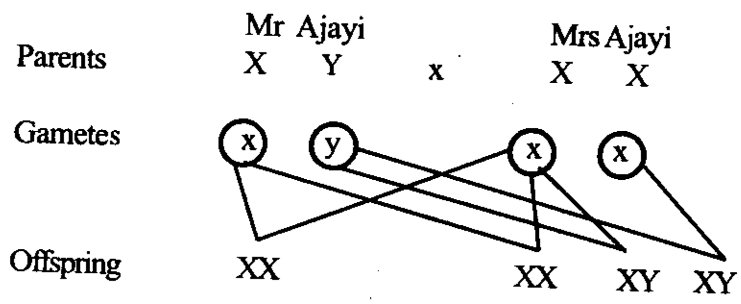
In human beings, there are 23 pairs (46) chromosomes in each body cell. Of these, 22 pairs are called **autosomes** and have no direct effect on the sex of the individual. One pair is directly concerned with sex determination. This one pair (two chromosomes) is referred to as **sex chromosomes.**

In the male, the two sex chromosomes in each body cell are called **X** and **Y** chromosomes. Each male gamete carries either an **X** or a **Y** chromosomes. In the female, all the cells of the body contains two **X** chromosomes. All eggs contain one **X** chromosome each.

At fertilisation, the combination of an egg with a sperm carrying either an **X** or a **Y** chromosome occurs by chance. The chances of an egg combining with either of the two types of sperm are equal. If a sperm with an **X** chromosomes combines with an egg (having **X** chromosome), the zygote has two **X** chromosomes and form a female baby. But if a sperm with a **Y** chromosome combines with an egg (having **X** chromosome), the zygote has **X** and Y chromosomes and form a male baby.

This can be illustrated as shown in fig. 4.3.

With the use of cross diagram, the possible genotypes and phenotypes of four children that might be born by Mr and Mrs Ajayi.



Genotype	Phenotype
(i) 2XX (ii) 2XY	Girls Boys

3.6 Chromosomes: The Basis of Heredity

Chromosomes are rod or thread-like hodies found in the nucleus of a cell.

Function: The chromosomes houses or contains the genes which are responsble for the transmission of characters from parents to offspring.

Appearance: Chromosomes can be seen with a microscope only during cell division (mitosis or meiosis). They appear at the beginning of cell division as long slender threads (fig. 4.4). As cell division progresses, they shorten (condense) and thicken. After some time, each chromosome is observed to be made up of two threads called **chromatids,** held together at the **centromere.**

The bands represent the location of numerous genes

Fig 4.4 Structure of a chromosome

3.6.1 Number of Chromosomes

All organisms of the same species have the same number of chromosomes in each body cell. The number of chromosomes in a body cell known as the **diploid number** is double the number of chromosomes in a gamete known as the **haploid number**. The diploid number is represented by 2n while the haploid number is represented by n. Some examples of chromosome number in body cells are; dog 52 (26 pairs), cat 38 (19 pairs), domestic fowl 18 (9 pairs), garden pea 14 (7 pairs), fruit fly (drosophila 8 (4 pairs), housefly 12 (6 pairs), man 46 (23 pairs).

In human beings, there are naturally 46 chromosomes which occurs as 23 pairs (23 x 2 = 46). Each chromosomes of a pair occupies the same position as and is similar in shape and size to the other. Each pair is therefore called **homologous chromosomes** and only separate during meiosis. Chromosomes are numbered in multiples of 23 while is represented as n; i.e. 23 = n. Therefore, the 46 chromosomes are represented as 2n, i.e. 2 x n = 2 x 23 = 46. Since 46 chromosomes is twice n, it is called the diploid number of chromosomes while n (23) is called the haploid number.

3.6.2 Structure of Deoxyribonucleic Acid (DNA)

The DNA is found in chromosomes located in the nucleus of cells. It stores the organism's hereditary traits and directs the day to day metabolic activities of each cell in the organism. The chromosome is made up of deoxyribonucleic acid (DNA) and protein. The DNA molecule consists of two helical chains coiled around each other to form a double helix. The deoxyribose nucleic acid is a very large molecule made up of repeating units called **nucleotides.**

Each nucleotide is made up of

i) deoxyribose, a sugar molecule

ii) phosphate

iii) an organic nitrogen compound which may be **adenine, guanine, thymine or cystosine.**

The repeating units or chains are arranged in the form of a double helix and are held together by hydrogen bonds. The sides of the helix are formed by sugar and phosphate. The step in the ladder are formed by the organic nitrogen compounds in a definite way. That is, the two chains are held together by hydrogen bonds between the nitrogenous bases (fig. 4.6). Guanine always pairs with cytosine and adenine with thymine.

The two chains are also referred to as complementary strands of DNA since one is the exact opposite of the other. Guanine is the opposite of cytosine and adenine is the opposite of thymine. Thus, if guanine is present on a complementary DNA strand, it is cytosine that will occupy the same position on other strand and bind with it. Similarly adenine will bind with thymine.

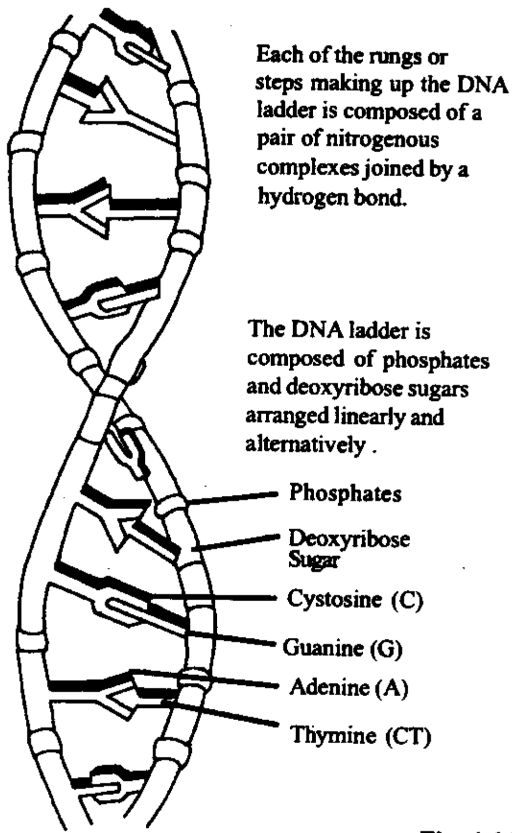


Fig. 4.6 Structure of a DNA molecule

Replication of DNA

DNA can replicate itself during cell division and is the only material that is passed on from parents to offspring. A DNA strand is held together by weak hydrogen bonds between the complementary base pairs. These bonds can break easily, causing the DNA to separate or 'unzip' into two half - strands. Free nucleotides present in the nuclear material then arrange themselves along each half-strand. Hydrogen bond form between the complementary bases, resulting in two identical DNA strands (fig. 4.7).

3.6.3 Role of Chromosome in the Transmission of Hereditary Characters

(1) A gene is located in chromosome which is responsible for the expression of a character hence genes are responsible for the transmission of hereditary characteristics from parents to offspring.

(2) Chromosomes in a body cell are arranged in pairs. In each pair, the chromosomes are exactly alike in size and shape and they carry the genes responsible for the transmission of the same characteristic arranged in the same order along their length.

(3) The genes relating to the same character such as tallness in pea plant (T) and shortness (t) occupy identical locations or loci on the chromosomes. The pairs of chromosomes that are alike are called homologous chromosomes.

(4) The genes on a homologous chromosome whether individual will be homozygous or heterozygous for certain characters, e.g. chromosomes relating to the same character are the same i.e. T and T for tallness, the individuals are said to be homozygous for that character but if they are different, i.e., T for tallness and t for shortness, the genes are said to be allelic or alleles and the individual is said to be heterozygous for that character.

3.6.4 Processes of Transmission of Hereditary Characteristics by Chromosomes

(i) The chromosomes carry the genes, that pass into the gamete during meiosis.

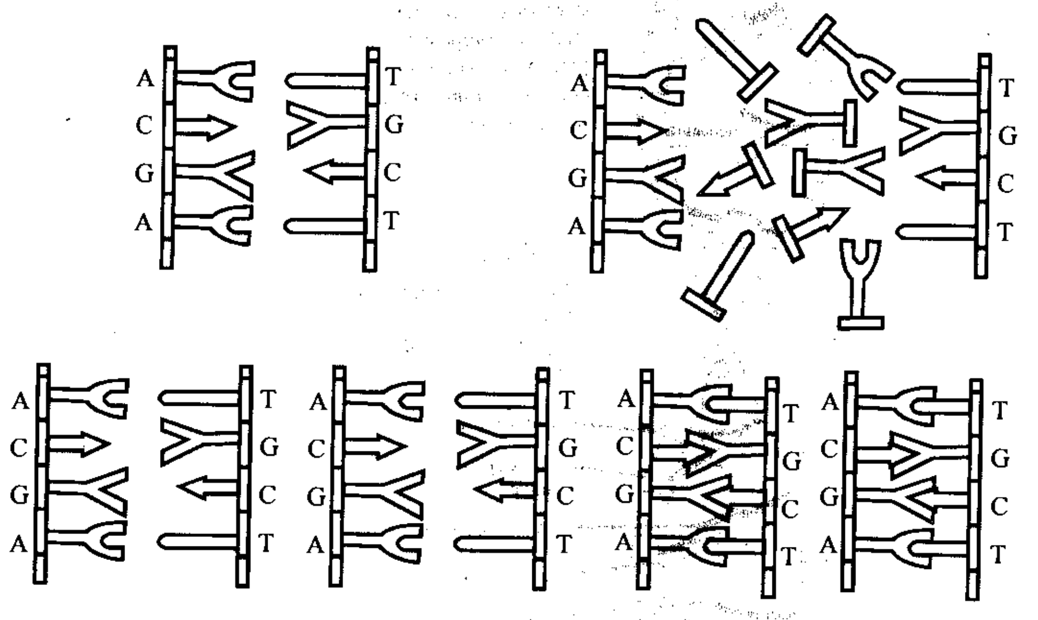


Fig. 4.7 Replication of DNA

(ii) During the first stage of meiosis, the homologous chromosomes separate into two daughter cells.

(iii) In the second stage of meiosis, the two chromatids in each chromosomes separate. This process brings about **the segregation of genes**. Each gamete therefore can only contain one gene for one of a pair of contrasting characteristics.

(iv) During fertilisation, the gametes fuse together. The zygote receives two genes for the same character - one from a chromosome in the egg from the female parent and the other from one chromosome in the sperm from the male parent.

(v) When the two genes are the same, the offspring is homozygous but when they are different, the offspring is a hybrid (heterozygous) with respect to that character.

(vi) A gene in a chromosome dictates the formation of a protein, usually an enzyme which affects the formation of cell products that bring about the expression of a character e.g. skin colour etc.

Activity C

i. Briefly describe the structure of a DNA molecule to your study mate
ii. Explain the roles of chromosome in the transmission of hereditary characters.

3.6.5 Heredity and Environment

The phenotypic response of gene action is a result of the coordinated effect of the entire set of gene a single gene may affect many characteristics, each expressed characteristic may be influenced by many genes. Each gene probably governs one basic reaction, but the characteristics are expressed as the phenotype result from many such reaction. Therefore to state that every characteristic of an organism is governed by one gene is incorrect. In some cases we are fortunate enough to find that one gene has an obvious effect on the mature organism and thus is studied readily. This is not, however, the situation that always exists.

The genes of an organism determine its potentialities, but the realisation of these potentialities depends on the environment in which the genes perform their function. The genotype may express itself differently in different environments giving rise to modifications of the phenotype. The genetic material provides the messages and directions for phenotypic growth, but development also depends upon various environmental factors (e.g. light, temperature, moisture and mineral supply). For example, with most plants, if the seed are germinated in the dark, chlorophyll will not be developed in the seedling. If these seedlings are exposed to light before they die, chlorophyll develops rapidly. The genes for chlorophyll production are present, but light is also essential for such manifesting. Also, if magnesium is lacking in the soil, chlorophyll formation will not occur because the chlorophyll molecule has, as one of its component parts, an atom of magnesium the potentiality for chlorophyll formation is present in the genes, but an essential atom is missing and the molecule cannot be synthesised.

The time of flowering in many plants is influenced by the duration of light, and in others by temperature. Water supply is another factor that significantly influences plant growth, severe stunting being an easily recognisable effect of water deficiency. It is important to understand that it is the genotype that is inherited and that the environment influences the way in which this genotype is expressed (as the phenotype).

Activity

Briefly explain the effect of an environment on the potentiality of an organism.

3.6.6 Probability in Genetics

Probability is a branch of mathematics which can be applied to those events that depend entirely on chance. Mathematically,

$$\text{Probability} = \frac{\text{No of times an event occurs}}{\text{Total number of trials}}$$

For example, a common event which depends on chance is the tossing of an unbiased coin. If a coin is tossed upwards, there are two ways the coin can fall. The coin may fall with the head up or with the tail up. The probability that the coin will fall with the head up is one out of 2, i.e. 50% or $^1/_2$ and the probability that the coin will fail with the tail up is one out of 2 i.e., 50% or $^1/_2$.

Probability is ususally expressed in units ranging from 0 - 1. Mendel's works are based on probability. Two principles are necessary to understand the importance of probability in genetics. These are;

(i) The result of one trial of a chanced event does not affect the result of latter trials of the same event.

(ii) The chance that two independent events will occur together simultaneously is the product of their chances of occuring separately.

Application of Probability to the Formation of Gametes

Suppose a plant has the genotype AA, what kind of gamete will it produce and in what proportion? Since only one of pair of chromosomes got segregated during meiosis, the probable gamete produced from the AA parent plant is $^1/_2$ A and $^1/_2$ A. If the parent plant is heterozygous (A) (a), the probable gamete will be $^1/_2$ A x $^1/_2$ a.

Application of Probability to the Formation of Offspring in Plants

(i) If a plant has genotype Aa, the probability of forming a gamete containing gene A is $^1/_2$ or 50% and that of forming a gamete containing gene a is also $^1/_2$ or 50%.

(ii) If a plant has genotype aa, the probability of forming a gamete containing gene a is 1

(iii) If a plant of genotype Aa is crossed with another plant of genotype aa, the probability of producing different genotypes in offspring are probability of Aa = probability of A x probability of a. = $^1/_2$ x 1 = $^1/_2$

Probability of aa = probability a x probabliltiy of a.

Application of Probability to the Formation of Offspring in Humans

Suppose a male carrier of albino gene marry a female albino, what kind of albino will be expected? The male is heterozygous (Aa) and the female is homozygous recessive (aa). Since the male is heterzygous, the probability that $^1/_2$ of the gamete will receive (A) or (a) gene is $^1/_2$ while that of the female is $^1/_1$.

Probable gene from male parent.

$^1/_2$A $^1/_2$a

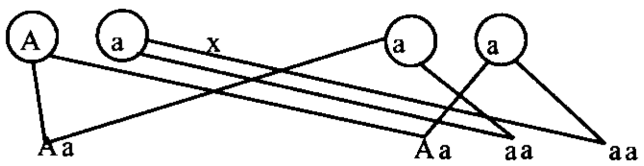
Probable gene from female parent = $^1/_1$a

	$^1/_2$A	$^1/_2$a	
$^1/_1$a	$^1/_2$Aa	$^1/_2$aa	half

As a check, cross the gamete as in the Mendelism F_1 generation

	male		female
P. generation	Aa	x	aa

P. gametes



$^1/_2$ (half) are carriers

The probability are that 1/2 of the offspring will be heterozygous and $^1/_2$ will be homozygous recessive.

Suppose both parents are carriers, probable gamete from one gamete.

$^1/_2$A $^1/_2$a

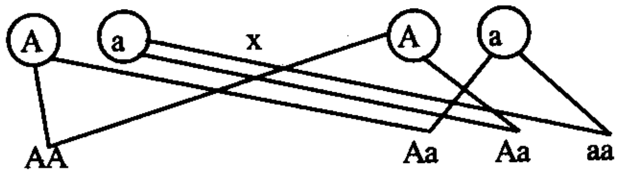
Probable gamete from the other gamete

	$^1/_2$A	$^1/_2$a
$^1/_2$A	$^1/_4$AA	$^1/_4$Aa
$^1/_2$a	$^1/_4$Aa	$^1/_4$aa

This can be crossed checked in a normal Mendelian process.

P. generation Aa x Aa

P. gametes



The probable offspring are AA, Aa, Aa and aa.

AA is equal to $^1/_4$ homozygous dominant (normal) ? probability of genotype ratio

Aa is equal to $^1/_2$ heterozygous (carriers)

aa ? $^1/_4$ homozygous recessive

Example: In Mr. Ajayi's farm, one pineapple fruit in every four is ripe, and two in every 5 are sweet. What is the chance that the pineapple fruit plucked will be ripe and sweet?

Solution:

$^1/_4 \times ^2/_5 = ^2/_{20} = ^1/_{10}$

The solution is obtained by finding the product of their independent chances using the 2nd principle of probability.

[illegible]

1a. Define probability

b. Briefly explain the application of probability to the formation of offspring in plants.

4.0 Conclusion

Gregor Mendel (1882 - 1884) carried out the first quantitative studies on inheritance. He published the results of his work in 1867. The work of Mendel therefore has become the foundation and nucleus of the modem genetics.

5.0 Summary

In this unit, we have learnt that;

i. Gregor Mendel (1882 - 1884) carried the first quantitative studies on inheritance

ii. Mendel worked with garden pea because of some interesting characteristics the plant possesses.

iii. Mendel used two major methods in conducting his experiments. These methods are grouped into monohybrid and dihybrid.

iv. Mendel's first law of inheritance which is also called the law of segregation of genes states that genes are responsible for the development of the individual and that they are independently transmitted from one generation to another without undergoing any altemation.

v. Mendel's second law of inheritance which is also called the law of independent assortment of genes states that each characteristics behaves as separate unit and is inherited independently of any other character.

vi. Back cross is the crossing of an organism with the homozygous recessive organisms from the original parental generation.

vii. Chromosomes are the basis of heredity and that they help in transmitting characters from parents to offspring.

viii. Gene determine the potentiality of an organism, but the environment influences the manner in which the genotype is expressed.

ix. Probability is the number of times an event occur divided by the total number of trials.

x. Probability can be applied to the formation of gametes, offspring in plants and to the formation of offspring in Human.

6.0 Tutor - Marked Assignment

i. Briefly explain how probability can be applied to the formation of offspring in plants.

ii. Explain the processes of transmission of hereditary characteristics by chromosomes.

7.0 Further Reading and other Resources

Sarojini T. Ramalingam (1996) *Modern Biology*

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Volume 4: Evolution and Genetics

Unit 5: Application of Genetics

1.0 Introduction

The practical application of knowledge of genetics have helped in no small measure to solve if not completely at least in part, some human problems. The knowledge of genetics has lead to the economic and scientific development of many countries of the world. In this unit, we shall discuss the importance of genetics to the field of agriculture, medicine and technology.

2.0 Objectives

By the end of this unit, you should be able to;

i. explain the importance of genetics in asexual and sexual reproduction

ii. explain the application of genetics in Agriculture

iii. explain the application of genetics in medicine and in technology.

3.0 Application of the Principles of Heredity

Genetics is useful in many field of human endeavour. The principles of heredity are used extensively in three important fields.

i. agriculture

ii. medicine and

iii. technology

3.1 Agriculture

Since ancient times, humans have been cultivating plants and domesticating animals to provide their needs. Their techniques made use of cross and self fertilisation and sexual and asexual reproduction.

3.1.1 Cross and Self Fertilisation

i. Meaning of Cross Fertilisation: This is the fertilisation of a plant as a result of the fusion of the gametes from another plant but of the same species. In these processes, new gene combination occur, so they introduce genetic variation into population. These variation can give rise to improved varieties of a species.

Advantages of Cross Fertilisation

(i) It leads to the production of healthier offspring

(ii) It produces viable seeds.

(iii) Offspring or individuals produced are more adapted to their environmental conditions

(iv) It leads to the formation of new varieties with good characteristics

ii. Self Fertilisation: This is the fertilisation of a plant as a result of the fusion of the gametes of flowers from the same plant. These processes produce populations of offspring that are genetically similar to the parent. They are thus useful for propagating individuals that show desirable traits so that such traits can be passed on unchanged to their progeny.

Advantages of Self Fertilisation

(i) It leads to the production of pure breeds line

(ii) Breeds with required characteristics are produced

(iii) It helps to concentrate and preserve specific qualities in animals

Disadvantages of Self Fertilisation

(i) It leads to the production of weak offspring.

(ii) It leads to inbreeding depression.

(iii) Individuals produced are less adapted to local environment.

3.1.2 Sexual Reproduction

This is the type of reproduction which involves the fusion of the male gamete e.g. sperm cell, and the female gametes, e.g. ova or egg cell to form a zygote which later develops to a young offspring.

Advantages

(i) It permits variability of individuals.

(ii) It enhances survival in new or changing environment.

(iii) It allows for production of hybrids of desirable traits.

(iv) It provides means for the maintenance of chromosome number from generation to generation.

(v) It enhances speculation or formation of new species.

Disadvantages

(i) It may lead to inbreeding depression.

(ii) It may lead to production of low quality offspring.

(iii) It might take time and energy to detect heat period.

(iv) It may transmit some diseases, e.g. HIV and other veneral diseases.

(v) It is a less rapid means of producing offspring.

3.1.3 Asexual Reproduction

This is the type of reproduction in which new organisms are produced from a single parent without the production of gametes.

Advantages

(i) It produces offspring which are identical.

(ii) It is a rapid means of producing offspring.

(iii) Offspring produced are easily adapted to environment.

(iv) It leads to the production of pure breeds.

Disadvantages

(i) It produces the same kind of individuals or species.

(ii) Hybrid of undesirable traits are produced.

(iii) It can easily spread diseases and pests.

(iv) Individuals produced are not a viable.

3.1.4 Inbreeding and Outbreeding

(a) Inbreeding involves the mating of more closely related animals than the average of the population from which they come, e.g. mating of father to daughter, son to mother or brother to sister.

- Inbreeding is done to maintain and build up certain desirable traits within a given population or stock. For example to build a stock of tomato plants with large size, the seeds of a large tomato fruit are sown. From the F_1 generation, only the seeds of large fruits are sown. This process of sowing the seeds of large tomato fruits is repeated until a true-breeding stock of tomato plants with large fruit size is obtained.

Advantages of Inbreeding

(i) It enables a desired character or quality to be developed in an animal

(ii) It helps to produce pure breed lines which can be used for cross breeding to produce hybrid vigour.

(iii) It helps to concentrate and preserve specific qualities in an animal.

Disadvantages of Inbreeding

(i) It leads to inbreeding depression (weak offspring)

(ii) It produces offspring with undersirable characteristics because of recessive genes showing up.

(iii) If inbreeding is carried out for too many generation, the population losses its reproductive vigour.

(iv) It then becomes susceptible to diseases and cannot withstand any environmental changes.

(v) The population tend to become homozygous. This provides opportunity for harmful traits to appear, since such traits are generally expressed by homozygous recessives.

b. **Outbreeding:** involves crossing individuals of genetically distinct populations

- It is the mating of unrelated individual animal or plant within the same breed or species.
- It is used extensively in plants breeding
- Often two individuals of a species, each having its own advantages trait, are crossed in order to combine the two traits in one individual.
- For example, a variety of maize that produces large cobs can be combined with another variety that is resistant to fungal disease to yield a hybrid with both large cob and resistance to fungal disease.
- Outbreeding is the opposite of inbreeding.

Advantages of Outbreeding

(i) It produces offspring that are superior to the average of either parents. This is called heresies or hybrid vigour.

(ii) Offspring grows more rapidly.

(iii) Offspring produced can withstand variation within the environment.

(iv) Outbreeding usually produces bigger and healthier individual that are more resistant to diseases giving them a better chance of survival. This is known as hybrid vigour.

Disadavantages of Outbreeding

(i) Breeds may not be easily available.

(ii) Experts may not be easily available.

(iii) Time and other resources might be wasted during the process

Activity A

Briefly explain how the knowledge of genetics can be applied in sexual and asexual reproduction

3.1.5 Other Applications of Genetics in Agriculture

1. **To increase yield:** The varieties of crops and breeds of animals so developed by breeders are capable of giving high yield in crops and in animal products e.g. meat, egg or milk. These high yield will help to solve the problem of food shortage. The wheat breeding programme in India initiated by U.S.A. has helped India to solve its wheat shortage problem within a short time of commencement.
2. **To improve quality of product:** The qualities of farm products enhance its usefulness and value. Breeders can improve value of crops and animal products. For examples, in the oil palm improvement programme at N.I.F.O.R, Benin City, Nigeria, the cross between the *Dura* palm and *Pisifora* palm gives the *Tenera* palm. The hybrid (*Tenera palm*) has the following advantages over the *dura* and *pisifera* palm.
   i. It (*Tenera*) has more oil than the *Dura.*
   ii. It can germinate quicker than the *Dura* with very thick shell and the *pisifera* which may have a very small or no nut at all.
   iii. It is also dwarf and has a greater production period.
3. **Development of early maturing varieties:** The knowledge of genetics has also led to the development of crop varieties and animal breeds which mature early e.g. maize and fowl can be eaten when they are six weeks old. The early maturing varieties can be harvested before the coming of unfavourable climatic conditions.
4. **Development of disease resistant varieties:** The knowledge of the principles of genetics has also helped in developing crop varieties and animal breeds which are resistant to certain diseases and pests whithin the locality.
5. **To obtain uniformity of plants:** One of the aims of plant breeders is breed crops which can grow and mature uniformly to facilitate mechanisation or ease of harvesting. Uniformly ripening varieties cut down wastage and labour.
6. **In animal breeding:** The knowledge of genetics has long been used to solve human food problem in animal production. Here, animal breeders making use of the knowledge of genetic, breed for higher meat quality, rapid growth, greater milk yield, increased egg production in poultry and endurance in beasts of burden.
7. **To produce crops and animals** that can adapt to adverse conditions.

Activity B

Briefly explain in your own words how the knowledge of genetics can be used to develop agriculture in Nigeria.

3.2 Application of Genetics in Medicine

Genetics has contributed immensely in various fields of medicine. They include:

1. **Determination of the paternity of a child:** Genetics is used in the determination of the paternity of a child whose fatherhood is being legally disputed. The individuals involved in law suit over parentage are required by the law to undergo the DNA test.
2. **Blood Transfusion:** Genetics is useful in determininig compatible blood groups - A, B, AB, and O prior to blood transfusion to prevent agglutination and death of the recipient. See table 4.1.

		Recipients			
		A	B	AB	O
Donor	A	✓	X	✓	X
	B	X	✓	✓	X
	AC	X	X	✓	X
	O	✓	✓	✓	✓

Table 4:1 ***Table of Blood Transfusion***

= Correct transfusion

x = Incorrect transfusion

3. **Marriage counselling:** Couples yet to go into marriage are advised on certain hereditary diseases such as hemophilia and sickle cell anaemia so that carriers do not go into marriage. The application of knowledge of heredity in marriage counselling is of great importance in reducing the incidence of hereditary diseases. When blood test prior to marriage reveal that a couple are both carriers of the sickle cell trait (AS), such a marriage is discouraged as any cross between the man and the woman may lead to the production of sicklers.

   When a man is Rh-positive and his wife is Rh-negative such marriage is discouraged to avoid incidents of **Still-births**. If such a marriage is allowed, the maternal blood continues to build up antibodies against the foetal blood. The level of antibodies in the maternal blood will continue to rise with subsequent pregnancies - leading to a rejection of the foetus by the maternal blood, a condition known as **erythroblastosis foetalis.** In this condition the baby is born dead as a result of Rh-incompatibility between the man and is wife. It is better for a man of Rh-positive to marry a woman who is also Rh-positive and for a man who is Rh-negative to marry a woman who is Rh-negative.
4. **Diagnosis of diseases:** Medical personnel do guide patients in detecting certain diseases using the principles of genetics so that diagnosis of such diseases can easily be done and treated where positive.
5. **Crime detection:** The use of blood group and fingerprints can help in detecting criminals by law enforcement agents.
6. **Development of test-tube babies:** It is now possible to produce children outside the mother's womb otherwise called test-tube babies. This has made some barren women to have their own babies.
7. **Choosing the sex of a baby:** It is now possible with the help of genetics to choose the sex of a baby a couple may want through sperm separation techniques.
8. **Knowing the sex of a baby:** It is now a common feature for couples to know after fertilisation and before birth, the sex of their baby by the use of scanners and other special techniques.

Activity C

Briefly explain in your own words, the role of genetics in diagnosis of diseases and in the development of test-tube babies.

3.3 Application of Genetics in Technology

Genetic engineering: The transfer of the nucleic acid molecule (DNA) of one organism (donor) to the nuclei acid molecule (DNA) of another organism (host) which lacks the ability to produce it (the transfered DNA) naturally but is able to replicate the newly introduced DNA is know as **genetic engineering.**

i. **Genetic engineering in insulin production:** Gene for insulin production in human can be transferred to *Escherichia coli* (a bacterium) to produce insulin for human treatments

ii. **Genetic engineering in crop improvement:** Serious attempts are being made by genetic engineers to transfer the nitrogen fixing genes from *Rhizobium leguminosarum* into cells of cereals and other non-leguminous plant crops to increase their nitrate in takes in the soil so as to increase food production.

Biotechnology: In the recent years, geneticists revolutionised the science of Biotechnology by actually manipulating the genetic material of living organisms to obtain our needs particularly in medicine and agriculture. The two fields that have emerged from these advances in genetics are genetic engineering and hybridoma technology.

[illegible]

Briefly explain the following terms

i. Biotechnology
ii. Genetic engineering

[illegible] Conclusion

The importance of genetics to man cannot be overemphasised. Their studies therefore should be intensified.

[illegible] Summary

In this unit, we have learnt that

i. The principles of heredity are used extensively in agriculture, medicine and in technology
ii. In agriculture genetics help to produce crops that are of high yield, early maturing, resistant to pest and diseases, resistant to adverse climatic conditions.
iii. Breeders have used the knowledge of genetics to breed animals that are capable of growing faster, have high rate of reproduction, produce more meat and milk.
iv. Genetics has contributed immensely in various fields of medicine. These include determination of the paternity of a child, blood transfussion, marriage conselling, diagnosis of disease, development of test-tube babies, choosing the sex of a baby and knowing the sex of a baby.
v. Genetic knowledge is also important in technological advancement e.g. genetic engineering which involve transfer of a DNA from the donor to the recipient.
vi. Genetic engineering is used to improve the growth of crops e.g serious attempts are being made by genetic engineers to transfer the nitrogen fixing genes from *Rhizobium leguminosarum* into cells of cereals and other non-leguminous plants crops to increase their nitrate intakes in the soil to increases food production.

[illegible]

1. Write short notes on the following
   i. Inbreeding
   ii. outbreeding
2. List five ways through which genetics can be apply in agriculture.

[illegible]

Idodo - Umeh (1996). *College Biology*

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Michael M. C., *Essential Biology*

Volume 5: Ecology

Unit 1: Basic Concepts and Principles in Ecology

Page

1.0 Introduction

The survival of any living organism is dependent on the influence of the external environment. The external environment provides the organism with its requirement for life, i.e. food, water, shelter, etc. Living organisms, therefore, interact with one another and the external environment.

Ecology, therefore, is the study of the relationship between living organisms and their environment. In other words, it is the study of the interactions of biotic (plants and animals) with their abiotic (physical or non-living) environment. Two aspects of ecology are recognized, these are

i. Auto Ecology - this deals with the study of a single individual and

ii. Synecology - study of a group of organisms e.g. plants and animals that occur together.

2.0 Objectives

By the end of this unit, you must be able to recall and summarise

i. Basic concepts of ecology

ii. Basic principles of ecology

3.0 Basic Concepts and Principles in Ecology

a. Ecosystem

Ecosystem are areas composed of a community of organisms interacting with the biotic and abiotic components of the environment. Examples of ecosystem range from very small, for example, a rock pool to the very large rivers, lakes, grasslands, deserts etc. The entire earth could be regarded as a large ecosystem in which there are several communities with several levels of interaction. Certain factors affect an organism in any ecosystem. These are biotic and abiotic factors.

b. Community

This is a naturally occuring group of organisms living in a habitat with each population interacting with each other. Visualise this: a rock pool habitat with algae, snail, pistia, crabs and worms, constitute a community.

c. Population

This refers to individuals of same species irrespective of age, sex in a defined area at the same time. For example, the total number of lions in Yankari game reserve forms the population of lions in that reserve.

d. Species

Organisms are said to belong to the same species if such individuals are capable of interbreeding and produce viable offsprings e.g. species of goats, species of dogs etc.

e. Habitat

The habitat of an organism is the place whrere it lives. It is the physical portion of the earth's surface such as land, air, water, ocean, or soil. There are a number of habitats in an ecosystem. These are

* Terrestrial/land habitat
* Aquatic habitat either
  a) fresh water habitats e.g. streams, rivers, pond and lakes or
  b) marine habitats e.g. salt water lakes, estuaries, seas and oceans
* Arboreal habitat for organisms living on/in trees

- Soil (Edaphic) habitat for soil organisms
- Microhabitats

These are specific localised areas within the habitats where organisms live e.g. the underside of a log, a hole in a tree and the underside of a leaf. These localised areas are characterised by their microclimates.

3.1 Factors which Affects Organisms in an Ecosystem

Factors which affect the life of an organism in an ecosystem are .

a. Abiotic factors - these are also referred to as physical factors and include the climatic factors of temperature, water, rainfall humidity, wind, light and edaphic factors that is those related to the nature of the soil particles.

   - Climatic factors - these are factors brought about by changes in the climate or weather such as temperature, rainfall, relative humidity (RH), light intensity and duration, wind speed and direction. Climatic factors determine, the type of vegetation zones such as forests, tundra, deserts etc.
   - Edaphic (or soil) factors - are related to the nature of the soil particles, mineral and humus content of the soil and the depth of the water table from the surface of the soil. Edaphic factors determine the type of vegetation that a particular habitat will support. The type of vegetation will in turn determine the types of animals that the habitat will support.

b. Biotic factor - factors due to the influence of other living organisms are referred to as biotic factors. Such factors coming from the influence of man, interactions with other organisms such as predation, competetion.

[redacted]

i. List five (5) ecosystems you are conversant with.

ii. Mention two abiotic factors and two biotic factors that influence or act on an organism in an ecosystem

iii. Ecology is concerned with two major aspects of studies, list them.

3.2 Ecotypes and Biotypes

a. Ecotypes

Variations exist among population of same species growing in a habitat. These are referred to as ecotypes and several plant ecotypes have been recognised e.g. *Campanula rotundifolia*. In this species, individuals that grow on the mountain slopes are quite different from those at the base. Variations among ecotypes are both phenotypic and genotypic and they result from natural selection acting on the genes in the gene pools. Populations here are distinct and could be clearly demarcated. Note that this is quite different from ecolines where the distribution is continuous and the population cannot be divided at any one point into two ecotypes.

b. Biotypes

A biotype is a uniform habitat with the same type of enviornmental conditions, same type of animals/plants. That is, there is no phenotypic (visual) variation. Such communities occur mostly in small ponds and artificial lakes.

3.3 Succession, Cohabitation, Coexistence and Ecological Niche

a. Succession

This is the gradual stage by stage (stepwise) building up of a stable complex and climax community from scratch. Succession is a process, which allows colonisation of an area. For example, a bare rock or bare burrow pit initially has no organisms; succession begins when algae or lichens colonise the bare surface. This is the beginning of primary succession. The algae and lichens are the pioneer plants. When algae/lichens die, they dry up and decay forming humus. Weathering breaks up the rock forming cracks into which soil enters. The cracks create more rooms and environment for more organisms. More algae, lichens and mosses grow in the cracks so also do liverworts. The death of these plants and some small animals such as ants and termites forms more fertile soil for higher plants such as pteridophytes and ferns to grow. More animal life is attracted and the plants and animal communities become more diverse and complex. Death of organisms increases the richness of the soil. More dust and soil particles may accumulate and the cracks may become larger, thus the organic communities increase in size and diversity; the habitat also expands. Successive generations of plants and animals become more and more complex with higher plants such as herbs, shrubs and trees, as well as numerous types of higher animals such as lizards, snakes, birds and mammals. Eventually, the place becomes populated with a variety of plants and animals. This is the climax condition, which is more stable and lasting.

Features of Succession
* It is predictable
* Directional
* Environment - modified
* Species disappear
* Species are replaced by new ones
* Increase of/or decrease in biomass from one stage to another
* Climax community has maximum biomass
* Climax community is stable with complex diverse organisms

b. Cohabitation

This is when organisms of different species live together in the same habitat but not in the same niche, due to niche diversification. They are able to inhabit the same place because they explore different resources in the habitat e.g. lion, leopard and cheetah, live in the same habitat because the lion feeds mainly on buffalos, the leopard feeds mainly on baboons and the cheetah on young waterbucks or kudus. Though they are carnivores, their feeding habits are diverse thereby avoiding competition. Similarly, squirrels and pack rats may feed on the same food such as grains but while squirrels are diurnal, pack rats are nocturnal. Sacral beetles feed on elephant and buffalo dungs in summer while termite take over in winter. Certain herbaceous plants flourish in spring and give way to deciduous plants in the summer, which produces leaves with canopy and block-off light in the forest.

c. Coexistence

This is a situation in which organisms of different species live together in the same habitat. They have the same population regulation mechanism and means of coexisting without detrimental consequences e.g. utilising the same resources at different times and stages of development. Slobodkin postulated that two organisms could coexist and cohabit the same habitat if they have one of the following characteristics.

1. They may compete for the same resources in the habitat.
2. They may serve as food for each other.
3. They may benefit from each other by living together.
4. They may be independent.

d. Ecological Niche

An organism's niche is the sum total of its activities in that ecosystem. In other words, it describes the position or status of an organism in space and time, it indicates the habitat in which the organism lives as well as what it does or the "job" it does, i.e. its entire way of life, its functional role in the community. Each species occupies its own niche. Where two or more species compete for the same niche, one has to become extinct (at least in that local habitat) or they have to separate into different niches in order to coexist or cohabitate. A situation where a species alters its behaviour in order to compete favourably in a habitat is referred to as niche differentiation.

[redacted]

Differentiate between the following ecological concepts;

i. Cohabitation and Co-existence
ii Ecotype and Ecocline

[redacted]

In this unit, you have studied the basic concepts and principles of ecology. You should, therefore, be conversant with basic ecological terms like species, population and community that were used in this units. Also, you should be able to define and explain all the basic ecological terms and concepts.

[redacted]

Ecology is concerned with the relationships between organisms and their environments. It is divided into auto-ecology and synecology. Note that certain aspects of auto-ecology have been covered (e.g. nutrition, respiration, reproduction) in other units. Also note that certain aspects of synecology e.g. parasitism, predation etc. have been covered in units 4 and 5.

Any organism inhabiting a particular environment is faced with factors such as biotic and abiotic that challenges its life. These factors in the long run modifies the organism as it now evolves a specific niche.

[redacted]

i. In any given ecosystem, both biotic and abiotic factors operate and affect the life of living organisms in that given ecosystem. List and explain these factors. }20 marks
ii. Describe the processes of ecological succession on a bare rock. }20 marks

[redacted]

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Volume 5: Ecology

Unit 2: Feeding Relationships in Ecology

1.0 Introduction

Feeding relationships among living organisms is another approach to studying living organisms in their habitats. This approach is justified because organisms in their natural habitats are faced with the problem of how to obtain enough energy and nutrients to survive, reproduced and grow. In this unit, we will look at the arrangement of organisms into these community groups of trophic levels.

Trophic levels refers to the levels or position at which organism feed for example, "producers", "decomposers", "herbivores".

2.0 Objectives

By the time you complete studying this unit, you should be able to;

i. Differentiate between autotrophs and heterotrophs

ii. Know the various trophic levels and

iii. Describe the feeding interactions among organisms in the ecosystems.

3.0 Feeding Relationships

Organisms in their natural habitats exhibits pronounced feeding relationships i.e. what they feed on and what feeds on them. This is because as earlier stated in 2.0, they need energy to survive, reproduce and grow.

3.1 Autotrophs and Heterotrophs

Organisms are divided into autotrophs and heterotrophs, this is based on how they obtain food.

* **Autotrophs**: They make use of very simple inorganic substances from their surrounding. A typical example of autotrophs are the green plants. They need only sunlight, water, carbondioxide and inorganic ions such as nitrate to survive, grow and reproduce. Those autotrophs that need light employ the process of photosynthesis to make or synthesise complex organic molecules e.g. carbohydrates from simple organic. Because they make use of light energy, they are referred to as photoautotrophs e.g. green plants and photosynthetic bacteria. Those that make use of energy from chemicals are referred to as chemoautotrophs.
* **Heterotrophs**: These are organisms that cannot synthesise organic molecules from inorganic. These organisms require an external source of organic carbon e.g. fungi, animals, and most bacteria. These organisms, therefore, have to ingest, digest, absorb, assimilate and excrete the wastes. Heterotrophic feding may be Holozoic, parasitic, saprophytic, carnivorous (plants) and symbiotic or mutualistic.
* **Holozoic nutrition**: Organisms that feed on relatively large pieces of dead organic matter are referred to as holozoons. Three classes of holozoons are recognised these are;
  a) *Carnivores*: They are animals that feed on other animals or flesh eaters or feeders e.g. lion, tiger, cheetah etc., are carnivores.
  b) *Herbivores*: These are animals that feeds mainly on plant materials e.g. sheep, cattle, goat etc.
  c) *Omnivores*: These are animals that feed on a mixture of plant and animal food e.g. most humans, pigs etc.

Other modes of feeding interactions, such as parasitism, symbiosis, commensalism and saprophytism will be studied in volume 5, unit 3.

Activity A

i. List the two types of autotrophs.

ii. The holozoons are divided into three, list them.

3.2 Trophic Levels

An ecosystem is made up of three main components or professions (fig. 2.1), all these are concerned with the feeding processes, circulation of chemical elements and the flow of energy. These "component professions" are producers, consumers and decomposers.

i. *Producers*: These are the autotrophs made up of the photoautotrophs (photosynthetic) and chemoautotrophs. They capture and bring energy into the ecosystem.

ii. *Consumers*: These obtain energy as ready-made food either directly or indirectly from the producers. That is, they are mainly heterotrophs. There are two types of consumers; namely the primary consumers and the secondary consumers: Primary consumers feed directly on the producers while the secondary consumers feed on the primary consumers. Consumers are made up of herbivores, carnivores and omnivores.

iii. *Decomposers*: These are organisms that obtain their energy from organic components present in dead and decaying bodies of plants and animals. They in turn release chemical elements in form of nitrates, phosphates, potassium etc., example of decomposers are fungi and bacteria.

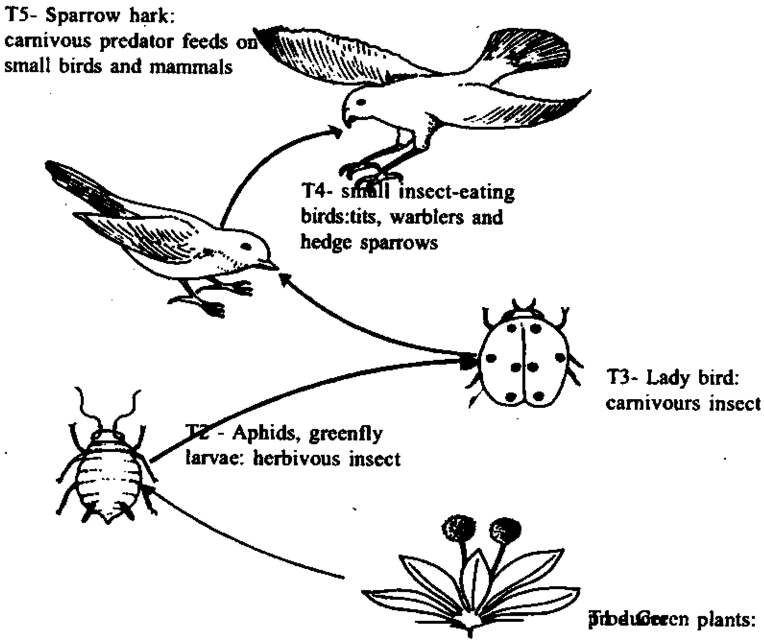

Figure 2.1: Trophic levels (T1-T5) in a food chain (source: Kilgour, 1985)

3.3 Food Chain

A food chain shows the feeding relationship between organisms in a natural community, indicating how energy is transferred from producers, consumers and decomposers. Note that producers (green plants) are always the first component of a food chain. A food chain may consist of three to five links or trophic levels; for instance, a typical pond ecosystem may have the following food chain.

Algae ⟶ Water fleas ⟶ Tadpole ⟶ Waterbeetle ⟶ Fish

(see table 2.1 for more examples of food chains in different ecosystem)

Habitat					
Trophiclevel	**Sea**	**Pond**	**River**	**Woodland Heathland**	**Grassland**
Producers T1	Phytoplankton, marine algae	Phytoplankton, freshwater algae	Phytoplankton freshwater algae	Tree leaf Heather	Grass
Primary consumer T2	Zooplankton, copepods microscope marine crustaceans.	Water fleas	Midge larvae	Greenfly, Butterfly, aphids caterpillars	Grasshopper
Secondary cosummers T3	Sand eels	Tadpoles	Trout	Ladybird Skylark	Lizard
Tertiary consumer T4	Mackerel	Water beetle	Man	Blu-tit Kestrel hawk	Snake
Quaternary consumer T5	Gannet	Perch		Sparrow hawk	

Table 2.1: ***Examples of food chains in ecosystems.***

3.5 Food Webs

Simple food chains are rarely found in an ecosystem. This is because most organisms may feed on different organisms in the same trophic level or different trophic levels. A food web, therefore, is a collection or matrix of food chains. It illustrates the complex parttern of energy flow throughout a community. Fig. 2.2. is an illustration of a food web in a typical guinea savanna ecosystem.

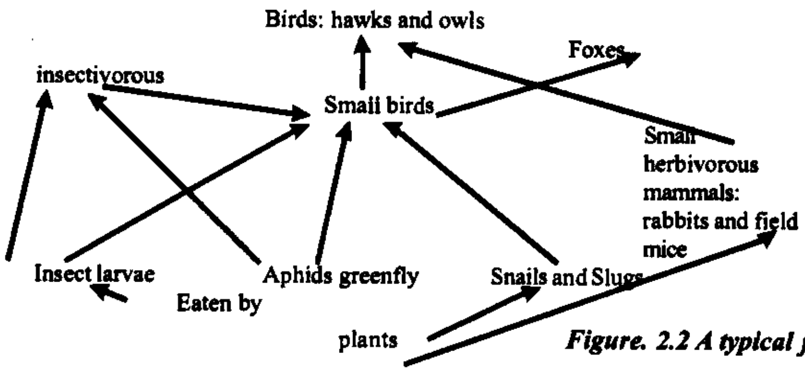

Figure. 2.2 A typical food web

3.5 Ecological Pyramids

Though food webs and chains are useful descriptions of feeding relationships community, they are not quantitative. That is, they do not give an indication of numbers or mass of a species feeding at a given trophic level. Quantitative feeding relationships in an ecosystem can be shown by either pyramids of numbers or biomass.

The pyramids of numbers show the total number of individuals at each trophic level. The largest number of individuals will be found at the producer (T1) level. That is a large number of leaves will be required to feed grasshoppers. Grasshoppers will in turn feed a few toads. Toads will in turn form a small part of a hawks diet. This relationship is illustrated in figures 2.3, 2.4, and 2.5.

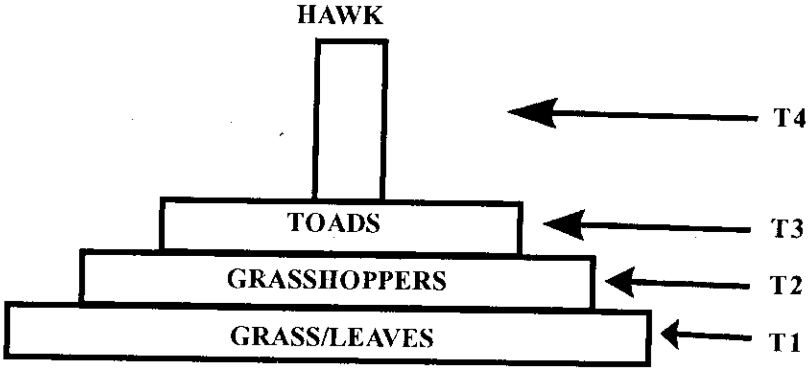

Figure 2.3: Ecological pyramids, showing quantitative (number or biomass) involved in a food chain. A more detailed illustration is shown in figure 2.4. note that an inverted pyramid of numbers will indicate the number of ectoparasites on an animals body (see figure 2.5).

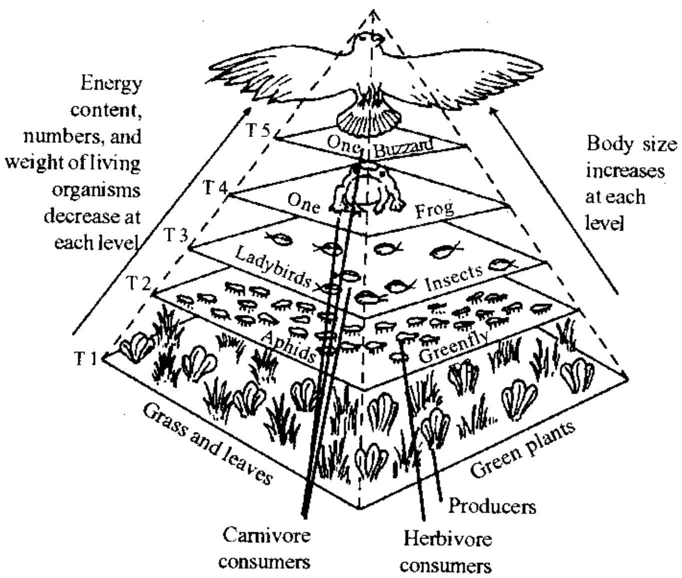

Figure 2.4 An illustrated ecological pyramid (Source: Kilgour, 1985)

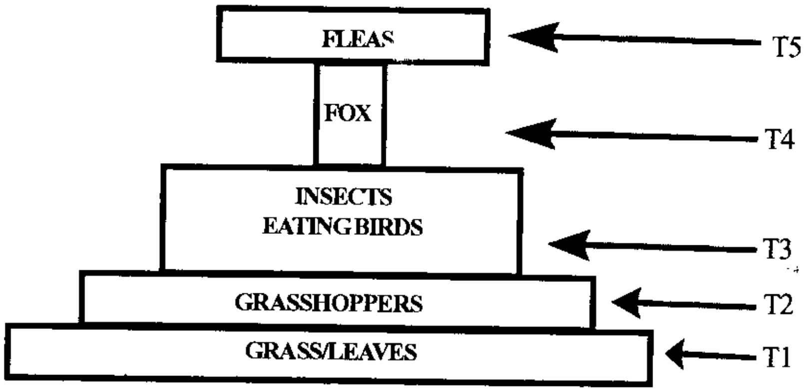

Figure 2.5: inverted pyramid of numbers showing ecotparasites (fleas) on a fox.

[redacted]

Write short note on the following;

i. **Pyramid of numbers**
ii. Pyramid of biomass
iii. Inverted pyramids.

4.0 Conclusion

In this unit, you have learned the various feeding relationships among organisms in a community. You should, therefore, be able to;

i. Differentiate between;
   a. Autotrophs and heterotrophs
   b. Food chains and food webs
   c. Pyramid of numbers and biomass
ii. Represent various trophic levels and
iii. Construct food chains and webs in different ecosystems.

5.0 Summary

* Feeding relationships in communities are conveniently analyzed by trophic levels.
* Producers, being photoautotrophs and a few chemoautotrophs are the basis of natural communities.
* Decomposers ensure that communities do not run out of inorganic substances necessary for energy and life.

6.0 Tutor - Marked Assignment

a. List three (3) main component professions in an ecosystem. What role does each play }20 marks
b. Illustrate two food webs, (i) One each for a stream ecosystem and (ii) a savanna ecosystem (20 marks).

7.0 Further Reading and other Resources

S. T. Ramalingam, *Modern Biology* , African Lib. Publishers Ltd.

O. F. G Kilgour (ed), 1985, *Mastering Biology* Macmillan publishers 515pp

Chapman J.L and Reiss, M.J., (2001), *Ecology: Principles and Applications 2nd ed,* Cambridge University press 330pp

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Volume 5: Ecology

Page

1.0 Introduction

Interactions among living organisms are also referred to as associations. Living organisms have a wide range of interactions and these interactions may occur between individuals from populations of same species or different species. Such interactions may be competition for food, mates or parasitism.

2.0 Objectives

By the end of this unit, you must be able to;

a. identify the different types of interactions among living organisms
b. cite specific examples of different organisms involved in these interactions.

3.0 Interactions in an Ecosystem

a. Competition

Competition arises when individuals struggle for a common resources which may be in short supply. Example: competition for food, light, mates etc. The phenomenom of competition was studied in Guaze. He used different species of paramecia. He postulated a law called **the law of competitive exclusion**. In summary, the law states that if two species are directly competing for a common resources which is in short supply, the species which is better adapted for exploiting the resource will survive while the other species goes extinct locally. But if their requirements are slightly different, both of them may co-exist. There are two kinds of competition, these are;

i. Intraspecific competition which occurs between individuals of same species e.g. *Paramecium, aurelia* and *Paramecium caudalum.*

ii. Inter-specific competition which occurs between individuals of different species. For example, competition for nutrients between rice plants and weeds.

Note: that intra-specific competition is usually more intense than inter-specific competition.

b. Predation

This is an interaction in which the predator, usually a carnivorous animal kills and feeds on another, referred to as the prey. Example, lion feeding on antelope, cat on mouse etc. the predator is, in most cases, stronger and bigger than the prey.

c. Parasitism

An organism that lives in or on other organism (host) and depends on it for food and shelter is known as a parasite. The parasite benefits, though the host is harmed but is not usually killed. Parasitism is an interspecific interaction. The relationship is responsible for numerous plant and animal diseases because it weakens the host's system and makes it less productive. There are different types of parasites.

i. Ectoparasites are those that live on the body of the host e.g. aphids on citrus plants, mistletoe plants on trees desire water and minerals salts, lice bugs and fleas live on skin of animals.

ii. Endoparasites are parasites that inhabit internal tissues and organ of plants and animals e.g. ematodes in tomato roots, blood parasites such as plasmodium and some trematodes; Ascaris, hookworms and tapeworms live in the intestines of animals.

iii. Facultative parasites are organisms that can live as parasites as well as being free.

iv. Obligate parasites are those that can survive only on/in a host. They cannot live freely e.g. plasmodium. Parasites that cause diseases are called pathogens.

Activity A

In each of the interactions so far studied, list two examples of organisms involved.

d. Symbiosis

Nowadays the term symbiosis is used to describe any close association between two species. If both species benefit from the association then it is said to be mutualism. This leads to a situation where the survival of each is dependent upon the other.

i. ***Root nodules***: Here, the legume plants such as cowpea, play host to rhizobium, a bacteria, the symbiont. The host here provides carbohydrates and shelter to the bacteria, which in turn fixes nitrogen from the air and converts it into amino acids. The host uses the amino acid.

ii. ***Mycorhiza***: This symbiotic interactive exists between fungi, the symbiont and certain roots of plants e.g. Pine growing in acid soils. An enzyme which the fungi uses to digest leaf litter is provided by the Pine (the host) while the fungi provides mineral ions to the Pine.

iii. ***Lichens***: Lichens are symbiotic association made up of algae and fungi, the algae lives within the fungus mycelium. While the fungi (host) provides shelter and mineral ions to the algae, the algae provides oxygen and photosynthetic products to the fungi.
Several other examples of symbiosis exist and include those of hydra and chlorella sp. (chlorella is an algae) and intestinal bacteria in the large intestine of man.

e. Commensalism

This interaction benefits only one of the interactants, the commensal. The other partner is not affected or harmed in any way. Examples are;

i. Epiphytes in forest grow on branches of trees to be near light while roots tap water from the soil in the crevices of tree barks. The tree provides support.

ii The remora fish attaches itself to the shark and is transported everywhere and eats food crumbs from leftover of the shark's meal but is not harmed by the shark, while the shark does not gain from this association.

iii. Flat worms on the gills of crabs feed on leftover scraps from the crab's meal while they do not harm the crab's gills.

iv. The cattle egret (white heron) in its association with cattle feeds on insects from the grass being fed on by the cattle but the cattle neither gain nor lose from the relationship. Obligate commensals stay with a single species.

f. Saprophytism

These are organisms that obtain their food from dead organic matter, such as dead plants and animals. Their feeding activities causes decay of organic matter. Saprophytes are bacteria, fungi (such as mucor and mushroom) and moulds.

Activity B

i. Take a walk around your community take care to observe/look out for the following;
* a parasitic plant growing on it's host
* epiphytes growing on tree trunks
* also, observe ticks on a dog's body

ii. List out all the kinds of interaction you have observed. Attempt to classify them.

4.0 Conclusion

In this unit, you have studied the different forms of interactions among living organisms. You should therefore be able to list out the different type of interactions with specific examples of organisms involved.

5.0 Summary

Interactions/associations/inter-relationships exist among populations of same or different species. These interactions vary from mutualism to the extreme forms of parasitism and predation with each having its apparent benefits and harmful effects. You would have noticed that these interactions could be between plants/plants, animal/animal or animal/plant.

6.0 Tutor - Marked Assignment

Question A.

i. Explain the term symbiosis

ii. Give three (3) examples of mutual symbiosis with their attendant benefits to individuals involved (20 marks).

b. i. List five interactions/associations that occur in an ecosystem

ii. Discuss the term, parasitism

7.0 Further Reading and other Resources

Ramalingam, ed. (2001), *Modern Biology,* Africa-Lib Publishers Ltd.,

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Unit 4: Adaptation by Animals to Different Environments

[illegible]

An adaptation is any genetically controlled characteristcs that increase an organism's fitness, that is, a characteristic that enhances an organism's chance of reproduction. Note that adaptation does not increase an organisms chance of surviving as it is sometimes erroneously stated. In many species, it is adaptive for the adults to die soon after completing reproduction. Adaptation may be structural, physiological or behavioural.

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By the time you conclude studying this unit, you must be able to;

i. Identify the various adaptive features exhibited by animal inhabiting environments
ii. Discuss some forms of co-evolution leading to adaptation.

[illegible]

Different habitats have different environmental conditions. Animals that live in such habitats, therefore, evolve adaptive features to survive the habitats. Below are different adaptations shown by animal in different habitats..

3.1 Morphological Adaptation

a. Aquatic animals

Animals here live in water. They possess various adaptive features and these include;

i. The development of a streamline shape in active swimmers like fish, that offer minimum resistance to water currents, so that they can be carried easily by water or move without hindrance. To maintain buoyancy, some have flattened bodies with bristle hair that trap air.
ii. Some have flattened bodies e.g. bivalve, stonefly and mayfly nymphs. These enable them to hide under stones and avoid water currents.
iii. The possession of appropriate organs such as external gills in tadpoles and some adults amphibians; internal gills and air and swim/gas bladders e.g. fish. Air breathing forms come up periodically towater surface to breath; they have the ability to stay under water for long periods of time. Their blood pigments have higher affinity for oxygen than animals in non-stressful environments e.g. whales and seals posses lungs, also snails such as Limnaea and Planorbis. They come up to water surface to breath. Mosquito larvae have breathing trumpets that extend above water surface.
iv. Aquatic animals posses locomotory organs such as strong tails and fins, and well-developed muscles e.g. fish tadpoles, seal. Some have webbed toes e.g. ducks; frog.
v. Some have feeding apparatus that strain food particles, e.g. head-nets of simulium Skates and whales filter phytoplanktons from water currents in their muscle bars; gill rakers and gills are used in fish and bivalves, for the same purpose respectively.
vi. Carnivores have strong jaws for capturing smaller animals in water e.g. sharks. Suctorial mouth of lamprey for cutting off small pieces of flesh from its host.
vii. Well-developed sense organs for detecting food and for moving in water e.g. lateral line system in fish to detect sound, vibration and movements in water. Some have large eyes, e.g. skates and rays, whales and deep sea-dwellers where it is permanently dark; also nostrils and external ears.

b. Terrestrial Animals

These are animals that live on land. Their adaptative feature include:

i. Highly developed sense organs such as eyes, ears, sensitive skin etc. These are used to detect food and enemies.

ii. They possess well developed internal organs as well, such as lungs and respiratory tracts, e.g. spiracle and trachea in insects, lung hooks in spiders, muscles of birds.

iii. Well-developed supporting skeletal system and limbs for movement.

iv. Have fore and hind limbs as in amphibians, reptiles, birds, and mammals, e.g. rats, lizards, toads, dogs, cats, etc. Fleet-footed ones include horses, antelopes, wolves, hooves of horses etc. enable them to move freely to find shelter, food, water and mate. Muscles are well developed to facilitate movement.

v. In birds, the bones are hollowed and have large air spaces to reduce weight during flight. Feathers provide excellent insulation. Lack of glands in the skin prevents heat loss by evaporation.

vi. Some animals posses scales, e.g. lizards to prevent loss of water, insects have adopted various mouths suitable for various type of feeding habits e.g. biting and sucking mouth parts.

vii. Monkeys have developed long tails and modified feet for climbing and holding, bees have stinging apparatus for protection etc.

viii. Those animals living underground have modified feet for digging e.g. the mole, spade-footed toad etc.

Activity A

i. Now that you have studied the various adaptive features exhibited by animals in aquatic and terrestrial habitats, list five (5) adaptive features possessed by animals living in the environments.

3.2 Physiological Adaptation

This deals with the modification of physiological processes in order to overcome certain environmental problems Below are some examples;

i. In desert animals like camels, the kidneys are well developed with an extra ordinarily long loop of Henle to absorb and conserve water.

ii. Other animals produce concentrated forms of urine in solid forms to avoid water loss e.g. insects. Others in order to avoid body fluid loss, excrete diluted urine e.g. Tilapia found in freshwater ecosystems.

iii. Certain animals have developed enzymes used for digesting food materials e.g. sulphide bacteria have evolved an enzyme to digest hydrogen sulphide, cloth moths have evolved enzymes that digest groups in wool.

NOTE: These are by no means the only physiological adaptations in animals. You must read more to get more examples.

3.3 Behavioural Adaptation

Animals alter their behavioural pattern to survive in their environments; for instance, desert animals avoid the excessive heat of the day by staying under shade and in damp places. This prevents excessive loss of water.

However, the most pronounced behavioural adaptations in animals have been evolved in what ecologists describes as (pair-wise) co-evolution in which one species develops adaptive features in response to the other. Below are some examples;

i. In response to predators, certain animals mimic the colouration of their background or habitat to avoid being seen by their predators. This exist in certain species of fish, insects and chameleons.

ii. Distateful animals are often brightly coloured, advertising their presence to warn the intending predators not to eat them, e.g. butterflies, wasps and some caterpillars are brightly coloured to warn birds. The birds will have to learn how to associate patterns their colours with distastefulness (Mullerian mimicry).

iii. Animals which are not distateful may converge on the warning colouration too. They use it as a disguise to pretend they are distateful when in fact they may be quite palatable (Batesian mimicry).

Activity II

i. You are presented with two animals; a camel and a horse. In which of these animals do you expect the loop of Henle in the kidneys to be longer? Give reasons.

ii. During the rainy season, a grasshopper in the savanna looks green but gradually changes to brown in the dry season. What do you think is responsbile for this and why?

iii. Why are distateful animals brightly coloured?

4.0 Conclusion

In this unit, you have studied the various adaptive features exhibited by animals in their various habitats. Therefore, you should be able to explain the importance of adaptive morphological features, physiological and behavioural patterns observed in animals.

5.0 Summary

Animals adapt to their habitats for survival and successful reproduction. Adaptive features either morphological, physiological or behavioural, evolved depending on the specific needs of the animal in question. In cases where two or more species are closely associated e.g. predator-prey or host-parasite, these features evolve and confer advantages on both species.

6.0 Tutor-Marked Assignment

a. Define the following terms and show how animals have employed these means of adaptation.

   i. Mullerian mimicry

   ii. Batesian mimicry

b. Write short note on morphological adaptations in animals.

7.0 Further Readings and other Resources

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Volume 5: Ecology

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1.0 Introduction

For the definition of adaptation, refer to unit 4. However one expects to see differences in the mode of adaptation of plant and animals to their environment but the basic aims of adaptations are the same, i.e. for both plants and animals.

2.0 Objectives

By the time you complete studying this unit, you must be able to;

a. Identify the various adaptative features exhibited by plants in different habitats.

b. Discuss some examples of co-evolution.

3.0 Adaptations in Plants

Adaptation in plants would be looked at from two perspectives: Adaptations to ensure the production of descendants (adaptation for reproduction) and adaptations for pre-reproductive survival (adaptations to different environments).

3.1 Adaptations for Reproduction in Plants

In certain species of Bryophytes and Pteridophytes e.g. *Marchantia* and *Selaginella* respectively, the female reproductive structure called the archegonium which is a flask-shaped structure containing the egg cell or ovum only opens when it is fully matured. This is to ensure protection for the egg cell. In addition, the archegonium contains chemical substances that attract the swimming antheriods from the antheriodium.

In flowering plants, they depend on external agents for pollination. The flowers of each species are adapted in shape, structure, colour and odour to the particular pollination agents on which they depend. This illustrates clear cases of evolution of adaptations. Evolving together, the plants and their pollinators become finely tuned to each others peculiarities. This process is known as co-evolution.

Some example of striking correspondences between the pollinators and the species they pollinate are given below;

i. Bright colour, ultra-violet patterns and sweet aromatic smell attract bees. Flowers pollinated by bees have showy bright coloured petals and are usually blue or yellow. They are hardly red in colour (because bees cannot see red at all), and the bees are active only during the day, the production of nectar and opening of petals of these flowers occur during the day.

ii. Humming birds are pollinators of certain flower species. Because humming birds see red colour very well, but sees blue colours only poorly, the flowers they pollinate are usually red or yellow, and nearly odourless. In addition, hummingbirds do not land on the flower while sucking the nectar (they only hover), such flowers lack a protruding portion for landing.

iii. Bats and moths are active during the night. Flowers pollinated by these species are mostly white and open during late afternoon and night usually with a heavy fragrance that helps to guide the pollinators.

iv. Wind pollinated flowers lack bright colours, special odours and even nectar. Most of them lack petals thereby exposing their sexual parts freely. The pollen of such flowers are very light and can be blown for long distances by wind.

Activity A

Visit a patch of land with flowers in bloom. Observe for a few hours the interactions between the insects and the plants. Make a list of the INSECTS you have seen. What benefits are both plants and insects obtaining?

3.2 Adaptations in Response to Environment

a. Adaptation by Xerophytes: Xerophytes are plants that grow in hot, dry areas. Such areas could be extremely cold at night. There is moisture for only a short period of time accompanied with high sunlight intensity and high temperatures. Oxygen shortages, especially when it is extremely hot or cold is common. E.g. as in deserts, semi-arid areas and temperate area. Plants here show the following adaptations:

i. Well-developed cuticularised epidermis.

ii. Leaves reduced to scale-like or needle-like structure or spines (e.g. *Acacia Opuntia* or *Cactus*). Where not reduced, the leaves are thick and succulent e.g. *Aloe, Agave.*

iii. Green photosynthetic stems, which may be thick and fresh called phyllocades e.g. *Cactus, Opuntia.*

iv. Leaves may be thin and dry as in *Asparagus, Equisetum.*

v. Non-succulent stems develop strengthened tissues, which make plants strong and flexible to withstand wind action.

vi. Leaves have few stomata, to reduce transpiration

vii. Stomata are sunken and protected elaborately with hairs to reduce evapotranspiration loss and promote gaseous exchange e.g. *Aloe, Agave, Oleander (Nerium)* etc.

viii. Branching is reduced or formed of phyllocades e.g. *Cactus*. In non-branching ones, there may be thorns/ spines; reduced branching reduces damage done to plants as a result of their inhabitating exposed windy areas.

ix. The epidermis has strengthening tissues too.

x. Extensive deeply seated roots that tap water efficiently from low water tables.

xi. Succulent body store water and the cuticle prevents water loss so also does the cork layer under the epidermis.

xii. Woody trees/plants with bark for protection against forest fire e.g. *Daniellia oliver, Butyros* *parkii* (shea butter) etc.

b. Adaptation by Hydrophytes: Hydrophytes are plants that spend all their li ages in w They are variously adapted as follows:

i. Poorly developed vascular tissues. Do not need vascular tissues.

ii. Poorly developed epidermal tissues, no cuticle, as there is abundance of water.

iii. Epidermal cells contain chloroplasts.

iv. Parenchyma develops as float organs-air bladders for bouyancy e.g. *Fucus*. Does not need well-developed stem as water provides support; poorly developed, stems that lack strengthening tissues.

v. Submerged leaves are divided as in *Salvinia*. This helps to prevent tearing by water currents.

vi. Floating leaves are expanded in order to capture maximum sunlight e.g. water lettuce, *pistia stratides.*

vii. Few stomata, if any are present and located on the upper epidermis of floating leaves.

viii. No differentiation of leaf mesophyll into palisade or spongy tissue.

xi. Attachment organs which hold fast may be present.

c. Adaptation by Halophytes: Halophytes grow in waterlogged area that are salty and calcareous. They show the following adaptations which have enabled them conquer this environment.

i. Have breathing roots to get air.

ii. Well-develop protective epidermal tissue to prevent harm to internal tissues.

iii. Extensive rooting system for penetrating deep into soil as water may pollute with heavy decaying matter and salt.

iv. Well-developed strengthening tissue to withstand decay.

v. Well-developed root vascular tissue with root system to absorb good water from deep inside the soil thus avoiding salty water at the top.

d. Adaptation by Mesophytes: Mesophytes are plants that grow in moderate conditions and include most tropical shrubs, trees, ephemerals, biennials and perennials. Here, wet and dry seasons alternate regularly with wide temperature ranges. They show the following adaptations.

i. Develop respiratory system with root hairs.

ii. Epidermal layer has thick cuticle.

iii. Anatomical tissues are well developed.

iv. In dorso-ventral leaves, stomata are more on lower surface than upper. In linear leaves, stomata are equally distributed.

v. Stomata not elaborately protected.

vi. Have protective structure, against browsing animals e.g. epidermal hairs, mucilage, thorns and spines e.g. Acacia spp, grasses, cocoa, cola nut, mahogany and locust bean trees.

vii. Some shed their leaves during the dry season to avoid excessive water loss e.g. savanna trees.

viii. Certain species dry up their aerial vegetative portions during the dry seasons leaving their reproductive portions underground that regenerate during the wet season e.g. rhizomes

ix. Those plants in heavy rainfall areas have larger leaves with a lot of stomata for fast transpiration.

e. Adaptations by Epiphytes: Epiphytes are plants found growing on other trees but not as parasites e.g. ferns, mosses, grasses, and some herbs. They are adaptetd as follows;

i. Their sizes are reduced so as to reduce water requirement

ii. Seeds and spores are small. This enables them colonise small pockets of soil in the tree trunks

iii. Leaves are few but root volume very large to absorb water

iv. Some have aerial roots that absorb moisture from the air.

Activity B

i. Take a walk to the field and collect specimen of plants growing on other plants (not as parasites).

ii. In waterlogged areas.

iii. Inside water

iv. On dry land/moderately dried area

Observe and note differences amongst these group of plants.

4.0 Conclusion

In this unit, you have studied the various adaptations shown by plants and have also studied how interactions between two species leads to the modification of their structures and / or behaviour (refer to reproductive adaptation in plants). It is expected, therefore, that you should be able to describe the various adaptive features exhibited by plants in different environments.

5.0 Summary

Adaptive features are genetically controlled and they increase an organisms fitness in its habitats; because habitats differ in their characteristics, species that live in those habits at evolve peculiar characteristics that enhance their fitness, and hence propagation of their kinds.

6.0 Tutor- Marked Assignment

a. List five adaptive features each exhibited by zerophytes, hydrophytes, halophytes and epiphytes.

b. Briefly explain how flowering plants have adapted to ensure their pollination by (i) bees (ii) hummingbirds (iii) bats and (iv) winds.

7.0 Further Reading and other Resources

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Volume 5: Ecology

Unit 6: Habitat Studies

1.0 Introduction

In this unit, you will leam the different methods employed in collecting organism from different habitats. This is an important aspect on ecological studies. For instance, soil is an environment and habitat, and because many organisms depend directly or indirectly on soil, procedures for investigating the various components of soils will be studied.

2.0 Objectives

By the end of this unit, you should be able to:

i. Identify the various equipment used in sampling or collecting organisms.

ii. Sample different habitats.

iii. Investigate the different components of soils.

3.0 Habitat Studies

Various methods are employed in collecting organism from different habitats. These methods will be discussed in this section.

3.1 Animal Sampling Methods

i. *Short vegetation and litters*: This involves the use of magnifying lens to locate small and delicate organisms. A pouter tube (see Figure 6.1) is then used to suck up the organisms.

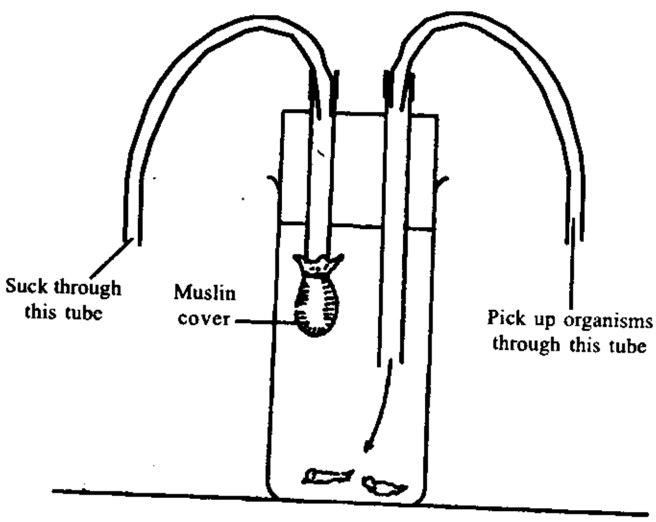

Figure 6.1 A pooter collecting tube

ii. *Tall vegetation or grasses:* In this method, a sweep net is used for collecting organisms. This is mostly used for insect's collection. The sweep net has a collecting device attached to the bottom (fig. 6.2).

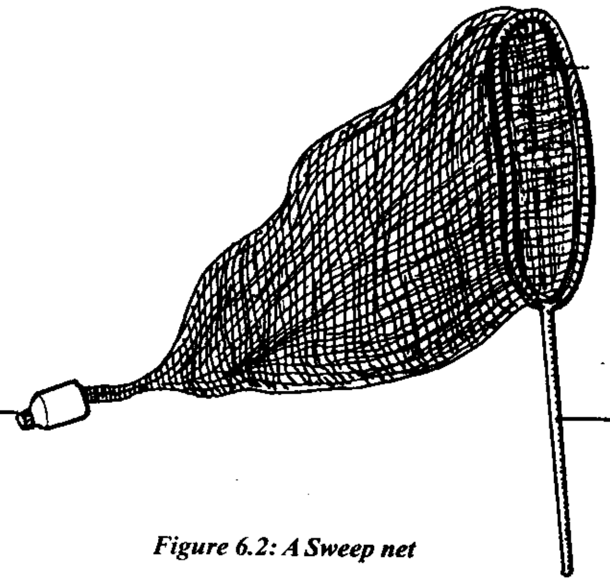

Figure 6.2: A Sweep net

iii. *Trees and shrubs:* This involves the placement of a white sheet or an inverted umbrella under the branch of trees. Beat the branches in quick succession three or four times. This is done so as to dislodge organisms from the branches onto the sheet of umbrella.

iv. *Ground/level/surface organisms.* This involves the use of a pitfall trap. This is simply a jar sunk into the ground; the top rim levels with ground surface. An irregular stone is used as cover (see fig. 6.3); the insects (adult and larvae) crawl into the jaw via openings created by the uneven stone.

v. *Light traps:* This is made up of a suspended hurricane lamb or electric bulb, covered with a mosquito net and provided with an entrance through which the insects get into the net. The type of trap is used in collecting nocturnal flying insects.

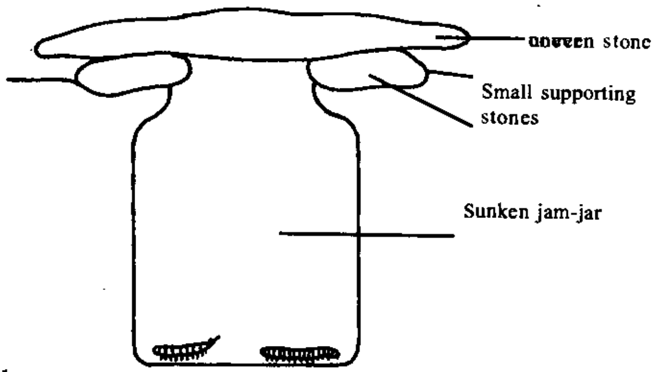

Fig. 6.3 A Pitfall trap

vi. *Soil organisms:* This involves the use of a tullgreen funnel placed over a beaker with the mould of soil on top of the tullgreen funnel. The beaker contains water or a preserving solution e.g. formaldehyde (4%). A heating device e.g. 60 watts bulb is placed above the soil mould and the mould heated for 6 to 8 hours. The heat drives the organisms into the beaker.

Alternatively, you can pour the soil mould containing organisms in a saturated sodium chloride solution stir continuously for a few minutes and then allow to settle.

The organisms will float on the surface of the solution where they are picked and recorded.

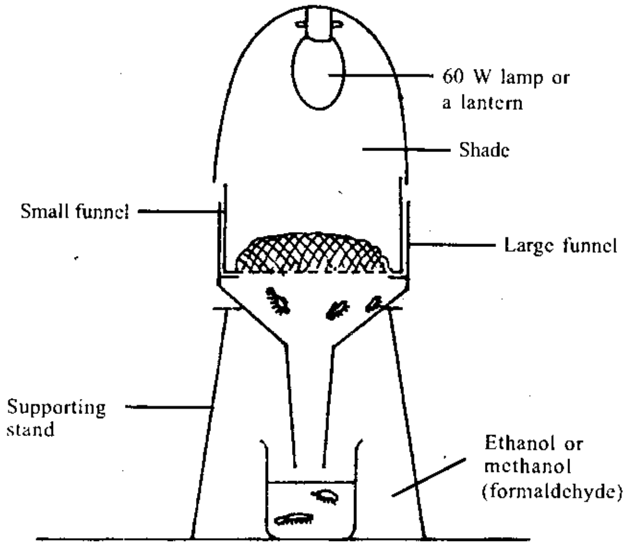

Figure 6.4 A tullgren funnel set up

vii. Aquatic organisms: Aquatic organisms e.g. Zooplankton and phytoplankton can be collected with mesh nets or fine sizes. Sediments dwelling organisms also known as benthos in deep lakes and rivers are collected with grabs e.g. Ekman grabs, Peterson grab etc.

In any of the above methods, several random samples are taken or collected in a defined area and mean counts made. The population of the animals species per square meter of a habitat is given as;

$$\frac{\text{Population in sample} \times 1 \text{ square meter}}{\text{area sampled}}$$

3.2 Plant Sampling Methods

An area or parcel of vegetation can be sampled using the following methods;

a. **Quadrat:** This is a square metal, wood or plastic frame: A quadrat is laid over the area to be investigated and plants in it counted. Note that animals could be counted too with this method.

b. *Belt transcet:* This is a meter-wide strip of vegetation demarcated by parallel ropes.

c. *Line transcets:* This is simply a rope running through the centre of plot to be studied.

d. The vegetation structure of a given area can be studied by the following method.

   i. Frequency expresses the distribution of a given plant species in an area. Randomly, quadrats are laid and the presence-absence data of a given species determined

   ii. Mapping: There are two kinds of maps;

   * Surface maps - marks out the various locations of species in quadrats or transects and shade such areas.

   * Cross- section maps - this shows the heights of the various vegetation patterns.

   iii. Density: Density of any particular species expresses its numerical strength in a given area.

$$\text{Density} = \frac{\text{No of individual of a species}}{\text{Total area of quadrats studied}}$$

Activity A

i. Construct wooden quadrat of 0.5m x 0.5m

ii. Use it to study
   a. The density
   b. The frequency of plant species of your choice

3.3 Soil Sampling Methods

a. The mineral composition of soil

Soil is made up of several mineral components including sand, silt, clay, gravel and mineral salts. The physical condition of any given soil depends in part on the mineral composition of such a soil. You can determine the composition of a given soil by:

i. Collecting the soil sample, feel the soil between your fingers to determine or estimate it ..ineral composition. A fresh sample of soil that feels gritty is likely sandy. The one that is sticky is m..s. likely clay soil while a silky feel is loamy soil.

ii. Pour a 200cm³ of water into a 250cm³ measuring cylinder. Pour 30g of the sampled soil into the c linder containing water. Shake and allow it to settle by sedimentati..a. The sedimentation will be in t e order of gravel, sand, silt, clay and lastly, floating organic matter (fig. 6.5).

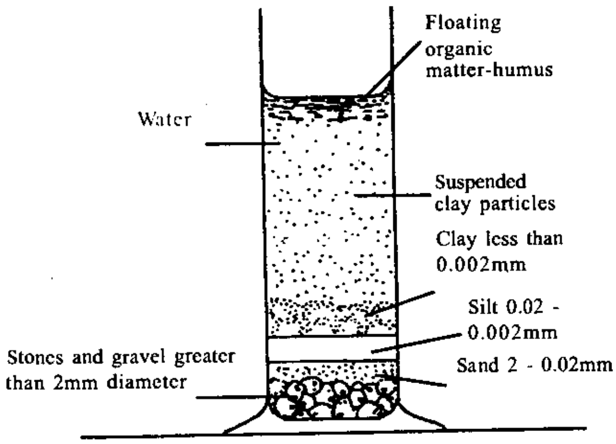

***Figure 6.5**: Separating soil components by physical analysis*

b. **Soil water:** To estimate the total water in a soil the following procedure can be adapted;

i. Place a weighed soil sample to dry to a constant weight in an oven at 110°C

ii. Reweigh and determine the loss in weight due to evaporation of total soil water (loss in weight = original weight - final weight).

iii. Percentage loss can be calculated from;

$$\frac{\text{Loss in weight}}{\text{Original wet weight}} \times 100 = \text{percentage of water in soil}$$

The total water varies between 10 and 35%

c. **Soil air:** Water will usually displace the air present in soils. To estimate the amount of air present in any given soil sample, study the set up below.

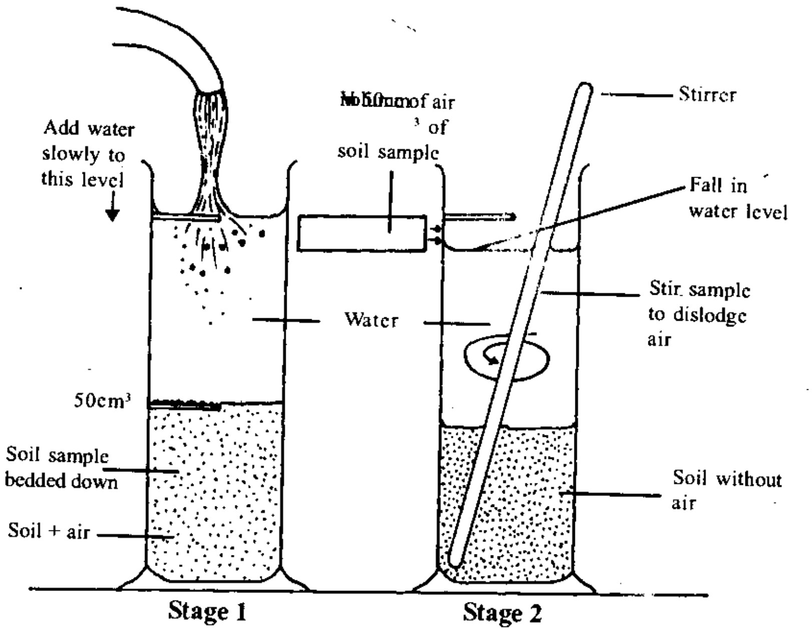

Figure 6.6: Set up to estimate the volume of air in a soil sample (after Kilgour, 1985)

The percentage volume of air in the soil is given as:

$$\% \text{ of air} = \frac{\text{Volume of air in soil}}{\text{Volume of soil sample}} \times 100$$

Note that the volume of water needed to restore the water in the measuring cylinder to its original level will be equal to the volume of air in the soil.

d. **Organic content:** The organic content of soil is as a result of the presence of humus. Humus is the end product of decomposition of dead organic matter. To estimate this, the following procedure is followed:

1. Obtain a sample of soil.
2. Oven-dry at 60°C for at least 24 hours.
3. Remove and put in a desicator to normalize temperature.
4. Weigh a given quantity into an evaporating dish.
5. Heat strongly over a Bunsen burner.
6. Allow to cool, and determine the loss in weight.

$$\% \text{ Organic matter} = \frac{\text{loss in weight}}{\text{weight of organic dry sample}} \times 100$$

3.4 Instrument used in Climatic and Aquatic Studies

Climatic factors could be measured with simple instruments used in studies

* Relative humidity is measured using hydrometer. Temperature is measured with a simple thermometer.

* Rainfall is measured using rain guage.
* Light intensity is measure using a photographic light meter.
* Wind speed is measured using an anemometer.
* Wind direction is measured using a wind vane.

Aquatic factors are measured with the following;

* Transparency/turbidity can be measured with a secchi dish or a turbid meter
* Tide is measured with a tide gauge.
* Flowrate can be measured with a flow meter.
* Electrical conductivity - a conducitivity meter.
* pH - which is the acidity or alkalinity of a solution is measured with a pH meter.

Activity B

You are provided with a sample of soil
Estimate:

i. The volume of soil
ii. Amount of humus/organic matter in the given sample

4.0 Conclusion

In this unit, you have learned several ways of understanding habitats. You should, therefore, be al

i. Identify the various tools employed in habitats studies
ii. Estimate populations of both plants and animals and
iii. Estimate the various components of the soil.

5.0 Summary

i. Habitats vary in their characteristic.
ii. Communitites, therefore, differ from one habitat to the other
iii. An integrated approach is, therefore, employed in studying these habitats
iv. Various instruments are used in measuring biotic and abiotic factors in a habitat.

6.0 Tutor-Marked Assignment

Two soil sample were investigated by a group of students and found to exhibit the following properties;

	oil samples	
Property	**A**	**B**
Water (%vol.)	30	6
Air (% vol.)	70	94
Humus (%)	25	10
pH	76	3

a. Which of these soil samples will support a more luxuriant plant growth?
b. Advance reasons for your answer (20 marks).

7.0 Further Reading and other Resources

Kilgour, O.F.G (1985), *Mastering Biological,* Macmillan Publishers 515pp

Odunfa, S.A., (1991) *Essentials of Biology*, Heinemann Educational Books, 221pp

Ramalingam, S.T, edition, *Modern Biology*, Published by African - Fep. Publishers Ltd.

Volume 5: Ecology

Unit 7 Population Studies

Page

[redacted]

A population is the total number of individuals of a given species i.e. adults of both sexes, juveniles, larvae, eggs, in a habitat at a given time (see unit 1). Because species do not exist singly in their natural habitat, the term that readily comes to mind when population is mentioned is density. Populatin density, therefore, refers to the number of individuals of a species per unit area of a habitat. It could be per square meter or per square kilometer. Natural population changes in size and several factors could be responsible for these changes.

[redacted]

By the time you complete this unit, you must be able to;

i. List factors that affects natural population

ii. Explain causes of food shortages and its impact on population

iii. Discuss methods of controlling human population.

[redacted]

Population of species in natural habitats grows or increases, however, this increase is not indefinite as populations are kept in check by several environmental factors. When a species is introduced into a new habitat where food is abundant and other factor affecting growth and reproduction are favourable, the s-shaped sigmoid growth curve is the typical growth pattern observed (see figure 7.1).

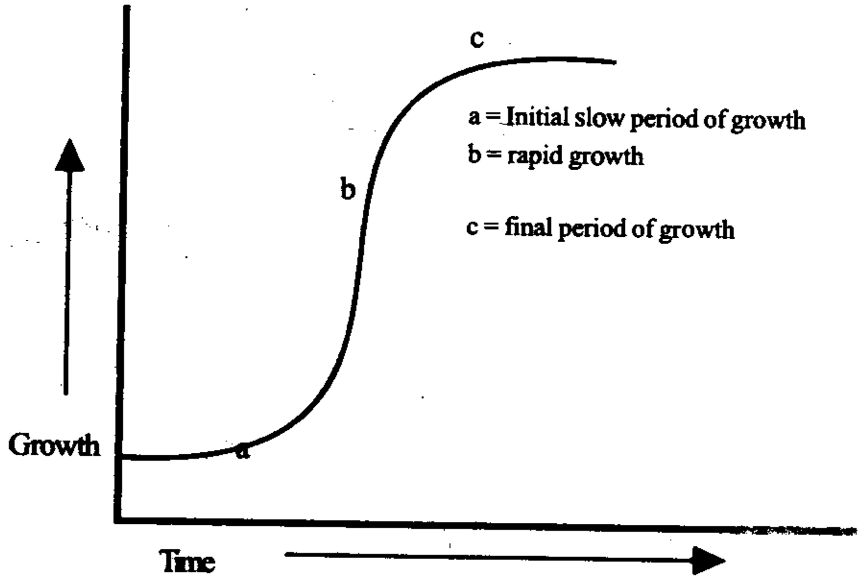

Figure 7.1: A typical sigmoid growth curve.

This sigmoid pattern of growth is typical of populations where food is abundant and factors that affect reproduction and growth are not limiting.

3.1 Overcrowding/Overpopulation

a. Overcrowding: (sometimes referred to as overpopulation) is when a population in a given habitat grows beyond the carrying capacity of that habitat. That is, the resources of the habitat are not enough to support all the individuals in that habitat. The following factors lead to overcrowding.

i. Natality: the birth of the young will naturally increase the population of a given species.

ii. Immigration: refers to the movement of individuals from other areas into a habitat.

The above two factors contribute to overcrowding as they add new individuals to the population. A population in which the percentage of individuals in the reproductive age bracket is high will have a high natality rate.

iii. High survival rate is another factor that leads to overcrowding. Survival rate is direct function of parental care. Species like rabbits, mice, dogs and humans protect their young and are therefore able to survive to the reproductive age and can reproduce before they die. This will naturally lead to increase in the size of the population. Where life expectancy is high and pre-sexual maturity age is low, populations will naturally increase.

b. Effects of Overcrowding:

Overcrowding leads to:

* Food shortage and shortage of other resources i.e. light, nutrient, space, etc.
* Outbreak of diseases
* Predation and parasites
* Competition for food, space, shelter, mates, etc.
* Toxic wastes are likely to build-up in such a habitat.

In order to avoid overcrowding and its consequent effects, living organisms employ the following methods;

* Plants employ mechanisms of dispersal, which ensure that seeds are dispersed far and wide. Agents of dispersal such as animals, water and wind ensure this. Also plants use explosive mechanisms of dispersal.
* Seasonal fluctuations in availability of food affect the carrying capacity of habitats. For instance, in the savanna, food is abundant during the rainy season but scarce during the dry season. To avoid overcrowding during the dry season, many animals emigrate out and return when the rains start. Another example is in birds. Certain birds migrate out of Europe during the winter to Africa to overwinter. For example, the European white stork migrate between nesting grounds in Europe and overwintering grounds in Africa.

3.2 Food Shortage

Food shortages are caused by two factors, these are draught and diseases. Food shortages lead to a decrease in population size. Decrease in population is caused by;

a. Competition

Food shortage will naturally lead to competition for the limited food amongst organism. This competition becomes more intense when it is between individuals or species that have similar ecological niche. Those who are better adapted will survive while those than cannot adapt or less adapted will die out.

b. Emigration

Lack of food will force individuals to move out of a habitat in search for food. Note that individuals only emigrate if chances of survival are highly threatened in the present habitat and better in the new habitat..

c. Mortality

Mortality refers to death of individuals in a given time. Food shortage will lead to death mostly especially in the vulnerable age groups i.e. the young and the old.

d. Reproductive Rate

When food is in short supply, the rate of reproduction is reduced. Birds will tend to lay fewer eggs and mammals will give fewer births. Lack of food also has a direct effect on sexual maturity. Longer period of time is required to increase in size or grow and attain sexual/reproductive maturity.

Activity A

i. List the effects of overcrowding.

ii. List the causes and effects of food shortage.

iii. Describe briefly the method plants employ to avoid overcrowding.

3.3 Human Populations

Populations in natural habitats show exponential growth as illustrated in figure 7.1. The limiting factors in the environment cause the population to stabilize. Such limiting factors are known as environmental resistance. However, human populations have been found to take exception to this because humans have controlled environmental factors. This have enabled them increase their average life span. This is achieved by lowering mortality through improved Medicare, food consumption, better shelter and hygiene. Also they have improved agricultural productivity. These have led to a continuous growth in human population.

3.4 Human Population Control

Factors that control human populations are:

* Diseases/outbreak of disease
* Famine
* War
* Natural disasters e.g. flood, earthquakes, fires, typhoons, etc.

However, as a civilized nation, these factors are unacceptable as means of population control. The acceptable alternatives are, therefore, birth control methods.

Birth control is employed through several means. These include:

i. Contraceptives: Women take contraceptive pills regularly. It may be taken once daily for three weeks of every month. A break is needed during the menstrual period. These pills prevent ovulation. Side effects are common. There are various types of contraceptives, one is advised to see a medical doctor before using any contraceptive.

ii. Withdrawal method: The penis is withdrawn just before ejaculation of the sperms. The draw back or disadvantage is that failure rate is high.

iii. Rhythm method: This method targets the release of the female egg and intercourse is suspended or avoided at such period. The problem is that ovulation period changes.

iv. Spermicides: These are tablets or creams for foams that kill the sperm as they are ejaculated into the vagina. The spermicide is applied into the vagina before sexual intercourse.

v. Use of condoms or barriers, which are worn over the penis. This prevents the sperms from entering the vagina.

vi. Intra-uterine device: A device inserted into the woman's womb and prevents implantation of the fertilized egg in the uterus.

vii. Abstainance: This involves self control; individual do not participate in sexual activity

3.5 Relationship between Availability of Food and Human Population

* Sufficient food leads to a healthy population. This has a direct bearing on the society as healthy people work harder than unhealthy people. Fewer death would also occur.
* Insufficient food means the population is weak and unhealthy and fall prey to infectious diseases. Such a population cannot be productive. Standard of living is highly reduced or poor and education is adversely affected.

Activity B

Visualize the phenomenon of overcrowding by performing this activity. Get a bottle, crush a fruit (say a ripe mango fruit), put it in the bottle. Do not cork or cover the bottle (leave it open). Keep the bottle containing the ripe mango fruit by the window. Twelve hours thereafter, fruit flies will enter the bottle. Trap them inside and cover the bottle with a fine wire mesh. Allow it to stand in a cool place for a few days. Count the flies daily and record your findings. At the end of the tenth day plot a graph to show the number of flies per day. Write short notes on your findings.

4.0 Conclusion

In this unit, you have studied the aspects of population concerning humans and other animals. You should therefore be able to;

i. Define overcrowding, its causes and subsequent effects

ii. Demonstrate a simple experiment to show overcrowding

iii. Describe the effects of availability of food, or lack of it to human population

iv. Discuss the effect of food shortage on humans and other organisms

v. Outline ways of controlling human population.

5.0 Summary

* Population of species in natural habitats are restricted or checked by several environmental factors to prevent species from exceeding the carrying capacity of their habitats. Humans however have overcome most of these environmental factors and the human population increases continuously.
* In natural habitats, populations of species show a sigmoid form of growth.
* Organisms emigrate to survive and grow better in their new habitats
* Abundance of food will lead to an increased standard of living among humans and therefore improvement in the society.

6.0 Tutor - Marked Assignment

a. List four factors that could lead to decrease in human population

b. List and explain six (6) methods of birth control by humans

7.0 Further Reading and other Resources

Ramalingam, 2001 ed *Modern Biology*, African Feb. Publ. Ltd.,

Chapman J. L, and Reiss, M. J. (2001) *Ecology: Principles and Applications 2nd Edition*. Cambridge University Press

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Volume 5: Ecology

Unit 8: Nutrient Cycles

1.0 Introduction

The major source of energy to the ecosystem is from the sun. The sun's energy is coupled with other natural available elements such as oxygen, carbon, nitrogen to form variuos materials. These materials are constantly recycled between the living and non-living components. Some of the most important elements in the metabolism of living organisms are carbon, nitrogen, oxygen, hydrogen, phosphorous and sulphur. However, over one hundred elements exists but oxygen, hydrogen and nitrogen are about 99% of the biosphere. The main nutrients for maintenance of life are carbon, oxygen, nitrogen and water; and the cycling of these nutrients is initiated by biological, physical and chemical processes. Therefore, there is need to understand these cycles and how delicate balance is maintained, this will be studied in this unit.

2.0 Objectives

At the end of this unit, you should be able to;

a. Describe the carbon and oxygen cycles, and the carbon-oxygen balance
b. Discuss the nitrogen and mineral cycle, and
c. Explain the water cycle.

3.0 Nutrient Cycling in Nature

Over one hundred nutrients have been identified in nature. But the most important one to life are carbon, oxygen, nitrogen and water. These nutrients will form the major contents of these unit.

3.1 The Carbon Cycle

Sources of carbon in the abiotic environment include:

* water bodies (oceans, seas and rivers)
* fuels (petroleum), coal, gas and coke
* limestone, marble, corals
* gas, released from decomposers or buring of fuels and
* in dead organisms.

The carbon cycle is simple the processes that bring about circulation of carbon compounds in the biosphere. The process of carbon cycling involves the following:

i. plants remove carbon from atmospheric carbondioxide in the presence of water and sunlight, and use it to form sugar or carbohydrate found in plants, during the process called photosynthesis.

ii. carbohydrate in plants are eaten by animals and man and becomes incorporated into their tissues. When they pass feaces, some carbon compounds are released into the environment

iii. when plants and animals respire, carbondioxide is produced from the breakdown of glucose and released into atmosphere.

iv. when plants and animals die, bacteria and fungi initiates decay, and in the process, locked up carbon are released as carbon dioxide into the atmosphere.

v. during the burning of petroleum, natural gas, coal, wood, carbon in these materials are oxidised to give carbon dioxide that is released into the atmosphere (see fig. 8.1).

vi. calcium carbonate is used by marine organisms to build shells; overtime, when they die, the carbon is released into water and eventually into the atmosphere.

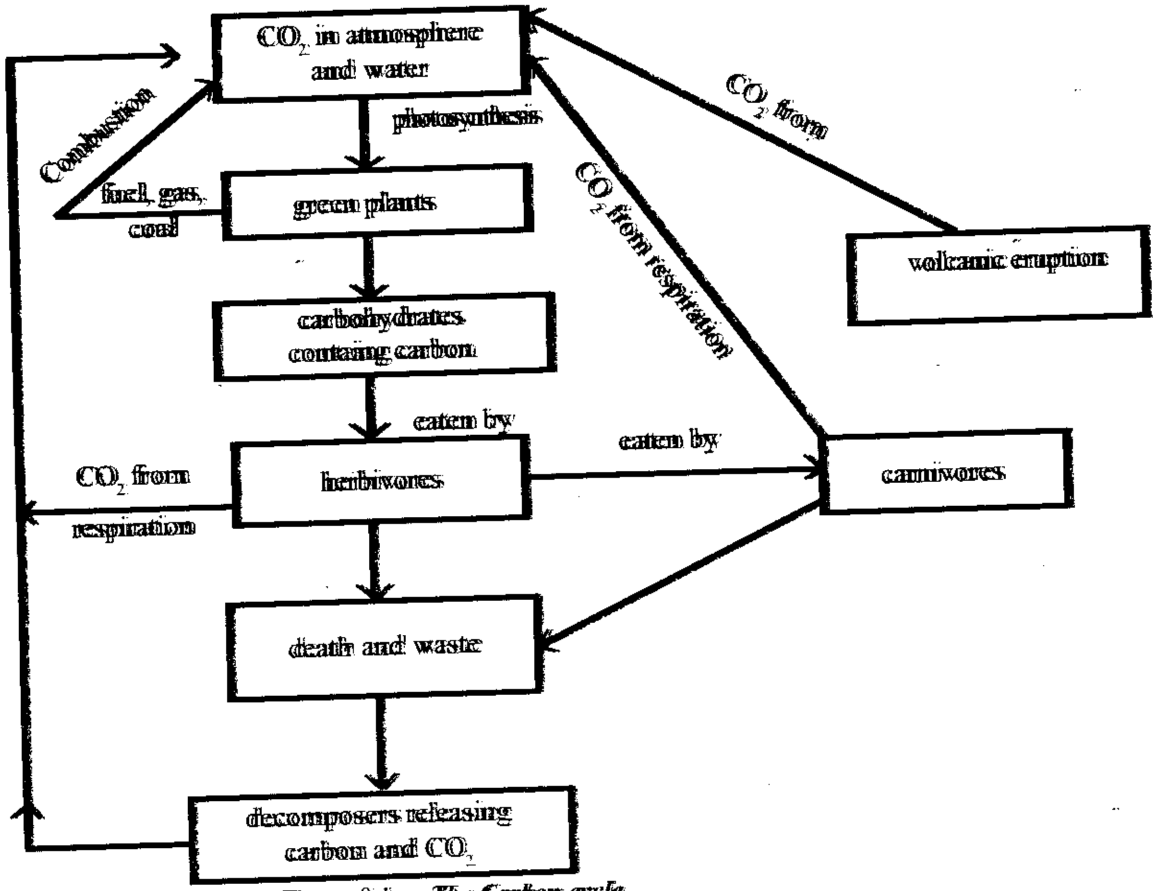
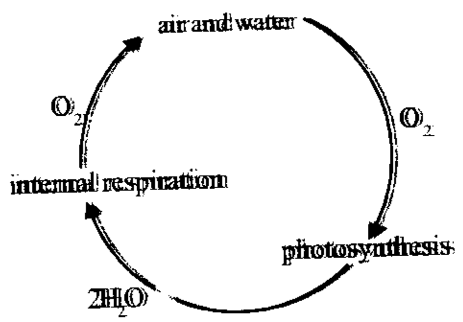


Figure 8.1: ***The Carbon cycle***

Source: *College Biology by G. Idodo - Umeh page: 532*

3.2 The Oxygen Cycle

Oxygen is about 20% of the atmosphere. The major source of oxygen to the atmosphere is through photosynthesis. For every molecule of carbondioxide used up by plant for photosynthesis, the same amount of oxygen is released into the atmosphere. Another source of oxygen is from water (fig. 8.2).



Source: *College Biology By G. Idodo - Umeh page 532*

3.3 Carbon-Oxygen-Balance

Oxygen content of the atmosphere is kept constant by the oxygen cycle. Respiration, combustion and decaying processes remove oxygen from atmosphere while photosynthesis increase atmospheric oxygen. Bush burning, deforestation and flaring of gases are some human activities that disturbs the carbon and oxygen cycles. Decrease in atmospheric oxygen by 8% has limited or no effect, but an increase in carbondioxide by 2% may cause "green house effect" i.e. an increase in heat energy released by the sun to earth, due to depeletion of the ozone layer of the atmosphere. This may cause global warming, melting of polar ice-caps leading to increase in sea volume or water. This may also lead to draught and climatic changes.

Pollution of aquatic environment has led to depletion of oxygen available to aquatic organisms, particularly fish.

3.4 Nitrogen Cycle

In living tissues, nitrogen is present in proteins and amino acids. In the abiotic environment as gaseous nitrogen, and as salts such as nitrates in the soil. Activities of bacteria also decomposes plants and animals into nitrites and nitrates. The nitrogen cycle, therefore, involves the movements and utilization of nitrogen between the abiotic and biotic environments. Nitrogen cycle involves:

i. Thunderstorm: During thunderstorm and lightening, atmosperic nitrogen reacts with oxygen to form nitric oxide. Nitric oxide is oxidised to nitrogen peroxide which dissolves in rain water to give nitrous and Nitric acids. These acids react with mineral salts present in the soil to form nitrates. Nitrates dissolve in soil water

3.5 Mineral Cycle

Nitrogen, oxygen and carbon are not the only elements or nutrients required by living organisms. Others include mineral salts, such as phosphates, sulphates etc. These mineral salts are found in the soil where they are released by various bacterial activities and the process of rock weathering. The cycle of these mineral salts can also be traced. Phosphates, sulphates and potassium are major component of certain fertilizers used in agriculture to replenish soil mineral.

3.6 Water Cycle

This is movement of water from the atmosphere to earth (i.e. precipitation = rain) and from the earth to atmosphere (i.e. evaporation). The sun's energy (solar energy) allows water to evaporate and when it cools, it condenses. At high altitude, the water condenses, and forms cloud. When the cloud is saturated, it precipitates and falls as rains.

Plants absorb the water from soil using their roots; some of the water is released via the leaves in a process called evapotranspiration, to the atmosphere again.

Aquatic organisms absorbs water from their environment, while animals drink water and excrete or respire some of the water. When both die, the water is returned during the process of decay to the soil or atmosphere.

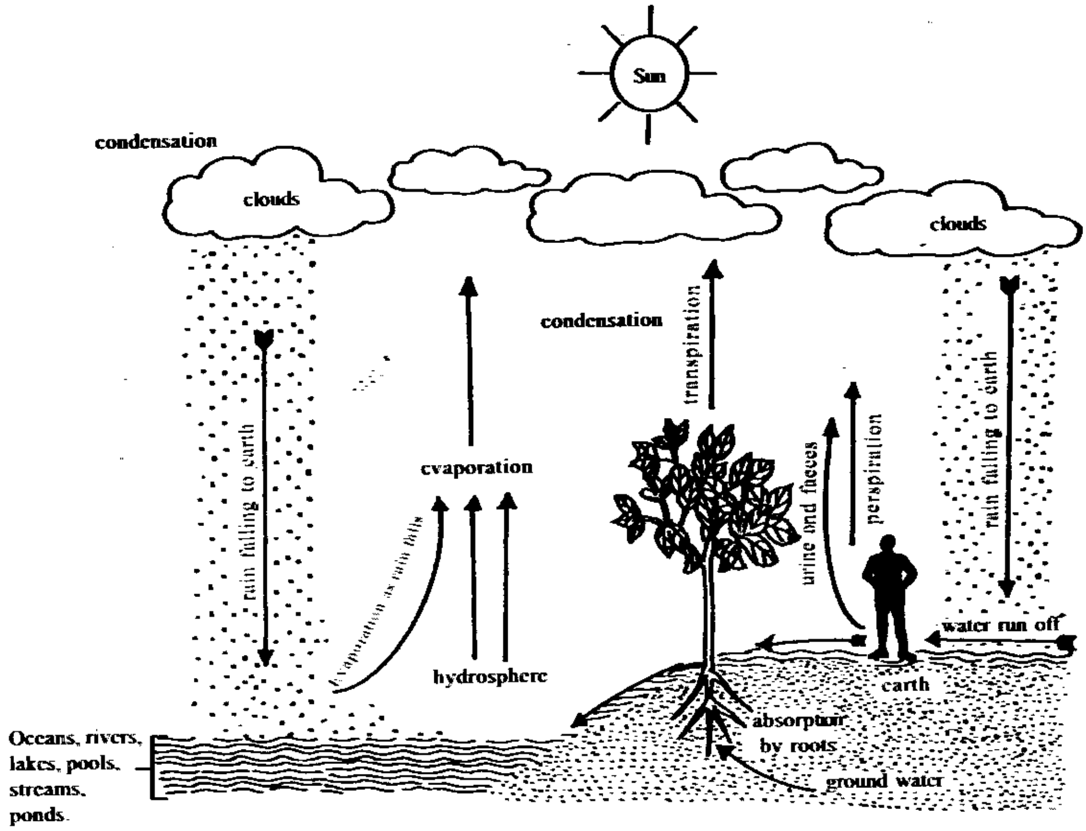


*Fig. 8.4: **Water cycle in nature***

***Source:** College Biology by G Idodo-Umeh Page 533*

Activity A

a. Write sbort note on the mineral cycle

b. Draw a diagram to show water cycle in nature

4.0 Conclusion

In tbis unit, you have studied the nutrient cycle. Therefore you should be able to describe the carbon, oxygen, nitrogen, mineral and water cycles.

5.0 Summary

i. Nutrients that can be traced in nature include carbon, oxygen, nitrogen, sulphates, phosphorous and water cycles. These nutrients that pass from the biotic to the abiotic environments are taken up by plants and converted into plant protein (fig. 8.3).

ii. **Nitrogen fixation:** Free living nitrogen fixing bacteria converts atmospheric nitrogen to protein e.g. *Azotobacter* and *Clostridium* while symbiotic bacteria e.g. Rhizobium, found in root nodules of legumes (groundnut, beans and [illegible]laria) use atmospheric nitrogen present in soil to manufacture proteins. When the host plant (the legumes) die the proteins and amino acids present in the root nodules are converted to soil nitrates.

iii. **Putrefaction (decay):** When plants and animals dies, they decay. Decaying process is caused by [illegible] process of protein break down is also called ammonification.

iv. **Nitrification:** The ammonia formed during ammonification is converted to nitrates by nitrifying bacteria.

- * The bacteria called *Nitrosomonas* converts ammonia to nitrites.
- * The bacteria *Nitrobacter* converts nitrites into nitrates. Nitrates in the soil are absorbed by the roots of plants and are converted into plant protein.

v. **Denitrification** bacteria (e.g. *Pseudomona denitrifications)* found in the soil, convert soil nitrates, nitrites or ammonia into gaseous or atmospheric nitrogen. This reduces nitrogen content of the soil.

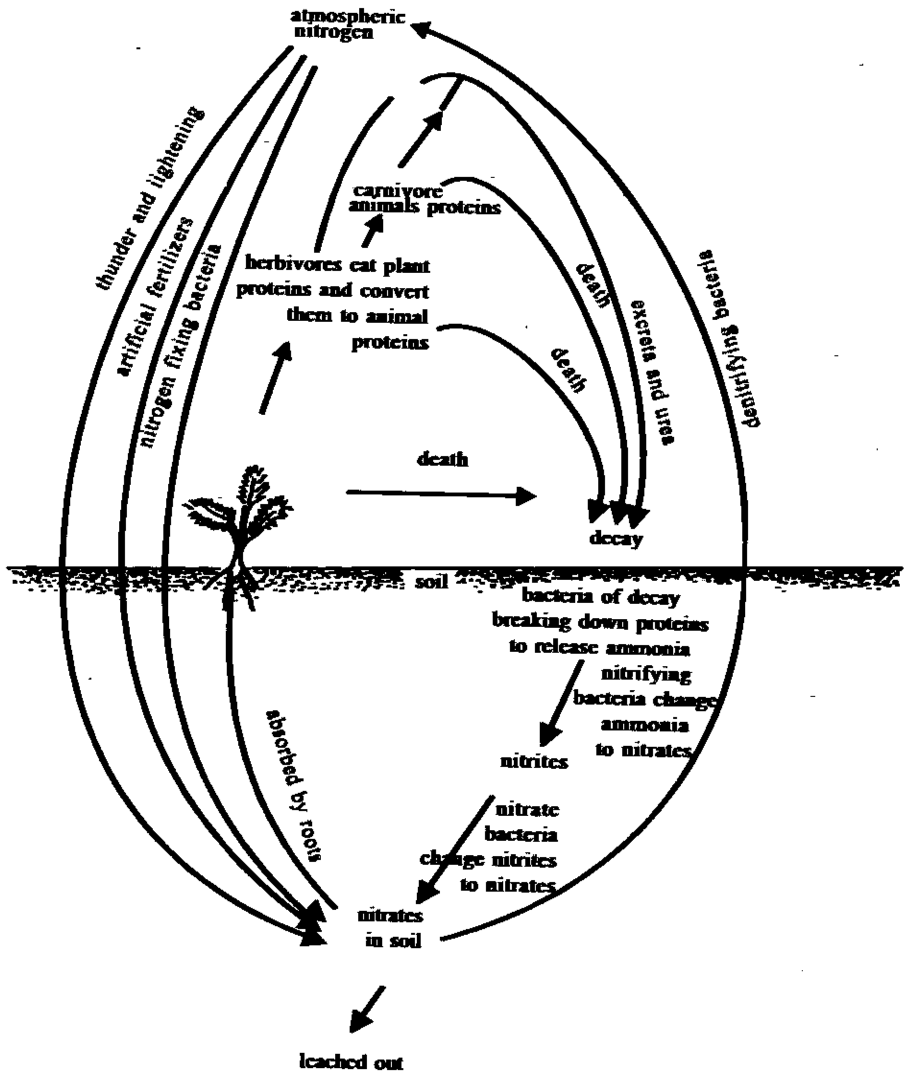


Figure 8.3: Nitrogen Cycle

Source: College Biology by G. Idodo-Umeh Page 535

Activity 8

a. Describe the main processess through which the carbon in the biotic component is returned to the abiotic component.

bi. List the processes through which inorganic nitrogen enters the biotic environment

ii. Write short notes on carbon-oxygen balance

[redacted]

a. Describe the carbon cycle (20 marks)

b. Use an annotated diagram only, to describe the water cycle. (20marks)

[redacted]

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Volume 5: Ecology

Page

1.0 Introduction

As human population increases, available space for human and wildlife decreases, demand for food agricultural produce and natural resources increase and, over time industries were established. The outcome of these is overcrowding, increased personal and community demand and eventually increased "pollution" which is a by-product of human development and industrialization. Pollutants are unwanted substances by man, which have been introduced into the environment consciously or otherwise, and eventually causes impurity and harm to the environment (including its biotic and abiotic components). Pollution is the result of by product of human activities which is unfavourable to the environment and constitute danger to man's health and his natural resources. In this unit, we shall look at various forms of pollution, their effects on our environment and environmental laws.

2.0 Objectives

By the time you complete studying this unit, you must be able to:

a. List the major types of pollution
b. Water, Air, Noise and Land pollution
c. Discuss the environmental laws.

3.0 Pollution and Environmental Health

Pollution is an unwanted change in the biological, chemical or physical characteristics of air, land and water. Pollution will likely affect human life, various organisms (plants and animals), our industries, living conditions health and cultural assets. Pollution may also deteriorate our natural resources. The major types of pollution are water pollution, air pollution, noise pollution and land pollution.

3.1 Water Pollution

Water pollution is the intentional (or otherwise) release of substances by man into an aquatic environment. These substances are harmful to the organisms therein, and make them undesirable for human usage. There are several pollutants of our aquatic environment these include:

a. **Human and Animal Wastes:** These include feaces, urine, abattoir wastes, kitchen wastes that are dumped into our rivers, lakes, lagoons and streams. These contain disease causing agents.

b. **Detergent and Soaps:** These contains phosphates, which can increase the quantity of phosphorous in aquatic environment, thereby causing excessive growth of algae and aquatic vegetation. The vegetation can block water ways, preventing use of boats, canoes, fishing nets and eventually kill aquatic organisms such as fish.

c. **Oil Spillage:** This covers the surface of water prevents supply of oxygen into water, reduce amount of light into water and kill aquatic organisms

d. **Various Chemicals:** Various chemicals such as gammalin 20, mercury, effluents from refineries and other industries are released into water. This is dangerous to man's health, fish, plants and animals in such water body.

f. **Fertilizers:** Fertilizers are used to improve soil fertility. During torrential rains, some fertilizer such as sulphates and phosphates are washed into aquatic environment, where they cause excessive growth of aquatic plants.

g. **Thermal Pollution:** Some factories use water to cool their machines. In this process heat is gained by the coolant (water) and when the coolant is released into aquatic environment, it increases the temperature and decreases oxygen, which may alter aquatic life.

h. **Acidity or Alkalinity:** Industrial effluents and waste may alter the pH (a measure of acidity or alkalinity) of aquatic environment, killing aquatic organisms.

3.2 Air Pollution

These are air-borne substances like gases, fumes, smoke, dust from quarries or cement factories, that alters the composition of air that organisms live on. Some air pollutants include:

a. **Carbondioxide:** obtained from combustion of oil, natural gas, coal, fire wood/bush burning and from industrial machines, exhaust of motorcycles, cars and aircrafts.

b. **Other Gases:** This include, sulphur dioxide, nitrogen dioxide which are produced by automobiles. When released into atmosphere, they combine with rain to form acid rains, which reduces soil fertility.

c: **Fumes and Organic Substances:** such as alcohol acids, gasoline etc. These increases the acidity of atmospheric air leading to eye and skin irritations.

d. **Dust and Soot:** Dust from construction of roads, cement companies and quarries. Sooth from combination of coal, fire wood and kerosine stoves. These alters the air composition, reduces vegetation cover and may cause breathing related problems in man, reduces visibility for man, animal, and aircrafts, affect respiration and photosynthesis by blocking stomata and surface of leaves.

e. **Chlorofluorocarbons (CFC):** These are used as coolants in refrigerators, air conditioners, propellants in aerosols spray cans and in making poly urethane foams. When CFC escapes into the atmosphere, they destroy the ozone layer, thereby allowing the utraviolet rays of the sun to strike the surface of the earth directly. This increases temperature and causes climatic changes. The effect of direct sun's rays may cause skin cancer, sun burns and eye cataract, and destroy aquatic microorganisms.

Activity A

a. List the causes of water pollution.
b. List the types of air pollutants and state their possible effects on man and his environment.

3.3 Noise Pollution

This is simply an unwanted loud sound. There are several sources of noise pollution. This include industrial machines, automobiles, Aeroplanes, guns and bombs, loud music, and television sets, druming, thunderstorm and signing.

Effects of noise pollution include:

* Deterioration of rearing and deafness (temporary or permanent)
* Increase in high blood pressure
* Increase anxiety or fright (as with thunderstorm and bombs)
* Emotional disturbance and stress
* Increased temper.

3.4 Land Pollution

This is simply dumping of rubbish on land by man. These rubbish may eventually make the land infertile, aesthetically unappealing and obstructive.

Land pollutants are several and may be broadly classified as biodegradable and non-biodegradable pollutants.

a. Biodegradable pollutants: These can be degraded by microorganisms and therefore they do not persist in nature.

i. Refuse from hospitals homes, markets which may harbour germs, provide breeding grounds for insects, pests and rats.

ii. Sewage, these are feaces and urine from home, and fluids e.g. milk and youghort from food factories.

Water or land polluted with sewage is of health risk because it contains harmful bacteria that may cause typhoid, dysentry and cholera.

b. Non-Biodegradables: These cannot be degraded by microorganisms. They persist in [illegible]. They may be chemicals, radionuclides and certain industrial products.

i. Poisonous chemicals: from factories and laboratories are harmful to man and plants e.g. Cadmium, mercury, zinc, carbide sulphuric acid etc. may poison ground water.

ii. Radioactive elements from hospitals, atomic and nuclear bombs, and laboratories may cause gene mutation, and death to man, animals and plants.

iii. Bottles, glasses, tyres, plastics and metals (carcas of automobiles): They may cause body damage, litter streets, roads, and water ways, provide breeding places for mosquitoes and rodents, and render the land difficult to cultivate.

iv. Pesticides and herbicides: This is used to spray crops to kill insects, and may be washed into water bodies where aquatic organisms may be killed too.

3.5 Environmental Law

Increase in human population leads to increase in demand for natural resources. This has resulted in depletion, industrialisation and environmental pollution. Inevitability of industrialization has led to ecological and human disasters on our planet. Various forms of pollutions have been studied (unit 3.1 - 3.4). The question is do we sit back and watch the degradation of our environment? The answer is no! Therefore, failure to arrest further degradation of environmental quality will jeopardise the health of our people, and cause serious political, sociological and economical implications. On this basis, the Federal Government of Nigeria established the Federal Environmental Protection Agency (FEPA) by Decree 58 of 30th December, 1988 with statutory responsibility of overall protection of the environment. They pass strict anti-pollution laws.

Guidelines and standards relating to six (6) areas of environmental pollution control were established. These include:

* Effluent limitations
* Water quality for industrial usage limitations
* Industrial emission limitations
* Noise exposure limitations
* Management of solid and harzardous wastes
* Pollution abatement in industries

Today, all states in the Federal Republic of Nigeria have their environmental laws.

Activity B

a. List the sources of noise pollution

ii. Enumerate the effects of noise pollution to man

b. Describe the sources of land pollution

ii. State, in two sentences, why environmental laws should be established.

4.0 Conclusion

In this unit, you have studied the major types of pollution, which include water, air, noise and land pollutions. You also studied the major guidelines and standards relating to environmental pollution in Nigeria. You should be able to list the different types and sources of pollutions, and their likely effects on man and his environment.

5.0 Summary

Pollution is a change in the environment that renders it harmful to life. Water pollution is caused by human and animal wastes, detergent and soaps, oil spillage, various chemicals, fertilizers, heat and industrial effluents. Air pollution is due to combustion of oil, emissions from automobiles and aircrafts, dust and fumes from factories and chlorofluorocarbons.

Noise pollution sources are industrial machines, automobiles and aircrafts, guns, bombs, loud music, thunderstorm and television sets. Land pollution is caused by biodegradable and non-biodegradable materials. Environmental law is enacted to protect the environment to benefit man now, and in the future.

6.0 Tutor - Marked Assignment

a. Define pollution (5marks).

ii. Give the major causes of atmospheric pollution and their likely effect to the environment (15 marks).

b. What are the effects of the following pollutants to man and his environments.
(i) Noise, (ii) Pesticides, (iii) Sewage, (iv) Chlorofluorocarbons (CFC)

7.0 Further Reading and other Resources

Ramalingam, S.T. *Modern Biology*

Odum, E. P. (1971), *Fundamentals of Ecology,* W. B. Saunders Company, Philadephia, London & Toronto

Idodo - Umeh G., *College Biology*

Unit 10: Conservation of Natural Resources

1.0 Introduction

Natural resources include renewable and non-renewable resources found in our environment. They include air, water, soil, wildlife and forests - these are renewable natural resources. Fossil fuels (petroleum and natural gas) and minerals are the non-renewable resources.

Man has been using these resources for ages and this has led to depeletion of the resources because the rate at which it is utilized is faster than the rate of its replenishment. The outcome is depletion of our environment.

To prevent or reduce the level of pollution, we must conserve our natural resources, by using the resources wisely and continuously for the good of mankind, and at the same time, preserve the natural environment from which they are sourced.

In this unit, we shall be concerned with control and reduction of pollution, conservation of renewable and non-renewable resources, and the advantages that conservation measures offers mankind.

2.0 Objectives

At the end of this unit, you should be able to;

i. Enumerate the methods of controlling and reducing pollution in our environment

ii. Discuss ways of conserving natural resources and

iii. State the advantages of conservation.

3.0 Natural Resources

Natural resources are all useful things provided in nature or in the environment to man, animals and plants. Some examples of natural resources include soil, water, forest and wildlife, minerals, sunlight air, petroleum and natural gas.

Natural resources can be classified into two:

* Non-renewable natural resources and
* Renewable natural resources

These resources are being used by man without the result being replenished now is depletion and pollution. To forestall these, there is the need for conservation.

3.1 Need for Conservation

Conservation is simply the use of natural resources in a way that it is being protected from damage. A conservationist (in ecological sense) is a person that is against "unplanned developments that breaks ecological as well as human laws".

The aim of conservation then is;

* to ensure the preservation of a quality environment that provides aesthetic, recreational and material needs to man as well;
* to ensure sustainable use of plants, animals and materials" by establishing a balance use, re-use and renewal".

The need for conservation include:

* to protect nature i.e. wildlife, forest, fisheries etc., to improve our lives
* for sustainable use of these resources
* to control the use of petroleum and minerals
* to control or prevent pollution.

The definition and aim of conservation has a broader scope than what you have just read above. We need to look at the problems of conservation in two ways;

a. Indirectly - by controlling human population and reduction of pollution, and
b. Directly - by conservation of our natural resources.

3.2 Control and Reduction of Human Population and Pollution Sources

a. **Control and reduction of human population:** This is an indirect method of conservation. Demand for world resources are increasing because of increasing human population. To conserve our natural resources, we must control our population if "quality survival" is required. To do this, we must be involved in family planning. Family planning is a means of controlling the number of children a couple can adequately cater for and, at the best time and space to have them.

b. **Control and reduction of pollution sources:** In unit 9, you studied sources of pollution into our environment. Here, you will study methods of controlling and reducing pollution as an indirect method of conservation of resources. These include;

* **Control and reduction of air pollution:** This can be achieved by
  - maintanenace of automobiles, aircrafts and industrial machines to reduce production of carbondioxide, carbon mono-oxide etc.
  - removal of sulphur from coal, petrol, and gases from industries
  - fixing of filters to chimney and catalytic converters to automobiles, to remove nitrogen, sulphur, carbon components that are usually released into the air etc.
  - reduce the use or find substitute to chloroflourocarbons which depletes ozone layer.

* **Control and reduction of noise pollution:** This can be achieved by:
  - Reducing volume of music, radio, and television.
  - Using car and motocycle horns sparingly.
  - Building and redesigning factory machines, cars, aeroplanes, to supress their noise level. this may include addition of silencers.

* **Control and reduction of radiation pollution:** This include:
  - ban on test of nuclear weapons, to reduce atmospheric, terrestrial and aquatic radiation pollution

* **Control and reduction of water pollution:** This will involve the treatment of sewage before releasing it into rivers, lakes or land by
  - Killing harmful bacteria.
  - Reducing toxic compounds.
  - Oil spillage should be prevented by taking precautions at exploration sites.
  - using organic manure on farm land instead of inorganic manure.
  - building storage places for nuclear wastes.

* **Control and reduction of land pollution:** land pollution can be reduced by:

- avoiding bush burning and unnecessary felling of trees.

- avoid overgrazing by animals.
- prevent soil erosion and practice crop rotation and manuring on farmland.
- practice collection and disposal of solid waste at appropriate sites.
- recycling of certain wastes such as plastics, bottles, tins, tyres etc. should be practiced. Other recyclable materials include television, computers, automobiles, including aeroplanes etc.
- mining companies should be made to restore land after mining activities or convert the open land into a fish pond or farm.

* **Control and reduction of pollution by Education and Legislation.** Awareness via radio, television, newspapers, schools, community leaders would make us to consiously reduce pollution activities Strict laws and penalties will also help to reduce pollution in the states and national levels.

Activity A

a. Give four points to justify the need for conservation.
b. Describe ways of controlling pollution sources in your state.

3.3 Conservation of non-renewable Resources

Non-renewable resources include petroleum, natural gas and several minerals. We have been exploiting and using these resources at alarming rate and we cannot replace them! Therefore, in order to conserve them, we must do the following:

i. Look for alternative or renewable sources of energy. These may include the use of:
- Wind to generate energy.
- Sun's energy (solar) to provide electricity.
- Moon's energy to provide light.
- Water energy, either from waves and tides of the seas or from constructing dams from rivers to give hydroelectric energy.
- Use of alcohol, from fermenting sugar, as alternative to petroleum gas.

ii. By reducing petroleum or fuel requirements and cutting down on wastages in our industries and homes. This can be achieved by: (a) using improved and fuel efficient machines and equipment. (b) improved and better methods of petroleum exploration, transportation and storage.
iii. Better methods of mining and mineral extraction.
iv. Recycling of minerals and solid wastes such as metal scraps, tins, glass, plastics etc. This will conserve non-renewable resources like metals, reduce problem of waste disposal and environmental pollution.

3.4 Conservation Of Renewable Resources

Renewable resources include the atmosphere, land, water, forest, wildlife (resources). The atmosphere, land and water can be conserved as you have studied in unit 3.2. Forest and wildlife have been greatly endangered and abused by pollution and human beings that have exploited them excessively.

a. Conservation of Forest: Forests can be conserved in the following ways:
- Employ forest guards to protect from misuse.
- Cut down only matured trees, but with permission.
- Plant new trees (afforestation) otherwise there will be no trees in future.
- Establish forest reserves.
- Avoid bush burning.
- Educate the people and impose laws and penalties that will prevent abuse of the forest.

b. Conservation of wildlife: We can conserve wildlife in the following ways;

- Preventing indiscriminate killing (poaching) of wildlife.
- Establishing game reserves where poaching/hunting will be prohibited, except by permission.
- Avoid the use of poisons (herbicides and insecticides) and traps in wildlife reserves. Poisons or chemicals may get into the animal's food chain and traps may maim animals, these may lead to their early death.
- Avoid deforestation that destroys habitats of animals.

c. Conservation of water bodies and aquatic resources: This can be achieved by:

- Avoiding wastage, use water wisely and economically.
- Reduce water pollution by preventing the dumping of sewage poisons and chemicals into water ways.
- Preventing deforestation, which tend to reduce rainfall and change the microclimate of an area.
- Preventing the draining of swamps and marshes which allows fish to escape, and increase salinisation of land.
- Reducing unproductive irrigation schemes and unnecessary damming of rivers.
- Educating the people on importance of water and, imposing laws and penalties on defaulters.
- Aquatic resources such as fish can be conserved by
    * banning the use of chemicals, poisons and dynamites to catch fish.
    * banning the use of nets that catch fish irrespective of their sizes or age.
    * regulating the number of fishermen and boats allowed to fish in rivers, lakes and seas.
    * imposing and limiting fishing periods.
    * banning the catching of endangered fish species.
    * establishing fish hatcheries from where the wildstocks can be replenished.

3.5 Advantages of conservation

a. It allows us to live in a healthy, clean and civilized environment.

b. It allows us to use our natural resources wisely to rich and improve quality of life.

c. It allows us to appreciate the aesthetics (beauty) of our environment-beauty of lakes, mountains, waterfall, wild animals and plants.

d. It allows us to relax and become stress free when we go on bird watching, camping, picnics and other outdoor recreational activities.

e. It attracts foreign exchange (i.e. source of revenue) by attracting tourists.

f. It allows and gives food and raw materials to industries, which is also an important source revenue.

g. It allows us to study living plants and animals in their natural environment.

Activity B

a. Describe how non-renewable resources can be conserved
b. Discuss how you would conserve water bodies and a named aquatic resource in your local government area.

4.0 Conclusion

In this unit, you have studied conservation of natural resources and the need to conserve natural resources. You have also studied the need to control pollution that are threatening the natural resources. The natural resources which are non-renewable and renewable resources needs to be conserved. The advantages of conservation to man and his future generation have also been studied.

5.0 Summary

The natural resources are renewable (air, water, wildlife, forest) and non-renewable (petrolleum, natural gas and minerals). Conservation of these resources is paramount if healthy environment is required now and in the future. Indirect conservation strategy include control and reduction of human population and pollution sources; direct method involves controlling the use of natural resources.

6.0 Tutor-Marked Assignment

a. List the natural resources that need to be conserved.
ii. Give four points to justify the need for conservation.
iii. Enumerate the advantages of conservation.
b. Discuss how you would conserve water bodies and a named aquatic resource in your state. (20 marks)

7.0 Further Reading And Other Resources

S. T. Ramalingam, *Modern Biology*

Idodo - Umeh, *College Biology* by G.

Odum E.P. (1971) *Fundamentals of Ecology*, W. B. Saunders co Philadelphia, London and Toronto,

Federal Environmetal Protection Agency (FEPA) (1991). Natural Interim Guidelines and Standards for

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NATIONAL OPEN UNIVERSITY OF NIGERIA

Form QST2
Questionnaire

In the questions below, we ask you to reflect on your experience of the course as a whole.

1	Course Code and Title..
2	Mother tongue ....
3	I am registered for a .... Degree/Programme
4	Why did I choose to take this course? ....
5	Which study unit did I enjoy the most and why?...
6	Which study unit did I enjoy the least and why?...
7	Was the course material easy to understand or difficult?.....................................
8	Which particular topic do I understand better than before and how?........................ ....
9	Does the course have any practical applications in the real world, e.g. for the work I currently do?...YES/NO? EXPLAIN.. ....
10	What aspects would I like to know more about or study further?............................
11	How could the course be improved?...
12	Other comments about the course (***Please Tick***)...

Items	Excellen t	Very Good	Good	Poor	Give specific examples, if poor
Presentation Quality					
Language and Style					
Illustrations Used (diagrams, tables, etc.)					
Conceptual Clarity					
Self Assessment Questions					
Facilitators response to TMA Questions					

In the questions below, we ask you to reflect on your experience of the course as a whole.

NATIONAL OPEN UNIVERSITY OF NIGERIA

Form QST1

Questionnaire

Dear Student,

While studying the units of this course, you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions, in order to improve the course. Therefore, we request you to fill out and send us the following questionnaire, which pertains to this course. If you find the space provided insufficient, kindly use additional sheet.

Course Code: ____________ Course Title: ______________________________

1. How many hours did you need for studying each of these units?

Unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. of hours															
Unit	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
No. of hours															

2. Which of these units do you find most difficult to understand?

3. Please give specific problem you find difficult with the unit.

____

____

____

____

4. How would you like the unit improved?

____

____

____

Please Mail to
The Course Coordinator...............THROUGH the Study Centre Manager
National Open University of Nigeria
Victoria Island,
Lagos.